RECONNAISSANCE INVESTIGATION OF WATER QUALITY, BOTTOM SEDIMENT, AND BIOTA ASSOCIATED WITH IRRIGATION DRAINAGE IN THE KENDRICK RECLAMATION PROJECT AREA, WYOMING, 1986-87

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 87-4255

by David A. Peterson, U.S. Geological Survey, Cheyenne, Wyoming;

William E. Jones, U.S. Fish and Wildlife Service, Billings, Montana; and

Anthony G. Morton, U.S. Bureau of Reclamation, Mills, Wyoming

Cheyenne, Wyoming

1988

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
2120 Capitol Avenue
P.O. Box 1125
Cheyenne, WY 82003

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CONVERSION FACTORS AND VERTICAL DATUM

For use of readers who prefer to use metric (International System) units, rather than the inch-pound units used in this report, the following conversion factors may be used:

Multiply inch-pound unit	By	To obtain metric unit
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
foot (ft)	0.3048	meter
inch (in.)	2.54	centimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

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 "Mean Sea Level of 1929."

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

$$°F = 9/5\ (°C) + 32$$

$$°C = 5/9\ (°F - 32)$$

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ABSTRACT

A reconnaissance investigation of the Kendrick Reclamation Project in central Wyoming was conducted during 1986-87 to determine if irrigation drainage has caused or has the potential to cause harmful effects on human health, fish, and wildlife, or other water uses. The investigation of the Kendrick Reclamation Project is one of nine similar investigations being conducted in the western conterminous United States as part of the Department of the Interior's Irrigation Drainage Program.

Samples of surface water were collected at 10 sites and ground water at 5 sites. Surface-water analyses included trace elements, radiochemicals, and pesticides. Concentrations in the water generally were less than national standards for public water supplies, with the exception of selenium. The median concentration of dissolved selenium was 7.5 μg/L (micrograms per liter) in 24 samples of surface and ground water. Of the 11 samples that contained dissolved-selenium concentrations greater than the national standard for public water supplies of 10 μg/L, 10 of the samples were collected at sites on streams that are not used for public water supplies; the eleventh sample was collected from a shallow well. Dissolved-selenium concentrations ranged from less than 1 to 300 μg/L.

Concentrations of dissolved selenium in the North Platte River, which supplies drinking water for several municipalities, ranged from less than 1 to 4 μg/L. The dissolved-selenium concentration and selenium discharge in the North Platte River increased in the downstream direction. The four principal tributaries that receive drainage from the Kendrick Reclamation Project contributed substantially to the increase in selenium concentration and discharge in the North Platte River.

Bottom-sediment samples contained selenium contents ranging from 0.9 to 25 μg/g (micrograms per gram). The largest selenium contents were measured in the bottom sediments of Poison Spring Creek (25 μg/g), Rasmus Lee Lake (17 μg/g), and Casper Creek (16 μg/g). Bottom-sediment samples from the North Platte River contained selenium contents of 1.2 μg/g or less.

On the basis of limited samples from four sites along the North Platte River, arsenic, boron, and mercury contents in the fish and invertebrates changed little from upstream from the project to downstream from the project. Selenium contents in fish increased slightly in the downstream direction. All contents measured were less than contents that could be indicative of causing physiological harm or other abnormalities in fish.

Contents of arsenic, boron, and mercury generally were small in biota from the sites in lakes and reservoirs. Boron contents in rooted plants (sago pondweed), however, were at contents that may be a concern relative to consumer organisms (birds) limited to a diet of aquatic vascular plants for any extended time.

Selenium contents were much larger in fish from Thirtythree Mile Reservoir and Illco Pond and in invertebrates from Rasmus Lee Lake than in fish from the North Platte River and in invertebrates from the other sites. Apparently some fish reproduction occurs in Thirtythree Mile Reservoir; however, selenium in the fish analyzed is at a content that potentially could have adverse physiological effects. Selenium contents in avocet livers and eggs from Rasmus Lee Lake, avocet and eared-grebe eggs from Goose Lake, and mallard livers from Illco Pond were at contents that could have toxic effects.

INTRODUCTION

During the last several years, there has been increasing concern about the quality of irrigation drainage, surface and subsurface water draining irrigated land, and its potential effects on human health, fish, and wildlife. Elevated concentrations of selenium have been detected in subsurface drainage water from irrigated land in the western part of the San Joaquin Valley in California. In 1983, incidences of mortality, birth defects, and reproductive failures in waterfowl were discovered by the U.S. Fish and Wildlife Service at the Kesterson National Wildlife Refuge in the western San Joaquin Valley, where irrigation drainage was impounded. In addition, potentially toxic trace elements and pesticide residues have been detected in other areas in western States that receive irrigation drainage.

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

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

Nine of the 19 locations were selected for reconnaissance investigations in 1986. These areas are:

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

Each reconnaissance investigation was conducted by interbureau field teams composed of a scientist from the U.S. Geological Survey as team leader, with additional Geological Survey, U.S. Fish and Wildlife Service, and U.S. Bureau of Reclamation scientists representing several different disciplines. The investigations were directed toward determining whether irrigation drainage: (1) has caused or has the potential to cause significant harmful effects on human health, fish, and wildlife or (2) may adversely affect the suitability of water for beneficial uses.

Purpose and Scope

This report describes the results of the reconnaissance investigation of the Kendrick Reclamation Project area. The report provides a preliminary evaluation of conditions in the area; description of areal and seasonal variations is not within the scope of the reconnaissance investigation. Samples of surface and ground water, bottom sediment, and biota were collected from the North Platte River, at the mouth of tributaries draining the project area, and at selected sites within and near the project area.

Acknowledgments

Personnel from the Wyoming Game and Fish Department generously donated time and use of equipment for collection of the biological samples. Cooperation for access from landowners in the area also is appreciated.

DESCRIPTION OF THE AREA

Location

The Kendrick Reclamation Project is located west of the city of Casper, in Natrona County in central Wyoming. The project area is bounded by the North Platte River on the southeast, Casper Creek on the northeast, and Casper Canal on the north and west (fig. 1). Drainage from the project is to the North Platte River. The drainage area of the North Platte River at Alcova, at the upstream edge of the investigation area, is 10,800 mi^2. The drainage area of the North Platte River at the downstream edge of the investigation area, is 12,500 mi^2, for a net increase of 1,700 mi^2. The area of the Kendrick Reclamation Project is about 188 mi^2, although much of the land within the project boundaries is not irrigated.

History and Water Use

President Franklin D. Roosevelt approved legislation authorizing the Kendrick Reclamation Project in 1935, but, as the result of several years delay due to diversion of funds and personnel during World War II, the first irrigation water was not diverted into the Casper Canal until 1946. Maximum capacity of the canal is 1,200 ft^3/s at the upstream end. The Kendrick Reclamation Project is under the jurisdiction of the North Platte River Projects Office of the U.S. Bureau of Reclamation in Mills, Wyo.

Forage crops are the most important on the project because the area is primarily used for stock-raising. The boundaries of the Kendrick Reclamation Project correspond to the boundaries of the Casper-Alcova Irrigation District, which includes about 24,000 irrigable acres of which about 20,000 acres are harvested annually. Alfalfa hay is grown on 55 percent of the irrigated land; other hay, irrigated pasture, and corn for silage account for 35 percent of the land use; cereal crops such as corn and oats account for 5 percent of the land use; and miscellaneous uses account for 5 percent of the land use. The high elevation and short growing season make it difficult to grow many more valuable crops. There are 102 full-time farms and 150 part-time farms on the project with a resident population of 529.

The North Platte River and the alluvium along the river are the sources of water for many domestic and industrial supplies, as well as for municipal water supplies for Casper and adjacent communities. Much of the ground water in the project area is too mineralized for domestic use. As a result, many of the farmers and ranchers transport drinking water from Casper. Livestock drink water from most of the creeks in the area, and in many places this is the only water available for them.

The North Platte River from Alcova Reservoir downstream to the Bessemer Bend area supports a blue-ribbon trout fishery. A good fishery exists downstream from Bessemer Bend to Casper. Generally, waterfowl production is limited due to the scarcity and type of habitat available along the river. However, a small number of waterfowl (particularly Canada geese) nest on islands in the river and a moderate number of waterfowl use the river for feeding and resting. Bald eagles and other raptors are commonly observed along the river.

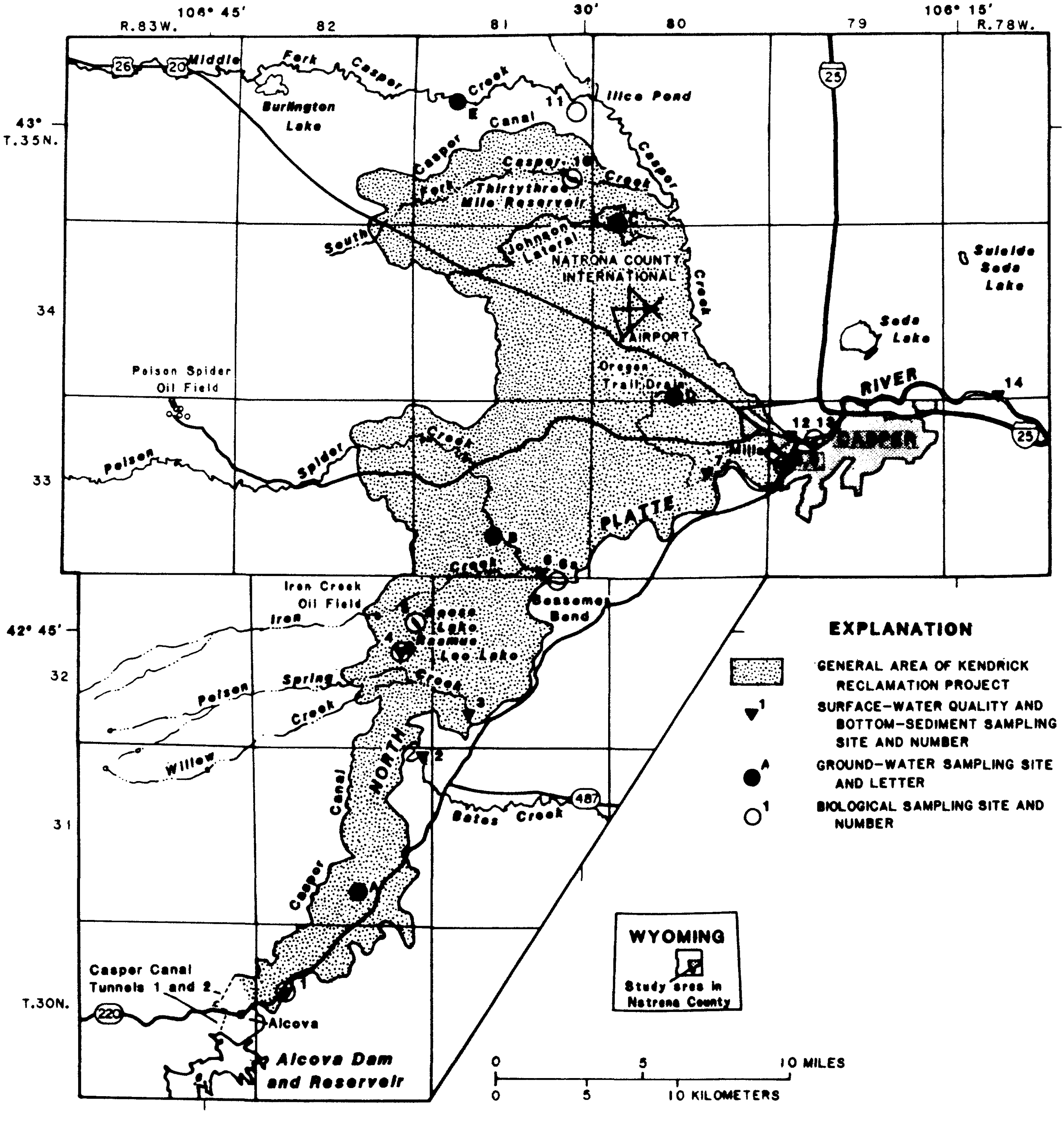


Figure 1.--Location of study area and sampling sites.

Within the project boundaries only a few open-water areas exist and these vary greatly in size, quality, and type of habitat for bird nesting and rearing. In most wetland areas, density of emergent vegetation and other conditions conducive to over-water nesters, such as the coot, are extremely limited. Also, for all sites observed (including those sampling sites selected), habitat conditions were, at best, marginal for any significant waterfowl nesting. Wetlands in the irrigation district are important because areas along the North Platte River corridor and those associated with the irrigation district comprise most of what few wetlands there are in this part of Wyoming.

No significant stream or lake fishery is known to exist within the boundaries of the project area. Little information exists concerning fish species inhabiting the area. However, some forage species, such as the fathead minnow, killifish, and carp, are known to be present. It also is likely that other species, such as the creek chub and Iowa darter, are also found at scattered locations throughout the area where permanent-water conditions prevail.

Physiography

A semiarid climate prevails in the investigation area. Average annual precipitation at Casper is 12 in.; 70 percent falls as rain during late spring and summer and a smaller percentage occurs as snow (National Oceanic and Atmospheric Administration, 1986). For 1986, the Casper weather station reported 15.9 in. of precipitation and 90 in. of snow. Mean daily temperatures averages 71 °F in summer and 22 °F in winter. The elevation of the area ranges from about 5,000 to 5,500 ft above sea level. The topography is characterized by rolling hills vegetated with grasses, shrubs, and sagebrush.

Geology and Soils

Soils in the area are derived principally from Cretaceous formations of marine origin. The following description is based on a geohydrologic map of the area by Crist (1974). The predominant formation is the Cody Shale, with smaller outcrops of the underlying Frontier Formation and Mowry and Thermopolis Shales, the overlying Mesaverde Formation and the equivalent Niobrara Formation, and Steele Shale. The Cody Shale contains gray soft shale and lenticular sandstone beds; gray limy shale is present at the base of the Cody Shale. The other Cretaceous formations also include gray and black limy and carbonaceous shale beds, sandstone beds, thin coal beds, and bentonite beds. Quaternary alluvium occurs along the larger streams and in the northern part of the area, near the Natrona County International Airport. Several of the Cretaceous formations present in the Kendrick Reclamation Project area have been described as seleniferous by Rosenfeld and Beath (1964, p. 23).

HYDROLOGIC SETTING

Water Supply

The water supply for the Kendrick Reclamation Project is stored in Seminoe and Alcova Reservoirs on the North Platte River 70 mi southwest, and 30 mi southwest of Casper, respectively. Water is delivered from Alcova Reservoir to the Casper Canal on demand. The annual volume of water diverted to the canal from the reservoir ranges from 2.92 to 3.97 acre-ft per irrigated acre. The volume of water delivered to the land via the canal and lateral system ranges from 1.75 to 2.58 acre-ft per acre per year. The canal and drain system is shown in figure 2. Irrigation water within the project area is supplied primarily by the Casper Canal; a small quantity of irrigation water is obtained from ground- or surface-water diversions.

Runoff

Numerous streams in the area convey runoff to the North Platte River in the 40 river mi between Alcova Reservoir and Casper. The four principal perennial tributaries draining the project are: Poison Spring Creek, Poison Spider Creek, Oregon Trail Drain, and Casper Creek. Intermittent streams and drains also contribute water to these four principal tributaries. Runoff also is impounded in Burlington Lake northwest of the Kendrick Reclamation Project area, as well as in natural depressions and stock ponds.

Return Flow

About 43 mi of both open and closed drains in the project area include the Kramer, Townsend, Middaugh, Townsend, Townsend Branch, Middle Branch, Bergesson Branch, Oregon Trail, Miller, Lovelace Meyer, Johnson-Dye, Garbutt, Johnson Reservoir, Sheppard, and Radden Drains. The return flow from the project area flows through these drains as well as streams tributary to the North Platte River.

Wastewater also is associated with the return flow. Wastewater, which is water transported in the canals and laterals but not used for irrigation, varies from 2,000 to 8,000 acre-ft per irrigation season and uses the same waterways as the runoff and return flows.

Ground Water

A study conducted by Crist (1974) indicated that the ground-water levels in the project area rise with the application of irrigation water in the spring and decline after the irrigation season concludes in September. The irrigation water infiltrates and recharges aquifers, causing an increase in the water levels. Discharge of ground water to streams and drains causes the water levels to decline after irrigation has ended for the season. Crist (1974, pl. 2) showed ground-water flow from irrigated areas to streams and drains at several locations in the project area. Recharge from surface-water irrigation has increased the quantity of ground water in storage and in some areas created shallow aquifers where previously there were none (Crist, 1974, p. 13-17).

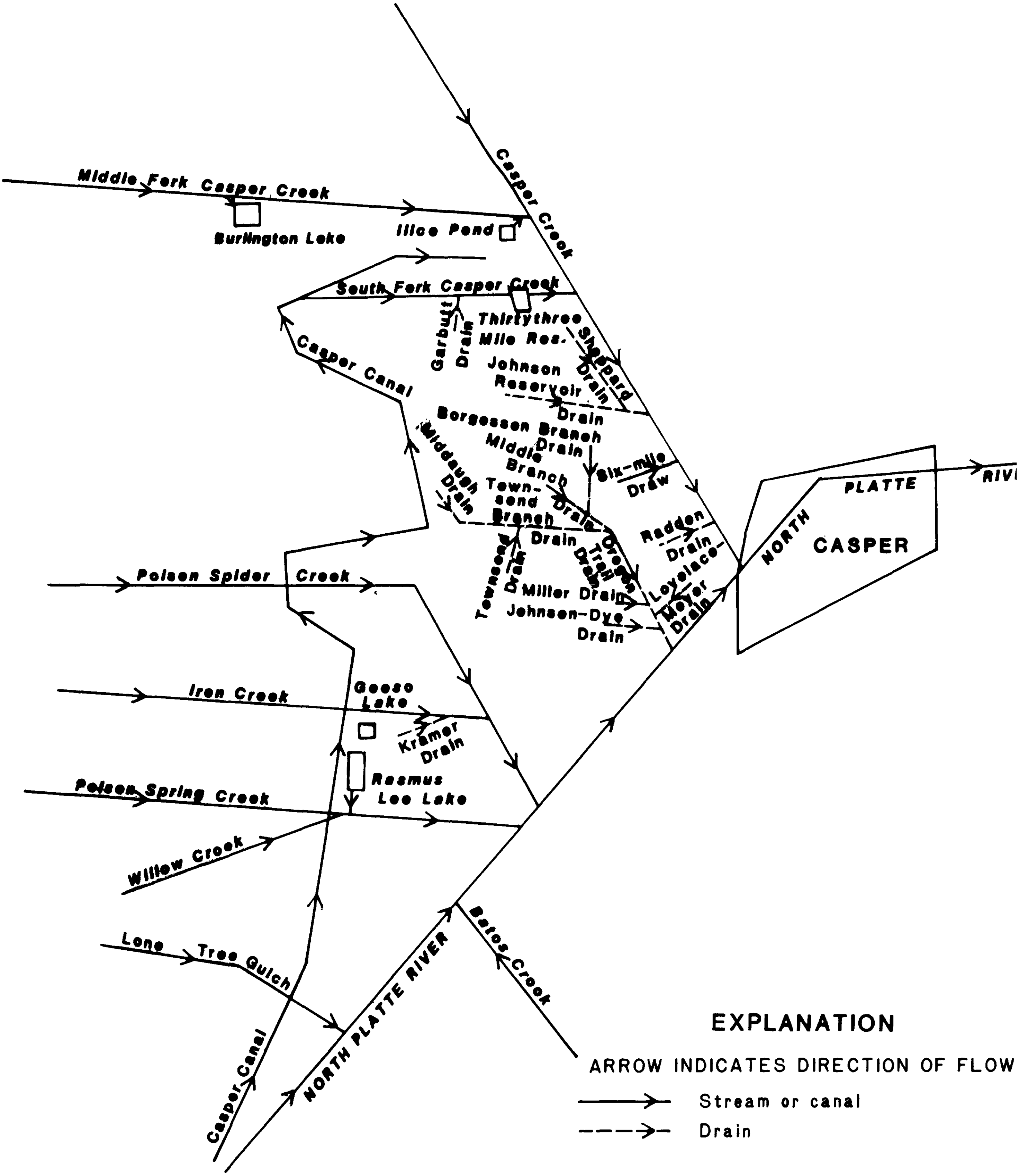


Figure 2.--Schematic diagram showing direction (arrows) of water flow through streams, irrigation canals, and drains.

PREVIOUS STUDIES

Reports

Elevated concentrations of selenium in surface and ground water in Natrona County were reported by Crist and Lowry (1972), and described in greater detail by Crist (1974). A summary of selenium data for surface water, ground water, and rock material from Crist (1974) is presented in table 1. According to Crist (1974), Poison Spring Creek, Poison Spider Creek, Oregon Trail Drain, and Casper Creek are the principal tributaries that contribute selenium from the project area to the North Platte River. Surface-water data indicated that the selenium discharge transported in Oregon Trail Drain was largest in late winter and early spring during low flow. Little correlation was determined between streamflow and selenium discharge in Poison Spring Creek, Poison Spider Creek, and Casper Creek.

Table 1.--Summary of selenium data for samples of surface and ground water, and for rocks collected within and adjacent to the Kendrick Reclamation Project by Crist (1974)

[Rocks include soils, unconsolidated deposits, and bedrock. Concentration in water is expressed in micrograms per liter; content of rocks is expressed in micrograms per kilogram of sample. <, less than]

Sample media	Number of samples	Number of samples less than detection limit	Concentration or content		
			Maximum	Minimum	Median
Surface water	253	75	1,200	<10	20
Ground water	597	109	6,500	<10	30
Rocks	179	38	4,200	<10	50

The selenium concentrations in ground-water samples collected by Crist (1974) had a large temporal and spatial variance. Of the 17 observation wells where water-quality was affected by irrigation, data from 5 of the wells indicated a trend of increasing selenium concentration during the 2 years of record; at 5 other wells, the selenium trends were masked by fluctuating concentrations; and at 7 of the wells, data indicated consistently small selenium concentrations. Samples from 4 of the 5 observation wells outside the area affected by irrigation had consistently small selenium concentrations of 10 μg/L (micrograms per liter) or less.

Larson (1985, p. 67) projected selenium concentrations in the North Platte River as a function of streamflow in the North Platte River and of selenium discharge from the four principal tributaries draining the Kendrick Reclamation Project. The resulting increases in selenium concentration in the North Platte River are shown by Larson for loads of 10 and 20 kg/d (kilograms per day) and streamflow ranging from 0 to 2,000 ft^3/s. During a sampling in June, 1979, dissolved-selenium concentrations in the four tributaries ranged from 45 to 200 μg/L and contributed a discharge of 7.6 kg/d to the North Platte River (Larson, 1985, p. 63). Concentrations of dissolved selenium in the North Platte River ranged from less than 1 to 2 μg/L at Alcova and from less than 1 to 14 μg/L downstream from Casper.

The water-soluble selenium content of rock samples collected from surface material and test holes by Crist (1974) ranged from less than 10 to 4,200 μg/kg (micrograms per kilogram of sample) for samples of Cretaceous rocks and from less than 10 to 520 μg/kg for samples of Quaternary rocks. The materials sampled and referred to as rock samples (Crist, 1974, p. 10) included soils, Quaternary unconsolidated deposits, and bedrock; the results are summarized in table 1. No specific rock type or locale within the study area was determined to contain a consistently large selenium content. Rock samples from the Mowry and Thermopolis Shales, Frontier Formation, Cody Shale, Niobrara Formation, Steele Shale, Mesaverde Formation, and Lance Formation, all of Cretaceous age, and the Wind River Formation and White River Formation, both of Tertiary age, and various alluvial and wind-blown deposits were collected and analyzed for water-soluble selenium content, using methods described by the American Society of Agronomy and American Society for Testing and Materials (1965).

Total selenium content in soils derived from the Niobrara Formation in south-central Wyoming ranged from 3.7 to 37 μg/g (micrograms per gram) (reported as parts per million) in six samples as reported by Rosenfeld and Beath (1964, p. 45); water-soluble selenium ranged from 3.8 to 13.5 percent of the total selenium. Three samples of alluvium overlying the Niobrara Formation contained 14 to 28 μg/g (reported as parts per million) total selenium; water-soluble selenium was 16 to 40 percent of the total selenium. The content of water soluble selenium was not related to depth within the sampled range of 0 to 40 in. below the surface (Rosenfeld and Beath, 1964, p. 45).

Geologic formations in Wyoming with potential to contain selenium were mapped by Case and Boyd (1985). The areas north, west, and south of Casper, including the Kendrick Reclamation Project, are shown to have localized potential for a large selenium content in bedrock, soils, and vegetation. Rosenfeld and Beath (1964, p. 10) reported plant specimens in the same area containing greater than 500 μg/g (reported as parts per million) selenium.

Environmental Assessment and Unpublished Data

Little information exists on fish and wildlife resources of the Kendrick Reclamation Project. The information available is of a general nature and consists principally of casual observations on species using the area. An environmental assessment, however, was prepared in 1981 on a proposal by the Casper Board of Public Utilities to supply water from the Kendrick Reclamation Project to Casper for municipal use. This assessment included an evaluation of wetland habitat, but was limited to those areas adjacent to the Casper Canal. Twenty-seven sites along the canal were identified as seep areas providing 5,192 acres of wetland habitat. Of this total, 1,590 acres were considered to have "highest wetland value." Rasmus Lee Lake and associated wetlands (732 acres) was included in the highest-value category. According to the Wyoming Game and Fish Department, (correspondence attached to the environmental assessment) Rasmus Lee Lake and surrounding area add significant value to the general area for wildlife by providing breeding habitat for an estimated 55 species and a migration stop for 88 species of birds. According to the environmental assessment, the only suitable open-water habitat available for waterfowl and shorebirds is the Casper Canal and Rasmus Lee Lake.

SAMPLE COLLECTION AND ANALYSIS

Objectives

In the analysis of surface- and ground-water samples, trace elements were emphasized because of previous indications of elevated concentrations. Constituents included in chemical analyses of water samples are listed in table 2; specific conductance, pH, and water temperature were measured at the sampling sites during sample collection. The types of samples collected and constituents to be analyzed were described in the DOI protocol (unpublished) for the reconnaissance investigations.

Bottom sediment samples were analyzed for trace elements and some of the major ions, for comparison of the values within the area and to the values reported in literature. Elements analyzed in bottom sediment are listed in table 3.

One basic objective of the biological sampling was to select an organism or group of organisms that represented diet items of either migratory birds or fish. Further, it was a basic goal to achieve consistency, if at all possible, from site to site in the kind of organisms sampled so that various areas could be compared. Constituents analyzed in biota are listed in table 4.

Sampling Sites

Samples were collected at 15 surface-water sites and at 5 ground-water sites (fig. 1). Water and bottom-sediment samples were collected during August 1986; water samples were also collected during October 1986. The samples collected during August reflect conditions while surface water was being applied for irrigation, whereas irrigation water was not being applied during October. The types of samples collected at each site are listed in table 5. For this report, surface-water, bottom-sediment, and biological sampling sites are numbered 1-14 and ground-water sampling sites are lettered A-E.

There were several considerations in selecting the biological sampling sites. These included: (1) knowledge of previous data that indicated potentially contaminated sites; (2) information from persons familiar with the area; (3) relation of the site to irrigation-water inflow and outflow; and (4) availability of biota.

With the exception of the North Platte River sampling, selection of the biota sampling periods was based on times when young-of-the-year birds and bird eggs were available (table 6). An attempt was made to collect young-of-the-year birds as late in the pre-fledgling stage as possible. This was to allow maximum exposure of young birds to contaminants present and add

Table 2.--Constituents analyzed in water samples

Trace elements, dissolved	Radiochemicals, dissolved	Pesticides, total
Arsenic	Gross alpha, as natural uranium	Diazinon
Barium	Gross beta, as cesium-137	Dicamba
Boron	Gross beta, as yttrium-90	Disyston
Cadmium	Radium-226	Ethion
Chromium	Uranium, natural	Guthion
Copper		Malathion
Lead		Methyl parathion
Mercury		Methyl trithion
Molybdenum		Orthophosphate defoliant
Nickel		Parathion
Selenium		Phorate
Silver		Picloram
Vanadium		Silvex
Zinc		Trithion
		2,4-D
		2,4-DP
		2,4,5-T

Table 3.--Constituents analyzed in bottom sediment

Major ions	Trace elements
Calcium	Aluminum
Magnesium	Magnesium
Phosphorus	Arsenic
Potassium	Barium
Sodium	Beryllium
	Bismuth
	Cadmium
	Cerium
	Chromium
	Cobalt
	Copper
	Europium
	Gallium
	Gold
	Holmium
	Iron
	Lanthanum
	Lead
	Lithium
	Manganese
	Mercury
	Molybdenum
	Neodymium
	Nickel
	Scandium
	Selenium
	Silver
	Strontium
	Tantalum
	Thorium
	Tin
	Titanium
	Uranium
	Vanadium
	Ytterbium
	Yttrium
	Zinc

Table 4.—Constituents analyzed in biota

Trace elements, total	Pesticides, total
Aluminum	cis-chlordane
Arsenic	trans-chlordane
Barium	Dieldrin
Beryllium	Endrin
Boron	cis-nonachlor
Cadmium	trans-nonachlor
Chromium	Oxychlordane
Copper	PCB-1254 (estimated)
Iron	p,p'-DDD
Lead	p,p'-DDE
Manganese	p,p'-DDT
Mercury	
Molybdenum	
Nickel	
Selenium	
Strontium	
Tin	
Vanadium	
Zinc	

Table 5.—Types of samples collected

[x, indicates that one or more samples were collected; —, no data available]

Site	Site name	Surface water	Ground water	Bottom sediment	Biota
1	North Platte River at Alcova	x	—	x	x
2	Bates Creek	x	—	x	—
3	Poison Spring Creek	x	—	x	—
4	Rasmus Lee Lake	x	—	x	x
5	Goose Lake	—	—	—	x
6	Poison Spider Creek	x	—	x	—
6a	North Platte River downstream from Poison Spider Creek	—	—	—	x
7	Oregon Trail Drain	x	—	x	—
8	Casper (treated public supply)	x	—	—	—
9	North Platte River at Mills	x	—	x	x
10	Thirtythree Mile Reservoir	—	—	—	x
11	Illco Pond	—	—	—	x
12	Casper Creek	x	—	x	—
13	North Platte River at Casper	—	—	—	x
14	North Platte River downstream from Casper	x	—	x	—
A	Well 31-82-27cdd01	—	x	—	—
B	Well 33-81-28daa01	—	x	—	—
C	Well 35-80-31ddd01	—	x	—	—
D	Well 34-80-33ddd01	—	x	—	—
E	Well 35-81-08bd01	—	x	—	—

Table 6.—Collection schedule for biological samples

[t, trace elements analyzed in one or more samples; p, pesticides analyzed in one or more samples; —, samples not collected]

Site No. (fig. 1)	Site name	Season	Type of biota: Birds (livers)	Birds (eggs)	Fish	Inverte-brates	Plants: Sago pond-weed	Fila-men-tous green algae
1	North Platte River at Alcova	Summer	—	—	t,p	t	—	—
6a	North Platte River downstream from Poison Spider Creek	Summer	—	—	t,p	t	—	—
9	North Platte River at Mills	Summer	—	—	t,p	t	—	—
13	North Platte River at Casper Creek	Summer	—	—	t,p	t	—	—
4	Rasmus Lee Lake	Spring	—	t,p	—	—	—	—
		Summer	t	—	—	t	t	t
5	Goose Lake (southeast shore)	Spring	—	t,p	—	—	—	—
10	Thirtythree Mile Reservoir (southwest end)	Summer	t	—	t,p	t	t	—
11	Illco Pond	Summer	t	—	t	t	t	t[1]
TOTAL ANALYSES BY								
TYPE OF CONSTITUENT			12	7,7	11,10	8	3	2
TOTAL SAMPLES BY TYPE OF BIOTA			12	7	[2]19	8	3	2

[1] Chara.
[2] Includes 8 fish-liver samples for arsenic, mercury, and selenium.

some degree of certainty to the likelihood that any contaminant found existed in that particular locale. Consequently, most birds were collected in late July and early August. All bird egg samples were obtained during the latter part of May and early June. Fish, invertebrates, aquatic vascular plants, and algae samples were also collected during the same period used for bird collections. Fish and invertebrate samples from the North Platte River were collected on August 12 and 13.

North Platte River

Four sites were selected along the North Platte River for sampling fish and benthic invertebrates. Site 1 was located about 4 river mi downstream from Alcova Dam and was considered to represent background river conditions unaffected by irrigation return flow from the Kendrick Reclamation Project. This was the only site where it was necessary to collect invertebrates other than dragonfly naiads. Although caddisfly larvae, mayfly nymphs, and stonefly nymphs were present and would have been the alternative choice to odonates, the individuals were small and few in number, so gastropods were used. These are common throughout the upstream reach of the river. Site 6a was on the left bank about $\frac{1}{8}$ river mi downstream from the mouth of Poison Spider Creek. The sampling site for fish, however, ranged from this point downstream for about 1 river mi. This site was selected because of the potential effects of drainage from Poison Spider Creek on the quality of water in the North Platte River. Site 9 and site 13 are upstream and downstream, respectively, from Casper Creek, which conveys substantial irrigation return flow from the Kendrick Reclamation Project into the North Platte River near Mills. At site 9 the sampling site for fish included a reach of the river extending from 1 to $1\frac{1}{2}$ river mi upstream from Casper Creek. Invertebrates were sampled near the first bridge upstream (about $\frac{1}{2}$ river mi) from Casper Creek. At site 13, the sampling site for fish extended downstream from the mouth of Casper Creek for about $1\frac{1}{2}$ river mi. Invertebrate sampling was along the left bank about $\frac{1}{4}$ river mi downstream from the mouth of Casper Creek. It should be noted that sites 9 and 13 could also be affected by domestic and industrial discharges from the cities of Mills and Casper.

Rasmus Lee Lake

Rasmus Lee Lake (site 4) was the main body of water involved in the investigation. Rasmus Lee Lake has a surface area of about 730 acres and a maximum depth of about 5 ft. Although an outlet is present, it is not functional at low lake levels. The lake receives water from natural runoff (snowmelt and precipitation) as well as irrigation return flow. No coot or other waterfowl nests were found, so liver and egg samples were obtained only from avocets. Avocet production also was limited due to availability of suitable nesting habitat and loss of eggs from flooding. Consequently, the liver from only one juvenile bird could be obtained. The remaining livers were collected from adult birds.

Several islands exist in the lake, and a number (about 24) of Canada-goose nests had been abandoned. Many of the abandoned nests contained unbroken eggs. The significance of the large proportion of abandoned nests is unknown. Several waterfowl carcasses were observed on May 29 and May 30 around the islands. However, the carcasses were badly decomposed and species could not be identified. Cause of death is unknown. The mortality may relate to duck hunting as the area is used to a limited extent for this purpose. A few Chironomid larvae were observed in the bottom sediments (reducing conditions). Only a few other invertebrates were observed either in the water or in the bottom sediment. The few invertebrates observed may have been due to the observation periods or habitat conditions or both. A few, small, unidentified fish were observed in the outlet channel and in shallow weed beds along the northern shore where several small streams conveying irrigation return flow enter the lake. No fish were observed, however, at any other location within the lake.

Goose Lake

Goose Lake has a surface area of about 30 acres, an average depth of about 2 ft, and is located in a closed basin (no outlet). Goose Lake was included in the investigation primarily as a control site because the lake receives little irrigation return flow. A small volume of water, however, may occasionally enter the lake from irrigated lands to the east and from surrounding hay fields during the irrigation season.

Bird eggs were considered one of the more important biological parameters in the investigation to analyze for metals. Accordingly, only bird eggs were collected from Goose Lake to aid in evaluating and interpreting analytical results for bird eggs obtained from other areas.

A part of the southern shore of the lake was suitable for avocet nesting, and an area of about 1 acre near the southeastern end contained adequate emergent vegetation for eared-grebe nesting. Even though 18 to 20 different species of shorebirds and waterfowl were observed at the lake, it is likely that nesting by species, other than avocet and eared grebes, was minor. Accordingly, only avocet and eared-grebe eggs were collected from Goose Lake.

Thirtythree Mile Reservoir

Thirtythree Mile Reservoir is an impoundment on South Fork Casper Creek with a surface area of about 10 acres. Maximum depth probably is about 10 ft at the dam. Much of the lake basin is filled with sediment. The general appearance of the habitat and isolation of the lake from any major disturbance suggested that a moderate number of waterfowl should be using the lake. Observations for several days, however, indicated that although a few birds use the lake, the time spent foraging or resting appeared to be of short duration. The scarcity of submerged vegetation and benthic invertebrates indicated that food supply could be a limiting or controlling factor. Because no birds were produced on the lake, the birds collected were limited to several adult blue-winged teal, which were using the area presumably for foraging and resting. The length of time they actually had used the reservoir is unknown. Because of the time of year (August 5 and 6), however, it is expected that they were perhaps residents of the general area for several months. Odonate invertebrates were extremely few, perhaps because of the lack of submergent vegetation and bottom-sediment characteristics. Accordingly, crayfish were substituted for odonates. It is known that crayfish is a common diet item for white pelicans in the drainage basin of the North Platte River, however, none of these birds were observed using Thirtythree Mile Reservoir. Fish samples collected included juvenile carp and fathead minnow.

Illco Pond

Illco Pond is a small impoundment (surface area about 1.5 acres and maximum depth about 5 ft) near Middle Fork Casper Creek. Although outside the project area, the pond received runoff and seepage from irrigated fields nearby, provided the most diverse habitat conditions of any of the sites investigated, and it appeared to be the "richest" relative to numbers and kinds of fish, invertebrate, and plant species of any of the sites investigated. Avocets nest on a small mud flat at the site, but nesting habitat for other shorebirds and waterfowl is limited. All avocet eggs produced on the site in 1986, however, were lost due to flooding. Two immature mallards were collected from the site, but because they were capable of flight, it is unknown if these birds were raised near the pond or elsewhere in the general area.

Sampling Methods

Water and bottom-sediment samples were collected by personnel of the U.S. Geological Survey from Cheyenne and Denver using methods described in U.S. Geological Survey (1977). Biological samples were collected by personnel of the U.S. Fish and Wildlife Service and the Wyoming Game and Fish Department.

Young-of-the-year American coot and American avocet were the primary age class and bird species targeted for collection of liver and egg samples. Because young-of-the year birds generally are confined to a given local area until flight stage, the chemicals present in their tissue can be assumed to have been obtained from food and water in the area where they were reared.

Standard equipment and techniques were used for collecting the biological samples. Birds were shot using steel shot, and the livers removed using stainless steel dissecting equipment. Collecting apparatus was routinely cleaned between sampling locations, and dissecting equipment vigorously cleaned prior to removal of each bird liver. Bird eggs were collected by removing one egg from individual nests until the necessary number was obtained. Fish were collected using electroshocking equipment and seine or sweep nets or both; pond invertebrates with a sweep net; stream invertebrates with a kick screen; clumps of aquatic vascular plants (sago pondweed) were uprooted using a tile spade; and algae by hand-picking using forceps.

Because it was a reconnaissance investigation and total samples that could be analyzed were limited, no duplicate field samples were collected. It was deemed unnecessary to identify organisms to a finer taxonomic classification than that which could be easily determined by macroscopic features.

Analytical Support

Analyses of trace elements, radiochemicals, and pesticides in samples of surface and ground water, and pesticides in samples of bottom sediment were made at the U.S. Geological Survey's water-quality laboratory in Denver, Colo., using methods described by Fishman and Friedman (1985) and Wershaw and others (1987). Water samples were filtered through a membrane filter with 0.45-micrometer-diameter pore size and acidified at the sampling site.

Analysis of trace elements in samples of bottom sediment were done by the U.S. Geological Survey's geochemistry laboratory in Denver, Colo. At the laboratory, the bottom-sediment samples were air dried, disaggregated, and sieved to retain particles smaller than 0.062 mm (millimeter). Analytical techniques used were described by Severson and others (1987).

All biological samples were analyzed at the U.S. Fish and Wildlife Service's Patuxent Analytical Control Facility (PACF) in Laurel, Md. Methods applicable to samples from Wyoming are described in the PACF analytical manual (unpublished). Laboratory quality-control procedures included duplicate analyses, spike reference samples, and procedural blanks.

DISCUSSION OF RESULTS

Analyses of all samples collected during this reconnaissance investigation are listed in tables at the back of the report. The titles and numbers of those tables are: On-site measurements and trace elements in surface and ground water, table 12; Radiochemicals in surface and ground water, table 13; Pesticides in surface water and bottom sediment, table 14; Trace elements in bottom sediment, table 15; Trace elements (dry weight) in biota, table 16; and Trace elements (wet weight) in biota, table 17.

Water

Standards and criteria used for evaluation of water quality include national standards that specify the maximum concentration of a contaminant in public water supplies as established by the U.S. Environmental Protection Agency (1986a,b,c). The primary maximum contaminant standards are health related and are legally enforceable. The secondary maximum contaminant standards apply to esthetic qualities and are recommended guidelines. The water quality criteria (U.S. Environmental Protection Agency, 1986c) include discussion of criteria for marine and fresh water aquatic life and human health.

Arsenic, Boron, Cadmium, and Mercury

Dissolved arsenic concentrations were small in samples of surface and ground water. The median concentration was less than 2 µg/L in 24 samples; the maximum concentration of dissolved arsenic was 16 µg/L, which was reported in a sample from Rasmus Lee Lake. Boron concentrations in water samples from several sites exceeded the 750-µg/L criterion for irrigation water recommended by the U.S. Environmental Protection Agency (1986c). The criterion is based on long-term irrigation of sensitive crops. The maximum concentration of dissolved boron in surface water samples was 1,100 µg/L; the maximum in ground water was 5,600 µg/L (table 12).

Concentrations of cadmium generally were small; maximum concentrations were 14 µg/L in a sample from Rasmus Lee Lake (site 4) and 6 µg/L in a sample from the North Platte River at Alcova (site 1) in August. The concentration of cadmium in Rasmus Lee Lake exceeded the maximum concentration of 10 µg/L for public water supplies (U.S. Environmental Protection Agency, 1986a) and is near the upper limit recommended for aquatic life by the U.S. Environmental Protection Agency (1986c). This cannot be confirmed because the limit for aquatic life is based on hardness, which was not measured in this investigation. A water sample collected in October from Rasmus Lee Lake had a cadmium concentration less than 1 µg/L.

A mercury concentration of 2.1 µg/L was measured in a water sample from site 4, Rasmus Lee Lake (fig. 3) in August, which is slightly less than the criterion of 2.4 µg/L for freshwater aquatic life established by the U.S. Environmental Protection Agency (1986c), but slightly larger than the maximum concentration of 2.0 µg/L for public water supplies (U.S. Environmental Protection Agency, 1986a). Mercury concentrations did not exceed 0.4 µg/L in the remainder of the samples collected in this investigation. Because of the small number of samples, it cannot be determined if the concentration of 2.1 µg/L indicates a potential problem.

Selenium

The median concentration of dissolved selenium in 24 water samples collected during this investigation was 7.5 µg/L. These samples consisted of 19 surface-water samples and 5 ground-water samples. The selenium concentrations varied from 300 µg/L to less than 1 µg/L (table 12). The maximum concentration of 300 µg/L was measured in a water sample collected from Oregon Trail Drain (site 7) on October 16 (fig. 4); water samples with selenium concentrations less than the analytical detection limit of 1 µg/L were collected from the North Platte River at Alcova (site 1) and at Mills (site 9) in August.

Eleven of the 24 water samples contained concentrations of selenium greater than the maximum concentration of 10 µg/L for public water supplies (U.S. Environmental Protection Agency, 1986a), but none of the sites where these excessive concentrations were present are used for public water supplies. Ten of the 11 samples were collected from surface-water sites which are not suitable year-around sources of potable water; the eleventh was from a shallow well that is used for livestock watering. Many residents

Figure 3.--Waterfowl on Rasmus Lee Lake during June, 1987. View is looking east, at the northern part of the lake. Land in foreground is seepage area.

Figure 4.--Oregon Trail Drain near site 7, looking upstream during June, 1987. White crust along lower part of bank is salt deposits.

in the project area haul their drinking water from Casper because of the large dissolved-solids and sulfate concentrations in the ground water. The possibility exists that some residents are consuming water with selenium concentrations greater than the national standard, but this was not confirmed because of the reconnaissance nature of this investigation.

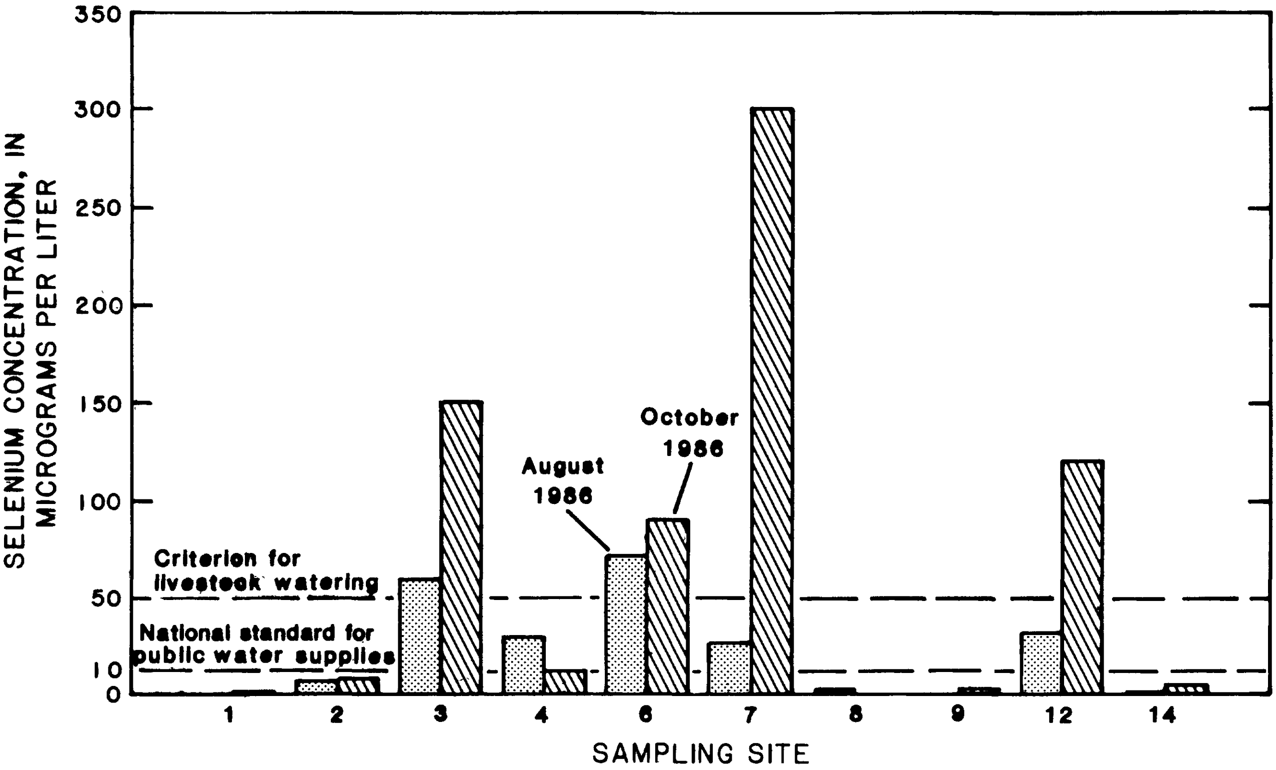
Six of the 24 water samples contained selenium concentrations greater than the maximum concentration of 50 µg/L for livestock consumption recommended by the National Academy of Sciences and National Academy of Engineering (1973, p. 316). The six water samples were from small streams that are accessible to livestock on the open range, but the amount of use for stock watering was not determined.

Selenium concentrations in the North Platte River, which is used for public water supplies, increased in the downstream direction, but did not exceed the national drinking water standard. The increase in selenium concentration in the North Platte River from Alcova (site 1) to downstream from Casper (site 14) was from less than 1 to 2 µg/L in August, and from 1 to 4 µg/L in October.

Selenium concentrations at the stream sites were larger in October than in August. The seasonal variation was particularly evident in the four principal tributaries (fig. 5). In contrast, streamflow was larger in August, during the irrigation season, than in October, when irrigation water was not being applied (table 12). An inverse relation between selenium concentrations and streamflow may indicate that irrigation water is diluting the seepage from ground water. Crist (1974) noted an inverse relation between selenium concentration and streamflow in Oregon Trail Drain, but not in Poison Spring, Poison Spider, and Casper Creeks.

Selenium discharges in the North Platte River and tributaries were calculated from the selenium concentration and instantaneous streamflow at the time of sampling, and expressed as selenium discharge in kg/d (fig. 6). Although samples were collected during a period of several days in August and in October, for the following discussion the samples are treated as if they were all collected on 1 day. Hydrologic conditions did not change substantially during the several days that samples were collected.

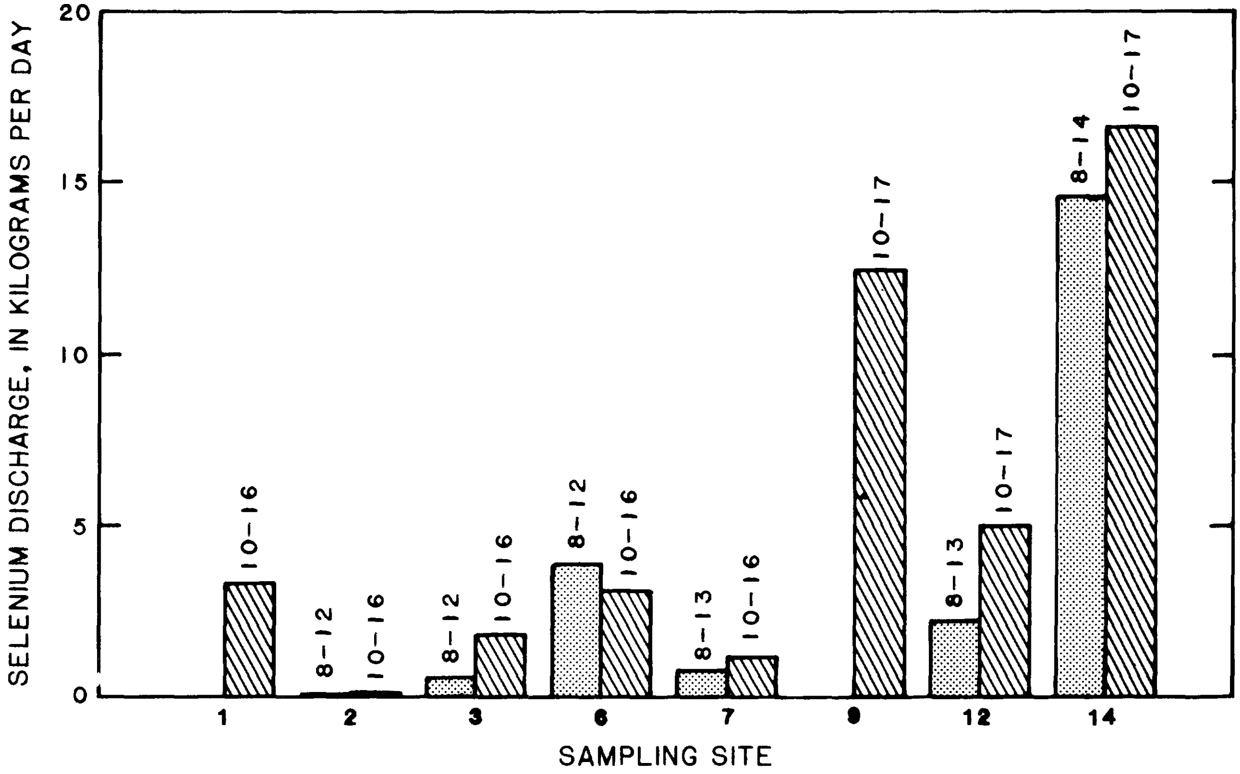
The discharge of selenium in the North Platte River increased in the downstream direction due largely to contributions from the four principal tributaries draining the Kendrick Reclamation Project. In August, the sum of the discharges shown in figure 6 for Poison Spring Creek (site 3), Poison Spider Creek (site 6), Oregon Trail Drain (site 7), and Casper Creek (site 12), totalled about one-half of the dissolved selenium discharge of 14.6 kg/d in the North Platte River downstream from Casper (site 14). In October, the same four tributaries contributed 11.0 kg/d of the 16.6 kg/d discharge in the North Platte River downstream Casper. The discharge in the North Platte River at Alcova in October was 3.3 kg/d, which, when added to the discharge from the four principal tributaries, indicates about 2.3 kg/d of selenium was contributed by Bates Creek and unmeasured sources between sampling sites at Alcova (site 1) and downstream from Casper (site 14).



EXPLANATION

SAMPLING SITE	NAME	SAMPLING SITE	NAME
1	NORTH PLATTE RIVER AT ALCOVA	7	OREGON TRAIL DRAIN
2	BATES CREEK	8	CASPER (TREATED PUBLIC SUPPLY)
3	POISON SPRING CREEK	9	NORTH PLATTE RIVER AT MILLS
4	RASMUS LEE LAKE	12	CASPER CREEK
6	POISON SPIDER CREEK	14	NORTH PLATTE RIVER DOWNSTREAM FROM CASPER

Figure 5.--Dissolved selenium concentrations in water. Concentrations were less than the analytical detection limit of 1 microgram per liter in August at sites 1 and 9. Site 8 was not sampled during October.



EXPLANATION

SAMPLING SITE	NAME		
1	NORTH PLATTE RIVER AT ALCOVA	7	OREGON TRAIL DRAIN
2	BATES CREEK	9	NORTH PLATTE RIVER AT MILLS
3	POISON SPRING CREEK	12	CASPER CREEK
6	POISON SPIDER CREEK	14	NORTH PLATTE RIVER DOWN-STREAM FROM CASPER

10-16 MONTH-DAY IN 1986

Figure 6.--Selenium discharge in the North Platte River, Bates Creek, and tributaries draining the Kendrick Reclamation Project. Discharge in the North Platte River at Alcova and at Mills during August is not shown, because the selenium concentrations were less than the analytical detection limit.

Selenium concentrations in surface and ground water appear to be smaller than those measured in a previous investigation by Crist (1974), but this cannot be statistically tested because of the small number of samples collected during the reconnaissance investigation. A summary of Crist's (1974) data (table 1) indicates median concentrations of 20 μg/L in surface water and 30 μg/L in ground water, compared to the median of 7.5 μg/L from surface and ground water in this investigation. This may not represent a decrease in concentrations, but rather, a change in the method of analysis during the interim between Crist's (1974) investigation and this one. According to J.M. Schoen (U.S. Geological Survey, oral commun., 1987) the method used for analysis of samples as reported by Crist (1974, p. 9) was accurate within about 10 percent at large concentrations in the range of hundreds of micrograms per liter, but subject to interference from other chemical constituents at small concentrations in the range of less than 10 to 20 μg/L.

Of the five wells sampled, measured selenium concentrations were 3 μg/L or less in samples from four of the wells. The water sample from well A, which is completed in alluvial terrace deposits at a depth of 55 ft, had a selenium concentration of 30 μg/L. Well A also was sampled by Crist (1974, p. 19, well 31-82-27cdd1); the median concentration was 10 μg/L in 13 samples. Crist (1974, p. 19) noted ground water at this site probably receives recharge from irrigation water.

Radiochemicals and Pesticides

Surface and ground-water sites were sampled for radiochemical constituents (table 13); surface-water sites also were sampled for pesticides in water and bottom sediment (table 14). Analyses for radiochemicals indicated radium-226 activities less than the primary standard of 3 pCi/L (picocuries per liter), for public water supplies, as described by Lappenbusch and Cothern (1985). Pesticide concentrations in the water and pesticide contents of bottom sediments generally were less than analytical detection limits, although small concentrations of 2,4-D, picloram, and dicamba were detected in water.

Bottom Sediment

The selenium content of bottom-sediment samples ranged from 0.9 to 25 μg/g (table 15). The largest selenium contents were measured in bottom sediment from Poison Spring Creek (25 μg/g), Rasmus Lee Lake (17 μg/g), and Casper Creek (16 μg/g). Samples from three sites along the North Platte River and from a site on Bates Creek contained 1.2 μg/g or less of selenium. Selenium contents of bottom-sediment samples at all of the sites in this investigation were greater than geometric mean selenium contents of 0.23 μg/g in soils of the western conterminous United States and of 0.45 μg/g in soils from the northern Great Plains, as reported by Shacklette and Boerngen (1984).

Other trace-element contents of bottom sediments in the project area that also were greater than the geometric mean contents reported by Shacklette and Boerngen (1984) include uranium at all of the sites (geometric-mean uranium concentration of 2.5 μg/g in soils from the western conterminous United States), and chromium, lithium, and nickel in samples from Poison Spider Creek, Oregon Trail Drain, and Casper Creek. According to R.C. Severson (U.S. Geological Survey, written commun., 1987), tests of subsamples analyzed for this investigation indicate the contents of boron, chromium, copper, nickel, vanadium, and zinc are enriched from 30 to 50 percent in the 0.062-mm size fraction compared to those in the 2-mm size fraction. The lithium content of bottom sediment from Bates Creek, the strontium content of bottom sediment from Poison Spring Creek, and the vanadium content of bottom sediment from Oregon Trail Drain are more than twice as large as the geometric-mean contents in soils from the northern Great Plains reported by Shacklette and Boerngen (1984).

Biota

Chemical, physical and biological interactions are dynamic and variable among aquatic habitats. Chemical interactions involving consumer-organism diet, including synergistic, antagonistic, or other interactions between trace elements are complex. The effects of these interactions can be extremely variable for different trophic levels of organisms, among species, as well as from site to site. Consequently, in natural systems no precise or universal guidelines have been established for specific contents of trace elements in birds, fish, or lower aquatic organisms that are indicative of various degrees of toxicity. Also, because of the complexity and variability in natural systems, chemical contents in biota from one area do not necessarily mean the same effects will occur in another area where the biota contain similar chemical contents. Consequently, the information from controlled-diet studies or derived from other areas can only be used as reference guidelines for determining whether or not a potentially harmful content exists in biota in a different area.

The trace elements analyzed in the biota samples were previously listed in table 4. A complete tabulation of the analytical results is presented at the back of the report (table 16, dry-weight contents; table 17, wet-weight contents). The results presented in the following discussion are limited primarily to arsenic, boron, mercury, and selenium because of their toxicity to wildlife and fish and the potential for the chemicals to occur at elevated contents.

Bird Livers

Bird production was poor, and pre-fledgling young-of-the-year birds were unavailable in August 1986 for collection at Rasmus Lee Lake, Thirtythree Mile Reservoir, and Illco Pond. With the exception of one avocet, all birds were either juvenile or adult and capable of flight. Consequently, the bird collections were made on the basis of availability and species using the area at the time of collection. All of the birds collected appeared healthy. Arsenic, boron, mercury, and selenium contents in livers from birds using Rasmus Lee Lake, Thirtythree Mile Reservoir, and Illco Pond are listed in table 7.

Comparisons among the three areas can only be superficial because different species of birds were collected and all of the birds, except one, could easily move to adjacent wetlands or fly to other areas that, perhaps, were not sampled during this investigation. Because of the time of year, however, it is likely that most of the birds were either hatched and raised in the local area or were adults that had been residents in the general area for some time. It is possible, however, that immature and adult birds may have foraged in areas outside the project boundary.

Arsenic

The arsenic contents of bird livers sampled were less than toxic contents. Arsenic was detected in only 3 of the 12 livers in birds collected from Rasmus Lee Lake, Thirtythree Mile Reservoir, and Illco Pond (table 7). Arsenic content of livers in three avocets from Rasmus Lee Lake ranged from 0.32 to 1.7 µg/g dry weight. Literature available on arsenic content of bird tissues is extremely limited, however, it appears that a large content of arsenic is required to cause problems for the birds. The significance, if any, of the contents of arsenic detected in the avocet livers is unknown.

Boron

The boron content of several livers was larger than expected and exceeded contents reported in the literature as causing effects on growth and reproduction. Boron contents varied with bird species and with location (table 7). Some degree of individualistic diet preferences in the same species or perhaps some other factor, such as sex, age, and size may have contributed to the substantial difference between the boron contents of the livers from the two avocets. Sex was not determined for avocets collected, but all the blue-winged teal were males; mallard 1 was a male and mallard 2 was a female. However, the boron content (130 µg/g dry weight) of the avocet liver from Rasmus Lee Lake substantially exceeds the largest concentration in mallard ducklings that resulted in some growth and survival problems (Patuxent Wildlife Research Center, written commun., 1987). The boron content of livers from mallard ducklings, which were maintained on a diet including 1,000 µg/g boron, ranged from 23 to 89 µg/g dry weight. These ducklings had smaller weight gain and increased mortality compared to normal ducklings (Patuxent Wildlife Research Center, written commun., 1987). Whether the same content would cause similar problems in avocets is unknown. The boron content of the immature mallard liver (26 µg/g dry weight) from Illco Pond and of the other avocet liver (28 µg/g dry weight) from Rasmus Lee Lake are within the range for adult mallards that experienced reproductive problems. The boron content of livers from these adult mallards, which were maintained on a diet including 1,000 µg/g boron, ranged from 6 to 74 µg/g dry weight.

Table 7.—Arsenic, boron, mercury, and selenium contents of bird livers

[<, less than]

Sample No.	Site and type of bird	Arsenic Dry	Arsenic Wet	Boron Dry	Boron Wet	Mercury Dry	Mercury Wet	Selenium Dry	Selenium Wet
	Rasmus Lee Lake (site 4)								
1	Avocet (juvenile)	<0.36	<0.10	<12	<3.2	6.2	1.7	51	13
2	Avocet (adult)	1.7	.42	<18	<4.3	1.1	.26	85	20
3	Avocet (adult)	.34	.08	<8.9	<2.0	1.9	.42	65	14
4	Avocet (adult)	<.37	<.10	28	7.3	5.1	1.3	53	14
5	Avocet (adult)	.32	.12	130	47	.8	.29	170	62
	Thirtythree Mile Reservoir (site 10)								
1	Blue-winged Teal (adult male)	<.34	<.09	<14	<3.4	3.8	.96	16	4.0
2	Blue-winged Teal (adult male)	<.33	<.10	<34	<10	5.9	1.8	14	4.2
3	Blue-winged Teal (adult male)	<.26	<.07	<15	<4.4	2.0	.58	16	4.4
4	Blue-winged Teal (adult male)	<.17	<.05	10	2.7	2.5	.68	14	3.6
5	Blue-winged Teal (adult male)	<.18	<.05	<7.8	<1.9	3.4	.85	13	3.2
	Illco Pond (site 11)								
1	Mallard (immature male)	<.19	<.05	<7.1	<1.9	<.18	<.05	43	12
2	Mallard (immature female)	<.17	<.04	26	6.4	<.19	<.05	56	14

Dry- and wet-weight contents, in micrograms per gram

Mercury

The mercury content of bird livers was less than contents known to cause toxic effects in birds. Mercury was not detected in the immature mallards from Illco Pond, but ranged from 0.8 to 6.2 μg/g dry weight (0.26 to 1.7 μg/g wet weight) in livers from avocets collected at Rasmus Lee Lake and from 2.0 to 5.9 μg/g dry weight (0.58 to 1.8 μg/g wet weight) in blue-winged teal collected at Thirtythree Mile Reservoir (table 7). The largest mercury content measured in the 12 birds sampled was 1.8 μg/g wet weight in a liver from a blue-winged teal, which is much less than the mercury residues (10.23 to 14.46 μg/g wet weight) measured in livers of black-duck ducklings. These ducklings were offspring produced from breeders fed 3 μg/g methyl mercury; the ducklings died after a few days being fed a mash diet also containing 3 μg/g methyl mercury (Finley and Stendell, 1978).

Selenium

The selenium content of bird livers indicates potentially toxic contents. Selenium was detected in all the bird livers, ranging from 51 to 170 μg/g dry weight (13 to 62 μg/g wet weight) in livers from avocets collected at Rasmus Lee Lake, from 13 to 16 μg/g dry weight (3.2 to 4.4 μg/g wet weight) in blue-winged teal at Thirtythree Mile Reservoir, and 43 and 56 μg/g dry weight (12 and 14 μg/g wet weight) in the two mallards at Illco Pond (table 7). The selenium content of bird livers in areas not contaminated by selenium generally is less than 12 to 16 μg/g dry weight (Ohlendorf and others, 1986).

The selenium content of livers from birds collected in the Kendrick Reclamation Project are greater than contents of female mallard livers (2.6 to 4.0 μg/g wet weight); most contents are within the range for male mallard livers (4.6 to 19 μg/g wet weight) where the birds experienced reproductive problems on a diet containing 8 μg/g dry weight selenium, as selenomethionine (Patuxent Wildlife Research Center, written commun., 1987).

Mallards fed 10 μg/g selenium experienced reproductive problems and produced significantly more abnormal embryos (18.3 percent) than control birds (Heinz and others, 1987). Livers from these birds had a selenium content ranging from 2.6 to 6.2 μg/g wet weight in females and from 6.1 to 12.0 μg/g wet weight in males. Comparison of the preceding data from other studies with data from the Kendrick Reclamation Project indicates that the avocets and mallards in the Kendrick Reclamation Project appear to have been using a selenium-contaminated area for some time. However, the juvenile avocet from Rasmus Lee Lake is the only bird that can be specifically linked to a given site.

Bird Eggs

Bird eggs were collected from Rasmus Lee Lake and Goose Lake. Goose Lake is a closed basin and was considered a possible control site because it receives only a small quantity of irrigation return flow. Although coot was the species targeted for collection, only avocet nests were found at Rasmus

Lee Lake, and only avocet and eared-grebe nests were found at Goose Lake. Arsenic and boron contents of bird eggs from both lakes were less than analytical detection limits. Mercury and selenium contents measured in the egg samples are listed in table 8.

Table 8.—Arsenic, boron, mercury, and selenium contents of bird eggs

[<, less than; —, no data]

Sample No.	Site and type of bird	Arsenic Dry	Arsenic Wet	Boron Dry	Boron Wet	Mercury Dry	Mercury Wet	Selenium Dry	Selenium Wet
	Dry- and-wet weight contents, in micrograms per gram								
	Rasmus Lee Lake (site 4)								
1	Avocet	<0.16	<0.04	—	—	1.66	0.39	64	16
2	Avocet	<.17	<.04	—	—	.85	.22	56	15
3	Avocet	<.34	<.09	<14	<3.5	.88	.23	55	14
4	Avocet	<.18	<.05	<7.5	<1.9	2.1	.55	79	20
5	Avocet	<.18	<.04	<7.9	<2.0	<.19	<.05	81	20
	Goose Lake (site 5)								
1	Avocet	<.16	<.04	<7.8	<2.0	.18	.04	51	13
1	Eared grebe	<.38	<.08	<9.7	<2.0	<.40	<.08	160	34
2	Eared grebe	<.28	<.06	<9.4	<2.0	<.31	<.06	100	21
3	Eared grebe	<.21	<.05	<8.5	<1.9	.57	.13	110	24

Although the information is limited, Goose Lake may not qualify as a control site because of the selenium contents of the eggs. However, the selenium content in bird eggs from Goose Lake may indicate that background selenium concentrations and contents for closed basins in the area may be rather large naturally. For this reconnaissance investigation, the number of egg samples analyzed was rather small and additional analyses would be necessary to demonstrate whether significant differences exist in trace-element contents in eggs between the two lakes.

Mercury

The mercury content of bird eggs generally was small and not likely to cause harmful effects. The mercury content ranged from less than the analytical detection limit to 2.1 μg/g dry weight (0.55 μg/g wet weight) in avocet eggs and from less than the analytical detection limit to 0.57 μg/g dry weight (0.13 μg/g wet weight) in eared-grebe eggs (table 8). The maximum mercury content of eggs, 2.1 μg/g dry weight (0.55 μg/g wet weight), is much smaller than the mercury residue detected (average of 6.14 μg/g wet weight) in the third black-duck egg of several clutches where hatching success was decreased (Finley and Stendell, 1978). The black ducks in that study were fed 3 µg/g mercury in their diet. Black-duck hens fed a diet containing 0.5 µg/g mercury produced eggs with mercury contents of 1 µg/g wet weight. In the wild, mallard eggs have been found that contain mercury in excess of 1 µg/g (Heinz, 1975). The mercury content of eggs at Rasmus Lee Lake and Goose Lake apparently is not unusually large.

Selenium

Selenium was detected in all egg samples and occurred at contents generally indicative of producing toxic effects in birds. The selenium content of 9 egg samples ranged from 51 to 160 µg/g dry weight.

The selenium content of avocet eggs from Rasmus Lee Lake and avocet and eared-grebe eggs from Goose Lake generally was larger than contents reported in the literature as causing selenium toxicity. Mallards fed a diet containing 8 µg/g selenium produced eggs with selenium contents ranging from 4.9 to 14.0 µg/g wet weight; duckling survival was decreased and teratogenic effects were noted (Patuxent Wildlife Research Center, written commun., 1987). Selenium contents ranged from 2.9 to 5.6 µg/g wet weight in mallard eggs that had a larger incidence of abnormal embryos than control eggs and a decreased duckling survival (Heinz and others, 1987). Although the eggs analyzed in this reconnaissance investigation indicate that selenium contents are elevated, adverse effects on embryos or bird production at Rasmus Lee Lake or Goose Lake cannot be certain based on information from controlled laboratory-diet studies or on similar contents in eggs from other areas that have been related to selenium toxicity.

Pesticides

Three avocet eggs from Rasmus Lee Lake and two eared-grebe eggs from Goose lake also were analyzed for pesticide residues. The only residue detected was p,p'-DDE, which was detected in all five eggs and ranged from 0.23 to 1.6 µg/g wet weight in avocet eggs and was 1.3 and 2.8 µg/g wet weight in the eared-grebe eggs. Blus (1982) reported that 3 µg/g of p,p'-DDE (fresh wet weight) in brown-pelican eggs was associated with impaired reproductive success and, at 4 µg/g, with total reproductive failure. Blus (1982) defined the critical content of p,p'-DDE to be 3 µg/g fresh wet weight. Sensitivity varies markedly among species, but the brown pelican is apparently extremely sensitive to p,p'-DDE. Accordingly, a p,p'-DDE content smaller than 3 µg/g fresh wet weight would not be expected to have significant effects on most species. Because the maximum content (2.8 µg/g wet weight) of eggs from Rasmus Lee Lake and Goose Lake is less than 3 µg/g fresh wet weight (the maximum Kendrick content would be even less expressed on a fresh-wet-weight basis), p,p'-DDE is not expected to be a significant concern.

Fish

Fish were collected from the North Platte River, Thirtythree Mile Reservoir, and Illco Pond. Arsenic, boron, mercury, and selenium contents detected in fish are listed in table 9.

Along the North Platte River, site 6a and site 13 were the two sites where increases in trace-element contents would have been expected because of inflow at site 6a from Poison Spider Creek and at site 13 from Casper Creek.

Arsenic

The maximum arsenic content (0.54 µg/g dry weight) of whole-body fish was less than the content reported in the literature as being toxic to fish. Arsenic in whole-body fish was detected more consistently in bottom-feeding fish, such as the white sucker and longnose sucker, than in rainbow trout. Although the arsenic content was slightly larger in bottom-feeding fish at the upstream sampling site along the North Platte River (site 1), the data indicate there was no significant increase of arsenic content in any of the whole-body fish from upstream sites to downstream sites.

In samples of whole-body fish from Thirtythree Mile Reservoir and Illco Pond, arsenic contents were small or less than analytical detection limits. The arsenic content of fathead minnows from Thirtythree Mile Reservoir, 0.10 µg/g wet weight, was larger than the content of fish from the North Platte River, but significantly less than the arsenic content of immature bluegills, 2.4 µg/g wet weight, which had poor growth and survival (Gilderhus, 1966).

Boron

Boron contents of fish were small and less than contents expected to cause harmful effects to fish. Except for the white sucker from site 1, boron was detected only in rainbow trout from the North Platte River. Although the boron content was slightly smaller in fish from site 1, the data from upstream to downstream were nearly the same. The significance of the boron contents of rainbow trout ranging from 11 to 14 µg/g dry weight (2.8 to 3.4 µg/g wet weight) is unknown.

Mercury

Mercury contents of fish were less than contents reported in the literature to cause harmful effects to fish. Small contents of mercury were detected in all fish samples from the North Platte River, but were less than the analytical detection limits in fish from Thirtythree Mile Reservoir and Illco Pond (table 9). The mercury content of rainbow trout ranged from 0.20 to 0.28 µg/g dry weight. The mercury content was largest in rainbow trout from the control site (site 1) and slightly decreased downstream. The mercury content of white suckers (0.35 and 0.44 µg/g dry weight) at sites 1 and 6a was slightly larger than the mercury content of the longnose suckers (0.29 and 0.26 µg/g dry weight) at downstream sites 9 and 13, but species differences may have been a factor.

Table 9.—Arsenic, boron, mercury, and selenium contents of whole-body fish

[<, less than]

Site and type of fish	Dry- and wet-weight contents, in micrograms per gram							
	Arsenic		Boron		Mercury		Selenium	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
North Platte River								
Rainbow trout (mature)								
Site 1	<0.18	<0.04	11	2.8	0.28	0.07	4.0	1.0
Site 6a	<.18	<.05	11	2.9	.21	.06	6.1	1.7
Site 9	.28	.07	14	3.4	.21	.05	7.5	1.8
Site 13	<.17	<.04	12	2.9	.20	.05	7.4	1.8
White sucker (mature)								
Site 1	.27	.07	8.2	2.3	.35	.1	1.9	.53
Site 6a	.25	.07	<7.0	<2.0	.44	.12	3.0	.86
Longnose sucker (mature)								
Site 9	.21	.07	<6.0	<1.9	.26	.08	2.8	.9
Site 13	.22	.06	<7.4	<1.9	.29	.08	4.5	1.1
Thirtythree Mile Reservoir								
Carp (fingerling)								
Site 10	<.23	<.04	<10	<2.0	<.21	<.04	49	9.5
Fathead minnow								
Site 10	.54	.10	<11	<1.9	<.21	<.04	35	6.4
Illco Pond								
Carp (fingerling)								
Site 11	<.28	<.04	<13	<2.0	<.30	<.05	21	3.2

Selenium

Selenium contents of fish from the North Platte River were less than contents at which toxicity would be expected. Selenium contents were smaller in bottom-feeding fish than in rainbow trout in the North Platte River. Selenium contents of rainbow trout ranged from 4.0 µg/g dry weight at site 1 to 7.5 µg/g dry weight at site 9. Selenium contents of bottom-feeding fish ranged from 1.9 µg/g dry weight at site 1 to 4.5 µg/g dry weight at site 13 and, therefore, appeared to generally increase in a downstream direction. However, selenium contents were nearly the same in bottom-feeding fish at sites 6a and 9. The greatest change in selenium content at consecutive downstream sites was 2.1 µg/g dry weight in rainbow trout from site 1 to site 6a and 1.7 µg/g dry weight in longnose sucker from site 9 to site 13. Sites 6a and 13 were the two sites where increases in selenium content were expected due to the effects of tributary inflow. Although this general pattern occurred, some exceptions were noted.

Selenium contents of fish from the North Platte River ranged from 0.53 to 1.8 µg/g wet weight. These contents are smaller than the content of 2 µg/g wet weight that, according to Baumann and May (1984), may be the minimum content that potentially could cause toxic effects.

Fish from the lake and pond sites had much larger selenium contents than fish from the North Platte River. The selenium content of fingerling carp from Thirtythree Mile Reservoir (49 µg/g dry weight) and from Illco Pond (21 µg/g dry weight) was about seven times and three times larger, respectively, than the largest selenium content of fish from the North Platte River (7.5 µg/g dry weight).

Selenium contents of fish from Thirtythree Mile Reservoir were 6.4 and 9.5 µg/g wet weight. These contents are nearly the same as that in adult bluegills (average of 6.7 to 9.7 µg/g wet weight), which was associated with a decrease in number of adult and larval fish (Gillespie and Baumann, 1986). Also, the selenium contents (3.2, 6.4, and 9.5 µg/g wet weight) of the three fish samples from the reservoir and pond sites all exceeded the content of 2 µg/g wet weight suggested by Baumann and May (1984) as a content which may be indicative of conditions which may cause toxic effects.

Pesticides

Rainbow trout and the bottom-feeding fish collected from the North Platte River sites 1, 6a, 9, and 13 and the carp and fathead minnows from Thirtythree Mile Reservoir were analyzed for the pesticides listed in table 4. None of the pesticides listed were detected in any of the fish samples.

Invertebrates

Arsenic, boron, mercury, and selenium contents of invertebrates from the North Platte River and lake and pond sites sampled during the investigation are listed in table 10. Invertebrates are important diet items to some fish and some species of birds. Boron and mercury contents of all invertebrates collected were less than the analytical detection limits. However, arsenic and selenium were detected in invertebrates from all sites except site 1, where the selenium content was less than the analytical detection limit.

Table 10.—Arsenic, boron, mercury, and selenium contents of invertebrates

[<, less than]

Type of invertebrates and site	Dry- and wet-weight contents, in micrograms per gram							
	Arsenic		Boron		Mercury		Selenium	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
North Platte River								
Gastropods (site 1)	1.4	0.42	<6.6	<1.9	<0.14	<0.04	<0.15	<0.04
Dragonfly naiads (site 6a)	1.1	.23	<9.7	<2.0	<.23	<.05	7.1	1.5
Dragonfly naiads (site 9)	1.4	.30	<9.3	<2.0	<.22	<.05	6.3	1.3
Dragonfly naiads (site 13)	.22	.28	<8.5	<1.9	<.20	<.04	7.2	1.6
Rasmus Lee Lake								
Odonates (site 4)	.62	.09	<14	<2.0	<.30	<.04	89	13
Thirtythree Mile Reservoir								
Crayfish (site 10)	1.5	.31	<9.2	<1.9	<.22	<.05	6.8	1.4
Illco Pond								
Odonates (site 11)	.97	.11	<17	<1.9	<.40	<.04	17	1.9
Crayfish (site 11)	1.6	.29	<11	<1.9	<.26	<.05	11	2

Arsenic

Arsenic contents measured in the invertebrates collected on the Kendrick Reclamation Project were small and would not be expected to cause harmful effects to common organisms such as birds or fish. The range of arsenic content of invertebrates collected during this investigation was rather small (0.62 to 1.6 μg/g dry weight) considering the different habitats and types of organisms collected. Moore and Ramamoorthy (1984) have reported no evidence of extreme bioaccumulation of arsenic in the majority of invertebrate species. Crayfish from Thirtythree Mile Reservoir and Illco Pond contained the largest arsenic contents, 1.5 and 1.6 μg/g dry weight, respectively. For the North Platte River sites, there was no distinct pattern in increasing or decreasing arsenic content in invertebrates from upstream to downstream.

Selenium

Selenium contents of invertebrates from the North Platte River were not equal to or larger than the contents believed detrimental to consumer organisms (birds and fish). However, contents of invertebrates from the lake and pond sites exceeded those determined in diet studies to cause toxicity.

The selenium content of dragonfly naiads from the North Platte River was relatively consistent among sampling sites. Dry-weight contents were 7.1 μg/g (site 6a), 6.3 μg/g (site 9), and 7.2 μg/g (site 13) with a maximum difference of 0.9 μg/g dry weight between site 9 and site 13. The actual content difference from site 1 to site 13 is larger, but, because different groups of organisms were sampled, a direct comparison cannot be made.

Invertebrates from the lake and pond samples had a considerable variation in selenium content that ranged from 6.8 μg/g dry weight in crayfish at Thirtythree Mile Reservoir to 89 μg/g dry weight in odonates from Rasmus Lee Lake. The selenium content measured in several of the invertebrates from the lake samples that could be diet items for birds and fish exceeded the selenium content of a diet (8 μg/g dry weight) that caused reproductive problems in mallards (Patuxent Wildlife Research Center, written commun., 1987) and exceeded the selenium content (10 μg/g dry weight) that caused markedly decreased growth and survival of juvenile rainbow trout (Goettl and Davies, 1978). However, a number of factors would need to be evaluated to estimate how much of the total selenium ingested by birds is from consumption of invertebrates inhabiting the lake and pond sites. It is rather unlikely, however, that the diet of most birds would be limited to a single group of invertebrates for an extended time.

Plants

Plant parts commonly are diet items for some species of migratory birds. Plants collected at the lake and pond sites included sago pondweed (*Potamogeton pectinatus*) at all three sites, filamentous green algae at Rasmus Lee Lake, and *Chara* at Illco Pond. Arsenic, boron, mercury, and selenium contents of plants are listed in table 11. The mercury content of plants collected at Rasmus Lee Lake, Thirtythree Mile Reservoir, and Illco Pond was less than analytical detection limits.

Table 11.—Arsenic, boron, mercury, and selenium contents of plants

[<, less than]

Site and type of plants	Dry- and wet-weight contents, in micrograms per gram							
	Arsenic		Boron		Mercury		Selenium	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Rasmus Lee Lake (site 4)								
Sago pondweed	8.5	0.91	390	42	<0.47	<0.05	10	1.1
Filamentous green algae	9.5	1.5	82	13	<.32	<.05	9.3	1.4
Thirtythree Mile Reservoir (site 10)								
Sago pondweed	6.4	.62	430	42	<.47	<.05	2.5	.25
Illco Pond (site 11)								
Sago pondweed	1.1	.11	630	62	<.47	<.05	2.9	.28
Algae (*Chara*)	1.6	.38	16	3.7	<.20	<.05	2.0	.46

Arsenic

Arsenic contents of plants sampled in this investigation were small and were not unusual for plants. The two largest arsenic contents measured were of sago pondweed (8.5 µg/g dry weight) and of filamentous green algae (9.5 µg/g dry weight) from Rasmus Lee Lake.

Boron

Boron contents of plants varied particularly among plant types, but several plant samples had contents that may possibly cause harmful effects if such plants were consumed for a long time. The effects of the ingestion of a small content of boron on bird reproduction in unknown. However, boron compounds introduced into bird diets have been shown to cause reproductive problems in mallards (Patuxent Wildlife Research Center, written commun., 1987). Sago-pondweed samples from the three lake and pond sites contained boron ranging from 390 to 630 µg/g dry weight. These values are between the boron content of two diets used in controlled studies of ducks: 300 µg/g dry weight, which did not produce significant reproductive effects; and 1,000 µg/g dry weight, which significantly decreased hatching success and production of fewer 21-day old ducklings (Patuxent Wildlife Research Center, written commun., 1987). Because the boron content between 300 and 1,000 µg/g dry weight at which results change from nonsubstantial to substantial has not been defined; the implication, if any, of the boron contents of the sago pondweed at the three sites is unclear.

Selenium

The selenium content of several plant samples exceeded contents determined in diet studies to have harmful effects. Selenium contents of plants sampled were largest in sago pondweed (10 µg/g dry weight) and filamentous green algae (9.3 µg/g dry weight) from Rasmus Lee Lake. Selenium contents of plants at the other sites were only about one-fourth of contents of plants at Rasmus Lee Lake. Selenium contents of plants at Rasmus Lee Lake exceeded the content of 8 µg/g dry weight determined in laboratory studies to cause toxicity in birds (Patuxent Wildlife Research Center, written commun., 1987). It is unlikely, however, that most birds would restrict their diet to plants for any extended time.

Atypical Contents of Trace Elements in Biota

The sample size used in this reconnaissance investigation is not adequate to statistically determine which data, if any, are atypical. Comparing specific content values with the other data for a specific group of tissues or organisms indicates, however, several content values which may be atypical. These include: aluminum (18,000 µg/g dry weight in rainbow trout from site 13 along the North Platte River); boron (130 µg/g in avocet liver from Rasmus Lee Lake); cadmium (7.5 µg/g dry weight in avocet liver from Rasmus Lee Lake); lead (1.2 µg/g dry weight in odonates from site 9 along the North Platte River); selenium (170 µg/g dry weight in avocet liver from Rasmus Lee Lake); strontium (1.5 µg/g dry weight in *Chara* from Illco Pond); tin (110 µg/g dry weight in mallard liver from Illco Pond); and zinc (350 µg/g dry weight in avocet liver from Rasmus Lee Lake).

SUMMARY

A reconnaissance sampling of water, bottom sediment, and biota in the area of the Kendrick Reclamation Project was conducted during 1986-87. Irrigation water supplied by the Kendrick Reclamation Project is distributed through the Casper Canal. Irrigation return flows are conveyed in constructed drains and natural drainages, which are tributary to the North Platte River. The four principal perennial tributaries that drain the project are Poison Spring Creek, Poison Spider Creek, Oregon Trail Drain, and Casper Creek. Wetlands created as a result of the irrigation practices are biologically important because other permanent water bodies and wetlands are few.

Concentrations of dissolved selenium in water were greater than the national standard for public water supplies of 10 µg/L in 11 of 24 samples from surface and ground water, but none of the sources of the 11 samples is used as a public water supply. Concentrations of dissolved selenium in the North Platte River, which supplies drinking water for several municipalities, ranged from less than 1 to 4 µg/L. Selenium concentrations in six surface-water samples exceeded the 50-µg/L limit for livestock watering recommended by the National Academy of Science and National Academy of Engineering.

Selenium concentrations in water were larger in October than in August at the stream sites, particularly in the four principal tributaries. On the basis of only two sample dates, the concentrations of selenium appeared to be inversely related to streamflow. An inverse relation between selenium concentration and streamflow may indicate that irrigation water is diluting seepage from ground water. A previous investigation noted an inverse relation between selenium concentration and streamflow in Oregon Trail Drain, but not in Poison Spring, Poison Spider, and Casper Creeks.

Dissolved-selenium concentrations and selenium discharge in water of the North Platte River increased in the downstream direction. The four principal tributaries that drain the Kendrick Reclamation Project were responsible for much of the increase. In August, the four tributaries contributed about one-half of the dissolved selenium discharge of 14.6 kg/d in the North Platte River downstream from Casper. In October, 1986, the four tributaries contributed 11.0 kg/d to a total discharge of 16.6 kg/d in the North Platte River below Casper.

Bottom-sediment samples contained selenium contents ranging from 0.9 to 25 µg/g. The largest selenium contents were measured in the bottom sediments of Poison Spring Creek (25 µg/g), Rasmus Lee Lake (17 µg/g), and Casper Creek (16 µg/g). Bottom-sediment samples from the North Platte River contained selenium content of 1.2 µg/g or less. Compared to geometric-mean contents in soils of the western United States and the northern Great Plains reported by other investigators, the contents of selenium and uranium at all of the sites were large, and the contents of chromium, lithium, and nickel in bottom sediments from Poison Spider Creek, Oregon Trail Drain, and Casper Creek also were large.

Arsenic, boron, and mercury contents generally were small in bird livers and bird eggs. Selenium contents in avocet livers and eggs from Rasmus Lee Lake, avocet and eared-grebe eggs from Goose Lake, and mallard livers from Illco Pond were mostly large enough to potentially cause toxic effects. However, all the livers, except one, were collected from immature or adult birds that could fly. Accordingly, because the birds cannot be tied to a specific site, it cannot be known for sure that the contamination came from the site being sampled.

Excluding the bird livers, however, at least one of the remaining biological samples analyzed from Rasmus Lee Lake, Thirtythree Mile Reservoir, and Illco Pond, contained selenium at a content indicative of a selenium-contaminated condition. Two water samples from Rasmus Lee Lake contained dissolved-selenium concentrations of 30 and 12 µg/L. Bottom sediment at Rasmus Lee Lake contained 17 µg/g total selenium--relatively large compared to other sites in this investigation.

Arsenic, boron, and mercury contents were small or less than analytical detection limits in fish from Thirtythree Mile Reservoir and Illco Pond, and also were small in invertebrates from Rasmus Lee Lake, Thirtythree Mile Reservoir, and Illco Pond. Boron contents in rooted plants (sago pondweed) from all three lake and pond sites, however, were large enough to be a minor concern relative to consumer organisms (birds) limited to a diet of aquatic vascular plants for any extended time.

Selenium contents were much larger in fish from Thirtythree Mile Reservoir and Illco Pond, and in invertebrates from Rasmus Lee Lake than in fish from the North Platte River and invertebrates from the other sites. Although some fish reproduction apparently occurs in Thirtythree Mile Reservoir, the selenium content in the fish analyzed potentially could have adverse physiological effects.

Samples of fish and invertebrates from four sites along the North Platte River indicated little change in contents of arsenic, boron, and mercury between sites upstream from and downstream from the Kendrick Reclamation Project. Selenium in fish increased slightly in the downstream direction. All contents measured were less than contents that could be indicative of physiological harm or other abnormalities in fish.

Results of this reconnaissance investigation at the Kendrick Reclamation Project indicate elevated concentrations of selenium in the water and of contents in bottom sediment, bird livers, and biological tissues from several aquatic trophic levels. Because of the limited number of samples and reconnaissance nature of this investigation, the relation, if any, between irrigation drainage and the elevated concentrations and content is unknown.

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SUPPLEMENTAL DATA

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Table 12.--On-site measurements and trace elements in surface and ground water

[Identification number: 8-digit, U.S. Geological Survey streamflow-gaging station number; 15-digit, latitude-longitude and sequence number; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 °Celsius; µg/L, micrograms per liter; <, less than; --, no data. Analyses by U.S. Geological Survey]

Site designation (fig. 1)	Identification number	Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Depth of well, total (feet)	Arsenic, dissolved (µg/L)	Barium, dissolved (µg/L)	Boron, dissolved (µg/L)	Cadmium, dissolved (µg/L)
1	06642000	08-05-86	0900	2,730	480	8.00	--	<1	30	1,000	6
	06642000	10-16-86	0730	1,350	440	8.10	--	2	<100	40	<1
2	06643000	08-12-86	0830	5.5	1,490	8.30	--	1	51	190	3
	06643000	10-16-86	0900	4.9	1,700	8.10	--	<1	<100	200	1
3	06643100	08-12-86	1000	4.1	7,700	8.40	--	5	30	--	<1
	06643100	10-16-86	1000	1.5	4,600	8.30	--	1	100	660	<1
4	424435106370300	08-05-86	1400	--	--	--	--	16	60	--	14
	424435106370300	10-16-86	1300	--	8,900	8.90	--	9	100	1,100	<1
6	06644000	08-12-86	1415	22	2,220	8.20	--	<1	43	340	4
	06644000	10-16-86	1200	14	3,100	8.20	--	<1	<100	450	<1
7	06644040	08-13-86	0800	12	1,200	8.50	--	<2	<53	200	<2
	06644040	10-16-86	1630	1.6	4,550	8.50	--	1	100	890	<1
8	424958106220900	08-14-86	1200	--	--	--	--	<1	20	--	<1
9	06644085	08-14-86	1100	3,000	470	8.40	--	<1	50	--	<1
	06644085	10-17-86	1100	1,700	510	8.40	--	2	<100	60	<1
12	06644500	08-13-86	1315	29	2,940	8.40	--	2	38	540	3
	06644500	10-17-86	0800	17	5,200	8.20	--	<1	100	800	<1
14	06645000	08-14-86	1245	3,000	570	8.80	--	<1	40	--	<1
	06645000	10-17-86	0930	1,700	610	8.50	--	2	<100	70	<1
A	423707106385101	08-07-86	0830	--	--	--	55	3	<10	--	1
B	424750106331501	08-07-86	1100	--	--	--	--	<1	10	--	1
C	425700106282801	08-07-86	1245	--	--	--	45	<1	<10	5,600	<1
D	425149106260201	08-07-86	1330	--	--	--	43	<1	<100	1,800	<1
E	430102106350901	08-07-86	1500	--	--	--	58	<1	100	580	<1

Table 12.--On-site measurements and trace elements in surface and ground water--Continued

Site designation (fig. 1)	Identification number	Date	Chromium, dissolved (µg/L)	Copper, dissolved (µg/L)	Lead, dissolved (µg/L)	Mercury, dissolved (µg/L)	Molybdenum, dissolved (µg/L)	Nickel, dissolved (µg/L)	Selenium, dissolved (µg/L)	Silver, dissolved (µg/L)	Vanadium, dissolved (µg/L)	Zinc, dissolved (µg/L)
1	06642000	08-05-86	<1	4	<5	<0.2	2	3	<1	<1	1	<10
	06642000	10-16-86	<10	<10	<5	<.1	9	<1	1	<1	2	<10
2	06643000	08-12-86	3	<10	<5	<.2	10	<2	7	<1	<6	<3
	06643000	10-16-86	<10	10	<5	<.1	13	1	8	<1	<1	<10
3	06643100	08-12-86	<1	1	<5	.4	6	7	60	<1	2	40
	06643100	10-16-86	<10	10	<5	<.1	5	6	150	<1	2	<10
4	424435106370300	08-05-86	<1	5	7	2.1	3	7	30	<1	5	40
	424435106370300	10-16-86	<10	20	<5	<.1	5	2	12	<1	6	20
6	06644000	08-12-86	4	<10	<5	<.2	6	3	72	<1	<6	24
	06644000	10-16-86	<10	10	<5	<.1	10	2	90	<1	<1	<10
7	06644040	08-13-86	4	<10	<5	<.1	7	5	27	<1	<6	4
	06644040	10-16-86	<10	20	<5	<.1	13	16	300	<1	2	10
8	424958106220900	08-14-86	<1	40	<5	<.2	3	5	3	<1	<1	<10
9	06644085	08-14-86	<1	5	<5	<.2	1	4	<1	<1	<1	<10
	06644085	10-17-86	<10	<10	<5	<.1	9	2	3	<1	3	<10
12	06644500	08-13-86	9	<10	10	<.2	8	4	32	<1	<6	7
	06644500	10-17-86	<10	20	<5	<.1	13	4	120	<1	1	10
14	06645000	08-14-86	<1	4	<5	<.2	2	4	2	<1	<1	<10
	06645000	10-17-86	<10	10	<5	<.1	9	2	4	<1	2	<10
A	423707106385101	08-07-86	<1	53	<5	.3	27	5	30	<1	3	150
B	424750106331501	08-07-86	<1	11	5	<.2	2	3	3	<1	<1	10
C	425700106282801	08-07-86	<1	5	<5	.4	15	4	<1	<1	<1	<10
D	425149106260201	08-07-86	<10	10	<5	<.1	1	2	<1	<1	41	40
E	430102106350901	08-07-86	<10	10	<5	<.1	6	2	<1	<1	<1	40

Table 13.—Radiochemicals in surface and ground water

[µg/L, micrograms per liter; pCi/L, picocuries per liter; <, less than; —, no data. Analyses by U.S. Geological Survey]

Site designation (fig. 1)	Date	Gross alpha, dissolved (µg/L as natural uranium)	Gross beta, dissolved (pCi/L as cesium-137)	Gross beta, dissolved (pCi/L as strontium/yttrium-90)	Radium-226, dissolved planchet count (pCi/L)	Uranium, natural dissolved (µg/L as U)
1	08-05-86	7.3	7.2	5.8	0.11	5.7
2	08-12-86	65	31	23	.22	30
3	08-12-86	5.7	7.6	6.0	.13	38
4	08-05-86	91	53	35	.24	27
6	08-12-86	26	28	20	.26	23
7	08-13-86	27	15	11	.27	15
8	08-14-86	7.0	7.2	5.6	.18	6.0
9	08-14-86	5.7	—	—	.19	6.0
	08-21-86	—	—	—	—	—
12	08-13-86	57	21	13	.212	27
14	08-14-86	13	8.4	6.6	.114	6.9
	08-21-86	—	—	—	—	—
A	08-07-86	360	160	100	.2	230
B	08-07-86	33	29	21	.4	19
C	08-07-86	4.3	1.2	.9	.2	<.4
D	08-07-86	12	1.7	1.1	.2	<.4
E	08-07-86	39	32	22	.1	30

Table 14.—Pesticides in surface water and bottom sediment

[μg/L, micrograms per liter; μg/kg, micrograms per kilogram; —, no data <, less than. Analyses by U.S. Geological Survey]

Site designation (fig. 1)	Date	Diazinon, total (μg/L)	Diazinon, total recoverable in bottom material (μg/kg)	Dicamba, total (μg/L)	Dicamba, total recoverable in bottom material (μg/kg)	Disyston, total (μg/L)	Ethion, total (μg/L)	Ethion, total recoverable in bottom material (μg/kg)	Guthion, total (μg/L)
1	08-05-86	<0.01	—	<0.01	—	<0.01	<0.01	—	<0.1
9	08-14-86	—	—	—	—	—	—	—	—
	08-21-86	<.01	<.1	<.01	<.1	—	<.01	<.1	—
12	08-13-86	<.01	<.1	<.04	<.01	<.1	<.1	<.01	<.1
14	08-14-86	—	—	—	—	—	—	—	—
	08-21-86	<.01	<.1	.01	<.1	—	<.01	<.1	—

Site designation (fig. 1)	Date	Malathion, total (μg/L)	Malathion, total recoverable in bottom material (μg/kg)	Methyl parathion, total (μg/L)	Methyl parathion, total recoverable in bottom material (μg/kg)	Methyl trithion, total (μg/L)	Methyl trithion, total recoverable in bottom material (μg/kg)	Orthophosphate defoliant, total (μg/L)	Parathion, total (μg/L)
1	08-05-86	<0.01	—	<0.01	—	<0.01	—	—	<0.01
9	08-14-86	—	—	—	—	—	—	—	—
	08-21-86	<.1	<.1	<.01	<.1	<.01	<.1	.07	<.01
12	08-13-86	<.01	<.1	<.01	<.1	<.01	<.1	—	<.01
	08-14-86	—	—	—	—	—	—	—	—
14	08-21-86	<.01	<.1	<.01	<.1	<.01	<.1	.06	<.01

Table 14.—Pesticides in surface water and bottom sediment—Continued

Site designation (fig. 1)	Date	Parathion, total recoverable in bottom material (µg/kg)	Phorate, total (µg/L)	Picloram, total (µg/L)	Picloram, total recoverable in bottom material (µg/kg)	Silvex, total (µg/L)	Silvex, total recoverable in bottom material (µg/kg)	Trithion, total (µg/L)
1	08-05-86	—	<0.01	0.01	—	<0.01	—	<0.01
9	08-14-87	—	—	—	—	—	—	—
	08-21-86	<.1	—	.01	<.1	<.01	<.1	<.01
12	08-13-86	<.1	<.01	.07	<.1	<.01	<.1	<.01
14	08-14-86	—	—	—	—	—	—	—
	08-21-86	<.1	—	.01	<.1	<.01	<.1	<.01

Site designation (fig. 1)	Date	Trithion, total recoverable in bottom material (µg/kg)	2,4-D, total (µg/L)	2,4-D, total recoverable in bottom material (µg/kg)	2,4-DP, total (µg/L)	2,4-DP, total recoverable in bottom material (µg/kg)	2,4,5-T, total (µg/L)	2,4,5-T, total recoverable in bottom material (µg/kg)
1	08-05-86	—	0.01	—	<0.01	—	<0.01	—
9	08-14-87	—	—	—	<.01	—	—	—
	08-21-86	<.1	<.01	<.1	—	<.1	<.01	<.1
12	08-13-86	<.1	.02	<.1	<.01	<.1	<.01	<.1
14	08-14-86	—	—	—	—	—	—	—
	08-21-86	<.1	<.01	<.1	<.01	<.1	<.01	<.1

Table 15.--Trace elements in bottom sediment

[µg/g, micrograms per gram; <, less than; --, no data. Analyses by U.S. Geological Survey]

	Site number (fig. 1), name, and sample-collection date in 1986			
	1	2	3	4
Element (unit)	North Platte River at Alcova (August 5)	Bates Creek (August 12)	Poison Spring Creek (August 12)	Rasmus Lee Lake (August 5)
Aluminum (percent)	5.6	6.0	6.1	5.1
Calcium (percent)	3.5	4.5	7.7	2.8
Iron (percent)	2.1	2.4	2.1	1.6
Magnesium (percent)	1.1	1.4	1.4	.75
Phosphorus (percent)	.07	.06	.07	.06
Potassium (percent)	1.5	1.5	1.3	1.6
Sodium (percent)	.94	.59	1.2	1.1
Titanium (percent)	.25	.25	.20	.21
Arsenic (µg/g)	5.7	6.0	11	4.3
Barium (µg/g)	730	740	500	660
Beryllium (µg/g)	1	1	1	1
Bismuth (µg/g)	<10	<10	<10	<10
Cadmium (µg/g)	<2	<2	<2	<2
Cerium (µg/g)	88	69	65	57
Chromium (µg/g)	47	65	64	45
Cobalt (µg/g)	7	10	8	6
Copper (µg/g)	17	19	18	11
Europium (µg/g)	<2	<2	<2	<2
Gallium (µg/g)	11	13	13	10
Gold (µg/g)	<8	<8	<8	<8
Holmium (µg/g)	<4	<4	<4	<4
Lanthanum (µg/g)	52	41	38	34
Lead (µg/g)	17	20	18	13
Lithium (µg/g)	31	46	39	29
Manganese (µg/g)	380	610	560	270
Mercury (µg/g)	<.02	.04	.03	.02
Molybdenum (µg/g)	<2	<2	<2	<2
Neodymium (µg/g)	42	33	30	28
Nickel (µg/g)	18	25	25	17
Scandium (µg/g)	6	8	6	5
Selenium (µg/g)	1.2	.9	25	17
Silver (µg/g)	<2	<2	<2	<2
Strontium (µg/g)	210	220	710	290
Tantalum (µg/g)	<40	<40	<40	<40
Thorium (µg/g)	17.6	15.3	13.2	11.8
Tin (µg/g)	<10	<10	<10	<10
Uranium (µg/g)	6.08	4.9	6.77	7.76
Vanadium (µg/g)	61	110	100	67
Ytterbium (µg/g)	3	2	2	2
Yttrium (µg/g)	22	19	17	15
Zinc (µg/g)	55	84	83	49

Site number (fig. 1), name, and sample-collection date in 1986				
6	7	9	12	14
Poison Spider Creek (August 12)	Oregon Trail Drain (August 13)	North Platte River at Mills (August 15)	Casper Creek (August 13)	North Platte River downstream from Casper (August 14)
5.8	6.7	5.8	6.2	5.4
2.6	4.9	3.0	3.9	3.0
2.4	2.4	2.4	2.8	2.1
1.3	1.2	1.1	1.4	1.2
.08	.09	.09	.09	.07
1.4	1.6	1.7	1.5	1.4
.80	.50	.71	.73	.77
.26	.25	.26	.25	.22
6.7	9.7	6.0	7.6	5.6
710	770	650	840	720
1	1	1	1	1
<10	<10	<10	<10	<10
<2	<2	<2	<2	<2
67	71	76	64	69
75	88	57	79	54
10	9	9	10	8
17	24	18	19	16
<2	<2	<2	<2	<2
12	15	13	13	11
<8	<8	<8	<8	<8
<4	<4	<4	<4	<4
40	42	40	39	39
17	19	21	22	18
44	52	35	48	32
410	220	390	890	330
.02	.02	--	.04	.02
<2	4	2	<2	<2
32	34	33	30	33
27	38	24	29	21
8	8	8	8	6
2.5	4.9	1.1	16	1.0
<2	<2	<2	<2	<2
200	260	180	280	180
<40	<40	<40	<40	<40
9.82	14.5	12.7	10.5	11.6
20	<10	<10	<10	<10
4.86	5.49	6.34	4.80	4.66
110	180	97	130	84
2	2	2	2	2
20	20	22	19	19
87	110	77	99	69

Table 16.--Trace elements (dry weight) in biota

[Contents are reported in micrograms per gram. Inv., invertebrates; <, less than; --, no data. Analyses by U.S. Fish and Wildlife Service's Patuxent Analytical Control Facility]

Site no. (fig. 1)	Matrix	Species	Date	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
1	Liver	Rainbow trout	08-12-86	--	0.26	--	--	--	--	--
1	Liver	White sucker	08-12-86	--	.23	--	--	--	--	--
1	Fish	Rainbow trout	08-12-86	74	<.18	4.7	<0.39	11	<0.39	<0.39
1	Fish	White sucker	08-12-86	28	.27	.68	<.34	8.2	<.34	<.34
1	Inv.	Gastropods	08-12-86	92	1.4	35	<.33	<6.6	<.33	12
4	Liver	Avocet	08-05-86	<4.5	.34	<.45	<.45	<8.9	<.45	21
4	Liver	Avocet	08-05-86	<11	<.37	<1.1	<1.1	28	1.6	17
4	Liver	Avocet	08-05-86	<6.5	.32	<.65	<.65	130	1.2	12
4	Liver	Avocet	08-05-86	<8.9	1.7	<.89	<.89	<18	7.5	2.3
4	Liver	Avocet	08-05-86	<6.1	<.36	<.61	<.61	<12	2.6	3.2
4	Egg	Avocet	05-30-86	<6.8	<.34	.81	<.68	<14	<.68	3.1
4	Egg	Avocet	05-30-86	<3.8	<.18	<.38	<.38	<7.5	<.38	1.7
4	Egg	Avocet	05-30-86	7.9	<.18	.95	<.40	<7.9	<.40	1.7
4	Egg	Avocet	05-30-86	--	<.16	--	--	--	--	--
4	Egg	Avocet	05-30-86	--	<.17	--	--	--	--	--
4	Inv.	Odonates	08-05-86	14	.62	1.7	<.69	<14	<.69	28
4	Plant	Sago pondweed	08-05-86	810	8.5	52	<.93	390	<.93	110
4	Plant	Filamentous algae	08-05-86	2,100	9.5	26	<.63	82	<.63	16
5	Egg	Eared grebe	05-29-86	<4.9	<.38	<.49	<.49	<9.7	<.49	2.8
5	Egg	Eared grebe	05-29-86	7.5	<.28	<.47	<.47	<9.4	<.47	.58
5	Egg	Eared grebe	05-29-86	9.3	<.21	.53	<.42	<8.5	<.42	3.3
5	Egg	Avocet	05-29-86	19	<.16	.60	<.39	<7.8	<.39	.53
6a	Liver	Rainbow trout	08-12-86	--	.37	--	--	--	--	--
6a	Liver	White sucker	08-12-86	--	.37	--	--	--	--	--
6a	Fish	Rainbow trout	08-12-86	60	<.18	6.0	<.36	11	<.36	.94
6a	Fish	White sucker	08-12-86	180	.25	6.6	<.35	<7.0	<.35	<.35
6a	Inv.	Odonates	08-12-86	840	1.1	6.3	<.49	<9.7	<.49	42
9	Liver	Rainbow trout	08-12-86	--	.25	--	--	--	--	--
9	Liver	White sucker	08-12-86	--	<.22	--	--	--	--	--
9	Fish	Rainbow trout	08-12-86	140	.28	4.3	<.40	14	<.40	<.40
9	Fish	Longnose sucker	08-12-86	210	.21	8.4	<.30	<6.0	<.30	<.30
9	Inv.	Odonates	08-12-86	870	1.4	11	<.47	<9.3	<.47	8.1
10	Liver	Blue-winged teal	08-06-86	<6.8	<.34	<.68	<.68	<14	<.68	12
10	Liver	Blue-winged teal	08-06-86	<17	<.33	<1.7	<1.7	<34	<1.7	6.2
10	Liver	Blue-winged teal	08-06-86	<7.7	<.26	<.77	<.77	<15	<.77	6.8
10	Liver	Blue-winged teal	08-06-86	210	<.17	2.7	<.36	10	1.5	20
10	Liver	Blue-winged teal	08-06-86	<3.9	<.18	<.39	<.39	<7.8	1.7	1.2
10	Fish	Carp	08-06-86	670	<.23	11	<.51	<10	<.51	16
10	Fish	Fathead	08-06-86	3,800	.54	33	<.53	<11	<.53	14
10	Inv.	Crayfish	08-06-86	1,300	1.5	61	<.46	<9.2	<.46	7.4
10	Plant	Sago pondweed	08-06-86	3,400	6.4	45	<.98	430	<.98	88
11	Liver	Mallard	08-06-86	<3.6	<.19	<.36	<.36	<7.1	<.36	1.9
11	Liver	Mallard	08-06-86	10	<.17	<.39	<.39	26	<.39	2.0
11	Fish	Carp	08-06-86	160	<.28	11	<.63	<13	<.63	1.5
11	Inv.	Crayfish	08-06-86	250	1.6	47	<.54	<11	<.54	4.8
11	Inv.	Odonates	08-06-86	240	.97	2.9	<.86	<17	<.86	13
11	Plant	Sago pondweed	08-06-86	490	1.1	27	<1.0	630	<1.0	6.3
11	Plant	Algae (Chara)	08-06-86	360	1.6	48	<.41	16	<.41	5.0
13	Liver	Rainbow trout	08-13-86	--	.36	--	--	--	--	--
13	Liver	Carp	08-13-86	--	.29	--	--	--	--	--
13	Fish	Rainbow trout	08-13-86	18,000	<.17	3.5	<.41	12	<.41	<.41
13	Fish	Longnose sucker	08-13-86	220	.22	7.4	<.37	<7.4	<.37	<.37
13	Inv.	Odonates	08-13-86	910	1.2	10	<.43	<8.5	<.43	9.4

Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
--	--	--	--	0.31	--	--	68	--	--	--	--
--	--	--	--	<.71	--	--	8.3	--	--	--	--
3.7	150	<0.79	27	.28	<0.39	<0.39	4.0	39	<3.9	<0.39	94
1.4	320	<.68	64	.35	<.34	<.34	1.9	47	4.8	.48	57
13	660	<.66	66	<.14	<.33	4.9	<.15	460	14	1.3	18
14	2,100	<.89	15	1.9	2.9	11	65	<.45	<4.5	<.45	120
30	1,800	<2.2	24	5.1	3.7	11	53	<1.1	28	<1.1	140
26	1,700	<1.3	14	.80	1.6	6.2	170	<.65	25	<.65	110
20	1,500	<1.8	15	1.1	1.5	1.2	85	<.89	<8.9	<.89	130
21	7,000	<1.2	16	6.2	2.1	2.0	51	<.61	16	<.61	350
4.7	420	<1.4	<6.8	.88	<.68	<.68	55	24	<6.8	<.68	82
5.3	210	<.75	<3.8	2.1	<.38	<.38	79	44	<3.8	<.38	74
3.6	320	<.79	<4.0	<.19	<.40	<.40	81	79	<4.0	<.40	130
--	--	--	--	1.6	--	--	64	--	--	--	--
--	--	--	--	.85	--	--	56	--	--	--	--
15	260	<1.4	26	<.30	<.69	14	89	4.3	<6.9	<.69	100
8.9	3,500	<1.9	260	<.47	<.93	37	10	260	18	3.0	31
2.0	1,500	<1.3	150	<.32	<.63	7.8	9.3	490	20	<.63	93
4.1	190	<.97	<4.9	<.40	<.49	1.4	160	54	<4.9	<.49	65
3.7	270	<.94	<4.7	<.31	<.47	<.47	100	44	<4.7	<.47	66
3.6	250	<.85	<4.2	.57	<.42	1.7	110	67	<4.2	<.42	76
4.2	120	<.78	<3.9	.18	<.39	<.39	51	67	<3.9	<.39	69
--	--	--	--	.21	--	--	97	--	--	--	--
--	--	--	--	<.29	--	--	18	--	--	--	--
3.9	120	<.72	19	.21	<.36	.36	6.1	61	<3.6	<.36	87
2.8	200	<.70	34	.44	<.35	.38	3.0	6.6	<3.5	<.35	59
23	1,100	<.97	50	<.23	.73	18	7.1	7.0	22	2.2	130
--	--	--	--	.24	--	--	200	--	--	--	--
--	--	--	--	<.23	--	--	12	--	--	--	--
4.4	160	<.80	15	.21	<.40	<.40	7.5	36	<4.0	<.40	100
2.2	210	<.60	23	.26	<.30	<.30	2.8	56	3.4	<.30	50
20	930	1.2	50	<.22	.68	4.4	6.3	5.5	19	2.0	120
190	9,300	<1.4	24	3.8	8.5	5.7	16	<.68	26	<.68	220
170	4,500	<3.4	26	5.9	3.8	6.6	14	<1.7	18	1.7	200
130	2,900	<1.5	25	2.0	3.4	5.5	16	<.77	38	.77	180
71	2,700	<.72	20	2.5	2.9	15	14	<.36	34	.36	180
120	3,500	<.78	16	3.4	2.9	<.39	13	<.39	33	.85	57
4.1	740	<1.0	11	<.21	<.51	5.1	49	280	10	1.5	370
4.7	2,600	<1.1	28	<.21	<.53	1.4	35	150	35	7.7	160
50	1,100	<.92	64	<.22	<.46	3.8	6.8	480	18	3.2	81
8.2	6,300	<2.0	250	<.47	1.4	45	2.5	200	92	6.7	43
230	1,100	<.71	18	<.18	5.2	2.4	43	<.36	110	<.36	71
51	4,000	<.78	18	<.19	3.2	<.39	56	.65	46	1.3	250
18	300	<1.3	51	<.30	<.63	<.63	21	280	<6.3	<.63	220
27	360	<1.1	74	<.26	.55	2.8	11	550	5.9	<.54	77
17	530	<1.7	22	<.40	<.86	5.3	17	9.8	<8.6	<.86	110
2.2	1,200	<2.0	430	<.47	1.0	10	2.9	200	<10	3.3	170
1.3	600	<.83	270	<.20	<.41	2.2	2.0	1,500	6.7	.80	67
--	--	--	--	.32	--	--	88	--	--	--	--
--	--	--	--	<.27	--	--	24	--	--	--	--
22	220	<.83	21	.20	<.41	<.41	7.4	47	4.1	1.7	110
3.3	240	<.74	39	.29	<.37	<.37	4.5	89	3.7	.81	81
21	1,000	<.85	94	<.20	<.43	4.7	7.2	6.6	17	2.2	110

Table 17.--Trace elements (wet weight) in biota

[Contents are reported in micrograms per gram. Inv., invertebrates; <, less than; --, no data. Analyses by U.S. Fish and Wildlife Service's Patuxent Analytical Control Facility]

Site no. (fig. 1)	Matrix	Species	Date	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium
1	Liver	Rainbow trout	08-12-86	--	0.055	--	--	--	--	--
1	Liver	White sucker	08-12-86	--	.058	--	--	--	--	--
1	Fish	Rainbow trout	08-12-86	19	<.045	1.2	<0.099	2.8	<0.099	<0.099
1	Fish	White sucker	08-12-86	7.8	.074	.19	<.095	2.3	<.095	<.095
1	Inv.	Gastropods	08-12-86	27	.42	10	<.097	<1.9	<.097	3.5
4	Liver	Avocet	08-05-86	<.98	.075	<.098	<.098	<2.0	<.098	4.7
4	Liver	Avocet	08-05-86	<2.8	<.096	<.28	<.28	7.3	.42	4.4
4	Liver	Avocet	08-05-86	<2.3	.12	<.23	<.23	47	.44	4.3
4	Liver	Avocet	08-05-86	<2.2	.42	<.22	<.22	<4.3	1.8	.56
4	Liver	Avocet	08-05-86	<1.6	<.096	<.16	<.16	<3.2	.68	.84
4	Egg	Avocet	05-30-86	<1.8	<.089	.21	<.18	<3.5	<.18	.81
4	Egg	Avocet	05-30-86	<.97	<.046	<.097	<.097	<1.9	<.097	.43
4	Egg	Avocet	05-30-86	2.0	<.045	.24	<.099	<2.0	<.099	.42
4	Egg	Avocet	05-30-86	--	<.039	--	--	--	--	--
4	Egg	Avocet	05-30-86	--	<.045	--	--	--	--	--
4	Inv.	Odonates	08-05-86	1.9	.087	.23	<.098	<2.0	<.098	3.9
4	Plant	Sago pondweed	08-05-86	87	.91	5.5	<.099	42	<.099	12
4	Plant	Filamentous algae	08-05-86	320	1.5	3.9	<.097	13	<.097	2.5
5	Egg	Eared grebe	05-29-86	<1.0	<.079	<.10	<.10	<2.0	<.10	.59
5	Egg	Eared grebe	05-29-86	1.6	<.059	<.099	<.099	<2.0	<.099	.12
5	Egg	Eared grebe	05-29-86	2.1	<.048	.12	<.095	<1.9	<.095	.74
5	Egg	Avocet	05-29-86	5.0	<.041	.15	<.099	<2.0	<.099	.14
6a	Liver	Rainbow trout	08-12-86	--	.082	--	--	--	--	--
6a	Liver	White sucker	08-12-86	--	.061	--	--	--	--	--
6a	Fish	Rainbow trout	08-12-86	16	<.048	1.6	<.097	2.9	<.097	.25
6a	Fish	White sucker	08-12-86	51	.070	1.9	<.098	<2.0	<.098	<.098
6a	Inv.	Odonates	08-12-86	170	.23	1.3	<.099	<2.0	<.099	8.5
9	Liver	Rainbow trout	08-12-86	--	.048	--	--	--	--	--
9	Liver	White sucker	08-12-86	--	<.048	--	--	--	--	--
9	Fish	Rainbow trout	08-12-86	33	.066	1.0	<.096	3.4	<.096	<.096
9	Fish	Longnose sucker	08-12-86	68	.070	2.7	<.097	<1.9	<.097	<.097
9	Inv.	Odonates	08-12-86	190	.30	2.4	<.10	<2.0	<.10	1.7
10	Liver	Blue-winged teal	08-06-86	<1.7	<.086	<.17	<.17	<3.4	<.17	3.0
10	Liver	Blue-winged teal	08-06-86	<5.2	<.10	<.52	<.52	<10	<.52	1.9
10	Liver	Blue-winged teal	08-06-86	<2.2	<.074	<.22	<.22	<4.4	<.22	1.9
10	Liver	Blue-winged teal	08-06-86	56	<.047	.74	<.097	2.7	.41	5.4
10	Liver	Blue-winged teal	08-06-86	<.96	<.046	<.096	<.096	<1.9	.42	.31
10	Fish	Carp	08-06-86	130	<.044	2.2	<.099	<2.0	<.099	3.2
10	Fish	Fathead	08-06-86	690	.098	5.9	<.096	<1.9	<.096	2.5
10	Inv.	Crayfish	08-06-86	280	.31	13	<.097	<1.9	<.097	1.6
10	Plant	Sago pondweed	08-06-86	330	.62	4.4	<.095	42	<.095	8.5
11	Liver	Mallard	08-06-86	<.96	<.050	<.096	<.096	<1.9	<.096	.50
11	Liver	Mallard	08-06-86	2.5	<.043	<.097	<.097	6.4	<.097	.50
11	Fish	Carp	08-06-86	26	<.043	1.7	<.099	<2.0	<.099	.24
11	Inv.	Crayfish	08-06-86	45	.29	8.3	<.097	<1.9	<.097	.85
11	Inv.	Odonates	08-06-86	27	.11	.33	<.097	<1.9	<.097	1.5
11	Plant	Sago pondweed	08-06-86	48	.11	2.6	<.10	62	<.10	.62
11	Plant	Algae (Chara)	08-06-86	85	.38	11	<.097	3.7	<.097	1.2
13	Liver	Rainbow trout	08-13-86	--	.070	--	--	--	--	--
13	Liver	Carp	08-13-86	--	.050	--	--	--	--	--
13	Fish	Rainbow trout	08-13-86	4,300	<.041	.82	<.098	2.9	<.098	<.098
13	Fish	Longnose sucker	08-13-86	57	.055	1.9	<.095	<1.9	<.095	<.095
13	Inv.	Odonates	08-13-86	200	.28	2.3	<.095	<1.9	<.095	2.1

Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Tin	Vanadium	Zinc
--	--	--	--	0.064	--	--	14	--	--	--	--
--	--	--	--	<.044	--	--	2.1	--	--	--	--
0.93	38	<0.20	6.7	.069	<0.099	<0.099	1.0	9.7	<0.99	<0.099	24
.40	88	<.19	18	.098	<.095	<.095	.53	13	1.3	.13	16
3.7	190	<.19	19	<.042	<.097	1.4	<.044	140	4.1	.39	5.4
3.1	470	<.20	3.3	.42	.63	2.4	14	<.098	<.98	<.098	27
7.9	460	<.56	6.2	1.3	.96	2.9	14	<.28	7.3	<.28	37
9.4	610	<.47	5.2	.29	.56	2.3	62	<.23	8.9	<.23	39
4.7	370	<.43	3.6	.26	.37	.28	20	<.22	<2.2	<.22	32
5.5	1,900	<.32	4.2	1.7	.55	.52	13	<.16	4.2	<.16	94
1.2	110	<.35	<1.8	.23	<.18	<.18	14	6.4	<1.8	<.18	22
1.4	54	<.19	<.97	.55	<.097	<.097	20	11	<.97	<.097	19
.89	79	<.20	<.99	<.046	<.099	<.099	20	20	<.99	<.099	32
--	--	--	--	.39	--	--	16	--	--	--	--
--	--	--	--	.22	--	--	15	--	--	--	--
2.2	37	<.20	3.7	<.042	<.098	2.0	13	.61	<.98	<.098	14
.95	380	<.20	28	<.050	<.099	4.0	1.1	28	1.9	.32	3.4
.31	230	<.19	23	<.050	<.097	1.2	1.4	76	3.1	<.097	14
.86	41	<.20	<1.0	<.085	<.10	.29	34	11	<1.0	<.10	14
.77	57	<.20	<.99	<.064	<.099	<.099	21	9.3	<.99	<.099	14
.82	55	<.19	<.95	.13	<.095	.38	24	15	<.95	<.095	17
1.1	32	<.20	<.99	.045	<.099	<.099	13	17	<.99	<.099	18
--	--	--	--	.046	--	--	21	--	--	--	--
--	--	--	--	<.048	--	--	3.0	--	--	--	--
1.1	31	<.19	5.1	.056	<.097	<.097	1.7	16	<.97	<.097	23
.79	55	<.20	9.4	.12	<.098	.11	.86	1.9	<.98	<.098	17
4.7	220	<.20	10	<.046	.15	3.7	1.5	1.4	4.5	.45	26
--	--	--	--	.047	--	--	39	--	--	--	--
--	--	--	--	<.050	--	--	2.6	--	--	--	--
1.1	38	<.19	3.6	.050	<.096	<.096	1.8	8.6	<.96	<.096	25
.72	68	<.19	7.6	.084	<.097	<.097	.90	18	1.1	<.097	16
4.2	200	.26	11	<.048	.15	.94	1.3	1.2	4.0	.42	26
48	2,400	<.34	6.2	.96	2.2	1.4	4.0	<.17	6.5	<.17	55
51	1,400	<1.0	7.8	1.8	1.1	2.0	4.2	<.52	5.5	<.52	61
36	830	<.44	7.0	.58	.96	1.6	4.4	<.22	11	<.22	52
19	720	<.19	5.4								
29	870	<.19	4.0	.68	.78	4.1	3.6	<.097	9.1	<.097	48
				.85	.71	<.096	3.2	<.096	8.3	.21	14
.79	140	<.20	2.2	<.042	<.099	.99	9.5	54	2.0	.30	71
.86	480	<.19	5.2	<.039	<.096	.25	6.4	27	6.3	1.4	29
10	230	<.19	14	<.047	<.097	.79	1.4	100	3.9	.68	17
.80	610	<.19	25	<.046	.14	4.4	.25	19	8.9	.64	4.2
62	290	<.19	4.8	<.049	1.4	.63	12	<.096	31	<.096	19
13	990	<.19	4.5	<.047	.80	<.097	14	.16	11	.31	62
2.8	47	<.20	7.9	<.046	<.099	<.099	3.2	43	<.99	<.099	34
4.8	64	<.19	13	<.046	.099	.50	2.0	99	1.0	<.097	14
1.9	60	<.19	2.5	<.045	<.097	.60	1.9	1.1	<.97	<.097	13
.22	120	<.20	42	<.046	<.10	1.0	.28	20	<1.0	.32	16
.31	140	<.19	64	<.046	<.097	.52	.46	340	1.6	.19	16
				.063	--	--	17	--	--	--	--
--	--	--	--								
--	--	--	--	<.047	--	--	4.2	--	--	--	--
5.3	53	<.20	4.9	.047	[illegible]	<.098	1.8	11	<.98	.39	25
.85	62	<.19	9.8								
				.075	[illegible]	<.095	1.1	23	.95	.21	21
4.8	230	<.19	21	<.045	[illegible]	1.0	1.6	1.5	3.8	.50	25

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