FIELD SCREENING OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE, WIND RIVER INDIAN RESERVATION, WYOMING, 1992-93

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CONVERSION FACTORS, VERTICAL DATUM, ABBREVIATED WATER-QUALITY UNITS, AND ACRONYMS

Multiply	By	To obtain
acre	4,047	square meter
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic yard (yd^3)	0.7646	cubic meter
foot	0.3048	meter
inch	25.4	millimeter (mm)
inch	2.54	centimeter (cm)
mile (mi)	1.609	kilometer
ton per acre-foot	0.0007357	megagram per cubic meter
ton per day(ton/d)	0.0105	kilogram per second

Temperature can be coverted to degrees Celsius (°C) or degrees Fahrenheit (°F) by using the following equations:

$$°C = 5/9(°F-32)$$
$$°F = 9/5(°C)+32$$

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, formerly called Sea Level Datum of 1929.

ABBREVIATED WATER-QUALITY UNITS USED IN THIS REPORT

µg/kg	micrograms per kilogram
µg/g	micrograms per gram
µg/L	micrograms per liter
µm	micrometer (micron)
µS/cm	microsiemens per centimeter at 25°C
mg/L	milligrams per liter
mL	milliliter

ABBREVIATIONS USED IN THE REPORT

DOI	U.S. Department of the Interior
NCBP	National Contaminant Biomonitoring Program
NIWQP	National Irrigation Water Quality Program
BIA	Bureau of Indian Affairs
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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ABSTRACT

Physical, chemical, and biological data were collected in 1992 and 1993 from irrigation drainage areas and wetlands of the Wind River Federal Irrigation Project, Wind River Indian Reservation, Wyoming. In this semiarid area of Wyoming, the natural and irrigation-impacted wetlands of the reservation are attractive to migratory and nesting aquatic birds, several species of fish, and three federally listed endangered species--bald eagles, peregrine falcons, and whooping cranes--that are know to use these wetland habitats seasonally. In response to increasing concern about the quality of irrigation drainwater and its potential adverse effects on fish, wildlife, and human health, an interagency field screening was conducted by the U.S. Geological Survey and the U.S. Fish and Wildlife Service, in cooperation with the Shoshone Tribe and Northern Arapahoe Tribe. This study was conducted under the guidance of the U.S. Department of the Interior National Irrigation Water Quality Program.

Most samples collected from irrigated sites in the Wind River Federal Irrigation Project had concentrations of inorganic constituents and organic compounds less than reported levels of concern in water, bottom sediment, and biota. However, in the Little Wind Unit irrigation area between Fort Washakie and Arapahoe, concentrations of selenium and mercury in water exceeded the U.S. Environmental Protection Agency's aquatic-life criterion for selenium, 5 μg/L (micrograms per liter), and the proposed 1985 mercury criterion for freshwater aquatic life protection (0.012 μg/L, 4-day average, not to exceed 2.4 μg/L on an hourly average). Of the 14 water samples analyzed from the Little Wind Unit in 1993, 6 samples had selenium concentrations that equaled or exceeded 5 μg/L, and 1 sample from McCaskey Drain had a selenium concentration of 17 μg/L. Mercury concentrations in water sampled in the study area during 1992-93 were 0.1 μg/L or less, except at four sites. One water sample collected in 1993 from Sharp Nose Draw in the Little Wind Unit had a mercury concentration of 4.9 μg/L, and three samples collected in 1992 from Little Wind Unit and Johnstown Unit had mercury concentrations of 0.2 μg/L. Natural concentrations of mercury in rivers and lakes have been reported to range from 0.01 to 0.05 μg/L, and concentrations of 0.1 to 2.0 μg/L have been reported to be fatal to sensitive aquatic species.

Bottom-sediment samples from Goose Pond and Sharp Nose Pond in the Little Wind Unit had selenium concentrations of 7.5 and 0.4 μg/g (micrograms per gram). Mercury concentrations in the study area were less than 0.02 μg/g at all bottom-sediment sampling sites investigated, except for Sharp Nose Pond in the Little Wind Unit where a mercury concentration of 0.02 μg/g was measured.

Selenium concentrations in some aquatic vegetation and invertebrates, fish, bird eggs, and bird livers collected from the Little Wind Unit also were greater than established levels of concern. At Goose Pond and Sharp Nose Pond, for example, selenium concentration in bird livers ranged from 13.9 to 22.9 μg/g and 6.93 to 14.0 μg/g, with five of the six samples collected exceeding the 10.0 μg/g level associated with reproductive failure in aquatic birds. Of the biota samples collected from the Little Wind Unit in 1993, no samples had concentrations of mercury greater than levels known to cause adverse effects to

sensitive aquatic species. Mercury concentrations of 3.60 to 5.10 μg/g in the livers of birds sampled from Sharp Nose Pond were greater than reported levels in dietary items for the protection of sensitive species of mammals and birds that regularly consume fish and other aquatic organisms.

INTRODUCTION

Background

Studies by the U.S. Fish and Wildlife Service (USFWS) in the Western United States have related incidences of mortality, embryo teratogenesis, and reproductive failures of aquatic birds and fish to high concentrations of selenium in irrigation drainage. These effects were discovered in 1983 at the Kesterson National Wildlife Refuge in the western San Joaquin Valley, California, where irrigation drainwater was impounded.

In response to widespread concern about the general nature and extent of contaminant problems associated with irrigation drainage, the U.S. Department of the Interior (DOI) developed the Irrigation Drainage Program (currently the National Irrigation Water Quality Program or NIWQP) in 1985 and formed an interbureau Task Group on Irrigation Drainage to address water-quality problems related to irrigation drainage for which the DOI may have responsibility. Subsequently, 26 areas that warranted reconnaissance-level studies were identified. The study areas relate to three areas of DOI responsibility: (1) irrigation or drainage facilities constructed or managed by the DOI; (2) National Wildlife Refuges managed by the DOI that receive irrigation drainage; and (3) other migratory-bird or endangered-species management areas that receive water from DOI-funded projects.

The discovery of the effects of selenium on the health of biota has led to more than a decade of scientific investigation regarding the quality of irrigation water and its potential harmful effects on humans, fish, and wildlife (Case and others, 1990; Feltz and others, 1991; Peterson and Nebeker, 1992). Selenium concentrations greater than the water-quality criterion for the protection of aquatic life (U.S. Environmental Protection Agency, 1987) have been detected in surface and subsurface drainwater from irrigated land (Feltz and Engberg, 1994), and arsenic, heavy metals, and pesticide residues have been detected in numerous areas of the Western United States that receive irrigation drainage. Concentrations can become toxic where naturally occurring selenium and associated constituents are leached from soil and underlying geologic formations by irrigation water and accumulated by evaporative and bioaccumulation processes. Wetlands and closed-basin ponds are particularly susceptible sites.

In 1990, the U.S. Geological Survey (USGS) collected and analyzed surface- and ground-water samples from irrigation drainage areas on the Wind River Indian Reservation. The analysis indicated that surface water from Mill Creek below Coolidge Canal had a selenium concentration of 5 μg/L and that selenium concentrations in ground water were as high as 65 μg/L (Druse and others, 1991, p. 457 and 487). During the Phase 2 comprehensive site-identification survey of the Riverton Reclamation Project, which was conducted as part of the NIWQP, the presence of selenium and other chemical constituents in irrigation drainage water was shown to be a potential problem to fish and aquatic birds in the area (Peterson and others, 1991, p. 43). Lemly (1993) and Lemly and Smith (1987) indicated that selenium concentrations greater than 2 ug/L can bioaccumulate in food chains and cause adverse reproductive effects in fish and aquatic birds.

As a result of these previous investigations, the quality of irrigation drainage in the Wind River Federal Irrigation Project of the Wind River Indian Reservation has become of interest. The area of this investigation is of added concern because of its use by many species of migratory and nesting aquatic birds and several species of fish. This investigation was conducted by interbureau field teams composed of scientists from the USGS and the USFWS in cooperation with the Shoshone Tribe and the Northern Arapahoe Tribe.

Purpose and Scope

This report gives the results of a reconnaissance, or field screening, of the physical and chemical conditions of four irrigation units comprising the Wind River Federal Irrigation Project study area. Descriptions of the general physiography, hydrology, and biota are given, and the concentrations of selected inorganic constituents and organic compounds in water, bottom sediment, and biota are presented. The concentrations of inorganic constituents and organic compounds identified in the study area are compared to various established guidelines and baseline information.

Physical and chemical data are presented for water, bottom sediment, and biota sampling sites judged to be representative of the irrigated areas and wetlands in the Wind River Federal Irrigation Project on the reservation. Water-quality data are presented in tables and graphs of this report for two irrigation seasons, August-September 1992 and June 1993. Of the 30 sites studied, water samples were collected at 25 sites late in the irrigation season of 1992, and at 22 sites early in the irrigation season of 1993. In addition to these water-quality samples, bottom-sediment samples and biota samples were collected in 1993 from wetland sites in areas where irrigation-induced contamination may pose a threat to fish and wildlife. Bottom-sediment samples were collected at 7 of the 22 water-sampling sites in 1993, and biota samples were collected from wetland areas at 6 sites. Concentrations of inorganic constituents and organic compounds (pesticides) in the four irrigation units evaluated are presented and areas of potential contamination induced by irrigation drainage are identified.

Data collected during this investigation will help the DOI determine whether irrigation drainage in the study area might be harmful to humans, fish, or wildlife. From these data, the DOI will determine whether a more detailed investigation is warranted.

Acknowledgments

For their assistance in site selection and sampling, special thanks are due to the Shoshone Tribe and Northern Arapahoe Tribe. Appreciation also is extended to those residents and landowners who assisted in obtaining or permitting access on private lands, who helped us locate specific sites, and who provided useful anecdotal information about the study area.

HISTORY OF IRRIGATION ON THE WIND RIVER INDIAN RESERVATION

Irrigation drainage activities on the Wind River Indian Reservation began in 1873, about 5 years after the reservation was established (Gerharz, 1946, p. 1). James Irwin, U.S. Government Agent on the reservation, and two government-sponsored farmers directed efforts to plow furrows and dig ditches that would ultimately be used to irrigate about 300 acres of land between the present towns of Wind River and Fort Washakie, Wyoming. During President Cleveland's administration in 1885-86, money was appropriated by Congress to construct an irrigation ditch near what is now the Sub-Agency Ditch, and by 1900, two additional Congressional appropriations were used to dig Ray Canal and another ditch east of what is now Coolidge Canal. In 1905, Congress established the Wind River Federal Irrigation Project on lands under the supervision of the Bureau of Indian Affairs (BIA) (McGreevy and others, 1969, p. I-55), and a small development (embankment) was constructed at the site of Ray Lake (Gerharz, 1946, p. 18). Subsequently, small Congressional appropriations were made almost every year to construct canals and lateral irrigation ditches. By the summer of 1919, the main development, an earthfill embankment of about 45,000 yd^3 (cubic yards) of material was constructed to contain Ray Lake. After several extremely dry years, the BIA used additional Congressional funds during the 1930s to construct dams and several new canals.

Irrigation of croplands in the Wind River Federal Irrigation Project proved to be productive to crop growth. However, irrigation drainage caused several problems including the waterlogging of soil and the accumulation of salt on the land surface and in the root zone (McGreevy and others, 1969, p. I-57).

DESCRIPTION OF STUDY AREA

The study area consists of four irrigation units of the Wind River Federal Irrigation Project on the Wind River Indian Reservation (fig. 1). Within this semiarid area, an irrigation network about 90 mi in length diverts approximately 170,000 acre-ft (acre-feet) of water annually through a series of unlined canals, ditches, and drains constructed in soil, weathered rock, and other unconsolidated geologic surface materials (Miller, 1993, p.13). Principal streams in the area are the Wind River, Little Wind River, and Popo Agie River. The Wind River, Little Wind River, and other perennial streams that flow eastward from the Wind River Range provide most of the irrigation water for the area.

Physical Setting

The irrigated areas investigated comprise river terraces and alluvial valleys of the Wind River near Crowheart and Kinnear, and alluvial valleys of the Little Wind River and its tributaries between Fort Washakie and Riverton (fig. 1). These lands are composed mostly of Quaternary alluvial sand and gravel deposited by the Wind River and Little Wind River, and colluvial slope deposits derived from local outcrops of Wind River and Fort Union Formations of Tertiary age and Cody Shale of Cretaceous age (McGreevy and others, 1969). The locations of these geologic outcrops in relation to irrigation drainage areas in the study area are important because soil forming from these geologic materials may contribute naturally occurring selenium and associated trace elements to irrigation drainwater where these elements can be concentrated by evaporation and bioaccumulation processes in low-lying basins and wetlands.

Selenium commonly occurs with such trace elements as uranium, arsenic, molybdenum, and vanadium, and is known to be present in varying concentrations in many of the geologic formations, soil, and vegetation of Wyoming (Case and Cannia, 1988). The locations of potentially seleniferous areas on the reservation, as identified and mapped by Case and Cannia (1988), are shown in figure 2. In the south-central part of the reservation, geologic formations and locally derived sediment and soil that have the potential to support seleniferous vegetation that may be highly toxic to animals (Case and Cannia, 1988) correspond with irrigated areas of the Little Wind irrigation unit (figs. 1 and 2). One such geologic formation, the Cretaceous Cody Shale, that is known throughout Wyoming to contain potentially high concentrations of selenium (Case and Cannia, 1988), trends northwest to southeast through the irrigation unit. Adjacent to this outcrop, exposures of Tertiary and Quaternary age sediment may contain materials derived from the older marine shale. These sediments were identified by Case and Cannia (1988) as having the potential to support vegetation that may be moderately and mildly toxic to grazing animals (fig.2).

Hydrologic Setting

Four irrigation units were investigated during this study: (1) Little Wind Unit, (2) Left-Hand Unit, (3) Johnstown Unit, and (4) Upper Wind Unit. The locations of these irrigation units on the reservation, as identified and named by McGreevy and others (1969), are shown in figure 1. The locations of sampling sites 1-23 in and near the Little Wind, Left-Hand, and Johnstown Units are shown in relation to the area's principal streams, lakes, and towns in figure 3. The locations of sampling sites 24-30 in and near the Upper Wind Unit are shown in relation to the Wind River and Dinwoody Lakes in figure 4. In addition to these major irrigation units, a few small privately operated irrigation areas exist in the upper Wind River valley, and along other perennial streams in the area.

Little Wind Unit

The Little Wind Unit contains 29,550 irrigable acres (Ruth Thayer, Bureau of Indian Affairs, written commun., 1992) and is irrigated by water diverted from the North Fork Little Wind River, South Fork Little Wind River, Little Wind River, Washakie Reservoir (capacity of 7,900 acre-ft), Trout Creek, Ray Lake (capacity of 7,100 acre-ft), and Mill Creek (fig. 3). The Little Wind Unit is subdivided into three systems named for their major canals--Ray System, Coolidge System, and Sub-Agency System. Water sampling sites 1-5 are located in the Ray System; sites 6-14 are located in the Coolidge System; and sites 15-18 are located in the Sub-Agency System (fig. 3). Figure 5, a schematic diagram of the Little Wind Unit, shows the routing and flow directions of the three systems in the irrigation unit. Of the three main canals, Ray Canal is the most upstream and westward of the diversions. Irrigation water of the Ray System, in general, flows southeast from the South Fork Little Wind River by way of Ray Canal and natural drains, sloughs, and draws into Trout Creek, 37-C Lateral, Ray Lake, Mill Creek, and finally into the North Popo Agie River upstream from the town of Milford (fig. 3). Coolidge Canal, east of Ray Canal, in addition to receiving water from the Ray System, diverts irrigation water from the Little Wind River and Trout Creek downstream from Ray Canal between the towns of Fort Washakie and Ethete. Return flow from irrigated areas served by Ray Canal and Coolidge Canal is discharged into a network of natural creeks and draws, and constructed drains that divert water back into the Little Wind River. Several ponds and wetlands, including Goose Pond (site 9) and Sharp Nose Pond (site 10), provide wildlife habitat in low-lying basin areas irrigated by Ray and Coolidge Canals (fig. 3).

The easternmost part of the Little Wind Unit is irrigated by water diverted by the Sub-Agency Ditch from the Little Wind River between the towns of Ethete and Arapahoe. Irrigation drainage in this part of the Little Wind Unit is accomplished principally by a series of constructed drains (fig. 5). Irrigation water is returned to the Little Wind River by means of Blue Cloud Road Drain and 35-A Drain. The Sub-Agency Ditch continues into the Left-Hand Unit.

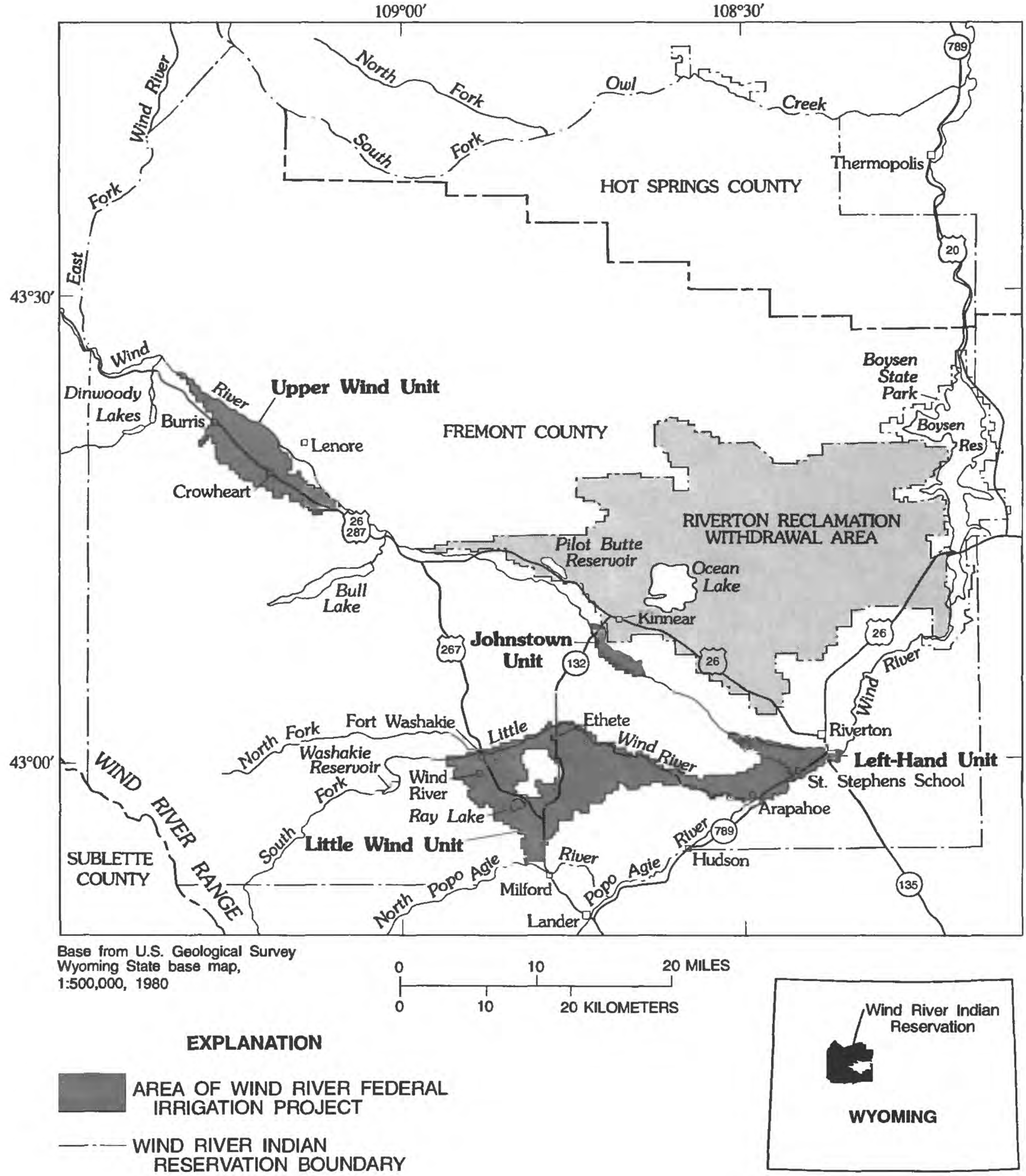
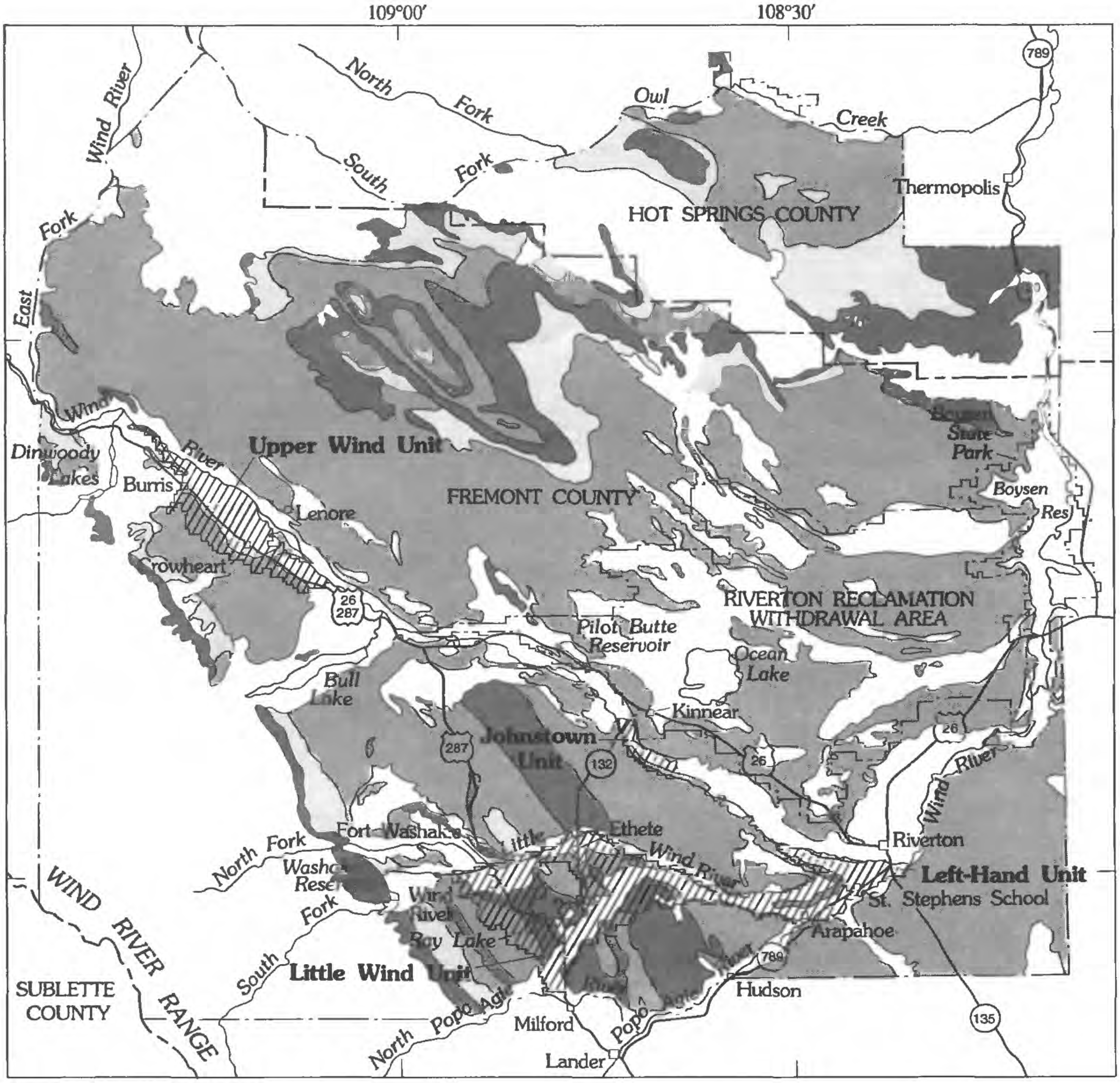


Figure 1. Location of study areas in the Wind River Federal Irrigation Project, central Wyoming.



Base from U.S. Geological Survey Wyoming State base map, 1:500,000, 1980

0 10 20 MILES

0 10 20 KILOMETERS

EXPLANATION

AREA OF WIND RIVER FEDERAL IRRIGATION PROJECT

GEOLOGIC FORMATIONS, EQUIVALENTS OF GEOLOGIC FORMATIONS, OR LOCALLY DERIVED SOILS THAT HAVE THE POTENTIAL TO SUPPORT SELENIFEROUS VEGETATION THAT:

- May be highly toxic to animals in localized areas
- May be moderately toxic to animals in localized areas
- May be mildy toxic to animals in localized areas
- Insufficient data for classification

—·— WIND RIVER INDIAN RESERVATION BOUNDARY

Figure 2. Distribution of potentially seleniferous areas in the Wind River Indian Reservation, central Wyoming (modified from Case and Cannia, 1988).

Left-Hand Unit

The Left-Hand Unit contains 1,938 irrigable acres (Ruth Thayer, Bureau of Indian Affairs, written commun., 1992) and is serviced by water diverted from the Wind River by Left-Hand Canal, south and west of Riverton, Wyoming (fig. 3). This water is used to irrigate the alluvial flats that lie just west of the confluence of the Wind and Little Wind Rivers. Although irrigation water from the Left-Hand Unit, in general, flows back toward the Wind River, some irrigation water drains east-southeast into the Little Wind River near St. Stephens School, upstream of the confluence of the Wind and Little Wind Rivers (fig. 3). Near the boundary of the Left-Hand Unit and the Sub-Agency System of the Little Wind Unit, as defined by McGreevy and others (1969), return flow from the two irrigation units may merge before flowing into the Little Wind River. Figure 6, a schematic diagram of the Left-Hand Unit, shows the relation of canals and drains to the Wind and Little Wind Rivers. The locations of water sampling sites 19 and 20 in the Left-Hand Unit are shown in figure 3.

Johnstown Unit

The Johnstown Unit contains 1,207 irrigable acres (Ruth Thayer, Bureau of Indian Affairs, written commun., 1992) and is serviced by water diverted from the Wind River by the Johnstown Canal, west of Kinnear, Wyoming (fig. 3). Agricultural lands of the Johnstown Unit are irrigated by a simple and relatively short irrigation network consisting of small ditches and turnouts that direct water from Johnstown Canal onto cultivated fields. Figure 7, a schematic diagram of the Johnstown Unit, shows the irrigation network in relation to the Wind River. Return flow is diverted back to the Wind River by the Johnstown Spur Road Drain and the 18-A Drain. The locations of water sampling sites 21-23 in and near the Johnstown Unit are shown in figure 3.

Upper Wind Unit

The Upper Wind Unit contains 10,726 irrigable acres (Ruth Thayer, Bureau of Indian Affairs, written commun., 1992) and incorporates two interconnected irrigation systems (fig. 4). Agricultural lands situated along upland benches and terraces formed on glacial till and underlying alluvium are irrigated by water diverted from Dinwoody Lakes (storage capacity about 5,000 acre-ft). This upper irrigation system consists of Dinwoody Canal, which carries water from the lakes down valley into Dry Creek Canal, Meadow Creek Canal, and Willow Creek Canal. Down-system from Dry Creek, numerous laterals and turnouts direct irrigation water across cultivated fields of the upland bench. Water returning from these fields flows into existing draws and drains, crosses the river bottom area to the northeast, and eventually flows back into the Wind River upstream from Little Sand Draw. Figure 8, a schematic diagram of the Upper Wind Unit, shows the three canals in relation to Dinwoody Lakes and the Wind River.

Nearer the Wind River, the lower river bottom irrigation system of the Upper Wind Unit receives water from the Upper Wind River "A" Canal and the Wind River "A" Canal (fig. 8). The Upper Wind River "A" Canal carries water routed directly from the Wind River. The Wind River "A" Canal carries water routed from Dry Creek. Irrigation water from cultivated fields of the river bottom system is returned to the Wind River through the same draws and drains used by the upper system. The locations of water sampling sites 24-30 in and near the Upper Wind Unit are shown in figure 4.

Biota

The Wind River Indian Reservation contains diverse wildlife and wildlife habitats within the plains, foothills, and mountains. An estimated 27 fish, 241 birds, and 66 mammals use these areas (Kathy Firchow, U.S. Fish and Wildlife Service, written commun., 1993). Little baseline data are available on the distribution and population dynamics of fish, waterfowl, upland birds, and endangered species.

Endangered Species

Information from USFWS databases indicates that several federally listed endangered species may inhabit the reservation. Peregrine falcons (*Falco peregrinus*) migrate through the area during spring and fall. Bald eagles (*Haliaeetus leucocephalus*) migrate through the reservation and winter along the Wind River. Whooping cranes (*Grus americanus*) may utilize summer range on the reservation and may be occasional visitors during spring and fall migrations. Prairie dog (*Cynomys* spp.) colonies occur in the area and may provide potential habitat for the endangered black-footed ferret (*Mustela nigripes*).

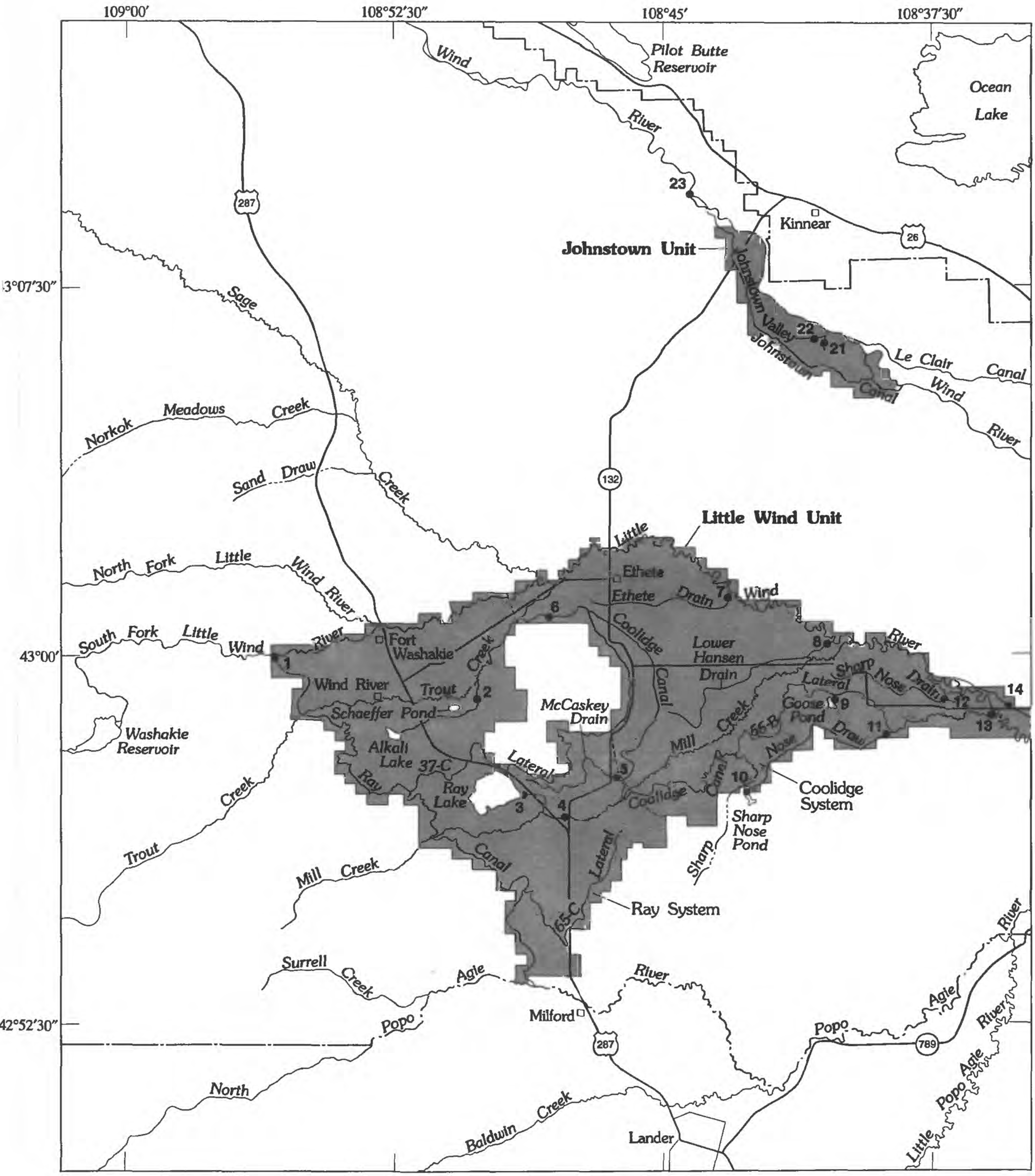
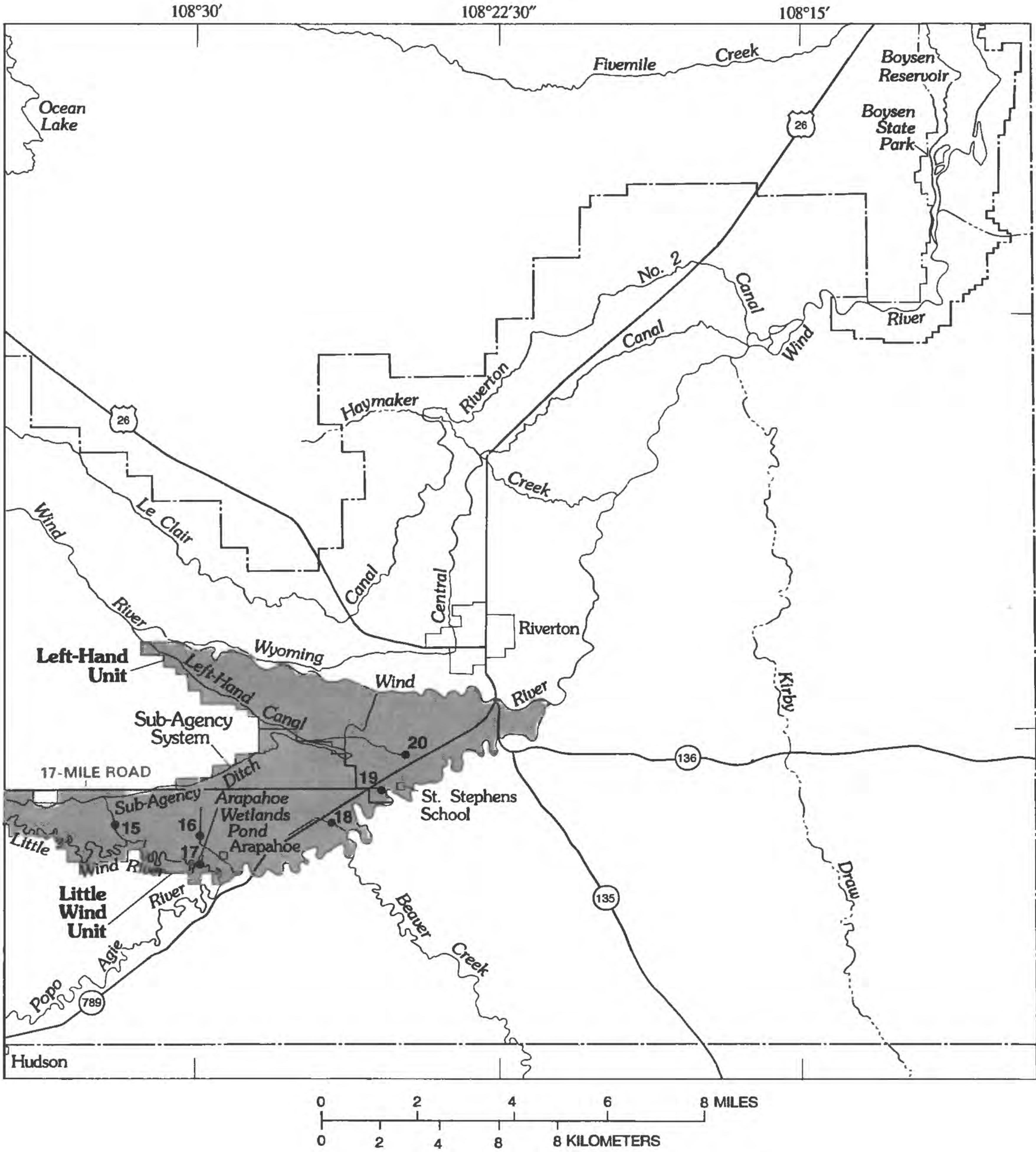


Figure 3. Location of sampling sites 1-23. Sites 1-18 are located in the Little Wind Unit, sites 19-20 are located in the Left-Hand Unit, and sites 21-23 are located in and near the Johnstown Unit.



EXPLANATION

AREA OF WIND RIVER FEDERAL IRRIGATION PROJECT--Dashed boundary separates the Ray System and the Coolidge System, and the Coolidge System and the Sub-Agency system in the Little Wind Unit

WIND RIVER INDIAN RESERVATION BOUNDARY

•17 SAMPLING SITE AND NUMBER

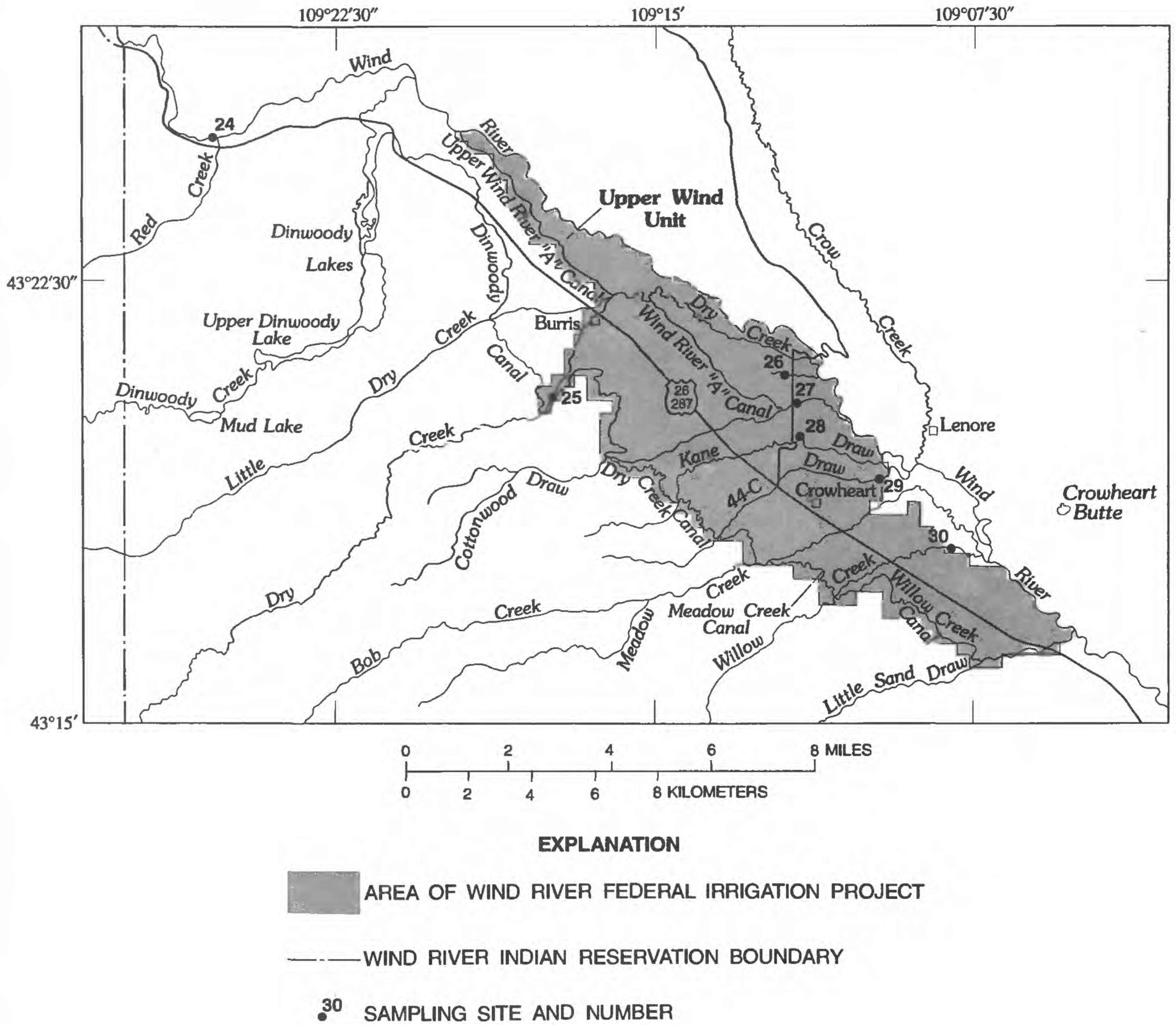


Figure 4. Location of sampling sites 24-30 located in and near the Upper Wind Unit.

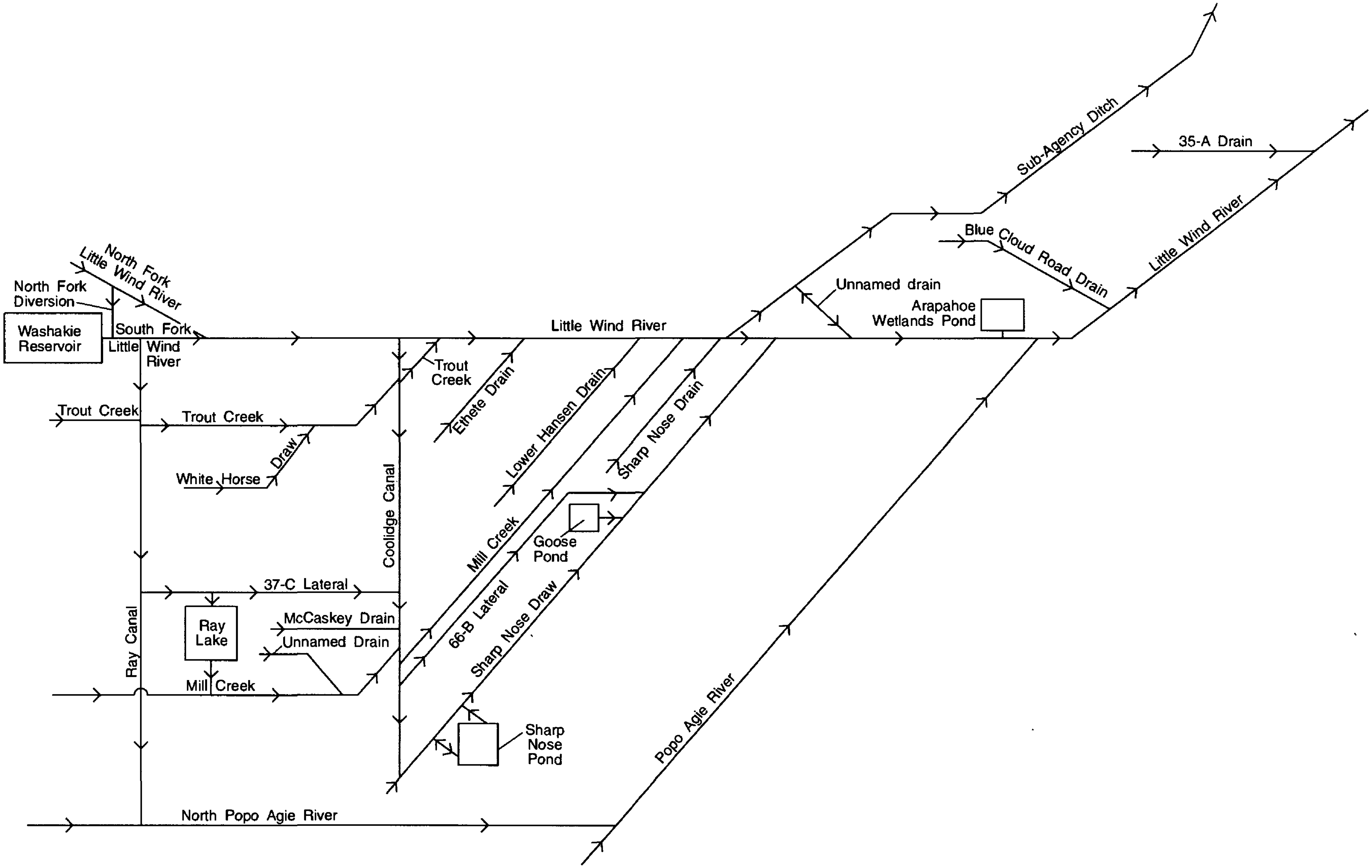


Figure 5. Irrigation network in the Little Wind Unit. Sub-Agency Ditch and Little Wind River continue into Left-Hand Unit.

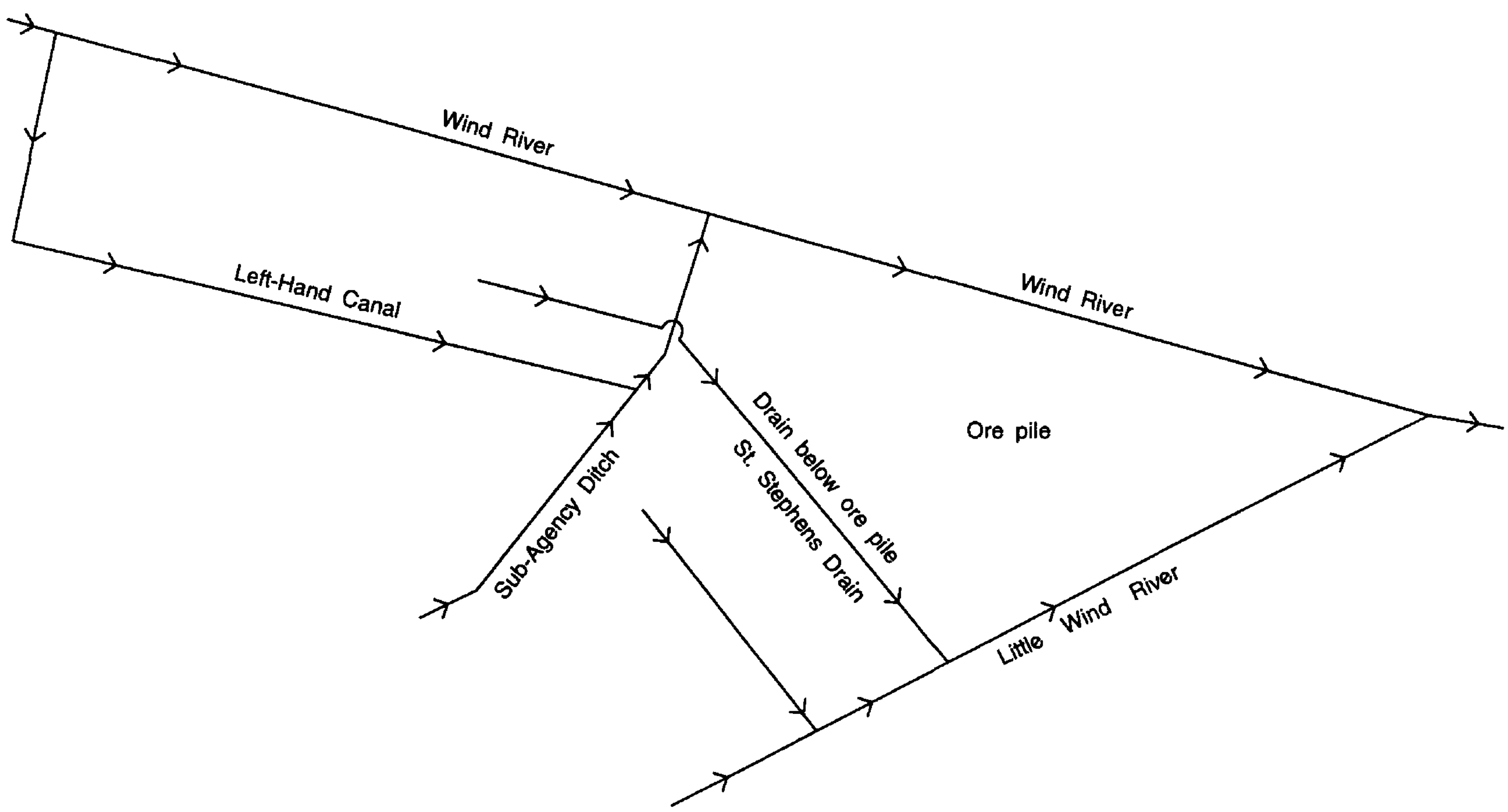


Figure 6. Irrigation network in the Left-Hand Unit.

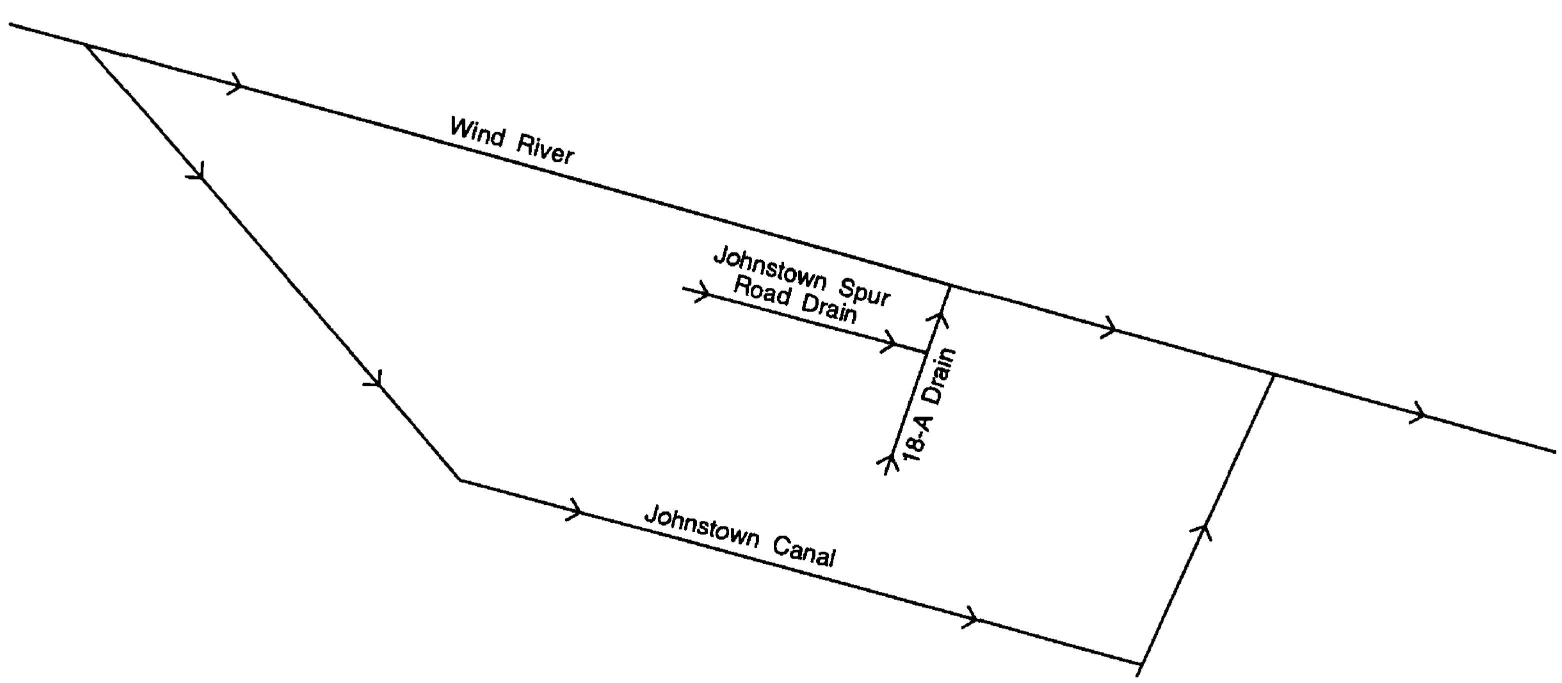


Figure 7. Irrigation network in the Johnstown Unit.

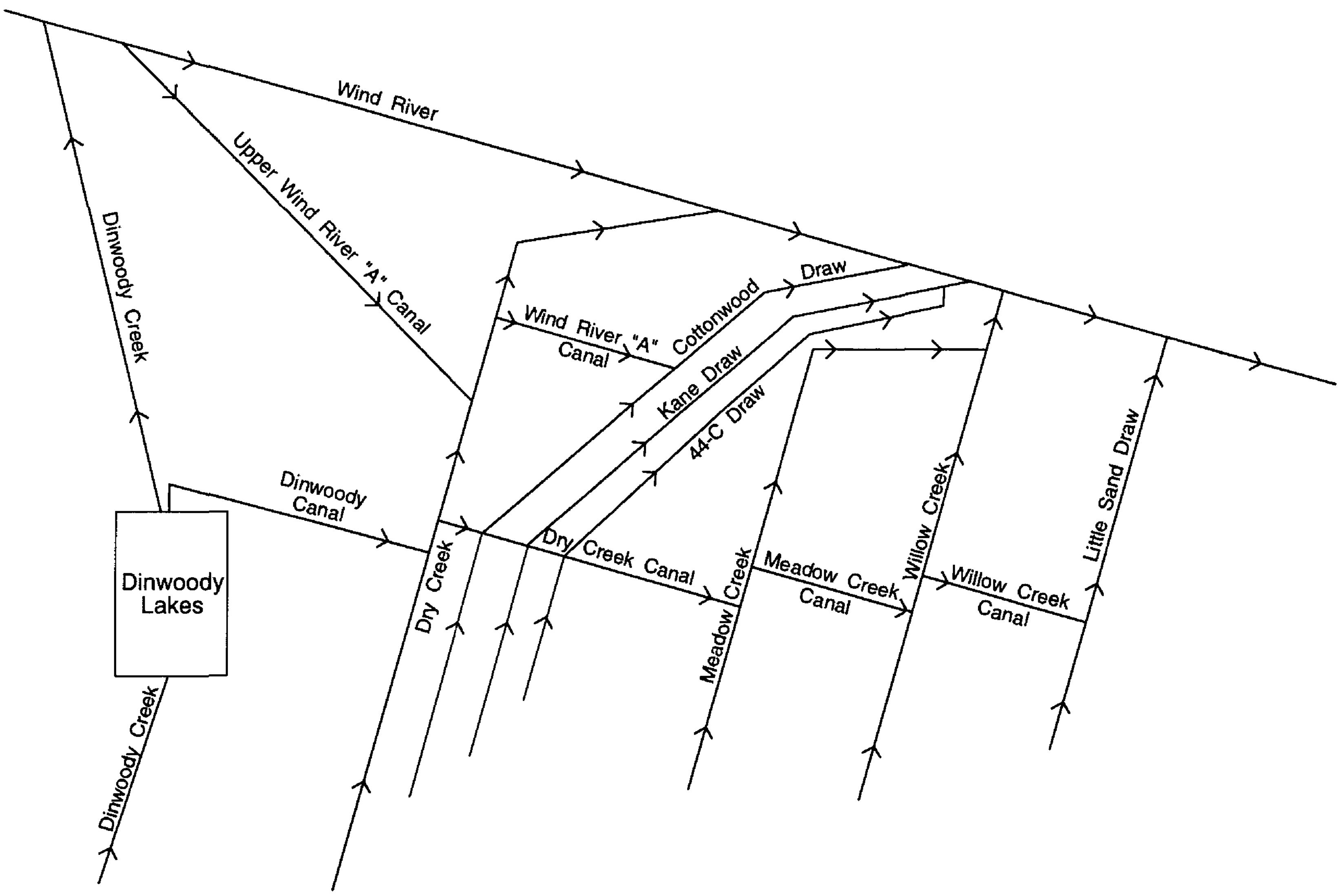


Figure 8. Irrigation network in the Upper Wind Unit.

Fisheries

Water on the reservation has historically contained Yellowstone cutthroat trout, ling (freshwater burbot), sauger, mountain whitefish, suckers, and minnow species (Baldes, 1981). Table 1 lists the various fish species that have been identified on the reservation. Water bodies supporting fish, and the resident species, are listed in Baldes (1981, table 5). Several populations of fish, mostly native species, are important because of their cultural significance, fishery value, or declining status. The ling, a native of many streams and some lakes on the reservation, is a culturally significant species that provides tribal members with an important fishery in several reservation lakes during the winter and in the Wind River and Little Wind River during the spring and fall. Baldes (1981) contends that the ling should be considered an imperiled species on the reservation and probably throughout Wyoming because of habitat losses resulting from reservoir drawdowns and the dewatering of rivers and streams for irrigation purposes.

Aquatic Birds

Wetlands of the Wind River Indian Reservation are extensively used by a variety of resident and migratory aquatic birds (table 2) (Smith, 1982). Information from USFWS databases indicates that these wetlands serve as spring and fall stopover areas for such diverse migratory aquatic birds as swans, cranes, grebes, sandpipers, and a number of diving and dabbling ducks. The wetlands provide nesting habitat for Canada geese, mallards, and other dabbling ducks, and for two heron rookeries (Kathy Firchow, U.S. Fish and Wildlife Service, oral commun., 1993). The wetlands in the study area have not been surveyed to document bird use.

Aquatic birds provide opportunities for bird watching and waterfowl hunting at reservation wetlands. Waterfowl hunting licenses are sold only to tribal members. Thirty licenses were sold during 1992, but no information was gathered on that year's harvest (Kathy Firchow, U.S. Fish and Wildlife Service, written commun., 1993).

Table 1. *Fish species of the Wind River Indian Reservation, central Wyoming* (from Baldes, 1981)

Common name	Species
Yellowstone cutthroat trout	*Salmo clarki*
South Paint Rock cutthroat trout	*Salmo clarki*
Snake River cutthroat trout	*Salmo clarki*
Rainbow trout	*Salmo gairdneri*
Brown trout	*Salmo truttu*
Golden trout	*Salmo aquabonita*
Brook trout	*Salvelinus fontinalis*
Lake trout	*Salvelinus namaycush*
Dolly Varden x Brook trout	*Salvelinus malma x Salvelinus fontinalis*
Mountain whitefish	*Prosopium williamsoni*
Ling	*Lota lota*
White sucker	*Catostomus commersoni*
Longnose sucker	*Catostomus catostomus*
Mountain sucker	*Catostomus platyrhynchus*
Northern red horse	*Moxostoma macrolepidotum*
Black bullhead	*Ictalurus melas*
Stonecat	*Noturus flavus*
Carp	*Cyrpinus carpio*
Creek chub	*Semotilus atromoculatus*
Flathead chub	*Hybopsis gracilis*
Lake chub	*Couesius plumbeus*
Longnose dace	*Rhinichthys cataractae*
Fathead minnow	*Pimephales promelas*
Plains killifish	*Fundulus kansae*
Sauger	*Stizostedion canadense*
Walleye	*Stizostedion vitreum vitreum*
Green sunfish	*Lepomis cyanellus*

Table 2. *Aquatic bird species potentially found on the Wind River Indian Reservation, central Wyoming*
(from Smith, 1982)

Common name	Species	Common name	Species
Common loon	*Gavia immer*	Ruddy duck	*Oxyura jamaicensis*
Red-necked grebe	*Podiceps grisegena*	Hooded merganser	*Lophodytes cucullatus*
Horned grebe	*Podiceps auritus*	Common merganser	*Mergus merganser*
Eared grebe	*Podiceps nigricollis*	Red-breasted merganser	*Mergus serrator*
Western grebe	*Aechmophorus occidentalis*	Sandhill crane	*Grus canadensis*
Pied-billed grebe	*Podilymbus podiceps*	Virginia rail	*Rallus limicola*
American white pelican	*Pelecanus erythrorhynchos*	Sora	*Porzana carolina*
Double-crested cormorant	*Phalacrocorax auritus*	American coot	*Fulica americana*
Great blue heron	*Ardea herodias*	Semipalmated plover	*Charadrius semipalmatus*
Snowy egret	*Egretta thula*	Piping plover	*Charadrius melodus*
Black-crowned night-heron	*Nycticorax nycticorax*	Killdeer	*Charadrius vociferus*
American bittern	*Botaurus lentiginosus*	American golden plover	*Pluvialis dominica*
White-faced ibis	*Plegadis chihi*	Black-bellied plover	*Pluvialis squatarola*
Tundra swan	*Cygnus columbianus*	Common snipe	*Gallinago gallingo*
Trumpeter swan	*Cygnus buccinator*	Long-billed curlew	*Numenius americanus*
Canada goose	*Branta canadensis*	Spotted sandpiper	*Actitis macularia*
Snow goose	*Chen caerulescens*	Solitary sandpiper	*Tinga solitaria*
Mallard	*Anas platyrhynchos*	Willet	*Catoptrophorus semipalmatus*
Gadwall	*Anas strepera*	Greater yellowlegs	*Tringa melanoleuca*
Northern pintail	*Anas acuta*	Lesser yellowlegs	*Tringa flavipes*
Green-winged teal	*Anas crecca*	White-rumped sandpiper	*Calidris fuscicollis*
Blue-winged teal	*Anas discors*	Least sandpiper	*Calidris minutilla*
Cinnamon teal	*Anas cyanoptera*	Long-billed dowitcher	*Limnodromus scolopaceus*
American wigeon	*Anas americana*	Semipalmated sandpiper	*Calidris pusilla*
Northern shoveler	*Anas clypeata*	Western sandpiper	*Calidris mauri*
Wood duck	*Aix sponsa*	Marbled godwit	*Limosa fedoa*
Redhead	*Aythya americana*	Sanderling	*Calidris alba*
Ring-necked duck	*Aythya collaris*	American avocet	*Recurvirostra americana*
Canvasback	*Aythya valisineria*	Black-necked stilt	*Himantopus mexicanus*
Greater scaup	*Aythya marila*	Wilson's phalarope	*Phalaropus tricolor*
Lesser scaup	*Aythya affinis*	Herring gull	*Larus argentatus*
Common goldeneye	*Bucephala clangula*	California gull	*Larus californicus*
Barrow's goldeneye	*Bucephala islandica*	Ring-billed gull	*Larus delawarensis*
Bufflehead	*Bucephala albeola*	Franklin's gull	*Larus pipixcan*
Harlequin duck	*Histrionicus histrionicus*	Forster's tern	*Sterna forsteri*
Black scoter	*Melanitta nigra*	Caspian tern	*Sterna caspia*

SAMPLE COLLECTION, MEASUREMENT, AND ANALYSIS

Sample collection, onsite measurement, and laboratory analysis for the study were conducted by the USGS and USFWS. The Wind River Environmental Quality Commission and the Office of the Tribal Water Engineer provided personnel to assist in planning and sample collection activities.

Sampling and analysis methodologies of water and bottom sediment followed guidelines and procedures established for Phase 2 Reconnaissance Investigations under the NIWQP. Water and bottom-sediment samples were collected and analyzed from selected sites in the four irrigation units by the USGS. Biota samples were collected and analyzed only from the Little Wind Unit irrigation area by the USFWS. Collection sites for water, bottom sediment, and biota were collocated in the Little Wind Unit, and 1993 sampling was coordinated for accuracy and scientific consistency. Bottom sediment and biota samples were collected only in 1993. At least one bottom-sediment sample was collected from each irrigation unit investigated. Biota samples were collected from White Horse Draw Wetland above Trout Creek in the Ray System, Goose Pond and Sharp Nose Pond in the Coolidge System, and Arapahoe Wetlands Pond in the Sub-Agency System.

Water-Quality Samples

Water-quality sampling sites were chosen from each of the four irrigation units to best identify areas where concentrations of chemical constituents, such as selenium, may have been concentrated as a result of irrigation drainage practices and evaporative and bioaccumulation processes. Thirty water-quality sites were sampled in 1992-93. These sites were chosen to be representative of irrigation water in canals, ditches, and drains, and in closed- and open-basin wetlands, marshes, and ponds associated with irrigation drain water. Table 3 lists the sites sampled in the four irrigation units and the types of analyses performed.

Water-quality samples were collected late in the 1992 irrigation season (August-September) and early in the 1993 irrigation season (June). Onsite measurements of air temperature, water temperature, barometric pressure, pH, specific conductance, and dissolved oxygen were made immediately after water-sample collection. Water samples for this study were collected, preserved, and analyzed according to USGS standardized guidelines and quality-control procedures (See and others, 1992; Knapton, 1985; Friedman and Erdmann, 1982). Discharge was measured at sites on creeks, canals, and drains using techniques described in Rantz and others (1982). Samples collected for analyses of organic compounds were filtered onsite through a 0.45-μm (micrometer) acetate filter into 250-mL (milliliter) bottles. Nutrient samples were preserved onsite with mercuric chloride. Dissolved trace-metal samples were filtered through an acetate filter into an acid-rinsed 250-mL bottle and preserved onsite with nitric acid. Dissolved major-ion samples were filtered through an acetate filter into 250-mL bottles. All samples were chilled immediately.

Physical properties (alkalinity, hardness, and dissolved solids), inorganic constituents (major ions, nutrients, and trace elements), and organic compounds (pesticides) were analyzed by the USGS National Water Quality Laboratory in Arvada, Colorado. Laboratory procedures are described in Fishman and Friedman (1989). Table 4 lists the inorganic constituents and organic compounds analyzed in water-quality samples. Trace elements and pesticides were analyzed in this study because of the potential adverse effects of high concentrations of these constituents on wildlife that may use wetlands in the study area.

Bottom-Sediment Samples

Bottom-sediment samples were collected from seven sites in the study area early in the irrigation season of 1993 at the same time water-quality samples were collected. Sampled sites included White Horse Draw Wetland above Trout Creek (site 2), Goose Pond (site 9), Sharp Nose Pond (site 10), and Arapahoe Wetlands Pond (site 17) in the Little Wind Unit; an unnamed wetland near the mouth of St. Stephens drain (site 19) in the Left-Hand Unit; Johnstown Spur Road drain (site 22) in the Johnstown Unit; and Willow Creek above Wind River (site 30) in the Upper Wind Unit (table 3).

Bottom-sediment samples were collected from the upper 5-10 centimeters of bed material in ponds, wetlands, and drains suspected of having high concentrations of chemical constituents. Samples were collected using a stainless steel spoon auger and composited in a stainless steel container. Composite samples consisted of at least five subsamples representing a cross section of bed material at each site. Samples from ponds, marshes, and wetlands were collected near the mouth of the largest inlet channel.

Table 3. *Sampling sites and types of analyses performed on water, bottom-sediment, and biota samples collected from the Wind River Indian Reservation, central Wyoming, 1992-93*

[PP, physical property; IC, inorganic constituent; OC, organic compound; X, sample collected and type of analysis conducted at each site; --, no data collected]

Site number	Location	Station number	Type of analysis						
			Water			Bottom sediment		Biota	
			PP	IC	OC	IC	OC	IC	OC
Fig. 3		**Little Wind Unit**							
	Ray System								
1	Ray Canal at Headworks	06228510	X	X	X	--	--	--	--
2	White Horse Draw Wetland above Trout Creek	425947108495101	X	X	X	X	--	X	--
--	(Alkali Lake upstream from site 2)	--	--	--	--	--	--	X	--
--	(Shaeffer Pond upstream from site 2)	--	--	--	--	--	--	X	
3	Ray Lake Outlet (Ray Lake)	425713108485601	X	X	X	--	--	X	--
4	Unnamed drain to Mill Creek on Ethete Road	425646108473901	X	X	X	--	--	--	--
5	McCaskey Drain above Coolidge Canal	425730108461201	X	X	X	--	--	--	--
	Coolidge System								
6	Coolidge Canal below Trout Creek	430045108480001	X	X	X	--	--	--	--
7	Ethete Drain above Little Wind River	430114108431001	X	X	X	--	--	--	--
8	Lower Hansen Drain above Little Wind River	430015108403601	X	X	X	--	--	--	--
9	Goose Pond	425905108401001	X	X	X	X	X	X	X
10	Sharp Nose Pond	425718108424201	X	X	X	X	X	X	--
11	Sharp Nose Draw above 66-B Lateral	425828108384001	X	X	X	--	--	--	--
12	Sharp Nose Drain above Little Wind River	425901108372101	X	X	X	--	--	--	--
13	Sharp Nose Draw near Mouth	425850108355001	X	X	X	--	--	--	--
14	Sub-Agency Ditch at Aux Gage	425857108352101	X	X	X	--	--	--	--
	Sub-Agency System								
15	Unnamed drain below Weber Feed Lot	425807108315101	X	X	X	--	--	--	--
16	Blue Cloud Road Drain	425803108295601	X	X	X	--	--	--	--
17	Arapahoe Wetlands Pond	425744108294901	X	X	X	X	X	X	X
--	(Little Wind River downstream from site 17)	--	--	--	--	--	--	X	X
18	35-A Drain near Turnout 153	425819108263701	X	X	X	--	--	--	--
		Left-Hand Unit							
19	St. Stephens Drain near Mouth	425852108252201	X	X	X	X	X	--	--
20	Drain below Ore Pile	425923108245301	X	X	X	--	--	--	--
		Johnstown Unit							
21	18-A Drain	430636108410701	X	X	X	--	--	--	--
22	Johnstown Spur Road Drain	430648108413201	X	X	X	X	--	--	--
23	Johnstown Canal at Headworks	06227596	X	X	X	--	--	--	--
Fig. 4		**Upper Wind Unit**							
24	Wind River above Red Creek	06220800	X	X	X	--	--	--	--
25	Dry Creek Canal at Headgate	06222510	X	X	X	--	--	--	--
26	Little Cottonwood Drain	432050109115601	X	X	X	--	--	--	--
27	Cottonwood Draw	432025109115401	X	X	X	--	--	--	--
28	Kane Draw	431945109115501	X	X	X	--	--	--	--
29	44-C Draw	431911109094101	X	X	X	--	--	--	--
30	Willow Creek above Wind River	431758109082301	X	X	X	X	--	--	--

Table 4. *Inorganic constituents and organic compounds analyzed in water samples collected from the Wind River Indian Reservation, central Wyoming, 1992-93*

Inorganic constituent		Organic compound
Major ions (dissolved)	Trace-elements (dissolved)	Dicamba (Mediben) (Banvel D), total
Calcium	Arsenic	Picloram (Tordon) (Amdon), total
Chloride	Boron	2, 4-D, total
Fluoride	Cadmium	2, 4-DP, total
Magnesium	Chromium	2, 4, 5-T, total
Potassium	Copper	Silvex, total
Sodium	Iron	
Sulfate	Lead	
	Mercury	
Nutrients (dissolved)	Molybdenum	
Nitrogen, nitrite	Selenium	
Nitrogen, NO_2+NO_3	Vanadium	
Nitrogen, ammonia	Zinc	
Phosphorus, ortho		

Analyses for major ions and trace elements in bottom-sediment samples were conducted by the USGS, Branch of Geochemistry Laboratory in Denver, Colorado. In addition to these constituents, four of the seven samples (table 3) also were analyzed for organic compounds by the USGS National Water Quality Laboratory in Arvada, Colorado. The analytical techniques and quality controls used in analyzing bottom-sediment samples are described in Stewart and others (1992), Harms and others (1990), and Fishman and Friedman (1989). The minimum reporting levels for inorganic constituents in bottom-sediment samples are given in Stewart and others (1992, table 1, p. 9).

Biota Samples

The USFWS conducted onsite investigations of wetland areas at Alkali Lake, Shaeffer Pond, White Horse Draw Wetland above Trout Creek, Ray Lake, Goose Pond, Sharp Nose Pond, and Arapahoe Wetlands Pond in the Little Wind Unit (fig. 3). The wetland basins, such as Goose Pond, were preferred collection sites for aquatic vegetation, invertebrates, bird livers, bird eggs, and fish because of the potential for evaporative concentration of chemical contaminants. Site selection for avian samples depended upon the occurrence of nesting aquatic birds at or near the wetlands in June 1993. In addition to these wetland areas, the Little Wind River downstream of Arapahoe Wetlands Pond was the preferred collection site for the fisheries resource because of its proximity to irrigation drainage areas and potentially seleniferous geologic materials identified by Case and Cannia (1988). Table 3 lists the sites sampled and the types of analyses performed on biota samples from each site. Onsite evaluations of biota involved surveys for aquatic bird nests and collection of aquatic bird eggs, juvenile aquatic birds, fish, aquatic vegetation, and aquatic invertebrates. The biological media sampled and the number of samples collected in 1993 are listed in table 5. All onsite collections were made following established Biological Section Guidelines of DOI Irrigation Drainage Reconnaissance Study Plans (DOI, written commun., 1987). Site-specific procedures used in this study are described below.

Onsite nest searches were conducted in suitable habitat at Shaeffer Pond, Ray Lake, Goose Pond, Sharp Nose Pond, and Arapahoe Wetlands Pond. Eggs were obtained from nests of the American coot, Sora rail, common snipe, blue-winged teal, and mallard. One bird egg was collected from each nest having a clutch of two or more eggs.

Juvenile pre-fledged gadwalls and blue-winged teal were collected onsite for liver samples using a shotgun and steel shot. Pre-fledged birds were chosen because these birds are incapable of flight and could not have ingested chemical constituents of concern (for example, selenium and mercury) from sources outside the reservation. All birds collected appeared healthy.

Table 5. *Biota sampled, sample type, and number of samples collected and analyzed from the Wind River Indian Reservation, central Wyoming, 1993*

[--, no data]

Biota matrix	Number of sites	Sampla type	Samples collected per site	Samples analyzed	
				Traca elements	Organic compounds
Aquatic birds					
Eggs	2	individual	1,5	6	0
Livers	2	individual	3	6	0
Gastrointestinal tracts	1	composite	1	0	1
Whole body - fish					
Fathead minnow	2	composite	3,4	6	1
Common carp	1	composite	3	3	--
White sucker	1	individual, composite	7	6	1
Aquatic invertebrates					
Water column (damselfly larve, *Odonata*)	3	composite	1	3	0
Benthic (midge larve, *Chironomidae*)	3	composite	1	3	0
Aquatic vegetation					
(various species)	3	composite	1	3	0

Livers and gastrointestinal tracts were removed with acetone-rinsed stainless steel dissection tools, placed in chemically cleansed glass jars, and frozen immediately.

Samples of submerged aquatic vegetation were collected onsite by hand and washed of any sediment or detritus. Samples were identified, placed on ice, and frozen as soon as possible.

Water column invertebrates (damselfly larvae, *Odonata*) were collected onsite using light traps similar to those described by Espinosa and Clark (1972) or with sweep nets. Benthic invertebrates (midge larvae, *Chironomidae*) were picked from bottom grab samples and from surface sweep net samples. Invertebrates were sorted, weighed, stored in chemically cleansed glass vials, and frozen immediately.

Fish were collected onsite using electroshocking equipment, gill nets, minnow traps, or light traps. Fish were measured, wrapped in hexane-rinsed aluminum foil, and frozen immediately. Species collected included fathead minnows, common carp, and white suckers.

Laboratory analyses of biota samples were conducted under contract with the USFWS Patuxent Analytical Control Facility, Laurel, Maryland. Trace elements were analyzed by the Research Triangle Institute in Research Triangle Park, North Carolina. Organic compounds were analyzed by Mississippi State Chemical Laboratory at Mississippi State University, Mississippi. Arsenic and selenium analyses were conducted according to methods described in Krynitsky (1987) using stabilized temperature, platform-graphite furnace, atomic absorption spectroscopy. Analysis for mercury was performed by cold vapor atomic absorption spectrophotometry as described by Monk (1961). Boron, cadmium, and lead were analyzed by inductively coupled plasma-atomic emission spectroscopy using the dry ash procedure described by Haseltine and others (1981). Organophosphates were analyzed using gas chromatography. Biota data, percentage moisture, and dry-weight concentrations presented in this report are those reported by the laboratories. All analyses were reviewed for quality assurance by Patuxent Analytical Control Facility. Data presented were rounded following USGS conventions.

All biota samples were submitted for trace-element analysis. Fish from Arapahoe Wetlands Pond and the Little Wind River, and the gastro-intestinal tract of gadwall from Goose Pond, were submitted for organochlorine analyses. All chemical concentrations for biota in this report are reported in μg/g (micrograms per gram) dry weight unless indicated otherwise.

CHEMICAL CHARACTERISTICS

The results of this field screening are presented below and in tables 6-11. The physical and chemical characteristics of water, bottom sediment, and biota from the sampling sites investigated (table 3) are presented separately.

Water

The physical properties and inorganic-constituent concentrations in water samples collected August-September 1992 and June 1993 are presented in table 6. Of the 30 sites investigated in 1992-93, eight sites were sampled only in 1992, 5 sites were sampled only in 1993, and the remaining 17 sites were sampled in both 1992 and 1993. Organic-compound concentrations for these water-sampling sites are given in table 7.

In samples collected from the study area, trace-element concentrations in the four irrigation units investigated varied more between units rather than within units. In samples collected from the Little Wind Unit, trace-element concentrations were higher in 1993 than in 1992. The highest selenium concentrations detected in water samples from the study area were from the Little Wind Unit. The maximum selenium concentration for samples collected in 1993 was 17 μg/L (site 5). The maximum selenium concentration for samples collected in 1992 was 4 μg/L (sites 13 and 16). Other trace element concentrations in water sampled from the study area followed similar trends. Boron concentrations ranged from 20 to 1,100 μg/L in 1993 and from 10 to 380 μg/L in 1992; lead concentrations ranged from less than 1 to 4 μg/L in 1993 and from less than 1 to 1 μg/L in 1992; mercury concentrations ranged from 0.1 to 4.9 μg/L in 1993 and from less than 0.1 to 0.2 μg/L in 1992; and zinc concentrations ranged from less than 3 to 38 μg/L in 1993 and from less than 3 to 21 μg/L in 1992.

Selenium concentrations in water samples collected in August-September 1992 and June 1993 are shown graphically in figure 9 relative to the U.S. Environmental Protection Agency (USEPA) aquatic-life criterion (5 μg/L) and the fish and wildlife toxicity threshold for waterborne selenium (2 μg/L) as defined by Lemly (1993), Peterson and Nebeker (1992), and Skorupa and Ohlendorf (1991). The Federal fresh-water aquatic-life criterion for selenium is presently a 4-day average concentration of 5 μg/L, no more than once every 3 years on the average, and a 1-hour average concentration of 20 μg/L, no more than once every 3 years on the average (U.S. Environmental Protection Agency, 1988). The USEPA water-quality criteria are not enforceable maximum acceptable concentrations until they are adopted as part of the State of Wyoming water-quality standards.

Of the 18 sites sampled in the Little Wind Unit (fig. 3, sites 1-18), water samples collected at 6 sites in June 1993 had selenium concentrations that equaled or exceeded the 5 μg/L aquatic-life criterion, and water samples collected at 12 sites in August-September 1992 and June 1993 had selenium concentrations that equaled or exceeded the 2 μg/L toxicity threshold. Concentrations of selenium in 1993 were equal to or greater than the 5 μg/L aquatic-life criterion at sites 4 and 5 in the Ray System, and at sites 7, 8, 11, and 12 in the Coolidge System of the Little Wind Unit (fig. 9). For the other three irrigation units of the study area, only one site in the Left-Hand Unit (site 19) had selenium concentrations of 2 μg/L in 1992 and 1993. Samples collected from the remaining sites in the Johnstown Unit and the Upper Wind Unit in both 1992 and 1993 had selenium concentrations that were at or below the minimum reporting level of 1 μg/L.

The highest waterborne selenium concentration of 17 μg/L was obtained from McCaskey Drain above Coolidge Canal (site 5) on June 8, 1993. On this same date, samples collected from an unnamed drain to Mill Creek on Ethete Road (site 4) and from Sharp Nose drain above Little Wind River (site 12) contained selenium concentrations of 7 μg/L and 6 μg/L, whereas water in Lower Hansen drain above Little Wind River (site 8) contained 8 μg/L of selenium on June 10, 1993. Water sampled on June 8, 1993 from the unnamed drain to Mill Creek on Ethete Road (site 4) also had 11,600 μg/L dissolved solids, 2,500 mg/L (milligrams per liter) sodium, 990 μg/L boron, 220 μg/L dissolved iron, and 4 μg/L dissolved lead (table 6). All other water samples had lead concentrations of 1 μg/L or less.

A mercury concentration of 4.9 µg/L[1] was obtained for one water sample collected from Sharp Nose Draw above 66-B Lateral (site 11) on June 8, 1993 (fig. 3, table 6). Mercury concentrations in water at all but three of the other sites sampled in August-September 1992 and June 1993 were less than or equal to 0.1 µg/L. Site 17 in the Little Wind Unit and sites 21 and 23 in the Johnstown Unit had waterborne mercury concentrations of 0.2 µg/L for samples collected in September 1992. Natural (background) concentrations of mercury in rivers and lakes have been reported in the range 0.01 to 0.05 µg/L (maximum) by Fitzgerald (1979).

The USEPA proposed mercury criteria for freshwater aquatic life protection in 1980 and 1985. The 1980 proposed criterion for mercury in freshwater is 0.00057 µg/L (24-hour average), not to exceed 0.0017 µg/L at any time (U.S. Environmental Protection Agency, 1980; Eisler, 1987). The 1985 proposed criterion for mercury in freshwater is 0.012 µg/L medium (4-day average), not to exceed 2.4 µg/L on an hourly average (U.S. Environmental Protection Agency, 1985). For sensitive aquatic species, Eisler (1987, p. 69) reports that freshwater mercury concentrations of 0.1 to 2.0 µg/L are fatal, and contends that concentrations of 0.03 to 0.1 µg/L are associated with significant sublethal effects.

Organic-compound concentrations in water samples collected in 1992 and 1993 are given in table 7. Although water samples from most sites contained concentrations less than the minimum reporting level, a Dicamba (Mediben, Banvel D) concentration of 0.2 µg/L was identified in water sampled from Blue Cloud Road Drain (site 16) and a 2,4-D concentration of 0.17 µg/L was identified in water sampled from 35-A Drain near Turnout 153 (site 18). These sites are in the Sub-Agency System of the Little Wind Unit.

Bottom Sediment

Inorganic constituent concentrations in bottom-sediment samples collected from the four irrigation units investigated in June 1993 are presented in table 8. Of the seven bottom-sediment sampling sites investigated, the highest concentrations of arsenic (11 µg/g), chromium (87 µg/g), manganese (530 µg/g), mercury (0.02 µg/g), selenium (7.5 µg/g), uranium (14.7 µg/g), and zinc (100 µg/g) occurred at either Goose Pond (site 9) or Sharp Nose Pond (site 10) in the Coolidge System of the Little Wind Unit irrigation area (fig. 3). Conversely, the lowest concentrations of these elements, except chromium, occurred in either Left-Hand Unit, Johnstown Unit, or Upper Wind Unit (table 8).

Selenium concentrations in bottom-sediment samples from the Johnstown Unit and the Upper Wind Unit were 0.3 and 0.1 µg/g (table 8). Higher selenium concentrations of 0.7 and 1.2 µg/g were detected in bottom sediment sampled from White Horse Draw Wetland above Trout Creek (site 2) in the Ray System of the Little Wind Unit and from St. Stephens Drain near mouth (site 19) in the Left-Hand Unit. For comparison, average selenium concentrations in bottom-sediment samples collected and analyzed from other DOI-investigated sites in 1988-90 (Stewart and others, 1992) were 0.47 µg/g--about twice that for soil (0.23 µg/g) in the Western United States.

Arsenic concentrations in bottom sediment were highest (11 and 7.1 µg/g), respectively, at Sharp Nose Pond (site 10) and White Horse Draw Wetland above Trout Creek (site 2) in the Little Wind Unit (table 8). These concentrations exceed the average arsenic concentration of 5.3 µg/g reported for other DOI-investigated sites in the West (Stewart and others, 1992). Goose Pond (site 9) in the Little Wind Unit had the highest uranium concentration (14.7 µg/g) and the highest selenium concentration (7.5 µg/g) of all bottom-sediment samples from the study area (table 8).

The concentrations of organic compounds in bottom sediment from four of the seven sites sampled in June 1993 are presented in table 9. Concentrations of organic compounds in bottom sediment from the Little Wind Unit and the Left-Hand Unit were less than the minimum reporting levels (table 9).

Biota

The concentrations of trace elements and organic compounds in biota samples collected from the Little Wind Unit irrigation area in June 1993 are presented in tables 10 and 11. Results of analyses show that trace-element concentrations in biota were generally low, with many being at or less than the minimum reporting levels. For organic compounds, all reported concentrations were less than the minimum reporting levels.

[1] The reported high concentration of mercury in water from Sharp Nose Draw (site 11) should be considered a preliminary value and be regarded with caution unless confirmed by additional sampling and analysis.

Table 6. *Physical properties and inorganic-constituent concentrations in water*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm of Hg, millimeters of mercury; ton/d,

Site number	Station number	Date sampled	Altitude (feet above sea level)	Discharge, instantaneous (ft^3/s)	Specific conductance, field (µS/cm)	pH, whole water (standard units)	Temperature, air (°C)
Fig. 3							Little Wind
1	06228510	08/10/92	5,710	185	77	8.4	--
2	425947108495101	06/07/93	5,480	.53	4,380	8.1	14.0
3	425713108485601	08/10/92	5,520	17	762	8.5	24.0
		06/08/93		.14	1,610	8.9	12.0
4	425646108473901	08/11/92	5,480	1.3	1,110	8.1	27.0
		06/08/93		.03	1,200	8.3	9.0
5	425730108461201	08/11/92	5,420	.20	1,220	7.6	24.0
		06/08/93		<.10	4,340	7.6	12.0
6	430045108480001	08/11/92	5,440	42	315	8.3	22.0
7	430114108431001	08/11/92	5,260	.30	1,270	8.2	33.0
		06/08/93		1.2	2,100	8.1	11.0
8	430015108403601	08/12/92	5,210	3.4	1,960	8.0	--
		06/10/93		4.0	2,280	8.2	18.0
9	425905108401001	06/10/93	5,210	--	1,030	8.3	15.0
10	425718108424201	06/10/93	5,400	--	236	9.1	19.0
11	425828108384001	06/08/93	5,200	2.4	2,650	8.3	15.5
12	425901108372101	08/12/92	5,150	5.3	1,170	8.1	20.5
		06/08/93		2.4	1,310	8.7	14.0
13	425850108355001	08/12/92	5,100	3.2	1,390	8.2	24.0
14	425857108352101	08/12/92	5,120	61	737	8.6	22.5
15	425807108315101	06/09/93	5,050	.40	1,010	8.2	16.0
16	425803108295601	08/12/92	5,040	3.2	1,050	8.0	31.0
		06/09/93		1	1,140	8.3	19.5
17	425744108294901	08/12/92	5,000	--	1,100	8.1	31.0
		09/09/92		--	1,140	8.1	17.5
		06/09/93		--	1,270	8.1	21.5
18	425819108263701	08/12/92	4,960	1.6	1,430	8.0	27.5
		06/09/93		1.0	1,620	8.9	23.0
							Left-Hand
19	425852108252201	08/13/92	4,930	2.9	1,160	8.1	20.0
		06/09/93		6.5	977	8.5	20.5
20	425923108245301	08/13/92	4,940	1.5	914	7.8	22.0
		06/09/93		2.8	1,170	7.9	21.0
		06/23/93		1.6	1,450	--	--
							Johnstown
21	430636108410701	09/09/92	5,230	<.10	740	7.9	18.0
		06/07/93		<.10	748	7.6	17.0
22	430648108413201	09/09/92	5,245	.69	618	7.8	18.5
		06/07/93		.37	627	8.1	13.0
23	06227596	09/08/92	5,300	11	231	8.6	22.5
Fig. 4							Upper Wind
24	06220800	08/20/92	6,400	367	253	8.6	27.0
25	06222510	08/20/92	6,360	204	40	8.2	21.0
26	432050109115601	08/21/92	5,930	21	408	8.4	22.0
27	432025109115401	08/21/92	5,950	22	537	8.3	22.0
		06/10/93		9.5	520	8.5	20.5
28	431945109115501	08/24/92	5,980	15	342	8.2	12.0
		06/10/93		1.2	380	8.3	16.0
29	431911109094101	08/24/92	5,860	15	383	8.4	12.5
		06/12/93		5.7	469	8.5	15.5
30	431758109082301	08/24/92	5,835	28	339	8.6	15.5
		06/12/93		58	149	8.4	16.5

samples collected from the Wind River Indian Reservation, central Wyoming, 1992-93

tons per day; analytical results in milligrams per liter except as indicated; µg/L, micrograms per liter; <, less than minimum reporting level; --, no data]

Temperature, water (°C)	Barometric pressure (mm of Hg)	Oxygen, dissolved	Oxygen, dissolved (percent saturation)	Hardness, total ($CaCO_3$)	Calcium, dissolved (Ca)	Magnesium, dissolved (Mg)	Sodium, dissolved (Na)
Unit							
21.0	616	6.9	96	34	9.1	2.7	1.8
10.0	616	9.1	102	1,780	300	250	530
21.0	621	7.1	99	244	53	27	67
15.0	620	11.0	135	406	77	52	200
23.0	626	8.2	118	286	50	39	140
12.0	620	11.2	129	2,590	280	460	2,500
22.5	626	6.4	91	613	130	70	43
13.0	621	6.1	72	2,700	520	340	260
18.0	627	8.0	103	125	32	11	15
18.5	630	7.9	103	448	110	42	110
12.0	626	9.2	104	854	200	86	220
11.0	631	8.9	98	820	190	84	150
15.0	634	8.4	101	986	230	100	180
15.0	631	7.4	89	407	74	54	65
18.0	629	9.4	121	84	21	7.7	12
17.0	630	8.0	101	960	170	130	300
12.0	632	9.9	111	451	98	50	81
14.0	630	14.8	175	538	110	64	97
13.5	633	8.7	101	474	99	55	130
19.0	631	10.0	131	287	67	29	46
14.0	636	8.2	96	398	100	36	60
17.0	635	10.2	128	390	100	34	79
16.0	635	9.6	118	419	110	35	91
20.0	635	15.0	200	399	92	41	92
15.0	636	8.8	105	448	110	42	92
19.5	637	6.5	85	446	88	55	100
17.0	634	7.2	90	460	120	39	140
21.0	637	18.2	247	506	120	50	170
Unit							
13.0	635	8.4	96	402	110	31	98
21.0	636	8.5	115	307	80	26	88
17.0	636	5.2	65	289	81	21	89
18.5	635	6.5	84	327	93	23	130
19.0	--	--	--	--	--	--	--
Unit							
10.0	633	9.2	99	357	110	20	28
12.0	620	2.4	28	246	59	24	63
18.5	632	13.0	168	301	91	18	21
12.5	620	11.6	134	303	90	19	19
16.0	620	9.1	114	98	27	7.5	11
Unit							
17.0	600	7.8	103	112	31	8.5	8.5
18.0	600	7.8	105	17	4.8	1.3	.7
18.0	610	10.4	138	191	50	16	14
18.0	606	7.2	96	237	62	20	26
19.5	615	7.6	103	221	57	19	24
13.0	610	8.7	104	147	39	12	21
16.5	613	7.8	100	158	42	13	21
16.0	613	7.9	100	171	42	16	21
12.5	618	9.0	105	198	48	19	27
18.0	615	8.0	105	164	46	12	7.2
13.5	616	8.5	101	70	20	4.9	3.1

Site number	Date sampled	Sodium (parcant)	Sodium adsorption ratio	Potassium, dissolvad (K)	Alkalinity, laboratory (as $CaCO_3$)	Sulfate, dissolved (SO_4)	Chlorida, dissolved (Cl)
Fig. 3							Little Wind
1	08/10/92	10	0.1	0.6	35	3.9	1.4
2	06/07/93	39	5.5	7.6	408	2,500	22
3	08/10/92	37	1.9	2.1	113	260	7.3
	06/08/93	51	4.3	3.5	125	720	13
4	08/11/92	51	3.6	3.3	201	370	7.3
	06/08/93	68	21.4	20	437	7,500	96
5	08/11/92	13	.8	3.3	128	540	15
	06/08/93	17	2.2	9.2	348	2,700	10
6	08/11/92	20	.6	1.4	89	67	3.6
7	08/11/92	35	2.3	4.2	229	450	9.3
	06/08/93	36	3.3	5.7	320	920	22
8	08/12/92	28	2.3	4.4	215	810	67
	06/10/93	28	2.5	5.6	250	1,100	18
9	06/10/93	25	1.4	5.2	117	430	6.9
10	06/10/93	23	.6	3.6	75	43	2.8
11	06/08/93	40	4.2	8.5	191	1,300	38
12	08/12/92	28	1.7	4.3	237	360	9.6
	06/08/93	28	1.8	2.6	246	480	9.3
13	08/12/92	37	2.6	6.7	262	470	17
14	08/12/92	26	1.2	2.6	162	210	7.2
15	06/09/93	24	1.3	5.2	266	260	15
16	08/12/92	30	1.7	3.9	248	300	9.1
	06/09/93	32	1.9	2.2	142	360	7.3
17	08/12/92	33	2.0	3.5	255	320	9.6
	09/09/92	31	1.9	3.9	301	320	9.7
	06/09/93	32	2.1	9.2	273	410	16
18	08/12/92	40	2.8	4.7	260	440	23
	06/09/93	42	3.3	5.7	261	610	22
							Left-Hand
19	08/13/92	34	2.1	2.9	287	310	11
	06/09/93	38	2.2	2.4	176	320	20
20	08/13/92	40	2.3	3.7	280	200	12
	06/09/93	46	3.1	5.8	233	380	10
	06/23/93	--	--	--	--	--	--
							Johnstown
21	09/09/92	14	.6	5.2	332	89	6.7
	06/07/93	35	1.7	11	170	290	16
22	09/09/92	13	.5	4.1	288	53	4.5
	06/07/93	12	.5	3.8	272	56	2.7
23	09/08/92	19	.5	1.6	89	35	3.3
Fig. 4							Upper Wind
24	08/20/92	14	.3	2.5	114	22	1.5
25	08/20/92	8	.1	.6	19	2.5	.2
26	08/21/92	14	.4	2.6	170	55	1.0
27	08/21/92	19	.7	2.6	225	75	1.4
	06/10/93	19	.7	2.2	149	110.	3.1
28	08/24/92	23	.8	1.8	174	18	.6
	06/10/93	22	.7	2.4	172	28	1.8
29	08/24/92	21	.7	2.2	200	16	.7
	06/12/93	23	.8	1.8	233	23	1.5
30	08/24/92	9	.2	1.2	119	64	.7
	06/12/93	9	.2	.8	55	21	.8

samples collected from the Wind River Indian Reservation, central Wyoming, 1992-93--Continued

Fluoride, dissolved (F)	Dissolved solids (residue at 180°C)	Dissolved solids (sum of constituents)	Dissolved solids (tons per acre-feet)	Dissolved solids, (ton/d)	Nitrite, dissolved (as N)	$NO_2 + NO_3$, dissolved (as N)	Ammonia, dissolved (as N)
Unit							
<0.1	39	40	0.1	19.5	<0.01	<0.05	0.01
.8	4,260	3,860	5.8	6.10	<.01	.13	.05
.2	477	485	.6	21.9	<.01	.06	.01
.2	1,190	1,141	1.6	.45	<.01	.14	.02
.2	764	741	1.0	2.68	<.01	<.05	.04
15	11,600	11,100	15.8	.94	<.01	<.05	.05
.4	918	879	1.2	.50	<.01	<.05	.02
.5	4,420	4,050	6.0	--	<.01	.17	.11
.2	175	187	.2	19.9	<.01	<.05	.01
.7	892	869	1.2	.72	<.01	<.05	.01
1	1,720	1,650	2.3	5.57	<.01	.65	.03
.7	1,550	1,440	2.1	14.2	<.01	.29	.01
.7	1,970	1,790	2.7	21.3	<.01	.50	.06
.3	744	706	1.0	--	<.01	<.05	.03
.1	145	135	.2	--	<.01	<.05	.03
.4	2,230	2,070	3.0	14.5	<.01	.66	.05
.9	788	748	1.1	11.3	.02	.52	.01
.8	978	915	1.3	6.34	.01	.86	.02
.5	988	941	1.3	8.54	.02	1.2	.03
.5	425	460	.6	70	<.01	<.05	.01
.7	712	656	1.0	.77	.03	4.3	.18
.8	721	686	1.0	6.23	.01	2.3	.03
.8	822	704	1.1	2.22	.02	2.8	.05
.8	740	712	1.0	--	<.01	<.05	.04
.9	784	759	1.1	--	<.01	<.05	.04
.6	926	843	1.3	--	<.01	.06	.05
.6	1,000	936	1.4	4.32	.02	2.9	.03
.6	1,170	1,140	1.6	3.16	<.01	.28	.03
Unit							
.7	794	738	1.1	6.22	<.01	.56	.03
.5	689	643	.9	12.1	<.01	.17	.05
.6	601	575	.8	2.43	<.01	<.05	.01
.5	808	783	1.1	6.11	<.01	.06	.03
--	--	--	--	--	--	--	--
Unit							
.4	458	466	.6	--	<.01	1.8	.02
.2	673	566	.9	--	<.01	<.05	.04
.3	389	365	.5	.73	<.01	.07	.03
.3	397	358	.5	.40	<.01	.91	.02
.2	132	139	.2	3.92	<.01	<.05	.02
Unit							
.2	157	143	.2	156	<.01	<.05	.02
<.1	21	22	.03	11.6	<.01	<.05	.03
.3	240	241	.3	13.6	<.01	<.05	.02
1	340	324	.5	20.2	<.01	.22	.03
.6	332	306	.5	8.52	<.01	.07	.03
.7	212	198	.3	8.59	<.01	.07	.02
.7	230	213	.3	.75	<.01	.11	.03
.6	240	219	.3	9.72	<.01	.12	.01
.7	283	262	.4	4.36	<.01	.19	.03
.3	214	203	.3	16.2	<.01	<.05	.02
.1	93	84	.1	14.6	<.01	<.05	.02

Table 6. *Physical properties and inorganic-constituent concentrations in water*

Sita number	Data samplad	Nitrogen, ammonia, diasolved (as NH_4)	Phosphorus, ortho, dissolved (as P)	Phosphata, ortho, dissolvad (PO_4)	Arsenic, dissolved (µg/L as As)	Boron, dissolvad (µg/L as B)	Cadmium, dissolvad (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)
Fig. 3								Little Wind
1	08/10/92	--	0.01	0.03	<1	310	<1	10
2	06/07/93	0.06	.03	.09	1	1,100	<1	<1
3	08/10/92	.01	<.01	--	<1	90	<1	<1
	06/08/93	.03	<.01	--	<1	150	<1	<1
4	08/11/92	.05	.15	.46	2	190	<1	<1
	06/08/93	.06	.07	.22	2	990	<1	<3
5	08/11/92	.03	.04	.12	1	80	<1	<1
	06/08/93	.14	.01	.03	1	290	<1	<1
6	08/11/92	--	.02	.06	1	80	<1	<1
7	08/11/92	.01	.05	.15	1	290	<1	<1
	06/08/93	.04	.02	.06	<1	450	<1	<1
8	08/12/92	.01	<.01	--	<1	380	<1	<1
	06/10/93	.08	<.01	--	<1	490	<1	<1
9	06/10/93	.04	.02	.06	2	200	<1	<1
10	06/10/93	.04	.04	.12	1	60	<1	<1
11	06/08/93	.06	.01	.03	<1	270	<1	1
12	08/12/92	--	.02	.06	<1	180	<1	<1
	06/08/93	.03	<.01	--	<1	230	<1	1
13	08/12/92	.04	.17	.52	2	230	<1	<1
14	08/12/92	--	.01	.03	1	120	<1	<1
15	06/09/93	.23	.08	.25	3	140	<1	<1
16	08/12/92	.04	.07	.22	2	160	<1	<1
	06/09/93	.06	.02	.06	3	150	<1	<1
17	08/12/92	.05	<.01	--	2	190	<1	<1
	09/09/92	.05	<.01	--	2	170	<1	<1
	06/09/93	.06	.01	.03	<1	190	<1	<1
18	08/12/92	.04	.05	.15	2	250	<1	<1
	06/09/93	.04	.03	.09	2	240	<1	<1
								Left-Hand
19	08/13/92	.04	.03	.09	3	160	<1	<1
	06/09/93	.06	.03	.09	2	110	<1	<1
20	08/13/92	--	.02	.06	2	120	<1	<1
	06/09/93	.04	.03	.09	2	120	<1	<1
	06/23/93	--	--	--	--	--	--	--
								Johnstown
21	09/09/92	.03	<.01	--	2	60	2	<1
	06/07/93	.05	.24	.74	1	100	<1	<1
22	09/09/92	.04	.02	.06	2	70	<1	<1
	06/07/93	.03	<.01	--	1	70	<1	<1
23	09/08/92	.03	<.01	--	1	20	1	<1
Fig. 4								Upper Wind
24	08/20/92	.03	.02	.06	1	20	<1	<1
25	08/20/92	.04	<.01	--	<1	10	<1	<1
26	08/21/92	.03	.03	.09	1	50	<1	<1
27	08/21/92	.04	.03	.09	1	110	<1	<1
	06/10/93	.04	.05	.15	1	100	<1	<1
28	08/24/92	.03	.02	.06	1	70	<1	<1
	06/10/93	.04	.02	.06	<1	80	<1	<1
29	08/24/92	.01	.02	.06	1	70	<1	<1
	06/12/93	.04	.01	.03	1	90	<1	<1
30	08/24/92	.03	<.01	--	1	30	<1	<1
	06/12/93	.03	<.01	--	<1	20	<1	<1

samples collected from the Wind River Indian Reservation, central Wyoming, 1992-93--Continued

Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L es Fe)	Lead, dissolved (µg/L as Pb)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Selenium, dissolved (µg/L as Se)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)
Unit							
1	--	<1	<0.1	<1	<1	1.6	21
1	37	<1	<.1	2	2	2.2	<10
1	--	<1	<.1	1	2	2.2	4
1	3	<1	<.1	1	2	<1.0	5
1	--	<1	<.1	<1	<1	8.9	6
2	220	4	<.1	2	7	11	<10
1	--	<1	<.1	1	3	5.1	<3
<1	280	<1	<.1	1	17	<1.0	<10
1	--	<1	.1	<1	<1	2.6	6
<1	--	<1	.1	1	<1	3.5	<3
<1	3	<1	<.1	2	5	1.2	<10
<1	--	<1	.1	3	3	1.8	<3
<1	4	<1	<.1	3	8	<1.0	<10
<1	15	<1	<.1	<1	<1	1.7	<3
2	45	<1	<.1	<1	<1	3.5	4
<1	23	<1	4.9	<1	5	2.2	<10
1	--	<1	<.1	3	3	3.1	3
<1	8	<1	.1	3	6	1.3	5
<1	--	<1	<.1	2	4	4.8	5
<1	--	<1	.1	1	1	3.0	<3
3	33	<1	.1	<1	2	11	<3
1	--	<1	<.1	2	4	12	5
1	5	<1	<.1	2	4	13	<3
<1	--	<1	<.1	2	<1	6	3
2	--	<1	.2	1	1	3.3	<3
<1	22	<1	<.1	<1	<1	2.5	10
2	--	<1	<.1	2	3	5.2	8
1	25	<1	<.1	<1	2	4.0	7
Unit							
<1	--	<1	<.1	2	2	11	4
2	13	<1	<.1	<1	2	8.7	<3
<1	--	<1	<.1	1	<1	5.0	5
2	130	1	<.1	2	<1	4.2	38
--	--	--	--	--	--	--	--
Unit							
<1	--	<1	.2	<1	<1	2.2	<3
1	180	1	<.1	1	<1	6.1	17
2	--	<1	<.1	2	1	5.8	<3
2	3	<1	<.1	1	1	4.8	5
1	--	<1	.2	<1	<1	1.9	<3
Unit							
1	--	<1	<.1	<1	<1	2.9	5
<1	--	<1	<.1	<1	<1	<1.0	<3
1	--	1	<.1	1	<1	3.8	4
1	--	<1	<.1	4	1	4.5	<3
1	12	1	<.1	3	<1	4.9	<3
<1	--	<1	<.1	2	<1	3.1	<3
1	33	<1	<.1	3	<1	4.6	<3
<1	--	<1	<.1	1	<1	6.4	4
1	15	<1	<.1	1	<1	7.9	<3
<1	--	<1	<.1	1	<1	2.1	6
1	44	<1	<.1	<1	<1	2.2	<3

Table 7. *Organic-compound concentrations in water samples collected from the Wind River Indian Reservation, central Wyoming, 1992-93*

[μg/L, micrograms per liter; <, less than minimum reporting level; --, no data]

Site number	Station number	Date sampled	Dicamba (Mediben) (Banvel D) total (μg/L)	Picloram (Tordon) (Amdon) total (μg/L)	2,4-D, total (μg/L)	2,4-DP, total (μg/L)	2,4,5-T, total (μg/L)	Silvex, total (μg/L)
Fig. 3				**Little Wind Unit**				
1	06228510	08/10/92	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	425947108495101	06/07/93	<.01	<.01	<.01	<.01	<.01	<.01
3	425713108485601	08/10/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/08/93	<.01	<.01	<.01	<.01	<.01	<.01
4	425646108473901	08/11/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/08/93	<.01	<.01	<.01	<.01	<.01	<.01
5	425730108461201	08/11/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/08/93	<.01	<.01	<.01	<.01	<.01	<.01
6	430045108480001	08/11/92	<.01	<.01	<.01	<.01	<.01	<.01
7	430114108431001	08/11/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/08/93	<.01	<.01	<.01	<.01	<.01	<.01
8	430015108403601	08/12/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/10/93	<.01	<.01	<.01	<.01	<.01	<.01
9	425905108401001	06/10/93	<.01	<.01	<.01	<.01	<.01	<.01
10	425718108424201	06/10/93	<.01	<.01	<.01	<.01	<.01	<.01
11	425828108384001	06/08/93	<.01	<.01	<.01	<.01	<.01	<.01
12	425901108372101	08/12/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/08/93	<.01	<.01	<.01	<.01	<.01	<.01
13	425850108355001	08/12/92	<.01	<.01	<.01	<.01	<.01	<.01
14	425857108352101	08/12/92	<.01	<.01	<.01	<.01	<.01	<.01
15	425807108315101	06/09/93	<.01	<.01	<.01	<.01	<.01	<.01
16	425803108295601	08/12/92	.20	<.01	<.01	<.01	<.01	<.01
		06/09/93	<.01	<.01	<.01	<.01	<.01	<.01
17	425744108294901	08/12/92	--	--	--	--	--	--
		09/09/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/09/93	<.01	<.01	<.01	<.01	<.01	<.01
18	425819108263701	08/12/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/09/93	<.01	<.01	.17	<.01	<.01	<.01
				Left-Hand Unit				
19	425852108252201	08/13/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/09/93	<.01	<.01	<.01	<.01	<.01	<.01
20	425923108245301	08/13/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/09/93	--	--	--	--	--	--
		06/23/93	<.01	<.01	<.01	<.01	<.01	<.01
				Johnstown Unit				
21	430636108410701	09/09/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/07/93	<.01	<.01	<.01	<.01	<.01	<.01
22	430648108413201	09/09/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/07/93	<.01	<.01	<.01	<.01	<.01	<.01
23	06227596	09/08/92	<.01	<.01	<.01	<.01	<.01	<.01
Fig. 4				**Upper Wind Unit**				
24	06220800	08/20/92	<.01	<.01	<.01	<.01	<.01	<.01
25	06222510	08/20/92	<.01	<.01	<.01	<.01	<.01	<.01
26	432050109115601	08/21/92	<.01	<.01	<.01	<.01	<.01	<.01
27	432025109115401	08/21/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/10/93	<.01	<.01	<.01	<.01	<.01	<.01
28	431945109115501	08/24/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/10/93	<.01	<.01	<.01	<.01	<.01	<.01
29	431911109094101	08/24/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/12/93	<.01	<.01	<.01	<.01	<.01	<.01
30	431758109082301	08/24/92	<.01	<.01	<.01	<.01	<.01	<.01
		06/12/93	<.01	<.01	<.01	<.01	<.01	<.01

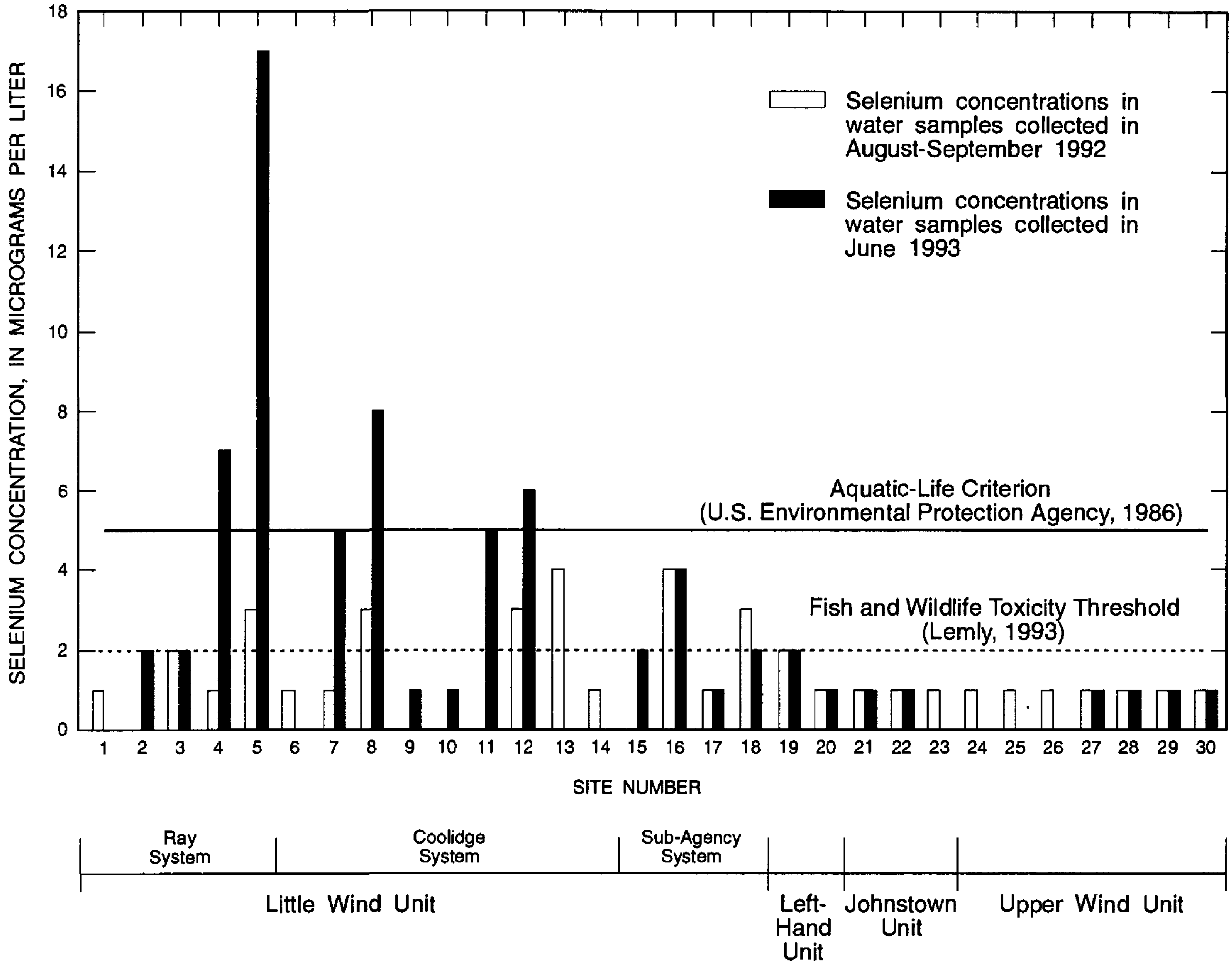


Figure 9. Selenium concentrations in water sampled at sites 1-30, Wind River Federal Irrigation Project, Wind River Indian Reservation, 1992-93. Minimum reporting level is 1 microgram per liter. Site numbers are keyed to figures 3 and 4.

The following discussion focuses on those areas having samples with elevated trace-element concentrations. Concentrations are given in dry weight in table 10, and in wet weight in table 11. Both dry-weight and wet-weight concentrations are given in the discussion in the following sections where concentrations are compared with cited references. Dry-weight and moisture percentage values, given in table 10, can be used to convert dry-weight concentrations to their wet-weight equivalents. The conversion is done by multiplying the dry-weight concentration by, 1 minus the percentage sample moisture expressed as its decimal equivalent.

Submerged Aquatic Vegetation

Submerged aquatic vegetation is an important dietary item for many species of dabbling ducks and for some diving ducks (Bellrose, 1980). Pondweed (*Potamogeton* spp.) and muskgrass (*Chara* spp.) are the dominant species of submerged aquatic vegetation observed in wetlands of the Wind River.

Most selenium concentrations in aquatic vegetation collected from the Little Wind Unit were below established levels of concern, except for a pondweed sample collected at Goose Pond (table 10). At Goose Pond (site 9), the selenium concentration of 4.82 µg/g dry weight from pondweed was slightly higher than that known to cause adverse effects for waterfowl (Lemly and Smith, 1987; Lemly 1993). This pondweed sample from Goose Pond also had the highest concentration of boron in the study area (457 µg/g dry weight). Other boron concentrations in aquatic vegetation from the Little Wind Unit study area (table 10) were 28.9 µg/g dry weight for muskgrass from Arapahoe Wetlands Pond (site 17) and 21.7 µg/g dry

Table 8. *Inorganic-constituent concentrations in bottom-sediment samples collected from the Wind River Indian Reservation, central Wyoming, 1993*

[Analytical results in micrograms per gram (µg/g) unless indicated otherwise; <, less than minimum reporting level]

	Little Wind Unit				Left-Hend Unit	Johnstown Unit	Upper Wind Unit
	Site number (fig. 3)						Site number (fig. 4)
Inorganic constituent	2	9	10	17	19	22	30
Date sampled	06/07/93	06/10/93	06/10/93	06/09/93	06/09/93	06/07/93	06/12/93
Major ions							
Calcium (percent)	2.3	4.9	1.5	4.0	2.8	3.7	1.9
Potassium (percent)	2.0	1.4	2.2	2.2	2.0	2.0	1.7
Magnesium (percent)	1.30	.56	1.20	.92	.56	1.10	.54
Sodium (percent)	.85	1.00	.48	1.50	1.90	1.90	1.70
Nutrient							
Phosphorus (percent)	.11	.07	.09	.06	.05	.08	.07
Trace elements							
Aluminium (percent)	5.7	3.8	6.5	6.4	6.1	6.4	5.3
Arsenic	7.1	4.0	11	3.7	2.8	1.8	1.9
Barium	550	520	860	770	840	1,100	580
Beryllium	2	<1	2	1	1	1	1
Bismuth	<10	<10	<10	<10	<10	<10	<10
Boron	3.3	3.9	.8	1.3	.8	.4	.3
Cadmium	<2	<2	<2	<2	<2	<2	<2
Cerium	56	36	59	62	45	78	36
Chromium	42	24	87	44	33	67	49
Cobalt	7	6	11	7	6	10	6
Copper	15	7	15	11	9	14	5
Europium	<2	<2	<2	<2	<2	<2	<2
Gallium	13	9	14	14	14	14	11
Gold	<8	<8	<8	<8	<8	<8	<8
Iron (percent)	2.1	1.5	2.9	2.3	1.3	1.9	1.3
Holmium	<4	<4	<4	<4	<4	<4	<4
Lanthanum	32	21	34	34	26	45	23
Lead	16	14	14	16	15	17	13
Lithium	28	10	48	22	13	11	11
Manganese	370	530	270	400	190	310	270
Mercury	<.02	<.02	.02	<.02	<.02	<.02	<.02
Molybdenum	<2	<2	<2	<2	<2	<2	<2
Neodymium	25	18	28	29	20	32	15
Nickel	15	8	30	15	12	24	16
Riobium	12	5	13	10	6	7	5
Scandium	7	3	11	6	4	6	4
Selenium	.7	7.5	.4	.4	1.2	0.3	0.1
Silver	<2	<2	<2	<2	<2	<2	<2
Strontium	230	420	150	360	440	510	170
Tantalum	<40	<40	<40	<40	<40	<40	<40
Thorium	10	<5	11	14	8	16	8
Tin	<5	<5	<5	<5	<5	<5	<5
Titanium (percent)	.19	.10	.26	.20	.14	.20	.16
Uranium	3.5	14.7	3.3	2.9	2.8	2.4	1.5
Vanadium	56	32	170	60	33	53	34
Ytterbium	2	1	2	2	1	1	<1
Yttrium	19	10	18	16	10	11	10
Zinc	66	30	100	46	34	45	23

Table 9. *Organic-compound concentrations in bottom-sediment samples collected from the Wind River Indian Reservation, central Wyoming, 1993*

[µg/L, micrograms per liter; µg/kg, micrograms per kilogram; <, less than minimum reporting level]

Organic compound	Little Wind Unit Fig. 3			Left-Hand Unit
	Site 9	Site 10	Site 17	Site 19
Date sampled	06/10/93	06/10/93	06/09/93	06/09/93
Dicamba (Mediben) (Banvel D), bottom material, total recovery dry weight (µg/kg)	<10	<10	<10	<10
Picloram (Tordon) (Amdon), bottom material, total recovery dry weight (µg/kg)	<10	<10	<10	<10
2,4-D, total in bottom material (µg/kg)	<10	<10	<10	<10
2,4-DP in bottom material (µg/kg)	<10	<10	<10	<10
2,4,5-T total in bottom material (µg/kg)	<10	<10	<10	<10
Silvex, total in bottom material (µg/kg)	<10	<10	<10	<10

weight for pondweed from Sharp Nose Pond (site 10). Although the effects of boron on waterfowl reproduction are not well documented, concentrations of 300 µg/g dry weight and greater are commonly viewed as concentrations of concern (Patuxent Wildlife Research Center, 1986; Smith and Anders, 1989).

Aquatic Invertebrates

Aquatic invertebrates inhabited all study area ponds where samples of biota were collected. Aquatic invertebrates, such as damselfly *(Odonata)* and midge fly *(Chironomidae)* larvae, are often consumed by several fish species and are a common dietary item for many species of waterfowl and shorebirds (Bellrose, 1980; Bent, 1962; Richards, 1988). Aquatic invertebrates are an important dietary item for nesting hens and young birds (Welty and Baptista, 1988; Woodin and Swanson, 1989).

All trace elements, except selenium, in aquatic invertebrates were at concentrations less than those that are reported to cause adverse effects to fish and wildlife, or were at concentrations less than the minimum reporting level (table 10). Selenium concentrations in aquatic invertebrates ranged from less than the minimum reporting level (less than 1.01 µg/g dry weight) at White Horse Draw Wetland above Trout Creek (site 2) to 8.20 µg/g dry weight at Goose Pond (site 9). Selenium concentrations of 6.98 and 8.20 µg/g dry weight, from samples of damselfly and midge larvae at Goose Pond (site 9), exceeded the 3 µg/g dry-weight level of selenium in food chain organisms associated with reproductive failure in fish and wildlife (Lemly, 1993). Aquatic invertebrates from areas unaffected by irrigation drainage practices generally contain selenium concentrations less than 4 µg/g dry weight (Eisler, 1985; Ohlendorf, 1989).

Fish

Comparative data for concentrations of various elements in fish tissue are not available for the Wind River Federal Irrigation Project area. However, the USFWS has participated in the National Contaminant Biomonitoring Program (NCBP) since 1967. Through the NCBP, the USFWS monitors concentrations of seven potentially toxic elements (arsenic, cadmium, copper, lead, mercury, selenium, and zinc) and selected organochlorine chemicals in fish from a national network of stations. Although data from the NCBP are not specific to the reservation, and include values for several fish species, the NCBP does enable comparison of the Wind River Indian Reservation data with the national database. Schmitt and Brumbaugh (1990) provide a more complete discussion of the NCBP and a summary of the analytical results from 1976 through 1984.

Table 10. *Trace-element concentrations in biota samples collected*

[All concentrations in micrograms per gram (µg/g), (dry weight); Aq., aquatic;

Sempie number	Date sampled	Biota	Common name	Moisture percent	Aluminum
					Fig. 3
					White Horse Draw
WRSPAI01	06/07/93	Aq. inv.	Midge larvae	85.67	4,230
					Goose Pond
WRGPAV01	06/02/93	Aq. veg.	Pondweed	87.44	945
WRGPAI05	06/02/93	Aq. inv.	Midge larvae	85.94	893
WRGPAI06	07/07/93	Aq. inv.	Damselfly larvae	90.11	418
WRGPCC20	07/14/93	Whole body	Common carp	74.97	49.9
WRGPCC21	07/14/93	Whole body	Common carp	75.07	47.3
WRGPCC22	07/14/93	Whole body	Common carp	75.51	48.6
WRGPGW01	07/07/93	Liver	Gadwall	64.81	<14.9
WRGPGW02	07/07/93	Liver	Gadwall	67.86	<25.3
WRGPGW03	07/07/93	Liver	Gadwall	61.75	<25.0
WRGPME01	06/04/93	Egg	Mallard	68.25	<24.7
					Sharp Nose
WRSNAV01	07/07/93	Aq. veg.	Pondweed	91.44	1,200
WRSNAI01	06/06/93	Aq. inv.	Damselfly larvae	86.00	432
WRSNBT01	07/08/93	Liver	Blue-winged teal	64.81	<144
WRSNBT02	07/08/93	Liver	Blue-winged teal	64.81	<173
WRSNBT03	07/08/93	Liver	Blue-winged teal	64.81	<172
WRSNFM02	07/14/93	Whole body	Fathead minnow	80.96	95.8
WRSNFM03	07/14/93	Whole body	Fathead minnow	81.60	140
WRSNFM04	07/14/93	Whole body	Fathead minnow	80.60	84.4
					Arapahoe Wetlands
WRAMAV01	06/03/93	Aq. veg.	Muskgrass	80.52	606
WRAMAI01	06/03/93	Aq. inv.	Damselfly larvae	85.80	161
WRAMAI02	06/03/93	Aq. inv.	Midge larvae	79.95	1,080
WRAMCE01	06/03/93	Egg	American coot	72.96	<24.7
WRAMRE01	06/04/93	Egg	Sora rail	75.54	<24.8
WRAMRE02	06/04/93	Egg	Sora rail	74.89	<24.9
WRAMSE01	06/04/93	Egg	Common snipe	73.25	<25.5
WRAMTE01	06/04/93	Egg	Blue-winged teal	66.25	<25.6
WRAMFM04	07/14/93	Whole body	Fathead minnow	78.22	44.1
WRAMFM05	07/14/93	Whole body	Fathead minnow	78.21	45.3
WRAMFM06	07/14/93	Whole body	Fathead minnow	79.12	42.3
					Little Wind River
WRLWWS04	08/06/93	Whole body	White sucker	79.98	119
WRLWWS05	08/06/93	Whole body	White sucker	69.41	112
WRLWWS06	08/06/93	Whole body	White sucker	69.26	125
WRLWWS07	08/06/93	Whole body	White sucker	74.48	188
WRLWWS08	08/06/93	Whole body	White sucker	77.37	118
WRLWWS09	08/06/93	Whole body	White sucker	77.51	202

from the Wind River Indian Reservation, central Wyoming, 1993

inv., invertebrate; veg, vegetation; <, less than minimum reporting level]

Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
Wetland (Site 2)					
1.65	103	<1.03	6.32	<1.03	7.32
(Site 9)					
3.14	39.7	<1.02	457	<1.02	<5.10
1.49	21.4	<.980	<4.90	<.980	<4.90
1.28	7.17	<.973	10.1	<.973	<4.86
<.502	3.44	<.102	.596	<.102	5.12
<.505	4.12	<.101	2.92	<.101	6.15
<.504	4.60	<.102	<.509	.169	3.47
<1.49	<7.46	<1.49	<7.46	<1.49	<7.46
<.505	<2.53	<.505	<2.53	<.505	2.56
<.500	<2.50	<.500	<2.50	<.500	<2.50
<.494	2.58	<.494	<2.47	<.494	<2.47
Pond (Site 10)					
1.93	133	<1.10	21.7	<1.10	<5.48
<.984	10.0	<1.00	4.98	<.984	<4.92
<2.88	<14.4	<2.88	<14.4	<2.88	<14.4
<3.47	<17.3	<3.47	<17.3	<3.47	<17.3
<3.43	<17.2	<3.43	<17.2	<3.43	<17.2
.762	133	<.100	<.502	<.100	2.35
.654	134	<.102	<.508	<.102	3.34
.553	118	<.101	<.507	<.101	2.70
Pond (Site 17)					
1.20	96.1	<.984	28.9	<.984	<6.89
<.856	20.1	<.856	<4.28	<.856	<4.28
<.833	33.4	<.833	<4.17	<.833	<4.17
<.493	2.72	<.493	<2.47	<.493	<2.47
<.496	3.42	<.496	<2.48	<.496	<2.48
<.497	3.84	<.497	<2.49	<.497	<2.49
<.509	<2.55	<.509	<2.55	<.509	<2.55
<.511	3.83	<.511	<2.56	<.511	<2.56
<.508	12.9	<.100	1.38	<.100	4.87
<.506	10.2	<.101	<.506	<.101	2.60
<.505	15.5	<.101	<.506	<.101	4.04
(downstream from Site 17)					
<.491	4.64	<.100	.843	.120	14.7
<.484	6.46	<.098	.556	<.098	14.5
<.491	4.39	<.100	<.498	<.100	11.4
<.489	5.80	<.098	<.492	<.098	38.4
<.489	5.81	.136	1.69	.198	40.2
<.490	9.73	.159	1.44	.225	15.0

Table 10. *Trace-element concentrations in biota samples collected*

Sample number	Copper	Iron	Lead	Magnesium	Mengenese
					Fig. 3
					White Horse Draw
WRSPAI01	15.1	4,829	7.87	2,050	150
					Goose Pond
WRGPAV01	6.07	2,320	<5.10	8,680	357
WRGPAI05	<4.90	2,020	<4.90	1,410	49.1
WRGPAI06	10.3	473	<4.86	1,340	42.0
WRGPCC20	4.27	143	1.48	1,380	19.3
WRGPCC21	4.29	150	1.92	1,430	20.0
WRGPCC22	15.0	129	1.10	1,410	23.2
WRGPGW01	184	1,530	<7.46	1,460	21.0
WRGPGW02	152	926	<2.53	660	11.7
WRGPGW03	180	1,370	<2.50	679	12.2
WRGPME01	4.01	134	8.05	279	2.18
					Sharp Nose
WRSNAV01	<5.48	1,210	<5.48	4,080	240
WRSNAI01	10.3	578	<4.92	785	72.5
WRSNBT01	52.2	1,560	<14.4	1,570	29.3
WRSNBT02	62.0	1,450	<17.3	1,610	32.3
WRSNBT03	51.8	1,770	41.2	1,670	32.7
WRSNFM02	5.94	219	.740	1,630	25.5
WRSNFM03	10.1	290	1.92	1,660	33.8
WRSNFM04	12.6	223	2.05	1,520	24.5
					Arapahoe Wetlands
WRAMAV01	<4.92	2,120	16.5	8,450	3,620
WRAMAI01	5.45	253	4.29	1,010	162
WRAMAI02	5.30	1,340	<4.17	1,300	50.4
WRAMCE01	3.34	86.3	4.17	430	2.20
WRAMRE01	<2.48	<49.6	<2.48	356	<1.98
WRAMRE02	<2.49	53.5	<2.49	307	2.39
WRAMSE01	3.36	119	<2.55	360	5.95
WRAMTE01	3.57	80.3	<2.56	307	<2.05
WRAMFM04	4.95	132	.657	1,400	12.0
WRAMFM05	4.78	117	<.506	1,400	12.4
WRAMFM06	5.40	125	.577	1,370	13.1
					Little Wind River
WRLWWS04	5.07	259	9.50	1,410	39.5
WRLWWS05	4.75	240	<.489	1,480	47.0
WRLWWS06	7.46	300	<.498	1,290	36.9
WRLWWS07	10.4	436	<.492	1,710	56.3
WRLWWS08	6.93	429	<.484	1,650	58.6
WRLWWS09	5.50	302	<.492	1,840	43.8

Mercury	Molybdenum	Nickel	Selenium	Strontium	Vanadium	Zinc
Wetland (Site 2)						
<0.202	<5.04	<5.04	<1.01	22.1	8.42	74.5
(Site 9)						
<.204	<5.10	<5.10	4.82	304	<5.10	28.9
<.196	<4.90	<4.90	8.20	39.0	<4.90	31.6
<.195	<4.86	<4.86	6.98	35.4	<4.86	86.9
<.100	<.509	<.509	5.51	223	<.509	178
<.101	.760	<.503	4.70	248	<.503	175
<.101	<.509	.759	4.93	265	<.509	181
.617	<7.46	<7.46	22.9	<2.98	<7.46	324
.359	3.40	<2.53	18.0	<1.01	<2.53	135
.323	3.45	<2.50	13.9	<1.00	<2.50	152
.130	<2.47	<2.47	4.71	7.20	<2.47	53.2
Pond (Site 10)						
<.219	<5.48	<5.48	<1.10	203	<5.48	29.7
<.197	<4.92	<4.92	1.85	8.77	<4.92	68.5
3.77	<14.4	<14.4	14.0	<5.75	<14.4	302
5.10	<17.3	<17.3	13.0	<6.93	<17.3	332
3.60	<25.7	<17.2	6.93	<6.86	<17.2	286
.307	<.502	<.502	2.79	123	.570	304
.292	<.508	<.508	2.90	146	.766	278
.228	<.507	<.507	2.74	109	<.507	242
Pond (Site 17)						
<.197	<4.92	<4.92	1.87	691	<4.92	27.0
<.171	<4.28	<4.28	1.75	29.1	<4.28	70.8
<.167	<4.17	<4.17	2.07	50.9	<4.17	42.1
.161	<2.47	<2.47	2.94	9.63	<2.47	51.6
.324	<2.48	<2.48	1.98	15.4	<2.48	49.7
.353	<2.49	<2.49	2.25	16.4	<2.49	57.2
.313	<2.55	<2.55	4.82	13.0	<2.55	52.0
.398	<2.56	<2.56	1.55	13.9	<2.56	45.8
.148	<.502	<.502	6.60	87.0	<.502	155
.159	<.506	<.506	7.30	93.2	<.506	147
.129	<.506	<.506	6.59	85.8	<.506	152
(downstream from Site 17)						
.209	<.498	2.16	4.00	102	<.498	45.7
.222	<.489	1.76	3.64	164	<.489	54.5
.187	<.498	<.498	3.19	118	<.498	42.5
.141	<.492	11.6	2.84	152	.559	73.9
.132	.716	4.67	4.01	175	.565	63.2
.146	.510	2.14	3.44	171	.658	82.1

Table 11. *Organic-compound concentrations in biota samples collected from the Wind River Indian Reservation, central Wyoming, 1993*

[Analytical results in micrograms per gram (µg/g), (wet weight); <, less than minimum reporting level; EPN, 0-ethyl 0-(4-nitrophenyl) phenylphosphonothioate]

Organic compound	Goose Pond Site 9 (fig. 3) (Gadwall gastrointestinal tract)	Arapahoe Wetlands Pond Site 17 (fig. 3) (Fathead minnow)	Little Wind River downatream from Site 17 (fig. 3) (White sucker)
Acephate	<0.5	<0.5	<0.5
Azinphos-methyl	<.5	<.5	<.5
Chlorpyrifos	<.5	<.5	<.5
Coumaphos	<.5	<.5	<.5
Demeton	<.5	<.5	<.5
Diazinon	<.5	<.5	<.5
Dichlorvos	<.5	<.5	<.5
Dichrotophos	<.5	<.5	<.5
Disulfoton	<.5	<.5	<.5
EPN	<.5	<.5	<.5
Ethoprop	<.5	<.5	<.5
Famphur	<.5	<.5	<.5
Fensulfothion	<.5	<.5	<.5
Fenthion	<.5	<.5	<.5
Malathion	<.5	<.5	<.5
Methamidophos	<.5	<.5	<.5
Methyl parathion	<.5	<.5	<.5
Mevinphos	<.5	<.5	<.5
Monocrotophos	<.5	<.5	<.5
Parathion	<.5	<.5	<.5
Phorate	<.5	<.5	<.5
Terbufos	<.5	<.5	<.5
Trichlorfon	<.5	<.5	<.5

Copper, lead, selenium, and zinc concentrations in some fish from the study area (table 10) exceeded the NCBP 85-percent baseline values. The following are noteworthy concentrations of these potentially toxic elements identified during this field screening.

Copper concentrations in all fish sampled from the Little Wind Unit ranged from 4.27 to 15.0 µg/g dry weight (1.07 to 3.67 µg/g wet weight) and exceeded the NCBP 85-percent baseline value of 1.0 µg/g wet weight. The maximum concentration of 15.0 µg/g dry weight was contained in a common carp from Goose Pond (site 9), and some fish sampled from Sharp Nose Pond (site 10) and Little Wind River downstream from Arapahoe Wetlands Pond (site 17) had copper concentrations higher than 7.46 µg/g dry weight (2.29 µg/g wet weight).

Lead concentrations in fish sampled from the Little Wind Unit ranged from the minimum reporting level (less than 0.506 µg/g dry weight) to 9.50 µg/g dry weight (1.90 µg/g wet weight) (table 10). All three samples of common carp from Goose Pond (site 9), two samples of fathead minnows from Sharp Nose Pond (site 10), and one white sucker from the Little Wind River downstream from Arapahoe Wetlands Pond (site 17) exceeded the NCBP 85-percent baseline value (0.22 µg/g wet weight).

Selenium concentrations in fish ranged from 2.74 to 7.30 µg/g dry weight (0.532 to 1.59 µg/g wet weight). All selenium concentrations in fish from Goose Pond (site 9) and Arapahoe Wetlands Pond (site 17) and five of six concentrations in fish from the Little Wind River downstream from site 17 were greater than the 85-percent baseline value (0.73 µg/g wet weight). Selenium concentrations in fish sampled from various sites in the study area are as follows: common carp from Goose Pond (4.70-5.51 µg/g dry weight); fathead minnows from Sharp Nose Pond (2.74-2.90 µg/g dry weight); fathead minnows from Arapahoe Wetlands Pond (6.59-7.30 µg/g dry weight); and white sucker from the Little Wind River downstream from Arapahoe Wetlands Pond (2.84-4.01 µg/g dry weight). Lemly (1993) indicates 4.0 µg/g dry weight selenium is a general level of concern for whole body fish, and that juvenile mortality and reproductive failure in fish may result. All of the common carp from Goose Pond and fathead minnows from Arapahoe Wetlands Pond had selenium concentrations that exceed these guidelines.

Zinc concentrations in common carp from Goose Pond (site 9) ranged from 175 to 181 µg/g dry weight (43.6 to 44.3 µg/g wet weight), exceeding the NCBP 85-percent baseline value (34.2 µg/g wet weight). Fathead minnows from Sharp Nose Pond (site 10) had concentrations that also exceeded the 85-percent baseline value, with zinc concentrations ranging from 242 to 304 µg/g dry weight (46.9 to 57.9 µg/g wet weight). Fathead minnows collected from Arapahoe Wetlands Pond (site 17) and white suckers collected from the Little Wind River downstream from Arapahoe Wetlands Pond had concentrations less than the 85-percent baseline value for zinc.

Chromium concentrations in fish sampled from the Little Wind Unit ranged from 2.35 to 40.2 µg/g dry weight. Some chromium concentrations in fish from Goose Pond (site 9), Arapahoe Wetlands Pond (site 17), and the Little Wind River downstream from Arapahoe Wetlands Pond exceeded the 4.0 µg/g dry-weight concentration suggested by Eisler (1986) as indicative of chromium contamination. White suckers from the Little Wind River also contained the highest chromium concentrations in the area, with a maximum value of 40.2 µg/g dry weight.

Bird Eggs and Livers

Aquatic bird eggs were sampled from Goose Pond (site 9) and Arapahoe Wetlands Pond (site 17) in the Little Wind Unit (table 10). Selenium concentrations in aquatic bird eggs from these sites ranged from 1.55 to 4.82 µg/g dry weight. The highest concentrations were 4.71 µg/g dry weight at Goose Pond and 4.82 µg/g dry weight at Arapahoe Wetlands Pond. These concentrations exceed the 3.00 µg/g dry weight toxic-effect threshold for selenium in aquatic bird eggs associated with reproductive failure (Lemly, 1993; Skorupa and Ohlendorf, 1991).

Livers were sampled from aquatic birds at Goose Pond (site 9) and Sharp Nose Pond (site 10) in the Little Wind Unit (table 10). Selenium concentrations in aquatic bird livers from these sites ranged from 6.93 to 22.9 µg/g dry weight. Five of the six liver samples collected at these two sites had selenium concentrations ranging from 13.0 to 22.9 µg/g dry weight, which exceeded the 10.0 µg/g dry-weight level associated with reproductive failure in aquatic birds (Lemly, 1993).

Copper concentrations in aquatic bird livers ranged from 51.8 to 184 µg/g dry weight (18.23 to 64.7 µg/g wet weight). At Sharp Nose Pond (site 10), copper concentrations ranged from 51.8 to 62.0 µg/g dry weight (18.23 to 21.82 µg/g wet weight), whereas two of the three bird liver samples from Goose Pond (site 9) had copper concentrations of 180 and 184 µg/g dry weight (68.8 and 64.8 µg/g wet weight) (table 10).

Henderson and Winterfield (1975) reported concentrations of copper in liver samples ranged from 56 to 97 µg/g wet weight in Canada geese that suffered acute copper toxicosis.

Lead concentrations in all aquatic bird liver samples from Goose Pond (site 9) were less than the minimum reporting level. One blue-winged teal liver sample collected from Sharp Nose Pond (site 10), however, had a concentration of 41.2 µg/g dry weight. Lead concentrations greater than 10 µg/g dry weight have been identified in lead-poisoned birds (Eisler, 1988). Although concentrations of the remaining two samples from Sharp Nose Pond were less than the minimum reporting level, it should be noted that these concentrations (less than 14.4 and less than 17.3 µg/g, table 10) are higher than those identified in lead-poisoned birds.

Mercury concentrations in aquatic bird livers collected in the Little Wind Unit ranged from 0.323 to 5.10 µg/g dry weight (0.124 to 1.79 µg/g wet weight). Although these are lower than concentrations determined to cause adverse effects to black ducks in experimental studies (Finley and Stendall, 1978), mercury concentrations in bird livers at Sharp Nose Pond (site 10) are higher than the suggested levels in dietary items for the protection of sensitive species of mammals and birds that regularly consume fish and other aquatic organisms (Eisler, 1987).

Zinc concentrations in aquatic bird liver samples collected from Goose Pond (site 9) and Sharp Nose Pond (site 10) ranged from 135 to 332 µg/g dry weight. Eisler (1993) reports that experimentally derived zinc concentrations ranging from 21 to 33 µg/g dry weight were found in normal bird livers, and that zinc concentrations ranging from 75 to 156 µg/g dry weight were found in livers of zinc-poisoned birds.

SUMMARY

Physical, chemical, and biological data were collected in 1992 and 1993 from irrigation drainage areas, wetlands, and ponds of the Wind River Federal Irrigation Project, Wind River Indian Reservation, Wyoming. The study was conducted as an interagency field screening under the guidance of the DOI in response to increasing concern about the quality of irrigation drainwater and its potential adverse effects on fish, wildlife, and human health. In this semiarid area, the wetlands and ponds of the reservation are attractive to migratory and nesting aquatic birds, several species of fish, and three federally listed endangered species--bald eagles, peregrine falcons, and whooping cranes that are known to use the wetland habitats seasonally.

The Wind River Federal Irrigation Project consists of four irrigation units: Little Wind Unit, Left-Hand Unit, Johnstown Unit, and Upper Wind Unit. The irrigation network has a length of about 90 mi and diverts about 170,000 acre-ft of water annually through a series of unlined canals, ditches, and drains.

In water samples from the four irrigation units, trace-element concentrations (inorganic constituents) generally were highest in the Little Wind Unit irrigation area, and some of the 1993 concentrations were greater than those measured in 1992. The highest selenium concentrations in water samples collected in the Little Wind Unit were 17 µg/L in 1993 and 4 µg/L in 1992. Similarly, boron concentrations in water samples collected from the study area ranged from 20 to 1,100 µg/L in 1993 and from 10 to 380 µg/L in 1992; lead concentrations ranged from less than 1 to 4 µg/L in 1993 and from less than 1 to 1 µg/L in 1992; mercury concentrations ranged from 0.1 to 4.9 µg/L in 1993 and from less than 0.1 to 0.2 µg/L in 1992; and zinc concentrations ranged from less than 3 to 38 µg/L in 1993 and from less than 3 to 21 µg/L 1992.

Of the 14 water samples collected from the Little Wind Unit in 1993, laboratory analyses showed that 6 sampling sites had selenium concentrations that equaled or exceeded the 5 µg/L U.S. Environmental Protection Agency freshwater aquatic-life criterion, and 1 sampling site at McCaskey Drain above Coolidge Canal had a selenium concentration of 17 µg/L. From Sharp Nose Draw in the Little Wind Unit, a mercury concentration of 4.9 µg/L was measured in water sampled June 8, 1993. Natural (background) concentrations of mercury in rivers and lakes have been reported ranging from 0.01 to 0.05 µg/L, and concentrations ranging from 0.1 to 2.0 µg/L have been reported to be fatal to sensitive aquatic species. Mercury concentrations at three sites sampled in the study area during the 1992 irrigation season were 0.2 µg/L, and water samples collected during the 1992 and 1993 irrigation seasons at all other sites in the study area were less than or equal to 0.1 µg/L.

Organic-compound concentrations in water samples from the study area generally were less than the minimum reporting level. However, samples from two sites in the Sub-Agency System of the Little Wind

Unit near Arapahoe had detectable concentrations of Dicamba (0.20 μg/L) and 2,4-D (0.17 μg/L).

Trace-element concentrations in bottom-sediment samples were similarly highest in the Little Wind Unit. Selenium concentrations in the study area had a range of 0.1 to 7.5 μg/g and mercury concentrations were 0.02 μg/g or less for all samples. The highest selenium and mercury concentrations were in bottom-sediment samples from Goose Pond and Sharp Nose Pond. Organic-compound concentrations in bottom-sediment samples from four sites in the study area were all less than the minimum reporting level.

Biota samples collected in 1993 from the Little Wind Unit irrigation area consisted of submerged aquatic vegetation, aquatic invertebrates, fish, bird eggs, bird livers, and bird gastrointestinal tracts. In samples of submerged aquatic vegetation, boron concentrations ranged from 21.7 to 457 μg/g dry weight. Selenium concentrations were less than levels of concern, except for a concentration of 4.82 μg/g dry weight from a pondweed sample collected at Goose Pond. Trace-element concentrations in samples of aquatic invertebrates also were less than levels of concern, except for selenium concentrations of 6.98 and 8.20 μg/g dry weight measured from damselfly and midge larvae samples from Goose Pond, exceeding the 3 μg/g level of selenium in food chain organisms reported to be associated with reproductive failure in fish and wildlife. In fish, concentrations of selenium ranged from 2.74 to 7.30 μg/g dry weight and chromium concentrations ranged from 2.35 to 40.2 μg/g dry weight, indicating that some sites have selenium and chromium concentrations greater than reported levels of concern. Aquatic bird eggs contained concentrations of all trace elements, except selenium, that were less than levels of concern. Selenium concentrations of 4.71 and 4.82 μg/g dry weight were measured from bird eggs collected at Goose Pond and Arapahoe Wetlands Pond. Five of the six livers sampled from aquatic birds at Goose Pond and Sharp Nose Pond contained selenium concentrations (13.0 to 22.9 μg/g) in excess of the 10.0 μg/g level associated with reproductive failure in aquatic birds. Liver samples from birds at these sites also contained high dry-weight concentrations of copper at Goose Pond (152 to 184 μg/g); lead (41.2 μg/g) and mercury (5.10 μg/g) at Sharp Nose Pond; and zinc at Goose Pond and Sharp Nose Pond (135 to 332 μg/g).

The results of the study indicate that most sites in the Wind River Federal Irrigation Project have concentrations of inorganic constituents and organic compounds (pesticides) in samples of water, bottom sediment, and biota that are less than levels of concern. However, in the Little Wind Unit irrigation area between Fort Washakie and Arapahoe, selenium and mercury concentrations in some water samples equaled or exceeded the USEPA's aquatic-life criterion for selenium (5 μg/L) and the proposed 1985 mercury criterion for freshwater aquatic life protection (0.012 μg/L, 4-day average, not to exceed 2.4 μg/L on an hourly average). The highest concentrations of selenium and other trace elements in water and bottom-sediment samples were from the Little Wind Unit--Ray and Coolidge Systems. In these areas, the soil and underlying geologic materials have been previously identified as potentially supporting vegetation that may be moderately to highly toxic to grazing animals. The presence of selenium in the area also is indicated by the results of biota sampling and analyses in 1993 that show selenium concentrations are greater than established levels of concern in some aquatic vegetation and invertebrates, fish, bird eggs, and bird livers collected from the Little Wind Unit.

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