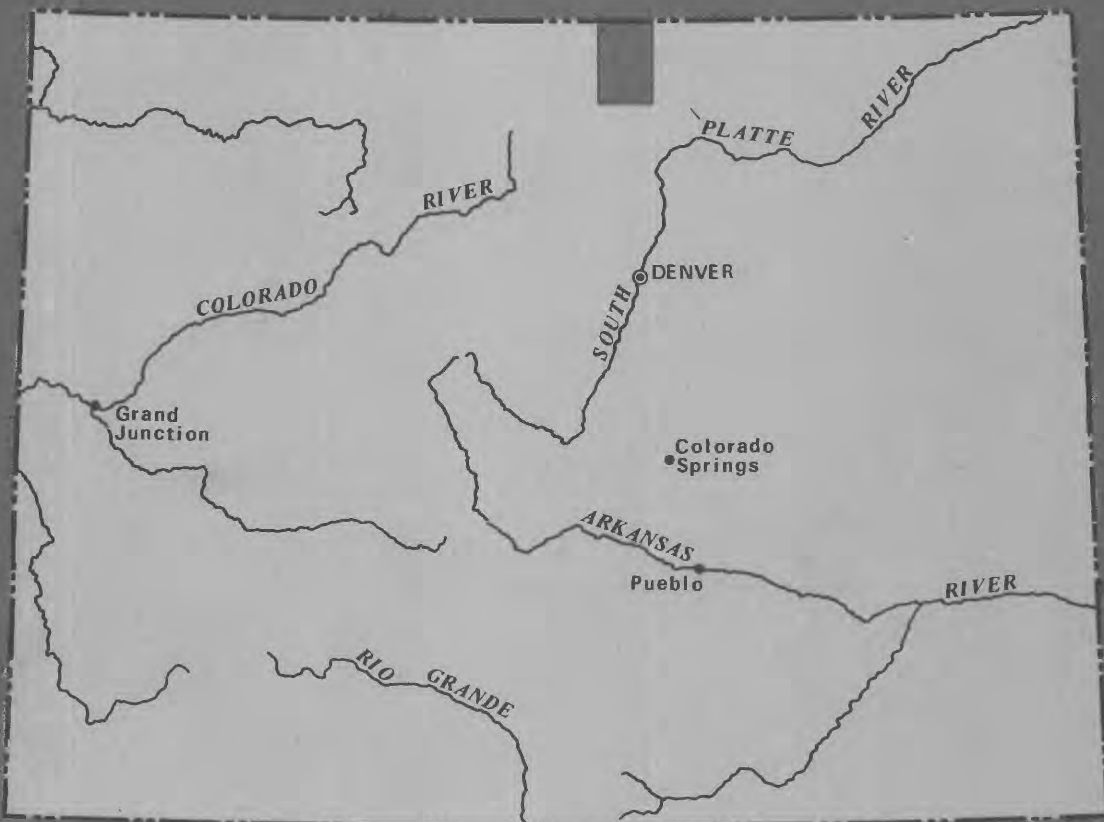
GROUND-WATER RESOURCES OF THE ALLUVIAL AQUIFERS IN NORTHEASTERN LARIMER COUNTY, COLORADO

U. S. GEOLOGICAL SURVEY



Water-Resources Investigations 77-7

Prepared in cooperation with the
Larimer County Board of
County Commissioners

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By R. Theodore Hurr and Paul A. Schneider, Jr.

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January 1977

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

V. E. McKelvey, Director

Open-File Report

For additional information write to:

District Chief
U.S. Geological Survey
Water Resources Division
Colorado District, Mail Stop 415
Box 25046, Denver Federal Center
Lakewood, Colorado 80225

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METRIC CONVERSION

English units used in this report may be converted to metric units by using the following conversion factors:

To convert English units	*Multiply by*	*To find metric units*
inches	25.4	millimeters (mm)
feet	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles	2.59	square kilometers (km^2)
feet per mile	.1894	meters per kilometer (m/km)
acres	.4047	hectares (ha)
acre-feet	1,233	cubic meters (m^3)
cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)
	28.32	liters per second (L/s)
gallons per minute (gal/min)	.06309	liters per second (L/s)

GROUND-WATER RESOURCES OF THE ALLUVIAL AQUIFERS

IN NORTHEASTERN LARIMER COUNTY, COLORADO

By R. Theodore Hurr and Paul A. Schneider, Jr.

ABSTRACT

Ground water is a source of municipal, domestic, stock, and irrigation supply for most of northeastern Larimer County, Colo. A study of the alluvial aquifers in the northeastern part of the county was conducted to determine volume of water in storage, rate and location of ground-water withdrawals, and chemical quality of the water with particular attention to dissolved solids, hardness, sulfate, and selenium. Because selenium has been reported in the municipal water supply of the city of Wellington, which obtains water from the alluvium, emphasis was given to investigating the alluvial aquifers associated with Boxelder Creek.

The area is underlain by Paleozoic and Mesozoic sedimentary rocks that crop out along the mountain front to the west and dip generally eastward. Overlying these bedrock formations are Quaternary alluvial deposits, represented by terrace deposits between streams and valley-fill deposits along streams. Buckeye terrace, northwest of Wellington, is recharged principally by seepage from applied irrigation water, contains about 32,000 acre-feet (39.5 million cubic meters) of ground water in storage, and supplies water to 50 irrigation wells with yields ranging from 80 to 1,200 gallons per minute (5.0 to 76 liters per second). The aquifer in the valley-fill deposits along Boxelder Creek and its tributaries is recharged principally by loss of streamflow, by seepage from ditches and canals traversing the area, and by seepage from applied irrigation water. This aquifer contains 101,000 acre-feet (125 million cubic meters) of ground water in storage and supplies water to 3 municipal and 198 irrigation wells. Yields of these wells range from 90 to 1,840 gallons per minute (5.7 to 116 liters per second).

The concentration and distribution of dissolved solids, hardness, sulfate, and selenium in the alluvial aquifers is controlled by the quality of applied irrigation water, by the amount of water lost to evapotranspiration during irrigation, and by solution of soluble material in the alluvium and in the bedrock at the base of the alluvium. Ground water at the north end of the Buckeye terrace contains only about 300 milligrams per liter dissolved solids because there is no ground-water inflow and recharge is from surface water containing less than 90 milligrams per liter dissolved solids. Concentrations of all constituents increase downgradient to the south due to solution and evaporative concentration.

Ground-water quality in the alluvium along Boxelder Creek below the mouth of its canyon is controlled by the quality of the recharge from water diverted out of Boxelder Creek for irrigation application (about 1,000 milligrams per liter dissolved solids) and underflow from Rawhide Creek (about 1,600 milligrams per liter dissolved solids). Below the point where Boxelder Creek begins to carry the flow of Park Creek Lateral, recharge from conveyance losses and applied surface-water irrigation either improves the quality of the ground water or just about holds it constant. From about Wellington south, the ground water shows a continual increase in dissolved-solids concentration, modified by underflow from Coal Creek (700 milligrams per liter dissolved solids) and Indian Creek (1,200 milligrams per liter dissolved solids).

In 15 of the 43 wells sampled between May 29 and June 4, 1974, the selenium concentration exceeded 10 micrograms per liter, the maximum recommended by the U.S. Environmental Protection Agency for drinking water. The range of concentration was from 0 to 44 micrograms per liter and the median was 8 micrograms per liter. Analyses of other constituents showed no concentrations in excess of the drinking-water standards or recommendations.

INTRODUCTION

Purpose and Scope

Ground water is a source of municipal, domestic, stock, and irrigation water supply for most of northeastern Larimer County, Colo. This report presents the results of a study made to determine the quantity, availability, and quality of the ground water. This information should be useful particularly for land-use planning and the utilization and protection of the ground-water resource.

In 1974, the U.S. Geological Survey, in cooperation with the Larimer County Board of County Commissioners, began a study of the alluvial aquifers in the northeastern part of the county to determine volume of water in storage, location and rate of ground-water withdrawals, and chemical quality of the water, particularly dissolved solids, hardness, sulfate, and selenium. Because selenium concentrations in excess of the drinking-water standards recommended by the U.S. Environmental Protection Agency (1975) had been reported in the municipal water supply of the city of Wellington, which obtains water from the alluvium, emphasis was given to investigating the alluvial aquifers associated with Boxelder Creek.

Previous work in the area provided most of the physical description of the aquifers. The locations of municipal and irrigation wells were determined in the field. Maps describing the configuration of the bedrock surface, the water table, and the thickness of saturated alluvium were constructed from existing drillers' and test hole logs, and water-level measurements made during this study. Water samples were collected from streams, canals, springs, and wells and analyzed for inorganic chemical constituents. Some wells were sampled several times in order to determine possible seasonal variations in water quality.

Location

The area studied (fig. 1) occupies about 300 square miles (780 km^2) and extends from the mountains on the west to the Larimer-Weld County line on the east, and from the Colorado-Wyoming State line on the north to the valley of the Cache la Poudre River on the south. Two creeks, Dry Creek and Boxelder Creek, both tributary to the Cache la Poudre River, drain the area. Dry Creek immediately to the east and running parallel to the mountain front has no significant alluvium associated with it, except near its mouth. The principal alluvial aquifers are associated with Boxelder Creek. Other alluvial aquifers are in high-level terraces in the northern part of the study area.

GEOLOGIC SETTING

The geology for most of the study area was described by Hershey and Schneider (1972). The area is underlain by Paleozoic and Mesozoic sedimentary rocks. These rocks crop out along the eastern edge of the mountain front, dip generally eastward, and are overlain in the northern part of the area by rocks of Tertiary age and in the southern part of the area by rocks of Quaternary age. The Quaternary rocks consist of terrace deposits between the streams and valley-fill deposits along the streams.

Bedrock Formations

The bedrock underlying most of the study area is Pierre Shale of Late Cretaceous age as shown on plate 1. Bedrock in the east central part of the area is Fox Hills Sandstone and Laramie Formation also of Late Cretaceous age. Along the north edge of the study area, the bedrock is the White River Group and the Arikaree Formation, both of Tertiary age.

Pierre Shale

The Pierre Shale is a marine deposit of shale and sandstone approximately 5,900 feet (1,800 m) thick in the study area. Scott and Cobban (1965) have subdivided it into four units, the lower shale unit, the lower sandstone unit, the upper shale unit, and the upper transition member. Although the yield of water to wells is usually small, as much as 40 gallons per minute (2.5 L/s) has been obtained from the sandy sections in the Pierre Shale.

Fox Hills Sandstone

The Fox Hills Sandstone is a marine sandstone which has a thickness, based on the interpretation of geophysical logs, of about 50 to 100 feet (15 to 30 m). This formation is a yellowish, gray to white, fine-grained sandstone, interbedded in the lower part with yellow to gray shale.

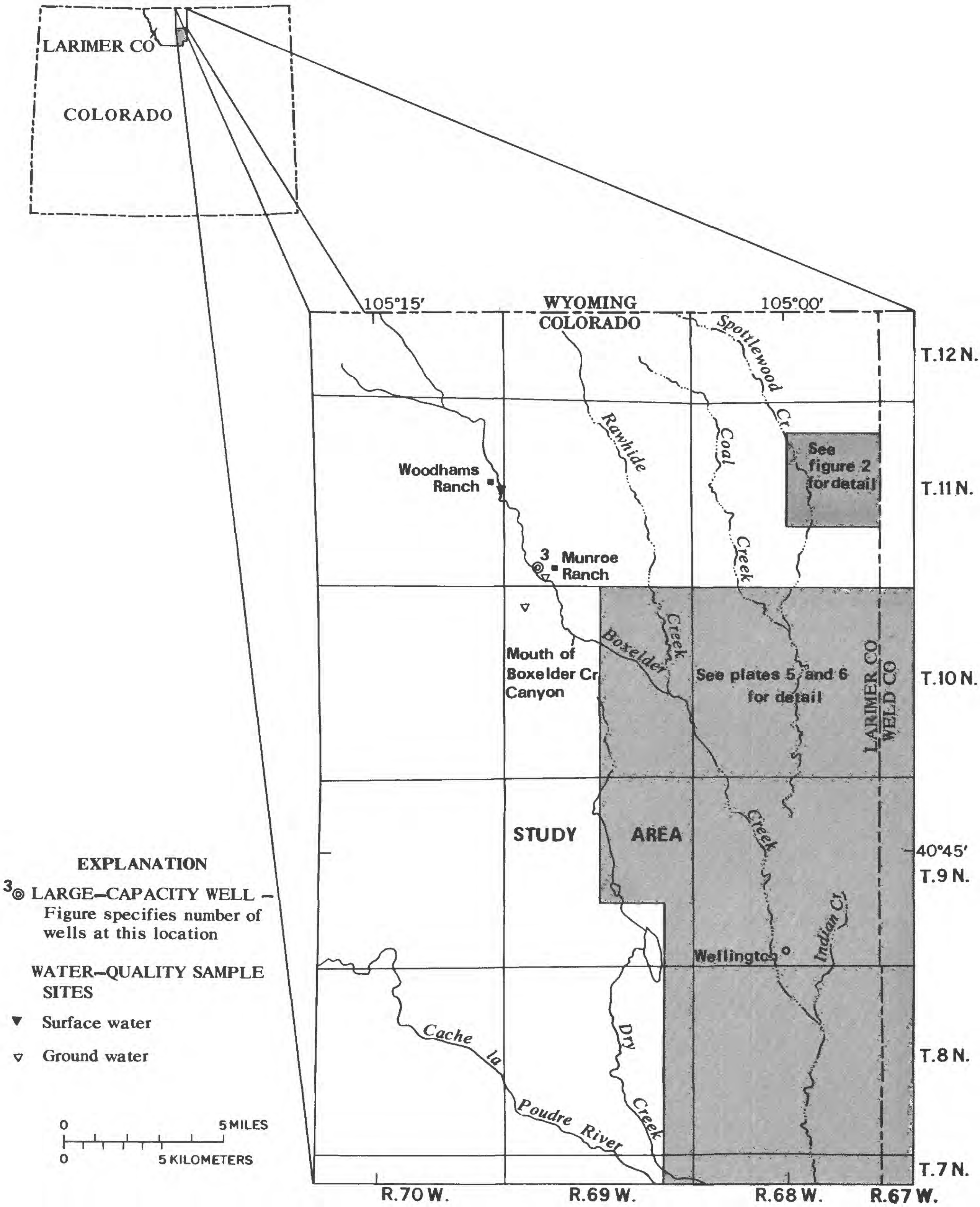


Figure 1.--Location of study area, and selected wells and water-quality sample sites.

Laramie Formation

The Laramie Formation consists of sand and clay which were deposited in a fresh- to brackish-water environment. The formation is divisible into two units, the lower Laramie, about 200 feet (60 m) thick, and the upper Laramie about 500 to 600 feet (150 to 180 m) thick. The total thickness of about 750 feet (230 m) is based on interpretation of geophysical logs. The total thickness is not present in the study area.

The lower unit of the Laramie Formation combined with the underlying Fox Hills Sandstone is collectively referred to as the Laramie-Fox Hills aquifer, and well yields are as much as 35 gallons per minute (2.2 L/s) in western Weld County near the study area. This aquifer also supplies water to wells in much of the Denver Basin in east-central Colorado. The lower unit of the Laramie Formation consists of a series of sand and sandstone beds interlayered with clay beds. The individual sand or sandstone beds range in thickness from a few inches to several feet. The thicker beds near the middle and top of the lower Laramie tend to be resistant to weathering and form ridges and outcrops. The clay between these resistant sandstone beds is frequently mined or quarried because of its high kaolinite content. Deposits of lignite coal also occur near, both below and above, the top of the lower Laramie.

The upper Laramie is predominantly clay with occasional sandstone beds and lenses. The clay ranges in color from buff to gray. It also contains many thin lignite seams and zones of ironstone concretions.

Alluvial Formations

Terrace Alluvium

Within a large part of the drainage basin of Boxelder Creek there is a terrace west of Boxelder Creek that nearly parallels (pl. 1) and, for the most part, is hydrologically separate from Boxelder Creek valley. This terrace, referred to as the Buckeye terrace in this report, is well defined topographically only in T. 10 N. and the northern part of T. 9 N. Farther south, erosion has so modified its shape that it is difficult to discern the limits of the terrace by its topographic expression. Geologically, however, the terrace features can be traced southward to the middle of T. 8 N. where they are terminated by the processes which formed the present-day valley of Boxelder Creek. Interpretation of data from wells, test holes, ensilage pits, and outcrops indicate well-defined cross-sectional areas and lateral limits for the terrace deposits (pl. 2).

The terrace alluvium is mostly poorly sorted quartz and feldspar which ranges in size from silt to coarse gravel. Abundant silt and clay lenses make the terrace alluvium much less sorted than the valley-fill alluvium. Zones in the terrace are cemented by calcium carbonate and limonite.

Terraces on the east side of Boxelder Creek valley and north of Wellington are less extensive in area, but have the same height above the stream, as the Buckeye terrace. Other isolated terraces, at a much higher level above the present streams, are scattered as far north and east as Hereford, Colo. (not included in this report).

Valley-Fill Alluvium

The valley fill along Boxelder Creek is an arkosic deposit of gravel and sand, and contains sandy clay with zones cemented by calcium carbonate and limonite. Generally the deposit is poorly sorted. The width of the valley ranges from less than 0.5 to about 3 miles (0.8 to 4.8 km). The thickness of the valley fill along Boxelder Creek is nearly zero at the mouth of Boxelder Creek canyon (fig. 1). Downstream the thickness gradually increases to slightly more than 100 feet (30 m) in the vicinity of Wellington, and then decreases to about 60 feet (21 m) at the southern edge of the study area. The maximum thicknesses are: along Rawhide Creek, 20 feet (6 m); along Coal Creek, 50 feet (15 m); and along Indian Creek, 20 feet (6 m).

GROUND-WATER RESOURCES

Ground water occurs in the porous and permeable beds both in the bedrock and in the alluvial aquifers. Water in the alluvium has been derived by recharge from applied surface water over the years. Recharge from precipitation and leakage from Boxelder Creek have also contributed, but probably to a lesser extent. Ground-water withdrawals by wells and seepage back to Boxelder Creek in the southern reaches of the valley are the principal methods of discharge of water from the alluvial aquifers. Springs and seeps around the periphery of the terraces also account for some discharge. Some ground water is removed from Boxelder Creek alluvium by vertical movement into underlying bedrock aquifers and horizontal movement into the alluvium of the Cache la Poudre River valley. The only significant removal of ground water by evapotranspiration is by phreatophytes and from areas of shallow depth to water around some of the lakes and reservoirs.

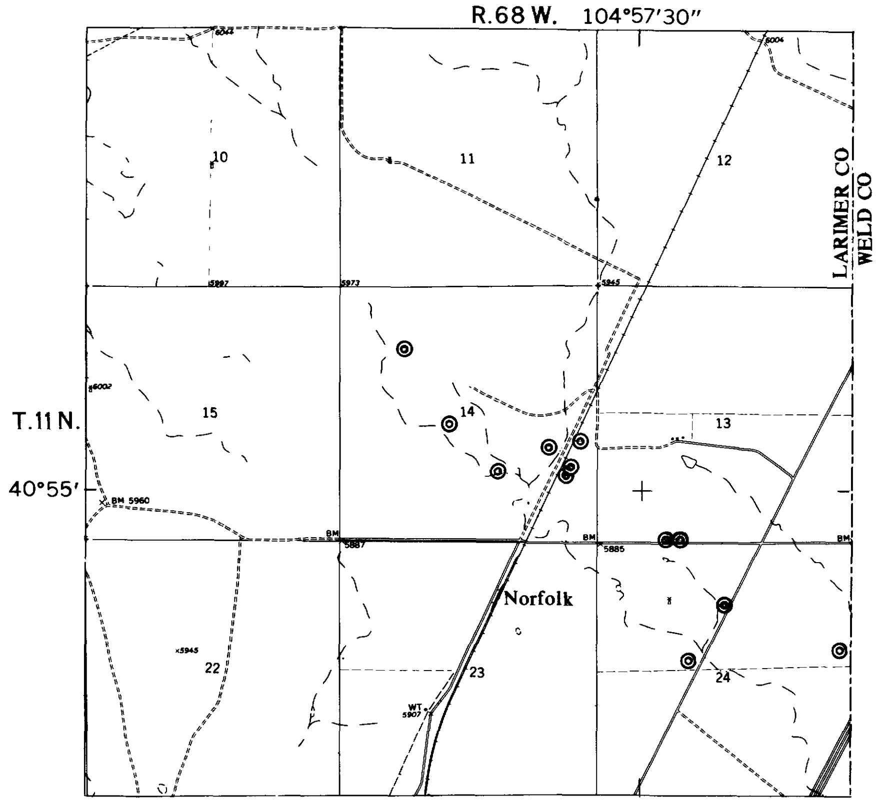
Alluvial Aquifers

Terrace Aquifers

Ground water in the terrace aquifer associated with Spottlewood Creek moves southeastward. Recharge to this aquifer is derived principally from storm runoff carried by Spottlewood Creek and smaller creeks which normally are ephemeral streams. Lithologic logs of wells indicate that the aquifer consists of as much as 55 feet (17 m) of fine to coarse gravel and mixed coarse sand to fine gravel. The base of the aquifer is clay or shale. Assuming an average effective porosity of 0.2, the volume of water in storage is estimated to be 25,000 acre-feet (31 million m^3). There are 12 large-capacity wells (greater than 100 gal/min or 6.3 L/s) tapping this aquifer (fig. 2) and the reported yields range from 160 to 1,100 gallons per minute (10 to 69 L/s). Some of the pumped water is used locally for irrigation and

EXPLANATION

◎ LARGE–CAPACITY WELL – Yield greater than 100 gallons per minute



Base from U.S. Geological Survey
1 :24,000 Carr West, 1972

0 — 1 MILE

0 — 1 KILOMETER

Figure 2.—Location of large–capacity wells tapping the alluvial aquifer in the Spottlewood terrace.

some is exported to supply domestic water to individual farms northwest of Wellington, Colo.

The terrace alluvium on the uplands between Coal Creek and Boxelder Creek north of Wellington does not contain much ground water because there are no streams or surface-water irrigation to supply recharge. The ground water which is present is recharge from precipitation. The yield to wells is small, generally less than about 5 gallons per minute (0.3 L/s); consequently, only stock and domestic wells tap this alluvium. Because most of this semiarid terrace is unirrigated rangeland with only about 5 to 10 farm-ranch units, information about ground-water conditions is scant.

Ground water in the alluvium of Buckeye terrace west of Boxelder Creek is derived from recharge by irrigation water diverted from the Cache la Poudre River and its tributaries. The shape and slope of the water table (pl. 3) indicate that ground-water movement is to the southeast, and that this aquifer is separated from the valley-fill aquifer of Boxelder Creek except at the south end where the two merge. The rate of movement (pore velocity) varies from place to place, but averages between about 2,500 to 4,000 feet (800 to 1,200 m) per year. The saturated thickness (pl. 4) ranges from zero to slightly more than 20 feet (6 m). Using a specific yield of 0.2 (Weeks, 1972, p. 60) and assuming that this is the average value for the effective porosity, the volume of water in storage is about 32,000 acre-feet (39.5 million m^3). Locally, the aquifer may be under artesian conditions, so that the storage coefficient may be about $1x10^{-3}$. This value represents the release of water from artesian storage and is not indicative of the volume of water in storage.

Discharge from the terrace aquifer occurs as seepage to surface water, ground-water flow to other aquifers, and ground-water withdrawal by wells. In the vicinity of Waverly, Colo. (pl. 3), the discharge issues as seeps and springs or flows into the alluvium associated with Dry Creek. Southeast of Waverly the ground water seeps into Demmel Lake Reservoir No. 2, Bee Lake Reservoir No. 5, and Reservoir No. 6. South of Reservoir No. 6 (pl. 3) the ground-water movement is to the alluvium of Boxelder Creek. Undoubtedly there is also downward movement into permeable zones in the underlying Pierre Shale. Wells are used to supply stock, domestic, and irrigation water. There are 50 wells constructed for irrigation which tap the terrace aquifer. The locations of these wells are shown on plate 5. Yields range from 80 gallons per minute (5.0 L/s) to slightly more than 1,200 gallons per minute (76 L/s). The estimated total annual withdrawal by these wells is 4,000 to 5,000 acre-feet (5 to 6 million m^3). This amount varies from year to year depending on the availability of surface water.

Valley-Fill Aquifers

The valley-fill aquifer associated with Boxelder Creek is recharged in the upper end of the Boxelder Creek valley by streamflow as the creek emerges from the mountains northwest of Buckeye, Colo. Seepage from ditches and canals traversing the area, and seepage from applied irrigation water recharge the valley-fill aquifer in the lower reaches of Boxelder Creek valley. The latter source of recharge is typified by the comments of some irrigators on the difficulty of irrigating the entire length of their fields because of the rapid rate at which the water seeps into the soil. The shape and slope of the water table (pl. 3) indicate that movement of ground water is generally parallel to the direction of Boxelder Creek valley. The rate of movement (pore velocity) is about 3,000 feet (900 m) per year. The saturated thickness (pl. 4) ranges from zero to a little more than 80 feet (24 m) which, assuming an effective porosity of 0.2, represents about 101,000 acre-feet (125 million m^3) of ground water in storage.

Rawhide Creek, Coal Creek, and Indian Creek are part of the Boxelder Creek ground-water system. Ground water in the alluvium along Rawhide Creek and the upper part of Coal Creek is derived partly by recharge from precipitation, but principally by streamflow during periods of runoff. The alluvium associated with Indian Creek and the lower 3 miles (4.8 km) of Coal Creek is recharged by seepage losses from canals and applied irrigation water.

Ground water is discharged from the alluvium of Boxelder Creek by underflow into the alluvium along the Cache la Poudre River, by seepage into Boxelder Creek along the lower reaches of the stream, and by withdrawal by wells. Locally there are areas of shallow depths to water that allow some evapotranspiration of ground water directly from the water table.

Ground-water underflow from the alluvium along Boxelder Creek into the alluvium along the Cache la Poudre River is approximately 6,700 acre-feet (8.3 million m^3) per year. This flow rate was calculated through an east-west section 1 mile (1.6 km) south of the north edge of T. 7 N., which is the approximate southern limit of alluvium along Boxelder Creek.

North of Larimer County Canal the valley-fill aquifer is not in hydraulic connection with Boxelder Creek. South of the canal, ground water contributes to the flow of Boxelder Creek from the canal to its confluence with the Cache la Poudre River. Descriptions of these conditions are discussed in more detail under the section Stream-Aquifer Relationships.

Wells are used to provide water for stock and domestic use, for municipal supply, and for irrigation. The city of Wellington has three wells that supply a population of 1,200. These wells pumped about 210 acre-feet (260,000 m^3) in 1974 (Woodrow Monte, oral commun., 1975). Irrigation water is supplied by 198 wells tapping the valley fill along Boxelder Creek and its tributaries. Seven of these wells are in the alluvium along Indian Creek, 11 are in the alluvium along Coal Creek, and 1 is in the alluvium along Rawhide Creek. The remainder are along Boxelder Creek. The location of these irrigation and municipal wells is shown on plate 5. Yields range from 90 to 1,840 gallons per minute (5.7 to 116 L/s), and the estimated total annual withdrawal is about 20,000 acre-feet (24.7 million m^3).

Stream-Aquifer Relationships

Based on stream-aquifer relationships three reaches along Boxelder Creek may be defined. In the upper reach, above the mouth of Boxelder Creek canyon, the water table in the alluvium is above the level of the stream, so that ground-water flow is toward the stream and the stream is gaining. Between the mouth of Boxelder Creek canyon and Larimer County Canal, the alluvium can transmit more water than the stream and recharge can supply, so that the stream loses water to the ground-water system during periods of flow in the stream. Between Larimer County Canal and the mouth of Boxelder Creek at the Cache la Poudre River, recharge and underflow have raised the water table above the level of Boxelder Creek. Ground-water flow is toward the streams and the stream is gaining by seepage from ground water. A tabulation of observations made during May 28 to June 6, 1974, is shown in table 1.

Because the channel of Boxelder Creek is directly tributary to the Larimer County Canal, all of the flow of the creek discharges at all times into the canal. The canal is equipped with a headgate for releasing water back into Boxelder Creek below the canal. However, this headgate, which discharges through a 12- to 16-inch (300- to 400-mm) culvert, appears to be seldom used.

Below the Larimer County Canal, Boxelder Creek is fed by discharge from a system of ground-water drain tiles. Discharge from this system is about 0.5 to 1 cubic foot per second (0.14 to 0.28 L/s). Seepage conditions along the creek for 0.5 to 0.75 mile (0.8 to 1.2 km) below the canal indicate that ground water is contributing to the flow of the creek and vegetation along the banks of the creek indicates that the flow is probably perennial. The creek continues to flow and appears to be increasing in flow to its mouth at the Cache la Poudre River. On March 13 and 14, 1975, flow measurements were made along Boxelder Creek to quantitatively determine the seepage gains and losses. These measurements, shown in table 2, confirm the previous observations.

WATER QUALITY

An objective of the study was to determine the areal distribution and the hydrologic and geologic controls of certain chemical constituents in the water of the alluvial aquifers. The concentration of selenium and other trace metals in excess of background levels have been reported in rocks of Cretaceous age, and in soils derived from these rocks, at many places in the western United States (Rosenfeld and Beath, 1964). Engberg (1973) presented data for Nebraska which suggests that the presence of selenium in ground water might be related to the Pierre Shale of Cretaceous age. It was theorized, therefore, that the bedrock in northern Larimer County, particularly the Pierre Shale and the Laramie Formation, both of Cretaceous age, might have some control on water quality in the overlying alluvial aquifers. Other factors that could affect water quality were also considered; they included the quality of surface water used for irrigation in the area, the effects of recharge and reuse of ground water, and the effects of stream-aquifer relationships.

Water samples were collected for chemical analysis from 6 surface-water sampling sites and 44 wells between May 28 and June 4, 1974, and at 1 additional well on July 3, 1974, in order to determine areal variations in water quality. Water from eight of the wells was sampled at approximately monthly intervals in order to examine possible temporal variations in water quality. The locations of the surface-water sampling sites and wells are indicated on figure 1 and plate 6, and the results of the analyses are listed in tables 3 and 4. (The location and well-numbering system used in this report is described in the Supplemental Information section.) Water samples from five wells in the vicinity of Wellington were analyzed by emission spectrographic techniques to check for the presence and concentration of other trace elements besides selenium. These analyses are given in table 5. No concentration of the elements analyzed exceeded the U.S. Environmental Protection Agency's (1975) drinking-water recommendations.

The quality of ground water in the terrace and valley-fill aquifers depends initially on the quality of the surface water used for irrigation. Basically, there are two sources of surface water: flow of Boxelder Creek at the mouth of Boxelder Creek canyon, and diversions from the Cache la Poudre River brought into the area by Park Creek Lateral, North Poudre Ditch, Larimer County Canal, and the Larimer and Weld Canal (table 3). Surface water exiting the mouth of Boxelder Creek canyon on May 29, 1974, contained about 1,000 mg/L (milligrams per liter) dissolved solids although ground water contributing to the flow contained 540 to 1,700 mg/L dissolved solids. The selenium concentration was 1 μg/L (microgram per liter) or less in surface water (table 3, Boxelder Creek at Woodhams Ranch, and Boxelder Creek near Monroe Ranch) and 2 μg/L in ground water (table 4, well SB11-69-31ADD). Analyses of water carried by the four ditches diverting water from the Cache La Poudre River (table 3) show less than 90 mg/L dissolved solids and 1 μg/L or less selenium. Although water recharging the alluvial aquifers from applied irrigation water will be higher in dissolved constituents than the applied water, the low selenium concentrations in surface water entering the area preclude surface water as the source of selenium in the ground water.

Selenium was the only constituent for which the concentration in any of the samples of water from the terrace and valley-fill aquifers exceeded drinking-water standards recommended by the U.S. Environmental Protection Agency (1975) (tables 6 and 7). For the samples collected between May 29 and June 4, 1974, 15 of 43 selenium concentrations exceeded the drinking-water standards. The mean concentration was 11 μg/L and the median was 7 μg/L. The frequency distribution of selenium concentrations for these samples is shown in figure 3.

The selenium concentration in the samples collected monthly from eight wells is shown in figure 4. The maximum range in selenium concentration for any single well was 13 μg/L (from 9 to 22 μg/L for well SB9-68-33AAD). Five of the wells had ranges that spanned the limit for drinking water. Only two wells were under the limit for all samples collected, and one well was over the limit for all samples.

Table 1.--*Streamflow conditions for Boxelder Creek above Larimer County Canal, May 28-June 6, 1974*

[Streamflow is estimated discharge in Boxelder Creek downstream from point of inflow or outflow; + indicates flow less than 0.1 cubic foot per second]

Location	Distance above mouth, in miles	Description	Estimated discharge, in cubic feet per second			Remarks
			Inflow	Outflow	Streamflow	
SE¼SE¼ sec. 13, T. 11 N., R. 70 W.	41.3	South Fork Boxelder Creek above Woodham's Ranch----			<1	
SE¼SE¼ sec. 13, T. 11 N., R. 70 W.	41.2	Spring east side of Woodham's Ranch----------	1-2		2	Spring issues from alluvium.
SE¼SW¼ sec. 19, T. 11 N., R. 69 W.	39.2	Diversions for Monroe Ranch-------------		All	0	
SE¼NE¼ sec. 31, T. 11 N., R. 69 W.	36.0	Boxelder Creek at Monroe Ranch-------------------			1	
NW¼SE¼ sec. 9, T. 10 N., R. 69 W.	30.4	Unnamed ditch below mouth of Boxelder Creek canyon-		5	+	Streamflow was leakage through diversion structure.
NW¼SW¼ sec. 10, T. 10 N., R. 69 W.	29.4	Boxelder Creek below county road-------------			0	
NW¼NE¼ sec. 23, T. 10 N., R. 69 W.	27.2	Discharge from Park Creek Lateral------------------	10-20		10-20	
SE¼NW¼ sec. 24, T. 10 N., R. 69 W.	25.9	Diversion by irrigation ditch--------------------		All	.5-1	Streamflow was leakage through diversion structure.

NW¼NE¼ sec. 31, T. 10 N., R. 68 W.	23.4	Boxelder Creek, on ABS land, 0.25 mile south of county road-------------			0	
SE¼NE¼ sec. 6, T. 9 N., R. 68 W.	21.9	Irrigation tailwater-------	<.5		<.5	
SW¼SW¼ sec. 5, T. 9 N., R. 68 W.	21.3	Boxelder Creek------------			0	
SE¼SE¼ sec. 33, T. 9 N., R. 68 W.	14.6	Boxelder Creek south of Wellington-----------			0	No flow between this location and previous location.
SE¼NE¼ sec. 4, T. 9 N., R. 68 W.	14.1	Seepage from sewage treatment lagoons--------	.1		.1	
SE¼ sec. 4, T. 8 N., R. 68 W.	13.7	Irrigation tailwater-------	+		+	Coming off fields on west side of creek.
SE¼SE¼ sec. 10, T. 8 N., R. 68 W.	12.0	Inflow from Indian Creek---	+		+	
SW¼SW¼ sec. 11, T. 8 N., R. 68 W.	11.8	Discharge from borrow ditch------------------	+		3-5	Both tail and waste water.
SW¼NW¼ sec. 14, T. 8 N., R. 68 W.	11.5	Discharge into Larimer County Canal------------		3-5	0	

Table 2.--*Seepage and streamflow data for Boxelder Creek, March 13-14, 1975*

[e indicates estimated flow]

Distance above mouth, in miles	Description	Discharge, in cubic feet per second: Inflow	Outflow	Gain (+) or loss (-) in reach	Remarks
29.5	Boxelder Creek, east edge sec. 9, T. 10 N., R. 69 W.	0.03	----		A flow of 3.04 cubic feet per second was being diverted from Boxelder Creek 0.5 mile upstream.
26.7	Boxelder Creek, east edge sec. 23, T. 10 N., R. 69 W.	----	0.83		Apparent gain was all or mostly tail water from irrigation.
	Reach total	0.03	0.83	+0.8	
26.7	Boxelder Creek, east edge sec. 23, T. 10 N., R. 69 W.	0.83	----		Inlet diverting all flow of Boxelder Creek.
25.9	Inlet to Boxelder Reservoir No. 1	----	0.83		
25.9	Boxelder Creek below inlet to Boxelder Reservoir No. 1	----	0		
	Reach total	0.83	0.83	0	
25.9	Boxelder Creek below inlet to Boxelder Reservoir No. 1	0	----		
14.6	Boxelder Creek, south edge sec. 33, T. 9 N., R. 68 W.	----	0		
	Reach total	0	0	0	

14.6	Boxelder Creek, south edge sec. 33, T. 9 N., R. 68 W.	0	----		
14.6	West borrow pit along south edge sec. 33, T. 9 N., R. 68 W.	.07	----		Seep from Reservoir No. 4.
12.0	Indian Creek near mouth	.89	----		
11.5	Boxelder Creek above Larimer County Canal	----	1.23		Total flow discharges into Larimer County Canal. Gain=0.09 cubic foot per second per mile.
	Reach total	0.98	1.23	+0.27	
11.4	Boxelder Creek below Larimer County Canal	0	----		
8.0	Inlet to North Gray Reservoir	----	0.78		
8.0	Boxelder Creek below inlet to North Gray Reservoir	----	1.80		
	Reach total	0	2.58	+2.58	Gain=0.75 cubic foot per second per mile.
8.0	Boxelder Creek below inlet to North Gray Reservoir	1.80	----		
7.4	North Gray Reservoir outlet	.05e	----		
5.9	Larimer and Weld Canals	0	0		
2.0	Wastewater from Lake Canal	.1 e	----		
1.8	Seepage from Cache la Poudre Reservoir inlet	.64	----		
1.8	Boxelder Creek below Cache la Poudre Reservoir inlet	----	5.88		
	Reach total	2.59	5.88	+3.29	Gain=0.53 cubic foot per second per mile.

Table 3.--*Chemical analyses of surface water*

[Analyses listed in downstream order. Constituents reported in milligrams per liter except as indicated; µg/L = micrograms per liter]

Source	Sample location	Date of collection 1974	Discharge (ft^3/s)	Silica (SiO_2)	Iron (Fe) (µg/L)	Manganese (Mn) (µg/L)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)
Park Creek Lateral------	(SB10-69-15CCC)	May 28	65	11	30	0	19	3.2	4.5	1.3	75	8.1
North Poudre Ditch------	(SB 9-69-12DDD)	May 31	103	7.9	110	0	9.6	2.8	3.7	.7	34	16
Larimer County Canal----	(SB 8-69-24CBD)	May 31	514	9.2	80	20	13	2.9	3.6	.9	41	16
Larimer and Weld Canals-	(SB 8-69-36CCB)	June 4	650	----	---	--	7.4	1.9	----	---	---	9.7
Boxelder Creek at Woodhams Ranch---------	(SB11-70-13DDD)	May 29	2	18	30	30	120	29	7.9	2.0	250	230
Boxelder Creek near Monroe Ranch----------	(SB10-69- 9DAD)	May 28	<.01	12	20	40	370	86	18	4.1	164	1,100

Source	Chloride (Cl)	Fluoride (F)	Nitrate (as N)	Residue (dissolved solids)	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Specific conductance (micromhos/cm at 25°C)	pH (units)	Temperature (°C)	Boron (B) (μg/L)	Selenium (Se) (μg/L)
Park Creek Lateral------	1.8	1.0	0.09	87	61	0	138	7.8	13.0	20	0
North Poudre Ditch------	.9	.1	.22	60	36	8	99	7.5	13.0	50	0
Larimer County Canal----	1.3	.2	.29	69	44	11	110	7.3	13.0	30	1
Larimer and Weld Canals-	---	---	----	47	26	-----	70	---	11.5	---	0
Boxelder Creek at Woodhams Ranch--------	2.8	1.1	.84	538	420	210	803	8.0	13.0	70	1
Boxelder Creek near Monroe Ranch----------	4.2	.9	.18	1,680	1,300	1,100	2,030	7.9	20.0	180	1

Table 4.--*Chemical analyses*

[Analyses are for samples of water from the terrace and valley-fill aquifers, unless cated; μg/L=micrograms per liter. Values shown in italics exceed drinking-water

Well number	Date of col-lection	Silica (SiO_2)	Iron (Fe) (μg/L)	Manga-nese (Mn) (μg/L)	Cal-cium (Ca)	Mag-nesium (Mg)	Sodium (Na)	Po-tas-sium (K)	Bicar-bonate (HCO_3)	Sulfate (SO_4)
SB 7-68- 3BBB1 and 2[a]	6- 3-74	--	---	---	400	140	-----	---	---	1,400
SB 7-68- 5DBC	6- 4-74	11	20	0	210	95	120	3.8	268	870
SB 7-68- 9ABB1	6- 4-74	--	---	---	340	170	-----	---	---	1,600
SB 7-68-10CBB	6- 3-74	17	40	0	360	140	160	5.4	302	1,500
SB 8-68- 4BAB	6- 1-74	--	---	---	320	98	-----	---	---	1,100
SB 8-68-10CBB	6- 3-74	--	---	---	260	89	-----	---	---	840
Do	7- 3-74	--	---	---	270	93	-----	---	---	560
Do	7-31-74	--	---	---	260	90	-----	---	---	880
Do	9- 4-74	--	---	---	280	90	-----	---	---	780
Do	10-14-74	--	---	---	200	97	120	---	431	840
Do	11- 5-74	--	---	---	280	86	140	---	429	820
Do	12-10-74	--	---	---	280	90	120	---	430	830
Do	3-14-75	--	---	---	260	88	120	---	420	800
SB 8-68-14BCC	6- 3-74	20	20	140	340	200	300	7.2	438	1,800
SB 8-68-15BBB	6- 4-74	21	20	0	230	75	99	5.0	422	660
SB 8-68-15BCB	6- 4-74	--	---	---	260	89	-----	---	---	820
SB 8-68-17DBA and 17DBB[a]	6- 4-74	17	20	10	280	180	300	5.9	358	1,700
SB 8-68-21ABB2	6- 3-74	19	30	20	370	100	130	4.7	316	1,300
SB 8-68-27CBB2	6- 3-74	--	---	---	320	94	-----	---	---	1,100
SB 8-68-28BBB2	6- 4-74	--	---	---	430	150	-----	---	---	1,600
SB 8-68-32DBC1 and 2[a]	6- 4-74	--	---	---	480	170	-----	---	---	1,800
SB 9-68- 6DAB1	5-30-74	--	---	---	270	88	-----	---	---	870
SB 9-68-17ABB	5-30-74	19	10	20	310	98	66	4.8	297	1,000
SB 9-68-19BBB	5-31-74	--	---	---	110	48	-----	---	---	270
SB 9-68-20ABA	5-31-74	--	---	---	270	92	-----	---	---	860
Do	7- 3-74	--	---	---	250	85	-----	---	---	720
Do	7-31-74	--	---	---	230	75	-----	---	---	610
Do	9- 4-74	--	---	---	160	53	-----	---	---	350
Do	10-14-74	--	---	---	190	66	39	---	386	410
Do	11- 5-74	--	---	---	200	58	45	---	377	470
Do	12-10-74	--	---	---	230	78	49	---	350	610
SB 9-68-22BBB1	6- 1-74	23	20	0	100	50	66	6.8	297	340
SB 9-68-27CBB	6- 1-74	29	30	0	100	48	49	5.4	359	250
Do	7- 3-74	--	---	---	100	52	-----	---	---	200
Do	7-31-74	--	---	---	110	51	-----	---	---	240
Do	9- 4-74	--	---	---	130	60	-----	---	---	270
Do	10-14-74	--	---	---	160	76	65	---	413	350
Do	11- 5-74	--	---	---	120	63	56	---	404	290
Do	12-10-74	--	---	---	130	62	56	---	412	280
Do	3-14-75	--	---	---	120	61	52	---	399	240
SB 9-68-28BLB2	5-31-74	20	80	0	340	93	73	5.3	320	1,000
SB 9-68-29ABA	5-31-74	--	---	---	260	81	-----	---	---	800
SB 9-68-30DAB	5-31-74	--	---	---	110	46	-----	---	---	300
SB 9-68-32AAB	5-31-74	--	---	---	290	78	-----	---	---	930
Do	7- 3-74	--	---	---	310	82	-----	---	---	930

[a]Samples from combined discharge of two wells.

otherwise indicated. Constituents reported in milligrams per liter except as indi-
standards recommended by the U.S. Environmental Protection Agency (1975)]

Chloride (Cl)	Fluoride (F)	Nitrate (as N)	Dissolved solids	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Specific conductance (micromhos/cm at 25°C)	pH (units)	Temperature (°C)	Boron (B) (µg/L)	Selenium (Se) (µg/L)
----	---	----	2,510	1,600	-----	3,000	---	10.5	---	10
18	0.9	3.3	1,480	920	700	1,950	7.5	10.5	350	*14*
----	---	----	2,650	1,600	-----	3,000	---	10.0	---	*20*
26	1.0	7.0	2,390	1,500	1,200	2,840	7.4	11.0	440	*15*
----	---	----	1,950	1,200	-----	2,300	---	11.0	---	6
----	---	----	1,740	1,000	-----	2,150	---	10.0	---	6
----	---	----	1,930	1,100	-----	2,200	---	10.5	---	5
----	---	----	1,830	1,000	-----	2,200	---	11.0	---	*14*
----	---	----	1,810	1,100	-----	2,050	---	11.5	---	*17*
----	---	----	1,680	900	550	2,000	---	12.0	---	*15*
----	---	----	1,760	1,100	700	2,200	---	12.0	---	*11*
----	---	----	1,740	1,100	720	1,950	---	11.5	---	9
----	---	----	1,710	1,000	670	1,800	7.0	10.5	---	6
44	.8	----	2,930	1,700	1,300	3,600	7.6	12.0	410	*18*
22	.6	----	1,320	880	540	1,800	7.4	13.5	340	9
----	---	----	1,630	1,000	-----	2,050	---	11.0	---	10
36	1.7	5.1	2,720	1,400	1,100	3,300	7.5	11.0	770	*37*
22	.7	6.4	2,130	1,300	1,100	2,540	7.4	11.0	410	*14*
----	---	----	1,750	1,200	-----	2,300	---	10.0	---	*12*
----	---	----	2,870	1,700	-----	3,200	---	11.5	---	*28*
----	---	----	3,260	1,900	-----	3,550	---	10.5	---	*44*
----	---	----	1,600	1,000	-----	1,900	---	11.0	---	6
14	.9	6.8	1,690	1,200	930	2,160	7.6	11.0	260	3
----	---	----	747	470	-----	1,120	---	10.0	---	6
----	---	----	1,630	1,100	-----	2,050	---	11.0	---	6
----	---	----	1,460	970	-----	1,925	---	11.5	---	6
----	---	----	1,270	880	-----	1,600	---	19.5	---	5
----	---	----	876	620	-----	1,280	---	11.0	---	3
----	---	----	877	750	430	1,300	---	12.0	---	2
----	---	----	987	740	430	1,500	---	11.5	---	4
----	---	----	1,290	900	610	1,600	---	12.0	---	4
13	.3	3.5	761	460	210	1,110	7.8	11.0	150	5
9.9	.4	7.2	701	450	150	1,020	7.8	11.0	180	*12*
----	---	----	828	460	-----	1,070	---	11.0	---	6
----	---	----	722	480	-----	1,125	---	10.0	---	6
----	---	----	793	570	-----	1,200	---	11.0	---	*11*
----	---	----	840	710	370	1,330	---	11.0	---	*14*
----	---	----	898	560	230	1,290	---	11.0	---	10
----	---	----	877	580	240	1,410	7.4	10.5	---	8
----	---	----	771	550	220	1,100	7.3	11.0	---	8
15	.8	9.6	1,750	1,200	970	2,130	7.5	11.0	260	6
----	---	----	1,590	980	-----	1,950	---	11.0	---	9
----	---	----	789	460	-----	1,160	---	11.0	---	10
----	---	----	1,750	1,000	-----	2,050	---	11.5	---	10
----	---	----	1,750	1,100	-----	2,050	---	12.0	---	0

Table 4.--*Chemical analyses of*

Well number	Date of col-lection	Silica (SiO_2)	Iron (Fe) (µg/L)	Manga-nese (Mn) (µg/L)	Cal-cium (Ca)	Mag-nesium (Mg)	Sodium (Na)	Po-tas-sium (K)	Bicar-bonate (HCO_3)	Sulfate (SO_4)
SB 9-68-32AAB--Continued	9- 4-74	--	---	---	290	70	-----	---	---	810
Do-------------------	10-14-74	--	---	---	270	72	88	---	308	820
Do-------------------	11- 5-74	--	---	---	280	72	87	---	308	800
SB 9-68-32CBA-----------	6- 1-74	--	---	---	190	72	-----	---	---	690
SB 9-68-33AAA1----------	7- 3-74	--	---	---	130	58	-----	---	---	220
Do-------------------	7-31-74	--	---	---	120	54	-----	---	---	280
Do-------------------	9- 4-74	--	---	---	130	58	-----	---	---	270
Do-------------------	10-14-74	--	---	---	130	55	62	---	440	280
Do-------------------	11- 5-74	--	---	---	130	60	63	---	442	280
Do-------------------	12-10-74	--	---	---	130	59	64	---	441	290
Do-------------------	3-14-75	--	---	---	130	58	64	---	421	270
SB 9-68-33AAD-----------	6- 1-74	29	70	0	140	63	62	5.8	467	330
Do-------------------	7- 3-74	--	---	---	140	66	-----	---	---	310
Do-------------------	7-31-74	--	---	---	140	61	-----	---	---	310
Do-------------------	9- 4-74	--	---	---	130	63	-----	---	---	290
Do-------------------	10-14-74	--	---	---	67	60	69	---	502	300
Do-------------------	11- 5-74	--	---	---	140	64	71	---	501	290
Do-------------------	12-10-74	--	---	---	140	62	71	---	502	280
Do-------------------	3-14-75	--	---	---	130	63	71	---	476	310
SB 9-68-33BAB-----------	6- 1-74	--	---	---	210	59	-----	---	---	550
SB 9-68-33CBA-----------	6- 1-74	19	20	0	330	96	83	4.8	310	1,100
Do-------------------	7- 3-74	--	---	---	330	97	-----	---	---	840
Do-------------------	7-31-74	--	---	---	330	93	-----	---	---	1,100
Do-------------------	9- 4-74	--	---	---	330	99	-----	---	---	970
Do-------------------	10-14-74	--	---	---	290	110	85	---	314	1,000
Do-------------------	11- 5-74	--	---	---	330	87	88	---	317	960
Do-------------------	12-10-74	--	---	---	340	100	85	---	319	1,100
Do-------------------	3-14-75	--	---	---	340	100	84	---	320	1,100
SB 9-68-33DDD-----------	6- 1-74	--	---	---	190	56	-----	---	---	490
SB 9-68-34ABA-----------	6- 3-74	17	30	0	120	83	170	4.2	378	630
Do-------------------	7- 3-74	--	---	---	110	81	----	---	---	600
Do-------------------	7-31-74	--	---	---	120	95	-----	---	---	680
Do-------------------	9- 4-74	--	---	---	75	38	-----	---	---	240
SB 9-69- 1DAC-----------	5-31-74	--	---	---	88	43	-----	---	---	230
SB 9-69-11AAC-----------	5-31-74	--	---	---	74	38	-----	---	---	76
SB 9-69-13BCC1 and 2[a]---	5-31-74	--	---	---	110	43	-----	---	---	230
SB10-68-30BBA-----------	5-30-74	--	---	---	270	80	-----	---	---	850
SB10-68-31ABC-----------	5-30-74	16	[b]980	80	240	77	54	4.6	278	740
SB10-69- 1BCC-----------	5-29-74	15	70	0	240	110	110	7.1	231	1,000
SB10-69- 6DBB[c]----------	5-29-74	12	10	0	49	26	6.6	1.7	259	16
SB10-69-14BDB-----------	5-29-74	17	40	30	430	110	21	3.5	304	1,300
SB10-69-16DDA-----------	5-29-74	--	---	---	65	17	-----	---	---	20
SB10-69-25CBA-----------	5-30-74	--	---	---	78	50	-----	---	---	54
SB10-69-26CBA-----------	5-30-74	--	---	---	70	49	-----	---	---	78
SB10-69-35CBA[d]----------	5-30-74	12	20	0	31	14	130	1.7	352	100
SB10-69-35CAB1 and 2[a]---	5-30-74	14	50	0	64	43	45	1.8	413	71
SB11-69-31ADD-----------	5-29-74	--	---	---	260	43	-----	---	---	650

[a] Samples from combined discharge of two wells.
[b] Pump powered by internal combustion engine. Iron concentration probably affected by
[c] Well probably taps rocks of Permian age. Well depth, 1,700 feet.
[d] Well taps Pierre Shale. Well depth, 200 feet.

Chloride (Cl)	Fluoride (F)	Nitrate (as N)	Dissolved solids	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$	Specific conductance (micromhos/cm at 25°C)	pH (units)	Temperature (°C)	Boron (B) (µg/L)	Selenium (Se) (µg/L)
----	---	----	1,640	1,000	-----	1,950	---	12.0	---	10
----	---	----	1,560	970	720	1,850	---	11.5	---	7
----	---	----	1,540	1,000	740	1,850	---	12.0	---	7
----	---	----	1,420	770	-----	1,800	---	12.5	---	*18*
----	---	----	689	560	-----	1,250	---	11.5	---	*16*
----	---	----	822	520	-----	1,190	---	13.0	---	6
----	---	----	836	560	-----	1,250	---	11.0	---	*13*
----	---	----	863	550	190	1,225	---	11.0	---	*17*
----	---	----	854	570	210	1,375	---	11.0	---	9
----	---	----	872	570	210	1,240	---	11.0	---	*12*
----	---	----	866	560	220	1,225	7.3	12.5	---	*13*
11	0.3	8.3	909	610	230	1,310	7.8	11.5	270	*16*
----	---	----	932	620	-----	1,340	---	12.0	---	10
----	---	----	932	600	-----	1,360	---	12.0	---	9
----	---	----	901	580	-----	1,320	---	11.0	---	*18*
----	---	----	876	410	3	1,375	---	12.0	---	*19*
----	---	----	819	610	200	1,310	---	11.0	---	*12*
----	---	----	848	610	190	1,310	---	10.5	---	*13*
----	---	----	944	580	190	1,250	7.4	11.0	---	*22*
----	---	----	1,150	770	-----	1,480	---	10.0	---	4
20	.8	5.1	1,830	1,200	970	2,210	7.5	11.0	290	6
----	---	----	1,960	1,200	-----	2,400	---	11.5	---	*11*
----	---	----	1,960	1,200	-----	2,300	---	11.5	---	5
----	---	----	1,900	1,200	-----	2,240	---	11.5	---	9
----	---	----	1,830	1,200	920	2,150	7.4	11.5	---	9
----	---	----	1,890	1,200	920	2,250	7.3	12.0	---	8
----	---	----	1,980	1,300	1,000	2,200	---	12.0	---	5
----	---	----	2,040	1,300	1,000	2,100	7.1	10.5	---	6
----	---	----	1,160	710	-----	1,600	---	11.0	---	*18*
18	.9	----	1,230	640	330	1,710	7.7	9.0	340	*20*
----	---	----	1,280	610	-----	1,800	---	11.0	---	*13*
----	---	----	1,410	690	-----	1,800	---	13.0	---	*15*
----	---	----	588	340	-----	-----	---	15.0	---	*13*
----	---	----	653	400	-----	1,000	---	9.5	---	8
----	---	----	435	340	-----	790	---	10.5	---	4
----	---	----	698	450	-----	1,100	---	10.5	---	4
----	---	----	1,580	1,000	-----	2,000	---	11.5	---	4
11	.9	2.8	1,290	920	690	1,690	7.7	15.0	280	6
7.2	.6	.40	1,610	1,100	860	2,080	7.7	13.5	240	3
3.0	.3	2.7	254	230	17	453	7.9	16.0	20	1
5.5	1.4	2.8	2,050	1,500	1,300	2,380	7.4	10.5	220	5
----	---	----	304	230	-----	540	---	14.0	---	0
----	---	----	512	400	-----	880	---	10.5	---	3
----	---	----	483	380	-----	950	---	16.0	---	4
21	.9	1.9	493	140	0	818	8.0	12.5	500	1
1.6	.9	3.6	461	340	0	769	7.8	10.5	240	2
----	---	----	1,190	830	-----	1,390	---	14.0	---	2

radiator jacket around pump discharge pipe.

Table 5.--*Emission spectographic analyses of ground water*

[Analyses are for samples of water from valley-fill aquifer. Values reported in micrograms per liter of the indicated element in solution]

Constituent	Well number and date of sample				
	SB 9-68-17ABB (May 30, 1974)	SB 9-68-27CBB (June 1, 1974)	SB 9-68-33AAD (June 1, 1974)	SB 9-68-33CBA (June 1, 1974)	SB10-68-31ABC (May 30, 1974)
Aluminum------	120	30	40	30	100
Antimony------	<5	<5	<5	<5	<5
Arsenic-------	<35	<35	<35	<35	<35
Barium--------	14	21	28	12	14
Beryllium-----	0	0	0	0	0
Bismuth-------	0	0	0	0	0
Boron---------	250	150	250	250	230
Cadmium-------	<5	<5	<5	<5	<5
Chromium------	0	0	0	0	0
Copper--------	<6	3	27	5	<5
Cobalt--------	<1	<1	<1	<1	<1
Gallium-------	<6	<3	<3	<6	<5
Germanium-----	<25	<10	<15	<27	<20
Iron----------	25	17	35	30	[a]1,000
Lead----------	.8	.4	.9	1	1
Lithium-------	60	65	80	67	47
Manganese-----	<12	<5	<7	<13	70
Molybdenum----	3	3	3	3	4
Nickel--------	<5	<5	<5	<5	<5
Silver--------	<3	<1	<2	<3	<2
Strontium-----	4,000	1,300	1,400	4,200	3,000
Tin-----------	<25	<10	<14	<27	<20
Titanium------	<18	<8	<10	<19	<14
Vanadium------	<12	<5	<7	<13	<10
Zinc----------	8	<5	6	<15	6
Zirconium-----	5	<1	<1	<1	2

[a]Pump powered by internal combustion engine. Iron concentration probably affected by radiator jacket around pump discharge pipe.

Table 6.--*Summary of water-quality standards and recommendations*

[Concentrations in milligrams per liter]

Constituent	Drinking-water standards: U.S. Public Health Service (1962): Where lower level supply available	Drinking-water standards: U.S. Public Health Service (1962): Cause for rejection	Drinking-water standards: U.S. Environmental Protection Agency (1975)[a]	Livestock recommendations: U.S. Environmental Protection Agency (1973)	Irrigation recommendations: U.S. Environmental Protection Agency (1973): Consistent use on all soils	Irrigation recommendations: U.S. Environmental Protection Agency (1973): For use up to 20 years[b]
Aluminum	------	----	------	5	5	20
Ammonia (as N)	------	----	------	------	----	-----
Arsenic	0.1	0.5	0.5	.2	.1	2
Barium	------	1	1	------	----	-----
Beryllium	------	----	------	------	.1	.5
Boron	------	----	------	5	.75	2
Cadmium	------	.01	.01	.05	.01	.05
Chloride	250	----	------	------	----	-----
Chromium	------	.05	.05	1	.1	1
Cobalt	------	----	------	1	.05	5
Copper	1	----	------	.5	.2	5
Cyanide	.01	.2	.2	------	----	-----
Fluoride	-(See separate table 7)-			2	1	15
Iron	.3	----	------	------	5	20
Lead	------	.05	.05	.1	5	10
Lithium	------	----	------	------	2.5	2.5
Manganese	.05	----	------	------	.2	10
Mercury	------	----	.002	.01	----	-----
Molybdenum	------	----	------	------	.01	[c].05
Nickel	------	----	------	------	.2	2
Nitrate (as N)	10	----	10	------	----	-----
Nitrate + nitrite (as N)	------	----	------	100	----	-----
Nitrite (as N)	------	----	------	10	----	-----
Selenium	------	.01	.01	.05	.02	.02
Silver	------	.05	.05	------	----	-----
Solids, dissolved	500	----	------	------	([d])	-----
Sulfate	250	----	------	------	----	-----
Vanadium	------	----	------	.1	.1	1
Zinc	5	----	------	25	2	10

[a]To become effective June 1977.
[b]On fine-textured soils of pH 6.0 to 8.5.
[c]For only acid fine-textured soils, or acid soils with relatively high iron oxide content.
[d]No limit although productivity will decrease as concentration of dissolved solids increases.

Table 7.--*Recommended standards for fluoride in drinking water*

[Modified from U.S. Public Health Service (1962), p. 8; concentrations in milligrams per liter]

Annual average of maximum daily air temperatures[a]	U.S. Public Health Service (1962) recommended control limits			U.S. Environmental Protection Agency (1975)
	Lower	Optimum	Upper	Maximum
50.0-53.7	0.9	1.2	1.7	2.4
53.8-58.3	.8	1.1	1.5	2.2
58.4-63.8	.8	1.0	1.3	2.0
63.9-70.6	.7	.9	1.2	1.8
70.7-79.2	.7	.8	1.0	1.6
79.3-90.5	.6	.7	.8	1.4

[a]Based on temperature data obtained for a minimum of 5 years.

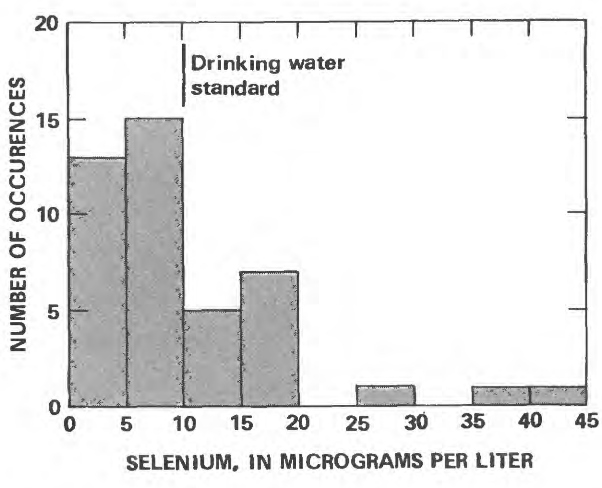


Figure 3.—Frequency distribution of selenium concentrations for samples of water from the terrace and valley–fill aquifers collected between May 29 and June 4, 1974.

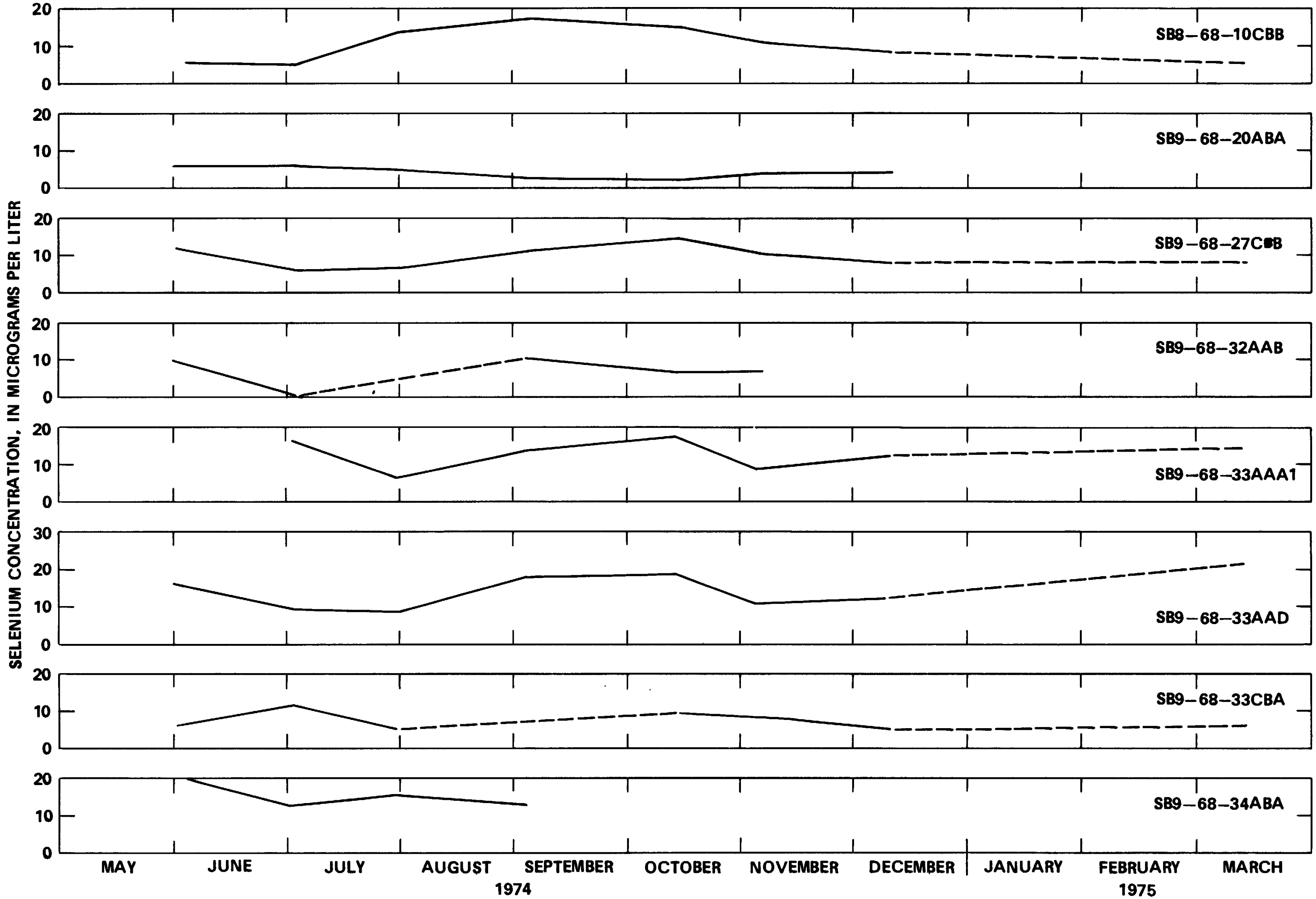


Figure 4.—Selenium concentration in samples of ground water from selected wells tapping the valley–fill aquifer associated with Boxelder Creek and its tributaries.

Prior to 1962, the recommended safe drinking-water limit had been set at 50 μg/L selenium (U.S. Public Health Service, 1962). The concentration of selenium was less than 50 μg/L in all water samples collected during the study. The U.S. Public Health Service (1962) drinking-water standards for 1962 recommended that the limit be reduced to 10 μg/L because of possible harmful effects on human physiology. More recently, the 10-μg/L limit has been questioned because of demonstrated nutrient benefits of low-level concentrations of selenium in the feed supply of stock and poultry (Frost, 1973).

The concentration of dissolved solids in water from the terrace and valley-fill aquifers has a strong, positive correlation with the sulfate and hardness concentrations. The relationships are well enough defined, in fact, that any one of the three constituents can be used to estimate the concentrations of the other two, as shown on plate 6. For example, the plate shows that for a dissolved-solids concentration of 1,500 mg/L the sulfate concentration will be about 800 mg/L and the hardness concentration will be about 950 mg/L. Selenium concentration, on the other hand, has a less well-defined relationship with dissolved solids. As shown by the explanation to plate 6, a 1,500-mg/L concentration of dissolved solids would indicate a selenium concentration of about 10 μg/L. Observed selenium concentrations ranged from about 2 to 20 μg/L.

The concentration of dissolved constituents in the ground water in the terrace and valley-fill aquifers along Boxelder Creek ranged from 304 to 3,260 mg/L dissolved solids, from 230 to 1,900 mg/L hardness as $CaCO_3$, from 20 to 1,800 mg/L sulfate, and from 0 to 44 μg/L selenium. The largest variation in concentration of constituents in repeat samples collected from the same well at different times was 588 to 1,410 mg/L dissolved solids, 620 to 970 mg/L hardness as $CaCO_3$, 350 to 860 mg/L sulfate, and 9 to 22 μg/L selenium.

The method of evaluating the water-quality data was to examine the magnitudes and areal variations of the various constituents in the water and the relationship of these constituents to other constituents. Plate 6 shows the distribution and relationships of dissolved solids, sulfate, hardness, and selenium of water samples collected in the terrace and valley-fill aquifers along Boxelder Creek.

The evaluation indicates that the quality of water in the alluvial aquifers is controlled by the quality of applied irrigation water, by concentration as a result of evapotranspiration loss during irrigation, by cyclic deposition and solution of chemical constituents in the soil during and after the application of irrigation water, and, to a lesser degree, by solution of soluble material in the alluvium and in the bedrock at the base of the alluvium. Ground water at the north end of the Buckeye terrace contains only about 300 mg/L dissolved solids because there is no ground-water inflow from adjacent areas into Buckeye terrace alluvium, and recharge is from surface water containing less than 90 mg/L dissolved solids. Concentrations of all constituents increase downgradient to the south probably due to solution and evaporative concentration.

Ground-water quality in the alluvium along Boxelder Creek below the mouth of the Boxelder Creek canyon is influenced by the quality of the recharge from water diverted out of Boxelder Creek near the mouth of the canyon for irrigation application (about 1,000 mg/L dissolved solids) and underflow from the alluvium along Rawhide Creek (about 1,600 mg/L dissolved solids) into the alluvium along Boxelder Creek. South of sec. 23, T. 10 N., R. 69 W. where Boxelder Creek begins to carry the flow of Park Creek Lateral (about 90 mg/L dissolved solids), to Wellington, there is little noticeable change in ground-water quality. Recharge from conveyance losses and applied surface-water irrigation either improves the quality of the ground water or just about holds it constant. From about Wellington south, the ground water shows a continual increase in dissolved-solids concentration, modified by underflow from the alluvium along Coal Creek (700 mg/L dissolved solids) and Indian Creek (1,200 mg/L dissolved solids) into the alluvium along Boxelder Creek.

The water-quality variations observed in secs. 14-15, T. 8 N., R. 68 W., are indicative of the processes affecting water quality. The sample collected from the NW¼NW¼ sec. 15 (SB8-68-15BBB in table 4) indicates about 10 to 20 percent better water quality than samples collected both north and south. The well sampled was a domestic well that did not fully penetrate the aquifer. Recharge of better quality water from above and solution from the bedrock below with little or no vertical mixing can account for this variation. The sample collected in the SW¼NW¼ sec. 14 (SB8-68-14BCC in table 4) was from the discharge of a drain-tile system that drained 100 to 200 acres (40 to 80 ha) of nonirrigated land. The fact that a drain-tile system was constructed is indicative of a shallow depth to water. Under these conditions, evapotranspiration can account for the increased concentrations of dissolved constituents.

No specific geologic conditions which control ground-water quality could be identified from the data collected during the study. The apparent lack of geologic controls on water quality of the alluvial aquifers can be attributed to the following factors:

1. The controls, if they exist, are geographically broader than the study area and, therefore, were not observed.

2. The geochemical environment (oxidation-reduction potential and pH), which produces ion mobility, does not have a wide range over the area and, therefore, the range of concentrations of selenium and the other trace metals in the water is small.

3. Differences in well construction and depth of penetration may obscure the geologic control on water quality.

The spatial and temporal variations in water quality of the alluvial aquifers along Boxelder Creek indicate that there is no single source or area responsible for the observed areal distribution of chemical concentrations. What is shown are variations which appear to be the result of the irrigation practices in the area. Leaching from the bedrock may account for some low-level selenium concentrations, but the higher observed concentrations are the result of the same processes which concentrate the other constituents.

SUMMARY OF CONCLUSIONS

The quality of ground water in the alluvial aquifers associated with Boxelder Creek is affected by irrigation practices in the area. Irrigation water is supplied by surface-water diversions from the Cache la Poudre River and its tributaries, and by ground-water withdrawals. There are 251 large-capacity wells in the study area; 3 of these provide the municipal supply for the city of Wellington. Well yields range from about 80 gallons per minute (5 L/s) to a little over 1,800 gallons per minute (114 L/s). Total volume of water in storage is about 133,000 acre-feet (165 million m^3)--32,000 acre-feet (39.5 million m^3) in the alluvium of Buckeye terrace and 101,000 acre-feet (125 million m^3) in the valley-fill aquifer associated with Boxelder Creek. Ground-water withdrawals for irrigation are estimated to be about 25,000 acre-feet (31 million m^3) annually. The municipal wells pumped 210 acre-feet (260,000 m^3) in 1974.

The factors affecting water quality are the quality of applied irrigation water, the amount of water lost to evapotranspiration during irrigation, and, to a lesser degree, solution of soluble material in the alluvium and in the bedrock at the base of the alluvium. Ground water at the north end of the Buckeye terrace contains only about 300 mg/L dissolved solids. Recharge is from surface water containing less than 90 mg/L dissolved solids. Concentrations of all constituents increase downgradient to the south due to solution and evaporative concentration.

Ground-water quality in the alluvium along Boxelder Creek below the mouth of the canyon is controlled by the quality of the recharge from water diverted out of Boxelder Creek for irrigation application (about 1,000 mg/L dissolved solids) and underflow from Rawhide Creek (about 1,600 mg/L dissolved solids). From the point where Boxelder Creek begins to carry the flow of Park Creek Lateral south to Wellington, there is little noticeable change in ground-water quality. From about Wellington south the ground water shows a continual increase in dissolved-solids concentration, modified by underflow from Coal Creek (700 mg/L dissolved solids) and Indian Creek (1,200 mg/L dissolved solids).

There is an apparent lack of geologic controls on water quality of the alluvial aquifers which can be attributed to the following factors:

1. The controls, if they exist, are geographically broader than the study area and, therefore, were not observed.

2. The geochemical environment which produces ion mobility does not vary much over the area and, therefore, the range of concentrations of selenium and the other trace metals in the water is small.

3. Differences in well construction and depth of penetration may obscure the geologic control on water quality.

The concentration distribution of dissolved solids, hardness, sulfate, and selenium indicates no particular geologic source for these constituents, but rather that it is the result of evaporative concentration of applied irrigation water.

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SUPPLEMENTAL INFORMATION

System of Well Numbering

The well locations and sample sites in this report are based on the U.S. Bureau of Land Management system of land subdivision. The number shows the location of the well or site by quadrant, township, range, section, and position within the section. A graphic illustration of this method of well location is shown in figure 5. The first letter "S" preceding the location number means that the well is located in the area governed by the sixth principal meridian. The second letter indicates the quadrant in which the well is located. Four quadrants are formed by the intersection of the base line and the principal meridian--A indicates the northeast quadrant, B the northwest, C the southwest, and D the southeast. The first number indicates the township, the second the range, and the third the section in which the well is located. The letters following the section number locate the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section. The letters are assigned within the section in a counter-clockwise direction, beginning with (A) in the northeast quarter. Letters are assigned within each quarter section and within each quarter-quarter section in the same manner. Where two or more locations are within the smallest subdivision, consecutive numbers beginning with 1 are added in the order in which the wells were inventoried. For example, SB10-69-16DDA indicates a well in the northeast quarter of the southeast quarter of the southeast quarter of sec. 16, T. 10 N., R. 69 W. The "S" refers to the sixth principal meridian. The "B" indicates the township is north of the base line and that the range is west of the principal meridian.

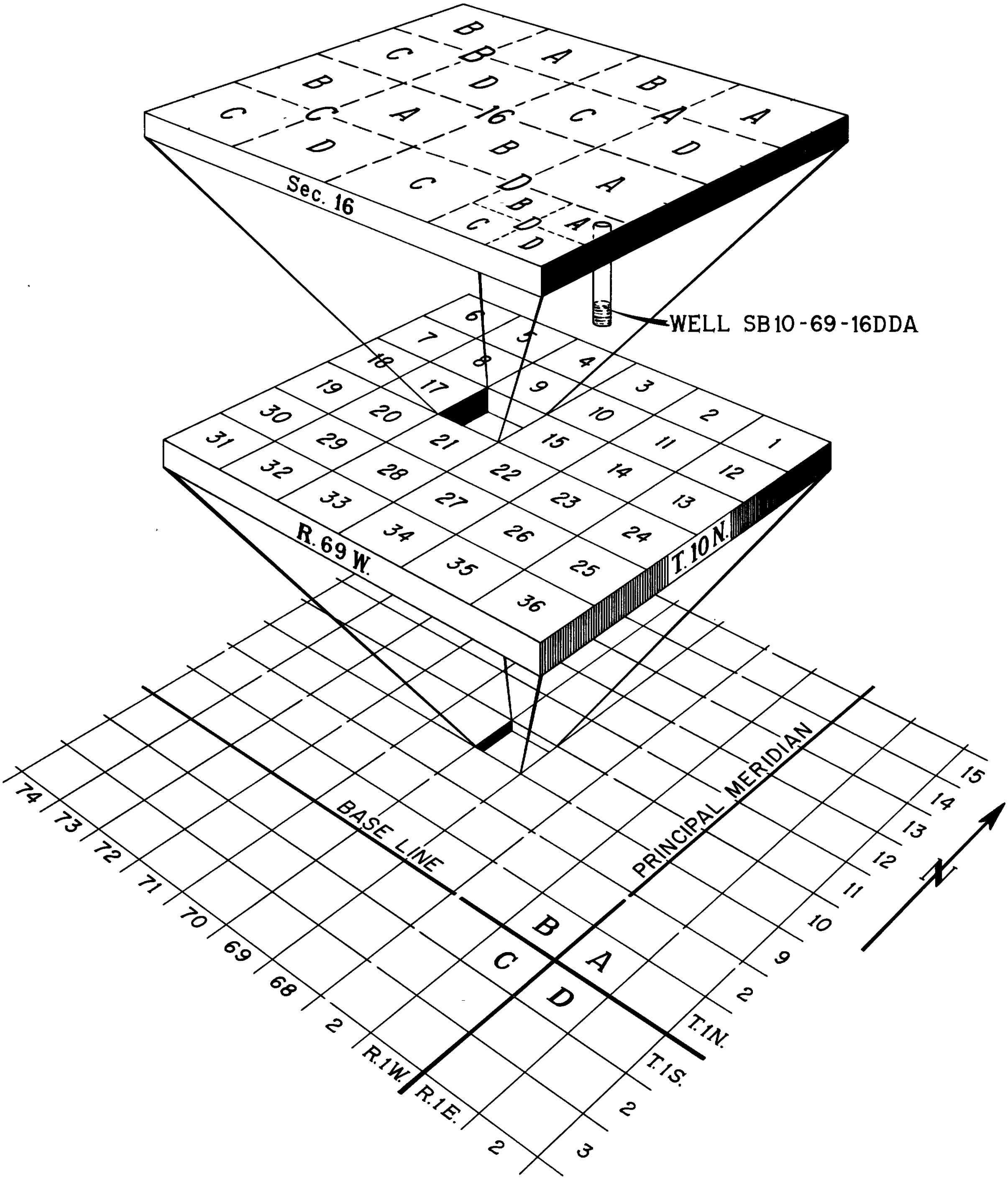

Figure 5.--System of numbering wells and sample sites.

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