Reconnaissance of Surface-Water Quality in the North Platte Natural Resources District, Western Nebraska, 1993

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By G.V. Steele *and* J.C. Cannia

Abstract

During the summer of 1993, the surface-water quality of the North Platte Natural Resources District, western Nebraska, was characterized at eight sites. Each site, sampled near the beginning, middle, and conclusion of the irrigation season, represents a major surface-water feature—the North Platte River at the Wyoming-Nebraska State line, the North Platte River at Bridgeport, the North Platte River at Lisco, Fort Laramie and Interstate Canals, Gering and Nine-Mile Drains, and Pumpkin Creek. The primary constituents analyzed included major ions and field measurements, nutrients, fecal bacteria, pesticides, uranium, and trace elements. Analysis of the data indicated that the surface water within the North Platte Natural Resources District generally varies in type from a calcium magnesium bicarbonate sulfate to a sodium magnesium bicarbonate sulfate, with generally small amounts of trace elements. Throughout the summer, water quality of the North Platte River remained fairly consistent in percentages of major ions, whereas the water quality of Gering Drain and Pumpkin Creek varied. In addition, nitrate concentrations in the surface water did not exceed 5.8 milligrams per liter. The herbicides atrazine and 2,4–D were detected only in the two drains and Pumpkin Creek, fecal bacteria counts varied extensively, and uranium concentrations varied from 9.8 to 59 micrograms per liter.

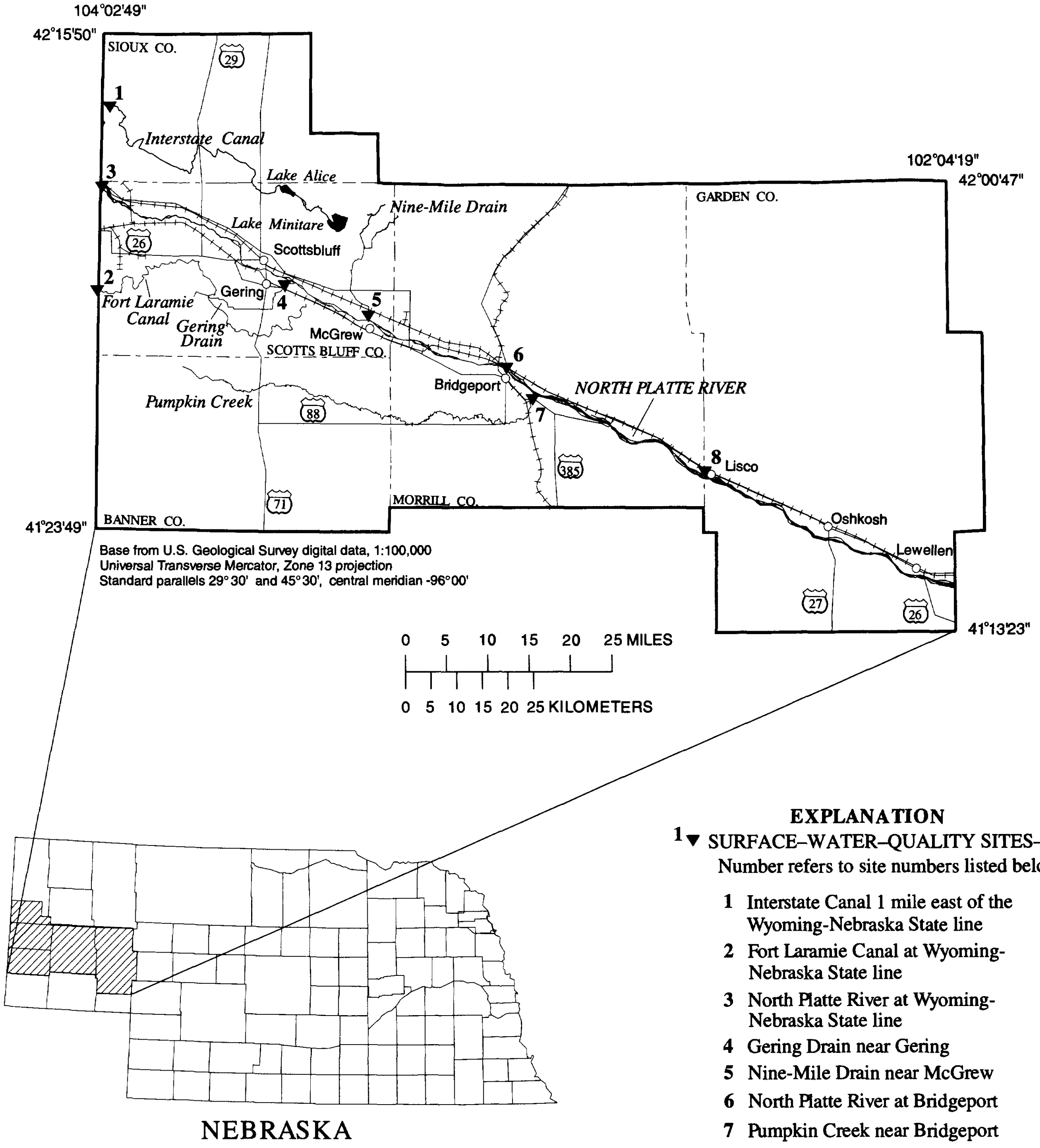
INTRODUCTION

During the past two decades, public awareness regarding water-quality issues has increased substantially and resulted in the proliferation of laws designed to protect the Nation's water resources. Some States, such as Nebraska with legislative bill LB108, have passed or are in the process of passing legislation that acknowledges ground and surface waters are not separate entities, but are commonly connected hydraulically. Thus, the quality of one can appreciably affect the quality of the other. To understand this interaction, it is essential to recognize and identify the chemical composition of both the ground water and the surface water.

Verstraeten and others (1995) assessed the ground-water quality of the North Platte Natural Resources District (NPNRD) in 1991. They reported high concentrations of nitrates and radionuclides in ground water within the NPNRD. If ground water discharges into surface-water bodies within the NPNRD, the quality of the surface water can either improve or degrade, depending on local conditions. In addition, irrigators in semiarid, midcontinental areas, such as the NPNRD, use surface water to supplement precipitation. The quality of the surface water can be an important consideration in deciding which crops to grow and in making water-management decisions downstream in the drainage basin. Thus, the governing board of the NPNRD decided that it was necessary to describe the surface-water quality within their district.

The U.S. Geological Survey (USGS) entered into a cooperative surface-water-quality study with the NPNRD in 1993. The objective of the study was to characterize the surface-water quality at selected, representative sites within the NPNRD (fig. 1) during 1993 and to determine if water-quality changes occur during the irrigation season.

The study area is the NPNRD (fig. 1). The North Platte River, its primary southern tributary Pumpkin Creek, and the Interstate and Fort Laramie Canals are the major surface-water drainages in the NPNRD.



EXPLANATION

1▼ SURFACE–WATER–QUALITY SITES—
Number refers to site numbers listed below

1 Interstate Canal 1 mile east of the Wyoming-Nebraska State line
2 Fort Laramie Canal at Wyoming-Nebraska State line
3 North Platte River at Wyoming-Nebraska State line
4 Gering Drain near Gering
5 Nine-Mile Drain near McGrew
6 North Platte River at Bridgeport
7 Pumpkin Creek near Bridgeport
8 North Platte River at Lisco

Figure 1. Location of study area and sampling sites, western Nebraska.

Pumpkin Creek drains much of northern Banner and southern Morrill Counties. Fort Laramie and Interstate Canals divert water from the North Platte River about 35 miles upstream from the Wyoming-Nebraska State line.

Purpose and Scope

This report describes the general quality of the surface water in the NPNRD. The authors describe the quality of the surface water from analysis of samples collected within the NPNRD. This report also includes data for major ions, field measurements, nutrients, bacteria, pesticides, uranium, and other trace elements. Where appropriate, constituents were compared to Maximum Contaminant Levels (MCL) set by the U.S. Environmental Protection Agency (USEPA). This report discusses some of the temporal and spatial variations in concentrations. The NPNRD will use the concentrations of the constituents as a benchmark for later surface-water-quality assessments.

Previous Investigations

Gordon (1966) reported evidence of surface-water-quality changes in the North Platte River. A 27-percent increase in dissolved solids occurred between the Wyoming-Nebraska State line and Bridgeport, Nebraska, 60 miles downstream. Gordon attributed most of the chemical changes within the river water to return flow from irrigation. He stated that the greatest effects on surface-water quality were in the part of the stream with the least flow. Furthermore, the irrigation-return water from north of the North Platte River generally was of better quality than the irrigation-return water from the south side of the North Platte River. He attributed this difference to two primary factors—the differences in the quality of water applied during irrigation and the nature of the soils on the two sides of the river.

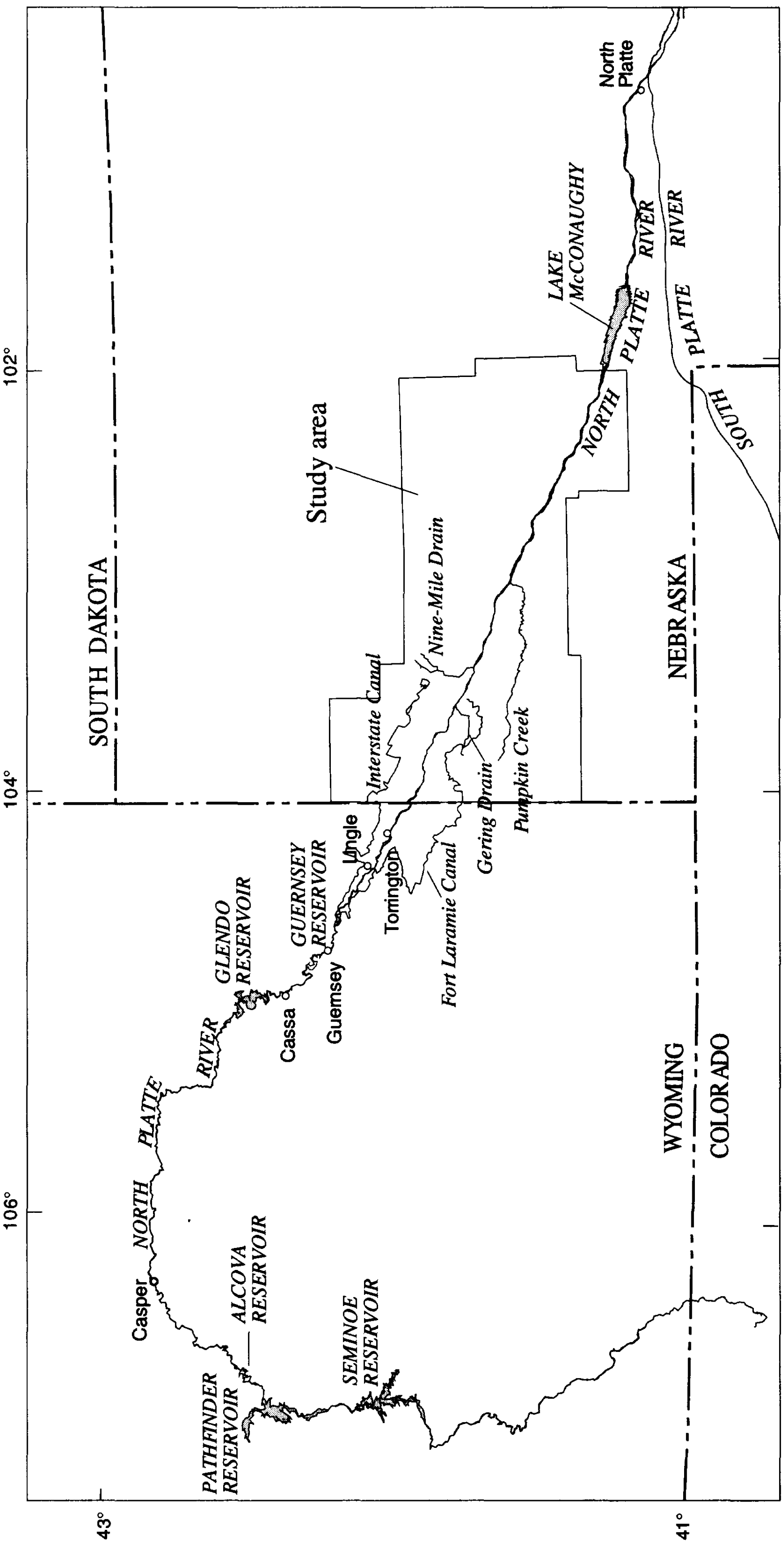
Engberg (1983) reported mean specific-conductance values for the North Platte River at the Wyoming-Nebraska State line were 802 microsiemens per centimeter (µS/cm) at 25 degrees Celsius (25°C) and 931 µS/cm downstream at Bridgeport. Engberg attributed the 15-percent increase to return flow from irrigation. In addition, Engberg (1983) reported that calcium and sodium were the principal cations and bicarbonate and sulfate were the principal anions in the North Platte River. Furthermore, sodium was usually higher at the end of the irrigation season than at any other time. At Pumpkin Creek, a tributary to the North Platte River, Engberg (1983) reported that calcium and bicarbonate were the principal cations and anions, respectively, and the mean specific conductance was 592 µS/cm.

Gordon's (1966) and Engberg's (1983) studies were the only studies undertaken to evaluate the surface-water quality of the North Platte River downstream from the Wyoming border. In the 1970's the USGS began collecting bimonthly surface-water-quality data at the North Platte River gaging station at Lisco (fig. 1). These data show the presence of selenium and other metals such as chromium, lead, and mercury, as well as major ions, nutrients, pesticides, and selected trace elements in the North Platte River. However, these data do not provide information about the general sources of the constituents. Two discontinued sites—North Platte River at Torrington and North Platte River near Lingle (fig. 2)—are the closest upstream sites for which some water-quality data are available for comparison. Other upstream water-quality stations with comparative water-quality data include the North Platte River near Guernsey, Wyoming, the North Platte River near Cassa, Wyoming, and the North Platte River below Glendo Reservoir, Wyoming (fig. 2).

Approach and Methods

Eight sites that represented the major surface-water features within the NPNRD were selected for sampling (fig. 1). The sites, excluding the Fort Laramie Canal, which was dry, were sampled near the beginning of the irrigation season (May 1993). All eight sites were sampled near the middle (July) and conclusion (September) of the irrigation season in 1993. All sample collections used standard USGS procedures as described by Wells and others (1990).

Samples were collected using equal-width-increment (EWI) sampling procedures or centroid-of-flow (COF) sampling procedures as described by Wells and others (1990). The discharges were obtained from rating tables of discharge-versus-gage height or from Wyoming Water Control Office personnel in Torrington, Wyoming.



Base from U.S. Geological Survey 1:100,000 DLG data
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30'; central meridian -96°00'

Figure 2. Major reservoirs along the North Platte River.

The first type of sampling procedure, EWI, was used where the flow was not well mixed—at all North Platte River sites and the Pumpkin Creek and Gering Drain sites. The second type, COF, was used at the Nine-Mile Drain and both canals. Here, the flow was well mixed with minimal influx from other surface-water bodies. In addition, collection of specific conductance and pH cross sections confirmed that the water was well mixed. Analysis of each cross-section profile indicates that flow was well mixed at all three locations and that the COF method was viable.

Major ions, nutrients, triazine herbicides, chlorophenoxy-acid herbicides, bacteria, uranium, and trace elements were the primary constituents analyzed in this study. Field measurements, collected onsite, included water and air temperature, dissolved oxygen, pH, and specific conductance. All water-quality samples were collected by wading the stream or suspending the sampler by hand from a bridge. Samples were subsequently processed onsite by using protocols similar to those described by Wells and others (1990). All pesticide samples were analyzed for triazine herbicides and 2,4–D and other (chlorophenoxy-acid) herbicides by using immunoassay kits.

If the immunoassay analyses showed detection of these herbicides above 1 microgram per liter (μg/L), the samples were sent to the USGS National Water-Quality Laboratory in Arvada, Colorado, for gas chromatography/mass spectrometry (GC/MS) analysis. Standard USGS procedures (Fishman and Friedman, 1985) were used for water-quality laboratory analysis and quality assurance/quality control (QA/QC). Quality-control measures reduced the chance of contamination of the water-quality samples. Equipment blanks, using organic-free and inorganic-free water, along with one complete set of duplicate samples, were used as a quality-assurance check.

During the July 1993 sampling period, Pumpkin Creek was randomly chosen as the QA/QC site. Here, the QA/QC samples were processed immediately following the processing of the regular samples. All QA/QC samples were treated as having come from separate stations with decontamination procedures used between both the equipment blank and duplicate QA/QC sample sets. As a QA/QC measure, 10 percent of the samples with immunoassay nondetections were sent to the USGS National Water-Quality Laboratory.

DESCRIPTION OF STUDY AREA

The NPNRD is located in the High Plains section of the Great Plains province (Fenneman, 1931). It is diverse in landforms including ridges, escarpments, bluffs, river valleys, tablelands, and sandhills. The diverse landforms relate to the geologic units from which they are formed. The geologic units present near the land surface are sediments of Cretaceous through Quaternary age. Darton (1903), Wenzel and others (1946), Smith and Souders (1975), Swinehart and others (1985), Souders (1986), and Verstraeten and others (1995) described the geology of the NPNRD.

Climate

The semiarid climate in the NPNRD is typical of midlatitude sites located east of major mountain ranges. Annual precipitation ranges from 13 inches in the west to 19 inches in the east (Olsson and Associates, 1993). Most of the precipitation occurs in May and June as rainfall from thunderstorms. The mean annual temperature is 48.5°F (Verstraeten and others, 1995). Temperature extremes range from 10° to 40 degrees Fahrenheit (°F) in January to 50° to 90°F in July.

Surface-Water System

The headwaters of the North Platte River are in the Rocky Mountains of north-central Colorado. Flow in the North Platte River starts north-northwest before heading east-northeast to central Wyoming. It then flows southeast over the Wyoming-Nebraska State line to its confluence with the South Platte River near the city of North Platte (fig. 2). Seminoe, Pathfinder, Alcova, Glendo, and Guernsey Dams in Wyoming and Kingsley Dam (Lake McConaughy) in Nebraska (fig. 2) impound the flow of the North Platte River. These reservoirs primarily supply water used for irrigation storage, hydroelectric power generation, and recreation.

The North Platte River watershed is highly developed within the NPNRD. The NPNRD contains 27 surface-water irrigation districts and numerous drains, small dams, lakes, and flood-control projects. Surface water, diverted from the North Platte River and its tributaries through an extensive system of canals, dams, and laterals, is the major supply of irrigation water within the NPNRD (Steele, 1988). The irrigation districts use water from natural flows, water stored in reservoirs, or a combination of natural flows and stored water.

Tributaries to the North Platte River within the NPNRD are a mix of ephemeral, intermittent, and perennial streams. In addition, streamflow records for 1993 indicate that the portion of the North Platte River that flowed within the NPNRD was generally a gaining stream.

Land Use

Land use within the NPNRD is primarily agricultural. Rangeland for grazing cattle and sheep accounts for approximately 74 percent and cultivated land accounts for approximately 25 percent of the land within the NPNRD. The remaining 1 percent consists of wildlife refuges, barren land, and land used for residential, recreational, and light industrial purposes.

Agriculture (irrigation and livestock), commercial, industrial, and domestic entities use most of the water within the NPNRD. Surface water is the source for nearly 84 percent of the water within the NPNRD and is primarily used for irrigation (Verstraeten and others, 1995). The Nebraska Department of Water Resources regulates the supplies and diversions from the North Platte River and its tributaries. Agricultural entities in Scotts Bluff County are the largest users, with 67.5 percent of the total allotted surface-water irrigation (Hill and Frankforter, 1994). In Morrill and Sioux Counties, agricultural entities use 30.3 percent, and in Banner and Garden Counties, 2.2 percent. During 1990, the total amount of surface water applied for irrigation within the NPNRD was approximately 570,000 acre-feet (Hill and Frankforter, 1994).

WATER QUALITY

Based on data collected during the study by Verstraeten and others (1995), the surface-water constituents of greatest concern to the NPNRD are nitrates, pesticides, and uranium. Table 1 lists the surface-water-quality data collected during this study for these constituents. All water-quality data, except the triazine immunoassay test results, are listed in tables 2 and 3, as supplemental data at the end of this report, and are stored in the USGS Water Data Storage and Retrieval (WATSTORE) data base. Results were compared to the USEPA primary or secondary MCL for safe drinking water (U.S. Environmental Protection Agency, 1991).

Major Ions and Field Measurements

Analysis of the surface-water-quality data indicates that the predominant type of water in the NPNRD varies between calcium magnesium bicarbonate sulfate and sodium magnesium bicarbonate sulfate, similar to that reported by Engberg (1983). Many of the sites remained fairly consistent in terms of chemical quality throughout the study period. However, two sites—Gering Drain and Pumpkin Creek—showed variations in concentrations of calcium, sodium, bicarbonate, and sulfate throughout the study period.

The water quality of the North Platte River remained fairly consistent throughout the study period in terms of major ions or type of water. Generally, little variation in concentrations of major ions occurred from May through September 1993 (fig. 3). In addition, dissolved-oxygen concentrations ranged from 5.8 to 8.8 milligrams per liter (mg/L), pH values ranged from 8.0 to 8.6 standard units, and specific-conductance values ranged from 735 to 1,250 µS/cm at 25°C. The specific-conductance values generally increased downstream from the Wyoming-Nebraska State line.

Dissolved-solids concentrations exceeding 500 mg/L were measured at all sites except the Fort Laramie Canal. Pumpkin Creek and the North Platte River at Lisco were the only two sites where the maximum concentrations of dissolved solids were not detected in the May or July sampling period, but rather in September. Concentrations of dissolved solids ranged from 396 to 852 mg/L, with a mean concentration of 577 mg/L.

Analyses of water samples collected from the Fort Laramie and Interstate Canals showed little change in the major-ion chemistry during the study period (fig. 4). The analyses indicate that water from these two irrigation canals was nearly identical with respect to the percentage of major ions. Dissolved oxygen, pH, and specific-conductance values for the two canals ranged from 8.0 to 9.2 mg/L, 8.2 to 8.7 standard units, and 619 to 723 µS/cm, respectively.

Table 1. Concentrations of nitrate, selected pesticides, and uranium in the surface water of the study area, May, July, and September 1993

[--, no laboratory analysis; <, less than indicated reporting level; mg/L, milligrams per liter; µg/L, micrograms per liter; MCL, Maximum Contaminant Level]

Station name	U.S. Geological Survey station number	Date of sample	Time	Nitrate as N (mg/L)[1]	Atrazine (µg/L)[2]	2,4-D (µg/L)[3]	Uranium (µg/L)[4]
Interstate Canal, 1 mile east of the Wyoming-Nebraska State line	06656610	05-13-93	1230	<0.05	<0.05	<0.01	12
		07-08-93	1200	.09	<.05	--	11
		09-09-93	1200	.05	<.05	<.01	9.9
Fort Laramie Canal at Wyoming-Nebraska State line	06656200	07-08-93	1000	.04	<.05	--	11
		09-09-93	1000	.03	--	--	9.8
North Platte River at Wyoming-Nebraska State line	06674500	05-12-93	0710	1.2	--	--	26
		07-07-93	0800	.25	<.05	--	13
		09-07-93	1030	.67	<.05	<.01	16
Gering Drain near Gering	06681500	05-13-93	1015	5.7	--	--	59
		07-08-93	0600	1.3	--	.29	21
		09-09-93	1430	1.2	<.05	--	19
Nine-Mile Drain near McGrew	06682500	05-13-93	0705	4.5	--	<.01	28
		07-08-93	1600	4.3	.46	--	27
		09-08-93	1500	3.4	<.05	<.01	24
North Platte River at Bridgeport	06684498	05-12-93	1100	2.8	--	--	34
		07-07-93	1200	2.0	<.05	--	26
		09-07-93	1600	2.5	<.05	--	24
Pumpkin Creek near Bridgeport	06685000	05-11-93	1355	3.6	<.05	--	23
		07-08-93	1400	3.7	<.05	.39	22
		09-07-93	1800	2.4	<.05	.01	26
North Platte River at Lisco	06686000	05-12-93	1310	2.6	<.05	<.01	33
		07-07-93	1400	1.7	<.05	--	--
		09-08-93	1200	2.3	<.05	<.01	25

[1]MCL 10 mg/L of nitrate as N (U.S. Environmental Protection Agency, 1991).
[2]MCL 3 µg/L (U.S. Environmental Protection Agency, 1991).
[3]MCL 70 µg/L (U.S. Environmental Protection Agency, 1991).
[4]MCL 20 µg/L (U.S. Environmental Protection Agency, 1991).

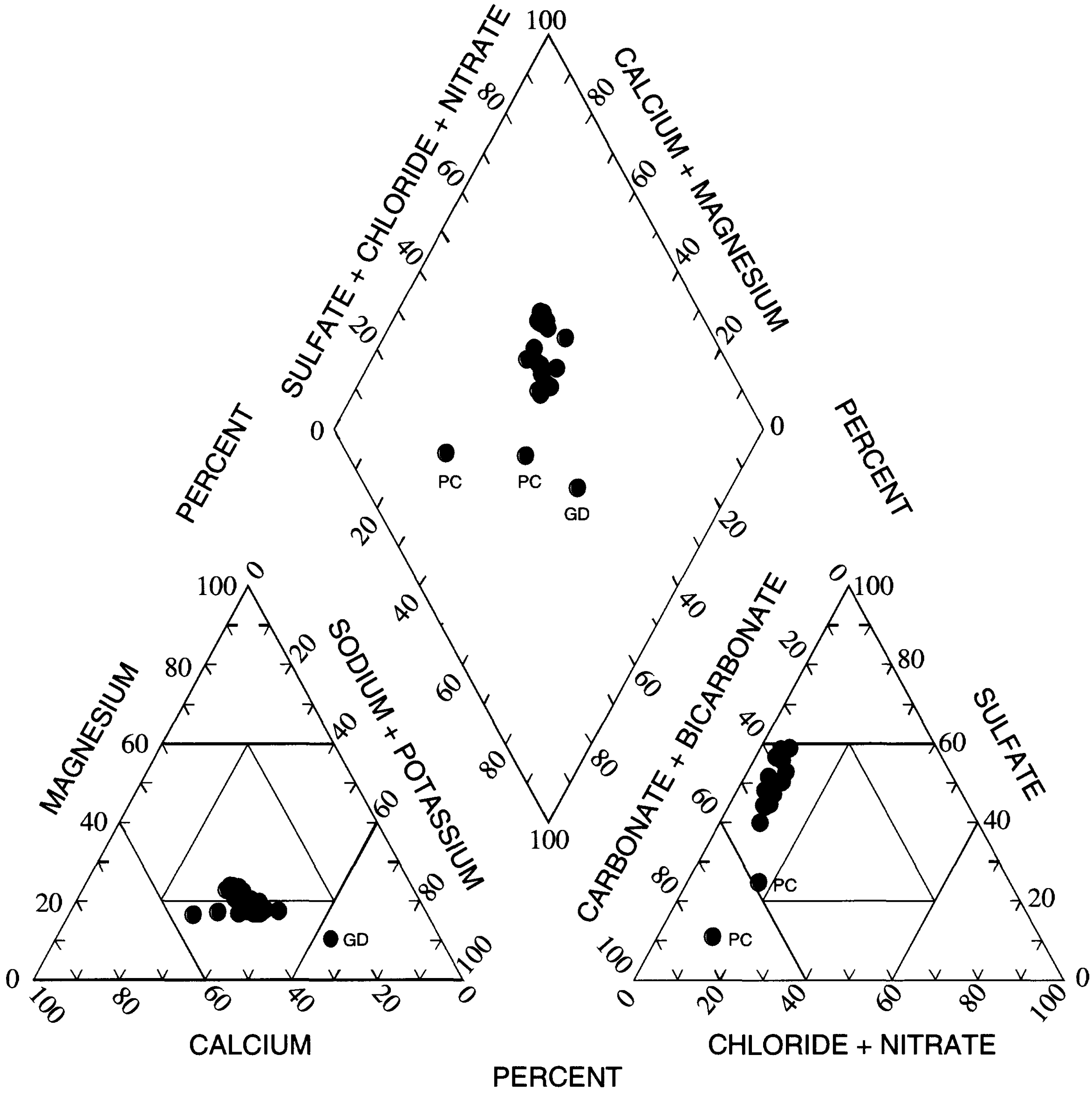


Figure 3. Chemical composition of surface water in the study area, 1993 (GD, Gering Drain; PC, Pumpkin Creek).

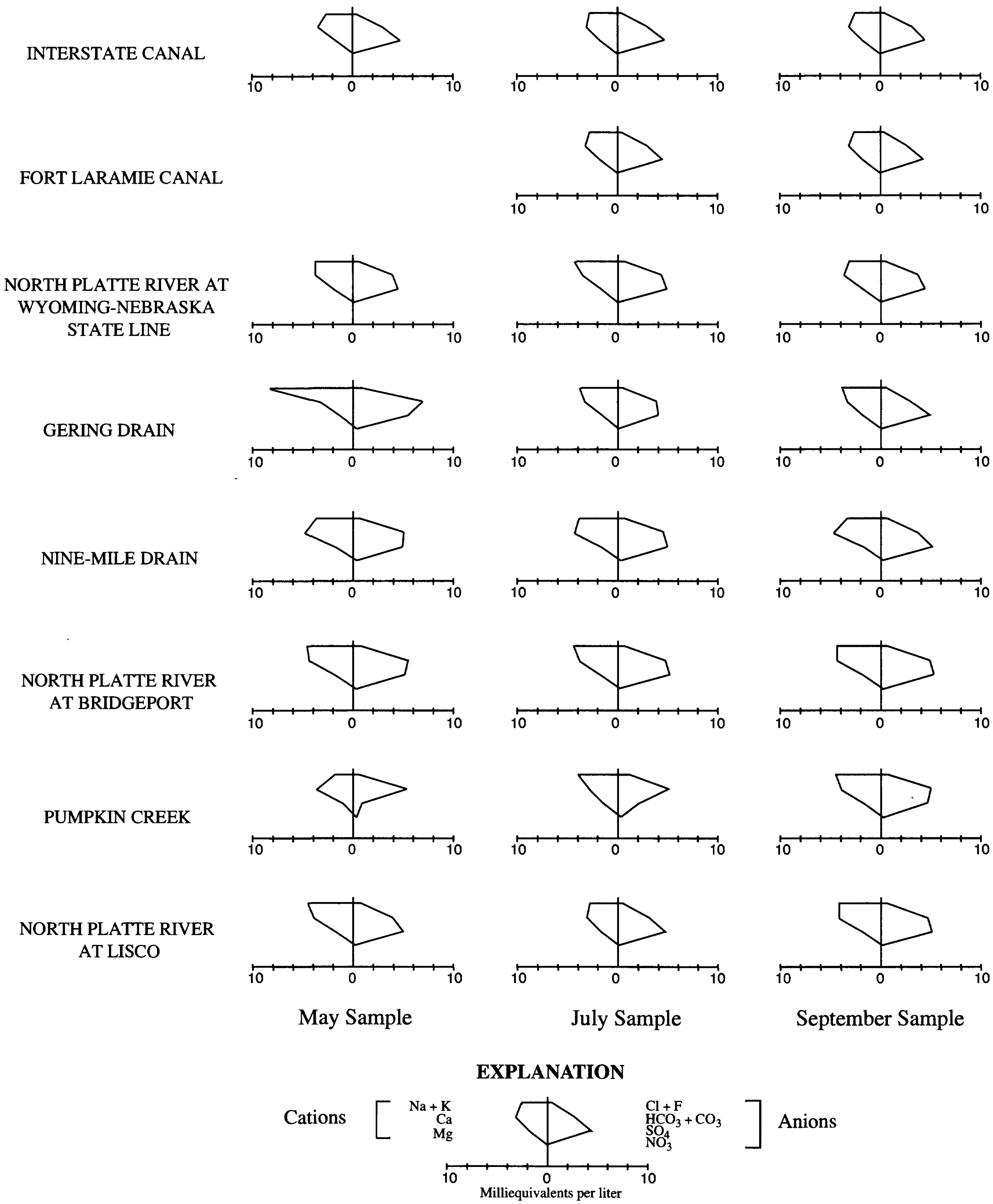


Figure 4. Concentrations of major ions in surface water of the study area, 1993.

The highest specific-conductance value, 723 μS/cm, measured in the Interstate Canal, occurred within days after the beginning of diversion for irrigation, whereas the lowest conductances occurred in September, when irrigation diversions decrease.

Samples collected in the Gering Drain showed that the major-ion chemistry changed between the first two sampling periods. From May to July 1993, the water chemistry varied from a very sodium-rich bicarbonate to a slightly sodium-rich sulfate bicarbonate type (figs. 3 and 4). From July to September 1993, the chemical change in the water was not as large, although sulfate concentrations decreased from May to July 1993 and increased from July to September 1993.

The reason for the variations in the sulfate concentrations is not clear, but it may be attributable to (1) an increase in irrigation water leaching sulfate out of the soils (Hem, 1985), (2) dissolution of barite or other sulfate minerals by natural weathering, or (3) oxidation of sulfur commonly found in water in biogenic deposits (deposits produced by actions of living organisms) (Hem, 1985) and brought to the surface during the pumping of oil wells.

Specific-conductance readings from the Gering Drain decreased from a high of 1,250 μS/cm in May to 814 μS/cm in September, whereas pH values varied slightly from 8.0 to 8.1 standard units. Dissolved-oxygen concentrations at this site ranged from 7.7 to 8.8 mg/L. The conductance reading of 1,250 μS/cm also was the highest reading for the study.

Water in Nine-Mile Drain remained relatively consistent in terms of major-ion chemistry (fig. 4). The largest changes during the study period were a decrease in bicarbonate and an increase in sulfate. Specific-conductance values during the study period ranged from 885 to 988 μS/cm. Dissolved oxygen ranged from 7.8 to 9.3 mg/L and pH ranged from 8.0 to 8.1 standard units.

Pumpkin Creek showed the largest changes in water chemistry of all eight sites (fig. 4). The water type at Pumpkin Creek changed from a calcium bicarbonate in May 1993 to a sodium bicarbonate in September 1993. The sulfate concentration increased throughout the study period by almost one order of magnitude. As in the Gering Drain, some of the increase in sulfate concentration for this site may be attributable to the same factors plus oxidation of sulfur in animal waste. During the study, dissolved oxygen, pH, and specific-conductance values ranged from 8.3 to 9.8 mg/L, 7.8 to 8.2 standard units, and from 608 to 888 μS/cm, respectively.

Nutrients

Nitrates, as well as other nutrients in streams, are derived from many sources, both anthropogenic and natural (Goolsby and Battaglin, 1993). These sources include, but are not limited to, agricultural fertilizers, animal waste, sewage waste, legumes, and organic matter in soils. Because nitrite (NO_2^-) is relatively unstable in aerated water (Hem, 1985) and is not present in freshwater in the same quantities as nitrate (NO_3^-) (National Research Council, 1978), for this report all analyses for nitrite plus nitrate are considered nitrate as N. Because nitrates in fertilizer are used in agriculture throughout the District, the NPNRD considers nitrate as N to be one of the more important constituents. Therefore, discussion of analytical results is limited only to concentrations of nitrate as N, although samples were analyzed for other nutrient species. The other nutrients sampled during the study included ammonia, nitrite, phosphate, and phosphorus.

The highest concentration of nitrate as N (5.80 mg/L) was detected in a sample collected from the Gering Drain on May 13, 1993. This high concentration probably can be partly attributed to surface runoff following application of pre-emergent fertilizer on row crops south of the North Platte River. The lowest concentration of nitrate as N, 0.03 mg/L, was detected in a sample collected from Fort Laramie Canal on September 9, 1993. Nine-Mile Drain, the North Platte River at Bridgeport and Pumpkin Creek all showed that concentrations of nitrate as N were highest in samples collected in May and July (table 1). The median concentration of nitrate as N for 22 analyses was 2.2 mg/L. All samples showed concentrations of nitrate as N well below the MCL (U.S. Environmental Protection Agency, 1991) of 10 mg/L.

Bacteria

Analyses of bacteria present in the surface water of the NPNRD were limited to fecal coliform and fecal streptococci bacteria. Fecal coliform bacteria generally are associated with human waste, and fecal streptococci bacteria are associated with waste from warmblooded mammals. All sample locations showed colonies of both types of bacteria; however, the amounts present varied extensively. Fecal coliform bacteria had a maximum count of 3,900 colonies per 100 milliliters (col/100 mL), a minimum of 7 col/100 mL, and a mean and median of 545 and 140 col/100 mL, respectively. Fecal streptococci bacteria had a maximum count of 32,000 col/100 mL, a minimum of 20 col/100 mL, and a mean and median of 3,524 and 210 col/100 mL, respectively.

Maximum counts of both fecal coliform and fecal streptococci bacteria occurred at Pumpkin Creek. The source for the high fecal coliform bacteria counts at Pumpkin Creek has not been determined, but the high fecal streptococci bacteria count may be attributable to a feedlot located directly upstream from the site. The minimum count of fecal coliform bacteria occurred at the Fort Laramie Canal, and the minimum count of fecal streptococci bacteria was at the Interstate Canal. The results probably are related to two factors: (1) relatively large areas of rangeland combined with relatively few livestock per acre upstream from the diversion points in Wyoming, and (2) a lack of input from other surface-water systems after the water is diverted into the canal.

Pesticides

Occurrence of pesticides in streams generally is the result of runoff from fields on which those pesticides have been applied. Atrazine and 2,4–D are two common pesticides applied in the NPNRD. All detections of pesticides in the surface water occurred in tributaries of the North Platte River (fig. 5)—Pumpkin Creek and the Gering and Nine-Mile Drains. Row crop agriculture is extensive in this area. Also, stream discharges are not as great in the tributaries as in the North Platte River; pesticide concentrations, if present, are less likely to become diluted.

Pesticides were detected in four samples. Atrazine, with a single occurrence, was detected in the Nine-Mile Drain, whereas 2,4–D was detected three times—Gering Drain (1 detection) and Pumpkin Creek (2 detections). Three of these four detections occurred during the month of July. The only other detection was in Pumpkin Creek during September.

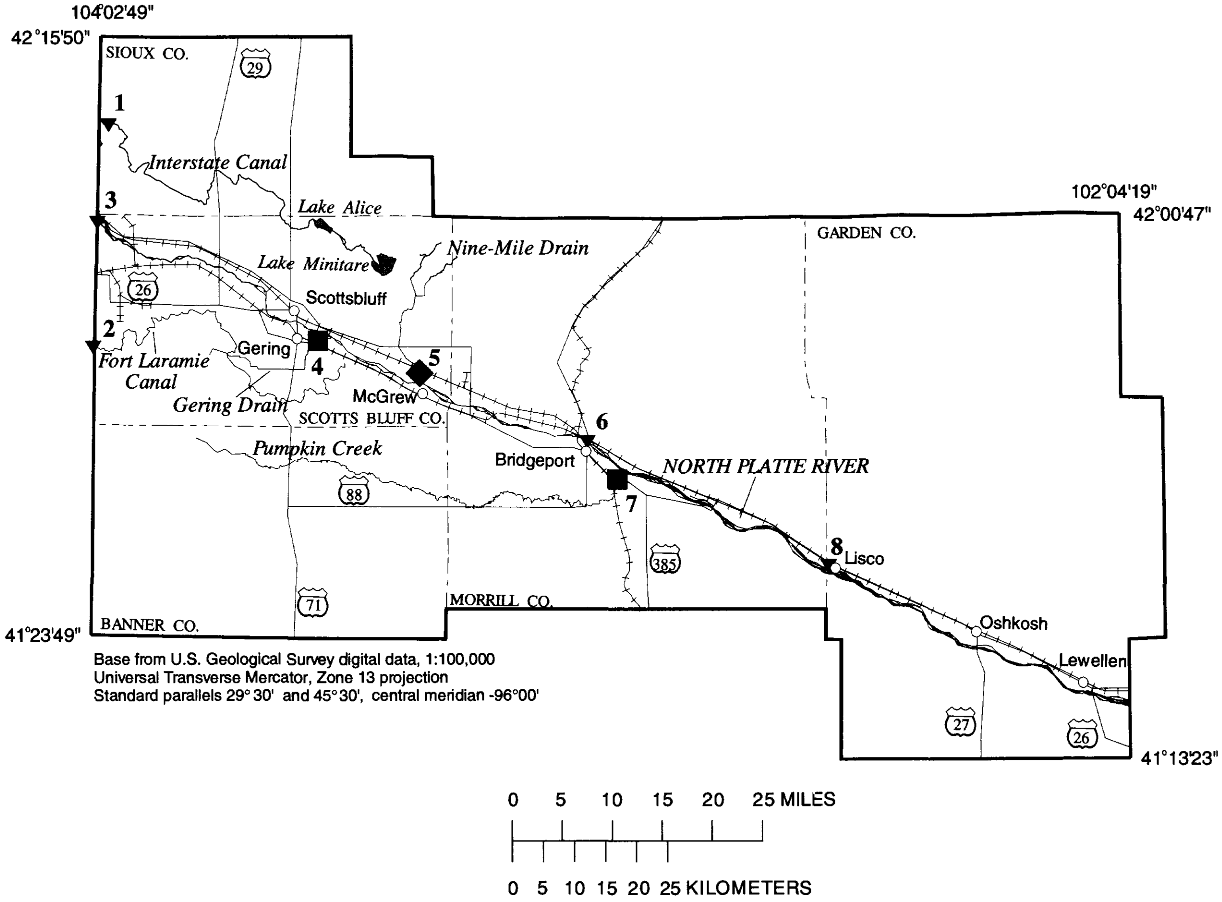
All other triazine herbicide and chlorophenoxy-acid herbicide concentrations were below the reporting limits of the analytical instruments or were not analyzed for at the laboratory because of a negative response with the immunoassay kit. All concentrations of atrazine and 2,4–D were below the MCL (U.S. Environmental Protection Agency, 1991) of 3 and 70 μg/L, respectively. Table 1 lists the laboratory-determined concentrations of atrazine and 2,4–D herbicides.

Uranium

Uranium was the only radionuclide sampled and analyzed during this study. Mean concentrations of uranium at each site were compared with the MCL (U.S. Environmental Protection Agency, 1991) of 20 μg/L. Mean concentrations of uranium above 20 μg/L were detected in the Gering and Nine-Mile Drains, the North Platte River at Bridgeport and at Lisco, and in Pumpkin Creek. Only one occurrence of uranium above 20 μg/L was detected in the North Platte River at the Wyoming-Nebraska State line. Uranium concentrations exceeding 20 μg/L were not detected in samples from either of the two canals (table 1).

At most sites, the highest concentrations occurred in May, whereas the lowest concentrations occurred in September. The mean concentration for the 22 analyses was 23 μg/L; the maximum, at the Gering Drain, was 59 μg/L in May 1993; and the minimum, at the Fort Laramie Canal, was 9.8 μg/L in September 1993. One sample, the North Platte River at Lisco, July 7, 1993, was inadvertently destroyed and was not analyzed.

Verstraeten and others (1995) reported that the largest median uranium concentrations were detected in ground-water samples collected from Quaternary-age water-bearing units. In addition, analysis of 1993 streamflow data indicated that these Quaternary-age water-bearing units were in direct hydraulic contact with the streams in the NPNRD. Therefore, because streams within the NPNRD generally are gaining, and low uranium concentrations were detected in samples collected from three sites where surface water enters the NPNRD, it is probable that most of the uranium concentrations detected in the surface water resulted from discharge from: (1) the ground-water system, (2) surface runoff following ground-water or surface-water irrigation, and (3) inflow from tributaries.



EXPLANATION

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2 Fort Laramie Canal at Wyoming-Nebraska State line
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7 Pumpkin Creek near Bridgeport
8 North Platte River at Lisco

◆ Detection of atrazine

■ Detection of 2,4–D

Figure 5. Locations of sites having detections of pesticides in samples collected from the study area, western Nebraska, 1993.

Trace Elements

Samples were analyzed for arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, selenium, silver, strontium, vanadium, and zinc. Concentrations of beryllium, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, and silver were either undetected or slightly above the reporting limit of the analytical method. Iron, although generally present in concentrations below or near the reporting limit of 3 µg/L, was present in maximum concentrations of 56 (Gering Drain) and 62 µg/L (Pumpkin Creek). Strontium was the most frequently detected trace element, with a mean concentration of 763 µg/L. It was followed by boron (mean of 144 µg/L), barium (mean of 90.3 µg/L), and lithium (mean of 37.2 µg/L). The remaining five trace elements, although detected at most sites, were not detected in concentrations that significantly exceeded the reporting limits.

Gering Drain and Pumpkin Creek generally contained the highest concentrations of individual trace elements. Some of the high concentrations of trace elements in the Gering Drain may be attributable to surface-water runoff from industrial sites located in Gering that are in close proximity to the Gering Drain. Also, both Gering Drain and Pumpkin Creek drain the southwestern part of the NPNRD, which contains a large area of Tertiary-age sediments (Swinehart and others, 1985) exposed at the land surface. These Tertiary-age sediments can contain many of the trace elements (Tychsen, 1954) detected in the samples.

SUMMARY

Selection and sampling of eight representative surface-water sites within the NPNRD allowed for a characterization of its surface-water quality. Surface water was sampled and analyzed near the beginning, middle, and conclusion of the 1993 irrigation season. Results were compared to the USEPA established or proposed MCLs for safe drinking water.

Generally, higher specific-conductance readings occurred in May, and lower readings occurred in September. In addition, an increase in specific conductance generally was detected in the North Platte River downstream from the Wyoming-Nebraska State line. Conductance values ranged from a low of 608 µS/cm in Pumpkin Creek to a high of 1,250 µS/cm in the Gering Drain.

Analysis of the surface-water-quality data indicates that the predominant type of water within the NPNRD varies between calcium magnesium bicarbonate sulfate and sodium magnesium bicarbonate sulfate. Only Gering Drain and Pumpkin Creek showed substantial variations of calcium, sodium, bicarbonate, and sulfate throughout the study period. Sulfate concentrations increased by almost one order of magnitude at Pumpkin Creek. This increase may be partly attributed to: (1) an increase in irrigation water leaching sulfate out of the soils, (2) dissolution of barite or other sulfate minerals by natural weathering, or (3) oxidation of sulfur commonly found in water located at biogenic deposits and brought to the surface during the pumping of oil wells, or (4) oxidation of sulfur in animal waste.

Samples from the North Platte River showed that concentrations of major ions or type of water remained fairly consistent throughout the study. In addition, samples from the two canals were almost identical with respect to percentages of major ions.

Nitrate as N, bacteria, and pesticide concentrations varied throughout the study. The maximum and minimum nitrate as N concentrations, 5.8 and 0.03 mg/L, respectively, were well below the USEPA MCL of 10 mg/L. The highest nitrate as N concentrations occurred during May and July, when fertilizer runoff is most prevalent.

Fecal coliform and fecal streptococci bacteria counts varied greatly from a minimum of 7 and 20 col/100 mL to a maximum of 3,900 and 32,000 col/100 mL, respectively. Maximum counts for both types of bacteria occurred at Pumpkin Creek. The source for the high fecal coliform bacteria count could not be readily determined, but the high fecal streptococci bacteria count may be attributable to a feedlot located directly upstream from the site. The minimum count for fecal coliform bacteria occurred at the Fort Laramie Canal, and the minimum count for fecal streptococci bacteria occurred at the Interstate Canal. These results probably relate to relatively large acres of rangeland combined with relatively few livestock per acre upstream from the diversion points in Wyoming.

Samples for the selected herbicides were tested with immunoassay kits; if the immunoassay test detected the herbicides, concentrations were then determined by laboratory analysis. Concentrations of atrazine were detected in Nine-Mile Drain, whereas concentrations of 2,4–D were detected at the Gering Drain and Pumpkin Creek. Three of the four detections of these pesticides were in July, and the fourth was in September.

Uranium was the only radionuclide included in this study. Most concentrations of uranium exceeded the USEPA MCL of 20 μg/L. Most uranium concentrations that exceeded the MCL occurred at sites located downstream from the Wyoming-Nebraska State line. The mean concentration of uranium during the study was 23 μg/L, slightly over the USEPA MCL. The maximum concentration, 59 μg/L, occurred at the Gering Drain, whereas the minimum concentration, 9.8 μg/L, was detected in samples from the Fort Laramie Canal. Data suggest that the streams within the NPNRD are gaining, uranium concentrations in waters entering the NPNRD were low, and uranium concentrations in the ground water were highest in the unconsolidated alluvial aquifers (Verstraeten and others, 1995). Therefore, it is probable that most of the uranium concentrations detected in the surface water resulted from discharge from: (1) the ground-water system, (2) surface runoff following ground-water or surface-water irrigation, and (3) inflow from tributaries.

Samples also were analyzed for 19 trace elements. Gering Drain and Pumpkin Creek generally contained the highest concentrations of individual trace elements. Nine trace elements were either undetected or only slightly above the reporting limit of the analytical method. Iron, although generally present in concentrations below or near the reporting limit of 3 μg/L, was detected twice, at Gering Drain and Pumpkin Creek, with concentrations of 56 and 62 μg/L, respectively. However, all other samples showed no detectable concentrations of iron or concentrations only slightly above the reporting limit.

Strontium was the most frequently detected trace element, with a mean of 763 μg/L. Boron, barium, and lithium followed, with means of 144, 90.3, and 37.2 μg/L, respectively.

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Supplemental Data

Table 2. Water-quality results for samples collected at stations on the North Platte River and Pumpkin Creek, western Nebraska, 1993

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm, millimeters; Hg, mercury; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; col/100 mL, colonies per 100 milliliters; T/acre-ft, tons per acre-foot; µg/L, micrograms per liter; --, no results; ND, no detections; e, estimated; <, less than; PE, *2 sigma* precision estimate. Note: Station names have been shortened to fit column. Proper names are listed in table 1 and fig. 1]

	North Platte River at Wyoming-Nebraska State line			North Platte River at Bridgeport			Pumpkin Creek near Bridgeport			North Platte River at Lisco		
Parameter and reporting unit	06674500			06684498			06685000			06686000		
Date	05–12–93	07–07–93	09–07–93	05–12–93	07–07–93	09–07–93	05–11–93	07–08–93	09–07–93	05–12–93	07–07–93	09–08–93
Time	0710	0800	1030	1100	1200	1600	1355	1400	1800	1310	1400	1200
Discharge (ft^3/s)	291	1,400	976	433	461	970	14	.32	9.4	796	700	1,290
Gage height (feet)	1.52	3.34	2.96	6.5	6.43	7.16	1.43	1.01	1.42	ND	1.23	1.91
Specific conductance (µS/cm)	845	735	778	1,020	841	919	608	801	888	941	859	924
pH (standard units)	8.1	8.3	8.4	8.5	8.4	8.6	8.5	8.5	8.8	8.4	8.5	8.7
Water temperature (°C)	13	17.5	15	15	20	16.5	13.5	28	16.5	18.5	24.5	15
Air pressure (mm of Hg)	658	654	661	670	663	661	673	663	661	ND	666	672
Dissolved oxygen (mg/L)	5.8	7.3	8.1	7.2	7.6	8.4	9.2	9.8	8.3	7.1	7.4	8.8
Dissolved oxygen (percent saturation)	64	89	93	82	97	100	100	145	99	ND	102	99
Hardness (mg/L as $CaCO_3$)	280	260	260	310	270	300	230	210	280	280	230	290
Alkalinity (mg/L as $CaCO_4$)	200	210	180	270	230	240	250	240	250	190	150	240
Calcium (mg/L)	73	69	71	87	75	85	71	55	78	78	60	82
Magnesium (mg/L)	23	20	21	22	21	22	13	17	20	21	20	21
Sodium (mg/L)	81	90	66	100	93	94	38	65	93	97	61	89
Sodium adsorption ratio	2	2	2	2	2	2	1	2	2	3	2	2
Potassium (mg/L)	8	11	5.4	11	10	9.4	9.8	40	9.7	11	4.7	9.4
Sulfate (mg/L)	210	230	210	240	240	250	34	98	220	230	220	240
Chloride (mg/L)	20	21	14	25	22	21	18	38	23	24	15	21
Fluoride (mg/L)	.5	.4	.4	.5	.5	.5	.5	.6	.5	.4	.4	.5
Silica (mg/L)	20	28	17	35	28	34	46	33	33	36	10	33
Dissolved solids (mg/L)	559	600	518	695	640	672	396	510	637	625	492	645
Dissolved solids (T/acre-ft)	.76	.82	.7	.95	.87	.91	.54	.69	.87	.85	.67	.88
Nitrite, as N (mg/L)	.03	.004	.005	<.01	.005	.004	.06	.202	.022	<.007	.01	.003
Nitrate, as N (mg/L)	1.17	.247	.668	2.8	2	2.5	3.54	3.5	2.38	2.6	1.69	2.3
Nitrite plus nitrate, as N (mg/L)	1.2	.251	.673	2.8	2	2.5	3.6	3.7	2.4	2.6	1.7	2.3
Ammonia, as N (mg/L)	.08	<.002	.021	.01	.002	.006	.07	.085	.058	.01	<.002	.006
Phosphorus (mg/L)	.01	.004	.006	.02	.033	.03	.03	.146	.039	<.01	.005	.026
Fecal coliform (col/100 mL)	e130	--	e100	e150	--	430	1,500	--	3,900	e50	--	270
Fecal streptococci (col/100 mL)	e86	240	3,200	e140	260	e2,800	e440	e32,000	16,000	e110	110	--
2,4–D (µg/L)	ND	ND	<.01	ND	ND	ND	ND	.39	.01	<.01	ND	<.01
2,4–DP (µg/L)	ND	ND	<.01	ND	ND	ND	ND	<.01	<.01	<.01	ND	<.01
2,4,5–T (µg/L)	ND	ND	<.01	ND	ND	ND	ND	<.01	<.01	<.01	ND	<.01
Alachlor (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05

Table 2. Water-quality results for samples collected at stations on the North Platte River and Pumpkin Creek, western Nebraska, 1993—Continued

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm, millimeters; Hg, mercury; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; col/100 mL, colonies per 100 milliliters; T/acre-ft, tons per acre-foot; µg/L, micrograms per liter; --, no results; ND, no detections; e, estimated; <, less than; PE, *2 sigma* precision estimate. Note: Station names have been shortened to fit column. Proper names are listed in table 1 and fig. 1]

Parameter and reporting unit	North Platte River at Wyoming-Nebraska State line			North Platte River at Bridgeport			Pumpkin Creek near Bridgeport			North Platte River at Lisco		
	06674500			06684498			06685000			06686000		
Ametryn (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Atrazine (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Cyanazine (µg/L)	ND	<.200	<.200	ND	<.200	<.200	<.200	<.200	<.200	<.200	<.200	<.200
Deethylatrazine (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Deisopropylatrazine (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	.06	<.05	.15	<.05	<.05
Dicamba (µg/L)	ND	ND	<.01	ND	ND	ND	ND	.83	<.01	<.01	ND	<.01
Metolachlor (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Metribuzin (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	.06	<.05
Picloram (µg/L)	ND	ND	<.01	ND	ND	ND	ND	<.01	<.01	<.01	ND	<.01
Prometon (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Prometryn (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Propazine (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Silvex (µg/L)	ND	ND	<.01	ND	ND	ND	ND	<.01	<.01	<.01	ND	<.01
Simazine (µg/L)	ND	<.05	<.05	ND	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Uranium (µg/L)	26	13	16	34	26	24	23	22	26	33	ND	25
Uranium, natural PE (µg/L)	3.8	1.9	2.3	5	3.9	3.7	3.5	3.3	4	4.9	ND	3.7
Arsenic (µg/L)	3	5	3	5	4	5	8	7	6	5	2	5
Barium (µg/L)	85	85	72	88	89	89	240	150	120	91	60	88
Beryllium (µg/L)	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
Boron (µg/L)	120	160	100	170	150	150	140	150	150	160	110	150
Cadmium (µg/L)	<1.0	<1.0	2	<1.0	<1.0	<1.0	1	2	<1.0	<1.0	<1.0	<1.0
Chromium (µg/L)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Cobalt (µg/L)	<3.0	<3.0	3	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Copper (µg/L)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Iron (µg/L)	5	7	4	<3.0	<3.0	<3.0	<3.0	62	<3.0	<3.0	8	10
Lead (µg/L)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Manganese (µg/L)	12	3	3	3	4	2	8	30	5	3	2	2
Mercury (µg/L)	.2	.2	<.1	.1	.2	<.1	.2	.2	<.1	.2	.2	2
Molybdenum (µg/L)	<10	<10	<10	<10	10	<10	10	<10	<10	<10	10	<10
Nickel (µg/L)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium (µg/L)	3	3	2	4	3	3	3	4	4	4	4	3
Silver (µg/L)	2	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Strontium (µg/L)	710	780	580	910	800	850	680	680	800	880	550	810
Vanadium (µg/L)	6	11	7	12	9	9	24	19	11	9	<6	9
Zinc (µg/L)	6	6	6	6	9	8	6	20	10	10	7	<3.0

Table 3. Water-quality results for samples collected at stations at Gering Drain, Nine-Mile Drain, and the Fort Laramie and Interstate Canals, western Nebraska, 1993

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm, millimeters; Hg, mercury; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; col/100 mL, colonies per 100 milliliters; T/acre-ft, tons per acre-foot; µg/L, micrograms per liter; --, no results; ND, no detections; e, estimated; <, less than; PE, *2 sigma* precision estimate. Note: Station names have been shortened to fit column. Proper names are listed in table 1 and fig. 1]

Parameter and reporting unit	Interstate Canal near State line			Fort Laramie Canal near State line		Gering Drain near Gering			Nine-Mile Drain near McGrew		
	06656610			06656200		06681500			06682500		
Date	05–13–93	07–08–93	09–09–93	07–08–93	09–09–93	05–13–93	07–08–93	09–09–93	05–13–93	07–08–93	09–08–93
Time	1230	1200	1200	1000	1000	1015	0600	1430	0705	1600	1500
Discharge (ft^3/s)	1,300	1,900	1,700	542	489	16	101	187	65	46	208
Gage height (feet)	5.55	7.15	6.7	4.05	3.8	1.77	2.73	3.42	1.64	1.32	3.16
Specific conductance (µS/cm)	723	705	679	705	619	1,250	820	814	988	930	885
pH (standard units)	8.2	8.4	8.7	8.6	8.2	8.3	8.4	8.4	8.2	8.5	8.3
Water temperature (°C)	13.5	18	18	19.5	17.5	14	15	17.5	10	23	17.5
Air pressure (mm of Hg)	650	649	651	572	651	661	655	651	664	659	672
Dissolved oxygen (mg/L)	8.3	9.2	8.9	8	8.3	8.6	7.7	8.8	7.8	9.3	8.8
Dissolved oxygen (percent saturation)	94	115	111	117	102	97	89	108	80	126	105
Hardness (mg/L as $CaCO_3$)	270	230	240	240	240	230	230	250	320	300	310
Alkalinity (mg/L as $CaCO_4$)	150	140	150	150	130	340	190	140	240	220	180
Calcium (mg/L)	71	59	61	62	61	65	64	66	95	85	92
Magnesium (mg/L)	23	21	21	21	21	16	18	21	21	20	20
Sodium (mg/L)	60	58	54	58	55	180	80	82	78	81	70
Sodium adsorption ratio	2	2	2	2	2	5	2	2	2	2	2
Potassium (mg/L)	4.3	4.2	4	4.4	4.2	13	8.3	6.5	12	12	9.5
Sulfate (mg/L)	230	220	210	210	200	260	190	230	230	230	240
Chloride (mg/L)	15	13	12	13	12	29	14	16	22	20	20
Fluoride (mg/L)	.4	.4	.4	.4	.4	.5	.4	.4	.5	.2	.5
Silica (mg/L)	7.7	7.5	11	7.9	11	55	21	21	45	41	46
Dissolved solids (mg/L)	504	471	464	465	443	852	515	533	672	644	623
Residue, dissolved (T/acre-ft)	.69	.64	.63	.63	.6	1.16	.7	.73	.91	.88	.85
Nitrite, as N (mg/L)	<.01	.009	<.001	.007	<.001	.09	.016	.005	.03	.038	.011
Nitrate, as N (mg/L)	ND	.084	.047	.041	.027	5.71	1.28	1.2	4.47	4.26	3.39
Nitrite plus nitrate, as N (mg/L)	<.05	.093	.047	.048	.027	5.8	1.3	1.2	4.5	4.3	3.4
Ammonia, as N (mg/L)	.02	<.002	.003	<.002	.007	.08	.069	.006	.04	.008	.01
Phosphorus (mg/L)	<.01	.001	.001	<.001	<.001	.03	.053	.007	.02	.055	.02
Fecal coliform (col/100 mL)	e25	--	e23	100	e7	e30	--	e280	1,500	e630	660
Fecal streptococci (col/100 mL)	e55	e40	e20	180	e40	e23	1,800	e18,000	2,700	480	5,700
2,4–D (µg/L)	<.01	ND	<.01	ND	ND	ND	.29	ND	<.01	ND	<.01
2,4–DP (µg/L)	<.01	ND	<.01	ND	ND	ND	<.01	ND	<.01	ND	<.01
2,4,5–T (µg/L)	<.01	ND	<.01	ND	ND	ND	<.01	ND	<.01	ND	<.01
Alachlor (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	<.05	<.05

Table 3. Water-quality results for samples collected at stations at Gering Drain, Nine-Mile Drain, and the Fort Laramie and Interstate Canals, western Nebraska, 1993—Continued

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mm, millimeters; Hg, mercury; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; col/100 mL, colonies per 100 milliliters; T/acre-ft, tons per acre-foot; µg/L, micrograms per liter; --, no results; ND, no detections; e, estimated; <, less than; PE, *2 sigma* precision estimate. Note: Station names have been shortened to fit column. Proper names are listed in table 1 and fig. 1]

	Interstate Canal near State line			Fort Laramie Canal near State line		Gering Drain near Gering			Nine-Mile Drain near McGrew		
Parameter and reporting unit	06656610			06656200		06681500			06682500		
Ametryn (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	<.05	<.05
Atrazine (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	.46	<.05
Cyanazine (µg/L)	<.20	<.20	<.20	<.20	ND	ND	ND	<.20	ND	<.20	<.20
Deethylatrazine (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	.09	<.05
Deisopropylatrazine (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	.07	<.05
Dicamba (µg/L)	<.01	ND	<.01	ND	ND	ND	.07	ND	<.01	ND	<.01
Metolachlor (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	<.05	<.05
Metribuzin (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	<.05	<.05
Picloram (µg/L)	<.01	ND	<.01	ND	ND	ND	<.01	ND	<.01	ND	<.01
Prometon (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	<.05	<.05
Prometryn (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	<.05	<.05
Propazine (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	<.05	<.05
Silvex (µg/L)	<.01	ND	<.01	ND	ND	ND	<.01	ND	<.01	ND	<.01
Simazine (µg/L)	<.05	<.05	<.05	<.05	ND	ND	ND	<.05	ND	<.05	<.05
Uranium (µg/L)	12	11	9.9	11	9.8	59	21	19	28	27	24
Uranium, natural PE (µg/L)	1.7	1.6	1.5	1.7	1.5	8.9	3.2	2.9	4.1	4	3.5
Arsenic (mg/L)	2	2	2	2	2	27	5	6	5	5	5
Barium (mg/L)	61	56	59	62	60	56	95	81	86	86	88
Beryllium (mg/L)	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
Boron (µg/L)	100	100	90	90	90	370	130	140	170	150	140
Cadmium (µg/L)	<1.0	<1.0	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chromium (µg/L)	<5.0	<5.0	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Cobalt (µg/L)	<3.0	<3.0	3	<3.0	3	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Copper (µg/L)	<10	<10	<10	<10	<10	10	<10	<10	<10	<10	<10
Iron (µg/L)	<3.0	4	5	<3.0	7	<3.0	56	5	<3.0	4	3
Lead (µg/L)	<10	<10	20	<10	<10	<10	<10	<10	<10	<10	<10
Manganese (µg/L)	1	<1.0	1	<1.0	1	6	5	3	8	8	7
Mercury (µg/L)	.2	.2	<.1	.2	<.1	.2	.2	<.1	.2	.2	<.1
Molybdenum (µg/L)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Nickel (µg/L)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Selenium (µg/L)	4	4	3	3	3	6	4	<1	4	4	3
Silver (µg/L)	<1.0	<1.0	3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Strontium (µg/L)	640	540	520	560	520	1,200	620	660	1,000	980	1,000
Vanadium (µg/L)	<6	<6	6	<6	6	31	12	11	17	14	14
Zinc (µg/L)	5	5	7	3	5	9	7	8	10	10	6

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