HYDROGEOLOGIC ASSESSMENT OF HIDDEN LAKE SUBDIVISION WATER SUPPLY
FOR
GROUND WATER UNDER THE DIRECT INFLUENCE OF SURFACE WATER

Open File Report MBMG 401-D

HIDDEN LAKE SUBDIVISION WATER SUPPLY
PWSID #03374
4920 Country View
Billings, MT 59105

Prepared
for
Montana Department of Environmental Quality
Water Quality Division

by
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INTRODUCTION AND PURPOSE

This report summarizes the results of a hydrogeologic assessment for the Hidden Lake Subdivision Public Water Supply (PWSID #03374) located in Yellowstone County north of Billings, Montana. The Montana Bureau of Mines and Geology (MBMG) is under contract with the Montana Department of Environmental Quality (DEQ) to conduct preliminary assessments and hydrogeologic assessments for selected community water supplies. The project was funded under DEQ contract number 4300022 task order number 7.

The purpose of this hydrogeologic assessment is to determine if the infiltration gallery source used by the Hidden Lake Subdivision is under the direct influence of surface water as defined in 40 CFR part 141. A field inspection was completed on May 19, 1998 with Mr. Larry Vandenbosch, water system operator. **The results of the assessment indicate that the Hidden Lake Subdivision infiltration gallery may be under the direct influence of surface water as defined in 40 CFR part 141.**

This report summarizes information obtained during the field inspection and follow-up investigation that was used to make the above determination. Information on system location, construction, geology, hydrology, and water quality are summarized. Conclusions and recommendations are presented at the end of the report. Site maps, system design drawings, photographs and water quality reports are provided as appendices.

BACKGROUND

The Surface Water Treatment Rule (SWTR) of the Federal Safe Drinking Water Act of 1986 requires each state to examine public water supplies that use ground water to determine if there is a direct surface water influence. In Montana, the Water Quality Division (WQD) of DEQ is evaluating public water supplies for the SWTR. This project is known as the **Ground Water Under the Direct Influence of Surface Water (GWUDISW) program**. The SWTR defines ground water under the direct influence of surface water as any water beneath the surface of the ground with:

i) significant occurrence of insects or other macroorganisms, algae, or large diameter pathogens such as *Giardia lamblia*, or *Cryptosporidium*; or

ii) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity or pH, which closely correlate to climatological or surface water conditions.

The evaluation begins with a preliminary assessment (PA). If the PA indicates that the ground-water supply may be under the direct influence of surface water, further study is required. Further study may include conducting a hydrogeologic assessment, a water quality assessment, and/or conducting microscopic particulate analysis (MPA) sampling.

PRELIMINARY ASSESSMENT

A completed PA form for the Hidden Lake Subdivision infiltration galleries is included as appendix A-1. The Hidden Lake subdivision infiltration galleries are the only source of drinking water used by the subdivision residents. There are no other wells in the subdivision and ground water is difficult to find on the subdivision property. The water that is located is often of poor quality and not useable as a domestic water source. The Hidden Lake subdivision infiltration gallery system was assigned a total score of 55 points with 40 points automatically assigned for an infiltration gallery collection system. An additional 15 points were added because two of the three infiltration galleries are located 60 feet (ft) downgradient from surface infiltration ponds designed to recharge the ground-water supply and two of the infiltration galleries are located within 150 ft of a surface-water storage reservoir. **The total score of 55 points, out of a possible total of over 200, indicates the system is at moderate risk of being under the direct influence of surface water. Because the score is above 40 points, additional evaluation is required under DEQ guidelines.**

SYSTEM DESCRIPTION

Location

The Hidden Lake subdivision is located in Yellowstone County north of Billings, Montana, 3 ½ miles north of the junction of U.S. Highway 312 / U.S. Highway 87 (figure 1). The subdivision is located on Lorraine Road about ¼ mile east of the Roundup Road (Highway 87) (figure 2). The location of the subdivision and water system are shown on the Rattlesnake Butte 7.5-minute U.S. Geological Survey quadrangle map (figure 2.). The subdivision covers SE¼ section 26, T. 02 N., R. 26 E. The infiltration gallery, collection well and pump house for the subdivision water supply system are located approximately ¾ mile northeast of the subdivision near the Rattlesnake Reservoir at SE¼, NW¼, NE¼, NW¼, section 25, T. 02 N., R. 26 E. and N 45° 53' 55" latitude and W108° 26' 19" longitude (figure 2).

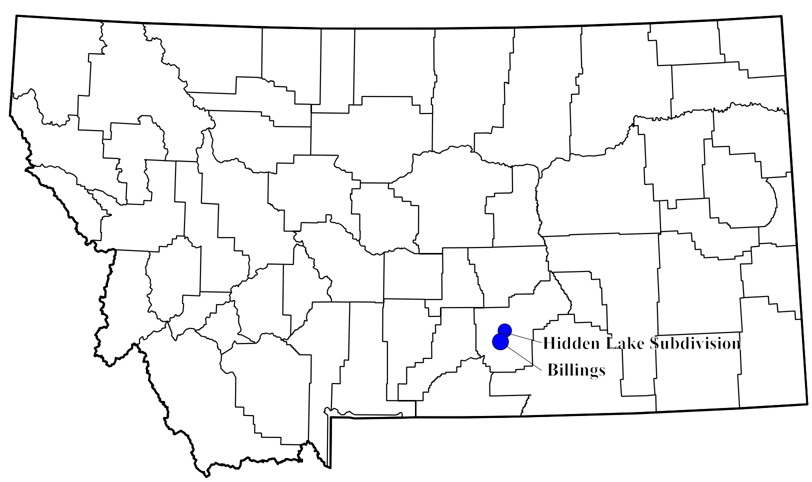

Figure 1. State map showing location of Hidden Lake subdivision relative to Billings, Montana.

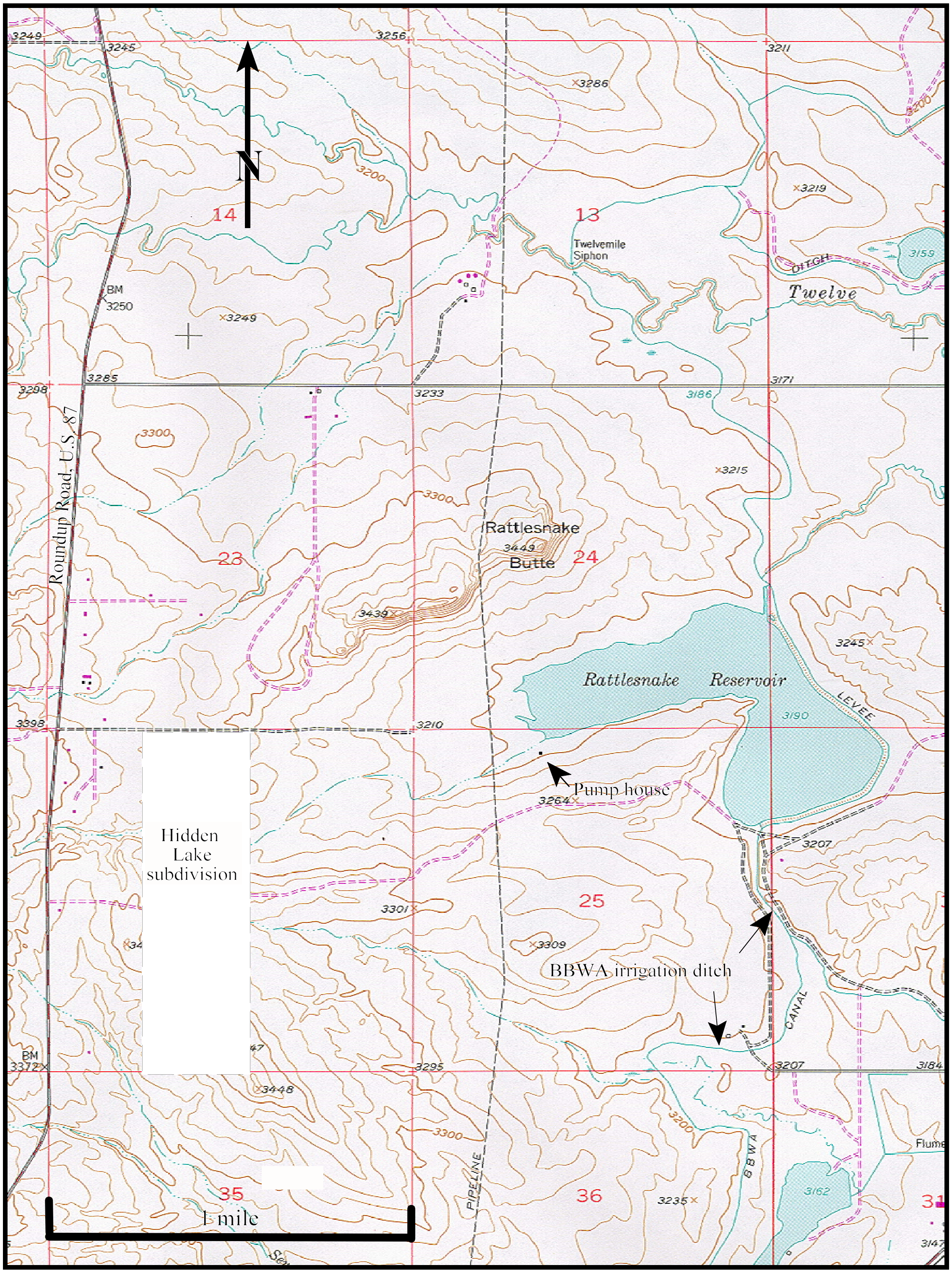

Figure 2. Topographic map of Hidden Lake subdivision area showing location of subdivision, pump house and infiltration galleries, Rattlesnake Reservoir and the BBWA irrigation ditch (Rattlesnake Butte 7.5-minute quadrangle, 1975).

Development of the Hidden Lake subdivision was begun in 1986. Of the 126 lots currently established at the subdivision, 60 have homes on them. Phase II construction will add another 140 lots for a proposed total of 266 lots in the final subdivision plan.

In 1988, a dry year, 30 user households on the water system pumped the system dry. In 1989 the Montana Department of Health and Environmental Sciences (DHES) Water Quality Bureau (now the Department of Environmental Quality (DEQ)) responded to a series of complaints about the water quality and quantity. The complaints included:

- Insufficient water supply
- Water quality problems since extension of the infiltration galleries
- Turbidity
- Strong hydrogen-sulphide odor from the water

An estimate of the production requirements for a water system supplying 60 homes was calculated assuming 3 users/lot (household) and 100 to 150 gpd per person (Solley and others, 1993). The current water demand would be about 18,000 gpd to 27,000 gpd. If the initially planned 266 homes are built the system demand would rise to 80,000 to 120,000 gpd. Water use is recorded with a water meter located in the pump house.

In July 1989, Aquoneering Consulting Engineers (ACE), a hydrologic consulting firm, conducted a site assessment. In their report, ACE estimated that the subdivision water-supply system should be capable of supplying at least 225 GPCD (gallons per day per person) or 53 gpm for each of the existing 60 homes (76,000 gpd) and 240 gpm (346,000 gpd) for each of the 266 homes to meet peak demands. This value is based on regional studies of similar sized water-supply systems and considers lawn watering and other uses. ACE also stated that the gallery system is relatively shallow **and is susceptible to a direct connection with surface water** (ACE, 1989). To control the influx of surface water, bentonite clay barrier layers have been installed over the top of most of the gallery sections. ACE also determined that the shallow ground-water system could not adequately supply the necessary water volume to the water-supply system.

In 1989-1990 ACE designed and contracted the installation of an artificial ground-water recharge system to increase the ground-water volume available to the infiltration galleries. The artificial recharge system was designed to support 60 homes (approximately 180 residents). Along with the system modifications in 1989, the north infiltration gallery was plugged off to control turbidity problems and the hydrogen-sulphide gas odor. The hydrogen-sulphide gas probably comes from decayed plant matter in the swampy areas around the reservoir or from marine shales in contact with the ground water. In 1997 the subdivision developers added a separate irrigation supply system with a lagoon and separate piping for lawn watering and other non-potable uses to relieve the demand on the main water-supply system.

Infiltration Gallery Configuration
The Hidden Lake water supply system consists of three infiltration galleries connected to a common collection well located at the pump house (Appendix D-2). The pump house and collection well are located about 150 ft west-southwest of the Rattlesnake Reservoir shoreline (figure 2). The collection well is an 84-inch diameter concrete well that is 19.5 ft deep with a concrete cover. The well can be accessed through a manhole lid located on the concrete well cover alongside the pump house (appendix C-1.). The manhole access and pump-house door are both locked. The pump house contains two 60 gpm pumps that draw water from the collection well, timers for the pumps, an inline pressure gauge and a liquid chlorinator equipped with a metering system (appendix D-1). Water is pumped uphill from the pump house to a 54,700 gallon storage tank at the subdivision through a 6-inch diameter pipe. A second set of pumps at the storage tank pump water from the storage tank into the distribution lines to the homes. The lines from the storage tank to the distribution system are reported to have inline back-flow preventers. Each home is reportedly equipped with a reverse osmosis water treatment system. The system appears clean and the water-system operator appears to keep good records of the daily system operations and maintenance.

Three gallery legs extend north, south and east from the collection well:

- The east leg extends toward Rattlesnake Reservoir for a distance of about 160 ft from the collection well and is buried 12 ft below the top of the collection well and about 5.5 ft below the water level in the well.

- The north gallery is 135 ft long and lies 14 ft below the top of the collection well. The north gallery was extended 438 ft northeast in 1988 but was plugged off in 1989.

- The west leg was initially 388 ft long and extended to 6.5 to 7 ft below the static water level. In 1988, the west gallery was extended 371 ft to the north.

According to the ACE report (1989), the three infiltration galleries are constructed of 8-inch diameter PVC pipe perforated with 3/4-inch diameter holes spaced 4 to 6 inches apart. The gallery pipe was laid in trenches that were backfilled with coarse sand and gravel and covered by a filter fabric. The east and north infiltration galleries extend along the shoreline of the Rattlesnake Reservoir and may be recharged by water infiltrating from the reservoir. Following lengthening in 1988 the north gallery began producing turbid water and a rotten egg odor (hydrogen sulphide gas). In 1989 the extension was mechanically plugged and blocked off from the water-supply system. Also in 1989, the design of the newly added portion of the west gallery allowed unfiltered surface water to leak into the gallery, thus producing highly turbid water. The covering above the west gallery leg was resealed with filter fabric and bentonite clay and the problem was apparently solved.

The shallow ground-water supply at the gallery site is supplemented by an artificial recharge system which uses surface water pumped into infiltration ponds located south of the pump house to recharge the shallow ground water (appendix C-2). The artificial-recharge-by-surface-water system was designed and installed as part of the Hidden Lake water supply system by ACE in 1989-1990 to augment the ground-water supply to the infiltration galleries. Surface water is pumped from the Billing Bench Water Association (BBWA) irrigation ditch located 1 mile east of the pump house, through a 2-inch diameter, black PVC pipe to infiltration ponds located at the pump house (figure 2). The water in the ponds percolates into the shallow aquifer 60 ft upgradient of the east and west infiltration galleries (appendices C-2 and C-3). Surface water is pumped from the BBWA irrigation ditch into the infiltration ponds between April 15 to October 15 each year when the irrigation ditch is flowing. The rest of the year the water supply system relies on ground-water reserves from the shallow aquifer. The artificial recharge system is intended to supply water to 60 homes.

In 1997 a separate water collection, storage and distribution system were constructed at the subdivision to be used for lawn irrigation and fire protection to reduce the water demand from the primary water-supply system. The irrigation system water is pumped from the BBWA irrigation ditch to a lagoon on the east side of the subdivision through a separate pump and piping system. Since installation of the artificial recharge system and the secondary irrigation water system, the water-supply system has not experienced a water shortage. However, if the subdivision is to be expanded ACE recommended laying a pipeline from the Billings City Water mains to the subdivision as an alternate source of water.

A series of observation wells and test boreholes have been installed around the infiltration galleries. Many did not have well caps at the time of the hydrogeologic assessment and may serve as conduits for ground-water contamination. The observed wells had stickups ranging from 2 to 4 ft above the land surface.

The reservoir and surrounding land are posted against trespassing. A locked cable-gate across the road, the rural setting, the distance from the subdivision and the locked pump house and collection well cover all restrict unwanted access to the water supply system.

GEOLOGY

Local Topography and Land Use

The subdivision is located about 5 miles northwest of the Yellowstone River on land formerly used for agriculture. The land around the subdivision is still used for grazing cattle and for dryland farming. The subdivision is located on rolling, hilly terrain with gently to moderately sloping drainages and occasional steep, cliff-forming outcrops of resistant sandstone ledges (appendices C-1 and C-2). The drainages are typically shallow and broad, and the land generally slopes to the northeast toward the Yellowstone River. The collection well and infiltration galleries are located near the bottom of a broad, shallow drainage at an elevation of 3,200 ft. The elevation of the hilltop to the west, at the headwaters of the drainage, is 3,575 ft; the elevation of the surface of the water-storage reservoir to the northeast, near the mouth of the drainage, approximately 3 miles east of the headwaters, is approximately 3,190 ft. The subdivision homes and water-storage tank are located on a hill southwest of the galleries at an elevation of 3,300 ft (Appendices C-3). The soils are mostly sandy, but some loam-type soils are also present. The area is semi-arid and is predominantly underlain by low-permeability marine shales and silts.

The infiltration galleries are located northeast of the subdivision, along a north-facing slope near the mouth of a broad, gently-sloping, dry drainage (appendices C-1). No distinct channel is present in the drainage bottom. The drainage basin is approximately 1,400 acres in size (2.25 square miles) and is approximately 1 - 1 ½ miles wide at the gallery site 1 ½ miles east of the head of the drainage (figure 2).

Regional Geology

The Hidden Lake subdivision is located north and west of the terrace benches of the Yellowstone River Valley on faulted blocks of Upper Cretaceous marine and near-marine sediments of the Bearpaw shale and older Upper Cretaceous Judith River Formation (appendix B-1). Table 1 shows the estimated thickness and relative stratigraphic positions of the geologic formations in the Hidden Lake area.

Table 1. Estimated thickness of geologic formations in Yellowstone County (Hall and Howard, 1929; Niebauer, 1941).

Geologic unit	Geologic age	Thickness, ft
alluvium	Quaternary	<1- 15
Lance Formation	Upper Cretaceous	1500
Bearpaw Shale		600-1000
Judith River Formation		up to 400
Claggett Formation		up to 600
Eagle		200 - 300
Telegraph Creek		170
Colorado Group Shales	Cretaceous	2,250

The water-supply site lies along the southern flank of the Lake Basin Fault system, an east-southeast trending structural lineament composed of a series of northeast trending normal, reverse and thrust faults that extends for approximately 100 miles across northern Stillwater County, central Yellowstone County and eastward into Bighorn County. Displacement along the faults is generally less than 500 ft but has been measured at almost 1,000 ft at Rattlesnake Butte (Hall and Howard, 1929).

The strata in the Hidden Lake area dip gently to the northeast except along the Lake Basin Fault Zone, where faulting has tilted and rotated some blocks. The strata are displaced between the numerous Lake Basin faults so that within the faulted area, older geologic strata are mapped at the land surface adjacent to younger strata (appendix B-1).

A thin layer of Quaternary alluvium made up of unconsolidated coarse gravel to fine silt covers the land surface along drainage bottoms and along the Yellowstone River valley. The unconsolidated sediments appear to be thin and localized along the lowest portions of the drainage bottoms and originate from the underlying Upper Cretaceous bedrock (Lopez, 1996). Terrace gravels ranging from Holocene to possibly as old as Pliocene cover benches along the Yellowstone River valley; thicknesses range from a few inches up to 60 ft. Terrace gravels up to 20 ft thick are found in erosional remnants locally on hilltops and typically overlie Bearpaw shale (Hall and Howard, 1929). Quaternary colluvium locally forms slopes of unconsolidated material along the margins of the Yellowstone River bottom and at the base of steep slopes.

The Upper Cretaceous Lance Formation is the youngest formation exposed at the study area aside from the Quaternary alluvium and colluvium. The formation is composed of alternating layers of lenticular shale and sandstone masses, and contains some thin unworkable coal deposits near the top (Hall and Howard, 1929). The formation resembles the Fort Union Formation and has similar properties. The upper one-quarter (Tullock member equivalent) contains yellow or brown sandstones with thin coal beds. The lower three-quarters is light-greenish to yellow shale with many heavy beds of sandstone and is laterally continuous with the Hell Creek Formation mapped to the north and east.

The Bearpaw shale underlies the Lance Formation and is a dark-blue to grey-black marine shale containing fossiliferous, calcareous concretions. The Upper Cretaceous Bearpaw shale is the dominant formation exposed at the land surface east of Billings and north of the Yellowstone River (Lopez, 1996).

The underlying Judith River Formation is predominantly composed of light brown to yellowish brown, very fine to fine grained sandstone beds up to 10 ft thick alternating with beds of shale, silts and bentonitic clays (Hall and Howard, 1929 and Lopez, 1996). The Judith River Formation in this area is fresh water in origin but changes to a more brackish water depositional environment to the east. The formation is up to 400 ft thick; only the upper portion is exposed at the land surface at the gallery site. Confined aquifers are often found at depth in the sandstone layers located between clays and shales within the Judith River Formation.

Beneath the Judith River Formation is the Claggett shale, a soft, brownish grey shale containing some sandstone layers (Lopez, 1996). The Claggett shale is up to 500 ft thick and is often fossiliferous. The formation outcrops 1 ½ miles southwest of the gallery site along the Roundup Road (appendix B-1).

The Eagle Sandstone, which forms the rim rocks at Billings, has been mapped in outcrop 5 miles to the west of the gallery site but probably lies about 1,000 to 1,400 ft below the land surface at the site (ACE, 1989). The sandstone formation is predominantly light brownish grey to very pale orange, very-fine- to fine-grained sandstone (Lopez, 1996). The sandstone occurs in multiple layers 10 ft to 50 ft thick, and contains interbedded layers of sandy shale up to 50 ft thick. The Eagle sandstone is the oldest formation exposed at the land surface northeast of Billings, in Yellowstone County.

Local Geology

The Hidden Lake area lies along the Lake Basin Fault Zone. The fault zone is composed of a series of nearly parallel, 5 to 7 mile long, steeply dipping, normal and a few reverse faults that dissect the geologic units into separate structural blocks (Hall and Howard, 1929). Strata along the lineament have been distorted into depressions along the north side of the trend and arched along the south side. Relative fault displacement is generally down to the east. The Hidden Lake infiltration galleries are located on the southern flank of the Lake Basin Fault system, on a segment of Judith River Formation. Two northeast-trending faults mapped by Lopez (1996) cross the study area along the north side of Rattlesnake Reservoir near the infiltration galleries and along the south side of the reservoir at the dam location. A third fault places the Lance Formation sandstone against Judith River Formation north of the galleries. The displacement along this fault is almost 1,000 ft. These faults form a series of branches that join together approximately 1 ½ miles southwest of the gallery site (appendix B-1), and have been mapped at about 1 mile intervals across the study area.

Outcrops at the gallery site are primarily Judith River Formation to the west and south of the galleries and Bearpaw shale to the north and east of the site (Lopez, 1996) (appendix B-1). Outside the Lake Basin Fault zone, the regional dip is gently to the northeast at 6 to 8 degrees. However, within this fault zone, including the gallery site, dips are more erratic as the result of fault movement (appendix B-1).

Thin, narrow deposits of Quaternary alluvium cover the land surface along the drainage bottom and around Rattlesnake Lake. Borehole logs from wells drilled around the infiltration galleries indicate that the maximum thickness of the unconsolidated alluvial material is less than 4 ft and the average thickness is less than 1 foot.

HYDROLOGY

Little work has been done to characterize the flow of ground water in the study area. Ground-water information was obtained from reports by ACE, U. S. Geological Survey (USGS) publications, Montana Bureau of Mines and Geology (MBMG) maps and the Montana Ground-Water Information Center (GWIC) water well and water quality database and DEQ water quality data reports. No field work was conducted as part of the hydrologic assessment.

Surface Water

The infiltration galleries lie about 5 miles northwest of the Yellowstone River between Sevenmile Creek and Twelve Mile Creek (figure 2). Both creeks, along with most other streams in the area, are ephemeral and drain to the southeast towards the Yellowstone River. The gallery site and collection well are located approximately 150 ft southwest of the Rattlesnake Reservoir. The 715 acre-ft reservoir serves as a regulatory water-storage area for the Billings Bench Water Association (BBWA) irrigation ditch and is the largest body of water in the area. The BBWA ditch draws water from the Yellowstone River near Park City, Montana and carries it northeast along the Yellowstone River valley through irrigated farm land and through the city of Billings before reaching the Rattlesnake Reservoir. The BBWA irrigation ditch flows past the mouth of the water supply system drainage one mile east of the gallery site.

Regional Ground-Water Flow

Many of the formations that underlie Yellowstone County are of Upper Cretaceous age and are composed predominantly of thick, marine shales (table 1). The Upper Cretaceous Bearpaw shale, Claggett Formation and the deeper Colorado shales yield little or no water due to the fine-grained nature of the shale bedrock (Hall and Howard, 1929). The ground water that is present in these formations is typically highly mineralized due to the marine origin of the bedrock material and is usually unsuitable for domestic purposes. Geologic formations containing sandstone units typically have ground water of adequate quantity and varied quality (Hall and Howard, 1929). Ground water is present and useable in wells in the sandstone layers of the Eagle sandstone, the Judith River, Lance and Fort Union Formations. Ground water in the alluvium along the drainage bottoms, along the Yellowstone River, and in the terrace gravels along the valley margins are also commonly used by wells. Due to the localized nature of the terrace gravels, water supplies in the gravels may be limited.

Ground water in the region is recharged by precipitation and infiltration of water through the land surface. The ground water is locally recharged by the infiltration of irrigation and surface water. The climate at Billings is semi-arid, with an average of about 15 inches of precipitation annually (30-year mean NCDC, 1999) so the supply of recharge water is limited. Most precipitation is received as rainfall in the spring. Infiltration of precipitation is reduced by the presence of the abundant clay and shale layers. Most recharge to the ground water occurs where more permeable, water-bearing layers are exposed at the land surface. Vertical water movement between aquifers is also limited due to the low permeability clay and shale layers.

Shallow ground water movement in the alluvium is controlled by land surface topography and the surface drainage patterns. Faults of the Lake Basin Zone in central Yellowstone County appear to generally complicate ground-water flow in the bedrock (Hall and Howard, 1929). In some areas the structures act as barriers to flow and in others they appear to provide a good conduit for water movement. Hall and Howard (1929) found that within the fault zone geologic units that typically contained water were dry and other less likely strata contained good quantities of water. In general, ground-water movement in the vicinity of the fault zone was difficult to interpret.

Local and Intermediate Ground Water Flow

Intermediate ground-water movement may occur through the more permeable layers within the Judith River Formation beneath the gallery site. A number of wells in the area draw water of acceptable quality from one of several confined sandstone layers within the Judith River Formation (appendix E-1). The depth of these wells range from 88 ft to 300 ft below the land surface. The quality of the water in these units varies widely depending upon the structural controls and circulation of ground water that is possible within the aquifers. Many of the aquifers are confined by low-permeability layers above and below the water-bearing layer.

The infiltration galleries are buried approximately 10 ft below the land surface and draw ground water from the shallow Judith River Formation. Drillers logs from observation wells around the infiltration galleries show that the more permeable aquifer material ranges from a sandy silt to a silty sand approximately 2.5 ft to 7.5 ft thick overlying a stiff, plastic clay logged at 5.5 ft to >15 ft below the surface. The saturated thickness of the aquifer in the boreholes ranged from less than 1 ft to greater than 7 ft (ACE, 1989). The permeability of the shallow aquifer materials is variable across the site. The permeability was so low in a trench dug by ACE (1989) north of the west gallery, that water would not flow into the trench. Useable water will only be available from the more permeable sands. Because of the low permeability of the clay, very little water will flow from the clay into the infiltration galleries.

The infiltration gallery is located within a fault-bounded block of Judith River Formation within the Lake Basin Fault Zone. On the northern border of the block the Judith River Formation is juxtaposed against Bearpaw shale but on the southern and western borders offset is confined within the Judith River Formation (appendix B-1). The areal extent of the aquifer and potential water sources are limited by the physical boundaries of the local strata and the fault system. The displacement of the strata across the faults causes it to be nearly impossible to follow one aquifer unit through the faulted area. The layers are displaced to different depths and tilting has changed the dips and reduced the exposed surface area of the aquifer layers. Because of faulting, ground water at the gallery site appears to be isolated from regional aquifers. Also, the limited areal extent of the shallow aquifer does not allow for significant quantities of recharge.

The faults appear to influence the direction and movement of ground water through the gallery area. Water-level measurements collected by ACE from monitor wells screened in the shallow aquifer at the gallery site indicate that the gradient of the potentiometric surface is downward to the northeast, following the dip slope of the strata. Recharge to the ground water at the infiltration galleries probably occurs in the higher elevation areas around the south and west sides of the drainage. However, because of the structural boundaries on the aquifer, most recharge probably occurs from infiltration through the land surface over or near the galleries. Aquifer recharge may occur faster in areas where the soil and unsaturated materials above the aquifer are more permeable. The shallow ground water probably discharges from the aquifer along permeable fault fractures or at steep breaks in the surface topography where the land surface intercepts the water table. This situation was not observed in the gallery area but may occur farther east where the Yellowstone River has incised into the bedrock.

ACE (1989) reported the results from aquifer tests conducted in 1985 to determine the hydraulic characteristics of the aquifer around the infiltration galleries. These tests were conducted by a previous consultant. For the tests, water was pumped from the individual infiltration galleries and water-level drawdowns were measured in observation wells located around the galleries. The test suggested that the best permeability in the shallow Judith River aquifer at the site is to the south and that most of the ground water flows from the south toward the galleries. The hydraulic conductivity of the aquifer around the east gallery leg was estimated to be 20 ft/day. Hydraulic conductivities around the west leg ranged from 10 ft/day to the north to 25 ft/day to the south. The water table gradient south of the gallery, where the infiltration ponds are now located, was 0.025 (2.5 ft/ 100 ft).

Artificial recharge system

The shallow Judith River aquifer is artificially recharged at the infiltration gallery site. Prior to installation of the artificial recharge system, the shallow aquifer could not supply adequate volumes of water to the water-supply system, particularly during the low recharge winter months (ACE, 1989). During the winter, the precipitation rates are generally low, and the ground is frozen, which can significantly reduce the rate of infiltration through the land surface.

Surface water is pumped into infiltration ponds south of the infiltration galleries where the water moves downward into the shallow aquifer and flows toward the galleries. Water infiltrating from the ponds must travel through 60 ft of silty-sand to sandy-silt aquifer material from the ponds to the galleries. The time of travel required for infiltrating water to move through the aquifer between the ponds and the galleries was estimated using the average linear velocity equation (Fetter, 1994):

$$V_x = k/N_{eff} * (dh/dl)$$

Where: V_x is the average linear velocity, k is hydraulic conductivity, N_{eff} is effective porosity of the aquifer material, and dh/dl is the gradient of the potentiometric surface.

Hydraulic conductivity estimates from aquifer tests conducted in 1985 were used to estimate the average linear velocity of ground water through the aquifer (ACE, 1989). The effective porosity was estimated for a silt (18 percent) and a very fine grained sand (20 percent) using a table presented by Fetter (1994). Aquifer test interpretation by ACE suggested that the specific yield (specific yield ≈ effective porosity) of the aquifer is 5 percent (ACE, 1989). The water-table gradient was estimated from previously reported water-level measurements in observation wells at the site and from water levels measured during the site visit. The water-table gradient is 0.025 to 0.03, sloping to the east-northeast.

The calculated average linear velocity of the ground water flowing from the infiltration ponds to the infiltration galleries ranges from 2.5 ft/day to 15 ft/day. At these rates it would take surface water added to the infiltration ponds approximately 4 to 24 days to reach the infiltration galleries. Water from artificial recharge could travel from the land surface into the infiltration gallery and water system in less than one month.

WATER QUALITY

Field Parameters

No water quality samples were collected during the HA site visit. Water-quality data were reviewed from MBMG, USGS, private consultants, and DEQ records for this report. Shallow ground water in the Billings, Montana area, particularly in the alluvium, tends to be calcium-magnesium bicarbonate type but tends to be higher in sodium and sulfate with increasing concentrations of dissolved minerals (Hutchinson, 1983). The dissolved minerals originate from primary mineralization in the bedrock. Water quality data from ground water in wells in aquifers in the area are shown in appendix E-1. Ground water in the Judith River Formation is predominantly sodium-bicarbonate to sodium-sulfate type. The engineers at ACE determined that ground water in deeper sandstone layers of the Judith River Formation at the gallery site were of poor quality and unusable for a domestic water supply and therefore, were not recommended as an alternate water source for the development. The poor water quality is probably due to poor ground water circulation through the fault displaced portion of the formation. Water in the Yellowstone River ranges from calcium-sodium sulfate to calcium-sodium bicarbonate type (USGS, 1999).

The Temperature, pH, specific conductance and redox (a measure of the oxidizing potential of the water) of the canal water discharge into the infiltration ponds and of the main water-supply line from the collection well were measured during the HA site visit. These data are presented in table 2.

Table 2. Field water quality measurements from the Hidden Lake water supply system measured May 19, 1998, and water quality data from other sources (USGS, 1999; GWIC, 1999).

Location	Temperature (°C)	pH	Specific Conductance (μmhos/cm)	Total dissolved solids (ppm)	Redox (mv)	Eh (mv)
Yellowstone River (at Sidney, MT) (USGS)	8.0-24.5	8.1-8.8	330-892	214-580	nd	nd
Ditch water at infiltration pond	15.3	8.3	204	133	165	374
Nearby Judith River Formation wells (6) (GWIC)	10.7-14.0	7.3-8.2	856-4,412	558-3,018	nd	nd
Nearby Bearpaw shale well (GWIC)	nd	nd	nd	1,157	nd	nd
Pump House Mainline	11.6	8.1	1,224	796	645	857

Water samples collected from the water supply system were submitted for analysis for standard ion concentrations in 1988 and again in 1993 by the system operator. A summary of the results are shown in table 3 (Mike Brayton (DEQ), personal communication, 1999).

Table 3. Water-quality data for water samples from the Hidden Lake water-supply system (Mike Brayton (DEQ), personal communication, 1999).

sample date	Specific Conductance (μmhos/cm)	Nitrate as Nitrogen (mg/L)	Sulfate (mg/L)	Total Dissolved Solids (mg/L)
October 1988		2.5		2,054
December 1988	3,000	4.0	1,275	2,194
August 1993	1,360	3.3	357	884 (est. from SC)

Between the 1988 and 1993 sampling, the water supply system was modified by the addition of the artificial recharge system. Table 3 shows that in 1988 the water from the infiltration galleries was higher in TDS and sulfate concentrations than in 1993, and showed values similar to water samples from nearby Judith River Formation wells (appendix E-1). Following installation of the artificial recharge system, the TDS and sulfate concentrations in the water dropped significantly, suggesting mixing of the ground water with the surface water from the infiltration ponds. Surface water is typically lower in TDS. Table 2 includes a representative sample of water quality for the Yellowstone River. The quality of the ground water at the infiltration gallery site suggests that it is a mixture of the artificially introduced surface water and the ground water that is available to the galleries.

Volatile Organic Compounds
Analysis for synthetic organic compounds in samples collected from the water system on 8/13/93 showed non-detect (ND) for the tested pesticide compounds and for volatile organic compounds (MDHES, 1993).

Nitrate and other Nutrients
Nitrate concentrations in water-system samples were reported four times between October 1988 and June 1994. Nitrate concentrations in the samples ranged from <0.01 milligrams per liter (mg/L) to 4.0 mg/L (table 4). All of the nitrate samples were collected after the artificial recharge system was installed. Nitrate was detected in three water samples collected in the fall, after the artificial recharge system had been in operation for the season, but only a very low concentration of nitrate (<0.01 mg/L) was detected in the one sample collected in the early summer (June, 1994).

Table 4. Nitrate concentrations in water samples from the Hidden Lake water-supply system (Mike Brayton (DEQ), personal communication, 1999).

Sample date	Nitrate as Nitrogen (mg/L)
October 1988	2.5
December 1988	4.0
October 1993	3.29
June 1994	<0.01

Nitrate in the ground water would most likely be derived from the irrigation ditch water or from recharge that originates from the wheat field south of the galleries. The low nitrate concentration measured in the June sample could be because during the early summer artificial recharge may not be a significant contributor to the ground water supply or the ditch water could have had lower nitrate concentrations. Water-quality data is available for the BBWA ditch from the BBWA office in the Billings Heights in Billings, Montana.

The artificial recharge water is drawn from the BBWA irrigation ditch. The ditch flows through agricultural land west of Billings and is used in that area for crop irrigation. The potential exists for return flows or surface runoff from the fields to be discharged into the ditch before the water reaches the Hidden Lake subdivision site. Therefore, the possibility exists for the ditch water to contain levels of pesticide, fertilizer or animal waste products (sources of synthetic organic compounds or nitrate). A field south of the infiltration ponds is tilled each year and planted in dryland crops. Pesticides or fertilizers may be added to this field that could migrate into the shallow ground water. Tests to date have not detected any synthetic organic compounds or high levels of nitrate but monitoring for this possibility is recommended.

Microbiological Water Quality

Monthly bacteriological testing of water samples showed four non-acute violations in the last three years; there were no acute violations (table 5). No violations have been reported since 1997. The water-supply system is chlorinated, and water samples are collected from the system after the chlorinator.

Table 5. Bacteria analysis results for water samples collected from the Hidden Lake subdivision water supply system (Mike Brayton (DEQ), personal communication, 1999).

Sample Date	Bacteria Analysis Result	Violation Type
10/27/97	Positive coliforms present	non-acute
1/22/96	Heavy growth non-coliforms	non-acute
9/26/95	TNTC (too numerous to count) non-coliforms	non-acute
8/21/95	Heavy growth confirmed	non-acute

The water system had reported prior turbidity problems related the extension of the north infiltration gallery. After the gallery extension, moderate turbidity was reported in only one sample collected on 1/25/95.

An M.P.E. (MPA) analysis was conducted on the water system on 4/27/1990. The report stated that the water appeared clean and contained very little visible debris (less than ¼ ml) (DEQ, 1990) (appendix E-2). The sample contained a few nematodes, rotifers and free-living protozoa. The DHES investigator concluded that the M.P.E. results were typical of a shallow ground-water source, and there was no evidence of surface water influence on the water supply at the time. However, this sample was collected prior to or immediately following the addition of the artificial recharge system to the water supply and may not reflect the current water quality.

CONCLUSIONS

Because the Hidden Lake water-supply system is designed to use surface water to recharge the ground water at the infiltration galleries, and because the ground water quality changed following the addition of the artificial recharge system, it appears that the water system may be under the direct influence of surface water.

Few sources of ground water are available in the area that are suitable for domestic use. Locating adequate water supplies with suitable water quality is a problem. The shallow aquifer at the infiltration gallery site is thin and is limited in areal extent by boundary faults which displace the water-bearing unit relative to adjoining strata. The areal extent and storage capacity of the aquifer are limited by the underlying low-permeability strata and by the boundary faults. The aquifer material is varied and permeability can range from very good to very poor (high to low). In some areas, the permeability of the bedrock is so low that water will not flow into wells or trenches screened in the formation. Because the water table is close to the land surface the aquifer is susceptible to the influence of infiltrating surface water.

The primary sources of water for the water supply system are probably water from the artificial recharge system and from the reservoir. The artificial recharge system at the site uses surface water from an irrigation ditch to recharge the aquifer at the gallery system. The ground-water quality measured in the infiltration galleries noticeably changed following the installation of the artificial recharge system. Based on aquifer test data at the gallery site, the estimated travel time for the artificial recharge water to flow from the ponds to the water supply galleries is less than one month and possibly as short as one week. The aquifer at the gallery site is directly influenced by surface water from the infiltration ponds in both quantity and quality.

Because the irrigation water used to recharge the shallow aquifer flows through agricultural and urban areas prior to reaching the water supply site, the irrigation water may be susceptible to contamination. The potential exists for the ditch water to contain potentially harmful levels of pesticides, fertilizers, animal waste products and/or other agricultural chemicals or pollution from urban sources. Additionally the ground-water quality could be threatened by the treatment of dryland fields near galleries. The last test conducted for synthetic organic-compound levels in the water supply was done prior to or immediately after installation of the artificial recharge system and probably reflects natural ground-water quality prior to the addition of the artificial recharge system.

The source of the water supply is obviously from the shallow ground water and from surface water pumped from the irrigation ditch to the infiltration ponds which are part of the water supply system. An MPA has not been conducted on the water system since the artificial recharge system has been in extended use.

RECOMMENDATIONS

Because the water system is designed to use surface water from infiltration ponds to recharge the ground water and because the depth to the water table is so shallow, **the water system may be under the influence of surface water.**

- It is recommended that an MPA be conducted on the system. The last MPA on record for the water system was conducted prior to or shortly after the artificial recharge system was installed. Sampling for the MPA should be conducted in the middle to late summer, after the irrigation ditch water has been pumped into the infiltration ponds for 4-6 months. The artificial recharge system is generally started around mid- to late-April each year.

- The shallow water table depth below the land surface and past problems with surface water flowing into the infiltration galleries indicate that the system is potentially sensitive to surface water influences. The infiltration gallery construction should be evaluated to confirm that an adequate seal exists between the gallery inlets and the land surface.

- Investigate the need to test the water system for synthetic organic compounds (fertilizers, pesticides) and for nitrate. The artificial recharge water source may contain synthetic organic compounds and nitrates.

- Cap or plug observation and test wells around infiltration galleries to eliminate potential conduits for contamination from the land surface to the shallow water table.

- Because the water system may be under the influence of surface water, the water supply may need to be chlorinated continuously and the chlorinator may need to be maintained frequently in order to prevent water quality problems. The MPA results would help to evaluate this need.

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Appendix A

A-1. Preliminary Assessment Form

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY
Metcalf Building
1520 E. 6th St.
Helena, MT 59620-0901

Preliminary Assessment of Groundwater Sources that may be under the Direct Influence of Surface water

SYSTEM NAME Hidden Lake Subdivision water supply system
PWS ID # 03370
SOURCE NAME Hidden Lake Subdivision COUNTY Yellowstone
DATE 5/19/98 NC NTNC C POPULATION 180 (approx.)

	Index Points
A. TYPE OF STRUCTURE (Circle One)	
Well	GO TO SECTION B
Spring	40
Infiltration Gallery/Horizontal Well	40
B. HISTORICAL PATHOGENIC ORGANISM CONTAMINATION	
History or suspected outbreak of *Giardia,* or other pathogenic organisms associated with surface water with current system configuration	40
No history or suspected outbreak of *Giardia* .	0
C. HISTORICAL MICROBIOLOGICAL CONTAMINATION (Circle all that apply)	
Record of acute MCL violations of the Total Coliform Rule over the last 3 years (circle the one that applies)	
No violations	0
One violation	5
Two violations	10
Three violations	15
Record of non-acute MCL violations of the Total Coliform Rule over the last 3 years (circle the one that applies)	
One violation or less	0
Two violations	5
Three violations	10
DHES-verified complaints about turbidity . . .	5
D. HYDROLOGICAL FEATURES	
Horizontal distance between a surface water and the source	
greater than 250 feet	0
175 - 250 feet	5
100 - 175 feet	10
less than 100 feet	15
unknown	15
E. WELL CONSTRUCTION	
Poorly constructed well (uncased, or casing not sealed to depth of at least 18 feet below land surface), or casing construction is unknown .	15
In wells tapping unconfined or semiconfined aquifers, depth below land surface to top of perforated intervals or screen	
greater than 100 feet	0
50 - 100 feet	5

25 - 50 feet	10
0 - 25 feet	15
unknown	15

F. WELL INTAKE CONSTRUCTION

In wells tapping unconfined or semiconfined aquifers, depth to static water level below land surface

greater than 100 feet	0
50 - 100 feet	5
0 - 50 feet	10
unknown	10

Poor sanitary seal, seal without acceptable material, or unknown sanitary seal type . . .	15

TOTAL SCORE 55

PRELIMINARY ASSESSMENT DETERMINATION (Circle the one that applies)

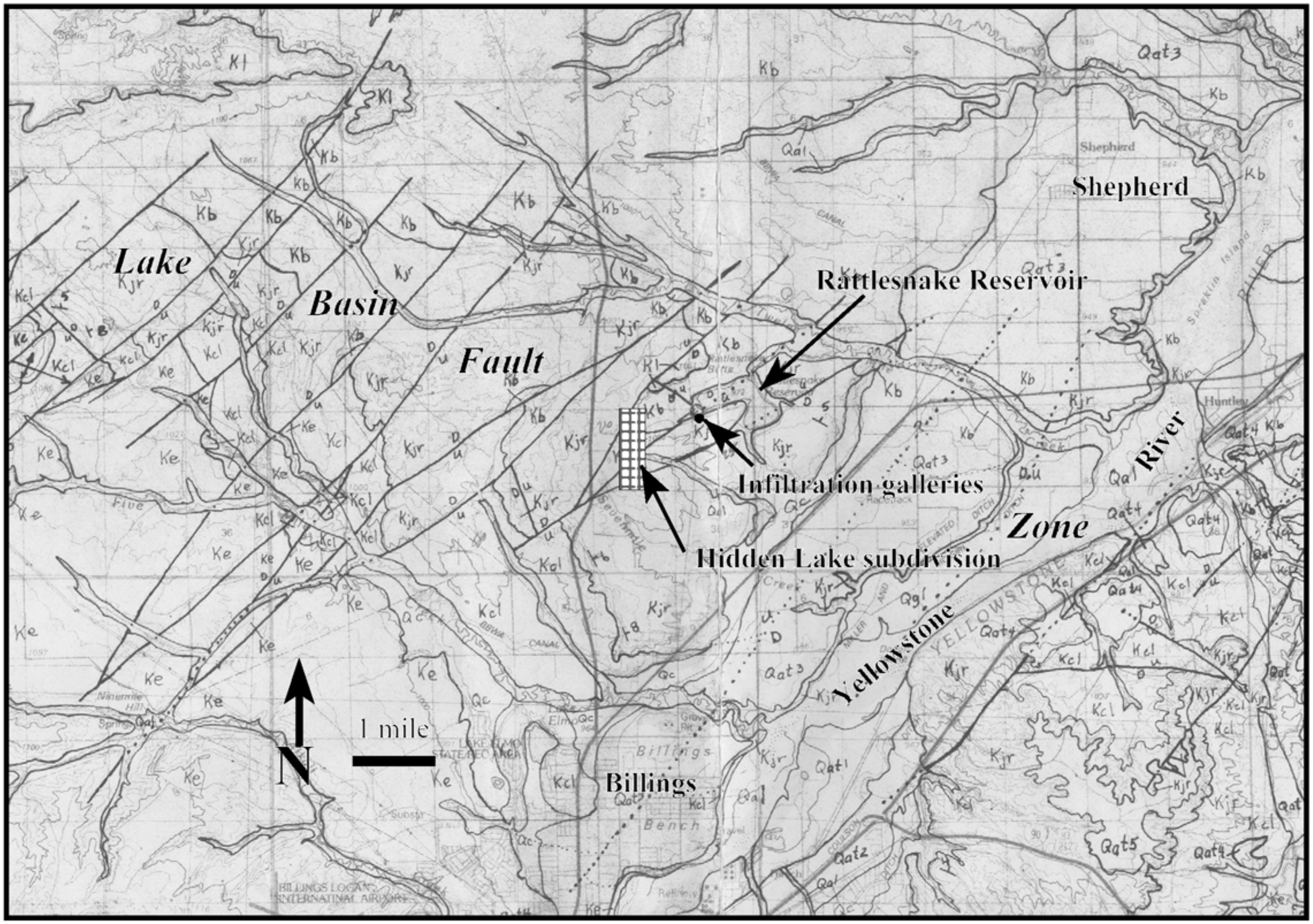
i) PASS: Well is classified as groundwater.
ii) FAIL:. Well must undergo further GWUDISW determination.
iii) FAIL: Spring or Infiltration Gallery; must undergo further GWUDISW determination.
iv) FAIL: Well will PASS if well construction deficiencies (section E or F) are repaired.
v) FAIL: Well may PASS if well construction details (section E or F) become available.

ANALYST James Rose **ANALYST AFFILIATION** MBMG

COMMENTS: The infiltration gallery system in at a shallow depth below the land surface (10 to 14 feet)and relies on artificial recharge of surface which is pumped from a nearby irrigation ditch to infiltration ponds 60 feet upgradient from the galleries. This water supply system is clearly under the influence of surface by design.

Appendix B

B-1. Site Geologic map



Map B-1. Geology map of the Hidden Lake Subdivision area (Lopez, 1996). Geologic formation shown include: (Ke) Cretaceous Eagle sandstone, (Kcl) Claggett, (Kjr) Judith River, (Kb) Bearpaw shale and (Kl) Lance Formations, (Qat) Quaternary alluvial terrace and (Qal) alluvium.

Appendix C

Site photos

C-1. Collection well and drainage basin view
C-2. Artificial recharge infiltration ponds
C-3. Infiltration ponds and subdivision
C-4. Rattlesnake Reservoir

Figure C-1. Looking west alongside pump house toward headwaters of the drainage. U. S. Highway 87 is just beyond the horizon. Note the manhole cover on collection well next to pump house.

Figure C-2. View looking north. Infiltration pond in foreground with inlet pipe. Pump house and Rattlesnake Butte in the distance across the drainage. West shoreline of lake visible in upper right corner. Observation wells are located on the flat area at the drainage bottom, behind the pump house.

Figure C-3. Looking southwest from the pump house across the tilled field at subdivision on the horizon. One of the infiltration ponds is located in the foreground behind the vegetated rise next to the pump house.

Figure C-4. Looking east at pump house toward Rattlesnake Reservoir. Collection well manhole next to pump house.

Appendix D

D-1. Schematic drawing of pump house layout
D-2. Plan view drawing showing the configuration of the infiltration galleries

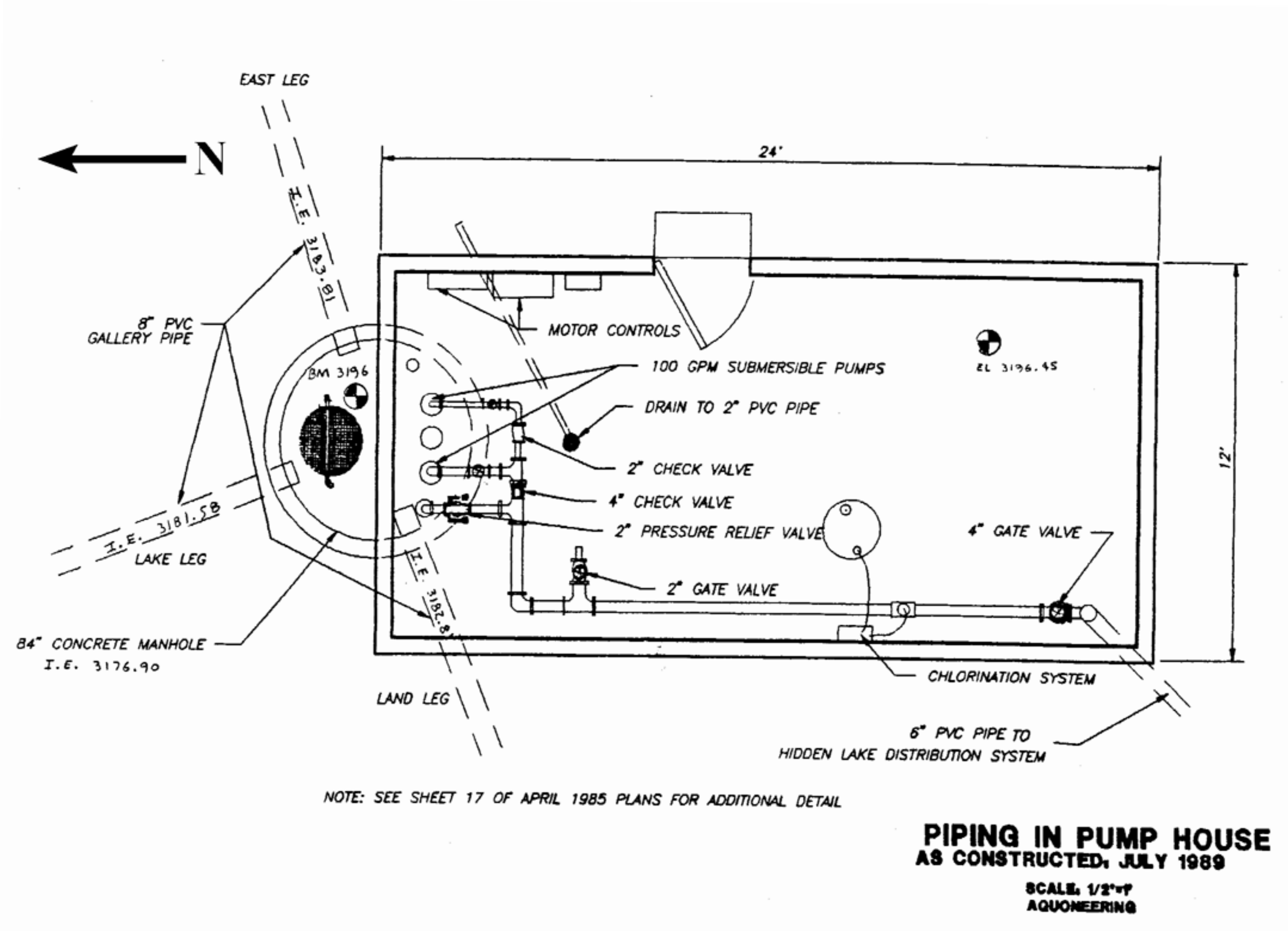
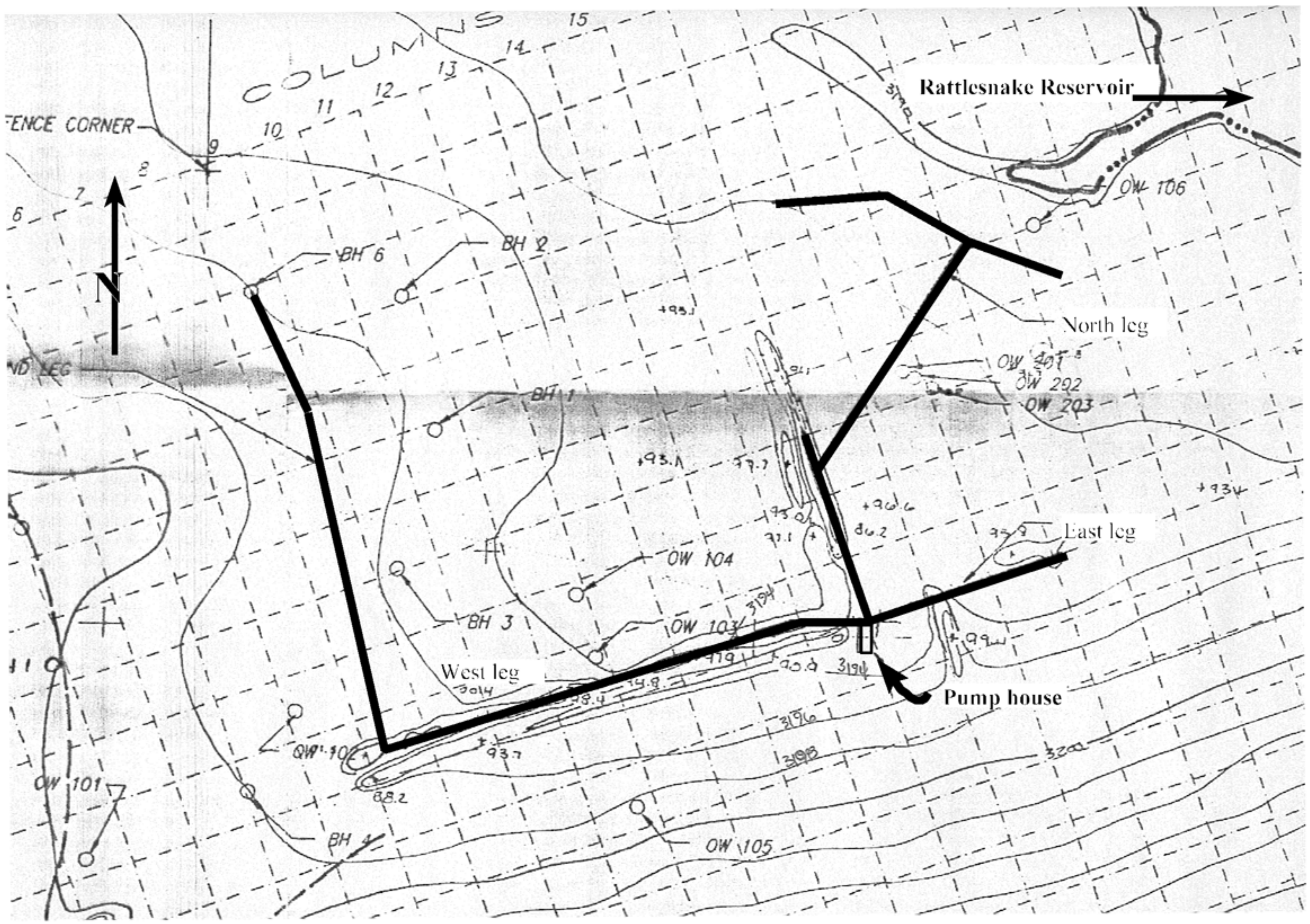


Figure D-1. Schematic drawing of Hidden Lake subdivision pump house.



D-2. Plan view drawing showing the configuration of the infiltration gallery system, pump houses, and Rattlesnake Reservoir (Aquoneering, 1989).

Appendix E

E-1. Well Location and Ground water quality data
E-2. Micro Particulate Analysis report

water quality report number	township	range	section	tract	well number	Water use	Aquifer	total depth ft	depth water enters ft	static water level ft	land surface elevation ft	sample source	sample date
79Q2055	02N	27E	24	DBDC	M:1002	stockwater	alluvium	10	10	4.1	3345	well	30-Oct-78
97Q0692	02N	27E	3	DDDC	M:153340	domestic	alluvium	23	20	9	3105	well	22-Mar-97
97Q0782	02N	27E	3	DDDC	M:153340	public water supply	alluvium	23	20	9	3105	well	15-May-97
98Q0038	02N	27E	3	DDDC	M:153340	public water supply	alluvium	23	20	9	3105	well	10-Jul-97
98Q0399	02N	27E	3	DDDC	M:153340	public water supply	alluvium	23	20	9	3105	well	17-Sep-97
97Q0812	02N	27E	10	AAA	M:13460	public water supply	alluvium	33	33	8		well	4-Jun-97
97Q0455	02N	27E	10	AAAC	M:13458	public water supply	alluvium	20	20	10	3105	well	24-Oct-96
97Q0817	02N	27E	10	AAAC	M:13458	public water supply	alluvium	20	20	10	3105	well	4-Jun-97
97Q0814	02N	27E	10	AAAD	M:144485	public water supply	alluvium	28	18	8	3105	well	4-Jun-97
97Q5010	02N	27E	11	CCCB	M:158558		alluvium	28	28	18.31	3115	well	5-Nov-96
79Q0904	02N	27E	11	DBAB	M:998	domestic	alluvium	15	15	5.4	3105	well	13-Sep-78
97Q0695	02N	27E	12	ACBD	M:158559	domestic	alluvium	23	23	13.42	3095	well	21-Mar-97
79Q0902	02N	27E	15	DAAA	M:999	domestic	alluvium	28	20	10.2	3112	well	13-Sep-78
79Q2056	02N	27E	16	CBBC	M:1000	domestic	alluvium	30	30	9.5	3128	well	30-Oct-78
97Q0690	02N	27E	22	DDCB	M:13628	domestic	alluvium	28	20	14	3115	well	22-Mar-97
97Q0786	02N	27E	22	DDCB	M:13628	domestic	alluvium	28	20	14	3115	well	15-May-97
97Q5011	02N	27E	22	DDCB	M:13628		alluvium	28	20	14	3115	well	6-Nov-96
98Q0110	02N	27E	22	DDCB	M:13628	domestic	alluvium	28	20	14	3115	well	24-Jul-97
98Q0402	02N	27E	22	DDCB	M:13628		alluvium	28	20	14	3115	well	17-Sep-97
98Q0111	02N	27E	32	BCDD	M:13832		alluvium	24	24	8	3135	well	25-Jul-97
97Q0785	02N	27E	2	BCBC	M:13395		terrace gravel	30	20	8	3105	well	15-May-97
98Q0128	02N	27E	2	BCBC	M:13395	domestic	terrace gravel	30	20	8	3105	well	24-Jul-97
98Q0398	02N	27E	2	BCBC	M:13395	domestic	terrace gravel	30	20	8	3105	well	17-Sep-97
97Q5012	02N	27E	23	CBCC	M:13657		terrace gravel	24	22	8	3110	well	
21Q0056	02N	26E	18	DDDD	M:993	domestic	Bearpaw	72	72		3420	well	27-Oct-21
98Q0150	02N	26E	22	DDCA	M:13311	Domestic stockwater	Eagle	192	172	48	3400	well	10-Aug-97
98Q0349	02N	26E	20	BBBB	M:13309	domestic	Judith River	225	180		3410	well	7-Sep-97
79Q0479	02N	26E	21	CCAA	M:994	stockwater	Judith River	240	200	107.28	3560	well	15-Sep-78
79Q3166	02N	26E	22	DDCA	M:996	domestic	Judith River	157	76	4.1	3400	well	3-Aug-79
21Q0058	02N	26E	23	C	M:997	domestic	Judith River	88	88	43		well	31-Oct-21
98Q0114	02N	27E	25	ABDA	M:161834	public water supply	Judith River	65	65		3015	well	28-Jul-97
79Q0493	02N	27E	30	BCCB	M:1003	domestic	Judith River	300	230	17.45	3160	well	16-Sep-78
98Q0404	02N	27E	33	AABA	M:149788	domestic	Judith River	200	30	18	3130	well	19-Sep-97
73Q5038	02N	26E	1	CADB	M:991	unused	Lakota	7094	4,200.00		3200	well	17-Aug-73
21Q0055	02N	26E	14	B	M:992	domestic					3230	spring	27-Oct-21
21Q0057	02N	26E	22	DA	M:995	domestic					3400	spring	31-Oct-21
21Q0065	02N	27E	24	BCC	M:1001	stockwater					3000	spring	31-Oct-21
79Q0245	02N	27E	35	ADCC	M:1004	stockwater					3085	spring	2-Aug-78

water quality report number	calcium mg/L	magnesium mg/L	sodium mg/L	potassium mg/L	iron mg/L	manganese mg/L	silica mg/L	CO3 mg/L	HCO3 mg/L	chloride mg/L	sulfate mg/L	nitrate as N mg/L	dissolved solids mg/L	dissolved constituents mg/L	lab pH	field pH	lab specific conductance umhos	field specific conductance umhos	temperature centigrade
79Q2055	81.8	30.1	93.9	3.5	0.18	0.11	19.7	7.7	373	17.4	187	0.255	625.99	815.25	8.47	7.52	946.4	989	12
97Q0692												.4 P				7.4		1669	11.4
97Q0782												.25 P				5.8		1400	11
98Q0038	132	80.4	87.8	6.56	0.039	0.124	21.9		398.9	62.04	330.1	2.0 P	919.47	1121.87	8.15	7.2	1119	1422	11.8
98Q0399												.8 P				7.3		865	12.8
97Q0812												12.7 P				7.1		2750	15
97Q0455	166.9	110	239.5	10.3	0.02	<.002	13		508.5	<5	920	8.5	1718.73	1976.73	8.25	7.58	2200	2350	13.3
97Q0817												8.6 P				7.6		2590	12.1
97Q0814												6.0 P				8.5		2590	12.3
97Q5010	76	41	117	4	<.03			0	345	24	307	2.35	741.3	916.35	7.5		1230		
79Q0904	193	163	317	11.6	0.04	<.01	31.3	0	571	120.8	1130	19.88	2268.3	2558.02	7.62	6.91	3037	3270	12
97Q0695												5.4 P				7.8		764	
79Q0902	112	81	268	6.1	0.06	<.01	24.6	0	386	38.2	778	4.247	1502.75	1698.61	7.95	7.26	2049	2070	11.5
79Q2056	419	620	2131	20.9	0.07	0.02	24.8	0	669	186.9	7121	1.581	10855.13	11194.57	7.9	7.52	11210	12500	12
97Q0690												1.2 P				7.6		1744	11.1
97Q0786												1.0 P				6.8		1810	10.4
97Q5011	91	42	73	5	<.03			0	293	9	321	0.3	685.63	834.3	7.6		1100		
98Q0110	70.6	35.4	83.1	5	<.003	<.002	19.4		250.83	7.6	261.8	<.25P	606.51	733.78	7.5	7.4	869	839	17
98Q0402												.27 P				7.4		787	17.7
98Q0111	92.4	72.9	573.6	4.9	<.003	<.002	22.4		585.6	30.1	1142	8.4 P	2235.19	2532.32	7.58	7.5	2720	2710	10.8
97Q0785												2.3 P				6.7		1290	9.5
98Q0128												2.8 P				7.6		1590	11.4
98Q0398												<.25 P				7.5		1520	12.8
97Q5012	11	4	530	2	<.03			0	498	22	805	0.31	1619.63	1872.31	7.8		2590		
21Q0056	8.2	5.1			2.6		8.4	50	506	15	412	0.54	1157.1	1007.84					
98Q0150	14.87	8.65	523.3	1.8	<.003	0.018	7.7		683.2	11.7	684.4	<.25 P	1589	1935.65	8.2	8.1	2680	2470	13.1
98Q0349	5.6	1.4	797.5	1.56	0.008	0.01	8.5		949.8	11.3	710.6	<.25 P	2004.38	2486.29	8.22	8.2	2980	2780	13.6
79Q0479	41	23.8	123	2.5	0.01	<.01	10.7	0	330	5.7	188	0.3	557.87	725.31	7.8	7.9	855.9	900	14
79Q3166	287	126	189	4.9	0.32	<.01	11.2	0	266	218	1038	4.292	2009.75	2144.71	7.46	7.31	2567	2850	11
21Q0058	3	2.3			0.76		7.5	13	314	5	220	0.23	628.47	565.79					
98Q0114	56.5	24.7	234.7	2.7	0.166	0.082	14.3		359.9	27.7	411.3	<.25 P	949.44	1132.05	7.87	8.2	1300	1315	10.7
79Q0493	69	38.2	966	4.1	0.03	<.01	8.6	0	632	484	1134	1	3017.66	3338.33	8.16	8.1	4412	4300	13.5
98Q0404	233.1	105.7	243.8	8.1	0.051	0.136	12.9	19.2	444.1	25.98	1152.3	43 P	2020.47	2245.8	8.6	7.4	2350	2340	12.3
73Q5038	6	4	1234					0	2025	485	356		3082.54	4110	7.6				
21Q0055	31	28			0.19		14	14	389	9	679	0.14	1369.96	1164.33					
21Q0057	131	54			0.14		13	0	340	9	572	<.023	946.63	1119.14					
21Q0065	452	189			0.22		18	0	376	99	2084	0.9	3355.34	3219.12					
79Q0245	34.8	34	142	2.9	0.01	<.01	23.1		319	24.95	235	1.468	655.87	817.73	8.27		1005		14.5

E-1. Well location and water quality data from wells in the Hidden Lake area (GWIC, 1999).

water quality report number	township	range	section	tract	well number	temperature centigrade	alkalinity mg/L	hardness mg/L	flouride mg/L	ORTHO-PO4 mg/L	aluminum ug/L	arsenic ug/L	boron ug/L	barium ug/L	beryllium ug/L	bromide ug/L	cadmium ug/L	chromium ug/L	copper ug/L	lead ug/L	lithium ug/L	molybdenum ug/L	nickel ug/L	selenium ug/L	silver ug/L	strontium ug/L	titanium ug/L	vanadium ug/L	zinc ug/L	zirconium ug/L
79Q2055	02N	27E	24	DBDC	M:1002	12	318.77	328.15	0.6												40									
97Q0692	02N	27E	3	DDDC	M:153340	11.4																								
97Q0782	02N	27E	3	DDDC	M:153340	11																								
98Q0038	02N	27E	3	DDDC	M:153340	11.8	327.17	660.53		<.05	<30.	1.9	510	27.1	<2.	115	<2.	8.6	5.2	<2.	75	<10.	16.5	2.4	<1.	1635	<10.	<5.	3.5	<20
98Q0399	02N	27E	3	DDDC	M:153340	12.8																								
97Q0812	02N	27E	10	AAA	M:13460	15																								
97Q0455	02N	27E	10	AAAC	M:13458	13.3	417.06	869.51	<1.	<2.0	<30.	2.2	375	32.4	<2.	<250.	<2.	14.1	8.8	<2.	102	<10.	12	12.1	<1.	2190	<10.	5.5	5.1	<20.
97Q0817	02N	27E	10	AAAC	M:13458	12.1																								
97Q0814	02N	27E	10	AAAD	M:144485	12.3																								
97Q5010	02N	27E	11	CCCB	M:158558		282.96	358.53																						
79Q0904	02N	27E	11	DBAB	M:998	12	468.32	1152.83	0.4												130									
97Q0695	02N	27E	12	ACBD	M:158559																									
79Q0902	02N	27E	15	DAAA	M:999	11.5	316.59	613.06	0.4												70									
79Q2056	02N	27E	16	CBBC	M:1000	12	548.69	3598.16	0.3												310			64						
97Q0690	02N	27E	22	DDCB	M:13628	11.1																								
97Q0786	02N	27E	22	DDCB	M:13628	10.4																								
97Q5011	02N	27E	22	DDCB	M:13628		240.31	400.1																						
98Q0110	02N	27E	22	DDCB	M:13628	17	205.72	321.99		<.05	<30.	2.6	164	17.6	<2.	144	<2.	8.2	52.6	<2.	51	<10.	7.6	2.7	<2.	752	<10.	<5.	<2.	<20
98Q0402	02N	27E	22	DDCB	M:13628	17.7																								
98Q0111	02N	27E	32	BCDD	M:13832	10.8	480.29	530.78		<.05	<30.	<2.	694	22.9	<2.	134	<2.	10.03	9.6	<2.	79	<10.	10.1	6.9	<2.	1901	<10.	<5	9.9	<20
97Q0785	02N	27E	2	BCBC	M:13395	9.5																								
98Q0128	02N	27E	2	BCBC	M:13395	11.4																								
98Q0398	02N	27E	2	BCBC	M:13395	12.8																								
97Q5012	02N	27E	23	CBCC	M:13657		408.45	43.93																						
21Q0056	02N	26E	18	DDDD	M:993		496.4	41.47																						
98Q0150	02N	26E	22	DDCA	M:13311	13.1	560.34	72.73		<.05	<30.	2	1197	8	<2.	80	<2.	25.8	9.7	<2.	113	<10.	2.6	2.4	<2.	751	<10	6.7	2.8	<20
98Q0349	02N	26E	20	BBBB	M:13309	13.6	779	19.75		<5.	<30.	<2	1014	9.4	<2.	<2500.	<2.	16.2	12.6	<2.	136	<10.	<2.	<2.	<1.	595	<10.	<5.	3.8	<20
79Q0479	02N	26E	21	CCAA	M:994	14	270.66	200.34	0.3												40									
79Q3166	02N	26E	22	DDCA	M:996	11	218.17	1235.26					350	80							60			77.4		3650				
21Q0058	02N	26E	23	C	M:997		278.22	16.96																						
98Q0114	02N	27E	25	ABDA	M:161634	10.7	295.18	242.76		<.05	<30.	<2	306	22.3	<2.	168	<2.	4.5	3.3	<2.	67	<10.	6	2.3	<2.	1310	<10	<5	<2.	<20
79Q0493	02N	27E	30	BCCB	M:1093	13.5	518.35	328.52	1.4				1760	<50.							150			4.1		2100				
98Q0404	02N	27E	33	AABA	M:149768	12.3	396.26	1017.11		<2.	<30.	<1.	497	9.9	<2.	<200.	<2.	13.7	4	<2.	140	<10.	21.8	1.7	<1.	3218	<10	<5	2.8	<20
73Q5038	02N	26E	1	CADB	M:991		1,660.85	31.45																						
21Q0055	02N	26E	14	B	M:992		342.4	192.66																						
21Q0057	02N	26E	22	DA	M:995		278.86	549.37																						
21Q0065	02N	27E	24	BCC	M:1001		308.38	1906.57																						
79Q0245	02N	27E	35	ADCC	M:1004	14.5	261.63	226.84	0.5												30									

E-1. (Continued).

PWS

Office Memorandum

STATE DEPARTMENT OF HEALTH
AND ENVIRONMENTAL SCIENCES

DATE: April 27, 1990

TO: Jerry Burns
FROM: Donna Howell
SUBJECT: MPE analysis of Hidden Lake's PWS

As conveyed to you over the phone, the Microscopic Particulate Examination (MPE) of the collection well serving Hidden Lake has been completed.

The sample represented 1573 gallons of water passed through the filter. The filter was extremely clean and contained very little visible debris.

The following are results of the MPE analysis:

- the entire 1573 gallons concentrated to a total of less than 1/4 ml debris.

- The 1573 gallons of water contained a few nematodes, rotifers and free-living protozoa. Silt less than 3 um in diameter was also present in small amounts.

Conclusions:

The MPE results were typical for a shallow groundwater source. There was no evidence of surface water influence on the water supply at this time. The sample was also collected during a period considered to be likely to reveal surface water influence if present, because of heavy precipitation in the area.

E-2. MPE analysis of the Hidden Lake Public Water Supply system.