METALS AND TRACE ELEMENTS IN WATER, SEDIMENT, AND VEGETATION AT ASH MEADOWS NATIONAL WILDLIFE REFUGE – 1993

By
Stanley N. Wiemeyer
U.S. Fish and Wildlife Service
Nevada Fish and Wildlife Office
Reno, Nevada
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Introduction

Ash Meadows National Wildlife Refuge (Refuge) is located in the Amargosa Valley of the Mojave Desert in southern Nye County, Nevada, approximately 65 miles northwest of Las Vegas. The Refuge encompasses over 23,000 acres of spring-fed wetlands and alkaline desert uplands. The Refuge was established in 1984 for the protection of threatened and endangered species of plants, invertebrates, and vertebrates and their habitats and provides habitat for at least 24 plants and animals found nowhere else in the world. A large underground aquifer system discharges at the Refuge in more than 30 seeps and springs, with total flows exceeding 10,000 gallons per minute year round. The seven major springs are: Fairbanks, Rogers, Longstreet, Crystal, Point of Rocks, Jackrabbit, and Big Springs (http://desertcomplex.fws.gov/ashmeadows) (Figure 1). The Fish and Wildlife Service (Service) collected data on polychlorinated biphenyl (PCB) concentrations in water, sediment, and biota from the Refuge in 1997 (Miesner and Martinez 1998) to investigate the potential for contamination from on-site electrical transformers. No PCB contamination was found.

Prior to the PCB study, information was needed on concentrations of metals and trace elements in various media at the Refuge. The objectives of this study were to: (1) obtain baseline data from the Refuge so that later trends in contaminant concentrations could be quantified; and (2) determine if environmental contaminants had the potential to adversely impact fish and wildlife resources at the Refuge.

Methods

Samples of water, sediment, and aquatic vegetation (usually algae) were collected on September 9, 1993 by Peter L. Tuttle of the Service. Water was collected at 14 sites, whereas sediment and vegetation were collected at 11 and 12 of the same sites, respectively. Vegetation samples consisted of algae at 10 sites with pondweed (presumably *Potamogeton* sp.) being collected at two sites. Sample volumes and weights are reported in Table 1. Details of collection methods were not found in a search of the files; however, methods were assumed to be similar to that of Tuttle et al. (1996) as the samples were collected by the same person during the same time frame and were analyzed at the same laboratory. The following collection methods were assumed to have been used. Unfiltered, but acidified water samples (Peter Tuttle, pers.

comm.., July 2005) were placed in 250 ml chemically clean nalgene containers, and stored on ice in the field and refrigerated at 4º C until time of analysis at the analytical laboratory. Sediment and vegetation samples were collected and placed in chemically clean glass jars with Teflon-lined lids, stored on ice in the field, frozen upon return to the laboratory, and kept frozen until time of analysis at the analytical laboratory.

Samples were analyzed at the Environmental Trace Substances Research Center, Columbia, Missouri under contract of the Patuxent Analytical Control Facility (PACF), Laurel, Maryland of, at that time, the National Biological Service, now with the Service. Arsenic and selenium analyses were conducted using hydride generation atomic absorption spectroscopy. Mercury analyses were conducted using cold vapor atomic absorption spectroscopy. The remaining metals and trace elements were analyzed using inductively coupled plasma emission spectroscopy. Analytical quality control/quality assurance (QA/QC) included the use of procedural blanks, duplicate samples, spiked samples and reference materials. QA/QC anomaly tests were not performed on at least a portion of this set of results. Samples were a part of two different catalogs submitted to the contract laboratory. Concentrations were not corrected for percent recovery. Residues in sediment and vegetation are reported on a dry weight basis.

Results

Water

Concentrations of most constituents in water were fairly consistent among sample sites, except for boron, molybdenum, and zinc where the concentrations at Peterson reservoir were much higher than at most other sites (Table 1). Water from the Jackrabbit Spring outflow had among the highest concentrations of several constituents, including aluminum, iron, manganese, molybdenum, and strontium. Water from the Point of Rocks spring pool had among the lowest concentrations of several constituents, including aluminum, arsenic, and boron.

Due to the proximity of the Refuge to the Nevada Test Site where historical nuclear weapons testing took place, the Department of Energy has monitored several springs for water quality, including a suite of radionuclides. A portion of these data are provided in Table 2. In addition to the constituents listed in Table 2, the samples were also analyzed for some of the following, but are not reported here: enriched tritium, gamma spectroscopy, gross alpha, gross beta, plutonium-238, plutonium-239/240, radium-226, radium-228, strontium-90, actinium-228, americium-241, antimony-125, cerium-144, cesium-134, cesium-137, cobalt-60, europium-152, europium-154, europium-155, lead-212, potassium-40, promethium-144, promethium-146, ruthenium-106, thorium-234, tritium, uranium-235, uranium-238, yttrium-88, carbon-14, technetium-99, and silicon.

Groundwater quality at the Refuge has been monitored by the U.S. Geological Survey (Westenburg and La Camera 1996, La Camera and Locke 1997, La Camera et al. 1999, Locke and La Camera 2003). These data have not reviewed due to uncertainties regarding their relevance to surface water and Service trust resources at the Refuge.

Sediment

Concentrations of metals and trace elements in sediment tended to vary more among sites than for water. Differences among sites exceeded an order of magnitude for aluminum, boron, beryllium, mercury, selenium, and zinc. The sediment sample from the north shore of Crystal Reservoir had among the highest concentrations of aluminum, barium, beryllium, cadmium,

chromium, iron, and manganese of any site. The sediment sample from Horseshoe Reservoir had among the highest concentrations of boron, barium, magnesium, manganese, strontium, and vanadium. The Jackrabbit Spring outflow had among the highest concentrations of cadmium, chromium, copper, iron, nickel, selenium, and vanadium. Concentrations of several constituents were relatively low in the sediment samples from the pools of Big Spring and Jackrabbit Spring.

Vegetation

Concentrations of metals and trace elements in vegetation also differed among sites, although the role played by the collection of different vegetation types from different sites is unclear. When examining the data for algae alone, order of magnitude differences occurred among sites for aluminum, barium, copper, iron, mercury, lead, selenium, and zinc. The vegetation sample from the Crystal Spring outflow tended to have lower concentrations of many constituents than other sites. Concentrations of several constituents tended to be higher in the algae sample from the spring outflow of Point of Rocks than those of other sites.

No consistent relationships in ranking of residue concentrations (highest to lowest) among sites for water, sediment, and vegetation were noted.

Discussion

Water

Concentrations of metals and trace elements in water were compared to State of Nevada aquatic life standards where applicable. However, such comparisons are limited because many aquatic life standards are hardness dependent and apply only to filtered samples (dissolved constituents). The Nevada aquatic life standard for total recoverable iron is 1000 µg/L. All samples collected for this study were far below this concentration. The Nevada aquatic life standard for total recoverable molybdenum is 19 µg/L; only the water sample from the south shore of Peterson Reservoir exceeded the standard. The 96-hour average aquatic life standard for total recoverable mercury is 0.012 µg/L. The detection limit in this study was much higher; therefore, one cannot determine if the standard was exceeded. The 96-hour average aquatic life standard for total recoverable selenium is 5.0 µg/L. All selenium concentrations in water in this study were at least an order of magnitude below this standard. Nevada standards for cadmium, copper, lead, nickel, and zinc are hardness dependent, whereas the standards for arsenic and chromium are for specific valences, and all of these only apply to dissolved constituents, not total recoverable. Nevada does not have aquatic life standards for aluminum, boron, barium, beryllium, magnesium, manganese, strontium, and vanadium. Eisler (2000b) indicated that a 1,000 to 2,000 µg/L of boron was non-hazardous in aquatic communities and that 10,000 to 12,000 µg/L may cause adverse effects to sensitive species of fish. Only the water sample from Peterson Reservoir contained more than 2,000 µg/L. Aluminum concentrations in water samples from the Crystal Spring pool, and the outflow from Jackrabbit Spring exceeded the Federal criterion (i.e., 87 µg/L). Toxicity of aluminum varies considerably with species and complexation (Sparling and Lowe 1996), with speciation being affected by several environmental variables, especially pH. Aluminum has a low solubility in the pH range of 6.0 to 8.0 and is considered to be biologically inactive. Solubility increases in more alkaline solutions (i.e., pH > 8.0), but biological implications are not well understood. The pH values in water samples from four springs sampled by the Department of Energy did not exceed 8.0 (Table 2).

Sediment

MacDonald et al. (2000) provided consensus-based sediment quality guidelines, specifically threshold effect concentrations (TEC) and probable effect concentrations (PEC), for several metals and trace elements in relation to biological effects in freshwater ecosystems. A TEC is a concentration below which harmful effects are not likely to be observed and a PEC is a concentration above which harmful effects are likely to be observed, both of which are expressed on a dry weight basis. The TEC for arsenic (i.e., 9.79 µg/g) was exceeded in the samples from Horseshoe Reservoir and the outflow from Jackrabbit/Big Spring. The PEC for arsenic (i.e., 33.0 µg/g) was not exceeded in any samples. The TECs for cadmium (i.e., 0.99 µg/g), chromium (i.e., 43.4 µg/g), copper (i.e., 31.6 µg/g), nickel (i.e., 22.7 µg/g), and lead (i.e., 35.8 µg/g) were not exceeded in any samples. The TEC for mercury (i.e., 0.18 µg/g) was exceeded in the sample from the pool of Crystal Spring. The PEC (i.e., 1.06 µg/g mercury) was not exceeded in this sample. The TEC for zinc (i.e., 121 µg/g) was exceeded in the sediment sample from the outflow from Jackrabbit/Big Springs, but the concentration in the sample did not exceed the PEC (i.e., 459 µg/g).

Persaud et al. (1993) identified a concern level for iron in sediment of 21,200 µg/g (dry weight). All iron concentrations in samples from this study were much lower. Persaud et al. (1993) also identified a concern level for manganese in sediment of 460 µg/g (dry weight). Manganese concentrations in sediment samples from this study were much lower. The toxicity threshold for selenium in sediment in relation to adverse effects for fish and wildlife was identified as $\geq$ 4 µg/g (dry weight) (Lemly and Smith 1987). All sediment samples from this study had concentrations lower than this level.

Vegetation

Algae made up 0.97 percent by volume of the diet and pondweed made up 16.29 percent by volume of the diet of 14 species of ducks in the western United States (Martin and Uhler 1951). Algae consumption by ducks was thought to be incidental in the process of taking other foods, whereas pondweed was the most important food. Even though algae may be unimportant as a food item in ducks, concentrations in both algae and pondweed were evaluated as a food source to waterfowl. Five species of waterfowl were listed as common at the Refuge (http://www.npwrc.usgs.gov/resource/othrdata/chekbird/r1/ashmead.htm), with 16 other species of waterfowl documented at the Refuge.

An aluminum concentration of 5,000 µg/g (dry weight) was considered an adverse dietary effect level in waterfowl (Sparling 1990). Only the algae sample from the Point of Rocks spring outflow exceeded this concentration, with more than one-half of the vegetation samples having less than one-half of this concentration. An arsenic concentration of 30 µg/g (dry weight) in the diet of mallard (*Anas platyrhynchos*) ducklings was associated with reduced weight gain (Camardese et al. 1990). All arsenic concentrations in vegetation from this study were well below this value. Weight gain of mallard ducklings that received a diet containing 30 µg/g (dry weight) boron was significantly reduced, whereas the reproductive success of adult mallards that received a diet containing 1000 µg/g (dry weight) was significantly reduced (Smith and Anders 1989). The vegetation samples from the Point of Rocks spring outflow, Jackrabbit/Big Spring outflow, and Peterson Reservoir equaled or exceeded the former boron concentration.

Eisler (2000a) proposed a threshold concentration of 10 µg/g (dry weight) chromium in the diet of wildlife, above which one might expect potential adverse effects on health and reproduction. All chromium concentrations in vegetation samples from this study were below

this threshold. Eisler (2000a) considered poultry diets containing < 200 µg/g (dry weight) copper to be safe. All vegetation samples from this study contained far lower copper levels.

Only the algae sample from the Crystal Spring pool had a mercury concentration that exceeded an avian dietary effect concentration of 0.5 µg/g (dry weight), that was associated with adverse reproductive effects in mallards (Heinz 1979). Mercury was detected in algae at only low concentrations in an extensive monitoring study along the Humboldt River in northern Nevada in 1998-2000 (Wiemeyer et al. 2004). The maximum concentration in 67 samples was only 0.14 µg/g (dry weight), although the detection limit in one year was 0.19 µg/g (dry weight). The presence of mercury in the algae sample for Crystal Spring pool at an order of magnitude higher is cause for concern.

All nickel concentrations in this study were far below a dietary concentration of 800 µg/g (fresh weight) nickel that was associated adverse effects to adult mallards (Eisler 2000a). All selenium concentrations in vegetation samples from this study were well below the lower threshold (i.e., 3 µg/g dry weight) of dietary exposure associated with reproductive effects in birds (U.S. Department of the Interior 1998). Vanadium concentrations in vegetation were well below an avian dietary concern level (i.e., 100 µg/g dry weight) (White and Dieter 1978). Zinc concentrations in vegetation from this study did not exceed clearly toxic levels presented by Eisler (2000a).

No useful data were found in tables dealing with proposed criteria for the protection of natural resources in Eisler (2000a, 2000b) on dietary concentrations of various metals and trace elements that may adversely affect fish. This is likely due to fish also accumulating such constituents from water-borne exposure.

General

Peterson Reservoir is very shallow and can dry up in a short amount of time if water is diverted from it (Sharon McKelvey, pers. comm.). Information on the conditions at this site is unavailable for the time of sample collection. The higher concentrations of boron and molybdenum in water and vegetation samples from this site may be due to evapo-concentration of these constituents in water.

Food Habits of Ash Meadows Listed Fish and Naucorid

A common route of contaminant exposure in fish and wildlife is through the diet. The three species of pupfish found at Ash Meadows (Warm Springs pupfish, *Cyprinodon nevadensis pectoralis*; Ash Meadows Amargosa pupfish, *C. n. mionectes*; and Devils Hole pupfish, *C. diabolis*) are opportunistic/omnivorous feeders (U.S. Fish and Wildlife Service 1990). The Ash Meadows speckled dace (*Rhinichthys osculus nevadensis*) feeds on drifting insects (U.S. Fish and Wildlife Service 1990). The Ash Meadows naucorid (*Ambrysus amargosus*) is thought to feed on aquatic insect larvae (U.S. Fish and Wildlife Service 1990). Since environmental media collected during the study did not include macroinvertebrates, review of data focused largely on the potential for indirect exposure to sensitive aquatic species through water and sediment.

Conclusions and Recommendations

Although aquatic life standards were exceeded in a few water samples, only the boron and molybdenum concentrations in the sample from Peterson Reservoir are of potential concern. However, only a small portion of the available data could be properly evaluated in relation to

aquatic life standards. Water samples should be collected in the future and should include both filtered and unfiltered samples that should be immediately acidified (i.e., pH 2.0) so that the analytical results may be properly and fully evaluated in relation to aquatic life standards. Water samples should also be analyzed for calcium and magnesium to calculate hardness so that analytical results may be evaluated for constituents having hardness dependent aquatic life standards. Analytical methods should utilize detection limits that are lower than water quality standards. Future collections should include at least one water sample from the Crystal Spring pool using ultra-clean sampling methods and a very low detection limit for mercury analysis.

Concentrations of metals and trace elements in sediment samples did not exceed probable effect concentrations in relation to adverse biological effects in freshwater ecosystems and only the concentration of mercury in the sample from the Crystal Spring pool is of concern. Mercury can be greatly biomagnified through the food chain, with the potential to adversely affect aquatic organisms, including macroinvertebrates and fish. Therefore, additional sampling of sediment from this site (preferably multiple samples) and downstream sites for mercury is highly recommended. The collection of additional sediment samples, for analysis of the full suite of metals and trace elements, from throughout the Refuge would provide useful data.

The presence of mercury in the algae sample from the Crystal Spring pool confirms the presence of elevated mercury concentrations at this site and the need for additional sampling of algae. The presence of the elevated concentrations of aluminum and boron in algae do not appear to be a significant concern, although additional sampling of algae from throughout the Refuge may be useful.

Future sampling throughout the Refuge should also include aquatic vegetation in addition to algae (e.g., pondweed or other species consumed by waterfowl), aquatic invertebrates, and other food items of the threatened and endangered species and migratory birds that are present. Species of fish that are not federally listed should also be collected and analyzed for metals and trace elements as surrogates to threatened and endangered fishes. Samples should be analyzed for the full array of metals and trace elements, including mercury. The results of the analyses of such materials would be helpful in assessing potential risk to a variety of Service trust resources, including threatened and endangered species and migratory birds.

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Table 1. Metal and trace element concentrations in water, sediment, and vegetation collected at Ash Meadows National Wildlife Refuge, 1993. Concentrations in water are in µg/L, whereas concentrations in sediment and vegetation are in µg/g on a dry weight basis.

Sample No.	Location	Sample Type	Al	Concentration As	B	Ba	Be	Cd	Cr	Cu
W039	Crystal Reservoir - north shore	water	30	11.	770	23	<0.2	<2	<10	<2
W040	Crystal Spring – pool	water	140	12.	340	62	<0.2	<2	<10	<2
W041	Crystal Spring – outflow, T ditch	water	30	11.	340	69	<0.2	<2	<10	<2
W042	Horseshoe Reservoir	water	40	13.	470	53	<0.2	<2	<10	<2
W043	Point of Rocks – spring pool	water	<30	11.	320	68	<0.2	<2	<10	<2
W044	Point of Rocks – spring outflow at Rd.	water	70	12.	370	66	<0.2	<2	<10	<2
W060	Jackrabbit Spring – pool	water	<30	15.	470	46	<0.2	<0.5	<2	<2
W061	Jackrabbit Spring – outflow at Big S. Rd.	water	260	16.	470	50	<0.2	<0.5	3	<2
W062	Big Spring – pool	water	<30	24.	490	43	<0.2	<0.5	<2	<2
W063	Jackrabbit/Big Spring outflow at Rd.	water	70	20.	520	51	<0.2	<0.5	<2	2
W064	Fairbanks Spring – pool	water	<30	8.6	320	54	<0.2	<0.5	<2	<2
W065	Rogers Spring – pool	water	<30	13.	320	55	<0.2	<0.5	<2	<2
W066	Longstreet Spring – pool	water	30	13.	330	58	<0.2	<0.5	<2	<2
W067	Peterson Reservoir – south shore	water	40	18.	2840	32	<0.2	<0.5	3	<2
S039	Crystal Reservoir - north shore	sediment	9750	5.9	17.	290.	0.56	0.3	6.6	4.5
S040	Crystal Spring – pool	sediment	4950	5.4	15.	184.	0.47	<0.2	5.2	8.5
S041	Crystal Spring – outflow, T ditch	sediment	1700	3.2	6.2	162.	0.23	<0.2	3.0	1.3
S042	Horseshoe Reservoir	sediment	6440	13.0	36.	241.	0.39	<1.0	6.0	4.2
S043	Point of Rocks – spring pool	sediment	1660	6.3	6.0	161.	0.24	<0.2	4.2	1.9
S044	Point of Rocks – spring outflow at Rd.	sediment	6610	1.7	7.6	231.	0.34	<0.2	6.4	5.6
S060	Jackrabbit Spring – pool	sediment	1510	4.1	9.9	69.1	0.20	<0.2	3.3	1.7
S061	Jackrabbit Spring – outflow at Big S. Rd.	sediment	8400	8.6	23.	153.	1.1	0.4	15.	8.0
S062	Big Spring – pool	sediment	944	1.9	6.5	42.8	0.10	<0.2	2.0	1.3
S063	Jackrabbit/Big Spring outflow at Rd.	sediment	3090	10.2	20.	106.	0.20	<0.2	5.0	4.1
S066	Longstreet Spring – pool	sediment	2460	3.0	<2.0	215.	0.32	<0.2	3.9	3.2

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Sample No.			Sample		Concentration						
					As	B	Ba	Be	Cd	Cr	Cu
V040		Crystal Spring – pool	fil. algae	3190	5.7	20	589	0.38	0.21	9.9	21.0
V041	Location	Crystal Spring – outflow, T ditch	fil. algae	1240	11.1	18	142	0.40	0.16	1.8	4.9
V042		Horseshoe Reservoir	pondweed	260	14.2	25	321	0.02	0.11	0.44	0.93
V043		Point of Rocks – spring pool	fil. algae	1990	5.7	29	649	0.28	0.16	7.5	5.3
V044		Point of Rocks – spring outflow at Rd.	fil. algae	9570	11.0	30	204	0.80	0.50	5.0	14.0
V060		Jackrabbit Spring – pool	algae	3170	3.9	19	1010	0.34	0.19	7.5	41.2
V061		Jackrabbit/Big Spring outflow at Rd.	algae	3110	9.5	42	2760	0.72	1.0	8.5	30.2
V062		Big Spring – pool	algae	1850	8.4	34	3870	0.48	0.16	5.6	17.0
V064		Fairbanks Spring – pool	algae	4290	6.2	28	2560	0.62	0.33	4.9	83.9
V065		Rogers Spring – pool	algae	442	5.8	17	3410	0.10	0.11	1.9	32.6
V066		Longstreet Spring – pool	algae	623	4.8	18	1120	0.10	0.14	1.4	11.0
V067		Peterson Reservoir – south shore	pondweed	2970	19.0	505	109	0.20	0.19	3.2	7.4

Al

Type

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Sample No.	Sample Type	Fe	Mg	Mn	Hg	Mo	Ni	Pb	Se	Sr	V	Zn	Vol. or Wt.[a]
					Concentration								
W039	water	<10	19600	<2	<0.2	10	<20	<40	<0.5	305	<3	10	250
W040	water	84	19600	<2	<0.2	<10	<20	<40	<0.5	874	<3	<5	250
W041	water	30	19200	<2	<0.2	<10	<20	<40	<0.5	848	<3	<5	250
W042	water	<10	26900	6.3	<0.2	<10	<20	<40	<0.5	890	<3	<5	250
W043					<0.2	<10	<20	<40	<0.5	815	<3	<5	250
W044	water	20	21800	<2	<0.2	<10	<20	<40	<0.5	893	<3	<5	250
W060	water	<10	20900	<2	<0.3	10	<2	<10	<0.4	875	<3	<2	250
W061	water	240	21600	2.0	<0.3	10	<2	<10	<0.4	903	<3	4	250
W062	water	20	17800	<2	<0.3	<10	<2	<10	<0.4	960	<3	<2	250
W063	water	55	23500	<2	<0.3	<10	<2	<10	<0.4	1110	<3	2	250
W064	water	<10	19500	<2	<0.3	<10	<2	<10	<0.4	813	<3	4	250
W065	water	<10	19600	<2	<0.3	<10	<2	<10	<0.4	811	<3	3	250
W066	water	10	19800	<2	<0.3	<10	<2	<10	<0.4	818	<3	2	250
W067	water	20	25100	<2	<0.3	53	<2	<10	<0.4	540	<3	15	250
S039	sediment	7150	14800	129.	<0.01	<1.0	3.7	14	<0.2	846.	8.1	19.0	99.4
S040	sediment	3400	9420	75.6	0.56	<1.0	3.0	8	0.3	391.	5.8	29.6	61.2
S041	sediment	1430	5440	45.9	<0.01	<1.0	<1.0	<4	<0.2	396.	2.3	7.3	108.4
S042	sediment	5540	19700	163.	<0.01	<5.0	<5.0	<20	0.3	2080.	14.	17.0	75.7
S043	sediment	1340	8120	29.1	<0.01	<1.0	1.0	<4	0.4	711.	2.0	11.0	70.3
S044	sediment	6020	67400	127.	<0.01	<1.0	4.6	13	0.3	84.3	9.9	34.2	57.7
S060	sediment	1720	9450	44.1	<0.007	<1.0	1.0	<4	<0.2	566.	3.2	5.6	90.6
S061	sediment	7520	11900	99.1	0.009	<1.0	6.6	15	2.8	598.	11.	32.9	65.0
S062	sediment	1260	4440	32.5	<0.007	<1.0	<1.0	<4	<0.2	196.	2.6	3.9	117.4
S063	sediment	3610	12200	118.	0.008	<1.0	3.0	7	0.6	772.	6.5	164.	78.1
S066	sediment	2250	4970	40.4	0.044	<1.0	2.0	<4	0.3	216.	3.6	14.0	89.4

Table 1. Metal and trace element concentrations in water, sediment, and vegetation collected at Ash Meadows National Wildlife Refuge, 1993. Concentrations in water are in µg/L, whereas concentrations in sediment and vegetation are in µg/g on a dry weight basis. (concluded)

Sample No.	Sample Type	Concentration Fe	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn	Vol. or Wt.[a]
V040	fil. algae	2540	1.6	7530	101.	1.0	10.	7.1	1.2	609	9.2	223.	53.2
V041	fil. algae	945	0.070	6200	45.7	<1.0	1.8	3.3	0.50	706	4.2	20.0	22.3
V042	pondweed	266	0.006	9010	108.	<1.0	0.3	0.9	0.30	19100	0.5	5.5	47.2
V043	fil. algae	1630	0.028	5230	44.0	<1.0	11.	4.1	2.1	382	6.6	78.0	53.9
V044	fil. algae	7210	0.024	20500	178.	<1.0	5.5	14.	1.2	655	11.	42.0	22.7
V060	algae	2710	<0.005	7760	52.1	<1.0	4.7	5.5	0.40	519	7.5	26.1	51.1
V061	algae	3120	0.022	12800	102.	<1.0	2.9	7.1	0.70	642	6.8	35.7	46.2
V062	algae	1900	0.010	8330	80.9	<1.0	2.2	3.1	0.69	468	5.1	32.5	52.6
V064	algae	3280	0.010	13200	202.	<1.0	13.	7.9	<0.2	676	9.4	168.	32.2
V065	algae	304	0.010	3970	72.0	1.0	10.	1.4	<0.2	146	4.5	302.	56.8
V066	algae	427	0.052	4080	85.2	1.0	5.7	4.1	<0.2	207	4.1	57.8	52.0
V067	pondweed	1760	0.010	22900	63.8	5.4	1.8	4.7	0.20	5510	6.6	14.0	47.3

[a] Sample volume for water in milliliters or sample weight for sediment and vegetation in grams.

Table 2. Selected water quality data from springs at Ash Meadows National Wildlife Refuge provided by the Department of Energy.

Location	Date	Alkalinity- (as $CaCO_3$) mg/L	Alkalinity-Carbonate (as $CaCO_3$) mg/L	Calcium mg/L	Chloride mg/L	Fluoride mg/L	Magnesium mg/L	pH
Big Springs		245						
		250						SU
		264						
	06/16/00	251	<2	42.7	27.6	1.4	18.5	7.35
Crystal Pool		240	<1	45.0	23.0	1.2	20.0	7.21
		250	<4	44.6	25.4	1.3	19.0	NA
Collection		250	<2	42.2	25.0	1.4	18.4	NA
	06/16/00	242	<2	47.2	25.2	1.7	20.7	7.25
	04/18/02	242	<1	49.0	21.0	1.6	22.0	6.80
Fairbanks Spring	06/16/00	1200	<2	48.4	22.7	1.6	21.2	NA
11/06/00		248	<4	44.4	24.3	1.6	20.2	NA
07/23/01		241	<2	47.9	23.2	1.6	20.6	7.15
Bicarbonate		240	<1	49.0	19.0	1.5	22.0	6.99
04/18/02		240	<4	48.4	21.0	1.5	21.1	NA
Longstreet Spring	06/16/00	242	<2	45.8	21.9	1.6	20.2	NA
11/06/00		242	<2	46.4	22.6	1.5	20.1	7.24
07/23/01			<1	50.0	19.0	1.3	22.0	6.89
04/18/02			<4	49.0	20.5	1.4	21.3	NA
			<2	45.6	22.2	1.4	20.3	NA
11/06/00								
07/23/01								
04/18/02								
Field								

Table 2. Selected water quality data from springs at Ash Meadows National Wildlife Refuge provided by the Department of Energy. (concluded)

Location	Collection Date	Potassium mg/L	Sodium mg/L	SC	Sulfate (as SO_4) mg/L	Temperature	TDS mg/L
Big Springs		8.29	94.3				
		9.50			98.	ºC	
		9.90	81.5	µS/cm			
	06/16/00	8.49	93.0	767	112.	28.7	
Crystal Pool		9.10	72.7	819		27.0	
		9.60	76.0	NA	88.6	NA	
		9.83	64.1	NA	106.	NA	520
	06/16/00	8.69	72.0	722	107.	30.7	440
Fairbanks Spring	06/16/00	8.03	68.0	770	75.0	29.0	467
11/06/00		8.80	73.0	NA	85.9	NA	457
07/23/01		8.67	60.9	NA	90.8	NA	470
04/18/02		7.51	67.8	675	83.8	27.6	420
Longstreet Spring	06/16/00	7.50	65.7	733	74.0	24.9	427
11/06/00		8.60	72.0	NA	82.4	NA	400
07/23/01		8.58	60.3	NA	84.8	NA	440
04/18/02		7.35	67.8	686	81.0	27.8	400
				715	70.0	26.2	391
11/06/00				NA	80.0	NA	404
07/23/01				NA	82.8	NA	450
04/18/02							390
							385
							400
11/06/00							
07/23/01							
04/18/02							

Note: mg/L = milligrams per liter; SU = standard units; SC = specific conductance (microsiemens per centimeter); ºC = degrees Celsius; TDS = total dissolved solids; NA = not analyzed or not reported. All were unfiltered grab samples that were acidified upon collection (Dan VanEtten, pers. comm., DOE, June 2, 2005).

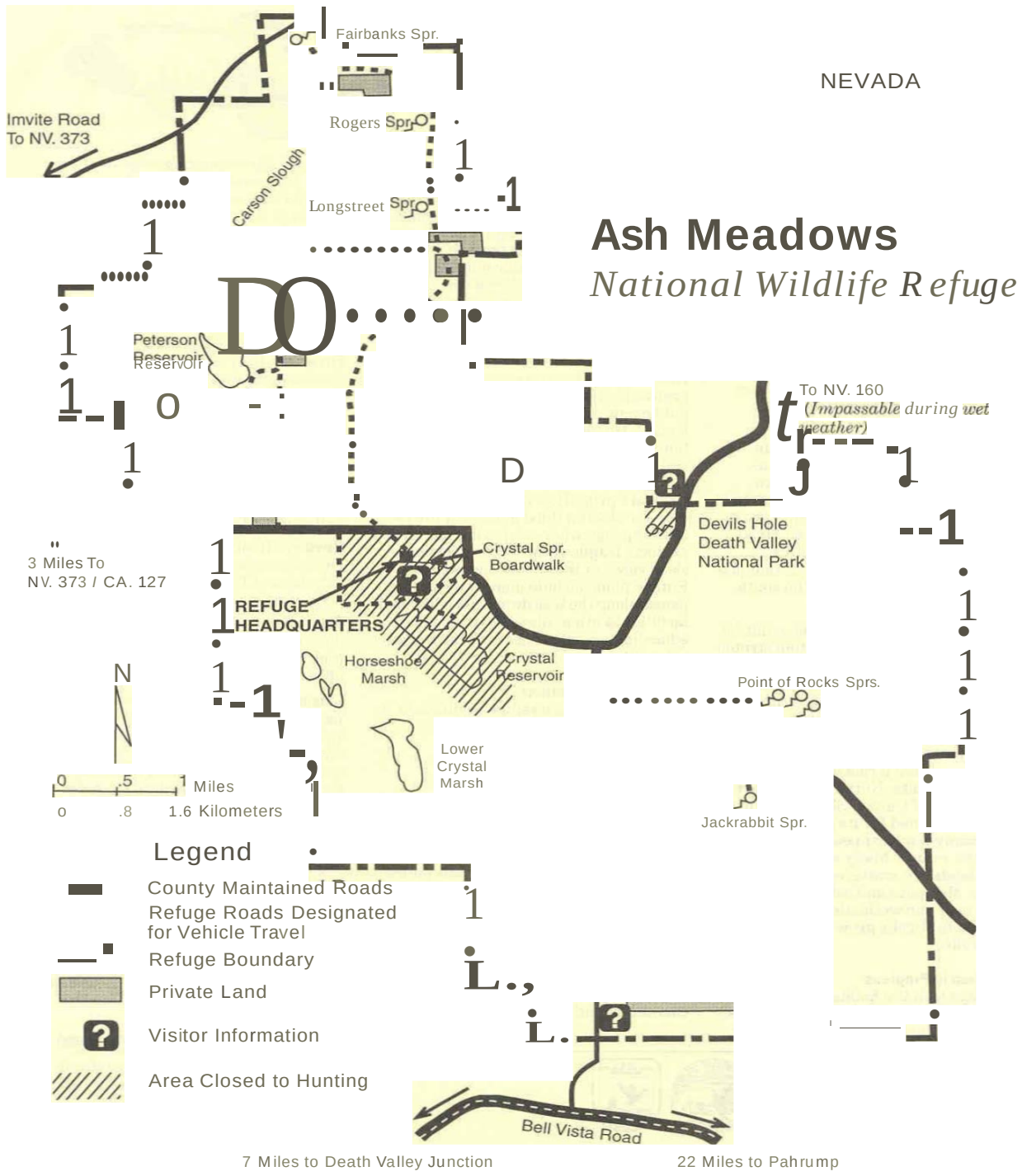

Figure 1. Ash Meadows National Wildlife Refuge, showing locations of springs and general areas of sample collection.