

**LONE MOUNTAIN RANCH (PWS No. MT0001820)
SOURCE WATER DELINEATION AND ASSESSMENT REPORT**

Prepared for:

**Lone Mountain Ranch
Big Sky, Montana**

August 31, 2010

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INTRODUCTION

This report is a Source Water Delineation and Assessment Report (SWDAR) pertaining to the Lone Mountain Ranch public water system, located in Big Sky, Montana, as shown on [Figure 1-1](#). The purpose of an SWDAR is to provide information that can be used to reduce risk or prevent contamination of the water supply wells used in the water system.

This SWDAR has been prepared to follow the state of Montana format for SWDARs (DEQ 1999) and has undergone state review and approval. The content requirements for an SWDAR have been determined by the Montana Department of Environmental Quality (MDEQ) Source Water Protection Section. Each SWDAR must include the following:

- Background information describing the community, its geography and climate, and the public works facilities;
- Hydrogeological analysis to map recharge areas to the water supply sources. There are several sub-areas mapped for each water supply source;
- Inventory of potential contaminant sources that could possibly impact water quality because they exist within the recharge areas; and
- Assessment of the relative risk of water quality impacts for the most important, or largest, potential sources of contamination.

This SWDAR was funded by a Source Water Protection Grant issued to Big Sky County Water and Sewer District No. 363, who operates four public water systems in the Big Sky area. Lone Mountain Ranch was included in the grant at the request of MDEQ due to proximity to the other water systems. The District water systems and the wells that were included in the District's SWDAR report are also shown on [Figure 1-1](#), and other selected figures of this report.

Community

Lone Mountain Ranch is located in Big Sky, Montana, approximately 40-miles south of Bozeman. The Ranch is a recreational business, providing a variety of outdoor recreation, lodging and dining services to guests. During the summer months, guests are involved in general summer recreation, including horseback riding, fishing, and hiking. During the winter months, Lone Mountain Ranch operates a Nordic ski area with an abundance of groomed trails. Special functions, such as weddings and parties, are also held at the Ranch. Lone Mountain Ranch provides services to a maximum guest capacity of about 100 people during both the summer and winter seasons.

There are no large industries or waste generation facilities located near to Lone Mountain Ranch. The upper watershed above the Ranch is a designated Wilderness Area. The Big Sky area and related commercial properties are located outside the immediate watershed of the Ranch.

Geography and Climate

Lone Mountain Ranch is located in the North Fork West Gallatin River watershed at an elevation of 6,600 feet. The area consists of high mountain valley, mountain forest, and alpine landscapes. The Ranch property is located in the lower reaches of a mountain-glaciated valley, where the valley is primarily stream cut within glacial landforms.

Climate data for the area indicate average moisture, cold winters and cool summers. Data pertaining to the climate conditions at Lone Mountain Ranch were obtained from two Big Sky weather stations, and are shown in Table 1-1. The Big Sky 3S climate monitoring station is located about 4-miles south and east of Lone Mountain Ranch. The Lone Mountain SNOTEL facility is located on the flanks of Lone Mountain at an elevation of 8,800 feet. The conditions at Lone Mountain Ranch are likely represented by the average precipitation values listed in Table 1-1.

TABLE 1-1
MONTHLY CLIMATE DATA

Month	Precipitation (in)			Big Sky 3S Temperature (F)		Big Sky 3S Snow Fall	
	Lone Mtn SNOTEL	Big Sky 3S	Average	Average Maximum	Average Minimum	Total (in)	Average Depth (in)
Jan	4.0	1.5	2.6	30.9	7.1	38.2	25
Feb	4.0	1.08	2.5	35.5	8.0	18.0	28
Mar	3.8	1.19	2.5	43.2	15.6	19.9	27
Apr	3.6	1.19	2.4	51.6	23.0	5.6	5
May	4.1	2.81	3.5	62.1	30.0	3.2	0
Jun	3.6	2.58	3.1	69.6	35.9	0.2	0
Jul	2.0	1.69	1.8	76.9	39.8	0.3	0
Aug	1.8	1.80	1.8	78.0	38.4	0.0	0
Sep	1.6	1.62	1.6	68.8	31.9	0.2	0
Oct	2.4	1.24	1.8	56.2	23.3	3.6	0
Nov	2.8	1.43	2.1	38.6	13.6	15.7	2
Dec	3.9	1.31	2.6	29.1	5.6	34.1	15
Total or Average	37.6	19.44	28.5	53.4	22.7	139.0	8.5

Public Water Supply

Lone Mountain Ranch provides water service to a maximum of about 100 guests and up to 85 seasonal employees through 24 transient service connections. The relatively large number of connections is required primarily because lodging occurs in a number of private cabins. A water and sewer system map for the Ranch is provided in the report map pocket, and a recent Sanitary Survey of the water system is included in Appendix A.

Two wells provide the source of supply to the water system, as shown on [Figure 1-2](#). Table 1-2 provides information on the well constructions. Both wells are approximately 30 to 40 feet in depth and produce groundwater from an unconfined aquifer¹. Well No. 1 is located inside a mechanical room within the Ouzel Guest Cabin. This room includes the power service, pump controls, and three hydropneumatic pressure tanks for both Well Nos. 1 and 2. Well No. 2 is located about 30 feet south of Well No. 1, and is not enclosed by a building. It connects to the mechanical room through a pitless adapter and waterline.

Water distribution is pressurized and extends from the Ouzel Guest Cabin mechanical room to the various service connections. Pressure is regulated by seven hydro-pneumatic tanks, including the three tanks

¹ According to the MDEQ Source Water Protection Program, this aquifer setting is classified as High Sensitivity.

located inside the Ouzel Cabin, a tank in the basement of the restaurant lodge, and three additional tanks located at cabins on the hillside to the northeast of the restaurant. These remote tank locations are also equipped with small booster pumps. There is no treatment of the water supply required or provided, however, water service to the restaurant and office facilities is treated by softening.

TABLE 1-2
LONE MOUNTAIN RANCH WELL DATA

	Well Name	
	Lone Mountain No. 1	Lone Mountain No. 2
Figure 1-1 Map ID	LMTN #1	LMTN #2
PWS Source Code	002	003
Well Location	456754	456752
NAD 83 Montana State Plane (m)	115820	115813
Well Location, TRS	SWSESW 26 6S3E	SWSESW 26 6S3E
GWIC No.	--	155024
Water Right Permit No.	W148650	G048373
Pump Capacity (gpm)	34	34
Date Installed	--	9/21/95
Total Depth (ft)	30 (est.)	40
Screen Interval (ft)	--	30.7 – 30.7
Diameter (in)	6	6
Surface Seal (ft)	--	20, bentonite
Static Water Level (ft)	--	12
Pumping Water Level (ft)	--	26
Capacity (gpm)	--	30
Drawdown (ft)	--	14
Specific Capacity (gpm/ft)	--	2.14
Aquifer Sensitivity	High	High

Wastewater Treatment

Lone Mountain Ranch is connected to the Big Sky Water and Sewer District for the purpose of wastewater treatment. A centralized sewer serves the buildings of the Ranch and conveys wastewater to the District treatment plant, located in Meadow Village.

Water Quality

Water quality data for Lone Mountain Ranch were obtained from the MDEQ database (personal communication, Melissa Levens). These data included a variety of parameters. The data for general parameters that were present in the database are provided in Table 1-3. In terms of these general parameters, the groundwater quality is hard and dominated by the calcium, magnesium and bicarbonate (alkalinity) ions.

Annual sampling results for nitrate plus nitrite were present from 1979 to 2000 in the MDEQ database. Two of these results are shown in Table 1-3 corresponding to the same sampling period as the general parameters. For the period of record, nitrate plus nitrite concentrations ranged from 0.1 to 0.18 mg/L as

N. These low levels are typical of low concentrations observed in groundwater, and generally indicate pristine conditions that have not been impacted from man-made nitrogen sources. These results comply with the maximum concentration limit (MCL) of 10 mg/L as N that is allowable in a public water system.

Lone Mountain Ranch submits coliform samples each month of the year for compliance with the Total Coliform Rule (TCR). With one exception, the water quality has been coliform-negative, and complies with this rule. The Sanitary Survey provided in Appendix A describes a violation of the TCR that occurred in a sample collected during April 2001. This violation has since been resolved and the water system is not presently under any orders from MDEQ.

The MDEQ database also indicated that Lone Mountain Ranch has sampled for organic compounds. It appears from the records available that sampling was conducted for volatile-organic and trihalomethane compounds in 1991. No detections were noted.

TABLE 1-3
SOURCE WATER QUALITY

Parameter	Result
Distribution, 12/20/94	
Alkalinity, as CaCO ₃	59
Calcium	14.3
Nitrate plus Nitrite (as N)	0.14
Specific Conductance, uS/cm	142
Distribution, 3/30/93	
Calcium	44
Magnesium	11
Nitrate plus Nitrite (as N)	0.18
Hardness, as CaCO ₃	152
pH, std. units	8
Sodium	4
Iron	0.05
Specific Conductance, uS/cm	272
Results are listed in units of mg/L unless noted otherwise.	

DELINEATION

Delineation consists of mapping Source Water Protection Areas – protection regions that surround the water supply wells. The protection regions provide a focus for gathering data on potential contaminants and planning management activities. The smaller inner regions receive the highest level of protection. The larger more distant regions are managed less stringently, relying partially on natural purification should a contamination event occur.

There are four regions that may be required for delineation of water supply wells, collectively forming the Source Water Protection Areas. These regions include:

- Control Zone This region is a circular area with a radius of 100-feet. It is centered on the well, and is delineated for all types of wells.

- **Inventory Region** In unconfined or semi-confined aquifer settings, the Inventory Region is computed based on groundwater hydraulics. It surrounds the well and extends up-gradient (“upstream”) to the 3-year time-of-travel boundary for groundwater to flow to the well (i.e., groundwater within the Inventory Region flows to the well in a time period of 3-years or less).
- **Recharge Area** This region includes the entire area contributing water to the well (i.e., the recharge area), and is mapped for all types of wells. The Recharge Area may coincide with a topographic boundary, but not necessarily. It is determined either through flow-balance calculations or hydrogeological boundary mapping.
- **Surface Water Buffer** In unconfined or semi-confined aquifer settings, it is also necessary to map all hydraulically connected surface waters flowing through the Inventory Region. These surface waters may act as conduits for the transport of acute contaminants, such as pathogens and nitrate. A ½-mile wide buffer area on either side of the surface water body is mapped for 10-miles upstream from the Inventory Region. It is assumed that only contaminant sources of pathogens and nitrate in this region could possibly affect wells.

Delineation Methods and Limitations

The methods of delineation and the associated errors, or limitations, vary by Source Water Protection Area, and are discussed in this section. The implications of these limitations are that boundaries of Source Water Protection Areas should not be considered exact, but more as guidelines. As a precautionary measure, important land uses occurring in proximity to Source Water Protection Area boundaries should be evaluated as if they occur in the inner-most zone (more stringently managed). As new information is learned about the hydrology of an area, it can be beneficial to revise the delineation of Source Water Protection Areas. Such revisions are particularly necessary when evaluating water supply wells. Source Water Protection Areas for water supply wells can be changed dramatically by the installation of a new neighboring well that exerts an interference drawdown effect on existing wells.

Control Zone

The control zone is mapped by drawing a 100-ft radius circle around the well. There is little potential for error in determining the control zone. A wrong well location will introduce error into the location of this mapped area.

Inventory Region

For unconfined and semi-confined aquifer settings, the Inventory Region is based on the physics of groundwater flow to a water supply well. Complex mathematical formulas coded in a computer program are used as a basis for mapping of the Inventory Region. Input data are required based on direct and indirect measurements of the groundwater flow system. For this application, a computer program called TWODAN (Fitts 1999) was applied and input data were developed from existing information on the area hydrogeology.

There are a variety of ways to introduce errors into the Inventory Region delineation². Base mapping data that are used to set up the models may not be consistent with one another. For example, geological

² Despite the opportunity for introduction of error into groundwater computer modeling, the approach taken is technically consistent with the standard of practice for the field of quantitative hydrogeology. The application of

mapping data may not match up correctly with stream channel mapping data. Simplifying assumptions concerning the physics of the groundwater system are also built into the computer model. No computer model can exactly represent the complexities of a groundwater flow system. Aquifer hydraulic data, upon which the model is based, also have associated uncertainty, and the true spatial distribution of these data cannot be known or represented. Time-varying aspects of the groundwater flow system, such as the direction of flow, are normally not well known and can be represented normally by use of a time-average value.

Recharge Area

The Recharge Area was mapped based on the topographical boundaries of the watershed sub-basin. This approach was taken in both the District SWDAR and this Lone Mountain Ranch SWDAR due to the complexity of the groundwater flow system throughout the Big Sky area. Such an approach could be applied uniformly to all the wells considered in the two projects. The actual recharge area to the Lone Mountain Ranch unconfined aquifer wells will be much smaller than the Recharge Area as mapped in this report.

The sub-basin areas were delineated using the Spatial Analyst Extension of ArcView GIS (ESRI 1999)³. Digital Elevation Models (DEMs) were downloaded from the U.S. Geological Survey to complete this work. The DEMs consist of 30-meter by 30-meter grid cells with a grid-centered elevation. Hydrologic Analysis Tools in the Spatial Analyst Extension were used to map topographic divides for sub-basins. Sub-basins were limited on average to a total area of approximately 1,000 acres or greater⁴.

There are several limitations that apply to the delineation of the sub-basins and, consequently, the Recharge Areas. Delineations are based on mapping data, such as the locations of stream channels and the land surface elevations. There are errors associated with these data, related to the accuracy of the original maps and changes in the land surface that may have occurred since the maps were first created. It is possible that stream channel locations may have associated errors of ± 500 -feet, which equates to $\frac{1}{4}$ -inch on a 1:24,000 topographic map. DEMs have an associated vertical accuracy of ± 7 -meters and a horizontal accuracy of ± 30 -meters.

Surface Water Buffer

The Surface Water Buffer is based on existing maps of surface waters that cross the Inventory Region for wells installed into unconfined or semi-confined aquifers. Specialized computer software (ArcView GIS 3.2, ESRI 1999) was used to draw $\frac{1}{2}$ -mile wide buffers on either side of these surface waters and for a distance of 10-miles upstream (or the top of the watershed, whichever is shorter). Occurrence of errors may result from inaccurate mapping of the area. If the maps do not show all of the surface waters or the surface waters are wrongly located, errors can result. The Surface Water Buffer is also limited to $\frac{1}{2}$ -mile wide buffers and a distance of 10-miles upstream by assumption. It is possible, but unlikely, that

TWODAN in Source Water Protection Planning substantially exceeds the minimum requirements imposed by state agencies, including Montana DEQ.

³ This work was completed by DTM Consulting, Inc. of Bozeman, Montana.

⁴ The GIS software can and will delineate any area enclosed by topographic divides, which can result in small sub-basin areas, on the order of a few acres in size. In order to create a more tractable GIS database, the size of the sub-basins that are mapped is limited. In this application, the minimum size of 1,000 acres appeared reasonable.

contaminants could enter the water source from beyond the ½-mile buffer and from beyond the 10-mile mark on the water body.

Hydrogeological Conceptual Model

In order to interpret and map the recharge areas to water supply wells, it is necessary to first evaluate how the groundwater flow system “works”. This evaluation is referred to as the hydrogeological conceptual model, and pertains to the groundwater flow system feeding the water supply wells. This section summarizes the hydrogeological conditions of the project area based on existing information obtained from the sources listed in Table 2-1, and also cited in the report references. Additional details concerning the conceptual model of the area are also provided in the section pertaining to delineation mapping which follows.

TABLE 2-1
HYDROGEOLOGICAL DATA SOURCES

Authors	Type of Study	Area
Big Sky County Water and Sewer District	Water system records for wells and water use	Mountain and Meadow Village areas
Kellog and Williams (1997)	Geological Mapping 1:100,000	Ennis 30' x 60' Quadrangle
Montana Bureau of Mines and Geology Groundwater Information Center (GWIC)	Well logs	Mountain and Meadow Village areas
Baldwin (1996, 1997)	Report to MDEQ and Master's Thesis: includes field data/maps of hydrogeology	Mountain and Meadow Village areas
Morrison Maierle (1986, 2001) MSE-HKM (1997) Western Groundwater Services (1999)	Well installation and/or testing reports by consultants	Mountain Village, Hidden Village, Blue Grouse Well, Meadow Village
Montana Natural Resources Information System (NRIS)	GIS database library for roads, streams, land use, and elevation	Mountain and Meadow Village areas
NOAA Western Regional Climate Center	Climate monitoring data consisting of monthly summaries	Station: Big Sky 3S
USDA NRCS Bozeman Office	SNOTEL climate monitoring	Station: Lone Mountain

Geology

Big Sky is an area of complex mountain geology. Information pertaining to the geology of the area is presented on Figures [2-1](#), [2-2](#), [2-3](#). The geological map appearing on [Figure 2-1](#) was prepared by Kellog and Williams (1997) and was obtained in Arc View GIS format directly from the U.S. Geological Survey (USGS). The cross section presented on [Figure 2-3](#) is based on the geological surface mapping, land surface topography (from USGS topo maps), and well logs for the project area obtained from the

Groundwater Information Center at the Montana Bureau of Mines and Geology. Copies of the well logs are provided in Appendix B.

Lone Mountain Ranch is located in the North Fork valley above Meadow Village. Surface geology in this area is dominated by till deposits that mantle bedrock mountainsides and occur in the North Fork valley at and above Lone Mountain Ranch. Glacial outwash deposits are mapped immediately below the Ranch, but it is also possible these deposits extend to the location of the water supply wells. Both the till and the glacial outwash deposits are loose mixtures of clay, silt, sand and gravel. Till is typically poorly sorted resulting in low permeability and low water production potential. In contrast, glacial outwash may be well sorted, exceptionally permeable, and provide for exceptionally productive wells. It is more likely that Well Nos. 1 and 2 are installed into glacial outwash than till for this reason, although geological mapping shows till at the well locations.

TABLE 2-2
HYDRAULIC DATA FOR UNCONSOLIDATED FORMATIONS

Well Name	Test	Transmissivity (ft ² /d)	Thickness (ft)	Conductivity (ft/d)
HV-1	24-hr constant rate, 7/21/99	1,170	10	120
MV-1	24-hr constant rate, 9/23/99	27,400	26	1,050
MV-2	4-hr step w/recovery, 9/17/23	13,500	21	640
MV-3	4-hr step w/recovery, 8/26/99	8,800	33	270
LMTN-2	Driller log	5,700	28	200
MTN-1	24-hr constant rate, 2/5/86	7,060	15	470
MTN-2	24-hr constant rate, 2/25/86	2,950	15	200
MTN-3	24-hr constant rate, 2/16/86	2,410	15	160
<p>Determination of transmissivity was based on Cooper-Jacob method and drawdown v. time data, or using the approximate Cooper-Jacob method based on specific capacity of test data (Driscoll 1986). Thickness is estimated from well log and conductivity is computed as transmissivity divided by thickness.</p>				

The bedrock geology consists of mixed sedimentary rocks that are folded into a syncline, or down-warp, referred to as the Big Sky syncline (Figures [2-1](#), [2-2](#), [2-3](#)). Lone Mountain Ranch is essentially in the hinge area of the syncline. Exposed bedrock on the hillside to the northeast from the Ranch dips to the south, forming the northerly syncline limb. Rocks in Meadow Village and South Fork Meadow, which are primarily concealed by till and outwash deposits, dip to the north, forming the southerly limb of the syncline. From Lone Mountain Ranch, the bedrock formations extend uphill to the north and are exposed along the flanks of the Spanish Peaks. These exposed areas likely coincide with groundwater recharge

areas. The proximity of Lone Mountain Ranch to the bedrock recharge areas suggests that a deep bedrock well at the Ranch may encounter unusually fresh groundwater for the Big Sky area.

Hydraulic Properties

Data pertaining to groundwater hydraulic parameters were determined from existing well tests in the area, and are presented in Tables 2-2 and 2-3. These data indicate transmissivity ranges from 1,170 to 27,400 ft²/d for unconsolidated formation well tests. It is substantially lower, ranging from a low of 3 ft²/d (Blue Grouse) to a high of 2,730 ft²/d (MTN-6) in bedrock formation well tests. At the location of Lone Mountain Ranch, the aquifer hydraulic properties are estimated as for Hidden Village No. 1 due to the more detailed testing conducted in this well, and to allow use of the same computer model for delineation of these wells. Hidden Village No. 1 is located within 3,500 feet from the Lone Mountain Ranch wells.

TABLE 2-3
FORMATION HYDRAULIC DATA FOR BEDROCK WELLS

Well Name	Test	Transmissivity (ft ² /d)	Thickness (ft)	Conductivity (ft/d)
HV-2	Driller Log	40	141	0.3
BG	89.5-hr constant rate, 8/7/97	3	14	0.2
AG-1	Driller log	415	30	14
AG-2	Driller log	45	100	0.5
AG-3	Driller log	1,645	118	14
Lone Moose Test Well	Driller log	20	48	0.5
LM-2	Driller log	1,500	13	115
MTN-4	48-hr constant rate, 12/18/85	1,450	82	18
MTN-5	24-hr constant rate, 2/21/97	450	32	15
MTN-6	24-hr constant rate, 7/26/96	2,730	40	70
<p>Determination of transmissivity was based on Cooper-Jacob method and drawdown v. time data, or using the approximate Cooper-Jacob method based specific capacity of test (Driscoll 1986). Thickness is estimated from well log and conductivity is computed as transmissivity divided by thickness.</p>				

Groundwater Recharge

Groundwater recharge was estimated for infiltration due to snow melt and rain based on two methods. A monthly water balance method used existing precipitation data to estimate deep percolation, accounting for runoff and evapotranspiration. A stream base flow method equated the stream base flow measured during September to the groundwater recharge rate, and determine a unit area recharge rate based on the

watershed area. The results are summarized in Table 2-4 and analysis worksheets are provided in Appendix C. These data indicate an infiltration recharge rate ranging from 2.6 to 13.6 inches per year. The average rate for the watershed may be approximately 4.8 inches per year. The recharge rate at and above Lone Mountain Ranch may span the entire range that was estimated, as the terrain varies from high mountain valley to alpine conditions.

TABLE 2-4
GROUNDWATER RECHARGE ESTIMATES

Monthly Water Balance Method				
Site Location	Annual Precipitation (in)	Runoff (in)	Actual Evapotranspiration (in)	Groundwater Recharge (in)
Lone Mountain	37.6	9.4	14.6	13.6
Big Sky 3S	19.4	2.9	13.9	2.6
Stream Base Flow Method				
Location	Date	Flow (cfs)	Watershed Area (acres)	Groundwater Recharge (in)
West Fork above W. Gallatin River	September 1995	27.7	50,533	4.8

Groundwater Flow Direction

Mapping of groundwater elevations as a method to determine groundwater flow direction is provided by Baldwin (1996 and 1997) for parts of the Big Sky area. Based on this information, the area of Lone Mountain Ranch appears to be a groundwater discharge zone, meaning that groundwater is flowing to this area in order to discharge into the North Fork channel. Groundwater flow direction is generally southerly toward the channel area. It is southwesterly on the east side of the channel, and southeasterly on the west side of the channel. The hydraulic gradient of the groundwater system at Lone Mountain Ranch is relatively steep, ranging from approximately 0.1 to 0.5 ft/ft.

TWODAN Modeling

TWODAN is an analytic element model for groundwater flow under steady-state conditions (Fitts 1999). It can represent a variety of complex features, including non-uniform groundwater flow, changes in aquifer hydraulic properties with location, boundary conditions, such as streams, and multiple pumping wells. A TWODAN model was created to map the Inventory Region of the Lone Mountain Ranch wells. The same model was also used for delineation of Hidden Village Well No. 1 (HV#1).

Model setup and simulation results for Lone Mountain Ranch Well Nos. 1 and 2 are shown on Figures [2-4](#) and [2-5](#). The geological map for Meadow Village ([Figure 2-1](#)) and the surface hydrology GIS data were used as a model base map. For the purposes of delineation modeling, the aquifer was assumed to have a maximum thickness of 9.15 m, or 30 ft, which is representative of the saturated thickness at the location of the Lone Mountain Ranch wells.

Groundwater hydraulic properties were determined based on well testing data reported earlier. Three hydraulic conductivity zones were established in the model: zone 1 represents bedrock formations; zone 2 represents lower transmissivity alluvial deposits; and zone 3 represents high transmissivity alluvial

deposits. The parameters used in each zone are shown on [Figure 2-4](#). The Lone Mountain Ranch wells were located within the zone 2 region, which had a transmissivity of 1,200 ft²/d.

Surface water features represented by line-sinks were included in the model only at the eastern boundary of the alluvial deposits, as annotated onto [Figure 2-4](#). Although exchange between groundwater and surface water likely occurs elsewhere within the model area, a more conservative (i.e., larger) delineation area is determined if the surface water features are not included in the model, other than were absolutely necessary.

Infiltration recharge was applied based on the rate determined from the monthly water balance method for the Big Sky 3S station. It was reduced slightly to account for the thinner aquifer represented in the model.

Groundwater flow pathlines for Lone Mountain Ranch Well Nos. 1 and 2 are shown on [Figure 2-5](#), and are drawn for steady-state pumping at the maximum production rate of 34 gpm from both wells. The pathlines extend up-gradient for a 3-year time-of-travel, with arrowheads located at 1-year intervals. The 1-year time-of-travel (TOT) and the 3-year TOT boundaries are also shown on the figure. These areas have been extended symmetrically about the North Fork channel because it is possible for the groundwater flow direction to shift seasonally or to slightly deviate from the model. The configuration of these pathlines is directly related to the selected model setup. Although this model setup was chosen to best represent the groundwater flow system, differences may exist between the actual and modeled conditions.

Source Water Protection Areas

Source Water Protection Areas for Lone Mountain Well Nos. 1 and 2 are shown on [Figure 2-6](#). These areas include the Inventory Region, the Recharge Area, and the Surface Water Buffer. The Control Zone was shown on [Figure 1-2](#). The Inventory Region is mapped by the 3-year TOT boundary as determined by the TWODAN modeling. The Recharge Area is mapped to coincide with the sub-basin boundary, or North Fork watershed, and was determined by GIS analysis of DEM data, as explained earlier. The Surface Water Buffer extends ½-mile to either side of the North Fork channel, and to the channel headwaters. It also is mapped by GIS software.

[Figure 2-7](#) provides two management areas (MAs) that are recommended for use in Source Water Protection Planning. These areas were developed based on the Source Water Protection Areas, and are adjusted to reasonably correspond to township-range-section designations. The Inventory Region MA extends beyond the Inventory Region to account for uncertainty. The Recharge Area MA generally follows the watershed boundary. Because the actual recharge area to the wells is likely much smaller than the watershed, it was not considered necessary to fully enclose the watershed boundary with the Recharge Area MA boundary.

In terms of Source Water Protection Management, the intentions of these areas are as follows:

- The Control Zone is the most stringently managed as groundwater contamination within this zone likely will migrate to the well before detection.
- The Inventory Region MA is used for detailed inventory of potential contaminant sources and land use activities. It may be considered that contamination in this area will possibly impact the well prior to natural attenuation or cleanup. However, it should be possible to identify contamination events before the contamination actually enters the well.

- The Recharge Area MA is used to determine the general area of interest for the water supply sources. Large land development projects, large industrial land uses, and large sources of nitrates and pathogens in this area should be reviewed to ensure they will not be detrimental to the water resources supplying the wells.

INVENTORY

This section describes the potential contaminant sources that occur within the Source Water Protection Areas including the Control Zone, Inventory Region Management Area, Recharge Area Management Area, and the Surface Water Buffer. These potential contaminant sources were identified by review of existing maps, searching of state and federal databases, and a field survey of the area.

Land Use

A review of land uses provides a general overview of groundwater contamination potential. Typically groundwater contamination will be associated with high density urban and heavy industrial land uses. Significant contamination has also occurred in association with light manufacturing and small commercial properties.

Parcel mapping for the area of Lone Mountain Ranch is provided on [Figure 3-1](#)⁵. The vast majority of the land area is undeveloped open land and the upper part of the watershed, not shown, is a designated Wilderness Area. The next most abundant land uses are large parcel residential, typically of 20-acre or greater in size and with one single-family home, possibly including a guest home or cabin. Lone Mountain Ranch is the only commercial property in the area.

From consideration of land uses, groundwater contamination is of low potential throughout the area. Lone Mountain Ranch operations have the highest potential for groundwater contamination in comparison to the other land uses.

Septic and Sewer Hazards

Septic systems used for on-site wastewater discharge can be a source of nitrate and pathogen contamination in groundwater. Septic system density outside of the sewer service area was evaluated based on population, as reported in the year 2000 census blocks. The septic hazard throughout the area is low, and therefore septic systems are not considered a significant source for Lone Mountain Ranch Well Nos. 1 and 2. It is noteworthy that Lone Mountain Ranch is fully connected to the sanitary sewer and does not use on-site sewage systems for wastewater treatment and disposal.

Sanitary sewers are considered to mitigate the risk of groundwater contamination from septic systems. However, sewer leaks can be a significant source of nitrate and pathogens, and such leaks have impacted well water supplies in other areas (e.g., Missoula, MT). Lone Mountain Ranch is served by a network of sewers that connect various buildings to the main line leading to Meadow Village. These sewer lines are shown on the site map included in the report map pocket. Sewer lines in proximity to Lone Mountain Ranch Well Nos. 1 and 2 are also shown on [Figure 1-2](#). Of the existing potential contaminant sources in

⁵ Land use mapping by the USGS and that is available from the NRIS website was reviewed. These data indicated a single Open land use for the entire Big Sky area. Consequently, it was concluded the mapping information was not current, and for this reason is not displayed in the SWDAR.

the area, a leak from the local sewer is considered the most significant potential source of contamination to the wells.

Point Sources

Point sources of groundwater contamination include a wide array of possibilities. The classic example of a point source is a leaking underground gasoline storage tank. Other types of point sources may include a landfill, a dry cleaner's septic system, an above ground bulk chemical storage facility, and a mine.

Point sources were identified by database review and by a field survey. The field survey appeared to be a more effective means for identifying potential point sources. Database searching included the MDEQ Source Water Protection Program website query program. Each data type corresponding to a potential contaminant source was reviewed within an approximately 3-mile radius from the Lone Mountain Ranch water supply wells. The U.S. EPA Envirofacts database was also searched for hazardous waste generators and handlers based on the Big Sky postal code, 59716. The categories of contaminant sources that were reviewed include the following:

- Montana Comprehensive Environmental Cleanup Sites
- EPA CERCLIS Sites
- EPA Toxic Release Inventory
- Landfills (Active, Inactive)
- Underground Storage Tanks (Active, Inactive, Leaking)
- Mines, abandoned and existing
- Stormwater and Wastewater Discharges
- RV Dump Sites
- Crude Oil Pipelines
- Hazardous Spill Sites
- Railroads
- Confined Animal Feeding Areas

TABLE 3-1
POINT SOURCES

Map ID	Location	Description	Significant Source ¹
None	Lone Mountain Ranch	Maintenance facility (2 AST)	No (downgradient)

¹Significant sources are included in the Susceptibility Assessment of Section 4.
UST – underground storage tank; AST – above ground storage tank.

Field Survey

Table 3-1 provides a listing of potential contaminant sources identified from the field survey, showing that only one insignificant source is located within the Inventory Region MA of Well Nos. 1 and 2. This potential source is the Lone Mountain Ranch Maintenance Shop, and is located where shown on [Figure 3-3](#). This potential contaminant source is down-gradient from the wells, and also located on the west side of the North Fork channel, thus, contaminant migration to the wells does not appear possible. It is noteworthy, however, that this source includes two above ground steel fuel storage tanks. One is 1,000 gallon and stores gasoline. The other is 500 gallons and stores diesel.

Database Search

The database search did not identify any significant potential contaminant sources relevant to Lone Mountain Ranch. One of the most abundant source types was related to historic mining activities in the area. Several exploration sites were identified to the east of the Recharge Area MA, however one of the sites appears on the east boundary. This site was a raw prospect named Last Chance Prospect and has the location SW ¼, NW ¼, NE ¼, Section 23, Township 6S, Range 3E. It is located 1.5 to 2 miles from the wells and is not considered a significant potential source of contamination.

SUSCEPTIBILITY ASSESSMENT

The state of Montana has developed a method to determine the susceptibility of a well to be contaminated by a given potential source of contamination. The susceptibility categories that may be assigned include very-low, low, moderate, high, and very-high. Very low susceptibility indicates that a potential contaminant source has less likelihood of impacting a well in comparison to a source with a designated very-high susceptibility. The actual risk, as a quantified probability to contaminate the well, is not determined by this method. The method results are qualitative and are intended for use in prioritizing management activities.

Method Summary

Susceptibility assignments (to a well) are made for each significant potential contaminant source identified in the source inventory, including point and non-point sources. The method is conservative, resulting in generally high susceptibilities even when a quantified risk of contamination may be very low. Some of the conservative nature of the method is eliminated by only applying the method to significant potential sources of contamination. Significant potential contaminant sources that are normally considered in a susceptibility assessment include the following:

- Septic systems
- Animal feeding operations
- Underground storage tanks
- Leaking underground storage tanks
- State and federal superfund sites
- RCRA large quantity generators
- Underground injection wells
- Wastewater treatment / spray irrigation / lagoons
- Landfills
- Abandoned mines
- MPDES wastewater discharges
- Municipal sanitary sewers
- Municipal storm sewers
- Storm water discharges
- Highways, railroads and pipelines
- Cultivated cropland

There are two steps to determining susceptibility. First, the potential contaminant source is assigned a hazard level, based simply on its occurrence within a source water protection area. Hazard levels are categorized as low, moderate, and high. Those sources that are nearest to a source water intake (or

occupy a large land area) will have a higher hazard classification than sources that are farther away (or occupy a small land area).

In step two, the occurrence of barriers, either natural or engineered, that may protect the water source intake from the potential contaminant source are evaluated. An upward groundwater flow direction and/or a low permeability clay layer above an aquifer are types of natural barriers. Properly constructed wells and wells with deep seals into confining layers are examples of engineered barriers. If there are no barriers then little protection exists to prevent contamination of water in the event of a spill or leak. If one or more barriers are present, a spill or leak is likely to be captured or impeded.

Once the hazard level and number of barriers has been determined for each significant contaminant source, a susceptibility level can be designated. Table 4-1 summarizes the susceptibility categories with respect to the hazard level and the existence of barriers.

TABLE 4-1
SUSCEPTIBILITY CATEGORIES

Presence of Barriers	Hazard Level		
	High	Moderate	Low
No Barriers	Very High	High	Moderate
One Barrier	High	Moderate	Low
Multiple Barriers	Moderate	Low	Very Low

Table entries are the susceptibility (to be contaminated) of a water source intake to a specified potential contaminant source. The susceptibility level is determined based on the hazard level of the potential contaminant source and the number of barriers that exist to protect the water source from contamination.

Natural and Engineered Barriers

Natural and engineered barriers reduce the risk of contaminants migrating to a water supply well. Barriers may be assigned based on natural conditions or engineered systems related to the well. Table 4-2 provides a listing of barriers pertaining to the project wells where barriers exist.

One type of barrier was identified for Well No. 2. Compliance with the state of Montana water well construction rules is considered an engineered barrier, and this well appears to comply with the rules. Compliance is shown by a 20-foot bentonite surface seal on the well log for this well. The log for Well No. 1 does not indicate any information pertaining to the well seal, and consequently, a barrier is not assigned to this well.

It is noteworthy that the surface seal of Well No. 2 was installed during drilling and driving of the 6-inch permanent well casing. This type of surface seal, although allowed in the state of Montana and rule-compliant, does not meet the water well standards published by the American Water Works Association, or the rules for water well construction in several other US states (e.g., Oregon, Washington). The Montana surface seal is prone to an incomplete installation with gaps, and consequently it may not completely fill the annular space between the well casing and borehole wall. It is advisable that any well installations used for potable supply be sealed by grouting under pressure into a borehole with a diameter at least 4-inches larger than the permanent casing diameter (e.g., 10 inch borehole for a 6-inch casing well).

**TABLE 4-2
BARRIER ASSIGNMENTS**

Well Name	Barrier No. and Type	Description
LMTN-2	1 – Engineered	Well is constructed in compliance with state of Montana water well construction rules.

Source Water Susceptibilities

Susceptibility designations are provided for each significant potential contaminant source and with respect to individual wells in Table 4-3. The sanitary sewer lines were the only significant potential contaminant source identified. The sewer collection system serves 20 to 50% of the area of the Inventory Region, as shown on Figure 3-2 and 3-3. According to the DEQ Source Water Protection Program, this condition is classified as a Moderate hazard level. Because there are no apparent barriers for Well No. 1, the susceptibility designation is High. The susceptibility designation for Well No. 2 is Moderate because this source was assigned one engineered barrier.

**TABLE 4-3
SUSCEPTIBILITY DESIGNATIONS**

Source Type	Contaminants	Contaminants Origin	Well Name	Hazard Rating	No. Barriers	Susceptibility
Sanitary Sewer	Pathogens, nitrate	Leak	LMTN-1	Moderate (20-50%)	0	High
			LMTN-2	Moderate (20-50%)	1	Moderate

RECOMMENDATIONS

Recommendations are provided in this section for guidance purposes only and are completely voluntary on the part of Lone Mountain Ranch. There are no regulatory obligations established by the inclusion of these recommendations in this SWDAR. The recommendations described below are considered to be beneficial to long-term source water protection and source development.

- Lone Mountain Ranch should participate in a Source Water Protection Plan (SWPP) for the Big Sky area. It is likely Big Sky Water and Sewer District will prepare an SWPP for the area of their water systems. This SWPP will overlap with the Source Water Protection Areas for Lone Mountain Ranch. Lone Mountain Ranch can likely participate as a committee member when the SWPP is prepared. This representation will enable the Ranch to possibly obtain greater benefit from SWPP activities in the area.
- This SWDAR should be distributed to the Gallatin Local Water Quality District (GLWQD) for information purposes. The GLWQD boundary may be extended to the Big Sky area as a result of interest by the Big Sky Water and Sewer District. Lone Mountain Ranch can benefit from the GLWQD activities, such as water quality and level monitoring, education, and contaminant source inventory data collection.

- Lone Mountain Ranch should annually update the contaminant source inventory of this report and submit new data to MDEQ every 5-years. This work could be completed by the GLWQD if the GLWQD boundary is extended to Big Sky. The next submittal of inventory data to MDEQ should occur during June 2007.
- Lone Mountain Ranch should provide training to key staff regarding groundwater contamination potential. This training may be partially available through electronic media programs distributed by the Montana Water Center (994-6690) at Montana State University in Bozeman. The intention of the training is to inform staff of possible sources of groundwater contamination, such as fuels, solvents, fertilizers, pesticides, sewers, manure, surface water runoff, and other source types.
- Lone Mountain Ranch should review operations that presently occur within the Control Zone of the wells, as illustrated on [Figure 1-2](#) (100-ft radius). There should be no application of chemicals or storage of chemicals within these areas (e.g., fertilizer, manure, pesticides, motorized machines).
- Lone Mountain Ranch should consider water treatment or new source development when planning improvements to resort. Shallow groundwater sources, such as Well Nos. 1 and 2, are more vulnerable to contamination than deep well sources. New shallow wells comparable to Well Nos. 1 and 2 would require disinfection treatment (at a minimum) under the present rules, however the state does not impose these rules on existing sources. Deep groundwater may be feasibly developed at Lone Mountain Ranch from bedrock aquifers (although quantity and quality is uncertain). A deep well supply could be adequately protected from surface contamination by the installation of a deep surface seal. A feasibility study including cost data should be completed to assess alternatives for use of shallow wells with treatment versus deep wells without treatment.

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APPENDIX A
SANITARY SURVEY

APPENDIX B

WELL LOGS

APPENDIX C
GROUNDWATER RECHARGE ESTIMATES