HYDROGEOLOGIC DATA RELATED TO THE POTENTIAL FOR STOCK-WATER DEVELOPMENT ON FEDERALLY OWNED RANGELAND NEAR DILLON, MONTANA

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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For readers who may prefer to use the International System (SI) of units rather than inch-pound units, the conversion factors for the terms used in this report are listed below.

Multiply inch-pound unit	By	To obtain SI unit
foot	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon per minute (gal/min)	0.06309	liter per second
mile	1.609	kilometer

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ABSTRACT

Existing hydrogeologic data and information were synthesized for 20 principal sites and 11 alternative sites on federally owned rangeland near Dillon, Montana, to assist the U.S. Bureau of Land Management in evaluating the potential for developing additional stock-water supplies. Hydrologic and geologic conditions at most of the sites were verified by onsite inspection during the summer of 1984. Each site is described in terms of location, altitude of land surface, inferred aquifer(s), estimated depth to water, estimated drilling depth, estimated yield, estimated dissolved-solids concentration, hydrogeologic setting, and development. A plate shows the location of wells and springs, dissolved-solids concentrations and chemical-constituent diagrams for water samples, and ownership status for selected rangeland areas near Dillon as well as the location of principal and alternative sites.

INTRODUCTION

The U.S. Bureau of Land Management is interested in developing additional water supplies at 20 sites on federally owned rangeland near Dillon (pl. 1) in accordance with the objectives of management plans currently (1984) in effect. The land has historically been used for livestock grazing, but because of the limited and frequently seasonal availability of present water supplies, the land has not been optimally utilized. The rangeland generally is situated in upland areas that receive scant precipitation and is not adjacent to a source of perennial streamflow. Springs occur at isolated locations throughout the study areas and a few wells have been drilled. Lack of drill-hole information over much of the area severely limits knowledge of the ground-water resources. Also, the position of this land on the leading edge of the structurally complex Overthrust Belt complicates evaluation and assessment of ground-water availability. The resulting difficulty in obtaining even minimal quantities of water in some test holes drilled in or near the study areas clearly illustrates the importance of careful site selection.

The purpose of this project was to synthesize existing hydrogeologic data and information, coupled with onsite verification, for the sites having the greatest priority for successful water-well development. For this study, well development was not considered to be economically feasible if estimated depths to water exceeded about 500 feet below land surface. The project was conducted for the Bureau of Land Management.

Most drillers' logs of wells drilled in the study areas or on adjacent private land were obtained from files of the Montana Bureau of Mines and Geology. Reported water-level and production data were compiled on plate 1 along with reported spring

locations from allotment files of the Bureau of Land Management. Other information obtained during onsite verification included measured water levels in wells, spring discharge, and water-quality data, which were subsequently added to plate 1.

Geologic maps and reports encompassing parts of the study areas were compiled (see Selected References list). The Bureau of Land Management's complete infrared aerial photographic coverage of the study areas was used to verify reported locations of existing springs. The aerial photographs were also useful in identifying other seep areas having the potential for the development of alternate supplies of shallow ground water.

Subsequent onsite visits within the study areas during the summer of 1984 emphasized verification of well locations and water levels, spring locations and flow rates, reported geology, and identification of many of the more promising sites for possible shallow ground-water development. Nine water-quality samples from springs in the study areas had dissolved-solids concentrations ranging from 298 to 966 mg/L (milligrams per liter). The chemical-constituent diagrams plotted on plate 1 illustrate the concentrations of the major anions and cations in each sample relative to one another. The resulting patterns provide a simple visual method for distinguishing similarities and differences in composition of ground water between springs.

RANGELAND AREAS

East front Tendoy Mountains area

Principal location: Site 1

Land-line description: SW¼SE¼SW¼ sec. 7, T. 11 S., R. 10 W.
(Red Rock 7.5' topographic map)

Altitude of land surface above sea level: 7,000 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 600 to 750 feet

Estimated drilling depth: 650 to 800 feet

Estimated yield: 2 to 15 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,500 mg/L

Hydrogeologic setting: This site is located on a hillside facing northeast in the foothills of the Tendoy Mountains. It is probably underlain, in descending order, by about 400 feet of Quadrant Formation quartzite, about 200 feet of Big Snowy Group and Amsden Group shales, and Madison Group limestone to an unknown depth. The overlying quartzite and shales are most likely not saturated at this site. The nearest known evidence of shallow ground water is a developed spring in Bell Canyon 1 mile to the south (altitude of 6,570 feet) and a grove of aspen trees in Limekiln Canyon 1.5 miles to the northwest (altitude of 6,360 feet). Both appear to be associated with faulting -- the former with a fault through the Quadrant (Scholten

and others, 1955), and the latter with a fault noted in the Madison. The level of saturation at this site is probably at an altitude similar to that at the aspen grove of Limekiln Canyon.

Yield at any particular site within the Madison limestone is dependent on the degree of existing secondary permeability owing to faulting, fracturing, and solution. The nearby Red Rock 4 well in the SW¼SW¼ sec. 34, T. 11 S., R. 10 W., has produced evidence that secondary permeability exists in at least one place along the front of the Tendoy Mountains. The phenomenon of air blowing out of the hole witnessed during an atmospheric pressure change indicates extensive unsaturated fracture permeability, and the driller's 3-hour bailer test showing no perceptible drawdown at a discharge of 15 gal/min indicates saturated fracture permeability at this site.

Scholten and others (1955) have mapped a major northeast-trending fault in close proximity to site 1. Drilling in limestone along a fault such as this could enhance the chances of producing a larger yield well.

Development: The large estimated depth to water could preclude a successful well.

Alternative location to site 1: Site 1A

Land-line description: SW¼NW¼SW¼, sec. 1, T. 11 S., R. 11 W.
(Garfield Canyon 7.5' topographic map)

Altitude of land surface above sea level: 6,350 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 5 to 15 feet

Estimated yield: 2 to 5 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,000 mg/L

Hydrogeologic setting: The site is located in the bottom of Limekiln Canyon in close proximity to the two largest aspen trees. Aspens are shallow rooted and commonly function as phreatophytes, deriving their water supply from the saturated zone. A north-northwest lineament has been noted on infrared aerial photography intersecting the canyon bottom at this site. An onsite check confirmed the presence of a fault along the lineament trend. Scholten and others (1955) also mapped a fault trace along Limekiln Canyon that passes near or through the site.

Development: A spring might be developed near the aspen in the bottom of the canyon and the intersection of the fault traces. If the water table is too deep to produce an adequate supply by conventional excavation, another viable alternative might be a horizontal well drilled into the steep north side of the canyon wall a couple hundred feet upstream from the aspen grove and along the north-northwest trending lineament/fault in limestone of the Madison Group.

Alternative location to site 1: Site 1B

Land-line description: NW¼NW¼NW¼ sec. 19, T. 11 S., R. 10 W.
(Kidd 7.5' topographic map)

Altitude of land surface above sea level: 6,570 feet

Inferred aquifer(s): Pennsylvanian Quadrant Formation and (or) Mississippian Madison Group

Dissolved-solids concentration of water: 966 mg/L; sampled

Hydrogeologic setting: This is the site of an existing developed spring in Bell Canyon. Water from this spring could be piped north to within one-half mile of site 1. The yield was measured at 1.7 gal/min at the intake to the lower stock tanks on Aug. 29, 1984.

Development: If the measured discharge represents the total quantity currently available from this spring, additional development may be necessary to increase the yield to supply another site.

Alternative location to site 1: Site 1C

Land-line description: NW¼NW¼NW¼ sec. 23, T. 11 S., R. 11 W.
(Deer Canyon 7.5' topographic map)

Altitude of land surface above sea level: 7,600 feet

Inferred aquifer(s): Proterozoic gneiss and (or) Mississippian Madison Group

Estimated yield: 2 to 5 gal/min

Estimated dissolved-solids concentration of water: less than 500 mg/L

Hydrogeologic setting: This site is located just outside of land managed by the Bureau of Land Management, in the bottom of a canyon about 800 feet below the main ridge crest of the Tendoy Mountains. Viewed from a hillside to the south, thick brush is evident in the gully bottom and a healthy stand of aspen is growing on the southeast wall of the canyon. Scholten and others (1955) mapped a thrust fault at this site, placing Proterozoic gneiss over Madison limestone.

Development: A horizontal well drilled into the southeast canyon wall in the vicinity of the aspen grove might tap the trees' source of water supply and (or) water from the fault zone. Accessibility could be a problem. One spur ridge (shown on the Kidd 7.5- minute topographic map), directly west of the site and connected to the main ridge crest, may have a gentle enough slope to permit entry to the canyon by vehicle. Spring development by conventional means could be an alternative to a horizontal well.

Principal location: Site 10

Land-line description: NE¼NW¼SW¼ sec. 36, T. 10 S., R. 11 W.
(Garfield Canyon 7.5' topographic map)

Altitude of land surface above sea level: 6,900 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 550 to 900 feet

Estimated drilling depth: 650 to 950 feet

Estimated yield: 2 to 15 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,500 mg/L

Hydrogeologic setting: This site is located on State land on a wide, flat spur ridge facing northeast in the foothills of the Tendoy Mountains. It is situated on Madison Group limestone near the axis of a syncline. Nearby, the bedding strikes west-northwest and dips about 20° to the south-southwest. If the closest grassy areas noted in the NE¼SW¼SE¼ sec. 36, T. 10 S., R. 11 W., and in the SW¼NW¼NW¼ sec. 1, T. 11 S., R. 11 W., are due to seepage from a minor supply of perched ground water, then a small amount of ground water might be initially found in drilling at about 300 feet below land surface. The level at which water would stand in a well at this site most likely ranges from an altitude similar to that beneath the aspen grove in Limekiln Canyon (6,350 feet) to about 6,000 feet, assuming a water-table gradient of about 200 ft/mi from Clark Canyon Reservoir.

Development: The large estimated depth to water could preclude a successful well.

Alternative location to site 10: Site 1A (as previously described)

Alternative location to site 10: Sites 10A and 10B

Land-line descriptions: Site 10A, NE¼SW¼SE¼ sec. 36, T. 10 S., R. 11 W.
(Garfield Canyon 7.5' topographic map)

Site 10B, SW¼NW¼NW¼ sec. 1, T. 11 S., R. 11 W.
(Garfield Canyon 7.5' topographic map)

Altitude of land surface above sea level: 6,640 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated yield: less than 2 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,000 mg/L

Hydrogeologic setting: Both sites are located in gullies. The attitude of bedding is similar to that at site 10. The patches of broad-bladed grasses in the gully

bottoms and on the hillsides above may be associated with enhanced permeability along bedding planes and perched ground water.

Development: A horizontal well drilled into the northwest wall at the base of the canyon at the site in sec. 1 or into the south-southwest wall near the base of the gully at the site in sec. 36 might supply enough water for a stock tank.

Principal location: Site 16

Land-line description: SW¼SW¼NE¼ sec. 33, T. 11 S., R. 10 W. (Kidd 7.5' topographic map)

Altitude of land surface above sea level: 6,320 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 550 to 650 feet

Estimated drilling depth: 600 to 700 feet

Estimated yield: 5 to 20 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,500 mg/L

Hydrogeologic setting: This site is located on the flanks of the Tendoy Mountains on steeply west-northwest dipping limestone of the Madison Group. About one-half mile away, in the Red Rock 4 well, water also is derived from the Madison at a reported depth of 387 feet. The altitude of the water level in this well is similar to that of Red Rock River 2 miles away. The level of saturation in the Madison at the proposed site would probably be similar to that in the existing well. The yield could also be as much as that in the existing well if a similar degree of secondary permeability was present in the drill hole.

Development: The large estimated depth to water could preclude a successful well.

Alternative location to site 16: Site 16A

Land-line description: NE¼SW¼SW¼ sec. 34, T. 11 S., R. 10 W., next to Red Rock 4 well (Kidd 7.5' topographic map)

Altitude of land surface above sea level: 6,120 feet

Aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 390 feet

Estimated drilling depth: 430 feet

Estimated yield: 10 to 25 gal/min

Hydrogeologic setting: See hydrogeologic setting for sites 16 and 1.

Development: A hole could be drilled next to the Red Rock 4 well, which was accidentally blocked during rehabilitation. Based on the yield information on the driller's log for the Red Rock 4 well (15 gal/min with no perceptible drawdown), a new well probably would be capable of yielding more than 15 gal/min, if needed.

Alternative location to site 16: Site 16B

Land-line description: SW¼NW¼NE¼ sec. 32, T. 11 S., R. 10 W. (Kidd 7.5' topographic map)

Altitude of land surface above sea level: 6,700 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 5 to 10 feet

Estimated yield: 2 to 5 gal/min

Estimated dissolved-solids concentrations of water: 500 to 1,000 mg/L

Hydrogeologic setting: This site is located in the bottom of McKenzie Canyon about one-half mile into Forest Service land. A meadow-like area at this location consists of tall, lush grasses, and broad-bladed grasses (visited August 30, 1984).

Development: Spring development could be attempted several places within this meadow. One possibility would be in the vicinity of the confluence of the two tributaries.

Principal location: Site 13

Land-line description: SE¼NE¼SE¼ sec. 19, T. 11 S., R. 10 W. (Kidd 7.5' topographic map)

Altitude of land surface above sea level: 6,700 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 750 to 1,000 feet

Estimated drilling depth: 800 to 1,050 feet

Estimated yield: 5 to 20 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,500 mg/L

Hydrogeologic setting: This site is located on a northeast-facing hillside in the foothills of the Tendoy Mountains near a small manmade reservoir. It is one-eighth mile south of the "Reservoir Site" visited and assessed by F. N. Visher of

the U.S. Geological Survey in 1968 for the Bureau of Land Management. This site is also underlain by steeply dipping beds of Madison Group limestone. Based on the static water level reported in the Red Rock 4 well, the water level at this site is probably not much higher than the altitude of Red Rock River (5,700 feet) 3 miles to the east.

Development: The large estimated depth to water could preclude a successful well.

Alternative location to site 13: Site 1B (as previously described).

Henneberry Ridge area

Principal location: Site 2

Land-line description: SW¼SE¼NE¼ sec. 13, T. 9 S., R. 11 W.
(Eli Spring 7.5' topographic map)

Altitude of land surface above sea level: 6,530 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 375 to 500 feet

Estimated drilling depth: 400 to 550 feet

Estimated yield: 5 to 15 gal/min

Estimated dissolved-solids concentration of water: less than 1,000 mg/L

Hydrogeologic setting: This site is located on top of Henneberry Ridge on a veneer of Tertiary sediments overlying steeply dipping Madison Group limestone (Lowell, 1965). The closest springs (1 1/2 miles away) on the northeast flank of the ridge issue from the ground at an altitude of about 6,000 feet. On the southwest flank of the ridge, springs issuing from the Proterozoic gneiss are most likely fracture-controlled. The small amount of recharge due to precipitation along this limestone ridge probably percolates rapidly downward to the water table along nearly vertical bedding planes in the formation. Thus, the water-table gradient is probably relatively flat and the altitude of the water table at this site may not be much higher than that of the springs to the northeast.

Development: The estimated maximum depth to water could make this a marginal drilling site. The drilling depth to water could be decreased 40 to 50 feet by placing the well at the head of the gully one-quarter mile to the north in the SW¼NE¼NE¼ sec. 13.

Principal location: Site 3

Land-line description: NW¼NE¼SE¼ sec. 13, T. 8 S., R. 11 W.
(Bannack 7.5' topographic map)

Altitude of land surface above sea level: 6,480 feet

Inferred aquifer(s): Tertiary-Cretaceous Beaverhead Formation

Estimated depth to water below land surface: 700 to 800 feet

Estimated drilling depth: 750 to 900 feet

Estimated yield: 5 gal/min

Estimated dissolved-solids concentration of water: less than 1,000 mg/L

Hydrogeologic setting: This site is located on top of a narrow, north-trending ridge of Beaverhead Formation (Lowell, 1965) 1 1/2 miles north of Grasshopper Creek. Annual recharge from precipitation on the ridgetop is small and it is essentially isolated from receiving much recharge from the mountain mass 1 1/2 miles to the north by the intervening steep topographic relief.

The nearest surface evidence of water in the Beaverhead Formation is a spring on the south side of this ridgetop in the NE¼SW¼ sec. 19, T. 8 S., R. 10 W., at an altitude of 5,690 feet. As there are no overlying volcanic rocks to restrict or alter the flow path and there is little recharge from precipitation, the water level at this site probably is not much higher in altitude than the spring.

Development: The large estimated depth to water could preclude a successful well.

Alternative location to site 3: Site 3A

Land-line description: NE¼NE¼NE¼ sec. 11, T. 8 S., R. 11 W.
(Bannack 7.5' topographic map)

Altitude of land surface above sea level: 6,570 feet

Aquifer(s): Basalt and (or) granodiorite

Measured depth to water below land surface: 5.2 feet

Reported drilling depth: 400 feet

Reported yield: 1 to 3 gal/min

Estimated dissolved-solids concentration of water: 500 mg/L

Development: This well has not been used since it was drilled in 1974. The driller's report contains no information about the drawdown in the well associated with the reported yield of 1 to 3 gal/min. Subjecting the well to a pumping test after it has been developed can provide some useful information about its sustained yield and aquifer characteristics. If the yield is too small to justify the costs associated with pump installation, it may be possible to develop more capacity by selective downhole detonation of explosives, a technique sometimes used to fracture crystalline rock to increase yield.

Principal location: Site 8

Land-line description: SW¼SE¼SW¼ sec. 26, T. 8 S., R. 11 W.
(Eli Spring 7.5' topographic map)

Altitude of land surface above sea level: 6,150 feet

Inferred aquifer(s): Tertiary tuff, andesite agglomerate, and flows

Estimated depth to water below land surface: 200 to 250 feet

Estimated drilling depth: 250 to 400 feet

Estimated yield: 5 to 15 gal/min

Estimated dissolved-solids concentration of water: 500 mg/L

Hydrogeologic setting: This site is located about 1 mile south of Grasshopper Creek and 3 1/2 miles downstream from Bannack. The terrain consists of dissected hills of Tertiary volcanically derived sediments. The evenness of the landscape in this area is a reflection of the relative homogeneity of the unit. An unknown thickness of these sediments overlaps a northwest-trending syncline in Paleozoic and Mesozoic rocks exposed 3 miles to the southeast (Lowell, 1965). They may also overlie the Beaverhead Formation in places.

The closest developed spring, in the NE¼NE¼ sec. 2, T. 9 S., R. 11 W., issues from these sediments at an altitude of 6,170 feet. Two other springs issue from these sediments within 3 miles of the proposed site at an altitude of about 6,100 and 6,000 feet. All three of these spring sites are visible on aerial infrared imagery available in the Bureau of Land Management's Dillon Resource Area office. Although not checked onsite, two other sites appearing on the infrared imagery in sec. 36, T. 8 S., R. 11 W., at an altitude of about 5,850 feet (shown on the Eli Spring 7.5-minute topographic map) may also be due to ground-water seepage. The altitude of the water table at the proposed site is probably between 5,900 and 5,950 feet.

Development: Access to the site via Henneberry Ridge is marginal. A hole could be drilled at the site and cased the entire depth with perforations placed opposite all water-yielding zones. The drilling depth would depend somewhat on the hydraulic conductivity of the materials below the water table and the desired versus obtainable yield.

Principal location: Site X (proposed horizontal well)

Land-line description: NE¼NE¼ sec. 4, T. 8 S., R. 11 W.
(Bannack 7.5' topographic map)

Altitude of land surface above sea level: 6,500 feet

Inferred aquifer(s): Tertiary tuff, andesite agglomerate, and flows

Estimated yield: 2 to 5 gal/min

Estimated dissolved-solids concentration of water: less than 500 mg/L

Hydrogeologic setting: This site was not checked onsite. It is located on a hillside of volcanically derived Tertiary sediments less than one-quarter mile east of the edge of a fault thrusting Madison Group limestone on top of the sediments (Lowell, 1965). To the north and northeast, springs in the SE¼ sec. 28, the NW¼ sec. 26, and the NW¼ sec. 23 of T. 7 S., R. 11 W., seem to be closely associated with the thrust fault. Evidence suggestive of shallow ground water appears on the aerial infrared photography in the drainage about 500 feet south of this site.

Development: If subsequent onsite checking corroborates the infrared evidence, then a horizontal well could be drilled in a more or less westerly direction in the gully just below the proposed site. Such a well would have the potential of yielding a quantity of water similar to that of springs in the area issuing at about the same altitude. This well would most likely need to be cased, with perforations set along the entire length of the producing zone.

Principal location: Site Y (proposed well site with pipeline)

Land-line description: SW¼SE¼SW¼, sec. 19, T. 9 S., R. 10 W.
(Eli Spring 7.5' topographic map)

Altitude of land surface above sea level: 6,500 feet

Inferred aquifer(s): Mississippian Madison Group

Estimated depth to water below land surface: 450 to 600 feet

Estimated drilling depth: 500 to 650 feet

Estimated yield: 5 to 15 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,000 mg/L

Hydrogeologic setting: This site was not checked onsite. It is located on a ridgetop about 1 1/2 miles south of site 2. To the west, there is no evidence of ground-water seepage on the aerial infrared imagery in the gully bottom opposite the site (altitude of 6,050 feet). In the NW¼NW¼ sec. 36, T. 9 S., R. 11 W., the water table is reportedly at an altitude of 5,800 feet. Assuming a nearly flat water-table gradient (site 2 hydrogeologic setting), the depth to water at this site is probably in excess of 450 feet.

Development: The large estimated depth to water could preclude a successful well.

Principal location: Site Z (proposed well site)

Land-line description: SW¼SE¼NE¼ sec. 35, T. 9 S., R. 11 W.
(Eli Spring 7.5' topographic map)

Altitude of land surface above sea level: 5,980 feet

Inferred aquifer(s): Mississippian Madison Group or Proterozoic gneiss

Estimated depth to water below land surface: 100 to 200 feet

Estimated drilling depth: 250 feet

Estimated yield: 5 to 15 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,000 mg/L

Hydrogeologic setting: This site is located on a hillside almost directly in line with a concealed fault (Lowell, 1965) thrusting Madison limestone over Proterozoic gneiss. Approximately one-half mile away, in sec. 36, a 90-foot well drilled into gneiss has a reported depth to water of 70 feet (altitude of 5,800 feet) and a reported yield of 8 gal/min. The altitude of the water table in the vicinity of this site is also probably about 5,800 feet. By moving the drilling site north, closer to the road, and 200 to 400 feet west of the inferred fault line, it may be possible to intersect the fault plane beneath the water table at depths of 200 to 300 feet. Permeability, thus yield, may be enhanced along this fault zone.

Development: A well could be drilled at this site. The need for casing would depend on the competence of the rock materials penetrated at depth. Owing to the proximity of the site to a fault, the well would most likely need to be cased the entire depth, with perforations placed opposite water-bearing zones.

Principal location: Windmill Flat well (about 2.5 miles west of Henneberry Ridge base map)

Land-line description: SE¼NW¼SW¼NE¼ sec. 13, T. 9 S., R. 12 W.
(Grant 15' topographic map)

Altitude of land surface above sea level: 6,060 feet

Inferred aquifer(s): Tertiary sedimentary rocks

Measured depth to water below land surface: 131 feet

Reported drilling depth: 450 feet

Reported yield: unknown

Development: This well was visited in August 1984. A hole was drilled through the welded steel cap and the measured depth to static water level was 131 feet below land surface. Although, the hole has only 25 feet of surface casing, it is open to at least 350 feet. Making another attempt to clean and develop this drill hole might be worthwhile. By setting the intake to the pump assembly near the bottom of the hole, some 400 or more gallons of water would be available in the borehole as storage to supplement yield.

East Pioneer Mountains area

Principal location: Site 11

Land-line description: SW¼NW¼SW¼ sec. 19, T. 4 S., R. 9 W.
(Twin Adams Mountain 7.5' topographic map)

Altitude of land surface above sea level: 6,400 feet

Inferred aquifer(s): Cretaceous post-Kootenai sediments

Estimated depth to water below land surface: 500 to 650 feet

Estimated drilling depth: 550 to 700 feet

Estimated yield: 5 to 15 gal/min

Estimated dissolved-solids concentration of water: 500 to 1,000 mg/L

Hydrogeologic setting: This site is located on a rocky hillside on the flank of the East Pioneer Mountains. The closest evidence of ground-water seepage is a series of springs issuing from the ground at altitudes between 5,300 to 5,350 feet about 2 miles east of the site. One of these springs has a reported yield of 7 gal/min. Despite the gentle topography for about a mile upslope (west) of these springs, no further evidence of ground-water seepage was seen. Thus, the water-table gradient in this area must be something less than the surface relief of about 300 ft/mi. By assuming that the gradient is constant, the water table 2 miles to the west would most likely be deeper than 5,900 feet above sea level (or 500 feet below land surface).

Development: The large estimated depth to water could preclude a successful well. By moving the drilling site about one-half mile to the east, off the steep hillside, to the SE¼SW¼SW¼SE¼ sec. 19, the depth to water might decrease to a range of 150 to 250 feet.

Principal location: Site 15

Land-line description: NW¼SW¼NW¼ sec. 18, T. 5 S., R. 9 W.
(Twin Adams Mountain 7.5' topographic map)

Altitude above land surface above sea level: 6,020 feet

Inferred aquifer(s): Triassic Dinwoody and Woodside Formations

Estimated depth to water below land surface: 125 to 250 feet

Estimated drilling depth: 175 to 300 feet

Estimated yield: small

Estimated dissolved-solids concentration of water: 500 to 1,000 mg/L

Hydrogeologic setting: This site is located almost directly on the axis of a north-northeast trending anticline in the Dinwoody and Woodside Formations. A few hundred feet to the north or east of this site, Myers (1952) identified the basal member of the overlying Cretaceous Kootenai Formation consisting of alternating layers of coarse-grained, ridge-forming sandstone and mudstone. In other parts of central Montana, this basal member is commonly the preferred target of well drillers seeking a consistently reliable water supply. By moving the proposed site about 600 feet to the east and as much as 1,500 feet to the north, a well probably would be in the basal member of the Kootenai its entire depth.

The limbs of the anticline are steep to overturned; thus, the bedding is nearly vertical. Because the larger component of ground water commonly follows bedding planes, the altitude of the water table at the repositioned site may be about the same as the altitude of Birch Creek where it intersects the basal member of the Kootenai, or 5,800 feet above sea level. The altitude of the water table is probably not much different at the original site, but the potential yield in the Triassic rocks could be far less than that in the basal Kootenai.

Development: A well drilled at this site might require only surface casing. The depth of drilling below the saturated zone would depend mostly on the desired versus obtainable well yield from the bedrock.

McCartney Mountain area

Principal location: Site 4

Land-line description: SE¼SE¼NE¼ sec. 3, T. 3 S., R. 8 W.
(Nez Perce Hollow 7.5' topographic map)

Altitude of land surface above sea level: 6,500 feet

Inferred aquifer(s): Archean schist and gneiss

Estimated depth to water below land surface: 325 to 450 feet

Estimated drilling depth: 350 to 475 feet

Estimated yield: 5 to 10 gal/min

Estimated dissolved-solids concentration of water: 400 to 600 mg/L

Hydrogeologic setting: This site is located on the west slope of Nez Perce Hollow near the ridgetop. About 1 1/2 miles east of the site, a spring issues from the ground at an altitude of about 6,000 feet. One-half mile north and upslope of the site, a well drilled through an old mine shaft intersects the water table at an altitude of about 6,060 feet (July 25, 1984). By assuming a water-table gradient of about 125 ft/mi in this area, one might expect to intersect the water table at an altitude of about 6,175 feet at site 4.

However, the results of drilling the 620-foot Camp Creek dry hole 1 1/2 miles to the southeast indicates a different condition. Recently completed regional-scale geologic mapping of this area (Ruppel and others, 1983) shows a northwest-trending fault through the approximate center of Nez Perce Hollow. The springs and wells in Nez Perce Hollow are for the most part along the fault or northeast of it. Outcrops northeast of the fault consist mainly of gneiss with some sedimentary cover in part of sec. 1, as indicated by the driller's log of the well in the NW¼NW¼ sec. 1, T. 3 S., R. 8 W. Southwest of the fault, Tertiary sediments at least 470 feet thick in some places (Camp Creek driller's log) overlie the gneiss and schist bedrock in most of secs. 2, 11, and 12, T. 3 S., R. 8 W. Drillers' logs show that these sediments consist mainly of gravel and boulders in a clay matrix. A complicated series of imbricate thrust faults extends west of the crest of the ridge between sites 4 and 7. It is not clear from the available information whether some subsurface structural feature upgradient of the Camp Creek well is governing the occurrence of ground water in just that area or whether the occurrence of ground water throughout Nez Perce Hollow is mainly fracture controlled.

Development: Drilling a well at site 4 might not be successful, especially if water has not been found by the time the hole has been drilled 450 feet deep. Alternatively, the drilling site could be relocated about one-quarter mile farther east at an altitude of about 6,300 feet. There, a 250-to 300-foot hole could be adequate to determine whether or not the ground-water system northeast of the fault is continuous across it.

Alternative location to site 4: Site 4A

Land-line description: NW¼SW¼NW¼SE¼ sec. 35, T. 2 S., R. 8 W.
(Nez Perce Hollow 7.5' topographic map)

Altitude of land surface above sea level: 6,300 feet

Inferred aquifer(s): Archean biotite gneiss

Estimated depth to water below land surface: 125 to 200 feet

Estimated drilling depth: 150 to 250 feet

Estimated yield: 5 to 10 gal/min

Estimated dissolved-solids concentration of water: 400 to 600 mg/L

Hydrogeologic setting: See hydrogeologic setting for site 4. Siting a well on the northeast side of and close to the fault mapped by Ruppel and others (1983) as well as inline with other lineaments or fracture planes might enhance prospects for finding water.

Development: A well could be drilled at this site. If water is not found within 300 feet of land surface, additional drilling probably would be unproductive. Surface casing may be all that is necessary unless greatly fractured bedrock or fault gouge is penetrated at depth.

Principal location: Site 7

Land-line description: SE¼NE¼SE¼ sec. 10, T. 3 S., R. 8 W.
(Nez Perce Hollow 7.5' topographic map)

Altitude of land surface above sea level: 6,500 feet

Inferred aquifer(s): Archean gneiss and schist

Estimated depth to water below land surface: 500 to greater than 900 feet

Hydrogeologic setting: See hydrogeologic setting for site 4

Development: The potentially large estimated depth to water could preclude a successful well. This site might warrant re-evaluation if new subsurface information becomes available elsewhere in the area.

Sweetwater basin-Ruby Mountain area

Principal location: Site 5

Land-line description: NE¼NW¼SW¼ sec. 26, T. 9 S., R. 6 W.
(Red Canyon 7.5' topographic map)

Altitude of land surface above sea level: 7,090 feet

Inferred aquifer(s): Archean gneiss

Estimated depth to water below land surface: 350 to 600 feet

Estimated drilling depth: 400 to 650 feet

Estimated yield: 3 to 10 gal/min

Estimated dissolved-solids concentration of water: less than 500 mg/L

Hydrogeologic setting: This site is located on a ridgetop south of Sweetwater Creek on the northwest side of a fault (Ruppel and others, 1983) located approximately up the gully containing Virginia Springs (as shown on the Red Canyon 7.5-minute topographic map). There, Tertiary volcanic rocks overlie Archean gneiss. In Virginia Springs gully, the first evidence of ground-water seepage occurs at an altitude of about 6,600 feet. In late August 1984, a trickle of water was seen in the gully downstream from the spring issuing from the ground at an altitude of 6,500 feet in the NE¼ sec. 25. Water would probably not be found at site 5 at an altitude much higher than these springs and seeps.

Development: This is a marginal drilling site, owing to the range in the probable depth to water. If an attempt eventually is made to drill on this ridgetop, locating the hole in the saddle near the fault trace (SW¼NW¼NE¼SE¼ sec. 26, T. 9 S., R. 6 W., 7,030 feet above MSL) might enhance the well yield, provided the water table is close enough to land surface to justify installing a windmill. The need for casing will depend on the competence of the rock materials found at depth. If cased, perforations placed opposite all water-bearing zones would provide the greatest yield.

Alternative location to site 5: Site 5A

Land-line description: SE¼NE¼NW¼ sec. 22, T. 9 S., R. 6 W.
(Red Canyon 7.5' topographic map)

Altitude of land surface above sea level: 7,070 feet

Inferred aquifer(s): Archean gneiss

Estimated yield: less than 3 gal/min

Estimated dissolved-solids concentration of water: less than 500 mg/L

Hydrogeologic setting: This site is located in a grassy draw on the southwest slope of the ridgetop about 1 1/2 miles northwest of site 5. Besides evidence of ground-water seepage, infrared aerial imagery indicates a northwest-trending lineament in the gneiss at the site. On the opposite side of the ridge, a small spring issues from the ground at an altitude of about 7,100 feet.

Development: A small water supply possibly could be developed by drilling a horizontal well in the northwest wall of the draw approximately in alignment with the lineament. This close to the ridgetop, discharge could be subject to considerable seasonal fluctuation.

Principal location: Site 6

Land-line description: NE¼SW¼SW¼, sec 19, T. 8 S., R. 5 W.
(Red Canyon 7.5' topographic map)

Altitude of land surface above sea level: 6,900 feet

Inferred aquifer(s): Archean gneiss

Estimated depth to water below land surface: 350 to 600 feet

Estimated drilling depth: 400 to 650 feet

Estimated yield: less than 5 gal/min

Estimated dissolved-solids concentration of water: less than 1,000 mg/L

Hydrogeologic setting: This site is located on a ridgetop northeast of Sweetwater Creek. Ruppel and others (1983) mapped a fault in nearby Archean gneiss. This fault is also visible on SLAR (side-looking airborne radar) imagery (scale 1:250,000). The closest springs to the north and east of this site issue from the ground at altitudes between 6,200 and 6,400 feet. Many of the springs are situated on known faults. About 1 mile north of the site in the south fork of Sage Creek, a grassy area could be seen onsite near the fault trace corresponding to evidence on the infrared aerial photography of possible ground-water seepage (shown on the Red Canyon 7.5-minute topographic map).

Development: This is a marginal drilling site, owing to the range in the probable depth to water. If an attempt eventually is made to drill on this ridgetop, relocating the site about 800 feet to the north and east, closer to the fault trace, might enhance the well yield, provided the water table is close enough to land surface to justify installing a windmill. The need for casing will depend on the competence of the rock materials found at depth. If cased, perforations placed opposite all water-bearing zones would provide the greatest yield.

Alternative location to site 6: Site 6A

Land-line description: NW¼SW¼SW¼ sec. 18, T. 8 S., R. 5 W.
(Mine Gulch 7.5' topographic map)

Altitude of land surface above sea level: 6,540 feet

Inferred aquifer(s): Archean gneiss

Estimated depth to water below land surface: 20 to 250 feet

Estimated drilling depth: 50 to 300 feet

Estimated yield: 2 to 10 gal/min

Estimated dissolved-solids concentration of water: less than 1,000 mg/L

Hydrogeologic setting: This site is located in the south fork of Sage Creek north of site 6 on private land. The water table may be relatively close to land surface. However, the drilling depth will depend somewhat on the degree of fracturing of the gneiss bedrock.

Development: A well drilled at this site probably would have a larger yield and a shallower water level than at site 6. The need for other than surface casing in the well will depend on the competence of the rock materials found at depth.

Principal location: Site 14

Land-line description: NW¼NW¼NW¼ sec. 11, T. 9 S., R. 5 W.
(Belmont Park Ranch 7.5' topographic map)

Altitude of land surface above sea level: 6,650 feet

Inferred aquifer(s): Tertiary sedimentary rocks

Estimated depth to water below land surface: 450 to 700 feet

Estimated drilling depth: 550 to 800 feet

Estimated yield: less than 10 gal/min

Estimated dissolved-solids concentration of water: less than 1,000 mg/L

Hydrogeologic setting: This site is located on the ridgetop between Sweetwater Creek to the west and Robb Creek to the east. Annual precipitation on the ridge itself and the area south of it is small; thus, recharge to the ground-water system cannot be very great. East of the site, Robb Creek intercepts recharge from the mountains to the east as ground-water inflow at about the 6,000-foot level. The depth to water is probably something less than the difference in altitude between Sweetwater Creek and the site (800 feet). Water might be found at a drilled depth of less than 450 to 500 feet. However, to obtain an adequate sustained yield at this site, the intake might need to be set as much as 100 feet into the saturated zone.

Development: The potentially large estimated depth to water could preclude a successful well.

Red Rock Hills area

Principal location: Site 9

Land-line description: NE¼NW¼SW¼ sec. 21, T. 12 S., R. 8 W.
(Rock Island Ranch 7.5' topographic map)

Altitude of land surface above sea level: 7,230 feet

Inferred aquifer(s): Tertiary Cook Ranch or Sage Creek Formation

Estimated depth to water below land surface: 425 to 550 feet

Estimated depth of well: 450 to 600 feet

Estimated yield: 10 to 20 gal/min

Estimated dissolved-solids concentration of water: less than 1,000 mg/L

Hydrogeologic setting: This site is located at the southern end of the crest of the Red Rock Hills overlooking Spring Gulch to the northeast and Sage Creek to the south and southeast. About 2 miles southwest of the site, in sec. 31, a well drilled into the Beaverhead Formation (Scholten and others, 1955) intersected the water table 475 feet below land surface, at an altitude similar to that of Sage Creek south of it. Northeast of the site, several springs emanate from the Cook Ranch Formation along Spring Gulch. A well in the Cook Ranch Formation on the opposite side of Spring Gulch yielded 30 gal/min. As site 9 is also in Cook Ranch Formation, the estimated depth to water is based on extrapolations of apparent ground-water gradients along Spring Gulch.

Development: This is a marginal drilling site, owing to the range in the probable depth to water. If a well were drilled at this site, casing would be needed in the hole, with perforations opposite water-bearing zones to provide the greatest yield.

By relocating this site downslope and to the north, closer to Spring Gulch, the chances for obtaining a water supply at depths much less than 500 feet would improve greatly. For example, the depth to water in the NE¼SE¼NW¼NW¼ sec. 21, in the SW¼NE¼NE¼NW¼ sec. 8, and in the SW¼NE¼SW¼SW¼ sec. 5, T. 12 S., R. 8 W., is probably 300 to 350 feet below land surface. In the SW¼SE¼NW¼NE¼ sec. 21, T. 12 S., R. 8 W., the depth to water is probably 200 to 300 feet, and in NW¼SE¼NE¼NE¼ sec. 17, T. 12 S., R. 8 W., the depth to water is probably 150 to 250 feet. These sites are all situated on Cook Ranch Formation (Scholten and others, 1955).

Principal location: Site 12

Land-line description: NW¼SW¼SW¼ sec. 10, T. 13 S., R. 8 W.
(Lima 7.5' topographic map)

Altitude of land surface above sea level: 6,700 feet

Inferred aquifer(s): Tertiary Blacktail Deer Creek Formation

Estimated depth to water below land surface: 150 to 300 feet

Estimated drilling depth: 200 to 350 feet

Estimated yield: 5 to 10 gal/min

Estimated dissolved-solids concentration of water: less than 1,000 mg/L

Hydrogeologic setting: This site is located on the northeast-facing slope of a ridge. About 1 mile farther northeast, a spring issues from the ground in the Blacktail Deer Creek Formation (Scholten and others, 1955) at an altitude of 6,330 feet. (Another spring one-fourth mile west of the site is most likely supplied by a small amount of perched ground water.) The altitude of the water table at this site is probably above the altitude of the spring and below the altitude of the circular grassy patch (altitude of 6,600 feet) in the draw below.

The driller's log of a 640-foot well drilled into the Blacktail Deer Creek Formation in the NE¼NW¼ sec. 18, T. 13 S., R. 7 W., shows that the formation can contain much clay. Thus, the yield of a well at site 12 will probably not be large.

Development: A well could be drilled at this site. The well might need to be cased its entire length, with perforations set opposite water-bearing zones, to provide the greatest yield.

About one-fourth mile and 100 vertical feet downslope from site 12, in the SW¼NW¼SW¼ sec. 10, is a circular grassy patch that appeared on the aerial infrared photography just upslope of a lineament. If this lineament represents a fault that restricts ground-water flow, a well drilled in the grassy patch could intersect the water table at a fairly shallow depth.

SUMMARY

Hydrogeologic data and information are described for 20 principal sites for stock-water development. All but two of these sites were visited during the summer of 1984. Well development was not considered to be economically feasible if estimated depths to water exceeded about 500 feet below land surface. Thus, most of the sites were considered to be marginal at best for locating a wind-powered pump on a well. Several alternative well locations were considered and identified.

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