Phosphorus and *E. coli* in the Fanno and Bronson Creek Subbasins of the Tualatin River Basin, Oregon, During Summer Low-Flow Conditions, 1996

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 00–4062

Prepared in cooperation with the
UNIFIED SEWERAGE AGENCY OF WASHINGTON COUNTY, OREGON

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By KATHLEEN A. McCARTHY

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Portland, Oregon
2000

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Phosphorus and *E. coli* in the Fanno and Bronson Creek Subbasins of the Tualatin River Basin, Oregon, During Summer Low-Flow Conditions, 1996

By Kathleen A. McCarthy

SIGNIFICANT FINDINGS

As part of an ongoing cooperative study between the Unified Sewerage Agency of Washington County, Oregon, and the U.S. Geological Survey, phosphorus and *Escherichia coli* (*E. coli*) concentrations were measured in the Fanno and Bronson Creek subbasins of the Tualatin River Basin during September 1996. Data were collected at 19 main-stem and 22 tributary sites in the Fanno Creek subbasin, and at 14 main-stem and 4 tributary sites in the Bronson Creek subbasin. These data provided the following information on summer base-flow conditions in the subbasins:

- Concentrations of total phosphorus at 70% of the sites sampled in the Fanno Creek subbasin were between 0.1 and 0.2 mg/L (milligrams per liter), very near the estimated background level of 0.14 mg/L attributed to ground-water base flow. These data indicate that ground-water discharge could account for the phosphorus measured at most sites in this subbasin.
- Concentrations of phosphorus at all but one of the sites sampled in the Bronson Creek subbasin were also between 0.1 and 0.2 mg/L, indicating that ground-water discharge could account for the phosphorus measured at most sites in this subbasin.
- A few sites in the Fanno Creek subbasin had phosphorus concentrations above background levels, indicating a source other than ground water. Some of these sites— Pendleton Creek and the tributary near Gemini, for example—were probably affected by the decomposition of avian waste materials and the release of phosphorus from bottom sediments in nearby ponds.
- Concentrations of *E. coli*—an indicator of fecal contamination and the potential presence of bacterial pathogens—exceeded the current single-sample criterion for recreational contact in freshwater (406 organisms/100 mL [organisms per 100 milliliters]) at 70% of the sites sampled in the Fanno Creek subbasin.
- Concentrations of *E. coli* in the Bronson Creek subbasin exceeded the single-sample criterion at one-third of the sites sampled.
- Most occurrences of elevated *E. coli* levels were probably due to sources such as domestic pet and wildlife waste, failing septic systems, or improperly managed hobby farms. The data did not indicate any large breaks in sewer lines or other large-scale sources of bacterial contamination to surface water in either subbasin during this low-flow period.

INTRODUCTION

The Tualatin River drains a rapidly developing 712-square-mile basin in northwestern Oregon, just west of the Portland metropolitan area (fig. 1). The Unified Sewerage Agency (USA) of Washington County is charged with sanitary-sewer and stormwater management throughout most of the urban part of the basin (serving approximately 370,000 residents) and is in the process of developing management plans to address water-quality issues specific to individual sub-basins.

In 1990, USA began a cooperative investigation with the U.S. Geological Survey (USGS) to assess a number of water-quality issues throughout the Tualatin River Basin related to the establishment of and compliance with Total Maximum Daily Loads developed for the basin pursuant to requirements of the Federal Clean Water Act. As part of this ongoing study, phosphorus and *Escherichia coli* (*E. coli*) concentrations characteristic of summer low-flow conditions in the Fanno and Bronson Creek subbasins were investigated during September 1996. Phosphorus is regulated in the basin as a result of nuisance algal blooms and historically high pH levels in the Tualatin River main stem, and understanding phosphorus contributions from tributaries is critical for effective management of main-stem concentrations. In addition, a number of stream segments within the Tualatin River Basin—including both Fanno and Bronson Creeks—are on Oregon's 1998 303(d) list for water bacterial violations (http://waterquality.deq.state.or.us/wq /303dlist/ 303dpage.htm, accessed October 20, 1999). *E. coli* is a common microorganism that inhabits the intestinal tracts of humans and other warm-blooded animals. The presence of *E. coli* in water is therefore an indicator of fecal contamination and signals the potential presence of bacterial pathogens. Understanding where elevated bacterial concentrations occur in the subbasins is necessary for development of effective, relevant mitigation plans.

Purpose and Scope

Data collected during the September 1996 sampling of the Fanno and Bronson Creek subbasins are presented in this report. Summer base-flow phosphorus and *E. coli* concentrations in the two subbasins and their potential impact on water-quality conditions in the Tualatin River main stem are discussed.

Acknowledgments

Special thanks are extended to the USA water-quality laboratory staff—especially Jan Wilson, Tom Auran, and Bill Byrne—Jan Miller of the USA, and the USGS sampling teams—Clyde Doyle, Howard Harrison, Matt Johnston, and Stewart Rounds.

STUDY AREA DESCRIPTION

The Tualatin River Basin is described in a number of reports published as part of the ongoing USA/USGS cooperative investigation of the basin (for example, Kelly, 1997; Risley, 1997; and Kelly et al., 1999). Characteristics of the Fanno and Bronson Creek subbasins relevant to this particular study are described briefly below.

Fanno Creek subbasin.—Fanno Creek drains a 32-square-mile area in the southeastern part of the Tualatin River Basin and flows directly into the main-stem Tualatin River at river mile 9.3 (figs. 1 and 2). Many tributaries flow into Fanno Creek along its 15-mile route, and some of them—such as Sylvan Creek, Summer Creek, and Ball Creek—contribute substantial discharges to the Fanno Creek main stem. The subbasin—encompassing parts of Portland, Beaverton, Tigard, and Durham—is classified as 100% urban and has been intensively developed for many years.

Bronson Creek subbasin.— The Bronson Creek subbasin consists of approximately 5 square miles in the eastern part of the Tualatin River Basin (figs. 1 and 2). Bronson Creek flows into Beaverton Creek, which is a tributary of Rock Creek; Rock Creek flows into the Tualatin River at river mile 38.1. Bronson Creek has few tributaries, but several ponds—many artificially constructed—are present along the creek's flow path. The subbasin is only partially developed, but is currently undergoing rapid urbanization.

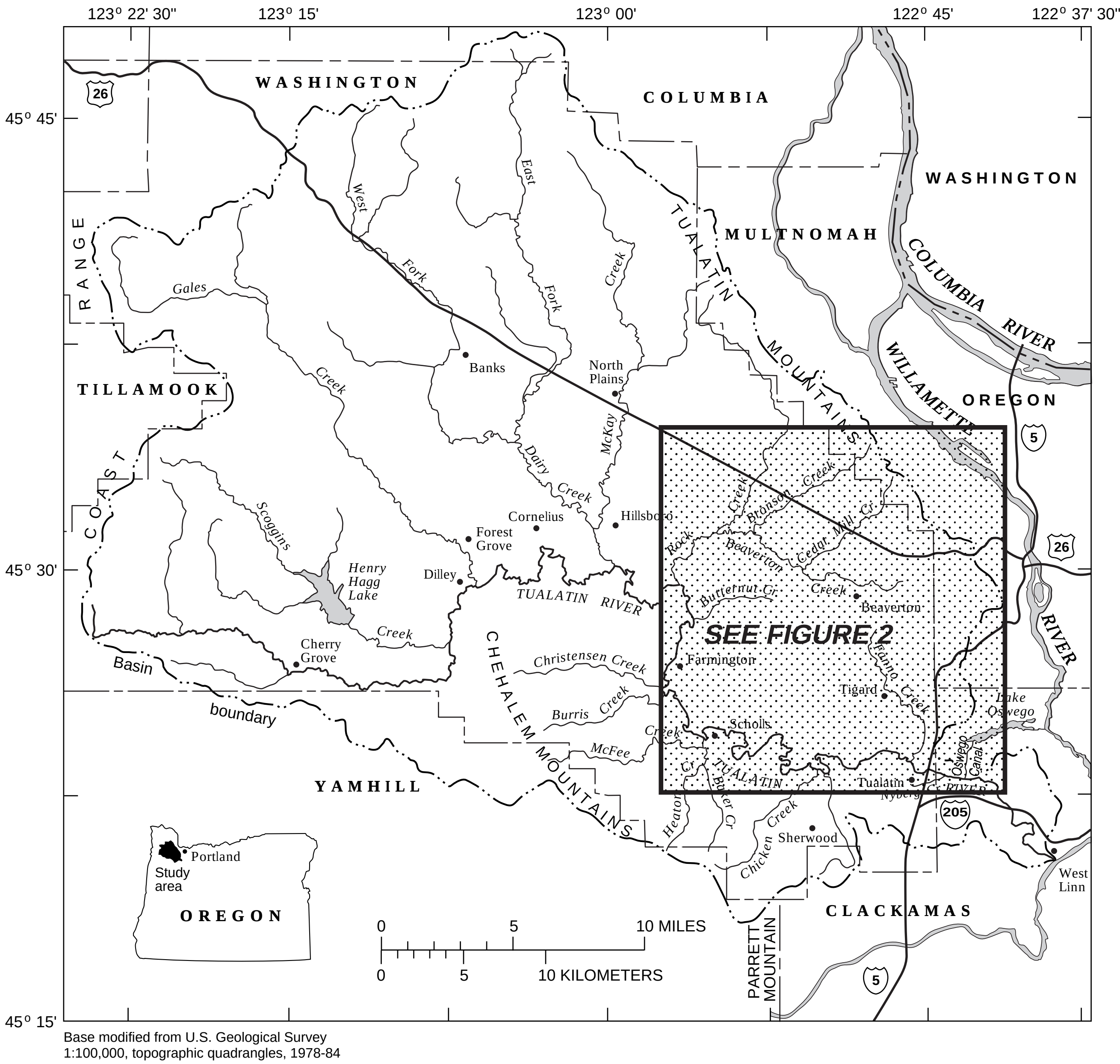

Figure 1. Location of study area.

Hydrology.—The annual discharge patterns in streams throughout the Tualatin River Basin are generally similar. The hydrograph of discharge in Fanno Creek during water years 1992–97 (fig. 3) shows that the period of lowest discharge for these streams typically occurs during the summer, when precipitation is relatively scarce. During this low-flow period, ground-water discharge is the predominant source of water to these streams.

Data for this study were collected during the late summer low-flow period (fig. 4). Although a minor rainfall event occurred before the Bronson Creek sampling, flows had returned to prestorm levels 4 days prior to sampling. Therefore, the data presented here should be representative of summer base-flow conditions in the Fanno and Bronson Creek subbasins.

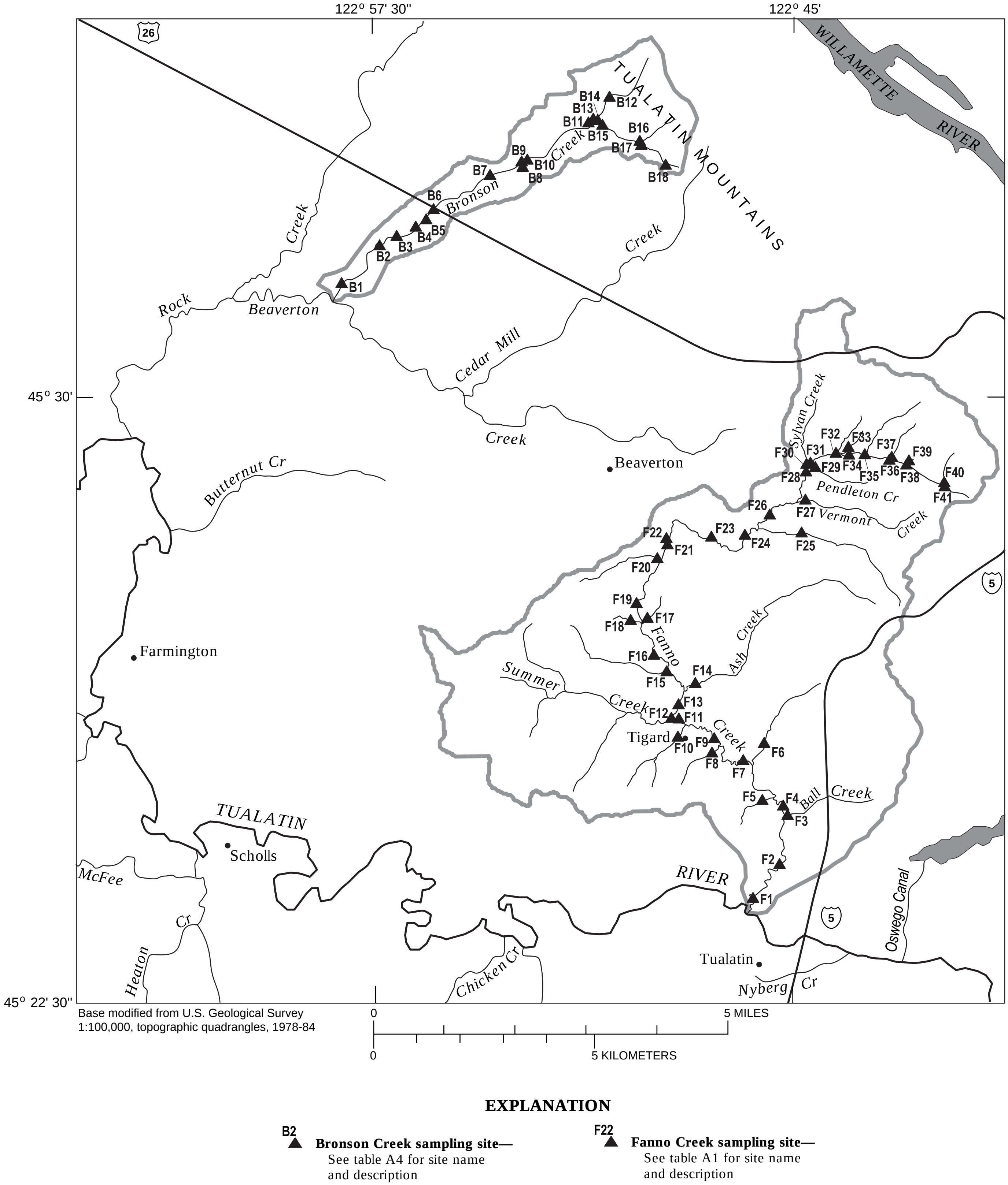

Figure 2. Location of Fanno and Bronson Creek subbasins and data-collection sites.

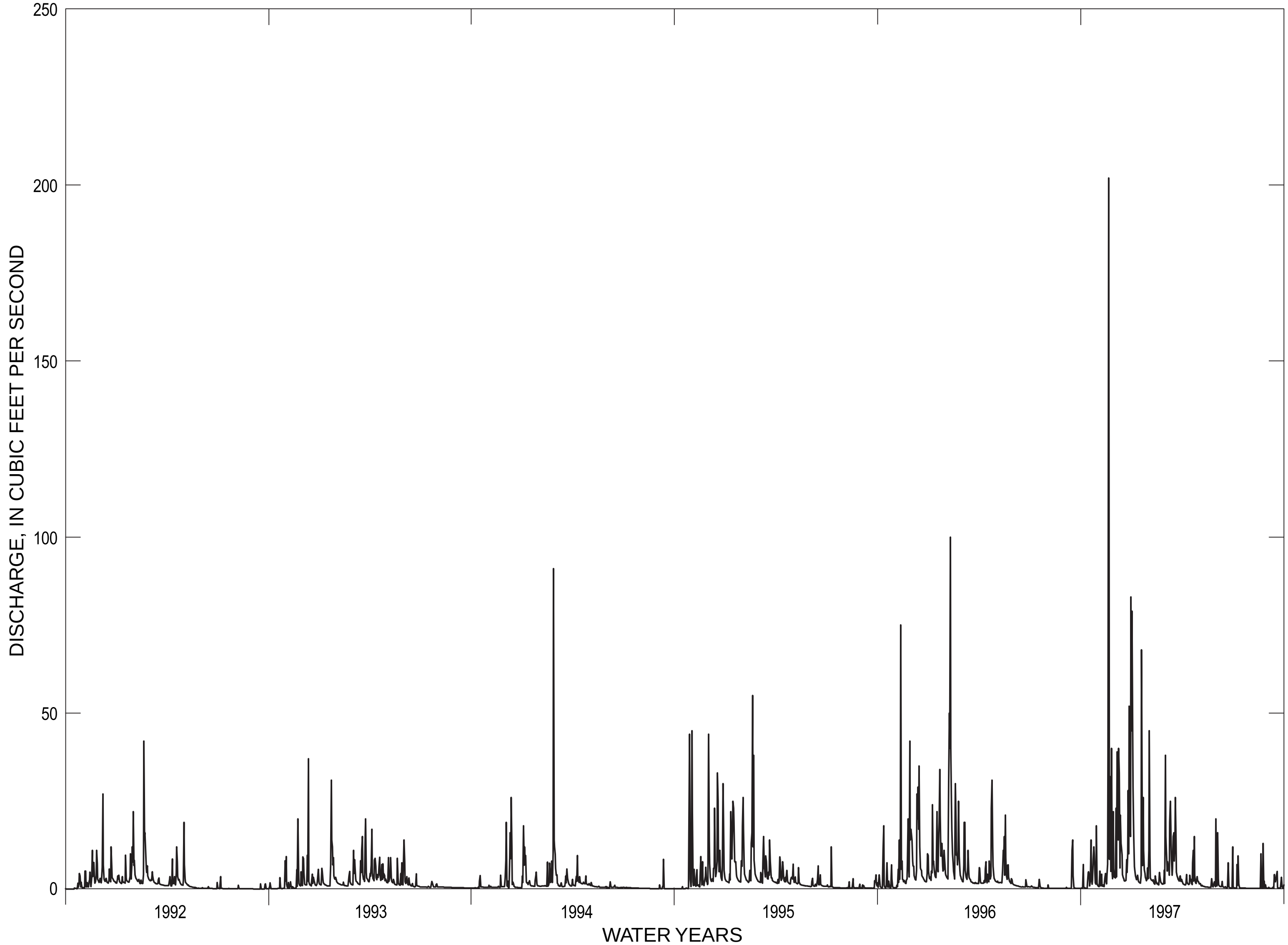

Figure 3. Fanno Creek at 56th (station 14206900), water years 1992–97.

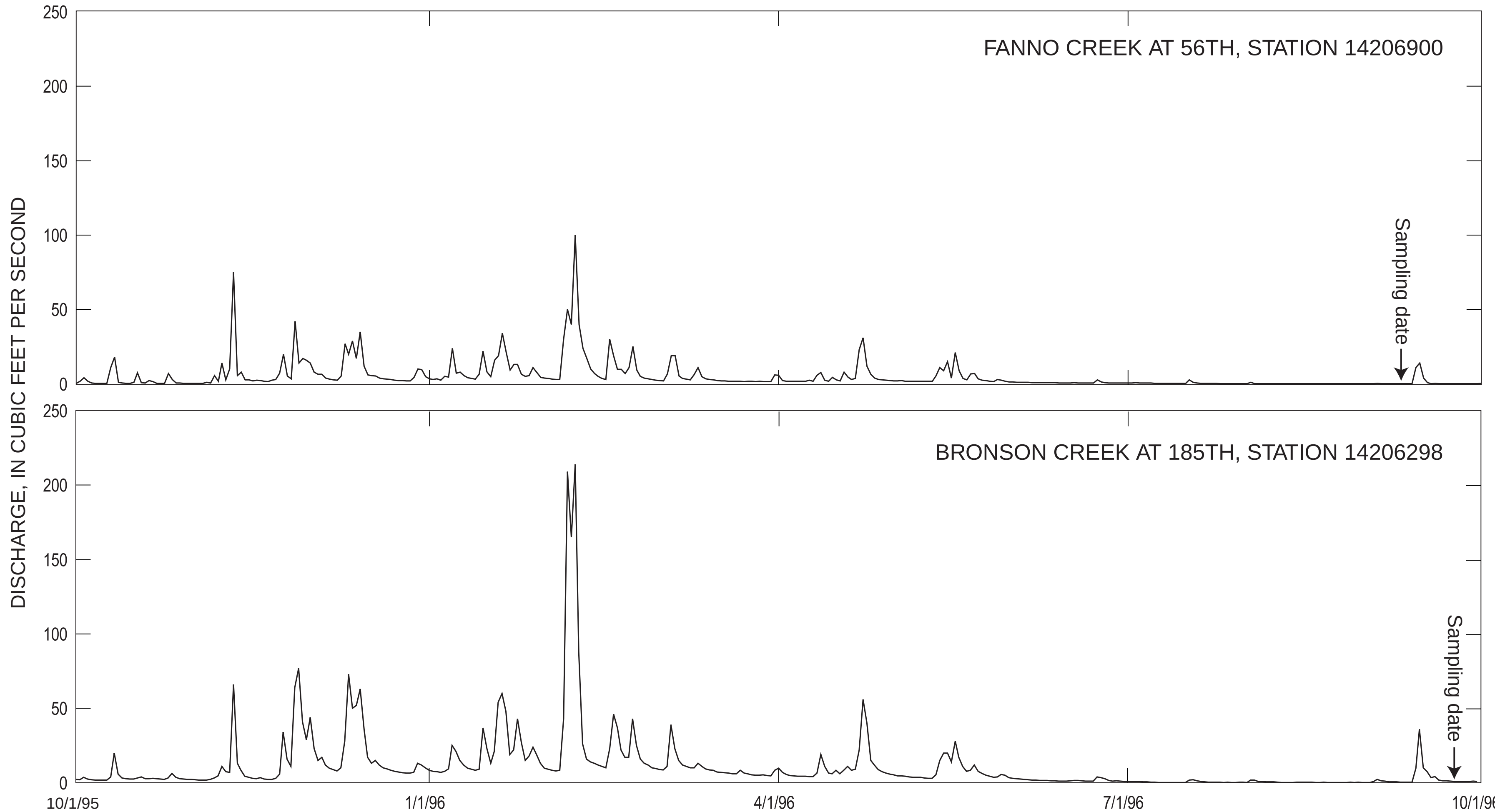

Figure 4. Fanno and Bronson Creeks, water year 1996.

DATA COLLECTION

Water-quality and stream-discharge data representing base-flow conditions were collected at 19 main-stem and 22 tributary sites in the Fanno Creek subbasin on September 10 and 11, 1996. In the Bronson Creek subbasin, 14 main-stem and 4 tributary sites were sampled on September 24, 1996.

Water-quality sampling and analyses.— Collection of water-quality samples was a joint effort by USA and USGS personnel. Water temperature, specific conductance, pH, and dissolved oxygen were measured in the field using Hydrolab™ multiparameter water-quality sensors. Grab samples were collected and analyzed for major ions, trace elements, nutrients, and bacteria at the USA water-quality laboratory. Methods used for sample collection, processing, and analyses of chemical constituents; and for field and laboratory quality control are described by Doyle and Caldwell (1996). Bacterial samples were processed and analyzed using U.S. Environmental Protection Agency method 600/4-85-076.

Quality assurance and quality control.— Duplicate samples were collected at two sites in the Fanno Creek subbasin and at one site in the Bronson Creek subbasin to help quantify the overall precision of the sampling and analytical methods. Results of duplicate analyses (presented with the regular data in the appendix) indicate acceptable precision.

Laboratory quality-control procedures included method blanks, travel blanks, spikes, and duplicate samples. The USA water-quality laboratory also participates in several performance-evaluation programs (e.g., the USGS Standard Reference Sample project, a monthly quality-assurance program run by the USGS Oregon District, an annual regional laboratory intercomparison study, and periodic reviews by the USGS Branch of Quality Systems) and has a record of high-quality performance (Kelly et al., 1999; Rounds et al., 1999).

Streamflow measurements.—USGS personnel conducted instantaneous flow measurements at the time of water-quality sample collection (tables A1 and A4, appendix). Flow in small streams is inherently difficult to measure, and the accuracy of the data range from excellent to poor, depending on site-specific conditions. The best discharge measurements typically were made by collecting the entire flow into a container and measuring the volume collected over a specific period of time. Other streamflow measurements were performed using standard USGS techniques and calibrated type AA or pygmy flow meters (Buchanan and Somers, 1969). The largest errors were associated with very shallow stream reaches and rocky streambeds. The accuracy of each streamflow measurement is indicated in tables A1 and A4 (appendix).

RESULTS

Phosphorus and *E. coli* data collected during this study are presented and discussed in the following sections. Other data—such as major-ion concentrations—are presented in the appendix.

Fanno Creek Subbasin

Phosphorus.—Recent water-quality investigations have revealed that ground water is a major source of phosphorus to surface water throughout the Tualatin River Basin (Doyle and Caldwell, 1996; Tualatin Basin Technical Advisory Committee, 1997; Kelly et al., 1999; Wilson et al., 1999). Near the mouth of Fanno Creek, the background total phosphorus concentration attributable to ground-water base flow has been estimated to be approximately 0.14 mg/L by both the Tualatin Basin Technical Advisory Committee (TBTAC) and the Oregon Department of Environmental Quality (ODEQ) (http://waterquality.deq.state.or.us/wq/TMDLs/TMDLs.htm, accessed October 22, 1999). Piezometers installed in the Fanno Creek streambed as part of the ongoing USA-USGS investigation also show that local ground water contains substantial levels of phosphorus (table 1), and accompanying water-level and seepage measurements showed that this ground water was discharging to Fanno Creek.

Concentrations of total phosphorus at nearly 80% of sites measured in the Fanno Creek subbasin during the 1996 sampling were less than 0.2 mg/L (fig. 5), suggesting that ground-water base flow could account for most of the phosphorus present. Concentrations of total phosphorus throughout the subbasin also correlated positively with barium, iron, and aluminum ($r > 0.85$), suggesting a common geological source of these constituents such as would be present in ground water. A few sites in the upper basin had total phosphorus concentrations less than 0.1 mg/L— possibly from a shallow, local ground-water system— and eight sites in the subbasin had concentrations greater than 0.2 mg/L. However, concentrations at all sites measured along the lower 6 miles of Fanno Creek were near estimated background levels. These data suggest that during summer low-flow conditions in the Fanno Creek subbasin, no anthropogenic or other sources of phosphorus in addition to ground water are contributing significantly to phosphorus loads in the Tualatin River main stem.

Table 1. Ground-water phosphorus data from piezometers installed in Fanno Creek

[Data-collection methods are described in Kelly et al. (1999)]

Location	River mile	Depth of screened interval (feet below streambed)	Date sampled	Total phosphorus (mg/L as P)
Upstream of Hall Boulevard	3.5	11.2	08-24-1995	0.81
Upstream of Hall Boulevard	3.5	11.2	09-04-1996	.96
Upstream of Hall Boulevard	3.5	6.2	08-24-1995	.31
Upstream of Hall Boulevard	3.5	6.2	09-04-1996	.16
Near Footbridge	.3	6.2	09-04-1996	.29

At most sites on the Fanno Creek main stem, dissolved orthophosphate (fig. 6) accounted for 30–50% of the total phosphorus measured (fig. 7). Concentrations of dissolved orthophosphate varied most at tributary sites and in the upper reaches of the Fanno Creek main stem (fig. 6). Except for Vermont Creek, which had the highest level measured in the subbasin (0.082 mg/L), dissolved orthophosphate concentrations tended to be highest in the lower subbasin and were generally between 0.06 and 0.08 mg/L (as phosphorus) along the lower 9 miles of Fanno Creek. This pattern of dissolved orthophosphate can probably be attributed to ground-water base flow. In general, base flows in tributaries and in the upper reaches of Fanno Creek result from relatively shallow, local ground-water systems, while base flow in the lower reaches of Fanno Creek includes flow from the deeper, more regional system (Tualatin Basin Technical Advisory Committee, 1997). Ground water in shallow, local systems comes from small, localized recharge areas and follows short flow paths from recharge to discharge. As a result, the composition of shallow ground water can vary considerably even within a subbasin. In contrast, ground water in deeper, regional flow systems includes contributions from a more extensive recharge area and follows longer, deeper flow paths from recharge to discharge. As a result, the composition of regional ground water tends to vary little at the subbasin scale. In addition, the regional ground-water flow system in the Tualatin River Basin has been shown to contain higher concentrations of orthophosphate than local flow systems (Kelly et al., 1999; Wilson et al., 1999).

Pendleton Creek, a small tributary that enters Fanno Creek at river mile 12.2, had the highest total phosphorus concentration in the subbasin (0.6 mg/L), at approximately four times the estimated background concentration (fig. 5). In addition, dissolved orthophosphate accounted for only 5% of the total phosphorus measured in Pendleton Creek (fig. 7). The preponderance of particle-associated phosphorus suggests that a source other than ground-water base flow contributes phosphorus to Pendleton Creek. Several nearly stagnant ponds are present along the creek's flow path, and the decomposition of avian waste and other bottom sediments in these ponds may be the source of additional phosphorus. Biological and chemical processes in these ponds may also contribute to elevated levels of turbidity, total and suspended solids, ammonia, total Kjeldahl nitrogen, bacteria, barium, iron, and aluminum, which were high in Pendleton Creek relative to most other sites in the subbasin (tables A1–A3, appendix).

***E. coli.*—**At approximately 70% of the sites sampled in the Fanno Creek subbasin, *E. coli* counts exceeded the current ODEQ single-sample criterion for recreational contact in freshwater—406 organisms/100 mL (fig. 8). Possible sources of *E. coli* to Fanno Creek include domestic pet and wildlife waste, failing septic systems, or improperly managed hobby farms. Furthermore, intensively developed areas tend to have elevated *E. coli* concentrations because of the increase in impervious surfaces associated with urban development. Washoff from such surfaces transfers microorganisms to streams more readily than runoff from undisturbed land. In contrast, *E. coli* levels measured during this same low-flow period in two nearby nonurbanized subbasins in the Tualatin River Basin (4 samples from Gales Creek and 5 samples from Dairy Creek; fig. 1) were less than the single-sample criterion (USA, unpub. data, 1996).

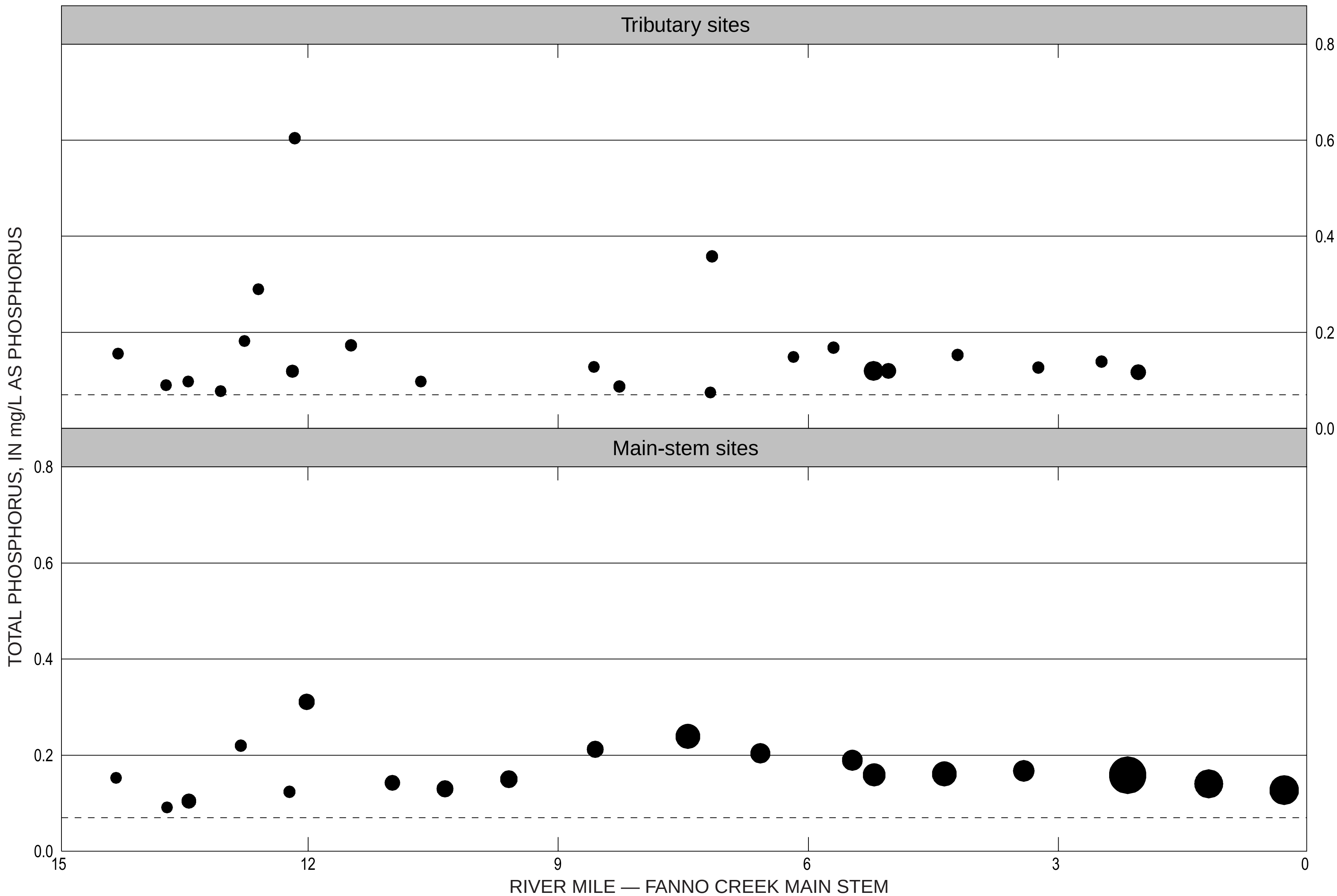

Figure 5. Total phosphorus in the Fanno Creek subbasin, September 1996. (Symbol diameters are proportional to the estimated instantaneous load, calculated as the product of discharge and concentration; dashed lines indicate Total Maximum Daily Load (TMDL) criterion of 0.07 mg P/L [milligrams phosphorus per liter].)

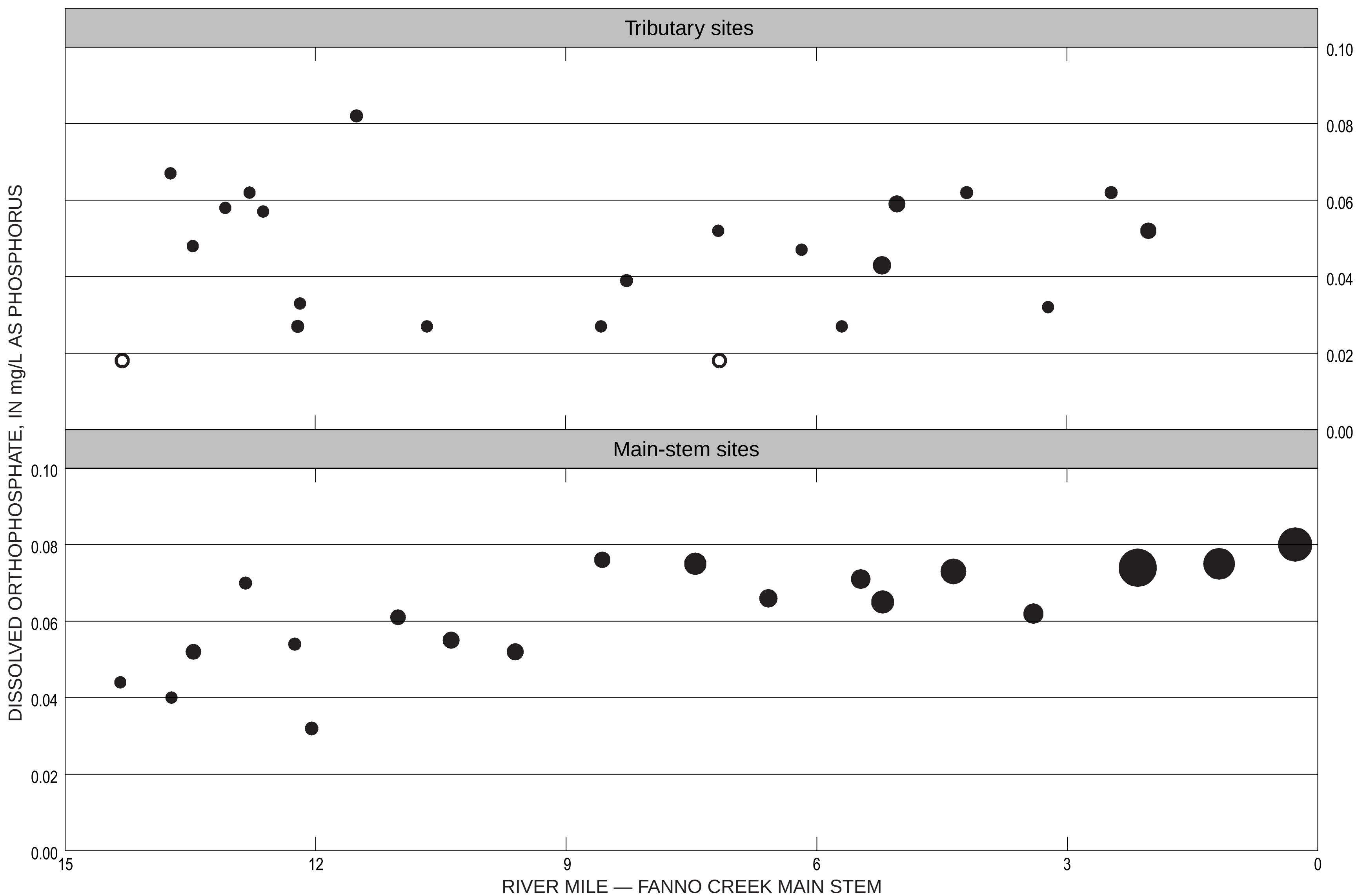

Figure 6. Dissolved orthophosphate in the Fanno Creek subbasin, September 1996. (Symbol diameters are proportional to the estimated instantaneous load, calculated as the product of discharge and concentration; solid symbols indicate measured concentration values; open symbols indicate estimated concentration values.)

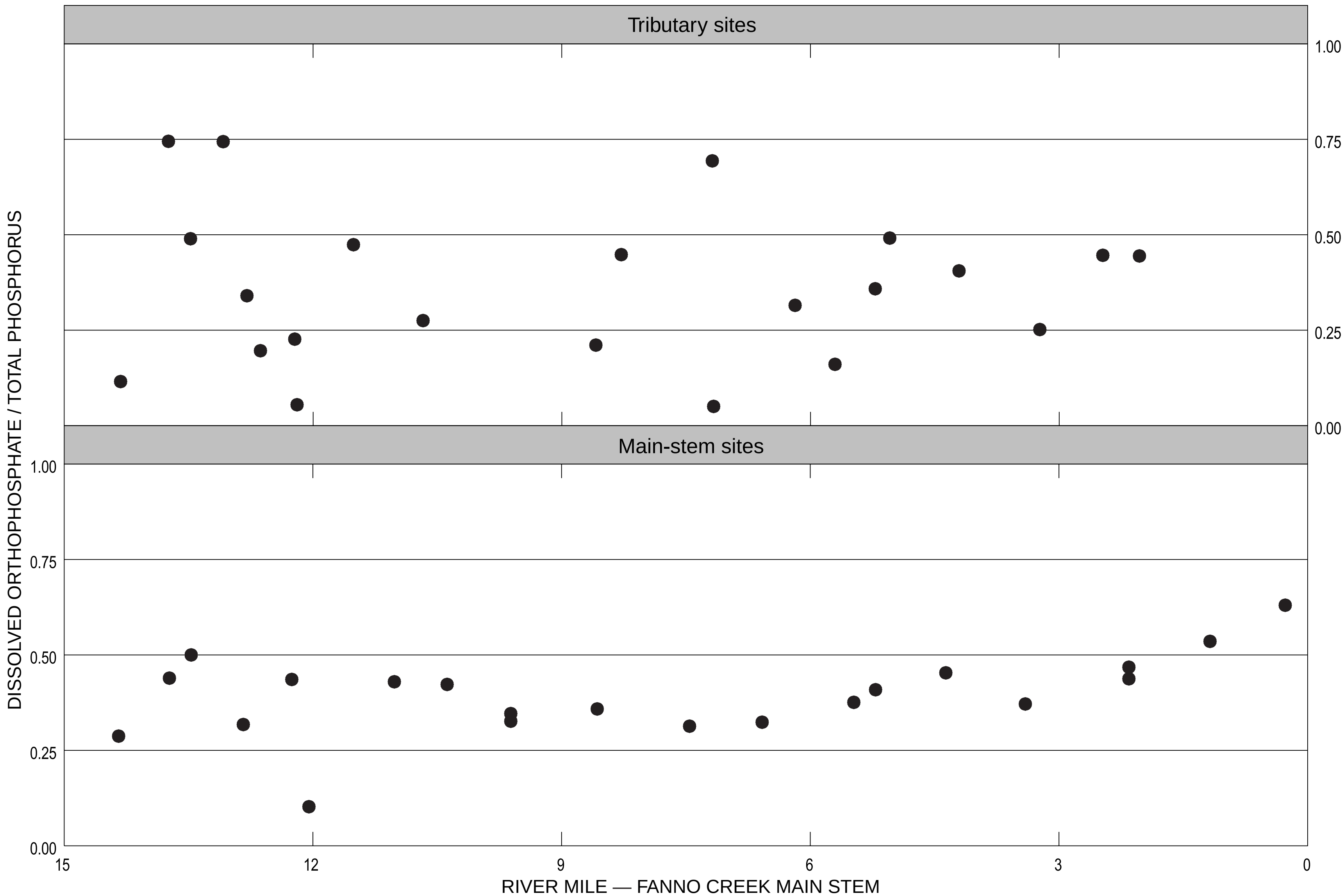

Figure 7. Ratio of dissolved orthophosphate to total phosphorus in the Fanno Creek subbasin, September 1996.

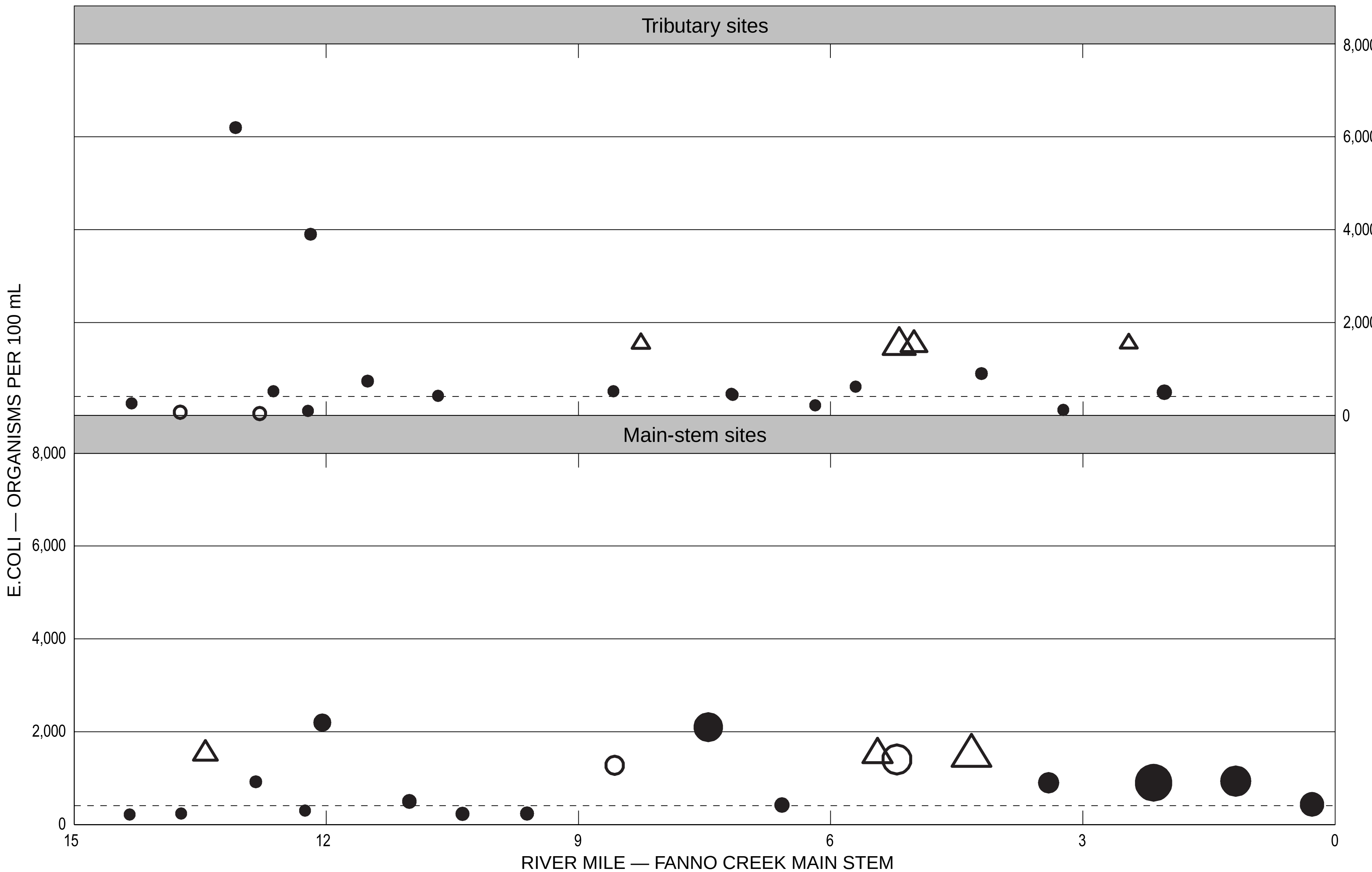

Figure 8. *E. coli* in the Fanno Creek subbasin, September 1996. (Symbol diameters are proportional to the estimated instantaneous load, calculated as the product of discharge and concentration; solid circles indicate measured concentration values; open circles indicate estimated concentration values; open triangles indicate actual concentration value is greater than the reported value; dashed lines indicate single-sample criterion of 406 organisms per 100 mL [milliliters] for recreational contact.)

E. coli counts varied considerably in the upper subbasin. The highest counts in the subbasin were measured in the tributary near Shattuck Road (Fanno Creek river mile 13.1) and in Pendleton Creek (Fanno Creek river mile 12.2), but a number of sites in the upper subbasin met the single-sample criterion. The tributary near Shattuck Road also had elevated concentrations of chloride and total Kjeldahl nitrogen, suggesting input from a sewage source such as a failing septic system. Avian wastes deposited in ponds along Pendleton Creek may act as an *E. coli* source to that stream. *E. coli* concentrations were more consistent in the lower subbasin—every site sampled along the lower 9 miles of Fanno Creek exceeded the single-sample criterion.

Bronson Creek Subbasin

Phosphorus.—At all but one of the sites in the Bronson Creek subbasin, total phosphorus concentrations were between 0.1 and 0.2 mg/L (fig. 9).

Near the mouth of Rock Creek, the nearest stream to Bronson Creek for which a background total phosphorus concentration has been estimated, the background total phosphorus concentration was estimated by the TBTAC and the ODEQ as 0.22 mg/L (http://waterquality.deq.state.or.us/wq/TMDLs/TMDLs.htm, accessed October 22, 1999). Bronson Creek is a tributary to Beaverton Creek, which in turn flows into Rock Creek. Ground water in the Bronson Creek subbasin is thus from a more localized flow system than ground water in the more downstream reaches of the Rock Creek subbasin, which probably accounts for the lower phosphorus concentrations in Bronson Creek. The phosphorus levels measured suggest that—with the exception of the most upstream site, Bronson Creek near Thompson Road (site B18)—ground-water base flow from local ground-water systems in this subbasin can account for phosphorus concentrations in Bronson Creek during summer low-flow conditions. Additionally, the consistency in total phosphorus concentrations measured at all sites except B18—including B12, the most upstream site on Bannister Creek, which drains an undeveloped and relatively pristine area—indicates that total phosphorus in this stream comes predominantly from a natural diffuse source, such as ground-water base flow, rather than anthropogenic point sources. The total phosphorus concentration measured at site B18 probably includes contributions from residential development in this part of the subbasin, but this influence was not apparent at any downstream sites. In contrast to previous studies (TBTAC, 1997), phosphorus concentrations remained fairly constant even as water passed through large instream ponds located along Bronson Creek between river miles 1.5 and 2.0.

Dissolved orthophosphate concentrations in the Bronson Creek subbasin were generally highest in the upper basin, except for the Thompson Road site (fig. 10). Ground-water base flow may account for this pattern of dissolved orthophosphate if the shallow, local ground-water system of the uppermost reaches of the Bronson Creek subbasin has higher dissolved orthophosphate concentrations than the relatively deeper ground water that feeds the lower reaches of Bronson Creek.

In addition to having the highest total phosphorus concentration in the subbasin, as well as the lowest ratio of dissolved orthophosphate to total phosphorus (fig. 11), Bronson Creek near Thompson Road (B18) had the highest measured values of turbidity, total and suspended solids, total Kjeldahl nitrogen, ammonia, BOD_5, iron, barium, and aluminum (tables A4–A6, appendix). Many of these high values may be explained by the local influence of residential development and the low stream discharge at this site—the lowest discharge measured in the subbasin. Low flows have limited ability to dilute contaminants; therefore, even relatively small inputs of contaminants can have an appreciable impact on water quality in very small streams.

The highest dissolved orthophosphate concentrations and the lowest values for temperature, turbidity, specific conductance, dissolved and suspended solids, total phosphorus, and iron were measured in Bannister Creek, the only significant tributary of Bronson Creek (tables A4–A6, appendix). These data probably represent the composition of the shallow, local ground water contributing base flow to Bannister Creek.

E. coli.*—E. coli* counts at one-third of the sites sampled in the Bronson Creek subbasin exceeded the current ODEQ individual-sample criterion for recreational contact in freshwater—406 organisms/100 mL (fig. 12). Bacterial counts that exceeded the criterion were measured at the Thompson Road site, in the vicinity of Kaiser Road, at the West Union site, and at the most downstream site on Bannister Creek. In contrast, no *E. coli* levels exceeding the criterion were measured at any of the sites sampled along the lower 3 miles of Bronson Creek. As in the Fanno Creek subbasin, possible sources of *E. coli* to Bronson Creek include domestic pet and wildlife waste, failing septic systems, or improperly managed hobby farms. Generally lower *E. coli* levels in the Bronson Creek subbasin compared to those in the Fanno Creek subbasin can probably be largely attributed to less intensive urbanization.

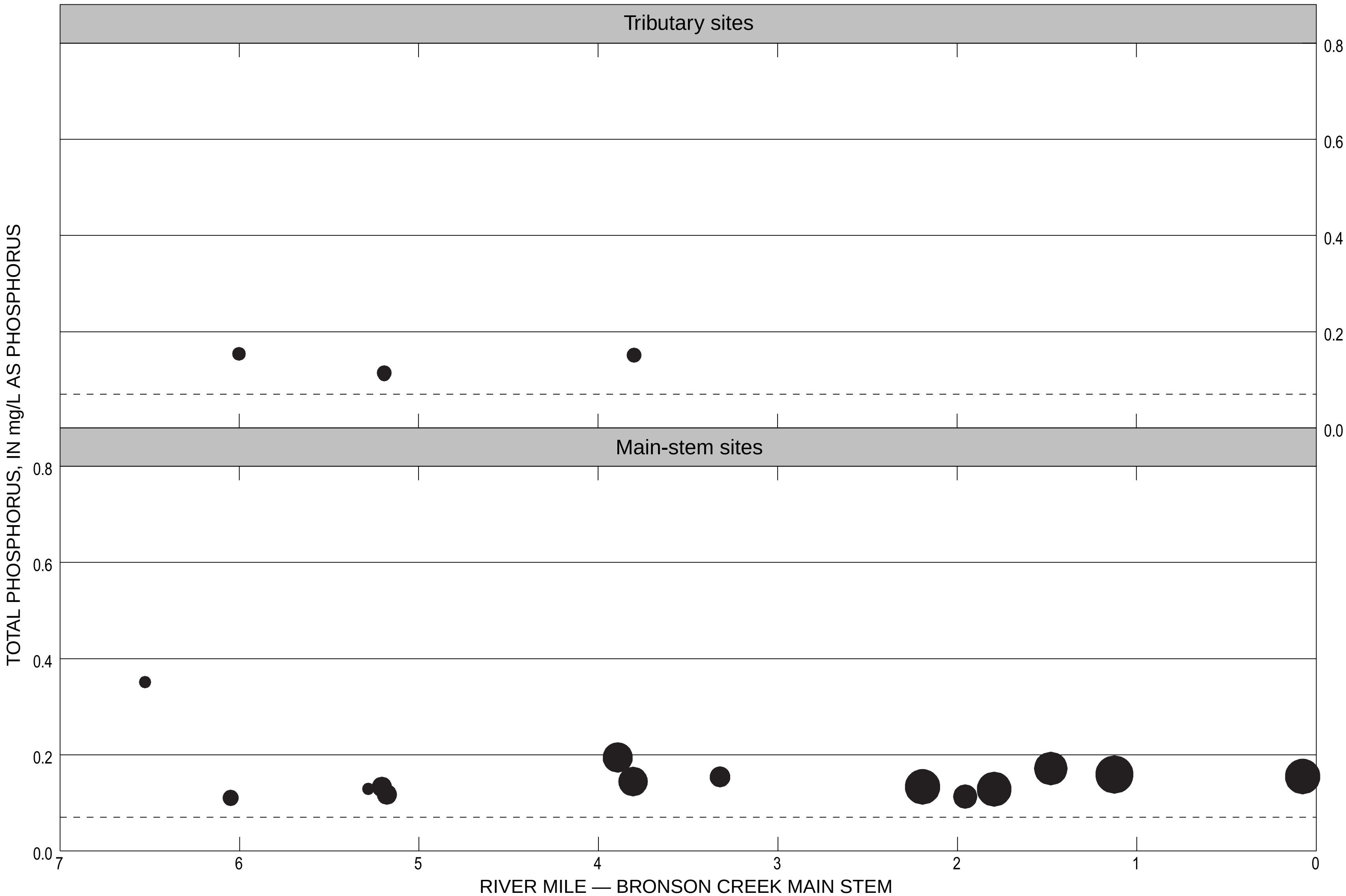

Figure 9. Total phosphorus in the Bronson Creek subbasin, September 1996. (Symbol diameters are proportional to the estimated instantaneous load, calculated as the product of discharge and concentration; dashed lines indicate Total Maximum Daily Load [TMDL] criterion of 0.07 mg P/L [milligrams phosphorus per liter].)

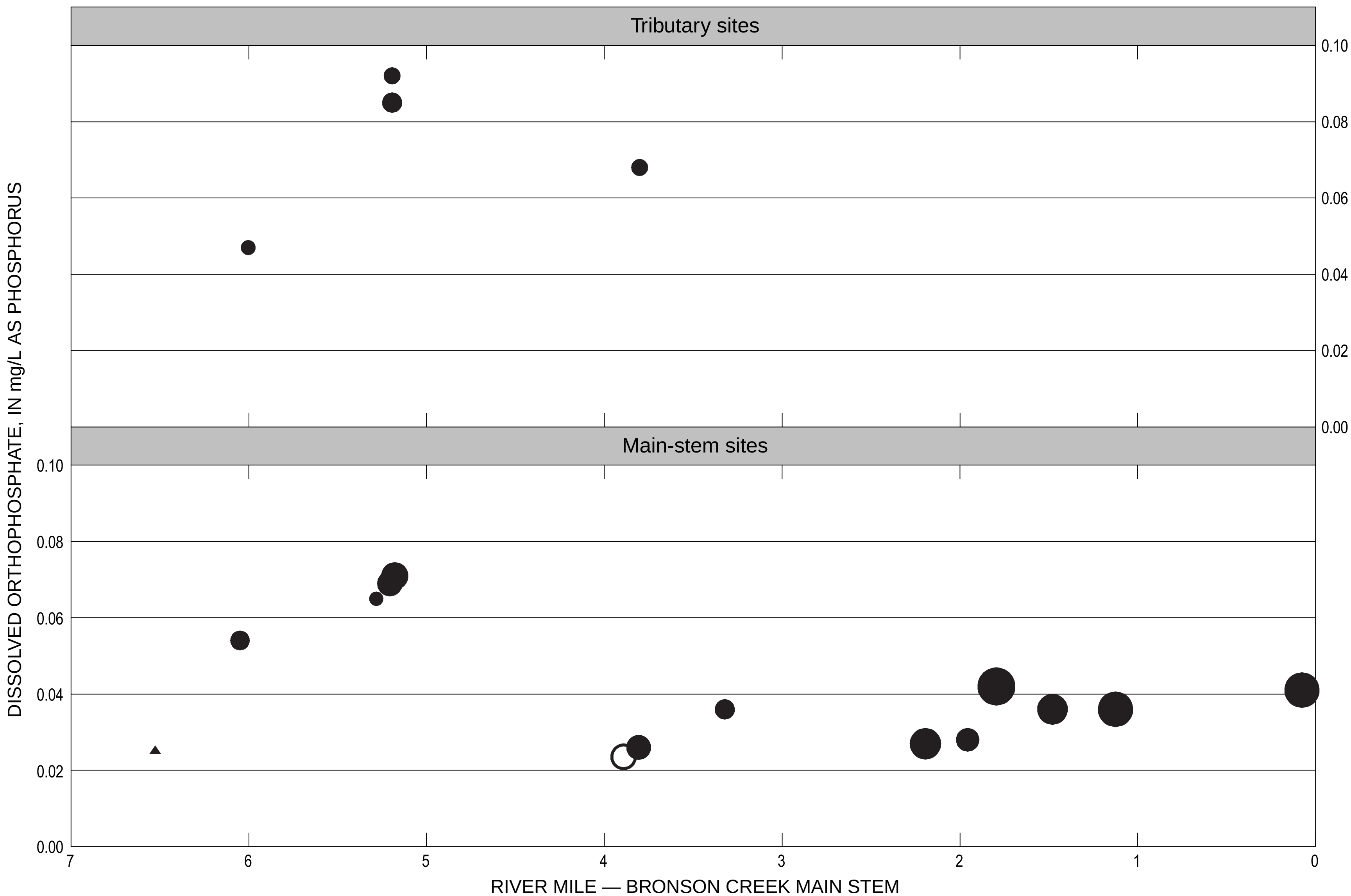

Figure 10. Dissolved orthophosphate in the Bronson Creek subbasin, September 1996. (Symbol diameters are proportional to the estimated instantaneous load, calculated as the product of discharge and concentration; solid symbols indicate measured concentration values; open symbols indicate estimated concentration values.)

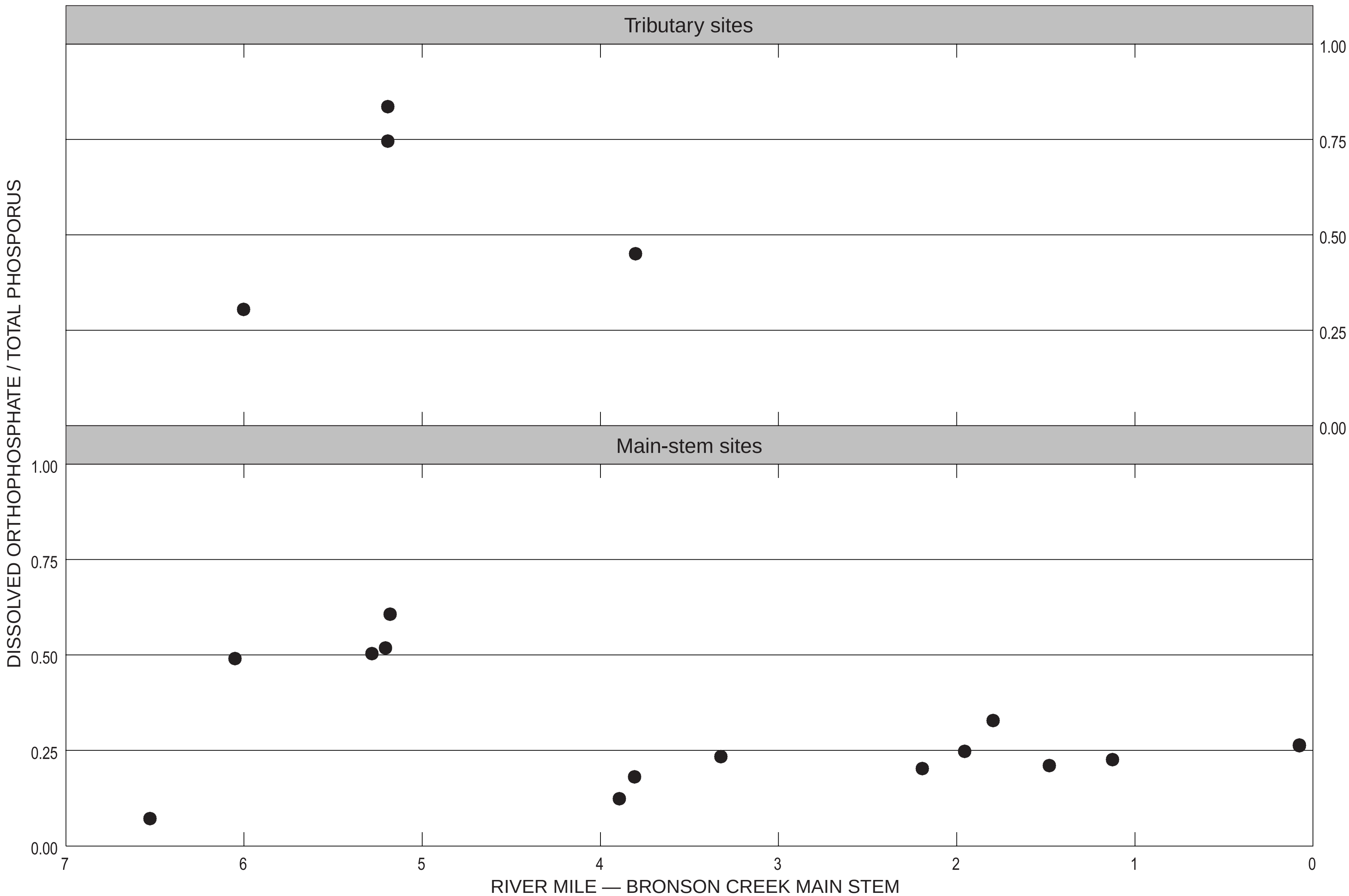

Figure 11. Ratio of dissolved orthophosphate to total phosphorus in the Bronson Creek subbasin, September 1996.

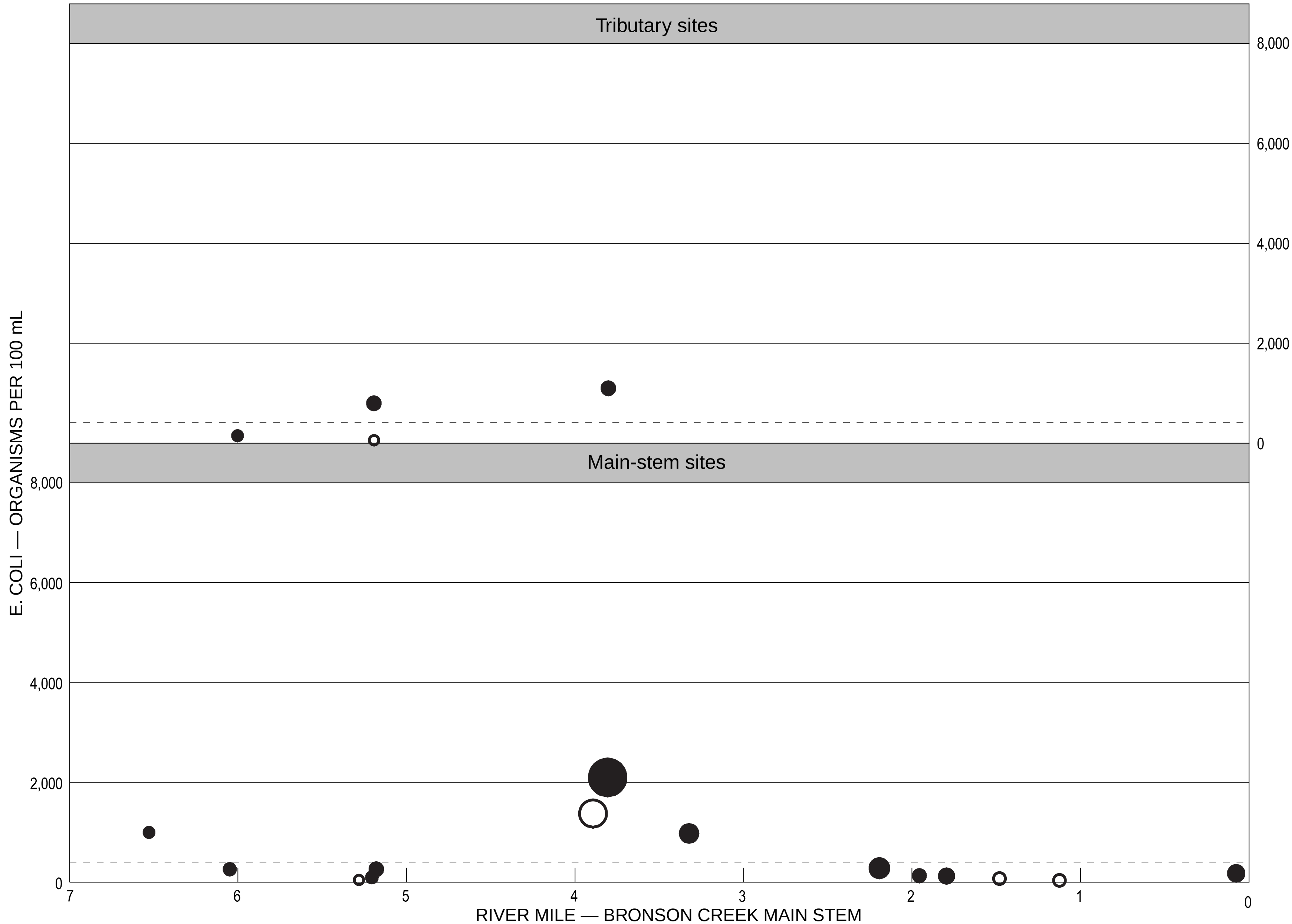

Figure 12. *E. coli* in the Bronson Creek subbasin, September 1996. (Symbol diameters are proportional to the estimated instantaneous load, calculated as the product of discharge and concentration; solid circles indicate measured concentration values; open circles indicate estimated concentration values; dashed lines indicate single-sample criterion of 406 organisms per 100 mL [milliliters] for recreational contact.)

SUMMARY

As part of an ongoing investigation of water-quality conditions in the Tualatin River Basin, the Unified Sewerage Agency and the U.S. Geological Survey measured phosphorus and *E. coli* concentrations in the Fanno Creek and Bronson Creek subbasins. These measurements were made during September 1996 to characterize summer base-flow conditions in the two subbasins. Documenting phosphorus and *E. coli* concentrations and understanding their distribution during low-flow periods is important for developing effective subbasin water-management plans as well as understanding sources that contribute to loads in the Tualatin River main stem.

Phosphorus.—Studies of water quality in the Tualatin River Basin have shown that ground water in this region is rich in phosphorus. The Tualatin Basin Technical Advisory Committee and the Oregon Department of Environmental Quality have estimated background phosphorus concentrations for a number of subbasins based on ground-water and surface-water data from these studies (http://waterquality.deq.state.or.us/wq/TMDLs/TMDLs.htm, accessed October 22, 1999). Data from most of the sites sampled during the September 1996 study indicate that during summer low-flow conditions in the Fanno and Bronson Creek subbasins, total phosphorus concentrations were near estimated background values associated with ground-water base flow. Some upstream sites in each subbasin had phosphorus concentrations somewhat higher than could be attributed to a ground-water source, suggesting additional sources were contributing to instream phosphorus loads. However, the lower several miles of both Fanno and Bronson Creeks were near background, indicating that anthropogenic or other sources of phosphorus in addition to ground water were not contributing substantially to phosphorus loads to the Tualatin River main stem during this low-flow period.

Data collected during this study suggest that ponds associated with some of the tributaries in the Fanno Creek subbasin (e.g., Pendleton Creek and the tributary near Gemini) may be contributing to increased phosphorus levels, but in contrast to earlier studies (Tualatin Basin Technical Advisory Committee, 1997), phosphorus concentrations did not diminish as water passed through large instream ponds located along Bronson Creek between river miles 1.5 and 2.0. This illustrates that the effects of ponds on water quality can be transient.

***E. coli.*—**Several sites in the Bronson Creek subbasin and most sites in the Fanno Creek subbasin exceeded the single-sample bacteria criterion for recreational contact in freshwater (406 organisms/100 mL). Most of the elevated levels measured are typical of urbanized areas, and generally higher levels in the Fanno Creek subbasin can probably be attributed to greater urbanization there than in the Bronson Creek subbasin. For comparison, *E. coli* levels measured during this same low-flow period in two non-urbanized subbasins located just west of the study area (4 samples from Gales Creek and 5 samples from Dairy Creek; fig. 1) were less than the single-sample criterion (USA, unpub. data, 1996).

Within the Fanno Creek subbasin, particularly high *E. coli* levels in the vicinity of Shattuck Road and in Pendleton and Summer Creeks may indicate additional inputs from sources such as domestic pet and wildlife waste, failing septic systems, or improperly managed hobby farms. The tributary near Shattuck Road also had elevated concentrations of chloride and total Kjeldahl nitrogen, which is consistent with input from a sewage source such as a failing septic system. Avian wastes deposited in ponds along Pendleton Creek may also contribute *E. coli* to the stream.

E. coli data collected during this study show that at a few sites—the tributary near Shattuck Road and Pendleton Creek in the Fanno Creek subbasin and the area near Kaiser Road on Bronson Creek—*E. coli* levels were relatively high. However, there was no evidence in either subbasin of large-scale sources of bacterial contamination to surface water during the summer low-flow period investigated.

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APPENDIX

Table A1. Discharge, phosphorus, nitrogen, and *E. coli* data collected in the Fanno Creek subbasin, September 10, 1996

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; P, phosphorus; NH_3, ammonia; N, nitrogen; mL, milliliters; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Fanno Creek river mile is point of entry for tributaries; ≤, less than or equal to; A, error ≤ 2%; B, error ≤ 5%; C, error ≤ 8%; D, error > 8%; E, estimated value; --, no data; <, less than; >, greater than; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Fanno Creek river mile	Site number	Instantaneous flow (ft^3/s) [61]	Quality of flow measurement	Total phosphorus (mg/L as P) [665]	Dissolved ortho-phosphate (mg/L as P) [671]	Ratio of dissolved ortho-phosphate to total phosphorus	Soluble NH_3 (mg/L as N) [608]	Total Kjeldahl nitrogen (mg/L as N) [625]	Soluble nitrate-nitrite (mg/L as N) [631]	*E. coli* (organisms per 100 mL) [31648]
Fanno Creek at 30th	**14.3**	**F41**	**0.007**	**C**	**0.15**	**0.044**	**0.29**	**0.064**	**0.58**	**1.1**	**220**
Tributary at Dosch & Highway 10	14.3	F40	.004	C	.16	E .018	E .11	.11	.48	.33	260
Fanno Creek at 39th	**13.7**	**F38**	**.071**	**A**	**.09**	**.040**	**.44**	**< .02**	**.86**	**.62**	**240**
Tributary at 38th &39th Drive	13.7	F39	.007	A	.09	.067	.74	< .02	.26	.30	E 40
Ivey Creek at 45th	13.5	F37	.004	C	.10	.048	.49	E .04	.16	.37	170
Fanno Creek at 45th	**13.5**	**F36**	**.8**	**D**	**.10**	**.052**	**.50**	**E .02**	**.22**	**.40**	**> 1,600**
Tributary near Shattuck	13.1	F35	.008	B	.08	.058	.74	E .03	3.51	.86	6,200
Fanno Creek at 56th	**12.8**	**F34**	**.082**	**C**	**.22**	**.070**	**.32**	**E .05**	**1.2**	**.26**	**920**
Taylor Creek near Seymour	12.8	F33	.002	A	.18	.062	.34	.143	.46	.35	E 8
Columbia Creek near mouth	12.6	F32	.009	D	.29	.057	.20	E .03	.68	.72	520
Fanno Creek upstream of Sylvan Creek	**12.3**	**F31**	**.087**	**B**	**.12**	**.054**	**.44**	**E .02**	**.42**	**.20**	**300**
Sylvan Creek	12.2	F30	.23	D	.12	.027	.23	.07	.45	.18	96
Pendleton Creek	12.2	F29	.023	C	.60	.033	.05	.445	1.77	.38	3,900
Fanno Creek at Oleson	**12.0**	**F28**	**.41**	**C**	**.31**	**.032**	**.10**	**.15**	**.89**	**.21**	**2,200**
Vermont Creek at Oleson	11.5	F27	.11	D	.17	.082	.47	.809	1.43	12.60	740
Fanno Creek at Nicole Road	**11.0**	**F26**	**.68**	**C**	**.14**	**.061**	**.43**	**E .04**	**.46**	**1.1**	**500**
Multnomah tributary at Oleson	10.7	F25	.06	D	.10	.027	.28	E .03	.39	.36	420
Fanno Creek at 86th	**10.4**	**F24**	**1.0**	**C**	**.13**	**.055**	**.42**	**E .03**	**.44**	**.85**	**230**
Fanno Creek near Allen	**9.6**	**F23**	**1.1**	**C**	**.15**	**.052**	**.35**	**.11**	**.73**	**.85**	**240**
Fanno Creek near Allen—DUPLICATE	**9.6**	**F23**	**--**	**--**	**.15**	**.049**	**.33**	**.11**	**.77**	**.85**	**210**
Wetland near Fanno Creek at Denny	8.6	F22	--	--	.13	.027	.21	< .02	.29	< .01	520
Fanno Creek at Denny	**8.6**	**F21**	**.67**	**C**	**.21**	**.076**	**.36**	**.11**	**.64**	**.55**	**E 1,300**

Table A1. Discharge, phosphorus, nitrogen, and *E. coli* data collected in the Fanno Creek subbasin, September 10, 1996—Continued

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; P, phosphorus; NH_3, ammonia; N, nitrogen; mL, milliliters; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Fanno Creek river mile is point of entry for tributaries; ≤, less than or equal to; A, error ≤ 2%; B, error ≤ 5%; C, error ≤ 8%; D, error > 8%; E, estimated value; --, no data; <, less than; >, greater than; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Fanno Creek river mile	Site number	Instantaneous flow (ft^3/s) [61]	Quality of flow measurement	Total phosphorus (mg/L as P) [665]	Dissolved ortho-phosphate (mg/L as P) [671]	Ratio of dissolved ortho-phosphate to total phosphorus	Soluble NH_3 (mg/L as N) [608]	Total Kjeldahl nitrogen (mg/L as N) [625]	Soluble nitrate-nitrite (mg/L as N) [631]	*E. coli* (organisms per 100 mL) [31648]
Tributary at Bel-Aire	8.3	F20	0.16	C	0.09	0.039	0.45	< 0.02	0.25	0.29	> 1,600
Fanno Creek at Tuckerwood	**7.5**	**F19**	**1.8**	**C**	**.24**	**.075**	**.31**	**E .04**	**.55**	**.39**	**2,100**
Tributary at Greenway School	7.2	F18	.04	D	.08	.052	.69	< .02	.18	.16	460
Tributary near Gemini	7.2	F17	.05	C	.36	E .018	E .05	E .02	1.92	.15	440
Fanno Creek at Scholls Ferry	**6.6**	**F16**	**1.2**	**B**	**.20**	**.066**	**.32**	**.068**	**.63**	**.30**	**420**
Tributary at Ironwood Loop	6.2	F15	.038	B	.15	.047	.32	E .03	.45	.51	220
Ash Creek at Greenburg	5.7	F14	.07	C	.17	.027	.16	.053	.59	.03	620
Fanno Creek at Tigard Street	**5.5**	**F13**	**1.4**	**B**	**.19**	**.071**	**.38**	**.075**	**.64**	**.32**	**> 1,600**
Summer Creek at mouth (Tiedeman)	5.2	F12	1.8	D	.12	.043	.36	.062	.47	.45	> 1,600
Fanno Creek at Tiedeman	**5.2**	**F11**	**2.3**	**C**	**.16**	**.065**	**.41**	**.062**	**.55**	**.38**	**E 1,500**
Tributary at Walnut	5.0	F10	.9	D	.12	.059	.49	E .03	.16	1.39	> 1,600
Fanno Creek at Main	**4.4**	**F9**	**2.8**	**C**	**.16**	**.073**	**.45**	**.063**	**.53**	**.46**	**> 1,600**
Tributary at A-boy (Main St. Apts.)	4.2	F8	.099	C	.15	.062	.41	< .02	.26	.33	900
Fanno Creek at Hall	**3.4**	**F7**	**2**	**D**	**.17**	**.062**	**.37**	**E .04**	**.46**	**.40**	**900**
Red Rock at Hunziker	3.2	F6	.1	D	.13	.032	.25	.056	.52	.06	120
Tributary at Fanno Creek Drive	2.5	F5	.12	A	.14	.062	.45	E .04	.27	1.87	> 1,600
Fanno Creek at Bonita	**2.2**	**F4**	**7.1**	**B**	**.16**	**.074**	**.47**	**E .04**	**.43**	**.49**	**900**
Fanno Creek at Bonita—DUPLICATE	**2.2**	**F4**	**--**	**--**	**.16**	**.070**	**.44**	**E .04**	**.45**	**.48**	**860**
Ball Creek at 74th	2.0	F3	.91	C	.12	.052	.44	E .04	.28	.39	500
Fanno Creek at Durham Road	**1.2**	**F2**	**4.5**	**B**	**.14**	**.075**	**.54**	**E .02**	**.36**	**.54**	**940**
Fanno Creek at Footbridge	**.3**	**F1**	**5.3**	**C**	**.13**	**.080**	**.63**	**< .02**	**.35**	**.59**	**440**

Table A2. Field, oxygen-demand, and solids data collected in the Fanno Creek subbasin, September 10, 1996

[C, Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; NTU, nephelometric turbidity units; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Fanno Creek river mile is point of entry for tributaries; <, less than; E, estimated value; --, no data; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Fanno Creek river mile	Site number	Temperature (degrees C) [10]	Field pH [400]	Field conductivity (µS/cm) [94]	Dissolved oxygen (mg/L) [299]	5-day biochemical oxygen demand (mg/L) [310]	Total chemical oxygen demand (mg/L) [340]	Total alkalinity (mg/L as $CaCO_3$) [410]	Total solids (mg/L) [500]	Total dissolved solids (mg/L) [515]	Total suspended solids (mg/L) [530]	Turbidity (NTU) [76]
Fanno Creek at 30th	**14.3**	**F41**	**16.1**	**7.6**	**160**	**9.4**	**< 2**	**14**	**79**	**180**	**150**	**29**	**10**
Tributary at Dosch & Highway 10	14.3	F40	14.7	7.4	270	9.3	< 2	17	130	240	210	29	23
Fanno Creek at 39th	**13.7**	**F38**	**14.4**	**7.5**	**200**	**9.0**	**< 2**	**E 10**	**84**	**170**	**170**	**1.0**	**6.1**
Tributary at 38th &39th Drive	13.7	F39	14.3	7.7	200	8.6	< 2	12	89	180	170	4.0	2.8
Ivey Creek at 45th	13.5	F37	14.0	7.3	200	8.8	< 2	E 10	86	170	160	5.6	4.6
Fanno Creek at 45th	**13.5**	**F36**	**14.5**	**7.5**	**210**	**9.7**	**< 2**	**E 8**	**93**	**180**	**170**	**3.6**	**7.0**
Tributary near Shattuck	13.1	F35	14.2	7.3	240	9.3	< 2	12	57	180	180	.8	1.8
Fanno Creek at 56th	**12.8**	**F34**	**13.9**	**7.3**	**210**	**6.3**	**> 15**	**34**	**92**	**180**	**180**	**6.0**	**10**
Taylor Creek near Seymour	12.8	F33	20.6	7.4	200	9.9	< 2	12	80	160	150	6.4	6.9
Columbia Creek near mouth	12.6	F32	13.2	7.5	190	9	2.1	26.1	72	270	160	100	40
Fanno Creek upstream of Sylvan Creek	**12.3**	**F31**	**15.1**	**7.5**	**200**	**8.2**	**< 2**	**11**	**87**	**160**	**160**	**1.6**	6.0
Sylvan Creek	12.2	F30	16.6	7.3	190	7	< 2	20.2	75	160	150	6.6	15
Pendleton Creek	12.2	F29	20.6	7.4	260	8.5	3.4	35.5	120	470	240	230	96
Fanno Creek at Oleson	**12.0**	**F28**	**13.2**	**7.4**	**200**	**6.5**	**2.1**	**28**	**86**	**260**	**170**	**91**	**56**
Vermont Creek at Oleson	11.5	F27	14.1	7.2	270	7.6	2.6	15	70	240	230	8.4	9
Fanno Creek at Nicole Road	**11.0**	**F26**	**15.2**	**7.0**	**210**	**5.4**	**< 2**	**21**	**80**	**170**	**170**	**3.8**	**7.7**
Multnomah tributary at Oleson	10.7	F25	13.6	7.3	240	8.5	< 2	21.7	93	170	170	2.8	8.4
Fanno Creek at 86th	**10.4**	**F24**	**14.4**	**7.3**	**210**	**7.0**	**< 2**	**21**	**81**	**160**	**160**	**3.0**	**5.1**
Fanno Creek near Allen	**9.6**	**F23**	**15.5**	**7.2**	**180**	**5.1**	**< 2**	**28**	**68**	**160**	**150**	**8.0**	**7.5**
Fanno Creek near Allen—DUPLICATE	**9.6**	**F23**	**--**	**--**	**--**	**--**	**2.3**	**28**	**67**	**150**	**--**	**8.4**	**--**
Wetland near Fanno Creek at Denny	8.6	F22	--	--	--	--	< 2	E 10	45	140	84	53.8	12
Fanno Creek at Denny	**8.6**	**F21**	**16.0**	**7.1**	**200**	**5.5**	**< 2**	**21**	**80**	**170**	**160**	**10**	**12**

Table A2. Field, oxygen-demand, and solids data collected in the Fanno Creek subbasin, September 10, 1996—Continued

[C, Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; NTU, nephelometric turbidity units; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Fanno Creek river mile is point of entry for tributaries; <, less than; E, estimated value; --, no data; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Fanno Creek river mile	Site number	Temperature (degrees C) [10]	Field pH [400]	Field conductivity (µS/cm) [94]	Dissolved oxygen (mg/L) [299]	5-day biochemical oxygen demand (mg/L) [310]	Total chemical oxygen demand (mg/L) [340]	Total alkalinity (mg/L as $CaCO_3$) [410]	Total solids (mg/L) [500]	Total dissolved solids (mg/L) [515]	Total suspended solids (mg/L) [530]	Turbidity (NTU) [76]
Tributary at Bel-Aire	8.3	F20	16.6	7.4	190	8.8	< 2	E 9	76	150	150	3.6	5.5
Fanno Creek at Tuckerwood	**7.5**	**F19**	**17.0**	**7.1**	**200**	**6.3**	**< 2**	**25**	**79**	**170**	**150**	**13**	**13**
Tributary at Greenway School	7.2	F18	16.2	7.6	240	7.3	< 2	E 9	110	180	180	2.4	2.5
Tributary near Gemini	7.2	F17	17.4	6.7	610	< 1	2.2	51.7	92	330	310	23	20
Fanno Creek at Scholls Ferry	**6.6**	**F16**	**16.8**	**7.1**	**250**	**4.5**	**< 2**	**22**	**88**	**190**	**180**	**8.2**	**10**
Tributary at Ironwood Loop	6.2	F15	16.2	6.8	260	3.6	< 2	24.9	120	210	210	5.2	8.7
Ash Creek at Greenburg	5.7	F14	18.5	7	330	2.4	< 2	25.9	130	230	230	6.4	7.1
Fanno Creek at Tigard Street	**5.5**	**F13**	**17.6**	**7.2**	**260**	**5.7**	**< 2**	**23**	**92**	**190**	**180**	**9.2**	**10**
Summer Creek at mouth (Tiedeman)	5.2	F12	18.7	7.4	270	7.2	< 2	13	110	210	200	9.8	8.2
Fanno Creek at Tiedeman	**5.2**	**F11**	**17.6**	**7.4**	**260**	**7.2**	**< 2**	**18**	**97**	**200**	**190**	**10**	**9.8**
Tributary at Walnut	5.0	F10	15.4	7.5	230	8.8	< 2	E 6	96	180	180	2.4	5.9
Fanno Creek at Main	**4.4**	**F9**	**17.6**	**7.5**	**260**	**7.2**	**< 2**	**18**	**100**	**190**	**190**	**7.6**	**8.5**
Tributary at A-boy (Main St. Apts.)	4.2	F8	15.3	7.6	250	8.5	< 2	E 7	120	220	210	14.2	4.6
Fanno Creek at Hall	**3.4**	**F7**	**18.3**	**7.6**	**260**	**7.3**	**< 2**	**15**	**110**	**210**	**200**	**11**	**9.2**
Red Rock at Hunziker	3.2	F6	17.2	7.1	220	3.6	< 2	20.8	95	180	160	17.6	11
Tributary at Fanno Creek Drive	2.5	F5	15.0	7.6	250	8.7	< 2	E 6	110	220	220	5.4	8
Fanno Creek at Bonita	**2.2**	**F4**	**17.2**	**7.2**	**250**	**5.8**	**< 2**	**17**	**100**	**190**	**190**	**5.8**	**6.0**
Fanno Creek at Bonita—DUPLICATE	**2.2**	**F4**	**--**	**--**	**--**	**--**	**< 2**	**16**	**100**	**200**	**--**	**5.6**	**--**
Ball Creek at 74th	2.0	F3	16.4	7.4	230	8.3	< 2	E 7	91	170	160	4	5.5
Fanno Creek at Durham Road	**1.2**	**F2**	**17.2**	**7.3**	**240**	**7.3**	**< 2**	**13**	**98**	**180**	**180**	**2.0**	**4.2**
Fanno Creek at Footbridge	**.3**	**F1**	**17.2**	**7.6**	**240**	**7.9**	**< 2**	**13**	**98**	**190**	**180**	**2.4**	**3.5**

Table A3. Major-ion data collected in the Fanno Creek subbasin, September 10, 1996

[mg/L, milligrams per liter; µg/L, micrograms per liter; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Fanno Creek river mile is point of entry for tributaries; E, estimated value; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Fanno Creek river mile	Site number	Total calcium (mg/L) [916]	Total magnesium (mg/L) [927]	Total sodium (mg/L) [929]	Chloride (mg/L) [940]	Sulfate (mg/L) [945]	Total barium (µg/L) [1007]	Total iron (µg/L) [1045]	Total manganese (µg/L) [1055]	Total aluminum (µg/L) [1105]
Fanno Creek at 30th	**14.3**	**F41**	**25**	**7.5**	**11**	**7.3**	**9.0**	**35**	**2,200**	**320**	**1,000**
Tributary at Dosch & Highway 10	14.3	F40	35	11	13	6.7	5.8	47	4,500	1,000	1,500
Fanno Creek at 39th	**13.7**	**F38**	**25**	**8.0**	**10**	**8.3**	**6.5**	**29**	**1,100**	**130**	**E 100**
Tributary at 38th & 39th Drive	13.7	F39	26	8.3	10	6.7	9.5	37	450	51	E 200
Ivey Creek at 45th	13.5	F37	23	7.9	10	6.7	6.9	31	1,200	380	E 200
Fanno Creek at 45th	**13.5**	**F36**	**25**	**8.7**	**10**	**6.1**	**5.7**	**31**	**1,100**	**240**	**E 300**
Tributary near Shattuck	13.1	F35	23	6.3	17	29.0	10.9	48	300	16	E 100
Fanno Creek at 56th	**12.8**	**F34**	**25**	**8.3**	**11**	**9.6**	**5.7**	**36**	**1,400**	**360**	**E 300**
Taylor Creek near Seymour	12.8	F33	24	6.0	11	10.6	6.7	36	1,700	1,400	E 200
Columbia Creek near mouth	12.6	F32	23	7.4	13	13.3	8.6	83	6,500	380	6,300
Fanno Creek upstream of Sylvan Creek	**12.3**	**F31**	**24**	**7.8**	**10**	**7.5**	**6.7**	**33**	**1,000**	**140**	**E 100**
Sylvan Creek	12.2	F30	22	7.3	9	8.3	10.0	38	2,200	450	810
Pendleton Creek	12.2	F29	32	12.8	14	9.5	6.7	170	16,400	1,200	16,000
Fanno Creek at Oleson	**12.0**	**F28**	**25**	**8.7**	**11**	**8.4**	**8.9**	**92**	**8,000**	**860**	**6,900**
Vermont Creek at Oleson	11.5	F27	28	10.2	12	8.2	6.7	46	1,400	86	550
Fanno Creek at Nicole Road	**11.0**	**F26**	**24**	**7.8**	**10**	**8.4**	**9.1**	**39**	**1,300**	**230**	**420**
Multnomah tributary at Oleson	10.7	F25	28	8.6	10	6.7	13.3	39	1,300	160	E 300
Fanno Creek at 86th	**10.4**	**F24**	**24**	**7.7**	**10**	**8.5**	**9.4**	**33**	**840**	**150**	**E 200**
Fanno Creek near Allen	**9.6**	**F23**	**21**	**6.7**	**8.3**	**7.3**	**8.6**	**37**	**1,300**	**340**	**520**
Fanno Creek near Allen—DUPLICATE	**9.6**	**F23**	**21**	**6.6**	**8.2**	**7.6**	**8.2**	**38**	**1,300**	**340**	**520**
Wetland near Fanno Creek at Denny	8.6	F22	12	3.5	13	4.6	9.3	34	2,600	170	2,000
Fanno Creek at Denny	**8.6**	**F21**	**23**	**7.6**	**10**	**8.0**	**8.1**	**43**	**1,800**	**550**	**890**

Table A3. Major-ion data collected in the Fanno Creek subbasin, September 10, 1996—Continued

[mg/L, milligrams per liter; µg/L, micrograms per liter; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Fanno Creek river mile is point of entry for tributaries; E, estimated value; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Fanno Creek river mile	Site number	Total calcium (mg/L) [916]	Total magnesium (mg/L) [927]	Total sodium (mg/L) [929]	Chloride (mg/L) [940]	Sulfate (mg/L) [945]	Total barium (µg/L) [1007]	Total iron (µg/L) [1045]	Total manganese (µg/L) [1055]	Total aluminum (µg/L) [1105]
Tributary at Bel-Aire	8.3	F20	21	6.4	12	6.6	10.7	36	1,600	160	E 300
Fanno Creek at Tuckerwood	**7.5**	**F19**	**23**	**7.5**	**11**	**8.2**	**8.5**	**43**	**2,000**	**360**	**1,200**
Tributary at Greenway School	7.2	F18	32	9.8	13	5.4	8.5	29	330	36	E 200
Tributary near Gemini	7.2	F17	41	10.2	34	78.5	9.4	67	3,800	630	490
Fanno Creek at Scholls Ferry	**6.6**	**F16**	**30**	**8.5**	**15**	**19**	**8.7**	**45**	**1,500**	**450**	**630**
Tributary at Ironwood Loop	6.2	F15	33	11.2	11	5.8	9.0	56	1,300	810	520
Ash Creek at Greenburg	5.7	F14	36	13.6	14	24.1	E 3	38	1,200	1,200	E 200
Fanno Creek at Tigard Street	**5.5**	**F13**	**29**	**9.2**	**15**	**20**	**8.0**	**45**	**1,500**	**390**	**860**
Summer Creek at mouth (Tiedeman)	5.2	F12	33	11.6	14	16.0	8.4	53	1,200	310	830
Fanno Creek at Tiedeman	**5.2**	**F11**	**31**	**10**	**14**	**17**	**8.9**	**49**	**1,500**	**330**	**990**
Tributary at Walnut	5.0	F10	27	9.9	10	7.4	7.2	27	1,000	170	E 200
Fanno Creek at Main	**4.4**	**F9**	**32**	**10**	**13**	**16**	**9.1**	**47**	**1,200**	**310**	**660**
Tributary at A-boy (Main St. Apts.)	4.2	F8	35	11.6	10	6.5	8.8	39	1,400	550	540
Fanno Creek at Hall	**3.4**	**F7**	**33**	**11**	**13**	**15**	**8.9**	**49**	**1,400**	**420**	**750**
Red Rock at Hunziker	3.2	F6	31	8.9	11	11.0	5.3	66	2,000	1,200	1,300
Tributary at Fanno Creek Drive	2.5	F5	33	12.2	10	6.5	11.0	30	1,400	340	E 300
Fanno Creek at Bonita	**2.2**	**F4**	**30**	**11**	**12**	**13**	**8.8**	**40**	**1,200**	**290**	**E 400**
Fanno Creek at Bonita—DUPLICATE	**2.2**	**F4**	**29**	**11**	**12**	**13**	**8.5**	**38**	**940**	**290**	**E 400**
Ball Creek at 74th	2.0	F3	28	9.9	10	6.1	9.6	32	1,100	190	E 300
Fanno Creek at Durham Road	**1.2**	**F2**	**31**	**11**	**12**	**11**	**9.4**	**38**	**800**	**230**	**E 200**
Fanno Creek at Footbridge	**.3**	**F1**	**30**	**9.9**	**12**	**12**	**8.7**	**36**	**580**	**160**	**E 100**

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Table A4. Discharge, phosphorus, nitrogen, and *E. coli* data collected in the Bronson Creek subbasin, September 24, 1996

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; NH_3, ammonia; mL, milliliters; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Bronson Creek river mile is point of entry for tributaries; ≤, less than or equal to; A, error ≤ 2%; B, error ≤ 5%; C, error ≤ 8%; D, error > 8%; E, estimated value; --, no data; <, less than; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Bronson Creek river mile	Site number	Instantaneous flow (ft^3/s) [61]	Quality of flow measurement	Total phosphorus (mg/L as P) [665]	Dissolved ortho-phosphate (mg/L as P) [671]	Ratio of dissolved ortho-phosphate to total phosphorus	Soluble NH_3 (mg/L as N) [608]	Total Kjeldahl nitrogen (mg/L as N) [625]	Soluble nitrate-nitrite (mg/L as N) [631]	*E. coli* (organisms per 100 mL) [31648]
Bronson Creek near Thompson Road	**6.5**	**B18**	**0.006**	**A**	**0.35**	**E 0.025**	**E 0.07**	**0.52**	**1.8**	**0.47**	**1,000**
South Bronson Creek near Laidlaw	**6.0**	**B17**	**.12**	**B**	**.11**	**.054**	**.49**	**< .02**	**.20**	**.63**	**260**
North Bronson Creek near Laidlaw	6.0	B16	.041	A	.15	.047	.31	E .05	.27	.13	150
Bronson Creek at Saltzman Road	**5.3**	**B15**	**.02**	**D**	**.13**	**.065**	**.50**	**E .02**	**.18**	**.63**	**E 10**
Bronson Creek upstream of Bannister	**5.2**	**B14**	**.19**	**C**	**.13**	**.069**	**.52**	**< .02**	**.21**	**.61**	**96**
Bannister at Laidlaw	5.2	B13	.082	C	.11	.085	.75	< .02	.14	.17	800
Bannister at 124th	5.2	B12	.038	A	.11	.092	.84	< .02	E .1	.40	E 20
Bronson Creek downstream of Bannister	**5.2**	**B11**	**.22**	**C**	**.12**	**.071**	**.61**	**< .02**	**.22**	**.52**	**260**
Bronson Creek upstream of Kaiser Road	**3.9**	**B10**	**.38**	**C**	**.19**	**E .024**	**E .13**	**E .03**	**.34**	**.56**	**E 1,000**
Bronson Creek at Kaiser Road	**3.8**	**B9**	**.49**	**C**	**.14**	**.026**	**.18**	**E .03**	**.33**	**.54**	**2,100**
Tributary downstream of Kaiser Road	3.8	B8	.056	C	.15	.068	.45	E .03	.45	2.6	1,100
Bronson Creek at West Union	**3.3**	**B7**	**.20**	**C**	**.15**	**.036**	**.23**	**< .02**	**.35**	**.78**	**980**
Bronson Creek at Bronson Creek Park	**2.2**	**B6**	**.8**	**D**	**.13**	**.027**	**.20**	**< .02**	**.38**	**.18**	**280**
Bronson Creek at Cornell	**2.0**	**B5**	**.4**	**D**	**.11**	**.028**	**.25**	**< .02**	**.32**	**.099**	**130**
Bronson Creek at 179th	**1.8**	**B4**	**.8**	**D**	**.13**	**.042**	**.33**	**E .03**	**.45**	**E .03**	**120**
Bronson Creek at 185th	**1.5**	**B3**	**.6**	**D**	**.17**	**.036**	**.21**	**< .02**	**.87**	**E .03**	**E 60**
Bronson Creek at Walker Road	**1.1**	**B2**	**.79**	**C**	**.16**	**.036**	**.23**	**< .02**	**.67**	**.10**	**E 60**
Bronson Creek near 205th	**.1**	**B1**	**.7**	**D**	**.16**	**.041**	**.26**	**E .03**	**.45**	**.14**	**180**
Bronson Creek near 205th—DUPLICATE	**.1**	**B1**	**--**	**--**	**.16**	**.042**	**.26**	**E .03**	**.46**	**.13**	**140**

Table A5. Field, oxygen-demand, and solids data collected in the Bronson Creek subbasin, September 24, 1996

[C, Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; NTU, nephelometric turbidity units; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Bronson Creek river mile is point of entry for tributaries; <, less than; E, estimated value; --, no data; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Bronson Creek river mile	Site number	Temperature (degrees C) [10]	Field pH [400]	Field conductivity (µS/cm) [94]	Dissolved oxygen (mg/L) [299]	5-day biochemical oxygen demand (mg/L) [310]	Total chemical oxygen demand (mg/L) [340]	Total alkalinity (mg/L as $CaCO_3$) [410]	Total solids (mg/L) [500]	Total dissolved solids (mg/L) [515]	Total suspended solids (mg/L) [530]	Turbidity (NTU) [76]
Bronson Creek near Thompson Road	**6.5**	**B18**	**11.0**	**7.6**	**200**	**9.3**	**3.9**	**24**	**57**	**210**	**150**	**61**	**48**
South Bronson Creek near Laidlaw	**6.0**	**B17**	**9.9**	**8.2**	**160**	**12**	**< 2**	**E 7**	**52**	**140**	**130**	**5.6**	**12**
North Bronson Creek near Laidlaw	6.0	B16	10.5	8.1	180	12	< 2	40	73	170	150	24	17
Bronson Creek at Saltzman Road	**5.3**	**B15**	**10.5**	**8.1**	**210**	**12**	**< 2**	**E 7**	**67**	**160**	**150**	**4.4**	**9.2**
Bronson Creek upstream of Bannister	**5.2**	**B14**	**9.9**	**7.6**	**200**	**9.8**	**< 2**	**E 6**	**64**	**150**	**150**	**3.0**	**9.3**
Bannister at Laidlaw	5.2	B13	9.6	7.4	180	9.4	< 2	E 6	66.8	150	150	2	3.8
Bannister at 124th	5.2	B12	10.4	7.7	160	10.9	< 2	< 5	56.8	140	130	3.6	4.9
Bronson Creek downstream of Bannister	**5.2**	**B11**	**9.8**	**7.5**	**200**	**10**	**< 2**	**E 7**	**65**	**150**	**150**	**3.0**	**8.2**
Bronson Creek upstream of Kaiser Road	**3.9**	**B10**	**10.2**	**7.2**	**240**	**7.1**	**< 2**	**13**	**77**	**190**	**180**	**8.2**	**18**
Bronson Creek at Kaiser Road	**3.8**	**B9**	**10.5**	**7.2**	**260**	**7.1**	**< 2**	**11**	**80**	**190**	**180**	**10**	**19**
Tributary downstream of Kaiser Road	3.8	B8	11.9	7.2	210	7.8	< 2	E 6	59	170	150	20	11
Bronson Creek at West Union	**3.3**	**B7**	**11.3**	**7.3**	**250**	**8.5**	**< 2**	**11**	**76**	**190**	**180**	**11**	**21**
Bronson Creek at Bronson Creek Park	**2.2**	**B6**	**10.6**	**7.6**	**260**	**9.0**	**< 2**	**15**	**86**	**170**	**170**	**3.2**	**10**
Bronson Creek at Cornell	**2.0**	**B5**	**13.2**	**7.5**	**230**	**11**	**< 2**	**13**	**85**	**170**	**160**	**4.0**	**8.0**
Bronson Creek at 179th	**1.8**	**B4**	**12.8**	**7.7**	**230**	**6.4**	**< 2**	**16**	**86**	**170**	**160**	**2.6**	**6.1**
Bronson Creek at 185th	**1.5**	**B3**	**14.8**	**7.6**	**190**	**8.7**	**2.6**	**26**	**67**	**160**	**140**	**12**	**12**
Bronson Creek at Walker Road	**1.1**	**B2**	**13.4**	**7.3**	**200**	**7.2**	**< 2**	**23**	**73**	**160**	**150**	**9.2**	**12**
Bronson Creek near 205th	**.1**	**B1**	**12.0**	**7.1**	**200**	**7.5**	**< 2**	**17**	**76**	**160**	**150**	**5.2**	**12**
Bronson Creek near 205th—DUPLICATE	**.1**	**B1**	**--**	**--**	**--**	**--**	**< 2**	**18**	**75**	**160**	**--**	**5.2**	**--**

Table A6. Major-ion data collected in the Bronson Creek subbasin, September 24, 1996

[mg/L, milligrams per liter; µg/L, micrograms per liter; number in brackets below parameter name indicates STORET (U.S. Environmental Protection Agency Storage and Retrieval system database) code; Bronson Creek river mile is point of entry for tributaries; <, less than; E, estimated value; bolded rows indicate main-stem sites and shaded rows indicate tributary sites]

	Bronson Creek river mile	Site number	Total calcium (mg/L) [916]	Total magnesium (mg/L) [927]	Total sodium (mg/L) [929]	Chloride (mg/L) [940]	Sulfate (mg/L) [945]	Total barium (µg/L) [1007]	Total iron (µg/L) [1045]	Total manganese (µg/L) [1055]	Total aluminum (µg/L) [1105]
Bronson Creek near Thompson Road	**6.5**	**B18**	**20**	**6**	**12**	**8**	**7**	**83**	**6,200**	**430**	**6,000**
South Bronson Creek near Laidlaw	**6.0**	**B17**	**16**	**5.4**	**10**	**5.1**	**5.2**	**30**	**1,700**	**110**	**1,300**
North Bronson Creek near Laidlaw	6.0	B16	21	7.5	8.1	4.0	< 2.5	44	3,300	240	2,100
Bronson Creek at Saltzman Road	**5.3**	**B15**	**21**	**7.2**	**13**	**10**	**4.3**	**36**	**1,400**	**46**	**910**
Bronson Creek upstream of Bannister	**5.2**	**B14**	**23**	**6.8**	**13**	**8.8**	**5.0**	**38**	**1,400**	**82**	**800**
Bannister at Laidlaw	5.2	B13	20	7.1	10	9.8	< 2.5	36	680	43	E 400
Bannister at 124th	5.2	B12	17	5.8	8.1	4.1	< 2.5	29	560	E 8	660
Bronson Creek downstream of Bannister	**5.2**	**B11**	**22**	**6.8**	**12**	**9.6**	**E 4**	**37**	**1,200**	**72**	**730**
Bronson Creek upstream of Kaiser Road	**3.9**	**B10**	**29**	**8.5**	**14**	**18**	**5.4**	**47**	**2,500**	**740**	**1,300**
Bronson Creek at Kaiser Road	**3.8**	**B9**	**30**	**8.9**	**14**	**18**	**E 4**	**47**	**2,600**	**690**	**1,500**
Tributary downstream of Kaiser Road	3.8	B8	22	6.2	13	9.2	10	49	1,400	120	1,300
Bronson Creek at West Union	**3.3**	**B7**	**29**	**8.9**	**14**	**17**	**E 5**	**48**	**2,500**	**320**	**1,900**
Bronson Creek at Bronson Creek Park	**2.2**	**B6**	**27**	**8.8**	**13**	**15**	**E 4**	**29**	**1,600**	**320**	**E 300**
Bronson Creek at Cornell	**2.0**	**B5**	**31**	**9.1**	**13**	**15**	**E 3**	**28**	**1,300**	**140**	**E 300**
Bronson Creek at 179th	**1.8**	**B4**	**31**	**9.0**	**12**	**13**	**7.7**	**27**	**910**	**57**	**E 300**
Bronson Creek at 185th	**1.5**	**B3**	**25**	**7.1**	**9.7**	**11**	**6.5**	**29**	**1,400**	**110**	**980**
Bronson Creek at Walker Road	**1.1**	**B2**	**26**	**7.6**	**9.8**	**11**	**6.6**	**35**	**1,500**	**130**	**1,100**
Bronson Creek near 205th	**.1**	**B1**	**29**	**7.9**	**9.6**	**10**	**8.7**	**38**	**1,700**	**350**	**780**
Bronson Creek near 205th—DUPLICATE	**.1**	**B1**	**29**	**8.0**	**9.4**	**10**	**8.4**	**39**	**1,700**	**350**	**800**

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