White Pine County Exhibit Q

September 25, 2011

Penny Woods, BLM Project Manager
PO Box 12000
Reno, NV 89520
775-861-6689 (FAX)
nvgwprojects@blm.gov (Email)

Dear Ms. Woods:

Thank you for the opportunity to comment on the Draft EIS (DEIS) for the Groundwater Development Project.

I have been on the faculty of the University of Nevada Las Vegas since 1960, and have specialized in research on the endemic fishes of Nevada, especially those confined to isolated springs in the desert environment. During that time I have published more than 85 scientific articles or chapters in the peer-reviewed literature, have recommended numerous fish species for listing under provisions of the Endangered Species Act, have served as a consultant to nonprofit organizations, to state and federal government entities in Nevada, Utah, Arizona, and California, and served as an expert witness in administrative hearings and court cases.

I have reviewed the Draft Environmental Impact Statement, especially the chapters covering Aquatic Biological Resources (chapter 3) and Monitoring, Management, and Mitigation (Chapter 2), and wish to offer the following comments for your consideration.

The Proposed Action, as well as Alternative A (or any alternative other than "no action") will produce a host of adverse environmental consequences that will be borne disproportionately by residents of the area directly affected (Eastern and Central Nevada and western Utah). Residents of the area into which water importation is proposed will, in general, be less adversely impacted. The environmental consequences borne disproportionately by residents of Eastern and Central Nevada, and western Utah, include substantial increases in atmospheric dust, vegetation change, land subsidence, spring, stream, and wetland failure, and the innumerable changes in lifestyle forced by these avoidable environmental changes. **The EIS must acknowledge this disproportionate adverse impact.**

The DEIS does an excellent job of identifying the aquatic biological resources dependent on the groundwater-dependent ecosystems that will be adversely affected by the proposed project. A major failing of the DEIS lies in its assertion that permanent damage to aquatic biological resources as a consequence of proposed groundwater development can be prevented or mitigated by the proposed MMM program. In fact, removal of the quantities of water from the groundwater system as described by the Proposed Action or any of the action Alternatives (including Alternative A) will result in an unacceptable and irretrievable loss of biodiversity.

The principle driving force behind the consequences described in the previous paragraph lies in the fact that the states of Nevada and Utah had, as of February 2006, granted water rights to 102% of the estimated "perennial yield" throughout the regional groundwater flow system (Deacon et al. 2007, Table 2). As of February 2006, applications for an additional 169% of the estimated "perennial yield" had been filed in the Nevada portion of the regional groundwater flow system. These applications included the approximately 330,000 acre-feet per year requested by the Southern Nevada Water Authority (SNWA asserts they are seeking about 180,000 acre-feet per year from those applications).

Because the perennial yield was already completely allocated by early 2006, additional water rights granted within the regional groundwater flow system can only increase the rate at which springs, streams, and wetlands disappear, groundwater tables fall, and phreatophyte communities fail. In fact, because "perennial yield" is really an estimate of the quantity of water in a groundwater flow system that is discharged from springs, streams, evapotranspiration, and interbasin flow, groundwater pumping in any amount reduces those discharges. This physical reality means that any mitigation proposal depending on groundwater pumping from deeper in the aquifer can, over the long term, only serve to exacerbate the problem allegedly being mitigated. **The EIS must acknowledge this physical reality specifically as it applies to proposed mitigation for the Shoshone ponds, and generally as it applies to other proposed mitigation activities. Pumping from deeper in the aquifer, over the long term, will exacerbate surface water supply problems in the aquifer! In other words, the proposed solution (mitigation) will make the problem worse!**

Section 3.7 (Aquatic Biological Resources) of the Clark, Lincoln, and White Pine Counties Groundwater Development Project DEIS completed by BLM is a thorough examination and evaluation of the probable effects of the proposed project on aquatic biological resources within the area of impact. The area of impact is defined by a regional groundwater model used for analysis of the project. The groundwater model used by BLM estimates impacts over a smaller geographic area than is estimated by other models that have been used to examine this problem (Elliott et al. 2006, Myers 2006, 2007, 2011a,b, Schaefer and Harrill 1995, and others). This suggests that the very serious impacts to Aquatic Biological Resources described in the DEIS may be considerably understated. **The EIS should address the issue of underestimating the geographic area over which impacts may occur.**

The effects of the project on Aquatic Biological Resources are controversial enough, and uncertain enough to anticipate a relatively high probability of litigation under provisions of the Endangered Species Act as a consequence of the proposed action. **The EIS should evaluate the consequences (i.e. construction delays, increased costs) of this kind of litigation, as well as the high probability that the proposed action and all the alternatives (including Alternative A) are likely to result in violations of Federal law (Endangered Species Act).**

The DEIS recommends using Alternative A (including the mitigation and monitoring identified in Chapter 2) as a starting point in reviewing the draft EIS. Alternative A proposes somewhat reduced groundwater pumping and a Monitoring, Management, and Mitigation process representing extensive and comprehensive efforts by SNWA and federal agencies to minimize environmental effects of the groundwater project. The DEIS and numerous other studies, analyses, and scientific papers (e.g. Bredehoeft and Durbin 2009, Deacon et al. 2007, Mayer and Congdon 2007, Patten et al. 2008, Walton 2011, and others) make it obvious that there will be far-reaching, permanent and extensive adverse effects to the Aquatic Biological Resources of the region. While the MMM effort is commendable and may temporarily reduce some impacts to the Aquatic Biological Resources of the region, it is clearly incapable of avoiding or mitigating unacceptable environmental consequences to these Resources. Principal reasons for this are as follows:

1. The MMM (Monitoring, Management, and Mitigation) program is structured so that an Executive Committee comprised of one manager from SNWA and one from each of the DOI (Department of Interior) Bureaus will have final decision-making authority.

This structure ensures that, over the long run decisions will be biased toward delivering water to Las Vegas. This is because the SNWA representatives' primary job responsibility is to deliver water to Las Vegas, while DOI Bureau managers have responsibilities to implement the policies of the federal administration for whom they work. One example of the sometimes contradictory effect of DOI Bureau managers attempting to discharge their primary responsibilities is that people holding these positions have, in the past, filed protests with the Nevada State Engineer against the SNWA applications for groundwater rights, and under a different federal administration, requested withdrawal of those same protests. **To even approach objectivity, the EIS must propose a different final decision-making system for the MMM program, or explain how this inherent structural bias toward delivering water to Las Vegas is to be balanced in a way that will not lead to increased jeopardy for Special Status species, increased probability that federal (ESA) and state (water law) laws and regulations will not be violated.**

2. The Stipulated Agreements governing the MMM program include the following provision: "Any commitment to funding by the DOI bureaus or the SNWA in the stipulation, including specifically any monitoring, management, and mitigation actions provided for in Exhibit A is subject to appropriations by Congress or the governing body of the SNWA as appropriate."

In the present (and long-term) political climate, funding from public sources is under extreme pressure. Long-term survival of the MMM program is therefore highly unlikely. The MMM program as described will, over the long term, make Aquatic Biological Resources in the area of impact increasingly dependent on continuation of the program, while the program itself becomes increasingly unlikely to exist. **The EIS must acknowledge that fact and explain how it is to be overcome.**

3. The MMM program, because of problems described as "Aquifer Response Time" (Walton 2011) or "time to full capture" (Bredehoeft and Durbin 2009), is capable of identifying groundwater supply problems that will get worse downstream in the groundwater flow system. It is not capable of preventing those problems from getting worse. **The EIS must explain how the MMM program can overcome this inherent problem stemming from the physics of how groundwater flow systems function.**

4. The Aquatic Biology MMM program focuses especially on Special Status Species and game species. This approach tends to overlook the numerous recently described species whose status has yet to be evaluated, as well as the numerous as yet undescribed species occurring in the area of impact. Because numerous new species have recently been described from the area of impact, and biodiversity in the area is poorly known, **the EIS must explain how the MMM program proposes to avoid loss of biodiversity of this large group of undescribed or uncategorized species.**

5. Shoshone Ponds in Spring Valley and Big Springs in Snake Valley are two habitats specifically identified as aquatic habitats likely to disappear as a consequence of the proposed action. Alternative A will not change that outcome. Mitigation measures suggested include the possibility of creating alternative or substitute aquatic habitats intended to replace those unavoidably lost, or maintaining the habitats by groundwater pumping from deeper in the aquifer. The latter strategy will simply exacerbate the long-term problem, as described above. Moving the habitat to an alternative, naturally maintained habitat could conceivably be considered appropriate for Shoshone Ponds (an artificial habitat intended to help maintain one or more specific Special Status species). It cannot be considered appropriate for any natural habitat such as Big Springs. This is because Big Springs presently supports a rich, largely natural biodiversity which includes Special Status species and probably includes some species as yet unrecognized, undescribed, or whose status has yet to be evaluated. The interactions and interdependencies helping to support those Special Status species and influencing the evolutionary trajectory of all species within that habitat are only incompletely known. At present it is inconceivable to even contemplate developing sufficient knowledge to permit construction of an artificial habitat that would come close to duplicating ecological conditions capable of supporting the biodiversity of any natural habitat/ecosystem. **The EIS must recognize this distinction between mitigation for artificial habitats and natural habitats, including recognition of the fact that replacement of natural habitats cannot be accomplished.**

To summarize, my principal objections to the Proposed Action are:

1. The adverse effects of the Proposed Action (dust, destruction/disappearance of phreatophyte communities, spring, stream, and wetland failure, land subsidence) will be borne disproportionately by residents of eastern and central Nevada and western Utah, while the principle benefits (economic growth) will accrue predominantly to the residents of Southern Nevada. (Provided the boom and bust cycle facilitated by the water importation scheme doesn't completely wipe out the benefits from economic growth.)

2. Some proposed mitigation measures (i.e. pumping from deeper in the aquifer) will, over the long term, exacerbate problems allegedly being mitigated.

3. The regional groundwater model used in the analysis of probable impacts suggests adverse impacts over a smaller geographical area than is indicated by several other recent, credible groundwater models. Yet that fact is not acknowledged in the DEIS.

4. The Proposed Action and Alternative A will produce severe environmental consequences likely to include violations of Federal and State law, as well as violation of the BLM obligation to serve its public trust responsibilities.

5. The final decision-making authority for the MMM program (the Executive Committee) is structured with a bias toward delivering water to Las Vegas.

6. Reliance on congressional appropriation or funding from SNWA to maintain the MMM program virtually guarantees a short lifespan for the program. The consequence will be to make biodiversity in the area increasingly dependent on a program increasingly likely to be eliminated.

7. Aquifer Response Time, or Time to Full Capture permit a monitoring program to identify problems in an aquifer likely to get worse. Once identified however, there is no way to reverse the situation.

8. Desiccation of surface water habitats will destroy all species dependent on those habitats. In the area of probable impact this will include not only the special status species, but also the many undescribed or unrecognized species. No mitigation program can compensate for this loss.

9. Natural habitats cannot be replaced.

10. The No Action alternative is the only one that would permit BLM to conform to its mission: "to sustain the health diversity and productivity of the public lands for the use and enjoyment of present and future generations." The Proposed Action will inevitably result in harmful irreversible and irretrievable impacts on public lands and resources.

11. Total project costs and sources of funding are not described.

12. An honest analysis of the purpose and need for the project (growth and development in Las Vegas) is not described.

13. The effect of a reduction in precipitation over the next hundred years as a consequence of climate change is not evaluated.

14. Approval of any alternative other than "No Action" will conflict with BLM's duties under NEPA and FLPMA.

15. Predicted land subsidence, desiccation of surface water habitats (springs, streams, wetlands), destruction of phreatophyte communities, increased atmospheric dust, adverse impacts on wildlife, encroachment on existing water rights, and devastating consequences to human and natural systems demand a recommendation for the "No Action" alternative.

16. The proposed MMM program will exacerbate some problems it claims to mitigate, identify some problems that can only get worse, establish a system biased toward delivering water to Las Vegas, and increase dependence of biodiversity on a human-dependent program increasingly likely to disappear over time.

17. Effects of a decline in the water table of less than 10 feet, while potentially substantial, are largely ignored.

18. The timeframe analyzed extends only 200 years into the future, while the effects will be felt throughout the life of the project -- which may extend much longer than 200 years.

19. Groundwater mining is supposedly illegal in Nevada, a major effect of the proposed project is likely to be another boom and bust cycle in Las Vegas.

20. There is no doubt about the far-reaching, extensive, irreversible and irretrievable environmental damage the project would cause.

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White Pine County Exhibit R

Probable Effects of Proposed Groundwater Pumping by Southern Nevada Water Authority in Spring, Cave, Dry Lake and Delamar Valleys, Nevada on Spring and Wetland-Dependent Biota.

June 29, 2011

Prepared for the Office of the Nevada State Engineer
on behalf of
Great Basin Water Network

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James E. Deacon, Ph.D.
Distinguished Professor Emeritus
Departments of Environmental Studies and Biology
University of Nevada Las Vegas

June 29, 2011

Probable Effects of Proposed Groundwater Pumping by Southern Nevada Water Authority in Spring, Cave, Dry Lake and Delamar Valleys, Nevada on Spring and Wetland Dependent Biota.

June 29, 2011

Prepared by
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Distinguished Professor Emeritus
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The probable hydrologic consequences of approving the Southern Nevada Water Authority's ("SNWA's") groundwater applications in Spring Valley and in Cave, Dry Lake, and Delamar Valleys have been examined and modeled by Myers (2006, 2007). I provided my expert opinion of the probable effects of SNWA's proposed groundwater development on native fish, snails, and some other wetland dependent biota in the affected area in my reports for the State Engineer's previous hearings on these applications. (Deacon 2006, 2007), and am updating my opinion, on the basis of those analyses, my own research, a review of the literature, materials admitted in the Nevada State Engineer's previous hearings on these applications, and an evaluation of information contained in the following numbered U.S. Fish and Wildlife Service exhibits submitted to the Nevada State Engineer prior to the Spring Valley water rights hearings: FWS 2035, 2036, 2037, 2038, 2039, 2042, 2043, 2044, 2046, 2047, 2048, 2049, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2098.

Myers has considerably amplified his analyses in subsequent studies (Myers 2011) and the BLM's Draft Environmental Impact Statement (DEIS) for SNWA's groundwater development and pipeline project contains additional analysis showing broadly similar hydrologic impacts of SNWA's proposed pumping in these valleys (BLM 2011). The conclusions and expert opinions in my 2006 and 2007 evidentiary reports, and in my verbal testimony before the Nevada State Engineer during the two previous hearings, have been reinforced by these more recent hydrologic analyses. So, those conclusions and expert opinions remain pertinent and valid, and are intended to be a part of my testimony for consideration by the Nevada State Engineer in this rehearing of the SNWA applications for water rights in Spring, Cave, Dry Lake, and Delamar Valleys. This report offers additional perspective in light of Myers' and the BLM's more recent analyses.

Myers (2011) concluded that approval of SNWA's groundwater applications in Spring Valley would substantially lower the groundwater table in Spring and Hamlin Valleys, dry springs and wetlands throughout Spring Valley, decrease interbasin flow to Snake and Tippet Valleys, and draw substantial amounts of groundwater from Steptoe Valley. The groundwater system would not come to equilibrium for thousands of years regardless of whether pumping occurred for the full application amount or was reduced to less than one third of that amount, and also regardless of whether pumping was from the locations identified in the applications or from locations more

evenly distributed throughout Spring Valley. In Snake Valley, flow from Big Spring would be reduced by up to a third, and require a long time to recover following cessation of pumping.

Deacon (2006, Table 1) identified fish and snail species from Spring and Snake Valleys potentially susceptible to adverse effects from the proposed SNWA groundwater development project. Myers' (2011) analysis shows that most spring and wetland habitats for species listed in Table 1 (Deacon 2006) are likely to dry. Populations dependent on those habitats would therefore disappear. In addition, the substantial amounts of groundwater drawn from Steptoe Valley would place some populations of the endemic relict dace (*Relictus solitarius*) in jeopardy. The relict dace, a genus endemic to only four valleys in central Nevada, is listed in the Nevada Natural Heritage Database as globally imperiled, and by the U.S. Fish and Wildlife Service as a species of concern.

Myers (2011) further concluded that approval and utilization of the SNWA groundwater applications in Cave, Dry Lake and Delamar Valleys would result in a rapid decline and, following cessation of pumping, a slow recovery of discharge from regional springs in the White River Flow System. Lag time for recovery of spring discharge would generally be more than twice the pumping time. Regional springs showing a decline or cessation of flow include those in White River Valley, Pahranagat Valley, Muddy River headwaters springs, some springs in Railroad Valley and Panaca Warm Spring. Approval and utilization of the SNWA applications, along with continued utilization of existing water rights would cause flow in the White River Flow System to cease.

Myers (2011) more recent analysis of the effect of the SNWA groundwater applications in Cave, Dry Lake and Delamar Valleys on the regional aquifer supports generalizations made in his earlier analysis (Myers 2007). This in turn supports the conclusions in my earlier report (Deacon 2007) that approval of the SNWA applications would result in adverse effects to the wetland dependent biota in portions of Railroad Valley, most of White River Valley, Pahranagat Valley, the Muddy River, Panaca Warm Spring, and Meadow Valley Wash. These adverse effects would also extend westward where they would be amplified by additional SNWA groundwater development projects in Three Lakes Valley, Tikapoo Valley, and Indian Springs Valley. With this amplification, measurable adverse effects to spring and wetland dependent biota would extend to Ash Meadows.

Deacon (2007) identified 157 endemic wetland species (20 listed by USFWS as endangered or threatened) likely to be adversely affected by the reduced spring discharge and wetland area caused by the proposed SNWA groundwater project. Principal mechanisms by which diminished spring flow would adversely affect spring and wetland dependent species were described (Deacon 2007). Table 2 of that report identified five bird and one mammal species also likely to be adversely affected by the reduced wetland area that would result from approval by the Nevada State Engineer of the SNWA groundwater applications. All six of these species are protected under NRS § 501 and are listed in the Nevada Natural Heritage Database. Four of them are listed under provisions of the Federal Endangered Species Act. Subsequent to my 2007 testimony, the Center for Biological Diversity submitted a formal petition to the U.S. Fish and Wildlife Service to list 42 species of springsnails under provisions of the Endangered Species Act (CBD 2009). The principal reason for the requested listing was the habitat loss and degradation that would

result from the proposed SNWA groundwater development project. Many of the species in the petition were also listed by Deacon (2007).

The effects on surface water habitats of the SNWA groundwater applications in Spring Valley, and in Cave, Dry Lake and Delamar Valleys described by Myers (2011) are supported by groundwater modeling done by BLM for its DEIS (BLM 2011). For example, the following statements are found in the Executive Summary:

"Game fish, native fish, special status species and other aquatic species would be adversely affected by flow reduction." DEIS at page 57.

"Pumping by alternatives could adversely affect two federally listed fish (Pahrump poolfish and White River spinedace), northern leopard frog, and special status fish and invertebrate species (springsnails and freshwater mussel, California floater). Pumping by all alternatives would conflict with recovery or conservation management objectives for the two federally listed species, northern leopard frog, and Bonneville cutthroat trout." DEIS at page 58.

“Pumping by all alternatives could adversely affect three federally listed birds (southwestern willow flycatcher and yellow-billed cuckoo), greater sage-grouse (federal candidate), and other special status bird and bat species, pygmy rabbit, and invertebrates. Pumping by all alternatives could conflict with recovery or conservation management objectives for the federally listed species…..Water level reductions in the Baking Powder Flat, Shoshone Ponds, and Lower Meadow Valley Wash Area of Critical Environmental Concern could adversely affect the resources being protected by the Area of Critical Environmental Concern designation and potentially compromise the objective of the designation.” DEIS at page 59.

“All of the groundwater development alternatives are expected to result in substantial reduction in flow (or potentially eliminate discharge) at Big Springs (Figure ES-42). Reductions of flow at Big Springs would reduce flows in Big Springs Creek, and reduce flows to Lake Creek and into Pruess Lake.” DEIS at page 68.

Monitoring, Management, and Mitigation

During my testimony at the February 4-15, 2008 SNWA water rights hearing for Cave, Dry Lake, and Delamar Valleys, I noted that the stipulated agreements between SNWA, U.S. Fish and Wildlife Service and other federal agencies established cooperative Monitoring, Management and Mitigation programs unlikely to prevent loss of biodiversity in areas affected by the SNWA groundwater project. This is true because the agreements are structured so that final or controversial decisions are to be made by management personnel (at both SNWA and the federal agencies), not by scientific personnel. Management personnel are employed to implement the policies of their employer, not primarily to protect the interests of biodiversity. (For example, primary responsibilities for SNWA management people are to deliver water to Southern Nevada and federal agency managers are responsible for implementing the policies of the federal administration in charge at any one particular time.)

Following the Cave, Dry Lake, and Delamar Valley hearing, a second major problem demonstrating that the Monitoring, Management and Mitigation programs cannot succeed in the

long run has been identified and analyzed, initially by Bredehoeft and Durbin (2009), and more recently by Walton (2011). Bredehoeft and Durbin (2009) call it the "Time to Full Capture Problem," and Walton (2011) refers to it as the "response time." This problem, a consequence of the physics controlling function of groundwater aquifers, demonstrates that monitoring as described in the stipulated agreements and in the BLM DEIS, can identify problems for surface waters that will only get worse before they can get better. That will mean a long-term declining biodiversity in those habitats as a consequence of the mechanisms described in Deacon (2007).

Conclusions:

Aquatic dependent species occupying surface water habitats in Spring and southern Snake Valleys will be adversely affected or eliminated if groundwater development of the magnitude requested by SNWA is permitted. Indeed these results can be expected from as little as one third of the magnitude requested, regardless of whether the pumping is evenly distributed or located as proposed by SNWA.

Aquatic dependent species occupying surface water habitats in White River Valley, Pahranagat Valley, headwaters springs and streams of the Muddy River, Panaca Warm Springs, some springs in Eastern Railroad Valley, some springs in Steptoe Valley, and springs and streams in the Ash Meadows National Wildlife Refuge will experience population decline or extinction. Indeed, all spring and wetland dependent species native to the areas mentioned above will experience decline or extinction.

The proposed SNWA groundwater project will increase risk to survival of at least 20 threatened or endangered species listed under the Endangered Species Act, 42 species of springsnails that have been petitioned for listing under the Endangered Species Act, and 157 species listed in the Nevada Natural Heritage Database. In other words, permitting as little as a third of the amount of groundwater pumping for which SNWA has applied would result in widespread environmental damage in both the four targeted valleys and in downgradient valleys within hydrologically connected interbasin flow systems.

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White Pine County Exhibit S

Probable Effects of Proposed Groundwater Pumping by Southern Nevada Water Authority in Spring, Cave, Dry Lake and Delamar Valleys, Nevada on Spring and Wetland-Dependent Biota.

Rebuttal to Southern Nevada Water Authority July 1, 2011 Evidentiary Submission

August 24, 2011

Prepared for the Office of the Nevada State Engineer
on behalf of
Great Basin Water Network

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James E. Deacon, Ph.D.
Distinguished Professor Emeritus
Departments of Environmental Studies and Biology
University of Nevada Las Vegas

INTRODUCTORY SUMMARY

Groundwater modeling submitted in evidence by GBWN (Myers 2011, GBWN Exhibits 001 through 005, and Bredehoeft 2011, GBWN Exhibit 009) demonstrate that the proposed SNWA Groundwater Development Project will result in extensive decline of groundwater level, spring discharge, and wetland area over a broad area of Eastern, Central, and Southern Nevada. BLM (2011) reaches a similar conclusion in their DEIS of the environmental effects of construction and operation of the SNWA Groundwater Development Project.

The SNWA (Exhibits 147 - 151, 363, 365-369), in defense of the Project, asserts that encroachment on pre-existing water rights and/or "unreasonable" adverse environmental effects to “Water-dependent Ecosystems” resulting from declining water tables, spring discharge, streamflow, and wetland area can be managed by modifying location and depth of groundwater wells, quantities of water withdrawn by each well, and/or management of biological resources, aquifer recharge, or by other means. They also argue that a comprehensive monitoring program will provide adequate information to guide a management program intended to avoid foreseeable environmental damage. Furthermore, if management of biological resources, or of the location, depth, and/or quantity of groundwater withdrawal or aquifer recharge does not prevent "unreasonable" environmental damage or violation of pre-existing water rights, mitigation measures will be adequate to compensate for the damage or violation.

Monitoring, Management, and Mitigation requirements, standards and “common goals” are defined in Stipulated Agreements (Exhibits SE_041, SE_080), and Monitoring Management and Mitigation Plans (Exhibits SNWA 365,366) negotiated between SNWA and agencies of the Department of Interior. In general, "unreasonable" adverse environmental effects are defined as more than a 50 foot decline of the water table, or a 15% decline in spring discharge (SNWA Exhibits 147 - 151, 363, 364-369). Mitigation is required if these “evaluation criteria” are exceeded as a consequence of SNWA groundwater pumping.

REBUTTAL

Stipulated Agreements (SE_Exh_041, SE_Exh_080):

Executive Committee: Stipulated Agreements provide for final decision-making by an Executive Committee (“…one manager from SNWA and one from each of the DOI Bureaus…”). In my evidentiary statement (June 29, 2011, GBWN Exhibit 014) I pointed out that, "because the agreements are structured so that final or controversial decisions are to be made by management personnel... not by scientific personnel," the long-term result will be decisions biased toward delivering water to Las Vegas, but only intermittently supportive of maintenance of aquatic habitats. Individuals occupying all of the Federal management positions represented on the Executive Committee have already demonstrated that bias. They signed and filed protests to the SNWA groundwater rights applications in Spring, Cave, Dry Lake, and Delamar Valleys, and

then later under a different Federal administration withdrew those same protests. This was done even though the following statements from their scientific personnel had been submitted as evidence in support of the protests:

- FWS exhibit 501 recommended “denial of applications for Dry Lake and Delamar Valleys,”
- FWS exhibit 598 noted the existence of 6 globally critically imperiled, 1 globally imperiled, and 1 endemic springsnail species in project basins and adjacent, down-gradient basins, the scientist pointed out that the "U. S. Fish and Wildlife Service, U. S. Bureau of Land Management, National Park Service, U. S. Forest Service, Smithsonian Institution, and The Nature Conservancy signed a Memorandum of Understanding (MOU) that formally recognized the importance of conserving the springsnail fauna of the Great Basin,"
- FWS exhibit 559 states that “any alteration to its water sources would affect every aspect of the Refuge's [Pahranagat National Wildlife Refuge] ability to support life,” and
- FWS exhibit 609 states "In conclusion, alteration and reduction of habitat has already caused unforeseen extinction and endangerment of endemic fishes along the course of the Pluvial White River. Further habitat reduction would be expected to cause more extinctions and loss of Nevada's unique fish fauna."

It is also important to note that protests to the SNWA applications for water rights by agency managers (who in the future will be serving on the Executive Committee) were withdrawn in spite of the fact that all of the fish species referred to in FWS Exhibit 609 are extinct, listed as endangered, or have been considered for listing. In addition, Deacon et al., appendix I (2007) identified 20 endangered or threatened wetland-dependent species (11 of them on Specially Designated Federal Lands) and an additional 137 spring-dependent species occurring in the area likely to be adversely affected by the groundwater project. CDD Exhibit 1140.

The above facts leave no doubt but that approval of the SNWA applications for groundwater rights in Spring, Cave, Dry Lake, and Delamar Valleys will lead to loss of springs, streams, wetlands (required habitat for federally listed species), and population reductions of federally listed species, as well as damage to public interest values specifically listed below in the Monitoring, Management, and Mitigation section of this report.

Funding: SE_Exh_041 and SE_Exh_080 (page 9, number 15) state: “Any commitment to funding by the DOI bureaus or the SNWA in the stipulation, including specifically any monitoring, management, and mitigation actions provided for in Exhibit A is subject to appropriations by Congress or the governing body of the SNWA as appropriate.”

This provision virtually guarantees a very short life span for the Monitoring, Management, and Mitigation program. Public funding for any program is notoriously

short-term. The consequence is that the program cannot possibly achieve the "common goals" to which it aspires, nor prevent "unreasonable" environmental damage.

Monitoring, Management, and Mitigation (SNWA_Exh_365 and SNWA_Exh_366):

The Monitoring, Management and Mitigation Program as described in the Stipulated Agreements will not accomplish the "common goals," nor prevent “unreasonable” environmental damage, nor will it protect most public interests in the water or the habitats they support. Under some specialized circumstances the Program may protect some Special Status Species (i.e. such as those currently living in artificial habitats), and some other narrowly defined Federal or non-federal public interests (i.e. such as delivery of water for consumptive use to public facilities) or some Private interests. Public and private interests in ecosystem services are either not protected, or are insufficiently protected. These interests include such things such as water and habitats that support wildlife, recreation, hunting and fishing, rural lifestyles, future opportunity for rural Nevadans, agriculture, domestic animals, scientific discovery, nutrient cycling, biodiversity, state and federal wildlife management areas, state and federal refuges, migratory birds, etc. The focus on “unreasonable,” “evaluation criteria,” “common goals,” and “Special Status Species,” permits the habitat with its complex physical, chemical, and biological interactions and relationships essential for maintenance of functioning, healthy ecosystems to be discounted or ignored.

Monitoring:
Monitoring is structured primarily to provide information about declining groundwater tables and declining spring discharge, streamflow, or wetland area that may affect Federal interests. This focus, while appropriate for some spring, stream, or wetland-dependent federal, non-federal, and private interests such as Special Status Species, will not prevent or minimize damage to private and/or public interests other than presently recognized Federal ones. In fact, even many Federal interests are left in jeopardy by the Monitoring, Management, and Mitigation Programs because of the “time to full capture” and/or the “response time” problems described respectively by Bredehoeft and Durbin (2009) and Walton (2011). Monitoring of surface water habitats (springs, streams, and wetlands), and the Special Status Species they support may identify problems that will become worse with time as the cone of depression expands. This is true because even complete cessation of groundwater pumping cannot reverse the consequences of groundwater withdrawal. The result is that, by the time a groundwater supply problem is identified for a Wetland-dependent Ecosystem, increasingly dire problems cannot be prevented. For example, Myers’ (2011) groundwater model suggests that, if groundwater pumping in Spring Valley is stopped entirely after 200 years of pumping at rates for which SNWA has applied, spring discharge at Big Spring in Snake Valley will continue to decline for an additional approximately 150 years.

Monitoring of Special Status Species will not identify undescribed, undesignated, or unknown species. It is virtually certain that many undescribed wetland-dependent species exist in the area of probable impact. For example: A previously unknown and still undescribed sculpin (White River sculpin) exists in the upper few meters of

Sunnyside Creek in White River Valley (e-mail from Gayton Scoppettone, US Fish and Wildlife Service, Reno, June 20, 2011), four new species of cave-adapted invertebrates have been described from Great Basin National Park since 2007 (Taylor and Holsinger 2011), Herschler (1998) described 58 new, previously unknown species of springsnails from the Great Basin, a recent scientific paper describes the high probability that many new species of amphipods will be recognized throughout the Great Basin in coming years (Witt et al. 2006).

Management:
When management is required because of a predictable impact to Wetland-dependent Ecosystems or Special Status Species, correcting the threat can only be successful if habitat size, spring discharge, streamflow, wetland area, wetted perimeter, exotic species, and other microhabitat characteristics can be stabilized or reversed. The long response times referred to above therefore doom most management efforts.

The very specific microhabitat requirements characteristic of springsnails (Ponder et al. 1989, O'Brian and Blinn 1999, Mlandeka and Minshall 2001, Sada 2008), dependence of endemic fish species in Ash Meadows, and in White River, Pahranagat, and Moapa Valleys on volume of flow for foraging success (Scoppetone et al. 1992), their narrow range of temperature tolerance with attendant susceptibility to waters that cool more rapidly as flows diminish (Scoppetone et al. 1992, Scoppetone and Rissler 2002), their susceptibility to introduced species (Minckley and Deacon 1968), severe recent restriction and therefore disconnection of habitats (Scoppetone et al. 2004), indicates low probability of predictable response by springsnails or fish to management actions. While other groups have not been examined as thoroughly, there is no reason to suspect this is a unique characteristic of springsnails or endemic fish.

Mitigation:
Mitigation or mitigation banking is triggered if management is inadequate to solve the problem identified by the monitoring program. Mitigation requirements include measures "designed and calculated to... repair or replace... Water Dependent Ecosystems... to achieve the Common Goals..." (SNWA Exhibit 363). "Replace" as used here makes it obvious that Common Goals can be considered met by building artificial habitats. This is specifically suggested for Shoshone Ponds in SNWA Exhibit 363 (page 8-2). Under certain specialized circumstances, this may be a valid option (i.e. for some Special Status Species currently living in artificial habitats). However, natural ecosystems cannot be "replaced" because all components and interactions of any given ecosystem are not known and therefore cannot be duplicated in other artificial or natural habitats.

Habitats not containing Special Status Species or natural habitats supporting biodiversity that may yet be unknown, undescribed, or undesignated are even more likely to be considered expendable or candidates for "mitigation" by creating artificial aquatic habitats. For those species, "mitigation" is equivalent to extinction because maintenance of intact ecosystems is impossible if the habitat supporting those ecosystems no longer exists. Furthermore, unknown species, precisely because they

are unknown are not likely to be moved. Undescribed or undesignated species may or may not be moved and are unlikely to be “Special Status Species.”

These facts ensure that mitigation and mitigation banking will, except for a few specialized circumstances, produce results not in the “public interest.”

CONCLUSIONS

1. Stipulated Agreements and the Monitoring, Management, and Mitigation Programs established by them will not protect the "public interest," accomplish the "common goals," or avoid "unreasonable" adverse environmental effects of proposed groundwater pumping by SNWA in Spring, Cave, Dry Lake, and Delamar Valleys.
2. The Executive Committee, as defined in Stipulated Agreements, assures that long-term decision-making will be biased toward water delivery to Clark County and against maintenance of biodiversity and surface water habitats with their attendant public interests and water rights.
3. “Unreasonable” environmental damage and most public interests are not protected by the Stipulated Agreements or the Monitoring, Management and Mitigation Program.
4. The Executive Committee over the long term will make decisions biased toward delivering water to Las Vegas and against protecting the public interest.
5. Springs, streams, and wetlands in the area affected will decline to the detriment of the public interest values they serve.
6. Dependence of the Monitoring, Management and Mitigation Program on federal appropriations or SNWA funding guarantees a short life span of a program presented as a long-term, sustainable program.
7. Some Special Status Species and some Federal, Private, non-federal public and private interests can be protected by the Monitoring, Management, and Mitigation Program.
8. Most public and private interests in ecosystem services such as wildlife, recreation, hunting and fishing, rural lifestyles, future opportunity for rural Nevadans, agriculture, domestic animals, scientific discovery, nutrient cycling, biodiversity, state and federal wildlife management areas, state and federal refuges, migratory birds, etc. will not be protected.
9. Because aquifer response time ("time to full capture" or "response time") is a fact, hydrologic monitoring will be capable of identifying surface water ecosystem issues (involving either Special Status Species or groundwater dependent ecosystems) that, after cessation of pumping, can only get worse before they improve.
10. The Monitoring program will not be able to monitor unknown components of the habitat.

11. The unique characteristics of wetland dependent ecosystems and specificity of microhabitat requirements of species dependent on them, severely restricts the likely success of the management program.
12. Heavy dependence of the mitigation program on "replacement" of water dependent ecosystems is not an appropriate, effective, or satisfactory response to the problem. Natural ecosystems cannot be replaced because all of their components and interactions are not known. It may be appropriate to substitute one artificial habitat for another.

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White Pine County Exhibit T

Fueling Population Growth in Las Vegas: How Large-scale Groundwater Withdrawal Could Burn Regional Biodiversity

JAMES E. DEACON, AUSTIN E. WILLIAMS, CINDY DEACON WILLIAMS, AND JACK E. WILLIAMS

Explosive growth in Las Vegas, Nevada, has stimulated demand for additional water supplies. To meet these needs, local officials hope to obtain rights to about 200,000 acre-feet (246.70 million cubic meters [m^3]) per year from a regional groundwater aquifer extending from Salt Lake City, Utah, to Death Valley, California. Officials from satellite communities are pursuing rights to an additional 870,487 acre-feet (1.07 billion m^3) per year. If granted, these new permits would trigger declines in groundwater across at least 78 basins covering nearly 130,000 square kilometers. Water-rights decisions have historically interpreted economic development as a more compelling public interest than maintenance of natural systems. If economic development continues to drive allocation decisions, consequent declines in the water table, spring discharge, wetland area, and streamflow will adversely affect 20 federally listed species, 137 other water-dependent endemic species, and thousands of rural domestic and agricultural water users in the region. Reducing consumption and implementing cost-effective technologies, such as recovery of urban runoff and shallow saline groundwater, indirect reuse of potable water, and desalinization, offer ways to meet metropolitan and ecological needs within the limits of the resource.

Keywords: groundwater, water rights, public trust, endangered species, ecological integrity

Some of the most rapid population growth in the United States is occurring in intermountain western and southwestern urban areas, where water is in short supply and aquatic ecosystems are stressed (Naiman and Turner 2000, Fitzhugh and Richter 2004). As a result, municipal water consumption is on the rise, and water from rural areas is being shifted toward municipal uses. Competition for water is felt keenly in southern Nevada, where water is scarce, human population growth is explosive, and conflicts over biodiversity and the human need for water have a long and litigious history.

With an annual growth rate of 5.5 percent and a population exceeding 1.8 million, Las Vegas, Nevada, is among the fastest-growing metropolitan areas in the nation. After use of local groundwater produced up to 2 meters (m) of land subsidence and a 91-m decline in the water table in parts of the metropolitan area (Burbey 1995), the community became dependent primarily on the now drought-stricken Colorado River as its major source of fresh water. Water demand has reached the limits of the current supply, exacerbated by daily per capita consumption that ranks among the nation's highest (both in terms of single-family consumption, at 660 liters [L] per person per day, and of total systemwide consumption, at 971 L per person per day; Western Resource Advocates 2006).

The Southern Nevada Water Authority (SNWA) is pursuing a multipronged approach to meet the growing municipal water demand (SNWA 2005). As a stopgap measure, in 2004 the SNWA purchased 1.25 million acre-feet (1.54 billion m^3) of Colorado River water from Arizona to be delivered over the next 15 years. The SNWA has advocated vigorously for new operating rules, currently under review by the secretary of the Department of the Interior, to be used during severe drought conditions on the Colorado River. The SNWA also plans to

James E. Deacon is an emeritus professor in the Departments of Environmental Studies and Biological Sciences, University of Nevada, Las Vegas, NV 89154. Austin E. Williams is a student at the School of Law, University of Oregon, Eugene, OR 97403. Cindy Deacon Williams is director of the Aquatic Science and Education Programs at the National Center for Conservation Science and Policy, Ashland, OR 97520. Jack E. Williams (e-mail: jwilliams@tu.org) is chief scientist for Trout Unlimited, Medford, OR 97504. *© 2007 American Institute of Biological Sciences.*

tap a regional deep carbonate aquifer extending across central and southern Nevada from Utah to California (SNWA 2004), a tactic simultaneously being pursued by other Nevada counties (e.g., Lincoln, Nye, and White Pine).

Great Basin spring systems, although small and isolated, harbor a large proportion of the region's biodiversity and have received significant conservation attention (Deacon and Minckley 1991, Sada and Vinyard 2002). Twenty species and subspecies listed under the federal Endangered Species Act (ESA) depend on springs, spring-fed wetlands, and streams in the 78-basin area most likely to be affected by the proposed SNWA groundwater withdrawals (table 1). Many listed taxa are "umbrella species" that provide protection to little-known, nonlisted sympatric species, including at least 137 spring-dependent animal taxa—primarily locally endemic aquatic springsnails, insects, and fishes. The Nevada Natural Heritage Program (2005) identifies 347 sensitive taxa within the area.

Our purpose here is to critically examine the SNWA proposals for large-scale groundwater withdrawal, evaluate their potential impacts on aquatic biodiversity, and evaluate whether Nevada water law can avoid decisions that are detrimental to the public interest. The literature demonstrates that deep carbonate and shallow basin-fill aquifers are interconnected across the various basins likely to be affected by groundwater withdrawal, and that the approval of the SNWA applications for water rights is likely to reduce or eliminate many spring and wetland communities in the region, with consequent adverse impacts on the rich diversity of spring- and wetland-dependent endemic species. We contend that large-scale groundwater withdrawal in Nevada, the most arid state in the United States, poses a major underappreciated threat to biodiversity.

The groundwater flow system

Carbonate rocks, deposited in a shallow sea during the Paleozoic, underlie a 259,000-square-kilometer (km^2) carbonate-rock province in the eastern two-thirds of the Great Basin (Fiero 1986). During the late Mesozoic, compression, uplift, and low-angle thrust faulting deformed this carbonate layer. East–west extension in the mid-Tertiary thinned the carbonate section, caused block faulting, and gave rise to the north–south orientation of mountain ranges characteristic of the basin and range. Later, predominantly northeast–southwest-oriented fractures and joints formed throughout the brittle limestone and dolomite deposits (Winograd and Thordarson 1975).

Although much of the original 12-km-thick carbonate layer in Nevada has become deformed, dismembered, and thinned, there remains a 110- to 160-km-wide central corridor of contiguous carbonate rocks, typified by an extensive interconnected subterranean fracture network extending 1 to 1.5 km or more below land surface. This corridor integrates a regional-scale drainage network extending from near the Utah–Nevada border through southern Nevada's Spring Mountains and into California, and is capable of transporting large volumes of water (Riggs et al. 1994).

Table 1. Native spring-dwelling and riparian species known from the area of projected groundwater decline in Lincoln, Clark, White Pine, Nye, and eastern Esmeralda counties, Nevada; eastern portions of Inyo and San Bernardino counties, California; western portions of Washington, Iron, Beaver, Millard, and Juab counties, Utah; and northwestern Mohave County, Arizona.

Taxon	Endangered species/ subspecies	Threatened species/ subspecies	Other species/ subspecies
Mammals	1	0	2
Birds	2	0	1
Fishes	11	2	31
Amphibians	0	0	4
Aquatic insects	0	1	50
Springsnails	0	0	49
Plants	1	2	NA
Total	15	5	137

NA, not available.

Note: Species and subspecies listed as endangered or threatened include the following: mammals, *Microtus californicus scirpensis;* birds, *Empidonax trailii extrimus* and *Rallus longirostris yumanensis;* fishes, *Plagopterus argentissimus, Gila seminuda, Rhinichthys osculus nevadensis, Moapa coriacea, Empetrichthys latos, Cyprinodon nevadensis mionectes, C. nevadensis pectoralis, Cyprinodon diabolis, Lepidomeda mollispinis pratensis, Lepidomeda albivallis, Crenichthys baileyi grandis, Cr. baileyi baileyi,* and *Crenichthys nevadae;* insects, *Ambrysus amargosus;* plants, *Centarium namophilum, Ivesia kingii* var. *eremica,* and *Nitrophila mohavensis.* A complete species listing is available from the authors.

Groundwater typically flows from high-elevation montane recharge areas to discharge areas in basin-fill sediments of valley lowlands. Flow occurs at various scales, resulting in the superimposition of numerous relatively shallow, localized basin-fill aquifers on the regionally integrated deep carbonate aquifer. Because of the fractured nature of the underlying carbonate rocks, water carried in the deep aquifer may originate from all elevations throughout the central corridor. Regardless, shallow aquifers discharge primarily by means of evapotranspiration and through local springs, whereas deep aquifers discharge mostly at regional warm springs (Prudic et al. 1995).

Regional springs in the 78 basins we examined are the primary natural discharge points from eight major groundwater flow systems (figure 1). Springs from Preston Big Spring southward to Ash Spring are supplied principally from montane recharge areas in east-central Nevada at the top of the regional drainage net. Muddy River springs are supplied principally from the north through the central corridor, but also may receive some recharge from nearby Sheep Mountains. Ash Meadows springs are supplied predominantly from recharge areas on the northern and northeastern slopes of the nearby Spring Mountains but, along with springs on the eastern side of Death Valley, are partially dependent on regional groundwater movement from the north-northeast through the central corridor (Dettinger et al. 1995). Las Vegas Valley and Pahrump Valley receive most of their groundwater from recharge in southern Nevada's Spring Mountains.

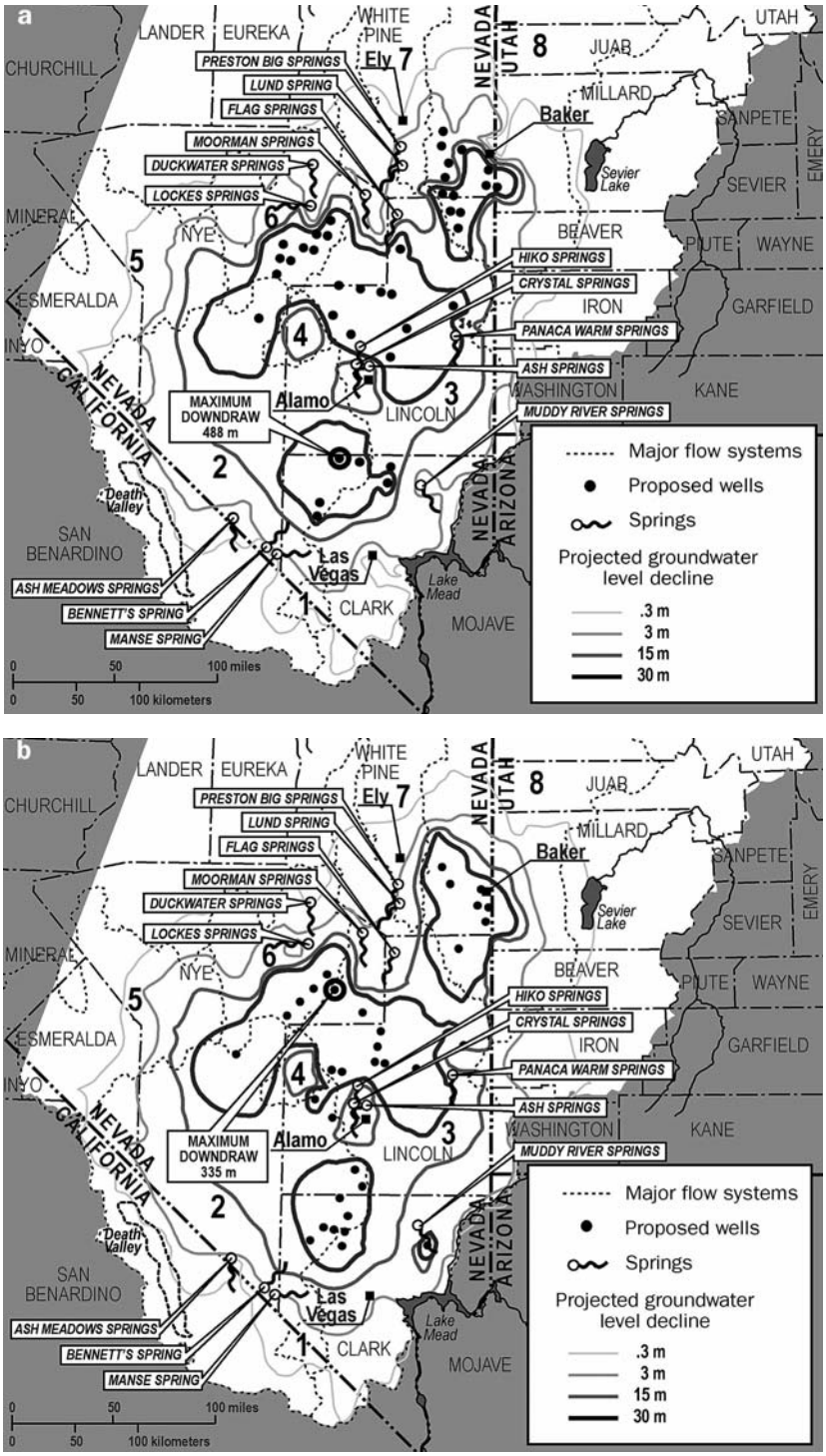

Figure 1. Simulated final steady-state groundwater level in (a) valley-fill and (b) deep carbonate aquifers in eight major flow systems of Nevada, Utah, and California, projected to occur as a consequence of pumping 180,800 acre-feet (223.01 million cubic meters) per year of water from specific well locations in specific quantities as proposed by the Southern Nevada Water Authority (SNWA). This simulation assumes no groundwater removal other than the 180,800 acre-feet (223.01 million cubic meters) per year projected to be pumped by the SNWA from 17 basins of east-central and southern Nevada. The eight major groundwater flow systems affected are numbered as follows: 1, Mesquite Valley; 2, Death Valley Flow System; 3, Colorado Flow System; 4, Penoyer Valley; 5, South-central Marshes Flow System; 6, Railroad Valley Flow System; 7, Goshute Valley Flow System; and 8, Great Salt Lake Desert Flow System. Modified from Schaefer and Harrill (1995) and Harrill and Prudic (1998).

The estimated annual groundwater recharge to the eight flow systems is about 900,000 acre-feet (1.11 billion m^3) per year (Harrill and Prudic 1998), with about 80 percent of that recharge attributable to the 78 basins we examined (table 2). Subsurface movement of water from one flow system to another supplements groundwater recharge from local sources. For example, approximately 21,000 acre-feet (25.90 million m^3) of water per year, principally from the White River flow system (a northern subdivision of the Colorado River flow system), supplements groundwater in the Death Valley flow system (Dettinger 1989). Because there is equilibrium between aquifer recharge and natural discharge, wells continuously extracting any part of the annual recharge virtually guarantee equivalent reductions in natural discharge (Dettinger et al. 1995).

Spring systems and groundwater withdrawal

The large number of endemic species occurring at regional springs in the carbonate-rock province is due in no small part to the reliability, consistency, and predictability of these wetland and aquatic habitats over millions of years. The springs in Ash Meadows, for example, have been major discharge points from the deep aquifer for the past two million to three million years, although three million years ago those springs were more widespread and discharge was greater than at present (Hay et al. 1986).

Climatic variation produced changes in groundwater levels in Ash Meadows over the past 116,000 years, including a 9-m decline in groundwater in the last 15,000 years as Pleistocene lakes disappeared (Szabo et al. 1994). Over the past century, the water table in the adjacent Pahrump and Las Vegas valleys has experienced an extreme drop attributable to groundwater pumping that dwarfs this climatically induced decline.

Development in Las Vegas Valley began in the early 1900s. Groundwater pumping led directly to the failure of major valley springs in about 1957 (Harrill 1976), causing extinction of the endemic Las Vegas dace (*Rhinichthys deaconi;* Miller 1984). Development in Pahrump Valley to the west of Las Vegas proceeded more slowly. Nonethe-

Table 2. Water rights currently allocated and applied for, expressed in acre-feet (and cubic meters) and as a percentage of perennial yield, in 78 basins likely to be affected by proposed large-scale groundwater pumping.

Flow system	Area in km^2	Basins with groundwater declines	Perennial yield in acre-feet (m^3)	Current rights in acre-feet (m^3)	Current rights, as percentage of perennial yield	Current rights plus rights applied for, in acre-feet (m^3)	Current rights plus rights applied for, as percentage of perennial yield
South-central Marshes	17,586	4	31,000 (38,237,937)	41,516 (51,209,232)	134	44,076 (54,366,946)	142
Death Valley	40,922	24	86,610 (106,831,862)	112,590 (138,877,720)	130	128,619 (158,649,200)	149
Railroad Valley	10,697	4	91,500 (112,863,588)	30,792 (37,981,373)	34	242,407 (299,004,632)	265
Penoyer Valley	1813	1	4000 (4,933,927)	14,461 (17,837,381)	362	17,662 (21,785,756)	442
Colorado	42,217	35	248,800 (306,890,281)	312,916 (385,976,203)	126	911,964 (1,124,891,030)	367
Goshute Valley	9428	1	70,000 (86,343,729)	95,928 (118,325,446)	137	119,349 (147,214,824)	170
Mesquite Valley	611	1	2200 (2,713,660)	1099 (1,355,597)	50	4407 (5,435,954)	200
Great Salt Lake Desert	46,620	8	185,500 (228,810,881)	125,700 (155,048,667)	68	480,489 (592,674,455)	259
Total	169,894	78	719,610 (887,625,865)	735,003 (906,612,851)	102	1,948,973 (2,404,022,800)	271

Note: Groundwater level decline is projected by Schaefer and Harrill (1995) only for parts of the South-central Marshes, Goshute Valley, and Great Salt Lake Desert flow systems, but is anticipated throughout all basins in the other five flow systems. Columns may not sum to totals because of rounding.

Source: Nevada Division of Water Resources Water Rights Database (20 February 2006; *http://water.nv.gov/Water%20Rights/permitdb/permitdb_index.cfm*); data for Snake and Hamlin valleys obtained from Utah Division of Water Rights, August 2005.

less, Raycraft Spring failed in 1957. Bennett's Spring dried in 1958, and Manse Spring followed in 1975 (Soltz and Naiman 1978, Harrill 1986), extirpating the endemic Pahrump poolfish (*Empetrichthys latos*) throughout its historic range (Deacon 1979) and eliminating a local population of the Spring Mountains pyrg (*Pyrgulopsis deaconi;* Hershler 1998). Groundwater declines of up to 30 m occurred by 1975 in Pahrump Valley (Harrill 1986), and declines of up to 91 m occurred by 1990 in Las Vegas Valley (Burbey 1995).

In Ash Meadows, after major groundwater development (initiated in the late 1960s) reduced both spring discharge and the water table (Dudley and Larson 1976), it was curtailed in 1977 and stopped by 1982 (Dettinger et al. 1995). Spring discharge recovered (e.g., Fairbanks Spring; figure 2), and the groundwater table rose steadily through 1987, but a slow decline began in 1988 and continues to the present (Riggs and Deacon 2004). An analysis by Bedinger and Harrill (2006) indicates that the decline is unrelated to climatic variation, and instead is due to groundwater withdrawal for irrigation at the Amargosa farms area about 25 to 30 km northeast of Devils Hole. Though some springs throughout the carbonate province tend to demonstrate

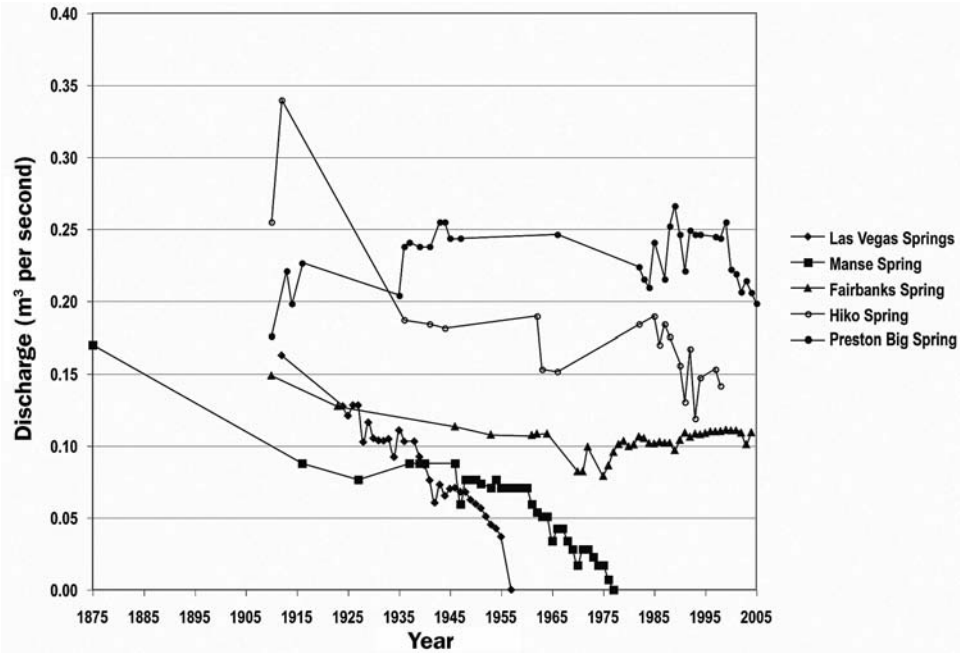

Figure 2. Annual mean discharge (cubic meters per second) from five representative springs in Nevada from 1875 to 2005. Data provided by Jon Wilson, US Geological Survey, Las Vegas, Nevada.

stable flow, in many valleys there is evidence of decline (figure 2).

As of February 2006, existing groundwater permits authorized withdrawal of 735,003 acre-feet (906.61 million m^3) per year from the 78 basins we examined (table 2). This included 156,908 acre-feet (193.54 million m^3) per year for municipal uses in the urban areas of Las Vegas and Pahrump and about 578,095 acre-feet (713.07 million m^3) per year supporting the present agricultural and rural livelihoods of the area's residents.

These existing permits appropriate 102 percent of the 78-basin area's cumulative perennial yield, slightly more water than the state engineer has determined is available each year over the long term. However, permitted withdrawals are not spaced evenly across the landscape, but range from 0 to 1660 percent of the perennial yields estimated for individual basins. For example, valid groundwater rights now exist for 376 percent of perennial yield in Las Vegas Valley, 331 percent in Pahrump Valley, and 113 percent in the seven basins (combined in the state engineer's records) that include Ash Meadows. Existing rights exceed 100 percent of perennial yield in five of the eight major flow systems underlying the 78-basin area.

Looming threats

The Las Vegas Valley Water District (now the SNWA) filed 147 applications in 1989 for rights to unappropriated groundwater from 26 of the 78 basins overlying the region's major groundwater flow systems. Since they were originally submitted, some applications have been withdrawn and others modified to accommodate rural interests (SNWA 2004). At present, the SNWA hopes to obtain rights to 180,800 of the 330,000 acre-feet (223.01 million of the 407.05 million m^3) per year of groundwater for which they have applied. Wells to supply the water are to be drilled into shallow valley-fill aquifers as well as the deep carbonate aquifer of central, eastern, and southern Nevada. The first phase is planned to begin supplying water to Las Vegas as early as 2007, with additional wells and associated pipelines proposed over the coming 50 years (SNWA 2004).

The SNWA estimates that by 2050, it will need to add 375,000 to 475,000 acre-feet (462.56 million to 585.90 million m^3) per year to the 471,786 acre-feet (581.94 million m^3) per year now supplied predominantly from the Colorado River (SNWA 2005). Negotiations with other Colorado River basin states reached an agreement in principle on 3 February 2006 that the SNWA would not exercise its right to about 120,000 acre-feet (148.02 million m^3) per year of surface water from the Virgin and Muddy rivers so long as efforts by all basin states to augment flows of the Colorado River provide Nevada with the equivalent of 75,000 acre-feet (92.51 million m^3) per year (Jenkins 2006). The agreement also permits Nevada and other basin states to claim "augmentation credit" for water added to the river from other sources. If this augmentation credit is included in the final Colorado River drought condition operations rule, the SNWA can claim a credit for any Nevada groundwater that passes through the Las Vegas sewage system, including any water resulting from the new permits for which it has applied. This results in a 70 percent bonus and constitutes a substantial additional incentive to develop the proposed groundwater project.

Groundwater to be removed from regional aquifers by the SNWA does not represent the total anticipated new demand on those aquifers. Stimulated by Las Vegas's growth, satellite communities within a few hours' drive of Las Vegas (e.g., Coyote Springs, Mesquite, Pahrump, Sandy Valley, Prim, and Lincoln County communities) are being planned or are expanding rapidly. As of 20 February 2006, those satellite communities were responsible for most of the pending applications for an additional 870,500 acre-feet (1.07 billion m^3) per year of groundwater from the 78 basins.

Probable future effects of groundwater development

Following the 1989 applications by the Las Vegas Valley Water District for rights to all unappropriated groundwater in much of eastern, central, and southern Nevada, considerable effort was directed toward evaluating the probable impacts of removing a total of 180,800 acre-feet (223.01 million m^3) of groundwater annually from the locations, and in quantities desired by the SNWA. Schaefer and Harrill (1995) produced a conceptual model of the effects on the regional groundwater table, based on the assumption that the project now administered by the SNWA was the only source of groundwater removal throughout the region. Their work suggested that effects would be evident throughout the 78 basins examined here. Schaefer and Harrill's work was evaluated and compared with the SNWA's ongoing modeling efforts by Principia Mathematica (1997), which developed its own numerical model. Several groundwater models have been developed for specific basins within the area of probable impact (Durban 2006, Elliott et al. 2006, Myers 2006), most recently focusing on Spring Valley, from which the SNWA hopes to extract about half of the 180,800 acre-feet (223.01 million m^3) per year it seeks.

Except for the SNWA model, all research models produced results consistent with those of Schaefer and Harrill (1995), which projected groundwater level declines of about 0.3 to 488 m throughout 78 basins extending from Sevier Lake, Utah, to Death Valley, California. They suggested that a new steady state might be reached in 100 to 200 years, with groundwater level declines of 15 to 152 m predominating in both shallow and deep aquifers. Evapotranspiration throughout the region would decline as water tables dropped below the level of phreatophytic root penetration. Over the first 100 years, regional springs fed by the carbonate aquifer would lose about 2 to 14 percent of their flow. They would continue to decline over the next 100 years, and might not stabilize before failing. The divergence of these conclusions from those of the SNWA is due largely to the fact that SNWA modelers tended to estimate higher levels of precipitation-induced recharge and evapotranspiration-induced discharge than other modelers. This tendency is particularly evident when

comparing the model submitted by the SNWA in support of the application for water rights in Spring Valley (Durban 2006) with the models submitted by the Western Environmental Law Center (Elliott et al. 2006, Myers 2006) in support of the center's protest against those applications.

Development dreams

While the location, depth, and quantity of withdrawal strongly influence the response in the aquifer, even the addition of only the incremental amount sought by the SNWA to the amount withdrawn under existing rights will produce greater evapotranspiration, spring discharge, and reductions in the groundwater table than those simulated by Schaefer and Harrill (1995). Within the 78 basins examined herein, total water demand would be increased to 127 percent of perennial yield by adding only the 180,800 acre-feet (223.01 million m^3) per year sought by the SNWA. Addition of the 870,487 acre-feet (1.07 billion m^3) per year sought by satellite communities would push demand to about 1.8 million acre-feet per year (2.2 billion m^3), or 250 percent of the region's estimated perennial yield. Approval of all applications pending as of February 2006 would put aquifer demand at 271 percent of perennial yield, although the state engineer, in accordance with decisions based on state law, is likely to authorize permits for less water than has been requested.

In Lincoln County, applications for groundwater rights by Vidler Water Company tend to locate points of withdrawal closer to regional discharge areas than do applications by the SNWA. Consequently, groundwater pumping by Vidler most likely will affect regional spring discharge more quickly than will SNWA's pumping, the impacts of which probably will manifest only decades later. Regional springs most likely to be influenced first by Vidler and later by SNWA wells include the Muddy River Springs and the large warm springs in Panaca Valley (Panaca Warm Springs), Pahranagat Valley (Ash, Crystal, and Hiko springs), and White River Valley (Preston Big, Lund, Moorman, and Flag springs).

In Nye County, proposed SNWA wells are likely to affect regional spring discharge in Railroad Valley (Duckwater, Lockes, and other springs) and Ash Meadows. Though the response will be long delayed by distance from the wellhead, regional springs in Ash Meadows are most likely to be adversely influenced by SNWA wells proposed for Indian Springs, Three Lakes, and Tikaboo valleys in the northeastern portion of the Ash Meadows flow system (Riggs and Deacon 2004). Even before a substantial reduction in spring discharge occurs in Ash Meadows, the first impact on existing water rights may be a lowering of the water level at Devils Hole, the one place in the entire carbonate-rock province where a surface-water right is objectively tied to groundwater level. In fact, there is mounting evidence to suggest that groundwater pumping from the regional aquifer already is producing a decline in the water level at Devils Hole (Bedinger and Harrill 2006).

State water management

The state engineer manages groundwater and surface waters under Nevada laws, which recognize connections between the two. Conflicts between users, whether of surface water or groundwater, are resolved according to prior appropriation principles. Thus, senior water rights, both surface and groundwater, limit junior water rights—a limitation that would constrain the groundwater withdrawal plans discussed above.

In evaluating the potential impacts of proposed groundwater permits on existing rights, the state engineer must make a determination of water availability based on the aquifer's perennial yield (similar to, but distinct from, sustainable yield). Permits beyond the perennial yield of the target aquifer may not be issued.

The Nevada Division of Water Resources' (1992) definition of perennial yield (i.e., "the amount of usable water from a ground-water aquifer that can be economically withdrawn and consumed each year for an indefinite period of time...[so long as it does] not exceed the natural recharge to that aquifer and ultimately is limited to maximum amount of discharge that can be utilized for beneficial use") can be a substantial barrier to conservation efforts. Although this definition conceptually prohibits the mining of groundwater, it offers little or no protection for surface water and thus is not a standard amenable to the maintenance of wetlands, springs, stream flows, or biodiversity. It also fails to maintain the groundwater table or subsurface interbasin flows. Furthermore, the technical accuracy of perennial yield estimates for some local and regional aquifers has been questioned (SNWA 2003).

Malmberg's (1967) estimate of perennial yield for Pahrump Valley provides an excellent example of the methods and assumptions commonly used. The maximum "salvageable discharge" available for appropriation included (a) all net spring discharge, (b) estimates of evapotranspiration from areas of shallow groundwater, (c) estimates of water salvageable from the amount that leaves the shallow aquifer as subsurface outflow from the basin, and (d) estimates of water salvageable from the amount that leaves the basin as subsurface outflow in the deep aquifer.

This method of determining perennial yield anticipates that permits issued will dry all springs and kill all phreatophytes, with attendant losses in biodiversity. It anticipates lowering of the groundwater table, a consequent increase in pumping costs, and the likelihood of land subsidence. It foresees reductions in both shallow and deep interbasin subsurface flows that supply down-gradient basins and their springs, thereby establishing a drain on shallow aquifers in surrounding valleys and in the regional deep carbonate aquifer (figure 3). These predictable consequences result directly from the issuance of permits equivalent to 100 percent of perennial yield. Unfortunately, despite the clear requirements of the law, permits commonly are issued for many times that amount.

Clearly, several factors confound attempts to unambiguously quantify the extent of expected detrimental impacts. Predicting the final steady state of the groundwater system in

response to massive groundwater removal is complicated by disagreement over recharge from precipitation, discharge from evapotranspiration, connectivity among aquifer components, and the time required to reach a new equilibrium. There is no question, however, that the state's definition of, and methodology for determining, the quantity of water that legally may be withdrawn fails to envision the maintenance of natural systems. As a result, it is nearly impossible for the state engineer to issue groundwater permits in support of urban development while protecting existing water rights, including those concerning recreational resources and biodiversity.

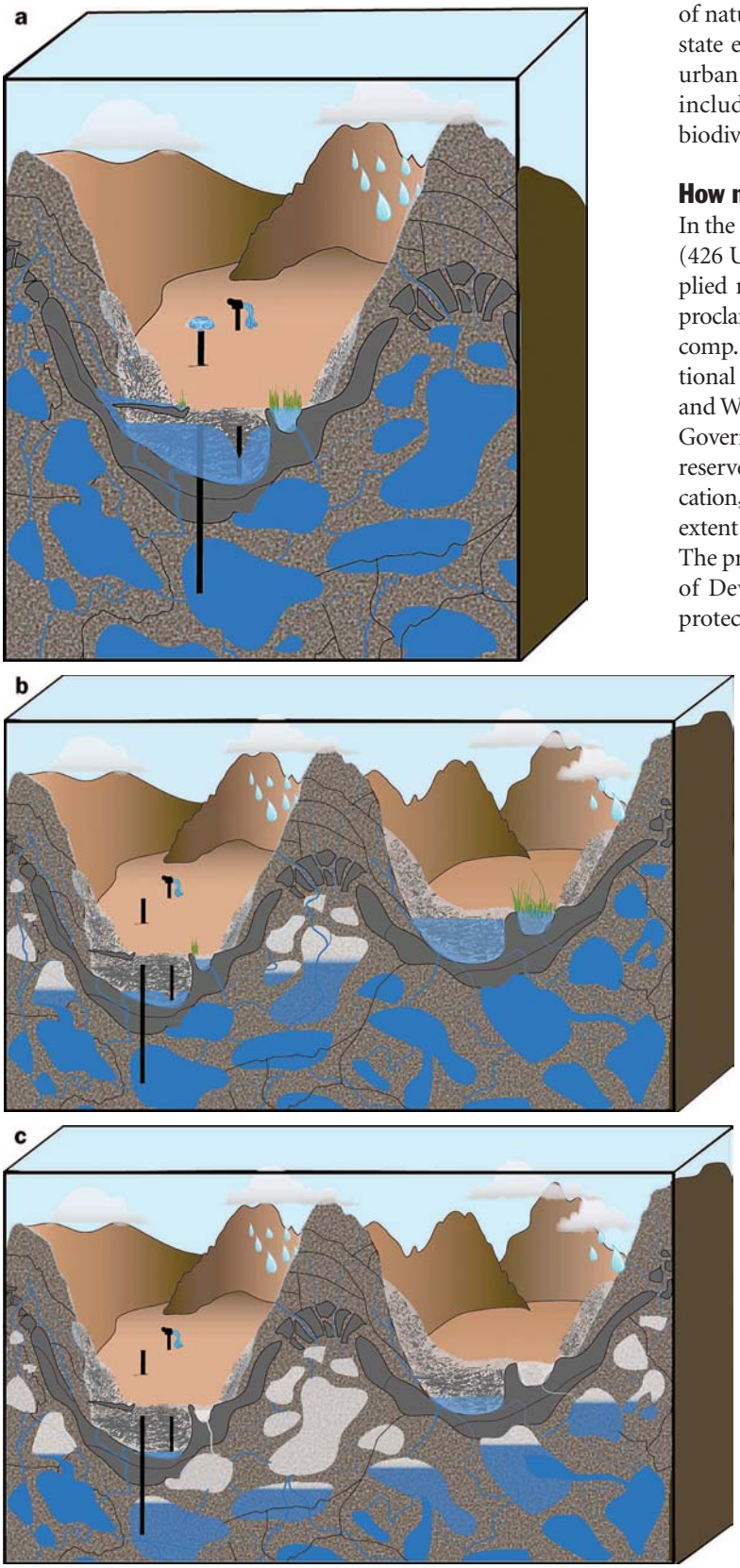

Figure 3. Conceptual diagrams of the effects of groundwater withdrawal on the variously integrated valley-fill and deep carbonate aquifers in Nevada. (a) Near-term effects: Wells in the valley-fill aquifer create a localized cone of depression; wells in the carbonate aquifer produce artesian flow; surface waters and biotic communities are imperceptibly affected. (b) Midterm effects: The water table in the valley-fill aquifer is substantially lowered, and local springs supported by this shallow aquifer fail; the carbonate aquifer loses its artesian pressure as the deep water table declines, and regional springs supported by this deep aquifer decline; groundwater from adjacent basins flows downgradient toward the reduced pressure caused by the lowering deep water table. (c) Late-term effects: A new steady state develops in both shallow and deep aquifers within the basin subjected to groundwater withdrawal; the downhill groundwater gradient toward the sites of withdrawal causes lowering of water tables and failure of local and regional springs in adjacent basins.

How might protection be achieved?

In the 1976 US Supreme Court case *Cappaert v. United States* (426 U.S. 128), the court ruled that Devils Hole had an implied reservation of water, noting that a 1952 presidential proclamation (Proclamation no. 2961, 3 CFR 147 [1949–1953 comp.]) made Devils Hole a disjunct part of Death Valley National Monument (now Death Valley National Park; Deacon and Williams 1991). The court stated that "when the Federal Government withdraws its land from the public domain and reserves it for a federal purpose, the Government, by implication, reserves appurtenant water then unappropriated to the extent needed to accomplish the purpose of the reservation." The presidential proclamation specified that the withdrawal of Devils Hole from the public domain was intended to protect the "unusual features of scenic, scientific, and educa-

tional interest...[including] a remarkable underground pool...[and] a peculiar race of desert fish." By this language, the federal government secured its right to the groundwater required to maintain the pool in Devils Hole and the endemic Devils Hole pupfish (*Cyprinodon diabolis*), vesting the right with a 1952 priority date. This implied reservation prohibits subsequent junior water users from receiving water rights that undermine conservation of the unique features of Devils Hole that led to its withdrawal, thereby benefiting not only the pupfish but also the endemic Devils Hole riffle beetle (*Stenelmis calida calida*), other species in the system, and the unique local ecology and geology.

The federal government also has reserved other centers of aquatic biodiversity because of their unique water resources and accompanying wildlife. Pahranagat National Wildlife Refuge (NWR), established in 1963 to provide habitat for migratory waterfowl, also protects an endemic subspecies of speckled dace (*Rhinichthys osculus* ssp.). Moapa NWR, established in 1979, provides habitat for the endangered Moapa dace (*Moapa coriacea*) and other rare aquatic spring endemics. Ash Meadows NWR, established in 1984 "to provide water habitat resources in Nevada for the protection of waterfowl and fish," protects a total of 15 federally listed species, including 9 that depend on springs or spring-fed wetlands, as well as 103 "at-risk" plant and animal taxa (USDOI 1982). If pressed, the courts would most likely determine that the federal government has implied rights to groundwater that are germane to the purposes of all these reservations, with a priority date corresponding to each reservation's date of withdrawal from the public domain. It is possible the implied reservation-of-water doctrine also would apply to lands acquired—as opposed to reserved—after statehood; however, that application has never been tested in court.

While the principles learned from *Cappaert* provide some protection when a species inhabits an area within reserved lands, the federal ESA may afford additional protection to threatened and endangered species that depend on habitat supported by discharge from groundwater aquifers. Current large-scale groundwater plans do not include the expenditure of federal monies, but the proposals do envision many well sites on and pipeline corridors across lands administered by the Bureau of Land Management, necessitating a federal permit and triggering the ESA's section 7 consultation provisions to ensure that federal actions do not jeopardize listed species. Furthermore, section 9 of the ESA prohibits "take" of listed species regardless of whether a federal action is involved.

All water within Nevada belongs to the public. The Nevada state engineer has a "continuing responsibility as a public trustee to allocate and supervise water rights so appropriations do not 'substantially impair the public interest in the lands and waters remaining'" (*Mineral County v. State Dep't of Conservation and Natural Res.,* 20 P.3d 800, 808–809 [2001], quoting *Illinois Central R.R. v. Illinois,* 146 U.S. 387, 452 [1892]). Traditionally, the public trust doctrine protected the public's interest in navigation, fishing, and commerce. However, the doctrine has evolved to encompass additional public values, including recreational and ecological uses.

Fahmy (2005) observed that, since the *Cappaert* decision, the state engineer increasingly has interpreted the "public interest" to include environmental values, such as endangered species. Beyond helping conserve "at-risk" species, Fahmy suggests that continuing judicious use of the public interest standard also could help maintain state sovereignty over water resources allocation and administration.

Achieving ecologically sustainable water use

Providing for the water needs of a growing Las Vegas Valley by relying on historical practices is a recipe for an ecological disaster involving loss of wetlands, spring-dependent species, and phreatophytic communities. New technologies can help increase water availability and efficiency of use, but in the long run they are futile unless combined with reduced growth of human populations. Reducing per capita consumption, however, could align Las Vegas residents' water use with the levels already realized in other major southwestern US cities (e.g., Albuquerque and Tucson; figure 4).

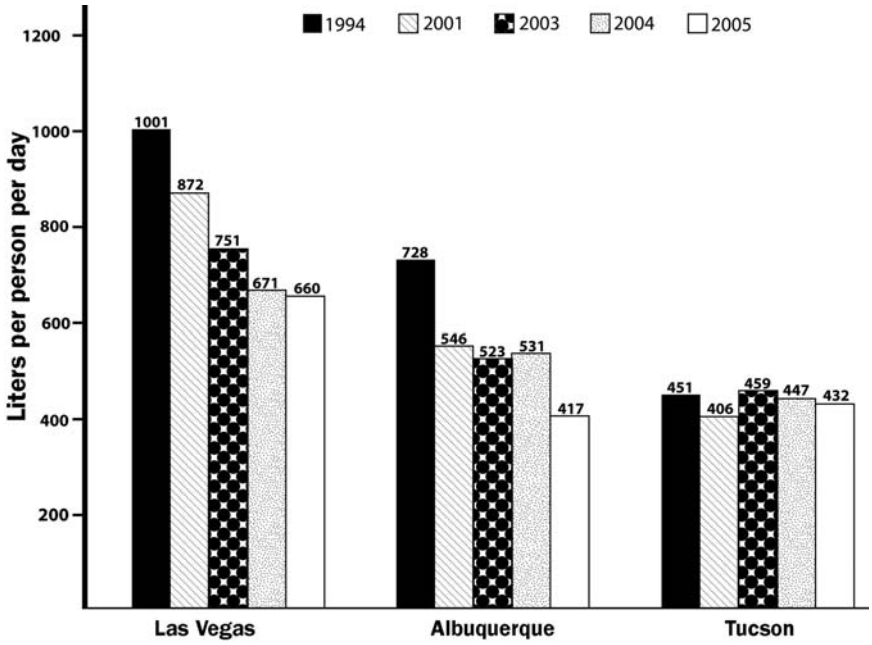

Figure 4. Changes in single-family, residential per capita water consumption in selected southwestern US cities from 1994 to 2005. Data from Western Resource Advocates (2006).

Water for lawns and other external uses outside the home offers the largest opportunity for cutting back single-family residential consumption. Mayer and colleagues (1999) calculated that approximately three-fourths of the residential water consumed in Las Vegas could be attributed to external rather than internal use. Western Resource Advocates (2006) calculated that, by 2030, converting 50 percent of the Las Vegas Valley's single-family residential landscaping to xeriscape would reduce demand by 80,000 acre-feet (98,678,547 m^3) per year, while indoor water conservation could reduce demand by more than 70,000 acre-feet (86,343,729 m^3) per year.

As in other southwestern cities, substantially lower consumption rates would result from increasing the price differential between tiers in the tiered rate structure already in place, and by implementing a range of other widely recognized measures to improve the efficiency of water use (Western Resource Advocates 2003, 2006). For new developments where retrofitting is unnecessary, low per capita consumption can be achieved even more easily simply by requiring serious water efficiency as a condition of development. Opportunities to reduce per capita water consumption to the low rate of 380 L per person per day have been identified for a new 648-hectare development in Las Vegas (Rocky Mountain Institute 2003). Comparable opportunities are available throughout the Las Vegas Valley.

As a reuse or recycling strategy for Las Vegas's tertiary effluent, membrane treatment could recover an amount of water comparable to that presently being obtained through "return-flow credit," a water-accounting system allowing Las Vegas to reuse water of Colorado River origin that is pumped from and then returned to Lake Mead. In addition, a membrane treatment system would make it possible to use saline water (originating as landscape irrigation water) from above the valley-fill aquifer. This shallow saline groundwater reportedly is accumulating at about 100,000 acre-feet (123,348,184 m^3) per year (SNWA 2006) and increasingly is flooding basements and creating other problems. Combined with urban runoff (which equals approximately 35,000 acre-feet [43,171,864 m^3] per year) and intermittently available floodwaters, both of which currently move through flood control channels to Las Vegas Wash and into Lake Mead, these sources have an apparent cumulative recovery potential of more than 135,000 acre-feet (166,520,048 m^3) per year. Following membrane treatment, this water could be used directly in the potable supply or indirectly as groundwater recharge. Membrane treatment would have the additional advantage of removing approximately 700,000 metric tons of salt per year (an amount approximating the total removed by all Bureau of Reclamation Colorado River Basin salinity control projects implemented to date), as well as a number of other environmental contaminants presently identified as problematic—including endocrine-disrupting compounds, personal care and pharmaceutical products, pesticides, chemicals used in plastic manufacturing, and artificial fragrances (Hinck et al. 2006)—and could substantially improve water quality in the Las Vegas Valley and the lower Colorado River.

One approach taken by several communities to manage consumption more efficiently is the direct or indirect reuse of highly treated effluent, a method that is becoming increasingly attractive as costs increase for water development, importation, and disposal. Reuse projects based on membrane treatment (microfiltration or reverse osmosis) of tertiary effluent are in place or under construction in Los Angeles, El Paso, Scottsdale, and many other places around the world (Durham et al. 2003). Such projects produce water that could be reused immediately in potable or irrigation supplies (direct reuse), reused later after recharging groundwater aquifers that are tapped to support domestic water supplies (indirect reuse), or both. Currently, most direct reuse projects are designed to meet irrigation water demands, whereas reuse projects designed to supply potable water generally involve indirect reuse. Preliminary calculations demonstrate that a membrane treatment system for Las Vegas would cost no more than a proposed effluent dilution project (about $800 million), would recover as much water as is recoverable by "return flow credit," and would improve water quality in Las Vegas and in the Colorado River downstream from Lake Mead (Walter Johnson, Clark County Water Reclamation District [retired], Las Vegas, Nevada personal communication, 17 November 2005).

Although the hydrogeology in southern Nevada is unique, concerns regarding the ecological impacts of groundwater withdrawal exist across the western United States. For example, the dependence of San Antonio, Texas, on groundwater from the Edwards Aquifer for municipal water supplies has had a growing impact on the endangered fountain darter (*Etheostoma fonticola*). Ultimately, minimum spring flows needed to avoid jeopardizing the darter's existence were established, and the Texas legislature mandated that the Edwards Aquifer Authority improve water management and conservation, leading San Antonio residents to reduce per capita water use by 24 percent between 1984 and 2000 (Fitzhugh and Richter 2004).

Richter and colleagues (2003) suggested defining ecologically sustainable water management as "protecting the ecological integrity of affected ecosystems while meeting intergenerational human needs for water and sustaining the full array of other products and services provided by natural freshwater ecosystems." Whether adhering to that standard of sustainability or to Nevada's considerably riskier standard of "perennial yield," we must acknowledge limits to water availability as we strive to strike a balance between human water demand and the needs of natural systems and future generations. Adherence to traditional standards virtually guarantees immediate ecological crises and unnecessary adversity for future generations. Those crises will manifest in litigation, "water wars," federal–state conflicts, and loss of springs, wetlands, phreatophytic communities, and biodiversity. Only through changed personal and community relationships with the Earth and its waters are we likely to succeed in conserving our ecological heritage while building a sustainable society.

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Appendix I:

A list of native spring-dependent species known from the area of projected groundwater decline in Nevada, California, Utah, and Arizona

Table 1. Twenty federally-listed spring-dwelling and riparian species of southern and central Nevada that are dependent upon groundwater for habitat maintenance. NWR = National Wildlife Refuge.

Common Name	Scientific Name	Federal Status	Habitat	Special Federal Designation Lands
Amargosa vole	*Microtus californicus scirpensis*	E	Spring-fed wetland areas	
Southwestern Willow Flycatcher	*Empidonax trailii extrimus*	E	Riparian areas of spring-fed streams	Pahranagat NWR; Ash Meadows NWR
Yuma clapper rail	*Rallus longirostris yumanensis*	E	Riparian areas of spring-fed streams	
Woundfin	*Plagopterus argentissimus*	E	Spring-fed streams	
Virgin River chub	*Gila seminuda*	E	Spring-fed streams	
Ash Meadows speckled dace	*Rhinichthys osculus nevadensis*	E	Springs	Ash Meadows NWR
Moapa dace	Moapa coriacea	E	Springs	Moapa Valley NWR
Pahrump poolfish	Empetrichthys latos	E	Spring pools	Desert National Wildlife Range
Ash Meadows Amargosa pupfish	*Cyprinodon nevadensis mionectes*	E	Springs	Ash Meadows NWR
Devils Hole pupfish	*Cyprinodon diabolis*	E	Spring pool	Death Valley National Park
Warm springs pupfish	*Cyprinodon nevadensis pectoralis*	E	Springs	Ash Meadows NWR
Big Spring spinedace	*Lepidomeda mollispinis pratensis*	T	Springs and spring-fed marshes	
White River spinedace	*Lepidomeda albivallis*	E	Springs and spring-fed creeks	
Hiko White River springfish	*Crenichthys baileyi grandis*	E	Springs	
Railroad Valley springfish	*Crenichthys nevadae*	T	Springs	
White River springfish	*Crenichthys b. baileyi*	E	Springs	
Ash Meadows naucorid so it's	*Ambrysus amargosus*	T	Springs and spring-fed streams	Ash Meadows NWR
Spring-loving centaury	*Centarium namophilum*	T	Spring-fed riparian areas	Ash Meadows NWR
Ash Meadows ivesia	*Ivesia kingii* var. *eremica*	T	Spring-fed riparian areas	Ash Meadows NWR
Amargosa niterwort	*Nitrophila mohavensis*	E	Spring-fed riparian areas	Ash Meadows NWR

Table 2. Native, spring-dependent species (n = 137) known from the area of projected groundwater decline, including those in Lincoln, Clark, White Pine, Nye and eastern Esmeralda counties, Nevada; eastern portions of Inyo and San Bernardino counties, California; western portions of Washington, Iron, Beaver, Millard, and Juab counties, Utah; and northwestern Mohave County, Arizona (see Figure 1, Deacon et al. 2007). Federally-listed species are included in Table 1 and not repeated here.

Common Name	Scientific Name	Location	Reference
Ash Meadows montane vole	*Microtus montanus nevadensis*	Nye Co., Ash Meadows NWR	Sada 1990
Pahranaget Valley montane vole	*Microtus montanus fucosus*	Lincoln Co., Pahranagat NWR	www.fws.gov
Railroad Valley belostoman	*Belostoma bakeri*	Nye Co.	Sada and Deacon 1994
Devils Hole riffle beetle	*Stenelmis calida calida*	Nye Co., Ash Meadows NWR	Sada 1990
Moapa warm springs riffle beetle	*Stenelmis calida moapa*	Clark Co., Moapa NWR	www.fws.gov
Ash Springs riffle beetle	*Stenelmis lariversi*	Lincoln Co.	Sada and Deacon 1994
Pahranagat Valley riffle beetle	*Microcylloepus moapus fraxinus*	Lincoln Co., Pahranagat NWR	Sada and Deacon 1994
Moapa riffle beetle	*Microcylloepus moapus moapus*	Clark Co., Moapa NWR	Sada and Deacon 1994
Ash Meadows skater	*Rhagovelia distincta*	Nye Co., Ash Meadows NWR	Sada and Deacon 1994
Moapa skater	*Rhagovelia becki*	Clark Co., Moapa NWR	Sada and Deacon 1994
Amargosa naucorid	*Pelocoris shoshone amargosus*	Nye Co.	Nevada Natural Heritage Program
Pahranagat Valley naucorid	*Pelocoris shoshone shoshone*	Lincoln Co., Pahranagat NWR	Sada and Deacon 1994
Moapa naucorid	*Usingerina moapensis*	Clark Co., Moapa NWR	Usinger 1956; www.fws.gov
Naucorid	*Ambrysus relictus*	Clark Co., Ash Meadows NWR	Polhemus and Polhemus 1994
Mormon naucorid	*Ambrysus mormon*	Lincoln Co.	Sada and Deacon 1994
White River naucorid	*Ambrysus woodburyi*	Nye Co.	Sada and Deacon 1994
Ash Meadows assiminea	*Assiminea* sp.	Nye Co., Ash Meadows NWR	Sada and Deacon 1994
Sportinggoods tryonia	*Tryonia angulata*	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Sada 1990; Hershler 2001

Tryonia	*T. clathrata*	Clark Co., Moapa NWR	Hershler 2001
Point of Rocks tryonia	*T. elata*	Nye Co., Ash Meadows NWR	Hershler 2001
Minute tryonia	*T. ericae*	Nye Co., Ash Meadows NWR	Hershler 2001
Monitor Valley tryonia	*T. monitorae*	Nye Co.	Hershler 2001
Amargosa tryonia	*T. variegata*	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Hershler 2001
Ash Meadows pebblesnail	*Pyrgulopsis erythropoma*	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Sada 1990
Crystal springsnail	*P. crystalis*	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Sada 1990
Distal-gland springsnail	*P. nanus*	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Sada 1990
Elongate-gland springsnail	*P. isolatus*	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Sada 1990
Fairbanks springsnail	*P. fairbankensis*	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Sada 1990
Longstreet springsnail	*P.* sp. (possibly extinct)	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Sada 1990
Median-gland springsnail	*P. pisteri*	Nye Co., Ash Meadows NWR	Hershler and Sada 1987; Sada 1990
Oasis Valley springsnail	*P. micrococcus*[1]	Nye Co., Ash Meadows NWR	Sada 1990; Hershler 1998; Liu et al. 2003
Corn Creek pyrg	*P. fausata*	Clark Co., Desert National Wildlife Range	Hershler 1998
Spring Mountains pyrg	*P. deaconi*	Clark and Nye Cos.	Hershler 1998
Blue Point pyrg	*P. coloradensis*	Clark Co., Lake Mead National Recreation Area	Hershler 1998
Pyrg	*P. avernalis*	Clark Co., Moapa NWR	Hershler 1998
Pyrg	*P. carinifera*	Clark Co., Moapa NWR	Hershler 1998
Pyrg	*P. merriami*	Nye Co.	Hershler 1998
Camp Valley pyrg	*P. montana*	Lincoln Co.	Hershler 1998
Hubbs pyrg	*P. hubbsi*	Lincoln Co.	Hershler 1998
White River Valley pyrg	*P. sathos*	Nye, Lincoln and White Pine Cos.	Hershler 1998
Flagg pyrg	*P. breviloba*	Nye Co.	Hershler 1998
Butterfield pyrg	*P. lata*	Nye Co.	Hershler 1998
Emigrant pyrg	*P. gracilis*	Nye Co.	Hershler 1998

Hardy pyrg	*P. marcida*	Nye, Lincoln and White Pine Cos.	Hershler 1998
Southeast Nevada pyrg	*P. turbatrix*	Clark and Nye Cos.	Hershler 1998
Sterile basin pyrg	*P. sterilis*	Nye Co.	Hershler 1998
Lake Valley pyrg	*P. sublata*	Lincoln Co.	Hershler 1998
Lockes pyrg	*P. lockensis*	Nye Co.	Hershler 1998
Big Warm Spring pyrg	*P. papillata*	Nye Co.	Hershler 1998
Carinate Duckwater pyrg	*P. carinata*	Nye Co.	Hershler 1998
Duckwater pyrg	*P. aloba*	Nye Co.	Hershler 1998
Duckwater Warm Springs pyrg	*P. villacampae*	Nye Co.	Hershler 1998
Southern Duckwater pyrg	*P. anatine*	Nye Co.	Hershler 1998
Flat-topped Steptoe pyrg	*P. planulata*	White Pine Co.	Hershler 1998
Southern Steptoe purg	*P. sulcata*	White Pine Co.	Hershler 1998
Sub-gulose Steptoe Ranch pyrg	*P. orbiculata*	White Pine Co.	Hershler 1998
Neritiform Steptoe Ranch pyrg	*P. neritella*	White Pine Co.	Hershler 1998
Landyes pyrg	*P. landyei*	White Pine Co.	Hershler 1998

Common Name	Scientific Name	Location	Reference
Columbia spotted frog	*Rana luteiventris*	NV, UT	NNHP (July 2005)
Arizona toad	*Bufo microscaphus*	NV	NNHP (July 2005)
Relict leopard frog	*Rana onca*	NV	NNHP (July 2005)
Amargosa toad	*Bufo nelsoni*	NV	NNHP (July 2005)
Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*	NV	NNHP (July 2005)
Bonneville cutthroat trout	*Oncorhynchus clarkii utah*	NV, UT	Behnke 2002
Oasis Valley speckled dace	*Rhinichthys osculus* ssp.	NV	NNHP (July 2005)
Hot Creek Valley tui chub	*Gila bicolor* ssp.	NV	NNHP (July 2005)
Kate Spring tui chub	*Gila bicolor* ssp.	NV	Deacon and Williams 1984
Blue Eagle Spring tui chub	*Gila bicolor* ssp.	NV	Deacon and Williams 1984
Bull Creek tui chub	*Gila bicolor* ssp.	NV	Deacon and Williams 1984
Green Springs tui chub	*Gila bicolor* ssp.	NV	Deacon and Williams 1984
Railroad tui chub	*Gila bicolor* ssp.	NV	Deacon and Williams 1984
Big Smoky Valley tui chub	*Gila bicolor* ssp.	NV	Deacon and Williams 1984
Charnock Springs tui chub	*Gila bicolor* ssp.	NV	Deacon and Williams 1984
Moapa roundtail chub	*Gila robusta* ssp.	NV	Deacon and Williams 1984
Least chub	*Iotichthys phlegothontis*	UT	Sigler and Sigler 1987
Big Smoky Valley speckled dace	*Rhinichthys osculus lariversi*	NV	Deacon and Williams 1984
Moapa River speckled dace	*Rhinichthus osculus moapae*	NV	Deacon and Williams 1984
Preston speckled dace	*Rhinichthys osculus* ssp.	NV	Deacon and Williams 1984
Meadow Valley speckled dace	*Rhinichthys osculus* ssp.	NV	Deacon and Williams 1984
Monitor Valley speckled dace	*Rhinichthys osculus* ssp.	NV	Deacon and Williams 1984
Amargosa Valley speckled dace	*Rhinichthys osculus* ssp.	NV	Deacon and Williams 1984
Amargosa Canyon speckled dace	*Rhinichthys osculus* ssp.	CA	Moyle et al. 1995

Colorado River speckled dace	*Rhinichthys osculus yarrowi*	NV, UT	Deacon and Williams 1984
Preston White River springfish	*Crenichthys baileyi albivallis*	NV	Deacon and Williams 1984
Morman White River springfish	*Crenichthys baileyi thermophilus*	NV	Deacon and Williams 1984
Amargosa pupfish	*Cyprinodon nevadensis amargosae*	CA	Moyle et al. 1995
Shoshone pupfish	*Cyprinodon nevadensis shoshone*	CA	Moyle et al. 1995
Mottled sculpin	*Cottus bairdi semiscaber*	NV, UT	Deacon and Williams 1984
Flannelmouth sucker	*Catostomus latipinnis*	AZ, NV	NNHP (July 2005)
White River desert sucker	*Catostomus clarkii intermedius*	NV	Deacon and Williams 1984
Meadow Valley desert sucker	*Catostomus clarkii* ssp.	NV	Deacon and Williams 1984
Virgin River desert sucker	*Catostomus clarkii utahensis*	AZ, NV	Deacon and Williams 1984
Bonneville mountain sucker	*Catostomus p. platyrhynchus*	NV, UT	Deacon and Williams 1984
Virgin River spinedace	*Lepidomeda mollispinis mollispinis*	AZ, NV	NNHP (July 2005)
(Snake Valley) springsnail	*Pyrgulopsis peculiaris*	NV	Hershler and Sada 2002
(Bonneville Basin) springsnail	*Pygulopsis kolobensis*	NV, UT	Hershler and Sada 2002
Hamlin Valley pyrg	*Pyrgulopsis hamlinensis*	UT	Hershler 1998
Longitudinal gland pyrg	*Pyrgulopsis anguina*	UT	Hershler 1998
Sub-globose Snake pyrg	*Pyrgulopsis saxatilis*	UT	Hershler 1998
ncn tryonia	*Tryonia margae*	CA	Hershler 2001
ncn tryonia	*Tryonia rowlandsi*	CA	Hershler 2001
California floater	*Anodonta* californiensis	UT	
White River belostoman	*Belostoma flumineum*	NV	Polhemus and Polhemus 2002
Amargosa River belostoman	*Lethocerus augustipes*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Cenocorixa wileyae*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Corisella decolor*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Corisella edulis*	NV	Polhemus and Polhemus 2002

ncn water boatmen	*Corisella inscripta*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Graptocorixa serrulata*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Hesperocorixa laevigata*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Sigara alternata*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Sigara omani*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Trichocorixa calva*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Trichocorixa reticulata*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Trichocorixa whleri*	NV	Polhemus and Polhemus 2002
ncn water boatmen	*Trichocorixa verticalis saltoni*	NV	Polhemus and Polhemus 2002
ncn toad bug	*Nerthra martini*	NV	Polhemus and Polhemus 2002
ncn water strider	*Aquarius remigis*	NV	Polhemus and Polhemus 2002
ncn water strider	*Gerris gillettei*	NV	Polhemus and Polhemus 2002
ncn velvet water bug	*Hebrus hubbardi*	NV	Polhemus and Polhemus 2002
ncn velvet water bug	*Merragata hebroides*	NV	Polhemus and Polhemus 2002
ncn water measurer	*Hydrometra australis*	NV	Polhemus and Polhemus 2002
ncn water treaders	*Mesovelia amoena*	NV	Polhemus and Polhemus 2002
ncn water treaders	*Mesovelia mulsanti*	NV	Polhemus and Polhemus 2002
ncn naucorid	*Ambrysus funebris*	NV	Polhemus and Polhemus 2002
ncn backswimmer	*Buenoa margaritacea*	NV	Polhemus and Polhemus 2002
ncn backswimmer	*Buenoa omani*	NV	Polhemus and Polhemus 2002
ncn backswimmer	*Buenoa scimitra*	NV	Polhemus and Polhemus 2002
ncn backswimmer	*Notonecta kirbyi*	NV	Polhemus and Polhemus 2002
ncn backswimmer	*Notonecta undulata*	NV	Polhemus and Polhemus 2002

ncn backswimmer	*Notonecta unifasciata*	NV	Polhemus and Polhemus 2002
ncn velvety shore bug	*Ochterus barberi*	NV	Polhemus and Polhemus 2002
ncn ripple bug	*Microvelia beameri*	NV	Polhemus and Polhemus 2002
ncn ripple bug	*Microvelia cerifera*	NV	Polhemus and Polhemus 2002
ncn ripple bug	*Microvelia gerhardi*	NV	Polhemus and Polhemus 2002
ncn ripple bug	*Microvelia hinei*	NV	Polhemus and Polhemus 2002
ncn ripple bug	*Microvelia torquata*	NV	Polhemus and Polhemus 2002

[1] Recent mitochondrial DNA sequencing has revealed that *Pyrgulopsis micrococcus* contains multiple, genetically distinct and geographically restricted lineages (Liu et al. 2003).

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