VARIABILITY IN BASE STREAMFLOW AND WATER QUALITY OF STREAMS AND SPRINGS IN OTTER AND ROSEBUD CREEK BASINS, SOUTHEASTERN MONTANA

By John H. Lambing and Rodger F. Ferreira

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 85-4302

Helena, Montana
March 1986

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

The following factors can be used to convert inch-pound units in this report to the International System (SI) of metric units.

Multiply inch-pound unit	By	To obtain SI unit
cubic foot per second (ft^3/s)	28.32	liter per second
foot	0.3048	meter
gallon per minute (gal/min)	0.06309	liter per second
inch	25.40	millimeter
mile	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
ton per day (ton/d)	0.0105	kilogram per second

Temperature can be converted from degrees Celsius (°C) to degrees Fahrenheit (°F) by the equation:

$$°F = 9/5\ (°C) + 32$$

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ABSTRACT

Three base-flow synoptic studies were conducted on Otter and Rosebud Creeks during October-November of 1977, 1978, and 1983 to assess the range of base-flow variability during years of widely different precipitation. In addition, water samples from a large areal distribution of springs in the Otter and Rosebud Creek basins were collected and analyzed to provide an indication of spatial and temporal variability of shallow ground-water quality throughout each basin.

The magnitude of base streamflow in Otter and Rosebud Creeks varies considerably in response to the precipitation available for ground-water recharge during the previous year. Maximum differences in base-flow magnitudes during the 3 study years were 3.8 cubic feet per second in Otter Creek and 53 cubic feet per second in Rosebud Creek. Streamflow gain-and-loss patterns were inconsistent from year to year in some reaches of Otter Creek, whereas trends in most reaches of Rosebud Creek were similar during each year.

The predominant ions of base streamflow are sodium, magnesium, and sulfate in Otter Creek and magnesium, calcium, sodium, sulfate, and bicarbonate in Rosebud Creek. The ionic composition of base flow during the study years varied only slightly in Otter Creek and moderately in Rosebud Creek. Dissolved-solids concentrations were more variable, with maximum differences between study years of about 1,200 milligrams per liter in Otter Creek and about 3,200 milligrams per liter in Rosebud Creek.

Springs in the Otter Creek basin are characterized by water containing primarily sodium, magnesium, and sulfate. Springs in the Rosebud Creek basin are characterized by water containing primarily magnesium, calcium, sodium, sulfate, and bicarbonate. Dissolved-solids concentrations in springs range from 720 to 5,700 milligrams per liter in the Otter Creek basin and from about 250 to 4,200 milligrams per liter in the Rosebud Creek basin. Although the areal variation in ionic composition and dissolved-solids concentrations of springs is large in both basins, variability of individual springs between sampling periods was small.

The large range of base streamflow magnitudes, gain-loss patterns, and water quality in Otter and Rosebud Creeks during climatologically different years indicates that natural variability of base flow can be significant. Such variability indicates that multiple measurements are necessary to properly describe base-flow characteristics.

INTRODUCTION

Surface mining of shallow coal deposits in southeastern Montana (fig. 1) is proceeding on a large scale in several areas and probably will expand to other areas. The effects of mining activities on surface- and ground-water resources can be determined only if an adequate pre-mining data base is established. Particularly important is a knowledge of base-flow characteristics of streams, because it is during such flow conditions that maximum dissolved-solids concentrations would likely occur. To accurately predict the effects of mining on the quantity and quality of surface water, the interaction between the surface- and ground-water systems needs to be understood. Such an understanding includes not only a delineation of gaining and losing stream reaches, but also an assessment of the natural variability in the quantity and quality of ground-water inflow to the streams.

Several synoptic studies have been conducted to describe the quantity and quality of base flow at several sites along the entire length of selected streams in southeastern Montana (Druse and others, 1981; Lee and others, 1981). The combined information available from these investigations enables an assessment of how well a single set of base-flow measurements represents "average" base-flow characteristics as generalized from studies conducted during years of widely different precipitation. Defining both spatial and temporal variability of flow magnitudes and water quality may indicate if refinement of techniques for estimating ground-water inflow is needed for use in existing salinity models developed for streams in southeastern Montana (Woods, 1981; Ferreira, 1984).

Sampling of springs can be used to identify the areal variability of water quality in shallow aquifers that contribute to downgradient changes in water quality of base streamflow. In addition, comparison of the quality of water from springs between different sampling periods can indicate ranges of constituent concentrations representative of natural variability. Documenting this background variability is essential to properly evaluate effects from surface coal mining. A pre-mining data base for springs, especially those downgradient from potential mine areas, can serve as a reference for detecting changes outside the expected range of natural conditions.

Purpose and scope

This investigation is part of the Federal Energy Program, which was initiated to provide an appraisal of pre-mining water resources and to assess the potential effects of coal development on those resources. The principal objectives of this investigation were: (1) To describe the areal and temporal variability in the magnitude and quality of base streamflow in Otter and Rosebud Creeks during years of widely different precipitation conditions, and (2) to describe the areal and temporal variability in water quality of springs in the Otter and Rosebud Creek basins.

This report presents data collected during autumn base-flow conditions of 1977, 1978, and 1983 on Otter and Rosebud Creeks (fig. 2), both of whose basins contain potentially mineable coal fields (fig. 1). Also presented are data collected from selected springs in the drainages of both creeks.

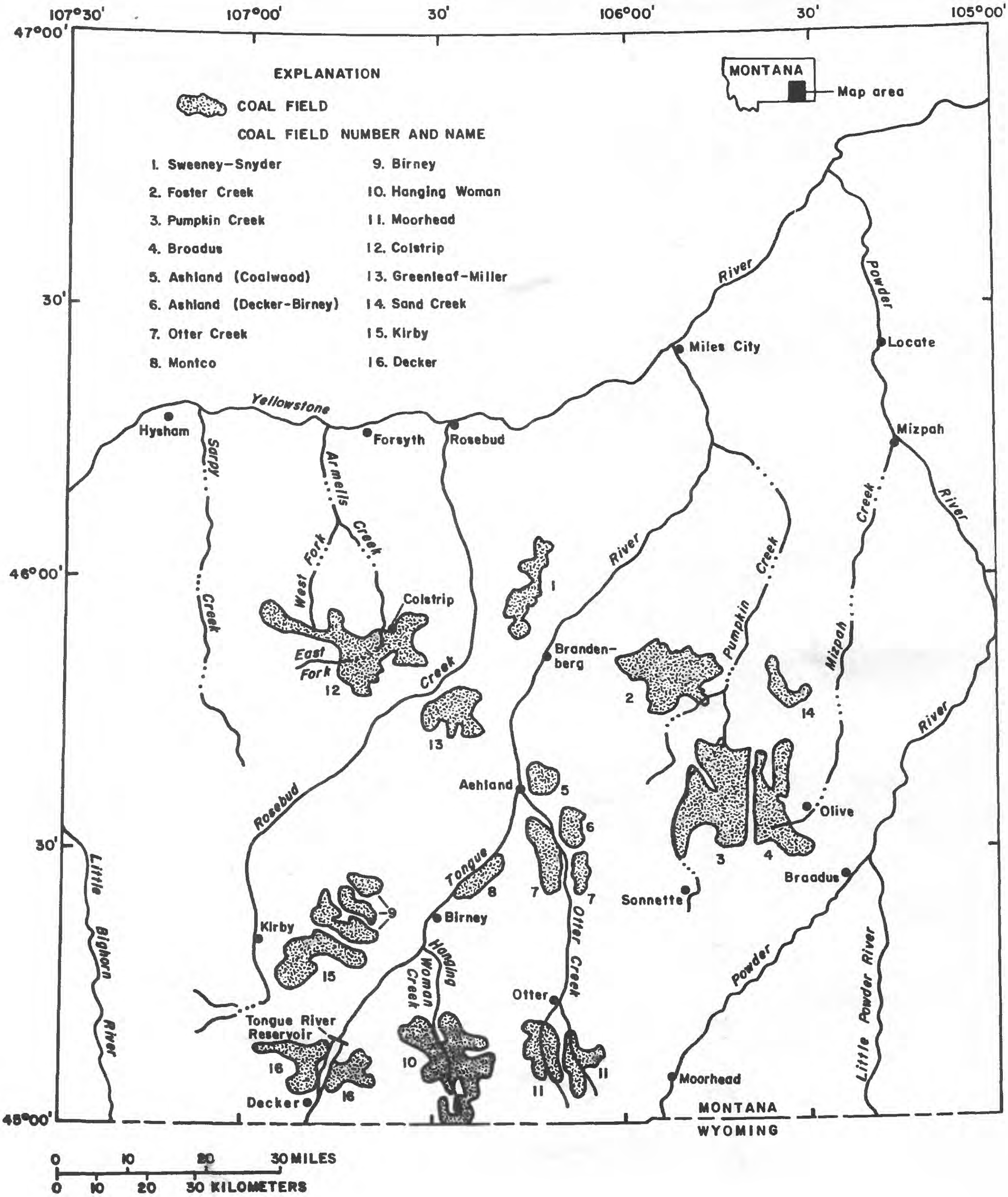

Figure 1.--Location of potentially mineable shallow coal deposits in southeastern Montana.

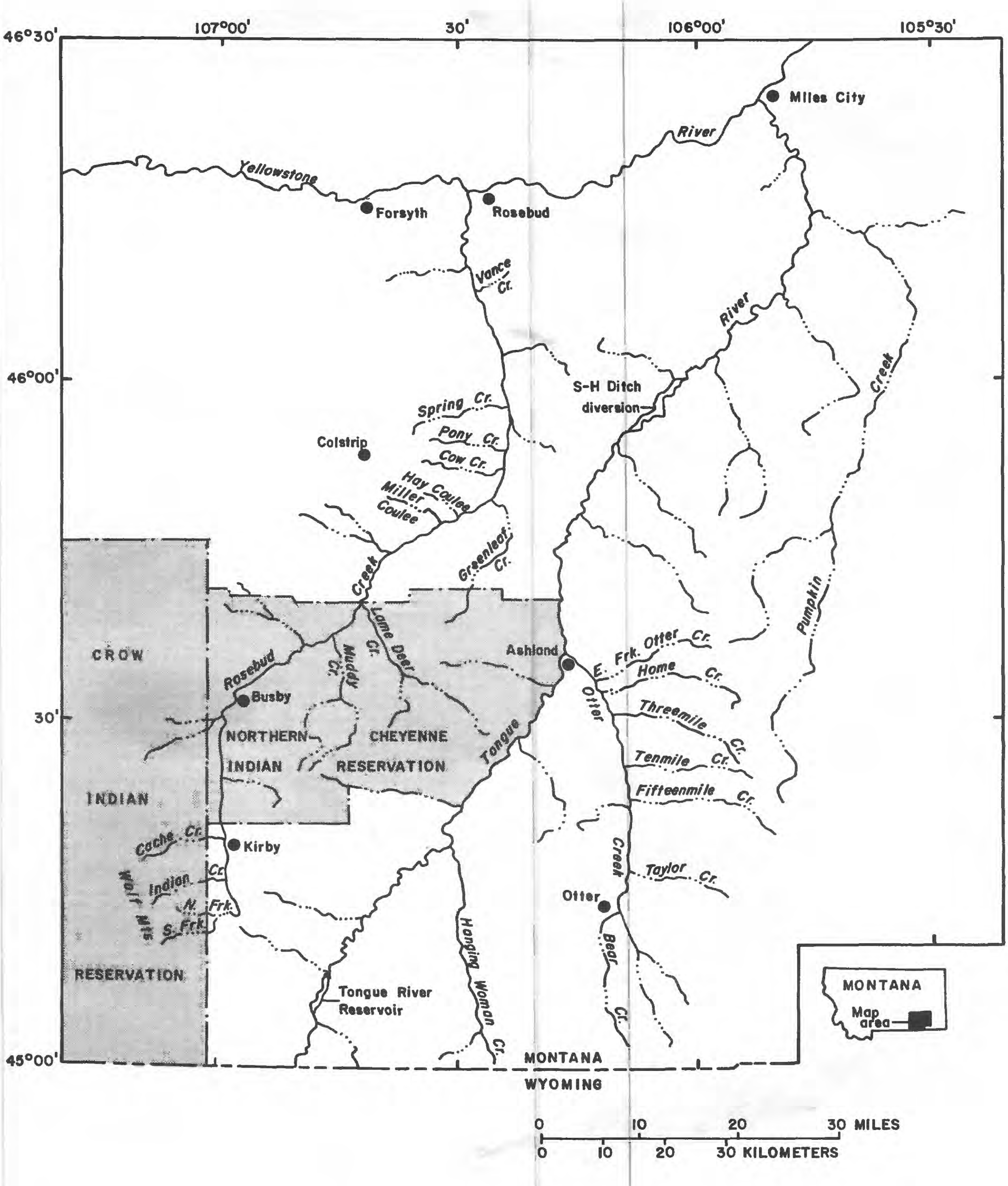

Figure 2.--Location of study area.

Geologic setting

Geologic formations having the most significant effect on streamflow characteristics are those that are transected by the streams. Bedrock formations transected by streams in the study area are the Hell Creek Formation of Late Cretaceous age and the Fort Union Formation of Paleocene age. Alluvium of Holocene age directly underlies the channels of the major streams. General descriptions of the formations occurring within the study area follow. For a more complete description of the geologic units and their associated water-yielding characteristics in southeastern Montana, the reader is referred to a map report by Lewis and Roberts (1978).

The Hell Creek Formation consists principally of gray to yellowish-gray silty, clayey, sandy, carbonaceous, and bentonitic shale and siltstone. Locally, a yellowish-gray to tan fine- to medium-grained silty sandstone containing thin coal beds predominates. The formation is as much as 850 feet thick in the study area.

The Fort Union Formation overlies the Hell Creek Formation. The Fort Union consists of the basal Tullock Member, the intervening Lebo Shale Member, and the overlying Tongue River Member.

The lower part of the Tullock Member is composed of interbedded medium- to light-gray shale, fine-grained light-gray sandstone and siltstone, and thin, persistent coal beds. The member grades upward to a light-gray carbonaceous shale and locally is capped by a resistant sandstone rimrock. Maximum thickness of the Tullock Member in the study area is 800 feet.

The Lebo Shale Member consists of predominantly dark shale interbedded with light-gray and brown to black carbonaceous shale, siltstone, and local thin coal beds. Locally, the member contains coarse-grained sandstone deposited in scoured channels. Thickness of the member may be as much as 600 feet in the study area.

The Tongue River Member is composed of fine- to medium-grained massive to locally crossbedded and lenticular sandstone and siltstone, attaining a thickness of 2,500 feet in places. The member commonly contains shale and numerous coal beds as much as 80 feet thick. Burning of coal beds along the outcrops has baked the overlying and underlying rocks to form red and lavender clinker.

Alluvium along the streams contains sand, silt, clay, and local lenses of gravel. Gravel consists of clinker fragments along many smaller streams. Deposits are as much as 40 feet thick along the smaller streams in the study area. This unit includes many low-lying terraces adjacent to streams.

Hydrologic setting

The principal aquifers in the study area are rock units within the Tongue River Member of the Fort Union Formation. Water is transmitted primarily through sandstone, coal, and clinker. Interbedded shale and relatively impermeable siltstone are confining layers that restrict ground-water recharge, movement, and discharge.

Water is contained in many localized shallow systems at depths generally less than 200 feet below land surface. The configuration of the water tables in these shallow systems generally parallels that of the surface topography. Ground water generally moves from near the basin divide toward the major stream in the drainage. Recharge of shallow aquifers occurs in the area between the drainage divide and the principal stream channel. Water movement at depths of greater than about 200 feet follows more regional patterns and is less affected by local factors such as topography and localized recharge.

Base flow in streams occurs when surface runoff is absent and streamflow consists of water discharged primarily from shallow aquifers into the stream channel. Upward leakage from deeper artesian aquifers to the streams may occur, but the quantity probably is small. Streamflow can be lost into the alluvium in reaches where the water table is below the streambed. Additional water losses can result from surface evaporation and from transpiration by aquatic and riparian vegetation during the growing season. Stream reaches in which there is a net increase in flow are termed "gaining reaches"; those in which there is a net loss of flow are termed "losing reaches."

Data collection

Investigation of the base-flow characteristics of Otter and Rosebud Creeks consisted of obtaining three sets of streamflow measurements on each creek during late October-early November of 1977, 1978, and 1983. Streamflow-measurement sites were selected along the mainstems of Otter and Rosebud Creeks to provide a uniform distribution of points that potentially could indicate variability in either streamflow or water quality due to geologic differences or major sources of tributary inflow. In addition to mainstem sites, tributary streams with flow were measured.

Data collection for the three sets of measurements began after frosts had rendered the vegetation dormant; therefore, quantities of either stream water or shallow ground water lost by transpiration were negligible. Records from gaging stations on the streams showed that streamflow during the study period was stable. No overland runoff from precipitation was present during any of the three sets of measurements. Although ground-water seepage from irrigated areas may have continued to augment flow following the seasonal discontinuance of irrigation, the quantity cannot be determined accurately and is probably minimal. As a result, the predominant factor affecting streamflow and water quality was presumed to be the interchange of flow between the surface- and ground-water systems.

Water-quality samples were collected at several streamflow-measurement sites during each of the study years. The absence of flow precluded sample collection at several of the designated sites in 1977 and 1983. The water samples were analyzed for common ions, nutrients, and selected trace metals by the U.S. Geological Survey laboratory in Denver, Colo.

Discharge and water-quality data were collected from selected springs in the Otter Creek and Rosebud Creek basins during June and July of 1984. Most of the springs sampled in 1984 had been sampled 5 to 10 years earlier. Comparison of data for springs that had been sampled previously provided an indication of the natural variability in the water quality of springs. Spring samples were analyzed for common ions and selected trace metals. Samples collected prior to 1984 were analyzed by the Montana Bureau of Mines and Geology laboratory in Butte, Montana. Samples collected in 1984 were analyzed by the U.S. Geological Survey laboratory in Denver, Colo.

Results of base-flow and water-quality measurements made during 1977 and 1978 on Otter and Rosebud Creeks are presented in reports by Druse and others (1981) and Lee and others (1981). Results of spring discharge and water-quality measurements made prior to 1984 are presented by Lee (1979).

MAGNITUDE OF BASE STREAMFLOW

Otter Creek

Otter Creek, which is perennial in most reaches, drains an area of about 700 mi^2 in southeastern Montana (fig. 2). The stream originates near the Montana-Wyoming border and flows about 90 river miles to its confluence with the Tongue River at Ashland, Mont. Major tributaries to Otter Creek generally contribute little or no surface inflow during base-flow conditions.

Otter Creek is underlain entirely by the Tongue River Member of the Fort Union Formation, but transects several different lithologic units. Most ground-water discharge to Otter Creek is from sandstones in the Tongue River Member and from the alluvium.

Twenty sites in the Otter Creek basin were selected for streamflow measurements (fig. 3). Fourteen of these sites were on the mainstem of Otter Creek and 6 were on major tributaries. In 1977, streamflow was measured at 10 sites on the mainstem of Otter Creek and at 5 sites on tributaries; no flow was observed at 4 mainstem sites and 1 tributary site. In 1978, only eight of the mainstem sites and one tributary were included in the base-flow investigation. Streamflow was present and measured at all nine sites. During the 1983 base-flow study, streamflow measurements or observations were made at all 20 sites. Streamflow also was measured at an additional site, O-10A (Otter Creek below Fifteenmile Creek, near Otter), which is a recently established streamflow-gaging station (fig. 3). In 1983, no flow was observed at three mainstem sites and two tributaries. Results of the 1977, 1978, and 1983 base-flow measurements and the net change in streamflow between mainstem sites on Otter Creek are given in table 1.

Differences in streamflow magnitudes during the three study periods can be attributed largely to variability in precipitation during the year preceeding the October-November measurement period. Precipitation quantities generally indicate the relative availability of water to recharge shallow aquifers, which subsequently is reflected in the annual variation of base flow. Monthly precipitation and departures from average at weather stations in the Otter Creek basin (fig. 3) during the 12 months prior to each study period are presented in table 2.

Streamflow profiles of Otter Creek during October base-flow conditions of 1977, 1978, and 1983 are presented in figure 4. Considerable variability in streamflow patterns and magnitudes are evident in the profiles. As indicated in table 2, 1977 precipitation was slightly less than normal, 1978 was very wet, and 1983 was very dry. The base-flow profile for 1978 reflects the abundant moisture available to recharge aquifers, as streamflow at every site was larger than during the 1977 and 1983 studies. The differences between profiles for 1977 and 1983 are not so clearly related to precipitation quantities. Although 1983 was considerably drier than 1977, streamflow in the middle reaches of Otter Creek was greater in 1983 than in 1977, and nearly identical in the upstream and downstream reaches. Carry-over of recharge waters from 1 to several years prior to the study may account for

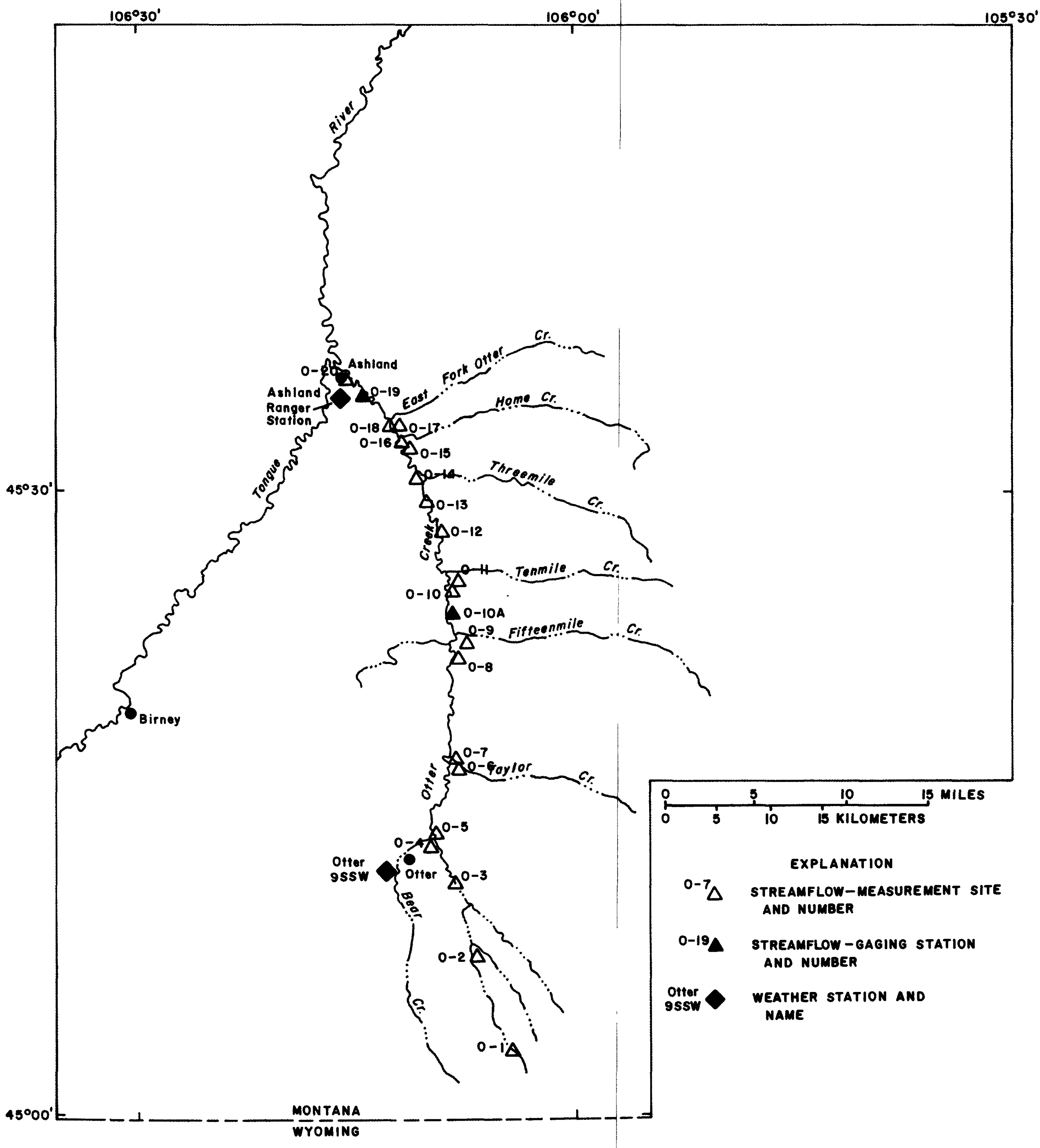

Figure 3.--Location of streamflow-measurement sites on Otter Creek.

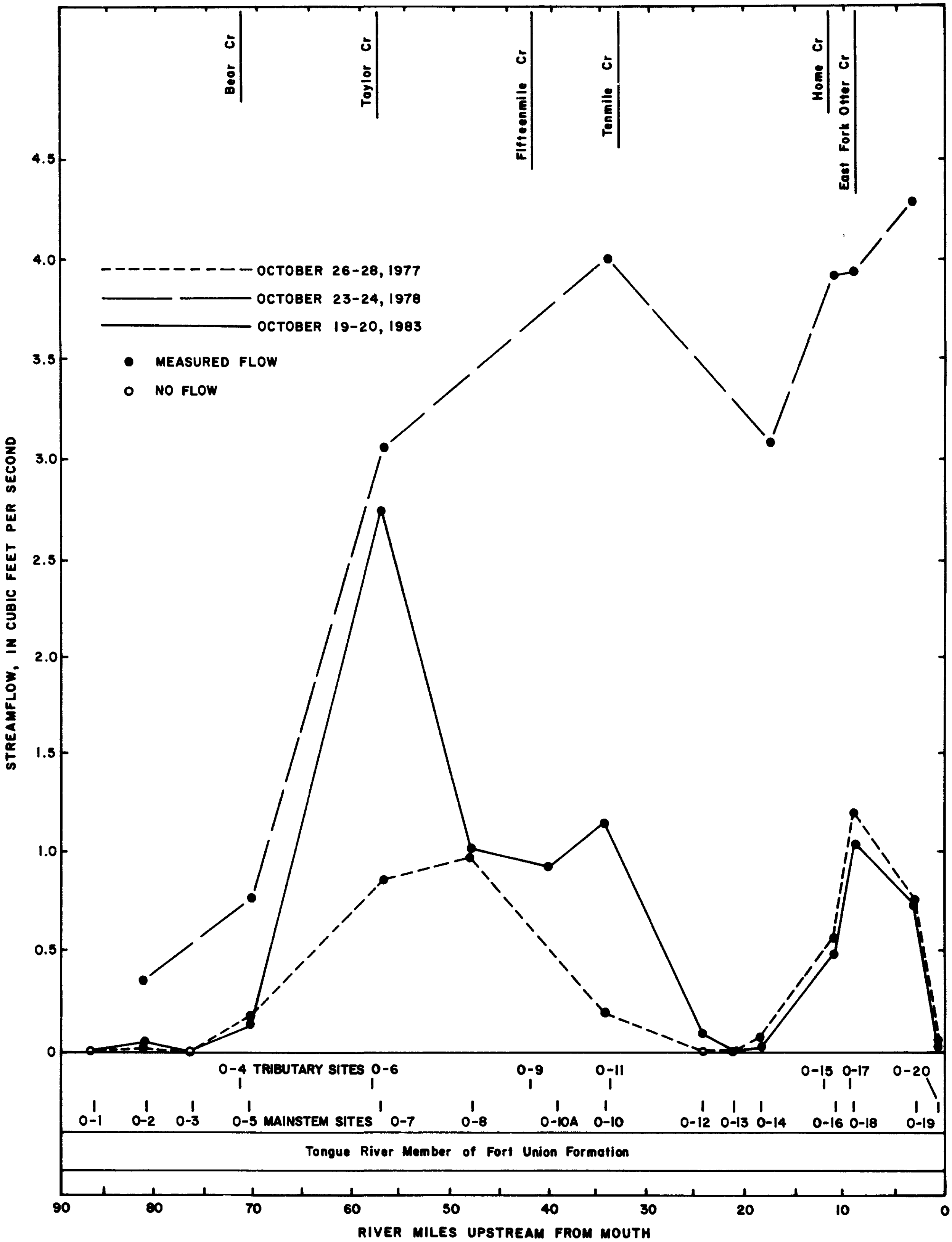

Figure 4.--Profiles of streamflow in Otter Creek during 1977, 1978, and 1983 base-flow conditions.

greater water availability during a dry year. Localized precipitation not reflected in available weather records also may be responsible, in part, for increased recharge of shallow aquifers in various parts of the drainage basin. The maximum difference in streamflow magnitude of Otter Creek between the 3 study years was 3.8 ft^3/s at site O-10.

Streamflow gain-and-loss patterns within specific reaches of Otter Creek also vary considerably from year to year as a result of water-table fluctuations. Streamflow magnitudes during the relatively dry years of 1977 and 1983 indicate that sustained base flow begins between sites O-3 and O-5, due primarily to ground-water inflow and partly to surface inflow from Bear Creek (site O-4). Bear Creek is perennial at its mouth owing to several springs discharging in the downstream parts of the drainage (Lee, 1979). All three profiles show a sharp increase in streamflow between sites O-5 and O-7. Taylor Creek contributes some surface inflow within this reach; however, most of the increased streamflow in Otter Creek is derived from ground-water sources, possibly through the alluvium of Taylor Creek and the alluvium of other large tributaries. Particularly significant is the fact that a much larger volume of ground water was entering this reach during 1983 than 1977, despite the fact that precipitation was less.

Significant differences are evident in streamflow magnitudes and gain-and-loss patterns between sites O-7 and O-10. During 1978, there was a net gain of flow between sites O-7 and O-10, whereas in 1977 and 1983 there was a net loss of flow. The pattern of overall streamflow loss through this reach was substantially different between 1977 and 1983. Between sites O-7 and O-8, there was a small gain in flow during 1977. In 1983, this same reach had a marked decrease in flow. The streamflow patterns again diverge between sites O-8 and O-10, with a substantial loss of flow during 1977 and a small gain of flow during 1983. Fifteenmile Creek (site O-9) contributed a small amount of surface inflow during both years; however, the contribution was masked by a larger loss of water to the alluvium in the reach between sites O-8 and O-10A. The variability of streamflow patterns within the reach between sites O-7 and O-10 exemplifies the effects of local ground-water recharge patterns within the drainage basin.

All three profiles indicate a net loss of streamflow between sites O-10 and O-14. Water-level measurements in observation wells completed in the alluvium in this reach indicate little or no ground-water inflow and a water table generally below the streambed as a result of water losses sustained by evapotranspiration through the summer (M. R. Cannon, U.S. Geological Survey, oral commun., 1984).

Similar trends for the three profiles occur again in the reach between sites O-14 and O-18. In this reach, a sharp increase in streamflow primarily is attributed to discharge from extensive clinker aquifers underlying the Home Creek and East Fork Otter Creek basins (M. R. Cannon, oral commun., 1984). With the exception of East Fork Otter Creek (site O-17) in 1983, these two tributaries also contributed surface inflow.

Streamflow patterns between sites O-18 and O-20 were nearly identical during 1977 and 1983. Almost all the streamflow present at site O-18 infiltrated into the channel before reaching the mouth of Otter Creek. In contrast, flow increased from site O-18 to O-19 during 1978. A higher water table in the alluvial aquifer of the Tongue River may have resulted in ground-water discharge into Otter Creek.

Rosebud Creek

Rosebud Creek, a perennial stream during most years, drains an area of about 1,300 mi^2 in southeastern Montana (fig. 2). The stream originates in the Wolf Mountains southwest of Kirby, Mont., and flows north about 200 river miles to its confluence with the Yellowstone River at Rosebud, Mont. Major tributaries to Rosebud Creek generally contribute little or no surface inflow during base-flow conditions.

Rosebud Creek is underlain by the Fort Union Formation in the upstream three-fourths of the drainage and by the Hell Creek Formation in the downstream reaches. Most ground-water discharge to Rosebud Creek is from sandstones in the Tongue River Member of the Fort Union Formation and from the alluvium.

Twenty-four sites in the Rosebud Creek basin were selected for streamflow measurements and observations in 1977 (fig. 5). Site R-6 was not used in 1977 and, for consistency, also was omitted in subsequent studies. Eighteen of the original sites were on the mainstem of Rosebud Creek and 6 were on major tributaries.

In 1977, streamflow was measured at all 18 of the mainstem sites and at 1 tributary. No flow was observed at five of the designated tributary sites. In 1978, only eight of the mainstem sites were included in the set of base-flow measurements. Streamflow was present and measured at all eight sites. During the 1983 set of measurements, all but 1 of the original 24 sites were utilized. Site R-4A, a recently established streamflow-gaging station (Rosebud Creek at reservation boundary, near Kirby), was substituted for nearby site R-4 (fig. 5). In addition, three previously unmeasured tributaries were flowing and measured: Indian Creek (RT-2), Cache Creek (RT-3), and Cow Creek (RT-13). In 1983, no flow was observed at seven mainstem sites and five of the originally designated tributaries. Results of the 1977, 1978, and 1983 base-flow measurements and the net change in streamflow between mainstem sites on Rosebud Creek are given in table 3.

Monthly precipitation and departures from average at two weather stations in the Rosebud Creek basin (fig. 5) during the 12 months prior to each study period are presented in table 4. Annual precipitation for the individual years indicate that 1977 had near-normal precipitation, 1978 was very wet, and 1983 was very dry.

Streamflow profiles of Rosebud Creek during October-November base-flow conditions of 1977, 1978, and 1983 are presented in figure 6. The three profiles clearly reflect relative precipitation quantities occurring during the individual years. Flow at all sites in 1978, the wettest year, was substantially larger than flow during the other 2 years. Flow during 1977 was intermediate between the very wet and very dry years. Flow during 1983, the driest year, was less at all sites than flow in the other 2 years. The maximum difference in base-flow magnitude during the 3 study years was 53 ft^3/s at site R-5.

Overall trends in gain and loss patterns for 1977, 1978, and 1983 are similar throughout most of the length of Rosebud Creek. The upstream reaches had a net gain in streamflow, whereas the downstream reaches generally had a gradual, net loss of flow. The most significant difference in streamflow trends occurred in the middle reach between sites R-4 and R-5. Streamflow sharply increased in 1978, moderately increased in 1977, and slightly decreased in 1983. The change in streamflow patterns in this reach probably corresponds to less recharge by precipitation and a progressive lowering of the ground-water table that eventually declined below the

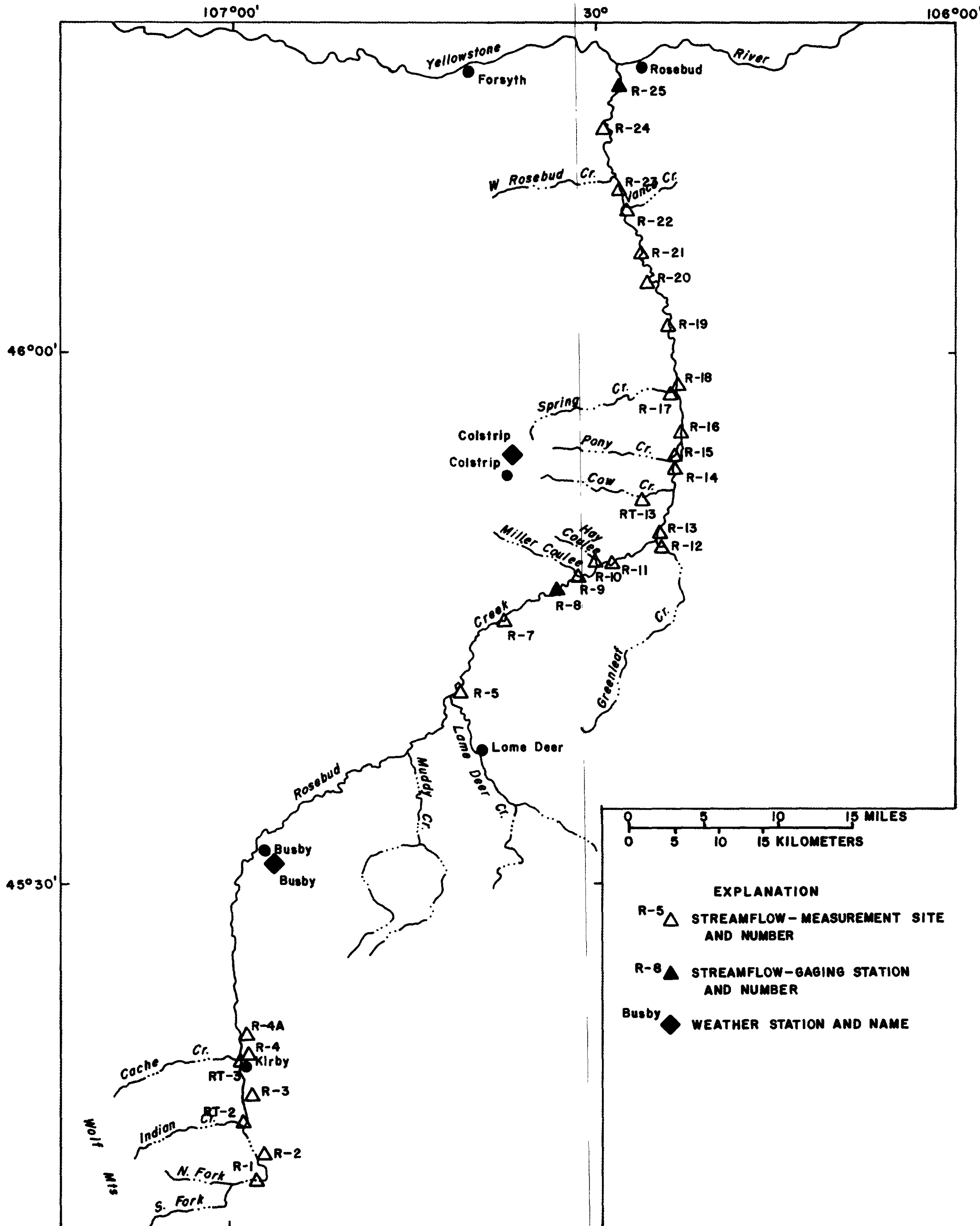

Figure 5.--Location of streamflow-measurement sites on Rosebud Creek.

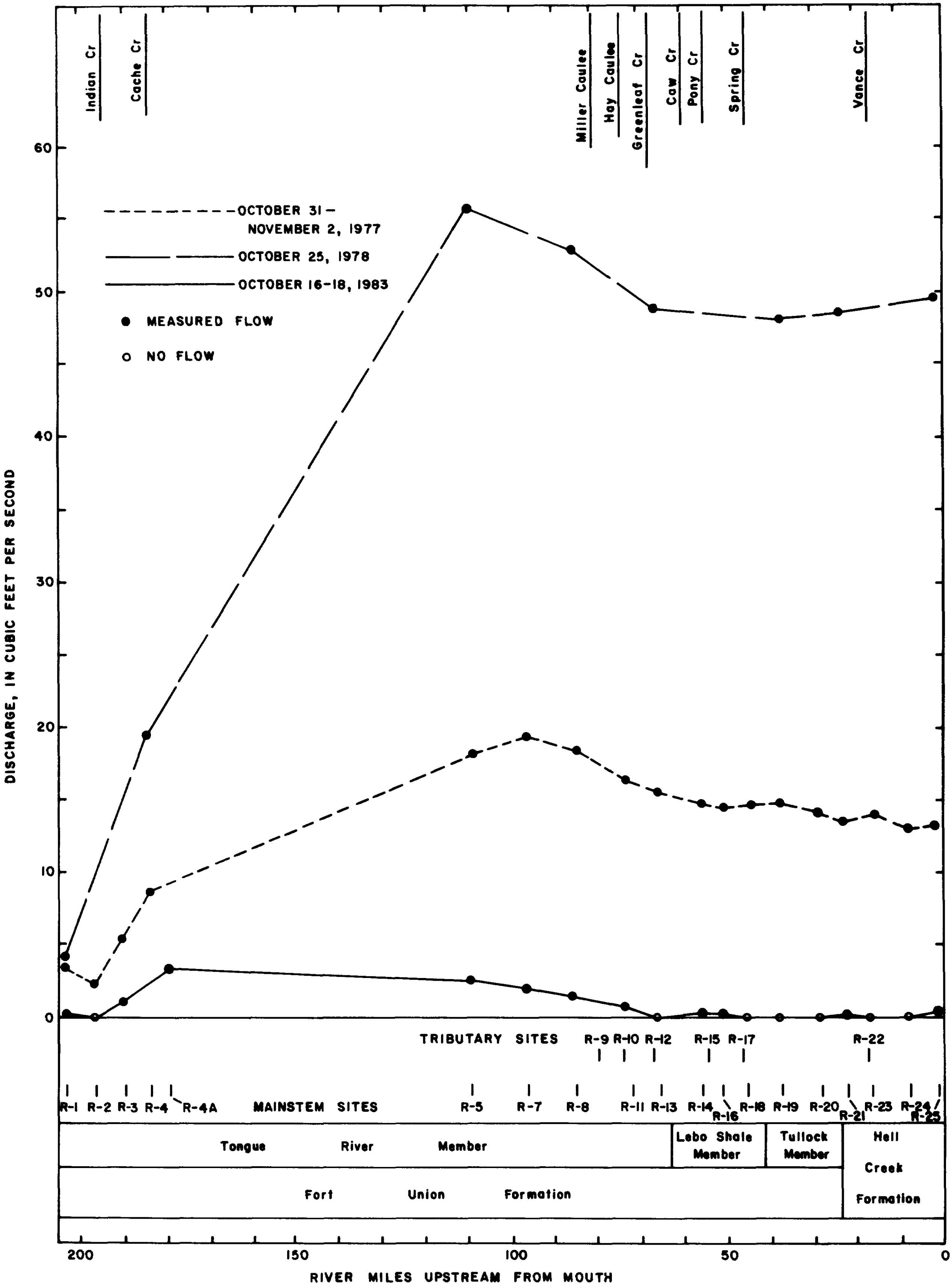

Figure 6.--Profiles of streamflow in Rosebud Creek during 1977, 1978, and 1983 base-flow conditions.

streambed in 1983 to induce flow from the channel into the alluvium. The 75-mile reach of Rosebud Creek between sites R-4 and R-5 is within the Northern Cheyenne Indian Reservation. Although streamflow data were not collected in this reach, the two major tributaries, Lame Deer and Muddy Creeks, are perennial and probably contribute a significant amount of surface inflow to Rosebud Creek.

As indicated by the 1983 profile, sustained base flow in dry years begins between sites R-2 and R-3. Streamflow generally continues to increase, except in 1983, to site R-5. These upstream reaches presumably receive ground-water inflow from sandstone of the Tongue River Member. Downstream from site R-5, streamflow fluctuates slightly through a series of gaining and losing reaches. The overall trend is a net loss of water, with most of the loss occurring between sites R-5 and R-11. During 1983, there was no flow at six of the mainstem sites from R-13 to R-24. The net loss of flow in the downstream reaches of Rosebud Creek indicates a lack of sustained ground-water discharge into the stream where it transects the Lebo Shale and Tullock Members of the Fort Union Formation, and the Hell Creek Formation. However, streamflow increased slightly between sites R-24 and R-25 in all 3 years, indicating some discharge from local units of the Hell Creek Formation during even the driest years.

WATER QUALITY OF BASE STREAMFLOW

Otter Creek

Water samples from six sites along Otter Creek were analyzed for major ions, nutrients, and selected trace constituents in 1977, samples from three sites were analyzed in 1978, and samples from nine sites were analyzed in 1983. During each year, water temperature was measured at all sites where streamflow was present. In 1978, specific conductance was measured at all sites where streamflow was present. In 1983, specific conductance and pH were measured at all sites where streamflow was present. Results of the chemical analyses and onsite water-quality measurements during base-flow conditions in Otter Creek are presented in table 5.

The predominant ions in Otter Creek during base flow are magnesium, sodium, and sulfate (fig. 7). The ionic composition of the water does not vary greatly among the sites, but downstream from site O-17 (East Fork Otter Creek) there is a slight increase in the percentage of sodium and bicarbonate (as estimated from total alkalinity). At those sites that have been sampled more than once, no significant differences in water type between individual years are evident.

Measured dissolved-solids concentrations in Otter Creek during the three base-flow studies ranged from 1,610 mg/L (milligrams per liter) at site O-8 to 3,500 mg/L at site O-10. The magnitude of streamflow and the geologic sources of ground-water inflow are the primary factors affecting the variability in dissolved-solids composition and concentrations. The profiles of dissolved-solids concentrations in figure 8 provide a visual comparison of the magnitudes and trends of concentrations between individual years. At sites where only specific-conductance measurements were available, a dissolved-solids concentration was estimated from a linear regression equation (see table 6) relating measured dissolved-solids concentrations to specific conductance.

Notable differences are evident among the three profiles, as well as some general similarities (fig. 8). The upstream reaches of Otter Creek have large

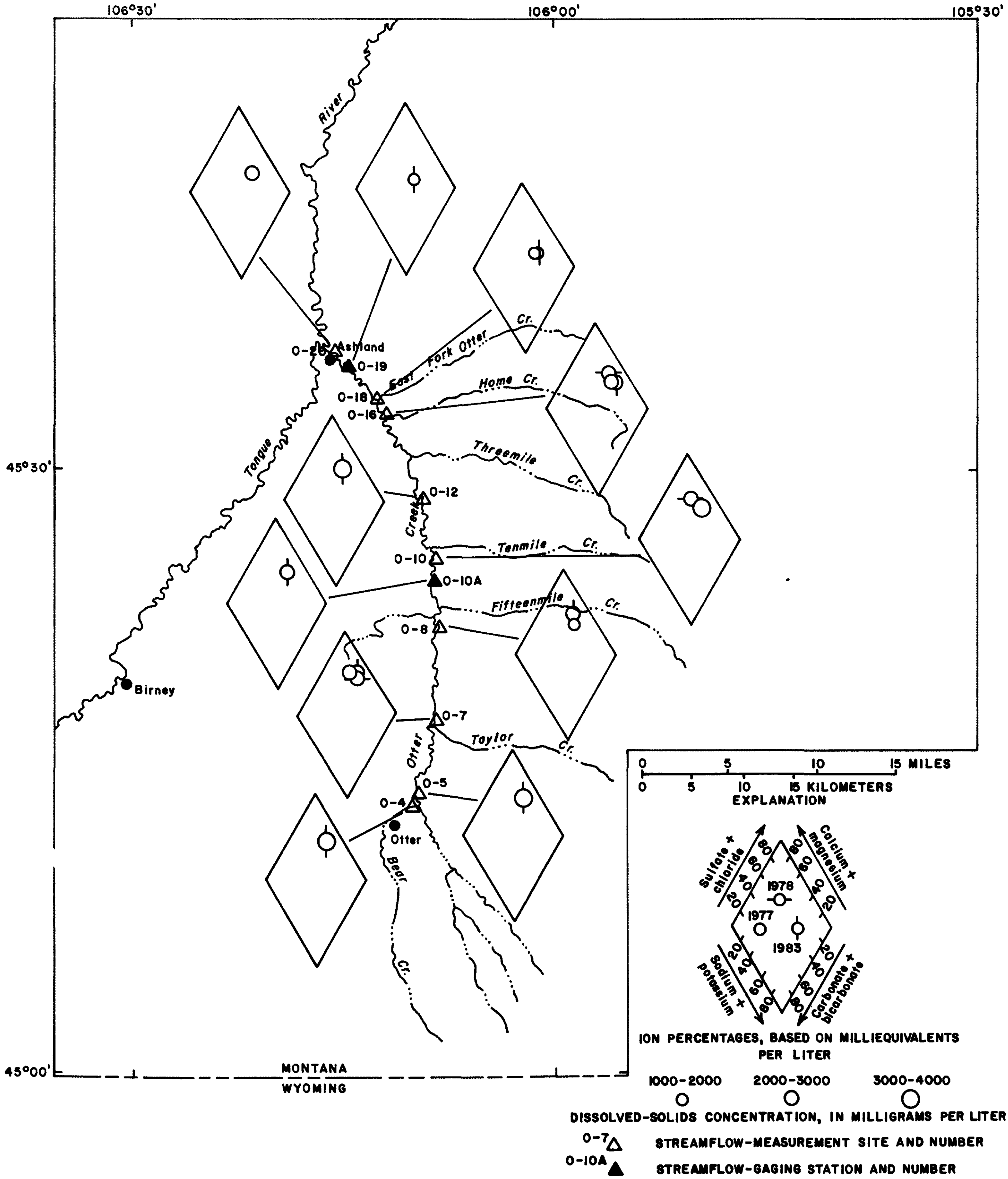

Figure 7.--Dissolved-solids concentrations and ion percentages at selected sites on Otter Creek during 1977, 1978, and 1983 base-flow conditions.

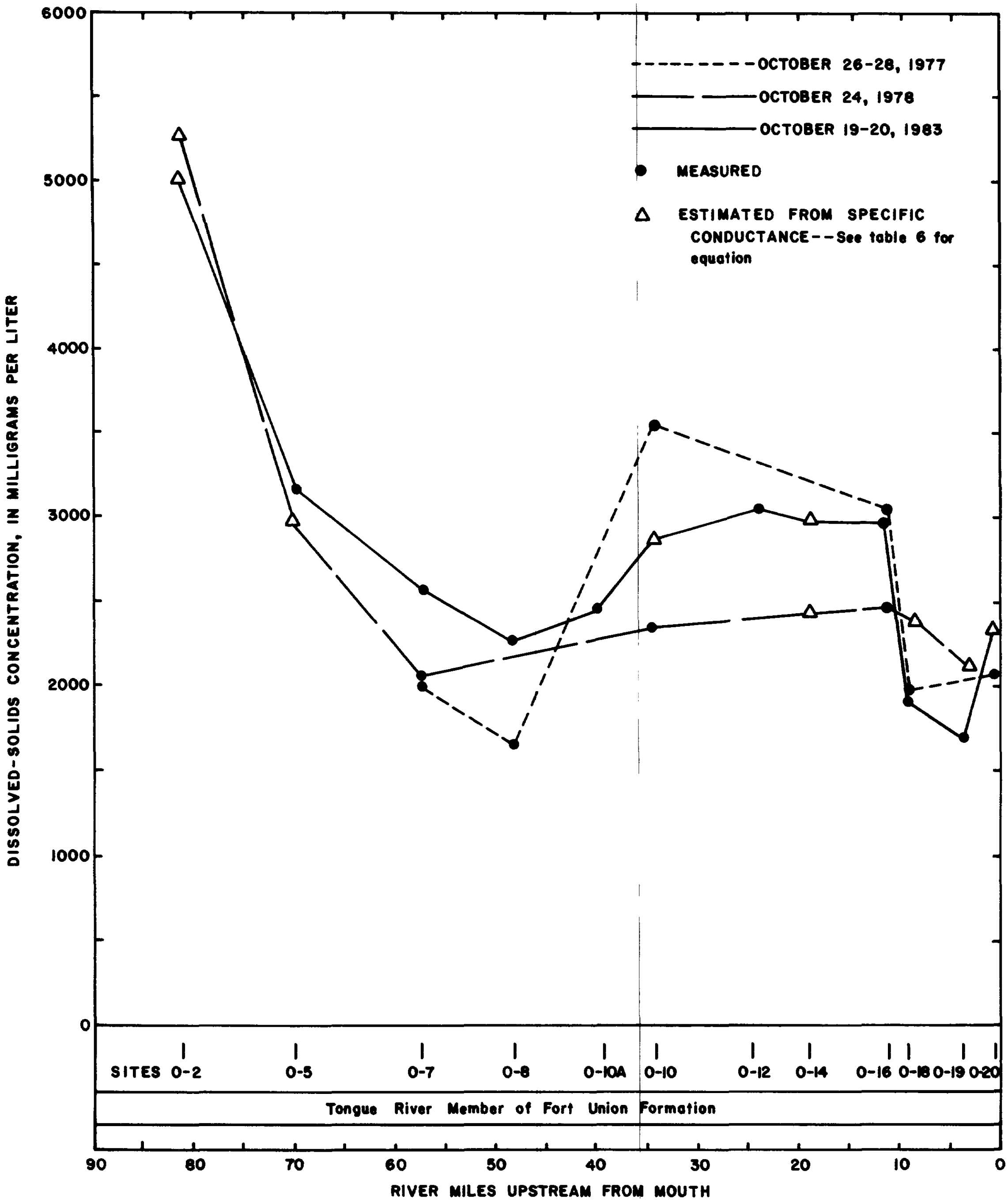

Figure 8.--Profiles of dissolved-solids concentrations in Otter Creek during 1977, 1978, and 1983 base-flow conditions.

concentrations of dissolved solids. Although no laboratory determinations of dissolved-solids concentrations were available for the most upstream site (O-2), estimates based on specific conductance indicate that concentrations of about 5,000 mg/L may occur in the headwaters of Otter Creek. From site O-2 downstream to site O-8, the trend is one of sharply decreasing concentration. Much of this decrease is a result of dilution from the increase of streamflow in this reach (fig. 4). The fact that dilution occurs indicates that the additional streamflow contains smaller concentrations of dissolved solids than that in the upstream reaches.

Dissolved-solids concentrations tend to increase in the middle reaches (O-8 to O-16) of Otter Creek. Streamflow variability is pronounced in this section of Otter Creek, as gaining and losing reaches show no consistent trend from year to year (fig. 4). However, the increasing concentrations present in the middle reaches during all 3 study years indicate that more mineralized ground water is discharging into Otter Creek in this area. In contrast, the dissolved-solids concentrations significantly decrease in the 2-mile reach between sites O-16 and O-18. This decrease corresponds to streamflow increases in Otter Creek that most likely result from clinker aquifers discharging water having small dissolved-solids concentrations. This trend of decreasing dissolved-solids concentration is predominant in the downstream reaches of Otter Creek (between sites O-16 and O-19), although some increase is noted at the mouth of the stream (O-20).

Differences in dissolved-solids concentrations of base flow in Otter Creek are evident between the individual study years; however, downstream trends in concentration generally are similar. Because of the estimates used at some sites, absolute differences in dissolved-solids concentrations are unknown, but relative differences can be described in general terms. Although some of the estimated concentrations of dissolved solids for 1978 were larger than values for 1977 or 1983, the 1978 profile indicates that dissolved-solids concentrations generally tend to be smaller during a wet year (1978) than during dry years (1977, 1983). This condition can be attributed to increased saturation of shallow aquifers and subsequent dilution of dissolved minerals. Differences in dissolved-solids concentrations between climatologically different years ranged from 10 mg/L at sites O-7 and O-16 to about 1,200 mg/L at site O-10.

To further evaluate the annual variability in dissolved solids during base flow, dissolved-solids loads at stream sites for individual years were compared (fig. 9). Dissolved-solids load is calculated by the equation:

$$L = Q \times C \times 0.0027 \qquad (1)$$

where L = dissolved-solids load, in tons per day;
Q = streamflow, in cubic feet per second;
C = dissolved-solids concentration, in milligrams per liter; and
0.0027 = a units conversion constant.

Profiles of dissolved-solids loads for the 3 study years indicate that loads transported by Otter Creek are larger during a wet year (1978) than during dry years (1977, 1983). Downstream trends in dissolved-solids loads correspond directly to trends in streamflow at most sites, whereas downstream trends in dissolved-solids concentration commonly are inverse to those of streamflow. The relationship between streamflow and load is not always consistent, indicating a complex pattern of interchange of significantly different waters between the surface- and ground-water system. The net gains or losses of dissolved-solids loads between sites on

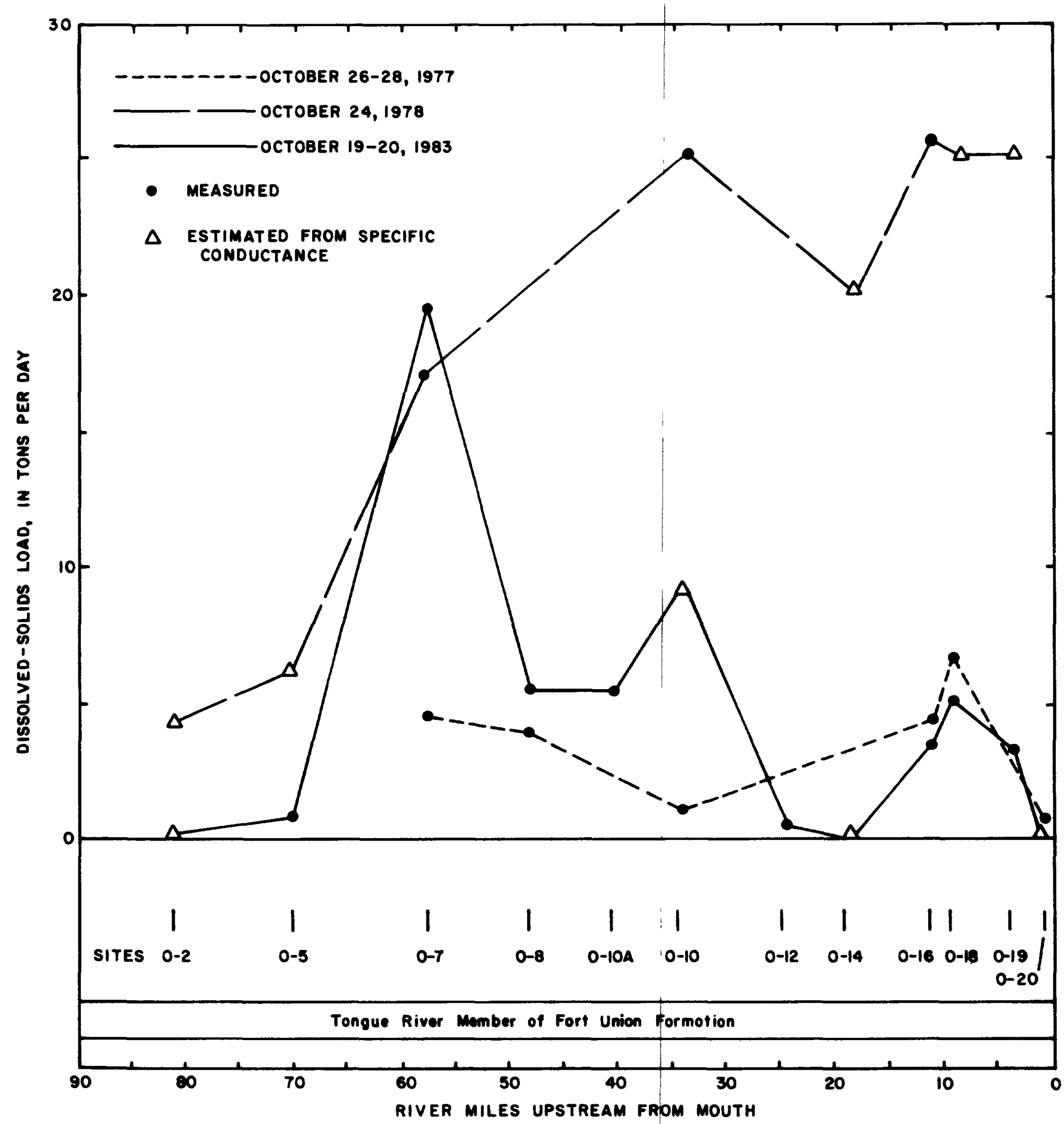

Figure 9.--Profiles of dissolved-solids loads in Otter Creek during 1977, 1978, and 1983 base-flow conditions.

Otter Creek are presented in table 6. For purposes of comparison, only those sites having dissolved-solids analyses or estimates from specific conductance for at least 2 of the study years were used to calculate downstream changes in dissolved-solids loads.

The complexity of surface water-ground water relationships is illustrated by reaches within which changes in dissolved-solids loads do not correspond to gains or losses of streamflow. In reaches where streamflow increases and load decreases, some of the original streamflow and its dissolved-solids load are lost into the alluvium in some areas while a larger inflow of ground water having a smaller load enters in another area. The opposite process occurs in those reaches where streamflow decreases and load increases. In this situation, some of the original streamflow and its load are lost to the alluvium, followed by a smaller inflow of ground water containing a larger load. The condition of decreasing streamflow and increasing load is a common occurrence during the summer; however, the process involved then usually is the result of ground-water inflow contributing load while evapotranspiration causes water losses that decrease streamflow.

Rosebud Creek

Water samples from nine sites along Rosebud Creek were analyzed for major ions, nutrients, and selected trace constituents in 1977, samples from four sites were analyzed in 1978, and samples from nine sites were analyzed in 1983. During each year, water temperature was measured at all sites where streamflow was present. In 1978, specific conductance was measured at all sites where streamflow was present. In 1983, specific conductance and pH were measured at all sites where streamflow was present. Results of the chemical analyses and onsite water-quality measurements during base-flow conditions in Rosebud Creek are presented in table 7.

The water in Rosebud Creek during base flow varies from a magnesium calcium bicarbonate type in the upstream reaches (R-1, R-4, R-4A) to a mixed composition in the middle and downstream reaches. Water type in the middle and downstream reaches fluctuated more than in upstream reaches between study years (fig. 10). In 1977 and 1978, magnesium, calcium, bicarbonate, and sulfate were predominant. In 1983, however, sodium and sulfate percentages increased and, in addition to magnesium, were the predominant ions at the midstream and downstream sites.

Measured dissolved-solids concentrations in Rosebud Creek during the three base-flow studies ranged from 563 mg/L at site R-4 to 4,150 mg/L at site R-21. Dissolved-solids concentrations in Rosebud Creek for each sampling period are illustrated in figure 11. At sites where only specific-conductance measurements were available, a dissolved-solids concentration was estimated from a linear regression equation (see table 8) relating measured dissolved-solids concentrations to specific conductance.

A marked contrast in the profiles of dissolved-solids concentrations is apparent in figure 11. All three profiles are similar in the upstream reaches to site R-5; however, the 1983 profile distinctly diverges from those of 1977 and 1978 in the middle and downstream reaches. Although the profiles for 1977 and 1978 are nearly identical throughout the entire length of Rosebud Creek, the middle and downstream reaches of the 1983 profile are characterized by concentrations much larger than those of the two previous sampling periods.

In each profile, concentrations slightly decreased from site R-1 to sites R-4 and R-4A as a result of dilution from inflow in this reach. Concentrations then increased from sites R-4 and R-4A to site R-5 in all three profiles; however, the increase was somewhat greater in 1983, with concentrations doubling between sites R-4A and R-5. The source of this increase in dissolved-solids concentration presumably is inflow derived from the Tongue River Member.

From site R-5 to the mouth of Rosebud Creek, dissolved-solids concentrations fluctuated very little during 1977 and 1978. Corresponding streamflow profiles for these years (fig. 6) show a gradual net decrease in streamflow, indicating that no major sources of ground-water inflow were contributing dissolved solids in the downstream reaches of Rosebud Creek. In contrast, sharp increases in dissolved-solids concentrations occurred between sites R-5 and R-16 during 1983. There was a

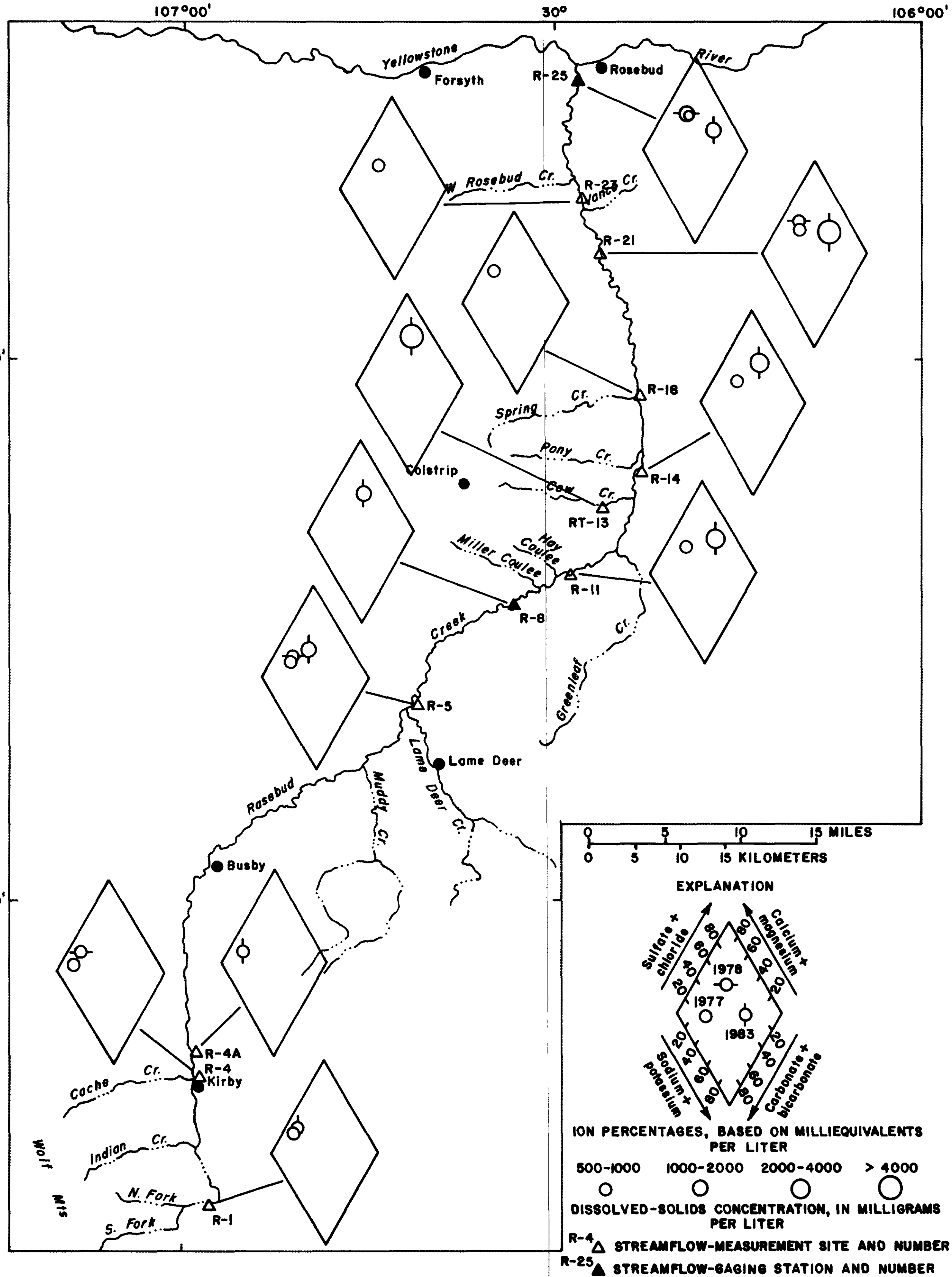

Figure 10.--Dissolved-solids concentrations and ion percentages at selected sites on Rosebud Creek during 1977, 1978, and 1983 base-flow conditions.

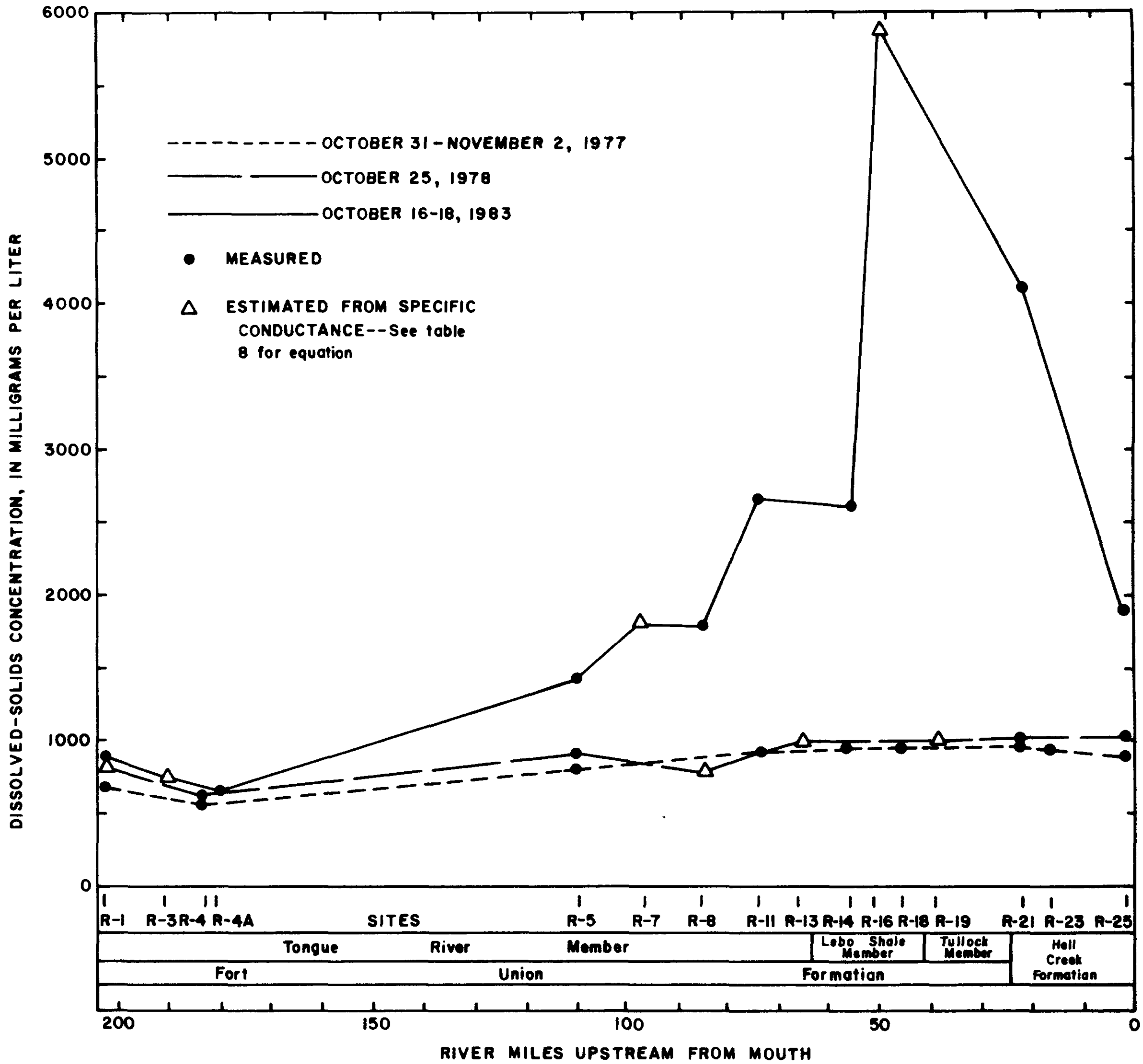

Figure 11.--Profiles of dissolved-solids concentrations in Rosebud Creek during 1977, 1978, and 1983 base-flow conditions.

net loss of streamflow in this reach, but assuming evaporation in October was negligible, small volumes of ground-water containing large dissolved-solids concentrations probably were discharging in areas interspersed among the losing reaches.

An estimated concentration of about 5,800 mg/L at site R-16 indicates that the largest increase in dissolved-solids concentration occurred between sites R-14 and R-16 in 1983. Pony Creek (site R-15) discharges into Rosebud Creek in this reach and, in 1983, had a specific conductance of 5,200 μS/cm (microsiemens per centimeter at 25° Celsius), indicating large dissolved-solids concentrations in the ground water of this area. This concept is supported by the large dissolved-solids concentration (7,390 mg/L) measured in Cow Creek (site RT-13), which is the next upstream tributary of Rosebud Creek. Both Pony Creek and Cow Creek originate near a surface coal mine in the vicinity of Colstrip. This large increase does not necessarily indicate a direct relation to coal-mining activities, because available pre-mining data are insufficient for conclusive interpretation. Unfortunately, neither specific-conductance nor dissolved-solids measurements were made in 1977 and 1978 to identify changes with time in water-quality conditions near the mouths of Pony and Cow Creeks and at site R-16.

Dissolved-solids concentrations in water from the alluvium near the headwaters of Cow Creek ranged from 2,540 to 5,170 mg/L (Montana Department of State Lands and U.S. Office of Surface Mining, 1983). Although it is believed that exposure of overburden during mining has increased the dissolved-solids concentrations in Cow Creek (Montana Department of State Lands and U.S. Office of Surface Mining, 1983), it is probable that the large concentrations measured in 1983 are the result of very small streamflow in Rosebud Creek, which consisted almost entirely of contributions from the drainages of Cow Creek and Pony Creek. In years of greater precipitation, the increased streamflow and saturation of shallow aquifers would dilute the dissolved-solids concentration in Rosebud Creek, as indicated by the 1977 and 1978 profiles.

The dissolved-solids concentration sharply decreased from site R-16 to the mouth of Rosebud Creek during 1983, although concentrations were still larger than those of 1977 or 1978. Streamflow in this reach was very small and several sites downstream from R-16 were dry. It is likely that either ground water with a small dissolved-solids concentration replaced the water lost downstream from site R-16 or some of the dissolved solids were precipitated on the streambed as water seeped through alluvial materials.

Although concentrations during very dry years, such as 1983, are substantially larger than during near-normal or wet years, such as 1977 and 1978, the relationship is not clearly defined. Dissolved-solids concentrations were very similar during 1977 and 1978; however, precipitation was considerably less in 1977 than in 1978. Other factors such as differential rates of evaporative water losses and transpiration by plants during the summer may have a prolonged effect on the depth of shallow water tables, which could complicate the relationship of concentration to precipitation amounts. Differences in measured dissolved-solids concentrations of base flow during the 3 climatologically different study years ranged from about 30 mg/L between 1977 and 1978 to about 3,200 mg/L between 1977 and 1983 at site R-21.

Profiles of dissolved-solids loads during base-flow conditions in Rosebud Creek are presented in figure 12. The profiles of load for each year are similar to those of streamflow (fig. 6). Substantially larger dissolved-solids loads were transported in Rosebud Creek during a wet year (1978) than during near-normal (1977) and dry (1983) years. Although the magnitudes of the loads are variable, downstream trends generally are similar for the three sampling periods.

The net gains or losses of dissolved-solids loads between sites on Rosebud Creek are presented in table 8 for sites having either dissolved-solids analyses or estimates from specific conductance for at least 2 of the study years. Unlike Otter Creek, gaining and losing trends in reaches having common measuring sites on Rosebud Creek generally were consistent among the three sampling periods. The only exception was the reach from site R-21 to site R-25 in which dissolved-solids load decreased in 1977 and increased in 1978 and 1983.

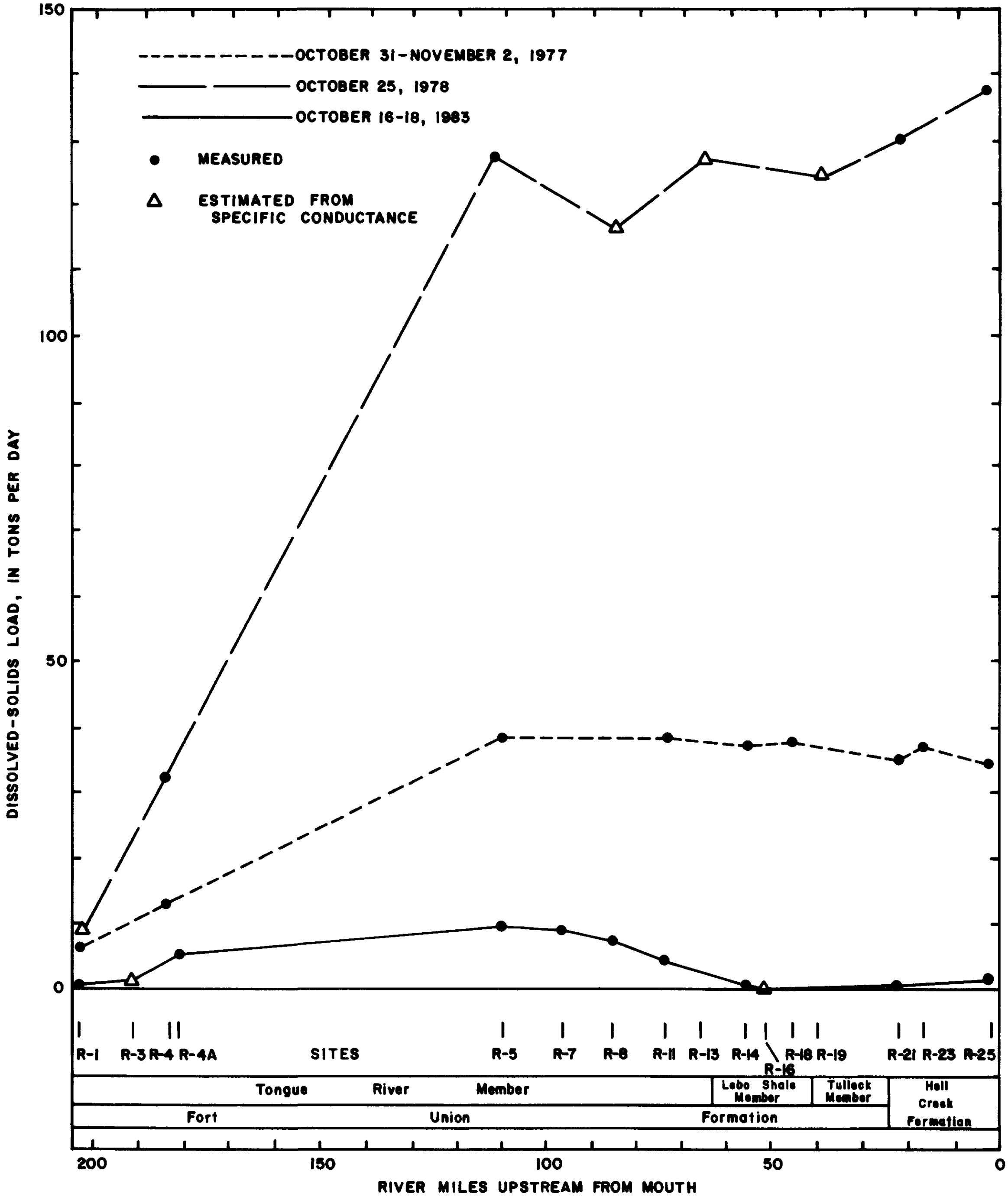

Figure 12.--Profiles of dissolved-solids loads in Rosebud Creek during 1977, 1978, and 1983 base-flow conditions.

WATER QUALITY OF SPRINGS

Otter Creek basin

Water-quality samples were collected from 19 springs in the Otter Creek basin during June 1984. Fifteen of these springs had been sampled previously (1974). Site OSP-12 also was sampled in 1980. Results of discharge measurements and chemical analyses of springs in the Otter Creek basin are presented in table 9.

The predominant ions in water from springs in the Otter Creek basin are sodium, magnesium, and sulfate; bicarbonate (as estimated from total alkalinity) also is present in significant proportions in several of the springs (fig. 13). The ionic composition of water from the springs varies considerably throughout the basin; however, distinct trends from one part of the basin to another are not obvious. In general, sodium becomes more prevalent than magnesium in the downstream part of the drainage basin, which is consistent with the trend observed in Otter Creek. Depending on the local geochemistry of the aquifer, some springs in relatively close proximity to one another may discharge water of considerably different ionic composition. With the exception of site OSP-3, no significant differences in water type are evident between sampling years.

Dissolved-solids concentrations in the springs of the Otter Creek basin vary widely, ranging from 720 to 5,700 mg/L. The smallest concentrations occur at site OSP-3, in the tributary drainage of Bear Creek, near the headwaters of Otter Creek. This spring is located near the top of a topographic drainage divide and therefore has dissolved-solids concentrations typical of recharge waters. The largest concentrations occur in the tributary drainage of Tenmile Creek (sites OSP-10 and OSP-11). Although the range of dissolved-solids concentrations in springs of the Otter Creek basin is large, concentrations differ little between sampling years at individual springs.

Rosebud Creek basin

Water-quality samples were collected from 12 springs in the Rosebud Creek basin during July 1984. All these springs had been sampled once previously between 1972 and 1975. Results of discharge measurements and chemical analyses of springs in the Rosebud Creek basin are presented in table 10.

The predominant ions in water from springs in the upstream part of the Rosebud Creek basin are magnesium, calcium, and bicarbonate (fig. 14). Data are sparse for mid-basin areas, although one spring (site RSP-9) indicates water type similar to springs in the upstream part of the basin. Three springs (sites RSP-10, RSP-11, and RSP-12) in the downstream parts of the basin discharge water having predominant ions of sodium, magnesium, and sulfate. The downstream increase in sodium and sulfate percentages in springs corresponds to similar downstream changes in the ionic composition of Rosebud Creek. Although water type of the springs varies throughout the basin, the ionic composition of water from individual springs was very similar between sampling years.

Dissolved-solids concentrations in the springs of the Rosebud Creek basin vary considerably, ranging from 247 to 4,190 mg/L. The smallest concentrations occur in the upstream and middle parts of the basin. The largest concentrations occur in the downstream part of the basin, near the transition from the Tongue River Member

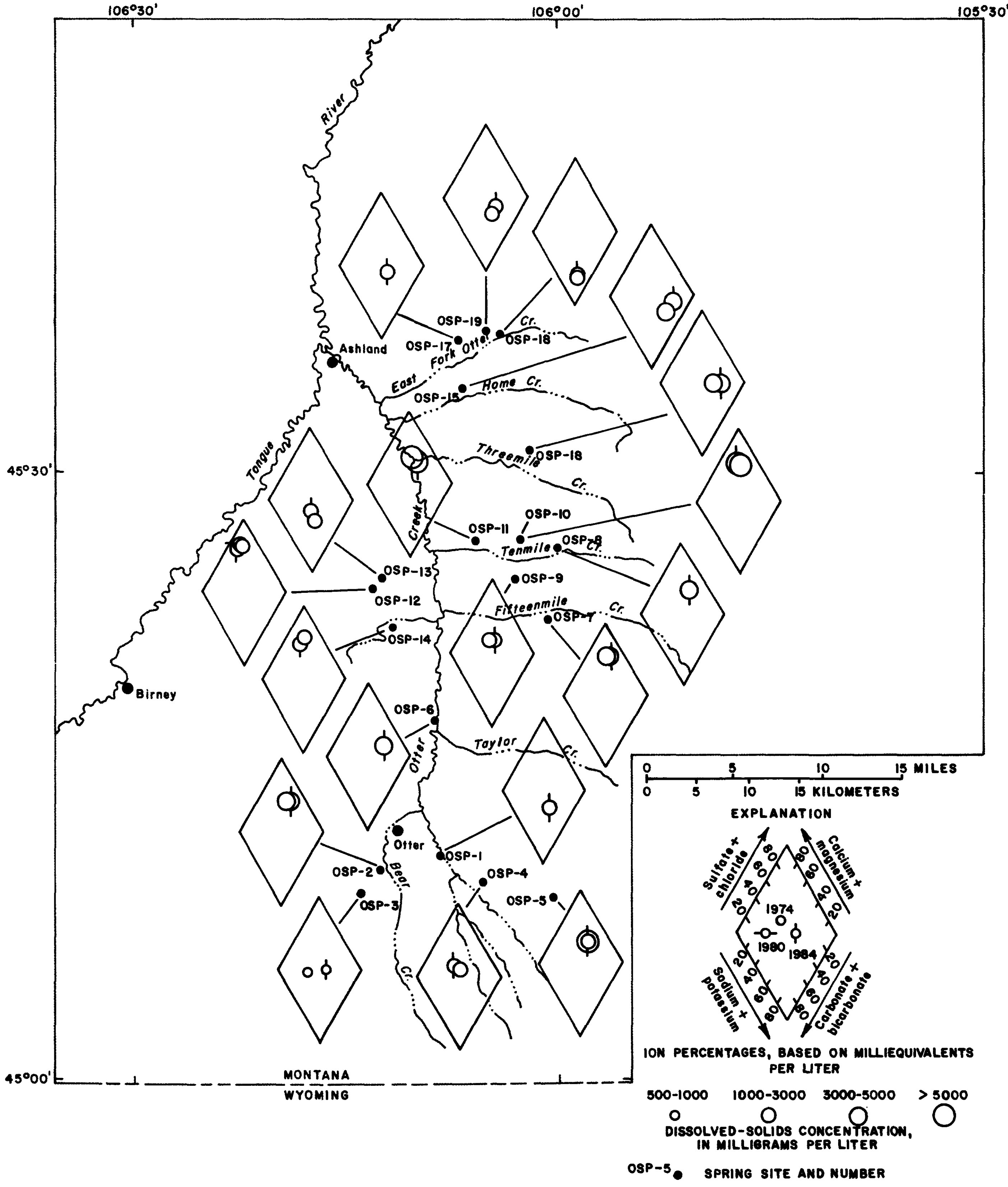

Figure 13.--Dissolved-solids concentrations and ion percentages of water from selected springs in the Otter Creek basin.

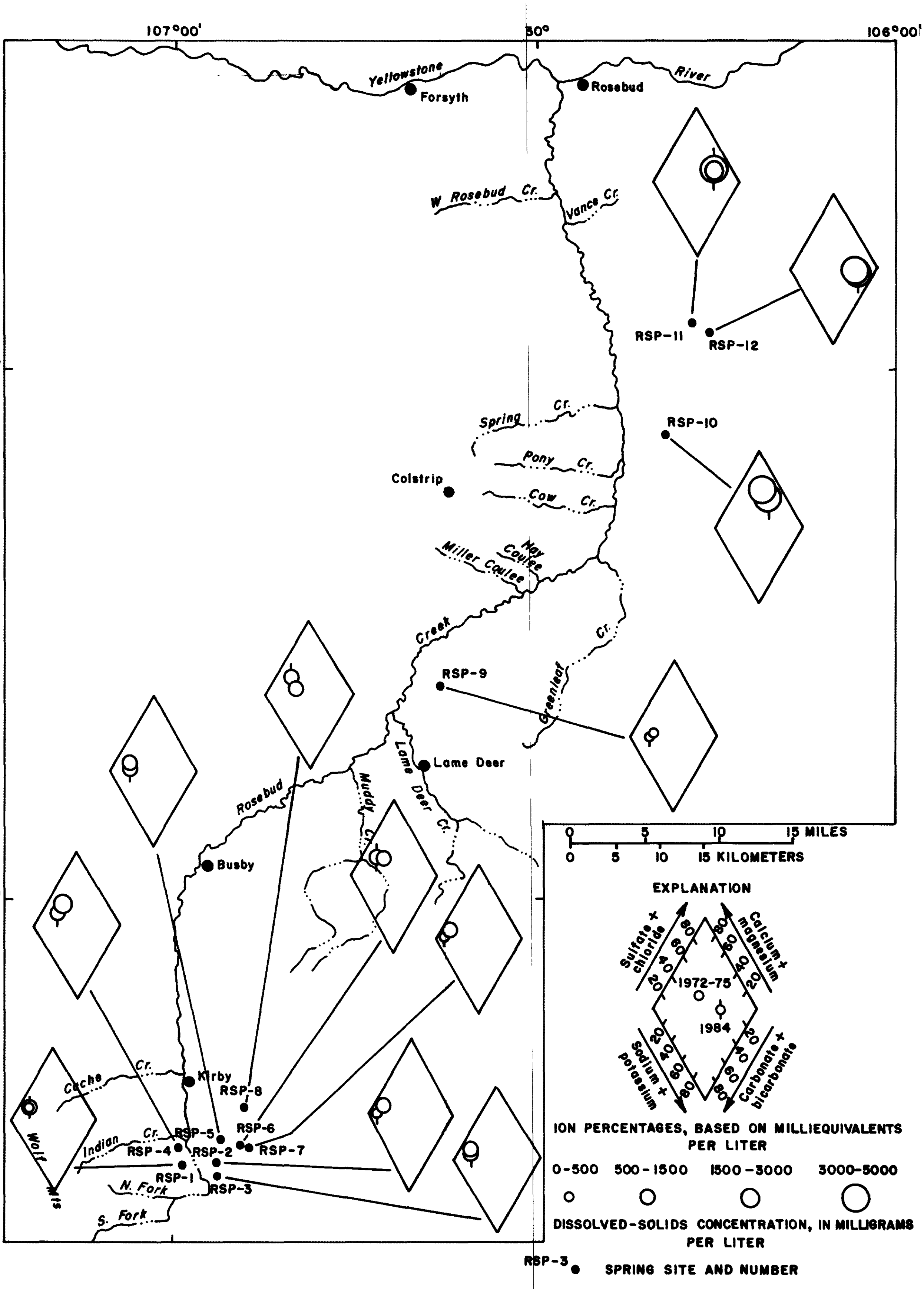

Figure 14.--Dissolved-solids concentrations and ion percentages of water from selected springs in the Rosebud Creek basin.

to the Lebo Shale Member of the Fort Union Formation. Springs sampled in 1981 and 1982 in the headwaters of Cow Creek near Colstrip (Western Energy Company, 1984) also have large dissolved-solids concentrations, ranging from about 2,200 to 4,500 mg/L. Although the spatial variation in the dissolved-solids concentrations of springs in the Rosebud Creek basin is considerable, the concentration at each site differed little between the individual sampling years.

APPLICATION OF RESULTS TO OTHER STUDIES

The comparison of streamflow and water-quality data for Otter and Rosebud Creeks collected during base-flow conditions in years of widely different precipitation indicates significant natural variability in base-flow magnitudes and constituent concentrations. In addition to large differences in streamflow quantities, the complex interactions between the surface-water and ground-water systems result in variable streamflow patterns from year to year in some reaches; that is, a gaining reach during one year may be a losing reach during another as a result of water-table fluctuations. Consequently, ground-water inflow or constituent loading estimated from a single base-flow synoptic study may not be representative of long-term average values, especially if the study were conducted during a year of climatological extremes.

Estimates of average base-flow characteristics could be improved by conducting a series of base-flow measurements for a number of years to better define the range of base-flow magnitudes and constituent concentrations associated with the natural variability in annual precipitation. However, multiple sets of base-flow measurements may not always be practical because such an approach requires a longer study period and greater costs, and there would be no guarantee that a wide range of climatological conditions would occur within the duration of the study. Given the above limitations, it may still be worthwhile to make at least two sets of base-flow measurements to detect major departures from general streamflow magnitudes, gain and loss trends, or water quality identified in the initial measurements.

The variability of base-flow magnitudes and water quality identified in Otter and Rosebud Creeks most likely occurs in other semiarid basins. Such variability could be a significant factor in the predictive capability of stream models that utilize input parameter values estimated from an individual set of measurements. Regardless of the potential error, however, a single base-flow study can be valuable for either generalizing base-flow characteristics, or providing the best available estimate of ground-water contributions to streamflow in studies where budget or time constraints limit data collection. Estimates of ground-water contributions might be improved if long-term streamflow records are available that can be used to determine the percentage of normal streamflow occurring at the gaging site during the study. Extrapolation of this percentage to measured streamflow at other sites could give a general indication of long-term average base flow magnitudes throughout the basin.

Widespread sampling of springs can further increase the understanding of the surface water-ground water systems by providing a general indication of ground-water quality throughout a basin. Such data can be useful in identifying the areal variability of ground-water sources that are assumed to be contributing to downstream changes in stream water quality. In both Otter and Rosebud Creeks, the water quality of streams generally reflected the areal variability in the water quality of springs. Therefore, the springs probably are discharging from the same aquifers that are contributing a significant percentage of flow to the streams in downgradient areas. Springs that discharge water of a very dissimilar ionic composition compared to local stream reaches may contribute only a negligible quantity of water.

Springs in the Otter and Rosebud Creek basins were sampled during various years, seasons, and precipitation conditions. At most springs, the difference in ionic composition or dissolved-solids concentration between sampling periods was small. This indicates that the natural variability of springs is apparently small and general water-quality characteristics probably can be adequately described by a single sample. However, two or more samples from springs during years of various precipitation conditions could better define an expected range of constituent concentrations.

SUMMARY

The results of three base-flow synoptic studies conducted on Otter and Rosebud Creeks during 1977, 1978, and 1983 are summarized in this report. The data from each of the individual study years, which represent widely different climatological conditions, are compared for the purpose of describing the natural variability in the quantity and quality of base flow. In addition, widespread sampling of springs was conducted to provide an indication of ground-water quality throughout the basins and to provide an understanding of the interactions between the surface-water and ground-water systems. The sampling of previously sampled springs also enabled an assessment of the natural variability of spring water quality.

Otter Creek base-flow characteristics vary considerably in response to the quantity of antecedent precipitation that is available for ground-water recharge and subsequent discharge to the stream. Streamflow was greater at all sites during 1978, a year of much greater-than-average precipitation; however, flow magnitudes for 1977 and 1983 were not so clearly related to precipitation quantities. Although precipitation was much less in 1983 than 1977, streamflow in the middle reaches of Otter Creek was larger in 1983 than 1977. Streamflow in the upstream and downstream reaches of Otter Creek was nearly identical in 1977 and 1983 despite the large precipitation difference. Carry-over of recharge waters from 1 to several years prior to the study or localized precipitation may have been partly responsible for increased ground-water availability in various parts of the basin. Such variability in local recharge conditions may contribute to water-table fluctuations that result in inconsistent gain-and-loss patterns within specific reaches from year to year. The maximum difference in base-flow magnitude in Otter Creek during the 3 study years was 3.8 ft^3/s.

Rosebud Creek base-flow characteristics are more clearly related to antecedent precipitation quantities than those of Otter Creek. Streamflow during the very wet year of 1978 was substantially larger at all sites on Rosebud Creek than during 1977 and 1983. Streamflow was at a minimum at all sites in 1983, which was a very dry year. Streamflow in 1977 was intermediate between the very wet and very dry years. Overall trends in gain-and-loss patterns during each of the individual study years were similar for most of the length of Rosebud Creek. Streamflow gains generally occur in the upstream reaches of Rosebud Creek, whereas streamflow losses are prevalent in the downstream reaches. The maximum difference in base-flow magnitude in Rosebud Creek during the 3 study years was 53 ft^3/s.

The predominant ions in Otter Creek during base flow are magnesium, sodium, and sulfate. The ionic composition of the water does not vary greatly among the sites, although sodium slightly increases and sulfate decreases in percentage in the most downstream reaches of Otter Creek. Measured dissolved-solids concentrations in Otter Creek during the three base-flow studies ranged from 1,610 mg/L at site O-8 to 3,500 mg/L at site O-10; however, estimates based on specific conductance indicate that concentrations of about 5,000 mg/L may occur in the headwaters of Otter Creek. Dissolved-solids concentrations fluctuate considerably along the length of Otter Creek, and significant decreases probably are associated with dilute water entering the stream from clinker aquifers. Although differences in the magnitude of dissolved-solids concentrations are evident between the study years, downstream trends in concentration generally are similar. Differences in dissolved-solids concentrations of base flow between climatologically different years ranged from 10 mg/L at two sites to about 1,200 mg/L at site O-10. Generally, dissolved-solids concentrations in Otter Creek tended to be smaller in a wet year (1978) than in dry (1977, 1983) years; however, larger dissolved-solids loads were transported during the wet year.

The water in Rosebud Creek during base flow varies from a magnesium calcium bicarbonate type in the upstream reaches to a mixed composition in the middle and downstream reaches. Water type in the middle and downstream reaches fluctuated more than in upstream reaches between study years. In 1977 and 1978, magnesium, calcium, bicarbonate, and sulfate were predominant in the middle and downstream reaches. In 1983, however, sodium, magnesium, and sulfate were the predominant ions.

Measured dissolved-solids concentrations in Rosebud Creek during the three base-flow studies ranged from 563 mg/L at site R-4 to 4,150 mg/L at site R-21; however, estimates based on specific conductance indicate that a maximum concentration of about 5,800 mg/L occurred at site R-16 in 1983. Dissolved-solids concentrations during years of near-normal (1977) and greater-than-normal (1978) precipitation were nearly identical and fluctuated very little throughout the entire length of Rosebud Creek. In 1983 (a dry year), concentrations in the upstream reaches of Rosebud Creek were similar to those in 1977 and 1978; however, the middle and downstream reaches were characterized by dissolved-solids concentrations much larger than those of the previous study years. Differences in dissolved-solids concentrations of base flow in Rosebud Creek during the three climatologically different study years ranged from about 30 mg/L between 1977 and 1978 to about 3,200 mg/L between 1977 and 1983 at site R-21. Substantially larger dissolved-solids loads were transported by Rosebud Creek during a wet year (1978) than during near-normal (1977) and dry (1983) years.

Springs in the Otter Creek basin have water dominated by sodium, magnesium, and sulfate; bicarbonate also is present in significant proportions in several springs. Although the ionic composition of water from the springs varies considerably throughout the basin, distinct areal trends are not evident. In general, sodium becomes more prevalent than magnesium in the downstream part of the basin. Dissolved-solids concentrations in the springs ranged from 720 to 5,700 mg/L. Both ionic composition and dissolved-solids concentrations at each site did not vary substantially between individual sampling years.

Springs in the upstream part of the Rosebud Creek basin have water dominated by magnesium, calcium, and bicarbonate. Sodium, magnesium, and sulfate are predominant in water from springs in the downstream part of the basin. Dissolved-solids concentrations in the springs ranged from about 250 to 4,200 mg/L. There was little difference in ionic composition and dissolved-solids concentrations at each site between sampling years.

Comparison of base-flow characteristics in Otter and Rosebud Creeks during years of widely different precipitation illustrates that large ranges in base-flow quantity and quality can occur. Such variability indicates that a single set of base-flow measurements may not be representative of average conditions. The potential error associated with this variability could be a significant factor in the predictive capability of stream models that utilize input parameter values estimated from a one-time base-flow study. Regardless of the potential error, however, a single set of measurements can be valuable either in generalizing base-flow characteristics, or in providing the best available estimate of ground-water contributions to streamflow in studies where budget or time constraints limit data collection.

REFERENCES CITED

Druse, S. A., Dodge, K. A., and Hotchkiss, W. R., 1981, Base flow and chemical quality of streams in the Northern Great Plains area, Montana and Wyoming, 1977-78: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-692, 60 p.

Ferreira, R. F., 1984, Simulated effects of surface coal mining and agriculture on dissolved solids in Rosebud Creek, southeastern Montana: U.S. Geological Survey Water-Resources Investigations Report 84-4101, 60 p.

Lee, R. W., 1979, Ground-water-quality data from the northern Powder River Basin, southeastern Montana: U.S. Geological Survey Water-Resources Investigations Open-File Report 79-1331, 55 p.

Lee, R. W., Slagle, S. E., and Stimson, J. R., 1981, Magnitude and chemical quality of base flow of Otter Creek, Tongue River, and Rosebud Creek, southeastern Montana, October 26-November 5, 1977: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-1298, 95 p.

Lewis, B. D., and Roberts, R. S., 1978, Geology and water-yielding characteristics of rocks of the northern Powder River Basin, southeastern Montana: U.S. Geological Survey Miscellaneous Investigations Map I-847-D, scale 1:250,000, 1 sheet.

Matson, R. E., and Blumer, J. W., 1973, Quality and reserves of strippable coal, selected deposits, southeastern Montana: Montana Bureau of Mines and Geology Bulletin 91, 135 p.

Montana Department of State Lands and U.S. Office of Surface Mining, 1983, Western Energy Company's Rosebud Mine--Final comprehensive environmental impact study: U.S. Office of Surface Mining 83-10, 387 p.

U.S. Department of Commerce, issued annually, Climatological data, Montana: Asheville, N.C.

U.S. Geological Survey, 1974, Stripping coal deposits of the Northern Great Plains, Montana, Wyoming, North Dakota, and South Dakota: U.S. Geological Survey Miscellaneous Field Studies Map MF-590, scale 1:1,000,000, 1 sheet.

Western Energy Company, 1984, Rosebud Mine--Colstrip, Montana--Hydrologic resources data, Volume 1, Surface-water quality section: 200 p.

Woods, P. F., 1981, Modeled impacts of surface coal mining on dissolved solids in the Tongue River, southeastern Montana: U.S. Geological Survey Water-Resources Investigations 81-64, 73 p.

Table 1.--*Measured streamflow at selected sites on Otter Creek and tributaries during 1977, 1978, and 1983 base-flow conditions*

[ft^3/s, cubic feet per second]

Site No.	Location (and formal station number where applicable)	Stream	Date 1977	Date 1978	Date 1983	Streamflow (ft^3/s) 1977	Streamflow (ft^3/s) 1978	Streamflow (ft^3/s) 1983	Net gain of ground water or loss (-) of streamflow between mainstem sites (ft^3/s) 1977	1978	1983
0-1	NW¼SW¼ sec. 4., T. 9 S., R. 46 E.	Otter Creek	10-26	--	10-19	No flow	--	No flow	--	--	--
0-2	NE¼SE¼ sec. 18, T. 8 S., R. 46 E. (06307665)	Otter Creek	10-26	10-23	10-19	0.01	0.29	0.02	0.01	--	0.02
0-3	NE¼NW¼ sec. 31, T. 7 S., R. 46 E.	Otter Creek	10-26	--	10-19	No flow	--	No flow	-.01	--	-.02
0-4	NE¼NW¼ sec. 24, T. 7 S., R. 45 E.	Bear Creek	10-26	--	10-19	.02	--	.01	--	--	--
0-5	SW¼SE¼ sec. 13, T. 7 S., R. 45 E.	Otter Creek	10-26	10-24	10-19	.18	.75	.17	.16	0.46	.16
0-6	NW¼SE¼ sec. 30, T. 6 S., R. 46 E.	Taylor Creek	10-26	--	10-19	.22	--	.08	--	--	--
0-7	NE¼NW¼ sec. 30, T. 6 S., R. 46 E.	Otter Creek	10-26	10-24	10-19	.79	3.05	2.76	.39	2.30	2.51
0-8	SE¼SW¼ sec. 35, T. 5 S., R. 45 E.	Otter Creek	10-26	--	10-19	.92	--	.95	.13	--	-1.81
0-9	NW¼SE¼ sec. 23, T. 5 S., R. 45 E.	Fifteen-mile Creek	10-26	--	10-19	.10	--	.04	--	--	--
0-10A[1]	SW¼NE¼ sec. 14, T. 5 S., R. 45 E. (06307717)	Otter Creek	--	--	10-19	--	--	.89	--	--	-.10
0-10	SE¼NW¼ sec. 2, T. 5 S., R. 45 E. (06307725)	Otter Creek	10-27	10-24	10-19	.15	3.97	1.15	-.87	.92	.26
0-11	NW¼NE¼ sec. 2, T. 5 S., R. 45 E.	Tenmile Creek	10-26	--	10-19	No flow	--	No flow	--	--	--
0-12	NW¼NW¼ sec. 22, T. 4 S., R. 45 E.	Otter Creek	10-27	--	10-19	No flow	--	.07	-.15	--	-1.08
0-13	SE¼NE¼ sec. 9, T. 4 S., R. 45 E.	Otter Creek	10-27	--	10-20	No flow	--	No flow	0	--	-.07
0-14	NE¼NW¼ sec. 4., T. 4 S., R. 45 E.	Otter Creek	10-27	10-24	10-20	.06	3.07	.02	.06	-.90	.02
0-15	NE¼SE¼ sec. 29, T. 3 S., R. 45 E. (06307735)	Home Creek	10-27	10-24	10-19	.06	.08	.03	--	--	--
0-16	NW¼SW¼ sec. 29, T. 3 S., R. 45 E.	Otter Creek	10-27	10-24	10-20	.55	3.81	.45	.43	.66	.40
0-17	SW¼NW¼ sec. 20, T. 3 S., R. 45 E.	East Fork Otter Creek	10-27	--	10-20	.05	--	No flow	--	--	--
0-18	SE¼SE¼ sec. 19, T. 3 S., R. 45 E.	Otter Creek	10-27	10-24	10-20	1.24	3.89	1.05	.64	.08	.60
0-19	NE¼SE¼ sec. 11, T. 3 S., R. 44 E. (06307740)	Otter Creek	10-28	10-24	10-20	.75	4.23	.74	-.45	.34	-.31
0-20	SW¼SW¼ sec. 2, T. 3 S., R. 44 E.	Otter Creek	10-28	--	10-20	.04	--	[2].01	-.71	--	-.73

[1] Alternative site at location of recently established streamflow-gaging station.
[2] Estimated discharge.

Table 2.--*Monthly and annual precipitation and departures from average at Otter Creek weather stations during 12 months prior to base-flow studies*

[Upper numeral is precipitation, in inches; lower numeral is departure from average. Average precipitation based on data from 1951-80. Precipitation data from U.S. Department of Commerce (issued annually)]

Study year	Month: N	D	J	F	M	A	M	J	J	A	S	O	Annual total
							Ashland Ranger Station						
1977	0.8 +.19	0.3 -.22	0.8 +.22	0.2 -.37	1.0 +.40	0.5 -.65	2.0 -.28	1.5 -.87	0.7 -.19	0.8 -.21	1.6 +.64	0.9 +.06	11.1 -1.28
1978	.8 +.19	.8 +.29	.6 +.02	1.0 +.43	.3 -.30	.8 -.35	9.7 +7.42	1.2 -1.17	1.2 +.31	1.0 -.01	1.5 +.54	.1 -.74	19.0 +6.63
1983	.3 -.31	.9 +.38	.1 -.48	.1 -.47	.5 -.10	.2 -.95	1.0 -1.28	2.3 -.07	.6 -.29	.8 -.21	.6 -.36	1.2 +.36	8.6 -3.78
							Otter 9SSW						
1977	1.33 +.34	0.70 -.30	1.32 +.22	0.39 -.48	2.87 +1.76	0.55 -2.05	2.35 -.49	4.01 +.62	0.79 -.60	1.07 -.20	1.73 +.19	1.58 +.27	18.69 -.72
1978	1.20 +.21	1.62 +.62	.97 -.13	1.62 +.75	.21 -.90	2.48 -.12	9.85 +7.01	1.62 -1.77	1.50 +.11	.95 -.32	2.76 +1.22	.18 -1.13	24.96 +5.55
1983	.20 -.79	1.91 +.91	.49 -.61	.13 -.74	1.23 +.12	.60 -2.00	1.34 -1.50	3.46 +.07	.25 -1.14	.64 -.63	.99 -.55	1.14 -.17	12.38 -7.03

Table 3.--*Measured streamflow at selected sites on Rosebud Creek and tributaries during 1977, 1978, and 1983 base-flow conditions*

[ft^3/s, cubic feet per second]

Site No.	Location (and formal station number where applicable)	Stream	Date			Streamflow (ft^3/s)			Net gain of ground water or loss (-) of streamflow between mainstem sites (ft^3/s)		
			1977	1978	1983	1977	1978	1983	1977	1978	1983
R-1	NE¼SE¼ sec. 20, T. 7 S., R. 39 E.	Rosebud Creek	10-31	10-25	10-16	3.51	4.12	0.02	--	--	--
R-2	NE¼SW¼ sec. 9, T. 7 S., R. 39 E. (06295100)	Rosebud Creek	10-31	10-25	10-16	2.25	--	No flow	-1.26	--	-.02
RT-2	SE¼SW¼ sec. 32, T. 6 S., R. 39 E.	Indian Creek	--	--	10-16	--	--	.17	--	--	--
R-3	NE¼NW¼ sec. 29, T. 6 S., R. 39 E.	Rosebud Creek	10-31	--	10-16	5.29	--	.67	3.04	--	.50
RT-3	NE¼SW¼ sec. 8, T. 6 S., R. 39 E.	Cache Creek	--	--	10-16	--	--	.67	--	--	--
R-4	SE¼NW¼ sec. 8, T. 6 S., R. 39 E.	Rosebud Creek	11-01	10-25	--	8.32	19.1	--	3.03	15.0	--
R-4A[1]	NE¼SW¼ sec. 36, T. 5 S., R. 38 E. (06295113)	Rosebud Creek	--	--	10-16	--	--	3.58	--	--	2.24
R-5	NW¼SW¼ sec. 8, T. 2 S., R. 41 E.	Rosebud Creek	11-01	10-25	10-17	18.0	55.5	2.56	9.68	36.4	-1.02
R-7	NW¼NW¼ sec. 23, T. 1 S., R. 41 E.	Rosebud Creek	10-31	--	10-17	19.0	--	2.02	1.00	--	-.54
R-8	SW¼NE¼ sec. 8, T. 1 S., R. 42 E. (06295250)	Rosebud Creek	10-31	10-25	10-18	18.3	52.6	1.47	-.70	-2.90	-.55
R-9	NE¼NW¼ sec. 3., T. 1 S., R. 42 E.	Miller Coulee	10-31	--	10-17	No flow	--	No flow	--	--	--
R-10	NW¼NW¼ sec. 34, T. 1 N., R. 42 E.	Hay Coulee	10-31	--	10-17	No flow	--	No flow	--	--	--
R-11	NW¼NE¼ sec. 34, T. 1 N., R. 42 E.	Rosebud Creek	11-01	--	10-17	16.5	--	.68	-1.80	--	-.79
R-12	NW¼NW¼ sec. 29, T. 1 N., R. 43 E. (06295350)	Greenleaf Creek	11-01	--	10-17	No flow	--	No flow	--	--	--

Table 3.--*Measured streamflow at selected sites on Rosebud Creek and tributaries during 1977, 1978, and 1983 base-flow conditions*--Continued

Site No.	Location (and formal station number where applicable)	Stream	Date 1977	Date 1978	Date 1983	Streamflow (ft^3/s) 1977	Streamflow (ft^3/s) 1978	Streamflow (ft^3/s) 1983	Net gain of ground water or loss (-) of streamflow between mainstem sites (ft^3/s) 1977	1978	1983
R-13	NE¼NE¼ sec. 19, T. 1 N., R. 43 E.	Rosebud Creek	11-01	10-25	10-17	15.9	48.9	No flow	-.60	-3.70	-.68
RT-13	SW¼SE¼ sec. 1, T. 1 N., R. 42 E. (06295380)	Cow Creek	--	--	10-18	--	--	.05	--	--	--
R-14	SE¼SE¼ sec. 29, T. 2 N., R. 43 E. (06295400)	Rosebud Creek	11-01	--	10-17	14.9	--	.04	-1.00	--	-.01
R-15	NE¼SE¼ sec. 29, T. 2 N., R. 43 E.	Pony Creek	11-01	--	10-17	No flow	--	[2].01	--	--	--
R-16	NW¼NE¼ sec. 16, T. 2 N., R. 43 E.	Rosebud Creek	11-01	--	10-18	14.6	--	.01	-.30	--	-.04
R-17	NW¼NW¼ sec. 4, T. 2 N., R. 43 E.	Spring Creek	11-01	--	10-18	No flow	--	No flow	--	--	--
R-18	NE¼SW¼ sec. 33, T. 3 N., R. 43 E.	Rosebud Creek	11-01	--	10-18	14.8	--	No flow	.20	--	-.01
R-19	SW¼SE¼ sec. 8, T. 3 N., R. 43 E.	Rosebud Creek	11-01	10-25	10-18	14.9	47.6	No flow	.10	-1.30	0
R-20	NE¼SW¼ sec. 30, T. 4 N., R. 43 E.	Rosebud Creek	11-01	--	10-18	14.3	--	No flow	-.60	--	0
R-21	NW¼SE¼ sec. 13, T. 4 N., R. 42 E.	Rosebud Creek	11-01	10-25	10-18	13.7	48.7	.02	-.60	1.10	.02
R-22	NW¼SW¼ sec. 34, T. 5 N., R. 42 E.	Vance Creek	11-01	--	10-18	[2].01	--	No flow	--	--	--
R-23	SW¼SE¼ sec. 28, T. 5 N., R. 42 E.	Rosebud Creek	11-01	--	10-18	14.3	--	No flow	.59	--	-.02
R-24	SW¼SE¼ sec. 5, T. 5 N., R. 42 E.	Rosebud Creek	11-02	--	10-18	13.0	--	No flow	-1.30	--	0
R-25	NW¼NE¼ sec. 21, T. 6 N., R. 42 E. (06296003)	Rosebud Creek	11-02	10-25	10-18	13.6	49.8	.16	.60	1.10	.16

[1]Alternative site at location of recently established streamflow-gaging station.
[2]Estimated discharge.

Table 4.--*Monthly and annual precipitation and departures from average at Rosebud Creek weather stations during 12 months prior to base-flow studies*

[Upper numeral is precipitation, in inches; lower numeral is departure from average. Average precipitation based on data from 1951-80. Precipitation data from U.S. Department of Commerce (issued annually)]

Study year	Month												Annual total
	N	D	J	F	M	A	M	J	J	A	S	O	
							Colstrip						
1977	0.54 -.13	0.22 -.41	0.81 +.25	0.25 -.31	1.44 +.70	0.18 -1.68	3.05 +.58	1.54 -1.77	2.25 +1.07	2.34 +.95	1.18 -.20	1.60 +.56	15.40 -.39
1978	.75 +.08	.68 +.05	.74 +.18	1.10 +.54	.16 -.58	.57 -1.29	9.27 +6.80	1.45 -1.86	2.29 +1.11	.27 -1.12	4.09 +2.71	.10 -.94	21.47 +5.68
1983	.41 -.26	.58 -.05	.35 -.21	.11 -.45	.23 -.51	.01 -1.85	1.63 -.84	2.09 -1.22	1.66 +.48	1.33 -.06	1.37 -.01	.98 -.06	10.75 -5.04
							Busby						
1977	0.92 +.32	0.37 -.24	1.05 +.49	0.56 +.11	0.82 +.17	0.73 -.63	3.46 +1.25	1.93 -.91	0.55 -.60	1.21 -.12	1.14 -.22	1.96 +1.11	14.70 +.73
1978	.72 +.12	1.12 +.51	.68 +.12	.81 +.36	.42 -.23	1.81 +.45	8.21 +6.00	1.22 -1.62	.84 -.31	.47 -.86	4.11 +2.75	.36 -.49	20.77 +6.80
1983	.53 -.07	.96 +.35	.36 -.20	.27 -.18	.46 -.19	.22 -1.14	1.53 -.68	1.66 -1.18	1.54 +.39	1.12 -.21	1.38 +.02	1.50 +.65	11.53 -2.44

Table 5.--*Water-quality data for selected sites on Otter Creek and tributaries during 1977, 1978, and 1983 base-flow conditions*

[ft^3/s, cubic feet per second; °C, degrees Celsius; μS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; ton/d, tons per day; μg/L, micrograms per liter; <, less than]

Site No.	Date	Discharge (ft^3/s)	Water temperature (°C)	Onsite specific conductance (μS/cm)	Onsite pH (units)	Hardness, as $CaCO_3$ (mg/L)	Hardness, non-carbonate as $CaCO_3$ (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Sodium adsorption ratio
0-2	10-23-78	0.29	11.0	6,500	--	--	--	--	--	--	--
	10-19-83	.02	8.0	6,200	8.3	--	--	--	--	--	--
0-4	10-19-83	.01	8.0	3,850	8.4	1,400	930	140	260	460	5.3
0-5	10-24-78	.75	4.0	3,620	--	--	--	--	--	--	--
	10-19-83	.17	8.5	3,450	7.7	1,400	880	200	230	450	5.1
0-6	10-19-83	.08	10.0	2,600	8.0	--	--	--	--	--	--
0-7	10-26-77	.79	9.0	2,620	8.2	1,000	480	110	180	300	4.1
	10-24-78	3.05	7.0	2,980	8.4	900	420	130	140	340	4.9
	10-19-83	2.76	8.5	3,000	8.3	1,100	660	130	200	390	5.0
0-8	10-26-77	.92	9.5	2,260	8.2	710	210	19	160	250	4.1
	10-19-83	.95	10.0	2,600	8.3	1,200	690	100	220	350	4.5
0-9	10-19-83	.04	14.0	4,120	8.5	--	--	--	--	--	--
0-10A	10-19-83	.89	14.5	3,280	8.6	1,000	480	75	200	420	5.7
0-10	10-27-77	.15	8.5	4,400	8.1	1,400	830	83	290	630	7.3
	10-24-78	3.97	6.5	3,000	8.3	1,100	590	110	200	380	5.0
	10-19-83	1.15	11.5	3,500	8.4	--	--	--	--	--	--
0-12	10-19-83	.07	11.0	3,300	8.4	1,200	530	110	230	530	6.6
0-14	10-24-78	3.07	6.5	3,120	--	--	--	--	--	--	--
	10-20-83	.02	3.0	3,700	8.5	--	--	--	--	--	--
0-15	10-24-78	.08	6.5	3,560	--	--	--	--	--	--	--
	10-19-83	.03	12.0	4,300	8.2	--	--	--	--	--	--
0-16	10-27-77	.55	10.0	3,890	8.3	1,200	520	96	230	570	7.2
	10-24-78	3.81	6.0	3,250	8.1	1,100	590	90	210	440	5.8
	10-20-83	.45	7.5	3,800	8.4	1,000	420	72	210	560	7.5
0-18	10-27-77	1.24	11.0	3,200	8.3	760	160	73	140	370	5.8
	10-24-78	3.89	7.5	3,060	--	--	--	--	--	--	--
	10-20-83	1.05	9.0	2,600	8.4	720	160	72	130	360	5.9
0-19	10-24-78	4.23	7.0	2,830	--	--	--	--	--	--	--
	10-20-83	.74	9.0	2,200	8.4	660	100	67	120	330	5.6
0-20	10-28-77	.04	11.0	2,600	8.3	820	250	82	150	390	5.9
	10-20-83	.01	7.0	2,950	7.9	--	--	--	--	--	--

Potassium (mg/L)	Alkalinity, total as $CaCO_3$ (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Dissolved solids, sum of constituents (mg/L)	Dissolved-solids load (ton/d)	Nitrogen, nitrite plus nitrate, dissolved as N (mg/L)	Nitrogen, ammonia dissolved as N (mg/L)	Nitrogen, nitrite plus nitrate, total as N (mg/L)	Nitrogen, ammonia, total as N (mg/L)
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
9.5	490	1,900	26	0.5	2.8	3,090	0.08	<0.01	0.01	<0.1	--
--	--	--	--	--	--	--	--	--	--	--	--
18	570	1,900	20	.6	25	3,170	1.46	.83	.03	.8	--
--	--	--	--	--	--	--	--	--	--	--	--
16	520	1,100	10	.8	16	2,040	4.35	--	--	.02	0.01
19	480	1,100	15	.6	15	2,050	16.9	--	--	.01	.02
15	490	1,500	16	.6	14	2,560	19.1	<.1	.02	<.1	--
17	500	840	9.8	.8	15	1,610	4.00	--	--	.25	.14
18	470	1,300	13	.5	6.6	2,280	5.85	<.1	.02	<.1	--
--	--	--	--	--	--	--	--	--	--	--	--
20	530	1,400	16	.6	6.6	2,440	5.86	<.1	.02	<.1	--
26	570	2,100	24	.6	4.1	3,500	1.42	--	--	.06	.07
20	510	1,300	15	.6	7.2	2,340	25.1	--	--	.01	.01
--	--	--	--	--	--	--	--	--	--	--	--
22	690	1,700	20	.7	14	3,040	.57	<.1	.02	<.1	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
26	680	1,600	14	1.2	7.1	2,950	4.38	--	--	.04	<.01
22	510	1,400	16	.6	2.9	2,490	25.6	--	--	.01	.01
24	620	1,700	17	1.1	12	2,960	3.60	<.1	.03	<.1	--
20	600	980	15	.9	12	1,970	6.60	--	--	.02	.03
--	--	--	--	--	--	--	--	--	--	--	--
11	560	960	11	.8	18	1,890	5.36	1.3	.04	1.3	--
--	--	--	--	--	--	--	--	--	--	--	--
6.0	560	850	11	.8	12	1,730	3.46	<.1	.05	<.1	--
20	570	1,100	10	1.0	13	2,110	.23	--	--	.47	.03
--	--	--	--	--	--	--	--	--	--	--	--

Nitrogen, organic, total as N (mg/L)	Nitrogen, ammonia plus organic, total as N (mg/L)	Nitrogen, total as N (mg/L)	Phosphorus, total as P (mg/L)	Phosphorus, dissolved as P (mg/L)	Boron, dissolved (μg/L)	Cadmium, dissolved (μg/L)	Cadmium, total recoverable (μg/L)	Iron, dissolved (μg/L)	Lead, dissolved (μg/L)	Lead, total recoverable (μg/L)	Manganese, dissolved (μg/L)	Manganese, total recoverable (μg/L)
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	3.5	3.6	0.28	0.01	360	<1	<1	60	<1	3	340	550
--	--	--	--	--	--	--	--	--	--	--	--	--
--	.8	1.6	.03	.02	340	<1	<1	60	<1	2	100	100
--	--	--	--	--	--	--	--	--	--	--	--	--
0.19	.20	.22	.01	.01	330	--	--	280	--	--	--	--
.39	.41	.42	.03	.02	340	--	--	30	--	--	--	--
--	.8	.9	.02	.01	360	<1	<1	60	<1	2	110	100
.42	.56	.81	.05	.02	300	--	--	30	--	--	--	--
--	.9	1.0	.01	.01	370	<1	<1	60	<1	2	50	50
--	--	--	--	--	--	--	--	--	--	--	--	--
--	1.0	1.1	.02	<.01	390	<1	1	60	1	3	40	50
.71	.78	.84	.03	.02	660	--	--	50	--	--	--	--
.47	.48	.49	.02	.01	390	--	--	30	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	1.4	1.5	.03	<.01	500	<1	1	40	<1	2	120	140
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
.71	.71	.75	.07	.05	680	--	--	30	--	--	--	--
.59	.60	.61	.03	.01	460	--	--	20	--	--	--	--
--	1.0	1.1	.03	.01	650	<1	<1	50	<1	3	90	100
.32	.35	.37	.06	.01	220	--	--	30	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	1.0	2.3	.01	<.01	540	<1	<1	50	<1	3	40	50
--	--	--	--	--	--	--	--	--	--	--	--	--
--	1.2	1.3	.03	<.01	540	<1	<1	40	<1	2	40	70
.56	.59	1.1	.04	<.01	470	--	--	30	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--

Table 6.--*Changes in dissolved-solids loads between sites on Otter Creek during 1977, 1978, and 1983 base-flow conditions*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; ton/d, tons per day]

Site No.	Date	Streamflow (ft^3/s)	Specific conductance (µS/cm)	Dissolved solids concentration (mg/L)	Dissolved solids load (ton/d)	Sum of known tributary loads entering reach between mainstem sites (ton/d)	Net gain of ground-water load or loss (-) of surface-water load between mainstem sites (ton/d)
O-2	10-23-78	0.29	6,500	[1]5,270	4.13	--	--
	10-19-83	.02	6,200	[1]5,020	.27	--	--
O-5	10-24-78	.75	3,620	[1]2,880	5.82	0	1.69
	10-19-83	.17	3,450	3,170	1.46	.08	1.11
O-7	10-26-77	.79	2,620	2,040	4.35	--	--
	10-24-78	3.05	2,980	2,050	16.9	0	11.1
	10-19-83	2.76	3,000	2,560	19.1	.46	17.1
O-8	10-26-77	.92	2,260	1,610	4.00	0	-.35
	10-19-83	.95	2,600	2,280	5.85	0	-13.2
O-10	10-27-77	.15	4,400	3,500	1.42	0	-2.58
	10-24-78	3.97	3,000	2,340	25.1	--	--
	10-19-83	1.15	3,500	[1]2,780	8.63	.36	2.42
O-14	10-24-78	3.07	3,120	[1]2,460	20.4	0	-4.70
	10-20-83	.02	3,700	[1]2,940	.16	0	-8.47
O-16	10-27-77	.55	3,890	2,950	4.38	--	--
	10-24-78	3.81	3,250	2,490	25.6	.61	4.59
	10-20-83	.45	3,800	2,960	3.60	.28	3.16
O-18	10-27-77	1.24	3,200	1,970	6.60	0	2.22
	10-24-78	3.89	3,060	[1]2,410	25.3	0	-.30
	10-20-83	1.05	2,600	1,890	5.36	0	1.76
O-19	10-28-78	4.23	2,830	[1]2,220	25.4	0	.1
	10-20-83	.74	2,200	1,730	3.46	0	-1.90

[1]Dissolved-solids concentration estimated from the following regression equation relating specific conductance (X) to dissolved-solids concentration (Y): $Y = 0.83X - 129$; $N = 18$, $R^2 = 0.81$.

Table 7.--*Water-quality data for selected sites on Rosebud Creek and tributaries during 1977, 1978, and 1983 base-flow conditions*

[ft^3/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; ton/d, tons per day; µg/L, micrograms per liter; <, less than]

Site No.	Date	Discharge (ft^3/s)	Water temperature (°C)	Onsite specific conductance (µS/cm)	Onsite pH (units)	Hardness, as $CaCO_3$ (mg/L)	Hardness, non-carbonate as $CaCO_3$ (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Sodium adsorption ratio
R-1	10-31-77	3.51	6.0	1,100	8.2	540	97	72	88	24	0.4
	10-25-78	4.12	4.5	1,250	--	--	--	--	--	--	--
	10-16-83	.02	10.0	1,220	7.7	700	250	98	110	37	.7
RT-2	10-16-83	.17	8.5	1,060	7.9	--	--	--	--	--	--
R-3	10-16-83	.67	9.0	1,080	8.2	--	--	--	--	--	--
RT-3	10-16-83	.67	9.5	955	8.1	--	--	--	--	--	--
R-4	11-01-77	8.32	2.5	910	8.4	470	66	75	69	25	.5
	10-25-78	19.1	6.0	950	8.1	530	120	83	79	30	.6
R-4A	10-16-83	3.58	8.5	1,020	8.2	540	50	81	82	39	.8
R-5	11-01-77	18.0	5.0	1,170	8.4	590	160	78	96	70	1.3
	10-25-78	55.5	5.5	1,200	8.3	600	170	77	100	73	1.3
	10-17-83	2.56	7.0	1,750	8.4	810	300	93	140	160	2.9
R-7	10-17-83	2.02	8.5	2,250	8.2	--	--	--	--	--	--
R-8	10-25-78	52.6	6.5	1,250	--	--	--	--	--	--	--
	10-18-83	1.47	7.0	2,480	8.1	990	520	100	180	240	3.3
R-11	11-01-77	16.5	6.0	1,250	8.6	590	170	73	100	81	1.4
	10-17-83	.68	8.0	3,400	8.1	1,100	650	130	200	440	5.7
R-13	10-25-78	48.9	7.0	1,400	--	--	--	--	--	--	--
RT-13	10-18-83	.05	6.0	7,800	8.4	4,000	3,300	380	730	840	5.8
R-14	11-01-77	14.9	7.5	1,360	8.5	600	180	76	100	90	1.6
	10-17-83	.04	9.0	3,300	8.4	1,400	900	130	250	340	4.0
R-15	10-17-83	.01	8.5	5,200	7.8	--	--	--	--	--	--
R-16	10-18-83	.01	7.0	6,500	8.7	--	--	--	--	--	--
R-18	11-01-77	14.8	7.5	1,340	8.0	640	230	75	110	38	.7
R-19	10-25-78	47.6	7.0	1,400	--	--	--	--	--	--	--
R-21	11-01-77	13.7	7.5	1,380	8.5	600	190	76	100	110	2.0
	10-25-78	48.7	7.0	1,400	8.5	640	230	73	110	92	1.6
	10-18-83	.02	8.0	5,100	8.2	1,500	730	200	240	730	8.2
R-23	11-01-77	14.3	7.5	1,340	8.6	600	190	74	100	94	1.7
R-25	11-02-77	13.6	9.0	1,320	8.5	540	140	71	87	120	2.3
	10-25-78	49.8	7.5	1,460	8.6	640	240	73	110	110	1.9
	10-18-83	.16	9.0	2,550	8.6	600	20	59	110	410	7.3

Potassium (mg/L)	Alkalinity, total as $CaCO_3$ (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Dissolved solids, sum of constituents (mg/L)	Dissolved-solids load (ton/d)	Nitrogen, nitrite plus nitrate, dissolved as N (mg/L)	Nitrogen, ammonia dissolved as N (mg/L)	Nitrogen, nitrite plus nitrate, total as N (mg/L)	Nitrogen, ammonia, total as N (mg/L)
7.0	450	200	4.1	0.6	14	676	6.41	--	--	0.01	<0.01
--	--	--	--	--	--	--	--	--	--	--	--
5.0	450	300	3.5	.6	15	833	.04	0.23	0.05	.2	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
8.0	400	120	3.8	.7	18	563	12.6	--	--	.10	.03
7.0	410	170	4.2	.6	17	640	33.0	--	--	.07	.01
8.5	490	150	5.1	.6	20	680	6.6	<.1	.04	<.1	--
10	430	270	4.9	.7	17	807	39.2	--	--	.01	.07
10	430	310	5.8	.6	16	853	128	--	--	.01	<.01
18	510	670	14	.7	11	1,400	9.9	<.1	.03	<.1	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
11	470	1,000	13	.6	10	1,840	7.30	<.1	.03	<.1	--
11	430	320	5.2	.7	16	860	38.3	--	--	<.01	.01
13	500	1,600	7.6	.6	13	2,690	4.94	<.1	.04	<.1	--
--	--	--	--	--	--	--	--	--	--	--	--
36	660	5,000	48	.9	16	7,390	1.00	--	--	<.1	.06
11	420	360	5.9	.7	16	912	36.7	--	--	.01	.04
9.0	450	1,600	20	.5	5.1	2,620	.28	<.1	.02	<.1	--
--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--
11	410	360	5.7	.7	15	862	34.4	--	--	<.01	<.01
--	--	--	--	--	--	--	--	--	--	--	--
12	410	390	6.2	.7	14	956	35.4	--	--	.01	.01
11	410	430	6.7	.6	15	983	129	--	--	.01	.01
17	760	2,500	29	.4	16	4,150	.22	<.1	.07	<.1	--
11	410	360	7.2	.7	14	907	35.0	--	--	.01	.01
11	400	370	6.4	.7	12	918	33.7	--	--	.05	.01
11	400	450	7.2	.6	15	1,020	137	--	--	.01	.01
9.1	580	960	21	.9	6.4	1,890	.82	<.1	.08	<.1	--

Nitrogen, organic, total as N (mg/L)	Nitrogen, ammonia plus organic, total as N (mg/L)	Nitrogen, total as N (mg/L)	Phosphorus, total as P (mg/L)	Phosphorus, dissolved as P (mg/L)	Boron, dissolved (μg/L)	Cadmium, dissolved (μg/L)	Cadmium, total recoverable (μg/L)	Iron, dissolved (μg/L)	Lead, dissolved (μg/L)	Lead, total recoverable (μg/L)	Manganese, dissolved (μg/L)	Manganese, total recoverable (μg/L)
0.38	0.39	0.39	0.05	0.03	90	--	--	30	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	.7	.9	.02	.01	130	<1	<1	7	<1	3	180	180
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
.39	.42	.52	.07	.02	110	--	--	20	--	--	--	--
.88	.89	.96	.02	.01	120	--	--	20	--	--	--	--
--	1.0	1.1	.06	<.01	110	<1	<1	12	1	1	30	60
.17	.24	.25	.04	.02	180	--	--	20	--	--	--	--
.58	.58	.59	.04	.01	180	--	--	20	--	--	--	--
--	1.0	1.1	.07	.01	360	1	<1	25	2	2	30	50
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	1.4	1.5	.04	.01	420	<1	<1	200	2	3	40	50
.24	.25	.25	.04	.01	190	--	--	20	--	--	--	--
--	1.2	1.3	.05	.01	520	<1	<1	120	<1	2	260	280
--	--	--	--	--	--	--	--	--	--	--	--	--
1.6	1.7	1.8	.80	--	3,100	--	--	110	--	--	--	--
.24	.28	.29	.03	.02	200	--	--	20	--	--	--	--
--	1.7	1.8	.06	.01	470	<1	<1	110	2	2	70	90
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
.30	.30	.30	.04	.01	210	--	--	20	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
.47	.48	.49	.07	<.01	210	--	--	30	--	--	--	--
.67	.68	.69	.04	<.01	200	--	--	10	--	--	--	--
--	1.4	1.5	.02	<.01	330	<1	<1	70	2	3	3,200	3,100
.38	.39	.40	.05	<.01	210	--	--	30	--	--	--	--
.65	.66	.71	.12	.01	210	--	--	40	--	--	--	--
.46	.47	.48	.04	<.01	220	--	--	10	--	--	--	--
--	1.2	1.3	.02	.01	500	1	<1	40	2	6	70	130

Table 8.--*Changes in dissolved-solids loads between sites on Rosebud Creek during 1977, 1978, and 1983 base-flow conditions*

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25° Celsius; mg/L, milligrams per liter; ton/d, tons per day]

Site No.	Date	Streamflow (ft^3/s)	Specific conductance (µS/cm)	Dissolved-solids concentration (mg/L)	Dissolved solids load (ton/d)	Sum of known tributary loads entering reach between mainstem sites (ton/d)	Net gain of ground-water load or loss (-) of surface-water load between mainstem sites (ton/d)
R-1	10-31-77	3.51	1,100	676	6.41	--	--
	10-25-78	4.12	1,250	[1]820	9.12	--	--
	10-16-83	.02	1,220	833	.04	--	--
R-4	11-01-77	8.32	910	563	12.6	0	6.19
	10-25-78	19.1	950	640	33.0	0	23.9
R-4A	10-16-83	3.58	1,020	662	6.40	1.27	5.09
R-5	11-01-77	18.0	1,170	807	39.2	0	26.6
	10-25-78	55.5	1,200	853	128	0	95.0
	10-17-83	2.56	1,750	1,400	9.86	0	3.28
R-8	10-25-78	52.6	1,250	[1]820	116	0	-12.0
	10-18-83	1.47	2,480	1,840	7.30	0	-2.38
R-11	11-01-77	16.5	1,250	860	38.3	--	--
	10-17-83	.68	3,400	2,690	4.94	0	-2.36
R-14	11-01-77	14.9	1,360	912	36.7	0	-1.60
	10-17-83	.04	3,300	2,620	.28	1.00	-5.66
R-21	11-01-77	13.7	1,380	956	35.4	0	-1.30
	10-25-78	48.7	1,400	983	129	--	--
	10-18-83	.02	5,100	4,150	.22	.12	-.18
R-25	11-02-77	13.6	1,320	918	33.7	0	-1.70
	10-25-78	49.8	1,460	1,020	137	0	8.00
	10-18-83	.16	2,550	1,890	.82	0	.60

[1]Dissolved-solids concentration estimated from the following regression equation relating specific conductance (X) to dissolved-solids concentration (Y): Y = 0.95 X -368; N = 22, R^2 = 0.99.

Table 9.--*Discharge and water-quality data for selected springs in the Otter Creek basin*

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

Site No.	Location	Date	Discharge (gal/min)	Water temperature (°C)	Onsite specific conductance (µS/cm)	Onsite pH (units)	Hardness, as $CaCO_3$ (mg/L)
OSP-1	NE¼NW¼ sec. 31, T. 7 S., R. 46 E.	06-25-84	0.9	9.5	2,430	7.5	--
OSP-2	SE¼NE¼ sec. 4., T. 8 S., R. 45 E.	02-27-74	1.5	2.5	3,700	7.5	1,600
		06-25-84	.9	14.0	4,200	7.5	--
OSP-3	NW¼SE¼ sec. 8, T. 8 S., R. 45 E.	02-02-74	7.0	6.0	1,190	7.9	300
		06-25-84	.4	17.0	1,310	8.1	--
OSP-4	SE¼SE¼ sec. 4, T. 8 S., R. 46 E.	02-07-74	--	2.0	2,590	7.8	--
		06-25-84	1.0	13.0	2,500	7.5	--
OSP-5	NE¼NW¼ sec. 7, T. 8 S., R. 47 E.	02-06-74	1.3	6.0	3,500	7.8	1,150
		06-25-84	.9	11.0	3,700	7.4	--
OSP-6	NW¼SW¼ sec. 18, T. 6 S., R. 46 E.	06-25-84	.9	12.5	5,600	7.1	--
OSP-7	NE¼NW¼ sec. 27, T. 5 S., R. 46 E.	01-16-74	.5	2.0	4,400	7.5	2,640
		06-25-84	.9	12.0	5,200	7.4	--
OSP-8	SW¼NW¼ sec. 36, T. 4 S., R. 46 E.	06-26-84	.4	13.5	4,100	7.5	--
OSP-9	NE¼SE¼ sec. 9, T. 5 S., R. 46 E.	01-16-74	2.0	4.5	2,320	7.8	990
		06-26-84	1.3	13.5	2,400	7.7	--
OSP-10	NE¼SE¼ sec. 28, T. 4 S., R. 46 E.	01-16-74	--	7.5	5,720	7.7	--
		06-26-84	.4	14.0	5,500	7.2	--
OSP-11	NW¼SW¼ sec. 29, T. 4 S., R. 46 E.	01-16-74	.8	8.0	5,750	7.9	2,400
		06-26-84	.4	16.5	6,400	7.5	--
OSP-12	NE¼NE¼ sec. 18, T. 5 S., R. 45 E.	01-12-74	.6	1.0	2,750	8.1	1,860
		10-28-80	--	7.5	3,220	7.0	1,910
		06-26-84	1.3	14.5	2,750	7.2	--
OSP-13	SE¼NW¼ sec. 8, T. 5 S., R. 45 E.	01-13-74	1.0	8.0	1,820	7.7	660
		06-26-84	.4	11.5	2,080	7.2	--
OSP-14	SE¼NE¼ sec. 29, T. 5 S., R. 45 E.	01-16-74	.2	6.0	2,900	8.0	1,430
		06-26-84	.4	13.5	2,500	7.5	--
OSP-15	SE¼NW¼ sec. 18, T. 3 S., R. 46 E.	01-18-74	.7	6.0	6,000	8.1	920
		06-26-84	.9	11.5	5,600	7.1	--
OSP-16	SE¼SE¼ sec. 34, T. 3 S., R. 46 E.	08-22-74	.3	16.5	3,900	7.8	880
		06-27-84	.9	13.0	4,200	7.7	--
OSP-17	NE¼NE¼ sec. 36, T. 2 S., R. 45 E.	06-27-84	.9	13.5	1,800	7.5	--
OSP-18	SW¼SW¼ sec. 33, T. 2 S., R. 46 E.	08-08-74	.2	15.0	1,700	8.6	820
		06-27-84	.4	15.0	1,260	7.8	--
OSP-19	NW¼NE¼ sec. 32, T. 2 S., R. 46 E.	08-08-74	4.0	12.0	2,390	8.0	660
		06-27-84	2.7	11.0	2,600	7.5	--

Hardness, noncarbonate as $CaCO_3$ (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Sodium adsorption ratio	Potassium (mg/L)	Alkalinity, total as $CaCO_3$ (mg/L)	Sulfate (mg/L)	Chloride (mg/L)
--	52	89	500	--	9.0	931	690	18
1,080	192	268	377	4.1	19	522	1,830	22
--	180	300	440	--	26	541	2,100	27
0	50	40	76	1.9	10	300	146	9.3
--	56	48	180	--	11	329	380	11
--	110	130	350	--	13	582	970	6.2
--	130	120	330	--	15	566	910	6.7
584	157	183	466	6.0	14	568	1,580	9.9
--	160	190	490	--	14	565	1,600	10
--	150	220	920	--	12	671	2,800	17
1,820	230	493	318	2.7	17	815	2,380	12
--	260	570	420	--	17	943	2,800	11
--	180	230	540	--	15	552	2,000	7.7
285	96	179	224	3.1	12	705	730	6.6
--	91	180	230	--	13	688	760	7.3
--	360	510	540	--	21	754	3,300	8.4
--	330	530	490	--	19	920	3,200	8.4
1,670	266	416	738	6.6	20	725	3,090	11
--	280	440	930	--	21	826	3,500	12
1,260	160	351	122	1.2	10	602	1,470	10
1,370	156	371	119	1.2	10	543	1,580	14
--	170	280	100	--	8.8	572	1,300	11
0	51	66	330	7.2	5.5	656	438	5.7
--	61	85	300	--	5.8	656	490	7.3
940	149	253	254	2.9	8.1	490	1,460	11
--	150	250	250	--	8.7	533	1,400	13
0	103	59	1,000	19	10	916	1,710	11
--	85	60	1,200	--	12	870	2,100	11
0	113	113	755	12	11	881	1,410	12
--	99	110	740	--	9.0	827	1,600	14
--	64	65	410	--	8.2	601	720	4.4
0	13	6.8	425	23.6	5.4	817	193	7.9
--	14	5.1	420	--	5.1	744	190	7.4
0	76	82	402	7.6	10	660	680	6.0
--	76	87	420	--	10	655	790	5.9

Fluoride (mg/L)	Silica (mg/L)	Dissolved solids, sum of constituents (mg/L)	Nitrogen, as NO_3 (mg/L)	Aluminum, dissolved (μg/L)	Boron, dissolved (μg/L)	Iron, dissolved (μg/L)	Manganese, dissolved (μg/L)	Strontium, dissolved (μg/L)
1.6	11	1,930	--	10	250	260	30	1,200
.6	18	3,370	6.2	--	--	30	40	--
.8	25	3,430	--	<10	1,100	80	20	4,000
1.3	21	720	.4	--	--	10	<10	--
1.5	22	908	--	<10	640	10	16	--
--	--	1,960	--	--	--	--	--	--
1.0	24	1,880	--	10	500	160	120	1,800
.7	13	3,120	8.0	--	--	30	50	--
.8	14	2,820	--	10	560	250	130	2,800
.4	12	4,540	--	<10	340	1,000	110	7,700
.5	17	3,970	4.9	--	--	<10	160	--
.4	16	4,670	--	<10	2,300	130	100	5,300
.8	16	3,330	--	10	970	50	20	3,300
.4	17	2,120	.1	--	--	<10	<10	--
.5	20	1,720	--	<10	800	20	<10	2,200
--	--	5,260	--	--	--	--	--	--
.4	19	5,160	--	<10	1,500	60	140	4,300
.5	18	5,450	3.7	--	--	<10	<10	--
.6	19	5,700	--	<10	720	140	<10	4,800
.6	17	2,510	.8	--	--	20	<10	--
.3	17	2,590	<.01	40	600	32	38	2,570
.6	18	2,240	--	<10	390	330	50	2,600
1.1	12	1,710	2.8	--	--	<10	<10	--
1.1	13	1,360	--	10	220	60	<10	1,900
.4	14	2,750	.5	--	--	<10	<10	--
.5	15	2,410	--	20	460	70	10	2,900
.5	12	4,030	4.6	--	--	<10	<10	--
.7	11	4,010	--	20	470	150	160	4,100
1.3	14	3,500	<.1	--	--	<10	40	--
1.2	14	3,090	--	<10	200	40	30	1,600
.6	13	1,650	--	10	220	590	40	2,100
1.0	9.2	1,570	5.4	--	--	<10	<10	--
1.2	9.8	1,100	--	10	190	60	31	640
.6	16	2,080	2.8	--	--	<10	<10	--
.6	17	1,800	--	10	320	150	50	2,800

Table 10.--*Discharge and water-quality data for selected springs in the Rosebud Creek basin*

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; <less than]

Site No.	Location	Date	Discharge (gal/min)	Water temperature (°C)	Onsite specific conductance (µS/cm)	Onsite pH (units)	Hardness as $CaCO_3$ (mg/L)	Hardness, noncarbonate as $CaCO_3$ (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)
RSP-1	SW¼NW¼ sec. 8, T. 7 S., R. 39 E.	07-29-74	5.0	9.0	625	8.2	330	81	50	50	12
		07-09-84	--	9.0	695	7.7	--	--	52	52	14
RSP-2	SW¼NW¼ sec. 10, T. 7 S., R. 39 E.	07-31-74	1.0	9.0	820	8.0	430	26	66	65	12
		07-09-84	.9	9.5	640	7.8	--	--	75	36	8.1
RSP-3	SW¼SW¼ sec. 10, T. 7 S, R. 39 E.	08-01-74	.2	14.0	1,330	7.8	780	164	120	117	17
		07-09-84	.4	13.5	1,320	7.2	--	--	120	110	17
RSP-4	SE¼NW¼ sec. 5, T. 7 S., R. 39 E.	08-01-74	4.0	9.0	1,800	8.0	1,000	451	94	183	49
		07-09-84	--	9.0	1,850	7.4	--	--	120	190	51
RSP-5	NW¼SW¼ sec. 34, T. 6 S., R. 39 E.	08-13-74	1.0	12.5	1,170	7.8	610	110	99	87	33
		07-10-84	.4	12.5	1,170	7.2	--	--	96	90	35
RSP-6	NW¼NW¼ sec. 2, T. 7 S., R. 39 E.	08-13-74	2.0	13.5	1,580	8.3	620	204	51	117	86
		07-10-84	.4	16.0	1,500	7.4	--	--	120	120	58
RSP-7	SE¼NW¼ sec. 2, T. 7 S., R. 39 E.	08-13-74	4.0	11.5	815	8.2	380	40	59	56	6.6
		07-10-84	.9	11.0	775	7.6	--	--	79	58	7.8
RSP-8	NE¼NE¼ sec. 23, T. 6 S., R. 39 E.	07-08-75	.8	9.5	1,880	6.9	780	48	106	125	182
		07-10-84	1.3	10.5	1,900	7.0	--	--	120	150	130
RSP-9	NE¼NW¼ sec. 2, T. 2 S., R. 41 E.	09-28-72	4.0	8.0	375	7.7	150	0	28	20	27
		07-10-84	.4	13.5	410	7.0	--	--	29	21	27
RSP-10	NE¼SE¼ sec. 12, T. 2 N., R. 43 E.	10-03-72	6.0	12.0	4,400	7.8	2,470	2,020	286	422	398
		07-10-84	4.5	11.0	4,400	7.6	--	--	280	310	500
RSP-11	SE¼NE¼ sec. 7, T. 3 N., R. 44 E.	08-27-75	6.0	14.0	3,550	6.5	470	57	96	105	546
		07-11-84	2.2	14.0	3,830	7.5	--	--	120	140	640
RSP-12	SW¼SE¼ sec. 8, T. 3 N., R. 44 E.	08-27-75	1.0	15.0	4,600	6.7	553	0	84	74	885
		07-11-84	.9	15.0	4,480	7.4	--	--	84	76	940

Sodium adsorption ratio	Potassium (mg/L)	Alkalinity, total as $CaCO_3$ (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Silica (mg/L)	Dissolved solids, sum of constituents (mg/L)	Nitrogen, as NO_3 (mg/L)	Aluminum, dissolved (µg/L)	Boron, dissolved (µg/L)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Strontium, dissolved (µg/L)
0.3	6.8	251	87	3.0	1.0	23	543	5.0	--	--	<10	<10	--
--	6.8	274	99	2.8	1.2	26	420	--	30	190	5	1	1,200
.2	5.6	406	55	5.9	.7	16	724	1.2	--	--	<10	<10	--
--	2.5	314	21	4.4	.5	15	352	--	10	40	7	4	410
.3	5.8	620	196	2.6	.5	21	1,240	.3	--	--	<10	10	--
--	5.5	606	190	2.6	.6	23	834	--	<10	70	460	<1	820
.7	11	548	544	5.9	.6	17	1,580	4.4	--	--	<10	<10	--
--	5.6	586	540	6.4	.8	18	1,290	--	<10	170	14	3	1,800
.6	7.2	501	151	7.0	.5	19	1,020	4.1	--	--	<10	<10	--
--	19	528	140	4.8	.5	25	735	--	<10	250	3,700	510	3,100
1.5	6.2	412	368	7.9	.5	10	1,120	1.5	--	--	<10	<10	--
--	5.2	530	370	6.6	.6	14	1,020	--	<10	70	390	300	1,900
.1	3.5	339	31	8.3	.3	12	616	26	--	--	<10	<10	--
--	3.3	386	43	5.2	.4	13	442	--	10	20	3	1	350
2.8	7.2	731	427	3.5	.3	11	1,300	.5	--	--	<10	150	--
--	7.4	673	490	4.9	.4	13	1,320	--	<10	60	980	170	2,900
1.0	3.0	150	51	3.8	1.4	24	341	<.1	--	--	50	<10	--
--	3.8	155	44	3.7	1.5	23	247	--	<10	140	9	39	770
3.5	18	456	2,750	12	.3	20	4,190	11	--	--	60	20	--
--	19	519	2,500	19	.4	16	3,970	--	<10	2,300	50	<10	7,000
9.1	9.4	416	1,370	13	.6	19	2,410	3.3	--	--	10	10	--
--	10	430	1,800	13	.6	20	3,010	--	<10	990	50	<10	3,200
17	6.8	553	1,810	17	.8	8.3	3,220	3.3	--	--	20	30	--
--	6.6	287	2,000	17	.8	8.3	3,310	--	<10	690	40	140	2,800