# Assessment of Water Quality for the Sun River and Muddy Creek, Sun River Watershed, West-Central Montana

MBMG Open-file Report 412

Submitted to:

Cascade County Conservation District and
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by

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Earth Science Information

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**CONTENTS**



**FIGURES**

## TABLES

**ACKNOWLEDGMENTS**

The author of this report extends thanks to those individuals and agencies that provided water-quality and streamflow data for the Sun River watershed. Special thanks go to Alan Rollo, Sun River Watershed Project coordinator, and Patricia Ladd, U.S. Geological Survey, for providing the majority of the data. Thanks are extended to Perri Phillips, Vicki Sullivan, and Carol Endicott, Montana Department of Environmental Quality, for providing technical assistance and guidance. Special thanks to Abbie Phillips and Josh Gilder, Montana Tech Students, for help in compiling the water-quality data. The U.S. Environmental Protection Agency through a TMDL development grant to the Cascade County Conservation District provided funding for this project. The grant was awarded through the Montana Department of Environmental Quality.

## ABSTRACT

This report describes the results of a surface-water quality assessment in the Sun River watershed. Three streams in the Sun River watershed are listed as water-quality impaired (Clean Water Act § 303 (d)) and in need of Total Maximum Daily Load (TMDL) development. The three streams are the Sun River, Muddy Creek, and Ford Creek. The probable causes or types of impairment include flow alteration, salinity, siltation, nutrients, pH, thermal modification, and other habitat alterations. The data presented in this report will assist in determining if the listed impairments are supported by sufficient and credible data. Additionally, it will be used to help develop a TMDL for the impaired streams in the Sun River watershed. The majority of the data summarized in this report was compiled from water-quality and streamflow records provided by the U.S. Geological Survey for gaging-stations on the Sun River and Muddy Creek.

The most obvious changes in water-quality on the Sun River are downstream increases in salinity, nutrients, and suspended sediment. These problems are especially notable on the lower Sun River, below the confluence with Muddy Creek. In that reach of the stream, median total-dissolved solids concentrations and specific conductance values are approximately twice as high as upstream. Increases in sulfate, sodium, magnesium, and chloride account for most of the increase in salinity. Median nutrient and suspended sediment concentrations increase by two to three times downstream from Muddy Creek. In the Muddy Creek drainage, nutrient and suspended sediment concentrations are an order of magnitude higher compared to the Sun River. The primary threat to water quality from nutrients is the potential to contribute to eutrophication. Nitrate and total phosphorus concentrations in the Muddy Creek drainage and in the Sun River below Muddy Creek were frequently above levels recommended to prevent growth of nuisance algae and other unwanted aquatic plants. Suspended sediment has been a prevalent water-quality problem in the Sun River watershed, especially in the Muddy Creek drainage. Water-conservation measures have been implemented to reduce flow in Muddy Creek and consequently, suspended sediment concentrations are decreasing.

Flow alteration in the Sun River watershed is primarily associated with the diversion of water for irrigation. Discharge records indicate that streamflow does fall below levels recommended for maintaining a healthy fishery. Elevated water temperatures are also a concern for fisheries. In late spring and summer, temperatures are frequently above optimum levels for fish and other aquatic life. Trace elements are generally not a concern in water from the Sun River. On Muddy Creek, however, selenium concentrations exceeded chronic aquatic-life standards in approximately twenty-three percent of the samples. The median pH in water from the Sun River and Muddy Creek was approximately 8.1. There were no values outside the recommended range of 6.5-9.0.

Other than decreases in suspended sediment concentrations in the Muddy Creek drainage, no obvious water-quality trends were noted. There is a lack of current water-quality data available for the stretch of the Sun River above Muddy Creek and therefore, it is difficult to evaluate how water quality may have changed over time.

# INTRODUCTION

With passage of the 1972 federal Clean Water Act, Congress charged states with development of Total Maximum Daily Loads (TMDL) for waterbodies in priority watersheds. Within the Sun River watershed, three streams have been listed as water-quality limited (Clean Water Act § 303 (d)) and in need of TMDL development. The streams are the Sun River, Muddy Creek, and Ford Creek. The Sun River Watershed Project, a group of federal, state, local, and private individuals, is working on a comprehensive watershed management plan that will include development of TMDL's for these three streams.

A critical first step in the development of a TMDL is identification of the sources and causes of the stream impairments. For the Sun River watershed, the probable causes of impairment include flow alteration, nutrients, siltation, salinity, pH, thermal modification, and other habitat alteration. The information used to determine impairment was compiled from federal and state monitoring and assessment programs, local surveys, volunteer monitoring, and data from STORET (an EPA-supported national water quality database). The Montana Department of Environmental Quality (DEQ) is currently reviewing the 303(d) list to determine if the causes and sources of impairment are supported by sufficient and credible data. Following this review, a final version of the 303(d) list will be compiled. The information presented in this report will assist the DEQ in the data review process. It will also assist in the next step of the TMDL process, which is identifying the water quality goals and determining how much water-quality improvement is needed to meet the goals.

## Purpose and Scope

The purpose of this report is to present the available water-quality data for the Sun River Watershed to assist with future watershed management planning and TMDL development. Specific objectives include: (1) summarizing existing surface-water quality and quantity data for the Sun River watershed; (2) analyzing historical data and accessing the broad-scale geographical and seasonal variability in the water quality and quantity for the Sun River watershed; and (3) compiling the data in a format useful for setting Total Maximum Daily Loads (TMDL) goals and determining future monitoring needs. The focus of this report will be assessment of water-quality data for the Sun River and Muddy Creek. The DEQ has completed an onsite evaluation and assessment for Ford Creek and is in the process of reviewing and compiling those data.

## Data Sources and Compilation Methods

The majority of the data used to compile this summary was obtained from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) and from the Montana Water Resources Data reports, published annually by the U.S. Geological Survey (USGS). Data was available for the Sun River watershed for surface-water stations on the Sun River and Muddy Creek. The type of data available included information on field parameters (water temperature, specific conductance, pH, and alkalinity), nutrients, dissolved solids, suspended-sediment, major ions, trace elements, and discharge. There was little information available on tributaries to the Sun River, other than Muddy Creek. The information in this report includes all data collected through water year 1998. A summary of the USGS stations within the watershed, their locations, and the period of record for the data collected at each station is presented in Appendix 1.

Additional data discussed in this report, primarily in comparison to the USGS data, were available from a number of federal and state agencies including the U.S. Bureau of Reclamation, the Montana Bureau of Mines and Geology, the Department of Environmental Quality (formerly the Water Quality Bureau of the Montana Department of Health and Environmental Sciences) and the Montana Department of Fish, Wildlife and Parks (formerly the Department of Fish and Game). Some of this information is discussed in the report but was not used in the statistical summaries because of problems in determining locations, obtaining the raw data, or determining sampling methods. Additional water-quality information was obtained from the Ground Water Information Center (GWIC) housed at the Montana Bureau of Mines and Geology.

The data were evaluated to determine basic statistical parameters (range, mean, and median), and spatial, seasonal, and temporal variability. Many of the water-quality analyses had values that were less than the detection or reporting limits (herein referred to as censored data). In order to compute basic statistics for a given constituent, and not exclude all the censored values, concentrations less than the detection limit were set to one-half the detection limit. Where applicable, the water-quality data have been compared to drinking-water standards and stream-segment standards. Detailed trend analyses using statistical trend tests were not completed on the data compiled for this report.

## Previous Studies

A number of water-quality investigations have been completed within the Sun River Watershed. Much of the work has focused on Muddy Creek, which is a major tributary to the Sun River. The following discussion focuses on those reports that discuss surface-water quality within the Sun River watershed.

A comprehensive summary of the early (prior to 1979) water quality investigations on Muddy Creek (and to some extent the Sun River) is included in a report titled "Muddy Creek Special Water Quality Project" completed by Systems Technology, Inc. in 1979. The report summarizes investigations by the Bureau of Reclamation (1967, 1970, 1974), the Montana Department of Fish and Game (Hill, 1976), and the Water Quality Bureau of the Montana Department of Health and Environmental Sciences (Braico and others, 1974; Ingman and others, 1979). The report was compiled for the Muddy Creek Task Force and discusses hydrology, water quality, and biological conditions along Muddy Creek.  The major water-quality problems identified in the report were elevated nutrient and suspended solids concentrations, high water temperatures, hydraulic modifications such as streambank incision, and impacts to biological communities.

Ingman and others (1984) evaluated the effects of Muddy Creek on the biology of the lower Sun River.  Data was collected on nutrients, suspended solids, turbidity, periphyton (algae) production, and periphyton and macroinvertebrate (insect) community structure. The report concluded that the Sun River would not support a good fishery within at least two miles below the Muddy Creek confluence due primarily to the increase in suspended sediment.

Walther (1981, 1982) conducted two studies on nutrient occurrence in ground and surface water on the Greenfields Bench and Muddy Creek. He found that nitrate levels in ground water were frequently elevated, occasionally above the established drinking water standard for public water systems of 10 mg/L (U.S. Environmental Protection Agency, 1986). He also showed that irrigation drains from the Greenfields Bench contributed a large percentage of the nitrate in Muddy Creek.

Osborne and others (1983) evaluated the ground-water contribution to Muddy Creek from the Greenfields Irrigation District.  The purpose of the investigation was to determine the sources and quantities of runoff to Muddy Creek.  Limited water quality data were collected from irrigation drains and canals within the Greenfields Irrigation District.

The U.S. Geological Survey has conducted a number of investigations in the Sun River watershed.  Knapton and others (1988) completed a reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in the Sun River area.  Data were collected on selected inorganic and organic constituents in water, bottom sediment, and biota and analytical results were compared to various criteria and baseline information. For samples collected on the Sun River, there were no apparent increases in trace element (arsenic, boron, mercury, and selenium) concentrations in biota downstream from irrigated lands.  The report documented that selenium concentrations were above recommended criteria in Freezout Lake Wildlife Management Area (WMA) and Benton Lake National Wildlife Refuge. The report concluded that elevated nitrate concentrations in ground water were the most serious threat to water quality within the Sun River Irrigation project.

Because of concern about the adverse effects of selenium on water quality and it's potential risk to wildlife, a number of detailed investigations were completed by the USGS, in cooperation with other federal agencies, within the Sun River Irrigation Project, Freezout Lake Wildlife Management Area and Benton Lake National Wildlife Refugee (Lambing and others, 1994; Nimick and others, 1996; Kendy and Olsen, 1997; Nimick, 1997; Kendy and others, 1999).  The results of these investigations indicate that selenium concentrations in water, bottom sediment, and biota in the Freezout Lake WMA can exceed established criteria and standards. The source of the selenium to the wetlands was identified as return flow (primarily ground-water discharge) from irrigated glacial-lake deposits. Selenium concentrations generally were higher in biota than in water and bottom sediment, indicating that selenium is bioaccumulating in the drains and wetlands associated with the seleniferous glacial-lake deposits. Although selenium concentrations exceed established criteria and standards in places, there were no indications of impairment to the biota.

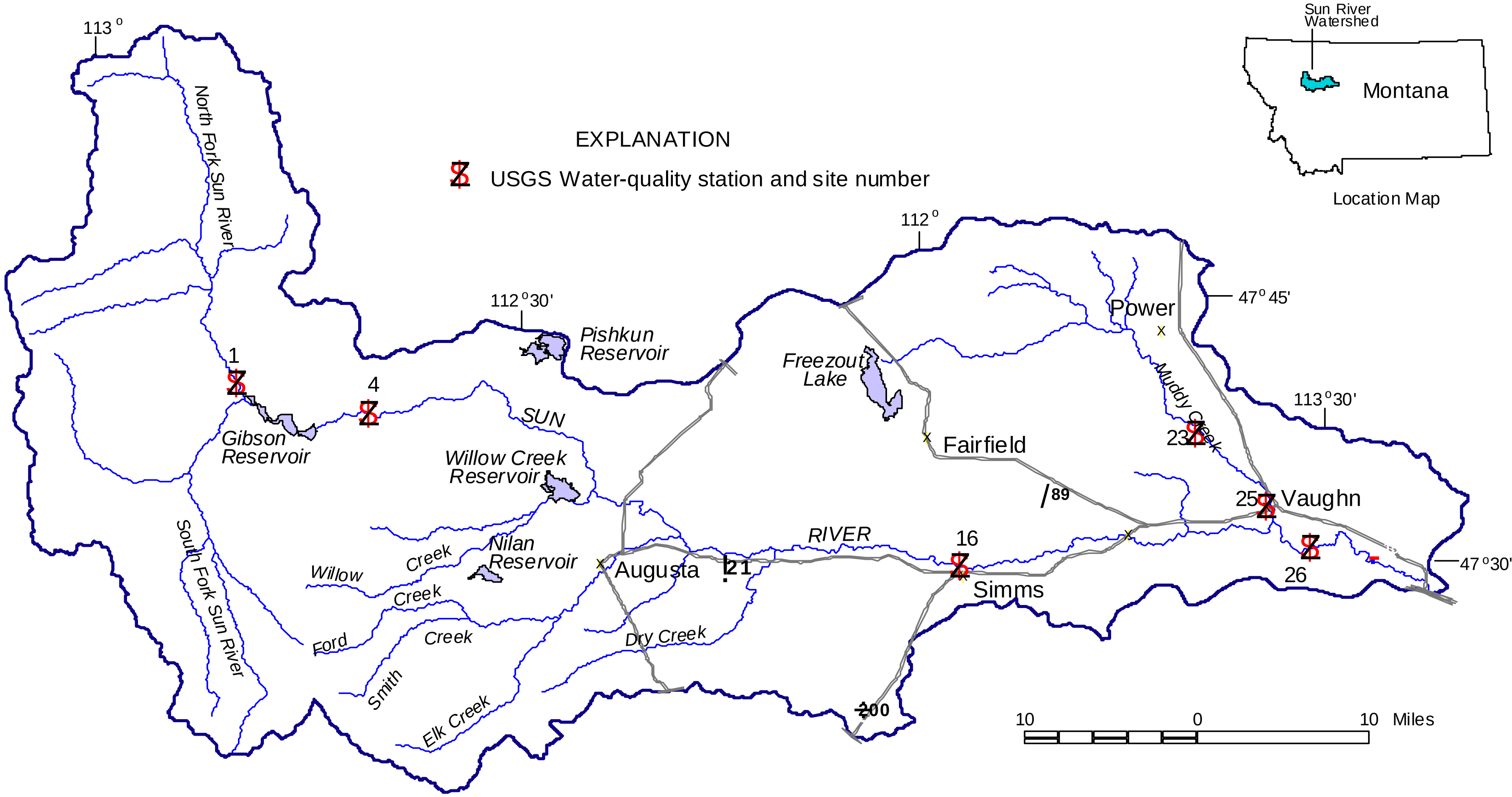
Including the work by Osborne and others (1983), the Montana Bureau of Mines and Geology (MBMG) has conducted a number of investigations on the Greenfields Bench. MBMG completed a water quality and hydrogeologic assessment for the town of Fairfield as part of development of the Montana Source Water Protection Technical Guidance Manuel (Miller, 1998). MBMG and the Montana Department of Agriculture (Miller and others, in preparation) are currently involved in two projects assessing water quality and residual pesticide concentrations in ground water and surface water on the Greenfields Bench. Data collection and interpretation are ongoing. Initial results indicate that very low levels of pesticides, primarily the pesticide Assert used for wild oat control, have been found in the shallow aquifer and surface water in drains discharging to Muddy Creek. MBMG and MDA are cooperating on an additional project that will assess how different irrigation methods affect transport of pesticides to ground water. Data collection for the irrigation project will begin in February 2000.

## DESCRIPTION OF STUDY AREA

The Sun River watershed is located in North-Central Montana (figure 1) and encompasses approximately 2,200 square miles. Land-surface altitude in the watershed ranges from approximately 3,350 feet in the valley to 9,000 feet along the continental divide, the western watershed boundary. The climate of the area is influenced by the topographic convergence of mountains and plains causing semi-arid conditions and variable temperatures. The mean annual temperature is 44° F. Precipitation in the watershed averages about 12-15 inches per year, with 80 percent of the precipitation falling from April through September.

Geologic units vary from Precambrian-age sedimentary rocks to Quaternary alluvial deposits (Maughan, 1971; Lemke, 1977; Mudge and others, 1982). The oldest rocks are of Precambrian to Paleozoic-age and are exposed in the western mountains. They consist of tightly folded and faulted, fine-grained mudstones, sandstones, and impure carbonates. Relatively flat lying and undisturbed Mesozoic rocks of Jurassic and Cretaceous-age underlie the plains in the eastern portion of the watershed. The Mesozoic rocks consist mainly of marine mudstones and sandstones. Quaternary deposits of glacial origin blanket large areas near the base of the mountains and across the plains. Alluvial deposits occupy parts of stream valleys and veneer many of the elevated plateaus bordering the Sun River.

Land use/land cover is 35 percent cropland, 28 percent rangeland, 35 percent forested, and 2 percent urban. The rangeland and forested areas are located primarily in the western end of the watershed. Cropland consists of approximately 30 percent irrigated




USGS STATION NAME AND NUMBER

1. North Fork Sun River near Augusta (6078500)
4. Sun River below Diversion Dam (6080900)
16. Sun River near Simms (6085800)
23. Muddy Creek near Vaughn (6088300)
25. Muddy Creek at Vaughn (6088500)
26. Sun River near Vaughn (6089000)

**Figure 1. Location of the Sun River watershed and selected USGS surface-water gaging stations.**

and 70 percent dryland. Irrigation water is diverted from the Sun River below Gibson Dam and passes through a series of reservoirs and canals before distribution to the fields.

Surface water within the Sun River watershed has been assigned water-use classifications by the DEQ. The surface water use classification is based primarily on water temperature, fisheries, and associated aquatic life. The Sun River above the confluence with Muddy Creek is classified as B1. The B1 classification is for multiple-use water suitable for domestic use after conventional treatment, growth and propagation of cold-water fisheries, associated aquatic life and wildlife, and agriculture and industrial uses. The Sun River below Muddy Creek is assigned a B3 classification. The primary difference between B1 and B3 water is that B3 is suitable for warm-water fisheries. Muddy Creek is classified as I (impacted) stream. Impacted water does not fully support drinking, recreation, or fisheries uses. Specific water-quality standards have been developed for each classification to protect the quality of the water and the present and future beneficial uses. For waterbodies with I (impacted) classifications, the state's goal is to improve the waterbody so they will fully support all appropriate beneficial uses.

## WATER QUANTITY

The Sun River is an important tributary of the Upper Missouri River. The headwaters form on the eastern slopes of the Front Range and the river empties into the Missouri River at Great Falls. The major tributaries are Muddy Creek, Elk Creek, and Mill Coulee. Irrigation water is diverted from the Sun River below Gibson Reservoir for use in the Fort Shaw and Greenfields Irrigation Divisions. A working group from the Sun River Watershed Project is developing a water budget that will address water-quantity issues in greater detail.

Streamflow measurements have been made at 30 gaging stations in the Sun River watershed (Appendix 1); 6 of the stations were active through water year 1998 and their locations are shown in figure 1. About 50 percent of the annual streamflow on the Sun River occurs in May and June when precipitation and runoff are high (figure 2). In the Muddy Creek drainage, where discharge is controlled by irrigation return flows, approximately 50 percent of the flow occurs in June, July, and August. The primary difference between the sites is that high streamflows are sustained over a longer period of time on Muddy Creek. Peak flow on the Sun River occurs in June; on Muddy Creek the peak usually occurs in July or August when more irrigation water is being discharged to wasteways and drains surrounding the Greenfields Bench. Variations in annual mean streamflow on Muddy Creek also reflect the influence of irrigation return flows. Annual mean flow on Muddy Creek shows little hydrologic variability compared to the Sun River where conditions are more representative of natural hydrologic conditions (figure 3). Fluctuations in streamflow on a seasonal and annual basis can affect water quality and are discussed in a subsequent section of this report.

The diversion of water from the Sun River for irrigation has affected streamflow, especially in the upper reaches. During the irrigation season, low streamflows and

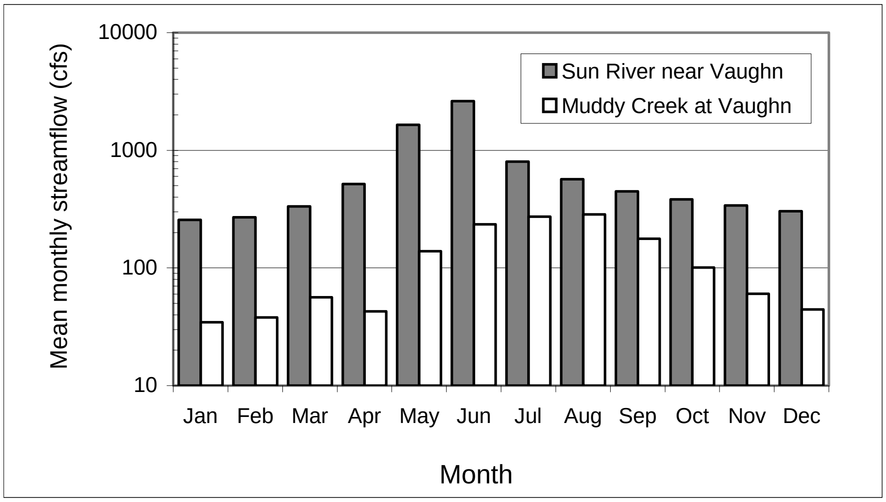



**Figure 2**. Comparison of mean monthly streamflow for the Sun River near Vaughn and Muddy Creek at Vaughn stations, Sun River watershed.

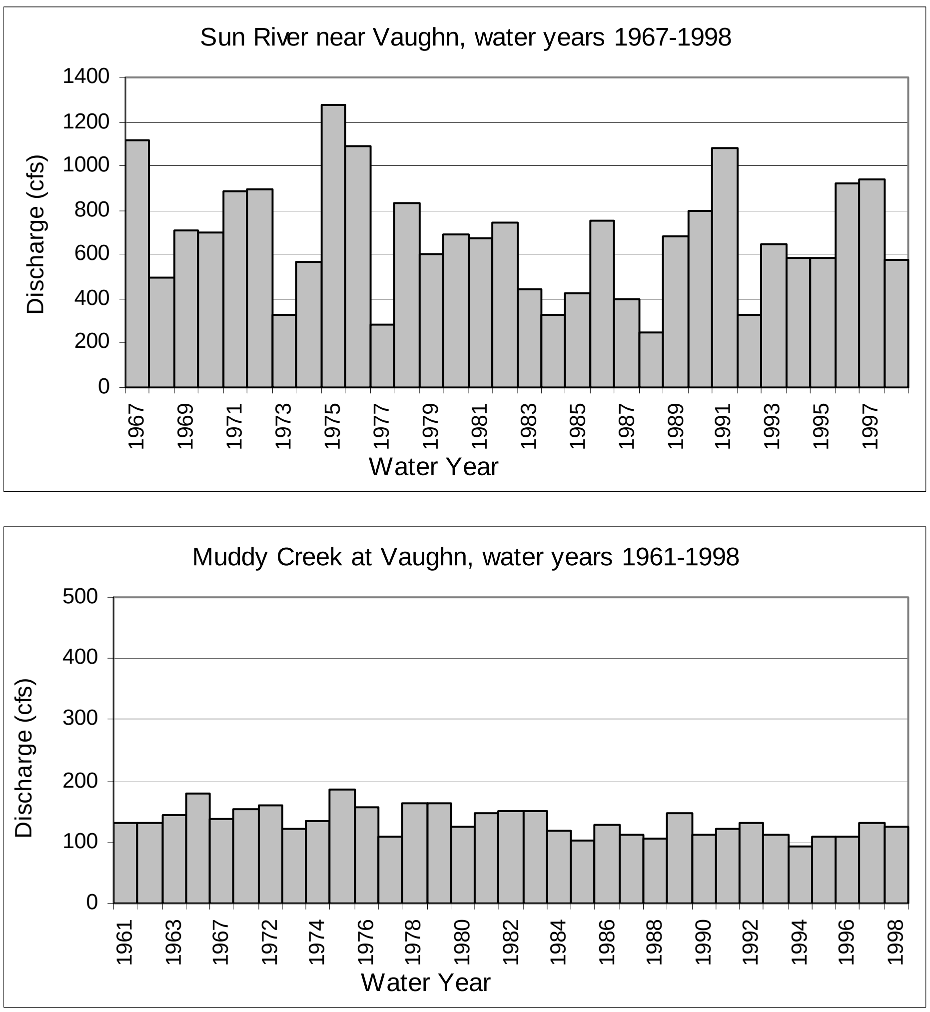



**Figure 3**. Annual mean streamflow at the Sun River near Vaughn and Muddy Creek at Vaughn stations in the Sun River watershed.

dewatering can impact fisheries. The Montana Department of Fish, Wildlife, and Parks recommends that to protect fisheries, streamflow above Elk Creek (figure 1) should be maintained above 100 cubic feet per second (cfs) and below Elk Creek, it should be above 130 cfs (Montana Department of Natural Resources, 1992). Historical streamflow data from the Sun River near Augusta gaging station (see Figure 14, Appendix 1 for location of this station) shows that prior to the construction of Gibson streamflow was rarely below 100 cfs (figure 4a). After 1930, streamflow at that station was often below 100 cfs. Current data for the Sun River near Simms station indicates that streamflow does drop below recommended levels during certain times of the year (figure 4b).

## WATER QUALITY

Water quality is variable within the watershed, depending on where and when samples are collected. Six of the USGS streamflow-stations had water-quality data that were evaluated for this report. These particular sites were used because water-quality data was available for at least 2 continuous years. The locations of the sites are shown in figure 1; tables 3, 4, 6 and 7 provide summaries of the water quality data. Most of the stations, with the exception of the station located on the Sun River below the Diversion Dam (site 4, figure1), include data that were collected within the last 10 years and should be representative of current conditions (table 1).

**Table 1**. Period of record for water-quality data for selected USGS surface-water gaging stations in the Sun River watershed.

| Station Name | Station Number | Water Year | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1965 | | | | | 1970 | | | | | 1975 | | | | | 1980 | | | | | 1985 | | | | | 1990 | | | | | 1995 | | | | | 2000 |
| North Fork Sun River | 6078500 | | | | | | | | | | | | | | | | | | | | | | | | | x | x | x | x | x | | | | | | | |
| Sun River below Diversion Dam | 6080900 | | | | x | x | x | x | x | x | x | x | x | x | x | x | | | | | | | x | | | | | | | | | | | | | | |
| Sun River at Simms | 6085800 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | x | x | | | |
| Muddy Creek near Vaughn | 6088300 | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | | | | | | | | x | x | | | | x | x | x | x | |
| Muddy Creek at Vaughn | 6088500 | | | | x | | | | x | x | x | x | x | x | x | x | x | x | x | | | | | | | | | | x | x | x | x | x | x | x | x | |
| Sun River near Vaughn | 6089000 | | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | |

## Major Dissolved Constituents

The chemical quality of water can be characterized by its dissolved ion composition and is an important indication of the suitability of water for various beneficial uses. Water samples from the Sun River ranged from a calcium-bicarbonate type water upstream to a mixed-water type downstream. In the lower reaches, below Muddy Creek, magnesium and calcium are the dominant cations and bicarbonate and sulfate are the dominant anions. Water from Muddy Creek is also a mixed water-type

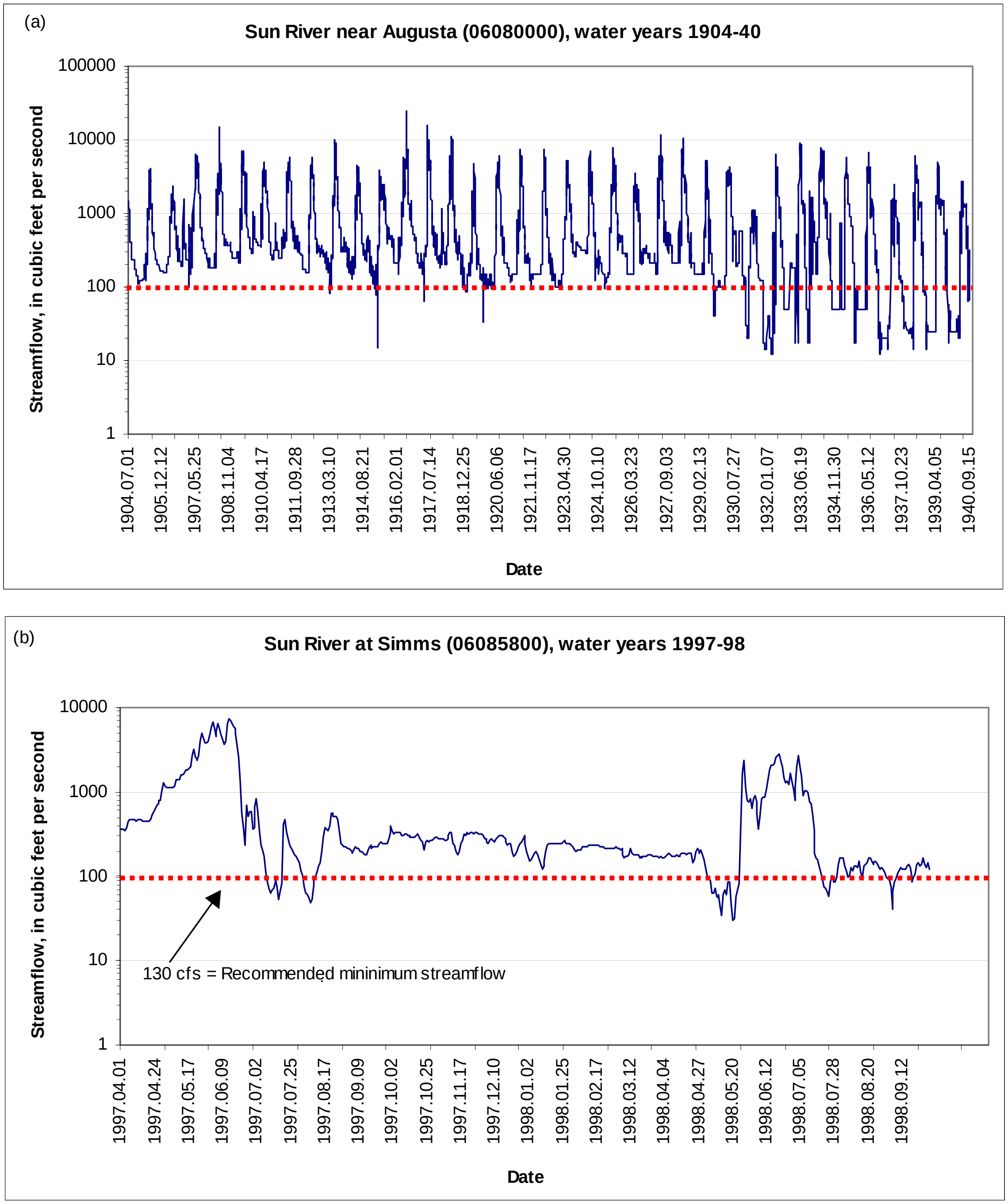
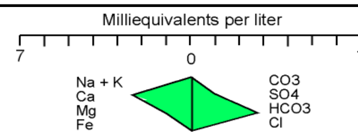
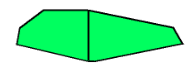
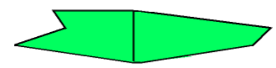
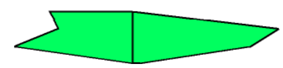



**Figure 4.** Historical streamflow data for two gaging stations in the Sun River watershed showing (a) effect of completion of Gibson Dam on streamflow and (b) recent streamflows for the gaging station near Simms. Recommend minimum streamflows are shown for each station. (See Appendix 1 for map showing location of the gaging stations.)

with magnesium, calcium, and sodium as the dominant cations and sulfate and bicarbonate as dominant anions. Table 2 summarizes the major cations and anions for four sites in the watershed. Stiff diagrams (Stiff, 1951) are included in table 2 to graphically illustrate the differences in water chemistry.

**Table 2**. Major cations and anions in surface-water from selected USGS stations in the Sun River watershed.

| Station | Major Cations | Major Anions | Stiff Diagrams |
|---|---|---|---|
| Sun River below Diversion Dam | Ca | $HCO_3$ |  |
| Sun River near Vaughn | Mg, Ca, Na | $HCO_3$, $SO_4$ |  |
| Muddy Creek near Vaughn | Mg, Na, Ca | $SO_4$, $HCO_4$ |  |
| Muddy Creek at Vaughn | Mg, Na, Ca | $SO_4$, $HCO_4$ |  |

The major change in water chemistry on the Sun River from upstream to downstream is an increase in salinity. The concentration of all common ions increases in the downstream direction, especially sodium, magnesium, and sulfate (tables 2 and 3). The increase in salinity can be measured by looking at changes in total-dissolved solids (TDS) concentrations. On the Sun River, TDS concentrations ranged from 92 mg/L to 1100 mg/L (table 4). The lowest concentrations were measured at the station below the Diversion Dam where the median value was 210 mg/L. The highest concentrations occur downstream at the station near Vaughn where the median was 464 mg/L. Dissolved-solids concentrations on Muddy Creek were higher than on the Sun River and ranged from 277 mg/L to 4520 mg/L, with a median value of 621 mg/L.

Specific conductance, which provides a qualitative indication of the TDS content of water, was measured at a number of stations where TDS data were lacking (table 4). Like total-dissolved solids concentrations, specific conductance values progressively increase from upstream to downstream (figure 5). On the Sun River, specific conductance ranged from 138 µS/cm to 1500 µS/cm. Median values were about two to three times higher at the downstream station near Vaughn compared to the stations above the confluence with Muddy Creek. On Muddy Creek, specific conductance ranged from 466 µS/cm to 5320 µS/cm with a median value of 954 µS/cm. Increases in specific conductance probably reflect changes in the surrounding geology and the increase in the amount of irrigation return flow discharging to the river.

**Table 3**. Summary of major dissolved-ion concentrations in surface water at selected USGS streamflow stations.

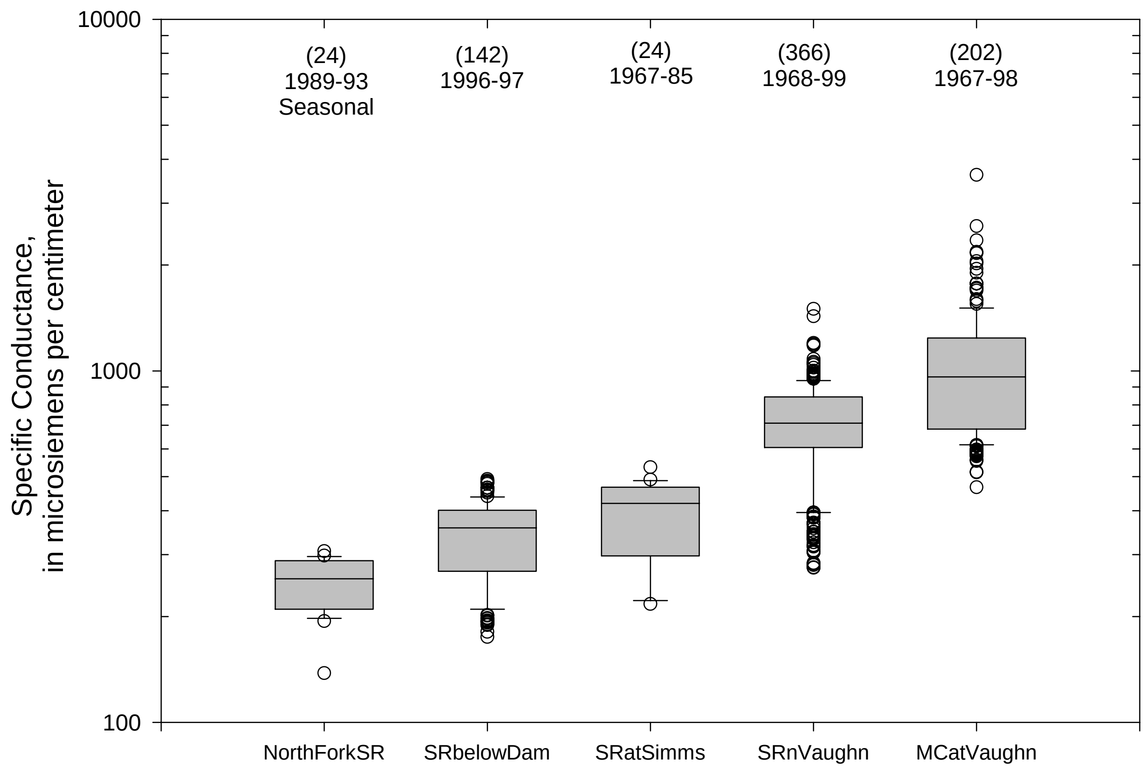
| Water Quality Constituent | | USGS STATION NAME | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sun River near Vaughn | Sun River at Simms | Sun River below Diversion Dam | North Fork Sun River | Muddy Creek at Vaughn | Muddy Creek near Vaughn |
| Calcium, dissolved (mg/L) | Mean | 60 | -- | 49 | -- | 64 | 58 |
| | Median | 60 | -- | 51 | -- | 63 | 54 |
| | Range | 34 – 93 | -- | 27 – 69 | -- | 37 – 120 | 32 – 170 |
| | n | 340 | -- | 148 | -- | 145 | 249 |
| Chloride, dissolved (mg/L) | Mean | 4.4 | -- | 0.8 | -- | 9.0 | 8.5 |
| | Median | 4.3 | -- | 0.8 | -- | 8.0 | 6.6 |
| | Range | 0.3 – 21 | -- | 0.1 – 2.1 | -- | 1.8 – 34 | 1.7 – 83 |
| | n | 339 | -- | 149 | -- | 143 | 250 |
| Flouride, dissolved (mg/L) | Mean | 0.4 | -- | 0.3 | -- | 1.0 | 0.9 |
| | Median | 0.4 | -- | 0.2 | -- | 1.0 | 0.9 |
| | Range | <0.1 – 1.1 | -- | <0.1 – 1 | -- | <0.1 – 1.5 | 0.3 – 1.5 |
| | n | 341 | -- | 148 | -- | 143 | 249 |
| Magnesium, dissolved (mg/L) | Mean | 38 | -- | 13 | -- | 63 | 63 |
| | Median | 39 | -- | 14 | -- | 64 | 62 |
| | Range | 10 – 84 | -- | 5.7 – 20 | -- | 25 – 150 | 27 – 330 |
| | n | 341 | -- | 148 | -- | 145 | 249 |
| Potassium, dissolved (mg/L) | Mean | 2.1 | -- | 0.9 | -- | 3.0 | 2.8 |
| | Median | 2.1 | -- | 0.9 | -- | 3.0 | 2.5 |
| | Range | 0.8 – 5.9 | -- | 0.3 – 2 | -- | 1.2 – 7.0 | 0.9 – 11 |
| | n | 341 | -- | 146 | -- | 143 | 249 |
| Silica, dissolved (mg/L) | Mean | 5.8 | -- | 5.4 | -- | 7.0 | 7.1 |
| | Median | 5.7 | -- | 5.3 | -- | 7.0 | 7.0 |
| | Range | 1.9 – 12 | -- | 3 – 21 | -- | 1.8 – 12 | 0.7 – 12 |
| | n | 340 | -- | 149 | -- | 143 | 249 |
| Sodium, dissolved (mg/L) | Mean | 43 | -- | 2.1 | -- | 81 | 78 |
| | Median | 42 | -- | 2.1 | -- | 73 | 70 |
| | Range | 6 – 140 | -- | 0.7 – 4.8 | -- | 19 – 320 | 23 – 750 |
| | n | 341 | -- | 148 | -- | 143 | 249 |
| Sulfate, dissolved (mg/L) | Mean | 177 | -- | 47 | -- | 305 | 286 |
| | Median | 180 | -- | 51 | -- | 280 | 245 |
| | Range | 24-610 | -- | 5.5 – 110 | -- | 79 – 980 | 79 – 2900 |
| | n | 341 | -- | 149 | -- | 143 | 248 |

[ n = number of samples, number in parenthesis is number of samples below the detection limit;  --, no data;  All concentrations in milligrams per liter (mg/L) ]

**Table 4**. Summary of water-quality parameters in surface water at selected USGS streamflow stations.

| Water Quality Constituent | | USGS STATION NAME: Sun River near Vaughn | Sun River at Simms | Sun River below Diversion Dam | North Fork Sun River | Muddy Creek at Vaughn | Muddy Creek near Vaughn |
|---|---|---|---|---|---|---|---|
| Temperature (degrees Celsius) | Mean | 10.3 | 10.7 | 6.8 | 7.9 | 10 | 9 |
| | Median | 11 | 9.8 | 6 | 7.3 | 11 | 9 |
| | Range | 0 – 27.5 | 0 – 21 | 0 – 21.5 | 0.5 – 14.5 | 0 – 23 | 0 – 27 |
| | n | 240 | 24 | 41 | 24 | 176 | 163 |
| Specific Conductance, field (µs/cm) | Mean | 706 | 389 | 364 | 256 | 1032 | 1015 |
| | Median | 710 | 419 | 357 | 246 | 961 | 954 |
| | Range | 275 – 1500 | 217 – 532 | 175 – 492 | 138 – 307 | 466 – 3610 | 517 – 5320 |
| | n | 366 | 24 | 131 | 24 | 202 | 269 |
| Total Dissolved Solids (mg/L) | Mean | 458 | -- | 199 | -- | 696 | 672 |
| | Median | 464 | -- | 210 | -- | 676 | 621 |
| | Range | 155 – 1100 | -- | 92 – 301 | -- | 277 – 1750 | 306 – 4520 |
| | n | 339 | -- | 148 | -- | 143 | 248 |
| pH, field (standard units) | Mean | 8.1 | -- | 8.0 | -- | 8.1 | 8.1 |
| | Median | 8.1 | -- | 8.0 | -- | 8.2 | 8.1 |
| | Range | 7.0 – 8.8 | -- | 6.9 – 8.5 | -- | 7.3 – 8.9 | 7.2 – 8.7 |
| | n | 221 | -- | 150 | -- | 117 | 181 |
| Suspended sediment (mg/L) | Mean | 103 | 33.6 | -- | 59.8 | 2422 | 1752 |
| | Median | 59 | 19.5 | -- | 21 | 566 | 446 |
| | Range | 10 – 910 | 2 – 236 | -- | 4 – 363 | 15 – 20,600 | 17 – 12,300 |
| | n | 72 | 20 | -- | 24 | 94 | 46 |
| Alkalinity, field (mg/L as $CaCO_3$) | Mean | 209 | -- | 133 | -- | 250 | 261 |
| | Median | 213 | -- | 140 | -- | 241 | 261 |
| | Range | 88 – 300 | -- | 84 – 158 | -- | 85 – 350 | 68 – 364 |
| | n | 216 | -- | 149 | -- | 59 | 237 |
| Sodium Absorption Ratio (SAR) | Mean | 1 | -- | 0.1 | -- | 1.7 | 1.7 |
| | Median | 1 | -- | 0.1 | -- | 2 | 2.0 |
| | Range | 0.2 – 3 | -- | 0 – 0.1 | -- | 0.6 – 5 | 0.7 – 8 |
| | n | 341 | -- | 149 | -- | 143 | 249 |
| Turbidity (NTU) | Mean | 22 | -- | -- | -- | -- | -- |
| | Median | 13 | -- | -- | -- | -- | -- |
| | Range | 0.4 – 170 | -- | -- | -- | -- | -- |
| | n | 48 | -- | -- | -- | -- | -- |

[ n , number of samples; --, no data; All concentrations in milligrams per liter (mg/L). ]



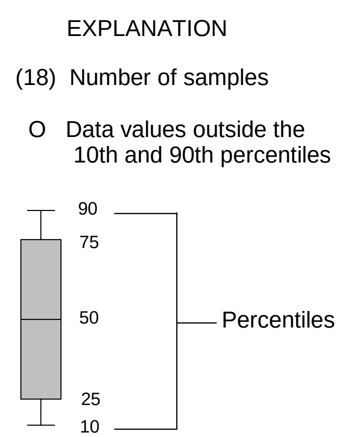




**Figure 5**. Distribution of specific conductance in the Sun River watershed. Boxplots for USGS stations are arranged from upstream (left) to downstream (right). The number of measurements and period of record for each location is indicated above the individual boxplots.

As a general indication of seasonal variations in water quality, mean monthly specific conductance values for the Sun River near Vaughn and the Muddy Creek at Vaughn station are shown in figure 6. Specific conductance at both sites is highest from late fall through early spring and peaks in March or April. During spring runoff and the onset of the irrigation season, specific conductance values decrease and remain relatively low until the end of the irrigation season (typically late September). Average specific conductance values are higher in the Muddy Creek drainage where the shale and glacial sediments contribute more salts to the surface water and ground water.

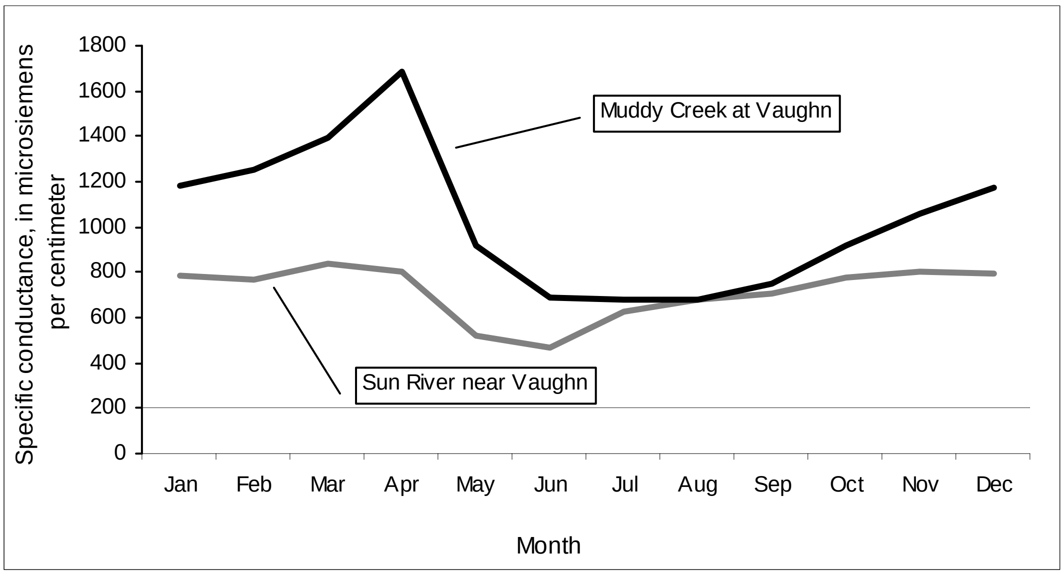



**Figure 6**. Mean monthly specific conductance values for the Muddy Creek at Vaughn and the Sun River near Vaughn stations in the Sun River watershed.

## Water-quality criteria for salinity and selected dissolved ions

A number of water-quality guidelines have been developed for dissolved solids and selected common ions that are used to evaluate the suitability of water for different beneficial uses (U.S. Environmental Protection Agency, 1986; Montana Department of Environmental Quality, 1995, National Academy of Sciences and National Academy of Engineering, 1972). The guidelines generally apply to water used for drinking or agriculture purposes, although there are some established recommendations for aquatic life. The following discussion compares the dissolved solids and dissolved ion data from the Sun River watershed to published guidelines for various water uses.

Secondary (optional) drinking-water standards are established for total-dissolved solids (TDS), sulfate, and chloride. The secondary drinking-water standard for TDS is 500 mg/L. Approximately 39 percent (132 of 339) of the samples from the Sun River below Muddy Creek exceeded 500 mg/L TDS. There were no exceedences above the confluence with Muddy Creek. In the Muddy Creek drainage, 65 percent of the TDS samples (254 of 391) were above 500 mg/L. The secondary standards for sulfate and chloride are 250 mg/L. The secondary sulfate standard was exceeded in 13 percent (44 of 341) of the samples from the Sun River near Vaughn station and 50 percent (195 of 391) of the samples from Muddy Creek. There were no exceedences of the chloride secondary-drinking water standard.

The aquatic-life standard for chloride is 860,000 µg/L for acute exposures and 230,000 µg/L for chronic exposures. This standard was not exceeded in any of the samples. There are currently no established guidelines for salinity or sulfate for aquatic life. However, Hart and others (1945) found that in most streams that support good-mixed fisheries, total-dissolved solids concentrations were generally less than 400 mg/L, specific conductance was below 500-2000 µS/cm, and sulfate concentrations were less than 90 mg/L. Surface water in the Sun River watershed is generally within these ranges, except for sulfate which is substantially greater than 90 mg/L in the Muddy Creek drainage and on the Sun River below Muddy Creek (tables 3 and 4).

Guidelines for suitability of water for agricultural use are based on salinity, measured either as total-dissolved solids (TDS) or specific conductance (table 5). In general, surface water in the Sun River watershed is excellent to very satisfactory for livestock use. Specific conductance values were less than 1500 µS/cm in most samples from the Sun River and about 90 percent of the samples from Muddy Creek (figure 5). Unless used on sensitive crops, water from the Sun River and Muddy Creek is also suitable for irrigation purposes. During the irrigation season (May to September) TDS and specific conductance values for the Sun River and Muddy Creek generally are within the range where there are no noticeable detrimental effects to crops (figure 7).

**Table 5**. Suggested guidelines for salinity in water used for irrigation and livestock

**IRRIGATION WATER**

Recommend level[1]

| Total Dissolved Solids (mg/L) | Specific Conductance (µS/cm) | CROP RESPONSE |
|---|---|---|
| <500 | <750 | No detrimental effects usually noticed |
| 500-1000 | 750-1500 | Can have detrimental effects on sensitive crops |
| 1000-2000 | 1500-3000 | May have detrimental effects on many crops, requires careful management |
| 2000-5000 | 3000-7500 | Can be used for salt-tolerant plants on permeable soils with careful management |

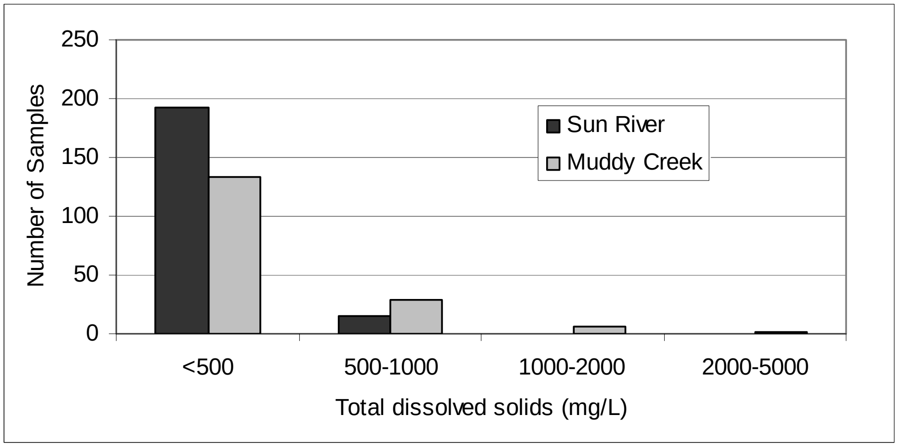
**LIVESTOCK WATER**

Recommended level[2]

| Total Dissolved Solids (mg/L) | Specific Conductance (µS/cm) | SUITABILITY FOR LIVESTOCK AND POULTRY |
|---|---|---|
| <1000 | <1500 | Relatively low salinity, excellent for all classes of livestock |
| 1000 - 3000 | 1500 - 5000 | Very satisfactory for all classes of livestock |

[1] Water Quality Criteria for Agriculture Uses, 1971

[2] National Academy of Sciences and National Academy of Engineering, 1972



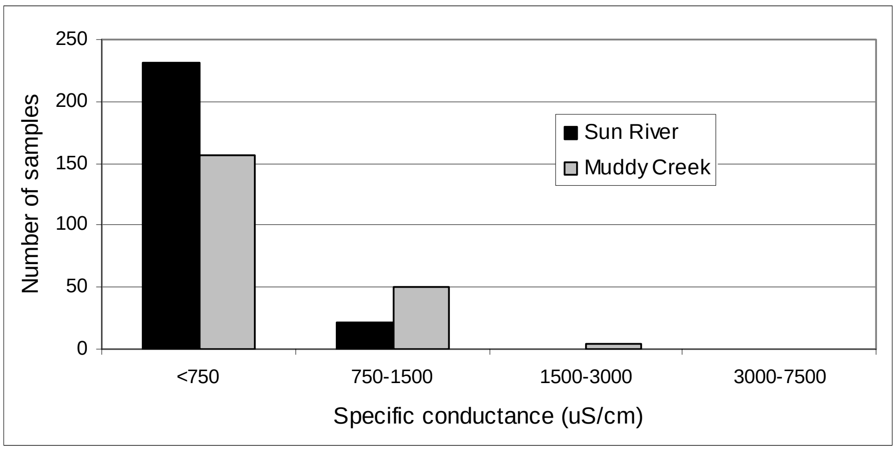




**Figure 7**. Frequency histograms of total-dissolved solids concentrations and specific conductance for the Sun River and Muddy Creek during the irrigation season (May to September).

The suitability of water for irrigation purposes can also be assessed by using sodium absorption ratios (SAR). SAR values increase from upstream to downstream on the Sun River (table 4). Maximum values ranged from 0.1 at the Diversion Dam site to 3.0 downstream at Vaughn. The highest SAR values were from Muddy Creek where the maximum was 8.0. The DEQ is using a SAR value of less than 4 to indicate no impairment for irrigation water (Perri Phillips, oral communication, 1999). There were no exceedences of this guideline for the Sun River and only a few samples (5 of 392) from Muddy Creek exceeded this value.

## Other Water-Quality Parameters

### Water temperature

The majority of the water temperature data collected within the Sun River watershed at the USGS stations represents instantaneous measurements made at the times that water-quality samples were collected. Because temperature is subject to diurnal fluctuations, the data presented here only represents a general indication of temperature conditions. Surface-water temperatures on the Sun River range from 0° to 27.5°C; for Muddy Creek the temperature range has been from 0° to 27°C (table 4). The highest temperatures generally occur in July. Depending on what type of aquatic life is present, the DEQ flags temperatures in the range of 18° to 23°C as possibly indicating impairment (Perri Phillips, oral communication, 2000). Temperatures above the 18° to 23°C range were measured at all the gaging sites. Temperature data is currently being collected at several locations on the Sun River by FWP and others on a continuous basis and this data will provide better information on which areas of the stream are experiencing water temperature problems.

Median water-temperatures on the Sun River tend to increase in the downstream direction, ranging from 6.8°C below the Diversion dam to 11°C near Vaughn. The actual magnitude of the temperature increase cannot be determined from the available data because the period of record is not the same for all stations and the samples were most likely collected at different times of the day. Hill (1976) collected temperature data on the Sun River between Gibson Dam and Vaughn and also found that the temperature increased slightly from upstream to downstream. He concluded that the increase in temperature was natural since the water temperatures at the mouths of the major tributaries and irrigation return-flow drains were similar to the temperature in the Sun River.

**pH**

The pH values for the Sun River ranged from 6.9 to 8.8, with a median value of 8.1; the pH values for Muddy Creek ranged from 7.3 to 8.9 with a median value of 8.1 (table 4). All reported pH values were within the recommended stream water-quality standard for pH (6.5-9.0).

**Suspended sediment and turbidity**

Suspended sediment concentrations are highly variable among the stations within the Sun River watershed (table 4). For the main stem of the Sun River, suspended sediment data is available for the station near Vaughn beginning in 1984 and for the station near Simms from March 1996 through December 1997. Median suspended sediment concentration at the Simms station is approximately 20 mg/L; downstream at the Vaughn station the median concentration is 59 mg/L. The increase in concentration between the two stations is primarily the result of inflow from Muddy Creek. In the Muddy Creek drainage, median suspended sediment concentrations ranged from 466 mg/L to 566 mg/L for the upstream (near Vaughn) and downstream (at Vaughn) stations, respectively.

The high concentration of suspended sediment in Muddy Creek is primarily the result of channel erosion and runoff during the irrigation season when streamflows are high.The relation between streamflow and suspended sediment for Muddy Creek and two stations on the Sun River is shown in figure 8. At all sites, suspended sediment concentrations increase with increasing streamflow. On the Sun River, below the Muddy

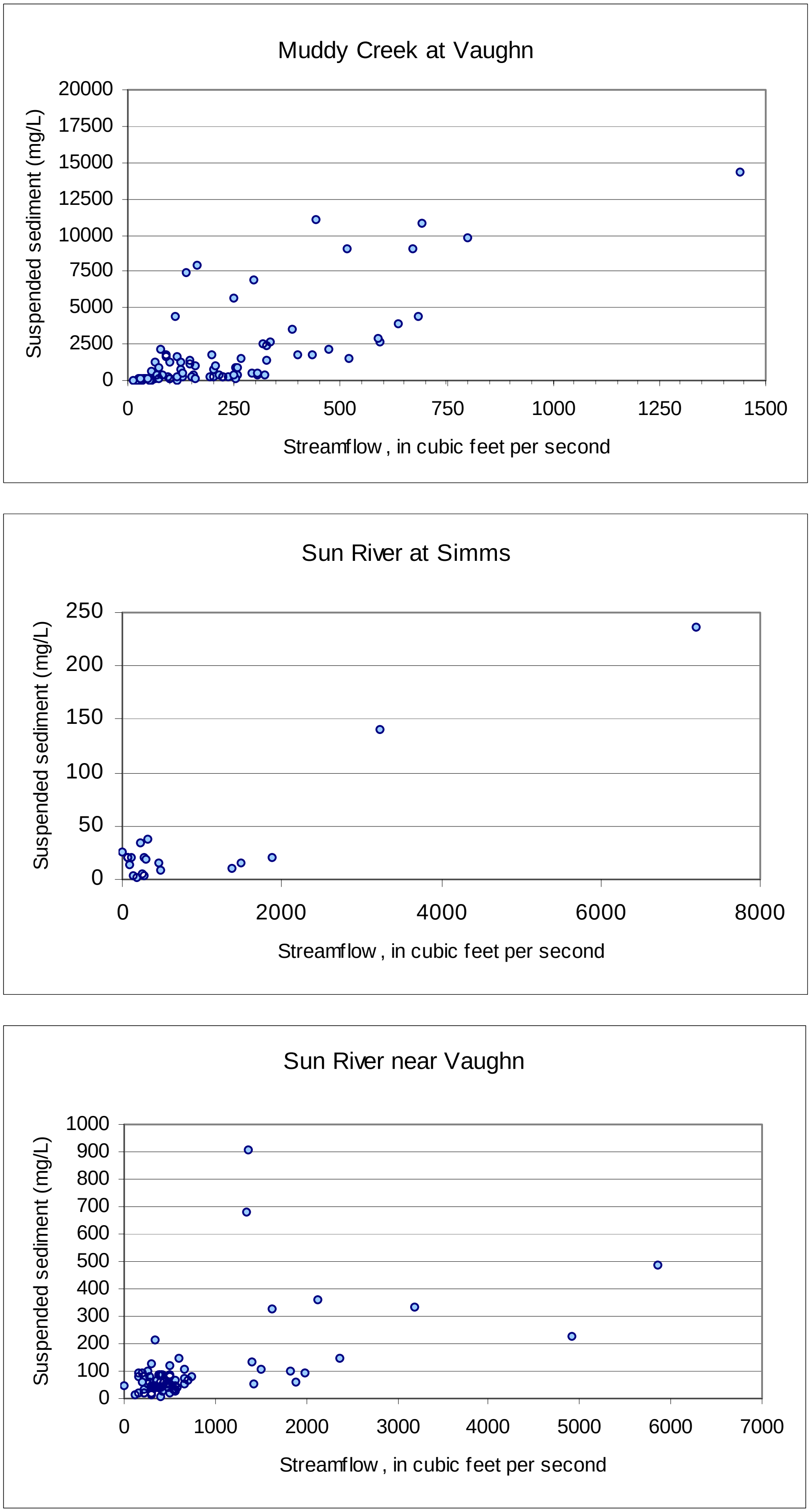



**Figure 8**. Relationship between streamflow and suspended sediment concentration for selected USGS stream-gaging stations in the Sun River watershed.

Creek confluence, some of the highest concentrations occurred at lower flows because of the sediment load from Muddy Creek.

Turbidity measurements have been taken at many locations within the Sun River watershed. However, different measurement methods have been used by different agencies making it difficult to compare the data. Recommended water-quality criteria are based on measurements reported in Nephelometric turbidity units (NTU). Turbidity data (in NTU's) for the Sun River are available only for the Sun River near Vaughn station. At this location, turbidity ranged from 0.4 to 170 NTU, with a median of 13 NTU (table 4). Ingman and others (1984) reported a similar range of turbidities from sites on the Sun River above and below the confluence with Muddy Creek. Their data showed that turbidity measurements were approximately seven times higher in the Sun River below the confluence with Muddy Creek. Unpublished turbidity data collected by the BUREC in 1974 documented an increase in turbidity between upstream and downstream stations on the Sun River. The largest increase occurred on the reach between Simms and Vaughn where three tributaries (Big Coulee, Mill Coulee, Muddy Creek) carrying irrigation return flow discharge into the Sun River. The turbidity ranged from 6-12 Jackson turbidity units (JTU) above the Simms station to 400 JTU downstream at the Vaughn station. The turbidity in the tributaries ranged from 95-550 JTU. The highest turbidities were measured in Muddy Creek.

Water-quality criteria for suspended sediment in streams have not been established, but elevated concentrations are known to affect fisheries and other aquatic life. While concentration alone can be an indicator of a potential pollution problem, duration of exposure is also important and both variables should be considered when evaluating the effects of suspended sediment on aquatic biota (Newcombe and MacDonald, 1991). In the Muddy Creek drainage, suspended sediment concentrations remain elevated from March through July, approximately two months longer than on the Sun River (figure 9).

## Nutrients

Nutrient concentrations were analyzed and reported using a number of different analytical methods and reporting conventions. In this report, all nutrient concentrations are reported as milligrams per liter as nitrogen or phosphorus (mg/L as N or P). Nitrogen or phosphorus data that were reported as $NO_2$, $NO_3$, or $PO_4$ were converted to equivalent concentrations of N or P using methods described Mueller and others (1995). Unless referred to as "total", the nutrient data discussed herein refers to dissolved-phase concentrations.

### Nitrogen

The most frequently analyzed nutrient was nitrogen (table 6). Nitrite plus nitrate (mg/L as N) was reported most often. Total nitrogen, nitrate, nitrite, and ammonia

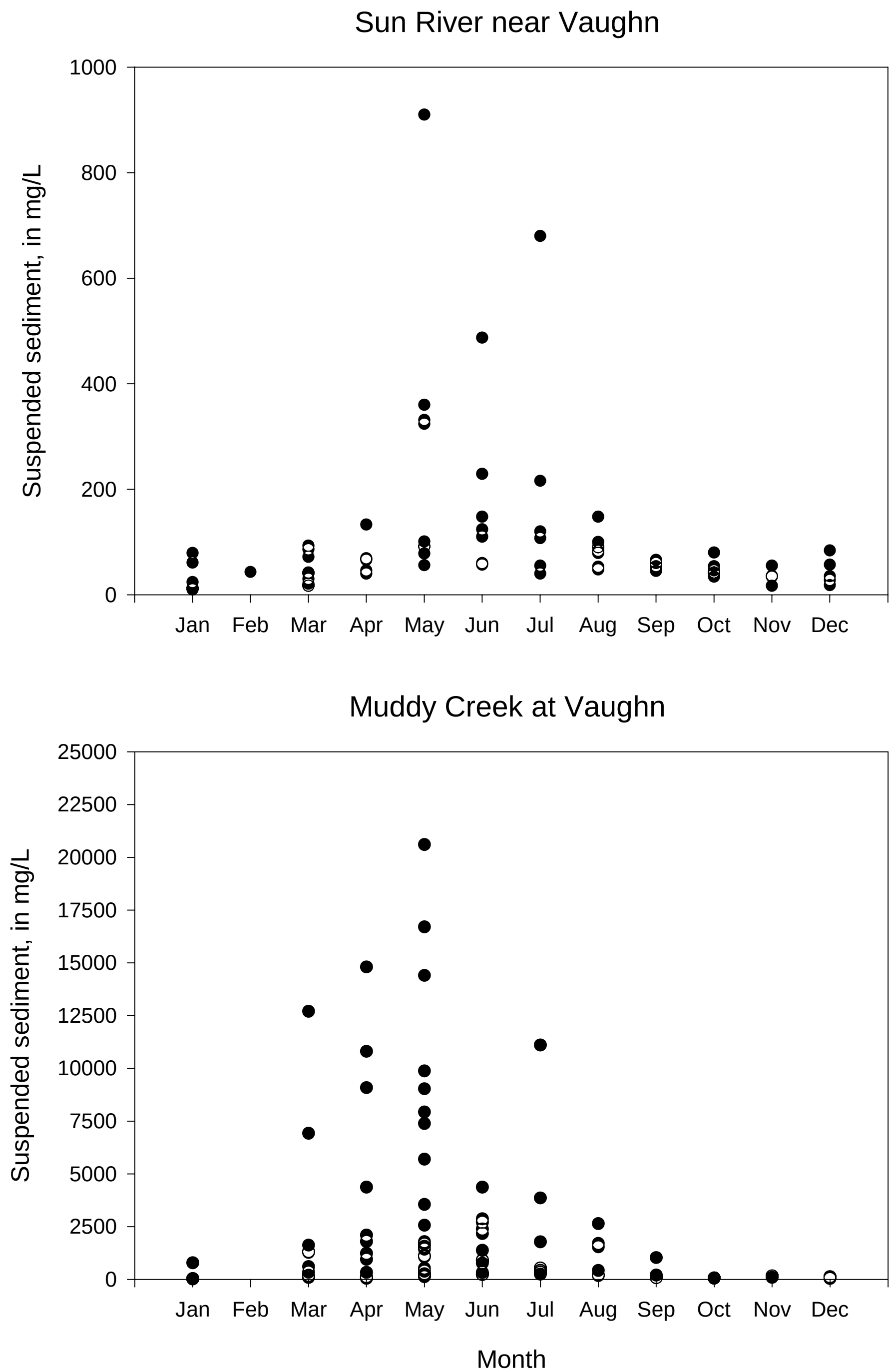



**Figure 9**. Monthly variation in suspended sediment concentrations at two USGS stream-gaging stations in the Sun River watershed.

concentrations were measured less frequently. Nitrogen dissolved in surface water in the Sun River watershed occurs almost entirely as nitrate. Therefore, concentrations reported as either nitrate or nitrite + nitrate are considered essentially equivalent and distinctions will not be made in subsequent discussions and graphs in this report.

On the main stem of the Sun River, nitrate concentrations ranged from <0.05 to 4.70 mg/L with the median values ranging from 0.06 mg/L at the Gibson Dam station to 0.54 mg/L at the station near Vaughn (table 6). Nitrate concentrations from Muddy Creek ranged from <0.1 to 22.0 mg/L with a median value of 2.0 mg/L. In the Muddy Creek draginage only two percent of the analyses had nitrate concentrations that exceeded the EPA drinking-water standard of 10 mg/L (U.S. Environmental Protection Agency, 1996). There were no exceedences of the standard from samples collected from the Sun River.

Dissolved-phase ammonia concentrations (in mg/L as N) for the Sun River ranged from <0.015 to 0.18 mg/L. The median concentration at the Simms and Vaughn stations was <0.015 mg/L and 0.02 mg/L, respectively. The highest ammonia concentrations were measured in samples from Muddy Creek where values ranged from <0.01 to 0.27 mg/L with a median value of 0.03 mg/L (table 6). Only a few samples (from the Sun River near Vaughn station) were analyzed for total ammonia concentrations. These samples were collected from 1986 through 1992 and ranged in concentration from <0.01 to 0.08 mg/L with a median concentration of 0.03 mg/L.

The Montana aquatic-life criterion for ammonia varies depending on the water temperature and pH at the time of sampling. The criteria can be calculated for pH values ranging from 6.5 to 9.0 and temperatures ranging from 0 to 30°C (Montana Department of Environmental Quality, 1995). The maximum criterion is 2.49 mg/L (at pH = 6.5 and temperature = 0) and the minimum criterion is 0.08 mg/L (at pH = 9.0 and temperature = 30°C). The criteria for both chronic and acute exposures were calculated for all ammonia samples (both total and dissolved-phase) where pH and temperature data was available. The calculated criterion was then compared to the measured concentration to determine if there were exceedences of the standard. Where pH data was available, there were no exceedences of the criterion. For most of the samples collected since 1996, pH data was not available and it was not possible to determine if the criterion was exceeded. However, the majority of the samples were below the 0.08 mg/L minimum criterion and it seems unlikely that there were any exceedences.

## Phosphorus

Phosphorus concentrations were most often reported as total phosphorus and orthophosphate (table 6). The highest phosphorus concentrations were measured in Muddy Creek and on the Sun River below the confluence with Muddy Creek. On the main stem of the Sun River, phosphorus concentrations for the Simms station ranged from <0.01 to 0.19 mg/L with a median value of below the detection limit of <0.01 mg/L. There was no phosphorus data available for the Gibson Dam site. The concentrations at the station near Vaughn ranged from <0.01 to 0.64 mg/L with a median value of 0.02

**Table 6**. Summary of nutrient concentrations in surface water for selected USGS streamflow stations.

| Water Quality Constituent | | USGS STATION NAME | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sun River near Vaughn | Sun River at Simms | Sun River below Diversion Dam | North Fork Sun River | Muddy Creek at Vaughn | Muddy Creek near Vaughn |
| Nitrate, dissolved (in mg/L as N) | Mean | 0.61 | 0.17 | 0.04 | -- | 2.32 | 2.47 |
| | Median | 0.54 | 0.12 | 0.02 | -- | 1.80 | 1.90 |
| | Range | <0.05 – 4.70 | <0.05 – 0.54 | <0.1 – 0.35 | -- | 0.07 – 11 | <0.05 – 22 |
| | n | 347 (18) | 20 (3) | 149 (48) | -- | 185 (1) | 273 (2) |
| Nitrite, dissolved (in mg/L as N) | Mean | 0.01 | <0.01 | -- | -- | 0.02 | 0.02 |
| | Median | <0.01 | <0.01 | -- | -- | 0.01 | 0.02 |
| | Range | <0.01 - 0.03 | <0.01 – 0.01 | -- | -- | <0.01 – 0.07 | <0.01 – 0.08 |
| | n | 76 (54) | 20 (17) | -- | -- | 51 (8) | 26 (1) |
| Nitrogen, total (in mg/L as N) | Mean | 0.96 | -- | -- | -- | -- | -- |
| | Median | 0.91 | -- | -- | -- | -- | -- |
| | Range | 0.51 – 1.60 | -- | -- | -- | -- | -- |
| | n | 13 (0) | -- | -- | -- | -- | -- |
| Ammonia, dissolved (in mg/L as N) | Mean | 0.03 | 0.015 | -- | -- | 0.05 | 0.05 |
| | Median | 0.02 | <0.015 | -- | -- | 0.03 | 0.03 |
| | Range | <0.01 – 0.18 | <0.015 – 0.05 | -- | -- | <0.01 – 0.27 | <0.015 – 0.23 |
| | n | 76 (15) | 20 (12) | -- | -- | 51 (14) | 26 (8) |
| Ammonia, total (in mg/L as N) | Mean | 0.03 | -- | -- | -- | -- | -- |
| | Median | 0.03 | -- | -- | -- | -- | -- |
| | Range | <0.01 – 0.08 | -- | -- | -- | -- | -- |
| | n | 36 (2) | -- | -- | -- | -- | -- |
| Phosphorus, total (in mg/L as P) | Mean | 0.05 | 0.024 | -- | -- | 0.18 | 0.11 |
| | Median | 0.02 | <0.01 | -- | -- | 0.09 | 0.06 |
| | Range | <0.01 – 0.64 | <0.01 – 0.19 | -- | -- | <0.01 – 1.71 | <0.01 – 0.86 |
| | n | 75 (19) | 20 (12) | -- | -- | 24 (4) | 26 (7) |
| Orthophosphate, dissolved (in mg/L as P) | Mean | 0.01 | <0.01 | <0.01 | -- | 0.02 | 0.02 |
| | Median | <0.01 | <0.01 | 0.01 | -- | 0.01 | 0.01 |
| | Range | <0.01 – 0.09 | -- | <0.01 – 0.03 | -- | <0.01 – 0.18 | <0.01 – 0.23 |
| | n | 214 (123) | 20 (20) | 80 (54) | -- | 111 (50) | 166 (62) |
| Orthophosphate, total (in mg/L as P) | Mean | 0.03 | -- | -- | -- | -- | -- |
| | Median | 0.01 | -- | -- | -- | -- | -- |
| | Range | <0.01 – 0.49 | -- | -- | -- | -- | -- |
| | n | 29 (13) | -- | -- | -- | -- | -- |

[ n, number of samples, number in parenthesis is number of samples below the detection limit; -- , no data. All concentrations in milligrams/liter (mg/L) ] mg/L. For Muddy Creek, concentrations ranged from <0.01 to 1.71 mg/L with a median concentration of 0.09 mg/L. Orthophosphate concentrations ranged from <0.01 to 0.09 mg/L as P, with a median value of 0.01 mg/L for all sites on the Sun River. Concentrations were only slightly higher in the Muddy Creek drainage, where values ranged from <0.01 to 0.18 mg/L with a median concentration of 0.01 mg/L.

**Seasonal and spatial variations in nutrient concentrations**

Seasonal variations in selected nutrients (nitrate, total phosphorus, orthophosphate) were evaluated for the Muddy Creek at Vaughn and the Sun River near Vaughn stations. These sites were selected because the water quality data is well distributed throughout the year and there is a fairly continuous period of record for each site (table 1).

Nitrate concentrations are affected by seasonal variations at both locations (figure 10). Concentrations are highest from November through March, and generally decrease from April through September. The decrease in nutrient concentrations during spring and summer is related to dilution from spring runoff and the onset of the irrigation season. There were no apparent seasonal variations for total phosphorus and orthophosphate concentrations. A significant number of orthophosphate concentrations were below the detection limit and it may be difficult to observe trends when concentrations are very low. The highest concentrations for total phosphorus were measured during the months with high streamflow, however, there was not enough data to show any clear monthly trend.

Graphs of nitrate, orthophosphate, and total phosphorus concentrations compared to streamflow confirm some of the seasonal relations discussed above and are shown in figure 11. Nitrate concentrations show an inverse relationship with streamflow. Concentrations are high when streamflow is low and are low when streamflow is high (figure 11a). The decrease in nitrate concentration with increasing streamflow is characteristic of streams in arid, agriculture regions where return flows high in nutrients dominate low flow conditions (Mueller and others, 1995). In the Muddy Creek drainage, the majority of streamflow is derived from irrigation return flow draining from the Greenfields Bench aquifer. When discharge is lowest, typically in March, the median nitrate concentration in Muddy Creek is 5.1 mg/L compared to 5.7 mg/L for ground water in the Greenfields Bench aquifer (unpublished MBMG data).

Although there was no apparent seasonal variation in orthophosphate concentrations, when compared to streamflow it does appear that concentrations are higher when streamflows are lower, as is shown in figure 11b. There was no obvious relation between streamflow and total phosphorus concentrations at either station (figure11c). Total phosphorus concentrations increase with increasing streamflow for many streams in agricultural regions because phosphorus from non-point sources is transported attached to sediment particles rather than dissolved in the water. Although suspended sediment concentrations do rise with increasing streamflow as was discussed

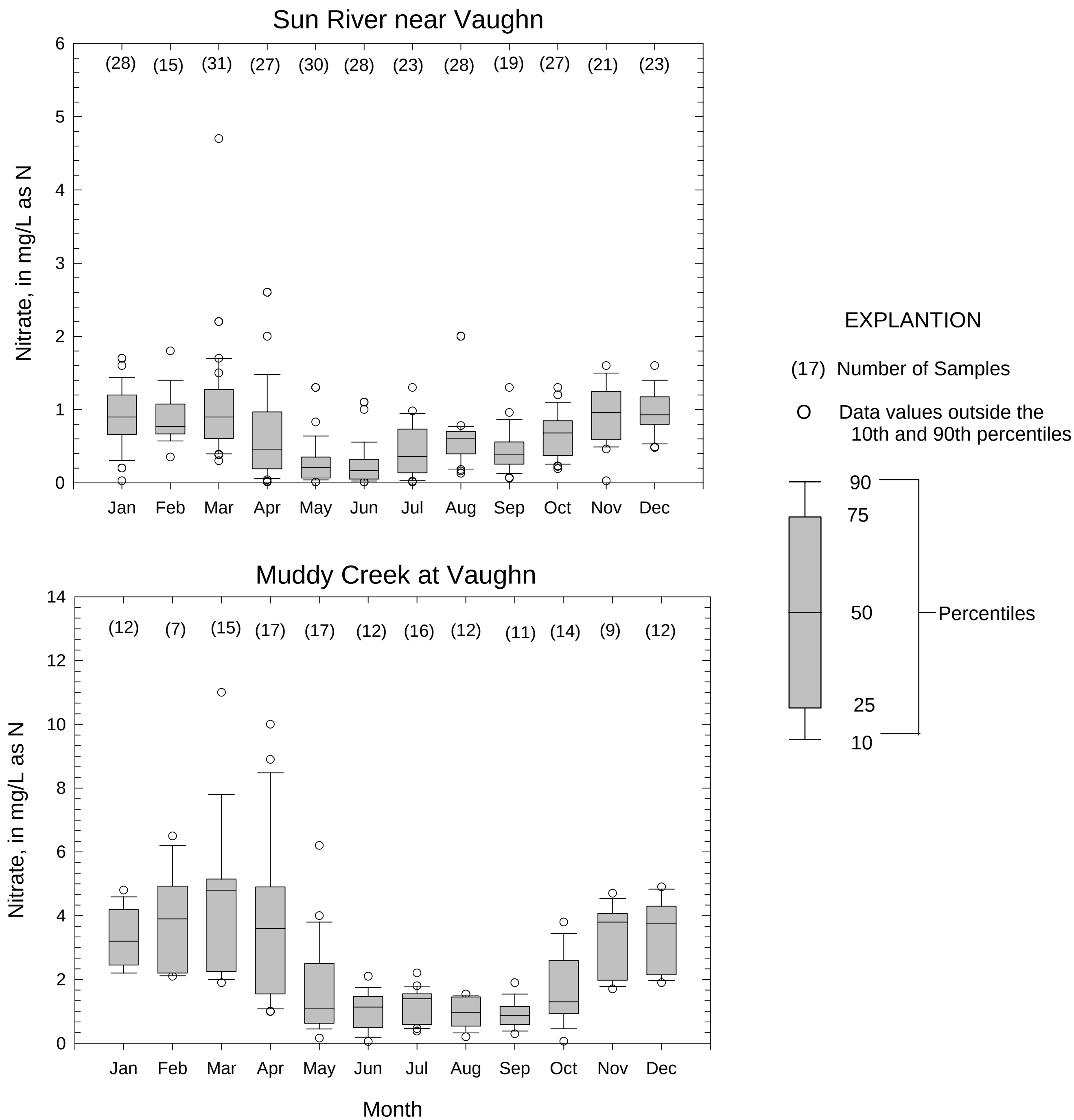



**Figure 10**. Monthly concentration of nitrate at the Sun River near Vaughn and the Muddy Creek at Vaughn stations in the Sun River watershed.

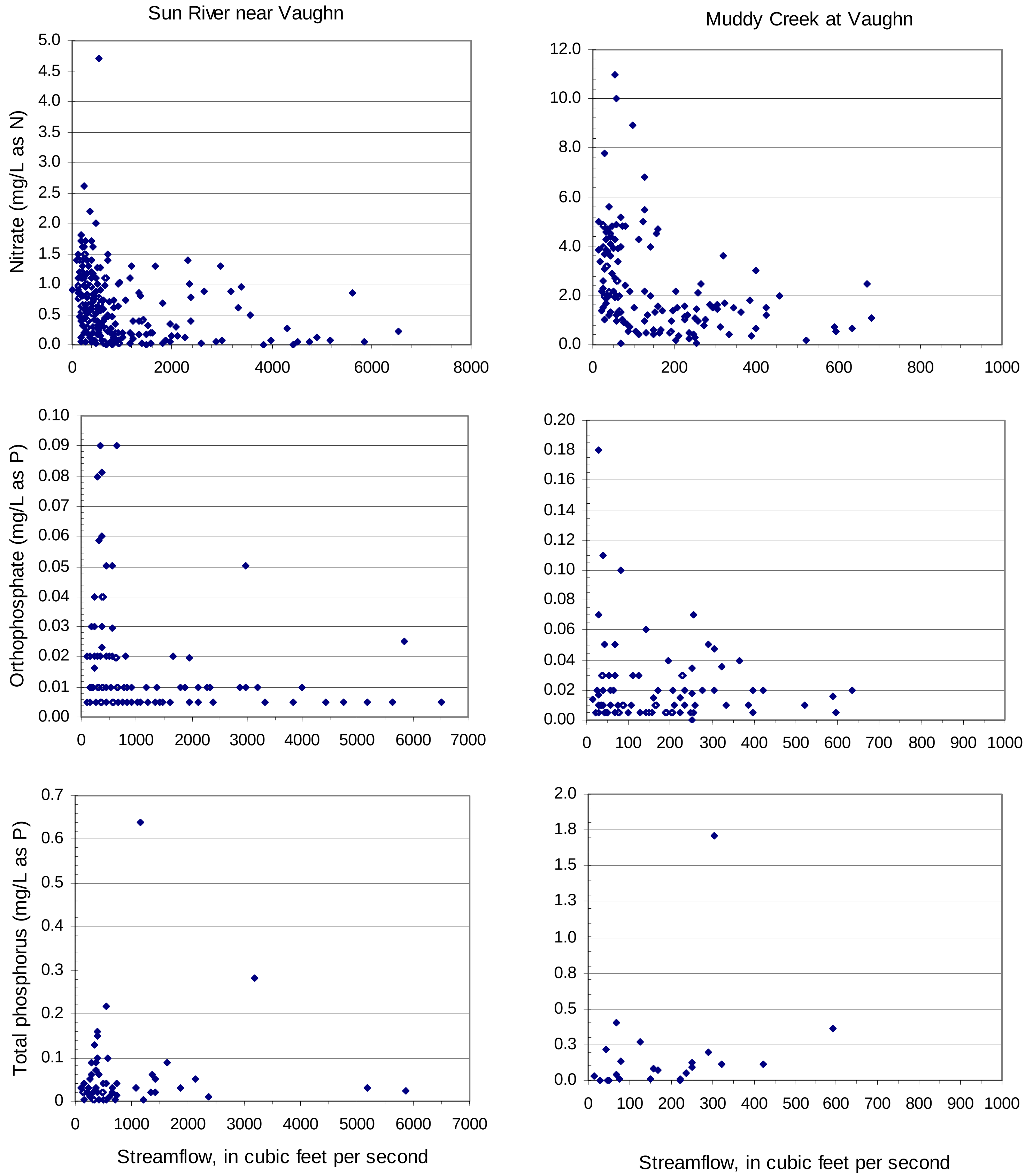



**Figure 11**. Relation of streamflow to (a) nitrate, (b) orthophosphate, and (c) total phosphorus concentration for two USGS stream-gaging stations in the Sun River watershed.

above, the same relation between streamflow and total phosphorus is not apparent. It may be that there is not enough data to show a trend. When compared to the other nutrients, significantly fewer total phosphorus analyses were completed and relatively few of those were collected under high flow conditions.

The spatial distribution for select nutrient concentrations in the watershed follows a pattern similar to that for most other water-quality parameters. In general, nutrient concentrations increase in the downstream direction and are highest in the Muddy Creek drainage. Nutrient concentrations (nitrate, total phosphorus, orthophosphate, and ammonia) were compared for three sites where current (water years 1996-1998) nutrient data were available (figure12). The Sun River at Simms station, upstream from Muddy Creek, had the lowest nutrient concentrations. In the Muddy Creek drainage, nutrient concentrations were several orders of magnitude higher than elsewhere in the watershed.

**Nutrient Concentrations and Stream Impairment**

Nitrogen, especially in the form of nitrate and ammonia, and phosphorus, usually in the form of orthophosphate, are required for plant growth. In excessive concentrations, however, these nutrients contribute to eutrophication and diminished water quality. At this time, no national criteria have been established for concentrations of nutrients in streams to prevent nuisance growth of algae and other unwanted aquatic plants. However, the Montana DEQ is recommending that total phosphorus concentrations should not exceed 0.03 mg/L and that total nitrogen concentrations should not exceed 0.35 mg/L. These target levels were developed using data collected from the Clark Fork River in western Montana (Dodds and others, 1997). The suitability of these guidelines to the Sun River watershed is unknown. However, when compared to these target levels, nutrient concentrations in the Sun River watershed are generally elevated as is discussed below.

Total phosphorus data is available at two stations on the Sun River and both stations on Muddy Creek (table 6). Over a period of 16 years (1986-1998), total phosphorus concentrations on the Sun River exceeded 0.03 mg/L in 15 percent of the samples from the station near Simms and 37 percent of the samples from the station near Vaughn. Total phosphorus data has been collected on Muddy Creek only since 1996. In that time period, approximately 67 percent of the analyses from the Muddy Creek at Vaughn site and 54 percent of the Muddy Creek near Vaughn analyses were above the DEQ guideline of 0.03 mg/L total phosphorus.

Total nitrogen data is available only for the Sun River near Vaughn station. Thirteen samples were collected from 1990 to 1992 and all thirteen analyses exceeded the recommended level of 0.35 mg/L. Since total nitrogen data was not available for most stations, dissolved-phase nitrate concentrations were compared to the recommended guideline. For the Sun River, none of the nitrate samples from the Diversion Dam site exceeded 0.35 mg/L, 10 percent of the samples from the Simms stations, and 43 percent of the samples from the Vaughn station exceeded 0.35 mg/L. On Muddy Creek approximately 95 percent of the nitrate samples exceeded 0.35 mg/L. A comparison of

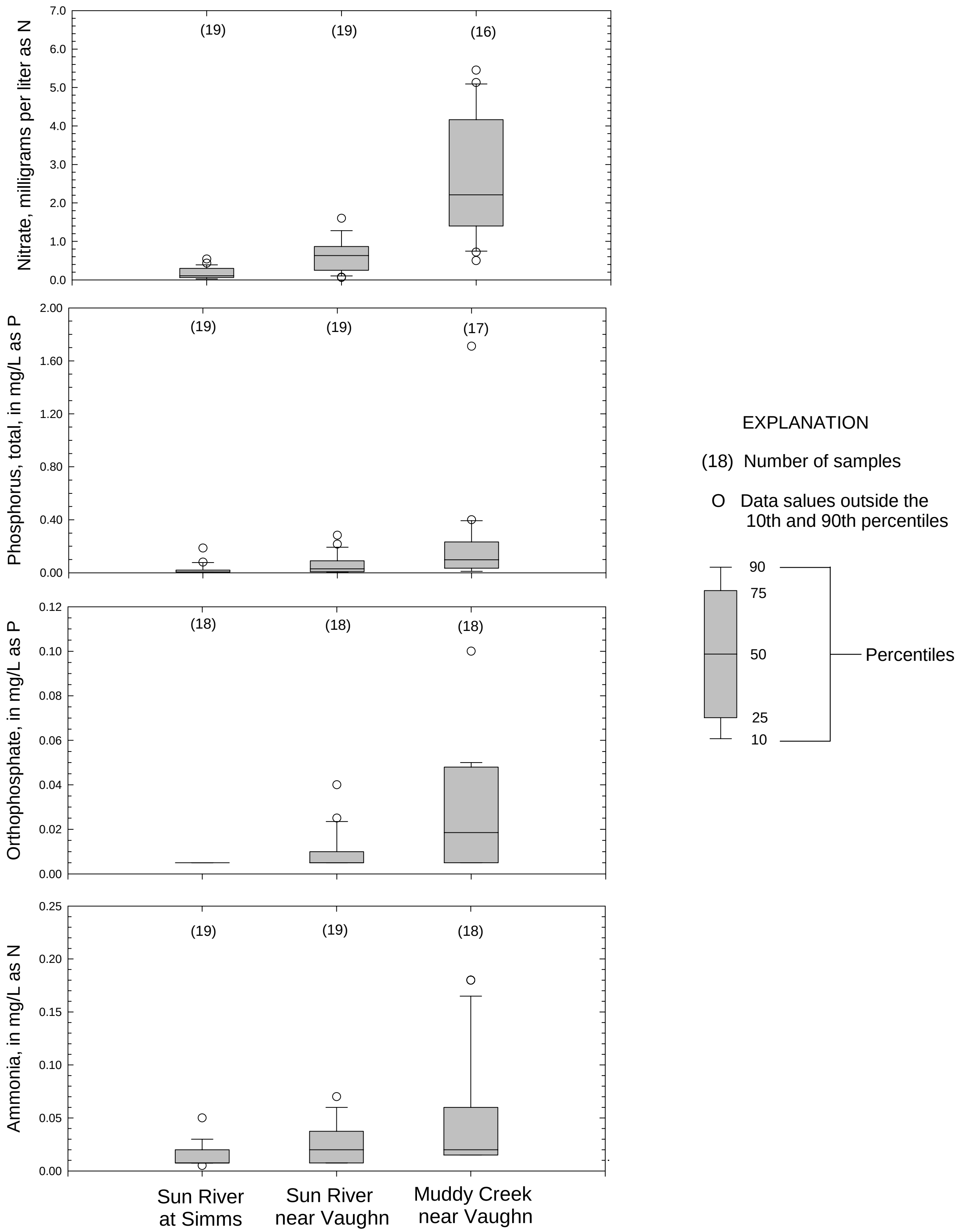



**Figure 12**. Distribution of nitrate, total phosphorus, and ammonia concentrations in surface water at selected USGS stream-gaging stations in the Sun River watershed.

the total nitrogen and nitrate data from the Sun River near Vaughn station indicated that total nitrogen concentrations were 10-50 percent higher than nitrate concentrations. The comparison of nitrate concentrations to the recommended nitrogen guideline therefore gives a conservative estimate of the number of samples exceeding the guideline.

## Trace Elements

Trace elements considered in this study are arsenic, boron, cadmium, cobalt, copper, iron, lead, manganese, mercury, selenium, and zinc. The only element that has been found in concentrations above a recommended criterion is selenium. Total selenium concentrations on the Sun River ranged from <1 to 3 µg/L (table 7). The only station where concentrations were above the detection limit (<1 µg/L) was the Sun River near Vaughn site where the median concentration was 1 µg/L. Selenium concentrations in the Muddy Creek drainage ranged from <1 to 14 µg/L. The median concentration on Muddy Creek was 3 µg/L for the station at Vaughn and 2 µg/L for the station near Vaughn.

**Table 7**. Summary of selenium concentrations at selected USGS streamflow stations.

| Water Quality Constituent | | USGS STATION NAME: Sun River near Vaughn | Sun River at Simms | Sun River below Diversion Dam | Muddy Creek at Vaughn | Muddy Creek near Vaughn |
|---|---|---|---|---|---|---|
| Selenium, total recoverable ( in µg/L) | Mean | 1.05 | <1 | -- | 3.8 | 3.8 |
| | Median | 1 | <1 | -- | 3 | 2 |
| | Range | <1 – 3 | -- | -- | <1 – 11 | 2 – 14 |
| | n | 22 (10) | 20 (20) | -- | 57 (1) | 28 (0) |
| Selenium, dissolved ( in µg/L) | Mean | 1.03 | -- | <1 | 2 | -- |
| | Median | 1 | -- | <1 | 2 | -- |
| | Range | <1 – 2 | -- | -- | 1 – 2 | -- |
| | n | 33 (14) | -- | 1 (0) | 3 (0) | -- |

[ n = number of samples, number in parenthesis is number of samples below the detection limit; µg/L, micrograms per liter ]

The standards established by the Montana Department of Environmental Quality and the U.S. Environmental Protection Agency for selenium are 50 µg/L for human consumption; for aquatic life the acute standard is 20 µg/l and the chronic standard is 5 µg/L. The highest concentrations of selenium were measured in samples from Muddy Creek where approximately 23 percent of the samples exceeded the chronic aquatic-life standard of 5 µg/L. There were no exceedences of the acute criterion. None of the selenium samples from stations on the Sun River exceeded either the chronic or acute criterion. Detailed investigations of the occurrence and distribution of selenium in the Sun River watershed have been completed by the USGS (Knapton and others, 1988; Lambing and others, 1994; Nimick and others, 1996; Kendy and Nimick, 1999).

# TEMPORAL DISTRIBUTION OF WATER QUALITY PARAMETERS

Two stations had sufficient data to plot concentration as a function of time for selected water quality parameters (figure 13). Nitrate concentrations show no obvious increases or decreases over time, except that in the Muddy Creek drainage all the samples with concentrations above about 6 mg/L were collected in the middle 1970's to early 1980's (figure 13a). Since that time, sample concentrations have remained below 6 mg/L. Suspended sediment concentrations have decreased significantly on Muddy Creek and seem to be decreasing on the Sun River (figure 13b). The decrease reflects the success of water-management strategies that have been implemented within the Muddy Creek watershed. The pH at both stations may be increasing with time as is inferred from the data shown in figure 13c. Statistically the change may not be significant since linear regressions of the data show low correlation ($r^2 = 0.26$ and 0.35). There were no obvious changes in total-dissolved solids or total phosphorus concentrations over time.

Because the effects of stream discharge and seasonal variations can complicate detection of water quality trends (Hirsch, 1991), the data shown in figure 13 provides only graphical observations of possible trends. A series of drier or wetter than normal years can create the appearance of a change in water quality that may actually be a consequence of variations in flow. In order to determine if there are significant changes in concentration over time a more rigorous statistical analysis would be necessary. Trend analyses were not completed for this data but could be useful in determining if concentrations for selected nutrients have changed over time in a significant way.

# SUMMARY

Water-quality data from a number of sources were evaluated to provide a general assessment of water quality in the Sun River watershed. The data will be used to develop TMDL's for the Sun River and Muddy Creek and to assist in watershed management and planning activities. The primary source of information summarized in this report was water-quality and streamflow data collected and published by the U.S. Geological Survey for gaging stations located on Muddy Creek and the Sun River. Other data were obtained from published and unpublished reports completed by various federal, state, local, and private agencies. Relatively little data were available from the tributaries of the Sun River, other than Muddy Creek, and they are generally not discussed in this report. The primary change in water-quality in the Sun River from upstream to downstream is an increase in salinity, measured either as total-dissolved solids or specific conductance. Along the main stem of the Sun River, dissolved-solids concentrations nearly double from a median of 210 mg/L upstream to 464 mg/L downstream. The largest increase in dissolved solids occurs below the confluence with Muddy Creek where the median concentration is 676 mg/L. This change in salinity is due primarily to increases in magnesium, sodium, and sulfate. Secondary-drinking water standards for dissolved-solids and sulfate were exceeded in approximately 40 and 13 percent of the samples from

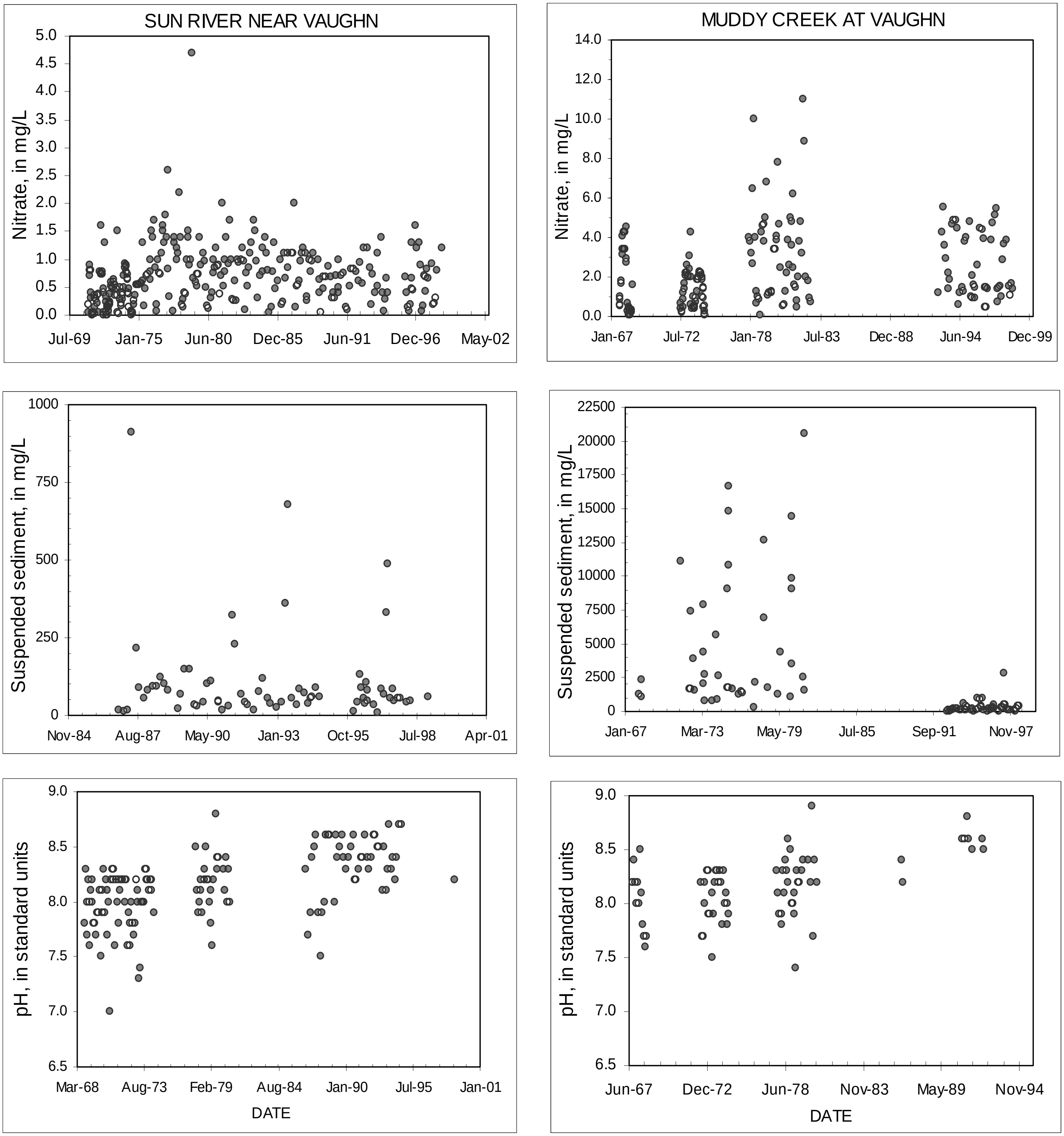



**Figure 13**. Temporal variations in nitrate, suspended sediment, and pH for the Sun River near Vaughn stations and the Muddy Creek at Vaughn station in the Sun River watershed.

the Sun River near Vaughn station. The number of samples exceeding the secondary-drinking water standards from Muddy Creek was approximately 65 percent for dissolved solids and 50 percent for sulfate. Water from the Sun River and Muddy Creek is generally suitable for agriculture purposes.

Water temperatures in the Sun River watershed are highest in June, July, and August. During those months, maximum daily temperatures above 23°C (73° F) can be common. Water temperature is a concern on the Sun River because of the possible adverse effects of sustained high temperatures on fisheries and other aquatic life. Although specific guidelines on optimum temperature ranges have not been established for the Sun River, a general recommendation is that temperatures should be maintained below 23°C (73° F). The median pH in the Sun River watershed is approximately 8.1, which is within the recommended range of pH for natural surface waters.

Suspended-sediment concentrations are highest in the Sun River below Muddy Creek and in the Muddy Creek drainage. On the Sun River, above Muddy Creek, concentrations ranged from 4 mg/L to 363 mg/L, below Muddy Creek concentrations ranged from 10 mg/L to 910 mg/L. On Muddy Creek concentrations were dramatically higher and ranged from 15 mg/L to 20,600 mg/L. Suspended sediment concentrations generally increases with increasing streamflow in the Muddy Creek drainage and on the Sun River above Muddy Creek. Suspended sediment concentration and streamflow were poorly correlated on the Sun River below the confluence with Muddy Creek.

There are no specific guidelines for acceptable levels of suspended sediment, but elevated concentrations for sustained periods of time are known to affect fisheries and other aquatic life. In the Muddy Creek drainage, suspended sediment concentrations are high from March through July. On the Sun River, concentrations are generally highest from May to July.

Nutrients have been a prevalent water-quality issue for many years in the Sun River watershed. The primary concern is that elevated levels of nitrogen and phosphorus can contribute to the growth of nuisance algae and other unwanted aquatic life. High nitrate concentrations can also affect suitability of the water for drinking water. The highest nutrient concentrations are found in the Muddy Creek drainage where agricultural return flows dominate streamflow. Nitrate concentrations ranged from <0.05mg/L to 22 mg/L, total phosphorus concentrations ranged from <0.01 mg/L to 0.23 mg/L. Nutrient concentrations on the Sun River are strongly influenced by discharge from Muddy Creek. Above the confluence with Muddy Creek, nitrate concentrations ranged from <0.05 mg/L to 0.54 mg/L. Total phosphorus concentrations ranged from <0.010 mg/L to 0.019 mg/L. Below the confluence with Muddy Creek, concentrations were significantly higher and more variable, with nitrate levels ranging from <0.05 mg/L to 4.70 mg/L and total phosphorus concentrations ranging from <0.010 mg/L to 0.64 mg/L. Seasonal variations in nutrient concentrations are related to changing hydraulic conditions. In general, higher concentrations of nitrate and orthophosphate occur during late fall and early spring, when streamflows are lowest. There were no seasonal patterns identified for total phosphorus.

Although there are no established criteria for nutrient concentrations, the DEQ is using a general guideline of greater than 0.03 mg/L for total phosphorus and 0.35 mg/L for total nitrogen to indicate possible impairment. Approximately 43 percent of the nitrate samples from the Sun River near Vaughn station exceeded 0.35 mg/L. At the Muddy Creek stations, over 90 percent of the nitrate samples were above 0.35 mg/L. Total phosphorus concentrations exceeded the DEQ guideline of 0.03 mg/L in 15 percent of the samples from the Sun River above Muddy Creek and in approximately 37 percent of the samples from below Muddy Creek. In the Muddy Creek drainage, total phosphorus concentrations exceeded 0.03 mg/L in over 50 percent of the samples. There were no exceedences of any established aquatic-life standards for ammonia; the drinking-water nitrate standard was exceeded in less than two percent of the samples from Muddy Creek.

Trace elements are generally not a concern in the Sun River watershed, except possibly for selenium. The highest concentrations of selenium are found in the Muddy Creek drainage where 23 percent of the samples collected exceeded the chronic aquatic-life criterion.

Changes in water-quality over time were evaluated graphically for selected water-quality parameters at two locations in the watershed, the Sun River near Vaughn and the Muddy Creek at Vaughn stations. There do not appear to be any major changes in the concentration of nutrients or dissolved solids since the late 1960's. The pH may be increasing in the Muddy Creek drainage and on the Sun River below the confluence with Muddy Creek, although the increase may not be statistically significant. The concentration of suspended sediment in Muddy Creek has decreased significantly in the last 10 years, due in large part due to implementation of water-conservation measures on Muddy Creek. There is a lack of current water-quality data available for the stretch of the Sun River above Muddy Creek and therefore, it is difficult to evaluate how water quality may have changed over time.

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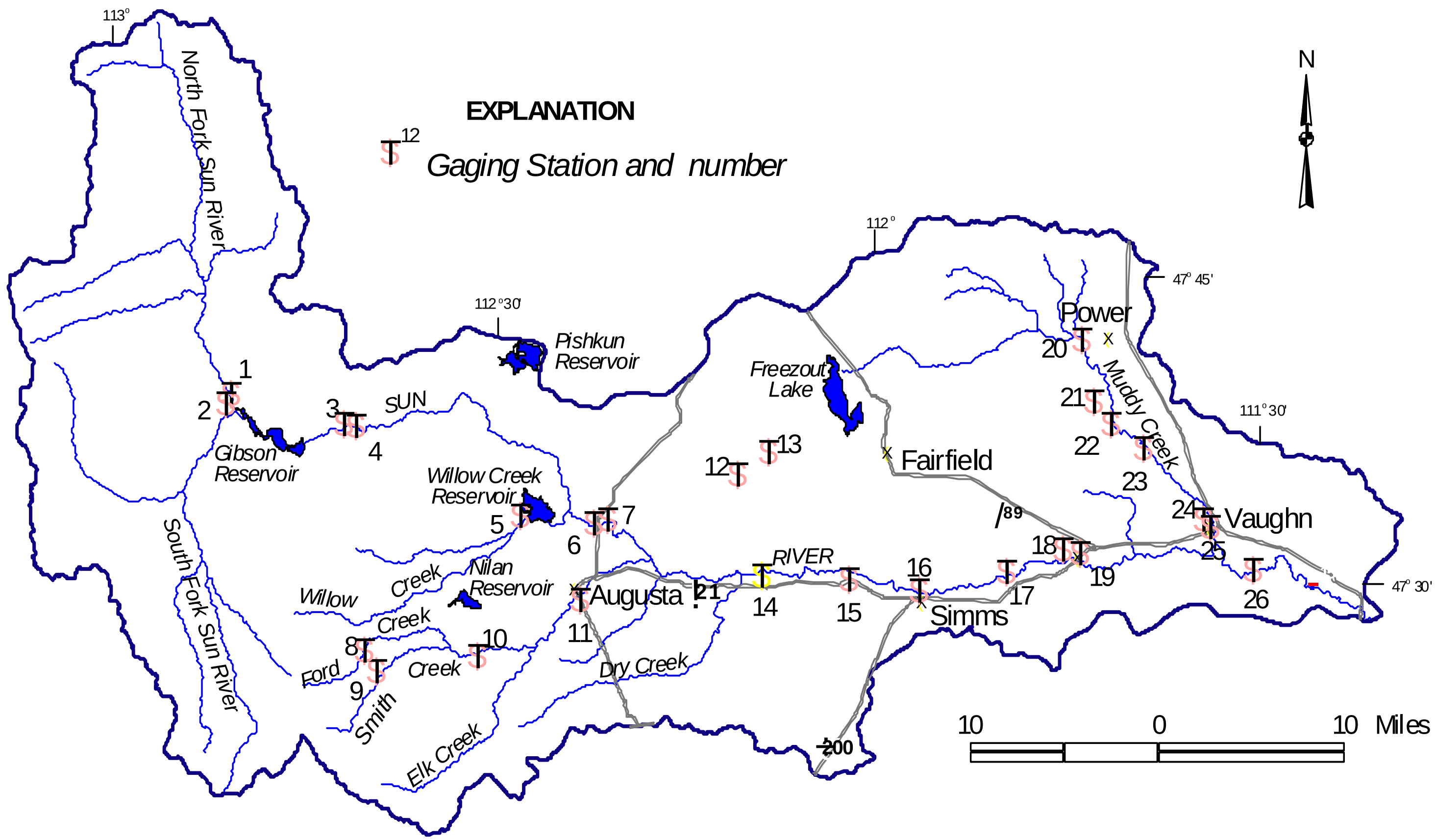
# APPENDIX 1.

## LOCATION MAP AND DESCRIPTION OF UGSG STREAMFLOW GAGING-STATIONS IN THE SUN RIVER WATERSHED




U.S. Geological Survey Surface-Water Station Name and Number

1. North Fork Sun River (6078500)
2. South Fork Sun River (6079000)
3. Sun River near Augusta (608000)
4. Sun River below Diversion Dam (6080900)
5. Willow Creek near Augusta (6081500)
6. Sun River Below Willow Creek (6082200)
7. Floweree Big Canal near Augusta (6081000)
8. Ford Creek near Augusta (6083500)
9. Smith Creek near Augusta (6082500)
10. Smith Creek below Ford Creek (6084000)
11. Elk Creek near Augusta (6084500)
12. Spring Valley Canal (6080700)
13. Spring Valley Canal (6080800)
14. Crown Butte Canal (6085000)
15. Crown Butte Canal (6085500)
16. Sun River at Simms (6085800)
17. Sun River at Fort Shaw (6086000)
18. Sun River Canal (6086500)
19. Sun River at Sun River (6087500)
20. Muddy Creek near Power (6088000)
21. Spring Coulee near Power (6088100)
22. Tank Coulee near Power (6088200)
23. Muddy Creek near Vaughn (6088300)
24. Sun River canal at Vaughn (6087000)
25. Muddy Creek at Vaughn (6088500)
26. Sun River near Vaughn (6089000)

Figure 14. Location of USGS surface-water gaging stations in the Sun River watershed. USGS reference number is in parenthesis.

**Basin Name: Sun**
**Hydrologic Unit Code: 10030104**

| Reference Number (fig. 14) | USGS Station Number | Station Name | County | Drainage Area ($miles^2$) | Streamflow Period of Record | | Water Quality Period of Record | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Daily Streamflow | Peak Flow | Daily Records | Periodic Records |
| 1 | 6078500 | North Fork Sun River near Augusta, MT | Teton | 258 | 1. 05/01/1911-09/30/1912<br>2. 10/01/1945-09/30/1968<br>3. 05/01/1989-10/31/1989<br>4. 04/01/1990-10/31/1990<br>5. 04/01/1991-10/31/1991<br>6. 04/01/1992-10/31/1992<br>7. 04/01/1993-09/30/1993 | 1911-1912<br>1946-68<br>1989-93 | | 1989-1993 (Sediment) |
| 2 | 6079000 | South Fork Sun River near Augusta, MT | Lewis and Clark | 252 | 05/01/1911-09/30/1912 | | | No |
| | 6079500 | Gibson Reservoir near Augusta | Lewis and Clark | 575 | 1930-P | | | 1952 (Chemistry) |
| | 6079600 | Beaver Creek at Gibson Dam near August, MT | Lewis and Clark | 20.8 | | 1959-1973 | | No |
| 3 | 6080000 | Sun River near Augusta, MT | Lewis and Clark | 609 | 1. 08/01/1889-12/30/1890<br>2. 07/01/1904-09/30/1940 | 1890<br>1905-29<br>1964 | | 1973 (Temperature) |
| | 6080500 | Pishkun Reservoir near Augusta | | | 1936-1995 | | | 1952 (Chemistry) |
| | | Willow Creek Feeder Canal | | | 1967-1968 | | | |
| 12 | 6080700 | Spring Valley Ca Bl S V D, Nr Fairfield, MT | Teton | | 11/01/1966-10/31/1967 | | | No |
| 13 | 6080800 | Spring Valley Ca Ab U T D, Nr Fairfield, MT | Teton | | 11/01/1966-10/31/1967 | | | No |
| 4 | 6080900 | Sun River Bl Diversion Dam, near Augusta, MT | Lewis and Clark | 609 | 10/01/1967-10/02/1980 | 1964<br>1968-1980 | SC: 1968-79 | 1968-1979 (Chemistry) |
| 7 | 6081000 | Floweree Big Canal near Augusta, MT | Teton | | 06/01/1912-11/30/1912 | | | No |
| 5 | 6081500 | Willow Creek near Augusta, MT | Lewis and Clark | 96.1 | 1. 06/01/1905-04/30/1911<br>2. 10/01/1911-09/30/1925 | 1905-1910<br>1912-25 | | No |
| 6 | 6082200 | Sun River Bl Willow Creek, near Augusta, MT | Lewis and Clark | 827 | 10/01/1967-10/31/1974 | 1964<br>1968-1975 | | No |

P = present

**Basin Name: Sun**
**Hydrologic Unit Code: 10030104**

| Reference Number (fig. 14) | USGS Station Number | Station Name | County | Drainage Area (miles$^2$) | Streamflow Period of Record | | Water Quality Period of Record | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Daily Streamflow | Peak Flow | Daily Records | Periodic Records |
| 9 | 6082500 | Smith Creek near Augusta, MT | Lewis and Clark | 25 | 04/01/1906-12/32/1912 | 1906-1912 | | No |
| | 6083000 | Nilan Reservoir near Augusta | | | | | | No |
| 8 | 6083500 | Ford Creek near Augusta, MT | Lewis and Clark | 19.4 | 04/01/1906-12/32/1912 | 1906-1912<br>1964 | | No |
| 10 | 6084000 | Smith Creek Below Ford Creek near Augusta, MT | Lewis and Clark | 74 | 10/01/1945-09/3/1952 | 1946-1952<br>1965, 1975 | | 1952 (Chemistry) |
| 11 | 6084500 | Elk Creek at Augusta, Mt | Lewis and Clark | 157 | 10/01/1904-11/30/1924 | 1905-24<br>1964, 1975 | | No |
| 14 | 6085000 | Crown Butte Canal at Riebeling, Mt | Lewis and Clark | | 06/01/1912-09/30/1912 | | | No |
| 15 | 6085500 | Crown Butte Canal near Simms, Mt | Cascade | | 06/10/1912-09/01/1912 | | | No |
| 16 | 6085800 | Sun River at Simms, MT | Cascade | 1320 | 1. 03/01/1966-09/30/1979<br>2. 04/01/1997-09/30/1997 | 1964,<br>1966-79,<br>1997-P | | 1996-P (Chemistry, Sediment) |
| 17 | 6086000 | Sun River at Fort Shaw, MT | Cascade | 1417 | 06/01/1912-09/30/1928 | 1913-1928 | | No |
| 18 | 6086500 | Sun River Canal at Sun River, MT | Cascade | | 06/01/1912-11/09/1912 | | | No |
| 24 | 608700 | Sun River Canal at Vaughn, MT | Cascade | | 07/21/1912-08/31/1912 | | | No |
| 19 | 6087500 | Sun River at Sun River, MT | Cascade | 1454 | 08/01/1905-09/30/1912 | 1906-1912 | | No |
| | 6087850 | Sun River above Muddy Creek, near Vaughn, MT | Cascade | 1526 | | | | 1973 |
| | 6087900 | Muddy Creek Tributary near Power, MT | Teton | 3.15 | | 1963-78, 1986 | | No |
| 20 | 6088000 | Muddy Creek near Power, MT | Teton | 137 | 1. 04/01/1935-10/31/1935<br>2. 10/01/1981-10/31/1981<br>3. 04/01/1982-10/31/1982<br>4. 04/01/1983-10/04/1983 | 1982-1983 | | 1992 (Chemistry) |

P = present

**Basin Name: Sun**

**Hydrologic Unit Code: 10030104**

| Reference Number (fig. 14) | USGS Station Number | Station Name | County | Drainage Area (miles$^2$) | Streamflow Period of Record | | Water Quality Period of Record | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Daily Streamflow | Peak Flow | Daily Records | Periodic Records |
| 21 | 6088100 | Spring Coulee near Power, MT | Teton | 30.4 | 1. 10/01/1981-10/31/1981<br>2. 04/01/1982-10/31/1982<br>3. 04/01/1983-09/30/1983 | 1982 | | 1992 (Chemistry) |
| 22 | 6088200 | Tank Coulee near Power, MT | Teton | 31 | 1. 10/01/1981-10/31/1981<br>2. 04/01/1982-10/31/1982<br>3. 04/01/1983-09/30/1983 | 1982 | | 1992 (Chemistry) |
| 23 | 6088300 | Muddy Creek near Vaughn, MT | Cascade | 282 | 1. 06/28/1968-09/30/1968<br>2. 10/01/1969-09/30/1987<br>3. 03/01/1996-09/30/1997 | 1968-1987, 1996-P | SC: 1968-82<br>T: 1968-79<br>Sediment: 1968-82 | Chemistry: 1968-82, 1992-P<br>Sediment: 1971-82, 1996-P |
| 25 | 6088500 | Muddy Creek at Vaughn, MT | Cascade | 391 | 1. 06/01/1925-12/31/1925<br>2. 10/01/1934-09/30/1968<br>3. 07/01/1971-09/30/1997 | 1925, 1934-37,1939-68, 1971-P | SC: 1968, 1972-82<br>T: 1971-79<br>Sediment: 1971-82 | Chemistry: 1968, 1972-82,1992-P Sediment: 1968, 1971-81, 1993-P |
| 26 | 6089000 | Sun River near Vaughn, MT | Cascade | 1854 | 04/01/1934-09/30/1997 | 1934-P | SC: 1969-present<br>T: 1969-79 | Chemistry: 1969-P Sediment: 1987-94, 1996-P<br>Biology: 1987-94 |
| | 6089300 | Sun River Tributary near Great Falls, MT | Cascade | 21.1 | | 1956-1973, 1975, 1979-80 | No | No |
| | 6090650 | Lake Creek near Power | Choteau | 83.8 | 1990-P | 1990-P | SC: 1992-96<br>T: 1992-95<br>Sediment: 1992-95 | 1990-96 (Chemistry) |

P = present