RECONNAISSANCE INVESTIGATION OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE IN THE AMERICAN FALLS RESERVOIR AREA, IDAHO, 1988–89

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CONVERSION FACTORS

For readers who prefer to use metric (International System) units rather than inch-pound units, conversion factors for the terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) as follows: °F = (1.8)(°C) + 32. Water temperatures are reported to the nearest 0.5 °C.

Chemical concentrations are given in milligrams per liter (mg/L) or micrograms per liter (µg/L), which are equal to parts per million (ppm) or parts per billion (ppb), respectively.

Weight measurements are reported in grams; to convert grams to ounces, multiply by 0.03527.

Proportions of major ions in water are reported in milliequivalents per liter (milligrams per liter of constituent divided by the atomic weight of the constituent).

Trace constituent concentrations in biota are reported as weight per unit of weight, or micrograms per gram (µg/g) and micrograms per kilogram (µg/kg). These reporting units are equivalent to parts per million and parts per billion, respectively.

Specific conductance is reported in microsiemens per centimeter (µS/cm) at 25 degrees Celsius.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada and formerly called "Sea Level Datum of 1929."

SITE IDENTIFICATION

As a means of identification, each U.S. Geological Survey water-discharge gaging station has been assigned an eight-digit sequential number in downstream order; for example, 13069565 (Aberdeen Wasteway near Aberdeen). Gaging stations on tributaries of the main stream are numbered similarly. The first two digits refer to the basin in which the station is located; 13 refers to the Snake River basin. The last six digits are the downstream order number.

Gaging sites that are not part of the regularly monitored network are given a 15-digit number based on latitude and longitude; for example, 424603112525501 (Rueger Springs). The first six digits denote the degrees, minutes, and seconds of latitude; the next seven digits denote the degrees, minutes, and seconds of longitude; and the last two digits, assigned sequentially, identify the site within a 1-second grid.

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ABSTRACT

Increased concern about the quality of irrigation drainage and its potential effects on human health, fish, and wildlife prompted the Department of the Interior to begin a program during late 1985 to identify irrigation-induced water-quality problems that might exist in the Western States. During 1988, the Task Group on Irrigation Drainage selected the American Falls Reservoir area, Idaho, for study to determine whether potentially toxic concentrations of trace elements or organochlorine compounds existed in water, bottom sediment, and biota.

The 91-square mile American Falls Reservoir has a total capacity of 1.7 million acre-feet and is used primarily for irrigation-water supply and power generation. Irrigated land upstream from the reservoir totals about 550,000 acres. Total water inflow to the reservoir is about 5.8 million acre-feet per year, of which about 63 percent is from surface-water runoff, 33 percent is from ground-water discharge, and about 4 percent is from ungaged tributaries, canals, ditches, sloughs, and precipitation. Ground-water discharge to the reservoir originates, in part, from irrigation of land upstream from and adjacent to the reservoir. The 1988 water year was a drought year, and water discharge was about 34 percent less than during 1939–88.

Water samples were collected during the post-irrigation (October 1987) and irrigation (July 1988) seasons and were analyzed for major ions and trace elements. Bottom-sediment samples were collected during the irrigation season and were analyzed for trace elements and organochlorine compounds. Biota samples were collected during May, June, July, and August 1988 and were analyzed for trace elements and organochlorine compounds.

Dissolved-solids concentrations in water ranged from 216 to 561 milligrams per liter. The similarity of dissolved-solids concentrations between the irrigation and post-irrigation seasons can be attributed to the large volume of ground-water discharge in the study area.

Most trace-element concentrations in water were near analytical reporting limits; none exceeded State or Federal water-quality standards or criteria. Trace elements that were present at all sites in analytically detectable concentrations (in micrograms per liter) included arsenic (2 to 7), boron (40 to 130), uranium (0.7 to 3.5), vanadium (1 to 6) and zinc (less than 3 to 42). The ranges of arsenic, cadmium, and mercury concentrations in water analyzed during this investigation were lower than concentrations in water analyzed during previous investigations. Selenium concentrations ranged from less than 1 (the reporting limit) to 6 micrograms per liter and did not exceed State or Federal water-quality standards or criteria.

Concentrations of most trace elements in bottom sediment were similar to geometric mean concentrations in study area soils and were within the expected 95-percent range of concentrations in soils in the Western United States. Mercury concentrations in 9 of the 18 bottom-sediment samples exceeded the 95th-percentile concentration for mercury in area soils. Selenium concentrations in 14 of the 18 samples equaled or exceeded the 95th-percentile concentration for selenium in area soils and, in 1 sample, exceeded the upper limit of the expected 95-percent range for selenium in Western United States soils.

Most organochlorine compounds in bottom sediment were lower than analytical reporting limits. Only DDE (0.2 micrograms per kilogram) and DDT (0.3 micrograms per kilogram) were detected in bottom sediment from the Portneuf River.

Except for mercury and selenium, concentrations of most trace elements in biota were not considered high enough to be harmful to humans or wildlife. Some mercury concentrations in fish exceeded the U.S. Fish and Wildlife Service National Contaminant Biomonitoring Program 85th-percentile concentration and were at levels that might not be safe for human consumption, especially for pregnant women. Elevated mercury concentrations in fish-eating waterbirds, such as double-crested cormorants, indicates biomagnification in the food chain. Selenium concentrations generally were low except in mallard livers (6.6 to 41.8 micrograms per gram, dry weight). This range is within the range of selenium concentrations (19 to 43 micrograms per gram, dry weight) reported in livers of ducks from Kesterson National Wildlife Refuge, California, where waterbird deformities, mortalities, and reproductive impairment were observed. Selenium concentrations in mayfly nymphs were at or near dietary concentrations (5 to 8 micrograms per gram, dry weight) that had adverse reproductive effects on mallards during laboratory toxicity studies.

p,p'DDE was detected in all waterbird eggs and juvenile mallard carcasses. Highest concentrations were in cormorant eggs (0.59 to 5.70 micrograms per gram, wet weight). p,p'DDE concentrations in four of five cormorant eggs exceeded the National Academy of Sciences, National Academy of Engineering criterion for protection of aquatic wildlife (1 microgram per gram, wet weight, for p,p'DDT and its metabolites). p,p'DDE was detected in all fish samples except rainbow trout. p,p'DDT was detected in one sample of Utah suckers. No concentrations of p,p'DDE or p,p'DDT in fish exceeded the criterion for protection of aquatic life.

Total PCB's were detected in all cormorant eggs and all fish samples. PCB's were not detected in other waterbird eggs. PCB concentrations in cormorant eggs (0.28 to 1.8 micrograms per gram, wet weight) were lower than concentrations that would be expected to cause adverse effects. Two of the three carp samples contained PCB concentrations higher than the recommended level for protection of fish and wildlife (0.4 micrograms per gram, wet weight).

Eggshell thinning was noted in cormorant and mallard eggs but was not considered great enough to cause reproductive problems.

Observations of the general health of fish and waterbird populations during the study indicated that the area did not appear to have a serious contaminant problem that could be associated with irrigation drainage. No waterbird or fish die-offs were observed, and nesting waterbird populations were noted to be increasing. Selenium concentrations in mallard livers, however, are of concern, as are p,p'DDE residues in cormorant eggs.

INTRODUCTION

Background

During the last several years, there has been increasing concern about the quality of irrigation drainage, both surface and subsurface water draining irrigated land, and its potential effects on human health, fish, and wildlife. Concentrations of selenium greater than water-quality criteria for the protection of aquatic life (U.S. Environmental Protection Agency, 1987) have been detected in subsurface drainage from irrigated land in the western part of the San Joaquin Valley in California. During 1983, incidences of mortality, birth defects, and reproductive failures in waterbirds were discovered by the U.S. Fish and Wildlife Service at the Kesterson National Wildlife Refuge in the western San Joaquin Valley, where irrigation drainage was impounded. In addition, potentially toxic concentrations of trace elements and pesticide residues have been detected in other areas in the Western United States that receive irrigation drainage.

Because of concerns expressed by the U.S. Congress, the DOI (Department of the Interior) initiated a program during late 1985 to identify the nature and extent of irrigation-induced water-quality problems that might exist in the Western States. During October 1985, an interbureau group known as the Task Group on Irrigation Drainage was formed within the DOI. The Task Group subsequently prepared a comprehensive plan for reviewing irrigation-drainage concerns for which the DOI has responsibility.

The DOI developed a management strategy and the Task Group prepared a comprehensive plan for reviewing irrigation-drainage concerns. Initially, the Task Group identified 19 locations in 13 States that warranted reconnaissance investigations. These locations relate to three specific areas of DOI responsibilities: (1) Irrigation or drainage facilities constructed or managed by the DOI, (2) national wildlife refuges that receive irrigation drainage, and (3) other migratory-bird or endangered-species management areas that receive water from DOI-funded projects.

Nine of the 19 locations were selected for reconnaissance investigations during 1986–87. The nine areas are:

Arizona-California	Lower Colorado-Gila River Valley
California	Salton Sea and Tulare Lake Bed
Montana	Sun River Reclamation Project
	Milk River Reclamation Project
Nevada	Stillwater Wildlife Management
Texas	Lower Rio Grande-Laguna Atascosa National Wildlife Refuge
Utah	Middle Green River basin
Wyoming	Kendrick Reclamation Project

During 1988, reports for seven of the reconnaissance investigations were published. Reports for the remaining two areas were published during 1990. On the basis of results of the first nine reconnaissance investigations, four detailed studies began during 1988: Salton Sea area, Stillwater Wildlife Management area, Middle Green River basin area, and the Kendrick Reclamation Project area. Eleven more reconnaissance investigations began during 1988. These areas are:

California	Sacramento Refuge Complex
California-Oregon	Klamath Basin Refuge Complex
Colorado	Gunnison and Uncompahgre River basins
	Pine River Project and Sweitzer Lake
Colorado-Kansas	Middle Arkansas River basin
Idaho	American Falls Reservoir
New Mexico	Middle Rio Grande Project and Bosque del Apache National Wildlife Refuge
Oregon	Malheur National Wildlife Refuge
South Dakota	Angostura Reclamation Project
South Dakota	Belle Fourche Reclamation Project
Wyoming	Riverton Reclamation Project

All reconnaissance investigations are being done by interbureau field teams composed of scientists from the U.S. Geological Survey, U.S. Fish and Wildlife Service, and U.S. Bureau of Reclamation. The investigations are directed toward determining whether irrigation drainage (1) has caused or has potential to cause significant harmful effects on human health, fish, and wildlife, or (2) may adversely affect the suitability of water for other beneficial uses.

Purpose and Scope

This report presents results of a reconnaissance investigation to determine whether potentially toxic concentrations of selected trace elements or organochlorine compounds associated with irrigation drainage exist in surface and ground water, bottom sediment, aquatic plants, benthic invertebrates, fish, and waterbirds in the American Falls Reservoir area. American Falls Reservoir was selected for investigation in part because several previous investigations of fish in the reservoir indicated that mercury and cadmium concentrations exceeded human health standards and periodic botulism-related die-offs of waterbirds have been known to occur. Also, rocks south and southeast of the reservoir contain naturally occurring selenium concentrations many times greater than those in the continental crust.

Samples of water, bottom sediment, aquatic plants, benthic invertebrates, fish, and waterbirds were collected from nine sites in the American Falls Reservoir area. The samples were analyzed for selected inorganic and organic constituents to determine whether concentrations exceeded known standards or criteria.

Acknowledgments

Appreciation is extended to Daniel M. Christopherson, Daniel M. Daley, and Frederick L. Greider of the Shoshone-Bannock Indian Tribes for their assistance in obtaining access to and information on the Fort Hall Indian Reservation and for assistance in collecting fish and waterbird samples; to Carol A. Schuler, U.S. Fish and Wildlife Service, Portland, Oreg., for assistance in processing biological samples; to Lawrence J. Blus, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Corvallis, Oreg., for measuring eggshell thickness; to William J. Davidson, Perry J. Johnson, Julia A. Mulholland, and Patricia A. Wakkinen, Idaho Department of Fish and Game, Boise, Idaho, for assistance in collecting fish and waterbird samples and the use of equipment and laboratory facilities; and to Karl E. Holte, G. Wayne Minshall, and Charles H. Trost, Department of Biology, Idaho State University, Pocatello, Idaho, for their free exchange of information.

STUDY AREA

Location

The 91-mi^2 American Falls Reservoir is located on the upper Snake River in Bannock, Bingham, and Power Counties in southeastern Idaho (fig. 1). The Snake River is a major tributary to the Columbia River. Water level in the reservoir, when full, is about 4,300 ft above sea level. The Snake River drainage basin upstream from the reservoir is about 13,580 mi^2 and includes part of Yellowstone National Park (fig. 2). North and west of the reservoir is the broad, 9,600-mi^2 eastern Snake River Plain. Land to the south and east of the Snake River and reservoir is mostly within the 524,000-acre Fort Hall Indian Reservation, Shoshone-Bannock Indian Tribes (fig. 1).

Largest population centers (Idaho Department of Commerce News, written commun., 1986) are Blackfoot, upstream from the reservoir on the Snake River (population 10,080); Pocatello/Chubbuck, on the Portneuf River southeast of the reservoir (population 56,440); and American Falls, at the reservoir dam (population 3,500).

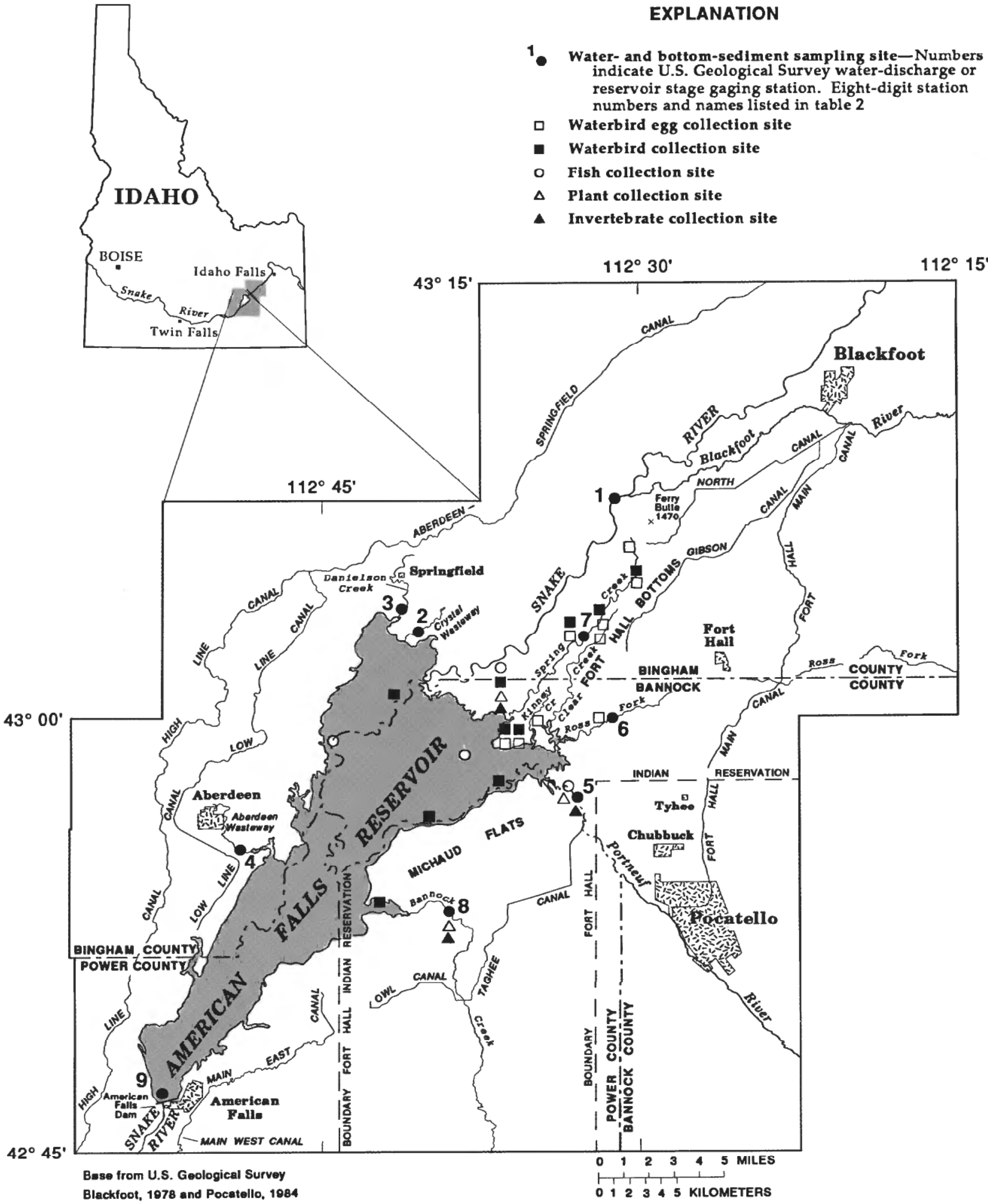

Figure 1.—Location of study area and sampling sites.

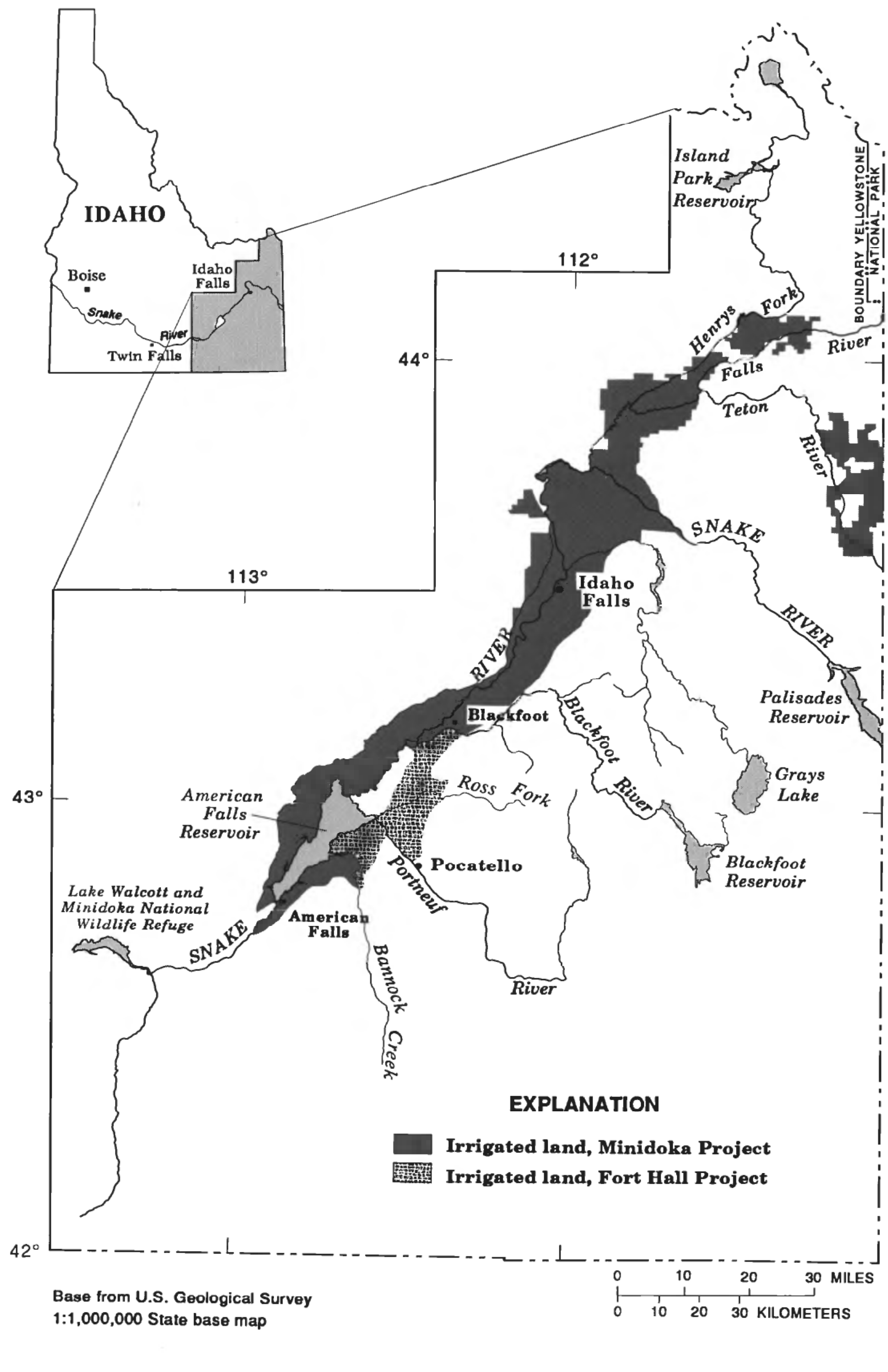

Figure 2.—Irrigated land upstream from American Falls Reservoir served by the U.S. Bureau of Reclamation Minidoka Project and the U.S. Bureau of Indian Affairs Fort Hall Project.

American Falls Dam was built during 1927 and replaced during 1978 by the American Falls Reservoir District. The reservoir is operated by the U.S. Bureau of Reclamation as part of the Minidoka Project, which provides water for irrigation of land in the upper Snake River basin in southern and eastern Idaho. Major project functions served by the reservoir include supplying water downstream for irrigation of about 500,000 acres within the Minidoka Project, power generation, flood control, fish and wildlife habitat, and recreation. The U.S. Bureau of Indian Affairs Fort Hall Project provides water for irrigation of land south and east of the reservoir within the Fort Hall Indian Reservation. The Minidoka National Wildlife Refuge is on the Snake River about 10 mi downstream from American Falls Reservoir (fig. 2). The 25,630-acre refuge was established during 1909 by the U.S. Fish and Wildlife Service.

History

The 1.7 million acre-ft American Falls Reservoir has the largest storage capacity of the five major reservoirs on the upper Snake River. Storage retention time is about 0.3 year. Principal industries in the three-county area are irrigated agriculture (mainly potatoes and sugar beets) and phosphate-ore processing (elemental phosphorus, phosphoric acid, and phosphate fertilizers). Irrigated agriculture is the major nonpoint source that might affect water quality in the reservoir watershed. Point sources include effluent from municipalities and phosphate-ore processing plants. The reservoir receives irrigation drainage from about 550,000 acres of irrigated land served by diversions from the Henrys Fork, Snake, Blackfoot, and Portneuf Rivers, Ross Fork, and Bannock Creek (fig. 2).

Large numbers of waterbirds use the reservoir for feeding, nesting, and rearing during spring, summer, and fall. Also, large numbers of migratory birds use the reservoir for resting and feeding during the spring and fall migration periods. The principal areas for waterbird use are near the upper end of the reservoir from Springfield to the mouth of Portneuf River and the mouth of Bannock Creek (fig. 1).

Significant waterbird die-offs in American Falls Reservoir occur periodically near Springfield and at the mouth of Bannock Creek. Botulism poisoning of waterbirds has been confirmed at the mouth of Bannock Creek and is suspected near Springfield (James A. Nee, U.S. Fish and Wildlife Service, oral commun., 1986).

Climate

The climate at American Falls Reservoir is semiarid; mean annual precipitation at the Pocatello airport from 1951 to 1988 was 10.86 in. Most precipitation is during the fall, winter, and spring. Highland and mountainous areas to the south and east receive greater amounts of precipitation than the Snake River Plain. The average daily minimum air temperature is 31 °F (-5 °C) and the average daily maximum air temperature is 61 °F (16 °C). The average annual extreme temperatures are -12 °F (-24 °C) and 98 °F (37 °C). Temperatures of 90 °F

(32 °C) and higher occur on the average of 32 days per year, and 32 °F (0 °C) or below occur on the average of 177 days per year. Frost-free periods range from 100 to 120 days. The prevailing winds average 10 miles per hour from the southwest. Evaporation from the reservoir is estimated to be about 180,000 acre-ft/yr, or 38 in/yr (Kjelstrom, 1988, p. 13).

Total precipitation during 1987 was 10.23 in., or about 3 percent less than the mean annual precipitation and, during 1988, was 7.92 in., or about 16 percent less than the mean annual precipitation.

Geology

The Snake River in southeastern Idaho approximates the boundary between the Snake River Plain, which is part of the Columbia Lava Plateau physiographic province (Fenneman, 1931, p. 238–244) and the Basin and Range province. The mountainous areas south of the Snake River are composed of various Precambrian rocks and Paleozoic marine sedimentary rocks (Trimble, 1976). The Snake River Plain north of the Snake River is composed chiefly of Quaternary basalt with interbedded sediments. American Falls Reservoir is underlain by a series of Pleistocene lakebeds deposited after intermittent basalt eruptions diverted and dammed streams to form lakes. The Lake Bonneville flood about 15,000 years ago (Scott and others, 1982, p. 581) caused much of the erosion and deposition of sediments in the reservoir area.

The regional geology south of the reservoir and in tributary drainage basins southeast of the reservoir has been reported by Carr and Trimble (1963), Armstrong and Oriel (1965), and Trimble (1976) and is part of the pre-Cretaceous overthrust belt of Idaho, Utah, and Wyoming. The overthrust belt in southeastern Idaho contains economically significant deposits of phosphate rock, mostly in the Permian Phosphoria Formation. The Phosphoria Formation is composed of four members. In the Meade Peak Member (the lowermost member), average selenium concentrations are 600 times greater than in the continental crust (0.05 ppm). In a vanadiferous zone of the Meade Peak Member, selenium concentrations are more than 11,000 times greater than in the continental crust (U.S. Department of the Interior and U.S. Department of Agriculture, 1977, p. 1–53).

The bedrock north of the reservoir is predominantly Quaternary olivine basalt of the Snake River Group. The basalt and the intercalated sediments are part of the eastern Snake River Plain regional aquifer system. In general, bare olivine basalt predominates north and west of the Aberdeen-Springfield Canal.

Soils

Major soil associations in irrigated areas north of and along the Snake River include the Bannock-Bock, Declo-Fingal, and Pancheri-Polatis (Salzmann and Harwood, 1973). These mildly to moderately alkaline, calcareous associations are composed of nearly level to moderately sloping, well-drained, deep, medium-textured loam over gravel and sand on alluvial terraces. Soil pH ranges from 7.4 to 9.0. The Bannock-Bock association on older, higher alluvial terraces along the Snake River is composed of well-drained, medium-textured loam soils underlain by sand and gravel. The Declo-Fingal association on lacustrine terraces above and north of the river and reservoir is composed of well-drained, medium to moderately coarse-textured loam and silt loam over sand and gravel. The Pancheri-Polatis association on basalt plains is composed of well-drained, deep, medium-textured soils underlain by Quaternary basalt. Major crops irrigated on these soils include potatoes, sugar beets, hay, and small grains.

Major soil associations in irrigated areas south of the Snake River include the Paniogue-Declo, Paniogue-Broncho, and Tindahay-Escalante (McDole, 1977). These mildly to strongly alkaline, calcareous soil associations are composed of nearly level, gravelly to sandy loams and silt loams underlain by sand and gravel on alluvial fans and terraces. Soil pH ranges from 7.4 to 9.6. The Paniogue-Declo association is composed of level to moderately sloping, deep, well-drained loams and silt loams formed on alluvial fans and terraces along the Snake and Blackfoot Rivers. The Paniogue-Broncho association is composed of level to moderately steep, deep, very well-drained loams and gravelly loams formed on alluvial fans and terraces near the mouth of Portneuf River. The Tindahay-Escalante association is composed of level to sloping, deep, very well-drained, loamy, coarse sand and sandy loams formed on alluvial fans and terraces near the mouths of Ross Fork, Portneuf River, and Bannock Creek.

The well-drained, loamy to sandy loam soils, the extensive irrigated agriculture surrounding the reservoir, and the semiarid climate provide a well-oxygenated and oxidizing chemical environment. Except for oxyanions such as selenium, the solubility of many potentially toxic trace elements in this kind of soil chemical environment is probably slight.

Table 1 lists the geometric mean, 95th percentile, and range of trace-element concentrations in 40 soil samples collected from Bannock, Bingham, and Power Counties (R.C. Severson, U.S. Geological Survey, unpubl. data, 1975), compared with concentrations in soils in the United States west of the 96th Meridian (Shacklette and Boerngen, 1984, p. 6). Mean trace-element concentrations in study area soils are similar to concentrations in Western United States soils.

HYDROLOGY

Water resources in the American Falls Reservoir area have been studied by Swendsen (1924); Stearns and others (1938); Stewart and others (1951); West and Kilburn (1963); Mundorff and others (1964); Mundorff (1967); Castelin (1974); Balmer and Noble (1979); Jacobson (1982, 1984); Kjelstrom (1986, 1988); and J.M. Spinazola and others (U.S. Geological Survey, written commun., 1988).

Major canals that deliver water to irrigated land south of the reservoir are the Fort Hall Main, Gibson, Taghee, Owl, and West and East Main Canals (figs. 1 and 3). Major canals that deliver water to irrigated land north of the reservoir are

Table 1.—*Geometric mean, 95th percentile, and range of trace-element concentrations in 40 soil samples from Bannock, Bingham, and Power Counties*[1] *and concentrations in soils in the United States west of the 96th Meridian*

[Concentrations in parts per million; study area data from R.C. Severson (U.S. Geological Survey, unpubl. data, 1975); Western United States data from R.C. Severson, U.S. Geological Survey, written commun., 1987, based on information in report by Shacklette and Boerngen (1984, p. 6); <, less than; —, not determined]

	Arsenic	Boron	Chromium	Copper	Lead	Lithium
			Study Area			
Geometric mean	5.2	32	64	17	19	20
95th percentile	10.9	69	98	20	30	25
Range	3.5-16.3	20-70	30-100	15-30	15-30	15-25
			Western United States			
Geometric mean	5.5	23	41	21	17	22
Upper limit of expected 95-percent range	22	91	197	90	55	55
Range	<.10-97	<20-300	3-2,000	2-300	<10-700	5-130

Table 1.—*Geometric mean, 95th percentile, and range of trace-element concentrations in 40 soil samples from Bannock, Bingham, and Power Counties*[1] *and concentrations in soils in the United States west of the 96th Meridian*—Continued

	Mercury	Molybdenum	Selenium	Uranium	Vanadium	Zinc
			Study Area			
Geometric mean	0.02	—	0.1	3.0	67	74
95th percentile	.03	—	.3	5.3	150	138
Range	<.01-.04	—	<.1-.4	2.4-5.4	50-150	52-144
			Western United States			
Geometric mean	.05	.85	.23	2.5	70	55
Upper limit of expected 95-percent range	.25	3.9	1.4	5.3	266	176
Range	<.01-4.6	<3-7	<.1-4.3	.68-7.9	7-500	10-2,100

[1]Bannock County, 12 samples; Bingham County, 11 samples; Power County, 17 samples.

AVERAGE ANNUAL DIVERSIONS (ACRE-FEET)

ABERDEEN - SPRINGFIELD CANAL	303,000
AMERICAN FALLS PUMPING PLANT	21,000
MICHAUD FLATS PUMPING PLANT	30,000
FORT HALL MAIN CANAL	150,000
NORTH CANAL	75,000

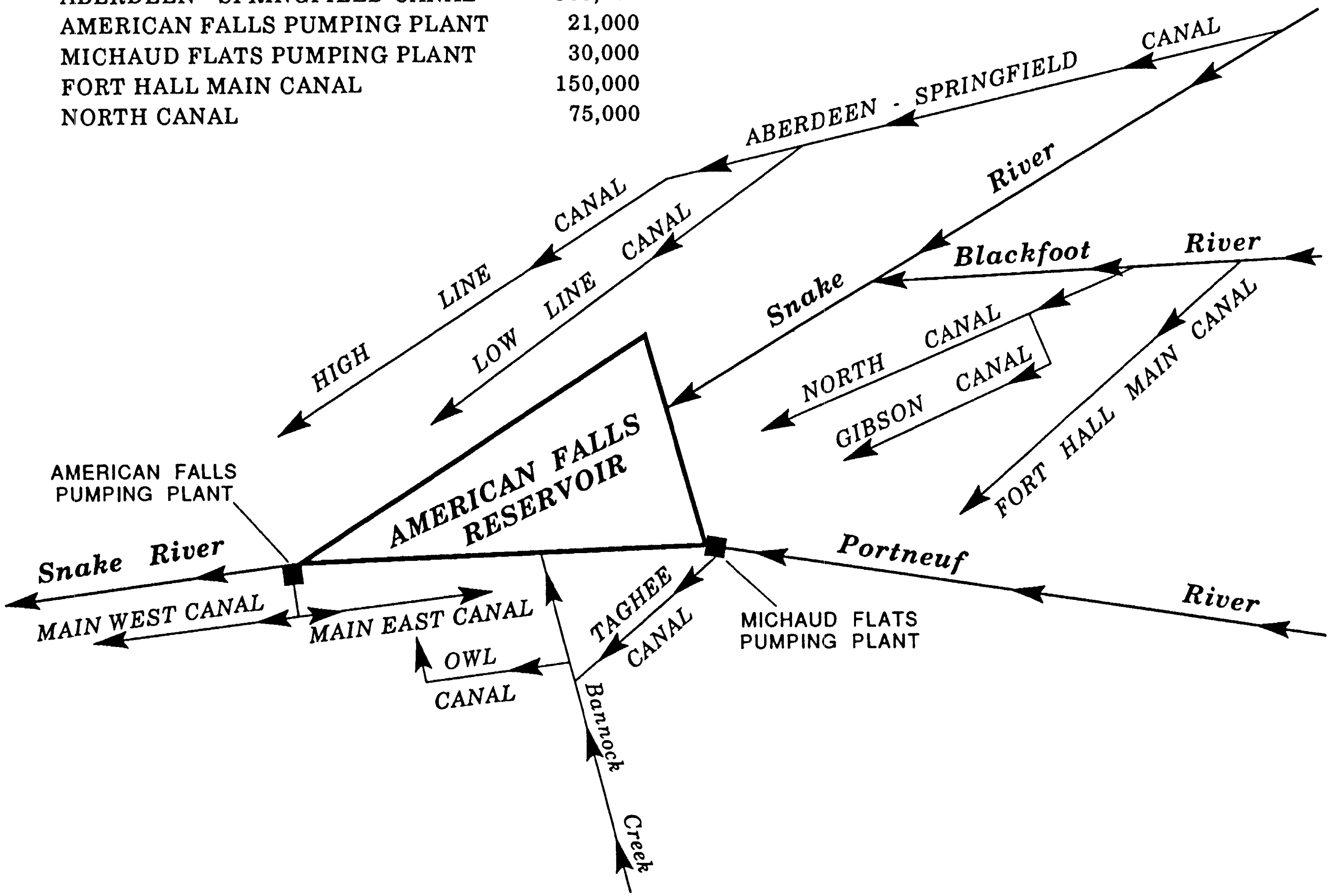

Figure 3.—Schematic diagram of the water distribution system.

the Aberdeen-Springfield, High Line, and Low Line Canals. Water delivered by these canals is diverted from the Snake River by the U.S. Bureau of Reclamation and from the Blackfoot River by the U.S. Bureau of Indian Affairs. Water is diverted into the canal systems from about April 15 to October 15. Canal flows are generally constant except during the beginning and end of the irrigation season, when weather and harvest schedules may dictate irrigation-water demand. Monthly mean diversions to the Aberdeen-Springfield and Fort Hall Main Canals during the 1988 irrigation season are shown in figure 4.

During 1988, the U.S. Geological Survey maintained eight water-discharge gages at sites of major inflow to the reservoir (fig. 1 and table 2). These gages measured most of the surface- and ground-water discharge entering the reservoir.

Total water inflow to the reservoir is about 5.8 million acre-ft/yr. Contributions include streamflow from the Snake River (3.5 million acre-ft/yr, or 60 percent of the total), Portneuf River (194,000 acre-ft/yr, or 3 percent of the total), and ungaged tributaries (109,000 acre-ft/yr, or 2 percent of the total); ground-water discharge (1.9 million acre-ft/yr, or 33 percent of the total); precipitation (50,000 acre-ft/yr, or less than 1 percent of the total); and flow from irrigation-drainage canals, ditches, and sloughs (65,000 acre-ft/yr, or 1 percent of the total) (Kjelstrom, 1986; 1988, p. 21; written commun., 1988). During the 1988 water year, mean annual discharge from the Snake River near Blackfoot into the reservoir was about 42 percent less than the mean annual discharge during 1939–88. The 1988 water year monthly mean discharge for the Snake River near Blackfoot averaged about 34 percent less than the mean monthly discharge during 1939–88 (fig. 5). Water year 1988 was considered a drought year (Harenberg and others, 1988).

Water-budget analysis indicates that average ungaged inflow to the reservoir (1952–83) was 1.96 million acre-ft/yr, of which about 94 percent was ground-water discharge (Kjelstrom, 1988, p. 16, 19). The average ungaged surface-water inflow into the reservoir (1912–83) was about 109,000 acre-ft/yr, much of which was irrigation drainage (Kjelstrom, 1988, p. 16). Largest among these inflows are Crystal Wasteway (26,870 acre-ft during 1988), Aberdeen Wasteway (14,940 acre-ft during 1988), Ross Fork (36,830 acre-ft during 1980), and Bannock Creek (24,840 acre-ft during 1980). Flow in Crystal Wasteway is largely ground water used for aquaculture production before being discharged into American Falls Reservoir. Flow in Aberdeen Wasteway consists of irrigation drainage and municipal sewage effluent. Flows in Ross Fork and Bannock Creek are mostly irrigation drainage.

Recharge to ground water in the American Falls area is mostly from irrigation upstream from the reservoir and is estimated to be about 900,000 acre-ft/yr (J.M. Spinazola, U.S. Geological Survey, written commun., 1988).

Deuterium and ^{18}oxygen isotope ratios from 11 springs discharging to the reservoir are shown in figure 6 and table 3 (Jacobson, 1984, p. 21; Wood and Low, 1988, p. 58). Stable isotopes of hydrogen (^{2}H, or deuterium) and oxygen (^{18}O or ^{18}oxygen) customarily are expressed as deviations from an arbitrary standard. Stable isotopes are expressed in δ (delta) notation:

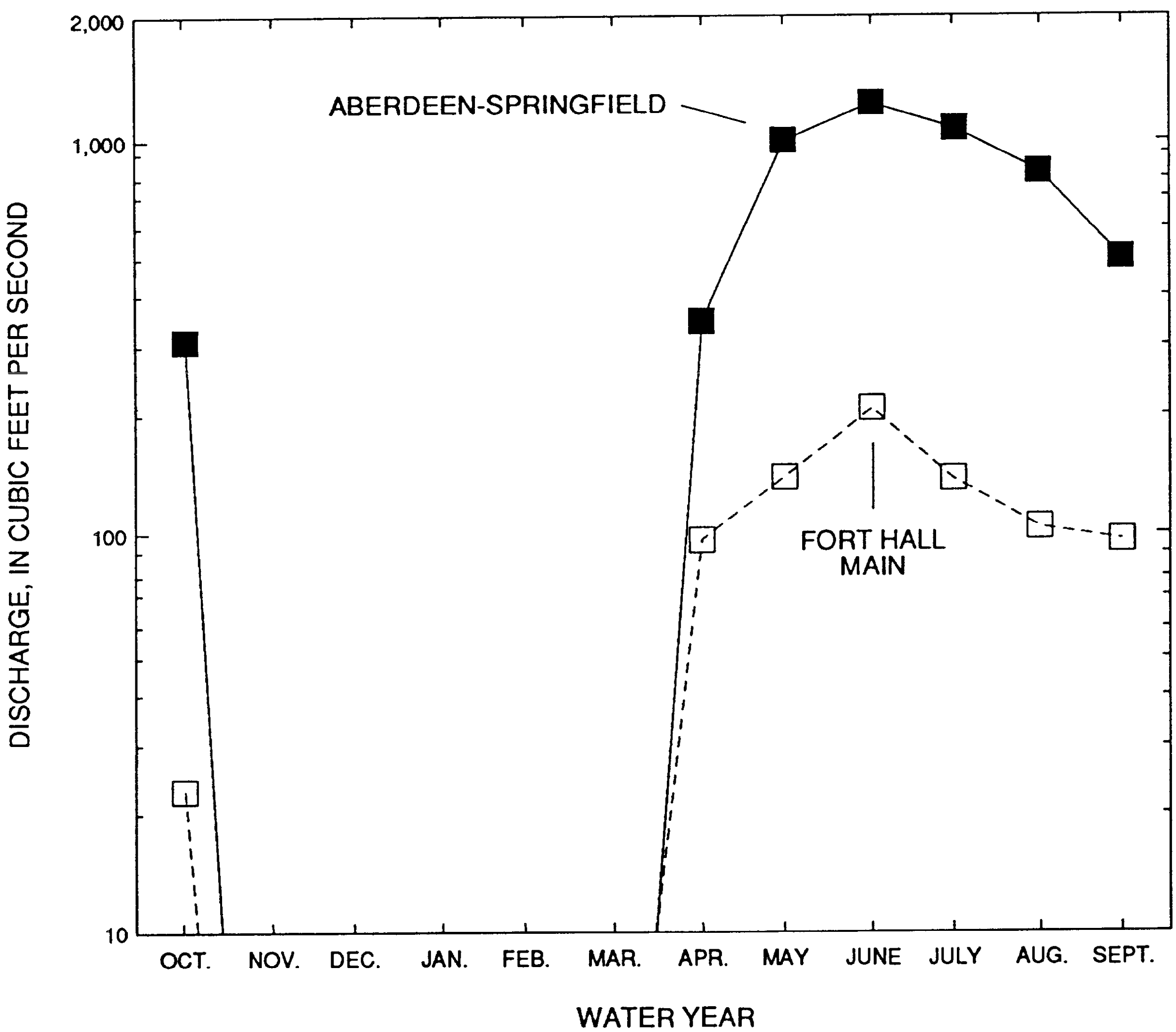

Figure 4.—Monthly mean diversions to Aberdeen-Springfield and Fort Hall Main Canals, 1988.

Table 2.—*List of U.S. Geological Survey water-discharge gaging stations*

Sampling site No. (fig. 1)	Gaging station No.	Name	Location
1	13069500	Snake River near Blackfoot	NW1/4SE1/4SE1/4 sec. 30, T. 3 S., R. 34 E.
2	13069532	Crystal Wasteway near Springfield	NE1/4SE1/4NW1/4 sec. 26, T. 4 S., R. 32 E.
3	13069540	Danielson Creek near Springfield	NW1/4NW1/4SW1/4 sec. 23, T. 4 S., R. 32 E.
4	13069565	Aberdeen Wasteway near Aberdeen	NE1/4SE1/4SE1/4 sec. 3, T. 6 S., R. 31 E.
5	13075910	Portneuf River near Tyhee	NW1/4SW1/4NE1/4 sec. 36, T. 5 S., R. 33 E.
6	13075960	Ross Fork near Fort Hall	SE1/4SE1/4SE1/4 sec. 7, T. 5 S., R. 34 E.
7	13075983	Spring Creek near Fort Hall	NW1/4NE1/4SW1/4 sec. 25, T. 4 S., R. 33 E.
8	13076200	Bannock Creek near Pocatello	SW1/4NW1/4SW1/4 sec. 19, T. 6 S., R. 33 E.
[1]9	13076500	American Falls Reservoir at American Falls	NE1/4SE1/4SW1/4 sec. 30, T. 7 S., R. 31 E.

[1]Reservoir stage gaging station.

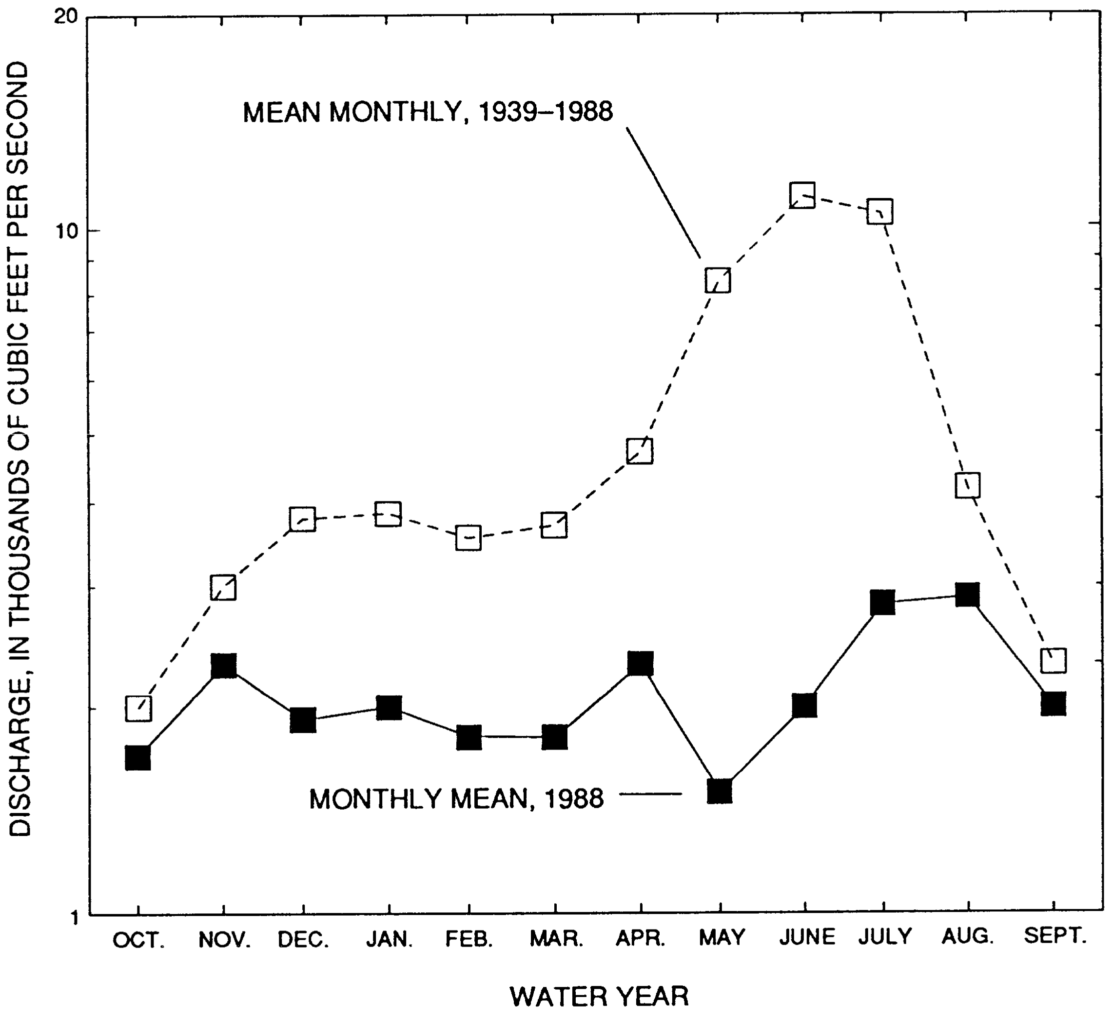

Figure 5.—Monthly mean discharge (1988 water year) and mean monthly discharge (1939–88 water years), Snake River near Blackfoot.

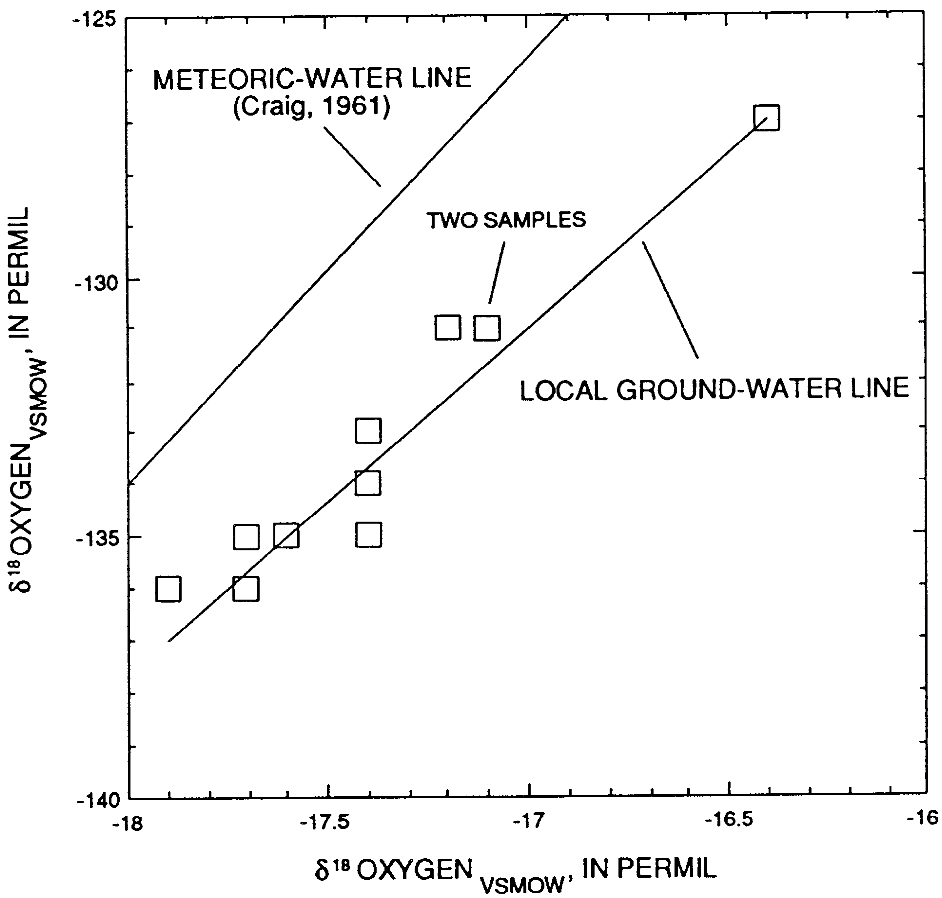

Figure 6.—Relation between deuterium and ^{18}oxygen isotope ratios in ground water.

Table 3.—*Deuterium (δ^2H) and ^{18}oxygen ($\delta^{18}O$) isotope ratios in ground water*

[Ratios in parts per thousand (permil)]

Identification No.	Name	Date (1980)	δ^2H	$\delta^{18}O$
424603112525501	Rueger Springs	12-12	-136	-17.7
430205112372001	McTucker Spring	12-10	-133	-17.4
430349112342101	Log Cabin Spring	12-10	-135	-17.4
430539112402301	Danielson Spring	12-10	-135	-17.7
430608112301901	Big Spring	12-10	-135	-17.6
430611112322000	Johannes Spring	12-10	-134	-17.4
13075810	Batiste Springs	12-11	-127	-16.4
13075890	Siphon Road Spring	12-18	-131	-17.2
13075915	Twenty Springs West	12-17	-131	-17.1
13075923	Tindaha Spring	12-17	-131	-17.1
13075973	Jimmy Drinks Spring	12-17	-136	-17.9

$$\delta = [(R_{sample}/R_{standard}) - 1] \times 1000$$

where

δ = parts per thousand or permil (‰), and
R = $^2H/H$ or $^{18}O/^{16}O$ ratio.

The standard to which natural-water isotopic measurements are referred is V–SMOW (Vienna Standard Mean Ocean Water). The isotope analyses have an analytical error of ±1.5 ‰ δ^2H and ±0.1 ‰ $\delta^{18}O$.

The δ^2H and $\delta^{18}O$ values shown in figure 6 are typical of values in the Snake River Plain regional aquifer system (Wood and Low, 1988, p. 15). The slope of the local ground-water line ($\delta D = 6.6\ \delta^{18}O - 19$, $r = 0.92$) is shifted slightly to the right of the meteoric-water line. The shift is typical of water that has undergone evaporation prior to recharge in a semiarid continental area (Gat, 1981, p. 223). Because the stable isotope values lie near the meteoric-water line, the ground water probably originates from local recharge. The spread of isotopic values along the local ground-water line (fig. 6) indicates that the ground water has undergone different degrees of evaporation prior to recharge and that some ground water is influenced by irrigation recharge.

Major aquifers in the American Falls Reservoir area are part of the eastern Snake River Plain regional aquifer system (Whitehead, in press). Ground water discharges to the Snake River and American Falls Reservoir from sand and gravel and basalt aquifers south of the river and reservoir and from basalt aquifers north of the river and reservoir.

PREVIOUS STUDIES

Several studies of water quality and biota in and near the reservoir have been done. Bushnell (1969) collected temperature, dissolved oxygen, nitrogen, phosphorus, and microbiological data to determine the eutrophic status of the reservoir. Gebhards and others (1971, p. 14) measured mercury concentrations in fish muscle tissue (average concentrations ranged from 0.120 to 0.910 ppm, wet weight), water (0.0018 ppm), and sediment samples (0.0160 ppm) from the reservoir. They determined that mercury concentrations in warm-water nongame fish species (Utah sucker, common carp, and Utah chub) were about twice those in cold-water game fish species (trout and whitefish). Mercury concentrations also were higher in reservoir fish than in fish from streams discharging into the reservoir. About 5 percent of the total number of fish they collected contained mercury concentrations higher than the U.S. Food and Drug Administration standard of 0.5 ppm, wet weight, for human consumption (Gebhards and others, 1971, p. 5). Gebhards and others (1971) also reported that background concentrations of mercury in native Idaho trout collected from various sites unaffected by humans ranged from 0.01 to 0.13 ppm, wet weight.

Runyan (1972, p. 58–59) concluded that uptake of mercury by trout in the reservoir was relatively low, possibly because of their short residence time, compared to yellow perch and black bullheads, in which mercury concentrations were higher. Jarmon (1973, p. 11, 84) concluded that yellow perch in the reservoir represented a mercury-contaminated population. He suggested that inorganic mercury concentrations and numbers of bacteria and molds in the reservoir sediments may explain elevated mercury concentrations in yellow perch.

Kent (1976, p. 34, 67) and Johnson and others (1977, p. 40–43) determined that organochlorine compounds, cadmium, and mercury in sediments accumulate in fish in the reservoir and, if consumed, could be a potential human health hazard. They suggested that the relatively high concentrations of DDT and its metabolites and PCB's in Utah suckers in the reservoir could be contributing to biomagnification of these contaminants in the reservoir food chain. Johnson and others (1977, p. 43) also stated that mercury and cadmium concentrations in fish samples collected during their study exceeded human health standards set by the U.S. Food and Drug Administration and the World Health Organization.

Johnson and Kent (1978, p. 1) indicated that three possible sources of mercury and cadmium in the reservoir are sewage effluent, irrigation drainage, or emissions from nearby phosphate and cement plants. They concluded that industrial and municipal facilities adjacent to the lower Portneuf River near Pocatello appeared to be contributing cadmium and mercury to the aquatic environment and that the sources of organochlorine compounds were agricultural pesticides.

The U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, collected and analyzed water samples monthly from the Snake River downstream from the reservoir dam during July 1977 to September 1979 as part of the U.S. Environmental Protection Agency's Basic Water Monitoring Program (U.S. Environmental Protection Agency, 1977). Water samples were collected periodically from the Portneuf River between 1966 and 1981 as part of a statewide surface-water monitoring program. The Idaho Department of Health and Welfare maintained an Ambient Water-Quality Monitoring site on the Portneuf River between 1969 and 1983.

Perry (1977, p. 77) concluded that nonpoint sources contributed significant amounts of sediment and nutrients to the reservoir. Perry and Tanner (1982) reported that Bannock Creek had serious sediment, coliform bacteria, and nutrient problems. Selenium concentrations were determined for 20 ground-water samples and 5 spring samples in the Michaud Flats area along the southeastern corner of the reservoir. Selenium concentrations in these samples ranged from 0 to 4 μg/L (Jacobson, 1982). Frenzel and Jones (1985) listed water-quality data collected from a tributary to the Portneuf River as part of a nonpoint source pollution study.

The U.S. Bureau of Reclamation (D.W. Zimmer, written commun., 1986) collected and the U.S. Geological Survey analyzed six bottom-sediment samples and one soil sample from near the mouth of Bannock Creek during June 1985. Total concentrations of some trace elements were: arsenic (3.2 to 9.5 ppm), chromium (54 to 94 ppm), copper (14 to 26 ppm), lead (14 to 24 ppm), vanadium (44 to 96 ppm), selenium (0.4 to 1 ppm), and zinc (52 to 97 ppm). Only selenium exceeded the range of selenium concentrations in area soils (table 1).

During July and August 1986, the U.S. Fish and Wildlife Service collected waterbirds (American coots and double-crested cormorants) and fish (Utah suckers, Utah chubs, mountain whitefish, and yellow perch) from the reservoir near the mouth of the Portneuf River, from the Minidoka National Wildlife Refuge at Lake Walcott, and from the Snake River downstream from American Falls Reservoir (James Nee, unpubl. data, 1986). They analyzed waterbird livers and whole fish for selected trace elements (tables 4 and 5).

Mercury concentrations were elevated (18 to 87 µg/g, dry weight) in double-crested cormorants collected at American Falls Reservoir (table 4) and in one double-crested cormorant (87.7 µg/g, dry weight) collected at the Snake River downstream from American Falls Dam (table 5). Mercury concentrations exceeded the NCBP (National Contaminant Biomonitoring Program) mean in more than two-thirds of the fish collected. Selenium concentrations were elevated in one American coot (20 µg/g, dry weight) and two double-crested cormorants (14 and 36 µg/g, dry weight) collected at American Falls Reservoir and in one American coot (11 µg/g, dry weight) and two double-crested cormorants (30 and 37 µg/g, dry weight) collected at the Snake River downstream from American Falls Dam. These data indicate that mercury and selenium might be biomagnifying in fish and birds at American Falls Reservoir and the Snake River downstream to Lake Walcott.

SAMPLE COLLECTION AND ANALYSIS

Objectives

The objective of the sampling plan was to determine whether there were concentrations of major ions and trace elements in water and trace elements and organochlorine compounds in bottom sediment and biota in and near American Falls Reservoir that could result in acute or chronic toxicity to fish, wildlife, and humans. Water and bottom-sediment samples were collected to represent environmental conditions during and after the irrigation season. Primary objectives of the biota-sampling plan were to determine concentrations of trace elements and organochlorine compounds in various trophic levels and to determine the potential for toxicity within the food chain. Aquatic plants and macroinvertebrates represented typical dietary items for fish and waterbirds.

A standard group of major ions and trace elements was designated by the DOI Task Group on Irrigation Drainage for irrigation drainage studies initiated during 1988. The organochlorine compounds analyzed in bottom sediment were selected on the basis of types of agricultural chemicals commonly used on irrigated land near the reservoir. Organochlorine compounds analyzed in the biota samples were a standard group of compounds having known potential for toxicity. Major ions, trace elements, and organochlorine compounds analyzed are listed in table 6.

Table 4.—*Concentrations of selected trace elements in waterbirds and fish from American Falls Reservoir near the mouth of the Portneuf River, July–August 1986*[1]

[Species—livers of waterbirds analyzed, whole bodies of fish analyzed; *, inductively coupled plasma analytical method; <, less than; concentrations in micrograms per gram, dry weight; wet weight = dry weight x (1 - percent moisture content expressed as a decimal); NCBP, National Contaminant Biomonitoring Program (Lowe and others, 1985), concentrations (1980–81) converted to dry weight assuming 75-percent moisture content; —, not determined]

Species	Percent moisture content	Ar-senic	Cad-mium*	Copper*	Iron*	Lead*	Mer-cury	Molyb-denum*	Nickel*	Selen-ium	Thal-lium*	Vana-dium*	Zinc*
American coot	73.4	<0.2	0.30	49	1,070	<0.3	1.0	3.6	0.3	6.4	<0.4	0.14	143
American coot	72.7	.3	.30	23	453	.5	.23	3.4	.2	4.1	<.4	.08	142
American coot	73.9	<.2	.25	42	652	<.3	.87	3.3	<.1	20	<.4	.11	163
Double-crested cormorant	69.1	<.2	1.4	16	1,940	<.4	31	3.2	<.1	14	<.5	.23	81.6
Double-crested cormorant	70.7	<.3	1.7	18	1,700	<.4	87	3.2	4.3	36	<.5	.20	88.0
Double-crested cormorant	74.0	<.2	.29	26	678	<.3	18	1.7	<.1	7.1	<.5	.12	99.3
Utah sucker	73.5	.3	.06	3.1	114	.5	.41	.32	.5	1.4	<.7	.12	56.2
Utah sucker	72.6	.2	.1	2.6	135	<.4	.42	.74	.5	1.3	<.7	.19	51.0
Utah chub	68.0	.9	.06	3.4	88	<.3	1	<.03	.1	.93	<.7	.15	51.6
Utah chub	71.5	.8	.06	3.7	70	<.3	.52	<.03	<.1	.98	<.7	.11	42.0
Utah chub	74.4	.4	.1	2.9	78	<.4	.80	.94	.9	1.0	<.7	.22	71.0
Utah chub	71.0	.5	<.02	4.1	55	<.3	.53	<.03	.2	.91	<.7	.12	66.7
Mountain whitefish	71.4	.1	.1	2.0	277	<.4	.48	.76	1.3	3.0	<.7	.33	103
Yellow perch	73.9	.05	.04	1.2	50	<.4	.44	.22	1.0	1.3	<.7	.05	56.3
NCBP geometric mean		.56	.12	2.7	—	.68	.44	—	—	1.9	—	—	95
NCBP 85th percentile		.88	.24	3.6	—	1.0	.72	—	—	2.8	—	—	160

[1]U.S. Fish and Wildlife Service (Boise, Idaho, unpubl. data, 1986).

Table 5.—*Concentrations of selected trace elements in waterbirds and fish from the Minidoka National Wildlife Refuge (Lake Walcott) and Snake River downstream from American Falls Reservoir, July–August 1986*[1]

[Species—livers of waterbirds analyzed, whole bodies of fish analyzed; *, inductively coupled plasma analytical method; <, less than; concentrations in micrograms per gram, dry weight; wet weight = dry weight x (1 - percent moisture content expressed as a decimal); NCBP, National Contaminant Biomonitoring Program (Lowe and others, 1985), concentrations (1980–81) converted to dry weight assuming 75-percent moisture content; —, not determined]

Species	Location	Percent moisture content	Arsenic	Cadmium*	Copper*	Iron*	Lead*	Mercury	Molybdenum*	Nickel*	Selenium	Thallium*	Vanadium*	Zinc*
American coot	Snake River	72.3	<0.2	0.10	18.8	3,390	<0.4	0.38	3.1	0.2	11	<0.5	0.37	118
American coot	Snake River	74.5	<.2	.24	7.8	8,120	<.4	.09	3.8	<.1	3.6	<.5	.76	130
American coot	Snake River	74.2	<.2	.19	21.8	1,690	<.4	.44	3.2	.2	5.4	<.5	.22	144
Double-crested cormorant	Snake River	70.6	<.3	1.4	24.6	325	<.3	10.4	3.8	.2	30	<.4	.03	122
Double-crested cormorant	Snake River	75.9	<.2	.34	21.8	541	<.3	8.2	2.5	<.2	5.9	<.4	.13	174
Double-crested cormorant	Snake River	71.1	<.3	2.8	21.1	1,650	<.4	87.7	3.3	<.1	37	<.5	.18	92.1
Utah chub	Snake River	75.6	.31	.07	2.7	94	.4	.85	<.03	.2	2.6	<.7	.18	52.3
Utah chub	Snake River	78.9	.28	.14	6.1	394	.6	1.7	<.05	.5	2.3	<.7	.92	79.2
Utah chub	Snake River	71.4	.14	.1	5.6	126	<.4	.50	1.0	1.0	3.0	<.7	.19	59.6
Utah chub	Snake River	79.5	.21	.42	6.7	209	.4	1.1	.89	1.0	2.3	<.7	.21	73.2
Utah chub	Lake Walcott	58.8	.62	.05	2.0	66	<.3	1.5	<.03	<.1	1.0	<.7	.16	62.0
Utah chub	Lake Walcott	65.0	1.7	.07	2.9	64	.6	1.1	<.03	.2	.85	<.7	.12	53.2
Utah chub	Lake Walcott	65.4	1.4	.04	1.9	71	<.3	.79	<.03	.2	.77	<.7	.1	51.2
Rainbow trout	Lake Walcott	80.1	.17	.07	6.2	206	<.3	.21	.1	.3	1.6	<.6	.36	165
Rainbow trout	Lake Walcott	78.6	.14	.1	2.5	210	<.4	.19	.25	.6	1.6	<.7	.12	109
Rainbow trout	Lake Walcott	76.6	.22	.08	5.8	205	<.3	.23	<.04	.3	1.7	<.7	.5	158
NCBP geometric mean			.56	.12	2.7	—	.68	.44	—	—	1.9	—	—	95
NCBP 85th percentile			.88	.24	3.6	—	1.0	.72	—	—	2.8	—	—	160

[1]U.S. Fish and Wildlife Service (Boise, Idaho, unpubl. data, 1986).

Table 6.—*Chemical constituents analyzed in water, bottom sediment, and biota*

Water (dissolved concentrations)	Bottom sediment (total concentrations)		Biota (total concentrations)	
Major ions and trace elements	Trace elements	Organochlorine compounds	Trace elements	Organochlorine compounds
Alkalinity	Arsenic	Aldrin	Aluminum	BHC
Arsenic	Boron[2]	Chlordane	Antimony	Chlordane
Boron	Cadmium	DDD	Arsenic	DDD
Cadmium	Chromium	DDE	Barium	DDE
Calcium	Copper	DDT	Beryllium	DDT
Chloride	Lead	Dieldrin	Boron	Dieldrin
Chromium	Mercury	Endosulfan	Cadmium	Endrin
Copper	Molybdenum	Endrin	Chromium	HCB
Fluoride	Selenium	Gross PCB	Copper	Heptachlor epoxide
Lead	Uranium	Gross PCN	Iron	Mirex
Magnesium	Vanadium	Heptachlor	Lead	Nonachlor
Mercury	Zinc	Heptachlor epoxide	Magnesium	Total PCB's
Molybdenum		Lindane	Manganese	Toxaphene
Nitrite plus nitrate as nitrogen		Methoxychlor	Mercury	
Potassium		Mirex	Molybdenum	
Selenium		Perthane	Nickel	
Sodium		Toxaphene	Selenium	
Solids[1]			Silver	
Sulfate			Strontium	
Uranium			Thallium	
Vanadium			Tin	
Zinc			Vanadium	
			Zinc	

[1]Residue on evaporation.
[2]Hot-water extractable.

Sampling Sites

Except for one site near the dam at American Falls Reservoir, water and bottom-sediment-sampling sites were selected to represent water and sediment inflow points to American Falls Reservoir, both during and after the irrigation season. Nine sites were located at or near the U.S. Geological Survey gaging stations listed in table 2. Collection of the same kinds of samples at all sites was attempted but was not totally achieved because of logistical problems during collection periods and lack of species at some sites. Locations of sampling sites are shown in figure 1.

Water samples were collected during October 1987 (post-irrigation season) and July 1988 (irrigation season) at eight inflow sites to and one site in American Falls Reservoir (fig. 1 and table 2) and were analyzed for major ions and trace elements. The water-sampling periods reflected likely times of potential influence of irrigation drainage on biota in the reservoir. Collection of water and bottom-sediment samples during July 1988 was coordinated as much as possible to coincide with the waterbird rearing period.

Danielson Creek (site 3, north of the Snake River) and Spring Creek (site 7, south of the Snake River), both of which originate as spring flow, contribute ground-water inflow to the reservoir. Irrigation drainage probably has little effect on the water quality of these two streams. Snake River near Blackfoot (site 1) is the largest inflow to the reservoir. Bannock Creek (site 8) and Aberdeen Wasteway (site 4) contribute surface-water discharge and irrigation drainage to the reservoir. Portneuf River (site 5) and Ross Fork (site 6) contribute a mixture of irrigation drainage and ground- and surface-water inflow to the reservoir. Crystal Wasteway (site 2) is ground water that has been used for aquaculture. Water from American Falls Reservoir (site 9) is the mixture of all inflows that eventually reach the Minidoka National Wildlife Refuge downstream.

Bottom-sediment samples were collected once during July 1988 at all nine water-sampling sites and were analyzed for trace elements. Bottom-sediment samples from Aberdeen Wasteway (site 4) and Portneuf River (site 5) also were analyzed for organochlorine compounds.

Waterbird eggs were collected during May along Spring, Clear, and Kinney Creeks, Ross Fork, and near the mouth of the Portneuf River. Waterbirds were collected during May and August 1988 near the mouth of the Snake River, near the mouth of the Portneuf River, and along Spring and Bannock Creeks. Fish were collected during July and August near the mouths of the Portneuf River (site 5), in Spring Creek, and in the Snake River channel within the reservoir (fig. 1). Plants and invertebrates were collected during July and August from the Portneuf River, Spring Creek, and Bannock Creek (sites 5, 7, and 8). Biota were analyzed for selected trace elements and organochlorine compounds.

The biological and physical conditions of the habitat near the water-sampling sites were rated using a system developed by the State of Wisconsin (Ball, 1982, p. 29). Evaluation of biological and physical habitat conditions was made on the basis of characteristics of watershed erosion and nonpoint source pollution; streambank erosion and failure and vegetative protection; channel capacity and deposition; stream-bottom scouring, deposition, and substrate; stream morphology and flow; and esthetics. A stream habitat with a numerical rating of less than 130 is good to excellent; 130 to 200, fair; and greater than 200, poor. Habitat quality at water-sampling sites during this investigation was good to fair (fig. 7). Principal characteristics that influenced habitat quality were nonpoint source pollution, streambank erosion, and channel deposition.

Water Sampling and Analytical Methods

Water samples were collected according to procedures described by Edwards and Glysson (1988). Equal-width, depth-integrated water samples were collected at all stream sites. Reservoir dip samples were collected near the water surface. All water samples were collected using samplers constructed of or coated with noncontaminating material. For each sampling period, samples from two sites were split and analyzed to assure the quality of the analytical data. Deionized water blanks also were prepared at the beginning and end of each sampling period and were analyzed for the same chemical constituents as the other water samples.

Onsite analyses included specific conductance, pH, water temperature, dissolved oxygen, alkalinity, and barometric pressure. Reservoir water samples and surface- and ground-water inflow samples were analyzed for major ions and trace elements (table 6). Water samples were analyzed by the U.S. Geological Survey National Water-Quality Laboratory in Arvada, Colo. Samples were treated according to requirements of the U.S. Geological Survey (Feltz and others, 1985). Laboratory analytical methods for water are described in reports by Fishman and Friedman (1985) and Thatcher and others (1977). Analytical reporting limits for trace elements are listed in table 7.

Bottom-Sediment Sampling and Analytical Methods

Bottom-sediment samples from the stream and reservoir sites were collected using a stainless-steel clamshell dredge or a stainless-steel scoop at 6 to 10 sections across the stream channel. Samples were composited and mixed, and a representative aliquot of the bottom sediment was analyzed for trace elements. Two size fractions of sediment—less than 0.062 mm (millimeter) and less than 2 mm—were analyzed. Samples from two sites were split and analyzed for quality assurance. Samples at two sites also were collected and sieved through a 2-mm mesh stainless-steel sieve and were analyzed for organochlorine compounds.

Bottom-sediment samples were analyzed by the U.S. Geological Survey Exploration Geochemistry Laboratory in Lakewood, Colo. Methods for analyzing trace elements in bottom sediment are described in reports by Severson and others (1987) and, for analyzing organochlorine compounds, by Wershaw and others (1987). Analytical reporting limits are listed in table 7.

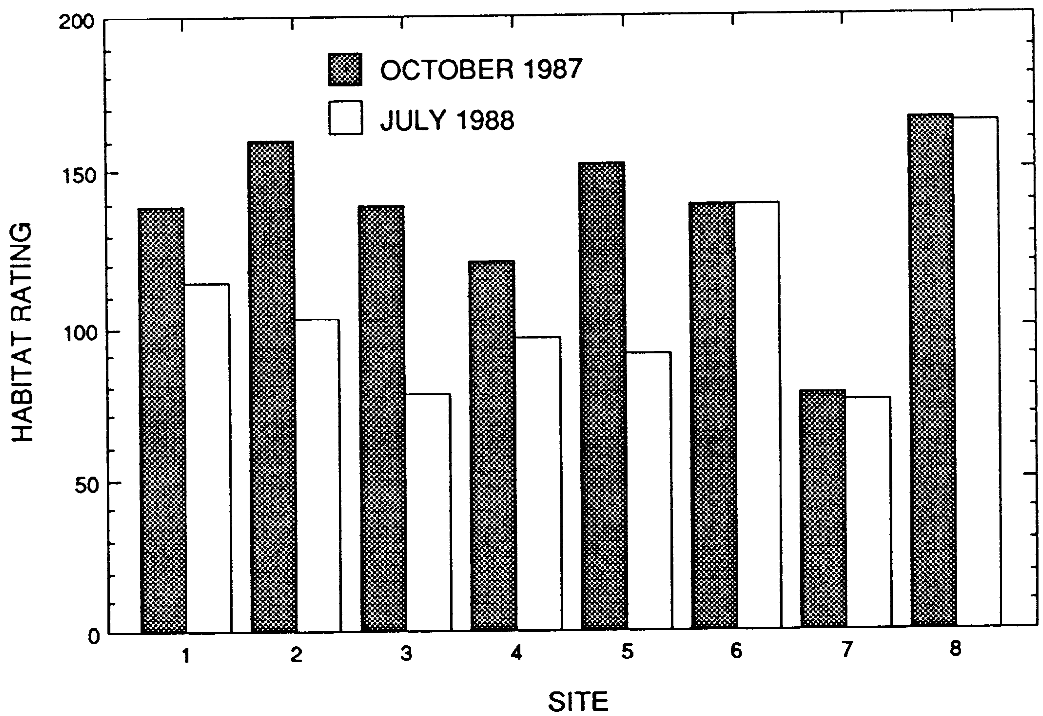

Figure 7.—Habitat quality at water-sampling sites, October 1987 and July 1988. (<130, Good to Excellent; 130–200, Fair; >200, Poor; locations of sites in figure 1)

Table 7.—*Analytical reporting limits for chemical constituents analyzed in water and bottom sediment*

[Trace elements reported in micrograms per liter for water and parts per million for bottom sediment; organochlorine compounds reported in micrograms per kilogram; —, not determined]

Chemical constituent	Analytical reporting limit	
	Water	Bottom sediment
	Trace elements	
Arsenic	1	0.1
Boron	10	.4
Cadmium	1	2
Chromium	1	1
Copper	1	1
Lead	5	4
Mercury	.1	.02
Molybdenum	1	.2
Selenium	1	.1
Uranium	.4	.04
Vanadium	1	4
Zinc	3	4
	Organochlorine compounds	
Aldrin	—	0.1
Chlordane	—	1
DDD	—	.1
DDE	—	.1
DDT	—	.1
Dieldrin	—	.1
Endosulfan	—	.1
Endrin	—	.1
Gross PCB	—	1
Gross PCN	—	1
Heptachlor	—	.1
Heptachlor epoxide	—	.1
Lindane	—	.1
Methoxychlor	—	.1
Mirex	—	.1
Perthane	—	1
Toxaphene	—	10

Biota Sampling and Analytical Methods

Biota samples (eggs, waterbirds, fish, aquatic plants, and benthic invertebrates) were collected from several sites in the reservoir area (fig. 1). Waterbirds, fish, aquatic plants, and invertebrates were collected by U.S. Fish and Wildlife Service personnel with assistance from the Shoshone-Bannock Indian Tribes and Idaho Department of Fish and Game.

Eggs were collected from nests of mallards (*Anas platyrhynchos*), American coots (*Fulica americana*), and double-crested cormorants (*Phalacrocorax auritus*) during May 1988 by Shoshone-Bannock Tribes personnel. (One year after collection, tribal biologists reported that two of the three duck nests may have been gadwall [*Anas strepera*] rather than mallard nests.) Mallard and coot eggs were collected near the mouths of Spring Creek, Kinney Creek, and Ross Fork. Cormorant eggs were collected from a colony adjacent to the reservoir about 1.5 mi northwest of the mouth of the Portneuf River. The eggs were packed in ice and shipped to the Idaho Department of Fish and Game laboratory, where they were weighed, outside dimensions measured, and contents removed, placed in acid-rinsed glass jars, and frozen. After a 1-year drying period, eggshell thicknesses were measured using a Starrett[1] micrometer.

Juvenile cormorants and juvenile and adult coots and mallards were collected during June and July 1988. Cormorants near fledgling age were collected from the same Portneuf River colony as the eggs. Coots and mallards were collected at random with a shotgun and steel shot near the mouths of Spring and Bannock Creeks and along the shoreline of the reservoir.

Sample collections at selected sites were limited because of access problems associated with high winds, early and rapid reservoir drawdown, limited availability of sampling equipment and personnel, and insufficient availability of target species.

After the waterbirds were collected, livers were excised, composited by species and collection site, placed in acid-rinsed jars, weighed, and frozen. Frequently, collection of only one or two individuals per site was possible, although collection of three individuals for a composite sample was recommended. Mallard carcasses were prepared for analyses by removing feathers, feet, bills, and gastrointestinal tracts, and then were frozen.

Fish in the reservoir and selected tributaries were collected by electroshocking. Species included rainbow trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), Utah sucker (*Catostomus ardens*), and common carp (*Cyprinus carpio*). Fish were weighed, wrapped in aluminum foil, triple wrapped in plastic bags, and frozen. All species except carp were composited into samples containing three fish. Carp samples were packaged individually because of their large size (3,260 to more than 5,000 grams per fish).

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[1] Use of brand or trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Benthic invertebrates and aquatic plants near the mouths of Spring Creek, Portneuf River, and Bannock Creek were hand-collected using tweezers and kick nets. Benthic invertebrates included mayfly nymphs (*Ephemeroptera*), freshwater shrimp (*Gammaridae*), and caddisfly larvae (*Hydropsychidae* and *Brachycentridae*). Caddisfly larvae were removed from their cases. Aquatic plants included sago pondweed (*Potamogeton pectinatus*) and horned pondweed (*Zannichellia palustris*). All samples were placed in chemically cleaned glass jars, weighed, and frozen.

Biota samples were packed in dry ice and shipped to analytical laboratories by overnight courier. Trace elements (table 6) were analyzed by the Environmental Trace Substances Research Center, University of Missouri, Columbia, Mo., and the Hazelton Laboratories America, Inc., Madison, Wis. Selected organochlorine compounds (table 6) were analyzed by the Mississippi State University Chemical Laboratory, Mississippi State, Miss. Antimony, arsenic, selenium, and thallium were analyzed by the hydride-generation atomic-adsorption method, and mercury was analyzed by the cold-vapor atomic-adsorption method. All other trace elements were analyzed by an ICP (inductively coupled plasma) scan without preconcentration. Organochlorine compounds were analyzed by electron-capture gas chromatography.

DISCUSSION OF WATER, BOTTOM-SEDIMENT, AND BIOLOGICAL DATA

Guidelines for Data Interpretation

Water-quality standards established by the State of Idaho, water-quality criteria recommended by the U.S. Environmental Protection Agency, water-quality criteria recommended by the National Academy of Sciences, and dietary concentrations and contaminant residues associated with adverse biological effects reported in toxicity studies were used as guidelines for evaluating chemical concentrations in water, bottom-sediment, and biota samples. These guidelines, compiled by the Task Group on Irrigation Drainage, consist of legally enforceable standards, recommended criteria for environmental protection, baseline values that represent natural background levels, and levels known (on the basis of laboratory and field research) to cause toxicity. Water-quality standards and criteria for selected chemical constituents for predominant water uses in the study area are listed in table 8.

Water

Major Ions

Major ions in water samples are listed in tables 9 and 10. Onsite data included pH, water temperature, and dissolved oxygen (table 9, back of report). Values of pH ranged from 7.7 to 8.7 and did not differ greatly between irrigation and post-irrigation seasons. Water temperatures ranged from 5 °C to 12.5 °C during October 1987 and 10.5 °C to 21 °C during July 1988. Dissolved-oxygen concentrations were higher than 7 mg/L, except in the reservoir during July 1988, when they were 5.5 mg/L.

Table 8.—*Water-quality standards and criteria for selected chemical constituents for predominant water uses*

[Concentrations in micrograms per liter as total or total recoverable, except as noted; —, not determined; mg/L, milligrams per liter; *, in water with 200 mg/L hardness as calcium carbonate ($CaCO_3$), 1-hour average]

Chemical constituent	Maximum contaminant level for drinking water (except where noted)	Recommended maximum allowable concentration in freshwater		
		Aquatic life	Irrigation supplies	Livestock supplies
Arsenic	[1]50	[2]850	[3]100	[3]200
Boron	—	—	[2]750	5 mg/L[3]
Cadmium	[1]10	[2]3.9*	[3]10	[3]50
Chromium	[1]50	[2]16*	[3]100	1 mg/L[3]
Copper	1 mg/L[4]	[2]18*	[3]200	[3]500
Lead	[1]50	[2]82	5 mg/L[3]	[3]100
Mercury	[1]2	[2]2.4	—	[3]10
Nitrite plus nitrate (as nitrogen)	10 mg/L[1]	—	—	—
Selenium	[1]10	[5]20*	[3]20	[3]50
Uranium	[6]35	—	—	—
Zinc	5 mg/L[4]	[2]120*	2 mg/L[3]	25 mg/L[3]

[1]Idaho Department of Health and Welfare (1985) and U.S. Environmental Protection Agency (1986b).
[2]U.S. Environmental Protection Agency (1986a).
[3]National Academy of Sciences, National Academy of Engineering (1973).
[4]U.S. Environmental Protection Agency (1986b).
[5]U.S. Environmental Protection Agency (1987).
[6]National Academy of Sciences (1983).

Proportions of selected major ions in water samples collected in the American Falls Reservoir area during irrigation and post-irrigation seasons are shown in figure 8. Calcium and bicarbonate generally were the predominant ions. Dissolved-solids concentrations ranged from 216 to 561 mg/L (table 9 and fig. 9). The highest dissolved-solids concentrations were at Crystal Wasteway (site 2), Portneuf River (site 5), and Bannock Creek (site 8). High dissolved-solids concentrations at Crystal Wasteway can be attributed to effluent from fish-rearing ponds upstream from the sampling site. High dissolved-solids concentrations at the Portneuf River site can be attributed to upstream municipal and industrial activities, basin geology, and ground-water discharges. Seepage losses along a 5-mi reach upstream from the Bannock Creek site were about 11 ft^3/s during October 1987 and about 3 ft^3/s during August 1987 (J.M. Spinazola, U.S. Geological Survey, written commun., 1988). High dissolved-solids concentrations at the Bannock Creek site can be attributed to the combined effects of seepage losses, evaporation, irrigation drainage, and basin geology.

During the irrigation season, dissolved-solids concentrations were similar to or slightly lower than concentrations during the post-irrigation season (table 9). The similarity in concentrations between seasons can be attributed to the large volume of ground-water discharge in the study area. Concentrations of nitrite plus nitrate reported as nitrogen ranged from less than 0.10 to 2.40 mg/L (table 9 and fig. 9) and were lower than the 10 mg/L standard for domestic water supplies (table 8).

Alkalinity, expressed in milligrams per liter as calcium carbonate (mg/L as $CaCO_3$), is a measure of the buffering capacity of a water and indirectly affects the toxicity of some trace elements. Similarly, hardness, also expressed in milligrams per liter as calcium carbonate, indirectly affects the toxicity of some trace elements. The level of toxicity reduction is related to the complexation of some trace elements with carbonate, bicarbonate, and calcium. Some water-quality standards and criteria are dependent on the concentration of alkalinity or hardness. Alkalinity concentrations ranged from 139 mg/L in the Snake River (site 1) to 282 mg/L in the Portneuf River (site 5). Hardness concentrations ranged from 170 mg/L in the Snake River (site 1) to 330 mg/L in Crystal Wasteway (site 2).

Trace Elements

Concentrations of dissolved trace elements in water from the study area are listed in table 10 (back of report). Most concentrations were near analytical reporting limits; none exceeded State or Federal water-quality standards or criteria (table 8). Arsenic, boron, uranium, vanadium, and zinc nearly always were present in detectable concentrations (table 10 and fig. 10). Arsenic concentrations ranged from 2 to 7 μg/L; boron concentrations ranged from 40 to 130 μg/L; uranium concentrations ranged from 0.7 to 3.5 μg/L; vanadium concentrations ranged from 1 to 6 μg/L; and zinc concentrations ranged from less than 3 to 42 μg/L. Cadmium, lead, and mercury concentrations were less than 1, less than 5, and less than 0.1 μg/L, respectively. Chromium, copper, and molybdenum concentrations ranged from less than 1 to 3 μg/L; and selenium concentrations ranged from less than 1 to 6 μg/L. Lemly and Smith (1987) suggested that selenium at concentrations greater

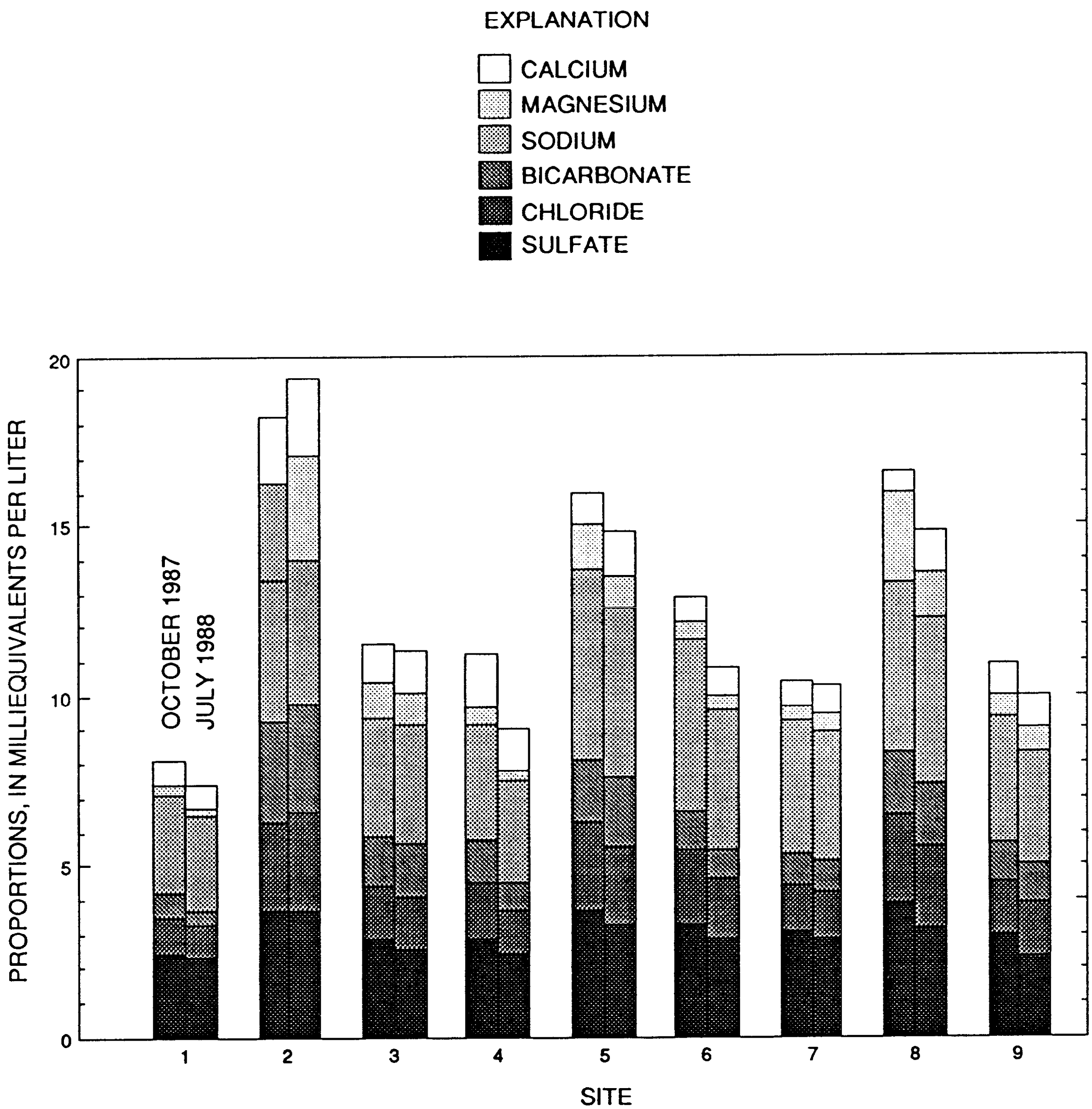

Figure 8.—Proportions of selected major ions in water, October 1987 and July 1988.
(Locations of sites in figure 1)

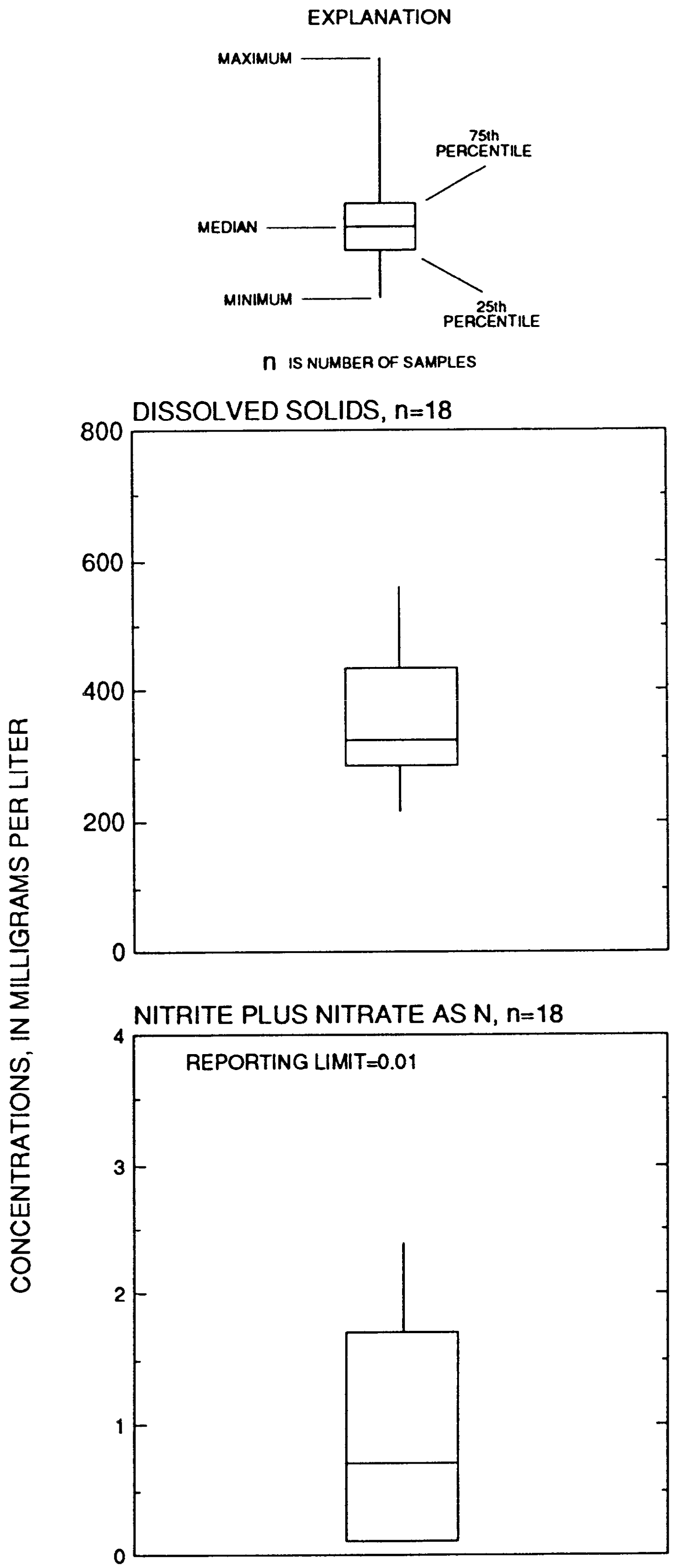

Figure 9.—Summary statistics for concentrations of dissolved solids and nitrite plus nitrate as nitrogen in water, October 1987 and July 1988.

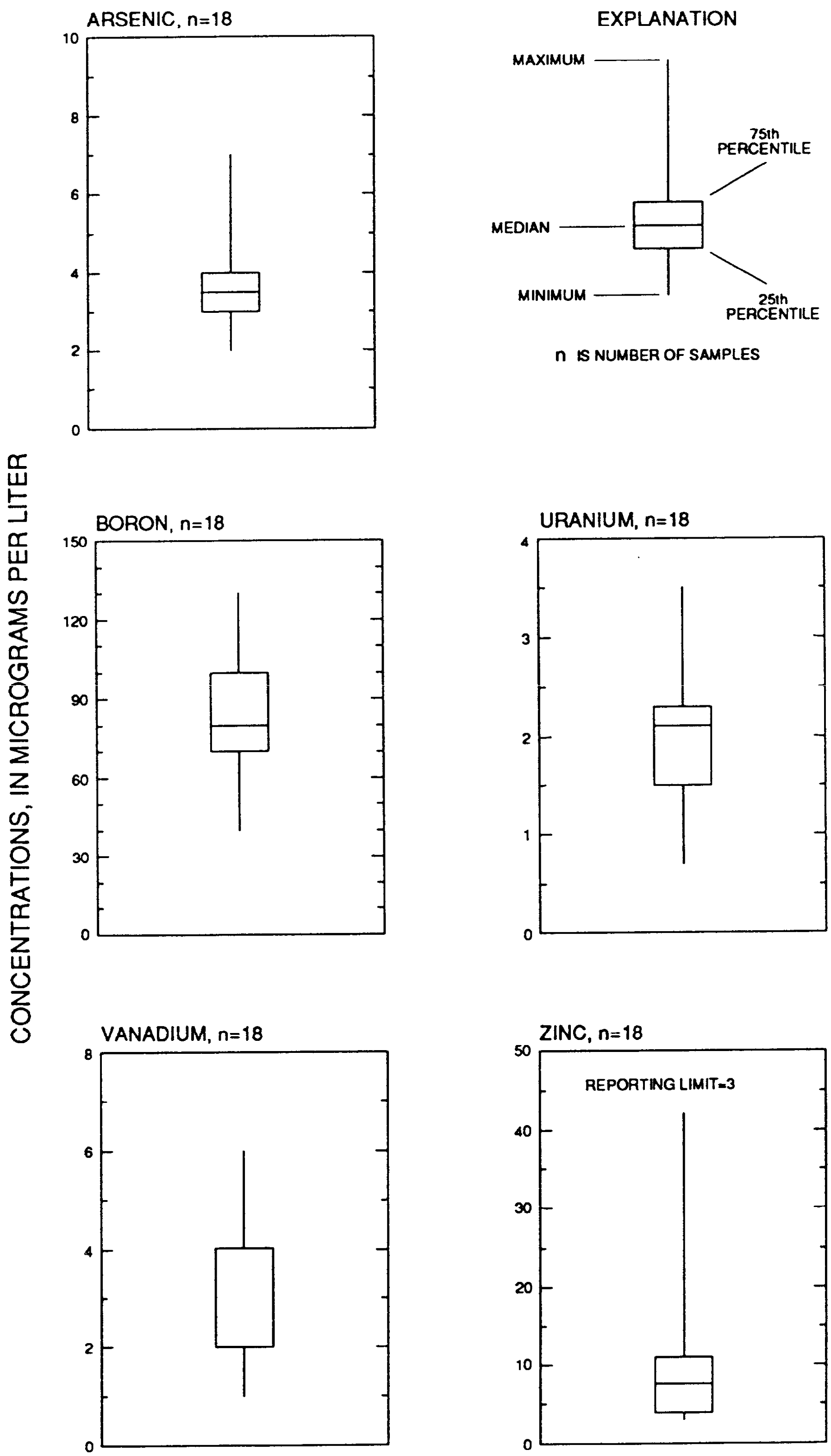

Figure 10.—Summary statistics for concentrations of arsenic, boron, uranium, vanadium, and zinc in water, October 1987 and July 1988.

than 2 to 5 µg/L in water can be biomagnified in food chains and can cause toxicity and reproductive failure in fish.

Kent (1976, p. 46) and Johnson and others (1977, p. 31) reported mean concentrations of total recoverable arsenic, cadmium, and mercury of 12.36, 9.11, and 0.87 µg/L, respectively, during their previous investigation of the reservoir. Mean concentrations of these constituents in water samples collected during this study were about 4, less than 1, and less than 0.1 µg/L, respectively (table 10).

Bottom Sediment

Trace Elements

Bottom sediment was collected from each water-sampling site during July 1988 and was analyzed for selected trace-element concentrations (table 11, back of report). Two sediment size fractions, less than 0.062 mm and less than 2 mm, were analyzed for each sample. Trace-element concentrations in both size fractions were compared with the 95th-percentile concentrations in 40 soil samples from three counties in the study area and with the upper limit of the expected 95-percent range in soils in the conterminous United States west of the 96th Meridian (R.C. Severson, U.S. Geological Survey, written commun., 1987, based on information in Shacklette and Boerngen, 1984, p. 6) (fig. 11 and table 1). Most of the trace-element concentrations in bottom sediment were similar to the geometric mean concentrations in soils in the surrounding three-county area and in the Western United States. Most concentrations that exceeded the geometric means were within the 95th percentile of concentrations in the study area and were within the upper limit of the expected 95-percent range of concentrations in Western United States soils (fig. 11 and table 1). However, selenium and mercury concentrations in bottom sediment at some sampling sites exceeded the 95th-percentile concentration observed in study area soils. Mercury concentrations in 9 of 18 samples exceeded the 95th-percentile concentration for mercury in area soils, but no concentrations exceeded the upper limit of the expected 95-percent range for mercury concentrations in Western United States soils. Selenium concentrations in 14 of 18 samples equaled or exceeded the 95th-percentile concentration for selenium in area soils and, in 1 sample (site 2), exceeded the upper limit of the expected 95-percent range for selenium concentrations in Western United States soils.

Bottom sediment contained detectable concentrations of arsenic, boron, chromium, copper, lead, mercury, selenium, uranium, vanadium, and zinc (fig. 11 and table 11).

Organochlorine Compounds

Bottom-sediment samples collected from Aberdeen Wasteway and the Portneuf River were analyzed for selected organochlorine compounds (table 12, back of report). Bottom sediment from Aberdeen Wasteway contained no organochlorine compounds at concentrations higher than analytical reporting limits. DDE (0.2 µg/kg) and DDT (0.3 µg/kg) were detected in bottom sediment collected from the

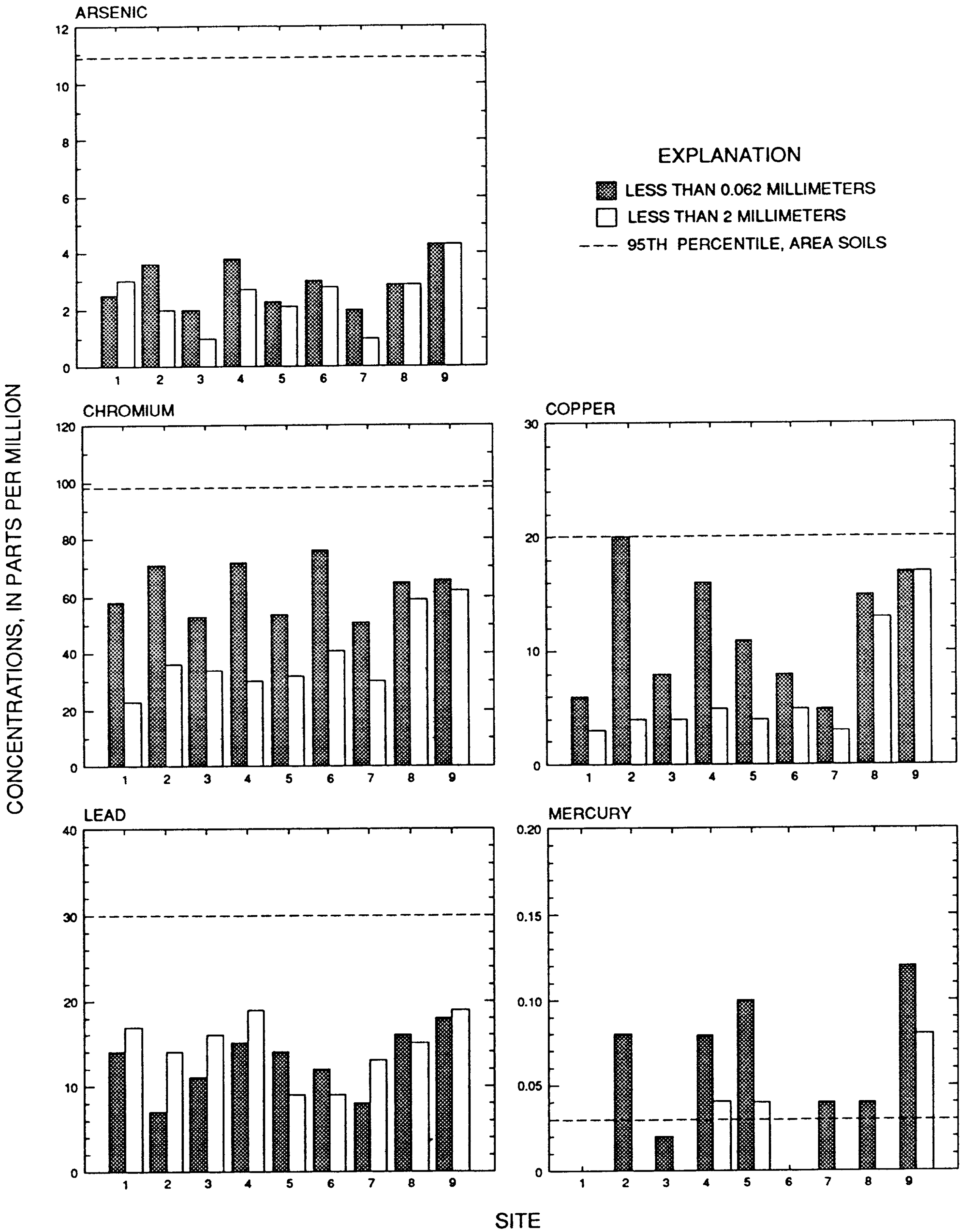

Figure 11.—Concentrations of selected trace elements in bottom sediments, July 1988, and 95th-percentile concentrations in area soils. (Locations of sites in figure 1)

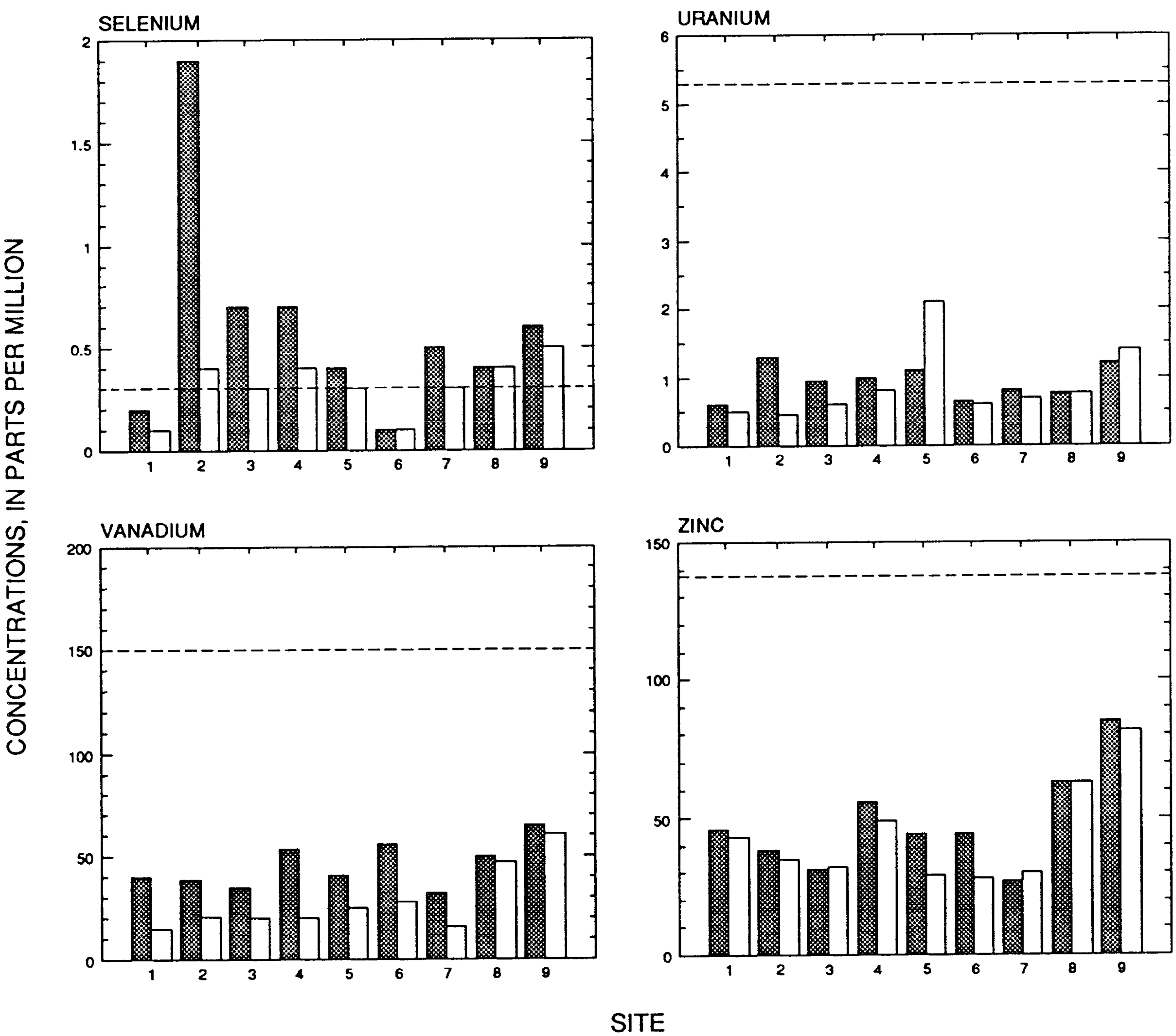

Figure 11.—Concentrations of selected trace elements in bottom sediments, July 1988, and 95th-percentile concentrations in area soils—Continued.

Portneuf River. Concentrations of other organochlorine compounds in Portneuf River bottom sediment were lower than analytical reporting limits.

Biota

Trace Elements

Trace-element concentrations in biota are expressed in micrograms per gram, dry weight, to eliminate the variable of moisture content, to facilitate comparability within and between different taxa, and to be consistent with the other irrigation drainage studies. Comparison with other toxicological data may require that the concentrations be expressed in wet weight, which can be obtained by multiplying the dry-weight concentration by a factor of 1 minus the percentage of moisture content, expressed as a decimal.

Except for mercury and selenium, concentrations of trace elements in biota were generally low (tables 13–16, back of report), compared with available baseline data, dietary concentrations, and contaminant residues associated with adverse biological effects reported in toxicity studies. Barium, beryllium, boron, cadmium, chromium, lead, molybdenum, nickel, silver, thallium, tin, and vanadium concentrations in all samples were lower than analytical reporting limits. Detectable concentrations of aluminum, antimony, arsenic, copper, iron, magnesium, manganese, strontium, and zinc were generally lower than levels that might be considered harmful to humans or wildlife. However, zinc concentrations in common carp (137.2, 67.5, and 92.2 μg/g, wet weight) exceeded the 1980–81 NCBP 85th percentile (40.09 μg/g, wet weight) reported by Lowe and others (1985). The biological implications of these levels are unknown, but it has been reported that common carp have a tendency to accumulate more zinc than other fish species (Lowe and others, 1985). Evaluation of the potential for synergistic or antagonistic effects among different contaminants is beyond the scope of this study.

The following discussion is limited to mercury and selenium because of their known toxicity to fish and wildlife and because concentrations of these trace elements were elevated in biota analyzed during this study.

Mercury

Mercury concentrations in waterbird eggs were lowest in mallard eggs (0.111 to 0.322 μg/g, dry weight) and highest in double-crested cormorant eggs (0.847 to 3.21 μg/g, dry weight; 0.14 to 0.49 μg/g, wet weight). These concentrations are lower than the 0.86 μg/g, wet weight, concentration reported to cause reproductive problems in mallards (Heinz, 1979, p. 396) and ring-necked pheasants (Spann and others, 1972) and also lower than the 1.3 to 2.0 μg/g, wet weight, sensitivity level reported for various avian species (Fimreite, 1979).

Mercury concentrations in waterbird livers were lowest in mallard livers (0.375 to 0.697 μg/g, dry weight) and highest in cormorant livers (6.0 to 6.20 μg/g, dry weight). The significance of these levels is not apparent because avian sensitivity to mercury varies. For example, mercury concentrations in livers of birds experimentally killed by methylmercury ranged from 17 µg/g, dry weight, in red-tailed hawks (*Buteo jamaicensis*), to 70 µg/g, dry weight, in jackdaws (*Corvus monedula*) (Eisler, 1987). Van der Molen and others (1982) reported that mercury concentrations in livers of grey herons experimentally killed by methylmercury ranged from 415 to 752 µg/g, dry weight. Finley and others (1979) concluded that mercury concentrations higher than 20 µg/g, wet weight, in soft tissues of birds should be considered extremely hazardous.

Mercury concentrations in livers of waterbirds at American Falls Reservoir were lower than reported lethal levels. Sublethal effects or possible synergistic effects with other contaminants in the study area are unknown. At comparatively low concentrations in birds and mammals, mercury affects reproduction, growth and development, behavior, blood and serum chemistry, motor coordination, vision, hearing, histology, and metabolism (Eisler, 1987). Interaction of mercury with other contaminants such as herbicides and pesticides may intensify hazards to avian populations (Mullins and others, 1977).

Elevated mercury concentrations in fish from American Falls Reservoir have been reported by Gebhards and others (1971); Runyan (1972); Jarmon (1973); Kent (1976); Johnson and Kent (1978); and Kent and Johnson (1979). Mercury concentrations in fish analyzed during this study were slightly elevated (table 15), as indicated by available data from toxicity studies. Mercury concentrations in whole fish ranged from 0.183 µg/g, dry weight, in one composite sample of Utah sucker to 1.67 µg/g, dry weight, in one carp. Mercury concentrations in fish proposed safe for human consumption should not exceed 0.25 µg/g, wet weight, for pregnant women and 0.40 to 1.00 µg/g, wet weight, for other adults (Khera, 1979; National Academy of Sciences, 1978; U.S. Environmental Protection Agency, 1980a, 1985; Eisler, 1987). The proposed criterion for mercury for protection of human health is 0.5 µg/g, wet weight (U.S. Environmental Protection Agency, 1980a, 1985). Two composite samples of Utah suckers and one carp from the reservoir contained mercury concentrations of 0.440, 0.386, and 0.448 µg/g, wet weight, respectively. These concentrations exceed the 0.18 µg/g, wet weight, NCBP 85th-percentile concentration and may be significant in relation to human consumption because of past and proposed future commercial harvests of these fish (Frederick L. Greider, Shoshone-Bannock Indian Tribes, oral commun., 1988). Also, these fish are consumed by fish-eating waterbirds, such as double-crested cormorants, so the possibility of biomagnification in the food chain exists.

The geometric mean concentration of mercury (fig. 12) in all fish collected during this study (0.17 µg/g, wet weight) was slightly lower than the 85th-percentile concentration (0.18 µg/g, wet weight) reported by Lowe and others (1985).

Mercury concentrations in aquatic plants ranged from less than the reporting limit in sago pondweed from the Portneuf River to 0.042 µg/g, dry weight, in horned pondweed from Bannock Creek.

Mercury concentrations in invertebrates ranged from 0.11 µg/g, dry weight, in mayfly nymphs from the Portneuf River to 0.448 µg/g, dry weight, in mayfly nymphs

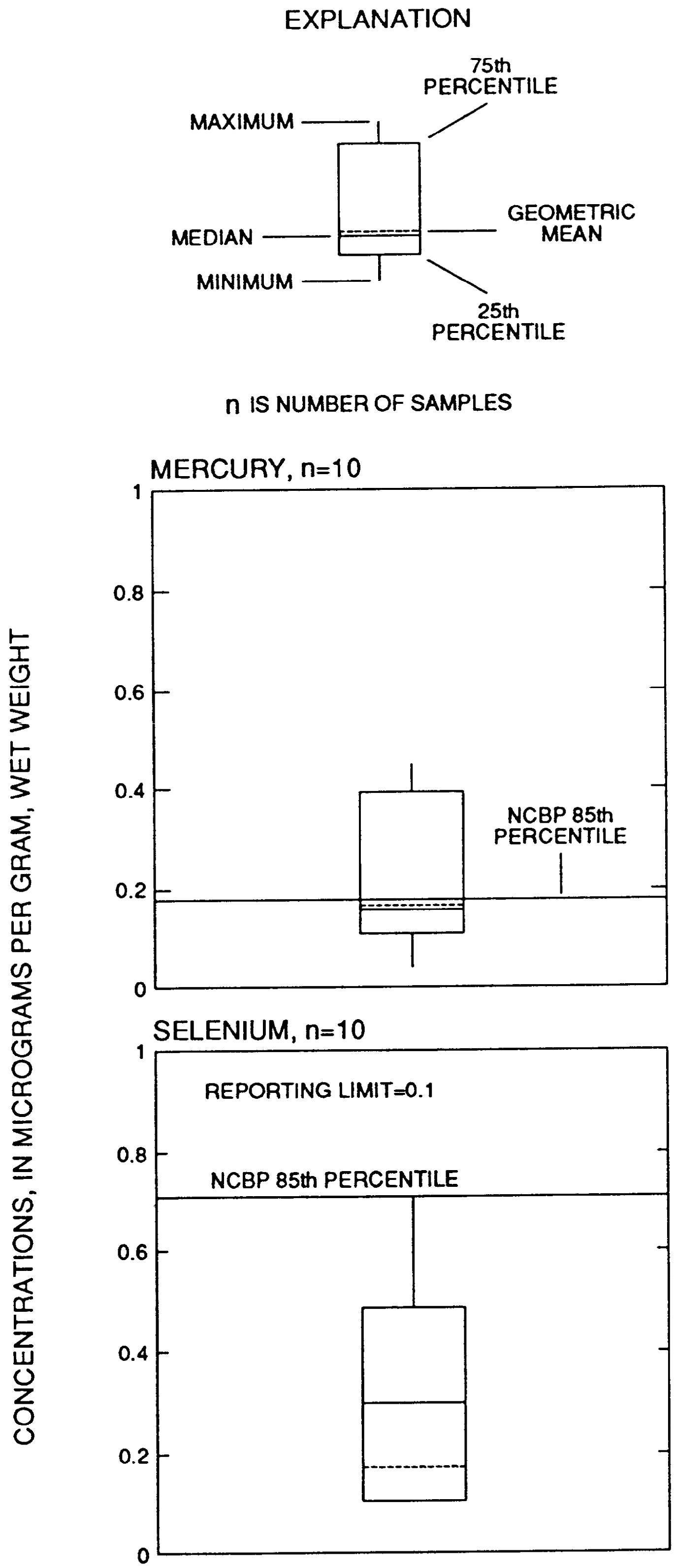

Figure 12.—Concentrations of mercury and selenium in fish, 1988, and 85th-percentile concentrations in fish collected for the U.S. Fish and Wildlife Service NCBP (National Contaminant Biomonitoring Program), 1980–81 (Lowe and others, 1985).
(The wet-weight concentrations given have been calculated from the dry-weight concentrations listed in table 15)

from Spring Creek. Huckabee and others (1979) reported on eight families of insects collected from mercury-contaminated and uncontaminated areas. During their study, mercury concentrations ranged from 0.5 to 5.0 µg/g, wet weight, in contaminated areas and from 0.05 to 0.21 µg/g, wet weight, in uncontaminated areas.

Selenium

Selenium concentrations were highest in double-crested cormorant eggs and ranged from less than 0.6 to 3.7 µg/g, dry weight (table 13). Selenium concentrations in mallard eggs ranged from 0.3 to 1.3 µg/g, dry weight and, in coot eggs, from less than 0.4 to 0.8 µg/g, dry weight. These levels are lower than those thought to cause reproductive problems in waterbirds (Ohlendorf and others, 1986a).

Geometric mean concentrations of selenium ranged from 2.4 µg/g, dry weight, in coot livers to 15.5 µg/g, dry weight, in mallard livers (table 14). The range of selenium in mallard livers (6.6 to 41.8 µg/g, dry weight) is within the 19 to 43 µg/g, dry weight, range in livers of ducks at Kesterson National Wildlife Refuge during 1983 (Ohlendorf and others, 1986a), where waterbird deformities, mortalities, and reproductive impairment were observed. At American Falls, five of the six composite samples of mallard livers were from juvenile waterbirds that had not yet migrated or moved to other feeding sites. Apparently, juvenile mallards are accumulating selenium from their food (primarily invertebrates) in the American Falls area because eggs and adults contained much lower concentrations.

Selenium concentrations in livers of American Falls coots were low (0.8 to 7.7 µg/g, dry weight), compared with concentrations in livers of Kesterson coots (21 to 63 µg/g, dry weight, during 1983). Cormorant livers also contained relatively low selenium concentrations, ranging from 4.3 to 5.5 µg/g, dry weight. In areas without selenium contamination, dry-weight concentrations are usually less than 3 or 4 µg/g in eggs and 12 to 16 µg/g in livers (Blus and others, 1977; Haseltine and others, 1981; King and others, 1983; Ohlendorf and others, 1986a; Heinz and others, 1987).

Selenium concentrations in fish ranged from less than 0.4 µg/g, dry weight, in one composite sample of Utah suckers from Spring Creek to 2.6 µg/g, dry weight (0.71 µg/g, wet weight), in a composite sample of rainbow trout from the Portneuf River upstream from American Falls Reservoir (table 15). This wet-weight concentration is lower than the 2 µg/g, wet weight, concentration reported as a level at which toxic effects in fish may be observed (Baumann and May, 1984).

Concentrations of selenium in fish collected from American Falls Reservoir are generally lower than concentrations in fish collected for the 1980–81 NCBP (Lowe and others, 1985). Only one concentration was as high as the NCBP 85th-percentile concentration of 0.71 µg/g, wet weight (fig. 12).

Selenium concentrations in plants ranged from less than the reporting limit in sago pondweed from Spring Creek to 0.96 µg/g, dry weight, in horned pondweed from Bannock Creek (table 16). Presser and Ohlendorf (1987) reported mean selenium concentrations of 35 to 85 µg/g, dry weight, in samples of filamentous algae, rooted plants, and net plankton collected during May 1983 at Kesterson National Wildlife Refuge.

Selenium was detected in all invertebrates; concentrations ranged from 1.4 µg/g, dry weight, in freshwater shrimp from Spring Creek to 8.1 µg/g, dry weight, in mayfly nymphs from the Portneuf River (table 16). These levels are lower than levels in food-chain organisms (22 to 175 µg/g, dry weight, in insects and fish) collected from Kesterson Reservoir during 1983 (Ohlendorf and others, 1986a). However, selenium concentrations of 5 to 8 µg/g, dry weight, in food-chain organisms are known to have toxic effects on fish and waterbirds (Heinz and others, 1987; Lemly and Smith, 1987).

Organochlorine Compounds

Organochlorine compounds in biota are expressed in micrograms per gram, wet weight, for comparability within and between different taxa and for consistency with other irrigation drainage studies.

In waterbird eggs and juvenile mallard carcasses, only p,p'DDE was detected in all samples and was highest in cormorant eggs (0.59 to 5.70 µg/g, wet weight, table 17, back of report). Blus (1982) reported that 3 µg/g, wet weight, of p,p'DDE residues in brown pelican eggs was associated with reproductive impairment, and 4 µg/g was associated with reproductive failure. The brown pelican is a species considered especially sensitive to organochlorine compounds, particularly p,p'DDE and endrin. Cormorants are not believed to be as sensitive. The National Academy of Sciences, National Academy of Engineering (1973) established a criterion of 1 µg/g, wet weight, for p,p'DDT and its metabolites for the protection of aquatic wildlife, including predators. Four of five cormorant eggs contained concentrations higher than this criterion. No other waterbird livers, eggs, or carcasses contained concentrations higher than this criterion.

Of all waterbird livers, eggs, and carcasses, total PCB's (polychlorinated biphenyls) were detected only in cormorant eggs; concentrations ranged from 0.28 to 1.8 µg/g, wet weight (table 17). These concentrations are lower than those expected to cause adverse effects (Eisler, 1986, p. 60).

p,p'DDD was detected in all fish samples except rainbow trout; the highest concentration was 0.08 µg/g, wet weight, in a carp from the reservoir near the mouth of the Snake River (table 18, back of report). p,p'DDE was detected in all fish samples; the highest concentration was 0.57 µg/g, wet weight (fig. 13), in the same carp that contained the highest concentration of p,p'DDD. p,p'DDT was detected in a composite sample of Utah suckers (0.03 µg/g, wet weight) (table 18). Concentrations of p,p'DDT and its metabolites, p,p'DDD and p,p'DDE, are similar to concentrations in fish collected for the NCBP (Lowe and others, 1985). None of the p,p'DDD, p,p'DDE, or p,p'DDT concentrations exceeded the 1 µg/g, wet weight,

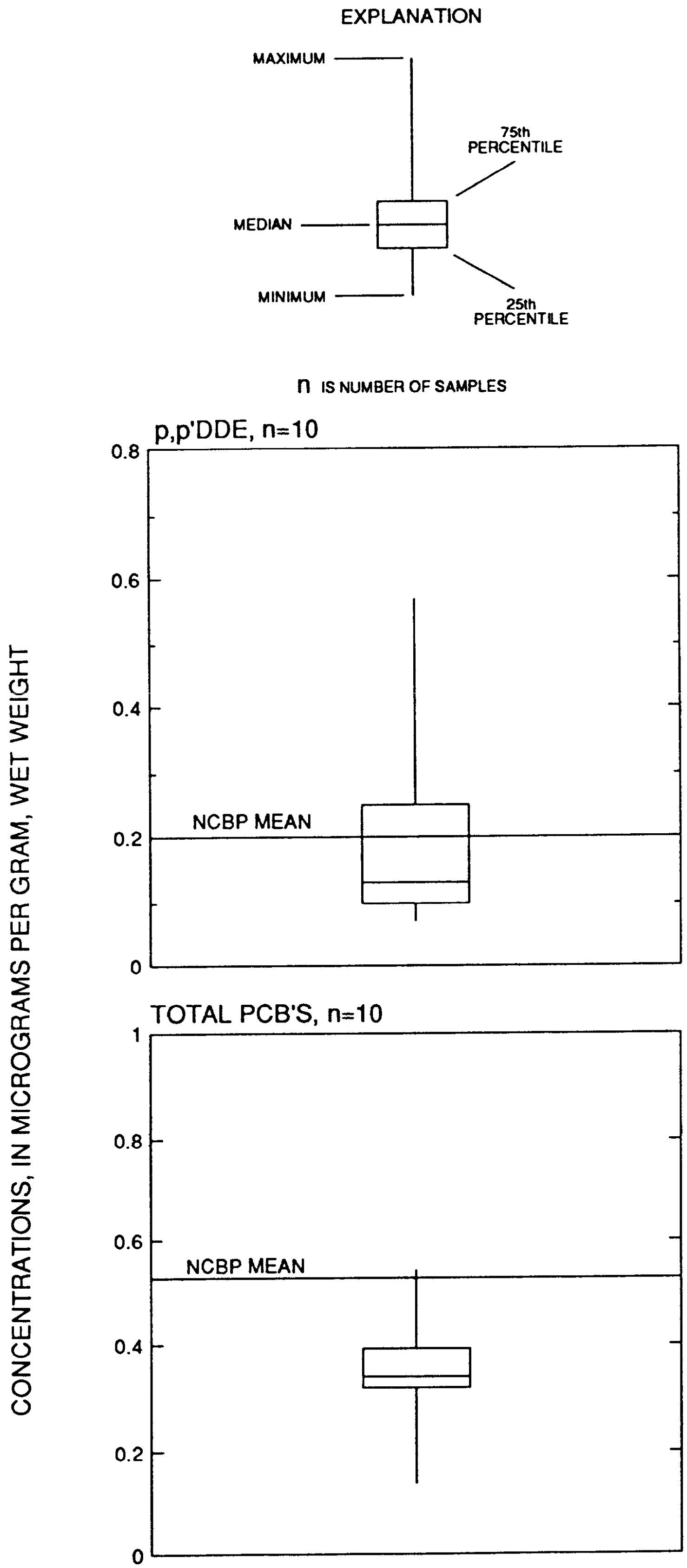

Figure 13.—Concentrations of p,p'DDE and total PCB's in fish, 1988, and mean concentrations in fish collected for the U.S. Fish and Wildlife Service NCBP (National Contaminant Biomonitoring Program), 1980–81 (Lowe and others, 1985).

criterion set by the National Academy of Sciences, National Academy of Engineering (1973) for the protection of aquatic wildlife.

Total PCB's were detected in all fish samples (table 18 and fig. 13). Concentrations ranged from 0.14 µg/g, wet weight, in a composite sample of Utah suckers from Spring Creek to 0.54 µg/g, wet weight, in the carp taken from the reservoir near the mouth of the Snake River. Even though all but one of the PCB concentrations were lower than the NCBP geometric mean, two of the three carp contained PCB's higher than the 0.4 µg/g, wet weight, concentration associated with reproductive toxicity in rainbow trout (U.S. Environmental Protection Agency, 1980b) and the recommended PCB level of 0.4 µg/g, wet weight (Eisler, 1986, p. 58), for protection of fish and wildlife.

Eggshell thickness measurements were compared with pre-1947 data (Blus and others, 1985; Anderson and Hickey, 1972) to determine percentage of thinning (table 19). The percentage of thinning in mallard eggs was greater than expected. However, only one egg was confirmed to be that of a mallard; the other two eggs may have been those of gadwalls. Cormorant eggshell thinning ranged from 0 to 12.7 percent. No eggshell thickness data for American coot eggs prior to 1947 exists, so comparisons were not made. Eggshell thinning was not considered great enough to cause reproductive problems (L.J. Blus, U.S. Fish and Wildlife Service, oral commun., 1989).

Data could not be collected to determine nesting success, survival rates, birth defects, and other characteristics. General observations of the health and diversity of biota during the field season indicate that the study area does not appear to have a serious avian reproductive, habitat destruction, or food-chain biomagnification problem that could be associated with irrigation drainage. Other observations spanning several field seasons (Charles H. Trost, Idaho State University, oral commun., 1989) attest to increasing trends in nesting populations of several waterbird species, including double-crested cormorants, snowy egrets (*Egretta thula*), and black-crowned night herons (*Nycticorax nycticorax*). Several large broods of mallards and gadwalls (*Anas strepera*) were observed in the Fort Hall Bottoms area during early July 1988, and no waterbird or fish die-offs were observed during the sample collection period.

SUMMARY

The 91-mi^2 American Falls Reservoir has a total capacity of 1.7 million acre-ft and is used primarily for irrigation-water supply and power generation. Irrigated land upstream from the reservoir totals about 550,000 acres. Inflow to the reservoir is from the Snake River (3.5 million acre-ft/yr), Portneuf River (194,000 acre-ft/yr), ungaged tributaries (109,000 acre-ft/yr), ground-water discharge (1.9 million acre-ft/yr), precipitation (50,000 acre-ft/yr), and irrigation-drainage canals, ditches, and sloughs (65,000 acre-ft/yr). Ground-water discharge to the reservoir originates, in part, from recharge from irrigated lands upstream from the reservoir.

Table 19.—*Percent thinning of eggshells, 1988*

[Mean thickness determined from three measurements of egg equator; percent thinning compared to pre-1947 data]

Species	Mean thickness (millimeter)	Percent thinning
Double-crested cormorant	0.420	2.8
Double-crested cormorant	.377	12.7
Double-crested cormorant	.433	0
Double-crested cormorant	.427	1.2
Double-crested cormorant	.407	5.8
Mallard[1]	.303	13.1
Mallard[1]	.307	12.1
Mallard	.330	5.4

[1]Possibly gadwall.

Water samples were collected from nine sites in the reservoir area during the post-irrigation (October 1987) and irrigation (July 1988) seasons and were analyzed for major ions and trace elements. Bottom-sediment samples were collected from nine sites during the irrigation season and were analyzed for trace elements. Bottom-sediment samples from two sites also were analyzed for organochlorine compounds. Biota samples (eggs, waterbirds, fish, aquatic plants, and benthic invertebrates) were collected from several sites in the reservoir area and were analyzed for selected trace elements and organochlorine compounds.

The predominant ions in water were calcium and bicarbonate. Dissolved-solids concentrations ranged from 216 to 561 mg/L. The similarity of dissolved-solids concentrations between the irrigation and post-irrigation seasons can be attributed to the large volume of ground-water discharge in the study area. Dissolved-solids concentrations were highest at Crystal Wasteway (site 2), Portneuf River (site 5), and Bannock Creek (site 8). High concentrations at site 2 may be attributed to aquacultural water use; at site 5, to upstream municipal and industrial water use, basin geology, and ground-water discharges; and at site 8, to seepage losses, evaporation, irrigation drainage, and basin geology.

Most trace-element concentrations in water were near analytical reporting limits, and none exceeded State or Federal water-quality standards or criteria. Water samples from all sites contained detectable concentrations of arsenic (2 to 7 μg/L), boron (40 to 130 μg/L), uranium (0.7 to 3.5 μg/L), vanadium (1 to 6 μg/L), and zinc (less than 3 to 42 μg/L). Means and ranges of arsenic, cadmium, and mercury concentrations in water analyzed during this investigation were lower than concentrations in water analyzed during previous investigations.

Concentrations of most trace elements in bottom sediment were similar to geometric mean concentrations in soils in three counties in the study area and in Western United States soils. Mercury concentrations in 9 of 18 samples exceeded the 95th-percentile concentration for mercury in area soils. Selenium concentrations in 14 of 18 samples equaled or exceeded the 95th-percentile concentration for selenium in area soils and, in 1 sample, exceeded the upper limit of the expected 95-percent range for selenium concentrations in Western United States soils.

Most organochlorine compounds in bottom sediment were lower than analytical reporting limits. Only DDE (0.2 μg/kg) and DDT (0.3 μg/kg) were detected in bottom sediment from the Portneuf River.

On the basis of biota samples collected, concentrations of most trace elements were low, with the exception of mercury, which was slightly elevated in fish, and selenium, which was elevated in mallard livers.

Mercury concentrations in fish in the study area have been elevated since the early 1970's. Some mercury concentrations in fish exceeded the NCBP 85th-percentile concentration and were at levels that might not be safe for human consumption, especially for pregnant women. Mercury accumulation in fish-eating waterbirds, such as double-crested cormorants, indicates biomagnification in the food chain.

Selenium was detected in about 25 percent of the water samples; the highest concentration was from Crystal Wasteway (6 µg/L). This concentration is greater than the 2 to 5 µg/L concentration that can be biomagnified in food chains and cause toxicity and reproductive failure in fish. Selenium also was detected in all bottom-sediment samples. Concentrations of selenium in fish collected from American Falls Reservoir were generally lower than the concentrations in fish collected for the 1980–81 NCBP. Only one concentration was as high as the NCBP 85th-percentile concentration of 0.71 µg/g, wet weight. Selenium concentrations in mallard livers were within the range of concentrations known to cause reproductive problems. Five of the six mallard liver samples were from juvenile birds, which had not yet migrated to other feeding sites. Indications are that these juvenile waterbirds are accumulating selenium from their food (primarily invertebrates). Selenium concentrations in two mayfly nymphs were at or near dietary concentrations (5 to 8 µg/g, dry weight) that had adverse reproductive effects on mallards during laboratory toxicity studies.

p,p'DDE was detected in most biota samples; the highest concentrations were in cormorant eggs. Some concentrations exceeded those associated with reproductive impairment (3 µg/g, wet weight) and reproductive failure (4 µg/g, wet weight) in brown pelicans, a species considered especially sensitive to p,p'DDE. Cormorants are not believed to be as sensitive to p,p'DDE. p,p'DDE concentrations in four of the five cormorant eggs exceeded the National Academy of Sciences, National Academy of Engineering criterion for protection of aquatic wildlife (1 µg/g, wet weight, for p,p'DDT and its metabolites). None of the fish samples contained concentrations higher than this criterion, but geometric mean concentrations of p,p'DDE in composite samples of Utah suckers and carp collected near the mouths of Spring Creek and the Snake River exceeded the 1980–81 NCBP geometric mean concentration.

Total PCB's were detected in all cormorant eggs but not in other waterbird eggs. PCB concentrations in cormorant eggs (0.28 to 1.8 µg/g, wet weight) were lower than concentrations that would be expected to cause adverse effects. Total PCB's were detected in all fish samples. Two of the three carp contained PCB concentrations higher than the proposed criterion for protection of fish and wildlife (0.4 µg/g, wet weight).

Eggshell thinning was noted in cormorant and mallard eggs but was not considered great enough to cause reproductive problems.

Observations of the general health of fish and waterbird populations during the study indicated that the area did not appear to have a serious contaminant problem that could be associated with irrigation drainage. Other observations attest to increasing trends in nesting populations of double-crested cormorants, snowy egrets, and black-crowned night herons. Several large broods of mallards and gadwalls were observed in the Fort Hall Bottoms area during early July 1988, and no waterbird or fish die-offs were observed during the sample collection period.

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Table 9.—*Onsite water-quality measurements and laboratory determinations of dissolved major ions in water*

[Water discharge, instantaneous, in cubic feet per second; specific conductance in microsiemens per centimeter at 25 degrees Celsius; pH in standard units; water temperature in degrees Celsius; concentrations in milligrams per liter; —, not determined; <, less than]

Sampling site No. (fig. 1)	Gaging station No.	Name	Date	Water discharge	Specific conductance	pH	Water temperature	Oxygen	Dissolved solids	Calcium	Magnesium	Sodium	Potassium
1	13069500	Snake River	10-22-87	2,110	386	8.5	6.5	8.3	230	48	13	15	2.8
1	13069500	Snake River	7-13-88	2,570	350	8.2	8.0	7.9	216	47	12	10	1.8
2	13069532	Crystal Wasteway	10-20-87	40	904	8.5	12.5	10.1	558	75	32	67	6.2
2	13069532	Crystal Wasteway	7-13-88	20	952	8.3	21.0	11.7	561	74	35	74	5.7
3	13069540	Danielson Creek	10-20-87	75	551	8.3	11.0	9.7	341	57	20	33	5.0
3	13069540	Danielson Creek	7-14-88	74	463	8.1	17.5	7.2	335	51	20	34	4.3
4	13069565	Aberdeen Wasteway	10-20-87	23	528	8.4	5.5	8.8	321	57	21	28	4.3
4	13069565	Aberdeen Wasteway	7-14-88	37	431	8.7	20.5	10.9	270	49	16	19	2.7
5	13075910	Portneuf River	10-22-87	483	722	8.0	11.5	7.8	447	75	30	43	8.0
5	13075910	Portneuf River	7-12-88	146	679	7.7	16.0	8.8	420	67	27	48	7.0
6	13075960	Ross Fork	10-22-87	35	600	8.2	10.5	8.4	368	67	26	27	5.7
6	13075960	Ross Fork	7-12-88	42	486	8.1	19.0	8.8	301	57	22	19	3.9
7	13075983	Spring Creek	10-22-87	408	486	8.2	9.5	9.0	273	62	16	21	3.4
7	13075983	Spring Creek	7-13-88	326	498	7.8	10.5	7.1	306	59	16	20	3.0
8	13076200	Bannock Creek	10-20-87	30	757	8.0	5.0	8.2	463	79	31	42	6.8
8	13076200	Bannock Creek	7-11-88	25	682	8.4	20.0	8.8	433	64	28	43	6.6
9	13076500	Reservoir	10-19-87	—	504	8.3	11.0	7.4	310	60	18	25	4.1
9	13076500	Reservoir	7-12-88	—	479	8.4	20.0	5.5	290	47	19	25	3.8

Table 9.—*Onsite water-quality measurements and laboratory determinations of dissolved major ions in water*—Continued

Sampling site No. (fig. 1)	Gaging station No.	Name	Date	Bicar-bonate	Alka-linity	Hard-ness	Chlo-ride	Sul-fate	Fluo-ride	Nitrite plus nitrate as nitrogen
1	13069500	Snake River	10-22-87	174	149	170	12	33	0.8	<0.10
1	13069500	Snake River	7-13-88	170	139	170	8.3	35	.4	.12
2	13069532	Crystal Wasteway	10-20-87	259	220	320	100	94	.5	2.10
2	13069532	Crystal Wasteway	7-13-88	254	208	330	110	110	.5	2.00
3	13069540	Danielson Creek	10-20-87	214	175	220	38	53	.6	.58
3	13069540	Danielson Creek	7-14-88	212	173	210	37	60	.5	<.10
4	13069565	Aberdeen Wasteway	10-20-87	208	173	230	22	72	.7	.48
4	13069565	Aberdeen Wasteway	7-14-88	185	152	190	12	57	.4	.12
5	13075910	Portneuf River	10-22-87	344	282	310	46	49	.4	2.40
5	13075910	Portneuf River	7-12-88	298	245	280	34	62	.4	2.10
6	13075960	Ross Fork	10-22-87	307	252	270	17	39	.5	1.70
6	13075960	Ross Fork	7-12-88	255	209	230	13	39	.4	.85
7	13075983	Spring Creek	10-22-87	235	193	220	18	33	.7	.89
7	13075983	Spring Creek	7-13-88	234	192	210	18	42	.6	.84
8	13076200	Bannock Creek	10-20-87	307	252	320	93	34	.2	.38
8	13076200	Bannock Creek	7-11-88	295	242	280	48	56	.4	1.60
9	13076500	Reservoir	10-19-87	223	191	220	24	43	.6	.59
9	13076500	Reservoir	7-12-88	201	165	200	24	48	.7	<.10

Table 10.—*Concentrations of dissolved trace elements in water*

[Concentrations in micrograms per liter; <, less than]

Sampling site No. (fig. 1)	Gaging station No.	Name	Date	Arsenic	Boron	Cadmium	Chromium	Copper	Lead	Mercury
1	13069500	Snake River	10-22-87	3	70	<1	2	1	<5	<0.1
1	13069500	Snake River	7-13-88	3	40	<1	<1	1	<5	<.1
2	13069532	Crystal Wasteway	10-20-87	7	130	<1	1	1	<5	<.1
2	13069532	Crystal Wasteway	7-13-88	2	120	<1	1	3	<5	<.1
3	13069540	Danielson Creek	10-20-87	3	100	<1	1	<1	<5	<.1
3	13069540	Danielson Creek	7-14-88	3	80	<1	<1	1	<5	<.1
4	13069565	Aberdeen Wasteway	10-20-87	4	90	<1	<1	<1	<5	<.1
4	13069565	Aberdeen Wasteway	7-14-88	3	60	<1	<1	1	<5	<.1
5	13075910	Portneuf River	10-22-87	4	100	<1	2	<1	<5	<.1
5	13075910	Portneuf River	7-12-88	4	100	<1	<1	1	<5	<.1
6	13075960	Ross Fork	10-22-87	4	80	<1	1	<1	<5	<.1
6	13075960	Ross Fork	7-12-88	3	50	<1	<1	1	<5	<.1
7	13075983	Spring Creek	10-22-87	3	80	<1	2	2	<5	<.1
7	13075983	Spring Creek	7-13-88	3	70	<1	<1	1	<5	<.1
8	13076200	Bannock Creek	10-20-87	4	70	<1	2	1	<5	<.1
8	13076200	Bannock Creek	7-11-88	4	90	<1	<1	1	<5	<.1
9	13076500	Reservoir	10-19-87	6	80	<1	<1	<1	<5	<.1
9	13076500	Reservoir	7-12-88	4	80	<1	<1	1	<5	<.1

Table 10.—*Concentrations of dissolved trace elements in water*—Continued

Sampling site No. (fig. 1)	Gaging station No.	Name	Date	Molyb-denum	Sele-nium	Ura-nium	Vana-dium	Zinc
1	13069500	Snake River	10-22-87	2	<1	0.7	1	4
1	13069500	Snake River	7-13-88	<1	<1	.7	1	8
2	13069532	Crystal Wasteway	10-20-87	2	6	3.2	4	5
2	13069532	Crystal Wasteway	7-13-88	2	1	3.5	6	17
3	13069540	Danielson Creek	10-20-87	1	<1	2.2	4	29
3	13069540	Danielson Creek	7-14-88	1	<1	2.1	2	42
4	13069565	Aberdeen Wasteway	10-20-87	2	<1	2.1	2	23
4	13069565	Aberdeen Wasteway	7-14-88	<1	<1	1.3	2	5
5	13075910	Portneuf River	10-22-87	1	1	2.0	3	3
5	13075910	Portneuf River	7-12-88	<1	<1	2.2	4	11
6	13075960	Ross Fork	10-22-87	1	<1	2.9	4	7
6	13075960	Ross Fork	7-12-88	<1	<1	2.2	3	3
7	13075983	Spring Creek	10-22-87	1	<1	1.4	2	<3
7	13075983	Spring Creek	7-13-88	<1	<1	1.5	2	6
8	13076200	Bannock Creek	10-20-87	1	1	2.5	2	10
8	13076200	Bannock Creek	7-11-88	<1	<1	2.3	4	9
9	13076500	Reservoir	10-19-87	1	4	1.7	2	3
9	13076500	Reservoir	7-12-88	<1	<1	1.6	2	11

Table 11.—*Concentrations of dissolved trace elements in bottom sediment, July 1988*

[Concentrations in parts per million, total; boron reported as total, hot-water recoverable; —, not determined; <, less than]

Sampling site No. (fig. 1)	Gaging station No.	Name	Date	Sediment size, less than (millimeter)	Arsenic	Boron	Cadmium	Chromium	Copper	Lead
1	13069500	Snake River	7-13	0.062	2.5	—	<2	58	6	14
1	13069500	Snake River	7-13	2	3.0	0.9	<2	23	3	17
2	13065932	Crystal Wasteway	7-13	.062	3.6	—	<2	71	20	7
2	13065932	Crystal Wasteway	7-13	2	2.0	.8	<2	36	4	14
3	13069540	Danielson Creek	7-14	.062	2.0	—	<2	53	8	11
3	13069540	Danielson Creek	7-14	2	1.0	1.1	<2	34	4	16
4	13069565	Aberdeen Wasteway	7-14	.062	3.8	—	<2	72	16	15
4	13069565	Aberdeen Wasteway	7-14	2	2.7	.8	<2	30	5	19
5	13075910	Portneuf River	7-12	.062	2.3	—	<2	54	11	14
5	13075910	Portneuf River	7-12	2	2.1	.9	<2	32	4	9
6	13075960	Ross Fork	7-12	.062	3.0	—	<2	76	8	12
6	13075960	Ross Fork	7-12	2	2.8	.8	<2	41	5	9
7	13075983	Spring Creek	7-13	.062	2.0	—	<2	51	5	8
7	13075983	Spring Creek	7-13	2	1.0	.7	<2	30	3	13
8	13076200	Bannock Creek	7-11	.062	2.9	1.3	<2	65	15	16
8	13076200	Bannock Creek	7-11	2	2.9	1.4	<2	59	13	15
9	13076500	Reservoir	7-12	.062	4.3	2.3	<2	66	17	18
9	13076500	Reservoir	7-12	2	4.3	3.1	<2	62	17	19

Table 11.—*Concentrations of dissolved trace elements in bottom sediment, July 1988*—Continued

Sampling site No. (fig. 1)	Gaging station No.	Name	Date	Sediment size, less than (millimeter)	Mer-cury	Molyb-denum	Sele-nium	Ura-nium	Vana-dium	Zinc
1	13069500	Snake River	7-13	0.062	<0.02	<2	0.2	0.60	40	46
1	13069500	Snake River	7-13	2	<.02	<2	.1	.50	15	43
2	13065932	Crystal Wasteway	7-13	.062	.08	<2	1.9	1.30	39	38
2	13065932	Crystal Wasteway	7-13	2	<.02	<2	.4	.45	21	35
3	13069540	Danielson Creek	7-14	.062	.02	<2	.7	.95	35	31
3	13069540	Danielson Creek	7-14	2	<.02	<2	.3	.60	20	32
4	13069565	Aberdeen Wasteway	7-14	.062	.08	<2	.7	1.00	54	56
4	13069565	Aberdeen Wasteway	7-14	2	.04	<2	.4	.80	20	49
5	13075910	Portneuf River	7-12	.062	.10	<2	.4	1.10	41	44
5	13075910	Portneuf River	7-12	2	.04	<2	.3	2.10	25	29
6	13075960	Ross Fork	7-12	.062	<.02	<2	.1	.65	56	44
6	13075960	Ross Fork	7-12	2	<.02	<2	.1	.60	28	28
7	13075983	Spring Creek	7-13	.062	.04	<2	.5	.80	32	27
7	13075983	Spring Creek	7-13	2	<.02	<2	.3	.70	16	30
8	13076200	Bannock Creek	7-11	.062	.04	<2	.4	.75	50	63
8	13076200	Bannock Creek	7-11	2	<.02	<2	.4	.75	47	63
9	13076500	Reservoir	7-12	.062	.12	<2	.6	1.20	65	85
9	13076500	Reservoir	7-12	2	.08	<2	.5	1.40	61	82

Table 12.—*Concentrations of organochlorine compounds in bottom sediment at two sites in the American Falls Reservoir area, July 1988*

[Concentrations in micrograms per kilogram in the less-than-2-millimeters size fraction; <, less than]

Sampling site No. (fig. 1)	Gaging station No.	Name	Date	Al-drin	Chlor-dane	DDD	DDE	DDT	Diel-drin	Endo-sulfan	En-drin	Gross PCB
4	13069565	Aberdeen Wasteway	7-14	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1
5	13075910	Portneuf River	7-12	<.1	<1	<.1	.2	.3	<.1	<.1	<.1	<1

Sampling site No. (fig. 1)	Gaging station No.	Name	Date	Gross PCN	Hepta-chlor	Hepta-chlor epoxide	Lin-dane	Meth-oxy-chlor	Mirex	Per-thane	Toxa-phene
4	13069565	Aberdeen Wasteway	7-14	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<10
5	13075910	Portneuf River	7-12	<1	<.1	<.1	<.1	<.1	<.1	<1	<10

Table 13.—*Concentrations of trace elements in waterbird eggs, May 1988*

[Concentrations in micrograms per gram, dry weight; wet weight = dry weight x (1 - percent moisture content expressed as a decimal); analytical reporting limit is in wet weight because of variable moisture contents among species and samples; ppm, parts per million; where all values are less than (<), no mean is reported; for individual less-than values, one-half of the value was used to calculate the mean; —, not determined]

Species	Location	Percent moisture content	Alu-minum	Anti-mony	Ar-senic	Barium	Beryl-lium	Boron	Cad-mium	Chro-mium
American coot	Spring Creek	76.9	<43	<0.108	0.268	<22	<2.2	<22	<2.2	<4
American coot	Spring Creek	74.9	<40	<.100	.594	<40	<2.0	<20	<2.0	<4
American coot	Spring Creek	74.0	<38	<.096	.238	<19	<1.9	<19	<1.9	<4
American coot	Clear Creek	75.5	<41	<.102	.371	<20	<2.0	<20	<2.0	<4
American coot	Kinney Creek	71.2	<35	<.087	.212	<17	<1.7	<17	<1.7	<3
Geometric mean			—	—	.312	—	—	—	—	—
Range			—	—	.212 - .594	—	—	—	—	—
Double-crested cormorant	Reservoir near Portneuf River	84.4	<64	<.160	.205	<32	<3.2	<32	<3.2	<6
Double-crested cormorant	Reservoir near Portneuf River	84.8	<66	<.164	<.033	<33	<3.3	<33	<3.3	<7
Double-crested cormorant	Reservoir near Portneuf River	84.8	<66	<.164	.145	<33	<3.3	<33	<3.0	<7
Double-crested cormorant	Reservoir near Portneuf River	83.7	<61	<.153	.178	<31	<3.1	<31	<3.1	<6
Double-crested cormorant	Reservoir near Portneuf River	85.1	<67	<.025	.255	<34	<3.4	<34	<3.4	<7
Geometric mean			—	—	.177	—	—	—	—	—
Range			—	—	<.033 - .255	—	—	—	—	—
Mallard[1]	Spring Creek	70.3	<34	<.084	.162	<17	<1.7	<17	<1.7	<3
Mallard[1]	Clear Creek	67.1	<30	<.076	.122	<15	<1.5	<15	<1.5	<3
Mallard	Ross Fork	65.7	<29	<.073	.073	<15	<1.5	<15	<1.5	<3
Geometric mean			—	—	.113	—	—	—	—	—
Range			—	—	.073 - .162	—	—	—	—	—
Analytical reporting limit (ppm, wet weight)			10	.025	.005	5	.5	5	.5	1

Table 13.—*Concentrations of trace elements in waterbird eggs, May 1988*—Continued

Species	Location	Percent moisture content	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel
American coot	Spring Creek	76.9	10.8	104	<43	823	<6.5	0.407	<22	<17
American coot	Spring Creek	74.9	<10.0	171	<40	598	<6.0	1.04	<20	<16
American coot	Spring Creek	74.0	<9.6	77	<38	500	<5.8	1.50	<19	<15
American coot	Clear Creek	75.5	<10.2	69	<41	449	<6.1	.343	<20	<16
American coot	Kinney Creek	71.2	<8.7	80	<35	486	<5.2	.465	<17	<14
Geometric mean			—	95	—	557	—	.633	—	—
Range			<7.3 – 10.8	69 – 171	—	449 – 823	—	.343 – 1.50	—	—
Double-crested cormorant	Reservoir near Portneuf River	84.4	<16.0	109	<64	<641	<9.6	1.76	<32	<26
Double-crested cormorant	Reservoir near Portneuf River	84.8	<16.4	86	<66	<658	<9.9	1.55	<33	<26
Double-crested cormorant	Reservoir near Portneuf River	84.8	<16.4	132	<66	658	<9.9	3.21	<33	<26
Double-crested cormorant	Reservoir near Portneuf River	83.7	<15.3	129	<61	675	<9.2	.847	<31	<24
Double-crested cormorant	Reservoir near Portneuf River	85.1	<16.8	87	<67	<671	<10.1	2.58	<34	<27
Geometric mean			—	107	—	—	—	1.80	—	—
Range			—	86 – 132	—	—	—	.847 – 3.21	—	—
Mallard[1]	Spring Creek	70.3	<8.4	84	<34	337	<5.0	.303	<17	<14
Mallard[1]	Clear Creek	67.1	<7.6	82	<30	334	<4.6	.322	<15	<12
Mallard	Ross Fork	65.7	<7.3	79	<29	350	<4.4	.111	<15	<11
Geometric mean			—	82	—	340	—	.221	—	—
Range			—	79 – 84	—	334 – 350	—	.111 – .322	—	—
Analytical reporting limit (ppm, wet weight)			2.5	10	10	100	1.5	.025	5	4

Table 13.—*Concentrations of trace elements in waterbird eggs, May 1988*—Continued

Species	Location	Percent moisture content	Selenium	Silver	Strontium	Thallium	Tin	Vanadium	Zinc
American coot	Spring Creek	76.9	0.4	<22	18	<0.4	<22	<22	74
American coot	Spring Creek	74.9	.8	<20	14	<.4	<20	<20	81
American coot	Spring Creek	74.0	<.4	<20	6	<.4	<20	<20	56
American coot	Clear Creek	75.5	<.4	<17	9	<.4	<17	<17	74
American coot	Kinney Creek	71.2	<.4	<19	9	<.4	<19	<19	60
Geometric mean			—	—	10	—	—	—	68
Range			<.4 – .8	—	6 – 18	—	—	—	56 – 81
Double-crested cormorant	Reservoir near Portneuf River	84.4	<.6	<32	<6	<.6	<32	<32	60
Double-crested cormorant	Reservoir near Portneuf River	84.8	2.6	<33	<7	<.7	<33	<33	64
Double-crested cormorant	Reservoir near Portneuf River	84.8	3.3	<33	<7	<.7	<33	<33	55
Double-crested cormorant	Reservoir near Portneuf River	83.7	3.7	<31	<6	<.6	<31	<31	47
Double-crested cormorant	Reservoir near Portneuf River	85.1	3.4	<34	<7	<.7	<34	<34	48
Geometric mean			1.6	—	—	—	—	—	54
Range			<.6 – 3.7	—	—	—	—	—	47 – 64
Mallard[1]	Spring Creek	70.3	1.3	<17	4	<.3	51	<17	46
Mallard[1]	Clear Creek	67.1	.6	<15	9	<.3	<15	<15	50
Mallard	Ross Fork	65.7	.3	<15	6	<.3	<15	<15	51
Geometric mean			.6	—	6	—	—	—	49
Range			.3 – 1.3	—	4 – 9	—	<15 – 51	—	46 – 51
Analytical reporting limit (ppm, wet weight)			.1	5	1	.1	5	5	2

[1]Possibly gadwall.

Table 14.—*Concentrations of trace elements in composite samples of waterbird livers, June–July 1988*

[Concentrations in micrograms per gram, dry weight; wet weight = dry weight x (1 – percent moisture content expressed as a decimal); analytical reporting limit is in wet weight because of variable moisture contents among species and samples; ppm, parts per million; where all values are less than (<), no mean is reported; for individual less-than values, one-half of the value was used to calculate the mean; —, not determined]

Species	Juvenile (J), adult (A)	Location	Number in composite sample	Percent moisture content	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
American coot	A	Spring Creek	2	74.0	<38	0.177	1.88	<19	<1.9	<19	<1.9	<4
American coot	A	Reservoir	3	72.6	<36	<.091	.493	<18	<1.8	<18	<1.8	<4
Geometric mean					—	—	.96	—	—	—	—	—
Range					—	<.091 – .177	.493 – 1.88	—	—	—	—	—
Double-crested cormorant	J	Reservoir	3	76.3	<42	<.105	.105	<21	<2.1	<21	<2.1	<4
Double-crested cormorant	J	Reservoir	3	77.0	<44	<.109	.165	<22	<2.2	<22	<2.2	<4
Geometric mean					—	—	.132	—	—	—	—	—
Range					—	—	.105 – .165	—	—	—	—	—
Mallard	J	Reservoir	2	71.3	<35	<.087	.101	<17	<1.7	<17	<1.7	<3
Mallard	J	Spring Creek	2	72.5	<36	<.091	.171	<18	<1.8	<18	<1.8	<4
Mallard	J	Spring Creek	3	73.9	<38	<.096	.172	<19	<1.9	<19	<1.9	<4
Mallard	J	Bannock Creek	2	72.3	40	<.090	.105	<18	<1.8	<18	<1.8	<4
Mallard	A	Bannock Creek	2	72.5	<36	<.091	.516	<18	<1.8	<18	<1.8	<4
Mallard	J	Reservoir	3	72.9	<37	<.092	.196	<18	<1.8	<18	<1.8	<4
Geometric mean					—	—	.178	—	—	—	—	—
Range					<35 – 40	—	.101 – .516	—	—	—	—	—
Analytical reporting limit (ppm, wet weight)					10	.025	.005	5	.5	5	.5	1

Table 14.—*Concentrations of trace elements in composite samples of waterbird livers, June–July 1988*—Continued

Species	Juvenile (J), adult (A)	Location	Number in composite sample	Percent moisture content	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel
American coot	A	Spring Creek	2	74.0	91.5	2,460	<38	731	11.5	1.77	<19	<15
American coot	A	Reservoir	3	72.6	29.2	2,160	<36	766	13.1	1.61	<18	<15
Geometric mean					51.7	2,305	—	748	12.3	1.69	—	—
Range					29.2 – 91.5	2,160 – 2,460	—	731 – 766	11.5 – 13.1	1.61 – 1.77	—	—
Double-crested cormorant	J	Reservoir	3	76.3	30.4	532	<42	759	13.9	6.20	<21	<17
Double-crested cormorant	J	Reservoir	3	77.0	42.2	443	<44	783	13.9	6.00	<22	<17
Geometric mean					35.8	485	—	771	13.9	6.10	—	—
Range					30.4 – 42.2	443 – 532	—	759 – 783	13.9	6 – 6.20	—	—
Mallard	J	Reservoir	2	71.3	29.6	1,130	<35	801	15.7	.697	<17	<14
Mallard	J	Spring Creek	2	72.5	12.7	945	<36	836	15.2	.625	<18	<14
Mallard	J	Spring Creek	3	73.9	73.9	720	<38	881	12.6	.375	<19	<15
Mallard	J	Bannock Creek	2	72.3	30.3	3,490	<36	794	17.7	.444	<18	<14
Mallard	A	Bannock Creek	2	72.5	80.7	2,980	<36	800	19.6	.382	<18	<14
Mallard	J	Reservoir	3	72.9	36.5	1,550	<37	775	13.3	.487	<18	<15
Geometric mean					36.8	1,521	—	814	15.5	.488	—	—
Range					12.7 – 80.7	720 – 2,980	—	775 – 881	12.6 – 19.6	.375 – .697	—	—
Analytical reporting limit (ppm, wet weight)					2.5	10	10	100	1.5	.025	5	4

Table 14.—*Concentrations of trace elements in composite samples of waterbird livers, June–July 1988*—Continued

Species	Juvenile (J), adult (A)	Location	Number in composite sample	Percent moisture content	Selenium	Silver	Strontium	Thallium	Tin	Vanadium	Zinc
American coot	A	Spring Creek	2	74.0	0.8	<19	<4	<0.4	<19	<19	164
American coot	A	Reservoir	3	72.6	7.7	<18	<4	<.4	<18	<18	128
Geometric mean					2.4	—	—	—	—	—	145
Range					.8 – 7.7	—	—	—	—	—	128 - 164
Double-crested cormorant	J	Reservoir	3	76.3	5.5	<21	<4	<.4	<21	<21	113
Double-crested cormorant	J	Reservoir	3	77.0	4.3	<22	<4	<.4	<22	<22	106
Geometric mean					4.9	—	—	—	—	—	109
Range					4.3 – 5.5	—	—	—	—	—	106 - 113
Mallard	J	Reservoir	2	71.3	14.6	<17	<4	<.4	<17	<17	171
Mallard	J	Spring Creek	2	72.5	30.2	<18	<4	<.4	<18	<18	180
Mallard	J	Spring Creek	3	73.9	41.8	<19	<4	<.4	<19	<19	182
Mallard	J	Bannock Creek	2	72.3	13.7	<18	<4	<.4	<18	<18	129
Mallard	A	Bannock Creek	2	72.5	8.4	<18	<4	<.4	<18	<18	149
Mallard	J	Reservoir	3	72.9	6.6	<18	<4	<.4	<18	<18	169
Geometric mean					15.5	—	—	—	—	—	162
Range					6.6 – 41.8	—	—	—	—	—	129 - 182
Analytical reporting limit (ppm, wet weight)					.1	5	1	.1	5	5	2

Table 15.—*Concentrations of trace elements in composite samples of fish, July–August 1988*

[Concentrations in micrograms per gram, dry weight; wet weight = dry weight x (1 − percent moisture content expressed as a decimal); analytical reporting limit is in wet weight because of variable moisture contents among species and samples; ppm, parts per million; where all values are less than (<), no mean is reported; for individual less-than values, one-half of the value was used to calculate the mean; —, not determined; NCBP, National Contaminant Biomonitoring Program (Lowe and others, 1985), concentrations (1980–81) converted to dry weight assuming 75-percent moisture content]

Species	Location	Number in composite sample	Percent moisture content	Alu-minum	Anti-mony	Arsenic	Barium	Beryl-lium	Boron	Cad-mium	Chro-mium
Rainbow trout	Portneuf River	3	72.6	66	<0.091	0.223	<18	<1.8	<18	<1.8	<4
Mountain whitefish	Reservoir, mouth of Spring Creek	3	74.5	<39	<.098	.357	<20	<2.0	<20	<2.0	<4
Mountain whitefish	Spring Creek	3	72.0	<36	<.089	.482	<18	<1.8	<18	<1.8	<4
Geometric mean				—	—	.415	—	—	—	—	—
Range				—	—	.357 - .482	—	—	—	—	—
Utah sucker	Portneuf River	3	73.8	153	<.095	.489	<19	<1.9	<19	<1.9	<4
Utah sucker	Reservoir, mouth of Spring Creek	3	72.5	131	<.091	.749	<18	<1.8	<18	<1.8	<4
Utah sucker	Spring Creek	3	77.1	61	<.109	.655	<22	<2.2	<22	<2.2	<4
Utah sucker	Reservoir, mouth of Snake River	3	73.2	48	<.093	.578	<19	<1.9	<19	<1.9	<4
Geometric mean				88	—	.610	—	—	—	—	—
Range				48 - 153	—	.489 - .749	—	—	—	—	—
Carp	Portneuf River	1	59.3	25	<.061	.256	<12	<1.2	<12	<1.2	<2
Carp	Reservoir, mouth of Spring Creek	1	64.3	<28	<.070	.336	<14	<1.4	<14	<1.4	<3
Carp	Reservoir, mouth of Snake River	1	73.2	<37	<.093	.612	<19	<1.9	<19	<1.9	<4
Geometric mean				—	—	.375	—	—	—	—	—
Range				<28 - 25	—	.256 - .612	—	—	—	—	—
NCBP mean				—	—	.56	—	—	—	.12	—
NCBP 85th percentile				—	—	.88	—	—	—	.24	—
Analytical reporting limit (ppm, wet weight)				10	.025	.005	5	.5	5	.5	1

Table 15.—*Concentrations of trace elements in composite samples of fish, July-August 1988*—Continued

Species	Location	Number in composite sample	Percent moisture content	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel
Rainbow trout	Portneuf River	3	72.6	<9.1	201	<36	1,020	9.1	0.383	<18	<15
Mountain whitefish	Reservoir near Spring Creek	3	74.5	<9.8	145	<39	1,180	<5.9	.455	<20	<16
Mountain whitefish	Spring Creek	3	72.0	<8.9	129	<36	1,110	<5.4	.264	<18	<14
Geometric mean				—	137	—	1,144	—	.347	—	—
Range				—	129 - 145	—	1,110 - 1,180	—	.264 - .455	—	—
Utah sucker	Portneuf River	3	73.8	<9.5	294	<38	1,370	13.0	.836	<19	<15
Utah sucker	Reservoir near Spring Creek	3	72.5	<9.1	305	<36	1,270	12.4	1.60	<18	<14
Utah sucker	Spring Creek	3	77.1	<11.0	236	<44	1,440	9.6	.183	<22	<18
Utah sucker	Reservoir near Snake River	3	73.2	<9.3	157	<37	1,160	14.6	1.44	<19	<15
Geometric mean				—	240	—	1,306	12.3	.771	—	—
Range				—	157 - 305	—	1,160 - 1,440	9.6 - 14.6	.183 - 1.44	—	—
Carp	Portneuf River	1	59.3	<6.1	103	<25	491	.4	.359	<12	<9.9
Carp	Reservoir near Spring Creek	1	64.3	<7.0	92	<28	812	<4.2	.471	<14	<11.2
Carp	Reservoir near Snake River	1	73.2	<9.3	108	<37	933	<5.6	1.67	<19	<14.9
Geometric mean				—	101	—	719	—	.923	—	—
Range				—	92 - 108	—	491 - 933	—	.359 - 1.67	—	—
NCBP mean				2.7	—	.68	—	—	.44	—	—
NCBP 85th percentile				3.6	—	1.0	—	—	.72	—	—
Analytical reporting limit (ppm, wet weight)				2.5	10	10	100	1.5	.025	5	4

Table 15.—*Concentrations of selected trace elements in composite samples of fish, July–August 1988*—Continued

Species	Location	Number in composite sample	Percent moisture content	Selenium	Silver	Strontium	Thallium	Tin	Vanadium	Zinc
Rainbow trout	Portneuf River	3	72.6	2.6	<18	13	<0.4	<18	<18	86
Mountain whitefish	Reservoir near Spring Creek	3	74.5	2.0	<20	156	<.4	<20	<20	18
Mountain whitefish	Spring Creek	3	72.0	1.4	<18	118	<.4	<18	<18	13
Geometric mean				1.7	—	136	—	—	—	15
Range				1.4 - 2.0	—	118 - 156	—	—	—	13 - 18
Utah sucker	Portneuf River	3	73.8	.8	<19	38	<.4	<19	<19	76
Utah sucker	Reservoir near Spring Creek	3	72.5	<.4	<18	33	<.4	<18	<18	76
Utah sucker	Spring Creek	3	77.1	1.7	<22	55	<.4	<22	<22	96
Utah sucker	Reservoir near Snake River	3	73.2	.1	<19	40	<.4	<19	<19	82
Geometric mean				.4	—	41	—	—	—	82
Range				<.4 - 1.7	—	33 - 55	—	—	—	76 - 96
Carp	Portneuf River	1	59.3	1.2	<12	21	<.2	<12	<12	337
Carp	Reservoir near Spring Creek	1	64.3	.3	<14	38	<.3	<14	<14	189
Carp	Reservoir near Snake River	1	73.2	.8	<19	34	<.4	<19	<19	344
Geometric mean				.6	—	30	—	—	—	280
Range				.3 - 1.2	—	21 - 38	—	—	—	189 - 344
NCBP mean				1.9	—	—	—	—	—	95
NCBP 85th percentile				2.8	—	—	—	—	—	160
Analytical reporting limit (ppm, wet weight)				.1	5	1	.1	5	5	2

Table 16.—*Concentrations of trace elements in plants and invertebrates from selected tributaries to American Falls Reservoir, August 1988*

[Concentrations in micrograms per gram, dry weight; wet weight = dry weight x (1 - percent moisture content expressed as a decimal); analytical reporting limit is in wet weight because of variable moisture contents among species and samples; ppm, parts per million; where all values are less than (<), no mean is reported; for individual less-than values, one-half of the value was used to calculate the mean; analytical reporting limits vary among samples; —, not determined]

Species	Location	Sample weight	Percent moisture content	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
Sago pondweed	Spring Creek	58	84.5	510	<0.161	4.0	137	<3.2	331	<3.2	<6
Horned pondweed	Bannock Creek	37	89.9	4,000	—	1.6	—	.17	—	3.54	6.9
Horned pondweed	Portneuf River	36	92.3	630	—	1.4	—	.03	—	2.3	3.5
Mayfly nymphs	Spring Creek	22	79.9	473	<.124	.326	<25	<2.5	<25	<2.5	<5
Freshwater shrimp	Spring Creek	12	85.4	253	<.171	3.23	255	<3.4	<34	<3.4	<7
Mayfly nymphs	Bannock Creek	30	82.3	4,090	—	1.2	—	.18	—	2.3	6.1
Caddisfly larva	Bannock Creek	33	81.4	3,670	—	1.3	—	.16	—	.4	6.0
Mayfly nymphs	Portneuf River	34	83.6	1,840	—	.82	—	.088	—	5.39	4.9
Caddisfly larva	Portneuf River	32	78.9	658	—	1.0	—	.03	—	.73	2.9
Analytical reporting limit (ppm, wet weight)				10	.025	.005	5	.5	5	.5	1

Table 16.—*Concentrations of trace elements in plants and invertebrates from selected tributaries to American Falls Reservoir, August 1988*—Continued

Species	Location	Sample weight	Percent moisture content	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel
Sago pondweed	Spring Creek	58	84.5	<16.1	826	<64	3,100	101	<0.161	<32	<26
Horned pondweed	Bannock Creek	37	89.9	8.19	3,290	3.2	—	1,380	.042	—	6.6
Horned pondweed	Portneuf River	36	92.3	6.76	481	1.0	—	113	.041	—	6.1
Mayfly nymphs	Spring Creek	22	79.9	12.9	682	<50	1,990	43.8	.448	<24.9	<20
Freshwater shrimp	Spring Creek	12	85.4	65.1	308	<68	2,530	11.0	.192	<34.2	<27
Mayfly nymphs	Bannock Creek	30	82.3	20.9	3,350	2.4	—	144	.13	—	3.4
Caddisfly larva	Bannock Creek	33	81.4	15.2	3,070	2.8	—	698	.16	—	4.7
Mayfly nymphs	Portneuf River	34	83.6	107	1,680	2.3	—	141	.11	—	3.7
Caddisfly larva	Portneuf River	32	78.9	14	610	1.6	—	151	.12	—	3.4
Analytical reporting limit (ppm, wet weight)				2.5	10	10	100	1.5	.025	5	4

Table 16.—*Concentrations of trace elements in plants and invertebrates from selected tributaries to American Falls Reservoir, August 1988*—Continued

Species	Location	Sample weight	Percent moisture content	Selenium	Silver	Strontium	Thallium	Tin	Vanadium	Zinc
Sago pondweed	Spring Creek	58	84.5	<0.6	<32	266	<0.6	<32	<32	25
Horned pondweed	Bannock Creek	37	89.9	.96	—	—	<.7	—	—	32
Horned pondweed	Portneuf River	36	92.3	.66	—	—	<.4	—	—	106
Mayfly nymphs	Spring Creek	22	79.9	1.8	<25	25	<.5	<25	<25	69
Freshwater shrimp	Spring Creek	12	85.4	1.4	<34	523	<.7	<34	<34	86
Mayfly nymphs	Bannock Creek	30	82.3	5.5	—	—	<.7	—	—	104
Caddisfly larva	Bannock Creek	33	81.4	2.4	—	—	<.7	—	—	110
Mayfly nymphs	Portneuf River	34	83.6	8.1	—	—	<.5	—	—	293
Caddisfly larva	Portneuf River	32	78.9	3.1	—	—	<.5	—	—	226
Analytical reporting limit (ppm, wet weight)				.1	5	1	.1	5	5	2

Table 17.—*Concentrations of selected organochlorine compounds in waterbirds and waterbird eggs, May–June 1988*

[Concentrations in micrograms per kilogram, wet weight; ND, not detected; egg concentrations corrected for moisture loss by multiplying reported data by the whole egg weight divided by the egg volume (0.51 x Length x Width^2); ppm, parts per million; —, not determined]

Specimen	Percent moisture content	Percent lipid content	β-BHC	Oxy-chlor-dane	p,p'DDE	p,p'DDT	Diel-drin	HCB	Hepta-chlor epoxide	PCB's, total
American coot liver	76.0	6.52	ND	ND	0.13	ND	ND	ND	ND	ND
American coot liver	75.0	7.04	ND	ND	.26	ND	ND	ND	ND	ND
American coot liver	75.5	11.1	ND	ND	.02	ND	ND	ND	ND	ND
American coot liver	71.0	12.0	ND	ND	.07	ND	ND	ND	ND	ND
American coot liver	74.0	11.1	ND	ND	.08	ND	ND	ND	ND	ND
Geometric mean			—	—	.08	—	—	—	—	—
Range			ND	ND	.02 - .26	ND	ND	ND	ND	ND
Cormorant egg	85.0	4.26	0.01	ND	5.30	ND	ND	ND	ND	0.28
Cormorant egg	84.5	4.88	ND	0.02	5.70	ND	0.06	0.01	0.02	.43
Cormorant egg	84.0	3.99	ND	.03	1.80	ND	ND	.01	.05	1.8
Cormorant egg	83.5	3.49	ND	ND	3.90	ND	ND	.01	ND	.36
Cormorant egg	85.0	3.96	ND	ND	.59	ND	ND	.01	ND	1.8
Geometric mean			—	—	2.63	—	—	.01	—	.68
Range			ND - .01	ND - .03	.59 - 5.70	ND	ND - .06	ND - .01	ND - .05	.28 - 1.8
Mallard egg[1]	69.5	14.6	ND	ND	.36	ND	ND	ND	ND	ND
Mallard egg[1]	69.0	15.5	ND	ND	.43	0.07	ND	ND	ND	ND
Mallard egg	67.5	16.9	ND	ND	.24	ND	ND	ND	ND	ND
Geometric mean			—	—	.33	—	—	—	—	—
Range			ND	ND	.24 - .43	ND - .07	ND	ND	ND	ND
Mallard carcass	74.0	6.58	ND	ND	.07	ND	ND	ND	ND	ND
Mallard carcass	75.2	2.78	ND	ND	.04	ND	ND	ND	ND	ND
Mallard carcass	75.2	3.58	ND	ND	.08	ND	ND	ND	ND	ND
Mallard carcass	72.8	7.51	ND	ND	.07	ND	ND	ND	ND	ND
Geometric mean			—	—	.06	—	—	—	—	—
Range			ND	ND	.04 - .08	ND	ND	ND	ND	ND
Analytical reporting limit (ppm, wet weight)			.01	.01	.01	.01	.01	.01	.01	.05

[1]Possibly gadwall.

Table 18.—*Concentrations of selected organochlorine compounds in composite samples of fish from American Falls Reservoir, July–August 1988*

[Concentrations in micrograms per gram, wet weight; ND, not detected; ppm, parts per million; —, not determined]

Species	Location	Number in composite sample	Percent moisture content	Percent lipid content	ρ-Chlordane	α-Chlordane	τ-Nonachlor	PCB's, total
Rainbow trout	Portneuf River	3	71.0	9.30	0.01	0.01	0.01	0.27
Mountain whitefish	Reservoir near Spring Creek	3	74.8	5.21	ND	ND	ND	.32
Mountain whitefish	Spring Creek	3	71.8	7.45	.02	.01	.01	.36
Geometric mean					—	—	—	.34
Range					ND – .01	ND – .01	ND – .01	.32 – .36
Utah sucker	Portneuf River	3	73.8	6.22	.02	.01	.02	.35
Utah sucker	Reservoir near Spring Creek	3	73.0	7.81	.01	.01	.01	.33
Utah sucker	Spring Creek	3	76.8	3.38	ND	ND	ND	.14
Utah sucker	Reservoir near Snake River	3	72.0	9.37	.01	.01	.01	.39
Geometric mean					.01	.01	.01	.28
Range					ND – .02	ND – .01	ND – .02	.14 – .39
Carp	Portneuf River	1	59.6	25.0	.06	.06	.05	.44
Carp	Reservoir near Spring Creek	1	64.2	15.6	.01	.01	.01	.32
Carp	Reservoir near Snake River	1	73.4	7.22	.01	.02	.02	.54
Geometric mean					.02	.02	.02	.42
Range					.01 – .06	.01 – .06	.01 – .05	.32 – .54
Analytical reporting limit (ppm, wet weight)					.01	.01	.01	.05

Table 18.—*Concentrations of selected organochlorine compounds in composite samples of fish from American Falls Reservoir, July–August 1988*—Continued

Species	Location	Number in composite sample	Percent moisture content	Percent lipid content	p,p'DDD	p,p'DDE	p,p'DDT
Rainbow trout	Portneuf River	3	71.0	9.30	ND	0.12	ND
Mountain whitefish	Reservoir near Spring Creek	3	74.8	5.21	0.02	.13	ND
Mountain whitefish	Spring Creek	3	71.8	7.45	.02	.10	ND
Geometric mean					.02	.11	—
Range					.02	.10 – .13	ND
Utah sucker	Portneuf River	3	73.8	6.22	.02	.13	ND
Utah sucker	Reservoir near Spring Creek	3	73.0	7.81	.05	.25	ND
Utah sucker	Spring Creek	3	76.8	3.38	.03	.09	ND
Utah sucker	Reservoir near Snake River	3	72.0	9.37	.05	.43	0.03
Geometric mean					.03	.19	—
Range					.02 – .05	.09 – .43	ND – .03
Carp	Portneuf River	1	59.6	25.0	.03	.07	ND
Carp	Reservoir near Spring Creek	1	64.2	15.6	.06	.23	ND
Carp	Reservoir near Snake River	1	73.4	7.22	.08	.57	ND
Geometric mean					.05	.21	—
Range					.03 – .08	.07 – .57	ND
Analytical reporting limit (ppm, wet weight)					.01	.01	.01