DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
REGION 1

ENVIRONMENTAL CONTAMINANTS PROGRAM

ON-REFUGE INVESTIGATIONS SUB-ACTIVITY

NV • Reconnaissance Assessment of Contaminants in
Pahranagat VaDey, Lincoln County, Nevada
Project ID: 1261-1N27
(filename: *\pahr299.wpd)*

by

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March *S, 1999*

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ABSTRACT

In 1995, U.S. Fish and Wildlife Service personnel initiated a study to identify and quantify potential human-induced envirorunental contaminant impacts to endangered species, species of concern, migratory birds, and Service lands in Pahranagat Valley, Nevada. Specific objectives included: 1) identification and characterization of contaminant source areas; 2) identification and characterization of environmental contaminants on Service lands; 3) assessment of contaminant concentrations in abiotic and biotic habitat components, fish, and migratory bird eggs; 4) characterization of the toxicity of water; and *5)* identification and quantification of contaminant threats to endangered species and migratory birds.

Total dissolved solids (as measured by specific conductance), pH, and concentrations of some soluble trace elements in water increased substantially between the spring sources and lakes on Key Pittman Wildlife Management Area and Pahranagat National Wildlife Refuge. Agricultural practices appeared to contribute to the mobilization of the contaminants from agricultural soils and the transport to down-gradient lakes. Reduced water inflow and high rates of evapotranspiration contributed to the concentration of dissolved constituents in lakes on the Wildlife Management Area and Refuge. Total dissolved solids, pH, arsenic, boron, and selenium in water, sediment, and biological tissues in one or more of these lakes exceeded Nevada water quality standards for applicable beneficial uses and/or concentration associated with adverse effects to aquatic invertebrates. fish, and birds. The highest contaminant concentrations were found in the terminal lakes. Organochlorine pesticides did not appear to represent a threat to fish and wildlife on the Wildlife Management Area or Refuge. Arsenic, mercury, and selenium were found at concentrations of concern in water, sediment, or biological tissues collected from areas occupied by endangered fishes. Detection of mercury and selenium in samples collected from spring source pools suggest that these elements are. at least in part, originating from the carbonate-rock aquifer.

INTRODUCTION

Pahranagat Valley in Lincoln County, Nevada supports a unique and ecologically important ecosystem in the arid northern Mojave Desert. Several springs emerging in the valley provide aquatic and palusbine habitats in two disjunct systems (Figure 1). Flows from Hiko Spring tenninate in wetlands of Key Pitbnan Wildlife Management Area (WMA) in the northern end of the valley and flows from Crystal Springs and Ash Springs terminate in wetlands of Pahranagat National Wildlife Refuge (NWR) in the southern end of the valley. Spring pools and outflow streams historically supported at least six native fishes and several native invertebrates. Wetlands provided important migration, foraging, and nesting habitat for a number of migratory birds. Wet meadows also provided habitat for a variety of terrestrial and semiaquatic species. The species assemblage in Pahranagat Valley includes five federally-listed endangered species and one threatened species (Table 1). Additionally, 22 species of concern have been identified in the Pahranagat Valley.

Habitat alteration and degradation have impacted the endemic fishes in Pahranagat Valley. Two of the endemic fishes, the Pahranagat spinedace *(Lepidomeda altivelis)* and desert

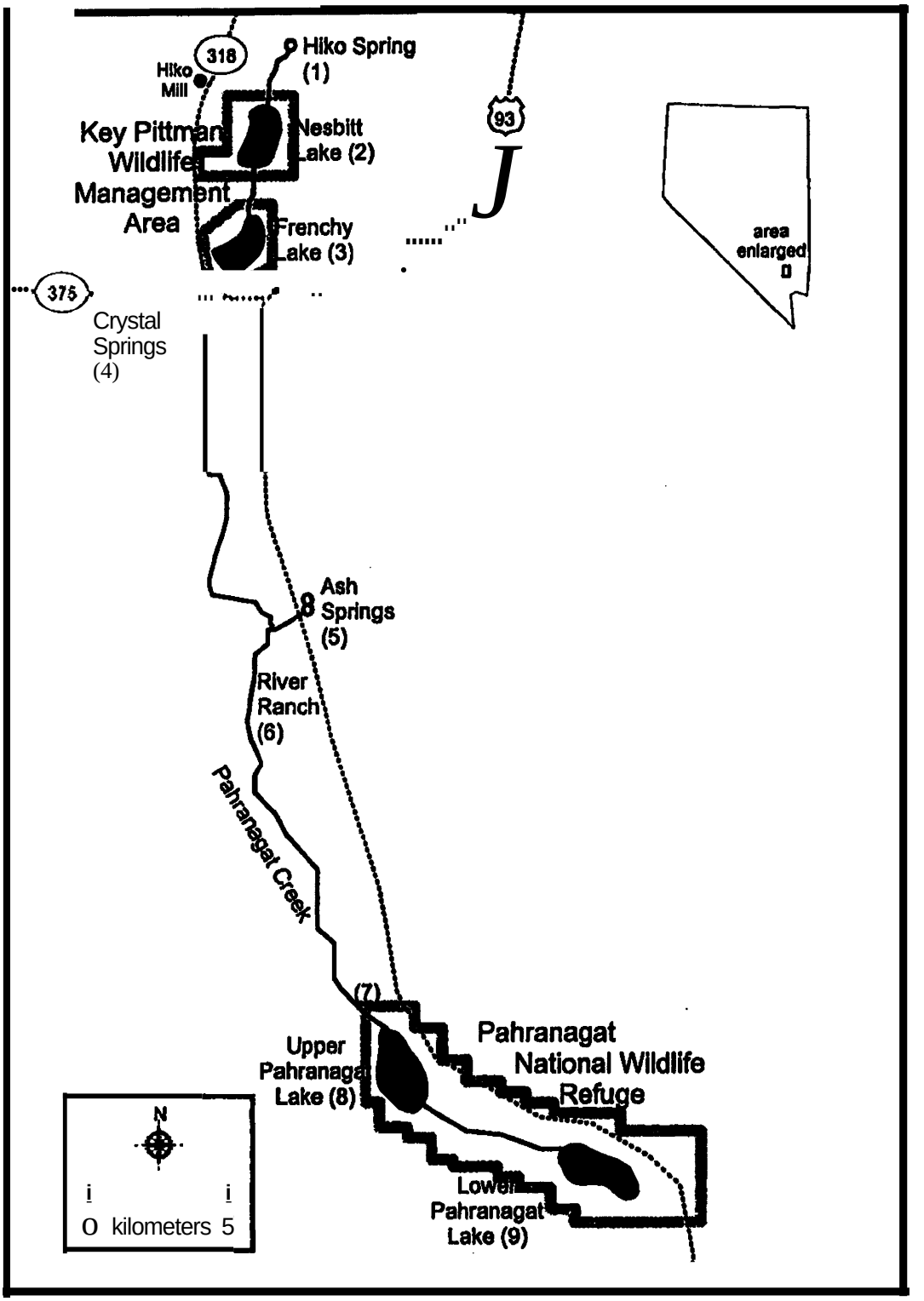

Figure 1. Map of major springs. outflow streams. and lakes in Pahranagat VaDey. Lincoln County. Nevada.

Table 1. Endangered species (E), threatened species (T), and species of concern (8) in Pahranagat Valley, Lincoln County, Nevada.

Common Name	Scientific Name	Federal Status
Mammals		
pygmy rabbit	*Brachylagus idahoensis*	S
Desert Valley kangaroo mouse	*Microdipodops megacephalus a/biventer*	S
Pahranagat Valley montane vole	*Microtus montanus fucusus*	S
spotted bat	*Euderma maculatum*	S
Allen's big-eared bat	*Idionycteris phyllotis*	S
small-footed myotis	*Myotis ciliolabrum*	S
long-eared myotis	*Myotia evotis*	S
fringed myotis	*Myotis thysanodes*	S
long-legged myotis	*Myotis volans*	S
Yumamyotis	*Myotis yumanensis*	S
big free-tailed bat	*Nyclinomopa macrotia*	S
pale Townsend big..eared bat	*Plecotus townsendi; pallescens*	S
Birds		
southwestern willow flycatcher	*Empidonax traillii*	E
American peregrine falcon	*Fa/co peregrinus anatum*	E
bald eagle	*Ha/iaeetus leucocepha/us*	T
western least bittern	*Ixobrychus exilis hesperia*	S
white..faced ibis	*Plegadis chihi*	S
black tern	*Chlidonias niger*	S
ferruginous hawk	*Buteo regalis*	S
western owl	*Athene cunicularla hypugea*	S
Fish		
Pahranagat roundtail chub	*Gila robusta jordan;*	E
White River springfish	*Crenichthys bailey;*	E
Hiko White River springfish	*Crenichthys baileyi*	E
Pahranagat speckled dace	*Rhinichthys osculus lIelifer*	S
Invertebrates		
Pahranagat pebblesnail	*Fluminicola merriami*	S
Grated tryonia	*Tryonia clathrata*	S
Amargosa naucorid	*Pelocoris shoshone shoshone*	S
Moapa warm spring riffle beetle	*Stene/mis calida moapa*	S
undescribed rime beetle	*Stenelmis* ap.	

sucker *(Catostomus clarlci ssp.*), became extinct (Mink1ey and Deacon 1968). The abundance and range of the remaining endemic fishes have declined substantially (Tuttle ct al. 1990). Three of the fishes, Pahranagat roundtail chub *(Gila robustajordan'1,* White River springfish *(Crenichthys bailey;* and Hiko White River springfish *(Crenichthys baileyi grandis),* are listed as endangered. A sixth fish species, Pahranagat speckled dace *(Rhinichthys velifer),* is a species of concern. Impacts to other aquatic or wetland dependent species are uncertain.

The contribution of environmental contaminants to the degradation of this system and the decline of endemic species is uncertain. However, water quality has been identified as a factor limiting the range of endemic fishes (Tuttle et al. 1990). Specific conductance of spring water emerging in Pahranagat Valley ranges from 400 to *S00* microseimens per centimeter (pS/cm; Eakin 1963). During the irrigation season (March 15 to October 15) spring discharge is used to irrigate agricultural fields. Spring discharge is allocated to Pahranagat NWR and Key Pittman WMA outside of the irrigation season. However, fanners maintain rights to "flush salts and alkali" from agricultural fields during this period (Lincoln County Conservation District *1980).* These practices, along with evaporative concentration, contribute to an increase in dissolved solids as water progresses through these systems. Because of increased evaporation rates and the lack of inflow to down..gradient wetlands, dissolved solids concentrations are greatest during late summer. Specific conductance in teonina! wetlands in Pahranagat NWR has exceeded 10,000 µS/cm (peter Tuttle, U.S. Fish and Wildlife Service, written comm., 1987).

Purpose and Scope

In 1995, a study team consisting of U.S. Fish and Wildlife Service (Service) personnel from the Pahranagat NWR, the Las Vegas Fish and Wildlife Service Sub-Office, and the Nevada Fish and Wildlife Office initiated a study to assess the role of environmental contaminants in the degradation of aquatic habitats and the decline of native species in Pahranagat Valley. The objectives of this study were to identify and quantify human-induced environmental contaminant impacts to endangered species, species of concern, migratory birds, and Service lands in Pahranagat Valley. Specific objectives included: 1) identification and characterization of contaminant source areas; 2) identification and characterization of environmental contaminants on Service lands; 3) assessment of contaminant concentrations in abiotic and biotic habitat components, fish, and migratory bird eggs; 4) characterization of the toxicity of water; and *S)* identification and quantification of contaminant threats to Service trust fish and wildlife resources (endangered species and migratory birds).

Study Area

Pahranagat Valley is located in west-central Lincoln County approximately 150 Ian north of Las Vegas. The valley occurs along the course of the pluvial White River. The hydrographic basin encompasses about 142,450 hectares, which includes about 4,850 hectares of private land, 540 hectares of State land, and 2,180 hectares of Service land. The remaining 134,880 hectares are primarily uplands administered by the Bureau of Land Management. Elevations in the valley

range from more than 1,900 m in the sUITOunding mountains to 900 m in the southem end valley. The climate in Pahranagat Valley is characterized by mild winters, hot summers, low precipitation (approximately 17 cm per year), and high evaporation rates (Mozejko 1986)

Upland plant communities in Pahranagat Valley are characteristic olthe creosote bush *(Larrea tridentala)* - burroweed *(Ambrosia dumosa)* vegetation association (Kanim 1986). Bottom lands in Pahranagat Valley are characterized by sedge and grass meadows with . interspersed willow *(Salix* spp.), cottonwood *(Populus* spP.), and ash trees (*Fraxinus* spp).

The Pahranagat Valley is mostly rural, with a total population olless than 2,000 people. The largest population concentration is in the town of Alamo. Livestock grazing is the principle land use in Pahranagat Valley. Cattle are grazed in irrigated pastures and riparian areas adjacent to the Pahranagat Creek and in the open range surrounding these bottom lands. Additionally, cattle are seasonally grazed on portions of Key Pittman WMA and Pahranagat NWR. Alfalfa, which is used to supplement the feed of local cattle, is the most important crop produced in Pahranagat Valley.

Three springs, Hiko, Crystal, and Ash are the primary source of surface water in Pahranagat Valley (Figure 1). These springs originate from a deep carbonate-rock aquifer which underlies a large portion of the eastern Great Basin. Several other springs and seeps occur in the valley, but contribute relatively minor water volumes to the Pahranagat Creek system. The Valley is divided into two hydrographic sub-basins. Hiko Spring provides approximately 0.17 cubic meters per second (ml/s; 5.9 cubic feet per second [cfs]) of water in the northern sub..basin (Hiko Springs Sub-basin). The source pool ofHiko Spring provides habitat forHiko White River springfish. Pahranagat roundtail chub were extirpated from this system after the 1950's. Near the spring pool, water is diverted to a network of pipes and used for crop and pasture irrigation during the irrigation season. Outside of this season, Hiko Spring provides water to Nesbitt Lake on Key Pittman WMA. Outflow from Nesbitt Lake flows approximately 2 km via surface channels to Frenchy Lake, the terminal lake in the Hiko Spring sub-basin. Frenchy Lake may be periodically desiccated.

Crystal Springs, the northern most spring in the Crystal and Ash Springs sub-basin, occurs approximately 0.5 km south of Frenchy Lake. However, a 15m rise in the land surface has separated the two sub-basins in recent geologic time. Crystal Springs consists of at least two springs that discharge a combined volume between 0.17 m^3/s (5.9 cfs) and 0.31 m^3/s (10.9 cls). Crystal Springs flows approximately 1 Ian in a heavily vegetated earthen channel before entering a concrete-lined canal. The source pools and to a limited extent, the earthen outflow channel, provide habitat for a small population of White River Springfish. Pahranagat speckled dace occur in the concrete-lined channel and down gradient earthen channels. Pahranagat roundtail chub were extirpated from this system sometime after 1950. Crystal Springs water is almost entirely consumed in pasture and crop irrigation during the irrigation season. Outside of the irrigation season, surface flows from Crystal Springs merge with the outflow from Ash Springs, approximately 7 km to the south, to form Pahranagat Creek. Ash Springs consists of at least 7 springs which discharge a combined volume of 0.56 m]/s (19.8 cfs). The large convoluted spring pool, and to a limited extent, the outflow stream, provide habitat for White River springfish.

Outflow from Ash Springs enters a remnant of the historic Pahranagat Creek. This relatively pristine reach of the creek on the Burns Ranch provides habitat for the bulk of the Pahranagat roundtail chub population. This reach extends approximately 4.5 Ian before entering a concrete-lined canal which provides irrigation water to much of the agricultural lands between

Ash Springs and Pahranagat NWR. Outside of the inigation season, water also enters the historic river channel extending to Pahranagat NWR. Most of this earthen channel down stream of the Bums Ranch becomes desiccated during the irrigation seasoD.

Pahranagat NWR receives water solely through a historic river channel north afthe refuge boundary. Water entering the refuge flows into Upper Pahranagat Lake. From 1991-94, approximately 6,500 acre-feet of water entered Pahranagat NWR annually (Clary et al. 1995). The majority of the water was received during the winter months (Figure 2). Flows to the refuge during the summer were minimal. Water is seasonally released from Upper Pahranagat Lake to irrigate the down gradient meadows and to flood or freshen a series of small impoundments and Lower Pahranagat Lake. During most years, Lower Pahranagat Lake serves as the tenninallake in the Crystal and Ash Springs sub-basin. However, when adequate water is available, water may be released to Maynard Lake, the southern most wetland in Pahranagat Valley.

Metal mining and milling began in the Pahranagat Valley with the 1865 discovery of silver, copper, and lead deposits approximately 16 Ian northwest of Hiko in the Mount Irish Range. To process the ore, a S-stamp mill was constructed near Hiko in 1867. However, milling using mercury amalgamation was largely unsuccessful due to the high sulfide content in the ore and the mill closed in 1869 (Tschanz and Pampeyan 1970). The historic mill site, consisting of stone foundation and tailings material, is located approximately 2 tan north of Nesbitt Lake.

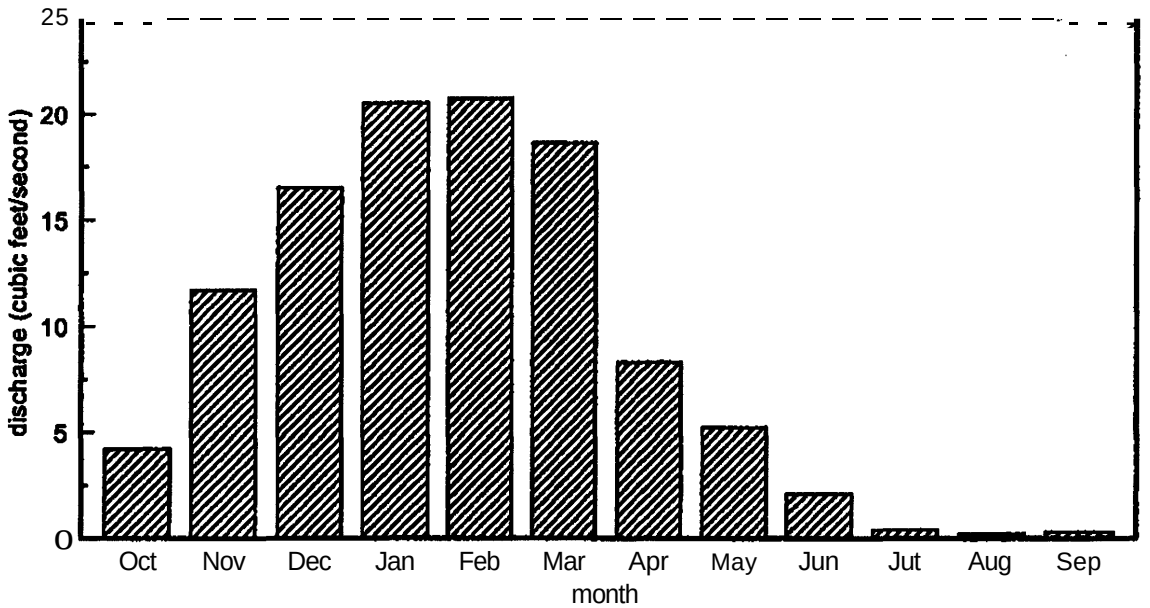

Figure 2. Mean monthly water flows entering Pahranagat National Wildlife Refuge, Lincoln County, Nevada. 1991·94. Data from Clary ct al. (1995).

METHODS

A combination of water quality assessment. analysis of trace element concentrations in water, sediment, and biota (vegetation, invertebrates, fish, and avian eggs), analysis of organochlorine concentrations in sediment, assessment of physical condition of fish. and toxicity testing were used to identify and characterize contaminant concerns in Pahranagat Valley. Nine sites in two disjunct spring and outflow systems were investigated (Figure 1). These sites represented a gradient of specific conductance, with the lowest levels occurring near the spring source and the highest levels occurring in terminal lakes. Specific sites in the Hiko Spring sub-basin included: 1) Hiko Spring pool (designated critical habitat for Hiko White River springfish); 2) Nesbitt Lake on Key Pittman WMA; and 3) Frenchy Lake (the tenninus of the system). Specific sites in the Crystal and Ash Springs sub-basin included:.4) Crystal Springs pool (designated critical habitat for Hiko White River springfish); *S)* Ash Springs pool (designated critical habitat for White River springfish and Pahranagat roundtail chub); 6) the combined outflows of each spring (Pahranagat Creek on the River Ranch); 7) the Pahranagat Creek entering Pahranagat NWR; 8) Upper Pahranagat Lake; and 9) Lower Pabranagat Lake (the tenninus of the system). Because of seasonal differences in water quality, sites in the lower portion of each sub·basin (sites 2, 3, 7, 8, and 9) were sampled during two time periods. Sampling in May 1995 coincided with peak migratory bird nesting. Sampling in August 1995 corresponded with the expected poorest water quality in the tenninal wetland areas. Trace element data collected from some of the sites in September 1993 were also evaluated to assess temporal differences in trace element concentrations.

Water quality parameters examined at each site included temperature, dissolved oxygen, pH, specific conductance, salinity, and turbidity. Temperature and dissolved oxygen were measured with a Yellow Springs Instruments model 57 oxygen meter. An Orion Research model SA250 pH meter was used to measure pH. Specific conductance and salinity were measured with a Yellow Springs Instruments model 33 S-C-T meter.

Whole (unfiltered) water was collected in mid·water column in 250 ml nalgene bottles and acidified to pH $\leq$ 2.0. Sediment was collected with a Wildco model number 2422 H12 core sampler and placed in a SOO..ml pre-cleaned nalgene container. Sediment samples included the top 5 em of the core. Each sediment sample consisted of a composite of *S* subsamples which were thoroughly mixed in the nalgene container with a stainless steel knife. Aquatic vegetation samples were collected by hand. Aquatic invertebrate samples were collected with a kick placed in precleaned SOO-ml natgene containers, and later sorted in the laboratory. Sediment, aquatic vegetation, and aquatic invertebrate samples were placed in 60 ml acid-washed glass containers with Teflon lined closures. Fish were collected from sites 1,4, *S,* 6, and 7 using unbaited minnow traps. Fish were collected from Nesbitt Lake on Key Pittman WMA (site 2) and Upper Pahranagat Lakes on Pahranagat NWR (site 8) using seines. Fish were placed in plastic bags and later sorted, processed, and placed in acid-washed glass containers in the laboratory. Due to shifts in species composition, consistent vegetation, invertebrate, and fish species could not be collected from all sites (Appendix *A).* American coot *(Fulica americana)* eggs were collected by hand and placed in a carton, stored on ice in the field, and later opened using pre-cleaned stainless steel instruments in the laboratory. Egg contents were placed in 60 ml acid-washed glass containers then frozen. Four sediment samples for organochlorine residue analysis were collected from sites 2 and 3 on Key Pittman WMA and sites 8 and 9 on Pahranagat

NWR. Two soil samples were also collected for trace element analysis from tailings materials at historic gold and silver mill sites. Soil samples consisted of 5 approximately equal subsamples collected with a stainless steel spoon and mixed in a 500 ml nalgene container. All samples were stored on ice in the field. Water was refrigerated and other samples were frozen following processing.

Samples were shipped to the Environmental Trace Substances Research Center, Columbia, Missouri, for chemical analysis. Water samples were shipped overnight in a with blue ice. Frozen samples were shipped overnight in a cooler containing dry ice. Chemical analyses were conducted following methods described in Patuxent Analytical Control Facility (1990). Arsenic and selenium concentrations were detennined using hydride generation atomic absorption spectroscopy. Mercury concentrations were detennined using cold vapor atomic absorption spectroscopy. Concentrations of aluminum, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, strontium, vanadium, and zinc were determined with inductively coupled plasma emission spectroscopy. Concentrations of trace elements in unfiltered water are expressed on a wet-weight basis. Unless otherwise indicated, trace element concentrations in other samples are expressed on a dry-weight basis.

Quality control and laboratory performance was assessed and approved by Patuxent Analytical Control Facility personnel. Quality control techniques included the use of procedural blanks, duplicate samples, spiked samples, and reference materials. Laboratory perfonnance was within the acceptable precision range prescribed in Patuxent Analytical Control Facility (1990).

During the summer sampling period, fish occurrence was quantified at each sampling location. Fish were collected during sample collections described above. All fish were identified to the species level and counted. Up to 50 fish of each species from each sample station were weighed, measured (fork length), and examined for external aberrations (lesions, tumors, parasites, asymmetry, etc.). A Fulton-type condition factor (Anderson and Gutreuter 1983) was applied to examine intra-specific variations in physical condition factors among sites. One-way ANOVA and Tukey's multiple comparison test were used to assess differences. Significance in statistical tests was assigned at $p < 0.05$.

Microtox® toxicity testing (5-, 1S-, and 30..minute procedures) was used to assess toxicity of wster samples collected in August 1995. Microtox® provides a rapid assessment of the relative toxicity of water samples using a strain of photoluminescent marine bacteria, *Photobacterium phosphoreum,* as a test organism. The Microtox® instrument measures bacterial luminosity, which is assumed to be a measure of metabolic activity. A decrease in luminosity following exposure of the bacteria to a water sample is interpreted as a depression in metabolic activity, and therefore provides an indicator of toxic response. Toxicity is expressed as the median concentration eliciting a *SO* percent reduction in light output (EC_{S0})' Procedures for Microtox® assessment of water samples are described in Henry and Hickey (1991). Water samples used for Microtox® toxicity testing were collected at the same time and locations as water collected for trace element analysis described above.

RESULTS AND DISCUSSION

Implications of dissolved solids, pH, and trace elements to fish and wildlife were assessed through exceedances of State and Federal water quality standards and exceedances of published fish and wildlife concern or effect levels. Nesbitt Lake and Upper Pahranagat Lake are classified as class C waters (NAC 445A.126). Beneficial uses of class C waters include municipal or domestic supply following treatment, irrigation water, watering of livestock, aquatic life, propagation of wildlife, recreation involving contact and noncontact with water, and industrial uses. No beneficial uses for other surface waters in Pahranagat Valley have been designated. Table 2 provides Nevada standards for protection of aquatic life or other beneficial uses for selected trace elements in water.

Based on the criteria identified above, concerns were identified with specific conductance, pH, arsenic, boron, mercury, and selenium. These concerns are discussed in more detail below. Concentrations of these and other trace elements are found in appendix A.

Specific Conductance

Field specific conductance, an indirect measure of dissolved solids, in the Pahranagat Valley ranged from about 500 microsiemens per centimeter *(J1S/cm)* at spring sources to 4,320 µS/cm at Lower Pahranagat Lake (Table 3). Specific conductance did not substantially increase as water progressed through the agricultural areas (Figure 3). However, substantial increases were observed in the lakes of both Key Pittman WMA and Pahranagat NWR, with the terminal lakes (Frenchy Lake and Lower Pahranagat Lake, respectively) having the highest specific conductance. The 1995 monitoring data also exhibit a seasonal component to specific conductance levels in the lakes and the inflow to Pahranagat NWR. Elevated specific conductance of the inflow water during May may reflect mobilization of dissolved solids as a result of flushing salts from agricultural soils outside of the irrigation season. Conversely, lower specific conductance levels in the lakes in May than in August likely reflect increased water inflows during the non-irrigation season and subsequent dilution within the lakes (Figure 2). Elevated specific conductance in the lakes during the August sampling period likely reflect reduced inflow coupled with increased evaporative water loss which concentrates the dissolved solids.

Tolerance limits of aquatic and emergent plants and aquatic vertebrates and invertebrates to dissolved solids vary widely, thus producing shifts in species composition (Rawson and Moore 1944; Stewart and Kantrud 1971; Swanson et al. 1984). In general, composition declined with increasing salinity. Elevated dissolved solids may avian reproduction. When relegated to water with a specific conductance greater than 20,000 µS/cm, duckling mortality resulted (Swanson et al. 1984; Mitcham and Wobeser 1988). Ducklings relegated to water with a specific conductance between 7,500 to 20,000 µS/cm suffered sublethal effects on growth, feathering, and other physiological functions. Weight gain of ducklings reared on water with specific conductance greater than 4,000 µS/cm was depressed. Summer samples of specific conductance in Lower Pahranagat Lake attained levels consistent with sublethal effects to ducklings. However, specific conductance in May was well below this potential level.

Table 2. Regulatory standards applicable to designated waters in Nevada. Standards are from Nevada Administrative Code (NAC) *44SA.119* and 44SA.l44, 1997.

Constituent	Municipal or Domestic Supply	Aquatic Life	Irrigation	Watering of Livestock	Propagation of Wildlife
pH	5.0..9.0	*6.S-9.0*	4.5-9.0	*5.0-9.0*	7.0-9.2
TDS' (mgIL)	1000			3000	
Arsenic (µg/L)	50	180[b, e]	100	200	
Barium (µg/L)	1000				
Beryllium (µg/L)	0		100		
Boron (µg/L)			*750*	5000	
Cadmium (µg/L)	10	-[c, d]	10	*SO*	
Chromium (µg/L)	*SO*	-[c,d]	100	1000	
Copper (µg/L)		-[c,d]	200	500	
Iron (µg/L)		1000	5000		
Lead (µg/L)	*SO*		*S000*	100	
Manganese (µg/L)			200		
Mercury (µg/L)	2	0.012'		10	
Molybdenum (µg/L)		19			
Nickel (µg/L)	13.4	..[c,d]	200		
Selenium (µg/L)	10	5[e]	20	*SO*	
Zinc (µg/L)		[cd]	2000	25000	

• Total dissolved solids

[b] The arsenic standards for aquatic life are specific for As+3. The 96-hour average aquatic life standard is given.

[o] The standard applies to dissolved fraction only.

[d] Standards for aquatic life are based on water hardness, which is expressed as mgIL $CaCO_3$. Fonnulae for 96-hour average standards for specific elements are as follows:

Cadmium:	0.8Sexp[0.7852 In(hardness)-3.490]
Chromium+[J]:	O.8Sexp[O.8190 In(hardness)+l.S61]
Copper:	O.8Sexp[O.8S4S In(hardness)-1.46S]
Lead:	0.2Sexp[1.273ln(hardness)-4.70S]
Nickel:	O.8Sexp[O.8460 In(hardness)+1.1645]
Zinc:	O.8Sexp[O.8473 m(hardness)+O.7614]

[e] The 96-hour average aquatic life standard is given.

pH

The pH in Pahranagat Valley ranged from near neutral (6.9 to 7.4) at the spring sources to 10.6 in the tenninal ponds (Table 3). The highest values were found during the summer sampling periods (Figure 3). Like specific conductance, elevated pH was likely attributable to evaporative concentration in these tenninal basins. The pH values found in each pond during these sampling periods exceeded the Nevada water quality standards for aquatic life, irrigation, watering of livestock, and propagation of wildlife (Table 2). Alkaline conditions are common in tenninal1akes and wetlands and other surface waters in the Great Basin (Hoffinan et a1. 1990a; Seiler et a1. 1993; Thodal and Tuttle 1996).

Table 3. Field measurements of temperature, pH, specific conductance (microsiemen per centimeter; *p.S/cm),* salinity (parts per thousand; ppt), and dissolved oxygen (milligrams per liter; mglL) in Pahranagat Valley, Lincoln County, Nevada, 1993..95.

Site No.	Location	Date	Temp. (°C)	pH	Specific Conductance (µS/cm)	Salinity (ppt)	Dissolved Oxygen (mi'L)
4	Crystal Springs	*09/07/93*	27	7.1	490	0.0	9.2
S	Ash Springs	*09/07/93*	33	7.4	*SSO*	0.0	*4.5*
7	PNWR' inflow	09/07/93	25	8.6	*7S0*	0.2	*7.5*
8	Upper Pahranagat Lake	09/07/93	30	8.8	1.400	0.5	11.9
9	Lower Pabranagat Lake	09/07/93	28	10.3	4.320	2.5	11.2
2	Nesbitt Lake	*05/04/95*	19	8.7	720	0.0	
3	Frenchy Lake	*05/04/95*	19	9.0	1,500	1.0	
4	Crystal Springs	*05104/95*	27	7.0	500	0.1	
S	Ash Springs	05/04/95	30	7.1	560	0.1	
6	Burns Ranch	*05104/95*	26	7.5	600	0.2	
7	PNWR& inflow	*05/04/95*	15	8.0	850	0.7	
8	Upper Pahranagat Lake	*05/03/95*	22	8.2	1,050	0.6	
9	Lower Pahranagat Lake	*05/03/95*	20	8.6	1,750	1.1	
1	Hiko Spring	*08123195*	26	7.2	*SSO*	0.5	4.5
2	Nesbitt Lake	*08123/95*	24	9.0	1,190	1.0	2.9
3	Frenchy Lake	*08123/95*	28	10.6	3,230	1.9	12.5
4	Crystal Springs	*08122195*	27	7.0	500	0.2	4.1
5	Ash Springs	*08122/95*	34	6.9	600	0.4	4.4
6	Bums Ranch	*08124/95*	30	7.6	SSe	0.3	7.0
1	PNWR[a] inflow	*08124195*	20	7.6	600	0.4	6.0
8	Upper Pahranagat Lake	*08121/95*	31	9.1	1,358	1.0	10.5
9	Lower Pahranagat Lake	*08121/95*	27	10.6	2,880	1.9	12.6

• Pahranagat National Wildlife Refuge

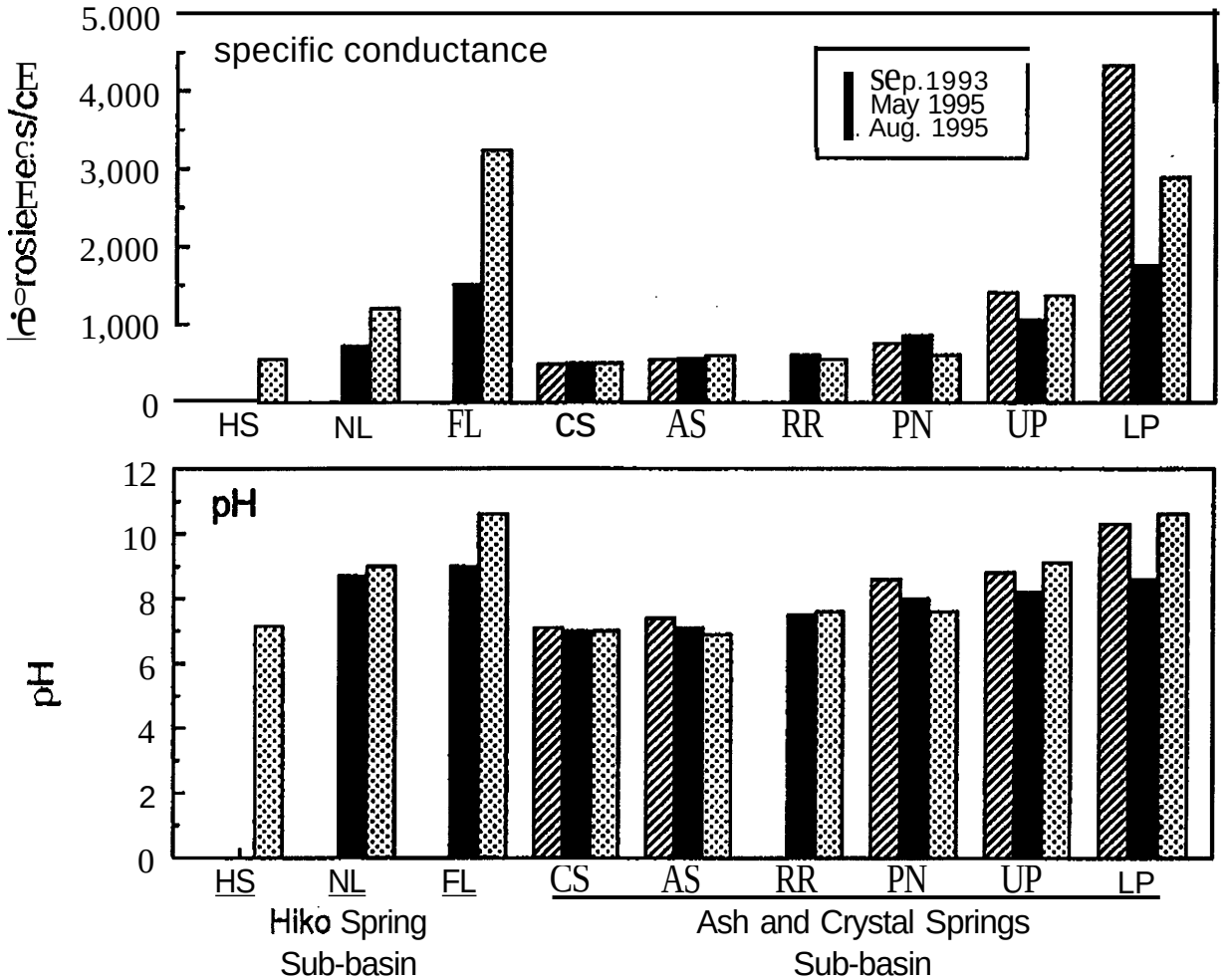

Figure 3. Specific conductance and pH in water at nine locations in Pahranagat Valley, Lincoln County. Nevada, September 1993 to August 1995. Measurement sites include Hiko Spring (H8), Nesbitt Lake (NL), Frenchy Lake (FL), Crystal Springs (CS), Ash Springs (AS), Pahranagat Creek on River Ranch (RR). inflow to. Pahranagat National Wildlife Refuge (PN>. Upper Pahranagat Lake (UP), and Lower Pahranagat Lake (LP).

Arsenic

Arsenic concentrations in unfiltered water from Pahranagat Valley ranged from 2 to 1S0 µg/L (Figure 4). Arsenic concentrations in water were not significantly correlated to specific . conductance (p =0.65; r^2=0.01, n=32). The maximum concentrations were found in lakes of Key Pittman WMA and Pahranagat NWR in May 1995. Elevated concentrations in the lakes during this period may be attributed to the practice of "leaching salts and alkali" from agricultural fields during the non-irrigation season which may result in mobilization and transport to the lakes. During this sampling period. concentrations in water from Key Pittman WMA and Pabranagat

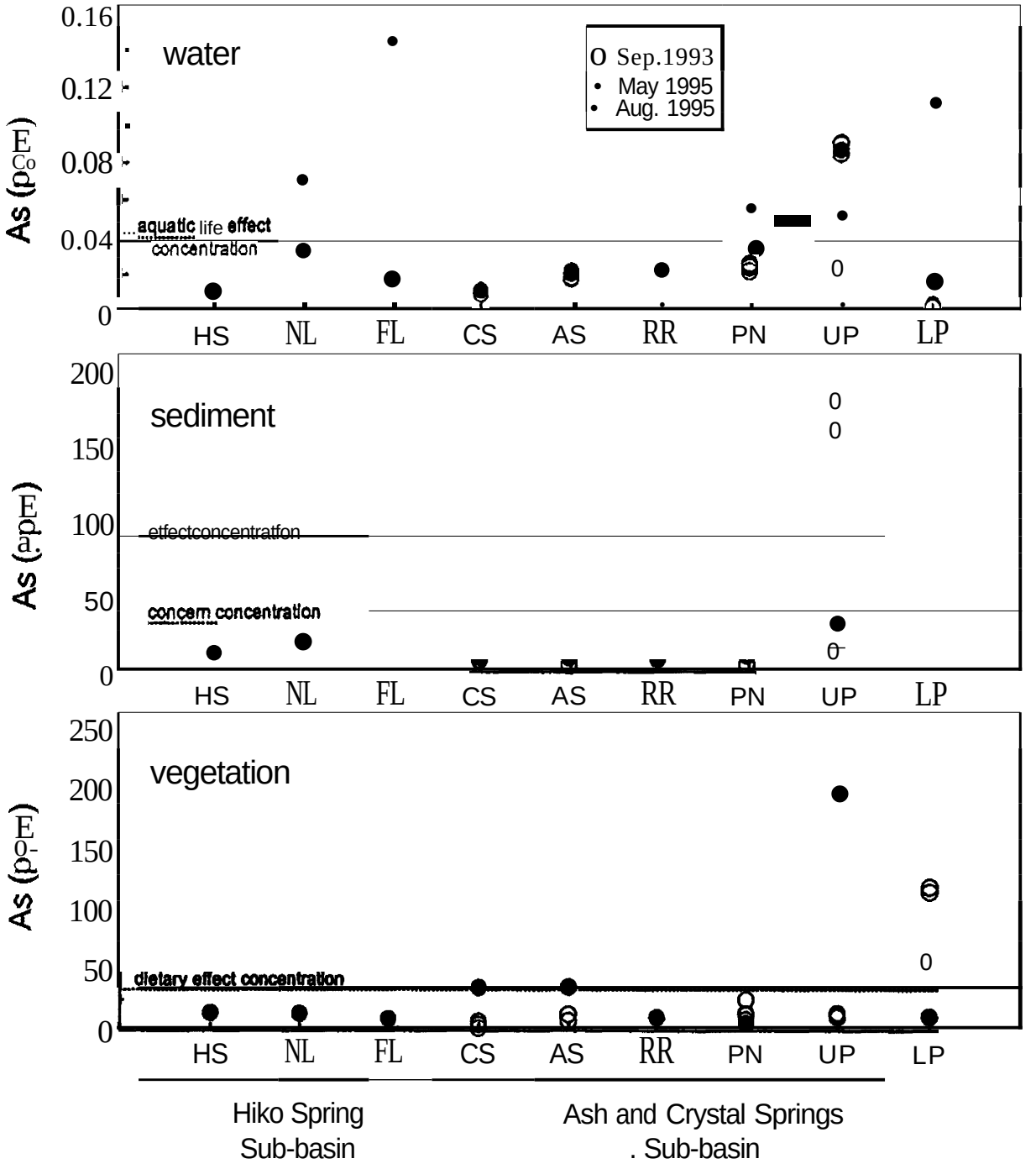

Figure 4. Arsenic concentrations (parts per million-ppm) in water, sediment (dry weight), and aquatic vegetation (dry weight) from nine locations in Pahranagat Valley, Lincoln County, Nevada, September 1993 to August *1995.* Collection sites include Hiko Spring (HS), Nesbitt Lake (NL). Frenchy Lake (FL), Crystal Springs (CS). Ash Springs (AS), Pahranagat Creek OD River Ranch (RR), inflow to Pahranagat National Wildlife Refuge (PN). Upper Pabranapt Lake (UP), and Lower Pahranagat Lake (LP).

NWR exceeded Nevada standards for municipal or domestic supply *(SO* µg/L) and irrigation (100 J1g/L). The Nevada standard for the protection of aquatic life is based on arsenic species. with a chronic (96-hour) aquatic life standard for trivalent arsenic (As+3) of 180 µg/L. Total arsenic in unfiltered water collected from all sites was below this aquatic life standard. However, arsenic concentrations in some samples collected from lakes on Key Pittman WMA and Pahranagat NWR exceeded concentrations associated with toxicity to amphibian embryos and larvae and low level toxicity to fish (40 µg/L; U.S. Environmental Protection Agency (USEPA] 1985; Birge et a1. 1979a).

Arsenic in sediments from all locations exceeded potentially toxic concentrations for sensitive benthic invertebrates (6 µg/g; Persaud et a!. 1993). Arsenic concentrations in sediment from Frenchy Lake in 1993 and 1995 and two samples collected from Upper Pahranagat Lake in 1993 exceeded a level associated with toxicity to a broader range of benthic invertebrates (33 µg/g).

Arsenic in diet may affect fish. Growth in salmonids maintained on a diet containing 30 µg/g arsenic was reduced (Oladimeji et al. 1984). Arsenic concentrations in all vegetation•. invertebrates, and fish samples collected from areas in Pahranagat Valley supporting native fishes were below this potential fish dietary concern level.

Arsenic may cause mortality or produce a variety of sublethal effects to avian species. Arsenic may be fatal (II-day LC_{50}) to sensitive avian species (brown-headed cowbird; *Molothrus ater)* at dietary levels as low as 100 ppm (Eisler 1994). Waterfowl appear to be more tolerant, with mortality (LC_{50}) of mallards (*Anas platyrhynchos)* occurring at dietary arsenic concentrations of 1.000 µg/g after 6 days and *S00* µg/g after 32 days (National Academy of Sciences 1977). Growth. development, and physiology of mallard ducklings may be affected at a dietary concentration of 30 µg/g arsenate (Camardese et al. 1990). but effects are more·severe at dietary concentrations between 100 and 400 µg/g (Camardese et a1. 1990; Hoffinan et ale 1992; Stanleyet a1. 1994). Avian reproduction was affected at a dietary level of 400 µg/g (Stanleyet al. 1994). Arsenic concentrations in potential avian dietary items (aquatic vegetation) collected from Upper Pahranagat Lake in 1993 and Lower Pahranagat Lake in 1995 exceeded a concentration associated with sublethal effects but were below levels associated with avian mortality (Figure 4). Arsenic concentrations in invertebrates and fish were below avian dietary levels of concern.

Arsenic may cause embryonic mortality and teratogenic effects in avian species (Eisler 1994). However, Stanleyet al. (1994) did not find reduced hatching or teratogenic effects in eggs from mallards maintained on diets containing up to 400 µg/g sodium arsenate. The mean arsenic concentration in associated with the maximum dietary concentration was 3.6 µg/g. All eggs collected from Key Pittman WMA and Pahranagat NWR were below this concentration.

Boron

Boron concentrations in unfiltered water from Pahranagat Valley ranged from 90 to 3,510 µg/L (Figure 5). Concentrations in water were significantly correlated with specific conductance ($p<0.001$, $r^2=0.831$, n=32) and pH ($p<0.001$, $r^2=0.711$, n=32). Concentrations in tcnninal ponds on Key Pittman WMA and Pahranagat NWR (Frenchy Lake and Lower Pahranagat Lake, respectively) exceeded the Nevada water quality standard for irrigation (750 µg/L). Boron in all

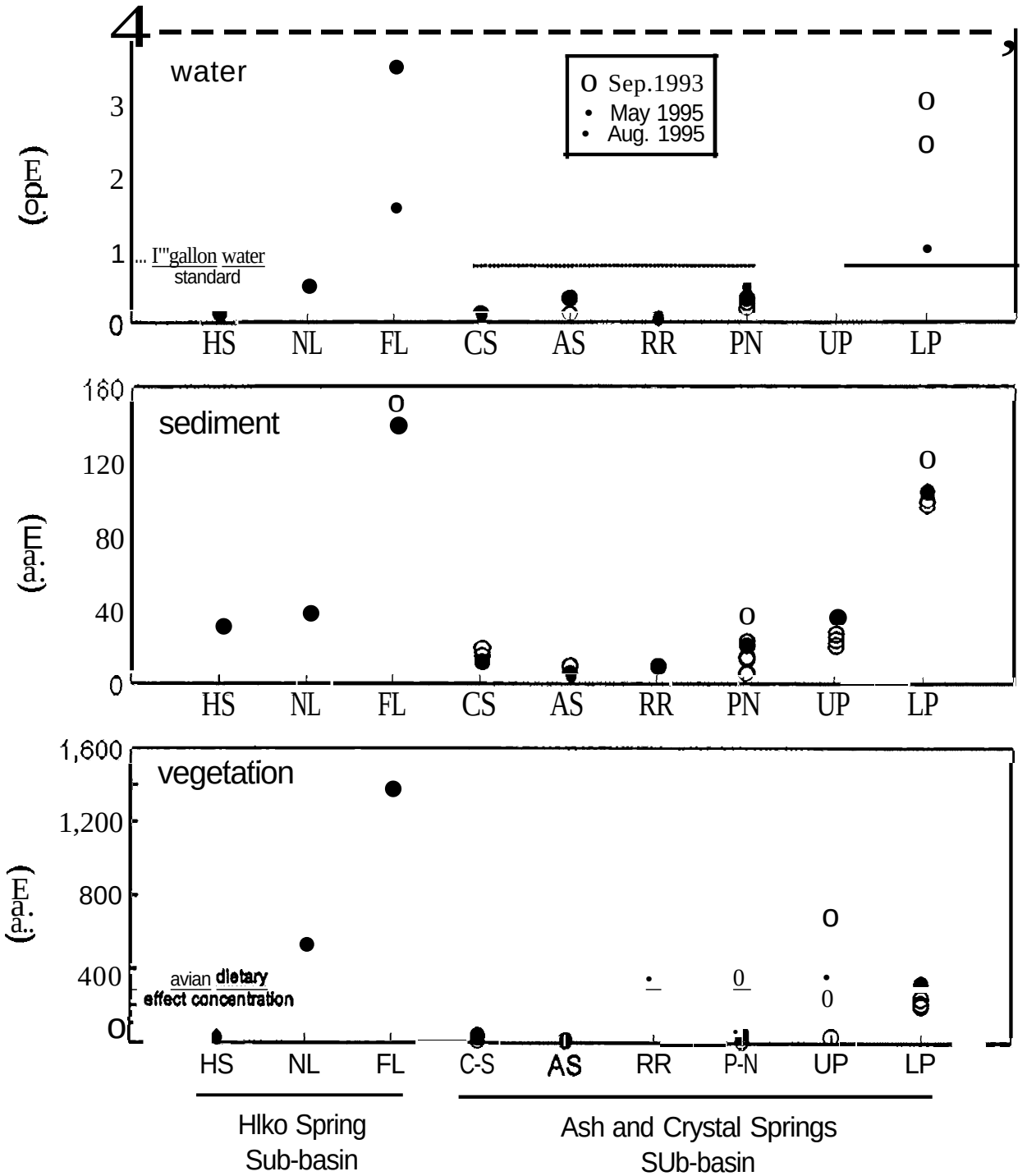

Figure *S.* Boron concentrations (parts per million-ppm) in water. sediment (dry and aquatic vegetation (dry weight) from nine locatioDS in Pahranagat Valley. Lincoln County, Nevada, September 1993 to August 1995. Collection sites include Hiko Spring (BS), Nesbitt Lake (NL). Frenchy Lake (FL), Crystal Springs (CS), Ash (AS). Pahranagat Creek on River Ranch (RR), inflow to Pahranagat National Wildlife Refuge (PN), Upper Pahranagat Lake (UP). and Lower Pahranagat Lake (LP).

water samples were below a maximum allowable toxicant concentration (between 6,400 and 13,600 µg/L) identified by Gersich (1984).

Hatching success of mallards maintained on a diet supplemented with 1,000 µg/g boron was reduced by almost 50% (Smith and Anders 1989). Body weights of hatchlings from adults maintained on diets supplemented with 300 and 1,000 µg/g boron were also lower. Weight gain of ducklings maintained on diets supplemented with 300, and 1,000 µg/g boron were depressed through 21 days. Productivity (number of ducklings through 21-days) of females maintained on a diet containing 1,000 J.1g1g boron was reduced. Delayed duckling growth rate and biochemical effects were found in female mallards maintained oo diets containing 100 and 400 µg/g (Hoffman et al. 1990b). In our study, boron concentrations in vegetation from lakes on Key Pittman WMA and Pahranagat NWR exceeded the 30 µg/g dietary concern concentration. Concentrations in vegetation from lakes on Key Pittman WMA and Pahranagat NWR exceeded the avian dietary effect concentration (300 µg/g). Vegetation from Frenchy Lake exceeded 1,000 µg/g. Boron concentrations in invertebrates and fish were below the avian dietary concern concentration (30 Boron io coot eggs did not exceed biologically significant levels.

Mercury

Total mercury was detected in 3 of 32 unfiltered water samples, inclu.ding one sample collected from Crystal Springs. Detectable concentrations were at or near the analytical detection limit of 0.2 µg/L. The chronic aquatic life standard Cor mercury (0.012 µg/L) is lower than the detection limit for mercury in our investigation. Therefore, at a minimum, water samples with detected concentrations of mercury exceeded this standard. Similarly, all samples with detected mercury concentrations exceeded a 0.1 µg/L effect level for fish (Birge 1979b).

Total mercury concentrations in sediment ranged up to 6.8 µg/g, with the highest concentrations typically found in the spring pools or their immediate outflow (Figure 6). Consistent with this. total mercury was also elevated in aquatic vegetation. invertebrates, and fish collected at this site. Total mercury in one or more sediment samples collected from Hiko Spring, Crystal Springs, Ash Springs, and River Ranch exceeded an effect concentration for sensitive freshwater invertebrates of 0.2 µg/g identified by Persaud et a1. (1993). Concentrations in Ash Springs exceeded a concentration associated with effects to a broader range of freshwater invertebrates (2.0 pg/g; Persaud et a1. 1993) and marine and estuarine invertebrates (1.3 µglg; Long and Morgan 1991).

Fish exposure to mercury results primarily through a dietary (Wiener and Spry 1996). Endangered fish in Pahranagat Valley are omnivorous (Hardy 1982; Williams and Williams 1982). Total mercury concentrations in aquatic vegetation and invertebrates from Ash Springs (up to 5.0 and 1.3 µg/g, respectively) were elevated relative to other sampling sites. However, concentrations of mercury in whole body fish from this and other sites in Pahranagat Valley. ranging from 0.1 to 1.6 (0.02 to 0.35 µg/g, wet weight), were well below a no-observed effect concentration (3.0 µg/g, wet weight) identified by Wiener and Spry (1996). Similarly, whole body concentrations were less than concentrations associated with behavioral effects in adult fish or toxic effects to fish embryos. Biomagnification of mercury

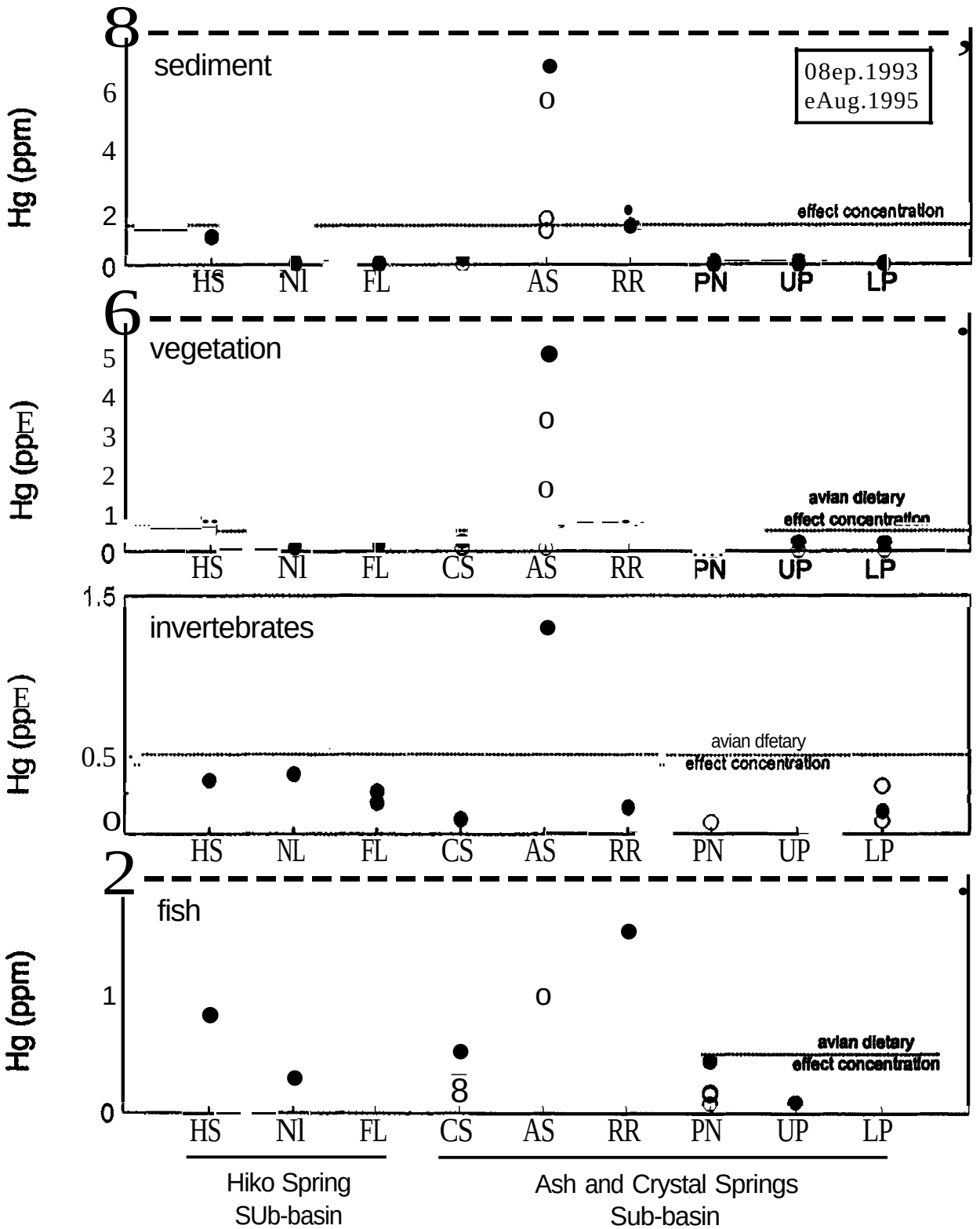

Figure 6. Mercury concentrations (parts per million-ppm; dry weight) in sediment, aquatic vegetation, aquatic invertebrates, and (ISh from nine locations in Pahranagat Valley, Lincoln County, Nevada, September 1993 to August 1995. Collection sites include Hileo Spring (HS), Nesbitt Lake (NL). Frenchy Lake (FL), Crystal Springs (CS), Ash Springs (AS), Pahranagat Creek on River Ranch (RR), inflow to Pahranagat National Wildlife Refuge (PN), Upper Pahranagat Lake (UP), and Lower Pahranagat Lake (LP).

in fish from the food chain did not appear to occur in areas supporting endangered fishes. Relatively low concentrations of mercury in fish may be related to the small body size (<7S nun) of the fish sampled (Lange et al. 1994).

Total mercury concentrations in plants, invertebrates, and fish from wetlands on Key Pittman WMA and Pahranagat NWR were below an avian dietary effect concentration ofO.S µg/g for methylmercury identified by Heinz (1979). Total mercury concentrations in coot eggs were below levels of concern in all but one egg. The wet weight concentration in this egg (1.3 µg/g, wet weight), exceeded an estimated lower threshold concentration for significant toxic effects for most aquatic bird eggs (1.0 µg/g, wet weight, Zillioux et al. 1993). The substantial difference between this single egg and other coot eggs collected in Pahranagat Valley suggests that exposure may have occurred outside ofPahranagat Valley.

Selenium

Selenium was detected in 1t of 32 unfiltered water samples. Detected concentrations ranged up to 4 µg/L. A detected concentration in one sample from Ash Springs (2.0 µg/L) may indicate that at least some selenium is originating from spring water. The incidence of detection of selenium was higher in samples collected in May 1995 (4 of 5 samples), suggesting that selenium may also be mobilized from agricultural soils as a result of the practice of "leaching of salts and alkali" from agricultural fields. Lemly (1996) indicated that a water-borne concentration of 2.0 µg/L may be associated with long-term adverse effects to fish and wildlife populations. Nine of the samples met or exceeded this 2.0 µg/L criterion.

A selenium concentration of 1.0 Jlg/g in sediment was the minimum concentration associated with effects to avian reproduction. with a concentration of 4.0 µg/g associated with severe effects (U.S. Department of the Interior [USDOI] 1998). Selenium concentrations in almost 50% of the sediment samples (13 of 28) exceeded 1.0 µg/g (Figure 7). Elevated selenium concentrations in sediment collected from Hiko. Crystal, and Ash Springs pools suggest that selenium is originating from the springs. Sediment samples from Key Pitbnan WMA did not exceed the 1.0 µg/g criterion. Selenium was detected in 14 of 1S samples (0.2 to 2.4 collected from Pahranagat NWR and its inflow. Eight of these samples exceeded the 1.0 µg/g criterion.

Lemly (1996) identified a whole body selenium concentration of 4.0 µg/g in fish as a threshold for health and reproductive effects. Selenium in two whole body fish samples, one collected from Nesbitt Lake (5.6 µg/g) and one from the Pahranagat Creek upstream of Pahranagat NWR (4.0 µg/g) met or exceeded this criterion. Selenium concentrations in fish collected from areas supporting endangered fishes were below this level. However, one sample collected from the Pahranagat Creek on River Ranch (3.6 µg/g) approached this criterion. This reach of the creek supports the bulk of the Pahranagat roundtail chub population (Tuttle et al. 1990).

Three of 11 invertebrate samples and 6 of 17 fish samples exceeded an avian dietary concern concentration of 3.0 µg/g (Lemly 1996). Samples exceeding this criterion were collected from lakes on Key Pittman WMA and Pahranagat NWR and from the Pahranagat Creek upstream of the refuge. One sample collected from Nesbitt Lake exceeded a critical

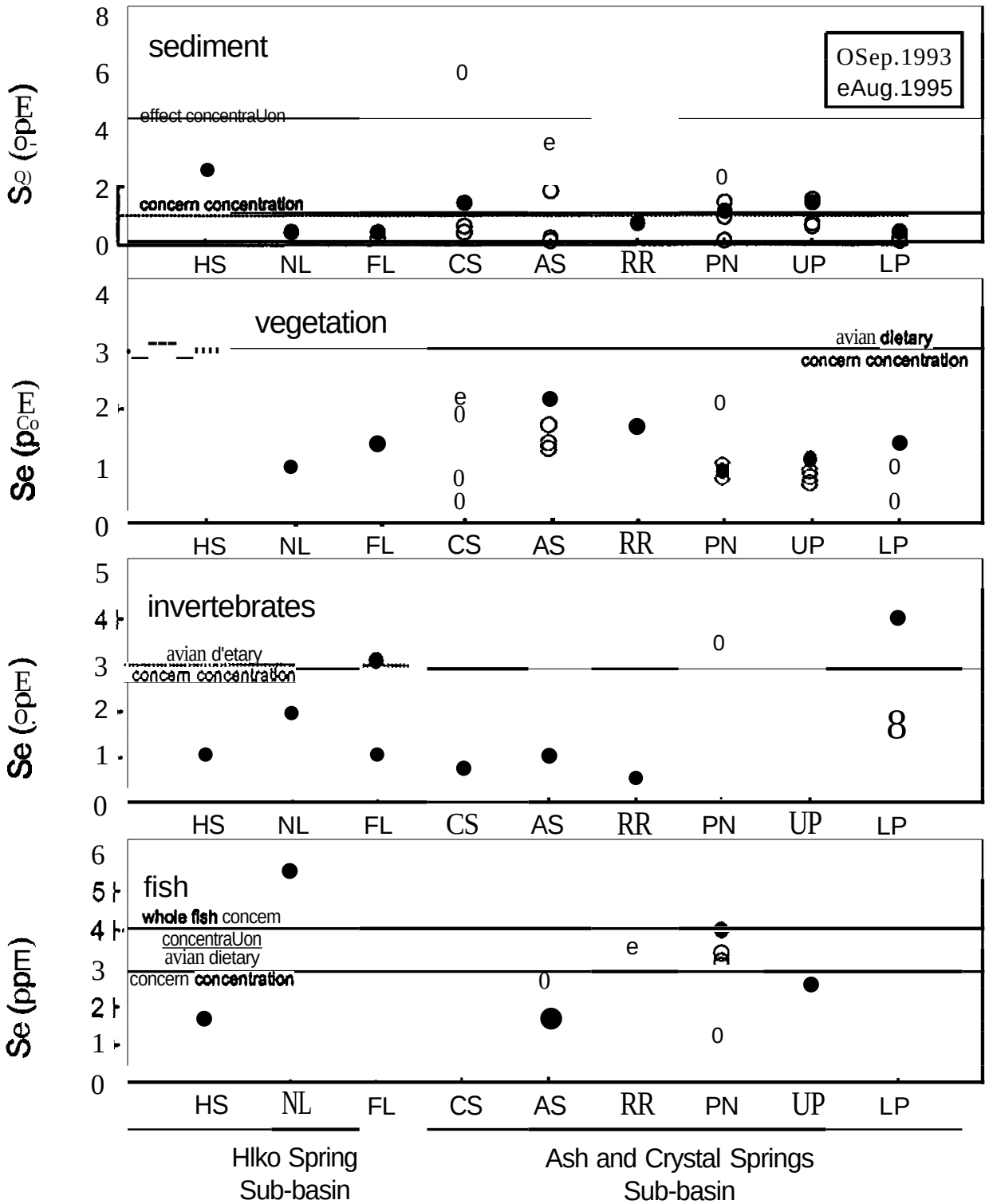

Figure 7. Selenium concentrations (parts per million-ppm; dry weight) in sediment, aquatic vegetation. aquatic invertebrates, and fish from nine locations in Pahranagat Valley. Lincoln County, Nevada, September 1993 to August 1995. ConectioD sites include Hiko Spring (HS). Nesbitt Lake (NL), Frenchy Lake (FL), Crystal Springs (CS). Ash (AS), Creek on River Ranch (RR), inflow to Pahranagat National Wildlife Refuge (PN), Upper Pabranagat Lake (UP), and Lower Pahranagat Lake (LP).

dietary threshold of 5.0 µg/g (USDOI 1998). Selenium concentrations in coot eggs were within the range of nonnal concentrations of selenium in aquatic bird eggs « 3.0 µg/g; Skorupa and Ohlendorf 1991).

Other Metals and Trace Elements

Aluminum concentrations in 11 of 32 unfiltered water samples exceeded the Federal criteria (87 µg/L; USEPA 1988). The higher alwninum concentrations were generally found in lakes on Key Pittman and Pahranagat NWR. Toxicity of aluminum in water varies considerably with chemical species and complexation (Sparling and Lowe 1996). Speciation is affected by several environmental parameters, particularly pH. Under circunmeutral to slightly alkaline conditions (pH 6.0 to 8.0), aluminum has a low solubility and is essentially biologically inactive. Aluminum solubility increases in more alkaline solutions (pH > 8.0), but the biological implications are poorly understood. Avian species may be adversely affected by excessive aluminum in diet. Six of 24 vegetation samples exceeded a dietary concentration associated with reduced growth and behavioral effects in waterfowl (5,000 µg/g; Sparling 1990). One sample exceeded a dietary concentration associated with reduced survival (10,000 µg/g; Appendix A). Concentrations in invertebrates and fish were below levels of concern.

The Nevada water quality standard for the protection of aquatic life for molybdenum is 19 µg/L. In our study, 13 of 32 unfiltered water samples exceeded this criterion. Low-level mortality (Lea) of rainbow trout was found at a molybdenum concentration of 28 µg/L, with a higher level of mortality (LC_{50}) at concentrations exceeding 190 µg/L (Birge and others, 1979a). Molybdenum concentrations in our study were well below levels associated with higher levels" of mortality.

Other trace elements were generally below levels of concern or insufficient information was available by which to assess biological implications.

Organochlorines

Composite sediment samples were collected near the inflows of Nesbitt Lake and Frenchy Lake on Key Pittman WMA and Upper and Lower Pabranagat Lakes on Pahranagat NWR to assess the occurrence of 20 organochlorine compounds (Appendix B). Organochlorine concentrations were below detection limits in all samples. The lack of detection suggests that organochlorines do not represent a threat to fish and wildlife in Pahranagat Valley.

Toxicity TestiDg

Assessment of toxicity, using 5-, *IS-,* and 30-minute Microtox® procedures indicated that unfiltered water collected from Nesbitt and Frenchy Lakes on Key Pittman WMA and Lower Pahranagat Lake elicited a reduction in metabolic activity of *P. phosphoreum* (Table 4). No

Table 4. Results of Microtox. toxicity tests on water samples collected from nine sites in . Pahranagat Valley, Lincoln County, Nevada, August 1995.

Site No.	Site Name	EC_{50} [a] (percent) 5 minute test	IS-minute test	3o-minute test
1	Hiko Spring	>100	>100	>100
2	Nesbitt Lake	47	33	31
3	Frenchy Lake	9	8	5
4	Crystal Springs	>100	>100	>100
5	Ash Springs	>100	>100	>100
6	River Ranch	>100	>100	>100
7	Pahranagat NWR inflow	>100	>100	>100
8	Upper Pahranagat Lake	>100	>100	>100
9	Lower Pahranagat Lake	4	6	6

a The median effect concentration of samples. expressed as percent, causing a 50 percent decrease in light output under identified conditions of exposure time.

toxicity was detected in other samples (EC_{50} > 100 percent for all tests). Toxic responses found in water from Frenchy Lake and Lower Pahranagat Lake may have been attributable to high pH (10.6 in both lakes; Dileanis et 81. 1996). The causative agent of observed toxicity in Nesbitt Lake is uncertain. The pH in this lake was consistent with the pH in Upper Pahranagat Lake, which did not elicit a response in the Microtox® testing. Additionally, specific conductance and concentrations of trace elements at sites exhibiting toxicity were below levels found at other sites in Nevada where no response was observed in Microtox® testing (Thodal and Tuttle 1996; and Tuttle et al. in preparation). Other potential toxic agents, such as ammonia, were not measured in our investigation.

Fish Assessment

Substantial changes in fish species composition were found at the various sampling locations. In addition to springfish, the spring pools and immediate outflow streams supported large numbers of convict cichlids *(Cichlasoma nigro/asciatum),* shortfm mollies *(Poedllia mexicana),* and mosquitofish *(Gambusia ajJinis).* Carp *(Cyprinus carpio)* were also found in some of the outflow streams. Species dominance shifted to Pahranagat speckled dace and mosquitoftsh in the down gradient streams and pools with a more variable water supply. Mosquitofish and black bullhead (*Ictalurus me/as)* were the most abundant species in the Pahranagat Creek immediately upstream of Pabranagat NWR. Deep water and dense vegetation limited the ability to capture fish in Nesbitt Lake, and mosquitotish and shiners

(Richardsonius sp.) were the only fish captured. Largemouth bass (*Micropterus salmoides)* and carp were the dominant fish species in Upper Pahranagat Lake, although low numbers of mosquitofish and green sunfish *(Lepomis cyanellus)* were also observed.

Fish were not found in Frenchy Lake or Lower Pahranagat Lake. The absence of fish in Frenchy Lake is likely due to the near desiccation of this lake in the early 1990's. The reason .for absence of fish in Lower Pahranagat Lake is less certain. Periodic fish kills have been documented in this lake. In one such incident more than 100,000 fish, primarily carp, died in Lower Pahranagat Lake in September 1987 (Peter Tuttle, U.S. Fish and Wildlife Service, written comm.,1987). The cause of these kills has not been established. Total dissolved solids and trace element concentrations in water, sediment, and biota in Lower Pabranagat Lake were less than concentrations found in other aquatic systems in Nevada supporting carp or other cyprinids (Hoffman et al. 199Oa; Tuttle et al. in preparation), suggesting that these constituents are not responsible for fish absence in Lower Pahranagat Lake. Like the results of toxicity testing, elevated pH may be at least in part responsible.

Fish flom all locations appeared to be in good physical condition and few abnormalities were observed. The highest incidence of abnonnalities, which typically included fm damage, was found in convict cichlids from the spring pools. Fin damage was assumed to result from the aggressive behavior of this highly territorial species. Differences in fish species composition prohibited comparison of Fulton's condition factor at all sites. Similar species composition was found in Hileo, Crystal, and Ash Springs and the Pahranagat Creek on River Ranch. Significant differences were found for Fulton's condition factor for springfish, convict cichlids, shortfm mollies, and mosquitofish from these sites (Table *S).* However, differences were not consistent among locations. Differences may have been due to variations in mean fish sizes among some sites.

Hiko Mill Site

A survey of the mill site found two distinctive tailings materials. These materials extended to Highway 318 approximately 100 m east of the site. Composite samples of each type of tailings material-were submitted for a metals scan. Mercury concentrations (0.05 and 0.22 $\mu g/g$) did not exceed levels of concern. Lead and copper were elevated in one sample' (484 and 81 $\mu g/g$, respectively). There was no indication that drainage from this site has affected, or has the potential to affect aquatic or palustrine habitats on Key Pittman WMA.

Table S. Numbers and mean lengths, and Fulton's condition factors (FCF) for fish captured at nine sites in Pahranagat Valley, Lincoln County, Nevada, 1995. "N" that the was Dot observed at the site. "P" that the fish was present, but was not Fulton's condition factors within a given sharing common capital1ettcrs were not significantly *(p>O.OS).*

Species, number, length, weight, and FCF	Collection Site								
	Hiko Spring	Nesbitt Lake	Frenchy Lake	Crystal Springs	Ash Springs	River Ranch	Pahranagat NWR inflow	Upper Pahranagat Lake	Lower Pahranagat Lake
springfish									
number	S0	N	N	IS	34	P	N	N	N
length (mm)	41 (6.6)	"	-	43 (9.4)	38 (5.9)				
weight (g)	1.5 (0.9)	-	-	1.5 (0.5)	1.0(0.5)				
FCP	2.0 (0.3)B	-	-	1.7 (O.3)A	1.7 (O.3)A				
convict									
number	S0	N	N	*S0*	*SO*	*SO*	N	N	N
length (mm)	43 (9.6)	-	-	*S3 (8.7)*	49(8.2)	37 (8.8)			
weight (g)	1.7 (1.3)	"	"	3.5 (1.7)	2.7 (1.5)	1.2 (1.0)			
FCF	1.9 (0.5)A	-	-	2.1 (0.3)B	2.1 (O.3)B	1.9 (0.3)A			
shortfin mollies									
number	*SO*	N	N	S0	*SO*	S0	N	N	N
length (mm)	44 (2.9)	"	-	36 (3.9)	40 (6.0)	42 (11.4)			
weight (g)	1.3 (0.3)	"	"	0.8(03)	0.9 (0.4)	1.5 (1.5)			
FCF	*1.S* (O.2)AB	-	-	1.8 {0.2)C	1.4 (O.3)A	1.6 (0.2)B			
mosquitofish									
number	22	P	N	28	50	50	P	P	N
length (mm)	37 (4.3)	-	"	30(3.5)	30(3.4)	31 (5.6)			
weight (g)	0.6(0.2)	"	-	0.3 (0.1)	0.3 (0.1)	0.4(0.2)			
FCP	1.2 (O.2)B	-	-	1.1 (0.2)AB	1.2 (O.2)B	1.0 (O.2)A			

Table 5. *(concluded)*

	Hiko Spring	Nesbitt Lake	Frenchy Lake	Crystal Springs	Ash Springs	River Ranch	Pahranagat NWR inflow	Upper Pahranagat Lake	Lower Pahranagat Lake
carp									
number	N	N	N	P	N	P	P	21	N
length (mm)	"	"	"	"	"	–	–	100 (17.8)	
weight (g)	"	"	"	–	"	"	"	*22.S (10.9)*	
FCP	"	–	▪	...	"	"	"	2.2 (0.3)	
shiners									
number	N	30	N	N	N	N	N	N	N
length (mm)	"	38 (2.7)							
weight (g)	–	0.7 (0.2)							
FCP	"	1.2 (0.1)							
black bullhead									
number	N	N	N	N	N	N	48	P	N
length (mm)	"	"	"	"	"	"	41 (2.6)		
weight (g)	"	"	–	"	"	"	1.0(0.2)		
FCF	"	–	"	"	"	–	*I.S (0.1)*		
largemouth bass									
number	N	N	N	N	N	N	N	*SO*	N
length (mm)	–	"	–	"	"	"	"	75 (13.3)	
weight (g)	–	–	"	"	–	"	"	6.0 (2.8)	
FCP	–	–	"	–	–	"	"	1.3 (0.1)	

SUMMARY

An investigation was initiated in 1995 to assess the role of environmental contaminants in the degradation of aquatic habitats and the decline of native species in Pahranagat Valley. The objectives of this study were to identify and quantify human-induced environmental contaminant impacts to endangered species, species of concern, migratory birds, and Service lands in Pahranagat Valley.

Based on the findings of our investigation, arsenic, mercury, and selenium may represent potential threats to endangered fishes in Pahranagat Valley. Mercury in sediment and possibly water and food chain organisms collected from habitats supporting endangered fishes exceeded concentrations associated with sublethal effects to aquatic species. However, concentrations in fish analyzed for this investigation indicate that life history characteristics (i.e., short life span and small body size) may restrict the accumulation of mercury in at least smaller fish. Implications for Pahranagat roundtail chub, which attains a larger body size, are uncertain. Selenium exceeded levels of concern in sediment and whole fish collected from endangered fishes habitats. Elevated mercury and selenium concentrations in sediment and/or biota from spring source pools combined with detection of these elements in at least one water sample at spring sources suggest that these elements are, at least in part, originating from the carbonate-rock aquifer. In this event, little may be done to rectify this concern. However, native fishes in Pahranagat Valley have persisted in habitats supported by the carbonate-rock aquifer springs since desiccation of the pluvial White River. This would suggest that these species are capable of surviving and reproducing under these conditions.

Total dissolved solids (as measured by specific conductance), pH, and concentrations of some trace elements in water increased substantially between the spring sources and lakes on Key Pittman WMA and Pahranagat NWR. The largest increases in these constituents typically occurred between the initial lakes and the terminal lakes on both the WMA and the NWR during the sununer sampling periods suggesting that water diversion and evaporative concentration were the dominant influences on water quality in these lakes. Increases in these constituents between spring sources and the inflow to Pahranagat NWR during the summer months suggests that agricultural runoff and drainage is not a major contributor of dissolved solids during the summer. However, higher concentrations of dissolved solids during the spring coupled with increased water inflows during this period indicate that large loads of dissolved solids are transported to Pahranagat NWR. The practice of flushing salts from agricultural fields may serve to increase overall loads entering the refuge.

Specific conductance. pH, arsenic, and boron in water collected from one or more lakes on Key Pittman WMA and Pahranagat NWR exceeded Nevada water quality standards for applicable beneficial uses andlor levels of concern for aquatic organisms. As previously mentioned, the highest concentrations of these and other constituents were found in the terminal lakes. Water collected from these lakes was found to cause decreased metabolic activity in Microtox® toxicity tests. which may be interpreted as a toxic response. The potential for toxicity to higher organisms was uncertain. Elevated selenium in aquatic invertebrates from Frenchy Lake and Lower Pahranagat Lake may represent a concern for aquatic birds. Implications to the endangered southwestern willow flycatcher *(Empidonax traillii extimus)* in Pahranagat Valley are uncertain. Similarly, elevated concentrations of arsenic -and

boron in aquatic vegetation may represent a threat to "herbivorous aquatic birds.

Organochlorine pesticides do not appear to represent a threat to fish and wildlife on Key Pittman WMA or Pahranagat NWR. Similarly, historic precious metal milling near the town of Hiko which used mercury amalgamation does not appear to represent a threat to fish and wildlife on Key Pitnnan WMA. Nutrients, including un-ionized ammonia, were not assessed in this investigation.

ACKNOWLEDGMENTS

Appreciation is expressed to Cynthia Martinez, Damian Higgins, and Christian Schoneman of the U.S. Fish and Wildlife Service and Barton Tanner of the Nevada Division of Wildlife for assisting in field data collection efforts. Appeciation is also expressed to Denise Baker, Stephanie Byers, and Stephen Zylstra for critical review of the manuscript.

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Appendix A. Concentrations of trace elements (parts per million; ppm) in water (wet weight), sediment (dry and biological tissues (dry collected from Pahranagat Valley, Lincoln County, Nevada, 1993-95.

site no.	location	date	matrix	species	Al	As	B	Sa	Be	Cd	Cr	Cu	Fe
									ppm				
4	Crystal Springs	09/08/93	water		0.03	0.009	0.10	0.08	< 0.0002	< 0.002	< 0.01	< 0.002	< 0.01
4	Crystal Springs	09/08/93	water		0.04	0.009	0.09	0.08	< 0.0002	< 0.002	< 0.01	< 0.002	0.02
4	Crystal Springs	09/08/93	water		0.46	0.009	0.09	0.09	< 0.0002	< 0.002	< 0.01	< 0.002	0.24
5	Ash Springs	09/08/93	water		0.03	0.018	0.11	0.12	< 0.0002	< 0.002	< 0.01	< 0.002	0.03
5	Ash Springs	09/08/93	water		< 0.03	0.021	0.11	0.13	< 0.0002	< 0.002	< 0.01	< 0.002	0.01
5	Ash Springs	09/08/93	water		< 0.03	0.017	0.11	0.13	< 0.0002	< 0.002	< 0.01	< 0.002	< 0.01
7	Pahranagat NWR Inflow	09/08/93	water		4.56	0.025 .	0.18	.0.15	< 0.0002	< 0.002	< 0.01	0.003	2.55
7	Pahranagat NWR Inflow	09/08/93	water		7.08	0.024	0.18	0.17	0.0003	< 0.002	< 0.01	0.004	3.94
7	Pahranagat NWR Inflow	09/08/93	water		0.34	0.021	0.27	0.08	< 0.0002	< 0.002	< 0.01	< 0.002	0.21
7	Pahranagat NWR Inflow	09/08/93	water		0.37	0.023	0.27	0.07	< 0.0002	< 0.002	< 0.01	< 0.002	0.22
7	NWR Inflow	09/08/93	water		0.77	0.024	0.27	0.08	< 0.0002	< 0.002	< 0.01	< 0.002	0.46
7	Pahranagat NWR Inflow	09/08/93	water		0.40	0.023	0.27	0.08	< 0.0002	< 0.002	< 0.01	< 0.002	0.24
8	Upper Pahranagat Lake	09/08/93	water		1.00	0.089	0.62	0.10	< 0.0002	< 0.002	< 0.01	0.002	OM
8	Pahranagat Lake	09/08/93	water		1.10	0.084	0.64	0.10	< 0.0002	< 0.002	< 0.01	< 0.002	0.47
8	Upper Pahranagat Lake	09/08/93	water		1.10	0.090	0.63	0.10	< 0.0002	< 0.002	< 0.01	0.003	0.49
9	Lower Pahranagat Lake	09/08/93	water		< 0.03	0.003	1.80	0.00	< 0.0002	< 0.002	< 0.01	< 0.002	< 0.01
9	Lower Pahranagat Lake	09/08/93	water		< 0.03	0.002	2.42	0.01	< 0.0002	< 0.002	< 0.01	< 0.002	< 0.01
9	Lower Pahranagat Lake	09/08/93	water		0.09	0.003	3.02	0.01	< 0.0002	< 0.002	< 0.01	< 0.002	0.01
2	Key Pittman Inflow	05/04/95	water		0.10	0.071	0.50	0.05	< 0.001	< 0.001	< 0.002	< 0.002	0.04
3	Frenchy Lake	05/05/95	water		< 0.02	0.145	1.57	0.01	< 0.001	< 0.001	< 0.002	0.002	0.03
7	Pahranagat NWR Inflow	05/03/95	water		0.32	0.056	0.46	0.11	< 0.001	< 0.001	< 0.002	0.006	0.39
8	Upper Pahranagat Lake	05/03/95	water		0.18	0.052	0.47	. 0.11	< 0.001	< 0.001	< 0.002	0.004	0.15
9	Lower Pahranagat Lake	05/03/95	water		0.08	0.112	1.00	0.03	< 0.001	< 0.001	< 0.002	0.003	0.03
1	Hiko Spring	08/23/95	water		0.04	0.012	0.11	0.10	< 0.001	< 0.001	0.005	0.002	0.05
2	Nesbitt Lake	08/23/95	water		0.43	0.033	0.50	0.03	< 0.001	< 0.001	0.002	< 0.002	0.20
3	Frenchy Lake	08/23/95	water		0.09	0.019	3.51	0.01	< 0.001	< 0.001	0.003	< 0.002	0.08
4	Crystal Springs	08/24/95	water		0.03	0.011	0.12	0.08	< 0.001	< 0.001	0.004	< 0.002	0.03
5	Ash Springs	08/22/95	water		0.05	0.020	0.33	0.13	< 0.001	< 0.001	0.003	< 0.002	0.03
6	River Ranch	08/24/95	water		0.05	0.022	0.05	0.04	< 0.001	< 0.001	0.003	< 0.002	0.17
7	Pahranagat NWR Inflow	08/25/95	water		1.71	0.040	0.32	0.12	< 0.001	< 0.001	0.006	0.004	1.32

Appendix A. (continued)

site no.	location	date	matrix	species	ppm Al	As	B	Sa	Be	Cd	Cr	Cu	Fe
8	Upper Pahranagat lake	08121/95	water		0.69	0.086	0.68	0.12	< 0.001	< 0.001	< 0.002	0.003	0.50
9	Lower Pahranagat Lake	08121195	water		0.03	0.017	1.65	0.01	< 0.001	< 0.001	< 0.002	< 0.002	0.05
3	Lake	09/08/93	sediment		14700	73.0	150	218	0.78	< 1.00	10.0	13.0	9900
4	Crystal Springs	09/07/93	sediment		19100	7.3	10	228	1.00	< 0.90	10.0	13.0	15500
4	Crystal Springs	09/07/93	sediment		12000	21.0	17	232	1.88	0.72	18.0	12.0	12700
4		09/07/93	sediment		12100	9.1	13	223	0.74	0.40	8.1	12.0	10900
5	Ash Springs	09107/93	sediment		6350	3.3	3	105	0.44	0.64	6.2	8.2	12600
5	Ash Springs	09/07/93	sediment		6440	18.0	8	203	0.76	0.70	12.0	8.5	10400
5	Ash Springs	09/07/93	sediment		4800	4.4	3	113	0.68	1.40	18.0	12.0	36400
7	Pahranagat NWR inflow	09/07/93	sediment		6820	4.3	4	96	0.36	0.30	4.5	7.0	7190
7	Pahranagat NWR inflow	09/07/93	sediment		12700	12.0	12	209	0.85	0.81	14.0	18.0	14500
7	Pahranagat NWR inflow	09107193	sediment		14100	15.0	13	215	0.95	0.94	17.0	21.0	15800
7	Pahranagat NWR inflow	09/08/93	sediment		10400	11.0	19	257	0.61	0.62	10.0	11.0	9110
7	Pahranagat NWR inflow	09/08/93	sediment		8360	10.0	21	295	0.50	0.50	8.1	7.9	7130
7	Pahranagat NWR inflow	09/08/93	sediment		9700	24.0	35	337	0.65	0.64	9.1	18.0	8380
8	Upper Pahranagat Lake	09/07/93	sediment		3550	14.0	19	405	0.24	< 0.20	3.6	5.6	2860
8	Upper Pahranagat Lake	09107193	sediment		7920	180.0	25	409	0.43	1.10	6.9	5.1	4810
8	Upper Pahranagat Lake	09107/93	sediment		6600	160.0	22	376	0.43	< 0.20	5.3	5.3	4740
9	Lower Pahranagat Lake	09/08/93	sediment		11500	31.0	120	167	0.67	0.50	8.3	9.7	8080
9	Lower Pahranagat Lake	09/08/93	sediment		5390	25.0	98	209	0.33	< 0.20	5.6	4.8	3680
9	Lower Pahranagat Lake	09/08/93	sediment		5210	30.0	95	207	0.31	< 0.20	4.0	4.4	3510
1	Hiko Spring	08/23/95	sediment		23283	13.9	31	498	3.16	< 1.82	22.0	31.3	22067
2	Nesbitt lake	08/23/95	sediment		7959	21.5	38	147	0.49	< 0.37	2.0	10.3	6071
3	Frenchy Lalce	08/23/95	sediment		10980	77.5	139	206	0.47	< 0.35	3.3	11.0	7745
4	Crystal Springs	08/24/95	sediment		9453	10.6	10	154	0.66	< 0.28	7.4	8.3	9316
5	Ash Springs	08/22/95	sediment		3786	8.8	4	138	0.42	< 0.26	4.0	6.7	3949
6	River Ranch	08/24/95	sediment		6744	7.7	8	.139	0.54	< 0.31	3.8	6.7	7336
7	Pahranagat NWR. inflow	08/25/95	sediment		9552	15.3	19	164	0.64	< 0.31	6.0	12.7	9701
8	Upper Pahranagat Lake	08/21/95	sediment		4277	33.0	36	327	0.32	< 0.43	0.8	10.7	4071
9	Lower Pahranagat Lake	08121/95	sediment		3621	32.8	102	174	0.20	< 0.31	< 0.5	4.1	2953

Appendix A. (continued)

site no.	location	date	matrix	species	Al	As	B	Sa	Be	Cd	Cr	Cu	Fe
					ppm								
	Hiko Mill	05/05/95	soil		6725	7.1	8	n	0.33 <	0.16	3.4	3.9	5378
	Hiko Mill	05/05/95	soil		16829	7.4	52	120	0.76	0.97	6.5	81.0	9921
4		09/08/93	vegetation	elodea	34	1.7	26	76	0.04	0.04	0.2	3.3	83
4	Crystal Springs	09/08/93	vegetation	algae	1810	4.5	36	598	0.26	0.16	22.0	6.6	1940
4		09/08/93	vegetation	coontail	6880	7.2	11	235	0.74	0.39	13.0	9.2	6350
5	Springs	09/08/93	vegetation	coontail	400	13.0	8	471	0.16	0.14	3.0	1.3	391
5	Ash Springs	09/08/93	vegetation	coontail	617	7.5	9	423	0.17	0.10	4.9	5.6	622
5	Ash Springs	09/08/93	vegetation	pondweed	8440	13.0 <	20	96	0.70	0.73	14.0	12.0	5550
7	Pahranagat NWR Inflow	09/08/93	vegetation	pondweed	7780	14.0 <	20	25S	0.49	0.67	28.2	13.0	8460
7	Pahranagat NWR Inflow	09/08/93	vegetation	pondweed	14300	25.0	40	181	0.71	0.85	15.8	25.0	10800
7	Pahranagat NWR Inflow	09/08/93	vegetation	pondweed	5810	9.0	351	232	0.35	0.31	4.5	6.9	3780
8	Pahranagat Lake	09/08/93	vegetation	pondweed	1710	10.7	687	196	0.12	0.18	1.7	7.7	1340
8	Upper Pahranagat Lake	09/08/93	vegetation	pondweed	6510	11.9	34	363	0.43	0.34	3.9	7.3	5030
8	Upper Pahranagat Lake	09/08/93	vegetation	coontail	3270	13.8	225	293	0.20	0.25	2.6	11.0	1990
9	Lower Pahranagat Lake	09/08/93	vegetation	najas	985	57.0	201	31	0.07	0.23	0.8	1.9	685
9	Lower Pahranagat Lake	09/08/93	vegetation	najas	290	114.0	213	143	0.02	0.26	0.3	0.9	200
9	Lake	09/08/93	vegetation	najas	609	118.0	239	165	0.04	0.47	0.5	0.8	413
1	Hiko	08/23/95	vegetation	elodea	255	14.4	25	67 <	0.28 <	0.83	2.4	26.6	797
2	Nesbitt Lake	08/23/95	vegetation	pondweed	737	13.6	543	159 <	0.11 <	0.32 <	0.5	3.0	503
3	Frenchy Lake	08/23/95	vegetation	widgeon grass	241	9.5	1396	38 <	0.21 <	0.61	7.8	9.8	339
4	Crystal Springs	08/24/95	vegetation	elodea	324	34.7	29	237 <	0.24 <	0.71	1.8	9.7	453
5	Ash Springs	08/22/95	vegetation	pondweed	543	35.2	11	456 <	0.22 <	0.65	2.4	36.2	677
6	Ranch	08/24/95	vegetation	coontail	784	10.4	277	167 <	0.24 <	0.72	2.8	26.3	1293
7	Pahranagat NWR Inflow	08/25/95	vegetation	coontail	710	6.0	53	124 <	0.14 <	0.41 <	0.7	28.3	724
8	Upper Pahranagat Lake	08/21/95	vegetation	pondweed	334	19804	413	115 <	0.16 <	0.48 <	0.8	9.4	274
9	Pahranagat Lake	08/21/95	vegetation	najas	2298	10.9	318	207	0.16 <	0.42 <	0.7	65.0	2355

Appendix A. (continued)

site no.	location	date	matrix	species	Al	As	B	Sa	Be	Cd	Cr	Cu	Fe
					ppm								
7	NWR inflow	09/08/93	invertebrate	crayfish	2560	6.2	8	192	0.14	0.1	3.6	49.3	1450
9	Pahranagat Lake	09/08/93	invertebrate	dragonfly nyad	16	0.9	10	1 <	0.01	0.0	0.1	16.0	50
9	Lower Pahranagat Lake	09/08/93	invertebrate	giant water beetle	40	1.0	7	O <	0.03	0.0	0.2	9.7	67
1	Hiko Spring	08/23/95	invertebrate	melanoides	192	2.4	3	225 <	0.04 <	0.1	0.3	10.0	179
2	Nesbitt Lake	08/23/95	invertebrate	corixid	61	1.7	14	9 <	0.13 <	0.4	2.9	18.2	258
3	Frenchy Lake	08/23/95	invertebrate	corixid	36	4.0	18	5 <	0.18 <	0.5	9.3	27.1	231
3	Frenchy Lake	08/24/95	invertebrate	dragonfly	43	3.2	19	1 <	0.11 <	0.3	2.2	16.5	96
4	Crystal Springs	08/24/95	invertebrate	melanoides	233	2.2	2	196 <	0.04 <	0.1	1.7	14.6	216
5	Ash Springs	08/22/95	invertebrate	melanoides	105	1.6	1	364 <	0.04 <	0.1	0.7	8.5	108
6	River Ranch	08/24/95	invertebrate	melanoides	57	6.6	1	297 <	0.03 <	0.1 <	0.2	17.7	218
9	Lower Pahranagat Lake	08/21/95	invertebrate	corixid	10	4.6	15	4 <	0.17 <	0.5	2.8	29.6	163
4	Crystal Springs	09/08/93	fish	mollies	423	26.4 <	2	93	0.05	0.1	0.8	10.0	384
4	Crystal Springs	09/08/93	fish	mollies	343	25.7 <	2	107	0.05	0.1	0.7	12.0	316
4	Crystal Springs	09/08/93	fish	cichlid	40	11.0 <	1	10 <	0.05	0.0	0.4	2.4	84
5	Ash Springs	09/08/93	fish	mollies	130	5.3 <	2	211	0.03	0.0	0.4	11.0	198
5	Ash Springs	09/08/93	fish	cichlid	12	1.7 <	2	53 <	0.01	0.0	0.4	1.8	37
5	Ash Springs	09/08/93	fish	cichlid	4	1.4 <	1	18 <	0.06 <	0.0	0.8	1.4	40
7	Pahranagat NWR inflow	09/08/93	fish	mosquitofish	814	5.0	1	7 <	0.01	0.0	1.7	1.9	592
7	Pahranagat NWR inflow	09/08/93	fish	mosquitofish	1160	8.3	1	7 <	0.01	0.0	2.2	2.1	802
7	Pahranagat NWR inflow	09/08/93	fish	mosquitofish	921	7.0	1	7 <	0.01	0.0	1.7	2.2	661
7	Pahranagat NWR inflow	09108l93	fish	mosquitofish	586	5.2	8	76	0.04	0.0	1.1	4.5	428
1	Hike Spring	08/23/95	fish	mosquitofish	34	2.0	2	33 <	0.09 <	0.3	1.7	10.2	110
2	Nesbitt lake	08/23/95	fish	shiner	369	3.1	9	17 <	0.12 <	0.4	3.1	4.4	356
4	Crystal Springs	08/24/95	fish	mosquitofish	74	1.8 <	2	30 <	0.12 <	0.3	2.1	8.4	136
5	Ash Springs	08/22/95	fish	mosquitofish	8	1.4 <	2	31 <	0.09 <	0.3	1.0	8.4	69
6	River Ranch	08/24/95	fish	mosquitofish	47	1.5	2	32 <	0.09 <	0.3	1.9	9.8	101
7	Pahranagat NWR inflow	08/25/95	fish	bullhead	283	1.9	11	20 <	0.21 <	0.6	11.6	13.3	379
8	Pahranagat Lake	08/22/95	fish	carp	48	1.8	5	53 <	0.10 <	0.3	1.4	31.3	190

Appendix A. (continued)

site no.	location	date	matrix	species	Al	As	B	Sa	Be	Cd	Cr	Cu	Fe
					ppm								
3	Frenchy Lake	05/24/95	avian egg	coot	< 4	1.0	5.5	0.9	< 0.08	< 0.2	1.0	3.9	107
2	Nesbitt Lake	05/24/95	avian egg	coot	< 4	0.8	2.9	2.0	< 0.07	< 0.2	1.0	2.9	114
3	Frenchy Lake	05/24/95	avian egg	coot	< 4	1.0	6.0	< 0.8	< 0.08	< 0.2	0.7	3.1	108
3	Lake	05/24/95	avian egg	coot	< 5	1.6	7.4	< 1.0	< 0.10	< 0.3	1.3	6.0	93
	Lake	05/24/95	avian egg	coot	< 4	1.5	6.4	2.0	< 0.09	< 0.3	1.1	5.2	126
9	Lower Pahranagat Lake	05/24/95	avian egg	coot	< 4	1.2	5.1	1.8	< 0.08	< 0.2	1.0	4.3	114
9	Lower Pahranagat Lake	05/24/95	avian egg	coot	< 4	1.2	5.2	4.6	< 0.09	< 0.3	1.1	6.2	118
9	Lower Pahranagat Lake	05/24/95	avian egg	coot	< 4	1.0	4.8	5.9	< 0.08	< 0.2	1.1	4.0	127
9	Lower Pahranagat Lake	05/24/95	avian egg	coot	< 4	1.4	4.2	0.9	< 0.07	< 0.2	0.4	8.5	52
9	Lower Pahranagat Lake	05/24/95		coot	< 4	1.6	6.0	2.3	< 0.09	< 0.3	1.1	2.5	109

Appendix A. (continued)

site no.	location	date	matrix	species	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn
					ppm									
4	Crystal Springs	09/08/93	water		0.0002	21.0	< 0.002	< 0.01	< 0.02	< 0.0'	< 0.001	0.24	< 0.003	0.038
4	Crystal Springs	09/08/93	water		< 0.0002	20.8	< 0.002	< 0.01	< 0.02	< 0.04	< 0.001	0.25	< 0.003	< 0.005
4	Crystal Springs	09/08/93	water		< 0.0002	20.9	0.005	< 0.01	< 0.02	< 0.04	< 0.001	0.25	< 0.003	< 0.005
5	Ash Springs	09/08/93	water		< 0.0002	18.0	< 0.002	< 0.01	< 0.02	< 0.04	< 0.001	0.37	< 0.003	0.010
5	Ash Springs	09/08/93	water		< 0.0002	16.2	< 0.002	< 0.01	< 0.02	< 0.04	< 0.001	OA1	< 0.003	< 0.005
5	Ash Springs	09/08/93	water		< 0.0002	17.4	< 0.002	< 0.01	< 0.02	< 0.04	< 0.001	0.40	< 0.003	< 0.005
7	Pahranagat NWR inflow	09/08/93	water		< 0.0002	26.7	0.067	0.01	< 0.02	< 0.04	0.004	0.50	0.015	0.010
7	Pahranagat NWR inflow	09/08/93	water		< 0.0002	26.8	0.096	0.01	< 0.02	< 0.04	0.004	0.49	0.018	0.023
7	NWR inflow	09/08/93	water		< 0.0002	26.5	0.013	0.01	< 0.02	< 0.04	< 0.001	0.79	0.004	< 0.005
7	Pahranagat NWR inflow	09/08/93	water		< 0.0002	25.5	0.014	0.01	< 0.02	< 0.04	< 0.001	0.77	0.004	< 0.005
7	Pahranagat NWR inflow	09/08/93	water		< 0.0002	27.5	0.023	0.01	< 0.02	< 0.04	< 0.001	0.83	0.005	< 0.005
7	Pahranagat NWR inflow	09/08/93	water		< 0.0002	26.9	0.014	0.01	< 0.02	< 0.04	< 0.001	0.82	0.004	< 0.005
8	Upper Pahranagat Lake	09/08/93	water		< 0.0002	74.0	0.029	0.03	< 0.02	< 0.04	< 0.001	0.77	0.012	< 0.005
8	Upper Pahranagat Lake	09/08/93	water		< 0.0002	76.3	0.030	0.03	< 0.02	< 0.04	0.001	0.79	0.012	< 0.005
8	Upper Pahranagat Lake	09/08/93	water		< 0.0002	75.2	0.030	0.03	< 0.02	< 0.04	0.001	0.78	0.012	< 0.005
9	Lake	09/08/93	water		< 0.0002	65.3	< 0.002	0.06	< 0.02	< 0.04	< 0.001	0.11	< 0.003	< 0.005
9	Lower	09/08/93	water		< 0.0002	78.1	< 0.002	0.07	< 0.02	< 0.04	< 0.001	0.14	< 0.003	< 0.005
9	Lake	09/08/93	water		< 0.0002	97.4	< 0.002	0.08	< 0.02	< 0.04	< 0.002	0.16	< 0.003	< 0.005
2	Key Pittman inflow	05/04/95	water		< 0.0002	59.9	0.002	0.030	< 0.002	< 0.01	0.004	0.35	0.004	< 0.004
3	Lake	05/05/95	water		< 0.0002	81.6	< 0.002	0.093	< 0.002	< 0.01	< 0.002	0.22	0.003	0.007
7	Pahranagat NWR inflow	05/03/95	water		< 0.0002	54.0	0.032	0.014	< 0.002	< 0.01	0.004	0.80	0.003	0.010
8	Upper Pahranagat Lake	05/03/95	water		< 0.0002	53.3	0.019	0.015	< 0.002	< 0.01	0.002	0.80	0.004	0.019
9	Lower	05/03/95	water		< 0.0002	97.7	< 0.002	0.029	< 0.002	< 0.01	0.002	0.62	0.002	0.010
1	Hiko Spring	08123195	water		< 0.0002	22.S	0.002	< 0.008	< 0.002	< 0.01	< 0.002	0.32	0.002	0.013
2	Lake	08/23/95	water		0.0003	60.8	0.013	0.035	< 0.002	< 0.01	< 0.002	0.12	0.002	0.009
3	Frenchy Lake	08/23/95	water		0.0002	15.8	0.002	0.150	< 0.002	< 0.01	< 0.002	0.10	0.002	0.011
4	Crystal Springs	08/24/95	water		< 0.0002	20.8	< 0.002	< 0.008	< 0.002	< 0.01	< 0.002	0.24	< 0.001	0.009
5		08/22/95	water		< 0.0002	18.1	< 0.002	< 0.008	< 0.002	< 0.01	0.002	0.39	0.002	0.007
6	River Ranch	08/24/95	water		< 0.0002	6.1	0.002	< 0.008	0.003	< 0.01	< 0.002	0.14	< 0.001	0.012
7	Pahranagat NWR inflow	08/25/95	water		< 0.0002	27.2	0.045	0.012	0.003	< 0.01	0.003	0.49	0.008	0.015

Appendix A. (continued)

site no.	location	date	matrix	species	Hg	Mg	Mn	Mo	Ni	Pb	Be	Sr	V	Zn
					ppm									
8	Pahranagat Lake	08/21/95	water		< 0.0002	68.7	0.057	0.020	< 0.002	< 0.01	0.004	0.82	0.011	0.007
9	Lower Pahranagat Lake	08/21/95	water		< 0.0002	83.7	< 0.002	0.036	< 0.002	< 0.01	< 0.002	0.15	< 0.001	0.005
3	Lake	09/08/93	sediment		0.02	59700	356	10.0	10.0	20.0	0.3	936	21.0	41
4	Crystal Springs	09/07/93	sediment		0.02	13600	188	< 5.0	10.0	30.0	0.7	144	22.0	54
4		09/07/93	sediment		0.33	10500	333	3.9	16.0	26.0	6.0	160	28.0	92
4	Crystal Springs	09/07/93	sediment		0.03	13200	245	< 1.0	7.3	19.0	0.5	190	19.0	40
5	Ash Springs	09107193	sediment		1.15	5640	103	< 1.0	4.1	12.0	< 0.2	43	29.5	27
5	Ash Springs	09/07/93	sediment		5.60	18400	122	< 1.0	5.1	15.0	1.9	281	28.0	66
5	Ash Springs	09/07/93	sediment		1.55	9640	286	< 1.0	8.8	16.0	0.3	106	103.0	63
7	Pahranagat NWR Inflow	09/07/93	sediment		< 0.01	4370	107	< 1.0	4.9	10.0	< 0.2	66	13.0	36
7	Pahranagat NWR Inflow	09/07/93	sediment		0.08	12100	259	< 1.0	14.0	25.0	1.2	157	22.0	86
1	Pahranagat NWR Inflow	09/07/93	sediment		0.09	12300	274	< 1.0	18.0	27.0	1.5	161	25.0	81
7	Pahranagat NWR Inflow	09/08/93	sediment		< 0.01	18600	356	< 1.0	7.2	18.0	1.2	598	14.0	39
7	Pahranagat NWR Inflow	09/08/93	sediment		< 0.01	16200	342	< 0.9	6.2	15.0	1.0	584	16.0	30
7	Pahranagat NWR Inflow	09/08/93	sediment		< 0.01	14600	400	1.0	8.4	18.0	2.4	773	19.0	44
8	Upper Pahranagat Lake	09/07/93	sediment		< 0.01	12500	315	< 1.0	2.0	7.0	1.6	912	7.0	16
8	Upper Pahranagat Lake	09/07/93	sediment		< 0.01	20300	287	< 1.0	4.7	14.0	0.8	1060	9.5	22
8	Pahranagat Lake	09/07/93	sediment		< 0.01	20100	258	< 1.0	4.0	10.0	0.7	989	8.7	21
9	Lower Pahranagat Lake	09/08/93	sediment		< 0.01	56400	186	8.7	7.2	20.0	0.2	1200	16.0	32
9	Lower Pahranagat Lake	09/08/93	sediment		< 0.01	66600	99	2.0	3.0	7.0	0.2	1990	10.0	14
9	Lower Pahranagat Lake	09/08/93	sediment		< 0.01	70300	95	2.0	3.0	7.0	0.3	1950	7.9	13
1	Spring	08/23/95	sediment		0.95	93617	250	< 12.2	24.4	33.7	2.7	574	79.6	148
2	Nesbitt Lake	08/23/95	sediment		0.06	32143	233	2.9	4.8	12.3	0.5	298	10.4	35
3	Lake	08/23/95	sediment		0.04	53186	272	3.7	5.6	8.1	< 0.5	765	13.9	34
4	Crystal Springs	08/24/95	sediment		0.18	12051	150	< 1.9	6.7	8.7	1.5	120	16.9	40
5	Ash Springs	08/22/95	sediment		6.79	16884	42	< 1.7	3.5	3.0	3.6	147	11.2	22
6	River Ranch	08/24/95	sediment		1.31	12072	241	< 2.1	5A	4.0	0.8	122	11.2	30
7	Pahranagat NWR Inflow	08/25/95	sediment		0.09	11194	273	< 2.1	8.7	6.0	1.2	144	14.5	45
8	Upper Pahranagat Lake	08/21/95	sediment		0.08	17817	363	< 2.9	4.5	4.9	1.5	891	15.4	23
9	Lower Pahranagat Lake	08/21/95	sediment		0.03	64440	70	< 2.1	2.1	< 2.6	0.5	1608	6.8	10

A. (continued)

site no.	location	date	matrix	species	Hg	Mg	Mn	Mo	Hi	Pb	Se	Sr	V	Zn
					ppm									
	Hiko Mill	05/05/95	soil		0.05	36473	124	< 1.1	4.2	5.0	< 0.2	63	7.7	20
	Hiko Mill	05/05/95	soil		0.22	17753	394	1.8	8.0	484.3	0.5	80	17.0	161
	Springs	09/08/93	vegetation	elodea	0.04	8630	67	2.0	1.5	0.5	0.4	158	1.9	40
4	Crystal Springs	09/08/93	vegetation	algae	0.07	4120	77	< 1.0	16.7	4.7	0.8	426	4.6	52
4	Crystal Springs	09/08/93	vegetation	coontail	0.08	8860	153	< 1.0	10.0	14.0	1.9	335	15.0	42
5	Ash Springs	09/08/93	vegetation	coontail	1.54	9140	12	< 1.0	2.1	2.6	1.3	655	3.0	112
5	Ash Springs	09/08/93	vegetation	coontal	3.30	9630	31	2.0	8.2	2.0	1.7	516	6.5	53
5	Ash Springs	09/08/93	vegetation	pondweed	0.06	5410	242	< 10.0	12.0	22.0	1.4	100	17.0	59
7	Pahranagat NWR Inflow	09/08/93	vegetation	pondweed	0.04	5860	350	< 10.0	16.5	17.0	1.0	144	17.0	75
7	Pahranagat NWR Inflow	09/08/93	vegetation	pondweed	0.06	8910	462	< 10.0	12.0	22.0	2.1	182	33.0	100
7	Pahranagat NWR Inflow	09/08/93	vegetation	pondweed	0.01	10900	360	< 0.9		9.6	0.8	831	10.0	28
8	Upper Pahranagat Lake	09/08/93	vegetation	pondweed	0.01	10300	538	1.0	2.4	4.7	0.8	631	3.8	20
8	Pahranagat lake	09/08/93	vegetation	pondweed	0.01	14800	230	< 1.0	4.4	12.0	0.7	1140	12.0	35
8	Upper Pahranagat Lake	09/08/93	vegetation	coontail	0.01	11000	251	< 1.0	3.0	6.7	0.9	713	5.7	32
9	Lower Pahranagat Lake	09/08/93	vegetation	najas	0.01	28400	20	1.0	1.0	1.8	1.0	299	1.6	10
9	Lower Pahranagat Lake	09108I93	vegetation	najas	< 0.01	78300	8	2.0	0.7	0.8	0.4	13000	1.0	1
9	Lower Lake	09108193	vegetation	najas	0.01	72400	15	2.0	0.8	1.4	0.4	12900	1.3	2
1		08/23/95	vegetation	elodea	0.54	7155	65	< 5.6	2.5	< 7.0	3.1	138	9.8	32
2	Nesbitt Lake	08/23/95	vegetation	pondweed	0.07	10108	39	< 2.1	3.5	< 2.7	1.0	839	1.7	16
3	Lake	08/23/95	vegetation	widgeon grass	0.14	14052	41	15.8	2.3	< 5.1	1A	175	0.6	34
4		08/24/95	vegetation	elodea	0.22	7723	94	< 4.7	4.6	< 5.9	2.2	170	4.2	85
5	Ash Springs	08/22/95	vegetation	pondweed	5.03	8714	11	< 4.3	4.0	< 5.4	2.2	289	4.7	27
6	River Ranch	08/24/95	vegetation	coontail	0.50	6732	182	< 4.8	3.6	< 6.0	1.1	173	2.5	101
7	Pahranagat NWR Inflow	08/25/95	vegetation	coontail	0.11	9310	92	< 2.7	2.1	< 3.4	< 0.9	421	2.8	18
8	Pahranagat Lake	08121195	vegetation	pondweed	0.19	83740	11	< 3.2	2.7	< 4.0	< 1.1	1919	2.3	7
9	Lower Pahranagat Lake	08121195	vegetation	najas	0.18	9504	678	< 2.8	3.1	< 3.5	1.4	865	4.1	26

Appendix A. (continued)

site no.	location	date	matrix	species	Hg	Me	Mn	Mo	Ni	Pb	se	St	V	zn
					ppm									
7	Pahranagat NWR inflow	09108I93	invertebrate	crayfish	0.07	3040	72	< 1.0	2.4	3.5	3.5	346	4.8	80
9	Lower Lake	09/08/93	invertebrate	dragonfly nyad	0.08	1330	2	< 1.0	0.2	< 0.4	1.9	6	< 0.3	131
9	Lower Pahranagat Lake	09/08/93	invertebrate	giant water beetle	0.30	829	5	1.0	0.2	< 0.4	1.6	8	< 0.3	100
1	Hiko Spring	08/23/95	invertebrate	melanoides	0.33	1452	6	< 0.7	1.1	< 0.9	1.1	700	0.8	46
2	Nesbitt Lake	08/23/95	invertebrate	corixid	0.37	1843	17	< 2.6	2.9	< 3.2	2.0	15	< 0.3	178
3	Lake	08/23/95	invertebrate	corixid	0.26	1973	9	4.9	10.9	< 4.4	3.1	19	< 0.4	177
3	Frenchy Lake	08/24/95	invertebrate	dragonfly	0.19	1122	3	< 2.1	2.6	< 2.6	1.1	4	< 0.3	139
4		08/24/95	invertebrate	melanoides	0.09	1178	8	< 0.7	2.4	< 0.9	0.8	529	0.5	67
5	Ash Springs	08/22/95	invertebrate	melanoides	1.30	2369	3	< 0.7	3.1	< 0.9	1.1	849	0.7	51
6	River Ranch	08/24/95	invertebrate	melanoides	0.16	1300	522	< 0.6	1.8	< 0.8	0.6	822	0.4	64
9	Lower Pahranagat Lake	08/21/95	invertebrate	corixid	0.14	3129	8	< 3.4	3.3	< 4.2	4.1	32	< 0.4	235
4		09/08/93	fish	mollies	0.16	1780	17	< 1.0	1.1	1.4	2.4	100	1.4	180
	Springs	09/08/93	fish	mollies	0.16	1780	19	< 1.0	1.1	1.4	2.0	105	1.0	200
4	Crystal Springs	09/08/93	fish	cichlid	0.24	1920	7	< 1.0	0.4	0.9	2.0	169	< 0.3	212
5	Ash Springs	09/08/93	fish	mollies	0.99	2080	7	< 1.0	0.4	0.9	2.7	164	1.0	161
5	Ash Springs	09/08/93	fish	cichlid	1.36	1910	1	< 0.9	0.2	< 0.4	1.7	231	< 0.3	155
5		09/08/93	fish	cichlid	1.50	1990	2	< 1.0	0.3	< 0.5	1.7	237	< 0.3	218
7	Pahranagat NWR inflow	09/08/93	fish	mosquitofish	0.18	2160	93	< 1.0	1.5	1.9	3.1	159	1.7	174
7	NWR inflow	09/08/93	fish	mosquitofish	0.17	2290	96	< 1.0	1.8	2.5	3.4	156	2.7	175
7	Pahranagat NWR inflow	09/08/93	fish	mosquitofish	0.18	2210	91	< 1.0	1.4	2.0	3.2	151	2.0	170
7	Pahranagat NWR inflow	09/08/93	fish	mosquitofish	0.08	3040	100	< 1.0	1.2	1.4	1.3	448	0.9	183
1	Hiko Spring	08/23/95	fish	mosquitofish	0.85	1493	19	< 1.7	1.0	< 2.2	1.7	84	< 0.2	281
2	Nesbitt Lake	08/23/95	fish	shiner	0.30	3425	13	< 2.4	2.3	< 3.0	5.6	123	0.6	169
4	Crystal Springs	08/24/95	fish	mosquitofish	0.52	1595	9	< 2.3	1.7	< 2.8	2.5	68	< 0.3	202
5	Ash Springs	08/22/95	fish	mosquitofish	1.45	1236	14	< 1.8	1.0	< 2.3	1.8	118	< 0.2	250
6	River Ranch	08/24/95	fish	mosquitofish	1.56	1473	23	< 1.8	1.3	< 2.2	3.6	125	< 0.2	242
7	Pahranagat NWR inflow	08/25/95	fish	bullhead	0.44	2000	22	< 4.2	10.5	< 5.2	4.0	129	1.1	129
8	Lake	08/22/95	fish	carp	0.09	2837	7	< 1.9	1.5	< 2.4	2.6	582	0.4	282

Appendix A. (continued)

site no.	location	date	matrix	species	Hg	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn
					ppm									
3	Frenchy Lake	05/24/95	avian egg	coot	0.34	524	1.4	< 1.6	1.0	< 2.0	2.3	12.8	< 0.2	44
2	Nesbitt Lake	05/24/95		coot	0.31	516	< 1.2	< 1.5	1.2	< 1.8	1.9	6.3	< 0.2	51
3	Frenchy Lake	05/24/95	avian egg	coot	0.29	340	1.0	< 1.6	1.0	< 2.0	1.9	7.4	< 0.2	36
3	Frenchy Lake	05/24/95	avian egg	coot	6.47	618	1.3	2.0	1.9	< 2.4	2.4	9.5	< 0.2	47
3	Lake	05/24/95	avian egg	coot	0.24	498	1.2	< 1.7	1.1	< 2.1	2.0	31.1	< 0.2	58
9	Lower Pahranagat Lake	05/24/95	avian egg	coot	0.26	460	1.1	< 1.5	0.9	< 1.9	1.6	26.3	< 0.2	51
9	Lower Pahranagat Lake	05/24/95	avian egg	coot	0.23	570	0.8	3.0	1.0	< 2.1	2.5	23.2	< 0.2	52
9	Lower Pahranagat Lake	05/24/95	avian egg	coot	0.25	540	0.9	< 1.5	0.9	< 1.9	1.6	27.3	< 0.2	62
9	Lower Pahranagat Lake	05/24/95	avian egg	coot	0.36	374	0.5	2.2	< 0.4	< 1.8	2.1	31.3	< 0.2	25
9	Pahranagat Lake	05/24/95	avian egg	coot	0.20	514	0.7	< 1.8	0.9	< 2.2	2.0	25.3	< 0.2	64

Appendix B. Organochlorine concentrations (ppm. dry weight) in sediment collected from Key Pittman Wildlife Management Area (WMA) and Pahranagat National Wildlife Refuge (NWR) in Pahranagat Valley. Lincoln County. Nevada. 1995.

Analyte	Key Pittman WMA		pabranagat NWR	
	Nesbitt Lake	Frenchy Lake	Upper Pahranagat Lake	Lower Pahranagat Lake
percent moisture	55.6	59.5	66.0	*SO.S*
HCB	< 0.23	< 0.25	< 0.29	< 0.20
PCB (total)	< 0.11	< 0.12	< 0.15	<0.10
alpha BHC	< 0.23	< 0.25	< 0.29	< 0.20
alpha chlordane	< 0.23	< 0,25	< 0.29	< 0.20
beta SHe	< 0.23	< 0.25	< 0.29	< 0.20
dieldrin	< 0.23	< 0.25	< 0.29	< 0.20
endrin	< 0.23	< 0.25	< 0.29	< 0.20
gamma BHC	< 0.23	< 0.25	< 0.29	< 0.20
gamma chlordane	< 0.23	< 0.25	< 0.29	< 0.20
heptachlor epoxide	< 0.23	< 0.25	< 0.29	< 0.20
mirex	< 0.23	< 0.25	< 0.29	< 0.20
o,p'-DDD	< 0.23	< 0.25	< 0.29	< 0.20
o.p'-DDE	< 0.23	< 0.25	< 0.29	< 0.20
D,pt-DDT	< 0.23	< 0.25	< 0.29	< 0.20
oxychlordane	< 0.23	< 0.25	< 0.29	< 0.20
p,p'-DDD	< 0.23	< 0.25	< 0.29	< 0.20
p.p'-DDE	< 0.23	< 0.25	< 0.29	< 0.20
p,p'-DDT	< 0.23	< 0.25	< 0.29	< 0.20
toxaphene	< 0.11	< 0.12	< *O.lS*	< 0.10
trans-nonachlor	< 0.23	S 0.25	≤ Q29	≤ 0.20