Interaction Between Groundwater and Surface Water Regimes and Mining-Induced Acid Mine Drainage in the Stockett-Sand Coulee Coal Field
TECHNICAL COMPLETION REPORT

Interaction Between Groundwater and Surface Water Regimes and Mining-Induced Acid Mine Drainage in the Stockett-Sand Coulee Coal Field

Project A-129MONT

to

Montana Joint Water Resources Research Center
Montana State University
Bozeman, Montana 59715

and

Montana Department of State Lands
Helena, Montana

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June 1, 1983
The work upon which this report is based was supported by funds provided by the Department of the Interior as authorized under the Water Resource and Development Act of 1978, P.L. 95-467, by the Montana Department of State Lands and by the Montana Bureau of Mines and Geology.

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ABSTRACT

Abandoned underground coal mines in the Stockett and Sand Coulee, Montana region have been discharging acid water for many years, causing severe pollution of Sand Coulee Creek and tributaries, and ground-water resources. A two-year investigation of the hydrogeology of the Sand Coulee Creek basin was conducted to formulate acid mine drainage mitigation techniques based on hydrologic systems controls and decentralized neutralization.

Periodic field inventories in 1980-83 located at least 17 acid discharge points flowing either perennially or seasonally. The measured total rate of acid discharge ranged from 1-3.3 ft$^3$/s. Most acid discharges were of very poor quality with field pH ranging from 2.2 to 5.4, acidity from 108 to 6002 mg/l as CaCo$_3$ and specific conductance from 1038 to 15,966 microsiemens per centimeter. Water types were mostly ferrous-aluminum sulfate with dissolved iron concentrations from 12 to 1065 mg/l.

Two stream gaging stations were installed on Sand Coulee Creek and one on Straight Creek. Although the watershed area of Straight Creek is only 4% that of Sand Coulee Creek, it had longer duration and sometimes greater magnitude baseflow, primarily composed of acid mine drainage. Acid water comprises roughly 60-90% of the baseflow of Sand Coulee Creek. Most baseflow is lost to evapotranspiration and subsurface seepage.

A regional inventory of 46 domestic wells indicated that approximately one-half utilized the Madison Limestone aquifer as the primary water source with most of the remainder equally divided between Kooten-
sandstone and Jurassic sandstone aquifers. Most alluvial ground water is polluted and has not been utilized by residents for many years. Vertical ground-water gradients are primarily downward which has allowed mine drainage contamination to reach the Jurassic and Madison aquifers. Water quality analyses and chemical modeling indicated the probable contamination of seven of sixteen sampled wells in these aquifers. Mine drainage water reaches lower bedrock aquifers through stream seepage, alluvial ground-water leakage and well bore leakage.

Proposed mitigation techniques included, infiltration control through cultivation of water consumptive crops and grain re-cropping in recharge areas, vertical connector wells or horizontal wells to dewater the Kootenai aquifer overlying the old coal mines, injection and neutralization of acid water in the Madison limestone and small-scale neutralization pits using flyash and alkaline Kootenai ground water.

Key words: Acid mine drainage, streamflow seepage, surface water-ground-water interaction, ground-water contamination, infiltration control, drainage wells.
The authors wish to thank the residents of the Stockett and Sand
Coulee, Montana area for their assistance and support of this investi-
gation.

Credit for technical support and field data collection go to Art
Middelstadt, MBMG hydro-technician, and Montana Tech students Herman
Moore, Walter Benjamin, Kim Knerr, Joe McElroy.
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1. INTRODUCTION

This report presents results of the Montana Water Resources Research Center project no. A-129MONT, Interaction between ground water and surface water regimes and mining-induced acid mine drainage (AMD) in the Stockett-Sand Coulee Coal Field. The second year of the project was 50% funded by the Montana Department of State Lands, Helena, Montana. The project was conducted by the Montana Bureau of Mines and Geology, Butte, Montana in 1981-83.

1.1 Problem Description

Coal in the Stockett-Sand Coulee area, near Great Falls, Montana, occurs within the upper part of the Morrison Formation (Jurassic) and is exposed along outcrops in the valley of Sand Coulee Creek and its tributaries. Unlike the Eastern Montana Tertiary coal deposits, the coal in this area is higher in grade (bituminous) as well as in sulfur content (0.5-5.5%) and is moderately high in ash (about 20%) (Silverman and Harris, 1967). Mining in the area commenced before the turn of the century via numerous adits which were constructed along the bottoms and sides of the major coulees. The last large-scale mine closed in 1952, but some recent exploratory drilling has been concentrated in the area between Great Falls and Stanford, where these coal deposits occur generally within 100-300 feet of land surface.

The extensive underground mining activity has allowed easy access for oxygen and water to enter the system of abandoned mines, and as a result, the area now has an extensive acid mine drainage problem. Ground water infiltrates through the overlying Kootenai Formation into the Morrison Formation, oxidizing pyrite within the abandoned mines and
discharging at low pH (2.3-5.0) from abandoned mine portals or through mine spoil backfill materials.

While the existing problem is primarily the result of mining activities, it is possibly being enhanced by non-water conservative summer-fallow cropping practices on the upland benches, which increase the amount of water that moves into the subsoil and then into the Kootenai Formation. Any future mining operations which become active in this area will have to confront the hydrologic impacts of their activities during and after mining. In light of the proposed construction of coal-fired generating facilities in the Great Falls area within 20 miles of this old mining district, the probability of new mines being established somewhere in the Great Falls-Lewistown coalfield, although remote, is as great as it has been in the last 30 years. A location map is shown in Figure 1.

1.2 Previous Work

Fisher (1909) published the first report on this area, describing the geology and coal resources in some detail and including a brief description of the mining operations active at that time. A chemical analysis of spring water near Stockett was made, which indicated that the water was alkaline and unpolluted.

Goers (1964) performed a geological study of the Stockett-Smith River area, which included field inventory of a number of water wells in this area.

Silverman and Harris (1967) described the geology and stratigraphy of the Great Falls-Lewistown Cretaceous coal field. A generalized stratigraphy and detailed isopachs of coal sequence were presented.
Also, geochemical characterization of a limited number of coal samples was performed.

McArthur (1970) performed a detailed short-term study of the environmental aspects of acid mine drainage in the Stockett-Sand Coulee area. He performed a detailed spring inventory and measured flows and pH over an eight month period for selected springs and surface-water stations. His work included an assessment of the hydrologic system, some water quality analyses and presentation of some alternatives for mine water neutralization, including limestone or lime treatment and mine flooding.

Hydrometrics (1982) submitted an extensive and comprehensive report on abandoned mine lands in the Belt-Sand Coulee area, concentrating on, but not limited to, the hydrology of acid mine water in this area. They provided a complete literature review, an assessment of amelioration alternatives and a re-inventory of the springs in this area. Some hydrologic data was collected, although only over a four month period.

1.3 Study Rationale

This project was designed to collect sufficient data to allow assessment of alternatives to centralized treatment of acid mine drainage. An ideal alternative to treatment would dispose of and/or prevent acid mine discharge in an inexpensive manner, easily applied over an extensive area, with reasonable maintenance. This investigation focused on the hydrogeologic background of two general amelioration techniques which may meet these criteria:
1) Infiltration control; whereby the amount of water infiltrating the old mine workings is reduced by minimizing ground-water recharge or dewatering the overlying aquifer; and

2) On-site neutralization methods involving surface neutralization of the numerous small acid seeps in small ponds or by gravity injection and neutralization of acid water within the underlying limestone of the Madison group rocks.

1.4 Project Objectives

Project objectives for the first year of study (FY 81) were as follows:

1) Initiation of a comprehensive inventory of all springs and water wells in the study area, including a re-inventory of springs recorded by McArthur (1970);

2) Establishment of 1-3 permanent stream gaging stations in the Sand Coulee drainage, including Straight (No-Name) Creek;

3) Initial monitoring of springs in the area for flow, pH and specific conductance;

4) Water quality analysis, to characterize ground- and surface-water quality and to support investigation of their interaction.

Project objectives in the second year included:

1) Continuation of acid discharge monitoring;

2) Streamflow monitoring via the gaging stations and seepage runs;

3) Completion of a comprehensive domestic well inventory, aquifer identification, static water levels and field water quality characteristics;
4) Collection and analyses of ground-water quality data;
5) Preparation of a proposal for implementation of AMD mitigation techniques using hydrologic systems controls.

1.5 Study Site Reference System

All springs and streamflow stations were numbered using an arbitrary sequential reference system, organized by drainage basin. Acid discharge reference codes used in this and previous investigations are shown in Table 1.

Straight Creek, as it is called by local residents, is not named as such on the U.S. Geological Survey (USGS) quadrangle map, but refers to the drainage through the town of Sand Coulee that is tributary to Sand Coulee Creek. This drainage is referred to by McArthur (1970) as "No-Name Creek".

Hereafter, the term "study area" is used to refer to the drainage area of Sand Coulee Creek from its headwaters to a point about two miles north of Tracy, Montana, where the creek enters the abandoned Missouri River channel. The principal towns of the study area are from north to south, Tracy, Sand Coulee, Centerville and Stockett, shown in Figure 1.

2. RESULTS

2.1 Springs

2.1.1 Spring Inventory and Monitoring

During the first year of the project, 17 springs were found to be discharging acid water from mine portals or spoil piles either perennially or intermittently (Figure 2). Nine springs flowed perennially,
while eight flowed only during or after spring precipitation and snowmelt periods. These springs in general corresponded to those observed by McArthur (1970) to be active in 1969. Five springs which flowed in 1969 (McArthur's 36-3, 36-6, 7-8, 7-9 and 18-5) were not observed to flow in 1980-81. Another seep in a spoil pile (13-2) found by McArthur has apparently become plugged in recent years. A large seep area near the old Giffen mine was not included in McArthur's inventory, possibly because the pH is not below 4 at all times of the year.

Table 2 describes the active springs; ranges of flow, conductance and pH.

These springs were monitored on a periodic basis, to evaluate annual variability in flow and water quality. The results are included in Appendix A. During the period from 6-1-80 through December 1981, results for the monitoring may not be representative of the average year. The winters of both 1979-80 and 1980-81 were very dry in the study area, despite ensuing wet spring seasons. However, the patterns of variability and response of the acid springs to precipitation events are probably typical. The net discharges of acid mine water for this two-year period may be slightly below the long-term average.

Based on the monitoring to date, the acid springs can, with several exceptions, be separated into two arbitrary groups. The first group consists of springs with high flow variability (those which have a ratio of high flow to low flow greater than 5 and very rapid response to major springtime precipitation or snowmelt events, usually responding within a few days). These springs are usually associated with mine adits located less than 150 vertical feet below the top of the overlying bench. The second group also exhibits springtime increases in
flow but to a much lesser degree. These adits are located a greater vertical distance from the adjacent uplands where the ground-water flow system is recharged.

Springs in the first group (variable discharge) are in all cases located north of the town of Stockett, including the springs near the towns of Sand Coulee and Centerville. Some of these springs with exceptionally high variability include AS-01 (from 43-500 gallons per minute (gpm)), AS-07 (from 12.5-250 gpm) and CS-10 (from 0-80 gpm). In May 1981, peak flows at springs were obtained within two weeks of the end of the period of most intense precipitation. The pH in springs of the first group ranges from 2.29-4.20, with most in the range 2.3-2.9. Most springs (AS-03, AS-02, AS-04, AS-01, AS-07) tend to become only slightly more alkaline during high flow periods in the spring, probably due to dilution by alkaline recharge. Others (AS-06, CS-10) become more acid, probably due to flushing of pockets of stagnant water of high acidity from the mines due to an increased flow caused by infiltration on the upland benches. Recharge water infiltrating into the mines must not be of sufficiently high alkalinity or volume to reduce the acidity of the discharge.

Figure 3 shows spring discharge measured on 5/28/81, immediately after intense spring rains. The flows are, in all cases, the highest observed for each acid spring during 1980-1981 and in some cases represented an order of magnitude increase over discharge at low flow. Actively discharging acid springs are common along the west side of the upland bench separating Straight Creek from Sand Coulee Creek and are east of this bench relatively scarce in the Centerville area. This suggests that the springs in the town of Sand Coulee are locally re-
charged and that ground water flows in these mines to the northwest, possibly conforming to the dip of the Morrison and Kootenai beds beneath this bench. The total measured acid discharge from all springs was a minimum of about 358 gpm (0.8 ft$^3$/s) on 3-5-81 and a maximum of about 1479 gpm (3.3 ft$^3$/s) on 5-28-81.

Specific conductance (S.C.) values of mine discharge (Figure 4), taken at the same date, are in most cases not greatly lower than at other times of the year and in several springs is actually higher than at low flow. S.C. ranges from 476-10,306 microsiemens per centimeter (us/cm), with the springs discharging water of less than 1000 us/cm being either alkaline or dominated by alkaline recharge. Most spring discharges are in the range from 2000-7000 us/cm. Dissolved ferrous iron concentrations and concentrations of suspended ferric hydroxide have a large influence on the S.C. of these waters, and for this reason S.C. is probably less indicative of other water quality characteristics than it is for most natural waters. Spatial patterns are not apparent in this S.C. data, but generally springs which emit from backfilled minespoil materials are of poorer water quality and higher conductance than those discharging from open adits.

Specific conductance variations indicate that, despite the large increases in flow in the spring, very little dilution by recharge water is taking place. Most conductance values decreased by less than 25% in May 1981, in response to over 6 inches (in.) of local precipitation. Several springs (AS-06, AS-07) actually increased in conductance, suggesting again that isolated pockets of poor quality water in the mines are being flushed in the spring and lie stagnant during much of the rest of the year.
The very rapid hydrologic response of most acid springs suggests substantial interconnection between the surface and the mine workings, probably along vertical joints and fractures sometimes visible along valley walls. The morphology of stream and coulee orientations in the region suggests structural control which may be another expression of this joint system.

Several open adits were found in the bottom of Mining Coulee, south of Sand Coulee, where high water marks indicated that large volumes of surface runoff pour directly into the old mine workings. The rapid response of AS-01, in particular, may be related to this apparent surface water infusion.

From well records, saturated sandstone strata occur throughout the Kootenai Formation although only the basal sandstone unit shows extensive continuity and saturation. Recharge along fractures may increase the pressure head within these beds and augment the rate of leakage from these perched aquifers through fractures into the underlying basal Kootenai. The conglomeratic sandstone unit at the base of the Kootenai probably forms the roof of many of the mine adits and is the primary source of ground-water leakage into the old workings.

Increase of seepage rates from the basal Kootenai into the mines increases ponding of water within the mines and flushes pools of acid mineralized water towards the portals. Due to the slope of the adits, they drain freely and oxygen has ready access, allowing pyrite oxidation to occur at a high rate.

The recharge-discharge relationship for most acid springs is believed to be quite local. For example if the mean annual flow rate from AS01, AS02, AS03 and AS07 is estimated to equal 300 gpm (0.668
cubic feet per second (ft$^3$/s)), assuming the approximately 3 square miles (mi$^2$) bench area south of Sand Coulee to be the recharge area, the annual recharge rate would equal 3 in. This represents about 19% of the mean annual precipitation, a reasonable estimate for this area.

Only a few springs fall into the second, low-variability category. They include CS-09, along Cottonwood Coulee two miles south of Stock-ett, and BS-01, the Giffen Mine East outflow. Both occur at elevations nearly 200 feet below the surrounding upland benches where ground water is recharged. This additional separation from recharge apparently dampens the spring response to rainfall and snowmelt infiltration. The Giffen Spring increased in flow by a factor of about 1.5 in May 1981; its water quality decreased considerably, with pH decreasing more than a whole unit and conductance increasing from 6000 to 8600. During fall and winter, at low flow, both pH and water quality improve somewhat.

The Giffen Spring (BS-01) produces relatively consistent baseflow, averaging 250 gpm (3040 acre-feet/year) during the 1981 water year. Local precipitation was probably slightly higher than the local average of 15 in./year, although no accurate precipitation data are available from this specific locality. Assuming 16 in. total for the year and assuming, quite liberally, that 50% (8 in.) of this precipitation contributed to ground water as infiltration rather than contributing to crop use, runoff, or evapotranspiration, then discharge from these mine workings was recharged from an area at least as big as 7.12 mi.$^2$, an area greater than the 3-4 mi.$^2$ available for recharge along the upland bench immediately to the east of the mine. It is probable that ground-water flow in the Kootenai moving down gradient from its recharge area towards the Belt Mountain foothills is being intercepted by the old
mine workings and discharging from the north-westerly sloping Giffin adit.

2.1.2 Spring Water Quality

Water quality data collected from springs in 1980 and 1981 are listed in Appendix A (A-2). Field pH for spring waters ranges from 2.38-3.98 for all sites except BS-01, the Giffin mine, where it ranges from 3.8-5.4. While none of these springs are alkaline, acidity shows a broad range, from 108 (BS-01) to 6002 (AS-03) milligrams per liter (mg/L) as CaCO₃. The waters are ferrous-aluminum-sulfate dominant, with minor calcium and magnesium. Iron (Fe) (12-1065 mg/L) and aluminum (Al) (1.72-752 mg/L) are the most abundant metals, although there are also high concentrations of trace metals including nickel (Ni) (0.24-5.31 mg/L) and zinc (Zn) (0.60-21.5 mg/L). Lesser (<1 mg/L) but detectable concentrations of cadmium (Cd), chromium (Cr), copper (Cu), and in some cases molybdenum (Mo) also occur. Both arsenic (As) (<80 parts per billion (ppb)) and selenium (Se) (<21 ppb) are at low concentrations.

Ferrous iron is dominant over ferric at the mine mouths, although some minor amounts of iron in excess or dissolved iron were recovered—probably ferric hydroxides in suspension in the water. FeSO₄⁰, AlSO₄⁺, and Al(SO₄)₂⁻ are all strong complexes in this solution. Sulfate activities are probably at a plateau in some of these waters, due to the fact that the majority of any sulfate added to the water is probably complexed by either iron, aluminum, or alkaline earths and many waters are saturated with respect to gypsum. As the iron oxidizes and drops out of solution downstream, the sulfate activities might be
expected to increase and possibly cause other sulfate species to attain saturation.

These waters are undersaturated with respect to all but a few mineral phases. One is gypsum; another is chalcedony, which becomes supersaturated in neutralized waters due to dissolution of silicates under acid conditions.

2.2 Ground Water

Ground water occurs in most all of the permeable rock units in the Stockett-Sand Coulee area. A description of the geologic formations in the area is given in Appendix B. From oldest to youngest age, aquifers are known to yield water to wells from the Mission Canyon formation of the Madison Group (Mississippian), the Swift Sandstone (Jurassic), sandstone beds in the lower Kootenai formation (Lower Cretaceous), glacio-fluvial and glacio-lacustrine deposits (Quaternary) and stream alluvium (Quaternary). Figure 5 is a schematic hydrogeologic section. Vertically stacked aquifers separated by shale aquitards frequently occur, and surface water-ground water interaction is a common phenomenon. Ground water movement is primarily horizontal within specific aquifers, in response to the hydraulic gradient. Vertical movement of ground water can occur when two aquifers are in direct contact with each other, when natural rock fractures or man-made features such as well bores allow vertical movement, or by slow leakage through aquitards.

An inventory of domestic water wells in the study area was completed in summer 1982. Field data are presented in Appendix C (C-1) and included owner, location, static water level, field specific con-
ductance and pH and water use information. Measured static water levels, and S.C.'s are shown in Table 4 and are referenced to a location map in Figure 6. Field data were correlated with the Montana Ground Water Appropriation forms which gave useful information on well completion, yield and the lithology encountered in drilling. A total of 46 domestic wells were inventoried on at least one occasion. The Madison limestone aquifer supplied 24 wells, Jurassic sandstones 11, Kootenai sandstones 10, and alluvium only 2. Five wells were completed in multiple aquifers and the water bearing source of two wells could not be estimated at all.

2.2.1 Madison Aquifer

The Mission Canyon Formation of Mississippian Age is the principal aquifer in the Madison Group Rocks. It is composed of massive light-gray limestone and thin dolomite interbeds which have been extensively karstified. Ground water flows through fractures and solution cavities that may occur from near ground surface to depths of at least 700 feet. The aquifer appears unconfined to moderately confined in the study area based on water level data, and some Madison wells in the Centerville and Tracy area expel and suck air with considerable force. Horizontal ground-water flow is generally from south to north (Feltis, 1980, 2). Vertical ground-water flow in the study area is downward with some deeper Madison wells having lower static water levels than shallower ones.

The primary recharge area for the Madison aquifer is on the flanks of the Little Belt Mountains where many square miles of Madison Group rocks are exposed to relatively high precipitation (20 in. or more
annually). Additionally, streams are reported to lose water as they traverse portions of the Madison outcrop. More limited recharge occurs in the study area where local doming of the Madison results in exposures of fractured limestone in the Centerville-Stockett area. Streamflow from Number Five Coulee and Cottonwood Coulee directly infiltrates Madison rocks. The Madison also probably receives recharge as leakage from overlying saturated alluvium. Results of water quality analyses indicates that some of this recharge is acid mine drainage water.

The best known discharge point for the Madison aquifer is Giant Springs just east of the city of Great Falls. Approximately 300 ft$^3$/s of ground water issues from large springs near and in the Missouri River (Patton, 1983). Between Tracy and Great Falls, the Madison aquifer may develop upward vertical leakage and discharge to overlying aquifers and to the pre-glacial Missouri River Channel south of Great Falls. Water quality and head data from the Madison, Swift and Kootenai aquifers is often similar, suggesting a high degree of inter-aquifer connectivity just north of the study area.

2.2.2 Swift Aquifer

The Madison Group is unconformably overlain by Jurassic marine sediments of the Ellis Group. Sandstone of the Swift Formation directly overlays the Mission Canyon Formation in much of the study area. The Swift is a fine- to medium-grained, well-cemented quartz sandstone from 0-40 feet thick. It appears cross-bedded or massive in outcrop, weathering to a pale orange to brown color. Beds of chert-pebble and brachiopod shell hash conglomerate may occur in the lower part. The Swift occurs over most of the study area and is well exposed
in the coulee bottoms of Cottonwood Creek north of Stockett and Number Five Coulee southwest of Stockett.

The Swift sandstone is known to yield water to three wells in the Tracy vicinity south of Stockett, and it is the probable source of two springs issuing near the bottom of Cottonwood Creek below the Morrison coal seam. Relatively little is known concerning the extent, thickness and water-yielding characteristics of the Swift sandstone between Stockett and Tracy. In the Sand Coulee Creek Valley north of Centerville, water wells drilled to the Madison sometimes do not encounter the Swift sandstone, indicating it is probably removed by erosion. One Swift well just northwest of Tracy was sampled and has a TDS of 1,994 mg/l, indicating potential contamination from AMD in nearby Sand Coulee Creek. Data are too sparse to construct a potentiometric map of the Swift, although flow is believed to occur from south to north.

The recharge-discharge regime of the Swift aquifer is not well known. Like the Madison, it is probably recharged where exposed along the flanks of the Little Belt Mountains and to a lesser extent in the study area, where local doming and erosion in coulees bring the ground surface close to the elevation of the Swift Sandstone. Since there is no observable confining bed between the Swift and Madison aquifers, they may act as a unit north of Tracy where the Madison becomes fully saturated. Similar heads and water quality between Tracy and Great Falls further suggest the inter-connectivity of the Madison and Swift aquifers.

The Swift Formation is overlain by the Morrison Formation which consists of 100-200 feet of gray shale with interbedded sandstone, limestone and coal. The Morrison coal bed or beds occur near the top
of the Jurassic section and were the target of mining in the area.

2.2.3 Kootenai Aquifer

The Lower Cretaceous freshwater Kootenai Formation is present at land surface over most of the study area and unconformably overlays the Morrison Formation. The basal unit of the Kootenai is a resistant, cross-bedded, coarse, salt and pepper sandstone bed, from 2-80 feet thick (Walker, 1974). Above this basal sandstone, the Kootenai consists of numerous, lensaic, poorly continuous sandstone beds, 1-50 feet thick, interbedded with green, gray and maroon mudstone. The Kootenai is typically 100-300 feet thick in the study area with 100-300 feet of the upper Kootenai member having been removed by erosion. The basal conglomeratic sandstone unit directly overlays the Morrison coal bed and is a relatively continuous aquifer supplying wells throughout the study area. More discontinuous sandstone beds occur stratigraphically higher on the Kootenai and occasionally yield water to wells and springs.

Horizontal ground-water flow in the basal Kootenai aquifer is generally from the topographically high benchlands to nearby coulees bisecting the Kootenai formation. There is a regional bedrock dip of approximately 3-6 degrees to the north-northwest and ground water migrates down dip, commonly resulting in springs and seeps on the northwest terminus of benches. Southern and eastern Kootenai outcrops are usually drier. In unmined areas, natural springs are common at the contact of the basal Kootenai with the less permeable Morrison Formation.

The many thin sandstone and shale beds in the Kootenai are quite
brittle and flexure of the South Arch in Tertiary time resulted in extensive fracturing of the Kootenai rocks. These fractures and related joint systems readily allow vertical ground-water movement and recharge from surface sources. The limited data available from domestic wells indicates that the basal Kootenai aquifer is sometimes confined in the middle of benches, and is frequently unconfined in wells near the edge of benches where the Kootenai section is bisected.

In relation to acid mine drainage, the removal of the coal bed underlying the basal Kootenai sandstone aquifer has resulted in leakage of ground water into the old mine workings. The old tunnels and rooms are efficient ground-water drains, which locally dewater the basal Kootenai sandstone and allow water to be conveyed down-gradient to old mine portals situated at the outcrop areas in the principal coulees. The normally alkaline Kootenai ground water is exposed to atmospheric oxygen and pyrite in the old mines where the chemical oxidation process occurs, producing AMD.

2.2.4 Quaternary Aquifers

Ground water occurs in stream alluvium deposits of Sand Coulee Creek and tributaries in the study area. These deposits are relatively thin south of Sand Coulee and Centerville, typically 10 to 30 feet thick. North of these towns, the valleys of Sand Coulee Creek have been filled with a combination of alluvial, glacial, and lacustrine deposits to thicknesses of up to 150 feet as recorded by water well drillers. The alluvial deposits are typically sand and fine-medium size gravel, gravelly clay, sandy loam, and sandy clay, brown to yellow-brown in color.
Evidence of glacial and lacustrine deposits comes from the widespread influence of Pleistocene continental glaciation throughout the Great Falls area as described by Alden (1932) and Walker (1974). Several water well logs in the Tracy vicinity record alternating deposits of yellow, sandy clay and gray silt, consistent with a postulated sequence of glacial deposits and lacustrine deposits from ice-marginal glacial lakes.

Water wells in the abandoned pre-glacial Missouri River Valley north of the study area are reported to obtain good yields of groundwater from scattered sand and gravel lenses (Walker, 1974). But the lateral occurrence and depth of these deposits are unpredictable. Wilke (1983) inventoried at least 5 water wells completed in Quaternary deposits found in the pre-glacial channel.

Although most of the alluvial deposits in the study area are saturated, little use is currently made of alluvial ground water due to AMD contamination. Only south of Stockett, above the highest elevation AMD source, is significant use made of alluvial ground water. The town of Stockett obtains a portion of its water supply from an alluvial infiltration gallery about 2 miles south of town. However, local residents report high iron problems occur in the spring when ephemeral AMD sources discharge upgradient from the collector.

The alluvial deposits of Sand Coulee Creek and tributaries are the intermediate receptor of most visible AMD in the study area. Stream channels cut into the alluvium carry most of the AMD discharge. However, in the Sand Coulee and Centerville vicinity, as the alluvial deposits deepen, streamflow is partially or entirely lost to the alluvium. AMD is therefore a continued source of recharge to the alluvium.
North of Tracy, the alluvium is apparently in direct contact with the Madison limestone. Reports from drillers indicate that the vertical gradient is downward, thereby allowing AMD contaminated alluvial ground water to recharge the Madison aquifer. Local residents also report that the acid alluvial ground water has caused failures of cement grout and steel casing in the alluvium and that downward leaking alluvial ground water has contaminated formerly good quality Madison aquifer ground water.

2.2.3 Ground Water Quality

The chemical quality of ground water in the Stockett-Sand Coulee area is quite variable due to the different types of rocks comprising the multiple aquifers, the effects of AMD, the hydraulic connections between aquifers and surface water-ground water interactions.

In general, it is possible to discuss each aquifer as having its own "characteristic" water quality and intra-aquifer trends. Variations from the typical condition are most often due to inter-aquifer mixing or to chemical reactions imparted by acid mine drainage water. Water quality data from laboratory analyses of sampled wells are presented in Appendix C (C-2).

2.2.5.1 Madison Aquifer

Water wells tapping the Madison aquifer southeast of the Missouri River near Great Falls usually have total dissolved solids (TDS, calculated) concentrations usually in the range of 400-600 mg/l. Giant Springs, several miles northeast of Great Falls, is thought to be a regional discharge point for the Madison aquifer. The spring has been
sampled 11 times between 1890 and 1983 and has had a TDS of 369 to 498 mg/l and approximately equal milliequivalence of $\text{Ca}^{2+}$, $\text{Mg}^{2+}$, $\text{HCO}_3^-$, and $\text{SO}_4^{2-}$ (Patton, 1983). Feltis (1980, 1) mapped TDS concentrations of Madison wells throughout northern Montana which showed a concentration gradient of less than 1000 mg/l near mountain uplifts to over 10,000 mg/l in the Williston basin. The density of wells sampled, however, except in the Great Falls and oil field areas, is quite low.

The chemical quality of Madison wells sampled in the Sand Coulee area is quite variable and does not fit expected patterns. Figure 7 is a histogram indicating that seven of twelve Madison samples were less than 600 mg/l, and five ranged from 600 to 2,413 mg/l. The five high TDS samples had milliequivalent ratios of sulfate to bicarbonate of from 1.7 to 7.7. Figure 8 is a Piper plot which graphically illustrates the progression of increased sulfate concentrations among the samples. An analysis of Giants Springs is included for comparison.

Since the high TDS wells are scattered throughout the study area, there is little evidence to support a water quality trend of this magnitude based on length of ground-water flow path. Anhydrite beds known to occur in the Charles Formation which, in places, overlies the Mission Canyon Formation, could be a source of sulfate and TDS increases. However, the Charles Formation is not known to occur in this area and lithologic logs of water-well drillers have not indicated any evaporitic zones in the study area.

Although natural sources cannot entirely be ruled out, at this time a plausible explanation for the anomalously high TDS and sulfate concentrations is the infiltration and mixing of AMD water with native Madison aquifer ground water. Higher TDS and sulfate concentrations
are a byproduct of the acid producing metal oxidation reactions that take place in the old mines and during surface water or ground-water transport of AMD. It is believed that the contaminated Madison wells are generally down-gradient from an AMD source, particularly if the well is in a tributary coulee bottom. The downward gradient and possible fractures associated with the coulee may provide the conditions favorable for contamination. Figure C-3 (Appendix C) shows the proximity of AMD sources to the Madison aquifer wells in the study area. Chemical models of the AMD and Madison ground-water interaction are presented in section 3.3.

2.2.5.2 Jurassic Aquifers

The Swift Formation is the most prevalent Jurassic aquifer in the study area, however, other water-bearing sandstones occur regionally in the Morrison Formation which overlies the Swift sandstone. Four Jurassic aquifer samples were collected in this investigation but lack of well log information prevented differentiating the specific water-bearing zones.

Three of the Jurassic aquifer samples are calcium-magnesium-bicarbonate types with TDS of 277 to 433 mg/l, and one, the Lyman well, is a calcium-magnesium-sulfate type, with a TDS of 1737 mg/l. The analyses are plotted on a Piper diagram in Figure 9.

Wilke (1983) reported analyses from three Morrison wells and two Swift wells in the Great Falls vicinity. Morrison wells had TDS (sum of constituents) range of 908-1480 mg/l and had mixed water types. The Swift wells had TDS values of 846 and 1020 mg/l and were calcium-sulfate and sodium-sulfate water types respectively.
The proximity and hydraulic connectivity of Swift and Morrison aquifers to each other and to adjacent aquifers may give reason to expect water quality variability. The Lyman well appears anomalously high in TDS and sulfate and may be affected by AMD water. No log exists for the well but it is drilled on the very edge of the Sand Coulee Creek Valley which is known to be a source of AMD leakage to lower bedrock aquifers.

2.2.5.3 Kootenai Aquifer

The Kootenai aquifer is the surficial bedrock aquifer over most of the study area and receives recharge directly from precipitation and surface sources. Four water samples from the Kootenai aquifer were collected in this investigation.

Three samples were collected from the basal Kootenai sandstone aquifer, two from wells and one from a spring. The two well samples had TDS values of 369 and 433 mg/l and were a magnesium-bicarbonate type. The spring was located about 400 meters north of the Giffen mine works and had a TDS of 295 mg/l, and was a calcium-magnesium-bicarbonate type.

One sample came from a well also near the Giffen mine but located on the bench. The water-bearing zone was a limey sandstone about 65 feet below ground surface and about 50 feet above the basal Kootenai sandstone. The TDS was 369 mg/l and it was a calcium-magnesium-bicarbonate type. The analyses are plotted along with the Jurassic well samples on a Piper diagram in Figure 9.

These results are similar to those of Wilke (1983) who sampled five Kootenai wells in the Great Falls vicinity and reported a TDS
range of 558 to 1,550 mg/l, with magnesium and bicarbonate being the principal constituents in three of the samples.

Total field alkalinity in the Kootenai samples ranged from 269 to 433 mg/l as CaCO$_3$ and field pH ranged from 6.63 to 7.48. Kootenai aquifer ground water is thought to be the principal source of leakage into old mine workings and hence is the water that becomes acidized. These analyses indicate that native Kootenai ground water is alkaline and of relatively good quality. The undisturbed Morrison coal bed is thought to be an aquitard and hence does not transmit appreciable quantities of ground water.

2.2.5.4 Quaternary Aquifers

The alluvial valleys of Sand Coulee Creek and tributaries contain ground water, although in most of the study area, it is not used domestically because of AMD contamination. Residents long ago abandoned alluvial wells and consequently there are very few existing alluvial wells. No alluvial wells could be found north of Stockett, and so no data could be collected on alluvial water quality.

The town of Stockett's alluvial collector well 2.5 miles south of Stockett was field checked in spring, 1981 and found to have a pH of 5.3. The alluvium there is up-gradient from most perennial AMD discharges, however, ephemeral AMD sources apparently discharge during wet weather, causing some seasonal contamination. Stockett residents complained of iron staining and bad taste during these occasions and in 1981 drilled a deep well to the Madison aquifer for a public supply. This has been the trend throughout the study area. Shallow alluvial wells have been replaced by deeper bedrock wells to escape AMD contam-
ination problems. However, as previously indicated, both Jurassic and Madison aquifers show evidence of contamination in selected wells.

Further suggestion of alluvial ground-water contamination came from rancher O. G. Johnson who lives about 2 miles north of Tracy. He reports that a number of shallow wells drilled across his property in Section 31 (T. 20 N., R. 5 E.) and Section 6 (T. 19 N., R. 5 E.) encountered only AMD affected water. As a result, they drilled deeper wells to the Madison aquifer but in at least one case, acid water disintegrated the cement grout and steel casing causing the well to be contaminated and abandoned.

Contamination of alluvial ground water may extend along the entire reach of the pre-glacial Missouri River, now occupied by Sand Coulee Creek. The extent of contamination will be mapped in a subsequent investigation by the MBMG and Montana Department of State Lands.

2.3 SURFACE WATER
2.3.1 Gaging Stations

Three gaging stations were installed within the Sand Coulee drainage in Fall, 1980. The three locations (Appendix D) are Sand Coulee Creek at Centerville, below the confluence with Cottonwood Creek (CF-03); Sand Coulee Creek at Tracy, above the confluence with Straight Creek (CF-02); and Straight Creek north of the town of Sand Coulee (AF-01). The stations were installed with modified 90 degree V-notch weir plates, having a 30 degree cutout at the base to a gage height of 1.12 feet. The 30 degree modification was designed to increase the resolution of low-flow determinations, up to a discharge of about 1 cfs.
Stevens Type A recorders were employed in the stilling wells. The Centerville weir accommodated flows up to 50 $\text{ft}^3/\text{s}$ (gage height 4.24 ft), while the Tracy and Straight Creek weirs could measure up to 13.4 $\text{ft}^3/\text{s}$ (gage height 2.83 ft). Design plans and rating equations used for the weirs are included in Appendix D (D-1).

Daily discharge data and stream hydrographs for the gaging stations are displayed in Appendix D (D-7). The short term data allow only tentative generalizations to be drawn, including:

1) Sand Coulee Creek shows high annual variability in discharge. During late winter and spring, its flow is dominated by runoff from snowmelt and spring rainstorms in the Sand Coulee area and in the upper reaches of the watershed in the Belt Mountains. In 1981, intense spring rainstorms in May caused flash flooding along Sand Coulee Creek in the Tracy-Centerville area, washing away the two original stilling well installations at CF-02 and CF-03. Peak flows fell gradually, and by October the main watercourse was essentially dry. It would not be unusual for Sand Coulee Creek to be dry by August in a year of "normal" precipitation and earlier in dry years. Bank and bed materials around these two stations were washed out a second time in May, 1982, again following a spell of very wet weather. The instability of the channel materials and limitations on station construction forced the abandonment of the sites. They could be reinstalled as open channel stations. Peak flows topped the weirs by over one foot (gage heights >5.0 feet).

Low flow periods exhibited both streamflow losses and gains between the Centerville and Tracy weirs. Concurrent streamflow records in November, 1981 indicated a possible loss of 5-15 gpm in that reach. An eleven day period in latter August, 1981 indicated very little change in flows at about 300 gpm.

2) Straight Creek, despite having a watershed area of only about 4 percent the size of Sand Coulee Creek, has baseflows similar in magnitude and sometimes of longer duration. Sand Coulee Creek was dry from November through March in water year 1981, while Straight Creek had base flows of 0-10 gpm. The AMD from the many abandoned mines tributary to Straight Creek is primarily responsible. During low flows most of the water in Straight Creek infiltrates to the alluvium before the confluence with Sand Coulee Creek.

Peak flow in 1981 occurred on May 16 and reached 21.6 $\text{ft}^3/\text{s}$. Summer flows generally ranged from 5.0 to 0.2 $\text{ft}^3/\text{s}$. 25
2.3.2 Seepage Profiles

A seepage profile can be viewed as an instantaneous detailed summary of variations in stream discharge throughout a watershed, although in practice the collection of this data takes as long as several days. In a stream like Sand Coulee Creek dominated by acid mine drainage, changes in water quality (pH, specific conductance, metal concentrations) also reflect variations in stream discharge and can point out stream gains or losses.

Acid mine drainage discharges into surface water systems and undergoes changes in both quality and quantity early in its downstream flow. Changes in surface-water quantity include losses, primarily streambed infiltration, and gains, primarily inflow from tributary drainages and seepage from shallow ground-water discharge. Changes in quality are primarily due to mixing with tributary streams and to precipitation reactions caused by oxidation of the acid water. Seepage profile data were collected to investigate these downstream changes in discharge and water quality and to relate them to the interaction of the ground water and surface water. All stream seepage profile sites are shown in Appendix D (D-2).

2.3.2.1 Number Five Coulee

The seepage profile on Number Five Coulee, conducted March 14, 1981 was terminated prematurely when a temporary restraining dam was breached. However, eleven measurements were made beforehand between the Giffen mine and the confluence with Cottonwood Creek. Streamflow measurements were made with a hand-held pressure-diaphragm current meter, readable to 0.1 ft/sec.
There were both gains and losses, but there appeared to be a tendency for decreasing streamflow possibly indicating losses to alluvium and bedrock. The net loss between successive measurements along the approximately four stream miles ranged from 24 to 104 gpm, and is depicted in Appendix D (D-3). The pH and specific conductance at the 11 sites remained relatively constant, with pH values from 6.05 to 6.68 and specific conductance values from 1159 to 1228 us/cm (see Appendix D (D-4 and D-5).

2.3.2.2 Sand Coulee-Cottonwood Creek

Seepage characteristics of Sand Coulee and Cottonwood Creeks were determined with 21 seepage run stations established from 8-26-81, 1500 hrs., to 8-29-81, 1000 hrs. (see Appendix D). These included tributary flows entering at DFO1 (Sand Coulee Creek), BF01 (Number Five Creek), and AF01 (Straight Creek), as well as 18 temporary stations installed along the main drainage of the area formed by Cottonwood and Sand Coulee Creeks (CF01-CF18). The three permanent gaging stations were included in the seepage profile. Discharge was measured at each station except these three using a portable reinforced plywood 90-degree V-notch weir, graduated in hundredths of a foot. At each station the weir was installed and leveled across the channel using clay and mud. The water level was allowed to rise to equilibrium behind the weir, at which time the gage height was noted. At stations where the stream gradient was high, equilibrium was achieved within a few minutes; under gentler gradients, slow rise in water level persisted for up to four hours. At all stations except one (CF01), an equilibrium gage height was attained. The relative error of the technique is estimated at $\pm 5$.
percent. The field pH and S.C. were measured at each station. In addition, seven water quality samples were collected and analyzed for major element chemistry and for both total recoverable and dissolved metals (Appendix D, D-6). The discharge at AF01 had been sampled and analyzed six weeks earlier, on 7-17-81, and in light of the low variability of discharge, conductance and pH between these two dates, the data from this earlier analysis were considered representative of AF01 during the seepage profile.

The results indicate that about 1078 gpm of surface water was input and about 1065 gpm was lost from Sand Coulee Creek as channel seepage and evapotranspiration between the uppermost point 5 miles south of Stockett and the mouth of the creek at the Missouri River.

Evapotranspirational losses in warm months complicate the interpretation of seepage profile data. Diurnal fluctuations of hydrographs from gaging stations on Sand Coulee Creek and Straight Creek indicate peak evapotranspirational withdrawals of 20 to 30 gpm and average daily withdrawals of 9 to 14 gpm. An estimate of the total direct evapotranspirational withdrawal over the entire stream length under study was made by using an average stream width of 4.7 feet, a length of 24 miles (DNRC, 1979) and the August, 1981 average daily corrected evaporation rate of 0.0168 ft/day, a mean of the U.S. Weather Bureau's Canyon Ferry and Moccasin experiment station pan data (U.S. Dept. of Commerce, 1982). The average evapotranspirational loss rate from the stream was thus estimated to be 52 gpm, or about 2.17 gpm per stream mile.

The total net streamflow losses to ground water, by difference, equalled 1013 gpm. Using more conservative criteria, stream losses to
infiltration and ground water would be occurring, when between two consecutive measurements, a loss remains after obtaining the minimum difference of each pair of measurements ± 5%, to allow for possible measurement error, minus 2.17 gpm/mi due to evapotranspirational effects.

Based on these criteria, seven of the eleven measured stream segments exhibited streamflow losses to infiltration ranging from rates of 7 to 108 gpm per stream mile. Losses to infiltration using the above criteria for all seven stream segments totaled 958 gpm. If all the gains in streamflow and evapotranspiration losses for the other four segments are subtracted, a net minimum overall streamflow loss to infiltration of 815 gpm remains.

A set of current meter measurements were made in August, 1982 to re-check stream seepage losses from several segments of Sand Coulee and Cottonwood Creeks. The results again confirmed a loss of about 100 gpm between Stockett and No. 5 Coulee on Cottonwood Creek. A very small gain was measured between No. 5 Coulee and CF03 and a gain of 168 gpm measured between CF03 and CF02.

A flow measurement was made on upper Sand Coulee Creek (T. 17 N., R. 5 E., 7, BA) about 17.5 stream miles above Centerville. At that point the flow was 2.9 ft³/s, pH was near 7.0 and S.C. equaled 672 us/cm. Sand Coulee Creek at Centerville just above Cottonwood Creek discharged only 1–2 gpm, indicating that the mainstem of Sand Coulee Creek also loses substantial amounts of water to subsurface seepage.

Water quality data collected during seepage profiles (Appendix D (D-7)) indicate the major impact which AMD had on streamflow. Cottonwood Creek above AMD influence had a pH of 7.33 to 8.26 and a
specific conductance of 418 to 476 us/cm. Downstream at Stockett, pH was 3.16 and S.C. equaled 1,641 us/cm. Just above Centerville, Cottonwood Creek had a pH of 3.34 and an S.C. of 1,233 us/cm.

Sand Coulee Creek below Centerville had pH values ranging from 3.42 to 2.60, and S.C. values of 1,267 to 3,151 us/cm. The pH decreased below the confluence with Straight Creek, and S.C. showed a tendency to increase in the downstream direction, with the highest value just above the confluence with the Missouri River.

Effects of both evapotranspiration and acid neutralization reactions will increase the total dissolved solids concentration of the stream. Stream pH is affected markedly by both the influx of more acid or alkaline tributary water and by oxidation of dissolved ferrous iron to the rust-red ferric hydroxide precipitate which coats the channel of Sand Coulee Creek and produces additional acid.
2.4 Hydrologic Summary

The Sand Coulee Creek watershed has a dynamic hydrologic system in which the effects of acid mine drainage from abandoned underground coal mines plays a significant role in terms of volume and water quality impacts. Peak stream flows are of short duration and influenced primarily by spring and early summer rainstorms over the entire basin which extends to the Little Belt Mountains. Baseflow in streams originates primarily as ground-water discharge from the surficial Kootenai Formation, which is extensively fractured, and transmits meteoric recharge as ground-water flow to the contact with the underlying less permeable Morrison Formation, where springs and seeps contribute to streamflow. Where the Morrison coal seam has been mined, ground water leaks into the old workings where pyrite is oxidized, creating acid water which discharges to streams from old mine portals. From Stockett and Sand Coulee to the Missouri River, the baseflow of Sand Coulee Creek is primarily composed of acid mine drainage water. Very little of the acid baseflow leaves the watershed as streamflow, most of the water leaving either as evapotranspiration or being lost to subsurface seepage to alluvial and bedrock aquifers.

3. Chemical Modeling of Ground-Water Quality

3.1 Introduction

One of the significant discoveries of this project was the unanticipated poor chemical quality of ground-water sampled from some domestic wells in the study area. The dissolved solids, sulfate, and occasionally trace metal content of some Madison aquifer wells were much higher than the Madison ground water typically possessed even
farther down the flow system, namely, in the Great Falls vicinity.

The predominately downward vertical gradients, regional fracturing and solution permeability associated with the area create conditions favorable for leakage of acid mine drainage from contaminated streams and alluvium into lower aquifers, principally the Swift and Madison.

Chemical modeling calculations were conducted in an attempt to explain the mechanisms and dynamics of potential AMD contamination of the alluvial, Swift and Madison aquifers.

The primary objective of the modeling calculations was to provide some ideas on the constraints that equilibrium or near equilibrium mineral-aqueous phase relationships place upon the chemical composition of ground water. These results are then used to evaluate the mixing of various "type" waters. The result is a minimum and maximum value for the amount of acid mine drainage responsible for the impacted water quality of wells in the (deeper) Madison aquifer. The methodology employed is similar to that described by Plummer et al. (1983), using the program PHREEQE (Parkhurst et al., 1980). Acid-mine drainage from adit AS-03 was used as an end member type water. Two water samples, from the Kunesh and Net wells, were used as end member "uncontaminated" Madison type waters. The following sections describe the results of a pure mixing model and two different reaction models. We will compare the predicted product phases with cuttings from the planned 1983 drilling program to evaluate which of these models most closely resembles the natural system for further predictive input.

3.2 Mixing Model

The product of a mixing model is simply a synthetic water analysis
in which $X$ percent of water A is mixed with $Y$ percent of water B ($X + Y = 100$) to yield a hypothetical water C, which is the best possible approximation of an observed water quality (water D). In order to accomplish this calculation, at least one constituent must be treated as "conservative," i.e., no additions or subtractions of this parameter occur. AS-03 drainage and the Kunish well water were used as waters A and B; sulfate, which constitutes the major anion species, was treated conservatively. The calculated mixing ratio is 19 percent AS-03 water and 81 percent Kunesh well water. Results of these calculations may be found in Table 3.

3.3 Reaction-Mixing Model 1

Because the mixing-model results provide a very poor correlation in terms of Fe, Ca, Mg, pH, and HCO$_3^-$, a reaction model was used to evaluate the dissolution of limestone and dolomite by the acid mine drainage. Reaction steps for this model are: (1) precipitation of gibbsite and amorphous ferric hydroxide; (2) dissolution of calcite and dolomite plus precipitation of Al(OH)$_3$ and Fe(OH)$_3$; (3) degassing to atmospheric partial pressure of carbon dioxide ($P_{CO_2}$); and (4) mixing 19 percent modified AS-03 water with 81 percent Knox water and increasing the $P_{CO_2}$ to atmospheric. Results of this approach, shown as analysis E in Table 3, provide a reasonably good match with the water in the Knox well.

3.4 Reaction-Mixing Model 2

The major drawback to the first reaction-mixing model is that it ignored the supersaturation of the water with respect to gypsum.
Gypsum precipitation would remove sulfate from the water, thereby requiring a greater percentage of acid mine drainage to result in hypothetical mix water similar to that from an impacted well.

For this model, a low total dissolved solids well water (Net well), was used, and a less severely impacted Madison aquifer well (Senior Citizens well, Centerville) was the control well. Mass balance calculations were not used to control the mixing ratio. Instead, the modeling steps were: (1) react AS-03 water with limestone precipitating Fe(OH)$_3$, Al(OH)$_3$, and fluorite at saturation levels, precipitating gypsum at slightly supersaturated levels, releasing CO$_2$ once $P_{CO2} = 10^{-0.75}$ atmosphere, and dissolving calcite until slightly undersaturated; (2) mixing water from the previous step with Net well water, dissolving a small amount of dolomite and precipitating small amounts of chalcedony and calcite. This procedure required 45 percent modified AS-03 water and 55 percent Net well water to approximately match the water quality in the Senior Citizens well.

3.5 Discussion

The models provide insight as to the probable range of mixing within the Madison aquifer of acid mine drainage waters with "pristine" ground water. The authors hypothesize that plumes of significantly degraded water within the Madison aquifer are probably restricted to the areas immediately down gradient from discharging mines, in the vicinity of leaky Madison well bores and near acid contaminated streams traversing Madison outcrops or alluvial subcrops.

4. Evaluation of Proposed Mitigation Alternatives
Previous analyses of acid mine drainage treatments for the Sand Coulee area (McArthur, 1970; Hydrometrics, 1982) focused on centralized neutralization or mine manipulation methods. Knowledge of the hydrodynamics and hydrogeology of the AMD problem gained in this investigation allows new evaluations of old techniques and the suggestion of some new mitigation alternatives.

Five AMD control techniques were proposed for field testing in the Stockett-Sand Coulee area based on this and previous work by the Montana Bureau of Mines (MBMG) and others. In addition to being summarized below, the five methods were presented on a proposal to the Montana Department of State Lands (DSL) (Appendix E). They subsequently agreed to provide funding for field testing of two methods: infiltration control through increased evapotranspiration and drainage wells.

An investigation of the extent of acid mine drainage contamination in the alluvium of the lower Sand Coulee Creek watershed was proposed and also funded by DSL for 1983-84.

4.1 Infiltration Control

A minimum of two test sites are proposed to monitor the effectiveness of perennial deep-rooted crops (e.g., alfalfa and sanfoin) and flexible-cropping techniques in reducing ground-water recharge to the Kootenai aquifer overlying the old coal mine workings. Research in dryland saline-seep control has shown intensive cropping techniques to be an effective tool in the control of shallow ground-water flow systems, when applied with a sound farm management plan. An organization such as the Triangle Conservation District, Conrad, Montana, would supply the required farm plan expertise to the farmers involved. Moni-
toring of ground-water level trends and of key AMD discharges would quantify the effectiveness of this approach.

4.2 Drainage Wells

Dewatering of the Kootenai aquifer with vertical wells may be possible, but is undesirable due to long-term pumpage requirements. We propose that horizontal test wells be drilled into the basal Kootenai sandstone aquifer upgradient from old mine workings at two sites. Gravity drainage of Kootenai ground water will eliminate pumpage, may substantially reduce AMD discharge of the test sites and will make more fresh water available for dilution of remaining AMD in receiving streams. Horizontal dewatering wells have been used successfully in Montana for highway construction and mining purposes in the past. Vertical connector wells which would allow gravity drainage of Kootenai ground water to the Madison aquifer, are another alternative which may be tested once detailed information on the aquifers and old mine workings is developed. Vertical test hole drilling and geophysical techniques would be used to map the location of old mine workings.

4.3 Subsurface Injection of AMD

Madison limestone rocks underlie the entire Sand Coulee watershed and could be an effective decentralized, disposal and neutralization medium for AMD. However, the Madison is also an important aquifer that must not be adversely impacted. Logging, sampling and analyses of Madison rocks from several test wells will indicate its physical characteristics. Aquifer testing and water quality sampling will be done to determine initial permeability characteristics estimate end products of
mixing AMD and Madison water. An initial 10-day injection test, and a second 100-day test would be conducted during which time extensive water quality and ground water level monitoring would be done. Following the tests, geophysical logs would be re-run on the test holes, aquifer test re-run to determine permeability changes and at least two new bore holes drilled and cored to sample precipitates. Hydrochemical modeling would be done to predict the long-term feasibility and impacts of an injection program.

4.4 Flyash Neutralization

MBMG studies have documented the effectiveness of flyash in neutralizing pyrite induced acidity and reducing iron mobility of mine tailing waters (Sonderegger and Donovan, 1982). A field test of the effectiveness and maintenance requirements of a small flyash pit in neutralizing small acid discharges in the Sand Coulee area would be conducted. Pits of about 200 ft$^3$ in size would be filled with flyash and acid inflows of 1 gpm or less allowed to seep upward through the pits, being neutralized prior to discharge from the lower end. Water quality sampling and pit excavations would establish the effectiveness of the technique.

4.5 Kootenai Neutralization

A simple and possibly effective AMD neutralization technique would be to mix naturally alkaline Kootenai ground water with small volumes of acid mine water. Mixing would occur in a pit where metals would be allowed to precipitate prior to discharge of the effluent. Typical AMD acidity and Kootenai ground-water alkalinity requires a 1 to 10
volumetric mix for theoretical neturalization. The technique will be evaluated by taking water quality samples and field measurements of the inflow and outflow.

4.6 Alluvial Ground-Water Contamination Mapping

The alluvial valley of Sand Coulee Creek joins an abandoned pre-glacial channel of the Missouri River. Residents all along lower Sand Coulee Creek abandoned alluvial wells years ago due to AMD contamination and even the Madison aquifer is contaminated in places. The many years of AMD seepage losses along the seven miles of old Missouri River alluvium have had a so-far undocumented impact on shallow ground-water supplies in the Great Falls area. It is proposed to conduct a reconnaissance shallow well drilling and sampling program in the old channel to document the extent of AMD contamination. Ground water flow gradients and the extent and severity of water quality conditions would be mapped.

5. Summary

The numerous abandoned underground coal mines in the Stockett-Sand Coulee area discharge a combined rate of 1-4 ft\(^3\)/s of acid water (pH = 2-5) with a high dissolved and suspended metal load. The sources of the water is primarily downward leakage from the surficial Kootenai formation. The acid water comprises 60-90 percent of the total flow of Sand Coulee Creek in baseflow periods. Most of this flow is lost to evapotranspiration and leakage to alluvial and deeper bedrock aquifers, namely, the Swift sandstone (Jurassic) and Mission Canyon limestone (Mississippian) of the Madison group rocks.
Ground-water quality in the Kootenai aquifer is good, with TDS in the 300 to 450 mg/l range and alkalinity averaging about 340 mg/l as CaCO$_3$. Water in the alluvium, downgradient from discharging acid sources is mostly contaminated such that very few domestic wells utilize this source. Water quality in the Swift and Madison aquifers is variable with unexpectedly high TDS and sulfate concentrations (maximum TDS = 2,413 mg/l, maximum sulfate = 1,580 mg/l) sampled in some domestic wells. This is believed to be caused by mixing with downward leaking AMD water from alluvium, well bores and places where contaminated streams traverse outcrops of Madison rocks.

A combination of AMD treatment techniques may prove to be the best long range mitigation approach. Five control measures were recommended for field testing: 1) infiltration control using intensive cropping methods in recharge areas; 2) connector and horizontal wells to dewater the Kootenai aquifer overlying the old mines; 3) injection and neutralization of acid water in the Madison limestone; 4) neutralization of small AMD sources in flyash pits; 5) neutralization of small AMD sources in pits with naturally alkaline Kootenai ground water.
### TABLE 1

Correlations of Mine Designations Used in the Sand Coulee drainage.

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<th>Hydrometrics No.</th>
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<td>CS-09A</td>
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<td>Goodwater Johnson Mine</td>
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<td>SCM-15</td>
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1. A: Straight Creek  
2. B: Number Five Coulee  
3. C: Sand Coulee Creek below Centerville  
4. D: Sand Coulee Creek above Centerville  
5. McArthur, 1970  
6. Hydrometrics, 1982
### TABLE 2

Acid Discharge Characteristics, 1980-83

<table>
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<tr>
<th>Site</th>
<th>Flow (gpm)</th>
<th>Observed Range</th>
<th>S.C. us/cm</th>
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<td></td>
<td>pH</td>
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<td>5363-6974</td>
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<td>3.84-4.20</td>
<td>3083-3487</td>
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<td>2.90-3.42</td>
<td>3352-3406</td>
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<td>0-38</td>
<td>2.80-3.10</td>
<td>1701-3469</td>
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<td>AS-07</td>
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<td>2.21-3.67</td>
<td>5023-10,306</td>
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<td>3.44-5.41</td>
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<td>3.02-6.3</td>
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Table 3. Major Element Water Chemistry for Modeling
AMD Contribution to Impacted Wells.

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<th>A</th>
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<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
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<td>Synthetic Mix</td>
<td>Knox Well</td>
<td>Reaction Path 1</td>
<td>Net Well</td>
<td>Senior Citizens Well</td>
<td>Reaction Path 2</td>
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<td>Lab No.</td>
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<td>83Q0001</td>
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<td>Ca</td>
<td>292.</td>
<td>79.9</td>
<td>120.2</td>
<td>487.</td>
<td>456.</td>
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<td>241.</td>
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<tr>
<td>Mg</td>
<td>190.</td>
<td>32.</td>
<td>62.</td>
<td>146.</td>
<td>121.</td>
<td>23.6</td>
<td>135.</td>
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<td>Na</td>
<td>17.1</td>
<td>10.1</td>
<td>11.4</td>
<td>28.9</td>
<td>11.4</td>
<td>7.1</td>
<td>23.1</td>
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<td>K</td>
<td>1.1</td>
<td>2.3</td>
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<td>3.1</td>
<td>4.1</td>
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<td>Fe</td>
<td>944.</td>
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<td>179.</td>
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<td>0.045</td>
<td>0.018</td>
<td>&lt;0.002</td>
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<td>0.00</td>
<td>0.54</td>
<td>0.016</td>
<td>0.53</td>
<td>0.002</td>
<td>0.004</td>
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<td>30.9</td>
<td>19.8</td>
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<td>HCO₃</td>
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<td>235.</td>
<td>190.</td>
<td>261.</td>
<td>343.</td>
<td>271.</td>
<td>440.</td>
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<td>Cl</td>
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<td>4.9</td>
<td>4.3</td>
<td>5.1</td>
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<td>SO₄</td>
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<tr>
<td>NO₃(as N)</td>
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<td>0.32</td>
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<td>---</td>
<td>5.69</td>
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<tr>
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\* pH = - \log_{10} \left( 0.19 \times 10^{-pH_A} + (0.81 \times 10^{-pH_B}) \right)
### TABLE 4

Selected Well Inventory Data for the Sand Coulee Area

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<thead>
<tr>
<th>NO.</th>
<th>Aquifer</th>
<th>Land Elevation ft, msl</th>
<th>Total Depth ft</th>
<th>Static Water Level ft, msl</th>
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<th>Date Measured</th>
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<tr>
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<td>92</td>
<td>Kootenai</td>
<td>4303</td>
<td>90</td>
<td>4228.12</td>
<td>677</td>
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<tr>
<td>93</td>
<td>Kootenai</td>
<td>4075</td>
<td>131</td>
<td>4057.32</td>
<td>506</td>
<td>6-21-82</td>
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<tr>
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<td>Jurassic</td>
<td>3390</td>
<td>100</td>
<td>3365.27</td>
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<td>700</td>
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<td>617</td>
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</table>

1 Refers to Figure 6.

2 All measurements by MBMG.
Figure 1. Location of study area.
Figure 2. Location of springs and acid discharges.
Figure 3. Discharge, in gallons per minute, of springs on May 28, 1981.
Specific Conductance
microsiemens
5/28/81
- Alkaline Spring
- Acid Spring

Figure 4. Specific conductance of springs in microsiemens/cm ($\mu$S/cm) on May 28, 1981.
Figure 5. Schematic cross section through a coulee. Not to scale. Kk=Kootenai Formation; Jm=Morrison Formation; Jsw=Swift Formation; Mm=Madison Group. Thickness of the coal and the Swift Formation are exaggerated. The symbol ▽ represents the water table.
Figure 6. Location of domestic wells inventoried by MBMG, 1982.

LEGEND

K1 Measured static water level
(Refer to table 4)

O Other inventoried wells
Figure 7. Frequency distribution of total dissolved solids (calculated, mg/L) for water samples from the Madison aquifer, Sand Coulee area, Montana.
Table 8. Piper plot of water analyses from Madison Group wells, Stockett-Sand Coulee area, Montana.

<table>
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<th>I.D.</th>
<th>Lab number</th>
<th>T.D.S. (mg/L)</th>
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<tr>
<td>C</td>
<td>81Q1088</td>
<td>2410</td>
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<tr>
<td>D</td>
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<td>1410</td>
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<tr>
<td>E</td>
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<tr>
<td>F</td>
<td>82Q0497</td>
<td>573</td>
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<td>G</td>
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<td>393</td>
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<td>H</td>
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<td>I</td>
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<td>J</td>
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<td>L</td>
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<td>1150</td>
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Figure 9. Piper plot of water analyses from Jurassic and Kootenai wells, Stockett - Sand Coulee area, Montana.
REFERENCES


Bituminous Coal Research, Inc., 1971, Studies of Limestone Treatment of Acid/Mine Drainage, Part II, EPA Grant No. 14010 EIZ.


Diebold, F. E., 1975, Treatment of Acid Mine Drainage from the Block P Mine and Dump at Hughesville, Montana, Dept. of Chemistry, Montana College of Mineral Science and Technology, Butte, Montana.


Montana Department of Natural Resources and Conservation, 1979, River Mile Index of the Missouri River, 141 p.


APPENDIX A

SPRING AND ACID DISCHARGE DATA
A-1

SPRING MONITORING DATA
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<th>AS01</th>
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<td>SC</td>
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<td>pH</td>
<td>SC</td>
<td>FLOW GPM</td>
<td>pH</td>
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<td>--</td>
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** trữ lượng: Sand Coulee**

**C Coding abbreviations:**
- A = Value above GS
- B = Hole abandoned
- C = Hole filled in
- D = Dry hole
- E = Hole placed by ice or snow
- F = Flowing well
- G = Shut off

**Remarks:** Spring Monitoring Data

E = estimated value

S.C. units in µS/CM (micro-mhos/cm @ 25 C)
<table>
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<th>Date</th>
<th>Flow GPM</th>
<th>pH</th>
<th>SC</th>
<th>Flow GPM</th>
<th>pH</th>
<th>SC</th>
<th>Flow GPM</th>
<th>pH</th>
<th>SC</th>
<th>SWL</th>
<th>SC</th>
<th>Temp</th>
<th>SWL</th>
<th>SC</th>
<th>Temp</th>
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A-2

SPRING WATER QUALITY LABORATORY ANALYSES
**State**: Montana  
**County**: Cascade  
**Location**: Site location 19N 123W  
**Sample Site**: 472312111104701  
**Station ID**: 472312111104701  
**Sample Source**: Mine drainage  
**Sample Handling**: 6720  
**Sample Date**: 09-Mar-01  
**Sample Analyzed**: Lab and analyst  
**Water Use**: Unused  
**Geologic Site**: Sand Coulee mining district  
**Water Quality**: Analysis  
**Lab No.**: 8002316

**Latitude-Longitude**: 47°23'12"N 111°10'45"W  
**UTM Coordinates**: 172 W427890 E484410  
**Topographic Map**: Southeast Great Falls 7.5"  
**Geologic Source**: 271MRS*  
**Drainage Basin**:  
**Agency/Project**: MEMA/AS-01  
**Date Sampled**: 20-Sep-80  
**Time Sampled**: 08:00 hours  
**Sample Site**: SW1/4  
**Sample Location**: 4120  
**Sampling Method**: Perforation interval  
**Logging Sampling Grab**: Water use

### Sampling Site Sand Coulee Mining District - No-Name Creek

**Geologic Source**: Morrison formation  
**Geological Source**: Sand Coulee mining district  
**Geologic Source**: No-Name Creek  
**Geologic Source**:  

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**Standards Deviation of Anion-Cation Balance (Sigma)**

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<td>Langier Saturation Index</td>
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**Remarks**: Fine white precipitate in water - becomes orange precipitate upon reaching creek - mine outflow - head of No-Name Coulee (Site AS-01)  
**Lab**: H4=41.1 MG/L * 40.7 MEOV/L, Sigma = 10.3, 114 TOTAL CATION MEOVS/L  
**Explanation**: MG/L = milligrams per liter, UG/L = micrograms per liter, MEO/L = milliequivalents per liter, FT = feet, MI = meters, (A) = measured, (C) = calculated, (R) = reported, 1K = total recoverable, TOT = total

**Other Available Data**

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**Percent MEO/L (for Piper plot)**

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<th>Na</th>
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**Note**: In correspondence, please refer to Lab number: 8002316
MONTANA BUREAU OF MINES AND GEOLOGY  
WATER QUALITY ANALYSIS  
LAB NO. 8101086  

MONTANA  
STATE  

LATITUDE-LONGITUDE  47023'12"N 111110'45"W  
SITE LOCATION  19N 04E 23 ACRE  

UTH COORDINATES  712 NS242670 E498410  
SAMPLE SOURCE  MINE DRAINAGE  

TOPOGRAPHIC MAP  SOUTHEAST GREAT FALLS 7 1  
LAND SURFACE ALTITUDE  3500.  

AGENCY + SAMPLE MBMG*ADH  
SAMPLE HANDLING  4420  
METHOD SAMPLED GRAB  
WATER USE UNUSED  

SAMPLING SITE  SAND COULEE MINING DISTRICT NO NAME CREEK  
GEOLOGIC SOURCE  MORRISON FORMATION  

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STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA)

Laboratory PH 2.56  
Field Water Temperature 12.1  

CALCULATED DISSOLVED SOLIDS SUM OF DISS. CONSTITUENT 5157.  
LAB SPEC.COND. (MICROMHOS/cm) LANGIIER SATURATION INDEX 

EXPLANATION: MG/L = MILLIGRAMS PER LITER; MG/L = MICROGRAMS PER LITER; MG/L = MILLIEQUIVALENTS PER LITER. FT = FEET, HT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

Remarks: Water very frothy and foam covered after discharge. Head of No. Name Coulee. (Site AS-01) 81.73 mg/l gives 100.5 mg/l cations gives .6 sigma.

Other available data:

Project: 80Q2316  
Cost: 

Last edit date: 19 FEB-82  
Processing Program: F1730P V2 (11/3/81)  

Explaination: mg/l = milligrams per liter; mg/l = micrograms per liter; mg/l = milliequivalents per liter. ft = feet, mt = meters. (m) = measured, (e) = estimated, (r) = reported. tr = total recoverable. tot = total.

Percent mg/l (for piper plot): 
Ca 44.6  Mg 51.8  Na 3.6  K 0.0  Cl 0.0  SO4 0.0  CO3 0.0  

Note: In correspondence, please refer to LAB NUMBER: 8101086.
STATE MONTANA
COUNTY CASCAD

LATITUDE-LONGITUDE 4702'3'N 11010'30'W SITE LOCATION YM 4E 23 AADC
UTM COORDINATES 717,5248190 6485575 MRNG SIT AS-02
TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 71 STATION IN 4723231111103001
GEOLGIC SOURCE 221HRSH * GREEN GRASS FLOODPLAIN
SOURCE LAND SURFACE ALTITUDE 3570. FT
AGENCY SAMPLeR MRMGRJD
BOTTLE NUMBER AS-02
DATE SAMPLED 09:30 HOURS SWL ABOVE (0) OR BELOW 65
LAB ANALYST MRMGREN
DATE CASED 09:01-10-81
SAMPLE HANDLING 0120
METHOD SAMPLED GRAB
WATER USE UNUSED

SAMPLING SITE SAND COULFFE MINING DISTRICT NO. NAME CREEK
GEOLGIC SOURCE MCGORMIN FORMATION

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TOTAL CATIONS 46.94 TOTAL ANIONS 112.76

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA)

PARAMETER VALUE VALUE
TEMPERATURE, AIR (C) 14.0 C CNDUCTIVITY, FIELD MICROHOS 5809.
FIELD PH 2.49 TOTAL HARKNESS AS CACO3 9.60.12
CALCULATED DISSOLVED SOLIDS
SUM OF DISS.
LAB SPEC. COND. (MICROMICRO/L) 5292. LANGYER SATURATION INDEX

PARAMETER VALUE
NICKEL, DISS (MG/L AS NI) 4.46 ALUMINUM DISS (MG/L-L) 481.
LEAD, DISS (MG/L AS LF) 0.04 SINTER DISS (MG/L AS Ag) .002
STONE CATION, DISS (MG/L AS ST) 404 CADIUM DISS (MG/L AS Cd) .19
TITANIUM, DISS (MG/L AS Ti) .069 CHROMIUM DISS (MG/L AS Cr) .20
LITHIUM, DISS (MG/L AS Li) 15 COPPER DISS (MG/L AS Cu) .23
ARSENIC, DISS (MG/L AS AR) 1.4 MERCURY DISS (MG/L AS Hg) .03
SCENIUM, DISS (MG/L AS SE) 1.4 ACIDITY, TOT (MG/L CACO3) 4560.

REMARKS: WATER IS PALE YELLOW - BECOMES ORANGE UPON REACHING CREEK *
SPRING DRAINAGE FROM MINE ADIT AS-02 * JUST ABOVE LANDFILL - SAND *
COULFFE * DISCHARGE FROM ADIT (CAVED) AND OLD WOOD DRAIN PIPE *
LAB: H=46.6 MG/L L 46.2 MEQ/L, SIGMA 77, 111.0 TOT CATION MEQ/L *

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER, FT = FEET, M = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED, TR = TOTAL RECOVERABLE, TOT = TOTAL.

OTHER AVAILABLE DATA

OTHER FILE NUMBERS:

PROJECT: COST:
LAST EIGNED DATE: 04-May-01 BY: TF *CLG

PERCENT MEQ/L FOR PIPER PLOT

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<th>SO4</th>
<th>HCO3</th>
<th>CO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALCIUM</td>
<td>47.7</td>
<td>40.8</td>
<td>3.3</td>
<td>0.0</td>
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<tr>
<td>SODIUM</td>
<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0062317

A-7
MONTANA BUREAU OF MINES AND GEOLOGY
DUTEF, MONTANA 59701 (406) 496-4101

WATER QUALITY ANALYSIS
LAB NO. 80R2318

STATE MONTANA
COUNTY CASCADE

LATITUDE-LONGITUDE 47°23’20”N 110°10’32”W
UTM COORDINATES 322 N5249180 E4186755
TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 7.1

GEOLOGIC SOURCE ?7THRS*111.HFL* * SAMPLE SOURCE HINE DRAINAGE

GREAT FALLS BASIN BR

AGENCY 1 SAMPLER MRBG*1JD

DATE SAMPLER 70-SEP-80

TIME SAMPLED 10:00 HOURS

LAB & ANALYST HINE

DATE ANALYZED 29-MAR-81

SAMPLE HANDLING 4120

METHOD SAMPLER GRAB

WATER USE UNUSED

SAMPLING SITE SAND COULEE MINING DISTRICT NO--NAME CREEK

GEOLOGIC SOURCE MORRISON FORMATION

CALCULATED DISSOLVED SOLIDS

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>MG/L</th>
<th>MEQ/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALCIUM (Ca)</td>
<td>4.26</td>
<td>1.36</td>
</tr>
<tr>
<td>MAGNESIUM (Mg)</td>
<td>1.06</td>
<td>1.53</td>
</tr>
<tr>
<td>SODIUM (Na)</td>
<td>2.02</td>
<td>0.88</td>
</tr>
<tr>
<td>POTASSIUM (K)</td>
<td>1.49</td>
<td>0.17</td>
</tr>
<tr>
<td>CHLORIDE (Cl)</td>
<td>5.6</td>
<td>0.16</td>
</tr>
<tr>
<td>FLUORIDE (F)</td>
<td>0.7</td>
<td>0.35</td>
</tr>
</tbody>
</table>

TOTAL CATIONS 74.00 TOTAL ANIONS 136.27

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) 3.58

FIELD WATER TEMPERATURE 13.8°C TOTAL ALKALINITY AS CaCO3 0.21
CALCULATED DISSOLVED SOLIDS

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>MG/L</th>
<th>MEQ/L</th>
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</thead>
<tbody>
<tr>
<td>CALCIUM (Ca)</td>
<td>4.26</td>
<td>1.36</td>
</tr>
<tr>
<td>MAGNESIUM (Mg)</td>
<td>1.06</td>
<td>1.53</td>
</tr>
<tr>
<td>SODIUM (Na)</td>
<td>2.02</td>
<td>0.88</td>
</tr>
<tr>
<td>POTASSIUM (K)</td>
<td>1.49</td>
<td>0.17</td>
</tr>
<tr>
<td>CHLORIDE (Cl)</td>
<td>5.6</td>
<td>0.16</td>
</tr>
<tr>
<td>FLUORIDE (F)</td>
<td>0.7</td>
<td>0.35</td>
</tr>
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</table>

TOTAL CATIONS 74.00 TOTAL ANIONS 136.27

PARAMETER VALUE PARAMETER VALUE

| TEMPERATURE, AIR (C) | 14.0 C | CNDOCTYLFIELD NICROMIOLS 5414. |
| FIELD PH | 2.62 | ALUMINUM DISS (MG/L-AL) 552. |
| LEAD DISS (MG/L AS P1) | 0.04 | SILVER DISS (MG/L AS AG) 0.004 |
| STRONTIUM DISS (MG/L-CR) | 0.007 | BORON DISS (MG/L AS B) 0.29 |
| TITANIUM DISS (MG/L AS TI) | 0.11 | CADMIUM DISS (MG/L AS CD) 0.057 |
| VANADIUM DISS (MG/L AS V) | 0.06 | CHROMIUM DISS (MG/L-CA) 0.70 |
| ZIRCON DISS (MG/L AS ZR) | 2.11 | COPPER DISS (MG/L-CL) 0.059 |
| ZINC DISS (MG/L AS ZN) | 0.011 | LITHIUM DISS (MG/L AS Li) 0.78 |
| ARSENCI DISS (UG/L AS AS) | 0.001 | MOLYBDENUM DISS (MG/L-MO) 0.02 |
| SELENIUM DISS (UG/L-SE) | 0.01 | MERCURY DISS (UG/L AS HG) 0.003 |
| ACIDITY TOT (MG/L-CACO3) | 4675. |

REMARKS: WATEER IS PALE ORANGE BECOMES BRIGHT RED UPON REACHING CREEK *
SPRING AS-03 FLOWING THROUGH SAND COULEE LANDFILL *
SAMPLE TAKEN JUST BELOW LANDFILL *
LAB: H1=3.47 MG/L * 3.47 MG/L, SIGMA .65 * 130 TOTAL CATION MEG/L |

EXPLANATION: MG/L = MILLIGRAMS PER LITER, MG/L = MICROGRAMS PER LITER, MG/L = MILLIEQUIVALENTS PER LITER, FT = FEET, FT = METERS, (H) = MEASURED, (R) = REPORTED, TOT = TOTAL RECOVERABLE, TOT = TOTAL.

OTHER AVAILABLE DATA

OTHER TITLE NUMBERS:

PROJECT: COST:
LAST EDIT DATE: 04-MAY-81

PERCENT MG/L (FOR PAPER PLOT)

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<thead>
<tr>
<th>COMPOUND</th>
<th>MG/L</th>
<th>NA</th>
<th>K</th>
<th>CL</th>
<th>SO4</th>
<th>HCO3</th>
<th>CA</th>
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<tbody>
<tr>
<td>56.5</td>
<td>40.9</td>
<td>2.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
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</table>

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 80R2318
**Montana Bureau of Mines and Geology**

**Butte-Montana**

**Water Quality Analysis**

**State:** Montana  
**County:** Cascade  
**Location:** Site ID: 472314111103901  
**Sampling Site:** Stockton - Sand Coulee Mining District  
**Geologic Source:** Morrison Formation

---

### Chemical Analysis Table

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
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<tr>
<td>Calcium (Ca)</td>
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<tr>
<td>Magnesium (Mg)</td>
<td>mg/L</td>
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<tr>
<td>Sodium (Na)</td>
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<td>Potassium (K)</td>
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<td>Iron (Fe)</td>
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<tr>
<td>Manganese (Mn)</td>
<td>mg/L</td>
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<tr>
<td>Silica (SiO2)</td>
<td>mg/L</td>
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<tr>
<td>Calcium (Ca)</td>
<td>mg/L</td>
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<tr>
<td>Bicarbonate (HCO3)</td>
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<tr>
<td>Magnesium (Mg)</td>
<td>mg/L</td>
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<td>Carbonate (CO3)</td>
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<td>Sulphate (SO4)</td>
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<td>Chloride (Cl)</td>
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<td>Fluoride (F)</td>
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</tr>
<tr>
<td>Phosphate (PO4)</td>
<td>mg/L</td>
<td>1.79</td>
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</table>

**Total Cations:** 81.79  
**Total Anions:** 161.17

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### Standard Deviation of Anion-Cation Balance (Sigma)

<table>
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<th>Parameter</th>
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<tbody>
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<td>Laboratory pH</td>
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<tr>
<td>Field Water Temperature</td>
<td>3.1</td>
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<tr>
<td>Calculated Dissolved Solids</td>
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</tr>
<tr>
<td>Sodium Adsorption Ratio</td>
<td>0.17</td>
</tr>
<tr>
<td>Lab Spec. Cond. (Micrograms/CM)</td>
<td>6710.</td>
</tr>
</tbody>
</table>

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**Parameters**:  
- Temperature, AT (°C): 10.0  
- Conductivity, Field Microhds: 8510.  
- Arsenic, Tr (µg/L as As): 3.30

**Other Available Data**

- **Project:**
  - Last Edit Date: 27-Apr-1981
  - Processing Program: F1730P V2 (11/1/81)
  - Printed: 27-May-1983
- **Percent Meq/L (for Piper Plot):**
  - Ca: 47.0
  - Mg: 50.5
  - Na: 2.1
  - K: 0.1
  - HCO3: 0.0100
  - CO3: 0.0
  - **Note:** In correspondence, please refer to Lab Number: 8100057
MONTANA BUREAU OF MINES AND GEOLOGY
WATER QUALITY ANALYSIS
LAB NO. 6082319

STATE MONTANA  COUNTY CASCADE
LATITUDE-LONGITUDE 47°23'34"N 111°10'46"W SITE LOCATION 15N 4E 14 URCD
UTM COORDINATES  Z12 H5248670 E485570 MRMG SITE AS-04
TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 71 STATION ID 4723341111104661
GEOLOGIC SOURCE 221MROB* SAMPLE SOURCE MINE DRAINAGE
AGENCY 1 SAMPLER MRMG*1 JD* LAND SURFACE ASSUMED 3540. FT < 50
AGENCY 2 SAMPLER MRMG*4 JD* SUSTAINED YIELD BOTTLE NUMBER AS-04
DATE SAMPLED 20-SEP-80 YIELD MEAS METHOD TOTAL DEPTH OF WELL
TIME SAMPPLED 12:00 HOURS SWL ABOVE (-) OR BELOW GS
LAB 1 ANALYST MRMG*1 NA* CASING DIAMETER
LAB 2 ANALYST MRMG*4 NA* CORE SAMPLE DIAM 41,70 CM
SAMPLE HANDLING 4170 COMPLETION TYPE PERFORATION INTERVAL
METHOD SAMPLED GRAB WATER USE UNUSED

SAMPLING SITE SAND COULEE MINING DISTRICT NO-MAN'S CREEK
GEOLOGIC SOURCE MORRISON FORMATION

<table>
<thead>
<tr>
<th></th>
<th>MG/L</th>
<th>MEG/L</th>
<th>MG/L</th>
<th>MEG/L</th>
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</thead>
<tbody>
<tr>
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<td>3.53</td>
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<td>MAGNESIUM</td>
<td>133.</td>
<td>4.25</td>
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<td>SODIUM</td>
<td>271.5</td>
<td>1.02</td>
<td>1.4</td>
<td>0.11</td>
</tr>
<tr>
<td>POTASSIUM</td>
<td>4.4</td>
<td>0.11</td>
<td>4.2</td>
<td>0.14</td>
</tr>
<tr>
<td>IRON</td>
<td>4.36</td>
<td>23.42</td>
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</tr>
<tr>
<td>MANGANESE</td>
<td>1.63</td>
<td>0.06</td>
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<td>1.74</td>
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<tr>
<td>SILICA</td>
<td>54.5</td>
<td>0.18</td>
<td>57.4</td>
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TOTAL CATIONS 44.07 TOTAL ANIONS 74.43

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA)

<table>
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<th>PARAMETER</th>
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<th>VALUE</th>
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<tbody>
<tr>
<td>LAB TEMP</td>
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<tr>
<td>AIR PH</td>
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<tr>
<td>DISC NI</td>
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<tr>
<td>DISC PS</td>
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<td>0.27</td>
</tr>
<tr>
<td>DISC K</td>
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<td>0.64</td>
</tr>
<tr>
<td>DISC CR</td>
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<td>0.01</td>
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<tr>
<td>DISC CO</td>
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<td>0.03</td>
</tr>
<tr>
<td>DISC Cl</td>
<td>0.57</td>
<td>0.03</td>
</tr>
<tr>
<td>DISC H</td>
<td>0.30</td>
<td>0.03</td>
</tr>
</tbody>
</table>

REMARKS: WATER IS TURBID - MILKY - BECOMES ORANGE UPON REACHING CREEK * KATE'S COULEE AT MINE ADIT (SITE AS-04) * ABOVE OLSON HOUSE * SAMPLE TAKEN AT TOP POOL OUTSIDE ADIT - FLOW JUST BELOW *

LAB: 81 MG/L, SIGMA 5.54, TOTAL CATION MEGA/L 52 *

EXPLANATION: MG/L = MILLIGRAMS PER LITER, MG/L = MICROGRAMS PER LITER, MG/L MILLISECULMETERS PER LITER, FT = FEET, FT = METERS, (M) = MEASURED, (F) = ESTIMATED, (R) = REPORTED, TR = TOTAL RECOVERABLE, TOT = TOTAL.

OTHER AVAILABLE DATA OTHER FILE NUMBERS:

PROJECT: COST:
LAST EDIT DATE: 04-MAY-81 BY: TP CLC
PROCESSING PROGRAM: F173CP V2 (11/3/81) PRINTED: 27-MAY-03
PERCENT MEGA/L (FOR PIPE FLAT)
CA 41.4 53.1 5.0 41.4
MG 0.5 0.2 99.8 0.0
NA 41.4 53.1 5.0 0.5
K 0.5 0.2 99.8 0.0
CL 0.0 0.0 0.0 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 6082319

A-10
### Water Quality Analysis

**Lab No.:** 81600050

**State:** Montana

**County:** Cascade

**Latitude-Longitude:** 47°23'34"N 111°10'43"W

**UTM Coordinates:** 712,524,800 E 33,85050 N

**Elevation Info:** Site Location 19N 4E 14 BkRg Site AS-04

**Drainage Basin:** South East Great Falls 7 1 000000

**Geologic Source:** Sample Source Mine Drainage

**Sample Collection:**
- **Agency/Sample:** Montana Minerals
- **Sample No.:** 81600050
- **Drainage Basin:** 7 1
- **DATE:** 03 Mar 01
- **Sample Description:** Total Depth of Well
- **Sampling Method:** Grab
- **Sample Handling:** Sample Handling

**Geologic Source:** Stockeet Sand Coulee Mining District

**Geologic Formation:** Morrison Formation

### Water Quality Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td><strong>Calcium (Ca)</strong></td>
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<td><strong>Magnesium (Mg)</strong></td>
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<td><strong>Potassium (K)</strong></td>
<td>4.70</td>
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<tr>
<td><strong>Iron (Fe)</strong></td>
<td>4.57</td>
<td><strong>Silica (SiO2)</strong></td>
<td>51.20</td>
</tr>
</tbody>
</table>

**Total Cations:** 45.78

**Total Anions:** 67.45

**Standard Deviation of Anion-Cation Balance (Sigma):** 0.31

**Lab Spec. Cond. (Microhgs/Ch):** 357.3

### Additional Data

**Field Water Temperature:** 11.0 °C

**Total Hardness as CaCO3:** 790.00

**Total Alkalinity as CaCO3:**

**Field pH:** 6.00

**Total Dissolved Solids:**

**Sodium Adsorption Ratio:**

**Sum of Diss. Constituent:**

**RTNAH Stability Index:**

**Langler Saturation Index:**

**Remarks:**
- Sample clear, little filterate
- Sample taken at Mine Adit above J. Gibson Homf
- Cold water upstream S.C., 12/6, downstream 3/18

**Explanation:**
- MG/L = Milligrams per liter
- UG/L = Micrograms per liter
- MG/AL = Milliequivalents per liter
- FT = Feet
- MI = Meters
- (N) = Measured
- (E) = Estimated
- (R) = Reported
- TR = Total Recoverable
- TOT = Total

**Other Available Data:**
- Cold Water Upstream S.C. = 12/6
- Downstream 3/18

**Other Field Numbers:**

**Project:**
- **Last Edit Date:** 22-Apr-81
- **Cost:**
- **Processing Program:** F1730P V2
- **Printer:** 27 MAY-83

**Percent K (Iron Plot):**
- **Ca:** 0.4, **Na:** 0.4, **K:** 40.4, **Cl:** 54.4, **HCO3:** 1.3

**Note:** In correspondence, please refer to Lab Number: 8160050
**MONTANA BUREAU OF MINES AND GEOLOGY**

**WATER QUALITY ANALYSIS**

**STATE:** MONTANA  
**COUNTY:** CASCADE  
**LATITUDE-LONGITUDE:** 47023'34"N 111D10'16"W  
**SITE LOCATION:** 19N 04E 14 RRCO  
**UTM COORDINATES:** Z12 H5248670 E466570  
**TOPOGRAPHIC MAP:** SOUTHEAST GREAT FALLS 7 1  
**STATION ID:** 472334111104601  
**BMBG SITE:** 3204  
**AGENCY/SMPLER:** MBOG*ARM  
**BOTTLE NUMBER:** 3504  
**DATE SAMPLED:** 15 JUL 01  
**LAB & ANALYST:** MBOG*RNA  
**SAMPLE HANDLING:** 4220  
**METHOD SAMPLED:** GRAB  
**SOURCE:** NO USE  

**SAMPLING SITE:** SAND COULEE MINING DISTRICT * NO-HA-NAME CREEK  
**GEOLOGIC SOURCE:** HARRISON FORMATION  

<table>
<thead>
<tr>
<th><strong>CALCIUM (CA)</strong></th>
<th><strong>Mg/L</strong></th>
<th><strong>MED/L</strong></th>
<th><strong>mg/L</strong></th>
<th><strong>MED/L</strong></th>
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<tbody>
<tr>
<td>161</td>
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<td>0.03 RICARBONATE (HC03)</td>
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<td><strong>MAGNESIUM (MG)</strong></td>
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<td>118</td>
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<td><strong>MED/L</strong></td>
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<td><strong>MED/L</strong></td>
<td><strong>MED/L</strong></td>
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<td>SULFATE (SO4)</td>
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<td><strong>MED/L</strong></td>
<td><strong>MED/L</strong></td>
<td><strong>MED/L</strong></td>
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<td><strong>MED/L</strong></td>
<td><strong>MED/L</strong></td>
<td><strong>MED/L</strong></td>
</tr>
<tr>
<td>2.00</td>
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<td>0.19</td>
</tr>
<tr>
<td><strong>SILICA (SiO2)</strong></td>
<td><strong>MED/L</strong></td>
<td><strong>MED/L</strong></td>
<td><strong>MED/L</strong></td>
<td><strong>MED/L</strong></td>
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<td>62.1</td>
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<td>PHOSPHATE TOT (As P)</td>
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**TOTAL CATIONS:** 49.14 **TOTAL ANIONS:** 61.22

**STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA):** 3.63

**FIELD WATER TEMPERATURE:** 13.7 **TEMPERATURE, AIR (C):** 22.4

**CALCULATED DISSOLVED SOLIDS:** 346.0 **CALCULATED DISS. SOLIDS (MG/L):** 346.0

**SUM OF DISS. CONSTITUENTS:** 346.0 **ACIDITY, TOT (MG/L-CAC03):** 1.0

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 22.4  
**UNIT:** C

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 3.05  
**UNIT:** ALUMINUM, DISS (MG/L-AL)

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 3.05  
**UNIT:** SILVER, DISS (MG/L-AG)

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 3.05  
**UNIT:** RUBIDII (MG/L-RB)

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 3.05  
**UNIT:** SELENIUM, TR (UG/L-SE)

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 3.05  
**UNIT:** ACIDITY, TOT (MG/L-CAC03)

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 3.05  
**UNIT:** Ca, Mg, Na, K, Cl, SO4, HCO3, CO3

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 3.05  
**UNIT:** Ca, Mg, Na, K, Cl, SO4, HCO3, CO3

**PARAMETER:** TEMPERATURE, AIR (C)  
**VALUE:** 3.05  
**UNIT:** Ca, Mg, Na, K, Cl, SO4, HCO3, CO3

**REMARKS:** WATER CLEAR BUT GASSY UPON FILTRATION

**PROJECT:** COST:  
**LAST EDIT DATE:** 10-DEC-82  
**PROCESSING PROGRAM:**  
**PERCENT MED/L (FOR PIPER PLOT):**  
**CA Mg Na K Cl SO4 HCO3 CO3**

**NOTE:** IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0101007
MONTANA BUREAU OF MINES AND GEOLOGY
 BUTTE, MONTANA 59701 (406) 429-4110
 WATER QUALITY ANALYSIS
 LAB NO. 0062320

STATE: MONTANA
COUNTY: CAGEC
LATTITUDE-LONGITUDE: 47°33'14" N 111°16'37" W
GAGE LOCATION (YH 14 BBDC HP)
UTM COORDINATES: 212532404920.004620
SITE NO.: 05 STF
TOPOGRAPHIC MAP: SOUTHEAST GREAT FALLS 71
SITE STAGE: 11143701
GEOLOGIC SOURCE: MREH
SAMPLING DATE: 20-SEP-80
FLOW MEAS METHOD: ESTIMATED
LAB + ANALYST: MREH*GA
DATE ANALYZED: 18-SEP-81
TOTAL DEPTH OF WATER: STREAM WIDTH:
METHOD SAMPLING: GRAB
WATER USE: UNUSED

SAMPLING SITE: SAND COUFL MINING DISTRICT NO NAME CREEK
DRAINAGE BASIN: MISSOURI RIVER BETWEEN HARISS MINING LITTLE BRINLY MO.

<table>
<thead>
<tr>
<th>Mg/L</th>
<th>Meq/L</th>
<th>Mg/L</th>
<th>Meq/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CALCIUM (Ca)</td>
<td>169.0</td>
<td>0.43</td>
<td>SIGAROATTE (HC03)</td>
</tr>
<tr>
<td>MAGNESIUM (Mg)</td>
<td>14.1</td>
<td>0.10</td>
<td>CARBONATE (CO3)</td>
</tr>
<tr>
<td>SODIUM (Na)</td>
<td>73.0</td>
<td>0.56</td>
<td>CHLORIDE (Cl)</td>
</tr>
<tr>
<td>POTASSIUM (K)</td>
<td>14.6</td>
<td>0.12</td>
<td>SULFATE (SO4)</td>
</tr>
<tr>
<td>IRON (Fe)</td>
<td>30.0</td>
<td>0.61</td>
<td>NITRATE (NO3)</td>
</tr>
<tr>
<td>MANGANESE (Mn)</td>
<td>1.63</td>
<td>0.06</td>
<td>FLUORIDE (F)</td>
</tr>
<tr>
<td>SILICA (SiO2)</td>
<td>50.0</td>
<td>0.00</td>
<td>PHOSPHATE (PO4)</td>
</tr>
</tbody>
</table>

TOTAL CATIONS: 111.66 TOTAL ANIONS: 65.72

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA)
LABORATORY PH: 7.87 TOTAL HARDNESS AS CACO3: 1002.35
FIELD WATER TEMPERATURE: 14.1°C TOTAL ALKALINITY AS CACO3: 0.33
CALCULATED DISSOLVE DISSOLUTION:
SOMATON-ABSORPTION RATIO: 0.33
SUM OF DISS. CONSTITUENT:
LAB SPEC. Cond. (MICROHGS/CM): 3566.1
LANGLIER SATURATION INDEX

PARAMETER | VALUE |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMPERATURE, ATC (°C)</td>
<td>15.0</td>
</tr>
<tr>
<td>FIELD PH</td>
<td>3.42</td>
</tr>
<tr>
<td>LEAD, DISS (Mg/L AS Pb)</td>
<td>0.04</td>
</tr>
<tr>
<td>STRONTIUM, DISS (Mg/L AS Sr)</td>
<td>1.08</td>
</tr>
<tr>
<td>VANADIUM, DISS (Mg/L AS V)</td>
<td>0.034</td>
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<tr>
<td>ZINC, DISS (Mg/L AS Zn)</td>
<td>0.33</td>
</tr>
<tr>
<td>ARSENIC, DISS (Mg/L AS As)</td>
<td>0.025</td>
</tr>
<tr>
<td>SELENIUM, DISS (Mg/L AS Se)</td>
<td>0.3</td>
</tr>
</tbody>
</table>

REMARKS: WATER IS BRIGHT ORANGE - BECOMES DEEP RED UPON REACHING CREEK.
SAMPLE TAKEN AT CONFLUENCE OF KATE'S CREEK WITH NO NAME CREEK FROM
KATE'S CREEK * OWNER REPORTS RAIN CAUSES WHITE PRECIPITATE *
LAB: HI = 15.9 MG/L, * HI = 15.9 MG/L, SIGMA = 44, 64.4 TOTAL CATION MGUS/L *

EXPLANATION: MG/L = MILLIGRAMS PER LITER, Meq/L = MICROGRAMS PER LITER, Mg/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MI = MILES. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT: COST: RY: 1F * STLC
PROCESSING PROGRAM: F1730F V2 (11/3/61) PRINTED: 27 MAY 63
PCT MT=100 (FOR PIPEFLOT) CAC: Mg NA K CL 204 CACO3 CO3
39.8 54.7 4.7 0.6 0.3 72.7 0.0 0.0
NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0062320
**MONTANA BUREAU OF MINES AND GEOLOGY**  
**GREAT FALLS, MONTANA 59401**  
(406) 457-4101  
**WATER QUALITY ANALYSIS**  
**LAB NO. B100059**

**STATE:** MONTANA  
**COUNTY:** CASCADE  
**LATITUDE-LONGITUDE:** 47°23'33"N 111°10'30"W  
**SITE LOCATION:** 17 N 4E 14 BURC  
**UTM COORDINATES:** 712 45240605 4486605  
**TOPOGRAPHIC MAP:** SOUTHEAST GREAT FALLS 7.1  
**STATION ID:** 423333111003000  
**DRainAGE BASIN:** R  
**AGENCY & SAMPLER:** BMGGJJD  
**SAMPLE SOURCE:** STREAM  
**LAND SURFACE ALTITUDE:** 3510, FT < 1  
**FLOW MEAS METHOD:** ESTIMATED  
**STAFF GAGE:** 150, GPM  
**FLOW STAGE:** STREAM STAGE  
**DEPTH TO SAMPLE:** TOTAL DEPTH OF WATER  
**STREAM WIDTH:**  

**WATER USE:** UNUSED

**SAMPLING SITE STOCKETT - SAND COUNTRY MINING DISTRICT**  
**DRAINAGE BASIN MISSOURI RIVER BETWEEN MARIAS RIVER AND LITTLE PRICKLY**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Calcium (Ca)</td>
<td>22.0</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>79.4</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>12.0</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>3.4</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>186.</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.98</td>
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<tr>
<td>Silica (SiO2)</td>
<td>30.6</td>
</tr>
<tr>
<td>Total Cations</td>
<td>22.14</td>
</tr>
<tr>
<td>Total Anions</td>
<td>57.75</td>
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</table>

**STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA):**

<table>
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<tr>
<th>Parameter</th>
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<tbody>
<tr>
<td>Field Water Temp.</td>
<td>46.2 C</td>
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<tr>
<td>Total Hardness As CaCO3</td>
<td>574.01</td>
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<tr>
<td>Total Alkalinity As CaCO3</td>
<td>0.23</td>
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<tr>
<td>Field Spec. Cond. (MicroSiO2)</td>
<td>3319</td>
</tr>
<tr>
<td>Langler Saturation Index</td>
<td></td>
</tr>
</tbody>
</table>

**REMARKS:** WATER IS ORANGE - TURBID * FE-HYDROXIDE PRECIPITATE  
SAMPLE FROM BELOW CULVERT ABOVE JUNCTION WITH STRAIGHT CREEK  
STREAM DRAINAGE FROM ACID SPRING AS-04 * UPSTREAM 3.0  
LAB: 57.9 CATION HERBS, .05 SIGMA, 42.6 MG/L EST HI *

**EXPLANATION:** MG/L = MILIGRAMS PER LITER;  
UG/L = MICROGRAMS PER LITER;  
MEQ/L = MILLIEQUIVALENTS PER LITER;  
FT = FEET;  
HI = METERS;  
(M) = ESTIMATED;  
(E) = REPORTED;  
TR = TOTAL RECOVERABLE;  
TOT = TOTAL.

**OTHER AVAILABLE DATA:**  
**OTHER FILE NUMBERS:**

**PROJECT:**  
**LAST EXIT DATE:** 27-APR 01  
**PROCESSING PROGRAM:** V1730F V2 (11/3/01)  
**PRINTED:** 27-MAY 03

**PERCENT MEQ/L (FOR PIPER PLOT):**

<table>
<thead>
<tr>
<th>Ion</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>S04</th>
<th>CaCO3</th>
<th>MgO</th>
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<tbody>
<tr>
<td>40.8</td>
<td>53.4</td>
<td>4.6</td>
<td>0.7</td>
<td>0.3</td>
<td>99.7</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
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**NOTE:** IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: B100059

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A-14
<table>
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<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>TEMPERATURE, AT (°C)</td>
<td>13.0</td>
<td>ALUMINUM, DISS (MG/L)</td>
<td>50.6</td>
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<tr>
<td>FIELD PH</td>
<td>5.02</td>
<td>SILVER, DISS (MG/L)</td>
<td>0.002</td>
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<tr>
<td>LEAD, DISS (MG/L AS PD)</td>
<td>0.04</td>
<td>BORON, DISS (MG/L AS B)</td>
<td>0.17</td>
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<tr>
<td>STRONTIUM, DISS (MG/L SR)</td>
<td>0.04</td>
<td>CALCIUM, DISS (MG/L AS CA)</td>
<td>1.07</td>
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<tr>
<td>TITANIUM, DISS (MG/L TI)</td>
<td>0.13</td>
<td>CHROMIUM, DISS (MG/L CR)</td>
<td>0.011</td>
</tr>
<tr>
<td>VANADIUM, DISS (MG/L V)</td>
<td>0.027</td>
<td>COPPER, DISS (MG/L AS CU)</td>
<td>0.007</td>
</tr>
<tr>
<td>ZINC, DISS (MG/L AS ZN)</td>
<td>0.87</td>
<td>LITHIUM, DISS (MG/L AS Li)</td>
<td>0.35</td>
</tr>
<tr>
<td>ZIRCONIUM, DISS (MG/L ZR)</td>
<td>0.004</td>
<td>MOLYBDENUM, DISS (MG/L MD)</td>
<td>0.02</td>
</tr>
<tr>
<td>ARSENIC, DISS (UG/L AS)</td>
<td>16.1</td>
<td>MERCURY, DISS (UG/L AS HG)</td>
<td>1.23</td>
</tr>
<tr>
<td>SELENIUM, DISS (UG/L SE)</td>
<td>0.3</td>
<td>ACTIVITY, TOTAL (MG/L CACO3)</td>
<td>561.</td>
</tr>
</tbody>
</table>

**Remarks:**
- SAMPLE CLEAR - NO PRECIPITATE *
- TOTAL HARDNESS AS CACO3 520.31
- TOTAL ALKALINITY AS CACO3 520.31
- FIELD WATER TEMPERATURE 10.0°C
- SOIL ABSORPTION RATIO 0.35
- STABILITY INDEX 1.00
- SATURATION INDEX 1.00

**Explaination:**
- MG/L = MILLIGRAMS PER LITER
- MG/L = MICRORAMS PER LITER
- MG/L = MILLIEQUIVOLNTS PER LITER
- FT = FEET
- MG = MILLIGRAMS
- L = METERS
- (R) = MEASURED
- (L) = ESTIMATED
- (0) = REPORTED
- TR = TOTAL RECOVERABLE
- TOT = TOTAL

**Other Available Data:**
- Project: DRIEY
- Cost: 10.0
- Last Edit Date: 04 MAY 01
- Processing Program: P1730P V2 (11/3/81)
- PERCENT MG/L (FOR DIVER PLOT)
  - CA: 10
  - Mg: 10
  - Na: 10
  - K: 10
  - SO4: 10
  - HCO3: 10
  - Cl: 10
- Note: In correspondence, please refer to Lab number: 800231

---

**Geologic Source:**
- HARRISON FORMATION

**Water Sample:**
- Date: 1979-03-20
- Time: 14:00 Hours
- Water Use: UNUSUAL

**Geographic Source:**
- SOUTHEAST GREAT FALLS 7.1
- STATION ID 7203521111111PRK

**Agency:**
- SAMPLER L.H. MONTGOMERY

**Sample Handling:**
- METHOD OF SAMPLE GROWN
- COLLECTION DATE 18-11-81
- CASING TYPE
- TOTAL CATION 15.27
- TOTAL ANION 22.41

**Standard Deviation of Anion-Cation Balance (Sigma):**
- 0.35
- LABORATORY PH 2.87
- TOTAL WATER TEMPERATURE 10.0°C
- CACO3 15.27
- TOTAL ALKALINITY 15.27
- FIELD WATER TEMPERATURE 10.0°C
- TOTAL CATION 15.27
- TOTAL ANION 22.41

---

**Sampling Site Name:**
- SAND CREEK MINING DISTRICT

**Sampling Site:**
- SAND CREEK MINING DISTRICT
- NAME: MONTANA

---

**State:**
- MONTANA

**County:**
- CASSIDY

**Latitude-Longitude:**
- 47°23'59.2"N 111°10'10.6"W

**Site Location:**
- 12MP SITE AG. 06

---

**MOHTANA BUREAU OF MINES AND GEOLOGY**

---

**WATER QUALITY ANALYSIS**

---

**LAB NO:**
- 800231
**Montana Bureau of Mines and Geology**

**Sample Site**: Sand Coulee Mining District, No-Name Creek

**Geologic Source**: Morrison Formation

**UTM Coordinates**: 712 NS249090 E486990

**Topographic Map**: Great Falls 7.5

**Geologic Source**: 12140846321828

**Agency + Sampler**: MHBQ1404-JJ

**Sample Handling**: 6120

**Sample Water Use**: Unused

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature, Air (°C)</td>
<td>13.0</td>
<td>Conductivity/FIELD MICROHMS</td>
</tr>
<tr>
<td>Field pH</td>
<td>2.30</td>
<td>Silver, Diss (mg/L-AL)</td>
</tr>
<tr>
<td>Lead, Diss (mg/L as Pb)</td>
<td>&lt;0.04</td>
<td>Barium, Diss (mg/L as Ba)</td>
</tr>
<tr>
<td>Strontium, Diss (mg/L as Sr)</td>
<td>1.16</td>
<td>Calcium, Diss (mg/L as Ca)</td>
</tr>
<tr>
<td>Titanium, Diss (mg/L as Ti)</td>
<td>0.050</td>
<td>Chromium, Diss (mg/L as Cr)</td>
</tr>
<tr>
<td>Vanadium, Diss (mg/L as V)</td>
<td>0.25</td>
<td>Copper, Diss (mg/L as Cu)</td>
</tr>
<tr>
<td>Zinc, Diss (mg/L as Zn)</td>
<td>13.0</td>
<td>Lithium, Diss (mg/L as Li)</td>
</tr>
<tr>
<td>Arsenic, Diss (mg/L as As)</td>
<td>72.6</td>
<td>Mercury, Diss (mg/L as Hg)</td>
</tr>
<tr>
<td>Selenium, Diss (mg/L as Se)</td>
<td>2.1</td>
<td>Activity, Tot (mg/L as Hg)</td>
</tr>
</tbody>
</table>

**Remarks**: Clear water - no precipitate

**Sample Source**: Mine drainage

**Analytical Methods**: Total hardness as CaCO3 1216.32

**Technical Notes**: Saturation Index

**EXPLANATION**: mg/L = Milligrams per liter; ug/L = Micrograms per liter; mg/L = Milliequivalents per liter. Ft = Feet, Mi = Meters. (M) = Measured, (E) = Estimated, (R) = Reported. TR = Total Recoverable. Tot = Total.

**OTHER AVAILABLE DATA**: Detail

**OTHER FILE NUMBERS**: 8002322

**PROJECT**: Cost:

**LAST EDIT DATE**: 05/01/81

**PROCESSING PROGRAM**: F1730P V2 (11/3/81)

**PRINTED**: 81/05/01

**NOTES**: In correspondence, please refer to lab number: 8002322
MONTANA BUREAU OF MINE AND GEOLOGY
BUTTE, MONTANA 59701 (406) 496-4101

WATER QUALITY ANALYSIS
LAB NO. 8000319

STATE MONTANA
COUNTY CASCADE

LATITUDE-LONGITUDE 47°20'42"N 111°21'06"W

UTH COORDINATES 712 H5239772 F4985740

TOPOGRAPHIC MAP SPRING CREEK 7 1/2'

GEOLOGIC SOURCE CORDIERITE

DRAINAGE BGN

AGENCY & SAMPLER HRMOLI J.W.

BOTTLE NUMBER VS 01

DATE SAMPLED 20 SEP 80

TIME SAMPLED 15:00 60

LAB 1 ANALYST HRMOLI J.W.

DATE ANALYZED 10-12-81

SAMPLE HANDLING 4U20

METHOD SAMPLED GRAL

WATER USE UNUSED

SAMPLING SITE SPRING CREEK MINING DISTRICT • FIVE CREEK

GEOLOGIC SOURCE MORRISON FORMATION

CALCIUM (Ca) 121 6.04 BICARBONATE (HCO3)

MAGNESIUM (Mg) 41.6 3.42 CARBONATE (CO3)

SODIUM (Na) 14.2 0.65 CHLORIDE (Cl)

PotASSIUM (K) 5.8 0.15 SULFATE (SO4)

IRON (Fe) 87.5 0.35 NITRATE (N)

MANGANESE (Mn) 19.0 0.01 FLUORIDE (F)

C Al (Sr20) 20.8 0.8 PHOSPHATE TOT (As P)

TOTAL CATIONS 13.63 TOTAL ANIONOS 11.56

STANDARD DEVIATION OF ANION CATION BALANCE (SIGMA)

LABORATORY pH 3.22 TOTAL HARDNESS AS CACO3 73.36

FIELD WATER TEMPERATURE 9.26 TOTAL ALKALINITY AS CACO3

CALCULATED DISSOLVED SOLIDS 120.0 RYNNAR STABILITY INDEX

SUM OF DISS. CONSTITUENT (MICROMG/CM) 120.0 LANGLER SATURATION INDEX

PARAMETER VALUE PARAMETER VALUE

TEMPERATURE AIR (C) 15.0 ALUMINUM DISS. (MG/L -AL) 3.04

FIELD pH 5.42 BORON DISS. (MG/L -B) 0.06

LEAD DISS. (MG/L - AS) 0.04 CALCIUM DISS. (MG/L -Ca)

STRONTIUM DISS. (MG/L -Sr) 0.31 MAGNESIUM DISS. (MG/L - Mg)

TITANIUM DISS. (MG/L - Ti) 0.018 CHROMIUM DISS. (MG/L - Cr)

VANADIUM DISS. (MG/L - V) 0.009 COPPER DISS. (MG/L - Cu)

ZINC DISS. (MG/L - Zn) 1.23 LITHIUM DISS. (MG/L - Li)

ZIRCONIUM DISS. (MG/L -Zr) 0.004 MOLYBDENUM DISS. (MG/L -Mo)

ARSENIC DISS. (UG/L - AS) 1.7 MERCURY DISS. (MG/L - Hg)

CERIUM DISS. (UG/L -SF) 0.3 ACIDITY (TOT) (MG/L-CACO3) 106

REMARKS: WATER TURBID - SLIGHTLY MILKY * BECOMES PALE TO BRIGHT ORANGE UPON

MIXING * GRIFFIN MINE OUTFLOW BS-02 * SAMPLE TAKEN FROM OUTFLOW FROM ADIT *

LAB: Hi = 0 KG/L, -2.2 SIGMA, 12.4 TOTAL CATION MEGAS/L, *

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER. MG/L

MILLIGRAMS PER LITER. FT = FEET, MT = METERS, (M) = MEASURED, (L) =

ESTIMATED; (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

OTHER AVAILABLE DATA

PROJECT:

COST:

LAST EDIT DATE: 04-MAY 81

PROCESSING PROGRAM: F1730R v2 (11/3/81)

PERCENT MG/L (FOR PIPE TEST)

CA Mg Na K Cl SO4 HCO3 CO3

58.0 33.4 6.3 1.5 0.9 0.1 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8000319

A-17
MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406) 496-4101
WATER QUALITY ANALYSIS
LAB NO. 8109060

STATE: MONTANA
COUNTY: CASCADE
LATITUDE-LONGITUDE: 47°16'47"N 111°01'05"W
UTH COORDINATES: 212 NG239930 4306000
TOPOGRAPHIC MAP: STOCKTET 7 1/2'
TOPOGRAPIC SOURCE: 221MHRN*
DRAINAGE BASIN BR:
AGENCY + Samplers: MBG*JJD
BOTTLE NUMBER: BS-01
DATE SAMPLED: 03-MAR-81
THE SAMPLED: 1500 HOURS
LAB ANALYST: MBG*JNA
DATE ANALYZED: 22-APR-81
SAMPLE HANDLING: 1120
METHOD SAMPLED: GRAB
WATER USE: UNUSED

SAMPLED SITE: STOCKTET - SAND COULEE MINING DISTRICT
GEOLOCIC SOURCE: HARRISON FORMATION

CALCIUM (CA) 64.7 3.23 RICarbonATE (HC03)
MAGNESIUM (MG) 22.4 1.84 CARBONATE (CO3)
SODIUM (NA) 7.7 0.33 CHLORIDE (CI)
POTASSIUM (K) 4.2 0.11 SULFATE (SO4)
IRON (FE) 29.1 1.56 NITRATE (AS N)
MANGANESE (MN) 0.221 0.01 FLUORIDE (F)
SILICA (SI02) 10.6 PHOSPHATE (P)

TOTAL CATIONS 7.19
TOTAL ANIONS 13.37

STANDARD DEVIATION OF AMOUNT-CATION BALANCE (SIGMA) 253.75

FIELD WATER TEMPERATURE 7.7°C TOTAL HARDNESS AS CaCO3 0.21
CALCULATED DISSOLVED SOLIDS
SUM OF DISS. CONSTITUENT 1584. LANGHIER SATURATION INDEX

PARAMETER VALUE PARAMETER VALUE
TEMPERATURE, AIR (C) 10.0 CNTRIBUTING FIELD MICRONHOS 1636.
FIELD PH 5.32 ALKALINITY, FIELD (AS CaCO3) 40.4
ALUMINUM, TR (MG/L AS AL) 1.72 IRON, TR (MG/L AS FE) 30.2
ACIDITY, TOT (MG/L AS CaCO3) 408.0 ARSENIC, TR (UG/L AS AS) 5.2
SELENIUM, TR (UG/L AS SE) 0.1 ALUMINUM, DISS. (MG/L AS AL) 1.16
NICKEL, DISS. (MX/L AS NI) 0.24 SILVER, DISS. (MG/L AS AG) 0.057
LEAD, DISS. (MG/L AS P) 0.05 BORON, DISS. (MG/L AS B) 0.14
COTRITIUM, DISS. (MG/L AS Ti) 0.17 CARBON, DISS. (MG/L AS CD) 0.027
TITANIUM, DISS. (MG/L AS TI) 0.012 CHROMIUM, DISS. (MG/L AS CR) 0.046
VANADN, DISS. (MG/L AS V) 0.055 COPPER, DISS. (MG/L AS CD) 0.042
ZINC, DISS. (MG/L AS ZN) 0.660 LITHIUM, DISS. (MG/L AS LI) 0.069
ZIRCONIUM, DISS. (MG/L AS ZR) 0.074 MOLYBDENUM, DISS. (MG/L AS MO) 0.27
ARSENIC, DISS. (UG/L AS A) 6.2 SELENIUM, DISS. (UG/L AS SE) < 1

REMARKS: WATER SLIGHTLY TURBID - BUT LITTLE ORANGE FILTERATE *
REMARKS: WATER SLIGHTLY TURBID - BUT LITTLE ORANGE FILTERATE *
LAR: 13.2 CATION HEAVY.. .25 SIGMA, 12.2 MG/L EST. M.
LAR: 13.2 CATION HEAVY.. .25 SIGMA, 12.2 MG/L EST. M.

EXPLANATION: MG/L = MILLIGRAMS PER LITER; UG/L = MICROGRAMS PER LITER; MG/L = MILLIGRAMS PER LITER; FT = FEET; MT = METERS; (M) = MEASURED; (E) = ESTIMATED; (R) = RECORDED; TR = TOTAL RECOVERABLE; TM = TOTAL

OW WA SP WI GW PW AT OTHER

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT: COST:
LAST EDIT DATE: 22-MAY-83
PROCESSING PROGRAM: F1730F V2 (11/13/81) PRINTED: 27-MAY-83

PERCENT MEO/L (FOR PIPER PLOT)
CA 58.5 33.4 6.1 7.0 1.0 92.0 0.0 0.0
MG 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
HA 58.5 33.4 6.1 7.0 1.0 92.0 0.0 0.0
K 58.5 33.4 6.1 7.0 1.0 92.0 0.0 0.0
Cl 58.5 33.4 6.1 7.0 1.0 92.0 0.0 0.0
SO4 58.5 33.4 6.1 7.0 1.0 92.0 0.0 0.0
HC03 58.5 33.4 6.1 7.0 1.0 92.0 0.0 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8109060

A-18
HORRISON SOURCE HARRISON FORMATION

CALCULATED DISSOLVED SOLIDS 878.14 SODIUM ABSORPTION RATIO .37
SUM OF DISS. CONSTITUENT 923.40 RYNAR STABILITY INDEX 7.41
LAB SPEC.COD.(MICROHOS/CM) 1144. LANGLER SATURATION INDEX -0.37

REMARKS: WATER LOOKS PALE ORANGE * ORANGE AND WHITE PRECIPITATE IN FILTER * R. SINGLES SPRING - GIFFEN MINE * SPRING EMITS OVER BROAD AREA NEAR WHERE MINE ADIT WAS PLUGGED TO SHUT OFF ACID MINE DISCHARGE *
LAB: FIU FF OF 0.17 MG/L GIVES <.035 SIGMA *

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MG/L MILLIEQUIVALENTS PER LITER. FT = FEET, HT = METERS. (H) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TT = TOTAL.

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT: COST:
LAST EDIT DATE: 02-FEB-93 BY: JKG
PROCESSING PROGRAM: F1730P V2 (11/3/91) PRINTED: 27-MAY-93
PERCENT MEQ/L. (FOR PIPER PLOT) CA MG NA K CL SO4 HCO3 CO3
61.7 30.4 6.7 1.1 1.3 75.8 22.2 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8002324
HUMIDITY BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406) 429-4101

WATER QUALITY ANALYSIS
LAB NO. 8902325

STATE MONTANA
COUNTY CASCADE

LATITUDE-LONGITUDE 47° 04' 43" N 111° 05' 03" W
UTH COORDINATES NAD 1983 4292070 4283550

TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 7.1

GEOL OGY SOURCE 221MRSH*

SAMPLE SOURCE MINE DRAINAGE

AGENCY & SAMPLER M8MG*JJ

BOTTLE NUMBER CS-01

DATE sampled 21-SEP-80

TIME SAMPLED 08:00 HOURS

LAB & ANALYST M8MG*FNA

DATE ANALYZED 18-FEB-81

SAMPLE HANDLING 4120

METHOD SAMPLED DRAB

WATER USED UNUSED

SAMPLING SITE SAND COULFFE MINING DISTRICT*SAND COULFFE CK

CALCULATED DISSOLVED SOLIDS 470

SODIUM (Na) 22.3

POTASSIUM (K) 2.4

IRON (Fe) 12.4

MANGANESSE (Mn) 0.09

SILICA (SiO₂) 68.9

TOTAL CATIONS 12.54

TOTAL ANIONS 20.76

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA)

LABORATORY PH 2.93

FIELD WATER TEMPERATURE 19.5°C

CALCULATED DISSOLVED SOLIDS 470

SUM OF DISS. CONSTITUENT 470

RYNAR STABILITY INDEX 0.42

LAB SPEC.COND.(MICROMHOS/CM) 1839

LANGLIER SATURATION INDEX

PARAMETER

VALUE

PARAMETER

VALUE

TEMPERATURE, AIR (°C) 10.0

CNDUCTVY, FIELD MICROMHOS 1622

FELD PH 2.00

ALUMINUM, DISS (MG/L-AL) 47.5

NICKEL, DISS (MG/L AS NI) 0.34

SILVER, DISS (MG/L AS AG) <0.02

LEAD, DISS (MG/L AS PB) <0.04

BORON, DISS (MG/L AS B) 0.12

STRONTIUM, DISS (MG/L AS SR) 1.0

SODIUM, DISS (MG/L AS NA) 780

TITANIUM DISS (MG/L AS Ti) 0.016

CHROMIUM, DISS (MG/L AS CR) 0.005

VASANADIM, DISS (MG/L AS V) 0.006

COFFER, DISS (MG/L AS CU) 0.030

ZINC, DISS (MG/L AS ZN) 16.0

LITHIUM, DISS (MG/L AS Li) 0.17

ZIRCONIUM DISS (MG/L AS ZR) <0.004

MOLYBDENUM, DISS (MG/L AS Mo) <0.02

ARSENIC, DISS (MG/L AS As) 1.0

MERCURY, DISS (MG/L AS Hg) <0.03

SELENIUM, DISS (MG/L AS Se) 0.4

ACIDITY, TOTAL (MG/L-CACO₃) 432

REMARKS: CLEAR WATER - COLORLESS *

EFFLUENT FROM WOODEN DRAIN PIPE FROM ADIT - BURIED UNDER SPOIL *

LAB: HI=6.2 Mg/L, 0.68 SIGMA, 20.5 TOTAL CATION MEQVS/L *

EXPLANATION: Mg/L = MILLIGRAMS PER LITER; UG/L = MICROGRAMS PER LITER; MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET; MT = METERS. (H) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TO = TOTAL.

ON WA 32 WI ON PW AT OTHER

OTHER AVAILABLE DATA OTHER SITE NUMBERS:

PROJECT:

LAST EDIT DATE: 04-MAY-81

COST:


PERCENT MEQ/L (FOR PIPER PLOT)

CA Mg Na K Cl SO₄ HCO₃ CO₃
37.4 51.9 3.2 0.5 0.9 27.1 0.0 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8902325

A-20
**MONTANA BUREAU OF MINES AND GEOLOGY**
**BUTTE, MONTANA 59701 (406) 496 4101**

**WATER QUALITY ANALYSIS**
**LAB. NO. P092327**

**STATE MONTANA**
**COUNTY CASCADIA**
**LATITUDE LONGITUDE 47°20'12"N 111°00'11"W**
**SITE LOCATION 100' SE 6 & CCAC**
**UTM COORDINATES 312 NS 242250 E 448510**
**STATION 18 4720821110091100**
**TOPOGRAPHIC MAP STOCKTIT 7 1/2**
**GEOLOGIC SOURCE 771HR3-1118PR3**
**SAMPLE SOURCE MINE DRAINAGE**
**DRAINAGE BATION BB**
**AGENCY & SAMPLER MRNGF JJD**
**BOTTLE NUMBER 05-09**
**DATE SAMPLED 21 SEP-30**
**TIME SAMPLED 1500 HOURS SWL ABOVE( ) OR BELOW GS**
**LAP & ANALYST MRNGF FNA**
**DATE ANALYZED 05 FEB-01**
**SAMPLE HANDLING 41900**
**METHOD SAMPLED GRAB**
**WATER USE UNSED**

**SAMPLING SITE SANG COUNCIL MINING DISTRICT* COTTONWOOD CA**

**GEOLOGIC SOURCE HILLCHILD FORMATION**

<table>
<thead>
<tr>
<th>ANION &amp; BATION</th>
<th>MG/L</th>
<th>MG/L</th>
<th>MG/L</th>
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<tr>
<td>CALCIUM (CA)</td>
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<td>MAGNESIUM (MG)</td>
<td>149.0</td>
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<td>12.24</td>
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<td>SODIUM (NA)</td>
<td>14.2</td>
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<td>0.84</td>
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<td>POTASSIUM (K)</td>
<td>1.8</td>
<td>0.02</td>
<td>0.02</td>
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<tr>
<td>IRON (Fe)</td>
<td>1057</td>
<td>56.73</td>
<td>56.73</td>
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<tr>
<td>MANGANESE (MN)</td>
<td>2.46</td>
<td>0.09</td>
<td>0.09</td>
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<tr>
<td>SILICA (SiO2)</td>
<td>113.0</td>
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</tbody>
</table>

**TOTAL CATIONS 87.00**

**TOTAL ANIONS 135.45**

**STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA)**

**LABORATORY PH 2.90**

**FIELD WATER TEMPERATURE 10.2 C**

**CALCULATED DISSOLVED SOLIDS 214.00**

**SUM OF DISS. CONSTITUENT 214.00**

**PARAMETER**

<table>
<thead>
<tr>
<th>VALUE</th>
<th>PARAMETER</th>
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</thead>
<tbody>
<tr>
<td>9.0 C</td>
<td>pH</td>
</tr>
<tr>
<td>2.45</td>
<td>FIELD PH</td>
</tr>
<tr>
<td>0.04</td>
<td>LEAD, DISS (MG/L AS Pb)</td>
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<tr>
<td>1.06</td>
<td>STRONTIUM, DISS (MG/L AS Sr)</td>
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<tr>
<td>0.77</td>
<td>TITANIUM, DISS (MG/L AS Ti)</td>
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<tr>
<td>0.21</td>
<td>VANADIUM, DISS (MG/L AS V)</td>
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<td>62.7</td>
<td>ZINC, DISS (MG/L AS Zn)</td>
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<td>2.590</td>
<td>ARSENIC, DISS (UG/L AS As)</td>
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<tr>
<td>1.0</td>
<td>SELENIUM, DISS (UG/L AS Se)</td>
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</tbody>
</table>

**EXPLANATION:**

- **MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MG/L = MILLIEQUIVALENT PER LITER. FT = FEET, M = METERS. (M) = ESTIMATED, (R) = REPORTED, TR = TOTAL RECOVERABLE, TOT = TOTAL.**

**OTHER AVAILABLE DATA**

- **PROJECT**
- **LAST EDIT DATE: 04-MAY-01**
- **PROCESSING PROGRAM: F1730P V2 (11/2/61) PRINTED: 27-MAY-03**
- **PERCENT MG/L (FOR PIPE FLOW) CA 1.40 NA K CL SO4 HCO3 CO3 57.1 40.7 2.1 0.1 0.4 97.5 0.0 0.0**

**NOTE:** IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0092327
MONTANA BUREAU OF MINES AND GEOLOGY
SUTTE-MONTANA 59701 (406) 496-4101
WATER QUALITY ANALYSIS
LAB NO. 8160061

STATE MONTANA
LATITUDE-LONGITUDE 47°02'12"N 111°05'10"W
UTH COORDINATES 719 5924395 E 488515
TOPOGRAPHIC MAP STOCKHILL 1/2'
GEOLoGIC SOURCE 2000 ONUS*11MLGS
DRAINAGE BASIN BR
AGENCY + SAMPLER HRB+JUD
BOTTLE NUMBER CS-09
DATE SAMPLED 03-MAR-81
TIME SAMPLED 14:00 HOURS
LAB + ANALYST HRB+JNA
DATE ANALYZED 22-APR-81
SAMPLE HANDLING 1120
METHOD SAMPLED GRAB
WATER USE UNSED

SAMPLING SITE STOCKHILL SAND COULEE MINING DISTRICT
GEOLoGIC SOURCE MORRISON FORMATION

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>MG/L</th>
<th>MFR/L</th>
<th>MG/L</th>
<th>MEO/L</th>
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<tbody>
<tr>
<td>CALCIUM (Ca)</td>
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<td>MAGNESIUM (Mg)</td>
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<td>CARBONATE (CO3)</td>
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<tr>
<td>SODIUM (Na)</td>
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<td>0.61</td>
<td>CHLORIDE (Cl)</td>
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<tr>
<td>POTASSIUM (K)</td>
<td>2.6</td>
<td>5.27</td>
<td>SULPHATE (SO4)</td>
<td></td>
</tr>
<tr>
<td>IRON (Fe)</td>
<td>10.5</td>
<td>57.71</td>
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<tr>
<td>MANGANASE (Mn)</td>
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<tr>
<td>SILICA (SiO2)</td>
<td>106.0</td>
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<td>PHOSPHATE (P)</td>
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TOTAL CATIONS 188.70
TOTAL ANIONS 184.24

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA)
FIELD WATER TEMPERATURE 8.6 C TOTAL HARDNESS AS CACO3 1536.90
CALCULATED DISSOLVED SOLIDS 2.82 SODIUM ABSORPTION RATIO 0.18
SUM OF DISS. CONSTITUENT RYZINAR STABILITY INDEX 6251.
LAB SPEC.COND. (MICROMHOS/CM) 0.16
LINGLOW SATURATION INDEX

PARAMETER VALUE
TEMPERATURE, AIR (C) 10.1 C
FIELD PH 2.53 C
IRON,TR (MG/L AS FE) 1270.0 C
ARSENIC,TR (UG/L AS AS) 6.0 C
ALUMINUM,DISS (MG/L AS AL) 50.0 C
SILVER,DISS (MG/L AS Ag) 0.072 C
BORDON,DISS (MG/L AS B) 0.33 C
CADMIUM,DISS (MG/L AS Cd) 1.12 C
CHROMIUM,DISS (MG/L AS Cr) 1.14 C
COPPER,DISS (MG/L AS Cu) 1.154 C
ZINC,DISS (MG/L AS Zn) 4.850 C
LITHIUM,DISS(MG/L AS Li) 0.728 C
MOLYBDENUM,DISS(MG/L AS Mo) 1.12 C
SELENIUM,DISS (UG/L AS Se) 0.6 C

REMARKS: SAMPLE CLEAR * NO PRECIPITATE * DOWNSTREAM THERE IS ORANGE AND WHITE PRECIPITATE AND GREEN SLIME * SAMPLE FROM SPRING AT SPOIL PILE BY TIMELINE * AT ROAD, PH=2.72, S.C.=6725 *

EXPLANATION: MG/L = MILLIGRAMS PER LITER; MG/L = MICROGRAMS PER LITER; MG/L MILLIEQUIVALENTS PER LITER. FT = FEET. MI = MILES. (M) = MEASURED. (M) = ESTIMATED. (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

OTHER AVAILABLE DATA AND OTHER FILE NUMBERS:

PROJECT: 19-007-82
LAST EDIT DATE: 17-MAY-83
PROCESSING PROGRAM F1730P 02 (11/3/81) PRINTED: 27-MAY-83

PERCENT MEO/L (FOR PIPER PLOT)
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<th>CONSTITUENT</th>
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<tr>
<td>Ca</td>
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<td>Mg</td>
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<tr>
<td>Na</td>
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<td>K</td>
<td>0.2</td>
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NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8160061
ANALYSIS NOT IN FILE: 9101000

A-22
**Montana Bureau of Mines and Geology**

**Water Quality Analysis**

**Lab No. 800232**

**State:** Montana  
**County:** Cascade  
**Site Location:** 19N 5E 20 BBD

**Topographic Map:** M254010  
**Station ID:** 47121111075910  
**Geologic Source:**  
**Drainage Basin:** I

**Agency:** USGS  
**Sample Handling:** 4120  
**Sample Method:** Grab  
**Water Use:** Unused

**Sampling Site:** Sand Coulee Mining District *Sand Coulee*  
**Geologic Source:** Morrison Formation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<th>Value</th>
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<tbody>
<tr>
<td>Calcium (Ca)</td>
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<td>Meg/L</td>
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<tr>
<td>Magnesium (Mg)</td>
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<td>Sodium (Na)</td>
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<td>Potassium (K)</td>
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<td>Total Cations</td>
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<td>Meg/L</td>
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<tr>
<td>Total Anions</td>
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<td>Meg/L</td>
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**Laboratory PH:** 2.31  
**Hardness as CaCO3:**  
**Calcium Saturation Index:**

**Field Water Temperature:** 11.2°C  
**Total Alkalinity:** 1.05  
**Sodium Adsorption Ratio:** 0.22

**Lar Spec. Cond. (Microhms/cm):** 2522.0  
**Langlair Saturation Index:**

**Remarks:** Water is murky — Filters poorly due to sediment. Water seeps over broad area of mine spoil. Some mixing with higher PH and natural spring discharge (PH from 3.5) *Outflow at road at 16 PM.*  
**Lab:** Seeps rapidly back into ground along drainage channel.

**Other Available Data:**

**Other File Numbers:**

**Project:**  
**Last Edit Date:** 04-05-81  
**Cost:** By: TP *GLC  
**Processing Program:** F1730P V2 (11/3/81)  
**Printed:** 27-MAY-83  
**Percent Meg/L (for Piper Plot)**

<table>
<thead>
<tr>
<th>Element</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>SO4</th>
<th>HCO3</th>
<th>CO3</th>
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<tbody>
<tr>
<td></td>
<td>60.7</td>
<td>34.7</td>
<td>4.0</td>
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<td>0.5</td>
<td>97.5</td>
<td>0.0</td>
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</table>

**Note:** In correspondence, please refer to Lab Number: 800232
APPENDIX B
GEOLOGY

A comprehensive description of the Mesozoic stratigraphy of the area is presented in Silverman and Harris (1967), and comments regarding the geology of the area are largely derived from their report and from field inspection.

B.1 Madison Group (Mississippian)

The Madison Group is the oldest geologic unit exposed in the area. Its top is exposed in several localities along the bottoms of Cottonwood, Number Five and Sand Coulees. Outcrops are not extensive; the largest observed exposure is about thirty feet thick. Feltis (1980, 3) shows the top of the Madison in this area to dip to the north-northwest at a relatively uniform dip of 50-70 feet/mile (about one degree). However, exposures in this area suggest that the top of the formation may be irregular, projecting local domes or knobs. It is probably located at shallow (<300 feet) depth in the subsurface throughout the study.

The Madison is overlain unconformably by Jurassic sediments of the Ellis Group. This unconformity is angular, as exposed 0.5 km north of Stockett, where folded Madison strata dip 25 degrees north-northeast beneath flat-lying sandstone of the Ellis. The Madison may exhibit more complex structure in the subsurface than the gently-dipping Cretaceous and Jurassic sediments which overlie it.

The lithology of the Madison is grey, coarsely-crystalline limestone and dolomitic limestone, with chert grains and a diverse
biohermal fossil assemblage. It occurs both in thin, flaggy beds and in massive biohermal strata. Some fossil casts have been refilled with either calcite or gypsum. Local residents report that the limestone is locally cavernous along Sand Coulee Creek farther south towards the mountains. Water well drillers have reported encountering cavernous zones in the upper Madison in the Stockett and Sand Coulee area.

B.2 Swift Formation and Ellis Group (Jurassic)

Sandstone of the Swift Formation, the upper member of the Ellis Group, is distinctive in outcrop as a cemented, cross-bedded, grey, massive- to flaggy-bedded sandstone. Outcrops are found along coulee bottoms in the upper reaches of the Sand Coulee Creek drainage, particularly south of Stockett. In some localities, it unconformably overlies the Madison, but it usually overlies yellow and grey shales and mudstones of the lower Ellis Group. The fine-grained sediments of the Ellis are poorly resistant to erosion and are not well exposed in the area.

B.3 Morrison Formation (Jurassic)

The Morrison Formation consists of 50-250 feet of grey mudstone, with interbedded lenses of limestone, sandstone, coal and shale. Coal mined in the Sand Coulee area is from bed(s) at or near the top of the Morrison. The uppermost coal bed is directly overlain by a cemented conglomeratic channel sandstone at the base of the Kootenai Formation (Cretaceous).

Although the upper coal seam was the primary target of mining in this area, at least one other minable seam may occur in the subsurface
of the area. In the Giffin mine workings, local residents report that mining took place at two separate levels separated by approximately 30 feet of interburden material.

Morrison outcrops are found in this area along the mid-slopes of the coulees. The upper part of the Morrison consists of coal, carbonaceous shale and fine-grained sandstone lenses, up to a total thickness of sixty feet. The coal bed ranges from 1-12 feet thick, with varying proportions of interbedded carbonaceous shale. The thickness of these shale strata was one of the controls on the profitability of mining.

Sandstone lenses in the Morrison are up to 35 feet thick. They are clean fluvial deposits and weather orange, making them difficult to distinguish from some of the sandstones in the overlying Kootenai. Perhaps the most diagnostic characteristic of the Morrison is its varied assemblage of interbedded lithologies, including shale, mudstone, coal, sandstone and fresh water limestone.

B.4 Kootenai Formation (Lower Cretaceous)

The Kootenai Formation is a sequence of numerous lensaic, discontinuous sandstone beds from one to 50 feet thick, interbedded with green and grey mudstone. It forms the coulee walls and underlies the upland benches between coulees throughout the study area. The basal sandstone unit of the Kootenai, the Third Cat Creek equivalent in this area, overlies the coal in the Upper Morrison with an erosional unconformity. This unit represents the first coarse channel deposits of the major river system which established itself across the Upper Jurassic land surface.

Except for the basal sandstone, the numerous sandstone beds in the
upper Kootenai are relatively discontinuous. Most individual beds cannot be traced over long distances.

B.5 Glacial Deposits

According to Coulton et al. (1961), the limit of Wisconsinan continental glaciation lies just to the north of the Sand Coulee area. No known till or drift deposits occur within the valley. There is a large pre-glacial channel of the Missouri River which runs east-west from the modern Missouri River south of Great Falls, at the Sand Coulee Creek delta, directly west to the town of Fife. The flow of Sand Coulee Creek turns abruptly to the west as it encounters this channel. The channel is filled with sand, gravel, silt and clay deposited by glaciers and glacial lakes over which the lower reach of Sand Coulee Creek flows at a gentle gradient of 9-10 feet/mile (about 2%).

B.6 Alluvial Deposits

Thin alluvial deposits of Quaternary and possibly Tertiary age lie along the coulee bottoms of Straight, Cottonwood, Number Five and Sand Coulee Creeks. North of Tracy, these alluvial deposits inter-finger with the outwash and lacusterine deposits of the ancient Missouri channel. Thickness of the alluvial cover is variable. Although little data on its thickness distribution are available, it is probable that nowhere south of Tracy is it greater than 100 feet.
APPENDIX C

HYDROGEOLOGICAL DATA
C-1

DOMESTIC WELL INVENTORY FIELD SHEETS
## Well Data Sheet

**Location:**
- **County:** Cascade
- **Township:** T. 17 N. 17 R. 1 W.
- **Section:** Sec. 2
- **Tract:** Tract 100A

**Owner:** Donald Jacobs

### Lithologic Log

<table>
<thead>
<tr>
<th>Interval (FT.)</th>
<th>From</th>
<th>To</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Log</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Well Details

- **Alt. Land Surf. at Well MSL:** 4,803 ft.
- **Total Depth Below LSD:** 90 ft.
- **Pumping Level Below LSD:**
- **Static Water Level Below LSD:**
- **Yield in Gallons Per Min.:**
- **Distance Tested:**
- **Time (HR.):**
- **If F, Shut-In Press. in PSI:**
- **Geological Source of H₂O:**

### Casing
- **Casing Dia.:**
  - In. From...
  - In. To...
- **Casing Type:**
- **Perforated Interval:**
  - Ft. To...
  - Ft. To...

### Perforation
- **Desc.:**
- **Pump Size (HP.):**
- **Type:**

### Date & Completion
- **Date Well Completed:**
- **How Drilled:**
- **By Whom:** Lic.
- **Well Use:**
- **Source of Info: Well Approp.:**
- **Driller:** Owner USGS SCS Other:

### Location
- **Has Well Location Been Verified:** Yes
- **By Whom:** Osborne Agency MBDL
- **Date Verified:** 8-19-62
- **Measure Point Above LSD:** 74.88 ft.
- **Date:** 2-19-62
- **Total Depth Below LSD:**
- **Pumping Level Below LSD:**
- **SWL Below LSD:**

### Yield & Temperature
- **Yield in GPM:**
- **Water Temp. °C:**
- **Specific Cond. at 25 °C:**

### Other
- **MBMG File Number:**
- **DNR File Number:**
- **Well Form Number:**
- **MBMG WQ Lab. Number:**
- **SYS 2000 Number:**
- **Other:**

**Remarks:**

- F = Flowing

MBMG Form 182 (9/79)
**Montana Bureau of Mines and Geology**

**Well Data Sheet**

- **County**: Cascade
- **T.**: 17N
- **R.**: 5W
- **Sec.**: 7
- **Tract**: G6A

**Owner's Name**: Schott

**Well Data**

- **Alt. Land Surf. at Well MSL**: 4210 ft.
- **Total Depth Below LSD**: 125 ft.
- **Pumping Level Below LSD**: __ ft.
- **Static Water Level* Below LSD**: __ ft.
- **Yield in Gallons per Min.**: __
- **How Tested**: __
- **Time (HR.)**: __
- **If F, Shut-in Press. In PSI**: __
- **Geological Source of H₂O**: __

**Casing Details**

- **Casing Dia.**: __in.
- **Casing Type**: __
- **Perforated Interval**: __ ft. to __ ft.

**Perforation Desc.**

- **Pump Size (HP)**: __
- **Type**: __

**Date Well Completed**: __

**How Drilled**

- **By Whom**: __
- **Lic.**: __

**Well Use**: __

**Source of Info: Well Approp. Driller**

- **Owner**: __
- **USGS**: __
- **SCS**: __

**Other**: __

**Has Well Location Been Verified**: Yes

**By Whom**: Osborne Agency MBMG

**Date Verified**: 8-19-82

**Meas. Point Above LSD**: 3.19 ft.

**Total Depth Below LSD**: 1163 ft.

**Pumping Level Below LSD**: __ ft.

**SWL* Below LSD**: 108.86 ft.

**Yield in GPM**: __

**Water Temp. °C**: __

**Specific Cono. at 25 °C**: 355

**MBMG File Number**: __

**DNR File Number**: __

**Well Form Number**: __

**MBMG WQ Lab. Number**: __

**Sys 2000 Number**: __

**Other**: __

**Remarks**: 397 - 30.6° C

- **F = Flowing**
- **MBMG Form 182 (9/79)**
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY CASCADE T. 18 NRS R. 4 EOW SEC. 11 TRACT AAAC

LAT. N. LONG. UTM N. E.

TOWN SUBDIVISION BLOCK LOT

OWNER'S NAME DONALD A. YUREK ADDRESS STOCKTON MT. 59480

PHONE NUMBER YEAR

ALT. LAND SURF. AT WELL MSL 4075 ft.
TOTAL DEPTH BELOW LSD 131 ft.
PUMPING LEVEL BELOW LSD 125 ft.
STATIC WATER LEVEL* BELOW LSD 26 ft.
YIELD IN GALLONS PER MIN. 2
HOW TESTED BAILER TIME (HR.) 1
IF F. SHUT-IN PRESS. IN PSI

GEOL. SOURCE OF H2O SANDY SHALE

CASING DIA. 6% in. FROM 0 ft. TO 65 ft.
Casing Type
PERFORATED INTERVAL 43' TO 61' ft.
PERFORATION DESC. 25" LITS
PUMP SIZE (HP.) TYPE
DATE WELL COMPLETED 2/14/1981
HOW DRILLED CABLE

BY WHOM PAT BYRNE LIC. 318
WELL USE STOCK = DOMESTIC
SOURCE OF INFO WELL APPROPR.

DRILLER OWNER USGS SCG OTHER:

HAS WELL LOCATION BEEN VERIFIED YES

BY WHOM NORMAN MOORE AGENCY MBMG
DATE VERIFIED 1/11/82

MEAS. POINT ABOVE LSD ft. DATE
TOTAL DEPTH BELOW LSD ft.
PUMPING LEVEL BELOW LSD ft.
SWL* BELOW LSD 770 ft. 1/11/82
YIELD IN GPM 7.2 1/11/82
WATER TEMP. °C 12.1 1/11/82
SPECIFIC CONG. at 25 °C 677 1/11/82

MBMG FILE NUMBER
DNR FILE NUMBER
WELL FORM NUMBER
MBMG WQ LAB. NUMBER
SYS 2000 NUMBER
OTHER:

REMARKS: 

*F = FLOWING
MBMG Form 182 (9/79)
SPRING
MONTANA BUREAU OF MINES AND GEOLoGY
WELL-DATA SHEET

COUNTY CASCADE T. 18 N S R. 4 E W SEC. 14 TRACT 1C1D

LAT. ___________ N. LONG. ___________ W. UTM ___________ N ___________ E ___________

TOWN ___________ SUBDIVISION ___________ BLOCK ___________ LOT ___________

OWNER’S NAME Rick Yurek ADDRESS EVANS RT. STICKETT

ALT. LAND SURF. AT WELL MSL 3880 ft.
TOTAL DEPTH BELOW LSD ___________ ft.
PUMPING LEVEL BELOW LSD ___________ ft.
STATIC WATER LEVEL* BELOW LSD ___________ ft.
YIELD IN GALLONS PER MIN. ___________
HOW TESTED ___________ TIME (HR.) ___________
IF F, SHUT-IN PRESS. IN PSI ___________

GEOLOGICAL SOURCE OF H2O ___________

CASING DIA. ___________ in. FROM ___________ ft. TO ___________ ft.
CASING TYPE ___________

PERFORATED INTERVAL ___________ ft. TO ___________ ft.
PERFORATION DESC. ___________

PUMP SIZE (HP.) ___________ TYPE ___________
DATE WELL COMPLETED ___________
BY WHOM ___________ LIC. ___________
WELL USE ___________
SOURCE OF INFO: WELL APPROP. ___________
DRILLER ___________ OWNER ___________ USGS ___________ SCS ___________
OTHER: ___________

HAS WELL LOCATION BEEN VERIFIED Yes
BY WHOM ___________ AGENCY ___________
DATE VERIFIED 6/24/82
MEAS. POINT ABOVE LSD ___________ ft. DATE ___________
TOTAL DEPTH BELOW LSD ___________ ft.
PUMPING LEVEL BELOW LSD ___________ ft.
SWL* BELOW LSD ___________ ft.

YIELD IN GPM 10.5 6/24/82
WATER TEMP. °C 54.2 6/24/82
SPECIFIC COND. AT 25 °C ___________
MBMG FILE NUMBER ___________
DNR FILE NUMBER ___________
WELL FORM NUMBER ___________
MBMG WG LAB. NUMBER ___________
SYS 2000 NUMBER ___________

REMARKS: Drilled Two wells both have a flow. Two wells have automatic shut-off. Two wells were pumped up to intake. Two wells at 18-14-11-RRAC.

OTHER: ___________

MBMG Form 182 (9/79)
COUNTY: CASCADE  T. 18 N  R. 4 E  SEC. 23  TRACT ABBB
LAT.  N. LONG.  W.  UTM  N  E
TOWN  SUBDIVISION  BLOCK  LOT
OWNER'S NAME: RALPH  SINGLE  ADDRESS: STAR RT. STORSETT

ALT. LAND SURF. AT WELL MSL:  3910  ft.
TOTAL DEPTH BELOW LSD:  65  ft.
PUMPING LEVEL BELOW LSD:  25  ft.
STATIC WATER LEVEL* BELOW LSD:  25  ft.
YIELD IN GALLONS PER MIN.: 
HOW TESTED:  TIME (HR.):
IF P, SHUT-IN PRESS. IN PSI:  
GEOLGICAL SOURCE OF H2O:  

CASING DIAM.  in. FROM  ft. TO  ft.
in. FROM  ft. TO  ft.
Casing Type: PLASTIC
PERFORATED INTERVAL:  ft. TO  ft.
ft. TO  ft.
ft. TO  ft.

PERFORATION DESC.:
PUMP SIZE (HP.)  TYPE:

DATE WELL COMPLETED:
HOW DRILLED:
BY WHOM:  LIC.:

DOMESTIC  OR  STICK:
SOURCE OF INFO: WELL APPROP.:
DRILLER:  OWNER:
USGS  SCS  OTHER:

HAS WELL LOCATION BEEN VERIFIED: Yes  

BY WHOM:  DATE VERIFIED: 6/4/82
MEAS. POINT ABOVE LSD:  ft.  DATE:
TOTAL DEPTH BELOW LSD:  ft.  
PUMPING LEVEL BELOW LSD:  ft.  
SWL* BELOW LSD:  ft.  

YIELD IN GPM:  3.  DATE:  6/4/82
WATER TEMP. C:  42°  DATE:  6/4/82
SPECIFIC COND. AT 25°:  528  DATE:  6/4/82
MBMG FILE NUMBER:  
ONR FILE NUMBER:  
WELL FORM NUMBER:  
MBMG WQ LAB. NUMBER:  
SYS 2000 NUMBER:  
OTHER:

REMARKS:

*F = FLOWING
MBMG Form 182 (9/79)
### Well Data Sheet

**County:** Cascade  
**Town:**  
**Owner's Name:** Eugene Vice  
**Address:** Eden RT. Stock  

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
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<tbody>
<tr>
<td>Total Depth Below LSD</td>
<td>4340 ft</td>
</tr>
<tr>
<td>Pumping Level Below LSD</td>
<td>90' ft</td>
</tr>
<tr>
<td>Static Water Level* Below LSD</td>
<td>39' ft</td>
</tr>
<tr>
<td>Casing Dia.</td>
<td>6 in.</td>
</tr>
<tr>
<td>Perforated Interval</td>
<td>5 in. from 68 ft to 70 ft, 15 in. from 71 ft to 72 ft</td>
</tr>
<tr>
<td>Perforation Desc.</td>
<td></td>
</tr>
<tr>
<td>Pump Size (HP)</td>
<td></td>
</tr>
<tr>
<td>Date Well Completed</td>
<td></td>
</tr>
<tr>
<td>By Whom</td>
<td>Franklin</td>
</tr>
<tr>
<td>How Drilled</td>
<td>Domestic &amp; Stock</td>
</tr>
<tr>
<td>Source of Info: Well Approp.</td>
<td></td>
</tr>
<tr>
<td>Driller</td>
<td>Owner X</td>
</tr>
<tr>
<td>Other:</td>
<td>USGS, SCS</td>
</tr>
<tr>
<td>Has Well Location Been Verified</td>
<td>Yes</td>
</tr>
<tr>
<td>By Whom</td>
<td>Heatman Moore Agency MMBG</td>
</tr>
<tr>
<td>Date Verified</td>
<td>6/07/82</td>
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<tr>
<td>Measure Point Above LSD</td>
<td>0 ft</td>
</tr>
<tr>
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<tr>
<td>Pumping Level Below LSD</td>
<td>0 ft</td>
</tr>
<tr>
<td>SWL* Below LSD</td>
<td>0 ft</td>
</tr>
<tr>
<td>Yield in GPM</td>
<td></td>
</tr>
<tr>
<td>Water Temp. °C</td>
<td>13.3 °</td>
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<tr>
<td>Specific Cond. at 25°C</td>
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<td>MMBG File Number</td>
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<td>DNR File Number</td>
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<td>Well Form Number</td>
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<tr>
<td>MMBG WQ Lab. Number</td>
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<tr>
<td>Sys 2000 Number</td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:**

*F = Flowing

MBMG Form 182 (9/79)
J. MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY: CASCADE
T. 16 S. R. 53 W. S.E. 1/4 SEC. 6 TRACT BBDB
LAT. __________ N. LONG. __________ W.
TOWN __________ SUBDIVISION __________ BLOCK __________ LOT __________
OWNER'S NAME: MATT FRISNEGGER
ADDRESS: STOCKTON

PHONE NUMBER ________ YEAR __________

LITHOLOGIC LOG

INTERVAL (FT.)
FROM TO DESCRIPTION

HO. TESTED __________ TIME (HR.) __________
IF SHUT-IN PRESS. IN PSI __________
GEOLOGICAL SOURCE OF H2O __________

CASING (IN) FROM __________ TO __________ ft.
CASING TYPE __________
PERFORATED INTERVAL __________ ft. TO __________ ft.
PERFORATION DESC __________
PUMP SIZE (HR.) __________ TYPE __________
DATE WELL COMPLETED __________
HOW DRILLED __________
BY WHOM __________ LIC. __________
WELL USE __________
SOURCE OF INFO: WELL APPROP. __________
DRILLER __________ OWNER __________ USGS __________ SCS __________
OTHER __________

HAS WELL LOCATION BEEN VERIFIED __________
BY WHOM __________ AGENCY __________
DATE VERIFIED __________
MEAS. POINT ABOVE LSD __________ ft. DATE __________
TOTAL DEPTH BELOW LSD __________ ft.
PUMPING LEVEL BELOW LSD __________ ft.
SWL* BELOW LSD __________ ft. DATE __________
YIELD IN GPM __________
WATER TEMP. °C __________
SPECIFIC COND. at 25 °C __________
MBMO FILE NUMBER __________
ONR FILE NUMBER __________
WELL FORM NUMBER __________
MBMO WQ LAB. NUMBER __________
SYS 2000 NUMBER __________
OTHER __________

REMARKS: Deeded 1/4 1/2 1/2 of 1/4
Deeded 1/4 acre of Big Rock Creek
water never used Montana
West city water
*F = FLOWING
MBMO Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY: CASCADE
T. 18 N. R. 5 E. W. SEC. 7 TRACT BBDA

LAT. N. LONG. W. UTM N. E.

TOWN SUBDIVISION BLOCK LOT

OWNER'S NAME: ANNA Dolena
ADDRESS: Box 61 SACKETT

PHONE NUMBER YEAR

ALT. LAND SURF. AT WELL MSL 3800 ft.
TOTAL DEPTH BELOW LSD 35 ft.
PUMPING LEVEL BELOW LSD ft.
STATIC WATER LEVEL* BELOW LSD ft.
YIELD IN GALLONS PER MIN.

HOW TESTED TIME (HR.)
IF F SHUT-IN PRESS. IN PSI
GEOLOGICAL SOURCE OF H2O

CASING DIA. 2 in. FROM ft. TO ft.
in. FROM ft. TO ft.

CASING TYPE

PERFORATED INTERVAL ft. TO ft.
ft. TO ft.
ft. TO ft.
ft. TO ft.

PERFORATION DESC.
PUMP SIZE (HP) TYPE
DATE WELL COMPLETED
HOW DRILLED
BY WHOM LIC.
WELL USE

SOURCE OF INFO: WELL APPROP.
DRILLER OWNER USGS SCs
OTHER:

HAS WELL LOCATION BEEN VERIFIED YES
BY WHOM Agency MBMG
DATE VERIFIED 6/4/82
MEAS. POINT ABOVE LSD ft. DATE
TOTAL DEPTH BELOW LSD ft.
PUMPING LEVEL BELOW LSD ft.
SWL* BELOW LSD 15.98 ft. 6/4/82
YIELD IN GPM
WATER TEMP. C
SPECIFIC COND. at 25 C 1.7 6/4/82
983 6/4/82
MBMG FILE NUMBER
DNR FILE NUMBER
WELL FORM NUMBER
MBMG WQ LAB. NUMBER
SYS 2000 NUMBER

OTHER:

REMARKS:

+F = FLOWING
MBMG Form 182 (9/79)

LITHOLOGIC LOG

INTERVAL (FT.)
FROM TO DESCRIPTION

TOTAL DEPTH BELOW LSD
PUMPING LEVEL BELOW LSD
STATIC WATER LEVEL* BELOW LSD
YIELD IN GALLONS PER MIN.

HOW TESTED TIME (HR.)
IF F SHUT-IN PRESS. IN PSI
GEOLOGICAL SOURCE OF H2O

CASING DIA. 2 in. FROM ft. TO ft.
in. FROM ft. TO ft.

CASING TYPE S
tc

PERFORATED INTERVAL ft. TO ft.
ft. TO ft.
ft. TO ft.
ft. TO ft.

PERFORATION DESC.
PUMP SIZE (HP) TYPE
DATE WELL COMPLETED
HOW DRILLED
BY WHOM LIC.
WELL USE

SOURCE OF INFO: WELL APPROP.
DRILLER OWNER USGS SCs
OTHER:

HAS WELL LOCATION BEEN VERIFIED YES
BY WHOM Agency MBMG
DATE VERIFIED 6/4/82
MEAS. POINT ABOVE LSD ft. DATE
TOTAL DEPTH BELOW LSD ft.
PUMPING LEVEL BELOW LSD ft.
SWL* BELOW LSD 15.98 ft. 6/4/82
YIELD IN GPM
WATER TEMP. C
SPECIFIC COND. at 25 C 1.7 6/4/82
983 6/4/82
MBMG FILE NUMBER
DNR FILE NUMBER
WELL FORM NUMBER
MBMG WQ LAB. NUMBER
SYS 2000 NUMBER

OTHER:

REMARKS:

+F = FLOWING
MBMG Form 182 (9/79)
### MONTANA BUREAU OF MINES AND GEOLOGY
#### WELL-DATA SHEET

**COUNTY:** CASCADEN  **T. 18 N**  **R. 5 E**  **SEC. 7**  **TRACT BCAC**

**LAT.**  **N. LONG.**  **W.**  **UTM**  **N**  **E**

**TOWN**  **SUBDIVISION**  **BLOCK**  **LOT**

**OWNER’S NAME:** Felix Menghini  **ADDRESS:** Box 62 Stockott

---

### ALT. LAND SURF. AT WELL MSL

<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 25</td>
<td>CLAY LOOSE ROCK</td>
</tr>
<tr>
<td>25 - 30</td>
<td>LOOSE SANDSTONE</td>
</tr>
<tr>
<td>30 - 32</td>
<td>CLAY</td>
</tr>
</tbody>
</table>

### LITHOLOGIC LOG

**DATE WELL COMPLETED:** 9/11/79

**HOW DRILLED:** GRAB

**SOURCE OF INFO. WELL APPROP.:** X

**DRILLER:**  **OWNER:**  **USGS:**  **SCS**

**OTHER:**

---

**HAS WELL LOCATION BEEN VERIFIED:** Yes

**DATE VERIFIED:** 7/1/79

**MEAS. POINT ABOVE LSD:** 3818 ft.  **DATE:** 7/1/79

**TOTAL DEPTH BELOW LSD:** 32 ft.  **DATE:** 7/1/79

**PUMPING LEVEL BELOW LSD:** 20 ft.  **DATE:** 7/1/79

**YIELD IN GALLONS PER MIN.:** 8

**HOW TESTED:** TIME (HR.) 1

**IF F, SHUT-IN PRESS. IN PSI:**

**GEOLOGICAL SOURCE OF H2O:** CLAY

---

**PUMP SIZE (HP):**  **TYPE:** 50T Pump

**DATE DRILLED:** 9/11/79

**SPECIFIC COND. AT 25°C:**

**MBMG FILE NUMBER:** 328

**MBMG WQ LAB. NUMBER:**

**SYS 2000 NUMBER:**

---

**MBMG Form 182 (9/79)**
**MONTANA BUREAU OF MINES AND GEOLOGY**

**WELL-DATA SHEET**

**COUNTY:** CASCADE  
**T. 18 N. 51 W. SEC. 11 TRACT**

**LAT.** [latitude]  
**LONG.** [longitude]  
**UTM** [universal transverse mercator]  
**N** [northing]  
**E** [easting]

**OWNERS NAME:** MARY BEAUX JACOBES  
**ADDRESS:** BUT MT.

---

**ALT. LAND SURF. AT WELL MSL:** 4240 ft.

**TOTAL PUMPING DEPTH BELOW LSD:** 90 ft.

**PUMPING LEVEL BELOW LSD:** [value]

**STATIC WATER LEVEL BELOW LSD:** 17 ft.

**YIELD IN GALLONS PER MIN.:** [value]

**HOW TESTED:** [description]  
**TIME (HR.):** [value]

**IF F, SHUT-IN PRESS. IN PSI:** [value]

**GEOLOGICAL SOURCE OF H₂O:** [description]

---

**CASING DIA.** [description]  
**FROM** [value]  
**TO** [value]

**CASING TYPE:** [description]

**PERFORATED INTERVAL** [description]  
**FROM** [value]  
**TO** [value]

**PERFORATION DESC.** [description]

**PUMP SIZE (HP.)** [description]  
**TYPE:** [description]

**DATE WELL COMPLETED:** [value]

**HOW DRILLED:** [description]

**BY WHOM:** [description]  
**LICENSE:** [value]

**WELL USE:** [description]

**SOURCE OF INFO: WELL APPROP.:** [description]

**DRILLER:** [description]  
**OWNER:** [description]  
**USGS:** [description]  
**SCS:** [description]

**OTHER:** [description]

---

**HAS WELL LOCATION BEEN VERIFIED:** [description]  
**BY WHOM:** [description]  
**HEADING:** [Agency]  
**DATE VERIFIED:** [value]

**MEAS. POINT ABOVE LSD:** [value]  
**DATE:** [value]

**TOTAL DEPTH BELOW LSD:** [value]

**TOTAL PUMPING LEVEL BELOW LSD:** [value]

**SWL* BELOW LSD:** [value]

**YIELD IN GPM:** [value]

**WATER TEMP. °C:** [value]  
**DATE:** [value]

**SPECIFIC COND. AT 25 °C:** [value]  
**DATE:** [value]

**MBMG FILE NUMBER:** [value]

**DNR FILE NUMBER:** [value]

**WELL FORM NUMBER:** [value]

**MBMG WQ LAB. NUMBER:** [value]

**SYS 2000 NUMBER:** [value]

---

**REMARKS:** [description]

---

**MBMG Form 182 (9/79)**
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY: CHASCOE  T. 14 S  R. 5 E W  SEC. 11  TRACT: 0AC
LAT.  N.  LONG.  W.  UTM  N.  E
TOWN  SUBDIVISION  BLOCK  LOT
OWNER'S NAME: DURKEE  ADDRESS

<table>
<thead>
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<th>PHONE NUMBER</th>
<th>YEAR</th>
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</thead>
<tbody>
<tr>
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<table>
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<tr>
<th>LITHOLOGIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERVAL (FT.)</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>FROM</td>
</tr>
<tr>
<td>No Log</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALT. LAND SURF. AT WELL MSL</th>
<th>4380 ft.</th>
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<tbody>
<tr>
<td>TOTAL DEPTH BELOW LSO</td>
<td>75 ft.</td>
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<tr>
<td>PUMPING LEVEL BELOW LSO</td>
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<tr>
<td>STATIC WATER LEVEL BELOW LSO</td>
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</tr>
<tr>
<td>YIELD IN GALLONS PER MIN.</td>
<td></td>
</tr>
<tr>
<td>HOW TESTED</td>
<td>TIME (HR.)</td>
</tr>
<tr>
<td>IF F, SHUT-IN PRESS. IN PSI</td>
<td></td>
</tr>
<tr>
<td>GEOLOGICAL SOURCE OF H2O KOOTENAI FORMATION</td>
<td></td>
</tr>
<tr>
<td>CASING DIA.</td>
<td>in. FROM</td>
</tr>
<tr>
<td></td>
<td>in. FROM</td>
</tr>
<tr>
<td>CASING TYPE</td>
<td></td>
</tr>
<tr>
<td>PERFORATED INTERVAL</td>
<td>n. TO</td>
</tr>
<tr>
<td></td>
<td>n. TO</td>
</tr>
<tr>
<td></td>
<td>n. TO</td>
</tr>
<tr>
<td>PERFORATION DESC.</td>
<td></td>
</tr>
<tr>
<td>PUMP SIZE (HP.)</td>
<td>TYPE</td>
</tr>
<tr>
<td>DATE WELL COMPLETED</td>
<td></td>
</tr>
<tr>
<td>HOW DRILLED</td>
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</tr>
<tr>
<td>BY WHOM</td>
<td>LIC.</td>
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<tr>
<td>WELL USE</td>
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<tr>
<td>SOURCE OF INFO: WELL APPROP.</td>
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</tr>
<tr>
<td>DRILLER</td>
<td>OWNER</td>
</tr>
<tr>
<td>OTHER</td>
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<table>
<thead>
<tr>
<th>HAS WELL LOCATION BEEN VERIFIED</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BY WHOM</td>
<td>T. Osborne</td>
</tr>
<tr>
<td>AGENCY</td>
<td>MBNG</td>
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<tr>
<td>DATE VERIFIED</td>
<td>8-19-82</td>
</tr>
<tr>
<td>MEAS. POINT ABOVE LSO</td>
<td>DATE</td>
</tr>
<tr>
<td>TOTAL DEPTH BELOW LSO</td>
<td></td>
</tr>
<tr>
<td>PUMPING LEVEL BELOW LSO</td>
<td></td>
</tr>
<tr>
<td>SWL* BELOW LSO</td>
<td>23.32 ft.</td>
</tr>
<tr>
<td>YIELD IN GPM</td>
<td></td>
</tr>
<tr>
<td>WATER TEMP.°C</td>
<td></td>
</tr>
<tr>
<td>SPECIFIC COND. at 2°C</td>
<td>506</td>
</tr>
<tr>
<td>MBMO FILE NUMBER</td>
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</tr>
<tr>
<td>DNR FILE NUMBER</td>
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<tr>
<td>WELL FORM NUMBER</td>
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</tr>
<tr>
<td>MBMO WQ LAB. NUMBER</td>
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<tr>
<td>SYS 2000 NUMBER</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
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</table>

| REMARKS |  |
|---------|  |
|         |  |
| *F = FLOWING |

MBNG Form 182 (9/79)
**MONTANA BUREAU OF MINES AND GEOLOGY**

**WELL-DATA SHEET**

<table>
<thead>
<tr>
<th>COUNTY</th>
<th>R.</th>
<th>T.</th>
<th>LAT.</th>
<th>LONG.</th>
<th>TRACT</th>
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<tbody>
<tr>
<td>T.</td>
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<tr>
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<th>LOT</th>
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<table>
<thead>
<tr>
<th>OWNER'S NAME</th>
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<tr>
<td></td>
<td>Sand Coulee</td>
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<table>
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<tr>
<th>PHONE NUMBER</th>
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<table>
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<tr>
<th>ALT. LAND SURF. AT WELL MSL</th>
<th>2660 ft.</th>
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<tr>
<td>TOTAL DEPTH BELOW LSD</td>
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<tr>
<td>PUMPING LEVEL BELOW LSD</td>
<td></td>
</tr>
<tr>
<td>STATIC WATER LEVEL BELOW LSD</td>
<td></td>
</tr>
<tr>
<td>YIELD IN GALLONS PER MIN.</td>
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</table>

<table>
<thead>
<tr>
<th>HOW TESTED TIME (HR.)</th>
<th>IF F, SHUT-IN PRESS. IN PSI</th>
</tr>
</thead>
<tbody>
<tr>
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<table>
<thead>
<tr>
<th>GEOLOGICAL SOURCE OF H2O</th>
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<thead>
<tr>
<th>CASING DIA.</th>
<th>FROM</th>
<th>TO</th>
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<table>
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<th>CASING TYPE</th>
<th>FROM</th>
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<table>
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<th>FROM</th>
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<tr>
<th>PUMP SIZE (HP.)</th>
<th>TYPE</th>
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<th>DATE WELL COMPLETED</th>
<th>05-12</th>
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<th>HOW DRILLED</th>
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<table>
<thead>
<tr>
<th>BY WHOM</th>
<th>LIC.</th>
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</thead>
<tbody>
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<table>
<thead>
<tr>
<th>WELL USE</th>
<th>SOURCE OF INFO: WELL APPROP.</th>
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<th>DRILLER</th>
<th>OWNER</th>
<th>USGS</th>
<th>SCS</th>
<th>OTHER:</th>
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<tr>
<th>HAS WELL LOCATION BEEN VERIFIED</th>
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<td>BY WHOM</td>
<td>AGENCY</td>
</tr>
<tr>
<td>---------</td>
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<table>
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<tr>
<th>DATE VERIFIED</th>
<th>MEAS. POINT ABOVE LSD</th>
<th>DATE</th>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOTAL DEPTH BELOW LSD</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PUMPING LEVEL BELOW LSD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SWL* BELOW LSD</th>
<th>YIELD IN GPM</th>
<th>WATER TEMP. °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<table>
<thead>
<tr>
<th>SPECIFIC COND. at 25°C</th>
<th>MBMG FILE NUMBER</th>
<th>DNR FILE NUMBER</th>
<th>WELL FORM NUMBER</th>
<th>MBMG WQ LAB. NUMBER</th>
<th>SYS 2000 NUMBER</th>
<th>OTHER:</th>
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<table>
<thead>
<tr>
<th>MBMG Form 182 (9/70)</th>
<th>SKETCH MAP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C-12</td>
</tr>
</tbody>
</table>

*F - FLOWING
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY CASCADE T. 19 N. R. 4 E. W. SEC. 12 TRACT ADDC
LAT. ___________ N. LONG. ___________ W. UTM ___________ N. ___________ E. ___________
TOWN ____________________ SUBDIVISION ____________________ BLOCK ___________ LOT ___________
OWNER'S NAME GORDON & VERA MINDT ADDRESS Box 62-A Sand Coulee MT

PHONENUMBER ____________________ YEAR ____________________

LITHOLOGIC LOG

INTERVAL (FT.) FROM TO DESCRIPTION
0 20 SAND SILT
20 120 GLACIAL DRIFT
120 136 WATER BEARING SANDSTONE

ALT. LAND SURF. AT WELL MSL 3420 ft.
TOTAL DEPTH BELOW LSD 136 ft.
PUMPING LEVEL BELOW LSD 136 ft.
STATIC WATER LEVEL* BELOW LSD 115 ft.
YIELD IN GALLONS PER MIN. 15
HOW TESTED BAILER TIME (HR.) 1
IF F. SHUT- IN PRESS. IN PSI

GEOL OICAL SOURCE OF H. O. SANDSTONE

CASING DI A. 6 in. FROM 0 ft. TO 120 ft.
CASING TYPE STEEL
PERFORATED INTERVAL n. TO n.
PERFORATION DESC. ____________________
PUMP SIZE (HP) TYPE ____________________
DATE WELL COMPLETED JAN 29, 1974
HOW DRILLED CABLE
BY WHOM THOMAS FRANKLIN LIC. 84
WELL USE DOMESTIC - LAWN & GARDEN
SOURCE OF INFO: WELL APPROP. X
DRILLER ___________ OWNER ___________ USGS ___________ SCG ___________
OTHER: ____________________

HAS WELL LOCATION BEEN VERIFIED YES
BY WHOM HERMANN MCGEE AGENCY MBMG
DATE VERIFIED 6/10/72
MEAS. POINT ABOVE LSD n. DATE ___________
TOTAL DEPTH BELOW LSD n.
PUMPING LEVEL BELOW LSD n.
SWL* BELOW LSD n.
YIELD IN GPM * 12
WATER TEMP. ºC 6/10/72 6/10/72
SPECIFIC COND. AT 25 ºC 23.39
MBMG FILE NUMBER ____________________
DNR FILE NUMBER ____________________
WELL FORM NUMBER ____________________
MBMG WQ LAB. NUMBER ____________________
SYS 2000 NUMBER ____________________
OTHER: ____________________

REMARKS: ____________________

*F - FLOWING
MBMG Form 182 (9/79)
**COUNTY**: CASCAD, **T.**: 19 N, **R.**: 4 E, **W. Sec.**: 12, **TRACT**: BDCA

**LAT.**: _, **N. LONG.**: _, **UTM**: N E

**TOWN**: , **SUBDIVISION**: , **BLOCK**: ____ **LOT**: __

**OWNER'S NAME**: JOHN PESKO, **ADDRESS**: STOCKETT MT 59480 (BOX 60A)

**PHONE NUMBER**: , **YEAR**: |

---

**LITHOLOGIC LOG**

<table>
<thead>
<tr>
<th>INTERVAL (FT)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM</td>
<td>TO</td>
</tr>
<tr>
<td>14</td>
<td>Top Soil</td>
</tr>
<tr>
<td>10</td>
<td>Brown Sandy Silt</td>
</tr>
<tr>
<td>47</td>
<td>Light Brown Sandy Clay</td>
</tr>
<tr>
<td>58</td>
<td>Broken Sandstone + Water</td>
</tr>
</tbody>
</table>

---

**CASING DIA.**: 5 in. from _ to 50 ft., **CASING TYPE**: __, **PERFORATED INTERVAL**: ft. to ft., **PERFORATION DESC.**: __, **PUMP SIZE (HP)**: __, **DATE WELL COMPLETED**: 8/26/1978, **HOW DRILLED**: CABLE, **BY WHOM**: PAT BYRNE LIC. 218, **WELL USE**: Domestic (water quality) |

**SOURCE OF INFO**: WELL APPROP. |

**DRILLER**: OWNER: USGS SCS, **OTHER**: __

**HAS WELL LOCATION BEEN VERIFIED**: YES, **BY WHOM**: __, **DATE VERIFIED**: 6/04/82

**MEAS. POINT ABOVE LSD**: ft., **DATE**: __, **TOTAL DEPTH BELOW LSD**: ft., **PUMPING LEVEL BELOW LSD**: ft., **SWL* BELOW LSD**: ft., **YIELD IN GPM**: __, **WATER TEMP. °C**: 7.9, **SPECIFIC COND. at 25 °C**: 222, **MBMG FILE NUMBER**: __, **DNR FILE NUMBER**: __, **WELL FORM NUMBER**: __, **MBMG WQ LAB. NUMBER**: __, **SYS 2000 NUMBER**: __, **OTHER**: __

**REMARKS**: __, **F* FLOWING**

**MBMG Form 182 (9/79)**

---

**SKETCH MAP**: 

- [To Sand Locus] 
- [To Centerville]
COUNTY: CASCADE  
T.: 19  
R.: 14  
SEC.: 12  
TRACT: DBAA

LAT. _______  N.  LONG. _______  W.  
UTM _______  N. _______  E. _______

TOWN _______  SUBDIVISION _______  BLOCK _______  LOT _______

OWNER’S NAME: RICHARD KAJALA  
ADDRESS: SAND LOUILL, MT

---

### Lithologic Log

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<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>0 - 80</td>
<td>Gravel Drift-Glump</td>
</tr>
<tr>
<td>80 - 125</td>
<td>Sticky Clay</td>
</tr>
<tr>
<td>125 - 147</td>
<td>Gravel-Cobble</td>
</tr>
<tr>
<td>147 - 158</td>
<td>Limestone</td>
</tr>
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</table>

---

**Other:**

- Lithologic Log:  
- Water Temp: °C
- Specific Cond: at 25 °C

---

**Diag:**

- Sketch Map:  
- Well Location: Yes

---

**Remarks:**

- MBMG Form 182 (9/79)
- F - Flowing
## Well Data Sheet

### General Information
- **County**: [Blank]
- **T.** [Blank]
- **R.** [Blank]
- **Sec.** [Blank]
- **Tract** [Blank]
- **Lat.** [Blank] N. Long. [Blank] W.
- **UTM** [Blank] N. [Blank] E.
- **Town**: [Blank]
- **Subdivision**: [Blank]
- **Block**: [Blank]
- **Lot**: [Blank]
- **Owner's Name**: Elizabeth Lyman
- **Address**: [Blank]

### Well Details
- **Phone Number**: [Blank]
- **Year**: [Blank]

### Lithologic Log

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<th>Interval (ft.)</th>
<th>Description</th>
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<td>FROM</td>
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<tr>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>120</td>
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</tbody>
</table>

### Additional Information
- **Alt. Land Surf. at Well MSL**: 1800 ft.
- **Total Depth Below LSD**: 180 ft.
- **Pumping Level Below LSD**: 114 ft.
- **Static Water Level* Below LSD**: 15 ft.
- **Yield in Gallons Per Min.**: [Blank]
- **How Tested**: [Blank]
- **Time (HR.)**: [Blank]
- **If F, Shut-In Press. in PSI**: [Blank]
- **Geological Source of H2O**: Juvenile unlit.
- **Casing Dia.**: [Blank] in.
- **Casing Type**: [Blank]
- **Perforated Interval**: 120 ft. to 131 ft.
- **Perforation Desc.**: [Blank]
- **Pump Size (HP.)**: [Blank]
- **Date Well Completed**: [Blank]
- **How Drilled**: [Blank]
- **By Whom**: [Blank]
- **Lic.**: [Blank]
- **Well Use**: [Blank]
- **Source of Info: Well Approp.**: [Blank]
- **Driller**: [Blank]
- **Owner**: [Blank]
- **USGS**: [Blank]
- **SCS**: [Blank]

### Verification
- **Has Well Location Been Verified**: Yes
- **By Whom**: [Blank]
- **Agency**: [Blank]
- **Date Verified**: 6-9-82
- **Meas. Point Above LSD**: [Blank] ft.
- **Date**: [Blank]
- **Total Depth Below LSD**: [Blank] ft.
- **Pumping Level Below LSD**: [Blank] ft.
- **SWL* Below LSD**: [Blank] ft.
- **Yield in GPM**: [Blank]
- **Water Temp. °C**: 725 / 6/4/82
- **Specific Cond. at 25 °C**: 2207 / 6/4/82
- **MBMG File Number**: [Blank]
- **DNA File Number**: [Blank]
- **Well Form Number**: [Blank]
- **MBMG WQ Lab. Number**: [Blank]
- **SYS 2000 Number**: [Blank]

### Remarks
- **Remarks**: [Blank]

### Other
- **MBMG Form 182 (9/79)**

*F = Flowing
# Montana Bureau of Mines and Geology
## Well-Data Sheet

**County:** Cascade  
**Town:**  
**Owner’s Name:** Mike Kayulla

### Well Information
- **Alt. Land Surf. at Well MSL:** 3440 ft.
- **Total Depth Below LSD:** 170 ft.
- **Pumping Level Below LSD:** 40 ft.
- **Static Water Level* Below LSD:** 76 ft.

### Yield and Other Details
- **Yield in Gallons Per Min.** 95.35
- **How Tested:** Pumped
- **Time (HR.)/Year:**
- **Geological Source of H2O:** Madison

### Casing Details
- **Casing Dia:** in.  
- **Depth:** ft.  
- **Casing Type:**
- **Perforated Interval:** ft.  
- **Perforation Description:**

### Pump Details
- **Pump Size (HP):**
- **Type:**

### Well Completion Details
- **Date Well Completed:** 06/12/55
- **How Drilled:** Chasen Drill
- **By Whom:** E.L. Flood LIC.
- **Well Use:** Domestic
- **Source of Info: Well Appro:**
- **Driller:** Owner
- **USGS SCs:**

### Verification Details
- **Has Well Location Been Verified:** Yes
- **By Whom:** Hermann Mont Agency MBMG
- **Date Verified:** 06/10/82

### Water Quality Details
- **Meas. Point Above LSD:** ft.  
- **Date:**
- **Total Depth Below LSD:** ft.  
- **Pumping Level Below LSD:** ft.  
- **SWL* Below LSD:** ft.  

### Yield in GPM
- **Water Temp °C:** 12.3
- **Specific Cond. @ 25 °C:** 11.6

### Other Information
- **MBMG File Number:**  
- **DNR File Number:**  
- **Well Form Number:**  
- **MBMG WQ Lab. Number:**  
- **SYS 2000 Number:**  

### Remarks
- **Remarks:**

---

*F = Flowing

MBMG Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY  
WELL-DATA SHEET

COUNTY: CALF
LAT: N
LONG: W
TOWN: SUBDIVISION: BLOCK: LOT:
OWNER'S NAME: HENNELYNCH  
ADDRESS: JUMP CASTLE BOX 71  
PHONE NUMBER: YEAR: 1982

ALT. LAND SURF. AT WELL MSL: ft.
TOTAL DEPTH BELOW LSD: ft.
PUMPING LEVEL BELOW LSD: ft.
STATIC WATER LEVEL* BELOW LSD: ft.
YIELD IN GALLONS PER MIN:
HOW TESTED: TIME (HR):
IF F, SHUT-IN PRESS. IN PSI:
GEOLOGICAL SOURCE OF H₂O:

CASING DIA. in. FROM ft. TO ft.
CASING TYPE:
PERFORATED INTERVAL FROM ft. TO ft.
PERFORATION DESC.
PUMP SIZE (HP) TYPE:
DATE WELL COMPLETED:
HOW DRILLED:
BY WHOM:
WELL USE:
SOURCE OF INFO: WELL APPROP.:
DRILLER:
OWNER:
USGS:

HAS WELL LOCATION BEEN VERIFIED:
BY WHOM:
DATE VERIFIED: 4-18-82
MEAS. POINT ABOVE LSD:
TOTAL DEPTH BELOW LSD:
PUMPING LEVEL BELOW LSD:
SWL* BELOW LSD: ft. 6-16-82
YIELD IN GPM:
WATER TEMP, °C:
SPECIFIC COND. AT 25 °C:
MBMG FILE NUMBER:
DNR FILE NUMBER:
WELL FORM NUMBER:
MBMG WQ LAB. NUMBER:
SYS 2000 NUMBER:

REMARKS: WATER QUALITY

*F = FLOWING

MBMG Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY CASCADE

LAT. N. LONG. W. UTM N E

TOWN

OWNER'S NAME George Sota

ADDRESS Send Later

PHONE NUMBER

LITHOLOGIC LOG

INTERVAL (FT.)

FROM TO DESCRIPTION

ALT. LAND SURF. AT WELL MSL

TOTAL DEPTH BELOW LSD

PUMPING LEVEL BELOW LSD

STATIC WATER LEVEL* BELOW LSD

YIELD IN GALLONS PER MIN.

HOW TESTED TIME (HR.)

IF F, SHUT-IN PRESS. IN PSI

GEOLITICAL SOURCE OF H2O Lime stone

CASING DIA. IN. FROM FT. TO FT.

CASING TYPE

PERFORATED INTERVAL FT. TO FT.

PERFORATION DESC.

PUMP SIZE (HR.) TYPE

DATE WELL COMPLETED

HOW DRILLED

BY WHOM LICENSE.

WELL USE

SOURCE OF INFO: WELL APPROP.

DRILLER OWNER USC SCGS

OTHER: Mike Pavilla

HAS WELL LOCATION BEEN VERIFIED Yes

BY WHOM

DATE VERIFIED 11/10/82

MEAS. POINT ABOVE LSD FT. DATE

TOTAL DEPTH BELOW LSD FT.

PUMPING LEVEL BELOW LSD FT.

SWL* BELOW LSD FT.

YIELD IN GPM

WATER TEMP. °C

SPECIFIC COND. AT 25 °C

MBMG FILE NUMBER

DNR FILE NUMBER

WELL FORM NUMBER

MBMG WQ LAB. NUMBER

SYS 2000 NUMBER

OTHER:

REMARKS:

*F = FLOWING

MBMG Form 182 (9/79)
# Montana Bureau of Mines and Geology

## Well-Data Sheet

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<thead>
<tr>
<th>County</th>
<th>Cascade</th>
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<tr>
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<td>T. 1905</td>
</tr>
<tr>
<td>Range</td>
<td>R. 4 Ew</td>
</tr>
<tr>
<td>Section</td>
<td>Sec. 13</td>
</tr>
<tr>
<td>Tract</td>
<td>Tract ADD</td>
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<td>Owner's Name</td>
<td>Charles Danielsen</td>
</tr>
<tr>
<td>Address</td>
<td>Sand Coulee MT.</td>
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<tr>
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## Lithologic Log

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<tbody>
<tr>
<td>0-10</td>
<td>Top Soil</td>
</tr>
<tr>
<td>10-30</td>
<td>Yellow Sandy Clay Loam</td>
</tr>
<tr>
<td>30-79</td>
<td>Sand, Gravel, Water with Soft Yellow Clay</td>
</tr>
<tr>
<td>79-122</td>
<td>Gray Silt</td>
</tr>
<tr>
<td>122-147</td>
<td>Brown Sandy Silt</td>
</tr>
<tr>
<td>147-153</td>
<td>Brown Sand</td>
</tr>
<tr>
<td>153-154</td>
<td>Broken Sandstone and Sand, Gravel and Water</td>
</tr>
<tr>
<td>154-157</td>
<td>Brown Sand</td>
</tr>
<tr>
<td>157-160</td>
<td>Soft Brown Clay</td>
</tr>
<tr>
<td>160-168</td>
<td>Brown Sand and Water</td>
</tr>
<tr>
<td>168-185</td>
<td>Broken Limestone, Sand Gravel and Water (40 GPM)</td>
</tr>
</tbody>
</table>

## Remarks

- Flowing on flooding
- Sometimes, old well capped

*F = Flowing

MBNG Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY CASCADe T. 2 NWS R. 114 E W SEC. 18 TRACT 1/2

LAT. __________ N. LONG. __________ W. UTM _______ N _______ E _______

TOWN __________ SUBDIVISION __________ BLOCK _______ LOT _______

OWNER'S NAME GEORGE KAYULLA ADDRESS SAND COVEE, MT

<table>
<thead>
<tr>
<th>PHONE NUMBER</th>
<th>YEAR</th>
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<table>
<thead>
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<td>TO</td>
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<tr>
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| FROM | TO |
| 20 | 60 |
| 60 | 80 |
| 80 | 100 |
| 100 | 120 |
| 120 | 140 |
| 140 | 160 |
| 160 | 180 |
| 180 | 200 |
| 200 | 220 |

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<th>DATE</th>
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<tr>
<th>WATER TEMP. °C</th>
<th>SPECIFIC COND. @ 25°C</th>
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<tr>
<td>123°C</td>
<td>906</td>
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<th>WELL FORM NUMBER</th>
<th>MBMG WQ LAB. NUMBER</th>
<th>SYS 2000 NUMBER</th>
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</table>

| REMARKS | 7-33-16-11-16 |

C-21
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY CASCADE T. 19 N.R. S. R. 4 E.O. W. SEC. 13 TRACT DADB

LAT. 48° 05' 00" N. LONG. 113° 00' 00" W. UTM 1684 N 1655 E

TOWN SUBDIVISION BLOCK LOT

OWNER'S NAME CHUCK PEO ADDRESS BOX 94, STAPLETON, MT

ALT. LAND SURF. AT WELL MSL 3457 ft.
TOTAL DEPTH BELOW LSD 175 ft.
PUMPING LEVEL BELOW LSD 175 ft.
STATIC WATER LEVEL* BELOW LSD 130 ft.
YIELD IN GALLONS PER MIN. 3.0
HOW TESTED PUMP TIME (HR.) 1
IF F, SHUT-IN PRESS. IN PSI
GEOLICAL SOURCE OF H2O LIMESTONE

CASING DIA. 7 in. FROM 0 ft. TO 62 ft.
CASING TYPE Steel
PERFORATED INTERVAL 62 ft. TO 130 ft.
PERFORATION DESC.
PUMP SIZE (HP) 1/2 TYPE SUB.
DATE WELL COMPLETED 12/24/91
HOW DRILLED
BY WHOM E.J. GROVE LIC. 17
WELL USE DOMESTIC
SOURCE OF INFO; WELL APPROP. X
DRILLER OWNER USGS SCS
OTHER:

HAS WELL LOCATION BEEN VERIFIED Yes
BY WHOM HARLEM MINE AGENCY
DATE VERIFIED 6/23/92
MEAS. POINT ABOVE LSD 0 ft. DATE
TOTAL DEPTH BELOW LSD
PUMPING LEVEL BELOW LSD 82.56 ft.
SWL* BELOW LSD 82.56 ft. 6/23/92
YIELD IN GPM 0.41
WATER TEMP. °C 59.9
SPECIFIC COND. AT 25 °C 1.025
MBMG FILE NUMBER
DNR FILE NUMBER
WELL FORM NUMBER
MBMG WQ LAB. NUMBER
SYS 2000 NUMBER
OTHER:

REMARKS:

*F = FLOWING
MBMG Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY  
WELL-DATA SHEET

COUNTY  CASCADE  T. 19 S  R. 46 W SEC. 19  TRACT DATA

LAT.  N. LONG.  W.  UTM  N. E.

TOWN  SUBDIVISION  BLOCK  LOT

OWNER'S NAME  SAND COULEE WATER USERS  ADDRESS  SAND COULEE, MT

PHONE NUMBER  YEAR

LITHOLOGIC LOG

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<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
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</tr>
<tr>
<td>0</td>
<td>S ( \text{Sandstone} )</td>
</tr>
<tr>
<td>5</td>
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<td>192</td>
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<td>S ( \text{Sandstone} )</td>
</tr>
<tr>
<td>198</td>
<td>S ( \text{Sandstone} )</td>
</tr>
</tbody>
</table>

PUMPING LEVEL BELOW LSD

TOTAL DEPTH BELOW LSD

STATIC WATER LEVEL* BELOW LSD

YIELD IN GALLONS PER MIN.

HOW TESTED

IF F, SHUT-IN PRESS. IN PSI

GEOLoGICAL SOURCE OF \( \text{H}_2\text{O} \)

Casing Dia. 1 1/2 in. FROM 0 ft. TO 34 ft.

Casing Type 160N

Perforated Interval FROM 0 ft. TO 34 ft.

Perforation Desc.

Pump Size (HP) 1 TYPE

Date Well Completed 2-15-60

How Drilled

By Whom

Lic.

Well Use

Source of Info: Well Appr. Driller

Owner

USGS

SGS

Other:

Has Well Location Been Verified 7/5

By Whom

Agency MBMG

Date Verified 6-5-82

Meas. Point Above LSD

Total Depth Below LSD

Pumping Level Below LSD

SWL* Below LSD

Yield in GPM

Water Temp. °C

Specific Cond. at 25 °C

MBMG File Number

DNR File Number

Well Form Number

MBMG WQ Lab. Number

SYS 2000 Number

Other:

Remarks: Well #2

Spec. 340 at 22.1 °C

59 x 10, at 11.6 °C

*F = Flowing

MBMG Form 182 (9/79)
### MONTANA BUREAU OF MINES AND GEOLOGY
#### WELL-DATASHEET

- **COUNTY**: Cascade
- **T.**: 19 N.
- **R.**: 46 E.
- **W.**: 14
- **TRACT**: 2

#### Owner's Information
- **Owner's Name**: Sand Coulee Water Users
- **Address**: Sand Coulee

#### Phone Number: ____________

#### Measurement Details
- **Alt. Land Surf. at Well MSL**: 3680 ft.
- **Total Depth Below LSD**: 210 ft.
- **Pumping Level Below LSD**: 150 ft.
- **Static Water Level Below LSD**: 60 gpm.

#### Testing Details
- **Yield in Gallons Per Min.**: 600 gpm.
- **How Tested**: By Pump Test
- **Time (HR.)**: 1

#### Geologic Information
- **If F, Shut-In Press. in PSI**: ____________
- **Geological Source of H2O**: Morrison Sandstone

#### Casing Details
- **Casing Dia. (In.)**: ____________
- **From**: ____________ ft. to ____________ ft.
- **Casing Type**: ____________

#### Perforation Details
- **Perforated Interval**: ____________
- **From**: ____________ ft. to ____________ ft.

#### Lithologic Log

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<th>DESCRIPTION</th>
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<tr>
<td>150</td>
<td>210</td>
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#### Other Details
- **Has Well Location Been Verified**: Yes
- **By Whom**: John Mittal (Res. S. C.

#### Date and Verification
- **Date Well Completed**: 10-11-73
- **Date Verified**: 6-5-82

#### Water Quality
- **Water Temp, °C**: ____________
- **Specific Cond. at 25 °C**: ____________

#### Other Details
- **MBMG File Number**: ____________
- **DNR File Number**: ____________
- **Well Form Number**: ____________
- **MBMG WQ Lab. Number**: ____________
- **Sys 2000 Number**: ____________

#### Remarks
- **Remarks**: ____________

---

*F = Flowing

MBMG Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY CASCADE T. 19 SWS R. 40 W Sec. 14 Trct DCEB

LAT. 0 N. LONG. 0 W. UTM N E

TOWN SUBDIVISION BLOCK LOT

OWNER'S NAME CHARLES FRANTZICH ADDRESS SAND CouLE, MT

PHONE NUMBER YEAR

ALT. LAND SURF. AT WELL MSL 3650 ft.

TOTAL DEPTH BELOW LSD 216 ft.

PUMPING LEVEL BELOW LSD 28 ft.

STATIC WATER LEVEL* BELOW LSD ft.

YIELD IN GALLONS PER MIN. 15

HOW TESTED TIME (HR.) 1

IF F, SHUT-IN PRESS. IN PSI

GEOLOGICAL SOURCE OF H2O 739.0 DATE

CASING DIA. in. FROM 0 ft. TO 112.5 ft.

CASING TYPE

PERFORATED INTERVAL ft. TO ft.

PERFORATION DESC.

PUMP SIZE (HP) TYPE

DATE WELL COMPLETED

HOW DRILLED

BY WHOM LIC.

WELL USE

SOURCE OF INFO: WELL APPROP. Y

DRILLER OWNER USGS SC3

OTHER:

HAS WELL LOCATION BEEN VERIFIED YES

BY WHOM J. BENJAMIN AGENCY MBMG

DATE VERIFIED 6-3-82

MEAS. POINT ABOVE LSD ft. DATE

TOTAL DEPTH BELOW LSD ft.

PUMPING LEVEL BELOW LSD ft.

SWL* BELOW LSD ft.

YIELD IN GPM

WATER TEMP. ºC 10.5 6-3-82

SPECIFIC COND. AT 25 ºC 1047 6-3-82

MBMG FILE NUMBER

DNR FILE NUMBER

WELL FORM NUMBER

MBMG WQ LAB. NUMBER

SYS 2000 NUMBER

OTHER:

REMARKS: 5'N 329º 20.5 ºC

74x10 10.5 ºC

*F = FLOWING

MBMG Form 182 (9/79)
COUNTY: CASCADE
T. 19 N. 4 W. SEC. 21

LAT.: N. LONG.: W. UTM: N. E.

TOWN SUBDIVISION BLOCK LOT

OWNER'S NAME: CHARLES E. MARKS ADDRESS: SANDBOULEE MT

PHONE NUMBER: YEAR:

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<th>INTERVAL (FT.)</th>
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LITHOLOGIC LOG

INTERVAL (FT.) | DESCRIPTION
---------------|-----------------

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<th>YIELD IN GALLONS PER MIN.</th>
<th>HOW TESTED</th>
<th>TIME (HR.)</th>
<th>IF F. SHUT-IN PRESS. IN PSI</th>
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HAS WELL LOCATION BEEN VERIFIED: YES

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<table>
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<tr>
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<tr>
<th>F = FLOWING</th>
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</table>

MBMG Form 182 (9/79)
**MONTANA BUREAU OF MINES AND GEOLOGY**

**WELL-DATA SHEET**

**COUNTY**

**T.**

**R.**

**SEC.**

**TRACT**

**LAT.**

**N.**

**LONG.**

**W.**

**UTM N**

**E.**

**TOWN**

**SUBDIVISION**

**BLOCK**

**LOT**

**OWNER’S NAME**

**ADDRESS**

---

**PHONE NUMBER**

**LITHOLOGIC LOG**

<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM</td>
<td>TO</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
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<tr>
<td>15</td>
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<tr>
<td>59</td>
<td>112</td>
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<tr>
<td>112</td>
<td>135</td>
</tr>
<tr>
<td>135-186</td>
<td>SOFT SANDSTONE</td>
</tr>
<tr>
<td>185-186</td>
<td>RED SHALE</td>
</tr>
<tr>
<td>186-210</td>
<td>CLAY MIXED W- SAND</td>
</tr>
<tr>
<td>210-248</td>
<td>MORRISON SANDSTONE</td>
</tr>
<tr>
<td>248</td>
<td>248</td>
</tr>
</tbody>
</table>

**DATE WELL COMPLETED**

**11-12-73**

**HOW DRILLED**

**CABLE TOOL**

**DATE VERIFIED**

**02-02**

**SOURCE OF INFO: WELL APPROP**

**Driller / Owner / USGS / SCS**

**OTHER**

---

**HAS WELL LOCATION BEEN VERIFIED**

**YES**

**BY WHOM**

**J. BENJAMIN**

**AGENCY**

**MBMG**

**MEAS. POINT ABOVE LSD**

**ft.**

**DATE**

**TOTAL DEPTH BELOW LSD**

**ft.**

**PUMPING LEVEL BELOW LSD**

**ft.**

**SWL* BELOW LSD**

**ft.**

**YIELD IN GPM**

**ft.**

**WATER TEMP, °C**

**SPECIFIC COND. AT 25 °C**

**MBMG FILE NUMBER**

**DON FILE NUMBER**

**WELL FORM NUMBER**

**MBMG WQ LAB. NUMBER**

**SYS 2000 NUMBER**

**OTHER**

**REMARKS:**

*F - FLOWING*

**MBMG Form 182 (9/79)**
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY: CASCADE
T. 11 S. R. 102 W. SEC. 8
LAT. N. LONG. W. UTN N. E.
TOWN SUBDIVISION BLOCK LOT
OWNER'S NAME: GLONDE SWAN
ADDRESS: COLD SPRINGS, MT

PHONE NUMBER: YEAR

LITHOLOGIC LOG

<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MEAS. POINT ABOVE LSD n. DATE
TOTAL DEPTH BELOW LSD n.
PUMPING LEVEL BELOW LSD n.
SWL* BELOW LSD n.
YIELD IN GPM
WATER TEMP. C.
SPECIFIC COND. AT 25 C

MBMO FILE NUMBER
ONR FILE NUMBER
WELL FORM NUMBER
MBMO WQ LAB. NUMBER
SYS 2000 NUMBER
OTHER:

REMARKS:

MBMO Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY CASCADE T. 19 N S R. 4 E NW SEC. 27 TRACT ACED
LAT. _______ N. LONG. _______ W. UTM _______ N _______ E _______

TOWN SUBDIVISION BLOCK LOT ______

OWNER'S NAME NORMAN YOUNG
ADDRESS SAND COVEE, MT

PHON NUMBER _______ YEAR _______

ALT. LAND SURF. AT WELL MSL 3825 ft.
TOTAL DEPT BELOW LSD 423 ft.
PUMPING LEVEL BELOW LSD 179 ft.
STATIC WATER LEVEL BELOW LSD 12 ft.

YIELD IN GALLONS PER MIN. _______
HOW TESTED _______ TIME (HR.) _______
IF F, SHUT-IN PRESS. IN PSI _______

GEOLOGICAL SOURCE OF H₂O _______

CASING DIA. _______ in. FROM _______ ft. TO _______ ft.
CASING TYPE _______

PERFORATED INTERVAL _______ ft. TO _______ ft.
PERFORATION DESC. _______

PUMP SIZE (HP.) _______ TYPE _______
DATE WELL COMPLETED _______ 4:25:61
HOW DRILLED _______
BY WHOM _______
WELL USE _______

SOURCE OF INFO: WELL APPROP. _______
DRILLER _______ OWNER _______ USGS _______ SCS _______

OTHER JOINED PERSON(s)

HAS WELL LOCATION BEEN VERIFIED YES
BY WHOM _______
DATE VERIFIED _______ 6-5-82
MEAS. POINT ABOVE LSD _______ ft.
TOTAL DEPT BELOW LSD _______ ft.
PUMPING LEVEL BELOW LSD _______ ft.
SWL* BELOW LSD _______ ft.

YIELD IN GPM _______
WATER TEMP. °C _______
SPECIFIC COND. 1.25 °C _______
MBMG FILE NUMBER _______
DNR FILE NUMBER _______
WELL FORM NUMBER _______
MBMG WQ LAB. NUMBER _______
SYS 2000 NUMBER _______

REMARKS: WELL HAS UNDER WATER IN CLOSED BAY MIN. 185 SC. OF SURFACE AVAILABLE

*F = FLOWING
MBMG Form 182 (9/79)
COUNTY: Cascade
LAT: [ ]
N. LON: [ ]
W.
UTM: [ ]
N. [ ]
E. [ ]
TOWN: [ ]

OWNER'S NAME: Robert Klasner
ADDRESS: Stockett, MT, 59480

ALG. LAND SURF. AT WELL MSL: 3625 ft.
TOTAL DEPTH BELOW LSD: 230 ft.
PUMPING LEVEL BELOW LSD: [ ]
STATIC WATER LEVEL BELOW LSD: 300 ft.
YIELD IN GALLONS PER MIN: [ ]
HOW TESTED: [ ]
TIME (HR): [ ]
IF F, SHUT-IN PRESS. IN PSI: [ ]
GEOL. SOURCE OF H₂O: Limestone

CASING DIA: [ ] in. FROM: 0 ft. TO: 60 ft.
CASING TYPE: [ ]
PERFORATED INTERVAL:

PERFORATION DESC: [ ]
PUMP SIZE (HP): [ ]
DATE WELL COMPLETED: 12/14/77
HOW DRILLED: [ ]
BY WHOM: [ ]
WELL USE: [ ]
SOURCE OF INFO: WELL APPROP: [ ]
DRILLER: [ ]
OWNER: [ ]
USGS: [ ]
SCS: [ ]

HAS WELL LOCATION BEEN VERIFIED: Yes
BY WHOM: [ ]
MBMG: [ ]
DATE VERIFIED: 6/01/82

MEAS. POINT ABOVE LSD: [ ] ft.
TOTAL DEPTH BELOW LSD: [ ] ft.
PUMPING LEVEL BELOW LSD: [ ] ft.
SWL* BELOW LSD: [ ] ft.
YIELD IN GPM: [ ]
WATER TEMP. °C: [ ]
SPECIFIC COND. AT 25 °C: [ ]
MBMG FILE NUMBER: [ ]
DNR FILE NUMBER: [ ]
WELL FORM NUMBER: [ ]
MBMG WQ LAB. NUMBER: [ ]
SYS 2000 NUMBER: [ ]

REMARKS: Would be flowing by the end of July 78

MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

PHONE NUMBER: [ ]
YEAR: [ ]

LITHOLOGIC LOG

INTERVAL (FT.)
FROM TO DESCRIPTION
0 - 2 Top Soil
2 - 14 Clay with gravel
14 - 56 Shale
56 - 830 Limestone
830 - approx 10 GPM
700' 10-15 GPM
Approx 50 GPM

SKETCH MAP

MBMG Form 182 (9/79)
<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM</td>
<td>TO</td>
</tr>
</tbody>
</table>

**LITHOLOGIC LOG**

**INTERVAL (FT.)**

**DESCRIPTION**

**ALT. LAND SURF. AT WELL MLS:** 3455 ft.

**TOTAL DEPTH BELOW LSD:** 220 ft.

**PUMPING LEVEL BELOW LSD:** 637 ft.

**STATIC WATER LEVEL* BELOW LSD:** 637 ft.

**YIELD IN GALLONS PER MIN.:**

**HOW TESTED:**

**TIME (HR.):**

**IF F, SHUT-IN PRESS. IN PSI:**

**GEOLOGICAL SOURCE OF H₂O:**

**WELL INTO LAKE OR RIVER:**

**WELL INTO MARINE:**

**WELL INTO HOLE FROM STREAM 10' AWAY:**

**CASING DIA.:**

**In. FROM:**

**ft. TO:**

**In. FROM:**

**ft. TO:**

**CASING TYPE:**

**STEEL**

**PERFORATED INTERVAL:**

**ft. TO:**

**ft. TO:**

**ft. TO:**

**ft. TO:**

**PERFORATION DESC.:**

**PUMP SIZE (HR.)**

**TYPE**

**DATE WELL COMPLETED**

**HOW DRILLED:**

**BY WHOM:**

**WELL USE:**

**STOCK**

**SOURCE OF INFO: WELL APPROP.:**

**DRILLER:**

**OWNER X USGS SCS**

**OTHER:**

**HAS WELL LOCATION BEEN VERIFIED:**

**YES**

**BY WHOM:**

**Herman Moore**

**AGENCY:**

**MBMG**

**DATE VERIFIED:**

**6/04/82**

**MEAS. POINT ABOVE LSD:**

**15 ft.**

**DATE**

**TOTAL DEPTH BELOW LSD:**

**ft.**

**PUMPING LEVEL BELOW LSD:**

**ft.**

**SWL* BELOW LSD:**

**633 ft.**

**DATE:**

**4/04/82**

**YIELD IN GPM:**

**WATER TEMP. °C:**

**13.7**

**DATE:**

**1/04/82**

**SPECIFIC COND. AT 25 °C:**

**1.067**

**DATE:**

**1/04/82**

**MBMG FILE NUMBER:**

**10576**

**ONR FILE NUMBER:**

**WELL FORM NUMBER:**

**MBMG WQ LAB. NUMBER:**

**SYS 2000 NUMBER:**

**OTHER:**

**REMARKS:**

**F = FLOWING**

**MBMG Form 182 (9/79)**
<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COUNTY</td>
<td>CASCADE</td>
</tr>
<tr>
<td>T.</td>
<td>7th</td>
</tr>
<tr>
<td>R.</td>
<td>E 50W</td>
</tr>
<tr>
<td>SEC.</td>
<td>7</td>
</tr>
<tr>
<td>TRACT</td>
<td>BDB</td>
</tr>
<tr>
<td>LAT.</td>
<td>N.</td>
</tr>
<tr>
<td>LONG.</td>
<td>W.</td>
</tr>
<tr>
<td>TOWN</td>
<td></td>
</tr>
<tr>
<td>SUBDIVISION</td>
<td></td>
</tr>
<tr>
<td>BLOCK</td>
<td></td>
</tr>
<tr>
<td>LOT</td>
<td></td>
</tr>
<tr>
<td>OWNER'S NAME</td>
<td>Jim Erickson</td>
</tr>
<tr>
<td>ADDRESS</td>
<td>Land Custer M.T.</td>
</tr>
<tr>
<td>ALT. LAND SURF. AT WELL MSL</td>
<td>2453 ft.</td>
</tr>
<tr>
<td>TOTAL DEPTH BELOW LSD</td>
<td>214 ft.</td>
</tr>
<tr>
<td>PUMPING LEVEL BELOW LSD</td>
<td></td>
</tr>
<tr>
<td>STATIC WATER LEVEL below LSD</td>
<td>35 ft.</td>
</tr>
<tr>
<td>YIELD IN GALLONS PER MIN.</td>
<td></td>
</tr>
<tr>
<td>HOW TESTED</td>
<td></td>
</tr>
<tr>
<td>TIME (HR.)</td>
<td></td>
</tr>
<tr>
<td>IF F. SHUT IN PRESS. IN PSI</td>
<td></td>
</tr>
<tr>
<td>GEOFICAL SOURCE OF H2O</td>
<td>Limestone</td>
</tr>
<tr>
<td>CASING DIAM.</td>
<td>0 in. FROM N. TO ft.</td>
</tr>
<tr>
<td>CASE IN</td>
<td>0 in. FROM N. TO ft.</td>
</tr>
<tr>
<td>CASING TYPE</td>
<td>Steel</td>
</tr>
<tr>
<td>PERFORATED INTERVAL</td>
<td>ft. TO ft.</td>
</tr>
<tr>
<td>PERFORATION DESC.</td>
<td></td>
</tr>
<tr>
<td>PUMP SIZE (HP.)</td>
<td>TYPE</td>
</tr>
<tr>
<td>DATE WELL COMPLETED</td>
<td></td>
</tr>
<tr>
<td>BY WHOM</td>
<td>Pat Byrne LIC.</td>
</tr>
<tr>
<td>WELL USE</td>
<td></td>
</tr>
<tr>
<td>SOURCE OF INFO; WELL APPROP.</td>
<td></td>
</tr>
<tr>
<td>DRILLER</td>
<td>OWNER X USGS SCS</td>
</tr>
<tr>
<td>OTHER:</td>
<td></td>
</tr>
<tr>
<td>HAS WELL LOCATION BEEN VERIFIED</td>
<td>Yes</td>
</tr>
<tr>
<td>BY WHOM</td>
<td>Herman Moore AGENCY MABLA</td>
</tr>
<tr>
<td>DATE VERIFIED</td>
<td>6/22/92</td>
</tr>
<tr>
<td>MEAS. POINT ABOVE LSD</td>
<td>ft.</td>
</tr>
<tr>
<td>TOTAL DEPTH BELOW LSD</td>
<td>ft.</td>
</tr>
<tr>
<td>PUMPING LEVEL BELOW LSD</td>
<td>ft.</td>
</tr>
<tr>
<td>SWL* BELOW LSD</td>
<td>ft.</td>
</tr>
<tr>
<td>YIELD IN GPM</td>
<td></td>
</tr>
<tr>
<td>WATER TEMP. °C</td>
<td></td>
</tr>
<tr>
<td>SPECIFIC COND.</td>
<td>% 25°C</td>
</tr>
<tr>
<td>MBMO FILE NUMBER</td>
<td></td>
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<tr>
<td>DNR FILE NUMBER</td>
<td></td>
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<tr>
<td>WELL FORM NUMBER</td>
<td></td>
</tr>
<tr>
<td>MBMO WQ LAB. NUMBER</td>
<td></td>
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<tr>
<td>SYS 2000 NUMBER</td>
<td></td>
</tr>
<tr>
<td>OTHER:</td>
<td></td>
</tr>
<tr>
<td>REMARKS: Well is part of family water system which has two wells in system</td>
<td></td>
</tr>
</tbody>
</table>

*F = FLOWING

MBMO Form 182 (0/79)
COUNTY: CASCADE  T. 19 N. 5 R.  W.  Sec. 18 Tract BACB

LAT. ______  LONG. ______  UTM ______  N ______  E ______

TOWN __________________________  SUBDIVISION __________________________  BLOCK ______  LOT ______

OWNER'S NAME: ANDY TESINSKY  ADDRESS: SAND CREEK MT.

ALT. LAND SURF. AT WELL MSL  3410 ft.
TOTAL DEPTH BELOW LSD  185 ft.
PUMPING LEVEL BELOW LSD  ______ ft.
STATIC WATER LEVEL* BELOW LSD  ______ ft.
YIELD IN GALLONS PER MIN.
HOW TESTED: ______  TIME (HR.): ______
IF F, SHUT-IN PRESS. IN PSI: ______
GEOLOGICAL SOURCE OF H2O: Source____

CASING DIA: ______ in. FROM ______ ft. TO ______ ft.
Casings ______ in. FROM ______ ft. TO ______ ft.
Casing Type: ______
Perforated Interval: ______ ft. TO ______ ft.
Perforation Desc: ______
Pump Size (HR): ______  Type: ______
Date Well Completed: ______
How Drilled: ______
By Whom: ______  Lic.: ______
Well Use: Domestic ______
Source of Info: Well Approp. ______
Driller: ______  Owner: ______  USGS: ______  SCs: ______
Other: ______

Has Well Location Been Verified: Yes ______
By Whom: Herman Moore  Agency: MBMG ______
Date Verified: 6/10/82 ______
Meas. Point Above LSD: ______ ft.  Date: ______
Total Depth Below LSD: ______ ft.  ______
Pumping Level Below LSD: ______ ft.  ______
SwL* Below LSD: ______ ft.  4/10/82 ______
Yield in GPM: ______
Water Temp, °C: ______  6/10/82 ______
Specific Cond. at 25 °C: ______  6/10/82 ______
MBMG File Number: ______
DNR File Number: ______
Well Form Number: ______
MBMG WQ Lab. Number: ______
Sys 2000 Number: ______
Other: ______

Remarks: ______

*F = Flowing
MBMG Form 182 (9/79)
**MONTANA BUREAU OF MINES AND GEOLOGY**

**WELL-DATA SHEET**

**COUNTY** CASCADE  
**T.** 19  
**R.** 5  
**S.E.** 18  
**TRACT** BL 80

**LAT.**  
**N. LONG.**  
**UTM**  
**N**  
**E**  

**TOWN**  
**SUBDIVISION**  
**BLOCK**  
**LOT**  

**OWNER'S NAME** LARRY McEWEN  
**ADDRESS** Sand Coulee, MT

**PHONE NUMBER**  
**YEAR**

### LITHOLOGIC LOG

<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
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<tbody>
<tr>
<td>FROM</td>
<td>TO</td>
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<tr>
<td>0</td>
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</tr>
<tr>
<td>20</td>
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<td>197</td>
<td>199</td>
</tr>
<tr>
<td>199</td>
<td>217</td>
</tr>
</tbody>
</table>

**MEAS. POINT ABOVE LSD**  
**DATE**  
**TOTAL DEPTH BELOW LSD**  
**Pumping level below LSD**  
**Swl* below LSD**  
**Yield in GPM**  
**Water Temp. °C**  
**Specific Cond. at 25° C**

**MBMG FILE NUMBER**  
**DNA FILE NUMBER**  
**WELL FORM NUMBER**  
**MBMG WQ LAB. NUMBER**  
**SYS 2000 NUMBER**  
**OTHER:**

**HAS WELL LOCATION BEEN VERIFIED** Yes  
**BY WHOM** Department of Agriculture  
**DATE VERIFIED** 6/10/87

**REMARKS:** Metallic taste since drilled. Entomother's old well caved in.

**F = FLOWING**

MBMG Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY: CASCADE
T. 19 N., R. 5 E., Sec. 18

LAT. N. LONG. W.

TOWN SUBDIVISION BLOCK LOT

OWNER'S NAME: TERRY NOR
ADDRESS: Box 95, Star, MT

PHONE NUMBER

LITHOLOGIC LOG

<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>0 - 2</td>
<td>Top Soil</td>
</tr>
<tr>
<td>2 - 20</td>
<td>Broken Sandstone</td>
</tr>
<tr>
<td>20 - 35</td>
<td>Yellow Clay</td>
</tr>
<tr>
<td>36 - 40</td>
<td>Sandstone</td>
</tr>
<tr>
<td>40 - 49</td>
<td>Yellow Clay</td>
</tr>
<tr>
<td>49 - 54</td>
<td>Broken Sandstone</td>
</tr>
<tr>
<td>54 - 64</td>
<td>Broken Sandstone</td>
</tr>
<tr>
<td>64 - 67</td>
<td>Broken Grey Sandstone</td>
</tr>
<tr>
<td>67 - 70</td>
<td>Grey Shale</td>
</tr>
<tr>
<td>70 - 85</td>
<td>Grey Shale</td>
</tr>
<tr>
<td>85 - 105</td>
<td>Hard Grey Limestone</td>
</tr>
<tr>
<td>105 - 125</td>
<td>Limestone</td>
</tr>
</tbody>
</table>

TOTAL DEPTH BELOW LSD: 3465 ft.
PUMPING LEVEL BELOW LSD: 175 ft.
STATIC WATER LEVEL BELOW LSD: 137 ft.
YIELD IN GALLONS PER MIN.: 40 gal.
HOW TESTED: TIME (HR.): 1
IF F, SHUT-IN PRESS. IN PSI:

GEOLOGICAL SOURCE OF H₂O: Madison Limestone

Casing Dia.: 2 in. FROM 0 ft. TO 100 ft.
Casing Type: Galv.
Perforated Interval: ft. TO ft.

PERFOMATION DESC.
PUMP SIZE (HP.): TYPE

DATE WELL COMPLETED

HOW DRILLED:

BY WHOM: Lic.

WELL USE: Domestic

SOURCE OF INFO: WELL APPROP.

DRILLER: OWNER: USGS, SCS

OTHER:

HAS WELL LOCATION BEEN VERIFIED

BY WHOM: Montana Dept. of Revenue MBMG
DATE VERIFIED: 6/20/82

MEAS. POINT ABOVE LSD: ft.
TOTAL DEPTH BELOW LSD: ft.
PUMPING LEVEL BELOW LSD: ft.
SWL* BELOW LSD: 79.76 ft.
YIELD IN GPM:
WATER TEMP. °C:
SPECIFIC COND. AT 25 °C:

MBMG FILE NUMBER:
DNR FILE NUMBER:
WELL FORM NUMBER:
MBMG WQ LAB. NUMBER:
SYS 2000 NUMBER:

REMARKS:

*F = FLOWING
MBMG Form 182 (9/79)
**MONTANA BUREAU OF MINES AND GEOLOGY**

**WELL-DATA SHEET**

**COUNTY**: CASCADE  
**T.**: 19  
**S.**: 5  
**R.**: SW  
**SEC.**: 18  
**TRACT**: DBAB

**LAT.**:  
**N. LONG.**:  
**W.**:  
**UTM**:  
**N.**:  
**E.**:  
**TOWN**:  
**SUBDIVISION**:  
**BLOCK**:  
**LOT**:  

**OWNER'S NAME**: Kudy Marko  
**ADDRESS**: Sand Coulee

---

**ALT. LAND SURF. AT WELL MBL**: 3455 ft.  
**TOTAL DEPTH BELOW LSD**: 190 ft.  
**PUMPING LEVEL BELOW LSD**: 145 ft.  
**STATIC WATER LEVEL BELOW LSD**:  

**YIELD IN GALLONS PER MIN.**:  
**HOW TESTED**:  
**IF F, SHUT-IN PRESS. IN PSI**:  
**GEOLOGICAL SOURCE OF H₂O**: LIMESTONE

---

**CASING DIA. IN**: FROM 6 in. TO 60 in.  
**CASING TYPE**: Steel  
**PERFORATED INTERVAL**:  
**PERFORATION DESC.**:  
**PUMP SIZE (HP)**: TYPE  
**DATE WELL COMPLETED**: 1940  
**HOW DRILLED**:  
**BY WHOM**:  
**WELL USE**:  
**SOURCE OF INFO. WELL APPROP.**:  
**DRILLER**: OWNER  
**OTHER**:  

**HAS WELL LOCATION BEEN VERIFIED**: Yes  
**BY WHOM**:  
**DATE VERIFIED**: 6/09/82  
**MEAS. POINT ABOVE LSD**:  
**TOTAL DEPTH BELOW LSD**:  
**PUMPING LEVEL BELOW LSD**:  
**SWL* BELOW LSD**:  

**YIELD IN GPM**:  
**WATER TEMP. °C**:  
**SPECIFIC COND. AT 25 °C**:  
**MBMG FILE NUMBER**:  
**DNR FILE NUMBER**:  
**WELL FORM NUMBER**:  
**MBMG WQ LAB. NUMBER**:  
**SYS 2000 NUMBER**:  
**OTHER**:  

**REMARKS**:  

*F = FLOWING

MBMG Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY CASCADE  R. 50 N. W.  SEC. 18  TRACT DCDC
LAT. 11             N. 01       W. 01
TOWN                SUBDIVISION        BLOCK   LOT
OWNER’S NAME CENTERVILLE  SENIOR CITIZENS Bl6  ADDRESS SAND CouKE

<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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</tr>
<tr>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>LITHOLOGIC LOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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</table>

<table>
<thead>
<tr>
<th>PHONE NUMBER</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| ALT. LAND SURF. AT WELL MSL | 3475 ft. |
| TOTAL DEPTH BELOW LSD        | 200 ft.  |
| PUMPING LEVEL BELOW LSD      | 172.92 ft. |
| STATIC WATER LEVEL* BELOW LSD|         |
| YIELD IN GALLONS PER MIN.    |           |
| HOW TESTED                   |           |
| IF F, SHUT-IN PRESS. IN PSI  |           |
| GEOLOGICAL SOURCE OF H₂O     | LIME STONE |
|                             | MARBON |

| CASING DIA. 6 in. FROM ft. TO ft. |
|                                     |
| CASING TYPE                         |
| PERFORATED INTERVAL ft. TO ft.      |
| PERFORATION DESC.                   |
| PUMP SIZE (HR.) TYPE                |
| DATE WELL COMPLETED                 |
| HOW DRILLED                         |
| BY WHOM LIC.                        |
| WELL USE                             |
| SOURCE OF INFO: WELL APPROP.         |
| DRILLER OWNER USGS SCGS             |
| OTHER: Heat - Present when drilled   |

HAS WELL LOCATION BEEN VERIFIED Yes
BY WHOM HERID N ROSS AGENCY MB MG
DATE VERIFIED 6/09/92
MEAS. POINT ABOVE LSD ft. DATE
TOTAL DEPTH BELOW LSD ft.
PUMPING LEVEL BELOW LSD ft.
SWL* BELOW LSD 122.92 ft. 6/09/92
YIELD IN QPM
WATER TEMP. °C 22.1° 6/09/92
SPECIFIC COND. 25 °C 22.92 6/09/92
MBMG FILE NUMBER
DNR FILE NUMBER
WELL FORM NUMBER
MBMG WQ LAB. NUMBER
SYS 2000 NUMBER
OTHER:

REMARKS: 0
*F = FLOWING
MBMG Form 182 (9/79)
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY: CASCADE
T. 19 N (Nor S) R. 5 W (Wor E) SEC. 19 TRACT AADC

LAT. _______ N. LONG. _______ W. UTM _______ N _______ E _______

TOWN _______ SUBDIVISION _______ BLOCK _______ LOT _______

OWNER'S NAME: THOMAS BEHRENT
ADDRESS: START RT, SMOOT COULEE MT

PHONE NUMBER: _______ YEAR: _______

ALT. LAND SURF. AT WELL MSL 3480 ft.
TOTAL DEPTH BELOW LSD 107 ft.
PUMPING LEVEL BELOW LSD 95 ft.
STATIC WATER LEVEL* BELOW LSD 31 ft.
YIELD IN GALLONS PER MIN. 7
HOW TESTED: BAILER
TIME (HR.): 2
IF F. SHUT-IN PRESS. IN PSI: _______

GEOLOGICAL SOURCE OF H2O: Limestome

CASING DIA.: 5⅞ in. FROM 0 ft. TO 100 ft.
CASING DIA.: 5⅞ in. FROM _______ ft. TO _______ ft.

CASING TYPE: _______
PERFORATED INTERVAL: 31 ft. TO 35 ft.
PERFORATION DESC.: TORCH
PUMP SIZE (HP): _______
DATE WELL COMPLETED: 3/17/78
HOW DRILLED: CABLE
BY WHOM: PAT RYNE LIC. 125
WELL USE: DOMESTIC
SOURCE OF INFO: WELL APPROP. X

DRILLER: _______ OWNER: _______ USGS: _______
SCS: _______
OTHER: _______

HAS WELL LOCATION BEEN VERIFIED: YES
BY WHOM: HERMAN MURRAY AGENCY MBMG
DATE VERIFIED: 5/24/82

MEAS. POINT ABOVE LSD _______ ft. DATE _______
TOTAL DEPTH BELOW LSD _______ ft.
PUMPING LEVEL BELOW LSD _______ ft.
SWL* BELOW LSD _______ ft.
YIELD IN GPM _______
WATER TEMP. °C _______
SPECIFIC COND. AT 25 °C _______

MBMG FILE NUMBER _______
DNR FILE NUMBER _______
WELL FORM NUMBER _______
MBMG WQ LAB. NUMBER _______
SYS 2000 NUMBER _______
OTHER: _______

REMARKS: _______

*F = FLOWING

MBMG Form 182 (9/79)
### Well Data Sheet

**County:** Cascade  
**T.:** 19  
**R.:** 5  
**Sec.:** 19  
**Tract:** ABAB

#### Basic Information
- **Owner's Name:** George Heal
- **Address:**

#### Lithologic Log

<table>
<thead>
<tr>
<th>Interval (ft.)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM</td>
<td>TO</td>
</tr>
</tbody>
</table>

#### Well Information
- **Pumping Level Below LSD:** 70' ft.
- **Static Water Level* Below LSD:** 7 ft.
- **Yield in Gallons per Min.:** 7
- **If F, Shut-In Press. In PSI:**
- **Geological Source of H₂O:** Limestone

#### Casing Details
- **Casing Dia.:** 6 in.
- **Casing Type:** Steel
- **Perforated Interval**
  - FROM ft. TO ft.
  - FROM ft. TO ft.
- **Perforation Desc.:**
- **Pump Size (hp):**
- **Date Well Completed:**

#### Drilling Information
- **By Whom:** Hermann Moore
- **Well Use:** Domestic;
- **Lic.:**
- **Source of Info.: Well Approp.
- **Driller:**
- **Owner:**
- **USGS:**
- **SCS:**

#### Verification
- **Has Well Location Been Verified:** Yes
- **By Whom:** Hermann Moore
- **Agency:** MBMG
- **Date Verified:** 4/2/82

#### Meas. Point Above LSD
- **Meas. Point Above LSD:**
- **Date:**
- **Total Depth Below LSD:**
- **Pumping Level Below LSD:**
- **SWL* Below LSD:**

#### Yield and Water Temperature
- **Yield in GPM:**
- **Water Temp. °C:**
- **Specific Cond. at 25 °C:**

#### MBMG File Number
- **MBMG File Number:**
- **DNR File Number:**
- **Well Form Number:**
- **MBMG WQ Lab. Number:**
- **SYS 2000 Number:**

#### Remarks
- **Remarks:**

#### Sketch Map
- **Sketch Map:**

---

*Note: * Refer to the sketch map for detailed location information.
MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATASHEET

COUNTY: CASCADE  T. 19 NWS  R. 5 E LW  SEC. 19 TRACT LAAO-1

LAT. N.  LON. W.  UTM N E

TOWN SUBDIVISION BLOCK LOT

OWNER'S NAME: Ronald Guisti  ADDRESS: Box 93 Sand Coulee

PHONE NUMBER  YEAR

ALT. LAND SURF. AT WELL MSL: 3487 ft.
TOTAL DEPTH BELOW LSD: 238 ft.
PUMPING LEVEL BELOW LSD: 220 ft.
STATIC WATER LEVEL* BELOW LSD: 140 ft.
YIELD IN GALLONS PER MIN.: 25 GPM
HOW TESTED: PUMP TIME (HR.): 2
IF F. SHUT-IN PRESS. IN PSI: 100

GEOLLOGICAL SOURCE OF H2O: Lime Venc Madison

Casing Dia. IN. FROM ft. TO ft.
Perforated Interval ft. TO ft.

Perforation Desc.
Pump Size (HP.): TYPE

Date Well Completed: 11/26/79
How Drilled: Cable

By Whom: Pat Byrne Lic. 318

Well Use: Domestic

Source of Info: Well Appro.

Driller:  Owner: USGS  SCS

Other:

Has Well Location Been Verified: Yes

By Whom: Herman Moss Agency MBMG

Date Verified: 5/20/82

Meas. Point Above LSD:  ft.  Date

Total Depth Below LSD:  ft.  6/20/82

Pumping Level Below LSD:  ft.  4/20/82

SWL* Below LSD:  10 ft.  6/20/82

Yield in GPM:  409/82

Water Temp. °C:  13.50  6/20/82

Specific Cond. at 25° C:  4/4  6/20/82

MBMG File Number
DNF File Number
Well Form Number
MBMG WQ Lab. Number
Sys 2000 Number

Other:

Remarks: Flowing Well

*F = Flowing

MBMG Form 182 (9/79)
**MONTANA BUREAU OF MINES AND GEOLOGY**  
**WELL-DATA SHEET**

**COUNTY**: Cascade  
**T.**: 19  
**R.**: 51W  
**SEC.**: 19  
**TRACT**: CAARD-2

<table>
<thead>
<tr>
<th>LAT.</th>
<th>LONG.</th>
<th>UTM</th>
<th>N</th>
<th>E</th>
</tr>
</thead>
<tbody>
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**TOWN** | **SUBDIVISION** | **BLOCK** | **LOT**
<table>
<thead>
<tr>
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</thead>
<tbody>
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</tbody>
</table>

**OWNER'S NAME**: Brian Guisti  
**ADDRESS**: Starr at Stockett

---

**LITHOLOGIC LOG**

<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM</td>
<td>TO</td>
</tr>
<tr>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>27</td>
<td>55</td>
</tr>
<tr>
<td>55</td>
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<td>72</td>
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<tr>
<td>85</td>
<td>180</td>
</tr>
<tr>
<td>180</td>
<td>290</td>
</tr>
</tbody>
</table>

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**PHONE NUMBER** | **YEAR**
<table>
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</tbody>
</table>

---

**ALT. LAND SURF. AT WELL MSL**: 350 ft.

**TOTAL DEPTH BELOW LSD**: 290 ft.

**PUMPING LEVEL BELOW LSD**: 285 ft.

**STATIC WATER LEVEL* BELOW LSD**: 205 ft.

**YIELD IN GALLONS PER MIN.**: 15

**HOW TESTED**: Boiler  
**TIME (HR.)**: 2

**IF F, SHUT-IN PRESS. IN PSI**: 3

**GEOLOGICAL SOURCE OF H2O Liq.**: Limestone Madison

**CASING DIA.**: 6/6 in.  
**FROM**: 0 ft.  
**TO**: 71 ft.  
**IN**:  
**FROM**:  
**TO**: 

**CASING TYPE**: Steel

**PERFORATED INTERVAL**:  
**FROM**:  
**TO**:  
**IN**:  
**FROM**:  
**TO**:  
**IN**:  
**FROM**:  
**TO**:  
**IN**:  
**FROM**:  
**TO**:  
**IN**:  
**FROM**:  
**TO**:  
**IN**:  
**FROM**:  
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**IN**:  
**FROM**:  
**TO**:  
**IN**:  
**FROM**:  
**TO**:  
**IN**:  
**FROM**:  
**TO**:  
**IN**:  

**PERFORATION DESC.**:  
**PUMP SIZE (HR.):**  
**TYPE**:  
**DATE WELL COMPLETED**: 8/24/78

**HOW DRILLED**: Carie

**BY WHOM**: Pat Byrne  
**LIC.**: 125

**WELL USE**: Domestic

**SOURCE OF INFO: WELL APPROPT.**: X

**DRILLER**: Owner  
**USGS**:  
**SCS**:  
**OTHER**:  

**HAS WELL LOCATION BEEN VERIFIED**: Yes

**BY WHOM**: Herman Moore  
**AGENCY**: MBMG

**DATE VERIFIED**: 6/20/82

**MEAS. POINT ABOVE LSD**: 450 ft.  
**DATE**:  
**TOTAL DEPTH BELOW LSD**: ft.

**PUMPING LEVEL BELOW LSD**: ft.

**SWL* BELOW LSD**: 196.9 ft.  
**DATE**: 6/20/82

**YIELD IN GPM**: 128  
**DATE**: 6/20/82

**WATER TEMP. °C**: 12.0  
**DATE**: 6/20/82

**SPECIFIC COND. at 25 °C**: 826  
**DATE**: 6/20/82

**MBMG FILE NUMBER**:  
**DNR FILE NUMBER**:  
**WELL FORM NUMBER**:  
**MBMG WQ LAB. NUMBER**:  
**SYS 2000 NUMBER**:  
**OTHER**:  

**REMARKS**:  

---

*F = FLOWING  
MBMG Form 182 (9/79)
## Montana Bureau of Mines and Geology
### Well Data Sheet

**County:** Cascade  
**T. 19N S. 5R W. Sec. 20 Tract ABCD**

<table>
<thead>
<tr>
<th>Lat.</th>
<th>Long.</th>
<th>UTM N E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Town:**  
**Subdivision:**  
**Block:**  
**Lot:**  

**Owner's Name:** Duane Knox  
**Address:** Box 72 Sand Coulee, MT

**Phone Number:**  
**Year:**

### Lithologic Log

<table>
<thead>
<tr>
<th>Interval (ft.)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 10</td>
<td>Top Soil</td>
</tr>
<tr>
<td>10 - 40</td>
<td>Shale</td>
</tr>
<tr>
<td>40 - 258</td>
<td>Lime Rock</td>
</tr>
</tbody>
</table>

### Other Information

**Perforation Desc.:**

**Pump Size (HP):**

**Date Well Completed:** 11/14/78

**How Drilled:** Water Rotary

**By Whom:** Sure Water Drillers, Lic. 178

**Well Use:** Domestic & Stock

**Source of Info:** Well Approp. X

**Driller:** Owner  
**Owner:** USGS  
**SCS:**

**Has Well Location Been Verified:** Yes

**By Whom:** Usa Hrd Map

**Date Verified:** 6/02/82

**Meas. Point Above LSD:**  
**Date:**

<table>
<thead>
<tr>
<th>Total Depth Below LSD</th>
<th>Pumping Level Below LSD</th>
<th>SWL* Below LSD</th>
<th>Yield in GPM</th>
<th>Water Temp.°C</th>
<th>Specific Cond. at 25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>215 ft.</td>
<td>258 ft.</td>
<td>150 ft.</td>
<td>10</td>
<td>12.3°</td>
<td>2911</td>
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</table>

**MBMG File Number:**

**DNLP File Number:**

**WQ Lab. Number:**

**WQMD Number:**

**SYS 2000 Number:**

**Other:**

**Remarks:** Water 180 GR 1000

*If = Flowing.

**MBMG Form 182 (6/79)**
<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 5</td>
<td>Fair sand</td>
</tr>
<tr>
<td>5 - 19</td>
<td>Yellow shale</td>
</tr>
<tr>
<td>19 - 41</td>
<td>Wood instructor</td>
</tr>
<tr>
<td>41 - 50</td>
<td>Wood instructor</td>
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<td>50 - 75</td>
<td>Wood instructor</td>
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<td>Wood instructor</td>
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<tr>
<td>79 - 92</td>
<td>Wood instructor</td>
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<tr>
<td>92 - 97</td>
<td>Wood instructor</td>
</tr>
<tr>
<td>97 - 100</td>
<td>Wood instructor</td>
</tr>
</tbody>
</table>

**Lithologic Log**

- **Casing Dia.** 7/8 in.
- **Casing Type.** Unknown
- **Perforated Interval.** Unknown
- **Perforation Desc.** Unknown
- **Pump Size (HP).** Unknown
- **Date Well Completed.** 11-9-81
- **How Drilled.** Unknown
- **By Whom.** Unknown
- **Wells Use.** Domestic
- **Source of Info.** Unknown
- **Driller.** Unknown
- **Owner.** Unknown
- **USGS.** Unknown
- **SCS.** Unknown

**Has Well Location Been Verified.** Yes

**By Whom.** Herman Moore, AGENCY: MBMG

**Date Verified.** 5/27/82

**Meas. Point Above LSD.** Unknown

**Total Depth Below LSD.** Unknown

**Pumping Level Below LSD.** Unknown

**SWL* Below LSD.** 24.73 ft.

**Yield in GPM.** 9.5

**Water Temp. °C.** 13.6

**Spec. Cond. at 25 °C.** 1/27/82

**MBMG File Number.** 1336

**DNR File Number.** Unknown

**Well Form Number.** Unknown

**MBMG WQ Lab. Number.** Unknown

**Sys. 2000 Number.** Unknown

**Other.** Unknown

**Remarks.** 010 well [160° went bad due to Fe**

---

*F = Flowing

**MBMG Form 182 (9/79)**
COUNTY: CASCADE
T. 20 N R. 5 W SEC. 31
LAT. _______ N. LONG. _______ W.
LAT. _______ N. LONG. _______ W.
TOWN: __________ SUBDIVISION: __________
OWNER'S NAME: Gene (Otto) Johnson
ADDRESS: Star Rt. 3, Ooklala Mt.

ALT. LAND SURF. AT WELL MBL
TOTAL DEPTH BELOW LSO
PUMPING LEVEL BELOW LSO
STATIC WATER LEVEL* BELOW LSO
YIELD IN GALLONS PER MIN.
HOW TESTED
SHUT-IN PRESS. IN PSI
GEOLOGICAL SOURCE OF H2O

CASING DIA. 6 in. FROM 0 ft. TO 100 ft.
Casing Type
PERFORATED INTERVAL
PERFORATION DESC.
PUMP SIZE (HP)
DATE WELL COMPLETED
HOW DRILLED
BY WHOM
DOMESTIC & STOCK
WELL USE
SOURCE OF INFO: WELL APPROP.
DRILLER
OWNER
USGS
SCS
OTHER:

HAS WELL LOCATION BEEN VERIFIED
BY WHOM
DATE VERIFIED
MEAS. POINT ABOVE LSO
TOTAL DEPTH BELOW LSO
PUMPING LEVEL BELOW LSO
SWL* BELOW LSO
YIELD IN GPM
WATER TEMP. °C
SPECIFIC COND. AT 25 °C
MBMG FILE NUMBER
DNR FILE NUMBER
WELL FORM NUMBER
MBMG WQ LAB. NUMBER
SY 2000 NUMBER
OTHER:

REMARKS:

*F - FLOWING

MBMG Form 182 (8/70)
**MONTANA BUREAU OF MINES AND GEOLOGY**

**WELL-DATA SHEET**

**COUNTY:** CASCADE  
**T.:** 20  
**R.:** 5  
**S.:** 31  
**TRACT:** 00B

**LAT.**  
**N. LONG.**  
**W.**  
**UTM**  
**N.**  
**E.**

**TOWN**  
**SUBDIVISION**  
**BLOCK**  
**LOT**

**OWNER’S NAME:** Gene (Otto) Johnson  
**ADDRESS:** Star Rt. Sand Coulee

---

**Alt. Land Surf. at Well MSL:** 3418 ft.

**Total Depth Below LSD:** 200 ft.

**Pumping Level Below LSD:** Unused ft.

**Static Water Level* Below LSD:** ft.

**Yield in Gallons Per Min.:**

**How Tested:**

**Time (HR.):**

**If F, Shut-in Press. in PSI:**

**Geological Source of H2O:** Limestone, Madison

---

**Casing Dia. (in. From ft. To ft.):**

**Casing Type:** Steel

**Perforated Interval (ft. To ft.):**

**Perforation Desc.:**

**Pump Size (HP) Type:**

**Date Well Completed:**

**How Drilled:**

**By Whom LIC.:**

**Well Use:** Unused

**Source of Info. Well Appro.:**

**Driller:** Owner

**Other:**

**Has Well Location Been Verified:** Yes

**By Whom:** Hermon Moore Agency MB/MB

**Date Verified:** 5/28/82

**Meas. Point Above LSD:** ft.  
**Date:**

**Total Depth Below LSD:**

**Pumping Level Below LSD:**

**SWL* Below LSD:** 72.15 ft.  
**Date:** 5/28/82

**Yield in GPM:**

**Water Temp. °C:**

**Specific Cond. at 25 °C:**

**MBMG File Number:**

**DNR File Number:**

**Well Form Number:**

**MBMG WQ Lab. Number:**

**SYS 2000 Number:**

**Other:**

**Remarks:** Water went bad

---

**Lithologic Log**

<table>
<thead>
<tr>
<th>INTERVAL (FT.)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FROM</td>
<td>TO</td>
</tr>
</tbody>
</table>

**Sketch Map**

---

*F = Flowing

MBMG Form 182 (9/79)
C-2

GROUNDWATER QUALITY LABORATORY ANALYSES
**Montana Bureau of Mines and Geology**

**WATER QUALITY ANALYSIS**

**Butte, Montana 59701 (406) 476-410**

**Lab No. 8200490**

**STATE** MONTANA

**COUNTY** CASCADE

**LOCATION** 17 HR 50.345'N 111°09'52.0"W

**Topographic Map** SouthEast Great Falls 7.5

**Geological Source** 330MESH *S* 4 Sample Source Will

**Drainage Basin** 83

**Agency** USGS

**Sample Number** ROHAIL 50-82

**Date Sampled** 1982/05/20

**Sample Handling** MAI TOTAL

**Sample Site** ROHAIL QUISTI 0.5 MI SW OF CENTREVILLE

**Geological Source** MONTANA GROUP OR LIMESTONE

**Calcium (Ca)** 113 mg/l 3.77 mg/l

**Magnesium (Mg)** 30.4 mg/l 13 mg/l

**Sodium (Na)** 13.1 mg/l 2 mg/l

**Potassium (K)** 4.2 mg/l 0.57 mg/l

**Iron (Fe)** <0.002 mg/l 0.11 mg/l

**Manganese (Mn)** <0.002 mg/l 5.67 mg/l

**Silica (SiO2)** 3.5 mg/l 0.03 mg/l

**Total Cations** 9.48 mg/l

**Total Anions** 10.70 mg/l

**Standard Deviation of Anion-Cation Balance (Sigma)** 5.13

**Field Water Temperature** 13.5°C

**Calculated Dissolved Solids** 411.42 mg/l

**Sum of Diss. Constituent** 472.30 mg/l

**Laboratory PH** 7.62

**Hardness as CaCO3** 440.22 mg/l

**Total Alkalinity as CaCO3** 188.40 mg/l

**Temperature, Air (°C)** 76.0

**Conductivity, Field Micromhos** 714.6

**Field pH** 7.53

**Aluminum, Diss. (mg/l - Al)** <0.003 mg/l

**Silver, Diss. (mg/l - Ag)** <0.002 mg/l

**Iron, Diss. (mg/l - Fe)** <0.02 mg/l

**Barium, Diss. (mg/l - Ba)** <0.002 mg/l

**Cadmium, Diss. (mg/l - Cd)** 0.002 mg/l

**Chromium, Diss. (mg/l - Cr)** 0.008 mg/l

**Copper, Diss. (mg/l - Cu)** 0.013 mg/l

**Lithium, Diss. (mg/l - Li)** 0.014 mg/l

**Boron, Diss. (mg/l - B)** <0.02 mg/l

**Magnesium, Diss. (mg/l - Mg)** 0.003 mg/l

**Potassium, Diss. (mg/l - K)** 0.007 mg/l

**Calcium, Diss. (mg/l - Ca)** 0.013 mg/l

**Cesium, Diss. (mg/l - Cs)** 0.002 mg/l

**Strontium, Diss. (mg/l - Sr)** 0.003 mg/l

**Titanium, Diss. (mg/l - Ti)** 0.007 mg/l

**Vanadium, Diss. (mg/l - V)** 0.003 mg/l

**Zinc, Diss. (mg/l - Zn)** 0.011 mg/l

**Zirconium, Diss. (mg/l - Zr)** 0.001 mg/l

**Remarks:** Water clear, taste and smell ok. Light brown stain on filter.

**Owners Address Box 93, SAND CASH LEWIS RAYSouthern.**

**Lab:** FR '92, HR 44.5 gives 10.0 MFC CATIONS FOR -0.13 SIGMA

**Explanation:** MG/l = Milligrams per liter, mg/l = micrograms per liter, mg/l = milliequivalents per liter, ft = feet, m = meters, (h) = measured, (r) = reported, t = total recoverable, tot = total.

**QW WA 52. W1 ON PW AT OTHER.**

**Other Available Data:**

**Other File Numbers:**

**Project:**

**Last Edit Date:** 27-JUL-02

**Processing Program:** F17300P V2 (11/3/01)

**Percent MEO/L (for piper plot):**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>mg/l</th>
<th>CL</th>
<th>mg/l</th>
</tr>
</thead>
<tbody>
<tr>
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<td>57.5</td>
<td>11</td>
<td>0.8</td>
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<td>Co3</td>
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**Note:** In correspondence, please refer to Lab Number: 8200490
MONTANA BUREAU OF MINEs AND GEOLOGY  
STATE MONTANA  
LA TITUDE-LONGITUDE 47°19'09"N 111°05'14"W  
TOPOGRAPHIC MAP STOKE T 7 1/2'  
TOPOGRAPHIC SOURCE * * * * SAMPLE SOURCE SPRING  
DRAINAGE BASIN RR  
AGENCY + SAMPLER HRMG*WJD  
BOTTLE NUMBER SHIRLEY  
DATE SAMPLED 22-JUN-82  
TIME SAMPLED 12:15 HOURS SWL ABOVE (-) OR BELOW GS FLOWING  
LAB + ANALYST HRMG*FNA  
DATE ANALYZED 16-JUL-82  
SAMPLE HANDLING  
METHOD SAMPLED WATER USE DOMESTIC  
SAMPLING SITE SHIRLEY, WILLIAM 2.5 MI UP COTTONWOOD CK  
GEOLoGIC SOURCE  

<table>
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<tr>
<th>Mgi/l</th>
<th>Meq/l</th>
<th>Mg/l</th>
<th>Meq/l</th>
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<td>42.1</td>
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<td>10.1</td>
<td>0.44</td>
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<td>2.8</td>
<td>0.07</td>
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<td>&lt;.002</td>
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<td>0.72</td>
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<tr>
<td>&lt;.001</td>
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<td>.36</td>
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TOTAL CATIONS 6.26  
TOTAL ANIONS 6.34  
STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) 0.20  

LABORATORY PH 7.55  
FIELD WATER TEMPERATURE 14.2°C  
CALCULATED DISSOLVED SOLIDS 307.04  
SUM OF DISS. CONSTITUENT 459.26  
LAB SPEC. COND. (MICROMHOS/CH) 569.6  

PARAMETER VALUE  
FIELD PH 6.75  
ALUMINUM, DISS (MG/L-AL) <.03  
SILVER, DISS (MG/L-AS) <.002  
Boron, DISS (MG/L-BO) <.02  
Cadmium, DISS (MG/L-FG CD) <.002  
Chromium, DISS (MG/L-CR) <.002  
Copper, DISS (MG/L-CU) .006  
Lithium, DISS (MG/L-LI) .007  
Molybdenum, DISS (MG/L-HO) <.02  
CALCIUM  
MAGNESIUM  
SODIUM  
POSS  
IRON  
MANGANESE  
SILICA  
CALCIUM  
MAGNESIUM  
SODIUM  
POSS  
IRON  
MANGANESE  
SILICA  

REMARKS: FROM STOKE T 7 FILTER CLEAN* WATER CLEAR  
WILLIAM SHIRLEY* RT 36 STOKE T MT 57400  
ARTESIAN SPRING  

EXPLANATION:  
MG/L = MILLIGRAMS PER LITER,  
UG/L = MICROGRAMS PER LITER,  
MEQ/L = MILLIEQUIVALENTS PER LITER,  
FT = FEET,  
MT = Meters,  
(M) = MEASURED,  
(E) = ESTIMATED,  
(R) = REPORTED,  
TR = TOTAL RECOVERABLE,  
TOT = TOTAL  

OTHER AVAILABLE DATA  
PROJECT:  
LAST EDIT DATE: 27-JUL-82  
PERCENT MEQ/L (FOR PIPER PLOT)  
CA MG NA K CL SO4 HC03 CO3  
49.3 42.5 7.0 1.1 1.7 10.3 87.8 0.0  
NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0200491
STATE: MONTANA
COUNTY: CASCADe
LATITUDE-LONGITUDE: 47°23'50"N 110°10'35"W
UTM COORDINATES: N 842650 E 771170
TOPOGRAPHIC MAP: SOUTHEAST GREAT FALLS 7.5" STATION ID: 4723501101013501
GEOLOGIC SOURCE: MINE IS NA CORRESPONDENCE
MRG SITE: FFFL
DRAINAGE BASIN #: 217708
AGENCY / SAMPLER: USGS WJD
BOTTLE NUMBER: SCWUM2
DATE SAMPLED: 17- JUN-82
TIME SAMPLED: 11:10 HOURS
LAB / ANALYST: USGS WJD
DATE ANALYZED: 07- JUL-82
SAMPLE HANDLING: PUMPED
METHOD SAMPLED: PERFORATED INTERVAL
WATER USE: PUBLIC SUPPLY

GEOLoGIC SOURCE: SOUTHEAST FORMATION

<table>
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<tr>
<th>Ion</th>
<th>mg/L</th>
<th>mg/l</th>
<th>mg/L</th>
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<tbody>
<tr>
<td>Calcium (Ca)</td>
<td>51.7</td>
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<td>RICARBONATE (HCO3)</td>
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<td>Magnesium (Mg)</td>
<td>69.9</td>
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<td>CARBONATE (CO3)</td>
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<tr>
<td>Sodium (Na)</td>
<td>17.2</td>
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<td>CHLORIDE (Cl)</td>
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<tr>
<td>Potassium (K)</td>
<td>2.9</td>
<td>0.07</td>
<td>SULFATE (SO4)</td>
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<tr>
<td>Iron (Fe)</td>
<td>0.01</td>
<td>0.00</td>
<td>NITRATE (AS N)</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>7.5</td>
<td>0.02</td>
<td>FLUORIDE (F)</td>
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<tr>
<td>Silica (SiO2)</td>
<td>2.5</td>
<td>0.00</td>
<td>PHOSPHATE TOT (AS P)</td>
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TOTAL CATIONS: 7.15
TOTAL ANIONS: 7.25

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA): 0.37

LABORATORY PH: 7.69
FIELD WATER TEMPERATURE: 15. C
CALCULATED DISSOLVED SOLIDS: 453.57
SUM OF DISS. CONSTITUENT: 678.06

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<th>Parameter</th>
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<th>Parameter</th>
<th>Value</th>
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<td>Conductivity, Field Microhos</td>
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<td>Field pH</td>
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<td>Alkalinity, Field (as CaCO3)</td>
<td>730.</td>
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<td>0.03</td>
<td>Nickel, DISS (mg/l.-al)</td>
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<tr>
<td>Silver, DISS (mg/l.-as Ag)</td>
<td>0.002</td>
<td>Lead, DISS (mg/l.-as Pb)</td>
<td>0.04</td>
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<tr>
<td>Boron, DISS (mg/l.-as B)</td>
<td>0.05</td>
<td>Strontium, DISS (mg/l.-as Sr)</td>
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<tr>
<td>Cadmium, DISS (mg/l.-as Cd)</td>
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<td>Titanium, DISS (mg/l.-as Ti)</td>
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<tr>
<td>Chromium, DISS (mg/l.-as Cr)</td>
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<td>Vanadium, DISS (mg/l.-as V)</td>
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<tr>
<td>Copper, DISS (mg/l.-as Cu)</td>
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<td>Lithium, DISS (mg/l.-as Li)</td>
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<td>Molybdenum, DISS (mg/l.-as Mo)</td>
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REMARKS: FILTER BROWN SILT * WATER CLOUDY
JOHN G. HIGHT PRES.

EXPLANATION: mg/l = MILLIGRAMS PER LITER, ug/l = MICROGRAMS PER LITER, mg/l = MILLILITER PER LITER, FI = FEET, HT = METERS, (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE, TOT = TOTAL.

RESERVOIR: MONTANA 52 WI OW PH AT OTHER
OTHER AVAILABLE DATA:
PROJECT: OTHER FILE NUMBERS:
COST:
LAST EDIT DATE: 23- JUL-81
PROCESSING PROGRAM: F1730P V2 (11/3/81)
PRINTED: 21- MAY-83

PERCENT MEQ/L (FOR PIPER PLOT):
CA mg NA K CL S04 HCO3 Cd
0.2 62.8 3.2 0.8 3.8 16.2 77.7 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8200492
<table>
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<th>Parameter</th>
<th>Value</th>
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<td>Field pH</td>
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<td>Alkalinity, Field Microhos</td>
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<td>Aluminum, Diss (mg/L - Al)</td>
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<td>Nickel, Diss (mg/L - As Ni)</td>
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<td>Silver, Diss (mg/L - Ag)</td>
<td>&lt;0.02</td>
<td>Lead, Diss (mg/L - As Pb)</td>
<td>&lt;0.04</td>
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<tr>
<td>Boron, Diss (mg/L - B)</td>
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<td>Yttrium, Diss (mg/L - As Y)</td>
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<td>Lithium, Diss (mg/L - Li)</td>
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<td>Holobrome, Diss (mg/L - Mo)</td>
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REMARKS: WATER CLEAR * TASTE AND SMELL OF SILTY FILTER
OWNERS ADDRESS SAND COULEE

EXPLANATION: MG/L = MILLIGRAMS PER LITER, USG/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER, FT = FEET, MT = METERS, (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED, TR = TOTAL RECOVERABLE, TOT = TOTAL.

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT:                         COST:                        
LAST EDIT DATE:  23 JUL 82                        
PROCESSING PROGRAM: F1730P V2 (11/3/81)    PRINTED:  27 MAY 83

PERCENT MEQ/L (FOR PIPER PLOT)
CA  Mg  Na  K  Cl  SO4  HCO3  CO3
57.6 34.3 7.2 0.9 1.6 39.0 58.6 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8200493

C-50
<table>
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<td>Potassium (K)</td>
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<td>Sodium (Na)</td>
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<tr>
<td>Chloride (Cl)</td>
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<tr>
<td>Sulfate (SO4)</td>
<td>0.02 mg/L</td>
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</tr>
<tr>
<td>Nitrate (NO3)</td>
<td>0.0 mg/L</td>
<td></td>
</tr>
<tr>
<td>Carbonate (CO3)</td>
<td>0.0 mg/L</td>
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<tr>
<td>Hydroxide (OH)</td>
<td>0.0 mg/L</td>
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**EXPLANATION:**
- **Ca/L = Milligrams per Liter**
- **C/H = Chloride (mg/L)**
- **SO4 = Sulfate (mg/L)**
- **NO3 = Nitrate (mg/L)**
- **CO3 = Carbonate (mg/L)**
- **OH = Hydroxide (mg/L)**

**CALCULATION:**

**TEMPERATURE:**

**PREDICTED TEMPERATURE:**

**STRAIN:**

**REMARKS:**

**CATIONS:**

**ANION BALANCE:**

**IONIC STABILITY INDEX:**

**SATURATION INDEX:**
STATE: MONTANA
COUNTY: CASCADE
LATITUDE: 47°22'42"N
LONGITUDE: 110°11'30"W
TOPOGRAPHIC MAP: SOUTH EAST GREAT FALLS 7.1
STATION ID: 472242111113001
LAND SURFACE ALTITUDE: 3600 FT
SUSTAINED YIELD: 0.6 GPM
YIELD HEAVY METHOD: BUCKET/STOPWATCH
TOTAL DEPTH OF WELL: 100.0 FT (E)
SAMPLE HANDLE: CASING DIAMETER
COMPLETION TYPE: PERFORATION INTERVAL

SAMPLING SITE: LAROCQUE, 1.2 MI SW OF SAND COULEE

GEOLGIC SOURCE: CASCAD1N

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<td>SODIUM</td>
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<td>MANGANESE</td>
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<td>0.42</td>
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<tr>
<td>SILICA</td>
<td>8.5</td>
<td>0.12</td>
<td>8.5</td>
<td>0.04</td>
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</table>

TOTAL CATIONS: 9.71  TOTAL ANIONS: 8.63

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA): 0.35

LABORATORY FH: 7.51  TOTAL HARDNESS AS CACO3: 392.04
FIELD WATER TEMPERATURE: 63.0  TOTAL ALKALINITY AS CACO3: 333.01
CALCULATED DISSOLVED SOLIDS: 639.19  RYZNAR STABILITY INDEX: 0.02
LAB SPEC. COND. (MICROMHOS/CH): 765.6  LANGFRIER SATURATION INDEX: 0.44

PARAMETER | VALUE | PARAMETER | VALUE
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<td>TEMPERATURE, AIR (°C)</td>
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<td>CONDUCTIVITY, FIELD MICROMHOS</td>
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<td>FIELD PH</td>
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<td>ALKALINITY, FIELD CACO3</td>
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<td>&lt;0.03</td>
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<td>SILVER, DISS (MG/L AS AG)</td>
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<td>LEAD, DISS (MG/L AS PD)</td>
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<td>STRONTIUM, DISS (MG/L AS SR)</td>
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<td>TITANIUM DISS (MG/L AS TI)</td>
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<td>ZINC, DISS (MG/L AS ZN)</td>
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<td>ZIRCONIUM DISS (MG/L AS ZR)</td>
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<td>MOLYBDENUM, DISS (MG/L-MO)</td>
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REMARKS: FILTER CLEAN*WATER CLEAR

EXPLANATION: MG/L = MILLIGRAMS PER LITER, USG/L = MICROGRAMS PER LITER, MG/L = MILLICHIQUELENTS PER LITER, FT = FEET, HT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT: 1
LAST EDIT DATE: 30-JUL-02
PROCESSING PROGRAM: F1730P V2 (11/3/01)
PERCENT MEQ/L (FOR PIPER PLOT):
C 46.7
H 45.1
CA K 7.3
Cl 0.9
SO4 1.5
HCO3 16.7
CO3 0.17

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8200495

C-52
MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406) 496-4101
WATER QUALITY ANALYSIS
LAB NO. 0200496
STATE MONTANA
COUNTY CASCADE
LATITUDE: LONGITUDE 47°23'00"N 111°00'59"W
UTH COORDINATES 7N C
TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 7.1
TOPOGRAPHIC MAP SEICEN ISLAND 7.1
GEOLOGIC SOURCE 330MDSN+ 1
DRAINAGE BASIN BR
AGENCY + SAMPLER LAGHURM
BOTTLE NUMBER 11470
DATE SAMPLED 20 JUN-82
TIME SAMPLED 18.45 HOURS
LAB + ANALYST LAGHURM
DATE ANALYZED 16 JUL-82
SAMPLE HANDLING METHOD SAMPLED DUMPED
WATER USE DOMESTIC

SAMPLING SITE: BRIAN GUISTI, S HI SW OF CENTERVILLE
GEOLOGIC SOURCE MONTANA GROUP OR LIMESTONE

CALCIUM (Ca) 89.0
MAGNESIUM (Mg) 42.4
SODIUM (Na) 10.2
POTASSIUM (K) 3.6
IRON (Fe) 0.002
MANGANESE (Mn) 0.001
SILICA (SiO2) 12.4
TOTAL CATIONS 0.51

HARDNESS (CaCO3) 398.75
TOTAL HARDNESS AS CaCO3 398.75
TOTAL ALKALINITY AS CaCO3 176.01
SODIUM ABSORPTION RATIO 0.22
RYZHAR STABILITY INDEX 7.16
LANGFORD SATURATION INDEX 0.14

REMARKS: WATER CLEAR, TASTE & SMELL OK, CLEAN FILTER
OWNERS ADDRESS: STAR RT STOCKETT
EXPLANATION: CaO/L = MILLIGRAMS PER LITER, MgO/L = MICROGRAMS PER LITER, Meq/L = MILLIEQUIVALENTS PER LITER, FT = FEET, MI = METERS, (m) = MEASURED, (F) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE, TOT = TOTAL.

OTHER AVAILABLE DATA

PROJECT: COST:
LAST EDIT DATE: 30 JUL 82 RY: TP TRCS
PROCESSING PROGRAM: F1730P V2 (11/3/81) PRINTED: 27 MAY 83

OTHER FILE NUMBERS:

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0200496
MONTANA BUREAU OF MINES AND GEOLOGY

WATER QUALITY ANALYSIS

UTTLE, MONTANA 59701 (406) 496-4101

LAB NO. 0200497

STATE: MONTANA

COUNTY: CASCADE

LATITUDE-LONGITUDE: 47°24'05"N, 111°09'51"W

SITE LOCATION: 19N 4E 13 ACRE

SOUTHEAST GREAT FALLS 7 E HMG SITE

GEOLOGIC SOURCE: 330 M H

DRAINAGE BASIN: 

AGENCY: SAMPLER: NM#RWG

BOTTLE NUMBER: KAVULLA

DATE SAMPLED: 21-JUL-92

TIME Sampled: 10:40 HOURS

SAMPLE HANDLING:

METHOD Sampled: PUMPED

WAY USE: DOMESTIC

SAMPLING SITE: KAVULLA, GEORGE* SAND COULEE, MT

GEOLOGIC SOURCE: HARRISON GROUP OR LIMESTONE

CALCULATIONS:

MC/L (CA) 111. 5.54 BICARBONATE (HCO3) 206. 4.60

MAGNESIUM (MG) 44.4 3.65 CARBONATE (CO3) 70.0

SODIUM (Na) 13.6 0.57 CHLORIDE (Cl) 9.7 0.27

SULFATE (S) 3.2 0.00 SULFATE (SO4) 236. 4.91

NITRATE (NO3) 0.007 0.00 NITRATE (AS N) 1.07 0.00

MANGANESE (Mn) 0.0004 0.00 FLUORIDE (F) 0.57 0.03

PHOSPHATE (PO4) 12.3 0.00 PHOSPHATE (AS P) 0.57 0.03

TOTAL CATIONS 9.87 TOTAL ANIONS 9.90

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) 0.46

LJABORATORY pH 7.15 TOTAL HARDNESS AS CACO3 450.92

FIELD WATER TEMPERATURE 75.15 TOTAL ALKALINITY AS CACO3 254.75

CALCULATED DISSOLVED SOLIDS 252.74 SODIUM ABSORPTION RATIO 0.28

SUM DISS. CONSTITUENT 252.74 RYZHAR STABILITY INDEX 7.02

LAB SPEC. COND. (MICROMOS/CH) 046.1 LANGIER SATURATION INDEX 0.07

PARAMETER VALUE PARAMETER VALUE

TEMPERATURE, AIR (°C) 75.1 LED (AS CACO3) 245.3 NICKEL, DISS (MG/L AS NI) 0.01

FIELD PH 6.38 ALKALINITY, LED (AS CACO3) 245.3 NICKEL, DISS (MG/L AS NI) 0.01

ALUMINUM, DISS (MG/L-AL) 0.03 LEAD, DISS (MG/L AS P) 0.06

SILVER, DISS (MG/L AS AG) <0.002 LEAD, DISS (MG/L AS P) 0.06

BORON, DISS (MG/L AS B) <0.002 STRONTIUM, DISS (MG/L AS Sr) 0.06

CARBON, DISS (MG/L AS CO) <0.002 TITANIUM DISS (MG/L AS Ti) <0.001

CHROMIUM, DISS (MG/L- CR) 0.004 VANDIUM DISS (MG/L AS V) 0.003

COPPER, DISS (MG/L AS Cu) 0.01 ZINC, DISS (MG/L AS Zn) 0.73

LITHIUM, DISS (MG/L AS Li) 0.02 ZIRCONIUM DISS (MG/L AS Zr) <0.003

MOLYBDENUM, DISS (MG/L-HO) <0.02

REMARKS: FILTER LIGHT BROWN WATER CLOUDY

GEORGE KAVULLA*SAND COULEE, MT

EXPLANATION: MG/L = MILLIGRAMS PER LITER; USG/L = MICROGRAMS PER LITER; MC/L = MILLIEQUIVALENTS PER LITER. FT = FEET, MT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE, TOT = TOTAL.

OTHER AVAILABLE DATA

PROJECT:

COST:

PERCENT MEQ/L (FOR PIPER PLOT)

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0200497

PRINTED: 27 MAY 93

SYMBOL: TP

PERCENT MEQ/L: 50.8

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0200497

C-54
## Water Quality Analysis

**Location:** Montana

**Sampling Site:** Lyman, First House across road from Tracy

**Geologic Source:** Jurassic Undifferentiated

### Sampling Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Calcium (Ca) MG/L</td>
<td>3.54</td>
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<tr>
<td>Magnesium (Mg) MG/L</td>
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<tr>
<td>Sodium (Na) MG/L</td>
<td>0.27</td>
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<td>Potassium (K) MG/L</td>
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<td>Iron (Fe) MG/L</td>
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<td>Manganese (Mn) MG/L</td>
<td>0.004</td>
</tr>
<tr>
<td>Silica (SiO2) MG/L</td>
<td>25.3</td>
</tr>
</tbody>
</table>

### Field Data

- **Temperature, Air (ºC):** 72.1º
- **Field pH:** 7.54
- **Calcium Carbonate (CaCO3):** 35.72%
- **Total Hardness as CaCO3:** 135.72
- **Total Alkalinity as CaCO3:** 415.03
- **Sum of Diss. Constituent:** 1737.03
- **Sodium Absorption Ratio:** 0.33
- **Langler Saturation Index:** 5.13
- **Laboratory PH:** 7.54

### Analytical Data

- **RIYNAR Stabilty Index:** 5.13
- **Langler Saturation Index:** 2.12

### Remarks

- **Filter Clean/Watfr Clear:**** Evelyn Lyman/Sand Coulee, MT

### Explanation

Hg/L = Milligrams per Liter, ug/L = Micrograms per Liter, MgO/L = Milliequivalents per Liter. FT = Feet, MT = Meters. (M) = Measured, (E) = Estimated, (R) = Reported. TR = Total Recoverable. TOT = Total.

**Other Available Data:**

- **Project:** F1730P V2 (11/3/93)
- **Processing Program:** F1730P V2 (11/3/93)
- **Percent Reo/L:** (for 500 PLQ)
- **Ca, Mg, Na, K, Cl, NO3, HCO3, CO3:** 62.0 33.7 4.2 0.5 1.9 68.0 29.3 0.0

**NOTE:** In correspondence, please refer to Lab Number: 80049N

---

**C-55**
MONTANA BUREAU OF MINES AND GEOLOGY
WATER QUALITY ANALYSIS
BUTTE, MONTANA 59701 (406) 496-4101
LAB NO. B200499

STATE MONTANA
COUNTY CASCADE

LATITUDE & LONGITUDE 47°23'46"N 111°00'09"W
SITE LOCATION 19N SF 10*CBD
UTH COORDINATES N 7 E

TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 7 1
* SAMPLE SOURCE WELL

AGENCY & SAMPLER MRRG*HRR
BOTTLE NUMBER NET

DATE SAMPLED: 14-JUL-92
TIME SAMPLED: 12 HOURS

LAB ANALYST MRRG*FA
DATE ANALYZED: 18-JUL-92

SAMPLE HANDLING
METHOD SAMPLER PUMPED
WATER USE DOMESTIC AND STOCK

SAMPLING SITE TERRY NET*. 75 MI NW OF CENTERVILLE
GEOLeGIC SOURCE MADISON GROUP OR LIMESTONE

<table>
<thead>
<tr>
<th>CATION</th>
<th>MG/L</th>
<th>MEQ/L</th>
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<tbody>
<tr>
<td>CALCIUM (CA)</td>
<td>65.5</td>
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<tr>
<td>MAGNESIUM (Mg)</td>
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<td>SODIUM (Na)</td>
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<td>POTASSIUM (K)</td>
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<td>IRON (Fe)</td>
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<td>MANGANESE (Mn)</td>
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<td>0.00</td>
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<tr>
<td>SILICA (SiO2)</td>
<td>15.7</td>
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</tr>
</tbody>
</table>

TOTAL CATIONS | 5.60 |

STANDARD DEVIATION OF ANION: CATION BALANCE (SIGMA) 3.01

LABORATORY pH | 7.68 |
FIELD WATER TEMPERATURE | 12.5 C |
CALCULATED DISSOLVED SOLIDS | 323.46 |
SODIUM ABSORPTION RATIO | 0.19 |
LICKER Lock SATURATION INDEX | 6.03 |

PARAMETER | VALUE | PARAMETER | VALUE
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>TEMPERATURE, AIR (C)</td>
<td>85.7</td>
<td>CONDUCTIVITY,FIELD MICROMhos</td>
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<td>FIELD pH</td>
<td>7.12</td>
<td>ALKALINITY,FIELD (AS CACO3)</td>
<td>23.2</td>
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<td>ALUMINUM, DISS (MG/L-AL)</td>
<td>0.04</td>
<td>NICKEL,DISS (MG/L AS NI)</td>
<td>0.02</td>
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<td>SILVER,DISS (MG/L AS Ag)</td>
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<td>LEAD,DISS (MG/L AS PD)</td>
<td>0.05</td>
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<tr>
<td>BORON,DISS (MG/L AS B)</td>
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<td>STRONTIUM,DISS (MG/L-9R)</td>
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<td>CADMIUM,DISS (MG/L AS Cd)</td>
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<td>TITANIUM DISS(MG/L AS TI)</td>
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<td>CHROMIUM, DISS (MG/L-CR)</td>
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<td>VANADIUM,DISS(MG/L AS V)</td>
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<td>COPPER,DISS (MG/L AS CU)</td>
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<td>ZINC,DISS (MG/L AS ZN)</td>
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<td>LITHIUM,DISS (MG/L AS Li)</td>
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<td>ZIRCONIUM DISS(MG/L AS ZR)</td>
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REMARKS: WATER CLEAR*SMELL AND TASTE OK*SOLID BROWN SPOTS ON FILTER SIT
OWNERS ADDRESS BOX 75 SIGA RT STOCKETI
LAB: Fu CA 76.4, MG 27.9 GIVES 6.51 MEQ CATIONS FOR ---84 SIGMA
EXPLANATION: MG/L = MILLIGRAMS PER LITER, HU/L = MICROGRAMS PER LITER, MEQ/L = MILLIEQUIVALENTS PER LITER. FT = FEET, FT = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE, TOT = TOTAL.

C-56
MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406) 498 4101

WATER QUALITY ANALYSIS
LAB NO. B200500

STATE MONTANA
COUNTY CASCADE
LATITUDE: LONGITUDE 47°22'48"N 111°09'46"W
LATITDE: LONGITUDE 19N 46 12 D34AA
UN COORDINATES 7 N 16 E
DRATAGE BASIN: SOUTHEAST GREAT FALLS 7 1

TOPOGRAPHIC MAP: SOUTHEAST GREAT FALLS 7 1
AGENCY + SAMPLE MARK AJB
DORTE NUMBER: KAJAL A
DATE SAMPLED: 20 JUN 02
TIME SAMPLED: 15:15 HOURS
LAB + ANALYST: MARK AFINA
DATE ANALYZED: 14 JUL 02
SAMPLE HANDLING: PUMPED
WATER USE: DOMESTIC

WATER USE: DOMESTIC

SAMPLING SITE: FAST ACROSS HIGHWAY TRACY 3RD HOUSE ON RIGHT
GEOLUCIC SOURCE: MARISSON GROUP OR LIMESTONE

<table>
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<th>Parameter</th>
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<th>Value</th>
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<td>CALCIUM (Ca)</td>
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<td>SODIUM (Na)</td>
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<td>POTASSIUM (K)</td>
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<td>IRON (Fe)</td>
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<td>CHLORIDE (Cl)</td>
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<td>SILICA (SiO2)</td>
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<td>SULFATE (SO4)</td>
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</table>

TOTAL CATIONS 6.54
TOTAL ANIONS 6.95

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) 0.01

FIELD WATER TEMPERATURE 7.58

LABORATORY pH 7.58

TOTAL HARDNESS AS CACO3 290.35
TOTAL ALKALINITY AS CACO3 191.67

CALCULATED DISSOLVED SOLIDS 387.15
SODIUM ABSORPTION RATIO 0.30

SUM OF DISS. CONSTITUENT 505.73
RYSHAR STABILITY INDEX 7.10

LAB SPEC. COND. (MICROMOS/C M) 617.2
LANGER SATURATION INDEX 0.24

PARAMETER VALUE
TEMPERATURE, AIR (C) 05. F
FIELD pH 7.35
ALUMINUM DISS (MG/L - AL) 0.004
SILVER DISS (MG/L AS AG) 0.003
BORON DISS (MG/L AS B) 0.004
Cadmium DISS (MG/L AS Cd) 0.004
CHROMIUM DISS (MG/L AS Cr) 0.004
COPPER DISS (MG/L AS Cu) 0.004
LITHIUM DISS (MG/L AS Li) 0.004
MOLYBDENUM DISS (MG/L - H2O) 0.02

PARAMETER VALUE
CONDUCTIVITY, FIELD MICROHMS/M 440.
ALKALINITY, FIELD MICROHMS/M 440.
LEAD DISS (MG/L AS Pb) 0.01
STRONTIUM DISS (MG/L AS Sr) 0.73
TITANIUM DISS (MG/L AS Ti) 0.004
VANADIUM DISS (MG/L AS V) 0.016
ZINC DISS (MG/L AS Zn) 0.15

crc DISS (MG/L AS Cr) 0.002

REMARKS: FILTER RUSTY BROWN WATER CLOUDY
RICHARD KUJALA BOX 539 SAND COULEE
LAB: FU CA 00.4, Mg 20.4, NA 12.7 GIVES 6.96 MEQ CATIONS FOR .07 SIGMA
EXPLANATION: HG/L = MILLIGRAMS PER LITER, MG/L = MICROMOS PER LITER, HG/L = MILLIEQUIVALENTS PER LITER, FT = FEET, FT = KETERS, (H) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

QW NA S2 W1 QW FJ AT OTHER

OTHER AVAILABLE DATA

PROJECT: COST:
LAST EXIT DATE: 30- JUL -02
PROCESSING PROGRAM: F 730 P V2 (11/3/01)
PRINTED: 27 MAY 03
PERCENT MEQ/L (FOR PIPE PLOT)
CA 57.0 Mg 33.3 Na 1.0 Cl 50.4 HCO3 40.4 CO3 65.8 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: B200500
MONTANA BUREAU OF MINES AND GEOLOGY
CUTTLE, MONTANA 59701 (406) 496-4101
WATER QUALITY ANALYSIS
LAB NO. 8200501

STATE MONTANA
COUNTY CASCADE
LATITUDE-LONGITUDE 47°26'22"N 111°10'25"W
UTH COORDINATES Z N E
TOPOGRAPHIC MAP GREAT FALLS 7.1
GEOLOGIC SOURCE 330HBSN*
AGENCY & SAMPLER MRRG*FR
BOTTLE NUMBER JOHNSON
DATE SAMPLED 10-JUN-82
TIME SAMPLED 14:05 HOURS
LAB & ANALYST MGFR*NA
DATE ANALYZED 16-JUL-82
SAMPLE HANDLING PUMPED
METHOD SAMPLED FLOW
SAMPLE SITE JOHNSON RANCH 1.75 MI N OF TRACY
WATER USE DOMESTIC AND STOCK
GEOLIGIC SOURCE MADISON GROUP OR LIMESTONE

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<th>Parameter</th>
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<tbody>
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<td>BICARBONATE (HCO3)</td>
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<td>MAGNESIUM (MG)</td>
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<td>CARBONATE (CO3)</td>
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<td>SODIUM (Na)</td>
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<td>CHLORIDE (Cl)</td>
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<tr>
<td>POTASSIUM (K)</td>
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<td>SULFATE (SO4)</td>
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<td>IRON (Fe)</td>
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<td>NITRATE (NO3)</td>
<td>.796</td>
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<td>MANGANESE (MN)</td>
<td>.002</td>
<td>FLUORIDE (F)</td>
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<tr>
<td>SILICA (SiO2)</td>
<td>19.3</td>
<td>PHOSPHATE TOT (PO4)</td>
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<td>TOTAL CATIONS</td>
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<td>TOTAL ANIONS</td>
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<td>STANDARD DEVIATION OF ANION-CATION BALANCE (Sigma)</td>
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LABORATORY PH 7.47
FIELD WATER TEMPERATURE 7.0°C
CALCULATED DISSOLVED SOLIDS 1147.52
SUM OF DISS. CONSTANT 1361.13
LAB SPEC. COND. (MICRONOMS/CM) 1505.0
LAHGLI RE SATURATION INDEX 1.07

PARAMETER VALUE
| TEMPERATURE, AIR (°C) | 27.7 F |
| ALUMINUM, DISS (MG/L-AL) | .06 |
| SILVER, DISS (MG/L-AS) | .011 |
| EDRON DISS (MG/L AS E) | .23 |
| CADMIUM, DISS (MG/L AS CD) | .002 |
| CHROMIUM, DISS (MG/L-CR) | .008 |
| LITHIUM, DISS (MG/L-AS LI) | .067 |
| MOLYBDENUM, DISS (MG/L-HO) | .02 |

REMARKS: WATER CLEAR TASTE AND SMELL OK FILTER CLEAN
OWNERS ADDRESS STAR ST SAND COULEE

EXPLANATION: MG/L = MILLIGRAMS PER LITER, USG/L = MICROGRAMS PER LITER, HED/L = MILLIEQUIVALENTS PER LITER. FT = FEET, M = METERS. (M) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

OW WA S2 W1 OW S2 AT OTHER

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT:
LAST EDIT DATE: 05-JAN-83
COST:
BY TP TP
PERCENT HED/L (FOR PIPER PLOT)
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<th>CA</th>
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<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>SI04</th>
<th>HCO3</th>
<th>C03</th>
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<td>34.7</td>
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<td>2.1</td>
<td>61.7</td>
<td>36.2</td>
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NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8200501

C-58
<table>
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<th>Parameter</th>
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<tr>
<td>ALUMINUM, DISS (mg/L - Al)</td>
<td>&lt;0.02</td>
<td>NICKEL, DISS (mg/L - Ni)</td>
<td>0.02</td>
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<tr>
<td>SILVER, DISS (mg/L as Ag)</td>
<td>&lt;0.002</td>
<td>LEAD, DISS (mg/L - Pb)</td>
<td>0.006</td>
</tr>
<tr>
<td>BORON, DISS (mg/L as B)</td>
<td>&lt;0.02</td>
<td>STRONTIUM, DISS (mg/L - Sr)</td>
<td>0.009</td>
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<tr>
<td>CADMIUM, DISS (mg/L as Cd)</td>
<td>&lt;0.002</td>
<td>TITANIUM, DISS (mg/L - Ti)</td>
<td>0.001</td>
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<tr>
<td>CHROMIUM, DISS (mg/L - Cr)</td>
<td>&lt;0.002</td>
<td>VANADIUM, DISS (mg/L - V)</td>
<td>0.001</td>
</tr>
<tr>
<td>COPPER, DISS (mg/L as Cu)</td>
<td>&lt;0.02</td>
<td>ZINC, DISS (mg/L as Zn)</td>
<td>0.001</td>
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<tr>
<td>LITHIUM, DISS (mg/L as Li)</td>
<td>&lt;0.007</td>
<td>MOLYBDENUM, DISS (mg/L - Mo)</td>
<td>&lt;0.02</td>
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</table>

**Remarks:**

- WATER CLEAR: TASTE & SMELL OK. CLEAN FILTER.
- OWNERS ADDRESS: Star Rt Stockett
- LAB: Fu CA 59.3, Hg 27.7 GIVES 5.64 mg CATIONS FOR .13 SIGMA.

**Explanation:**

- mg/L = MILLIGRAMS PER LITER, ug/L = MICROGRAMS PER LITER, mg/L = MILLIEQUIVALENTS PER LITER.
- FT = FEET, MT = METERS, (M) = MEASURED, (F) = ESTIMATED, (R) = REPORTED.
- TV = TOTAL RECOVERABLE, TV = TOTAL.

**Other available data:**

**Project:**
- COST:
- LAST EDIT DATE: 05-JAN-03
- PROCESSING PROGRAM: f1730p v2 (11/3/01)
- PERCENT MEO/L (FOX FILTER PLOT):
- CA 49.0, NA 5.0, OH 50.4, HCO3 0.03
- OTHER FILE NUMBERS:

**Note:** In correspondence, please refer to lab number: 0000000.
MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406) 494-4101
LAB NO. B200503

STATE MONTANA
COUNTY CASSIDY

LATITUDE-LONGITUDE 47°19'58"N 111°10'41"W SITE LOCATION 18N 4E 11 AAAC
UTM COORDINATES Z N E
GRID M E H

TOPOGRAPHIC MAP STOCKETT 7 1/2' STATION ID 4/19591 11104101
GEOLGIC SOURCE 217KOTHX211MHMS *
DRAINAGE BASIN BE LAND SURFACE ALTITUDE 4070, 7.2 FT
AGENCY & SAMPLER MONA R R
BOTTLE NUMBER D. YUREK
DATE SAMPLED 21-JUN-82 YIELD MEAS METHOD BUCKET/STOPWATCH
TIME SAMPLED 16:00 HOURS TOTAL DEPTH OF WELL 131, 7.2 FT (R)
LAB & ANALYST HMRGKFXNA CASING TYPE STEEL
DATE ANALYZED 16-JUL-82 COMPLETION TYPE 03
SAMPLE HANDLING PUMPED PERFORATION INTERVAL
METHOD SAMPLED DOMESTIC AND STOCK
WATER USE

SAMPLING SITE DONALD YUREK RANCH 1.75 MI SW OF STOCKETT

GEOLGIC SOURCE KOTENAT FORMATION

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<th>MG/L</th>
<th>MG/L</th>
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<td>3.38</td>
<td>RICARBONATE (HCO3)</td>
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<tr>
<td>MAGNESIUM (Mg)</td>
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<td>CARBONATE (CO3)</td>
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<td>SODIUM (Na)</td>
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<td>POTASSIUM (K)</td>
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<td>IRON (Fe)</td>
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<td>MANGANESE (Mn)</td>
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<td>FLUORIDE (F)</td>
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<td>SILICA (SiO2)</td>
<td>7.5</td>
<td>0.00</td>
<td>PHOSPHATE TOT (AS P)</td>
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TOTAL CATIONS 7.47 TOTAL ANIONS 7.38

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) 0.41

LABORATORY PH 7.37 TOTAL HARDNESS AS CACO3 319.12
FIELD WATER TEMPERATURE 12.1 C TOTAL ALKALINITY AS CACO3 305.02
CALCULATED DISSOLVED SOLIDS 348.69 SODIUM ABSORPTION RATIO 0.66
SUM OF DISS. CONSTITUENT 552.39 RYHAR STABILITY INDEX 7.10
LAB SPEC. COND. (MICROMOSH/CH) 657.1 LANGHER SATURATION INDEX 0.19

PARAMETER VALUE VALUE
| TEMPERATURE, AIR (C) | 84. F | CONDUCTIVITY FIELD MICROMOSH | 677 |
| ALUMINUM DISS (MG/L-AL) | <0.03 | ALKALINITY FLD (AS CACO3) | 324 |
| SILVER DISS (MG/L-AG) | <0.002 | NICKEL DISS (MG/L-AG) | 0.01 |
| BORON DISS (MG/L-B) | <0.25 | LEAD DISS (MG/L-LE) | 0.04 |
| CADMIUM DISS (MG/L-CR) | <0.002 | STRONTIUM DISS (MG/L-SR) | 0.07 |
| CHROMIUM DISS (MG/L-CR) | <0.002 | TITANIUM DISS (MG/L-Ti) | 0.001 |
| COPPER DISS (MG/L-CU) | <0.002 | VANADIUM DISS (MG/L-V) | 0.01 |
| LITHIUM DISS (MG/L-LI) | <0.047 | ZINC DISS (MG/L-Zn) | 0.001 |
| MOLYBDENUM DISS (MG/L-MO) | <0.02 | ZIRCONIUM DISS (MG/L-Zr) | 0.003 |

REMARKS: WATER CLOUDY & TASTE AND SMELL OK*LIGHT BROWN SILTY FILTER.
OWNERS ADDRESS STOCKETT*RUNNING WATER CLEAR FOR 7 Min*FLOW 16.4 GPH* WATER
BECAME VERY CLOUDY AND FLOW 7.2 GPM FOR 8 Min*WATER CLEARED

EXPLANATION: MG/L = MILLIGRAMS PER LITER, UG/L = MICROMGRAMS PER LITER, MG/L = MILLIEQUIVALENTS PER LITER. FT = FEET, FT = METERS. (M) = MEASURED, (R) = ESTIMATED, (R) = REPORTED, TR = TOTAL RECOVERABLE, TOT = TOTAL.

OW NA 52 MI ON PN AT OTHER
OTHER AVAILABLE DATA Y
OTHER FILE NUMBERS:

PROJECT: 30-JUL-82 COST:
LAST EDIT DATE: 30-JUL-82 BY: TP *RCS

PERCENT MG/L (FOR PIPE PLOT)
CA H6 K CL SO4 CO3
45.3 40.1 12.4 2.5 1.1 1.0 0.0 0.0

NOTE: IN CORES respond, please refer to LAB NUMBER: B200503

C-60
MONTANA BUREAU OF MINES AND GEOLOGY
DUTE, MONTANA 59701 (406) 496-4101
WATER QUALITY ANALYSIS
LAB NO. 0200504

STATE MONTANA
COUNTY CASCADE
LATITUDE-LONGITUDE 47°24'.34"N 111°09'.30"W
SITE LOCATION 12N 14E 14 AARD
UTM COORDINATES Z N E 3
TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 7 1
GEOLOGIC SOURCE 3 3
DRAINAGE BASIN KJ
AGENCY & SAMPLER MRMG&WDP
BOTTLE NUMBER LYNCH
DATE SAMPLED 18-JUN-02
TIME SAMPLED 09:30 HOURS
LAB & ANALYST MRMG&FNA
DATE ANALYZED 14-JUL-02
SAMPLE HANDLING PUMPED
METHOD SAMPLER PUMPPED
WATER USE DOMESTIC

SAMPLING SITE MIDDLE OF FIELD & OFF TRACY SAND COUETT RD
GEOLOGIC SOURCE

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TOTAL CATIONS 7.62
TOTAL ANIONS 7.69

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) 0.31

LABORATORY pH 7.49
FIELD WATER TEMPERATURE 43.53
CALCULATED DISSOLVED SOLIDS 569.06
SUM OF DISS. CONSTITUENT 575.1
LAB SPEC.COMD. (MICROMHOS/CM) 0.27

PARAMETER                 VALUE
CLODUCTY, FIELD MICROMHOS 770.0
ALKALINITY,FU(LH AS CACO3) 216.0
NICKEL,DISS (MG/L AS NI)    <.01
LEAD,DISS (MG/L AS PO)      <.04
STRAINUM,DISS (MG/L AS TI)  .09
TIATINIUM,DISS (MG/L AS TI) .028
VANADIUM,DISS(MG/L AS V)    <.001
ZINC,DISS (MG/L AS ZN)      1.14
ZINC,DISS (MG/L AS ZR)      <.003

PARAMETER                 VALUE
ALUMINUM, DISS (MG/L-AL)   <.03
SILVER,DISS (MG/L AS AG)   <.002
BORON,DISS (MG/L AS B)     <.02
CadmUM,DISS (MG/L AS Cd)   <.002
CHROMIUM,DISS (MG/L AS CR) <.002
COPPER,DISS (MG/L AS Cu)   <.007
LITHIUM,DISS(MG/L AS Li)   <.002
MOLYBDENUM,DISS(MG/L-HO)   <.02

REMARKS: FILTER CLEAN*WATER CLEAR
Renee Lynch*Box 71*Sand Coulett*Log Unknown*Drilled March 1944

EXPLANATION: Mg/L = MILLIGRAMS PER LITER, ug/L = MICROGRAMS PER LITER, mg/L
MILLIEQUIVALENTS PER LITER. FT = FEET, FT = METERS. ( H) = KFASURF, ( I) =
ESTIMATED, ( R) = REPORTED. TR = TOTAL RECOVERABLE, TT = TOTAL.

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:
PROJECT:    COST: 30-JUL-02  TR $856
LAST EDIT DATE: 30-JUL-02  PRINTED: 27-MAY-03
PROCESSING PROGRAM: F1730P V2 (11/3/01)

PERCENT MEQ/L (FOR PAPER PLOT)
Ca Mg Na K Cl Na2SO4 HCO3 CO3
57.5 34.1 7.5 0.2 3.4 40.4 56.2 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8200504

C-61
MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA BUREAU OF MINES AND GEOLOGY
STATE MONTANA
LATITUDE-LONGITUDE 47°23'05"N 111°11'40"W
UTO COORDINATES 7 N 93 E
TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 71
GEOLOGIC SOURCE WELLS 217KO8M12051062506
DRAINAGE BASIN BB
AGENCY / SAMPLER MARSHALL & JOHNSON
BOTTLE NUMBER SWARTZB
DATE Sampled 22-JUN-82
TIME Sampled 16:30 HOURS
LAB 1 ANALYST MARSHALL & JOHNSON
DATE Analyzed 16-JUL-82
METHOD Sampled PUMPED
WATER USE DOMESTIC
SAMPLING SITE SWARTZENBURGER, GERALD
GEOLOGIC SOURCE KOOTENAI FORMATION

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<td>SILVER, DISS (MG/L AS AG)</td>
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<td>LEAD, DISS (MG/L AS Pb)</td>
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TOTAL CATIONS 9.36 TOTAL ANIONS 9.44

GREAT SWARTZENBURGER, GERALD
GEOLOGIC SOURCE KOOTENAI FORMATION

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REMARKS: FILTER COVERED WITH SILT * WATER CLOUDY
GERALD SWARTZENBURGER * SAND COULEE MT

EXPLANATION: MG/L = MILLIGRAMS PER LITER, MG/L = MICROGRAMS PER LITER, MG/L = MILLIEQUIVALENTS PER LITER, FT = FEET, MT = METERS, (H) = MEASURED, (E) = ESTIMATED, (R) = REPORTED, TR = TOTAL RECOVERABLE, TO = TOTAL.

OTHER AVAILABLE DATA

OTHER FILE NUMBERS:

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<td>PERCENT MEQ/L (FOR PIPER PLOT)</td>
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<td>24.0 69.2 5.1 0.9 1.2 5.4 93.4 0.0</td>
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NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0200505

Ready
### Water Quality Analysis

**Sample Information**
- **State**: Montana
- **County**: Cascade
- **Location**: Site 10, W.S.E. 18 RECS
- **Sample Source**: Well
- **Surface Altitude**: 3475.0 ft
- **Total Depth of Well**: 1100 ft (R)
- **Casing Diameter**: 8 in (R)
- **Completion Type**: PVC

**Sample Site**: Centerville Senior Citizens Center

**Geologic Source**: Madison Group or Limestone

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**Standard Deviation of Anion-Cation Balance (Sigma)**

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<td>Calcium</td>
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**Laboratory Data**

- **Field Water Temperature**: 6.52°C
- **Total Alkalinity**: 332.17 mg/L
- **Sodium Adsorption Ratio**: 0.30
- **Water Use Sampling Site**: 1.00
- **Analyzed Date**: 1/19/83
- **Handling Method**: Pumped
- **Water Use Domestic**: Yes

**Remarks**: White foam coats steel tape, drifts to hard white ppt, filter clean

**Explanation**: mg/L = milligrams per liter, ug/L = micrograms per liter, meq/L = milliequivalents per liter, ft = feet, m = meters, (M) = measured, (E) = estimated, (R) = reported, (T) = total recoverable, (T) = total

**Other Available Data**

- **Project**: Cost:
- **Last Edit Date**: 02-FEB-83
- **Processing Program**: F173DP V2 (11/3/81)
- **Percent Meq/L (for piper flow)**

**Notes**: In correspondence, please refer to Lab Number: 0300001
MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406) 476-4101

WATER QUALITY ANALYSIS
LAB NO. 8300002

STATE: MONTANA
COUNTY: CASCADE
LATITUDE-LONGITUDE: 47°02’52”N 111°00’55”W
SITE LOCATION: 19N 5E 7*BIDC
UTM COORDINATES: 794530 4270131
MRAG SITE: 7
TOPOGRAPHIC MAP: SOUTHEAST GREAT FALLS 7.1
GEOLoGIC SOURCE: 330MDSN*
DRAINAGE BASIN: E
AGENCY + SAMPLE: HRMG*MRM
BOTTLE NUMBER: GHREL-2
DATE SAMPLED: 30-DEC-82
TIME SAMPLED: 11:30 HOURS
LAB + ANALYST: HRM*MRN
DATE ANALYZED: 19-JAN-83
SAMPLE HANDLING METHOD: SAMPLED PUMPED
WATER USE: STOCK

SAMPLED SITE: HEAL WELL-2 TRACY
GEOLoGIC SOURCE: MADISON GROUP OR LIMESTONE

CALCIUM (Ca) 97.3 4.86 RICARBONATE (HCO3) 233.8 3.83
MAGNESIUM (Mg) 89.4 7.35 CARBONATE (CO3) 0.1
SODIUM (Na) 22.0 0.26 CHLORIDE (Cl) 12.8 0.39
POTASSIUM (K) 8.0 0.21 SULFATE (SO4) 428.0 0.91
IRON (Fe) <0.002 NITRATE (As) 1.53 0.13
MANGANESE (Mn) <0.03 0.00 FLUORIDE (F) 0.55 0.03
SILICA (SiO2) 8.7 PHOSPHATE TOT (As F) 10.9 0.3

TOTAL CATIONS 13.37 TOTAL ANIONS 13.29
STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA) -0.27
LABORATORY PH 7.56 TOTAL HARDNESS AS CACO3 610.93
FIELD WATER TEMPERATURE 7.3°C TOTAL ALKALINITY AS CACO3 191.76
CALCULATED DISSOLVED SOLIDS 784.76 SODIUM ABSORPTION RATIO 0.39
SUM OF DISS. CONSTITUENT 203.38 RYAN STABILITY INDEX 6.20
LAB SPEC. COND. (MICROMOS/CM) 1115. LANGIER SATURATION INDEX 0.33

PARAMETER VALUE PARAMETER VALUE
TEMPERATURE, AIR (C) 30.0 F CONDUCTIVITY, FIELD MICROMOS 1151.
FIELD PH 6.00 ALKALINITY, FILR (AS CACO3) 205.00
ALUMINUM, DISS (MG/L AL) <0.03 NICKEL, DISS (MG/L AS NI) <0.01
SILVER, DISS (MG/L AS AG) <0.02 LEBUR, DISS (MG/L AS Pb) <0.04
BORON, DISS (MG/L AS B) <0.10 STRONIUM, DISS (MG/L-SE) <0.01
CARBONATE, DISS (MG/L AS CO3) <0.02 TITANIUM, DISS (MG/L AS Ti) <0.10
CHROMIUM, DISS (MG/L AS Cr) <0.02 VANADIUM, DISS (MG/L AS V) <0.02
COBALT, DISS (MG/L AS CO) <0.08 ZINC, DISS (MG/L AS ZN) <0.015
LITHIUM, DISS (MG/L AS Li) <0.053 ZIRCONIUM, DISS (MG/L AS ZR) <0.003
MOLYBDENUM, DISS (MG/L-MO) <0.02 ARSENIC, DISS (UG/L AS AS) .3

REMARKS: CLEAR FILTER A LITTLE YELLOWISH, VERY FINE SILT ON FILTER AND SAND

EXPLANATION: MG/L = MILLIGRAMS PER LITER; UG/L = MICROGRAMS PER LITER; MG/L
MILLIEQUIVALENTS PER LITER; FT = FEET; MI = METERS. (M) = MEASURED; (F) =
ESTIMATED; (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL

OW WA SB WI OW FW AT OTHER

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT: 102-FEB-83
LAST LIST DATE: 11/3/81
PROCESSING PROGRAM: F173OF V2
PERCENT HCO3/L (FOR PIPER PLOT)
CA MG NA K CL SO4 HCO3 CO3
36.7 55.0 7.2 1.5 3.0 67.7 72.2 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8300002

C-64
MONTANA BUREAU OF MINES AND GEOLGY
DUFIF, MONTANA 59701 (406)496-4101
WATER QUALITY ANALYSIS
LAB NO. 6320000

STATE MONTANA
COUNTY CASCAD
LATITUDE LONGITUDE 4725.21'N 11105.16'W
œ SITE LOCATION 12H 04E 13 AAM
UTH COORDINATES N E
œ MEG Site
TOPOGRAPHIC MAP GREAT FALLS 12
œ DR赶ING BASIN
AGENCY + SAMPLE HARRISON
œ DILL SAMPLED 19 DEC 02
BOTTLE NUMBER MINE PIT
œ TIME SAMPLED 15:00 HOURS
LAB + ANALYST HARRISON
DATE ANALYZED 19 JAN 83
SAMPLE HANDLING PUMPED
METHOD SAMPLED PUMPED
WATER USE DOMESTIC

SAMPLING SITE M NAVAHA STAR RT SAND CouLEEN OF 7 SIDING
GEOLOGIC SOURCE MARSH LWOOD GROUP OR LIMESTONE

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LAPARATORY PH | 7.4 |
FIELD WATER TEMPERATURE | 3.76 C |
CALCULATED DISSOLVED SOLIDS | 549.44 |
SUM OF DISS. CONSTITUENT | 891.20 |
LAB SPEC. COND. (MICROMOS/CH) | 829.3 |
LANGLE SATURATION INDEX | 0.27 |

REMARKS: INITIAL TAP WATER RUSTY COLOR FOR 5 SEC; FILTER ALSO RUST COLORED

EXPLANATION: Mg/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, HGG/L = MILLIEQUIVALENTS PER LITER. FT = FEET, FT = METERS. (M) = MEASURED, (L) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT:
LAST EDIT DATE: 01 MAR 03
PROCESSING PROGRAM: F1730FP V2 (11/3/81)
PRINTED: 27 MAY 03

PERCENT HGG/L (FOR PIPER DIAGRAM)

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NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 6320000

C-65
Figure C-3. Location of acid discharge points and total dissolved solids in Madison wells.
APPENDIX D

SURFACE WATER DATA
FIGURE D 1  Diagram of weir at gaging stations AF01, CF02, and CF03.

The discharge rating equations are:

For gage heights (g.h) < 1.12 ft: \( Q(\text{ft}^3/\text{sec}) = 0.6672 \times (\text{g.h})^{0.5} \)

For gage heights (g.h) \( \geq 1.12 \text{ ft} \): \( Q(\text{ft}^3/\text{sec}) = (2.49 \times (\text{g.h} - 0.8176)^{0.8}) \times 0.7545 \)
Figure D-2. Streamflow stations established for seepage profiling.
Figure D-3. Streamflow quantities measured in 1981.
Figure D-4. Measurements of pH at the time of streamflow measurement.
Specific Conductance
Number Five Creek 3/4/81
All other stations 8/25/81
8/26/81

Figure D-5. Specific conductance values at the time of streamflow measurement.
STREAM WATER QUALITY DATA
MONTANA BUREAU OF MINES AND GEOLOGY
STATE MONTANA
COUNTY CASCADE
LATITUDE 47°32'41"N   LONGITUDE 112°04'43"W
UTM COORDINATES 27T H5209420 1482799
TOPOGRAPHIC MAP: SOUTHEAST GREAT FALLS 7.5
AGENCY: SAFFER MINE MINE
DATE SAMPLED: 15 JUL 81
TIME SAMPLED: 14:00 HOURS
LAB & ANALYST: MENGHA
DATE ANALYZED: 15 JUL 81
SAMPLE HANDLING: 4220
METHOD SAMPLED: 6KAR
WATER USE: UNUSES

SAMPLING SITE BAND COULEE MINING DISTRICT NO. 11
MISSOURI RIVER BETWEEN HARRAS RIVER AND LITTLE PRICKLY POPPY

WATER QUALITY ANALYSIS
LAB NO. 8101086

CALCIUM (Ca)   164.  0.10 BICARBONATE (HCO3)   1.9
MAGNESIUM (Mg)  137.  1.17 CARBONATE (CO3)   0.1
SODIUM (Na)     234.  1.02 CHLORIDE (Cl)      0.9
POTASSIUM (K)   3.3  0.06 SULFATE (SO4)     3940.  0.01
IRON (Fe)       0.4  0.78 NITRATE (NO3)   2.12  0.15
MANGANESE (Mn)  1.46 0.05 FLUORIDE (F)    7.74  0.36
SILICA (SiO2)   55.4                                      TOTAL ANIONS 62.77

TOTAL CATIONS 43.39

STANDARD DEVIATION OF ANALYT CATION BALANCE (SIGMA)

LAB OBSERVED: 4243.

PARAMETER       VALUE
TEMPERATURE, c   25
FIELD pH         3.60
NICKEL, DISS (mg/l as Ni) 1.81
LEAD, DISS (mg/l as Pb) 0.04
STREND, DISS (mg/l as Sr) 1.07
TITANIUM, DISS (mg/l as Ti) 0.014
VANADIUM, DISS (mg/l as V) 0.044
LITHIUM, DISS (mg/l as Li) 0.012
IRON, TR (mg/l as Fe) 421.0
ALUMINUM, TR (mg/l as Al) 230.0
ZINC, DISS (mg/l as Zn) 7.72

TOTAL CATIONS 50.29

MG/L  MG/L

PARAMETER       VALUE
CONDUCTIVITY, TET (MICROMHo/CM) 3948.
SODIUM ABSORPTION RATIO 0.33
RYSHAR STABILITY INDEX

PARAMETER       VALUE
AGILITY, TOT (MG/L AS CaCO3) 302.0
ZIRCONIUM, DISS (mg/l as Zr) 0.1

OTHER AVAILABLE DATA

REMARKS: WATER MURKY AND RUSTY COLOR
NO NAME CREEK DATING STATION MG-01
LAB: MG 50.88 MG/L GIVES 50.25 MG/L. CATIONS GIVES 1.3 (SIGMA)

EXPLANATION: MG/L = MILLIGRAMS PER LITER, MG/L = MICROGRAMS PER LITER, MG/L = MILLIEQUIVALENTS PER LITER, FT = FEET, MT = METERS. (H) = MEASURED, (E) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

TM WA 52 WI GW PH AT

OTHER FIELD NUMBERS:

PROJECT: Y
LAST EDIT DATE: 19 FEB 82
PROCESSING PROGRAM: F1730V02 (1/3/01) PRINTER: 27 MAY 83

PERCENT MG/L (FOR PIPER PLOT)
Ca  39.3
Mg  54.8
Na  5.0
K  0.4
Cl  0.3
SO4  99.7
NO3  0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8101086

D-6
**WATER QUALITY ANALYSIS**

**LAB NO. 3101511**

**STATE: MONTANA**

**COUNTY: CASCADE**

**SITE LOCATION: 19N 5E 17 AAGA**

**MAP REFERENCE: CF-03**

**MOUNTAIN RANGE: SOUTHEAST GREAT FALLS**

**STATION ID: 723311032401**

**SAMPLING POINT: LAND SURFACE ALTITUDE 3464 FT, < 1 FT**

**FLOW RATE: 375 GPM**

**STAFF GAGE: 17.84**

**DEPTH TO SAMPLE: 1.1 FT (M)**

**STREAM WIDTH: UNUSED**

**SAMPLING SITE: RIVER BETWEEN MARLIS RIVER AND LITTLEプリキサイト**

**DRAINAGE BASIN: MISSOURI RIVER BETWEEN MARLIS RIVER AND LITTLEプリキサイト**

**METHOD SAMPLED: 4220**

**METHOD SAMPLED: 4220**

**WATER USE: UNUSED**

---

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CALCIUM (CA)</strong></td>
<td>115</td>
<td><strong>BICARBONATE (HCO3)</strong></td>
<td>7.24</td>
</tr>
<tr>
<td><strong>MAGNESIUM (MG)</strong></td>
<td>58.0</td>
<td><strong>CARBONATE (CO3)</strong></td>
<td>4.77</td>
</tr>
<tr>
<td><strong>SODIUM (NA)</strong></td>
<td>15.2</td>
<td><strong>CHLORIDE (CL)</strong></td>
<td>0.66</td>
</tr>
<tr>
<td><strong>POTASSIUM (K)</strong></td>
<td>4.9</td>
<td><strong>SULFATE (SO4)</strong></td>
<td>0.13</td>
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<tr>
<td><strong>IRON (Fe)</strong></td>
<td>10.1</td>
<td><strong>NITRATE (NO3)</strong></td>
<td>0.54</td>
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<tr>
<td><strong>MANGANESE (Mn)</strong></td>
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<td><strong>FLUORIDE (F)</strong></td>
<td>0.03</td>
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<tr>
<td><strong>SILICA (SiO2)</strong></td>
<td>16.6</td>
<td><strong>PHOSPHATE TOT (PO4)</strong></td>
<td>1.43</td>
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<tr>
<td><strong>TOTAL CATIONS</strong></td>
<td>13.37</td>
<td><strong>TOTAL ANIONS</strong></td>
<td>10.25</td>
</tr>
</tbody>
</table>

**STANDARD DEVIATION OF ANION–CATION BALANCE (SIGMA):**

**LABORATORY PH: 3.35**

**FIELD WATER TEMPERATURE: 19.6 C**

**TOTAL HARDNESS AS CaCO3: 600.79**

**CALCULATED DISSOLVED SOLIDS: 0.27**

**SODIUM ABSORPTION RATIO: 0.15**

**RAZNOV STABILITY INDEX: 1567**

**LANGELI SATURATION INDEX: 13.17**

**PARAMETER: TEMPERATURE, AIR (C): 22.1 C**

**CONDUCTIVITY, FIELD MICROMOS: 1267.**

**FIELD PH: 3.42**

**ALUMINUM, DISS (MG/L-AL): 0.02**

**LEAD, DISS (MG/L-LE): 1.04**

**Boron, DISS (MG/L-B): 0.05**

**STRONTIUM, DISS (MG/L-SR): 0.42**

**CHromium, DISS (MG/L-Cr): 0.01**

**TITANIUM, DISS (MG/L-TI): 0.027**

**COPPER, DISS (MG/L-Cu): 0.000**

**YANADAM, DISS (MG/L-V): 0.012**

**LITHIUM, DISS (MG/L-Li): 0.005**

**ZINC, DISS (MG/L-Zn): 0.007**

**ZIRCONIUM, DISS (MG/L-Zr): 0.007**

**SELENIUM, DISS (MG/L-Se): 0.07**

**REMARKS:** WATER IS BRIGHT ORANGE * ABUNDANT FE HYDROXIDE FLOCCULENT *

**HMBG GAGING STATION CF-03 * 1 FILTER USED * FRESH FLOC BELOW DE-01**

**PERCENT H2O/L: 71**

**EXPANSION: Hg/L = MILLIGRAMS PER LITER, Mg/L = MICROGRAMS PER LITER, Hg/SE Milliequivalents PER LITER, FT = FEET, FT = FEET, (H) = MEASURED, (C) = ESTIMATED, (R) = REPORTED**

**OTHER AVAILABLE DATA:**

- **PROJECT:**
- **LAST EDIT DATE:** 17-FEB-92
- **COST:**
- **PROCESSING PROGRAM:** F1730F V2 (11/3/81)
- **PRINTED:** 27-MAY-83

**PERCENT H2O/L: (FOR PIPER PLOT):**

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<th>Parameter</th>
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<tbody>
<tr>
<td>Ca</td>
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<tr>
<td>Mg</td>
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<tr>
<td>Na</td>
<td>5.2</td>
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<tr>
<td>K</td>
<td>1.0</td>
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<tr>
<td>Cl</td>
<td>1.1</td>
</tr>
<tr>
<td>SO4</td>
<td>78.9</td>
</tr>
<tr>
<td>HCO3</td>
<td>0.0</td>
</tr>
<tr>
<td>CO3</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**NOTE:** IN CORRESPONDENCE. PLEASE REFER TO LAB NUMBER: 8101511 D-7
**MONTANA BUREAU OF MINES AND GEOLOGY**
**BUTTE, MONTANA 59701 (406) 426 4101**

**WATER QUALITY ANALYSIS**
**LAB NO. 0101512**

**STATE MONTANA**
**COUNTY CASSIDY**

**CITY LOCATIONS**
**STATION 1**
**SAMPLE SIZE: 3.2**
**SWELLING ALTITUDE: 29.25**
**WATER FLOW RATE: 1.23**
**FLOWS: 0.06**
**SAMPLE TIME: 10:10**

**DRY BAG**
**SAMPLE LOCATION: 1220**
**NUMBER OF SAMPLES: 06**

**DATE SAMPLED:** 29 AUG 01
**LAB ANALYST:** M. ROSENA
**DATE ANALYZED:** 29 AUG 01
**SAMPLE HANDLING:** 1220
**METHOD SAMPLED:** GRAB

**WATER USE:** UNK.

**SAMPLING SITE:** COTTONWOOD CREEK
**FLOW Alloy MONTANA BETWEEN MARIAS RIVER AND TOTLE PIGGSY MILL**

<table>
<thead>
<tr>
<th><strong>BASE</strong></th>
<th><strong>MG/L</strong></th>
<th><strong>MEQ/L</strong></th>
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<tr>
<td>CALCIUM</td>
<td>1.39</td>
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<td>MAGNESIUM</td>
<td>0.28</td>
<td>0.04</td>
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<tr>
<td>POTASSIUM</td>
<td>5.60</td>
<td>0.28</td>
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<tr>
<td>SODIUM</td>
<td>2.40</td>
<td>0.28</td>
</tr>
<tr>
<td>MANAGNESE</td>
<td>4.01</td>
<td>0.28</td>
</tr>
<tr>
<td>SILICA</td>
<td>5.60</td>
<td>0.28</td>
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</table>

**TOTAL CATIONS:** 14.15

**TOTAL ANIONS:** 14.17

**STANDARD DEVIATION OF ANION CATION BALANCE (SIGMA):**

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<thead>
<tr>
<th><strong>PARAMETER</strong></th>
<th><strong>VALUE</strong></th>
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<tr>
<td>TEMPERATURE</td>
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<td>FIELD WATER TEMPERATURE</td>
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<td>FIELD WATER TEMPERATURE</td>
<td>3.64</td>
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**LAB SPEC. COND. (MICROMhos/cm):** 14.79

**LANGFELT SATURATION (MEQ/L):**

<table>
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<tr>
<th><strong>PARAMETER</strong></th>
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<tbody>
<tr>
<td>NICKEL, DISS (MG/L AS NI)</td>
<td>3.33</td>
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<tr>
<td>LEAD, DISS (MG/L AS Pb)</td>
<td>3.04</td>
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<tr>
<td>STROUDINI, DISS (MG/L AS Sr)</td>
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<tr>
<td>TITANIUM, DISS (MG/L AS Ti)</td>
<td>4.01</td>
</tr>
<tr>
<td>VANADIUM, DISS (MG/L AS V)</td>
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<tr>
<td>ZINC, DISS (MG/L AS Zn)</td>
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<tr>
<td>ZIRCONIUM, DISS (MG/L AS Zr)</td>
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<tr>
<td>SODIUM, DISS (MG/L AS Na)</td>
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</table>

**REMARKS:** WATER WAS BRIGHT ORANGE * AMOUNT OF FE HYDROXIDE PRESENT *
**NO. FIVE CREEK FLOW 51 GPM, PH 2.46, S.C. 782 * COTTONWOOD CREEK
**UPSTREAM FLOW 122 GPM, PH 2.56, S.C. 2180 **

**OTHER AVAILABLE DATA**
**OTHER FILE NUMBERS:**

**PROJECT:**
**LAST EDIT DATE:** 19 FEB 82
**PROCESSING PROGRAM:** I1730V12 (11/3/80) **PRINTER:** 27 MAY 83

**PERCENT MEQ/L (FOR PIPER PLOT)**

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<tr>
<th><strong>CA</strong></th>
<th><strong>MG</strong></th>
<th><strong>K</strong></th>
<th><strong>Cl</strong></th>
<th><strong>CO3</strong></th>
<th><strong>HCO3</strong></th>
<th><strong>CO2</strong></th>
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</thead>
<tbody>
<tr>
<td>55.4</td>
<td>30.1</td>
<td>5.4</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**NOTE:** IN CORRESPONDENCE, PLEASE WRITE TO LAB NUMBER: 0101512.
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<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Temperature, air (°C)</td>
<td>18.0</td>
<td>Conductivity, field microh.</td>
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<td>Field pH</td>
<td>2.6</td>
<td>Alum. diss (mg/L as Al)</td>
<td>7.10</td>
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<tr>
<td>Lead, diss (mg/L as Pb)</td>
<td>0.4</td>
<td>Bicarb. diss (mg/L as Ca)</td>
<td>2.18</td>
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<tr>
<td>Strontium, diss (mg/L as Sr)</td>
<td>0.66</td>
<td>Calcium, diss (mg/L as Ca)</td>
<td>0.005</td>
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<tr>
<td>Titanium, diss (mg/L as Ti)</td>
<td>0.32</td>
<td>Sodium, diss (mg/L as Na)</td>
<td>1.10</td>
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<tr>
<td>Vanadium, diss (mg/L as V)</td>
<td>0.015</td>
<td>Copper, diss (mg/L as Cu)</td>
<td>0.20</td>
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<tr>
<td>Zink, diss (mg/L as Zn)</td>
<td>9.19</td>
<td>Lithium, diss (mg/L as Li)</td>
<td>1.9</td>
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<tr>
<td>Chromium, diss (mg/L as Cr)</td>
<td>0.10</td>
<td>Molybdenum, diss (mg/L as Mo)</td>
<td>0.05</td>
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<tr>
<td>Silicium, diss (mg/L as Si)</td>
<td>7.2</td>
<td>Acidity, H₂CO₃ (mg/L)</td>
<td>1.84</td>
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</table>

REMARKS: WATER IS RED BROWN * LARGE PARTICULATE HYDROXIDE FLOCCULENT |
LAB: pH 7.37 MG/L GIVES 53.11 MG CATIONS GIVES 5.11 SIGMA

EXPLANATION: MG/L = MILLIGRAMS PER LITER; UG/L = MICROGRAMS PER LITER; MG/L = MILLIEQUIVALENTS PER LITER; FT = FEET; HT = METERS; (H) = MEASURED; (R) = ESTIMATED; (F) = REPORTED; IR = TOTAL RECOVERABLE; TR = TOTAL |

OTHER AVAILABLE DATA

OTHER FILE NUMBERS:

PROJECT: F1730P V2 (11/3/81) PRINTED: 27 MAY 83

PERCENT eq/l (FOR PIPER PLOT)

CA Mg Na K Cl SO₄ HCO₃ CO₃
48.0 46.2 0.5 0.5 0.8 0.0 1.0

NOTE: If correspondence, please refer to lab number: B101513-90
MONTANA BUREAU OF MINES AND GEOLOGY
WATER QUALITY ANALYSIS
BUTTE-MONTANA 59701 (406) 476-4101
LAB NO. 010544

STATE MONTANA
COUNTY CASCADIA

LATITUDE LONGITUDE 47°26'50"N 111°01'30"W
UTM COORDINATES 824190 4780758

TOPOGRAPHIC MAP SOUTHWEST GREAT FALLS 7.5 MIN MAP SIGHT 00

DATE SAMPLER 23-AUG 01
TIME SAMPLER 10:00 HOURS
LAB & ANALYST MONTANA RIVER 151

DATE ANALYZED 10-01-01
SAMPLE HANDLING 1220
METHOD SAMPLED GRAB

WATER USE: UNUSED

SAMPLED SITE SAND COUNTY CREEK BRIDGE AT MISSOURI RIVER BR.
DRAINAGE BASIN MISSOURI RIVER BETWEEN MARIAS RIVER AND LITTLE PRICKLY PEAR

| Calcium (Ca) | Mg/L | Meq/L | 7.03 Bicarbonate (HCO3) | 191.1 |
| Magnesium (Mg) | 60.3 | 7.10 Carbonate (CO3) | 0.0 |
| Sodium (Na) | 30.0 | 1.67 Chloride (Cl) | 52.6 |
| Potassium (K) | 7.9 | 0.20 Sulfate (SO4) | 1426 |
| Iron (Fe) | 15.7 | 0.04 Nitrate (NO3) | 0.05 |
| Manganese (Mn) | 1.79 | 0.07 Fluoride (F) | 3.41 |
| Silica (SiO2) | 77.1 | 0.18 Phosphate (PO4) | 0.18 |

TOTAL CATIONS 188.93 TOTAL ANIONS 31.87

STANDARD DEVIATION OF ANION CATION BALANCE (SIGMA)

LABORATORY PH 3.27 TOTAL HARDSNESS AS CaCO3 807.17
FIELD WATER TEMPERATURE 13.2 C TOTAL ALKALINITY AS CaCO3 0.59
CALCULATED DISSOLVED SOLIDS SODIUM ABSORPTION RATIO RYAN STABILITY INDEX
SUM OF DISS. CONSTITUENT LAB SPEC. COND. (MICROMOS/CM) 2.3480

PARAMETER VALUE PARAMETER VALUE
TEMPERATURE, AT (°C) 25°C CATIONIC FIELDS MICROPHYS 3151
FIELD PH 2.91 ALUMINUM DISS (Mg/L-AL) 117
LEACH DISS (Mg/L AS HI) 1.39 SILVER DISS (Mg/L AS Ag) 0.0019
STRONTIUM DISS (Mg/L-SR) 0.04 CEREBUS DISS (Mg/L AS Sr) 0.01
TITANIUM DISS (Mg/L-Ti) 0.73 CALCIUM DISS (Mg/L AS Ca) 0.021
VANADIUM DISS (Mg/L-V) 0.06 CHROMIUM DISS (Mg/L-Cr) 0.032
ZINC DISS (Mg/L AS Zn) 5.60 COPPER DISS (Mg/L AS Cu) 0.12
ZIRCONIUM DISS (Mg/L AS Zr) 0.003 LITHIUM DISS (Mg/L AS Li) 0.10
SELENIUM DISS (Mg/L-Se) 0.1 ACIDITY, TOT (Mg/L-CaCO3) 0.13

REMARKS: WATER IS TURBID, MURKY, ALGAE-RICH; LARGE FLOCCULENTS OF ORANGE RED HYDROXIDE PRECIPITATE; BANKS RICH IN Fe-HYDROXIDE HUMP DEPOSITS AFTER MUD FLOOD; HIGH WATER P 5.4 ABOVE CHANNEL;

LAB: 14.31 Mg/L GIVES 34.21 Meq CATIONS GIVES 8.7 SIGMA

EXPLANATION: Mg/L = MILLIGRAMS PER LITER, Meq/L = MICROGRAMS PER LITER, Meq/I = MILLIEQUIVALENTS PER LITER, FT = FEET, MI = MILES, (M) = MEASURED, (R) = REPORTED, TR = TOTAL RECOVERABLE, TOT = TOTAL

OTHER AVAILABLE DATA:
OTHER FILE NUMBERS:

PROJECT: COST:
LAST EDIT DATE: 19-02-01 BY: TP + JAS
PROCESSING PROGRAM: T1730P V2 (11/3/91) PRINTED: 27-MAY-93

PERCENT MEQ/L (FOR PIEPL PLOT)
CA Mg Na K Cl SO4 HCO3 0.03
50.1 37.4 9.4 1.1 2.0 98.0 0.0 0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 010544 0-10
MONTANA BUREAU OF MINES AND GEOLOGY
BUTTE, MONTANA 59701 (406) 476-4101
WATER QUALITY ANALYSIS
LAB NO. 0101514

STATE MONTANA
COUNTY CASCAD
LATITUDE-LONGITUDE 47°23'20"N 111°08'24"W
SITE LOCATION 15N 5F 15' AAD
UTH COORDINATES 7N MNG SITE CF-12
TOPOGRAPHIC MAP SOUTHEAST GREAT FALLS 7.1
GEOLoGC SOURCE * * * SAMPLE SOURCE STREAM
DRAINAGE BASIN 88
AGENCY & SAMPLER MNG#12
BOTTLE NUMBER CF-12
DATE SAMPLED 27-AUG-81
TIME SAMPLED 12:00 HOURS
LAT & ANALYST MNG#FHA
DATE ANALYZED
METHOD HANDLING 4220
SAMPLE HANDLED GRAD

WATER USE UNUSED

SAMPLING SITE COTTONWOOD CREEK * AT CENTERVILLE SCHOOL
DRAINAGE BASIN MISSOURI RIVER BETWEEN HARIAS RIVER AND LITTLE PRICKLY P

<table>
<thead>
<tr>
<th>MINERAL</th>
<th>MG/L</th>
<th>MG/L</th>
<th>TOTAL CATIONS</th>
<th>TOTAL ANIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALCIUM (CA)</td>
<td>151</td>
<td>7.53</td>
<td>7.53</td>
<td>(CaO3)</td>
</tr>
<tr>
<td>MAGNESIUM (MG)</td>
<td>40.1</td>
<td>4.94</td>
<td>4.94</td>
<td>(CO3)</td>
</tr>
<tr>
<td>SODIUM (NA)</td>
<td>15.8</td>
<td>0.62</td>
<td>0.62</td>
<td>(Cl)</td>
</tr>
<tr>
<td>POTASSIUM (K)</td>
<td>5.1</td>
<td>0.13</td>
<td>0.13</td>
<td>(SO4)</td>
</tr>
<tr>
<td>IRON (Fe)</td>
<td>9.49</td>
<td>0.52</td>
<td>0.52</td>
<td>(As)</td>
</tr>
<tr>
<td>MANGANESE (MN)</td>
<td>9.93</td>
<td>0.03</td>
<td>0.03</td>
<td>(Fe)</td>
</tr>
<tr>
<td>SILICA (SiO2)</td>
<td>17.0</td>
<td>0.0</td>
<td>0.0</td>
<td>PHOSPHATE TOT (AS)</td>
</tr>
</tbody>
</table>

TOTAL CATIONS 13.85 TOTAL ANIONS 18.74

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA)
LABORATORY PH 3.50 TOTAL HARDNESS AS CaCO3 624.42
FIELD WATER TEMPERATURE 19.2°C TOTAL ALKALINITY AS CaCO3 6.28
CALCULATED DISSOLVED SOLIDS | SODIUM ABSORPTION RATIO 0.20 |
SUM OF DISS. CONSTITUENT | RYAN'S STABILITY INDEX |
LAB SPEC. COND. (MICROMOS/CH) 1598, LANGLEY SATURATION INDEX

<table>
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<tr>
<th>PARAMETER</th>
<th>VALUE</th>
<th>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMPERATURE, AIR (C)</td>
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<td>CONDUCTIVITY, FIELD MICROMOS 1233.9</td>
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REMARKS: FLOW BY SUBTRACTION FROM CF-03 HEIR (DF 01=CA.15 GPM) * MORE COMPACT FLOC-USED ? FILTERS
LAB: 4.90 MG/L GIVES 20.1 MG CATIONS GIVES 4.2 SIGMA
EXPLANATION: MG/L = MILLIGRAMS PER LITER, MG/L = MICROGRAMS PER LITER, MG/L = MILLIEQUIVALENTS PER LITER. FT = FEET, FT = METERS. (M) = MEASURED, (F) = ESTIMATED, (R) = REPORTED. TR = TOTAL RECOVERABLE. TOT = TOTAL.

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT:
COST:
LAST EDIT DATE: 17-FEB-82

PERCENT MG/L (FOR PIPER PLOT):
CA 54.7
MG 37.2
NA 5.2
K 0.0
CL 0.0
C03 0.0
C03 0.0
6.0
H 1.0
49.7
6.0
0.0

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 0101514 P-11
MONTANA BUREAU OF MINES AND GEOLOGY
DUTTE-MONTANA 57701 (406) 494-1101

WATER QUALITY ANALYSIS
LAB NO. 8101615

STATE: MONTANA
COUNTY: CASCADE

LATITUDE-LONGITUDE: 47°10'23"N 111°09'05"W
COUNTY SEASONAL 7K CAA S
LATITOE 102.51
UTM COORDINATES: ZN E
STATION ID: 471902911109001

TOPOGRAPHIC MAP: STOOLCI 7 1/2'
SAMPLE SOURCE: STREAM

GEOLOGIC SOURCE: DRAGRA
LAND SURFACE ALTITUDE: 3055 FT 10
AGENCY: SAMPLER: MARGARILIS
WATER FLOW RATE: 350.0 GPM
BOTTLE NUMBER: 01
FLOW MEASUREMENT: WEHR
DATE SAMPLIED: 20 AUG 81
STAFF GAGE: STREAM STAGE
TIME SAMPPMED: 18:00 HOURS
DEPTH TO SAMPLE:
LAB. ANALYST: MARGARILIS
TOTAL DEPTH OF WATER: 0.6 FT (M)
DATE ANALYZED: 28 SEP 81
STREAM WIDTH:
SAMPLE HANDLING: 4200

WATER USE: UNUSED

SAMPLING SITE: COTTONWOOD CREEK * BELOW BILL SHIRLEY FARM
DRAINAGE BASIN: MISSOURI RIVER BETWEEN HARIAS RIVER AND LITTLE PRICKLY PEAK

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TOTAL CATIONS: 6.23
TOTAL ANIONS: 6.21

STANDARD DEVIATION OF ANION-CATION BALANCE (SIGMA): 0.10

LABORATORY PH: 8.26
TOTAL HARDNESS AS CACO3: 261.54
FIELD WATER TEMPERATURE: 21.4 C
TOTAL ALKALINITY AS CACO3: 233.75
CALCULATED DISSOLVED SOLIDS: 333.14
SODIUM ABSORPTION RATIO: 0.30
SUM OF DISS. CONSTITUENT: 457.23
RYZHKAR STABILITY INDEX: 6.50
LAP SPEC. COND. (MICROMHOS/CM): 417.6
LANGIER SATURATION INDEX: 0.00

PARAMETER          VALUE          PARAMETER          VALUE
TEMPERATURE, AIR (°C) 20.1 C          NICKEL, DISS (MG/L AS Ni) 0.001
ALUMINUM, DISS (MG/L-AL) .310          LEAD, DISS (MG/L AS Pb) .04
SILVER, DISS (MG/L AS AG) <.002          TITANIUM, DISS (MG/L AS Ti) 2.77
Boron, DISS (MG/L AS B) <.002          VANDIUM, DISS (MG/L AS V) .0001
Cadmium, DISS (MG/L AS Cd) <.002          ZINC, DISS (MG/L AS Zn) .003
Chromium, DISS (MG/L- Cr) <.002          TITANIUM DISI (MG/L AS Ti) .003
COPPER, DISS (MG/L AS Cu) <.002          Molybdenum, DISS (MG/L AS Mo) .004
LITHIUM, DISS (MG/L AS Li) <.002          Selenium, DISS (MG/L AS Se) .004
SELENIUM, TR (UG/L AS Se) .04

REMARKS: WATER IS MURKY. SOME PP-HYDROXIDE PRECIPITATES. MUDY COLOR REQUIRED.
FILTERS. BELOW CONF OF STREAM THRU SHIRLEY RANG AND ACID STREAM DRAGING
RESERVOIR. pH HIGHLY UNSTABLE. ELECTRONIC FOG* CROSS REF 8101615

EXPLANATION:
MG/L = MILLIGRAMS PER LITER, UG/L = MICROGRAMS PER LITER, MG/L = MILLIEQUIVALENTS PER LITER.
Ft = FEET, H = HINTERS, (M) = MEASURED, () = ESTIMATED. TR = TOTAL RECOVERABLE, TOT = TOTAL.

OTHER AVAILABLE DATA
OTHER FILE NUMBERS:

PROJECT:
LAST EDIT DATE: 25 NOV 81
PROCESSING PROGRAM: F1730P V2 (11/3/81) PRINTED: 27 MAY 83
PERCENT HEG/L (FOR PIPER PLOT)
CA 45.6
Mg 45.0
Na 0.0
K 1.3
CI 1.8
SO4 17.6
CO3 80.6

NOTE: IN CORRESPONDENCE, PLEASE REFER TO LAB NUMBER: 8101615
### Water Quality Analysis

**Location:** Cascade County, Montana

**Site Name:** Montana Bureau of Mines and Geology

**Sample Information:**
- **Sample Source:** Stream
- **Sample Location:** Great Falls, Montana
- **Sample Date:** 27-Aug-81
- **Sample Time:** 10:30 AM
- **Sample Handling:** Unused

**Water Use:** Unused

**Sampling Site:** Sand Coulee Cr, upstream from Cottonwood Cr, Drainage Basin Missouri River between Marias River and Little Prickly Pain River

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**Laboratory Ph:** 7.96

**Field Water Temperature:** 25.0°C

**Calculated Dissolved Solids:** 252.51

**Sum of Diss. Constituent:** 331.26

**Ryznar Stability Index:** 7.79

**Langlier Saturation Index:** 0.09

**Total Cations:** 4.56

**Total Anions:** 4.61

**Standard Deviation of Anion-Cation Balance:** 0.26

**Other Available Data:**
- **Project:** 25-HOV-81
- **Cost:** 19N 5E 19*AACD
- **Last Edit Date:** 11/3/81
- **Processing Program:** F1730P V2
- **Percent Meq/l:** Ca Mg Na K Cl SO4 HC03 CO3 36.3 54.1 7.6 1.7 1.7 42.7 55.5 0.0

**Remarks:** Used 6 filters - 30-100 ml/filter. Gel-like ppt. on filter (soap?)

**Cross Ref:** B101835

**Explanation:** Mg/L = Milligrams per liter; UG/L = Micrograms per liter; Meq/L = Milliequivalents per liter. ft = feet, m = meters. (h) = measured, (e) = estimated, (r) = reported. TR = Total recoverable. TOT = Total.

**Note:** In correspondence, please refer to lab number: B101517

---

**Ready**
D-7

DAILY DISCHARGE DATA AND STREAMFLOW HYDROGRAPHS

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   CF03
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**TOTAL** | 1.385 | 0.507 | 1.090 | 20.892 | 56.553 | 151.753 | 142.171 | 45.706 | 15.701 | 7.654 |

**MEAN** | 0.045 | 0.016 | 0.039 | 0.674 | 1.085 | 4.075 | 4.730 | 1.474 | 0.599 | 0.252 |

**MIN** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.122 | 1.523 | 7.793 | 0.599 | 0.252 |

**AC-FT** | 2.747 | 1.006 | 2.163 | 41.439 | 117.172 | 306.997 | 281.993 | 90.657 | 31.307 | 15.578 |
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1) Record accuracy affected by siltation and corrosion of weir plate, worsening throughout year.

* Interpolated value.
| DAY | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|     |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 14.018 | 1.867 | 2.169 | 1.544 |
| 1   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 14.018 | 1.867 | 2.169 | 1.544 |
| 2   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 14.018 | 1.867 | 2.169 | 1.544 |
| 3   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 13.186 | 1.052 | 1.627 | 1.539 |
| 4   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 11.286 | 0.941 | 1.602 | 1.520 |
| 5   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 11.014 | 0.836 | 1.597 | 1.364 |
| 6   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 14.050 | 1.831 | 1.624 | 1.519 |
| 7   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 10.037 | 1.026 | 1.647 | 1.513 |
| 8   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 9.070 | 1.021 | 1.662 | 1.508 |
| 9   |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 7.733 | 1.016 | 1.651 | 1.503 |
| 10  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 6.766 | 1.011 | 1.647 | 1.490 |
| 11  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 6.669 | 1.005 | 1.646 | 1.492 |
| 12  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 6.376 | 1.000 | 1.641 | 1.497 |
| 13  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 5.572 | 0.955 | 1.636 | 1.482 |
| 14  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 5.158 | 0.970 | 1.631 | 1.477 |
| 15  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 5.099 | 0.981 | 1.622 | 1.472 |
| 16  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 4.657 | 0.970 | 1.611 | 1.467 |
| 17  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 4.410 | 0.973 | 1.616 | 1.462 |
| 18  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 3.917 | 0.977 | 1.610 | 1.457 |
| 19  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 3.623 | 0.964 | 1.605 | 1.451 |
| 20  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 3.796 | 0.979 | 1.600 | 1.446 |
| 21  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 4.607 | 1.754 | 1.595 | 1.441 |
| 22  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 3.361 | 1.749 | 1.590 | 1.435 |
| 23  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 3.083 | 1.744 | 1.585 | 1.431 |
| 24  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 2.650 | 1.739 | 1.580 | 1.426 |
| 25  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 2.523 | 1.734 | 1.575 | 1.421 |
| 26  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 2.672 | 1.728 | 1.569 | 1.416 |
| 27  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 2.792 | 1.723 | 1.554 | 1.410 |
| 28  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 7.951 | 2.350 | 1.713 | 1.554 |
| 29  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 16.109 | 2.056 | 1.706 | 1.549 |
| 30  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 13.896 | 1.703 | 1.539 | 1.502 |
| 31  |     |     |     |     |     | 0.000 | 0.000 | 0.000 | 0.000 | 83.539 | 276.114 | 109.434 | 96.594 |

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1) Weir capacity exceeded
2) Weir washout, no record from 5-2 through 8-20
* Interpolated value
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**MIN** 0.000 0.000 0.029

**AC-FA** 0.201 149.397 0.032

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2) Weir washout 4-12, flow not measured accurately afterwards.

* Interpolated value.
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1) Weir capacity exceeded; washout occurred 5-21, repaired 8-21.

* Interpolated value.
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1) Recorder inoperable 2-6 through 3-21.
2) Weir washout occurred 4-12, partial flow measurement only.
3) Interpolated value.
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DISCHARGE: DFS **
APPENDIX E

PROPOSED AMD MITIGATION ALTERNATIVES

The MBMG proposed 5 alternative acid mine drainage treatment measures for field testing to the Montana Department of State Lands in March, 1983. A description of the theory and proposed tests of each alternative are contained in this appendix.

E.1 State-of-the-Art in AMD Control

Lime and limestone treatment of acid mine drainage is a proven mitigation technique (Kim, et al., 1982; Bituminous Coal Research Institute, 1971; Hydrometrics, 1982). While lime (Ca(OH)_2) is more effective at neutralization per unit weight than limestone, several factors favor usage of limestone in crushed or pulverized form, including low cost per unit neutralization, local availability, fewer safety problems in handling a less reactive reagent, lower potential for harmful effects on the body of water receiving the effluent and denser sludge. Diebold (1975) found that one-inch crushed limestone fragments provided effective neutralization of iron and copper loads in Montana acid mine drainage at Hughesville, but not of manganese, zinc and cadmium. Even if centralized neutralization facilities are effective, they require significant capital and maintenance investments and are not easily adaptable to treatment of a number of polluting mines over a wide area without a sophisticated collection system, such as is the case at Sand Coulee. In addition, such facilities must be operated continuously, under a variety of discharge and climatic conditions.
Centralized lime neutralization facilities produce large quantities of amorphous sludge which present major handling and disposal problems. Large neutralization facilities are operated successfully, however, in areas where active mining is ongoing, and trained personnel and equipment are available. The lack of mining operations and dispersed nature of AMD sources in the Sand Coulee area are a major impediment to centralized neutralization.

Hydrometrics (1982) list 22 effluent treatment techniques for AMD control at Sand Coulee. They rule out all but three for various reasons: streamflow regulation, evaporation ponds and neutralization facilities. They list 17 mine manipulation techniques, three of which were designated as being potentially applicable: dam and flooding, hydraulic seals and seals using mine backfill. Eight hydrologic system control methods were listed, two of which were deemed potentially applicable: overburden water removal by wells and vegetative evapotranspiration.

Hydrometrics gave a qualitative rating of the potentially applicable methods to 10 acid discharges in the Stockett-Sand Coulee area. The highest rating of any technique was "fair", given to dam and flooding of the AS04 adit (Brown Mine). Most ratings of success were poor, undetermined, no potential or variable. Overburden water removal methods were rated as poor for all sources, due to inadequate information on the aquifers involved and potentially large costs associated with well installation, maintenance, water pumping and piping. Evapotranspirational controls were rated poor or variable for various AMD sources, primarily due to insufficient information on recharge areas and no previous documentation of this technique for AMD control.
The U.S. Bureau of Mines (Kim, et al., 1982) has recently assessed the long-term success of various acid mine drainage treatments. Their recent inspections of wet, dry and hydraulic and/or bulkhead seals constructed over 10 years ago in West Virginia, revealed failures of 5 clay seals and continued discharge of acid water to a receiving stream. They indicated that mine sealing and flooding of 43,000 acres of old coal mines in Pennsylvania which are below the local drainage elevation, began over 30 years ago and that the water in some mine pools is now slightly alkaline. However, they state that in deep mines above the drainage elevation, "flooding is generally ineffective owing to seepage through fractures and the tendency of the water to migrate to other discharge points." The latter situation is the predominate case in the Stockett-Sand Coulee coal field.

The U.S. Bureau of Mines study briefly mentioned that overburden dewatering methods in the eastern U.S. have had limited success but are highly dependent on favorable hydrogeologic conditions. They made no reference to evapotranspirational control methods as a means of reducing infiltration to mines.

Results of this investigation generally support the findings of the previous studies. Mine sealing is one control technique which has been attempted in the Stockett vicinity. In one case, near the Giffen mine, sealing was performed successfully, but within a few months after sealing, a small seep had developed in the center of a nearby tract of agricultural land. Within a year, the seep had developed into a large marshy area discharging a flow reportedly not greatly different than that of the original spring. Because of the unpredictability of the effects of such sealing efforts, a number of local residents are
opposed to its use, as indicated by the results of the resident
questionnaire carried out by Hydrometrics (1982).

E.2 Infiltration Control by Intensive Cropping Methods

Planting of water-consumptive crops such as alfalfa, sanfoin and
safflower and the use of continuous cropping rotations has been shown
to be effective in limiting the amount of infiltration allowed to
recharge shallow saline-seep ground-water systems (Miller et al.,
1981). It is conceivable that application of such cropping practices
could reduce infiltration to mine adits that cause acid discharge.
Saline-seep research has demonstrated that alfalfa sends roots to
depths of 15 feet or more, utilizing 18 in. of water annually, whereas
cereal grains root to only several feet and utilize 7 to 8 in. of water
annually. Recropping of cereal grains when soil moisture permits will
almost double the evapotranspirational water use over the former 2-year
crop-fallow system (Brown and Miller, 1978).

A drawback with this approach is that some of the recharge to
ground water occurs in the late winter (during snowmelt) or during
spring rains, when most crops are not consuming large amounts of water
and when direct evaporation is minimal. The soils on the benches are
thin and permeable, so that soil moisture may not be retained long
enough for it to be consumed by crops in the summer months. However,
in this area intensive cropping will decrease the volume of excess
infiltration to some extent, even if it does not eliminate it entirely.
Other infiltration control methods, such as draining of leaky upland
stock ponds or ephemeral natural potholes, may reduce infiltration sub-
stantially and should be considered.
Efforts to reduce infiltration by intensifying agriculture, would have to be monitored via observation wells in the Kootenai aquifer and measurement of AMD discharge for a number of years after implementation, before the degree of their success could be evaluated. Full root development and water use by alfalfa, for example, does not occur until the third year after planting.

Acid discharge sources fed primarily by local recharge areas currently in a crop-fallow rotation are the best candidates for testing this infiltration control method. Such areas include the cultivated benches above AS01, AS02, AS06, AS07, CS01 and CS02.

Effective implementation of cropping system charges for control of dryland saline seep has been shown to require technical assistance to the farmers involved (Dodge et al., in press). Long term adoption of intensive farming practices in the study area must prove to be practical and economical if wholesale reliance on subsidies is to be avoided.

E.3 Horizontal Wells and Connector Wells

Installation and pumping of standard vertical wells to dewater the Kootenai aquifer, which is contributing leakage to abandoned mines, is a potential mitigation measure. However, the continued costs of pumping and maintenance appear to make this an undesirable and expensive alternative.

It is possible to take advantage of, or create, favorable differences in hydraulic head within wells, to gravity drain water from one aquifer to another or to the surface. The two well designs possible for use in dewatering the Kootenai aquifer are the connector
well and the horizontal well. The connector well would drain ground water from the basal Kootenai sandstone aquifer to the Madison group limestone which has a lower head, thereby preventing that water from draining into old mines and becoming acidized. The horizontal well would be drilled from a coulee into the basal Kootenai sandstone, just upgradient from old mine workings, and allow ground water to drain to the coulee before it leaks into the mines.

Connector wells have been used to dewater shallow aquifers in mining applications. A recent U.S. Geological Survey publication (Bush, 1983) describes the successful test of one connector well to recharge 50 gpm under gravity flow from a shallow sand aquifer to the underlying Floridan Limestone aquifer in central Florida. There is limited evidence to suggest that some domestic wells in the Stockett-Sand Coulee area may act as connector wells. A drillers log on a private well in T. 19 N., R. 4 E., sec. 23, indicates that ground water was encountered in the basal Kootenai sandstone, but that drilling continued 356 feet into the Madison limestone where a cavity was encountered. The total well depth was 586 feet, 71 feet below the cavity level and the well was uncased below 20 feet. The reported static water level was 515 feet below ground surface, just at the level at the bottom of the cavity. Ground water from the Kootenai aquifer may flow down the well bore to the level of the cavity in the Madison. The instances of contaminated Madison wells mentioned in section 2.2.5.1 also illustrates the connector well principle. If applied to the AMD problem, the connector wells would inject fresh Kootenai water into the Madison group limestone.

Horizontal drainage wells have been most frequently used in
dewatering of mining headwalls and highway road cuts. In the Stockett-Sand Coulee area, horizontal wells could be drilled into the sides of coulees upgradient from existing AMD sources as a test of this technique. Their obvious advantage is the use of gravity drainage and the elimination of long-term pumpage requirements. Secondarily, the water removed through drainage would be typical alkaline Kootenai water and with a minimum of conveyance would be available for dilution of other AMD water in the receiving stream.

Favorable sites for horizontal well tests include several acid springs and mine discharges near Sand Coulee such as AS01, AS04, AS09, CS01 and CS02. The configurations of these coulees and predominantly local recharge sources create apparently favorable conditions for intercepting a sizeable portion of the ground-water flow field reaching the old mine workings.

The drilling distances would be variable, depending on the test site chosen and the quantities of water intercepted as the drilling progresses. It is estimated that a 500-1000 ft. hole would be attempted initially. The yield of a horizontal drainage well in the basal Kootenai sandstone is problematical, very much dependent on the quantity of saturated fractures encountered.

Vertical test wells would be drilled on the benches above these adits to the Morrison coal bed along the projected axis of the horizontal well. This will help confirm the extent of the old mine workings and provide elevation control on the basal Kootenai sandstone prior to drilling the horizontal wells.

The effectiveness of the horizontal wells in AMD control would be determined by measuring the discharge from the two adits with flumes or
weirs fitted with continuous recorders, both before and after operation of the drainage wells. The drainage well discharge would be measured continuously with recording flowmeters or flumes. Both adit and drainage well discharge would be sampled for water quality analyses during the flow tests.

E.4 Subsurface Injection of AMD

A potential AMD disposal and neutralization method may be gravity injection into the Madison limestone. The effectiveness and impacts of injection could be assessed with controlled field tests. The objectives of the tests would be to determine the effectiveness of AMD neutralization, porosity--permeability changes due to injection, extent of metal precipitation, and water quality impacts of AMD injection on the Madison aquifer.

Acid mine drainage leakage into the Madison aquifer is already occurring throughout the Stockett-Sand Coulee area in an uncontrolled fashion. There are several cases of Madison ground-water contamination reported by landowners and at least four additional suspected cases based on MBMG water quality data. AMD discharge in Sand Coulee, Number Five Coulee, Cottonwood Creek and Straight Creek is known to be lost to subsurface seepage, contaminating alluvial ground waters and probably the Madison as well. The results of controlled AMD injection tests would indicate whether such a procedure is preferable to uncontrolled leakage to several aquifers along the entire drainage network.

However, there is reason to question the applicability of such an injection program. As acid mine water is discharged into partially saturated zones of cavernous porosity in the Madison, several processes
will take place concurrently. If undiluted acid water comes in direct contact with limestone in the unsaturated portion of the Madison, it will tend to dissolve carbonates and may enhance porosity. As the pH rises above 4.5, both iron and aluminum will rapidly precipitate from solution as insoluble, amorphous hydroxides. As it reaches the saturated portion of the Madison, it may have little or no remaining acidity; what acidity remains will be buffered by the alkalinity of the Madison water, causing complete precipitation of the metal load down to the solubility of controlling metal hydroxide or carbonate species.

The major obstacle to the successful operation of such an injection well system would probably be the ability of the aquifer and well to resist becoming clogged with metal hydroxide precipitation products. Mines in the Sand Coulee area, those of poorest quality in the region, typically range from 600-1600 mg/L total dissolved metals, primarily iron and aluminum with much lesser quantities (<50 mg/L Zn, <10 mg/L Ni, Cu, Mo) of other metals. Assuming an average annual discharge of 40 gpm (2.5 liters per second (1/s)) for a hypothetical spring of typical water quality and metal load (TDS = 5000 mg/L; metals = 1.1 grams/L), and assuming a mean density of 3.0 g/cc for the metal precipitate (gibbsite - 2.4; ferric hydroxide - 3.3-4.3, depending on hydration), a total volume of 1024 ft³/year will precipitate from solution in the subsurface if the total discharge were to be injected into the Madison. Assuming a void ratio of 100 percent in this precipitate, approximately 1766 ft³/year would precipitate from injection water of just one spring. Such volumes could potentially clog even a large zone of cavernous porosity in the Madison over the period of a few years.

However, there are some factors which would support the feasibil-
ity of injection. First of all, the water would most likely be injected into the upper Madison which is partially unsaturated, and before it reaches the water table it may dissolve a significant volume of carbonates due to the water's high acidity, enhancing porosity and permeability. Secondly, our results indicate that acid streamflow is probably currently leaking into the underlying Madison in the Sand Coulee-Stockett area. Therefore, the injection concept may prove practical, provided that zones of cavernous porosity are present in the Madison to accommodate the anticipated metal load.

Certainly, however, the water quality impacts of such injection would have to be predicted and evaluated. Acid water injected into the aquifer would become neutralized with respect to metals and acidity. The Madison aquifer may, however, be degraded by the higher sulfate levels (2000-8000 mg/L) in the acid water, or by an increase in \( \text{Ca}^{2+} \) and \( \text{Mg}^{2+} \) concentrations due to carbonate and dolomite dissolution.

Many Stockett-Sand Coulee residents have abandoned alluvial wells for deeper Madison aquifer wells. Any acid water injection proposal would have to be sanctioned by residents and carefully monitored to determine overall impacts. We have proposed one possible approach to conducting controlled field tests and evaluation of the injection technique.

Initial well drilling, logging and testing would be conducted to locate a favorable site. The vertical gradient must be downward, and there should be some initial solution or cavernous permeability in the upper unsaturated Madison group limestone.

An initial 10-day injection test would be run. Following a favorable evaluation of the first test, a second 100-day test would be
conducted. Water quality analyses of the observation wells, injection well and mine discharge would be made three or more times throughout the tests. Field pH, S.C. and alkalinity measurements would be made frequently. Continuous water level data would be collected throughout the test periods. The nearest private Madison well would be sampled before and after the test periods.

Following the tests, geophysical logs would be run again on the injection well and observation well changes in porosity and permeability caused by metal hydroxide deposition and carbonate dissolution. Aquifer pumping tests or slug tests would be re-run to determine permeability changes. Two new wells would be drilled to determine the extent of metal deposition and obtain samples.

The results of field sampling would be used as input to hydrochemical modeling of the injection test. Analytical calculations and computer modeling would be employed to estimate the mechanisms and rate of acid neutralization and metal precipitation over time. The extent of porosity, permeability and water quality effects on the Madison aquifer would be evaluated. Recommendations regarding the long-term hydrogeologic feasibility and impacts of AMD injection to the Madison Group rocks would be made.

E.5 Flyash Neutralization

Flyash residue from coal-fired electric power plants is rich in calcium and has been tested and found to be effective in neutralizing pyrite induced acidity. Sonderegger and Donovan (1982) conducted acid titration and batch leach laboratory experiments with various mixtures of flyash and pyrite mine tailings and found that flyash has both
short-term and long-term buffering capacity. A one to ten, flyash to tailings mixture, was estimated to maintain a buffering capacity exceeding 100 years. Iron mobility in column leach tests with flyash was reduced by up to three orders of magnitude.

It is believed that small volumes of acid mine drainage water could be effectively neutralized by short-term retention and mixing with flyash in a small pit. An investigation would be needed to test the effectiveness and maintenance requirements of small flyash pits as a means to neutralize the numerous small acid water discharges in the Stockett-Sand Coulee area.

Pits of about 200 ft$^3$ in size would be excavated and filled with flyash. Acid inflows would be injected through the bottom of pits, where neutralization occurs prior to being discharged from the top of the downstream side of the pit. Water quality sampling and field testing of pH, S.C. and alkalinity of inflows and outflows would be done to document the rate of neutralization, bulk neutralization capacity of the flyash in the pit and affects on overall water chemistry and metals concentrations. The pit would be profiled afterwards, and maintenance and operation feasibility assessed.

E.6 Kootenai Water Neutralization

A simple and possibly effective AMD neutralization technique would be to mix alkaline ground water from the Kootenai aquifer with small volumes of acid mine drainage water. The mixing would occur in a pit where metals would be allowed to precipitate prior to discharge of the effluent.

Typical ground water from the lower Kootenai formation has an
alkalinity of 200 to 350 mg/l as CaCO$_3$. Assuming a mix of 2500 mg/l (as CaCO$_3$) acid mine water, a 10:1 volumetric ratio of Kootenai to AMD water is required theoretically to achieve neutralization.

A several month test would be conducted to evaluate the effectiveness and field procedures associated with utilization of Kootenai ground water in neutralizing acid mine drainage in the Sand Coulee area.

Water quality samples and field pH, S.C. and alkalinity data would be collected at inflows and outflows to document the effectiveness of the technique.

The flyash and Kootenai ground-water neutralization experiments would be conducted with the purpose of determining the minimal field installation required for non-mechanical but effective treatment of the numerous small and ephemeral acid seeps in the study area. Such an alternative could be adopted by individual residents at low cost to assist regional AMD clean up efforts.

E.7 Treatments in Combination

There will probably never be a single mitigation technique feasible for controlling all acid mine drainages. Once implementation and testing of the previously discussed techniques on an individual basis is completed, various combinations may enhance AMD control.

If the head and permeability characteristics of the basal Kootenai sandstone aquifer prove conducive for horizontal wells, this technique could be combined with mine flooding and bulkheading. The two treatments could complement each other. The horizontal well will provide a hydraulic pressure release mechanism, maintaining hydrodynamic equilib-
rium and helping prevent unplanned seepage. The flooding will slow acid producing reactions in the old mines and may increase head in the overlying sandstone, thereby improving yields from the horizontal well at the expense of mine flow. The discharge of alkaline ground water from a horizontal well may provide an opportunity to neutralize the remaining acid flow in a pit below the source as indicated in the previous section.

Reductions in acid mine baseflows and total volume from intensive farming methods in recharge areas may allow installation of retention ponds or neutralization pits (using flyash or limestone) to treat the remaining acid flow. Mine flooding and bulkheading could be combined with injection of surplus water to a deeper receiving zone such as the Madison group limestone. A closed system overflow pipe could siphon surplus mine pool water in a relatively unoxygenated state to a deeper receiving aquifer. If acid-forming reactions could be minimized in the mine and rapid injection of ground-water recharge slugs accomplished, the injection water may be of better quality than typical AMD water. Mine pool water injected in this manner may result in water quality impacts to the Madison aquifer less than those currently being experienced.