History of Flooding of the Butte Underground Mines and Berkeley Pit Water-Level Monitoring and Water-Quality Sampling 2006 Consent Decree Update Butte, Montana 1982-2006

prepared for

The Montana Department of Environmental Quality
Remediation Division
and
U.S. Environmental Protection Agency
Region VIII

November 2007

Prepared by

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1300 West Park Street
Butte, MT 59701-8997

Contract No. 400022-TO-18

Montana Bureau of Mines and Geology

Open File Report No. 566

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Executive Summary

The Record of Decision and Consent Decree for the Butte Mine Flooding Operable Unit stipulates that a yearly update of data collected from the Post Remedial Investigation/Feasibility Study and Consent Decree monitoring program be prepared. The report is to incorporate the most recent year's data with the existing information. This report presents data collected during the year 2006, combined with data collected since 1982, when the Anaconda Company suspended underground mine dewatering and mining in the Berkeley Pit.

Major new observations and developments discussed in this report are:

1. Influence of Montana Resources Central Zone ore body dewatering tests on East Camp bedrock water levels. The tests were conducted to determine the feasibility of future mining in this area.
2. West Camp pumping activities continue to maintain the ground-water level below the 5,435-foot elevation, stipulated in the 1994 Record of Decision. The volume of water pumped in 2006 was up 13 percent from 2005 (290.0 vs. 257.8 acre-ft). With more water pumped during 2006, the water levels decreased between 1.15-ft and 1.62-ft throughout the West Camp System.
3. The annual Berkeley Pit model was updated taking into account the continued diversion of Horseshoe Bend drainage water away from the pit, discharge of sludge from the treatment plant into the pit, and the addition of storm water flow from the Butte Hill. The date projected in the 2005 report of June 2020 was modified to November 2021, a change of 0.42 years (5 months), when the 5,410-foot water-level elevation would be reached at the Anselmo Mine.
4. Water-quality changes seen in East Camp alluvial well LP-9 continued. Well LP-9 was sampled once during 2006 and metal concentrations remain very elevated.
5. Water quality changed significantly in East Camp alluvial well LP-17. Between the years 2003-2005 an increase in concentration for cadmium, copper and zinc occurred; however, concentrations for these three trace metals decreased by 50% during 2006. Nitrate concentrations increased substantially during both 2006 sample events compared to 2005 results.

Water-level and water-quality data are presented in the same order and manner as the previous reports:

MBMG 376	Duaime, Metesh, Kerschen, Dunstan	1998
MBMG 409	Metesh, Duaime	2000
MBMG 410	Duaime, Metesh	2000
MBMG 435	Duaime, Metesh	2001
MBMG 456	Metesh, Duaime	2002
MBMG 473	Duaime, Metesh	2003
MBMG 489	Duaime, Metesh	2004
MBMG 518	Duaime, Metesh	2005
MBMG 527	Duaime, Metesh	2005
MBMG 549	Duaime, Metesh	2006

Total and yearly water-level changes for all sites are presented along with hydrographs for selected sites. Water-quality data follow the presentation of water-level data in each section where water-quality data are available, as not all sites are sampled.

Monitoring and sampling activities performed during 2006 reflect the long-term program outlined in the 2002 Consent Decree. Therefore, some monitoring sites that were part of the early monitoring program have been deleted, while others have been added. There have been some minor organizational changes in this year's report in an effort to make it more readable.

List of acronyms used in text

AMC	Anaconda Mining Company
ARCO	Atlantic Richfield Company
BP/ARCO	British Petroleum/Atlantic Richfield Company
BMFOU	Butte Mine Flooding Operable Unit
CD	Consent Decree
CWL	Critical Water Level
DEQ	Montana Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
HSB	Horseshoe Bend Drainage
HSB Falls	Horseshoe Bend Falls
MBMG	Montana Bureau of Mines and Geology
MCL	Maximum Contaminant Level
MR	Montana Resources
MSD	Metro Storm Drain
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SMCL	Secondary Maximum Contaminant Level

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Butte, Montana
1982-2006

SECTION 1.0 SITE BACKGROUND

Butte has a long history of mining dating back to 1864 with the development of gold placers in Missoula and Dublin gulches and along Silver Bow Creek, (Miller, 1978). However, placer mining only lasted for a short period of time. It was followed by the development of silver mining in 1866 (Miller, 1978). The major silver deposits were developed in the early 1870's and consisted of such mines as the Alice, Travona, Lexington and Colusa. However, with the repeal of the Sherman Silver Purchase Act in 1893, and the presence of high-grade copper outcrops, Butte mining shifted its focus to the development of copper deposits.

Mining expanded and mines deepened as mining companies followed the rich copper veins. With the expanded mining, improved methods to handle groundwater became a major concern; therefore, the mining companies began interconnecting mines to drain water to central pump stations to improve efficiency (Daly and Berrien, 1923). The Anaconda Copper Mining Company, which would eventually control a majority of the underground mines, began interconnecting selected mine levels for draining water to a central pump station as early as 1901. This water, which was acid in nature and contained high concentrations of dissolved minerals, necessitated specialized pumps and piping to transport the water. Once the water reached the surface it was routed to a precipitation plant for recovery of copper. Once the copper was removed from the water, the water was discharged to Silver Bow Creek. This practice of discharging untreated acidic-metal laden water to Silver Bow Creek continued until the late 1950's when the Anaconda Company began adding lime to the water to raise the pH and reduce the mineral content of the water (Spindler, 1977).

The cost of mining increased as the mines deepened and the ore grades lessened. Therefore, the Anaconda Company began open-pit mining operations in the Berkeley Pit in July 1955. As the open-pit mining expanded it consumed some of the primary underground mines (figure 1-1) that were important to

Butte's early development. The Berkeley Pit was dewatered by the underground mine pumping system, which was moved from the High Ore Mine to the Kelley Mine in 1967 (Miller, 1978). Mines located in the areas described by Sales (1914) as the Intermediate and Peripheral Zones, were shut down and eventually sealed off from the remainder of the operating mines. The remaining operating mines were isolated from the Emma and Travona mines along with the Orphan Boy and Orphan Girl mines. These areas were isolated to reduce the amount of water pumped from the underground workings and to lessen the amount of fresh air brought into the mines for worker safety. Active underground mining continued in the Kelley and Steward Mines until 1975 (Burns, 1994) when the Anaconda Company ceased underground mining operations; however, they continued to operate the underground pumping system, which not only kept the mines dewatered, but also did the same for the Berkeley Pit.

Open-pit mining expanded to east of the Berkeley Pit with the development of the East Berkeley Pit in 1980 (Burns, 1994). This open-pit mine was developed to remove both copper and molybdenum reserves. The Berkeley Pit continued to operate until shortly after the Anaconda Company's announcement in April 1982 that they were no longer going to operate the Kelley Mine pump station. When the pumping suspension was announced, the pump station was removing up to 5,000 gallons per minute of water. The East Berkeley Pit continued to operate until June 30, 1983 when the Anaconda Company closed all its Butte mine operations.

The Anaconda Company, which had been purchased by the Atlantic Richfield Company (ARCO) in 1977, sold its Butte operations to Dennis Washington in December 1985, who then formed Montana Resources (MR) (Burns, 1994), renaming the East Berkeley Pit the Continental Pit. MR resumed mining in the Continental Pit in July 1986.

Prior to the 1982 stoppage of underground mine dewatering, the Anaconda Company had already allowed the lower-most mine workings to flood to the 3,900 pump station in 1977. This followed the discontinuation of selective underground vein mining in 1975 (Burns, 1994).

Figure 1-1. Map showing location of selected unerground mines engulfed by development and expansion of the Berkeley Pit.

Section 1.1 Introduction

The year 2006 marks 25 years of water-level and water-quality monitoring since the Anaconda Company's announced stoppage of underground mine-dewatering and the suspension of open-pit mining in the Berkeley Pit. The Anaconda Company announced on April 23, 1982 the suspension of pumping operations at the Kelley Mine pump station, located at the 3,900-level of the mine. (The 3,900-level pump station was located at a depth of ~3,600-ft below ground surface.) At the same time, the Anaconda Company also announced the suspension of mining in the Berkeley Pit, beginning May 1982. However, they continued to operate the East Berkeley Pit (now referred to as the Continental Pit) until June 30, 1983, when they announced a suspension of all mining operations in Butte.

The Anaconda Company developed and implemented a groundwater-monitoring program following the 1982 suspension of mining. This program included a number of mine shafts, alluvial dewatering wells, existing domestic and irrigation wells, along with a number of newly installed alluvial monitoring wells. Monitoring included water-level measurements and water-quality sampling. This monitoring program continued until changes were made as part of the Butte Mine Flooding Operable Unit (BMFOU) Superfund investigation.

The U.S. Environmental Protection Agency (EPA) and the Montana Department of Environmental Quality (DEQ) approved and oversaw the BMFOU Remedial Investigation/Feasibility Study (RI/FS) that ran from the fall of 1990 through the spring of 1994. Major tasks of the RI/FS included the installation of a number of new monitoring wells, both bedrock and alluvial. Access was also gained into several previously capped underground mines for monitoring purposes. The 1994 Record of Decision (ROD) included a monitoring program that included portions of the 1982 Anaconda company-monitoring network, portions of the RI/FS monitoring network, and portions of a supplemental surface-water and groundwater network operated by the Montana Bureau of Mines and Geology (MBMG) since the summer of 1983.

The ROD included provisions for: 1) continued monitoring and sampling of both ground water and surface water, 2) diversion of the Horseshoe Bend Drainage (HSB) water away from the Berkeley Pit (to slow the pit water filling rate), 3) incorporation of the HSB water in the MR mining operations for treatment, 4) construction of a water treatment plant if changes in mining operations prevent treatment of

HSB water (e.g. mine shutdown), and 5) establishment of a maximum water level to which water in the underground mines and Berkeley Pit can rise, before a water treatment plant must be built and in operation.

The ROD monitoring program consisted of 73 monitoring wells, 12 mine shafts, and three surface water-monitoring sites, which can be broken down into the following categories:

1) East Camp bedrock wells – 18;

2) East Camp Mines – 7;

3) East Camp alluvial wells within active mine area – 19;

4) East Camp alluvial wells outside active mine area – 31;

5) West Camp mines – 3;

6) West Camp monitoring wells – 5; and

7) Outer Camp mines – 2.

The final monitoring network described in the 2002 Consent Decree (CD) replaced this monitoring network. The current monitoring program includes 63 monitoring wells, 11 mine shafts, and 4 surface-water sites. The Berkeley Pit and Continental Pit, as appropriate, are also part of the monitoring network. The monitoring network can be broken down into the following categories:

1) East Camp bedrock wells – 13;

2) East Camp mines – 6;

3) East Camp alluvial wells within the active mine area – 22;

4) East Camp alluvial wells outside the active mine area – 16;

5) Bedrock wells outside active mine area – 4;

6) West Camp mines – 3;

7) West Camp wells – 6;

8) Outer Camp mines – 2; and

9) Outer Camp wells – 2.

The 1994-ROD and 2002 CD both established critical maximum water levels (CWLs) for the East Camp bedrock system and West Camp bedrock system, while the 2002 CD specified compliance points that groundwater levels could not exceed. In the East Camp bedrock system, the maximum water level cannot exceed an elevation of 5,410-ft (mean sea level (msl), USGS datum), while in the West Camp bedrock system, the maximum water level cannot exceed an elevation of 5,435-ft msl (USGS datum). The compliance points in the East Camp consist of the following mine shafts and bedrock monitoring wells:

1) Anselmo
2) Granite Mountain
3) Kelley
4) Pilot Butte
5) Belmont Well #2
6) Well A
7) Well C
8) Well G

The West Camp compliance point is well BMF96-1D. In addition to the compliance point stipulations, water levels in the East Camp bedrock system must be maintained at a level lower than the West Camp water levels. (Refer to the CD and Explanation of Significance Differences to see the entire scope of activities addressed in the CD and an explanation of differences from items contained in the 1994 ROD.)

The CD addressed all current and future activities relating to the BMFOU and reimbursed EPA and DEQ for past costs associated with the site. Funding for the continuation of the long-term ground-water, surface-water, and Berkeley Pit/Continental Pit monitoring were included in the CD. The monitoring performed by the MBMG is under the direction of DEQ and EPA. British Petroleum/Atlantic Richfied Company (BP/ARCO) and the Montana Resources Group agreed in the CD to be responsible for all costs associated with the design, construction, operation, and maintenance of a water-treatment plant for treating HSB, Berkeley Pit, and other contaminated waters associated with the site.

The present study is the eleventh such report, summarizing 25 years of data collection. Notable changes and a comparison of trends for water levels and water quality are discussed. This report does not present a detailed overview of the history of mining on the Butte Hill, nor the Superfund processes that have followed since the EPA designated the flooding underground Butte Mines and Berkeley Pit a Superfund site in 1987. The reader is referred to the Butte Mine Flooding RI/FS, Butte Mine Flooding ROD, Butte Mine Flooding CD, and MBMG Open-File Report No. 376 for greater detail and information about the site.

Monitoring activities continued in 2006 in the East Camp, West Camp and Outer Camp systems (fig. 1-2). The East Camp System includes mines and mine workings draining to the Kelley Mine pump station when mining and dewatering were suspended in 1982. The West Camp System includes mines and underground workings that historically drained to the East Camp from the southwest portion of the Butte mining district, but were hydraulically isolated by the placement of bulkheads within the interconnected mine workings to separate the West Camp from the East Camp. The Outer Camp System consists of the western and northern extent of mine workings that were connected to the East Camp at some time, but were isolated many decades ago, with water levels returning to, or near, pre-mining conditions.

By the time water levels in the underground mines reached the elevation of the bottom of the Berkeley Pit in late November 1983, more than 66 percent of the underground workings had been flooded. More than 80 percent of the underground mine workings have been inundated with water through 2006. The upper 15 percent of the underground workings will never be flooded as they are at elevations above the specified CWL; therefore less than 5 percent of the underground workings remain to be flooded.

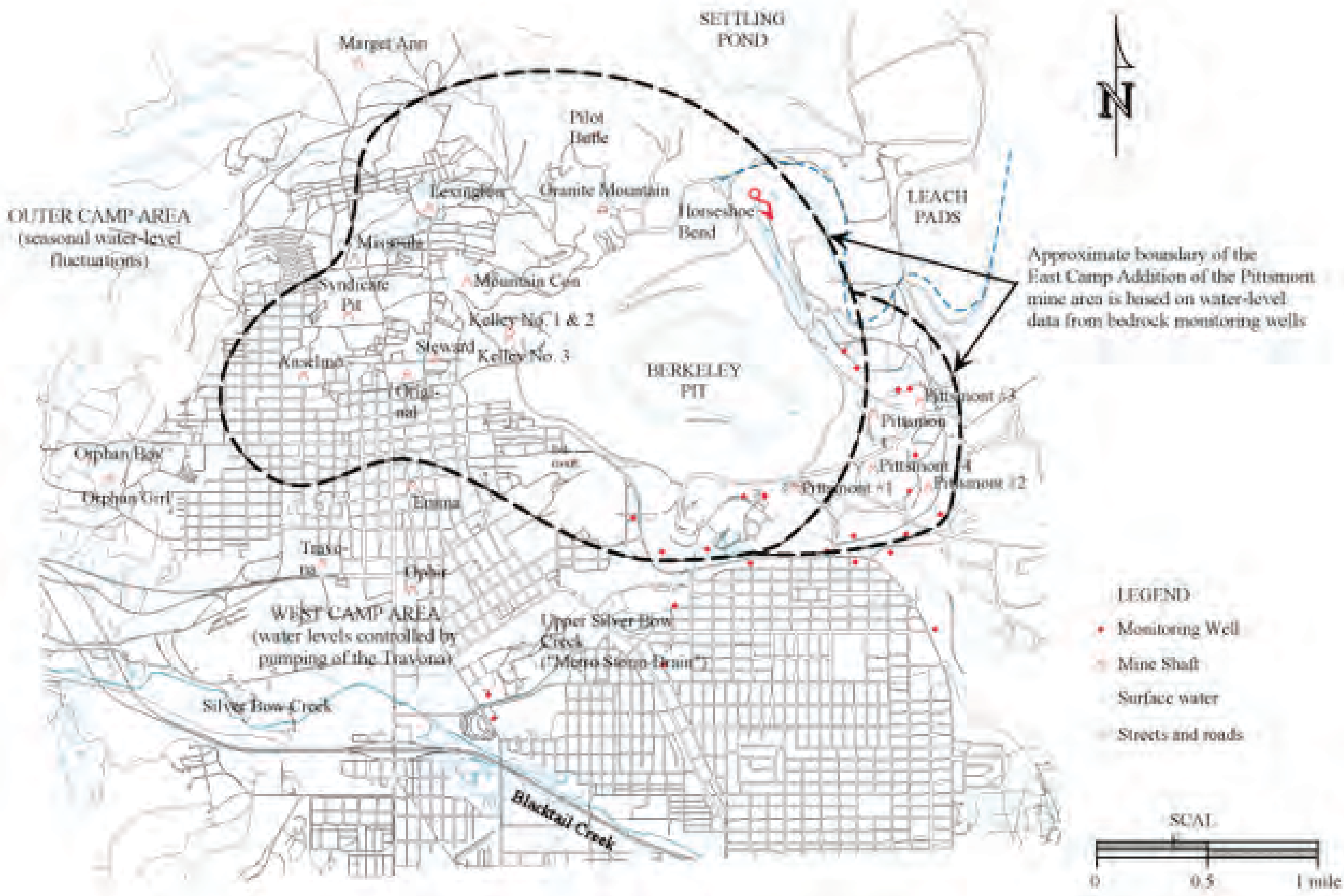


Figure 1-2. The mines of the Butte hill are presently considered in three groups: the East Camp, which includes the Berkeley Pit and the area east; the West Camp in the southwest part of the hill; and the Outer Camp which includes the outlying mines.

Section 1.2 Notable 2006 Activities and Water-Level and Water-Quality Observations

The main activities and observations for 2006 are listed below:

(1) Montana Resources (MR) continued mining and milling operations throughout 2006 following their November 2003 resumption of mining.

(2) MR backfilled the Pittsmont #3 shaft with mill tailings as part of future mine planning to isolate potions of the underground mine workings in the Central Zone from the Berkeley Pit. This backfilling temporarily raised water-levels in East Camp bedrock wells adjacent to the Pittsmont #3 shaft.

(3) MR conducted two pumping tests in the vicinity of the old Pittsmont Mine workings to evaluate dewatering options for future mining plans. Water levels in several East Camp bedrock wells showed drawdown from the pumping.

(4) MR injected a grout material into the Pittsmont 800 level workings to isolate portions of the underground workings from the Berkeley Pit.

(5) East Camp alluvial well LP-9 continues to show increases in metal concentrations from previous levels (pre 2003).

(6) The four East Camp alluvial wells installed in late 2005 and early 2006 were equipped with water-level transducers for semi-continuous water-level monitoring. Quarterly water samples were also collected.

(7) West Camp pumping rates were higher than previous years resulting in water-level decreases in West Camp mines.

Section 1.3 Precipitation Trends

Total precipitation for 2006 was 12.13 inches, compared to 13.24 inches in 2005. This amount is 0.61 inches below the long-term (1895-2006) average. Precipitation totals have been below average for seven of the past eight years and 18 of the last 25 years. The 2006 precipitation total was a decrease of almost five percent below the long-term average of 12.74 inches. Table 1.3.1 contains monthly precipitation statistics from 1982 through 2006, while figure 1-3 shows this information graphically in comparison to the long-term yearly average. Overall precipitation totals, since flooding of the mines began, are very similar to the long-term average (12.63 inches vs. 12.74 inches). Figure 1-4 shows departure from normal precipitation from 1895 through 2006.

Table 1.3.1 Butte Precipitation Statistics, 1982-2006.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Mean	0.51	0.47	0.80	1.06	1.95	2.16	1.49	1.37	0.98	0.70	0.62	0.54	12.63
Std. Dev.	0.36	0.29	0.40	0.63	0.76	1.26	1.16	0.87	0.67	0.52	0.40	0.40	3.11
Maximum	1.40	1.26	1.84	2.57	3.88	4.62	4.18	3.10	2.50	1.73	1.50	1.99	19.96
Minimum	0.10	0.11	0.18	0.00	0.89	0.50	0.00	0.15	0.07	0.00	0.07	0.11	8.32
Number of years precipitation greater than mean													7.00
Number of years precipitation less than mean													18.00

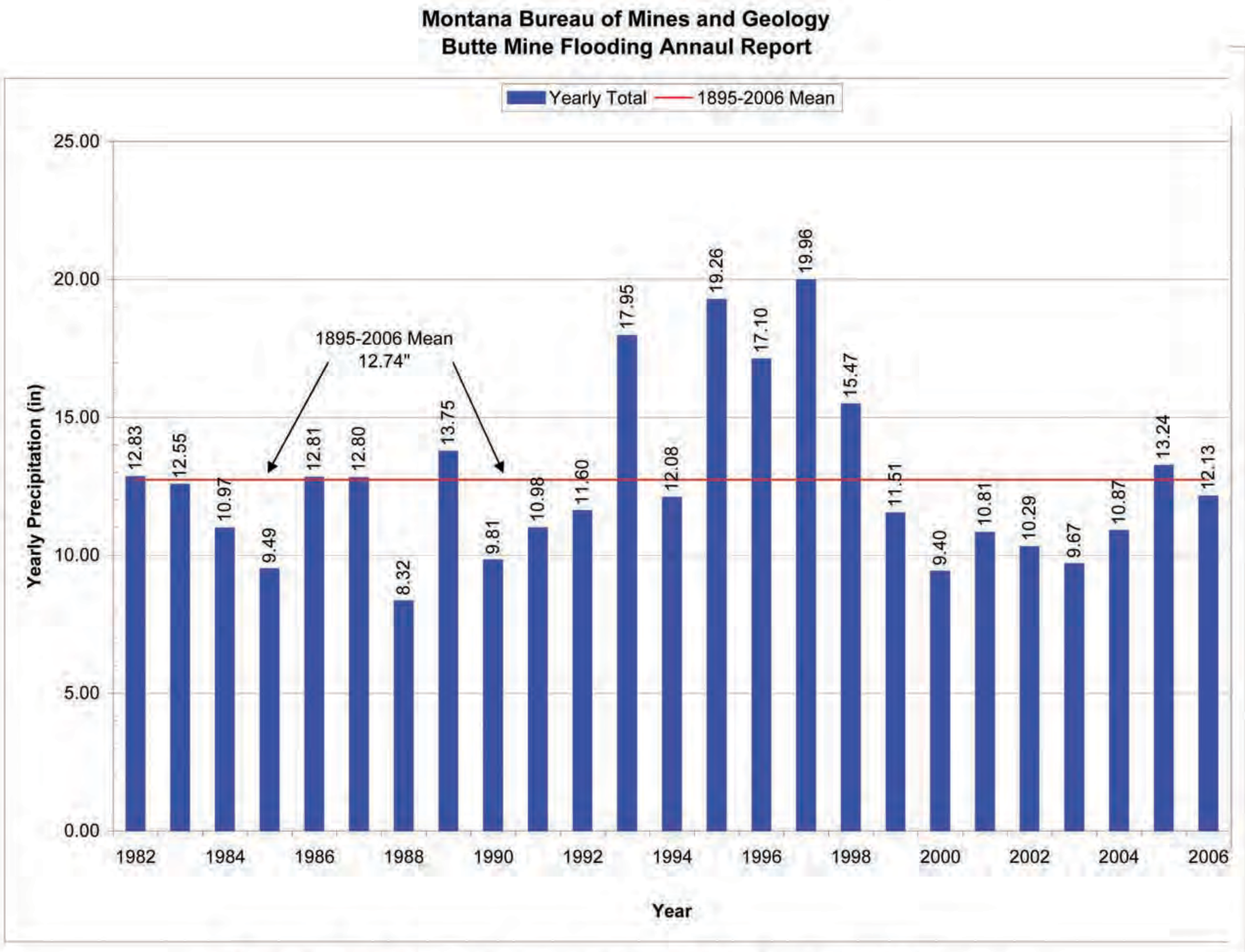


Figure 1-3. Yearly precipitation totals, 1982-2006, showing 1895-2006 mean.

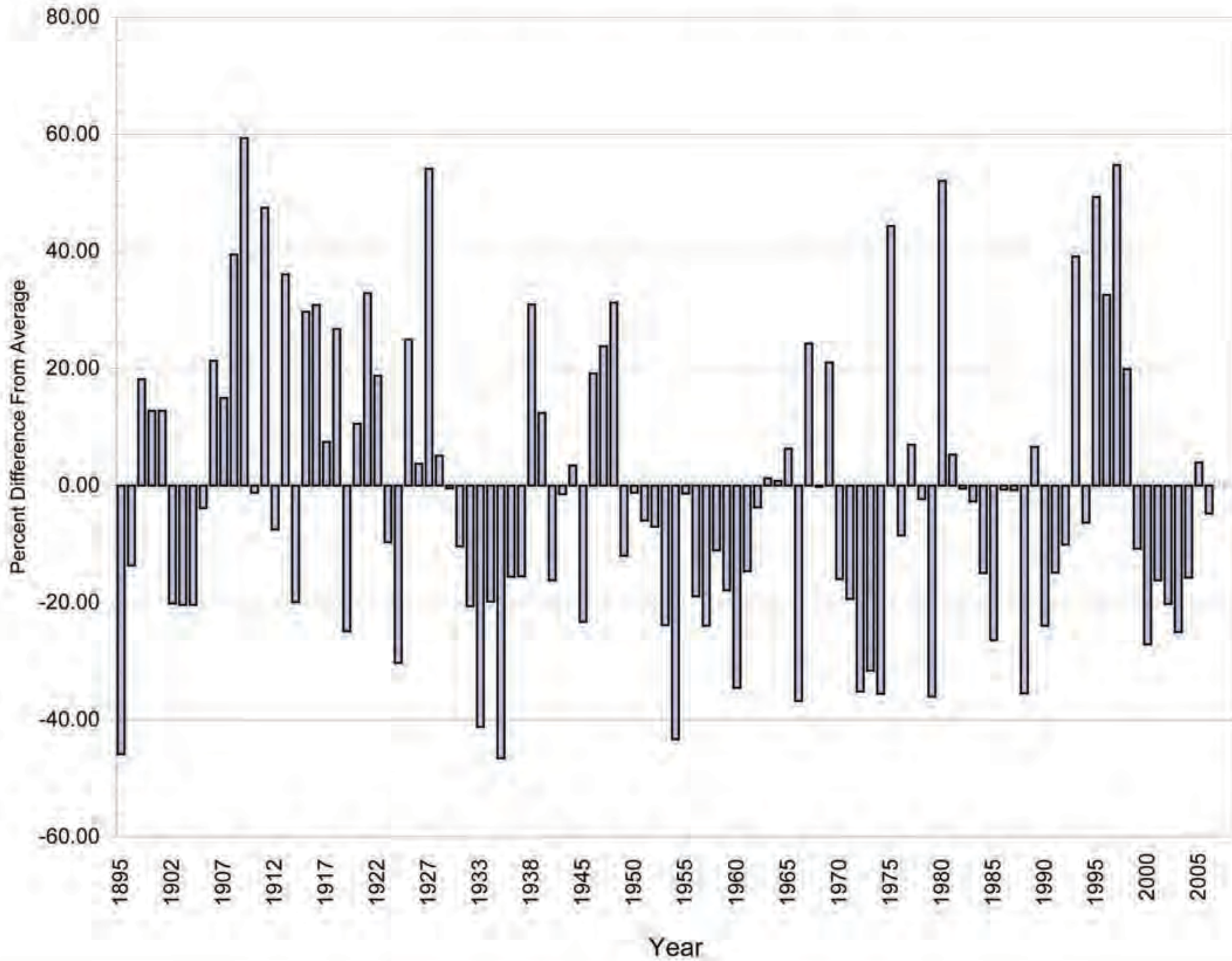


Figure 1-4. Percent precipitation variation from normal, 1895-2006

SECTION 2.0EAST CAMP SYSTEM

The East Camp is comprised of that portion of the bedrock aquifer affected by underground mine dewatering in 1982 and the overlying shallow alluvial aquifer (fig. 2-1). The East Camp Bedrock Monitoring System consists of the Anselmo, Belmont, Granite Mountain, Kelley, Steward, Lexington and Pilot Butte Mines, and the Berkeley Pit. It also includes the bedrock system adjacent to the East Camp mines and the shallow East Camp alluvial system. The East Camp alluvial system includes the alluvial aquifer within the active mine area and a portion of the alluvial aquifer outside the active mine area, primarily to the south. The East Camp alluvial system is discussed first, followed by the East Camp bedrock system.

Section 2.1 East Camp Alluvial System

The East Camp alluvial ground water monitoring system consists of the LP and MR97 series wells that are located within the active mine area, plus selected AMC, GS, AMW, and BMF05 series wells. All of the wells associated with the later four groups are located to the south of the active mine area, with the exception of wells AMC-5 and AMC-15. Each group of wells represents sites installed or monitored during different studies that have been incorporated in the BMFOU-CD monitoring program. Water-level elevations and monthly precipitation amounts are shown on hydrographs for selected wells. Water-quality results are shown and discussed for the sampled wells. Unlike the water-level monitoring program, water-quality sampling does not occur at every East Camp monitoring well and takes place only once or twice per year.

Four new alluvial monitoring wells were installed within the East Camp system during the later part of 2005 and early 2006. These wells were stipulated in the 2002 Consent Decree as a replacement for the domestic wells that were monitored from 1997 through 2002. The installation of dedicated monitoring wells enables the collection of more reliable water level data. The wells were situated in areas where data gaps existed and were equipped with transducers for increased water level data collection. The new wells are identified as BMF05 and are discussed with the GS series wells. These wells were sampled quarterly throughout 2006 to help establish baseline conditions.

Water-level conditions and water-quality characteristics vary throughout the alluvial system. Wells within or adjacent to historic mining activities show trends relating to the influence of those activities, i.e. elevated metals concentrations. Sites outside historic mining areas reflect conditions more typical of the regional hydrogeology.

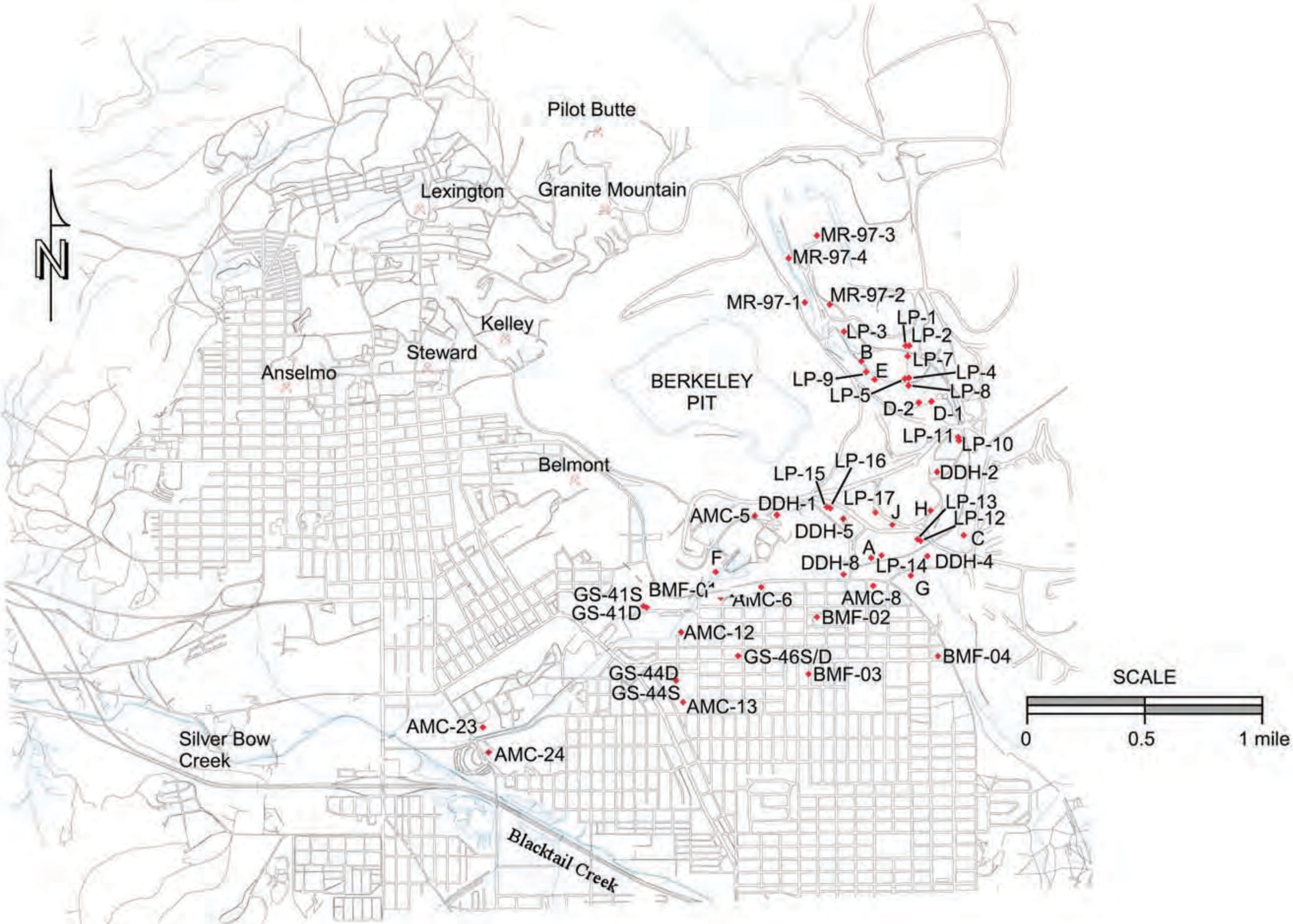


Figure 2-1. East Camp Monitoring Sites.

Section 2.1.1 AMC-Series Wells

The locations of the Anaconda Mining Company (AMC) wells are shown on figure 2-2; table 2.1.1.1 lists the annual water-level changes for these sites. Water levels increased in six of the AMC series wells for 2006, with one well remaining dry. This well has been dry since its installation in 1983. These increases are in contrast to changes seen in 2005 but are similar to those noted in a number of these wells during 2003 and 2004. Water levels had a net decline during the first 20 years of monitoring; however they have a net rise in the past four years. The overall water-level change is a net decline in all of these wells, with declines varying from just over 1-ft to more than 24-ft.

Table 2.1.1.1 AMC-series wells, annual water-level changes, in feet

Year	AMC-5	AMC-6	AMC-8	AMC-10	AMC-12	AMC-13	AMC-15
1983	-23.75	-2.30	-4.90	DRY	0.20	0.60	-5.80
1984	-4.50	-2.55	-3.75	DRY	-1.80	-1.10	-3.40
1985	-3.40	-3.90	-3.00	DRY	-2.45	-1.85	-2.80
1986	8.70	3.90	-0.90	DRY	1.90	1.00	-2.10
1987	0.10	0.40	1.50	DRY	0.60	0.10	0.00
1988	0.20	-0.40	0.30	DRY	-0.10	-1.00	0.80
1989	-2.30	-0.80	-0.90	DRY	-0.20	-0.10	0.10
1990	0.20	0.10	0.30	DRY	1.10	0.00	-0.10
1991	0.00	0.30	0.80	DRY	-0.60	0.30	-0.30
1992	0.40	-0.40	0.50	DRY	-0.30	0.00	-0.10
Change Yrs 1-10	**-24.35**	**-5.65**	**-10.05**	**0.00**	**-1.65**	**-2.05**	**-13.70**
1993	0.40	0.70	0.80	DRY	1.10	1.00	-0.40
1994	0.64	0.53	0.91	DRY	-0.19	-0.50	0.96
1995	0.64	1.01	0.51	DRY	1.23	1.13	0.97
1996	-0.05	0.62	2.14	DRY	0.74	0.69	2.60
1997	1.80	1.47	2.24	DRY	1.20	0.70	2.80
1998	-1.52	0.42	1.15	DRY	0.18	0.09	0.58
1999	-1.56	-2.03	-2.45	DRY	-1.56	-1.09	-1.50
2000	-2.46	-2.56	-3.88	DRY	-1.77	-1.17	-3.73
2001	-1.89	-1.92	-3.03	DRY	-0.55	-0.36	-2.34
2002	-0.89	-1.25	-1.77	DRY	-0.98	-0.73	-1.65
Change Yrs 11-20	**-4.89**	**-3.01**	**-3.38**	**0.00**	**-0.60**	**-0.24**	**-1.71**

Year	AMC-5	AMC-6	AMC-8	AMC-10	AMC-12	AMC-13	AMC-15
2003	6.97	3.50	0.97	DRY	0.53	0.03	0.37
2004	-1.13	0.13	1.42	DRY	-0.37	-0.42	0.43
2005	-1.68	-1.06	-0.45	DRY	-0.51	-0.22	-0.76
2006	0.73	0.97	2.72	DRY	1.24	0.72	1.72
Change Yrs 21-24	**4.89**	**3.54**	**4.66**	**0.00**	**0.89**	**0.11**	**1.76**
Net Change	***-24.35***	***-5.12***	***-8.77***	***0.00***	***-1.36***	***-2.18***	***-13.65***

Well AMC-5 is located within the active mine area, while wells AMC-6, and AMC-8 are located south of the active mine area and the Butte Concentrator facility (fig. 2-2). Well AMC-12 is located southwest of these wells. Hydrographs for wells AMC-5, AMC-12 (fig. 2-3) and AMC-6 and AMC-8 (fig. 2-4) show the long-term trends in the shallow alluvial ground-water system south of the pit. Monthly precipitation amounts are shown as bars and are plotted on the right-hand y-axis

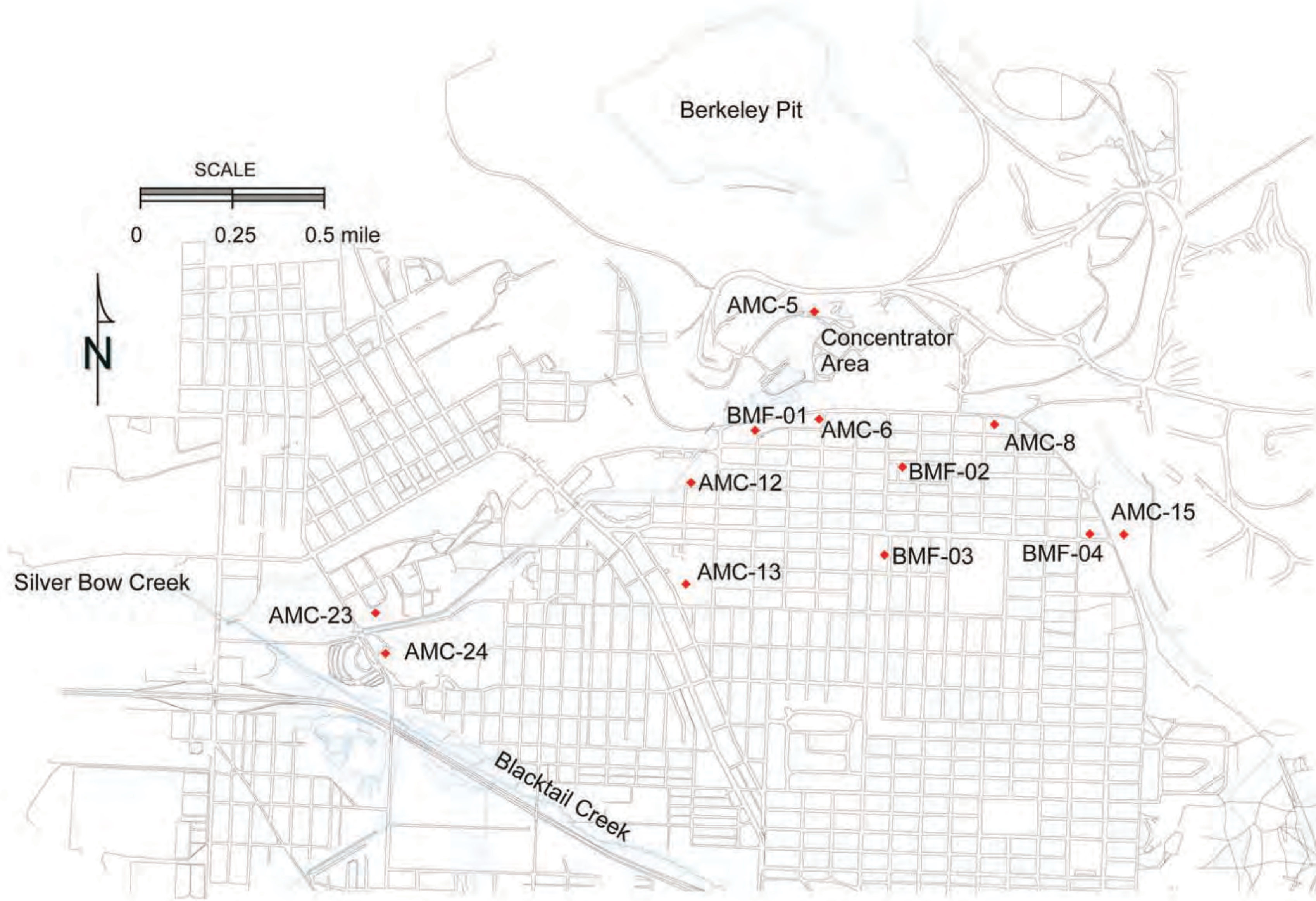


Figure 2-2. AMC and BMF wells.

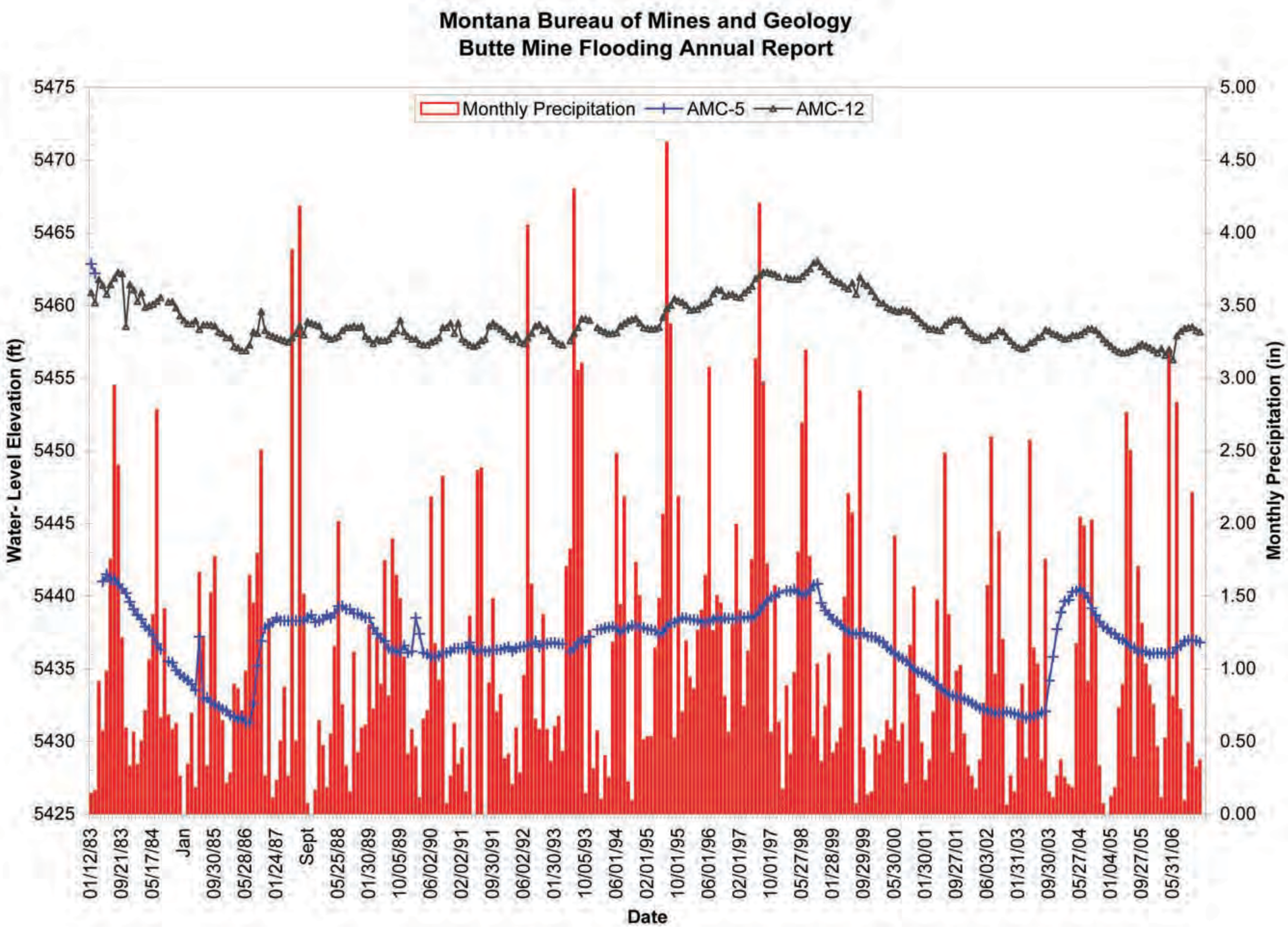


Figure 2-3. Water-level hydrographs for AMC-5 and AMC-12 wells.

Well AMC-5 exhibited the greatest water-level increase following MR's resumption of mining in 2003; followed by two years of water-level decline. This well is located just north of the Emergency Pond in the west corner of the concentrator yard. This pond received considerable inputs of fresh water prior to MR's start-up in the fall of 2003. The water-level trend for 2003-2005 shown on figure 2-3 for this well is very similar to the trend seen in 1986-1987, which coincides with the start-up of mining following ARCO's 1983 suspension of mining. It is apparent that filling the Emergency Pond with make-up water for milling operations has a considerable influence on alluvial water levels in the immediate area. The water level in well AMC-5 began to rise in the summer of 2006 following increased precipitation in April and June. The water level continued to rise throughout the remainder of the summer before leveling off in the fall. While the initial water-level increases coincide somewhat with early spring precipitation, the overall water-level trend for 2006 does not appear to respond to precipitation; it is more likely a response to operational changes within MR's water handling system.

Well AMC-6 is directly south of the concentrator facility and the Emergency Pond. Water-level trends during 2003-2004 were similar to those seen in 1986-1987 following the resumption of mining. However, water levels in 2005 appear to be less influenced by water levels in the Emergency Pond. Water levels in this well continued their strong downward trend that began the fall of 2004 through the summer of 2005. Beginning late-summer, minor water-level increases occurred which might have been in response to precipitation events (fig 2-4). Water levels rose in the spring of 2006 following precipitation events, while falling in the autumn. The water-level response in this well appears to be more strongly influenced by precipitation events, even though this well had a net water-level increase for 2006 and precipitation totals were below average.

The water-level trend since 2003 in well AMC-8 (fig2-4) was very similar to the 1986-1988 time period, with water levels declining following a period of increase associated with the resumption of mining. While water levels had a net decline for 2005 there was a slight increase during the late fall-early winter that originally appeared to have been in response to precipitation events; water levels continued to rise throughout almost all of 2006. The largest water-level increases actually occurred during the summer and fall of 2006. The 2.72-ft water-level rise in this well during 2006 was the largest seen in this series of wells by 1-ft.

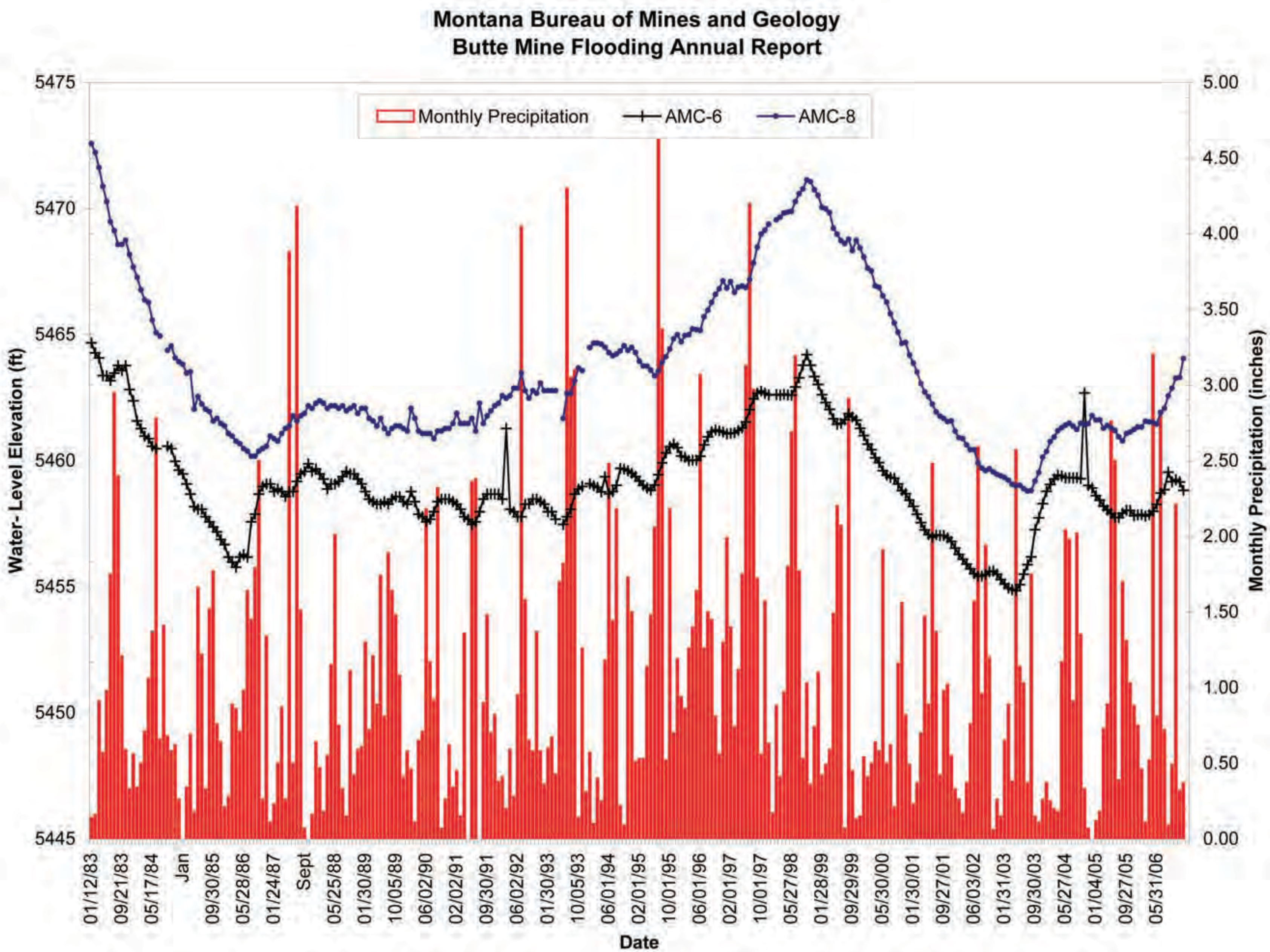


Figure 2-4. Water-level hydrographs for AMC-6 and AMC-8 wells.

Well AMC-12 water-level variations during 2006 differed from those between 2001 and 2005, with water levels rising more than 1-ft, with a majority of the increase occurring during the late spring and summer (fig. 2-3). The 2006 changes may be related to the end of construction activities in the nearby Metro Storm Drain (MSD) channel.

Well AMC-13 is located on the west side of Clark Park, south of wells GS-44S and GS-44D. This well's hydrograph shows both a response to precipitation events and possibly lawn watering (fig. 2-5a). Water levels began to rise in the spring and continued throughout the summer, before starting to decline in the fall. This trend is similar to that of prior years.

Well AMC-15 is located on the west side of the Hillcrest waste dump (fig. 2-2) in an area where reclamation has taken place. Water in this well is much deeper (90-ft) compared to the other AMC wells, and the hydrograph reflects this. There were minor seasonal changes in water levels for a number of years. However, the influence of the recent below-normal precipitation is shown by the steep decline in water levels beginning in late 1999 (fig. 2-5b), when this well did not show any significant response to precipitation. The water-level decline began leveling off in mid-2003, when the water level rose almost one-half foot from September through December 2003. The water level continued to rise (0.43-ft) throughout 2004, before declining in 2005. The water level remained level or declined slightly through the spring of 2006, before rising in July. Water levels continued to rise through the remainder of 2006 for a net increase of 1.76-ft for 2006. This recent trend does not show any consistent response to precipitation patterns.

2.5(a)

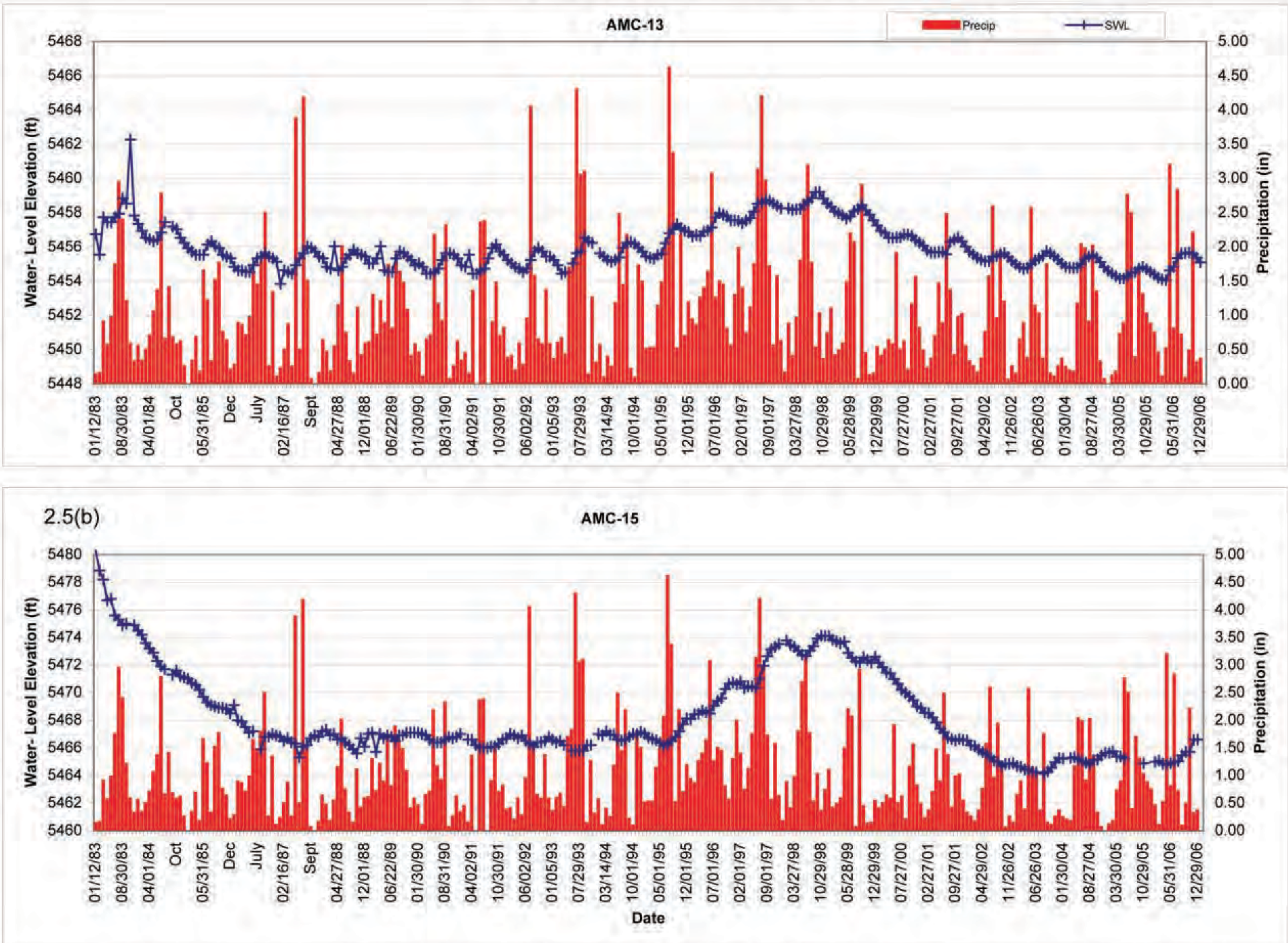


Figure 2-5. Water-level hydrographs for AMC-13 (a), and AMC-15 (b) wells.

Section 2.1.1.1 AMC Series Wells Water Quality

Concentration trends of the 2006 data collected from the AMC-series wells are summarized in Table 2.1.1.2. Well AMC-5, just south of the Berkeley Pit, has exceeded maximum containment levels (MCLs) and secondary maximum containment levels (SMCLs) throughout the period of record. The concentrations of most of the dissolved metals have shown a slight downward trend.

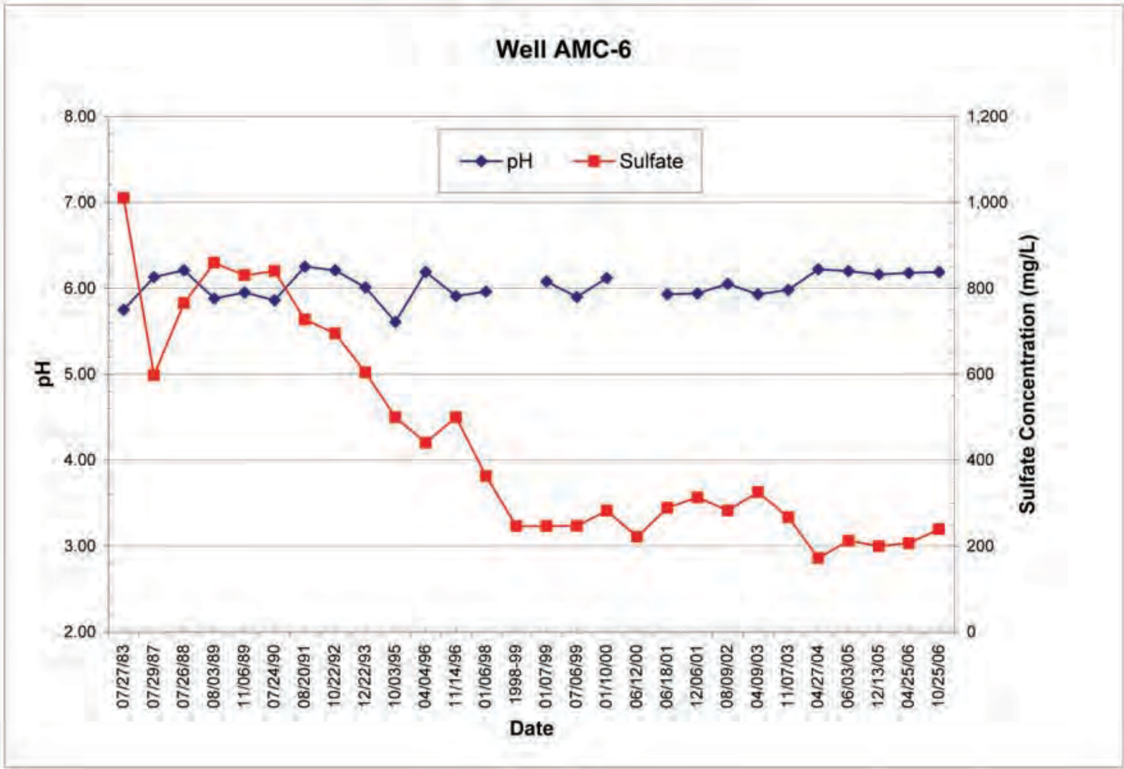
AMC-6 shows a continued, consistent trend of decreasing concentrations of nearly all dissolved constituents. At 16 ug/L (2006 samples), cadmium is the only constituent whose concentration exceeds a drinking water standard. The concentration of sulfate has increased slightly from 175 mg/L in 2004 to 200 mg/L (fig. 2-6).

Data for AMC-8 was questionable with respect to the concentration of cadmium in 2004. The analysis of a sample collected on 11/7/03 indicated a concentration of 3.9 ug/L, similar to concentrations in recent years. The analysis of a sample collected on 4/18/04 indicates a concentration of 21.3 ug/L, roughly an order of magnitude greater than the previous years. Both the 2005 and 2006 samples had concentrations similar to prior years (2003 and before) (2-3 ug/L). The concentrations of other dissolved constituents in the 2006 samples are consistent with previous results. As in the past, the concentration of other constituents have increased, but not at such a high rate. Sulfate, for example, ranged from 370 to 400 mg/L, a similar rate as previous years (fig. 2-6).

Table 2.1.1.2 Exceedences and trends for AMC series wells, 2006.

Well Name	Exceedences	Concentration	Remarks
AMC-5	Y	Variable	High iron, manganese, copper and zinc
AMC-6	Y	Downward	Downward trend continues
AMC-8	Y	Variable	Increasing sulfate
AMC-12	Y	Variable	Very high manganese, cadmium and zinc
AMC-15	Y	Variable	Unchanged in recent years, currently only sampled every two years

Access was restored to wells AMC-12 and AMC-15 allowing the wells to be sampled in 2006. As in the recent past, no strong trends are apparent in any of the AMC series wells; most show a slight downward trend over the period of record. Overall, metal concentrations in 2006 showed very little change from previous years. Wells closest to historic and current mining operations have the highest levels of contamination; well AMC-5 has very high levels of iron, manganese, cadmium, copper, and zinc. Well AMC-12 also has high-to very-high concentrations of iron, manganese, cadmium, and zinc; this well is located just south of the historic Silver Bow Creek drainage (Metro Storm Drain) which received untreated mine and process water for decades.



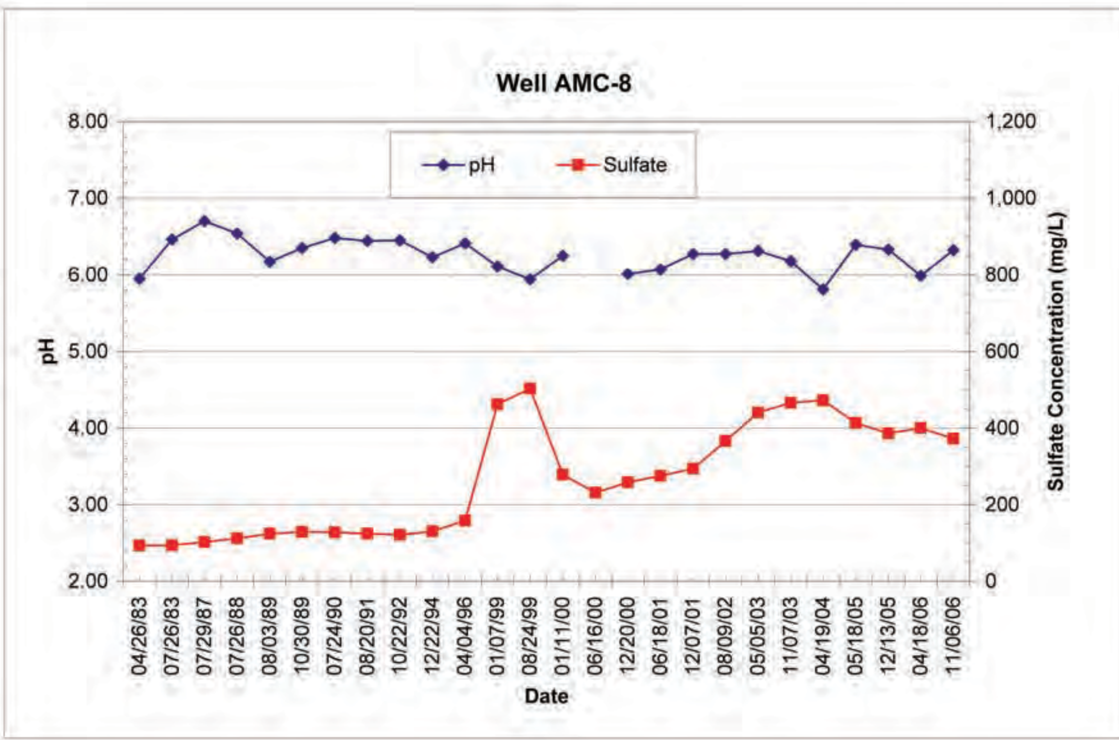


Figure 2-6. Graphs showing pH and sulfate concentrations changes over time for wells AMC-6 (top) and AMC-8 (bottom).

Section 2.1.2 LP-Series Wells

The locations of the LP-series monitoring wells are shown on figure 2-7. As discussed in Duaime and others (1998), these wells were installed in 1991 and 1992 as part of the BMFOU RI/FS study. Water-level monitoring and sampling of the LP-series wells continued throughout 2006. Table 2.1.2.1 presents a summary of annual water-level changes for these 17 sites. Well LP-11 was plugged and abandoned in 2001; well LP-03 was plugged and abandoned in 2002 to make room for the HSB water-treatment plant. Well LP-06, had been dry for over three years, before having a water-level rise of more than 3-ft during 2004; however, it had a corresponding decline in 2005. Therefore, wells LP-06 and LP-07 are dry. Water levels declined in six wells during 2006, compared to five wells during 2005. Water levels rose in the remaining seven wells during 2006. Wells north of the Pittsmont Waste Dump all had water-level declines for the year, with declines varying from just under one-half foot to almost 3-ft in wells LP-09 and LP-04, respectively. Since monitoring began, water levels have experienced a net decline in 14 of the LP series wells, ranging from 0.57-ft to 31.45-ft in wells LP-17 and LP-03, respectively. Net water-level increases are less than 1-ft in wells LP-12, 13, and 14.

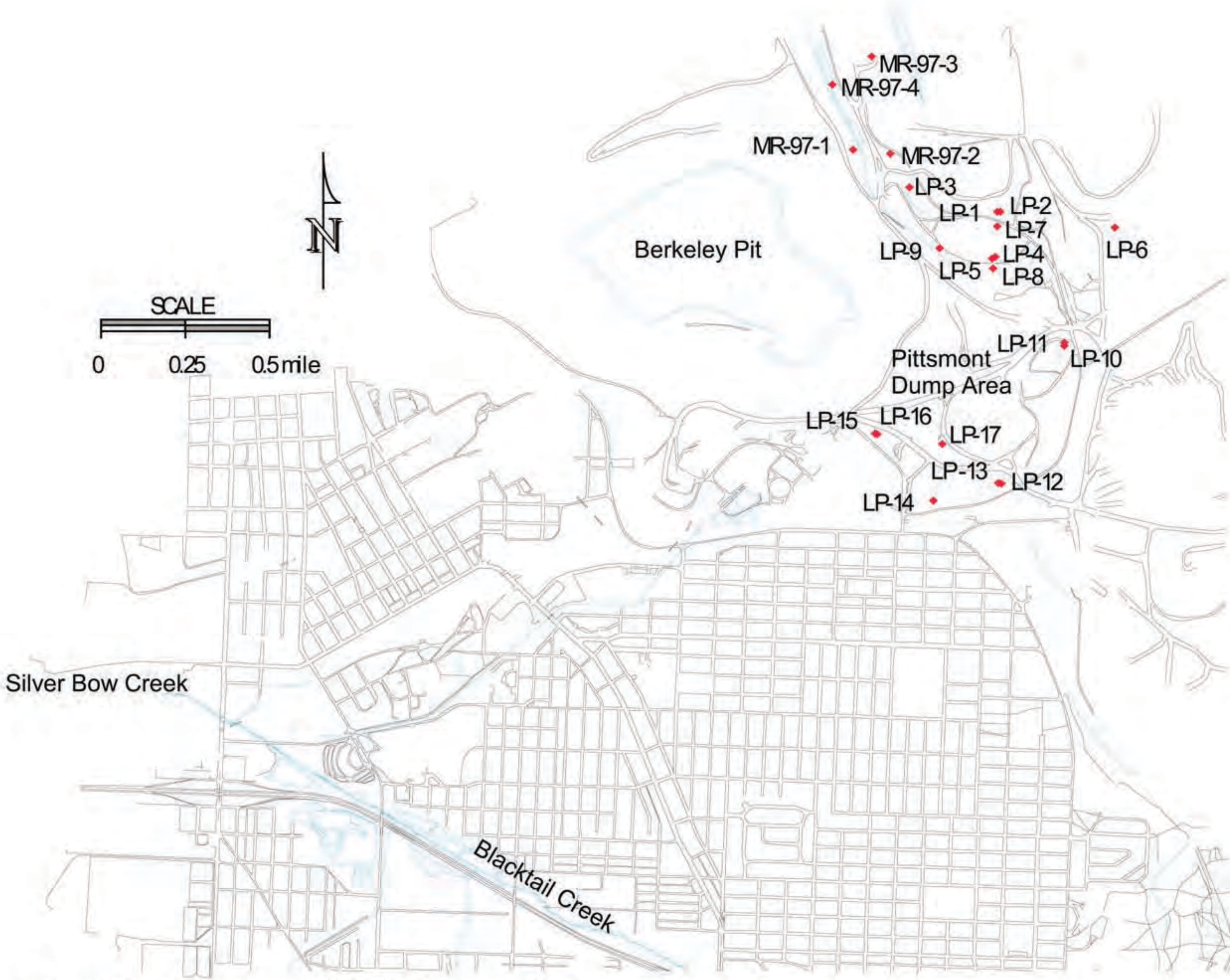


Figure 2-7. LP series and MR97 Wells location Map.

The decline in water levels to the north of the Pittsmont Waste Dump is a substantial change from trends seen in 2004 and 2005, and is more consistent with the water level trends (decline) observed between 1992 and 2003. The water-level declines had been especially true since the deactivation of the leach pads in 1999. However, as part of its resumption of mining, MR began leaching operations on a limited scale in 2004, continuing periodically throughout 2005. The wells with the greatest water-level rise (LP-04 and LP-10) are located south and down gradient of the leach pads where the leaching took place. No leaching operations were undertaken during 2006 by MR as part of their active mining operations. Figures 2-8 and 2-9 show water levels over time for five of the LP series wells, which are located south of the leach pads and north of the Pittsmont Waste Dump.

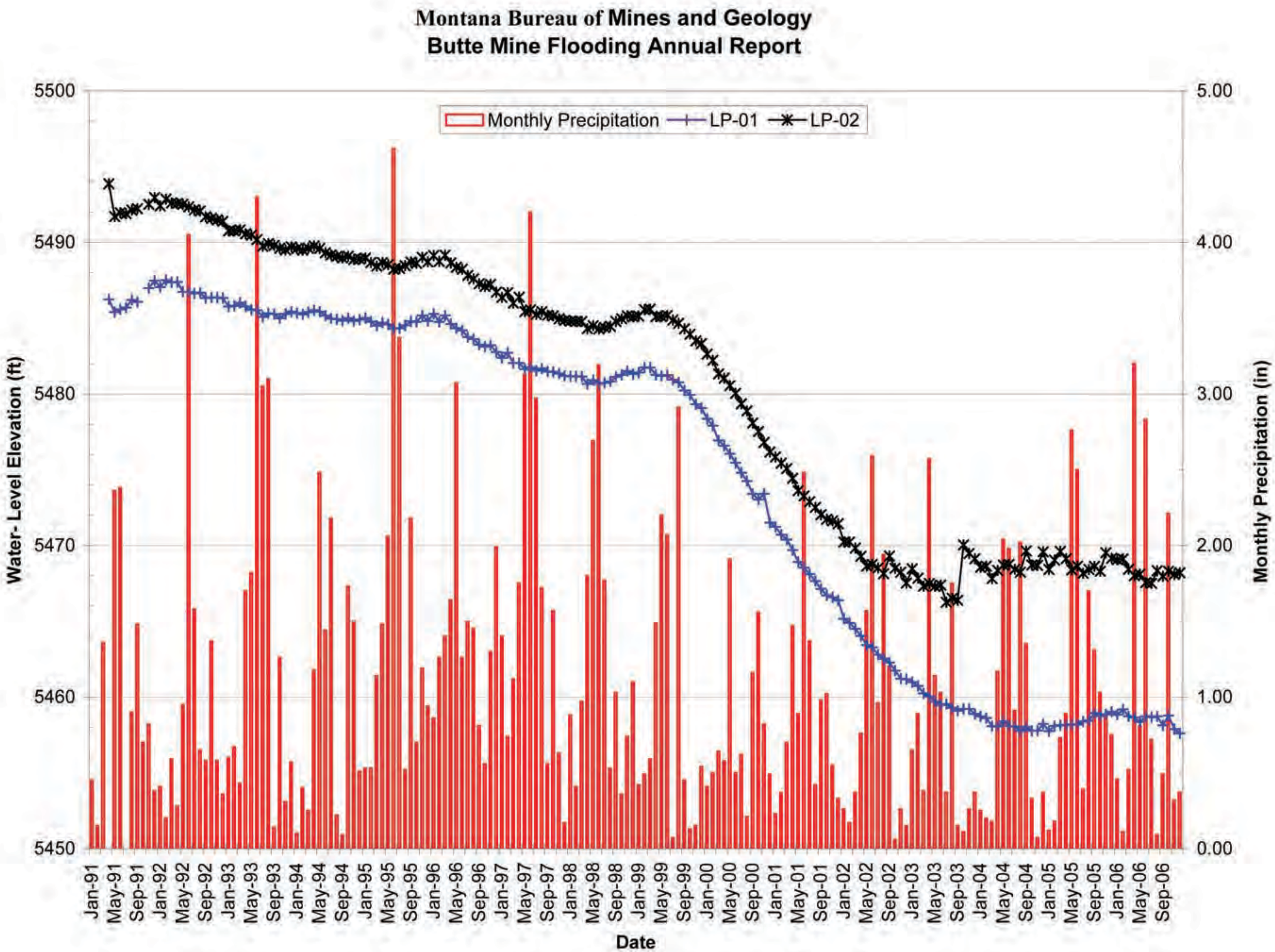


Figure 2-8. Water-level hydrographs for LP-01 and LP-02 wells.

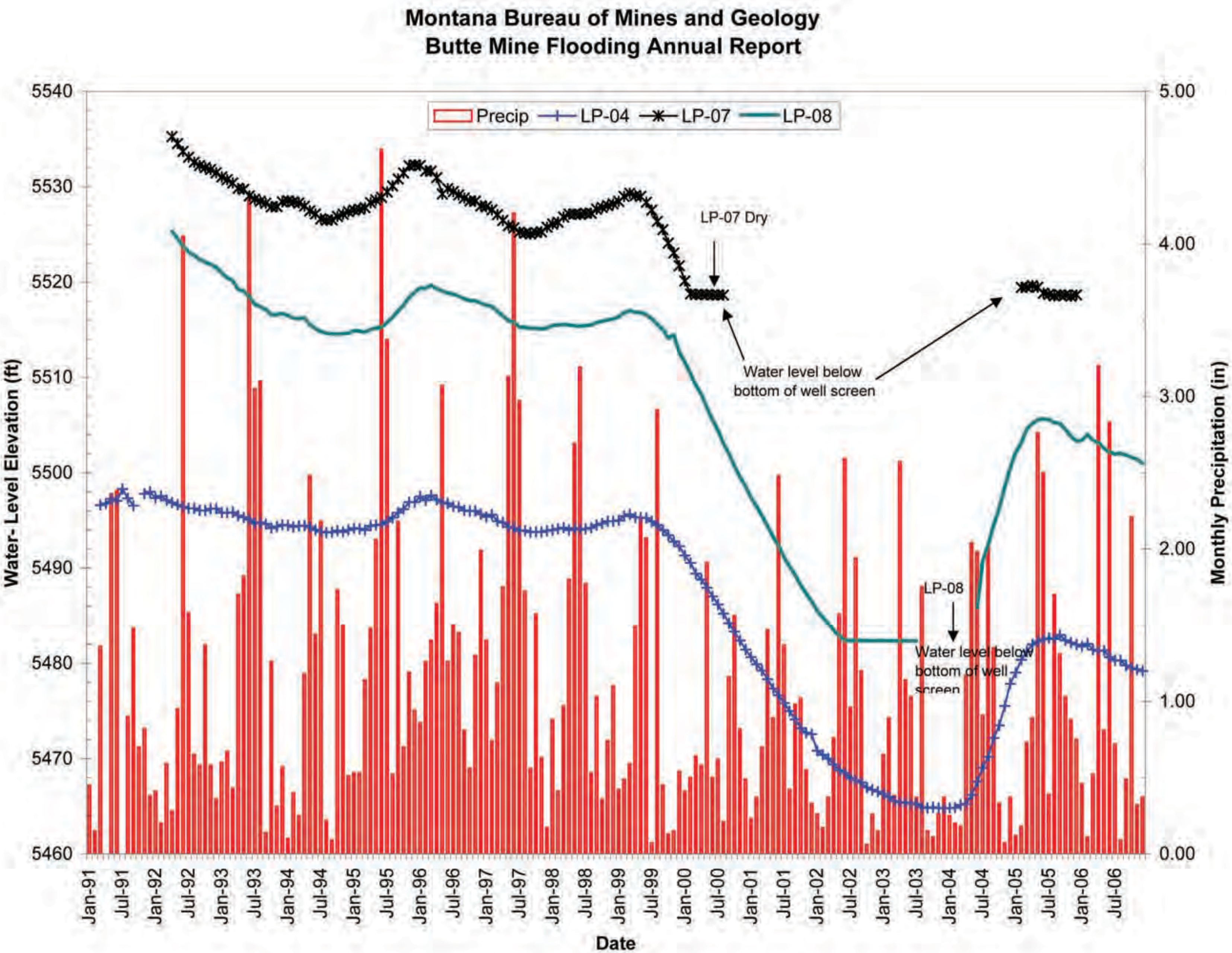


Figure 2-9. Water-level hydrograph for LP-04, LP-07 and LP-08 wells.

Wells LP-01 and LP-02 are located near the base of several leach pads and are screened in two different intervals. The wells are screened at depths of 129-159 feet and 177-197 feet, respectively, and are completed in the deeper portion of the alluvial aquifer. Well LP-01 is completed at a deeper depth and as shown on figure 2-8. Water levels increased gradually throughout 2005 before leveling off, dropping slightly in the spring of 2006 and remaining mostly steady through the fall. Water levels declined by over 1-ft the last two months of 2006. The water-level changes in this well are less erratic than those seen in the shallow well, LP-02, possibly the result of the increased lag-time associated with recharge events. Water levels in wells LP-01 and LP-02 show a greater response to operational practices associated with the leach pads than from precipitation events. This is consistent with interpretations of water-level responses made following MR's 1999 deactivation of the leach pads.

Figure 2-9 shows water levels over time for wells LP-04, LP-07, and LP-08, which are located south of wells LP-01 and LP-02 and north of the Pittsmont Waste Dump (fig. 2-7). These wells are completed at different depths also. Well LP-04 is screened from 125-145-ft below ground surface, while well LP-07 is screened from 90-95-ft below ground surface, and well LP-08 is screened 81-96-ft below ground surface. Based upon these well-completion depths, wells LP-07 and LP-08 would be considered to be completed in the upper portion of the alluvial aquifer, while well LP-04 would be considered to be completed in the deeper portion of the alluvial aquifer.

Table 2.1.2.1 Annual water-level change in LP-series wells

Year	LP-01	LP-02	LP-03	LP-04	LP-05	LP-06	LP-07	LP-08	LP-09
1991	1.23	-0.91	-2.02	1.38	4.35	-1.46	-	-	-0.70
1992	-1.14	-1.56	-0.66	-1.75	-1.08	0.80	-3.79	-3.78	-7.16
1993	-0.91	-1.69	1.84	-1.69	-2.42	-0.53	-3.06	-4.83	-2.24
1994	-0.53	-0.80	-1.61	-0.57	-1.42	-2.28	-1.03	-2.11	-2.90
1995	-0.08	-0.19	-1.74	2.94	0.34	0.47	4.91	4.30	3.35
1996	-2.05	-2.00	-0.73	-1.28	-3.40	2.01	-4.30	-1.14	-1.49
1997	-1.58	-1.86	-0.09	-1.73	-3.32	-1.37	-2.24	-2.63	-0.29
1998	0.12	0.23	-2.03	1.01	-0.03	-0.58	2.44	0.99	1.60
1999	-2.24	-1.76	-7.44	-2.64	-3.15	-1.65	-6.47	-3.52	-3.77
2000	-7.55	-7.16	-5.45	-10.83	-7.87	-0.20	-3.10	-14.03	-13.28
Change Years 1-10	-14.73	-17.90	-19.93	-15.16	-18.00	-3.79	-16.64	-26.75	-26.88
2001	-5.13	-4.73	9.51	-8.88	-5.47	Dry	Dry	-12.10	-3.04
2002	-5.21	-3.91	-2.01*	-6.03	-4.86	Dry	Dry	-4.11	-3.46
2003	-2.29	1.60	P&A*	-1.75	-2.00	Dry	Dry	-0.04	-1.15
2004	-0.65	0.46	P&A*	13.06	3.85	3.24	Dry	18.13	2.96
2005	0.81	-0.43	P&A*	4.12	3.40	-3.62	-0.79	2.85	2.08
2006	-1.43	-0.96	P&A*	-2.77	-2.06	Dry	Dry	-2.35	-0.44
Change Years 11-16	-13.90	-7.97	-11.52	-2.25	-7.14	-0.38	-0.79	2.38	-3.05
Net Change	28.63	25.67	-31.45	-17.41	25.14	-4.17	17.43	24.37	29.93

Table 2.1.2.1 (cont.) Annual water-level change in LP-series wells

Year	LP-10	LP-11	LP-12	LP-13	LP-14	LP-15	LP-16	LP-17
1991	-	-	-	-	-	-	-	-
1992	-0.50	-1.83	0.31	-0.07	0.70	0.54	0.89	-
1993	-0.83	-2.78	1.42	1.11	1.18	1.62	1.83	-
1994	-2.14	1.65	-1.41	-1.47	-0.09	0.26	-1.16	-
1995	-0.57	-0.23	-0.16	0.43	0.18	1.89	3.57	3.10
1996	1.20	0.23	1.87	1.74	2.07	1.79	1.77	1.66
1997	0.23	-0.09	2.42	2.24	2.64	1.99	1.77	2.32
1998	0.92	0.07	1.00	-0.62	0.39	-7.90	-9.69	-2.41
1999	-2.05	-2.12	-2.94	-2.36	-2.73	-4.39	-4.60	-3.95
2000	-1.37	-0.28	-3.60	-2.93	-3.64	-1.73	-2.18	-2.86
Change Years 1-10	5.11	-5.38	-1.09	-0.93	0.70	-5.93	-7.80	-2.14
2001	0.51	P&A*	-1.16	-1.30	-2.31	-0.72	-1.18	-1.50
2002	-0.15	P&A*	-1.83	-1.21	-1.65	-0.68	-0.86	-0.67
2003	-2.75	P&A*	-1.74	-0.26	0.46	1.08	0.89	0.09
2004	-1.41	P&A*	0.20	0.26	0.95	-0.06	0.52	0.71
2005	4.19	P&A*	1.53	0.78	-0.27	0.27	-0.27	0.26
2006	3.19	P&A*	4.48	2.78	2.95	1.43	1.33	2.68
Change Years 11-16	3.58	0.00	1.48	1.05	0.13	1.32	0.43	1.57
Net Change	**-1.53**	**-5.38**	**0.39**	**0.12**	**0.83**	**-4.61**	**-7.37**	**-0.57**

(*) Plugged and abandoned

The water-level trends are similar for wells LP-04, LP-07, and LP-08. It is interesting to note that while well LP-08 was dry for a period from mid-2003 through mid-2004, the subsequent water-level trend did not vary from that shown for well LP-04 once the water level rose back above the screen interval. It is apparent that the control on water levels is the same on all of these wells and the operation, or lack of operation of the leach pads whichever the case maybe has a much greater influence on water levels than precipitation. Well LP-07 has remained dry since the later part of 2000, except for a short period of time in early 2005.

Wells LP-14, LP-15, and LP-16 are located southwest of the Pittsmont Dump (fig. 2-7). A consistent increase in water levels occurred in these wells following their installation in 1992, until the Berkeley Pit landslide of 1998 (fig. 2-10). After that landslide, water levels declined in a similar manner in all three wells until beginning to rise in September 2003 and continuing through May of 2004. Since then water-level changes had been minor until May 2006 when water levels increased at a greater rate. Wells LP-15 and LP-16 are located near one another and were completed as a nested pair, with well LP-15 screened from a depth of 215-235-ft below ground surface and well LP-16 screened from 100-120-ft below ground surface. Water-level trends are similar in these wells regardless of completion depth. Water levels had a net increase in both wells for 2006. Neither of these wells shows any response to precipitation events.

Well LP-14 is located south of wells LP-15 and LP-16, but its overall water-level trend is similar to that seen in wells LP-15 and LP-16. The net water-level rise for 2006 was almost 3-ft and the increases do not appear to be related to precipitation events.

The general observation made in the last several yearly reports, that wells between the leach pads and Pittsmont Waste Dump were affected by leach-pad operations, including the 1999 leach-pad dewatering and historic-mine dewatering, remains true. Water levels in these LP-series wells were either controlled by the operation and subsequent dewatering of the leach pads, operation of the Yankee Doodle Tailings Dam, by the depressed water levels in the Berkeley Pit, or a combination of all three. The water-level response seen in wells adjacent and down gradient of limited leaching operations during 2004 - 2005 clearly demonstrates the relationship of water-level changes and the leach pads operations. The influence of precipitation is minimal, at most, on these wells.

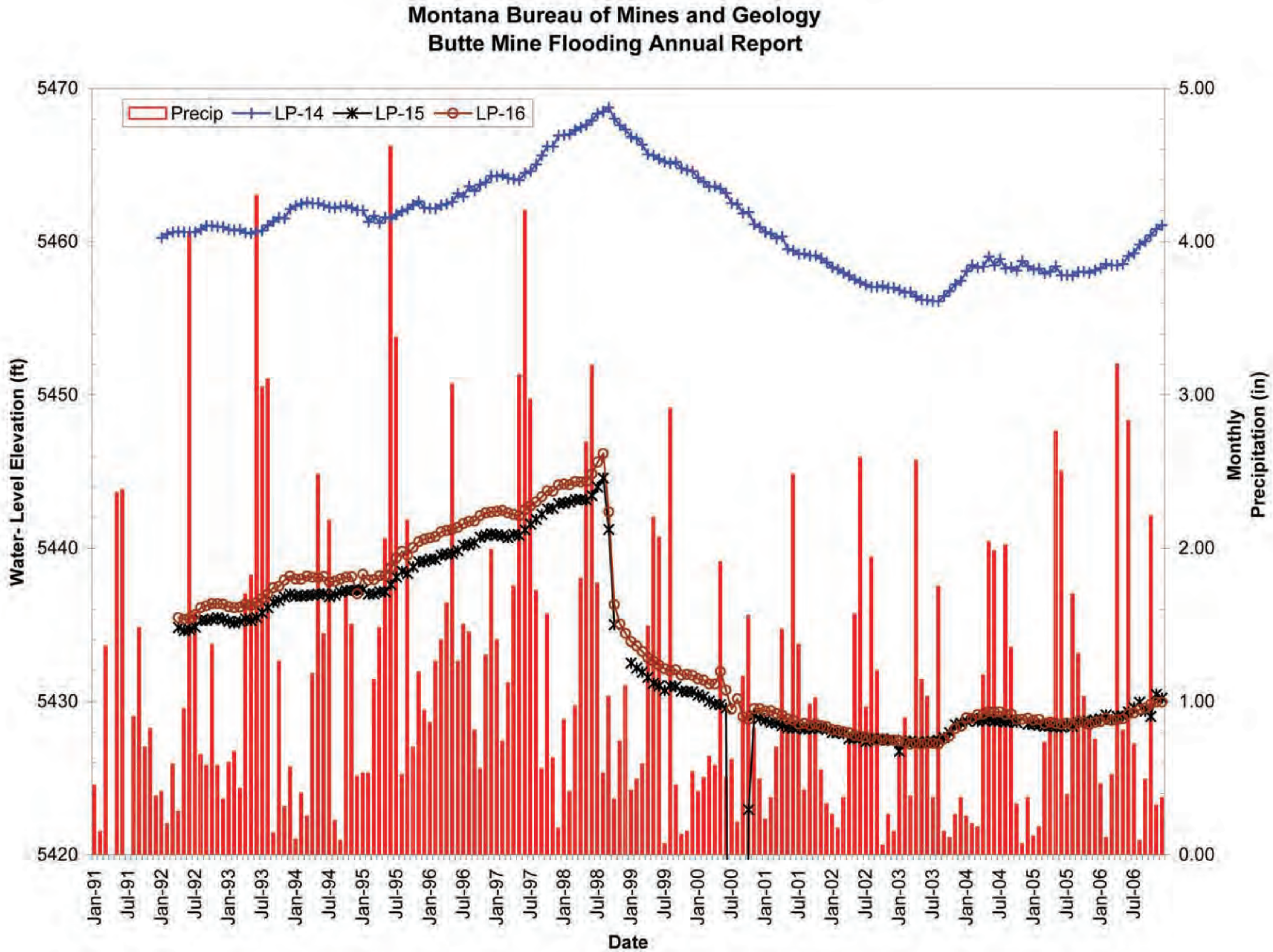


Figure 2-10. Water-level hydrograph for LP-14, LP-15, and LP-16 wells.

An alluvial aquifer potentiometric map (fig. 2-11) constructed using December 2006 water levels, shows how alluvial waters are flowing towards the Berkeley Pit from the north, east and south. Water contaminated by historic mining activities (Metesh, 2000) is flowing towards and into the Berkeley Pit, ensuring that there is no outward migration of contaminated water into the alluvial aquifer.

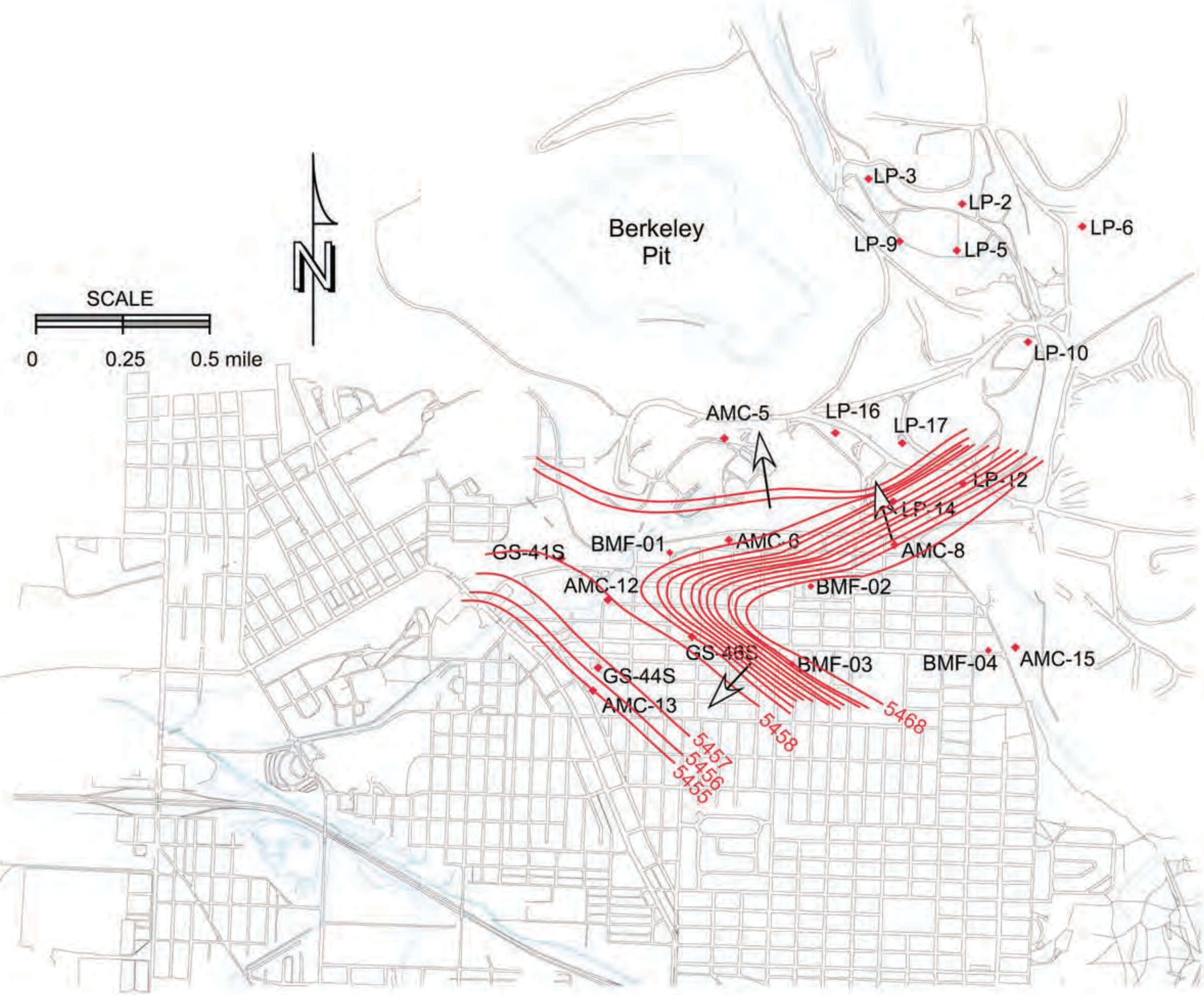


Figure 2-11. Alluvial aquifer potentiometric map for December, 2006; arrows indicate direction of ground-water flow implied by contours (contour interval is 1 foot).

Section 2.1.2.1 LP-Series Wells Water Quality

Current water-quality monitoring of the LP-series wells is restricted primarily to those wells west and south of the Pittsmont Dump (fig. 2-7) with the exception of three wells (LP-08, LP-09, and LP-10), which are south of the leach pad area and north of the Pittsmont dump. Water-quality trends in 2006 showed limited changes in several wells; the changes are summarized in Table 2.1.2.2.

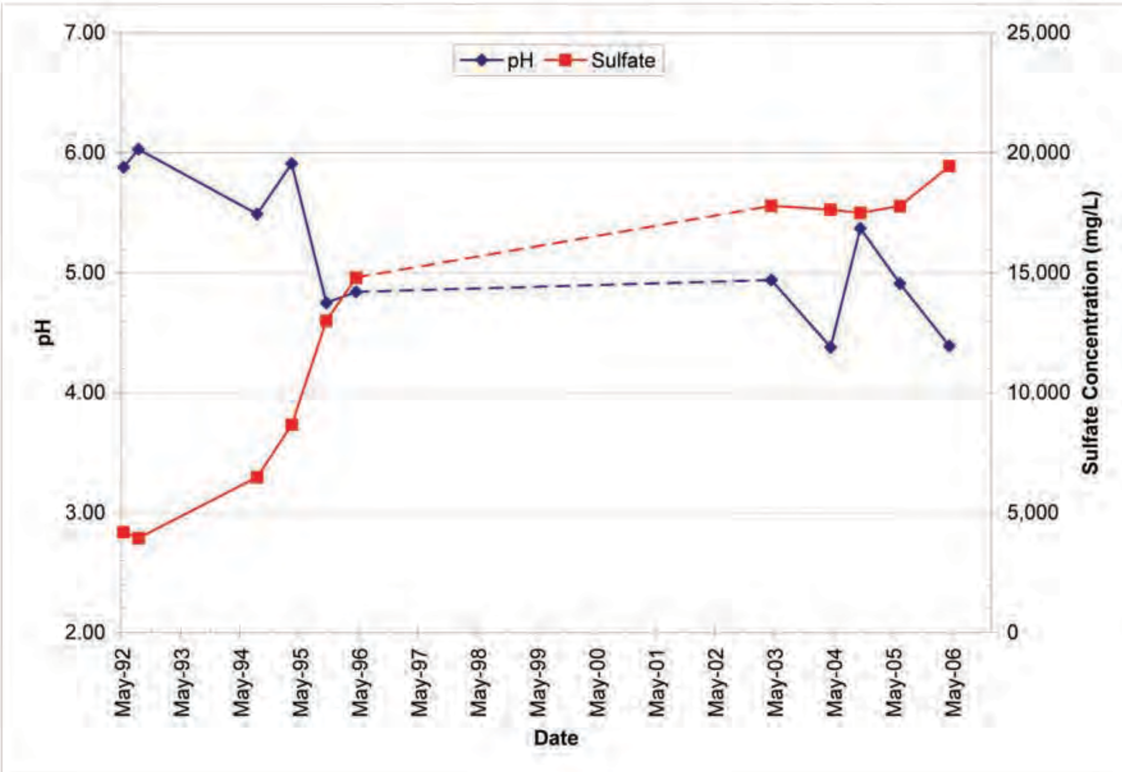
Well LP-08 was sampled during the spring 2005 and 2006 sampling events to determine if water-quality changes seen previously in well LP-09 were occurring further south. While the water in this well was highly contaminated, concentrations were less than historic levels in most cases (i.e. Al – 1,710,000 ug/L in 1992 and 600,000 ug/L in 2006), the exception being an increase in arsenic.

Well LP-9 was sampled in August of 1992 and then not sampled again until April of 2003; it has been sampled four times since. A comparison of the data indicates large increases in the concentration of most dissolved constituents starting in 2003. Data collected in 2006 show that the increase is sustained, if not greater (fig. 2-12).

The concentration of aluminum increased from <100 ug/L in 2002 to 50,000 ug/L in 2003 continuing upward to concentrations greater than 270,000 ug/L in 2006; arsenic increased from 4.4 ug/L to greater than 60 ug/L in 2005 and 2006; cadmium increased from 510 ug/L in 2002 to levels greater than 16,200 ug/L in 2006; and zinc increased from 165,000 ug/L in 2002 to levels greater than 2,200,000 ug/L in 2006. In general, the concentrations of dissolved metals increased by nearly an order of magnitude and approach those values seen in the pregnant solution of the up gradient leach pads. The trend that first appeared in the 2003 data certainly continued in 2006.

Well LP-17 had the most significant change in trend during 2006 with concentrations of cadmium, copper, and zinc decreasing by 50% from concentrations from 2003-2005. Nitrate concentrations were extremely high however in the 2006 samples.

The water-quality trend in other LP-series wells generally remained the same in 2006 as in recent years. A summary of exceedences and trends is presented in table 2.1.2.2.



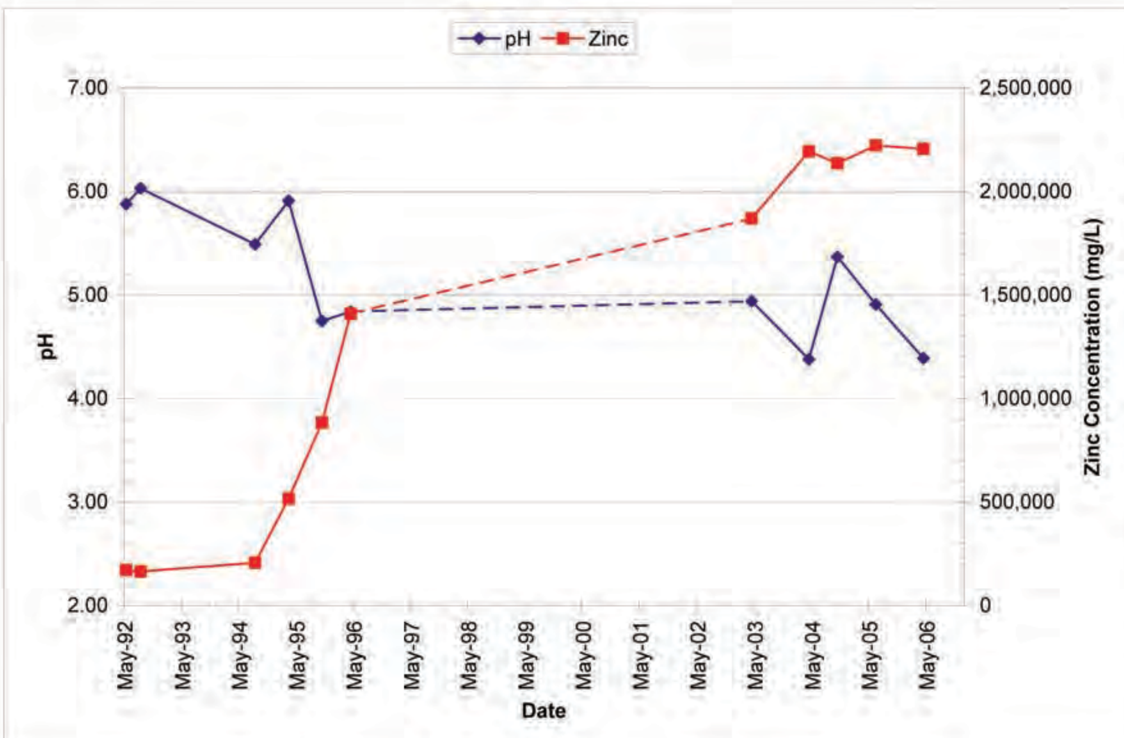


Figure 2-12. Sulfate and zinc concentration for well LP-9.

Table 2.1.2.2 Exceedances and trends for LP series wells, 2006

Well Name	Exceedances (1 or more)	Concentration Trend	Remarks
LP-08	Y	Downward	Downward trend with exception of arsenic.
LP-09	Y	Upward	Large increases since 1992.
LP-10	N	None	No significant changes in 2005, not sampled in 2006 due to access problems.
LP-12	Y	None	No significant changes in 2006.
LP-13	Y	None	No significant changes in 2006.
LP-14	Y	Variable	Slight increase in sulfate continues.
LP-15	Y	None	Net change is small for most analytes.
LP-16	Y	Variable	Downward sulfate trend continues.
LP-17	Y	Downward	Trend reversed.

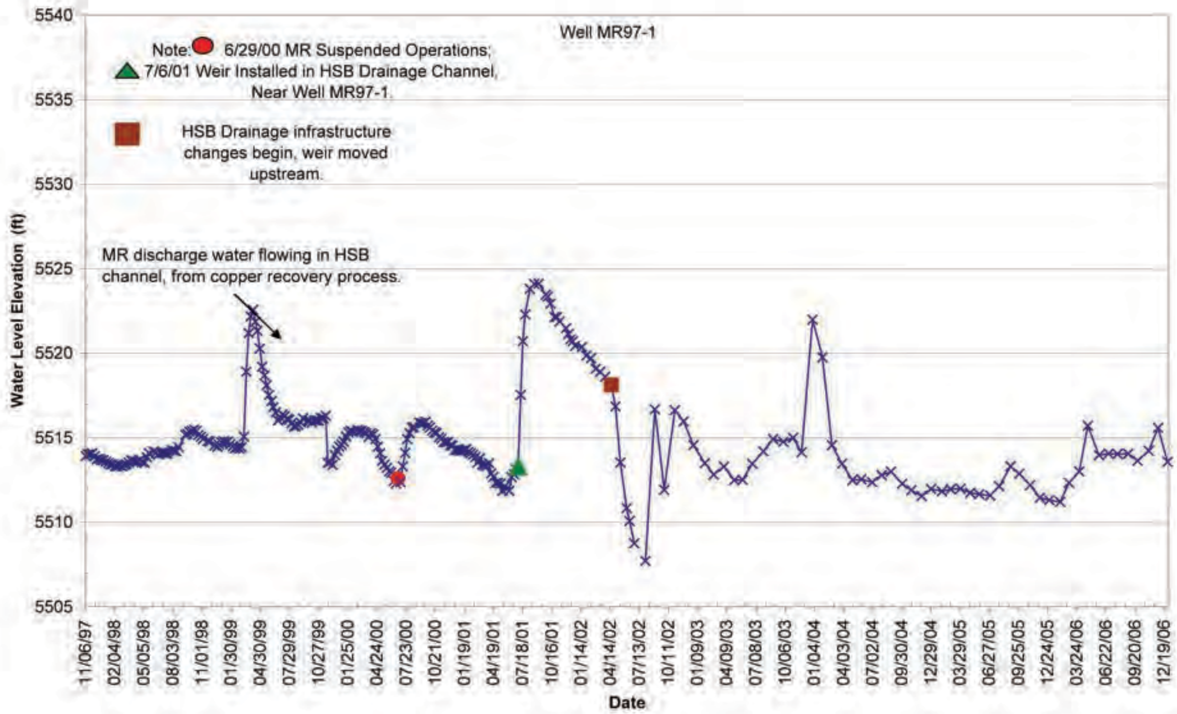
Section 2.1.3 Precipitation Plant Area Wells

Wells MR97-1, MR97-2, MR97-3, and MR97-4 (fig. 2-7) are adjacent to various structures (drainage ditches, holding ponds) associated with the leach pads and precipitation plant. Table 2.1.3.1 lists annual and net water-level changes for these wells. Water-level changes appear to correspond to flow in these ditches and water levels in ponds.

Table 2.1.3.1 Annual water-level changes in MR97-series wells.

Year	MR97-1	MR97-2	MR97-3	MR97-4
1997	-0.25	-0.84	-0.40	0.34
1998	1.07	-1.04	-0.67	2.20
1999	-0.27	-4.40	-3.91	0.02
2000	-0.20	-0.89	-2.88	-0.03
2001	6.17	-1.32	-0.29	0.78
2002	-5.88	-1.02	-0.47	1.60
2003	7.43	-0.70	-1.29	-2.45
2004	-10.01	-0.08	-4.28	1.86
2005	-0.67	-0.06	0.60	-1.84
2006	2.27	2.20	1.82	0.41
Net Change	**-0.34**	**-8.15**	**-11.77**	**2.90**

Water levels in well MR97-1 have shown the greatest degree of variations (fig. 2-13) due to the various changes in mining operations.



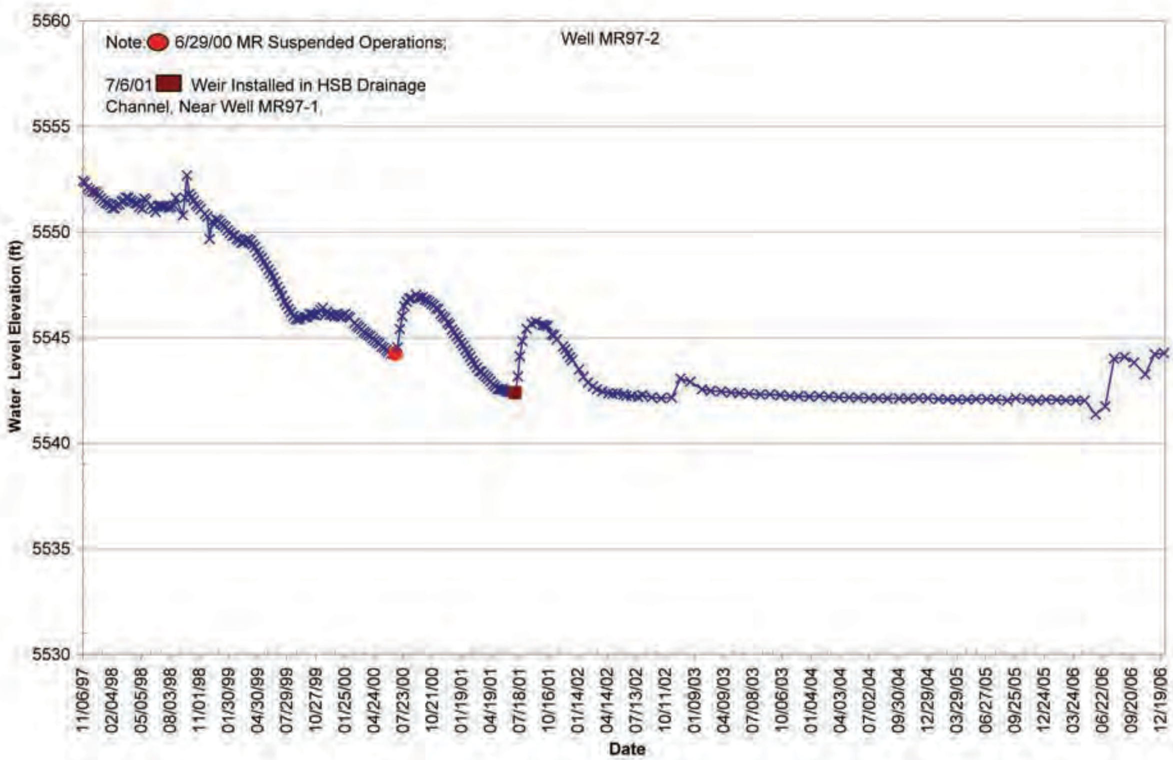


Figure 2-13 (Top) and 2-14 (Bottom). Water-level hydrographs for wells MR97-1 and MR97-2.

Water levels increased when MR began to discharge water from their Berkeley Pit copper recovery project into the pit (Spring 1999). These variations are characterized by an initial increase in water levels followed by a gradual decrease before leveling off. The channel that carries water back to the pit after the removal of copper is adjacent to well MR97-1. This channel had been unused since April 1996, when HSB drainage water was captured and prevented from flowing into the pit. Water-level increases were seen again following MR's summer 2000 suspension of mining. Water from the HSB drainage that had been pumped to the Yankee Doodle Tailings Dam since April 1996 was allowed to flow into the pit following the June 2000 mine shut-down. What is somewhat surprising is the HSB discharge water used the same drainage channel as the discharge water from the copper recovery project and the flow of water was only about one-third. If anything, with the decrease of flow in the channel, less water would be available for ground water recharge and water levels would either stabilize or drop. Instead, they rose before gradually declining over the next year.

Similar variations were observed in well MR97-1 during July 2001 and again in 2002, when a weir was installed (2001) and then relocated (2002) in the channel. The weir that was installed in 2001 was relocated upstream to the outlet of what was historically referred to in MR's precipitation plant operations as Pond 4. The weir was relocated as part of infrastructure changes relating to the HSB water treatment plant construction. The area occupied by Pond 4 was excavated and enlarged, then lined with lime rock during construction activities. The weir's relocation resulted in a drop in water levels in well MR97-1, because the weir and the accompanying impounded water were moved up gradient of this well. Water levels showed some minor fluctuations during early 2003, before rising several feet and then leveling off, until a substantial rise during December 2003. The December rise coincides with the resumption of MR's copper recovery project and the corresponding flow of discharge water in the drainage ditch near well MR97-1. Water levels subsequently declined the first part of 2004 before leveling off for most of the remainder of 2004 and early 2005. Water levels increased during the summer of 2005 before declining into the first part of 2006. Water levels rose into early summer 2006, leveled off and declined into the fall. The water level had a net rise of over 2-ft during 2006.

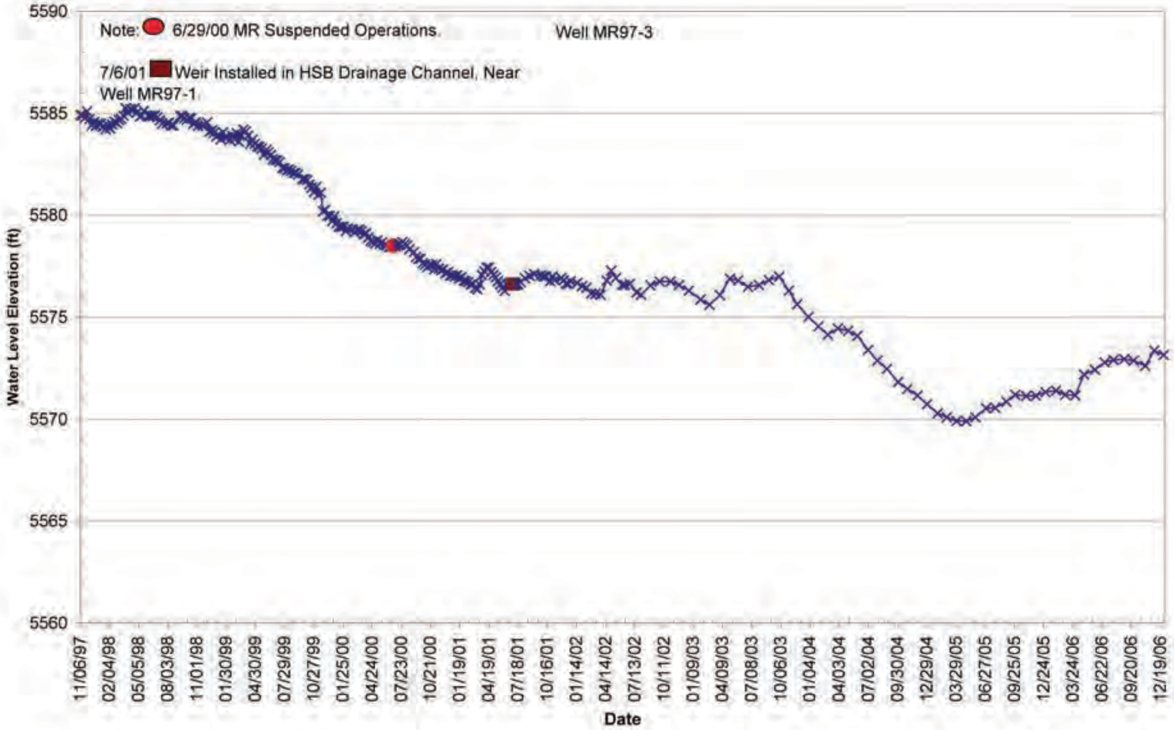
Wells MR97-2 and MR97-3 are adjacent to historic collection ditches associated with the leach pads. Water-level changes were apparent in these two wells during 1999-2000 when MR made operational changes in leaching operations. As a result, the amount and level of water in collection ditches became less and were reflected in a drop of water levels in wells MR97-2 and MR97-3 (fig. 2-14 and 2-15).

Water-level increases were also seen in wells MR97-2, MR97-3, and MR97-4 following MR's suspension of mining (fig. 2-14, 2-15, and 2-16). The response in water levels in well MR97-2, figure 2-14, was very similar to that seen in well MR97-1. A similar increase was seen in well MR97-2 following the 2001 weir installation. Water levels were stable at this site during 2003-2005 through mid-2006 and did not show the same fluctuations as noted in well MR97-1. However, water levels increased during June, July and November 2006, resulting in over a 2-ft net water-level increase for the year.

The water level in well MR97-3 showed only a minor response to the 2001 and 2002 construction activities. However, water levels rose the first part of 2003, before leveling off for the next 5 to 6 months and falling the last several months of the year (fig. 2-15). With the exception of a brief period early in 2004, water levels continued to drop in this well until spring 2005 when they rose for several months before leveling off. Water levels continued to rise throughout most of 2006 resulting in a net water-level increase of almost 2-ft. This MR-series well is the farthest away from the HSB drainage channel and appears to be the least responsive to operational changes and flows in the discharge channel.

Water-level changes during 2003 in well MR97-4, figure 2-16, were similar to those seen in well MR97-3, except the decline in water levels began earlier in 2003 and were greater. Since this well is closer to the precipitation plant facilities and HSB ponds and drainage ditches, it is possible that changes in operational flows in this area are responsible for the water-level declines observed the later part of 2003. Changes would be more pronounced in this well than in well MR97-3. The water-level increase seen during early 2004 possibly relates to water flowing into holding ponds associated with the precipitation plant as these operations were brought back on-line with MR's fall 2003 start up of mining. Water-level changes were similar to those observed in well MR97-3 until mid-2006 when they began to decline. Overall, water levels rose 0.41-ft in 2006 at this site.

Water levels have declined more than 8-ft in wells (MR97-2 and MR97-3) nearest the leach pads and ancillary facilities since their installation in 1997 (table 2.1.3.1), while having a decline just less than 0.4-ft in well MR97-1. Only well MR97-4 has a net water-level increase; this well is nearest the



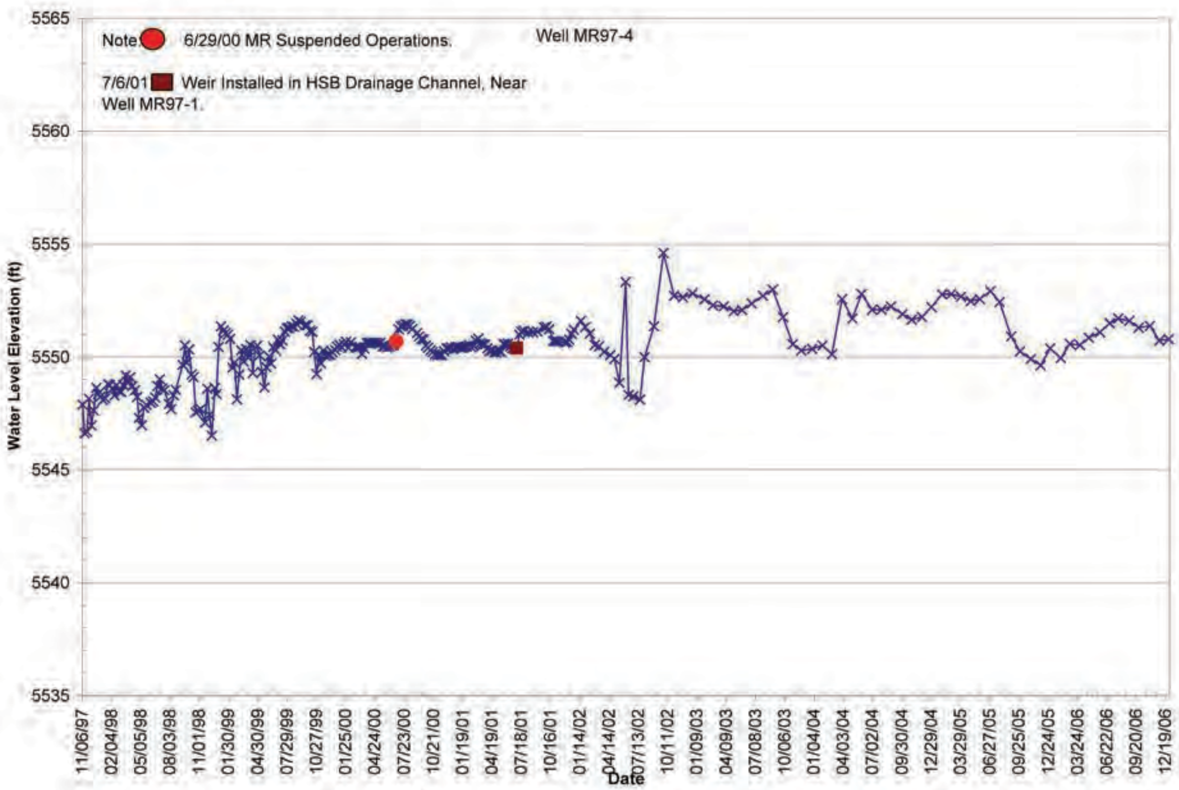


Figure 2-15 (Top) and Figure 2-16 (Bottom). Water-level hydrographs for wells MR97-3 and MR97-4.

precipitation plant and its facilities. It appears there is a direct influence on the shallow alluvial aquifer in this area by mining operations. Changes in mine operations (i.e. precipitation plant and leach pad) affect groundwater recharge in this area. Other changes, such as the weir installation and relocation, have affected groundwater levels in the area in the past.

No water-quality samples have been collected from this group of wells between 2001 and 2006. Previous sampling documented the presence of elevated metals in the area. This contamination is most likely the result of leach pad and precipitation plant operations.

Section 2.1.4 GS and BMF05-Series Wells

Continuous and monthly water-level monitoring of the six GS wells and four BMF05 wells continued throughout 2006. The locations of these wells are shown on figure 2-17. Table 2.1.4.1 contains annual water-level changes for these wells. Wells GS-41, GS-44, and GS-46 are nested pairs. That is, the wells are drilled adjacent to each other, but they are drilled and completed at different depths. The S and D identify the shallow and deep wells in each nested pair. Water levels had a net increase in all six wells during 2006, following the declines noted in 2004-5. Water levels have declined during seven of the past nine years. However, water levels have a net increase over the period of monitoring in five of the six GS-series wells. The net increase is less than 1-ft.

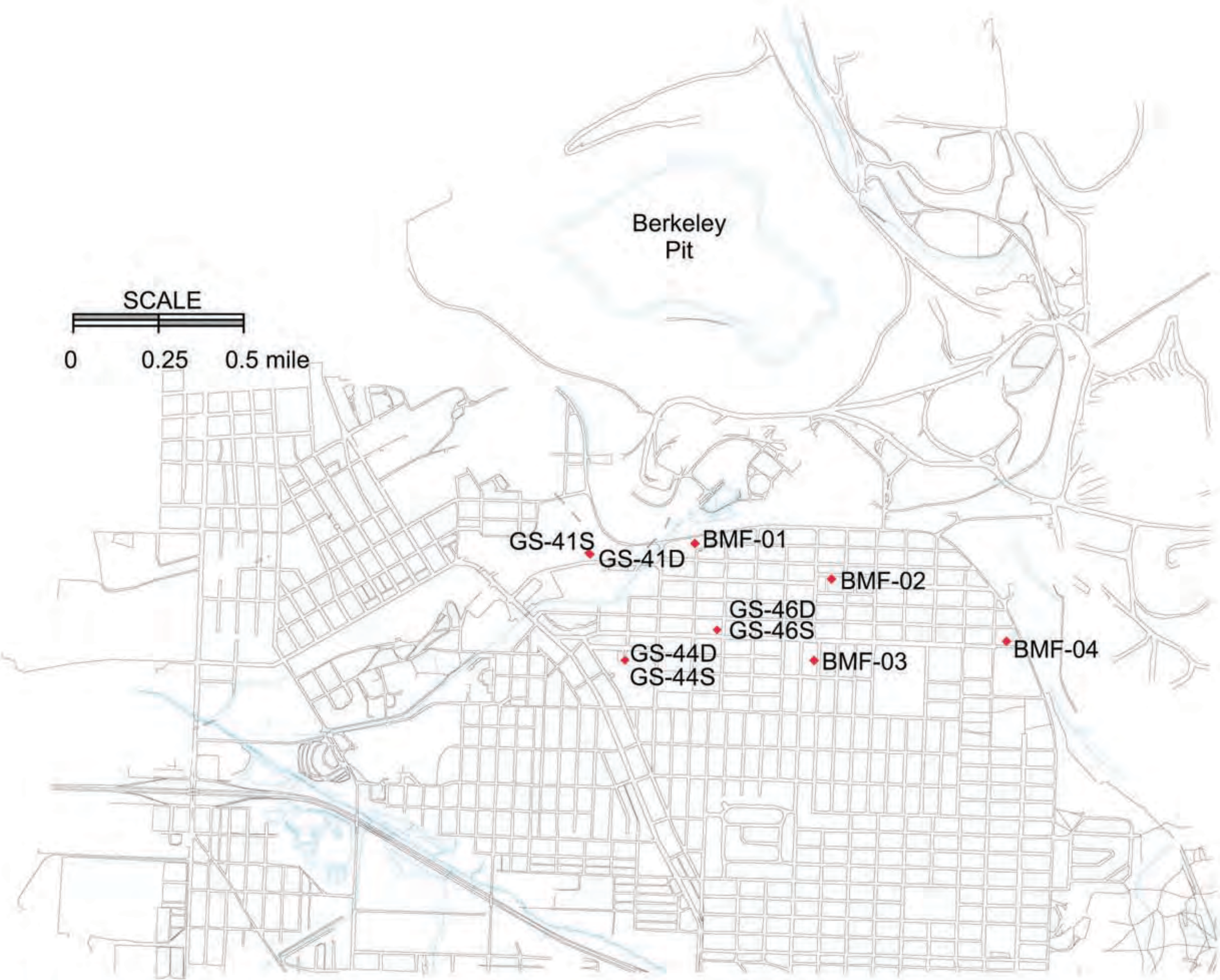


Figure 2-17. GS and BMF wells.

Table 2.1.4.1 Annual water-level changes in GS and BMF05-series wells.

Year	GS-41S	GS-41D	GS-44S	GS-44D	GS-46S	GS-46D	BMF 05-1	BMF 05-2	BMF 05-3	BMF 05-4
1993	0.76	0.78	0.62	0.66	0.80	0.78				
1994	0.20	0.23	0.00	0.00	0.18	0.24				
1995	1.35	1.26	1.32	1.26	1.38	1.30				
1996	0.59	1.65	1.12	0.89	0.98	1.20				
1997	1.32	0.20	0.58	0.79	1.09	1.18				
1998	-0.18	-0.06	0.09	0.07	1.17	0.24				
1999	-1.41	-1.49	-1.28	-1.25	-2.41	-1.65				
2000	-1.91	-1.78	-1.51	-1.39	-1.21	-2.07				
2001	-0.28	-0.41	-0.22	-0.38	-1.64	-0.92				
2002	-0.82	-0.81	-0.94	-0.82	-1.18	-1.18				
Change Years 1-10	**-0.38**	**-0.43**	**-0.22**	**-0.17**	**-0.84**	**-0.88**				
2003	0.19	0.26	0.27	0.17	-0.81	0.77				
2004	-0.31	-0.41	-0.76	-0.52	-0.08	-0.02				
2005	-0.60	-0.53	-0.40	-0.33	-0.59	-0.52				
2006	1.36	1.28	1.01	1.06	1.45	1.28	1.86	1.21	1.71	1.97
Change Years 11-14	**0.64**	**0.60**	**0.12**	**0.38**	**1.59**	**1.51**	1.86	1.21	1.71	1.97
Net Change	**0.26**	**0.17**	**-0.10**	**0.21**	**0.75**	**0.63**	**1.86**	**1.21**	**1.71**	**1.97**

Figures 2-18 through 2-20 are water-level hydrographs with monthly precipitation totals shown for well pairs GS-41, GS-44, and GS-46. The seasonal variations in water levels closely follow monthly precipitation trends. Water levels begin a gradual increase in the spring as precipitation increases and then decline throughout the fall.

Water-level changes in wells GS-41S and GS-41D were similar once again during 2006 (fig. 2-18) and the influence of precipitation was very noticeable. Water levels increased more than 1.25-ft in these two wells during 2006, resulting in a net increase since monitoring began in 1993.

Wells GS-44S and GS-44D had similar water-level changes throughout 2006 (fig. 2-19). The seasonal water-level changes are similar to those described for wells GS-41S and 41D. The water levels had an increase during 2006 of just over 1-ft. Since monitoring began well GS-44S has a slight net decline; while well GS-44D has a modest increase of 0.2-ft.

Overall, water-level trends were similar during 2006 in wells GS-46S and GS-46D (fig. 2-20), and followed the trends discussed previously for wells GS-41 and GS-44. Water levels increased more than 1.25-ft in both wells during 2006 and have a net water-level rise since monitoring began.

In both the GS-41 and GS-44 wells, the water levels in the shallow wells are higher than those of the deeper wells, implying that there is a downward vertical gradient. That is, water in the upper part of the alluvial aquifer is moving down, providing recharge to the lower portions of the aquifer. Water levels in wells GS-46S and GS-46D show the opposite. The water level in well GS-46D is higher than the water level in GS-46S. This implies that water has the potential to move upwards in the aquifer and possibly discharge into a surface-water body, such as Silver Bow Creek. However, as noted in the following section, the water quality in well GS-46D is of good quality and as such this would not be a concern.

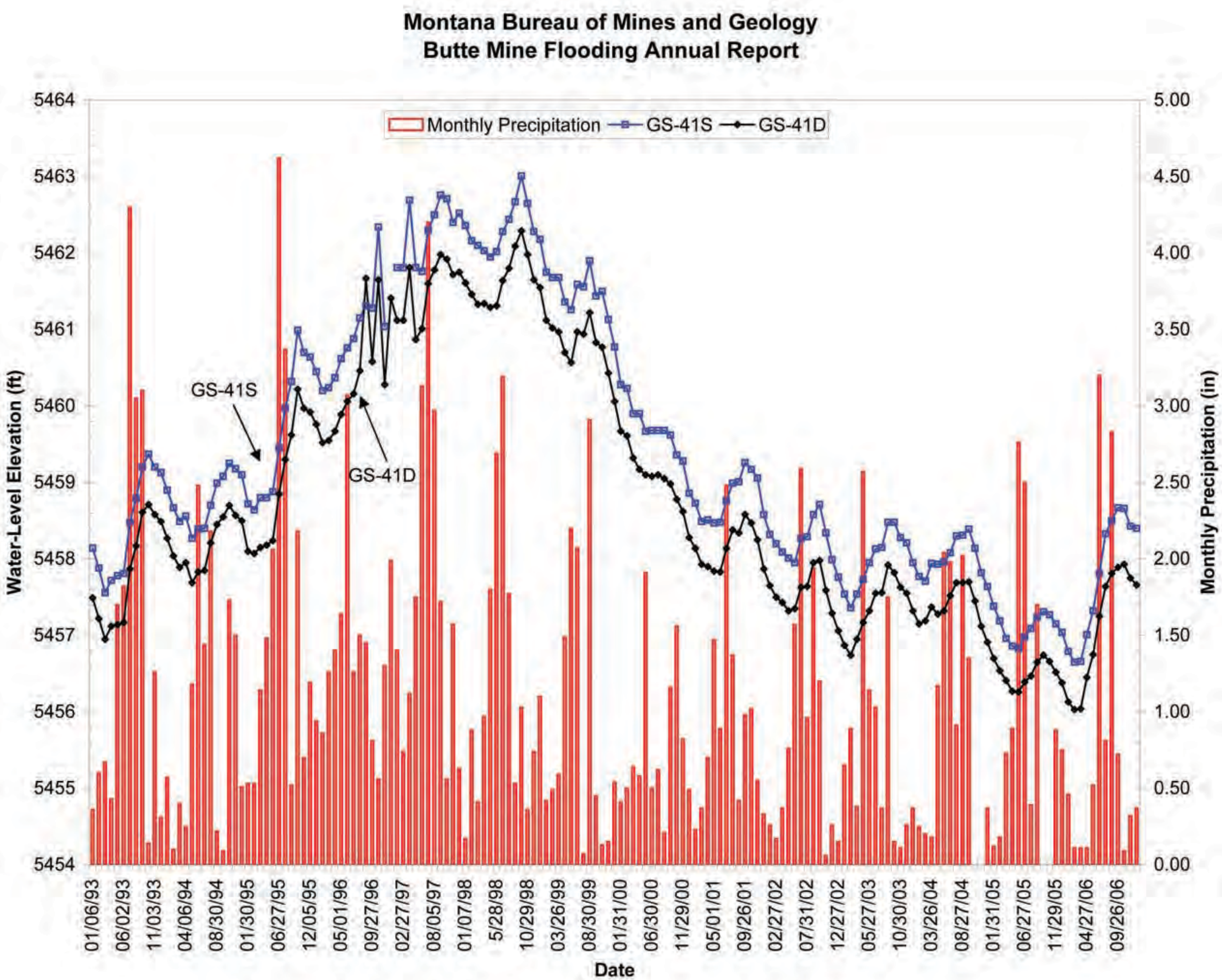


Figure 2-18. Water-level hydrographs for GS-41S and GS-41D wells.

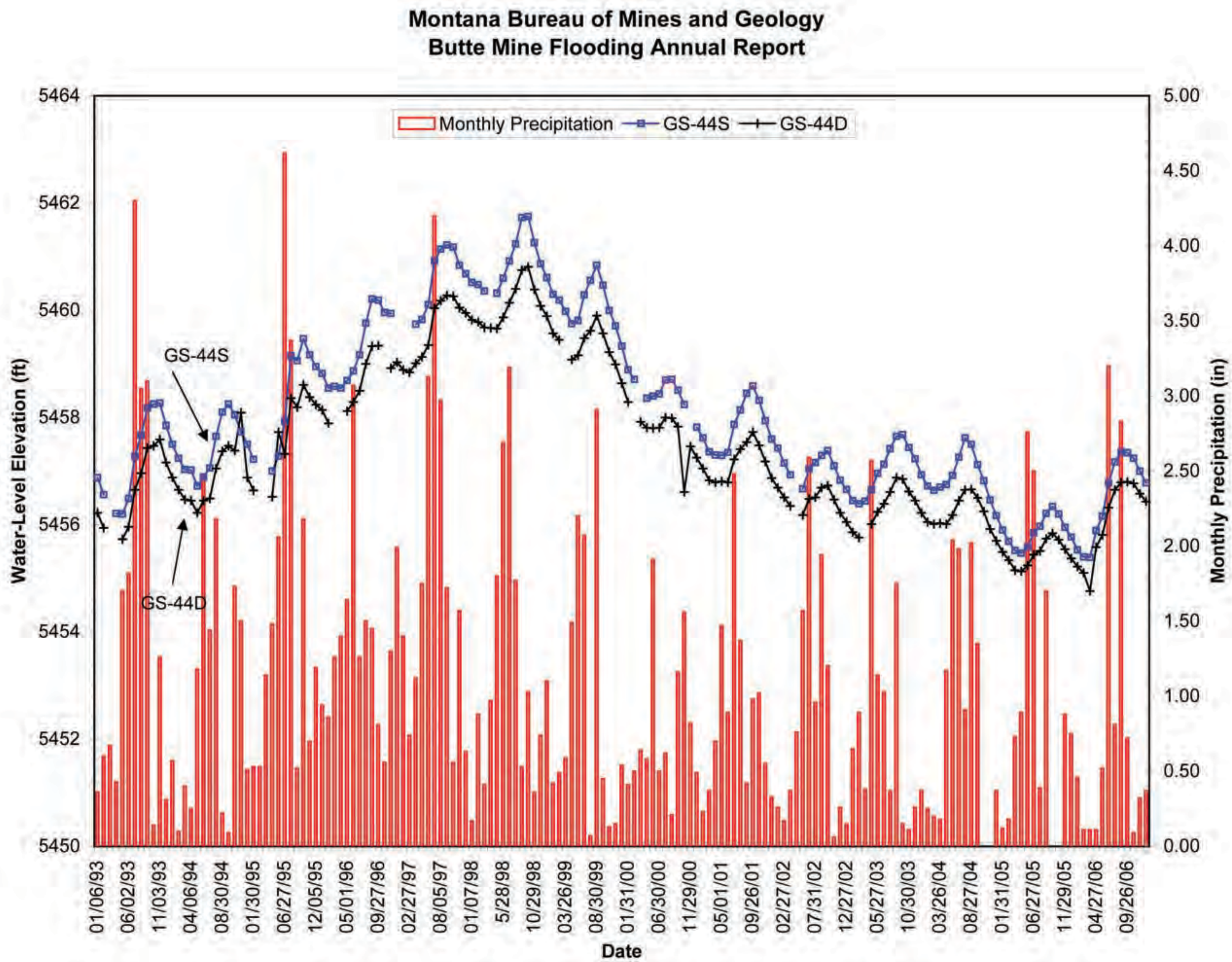


Figure 2-19. Water-level hydrographs for GS-44S and GS-44D wells.

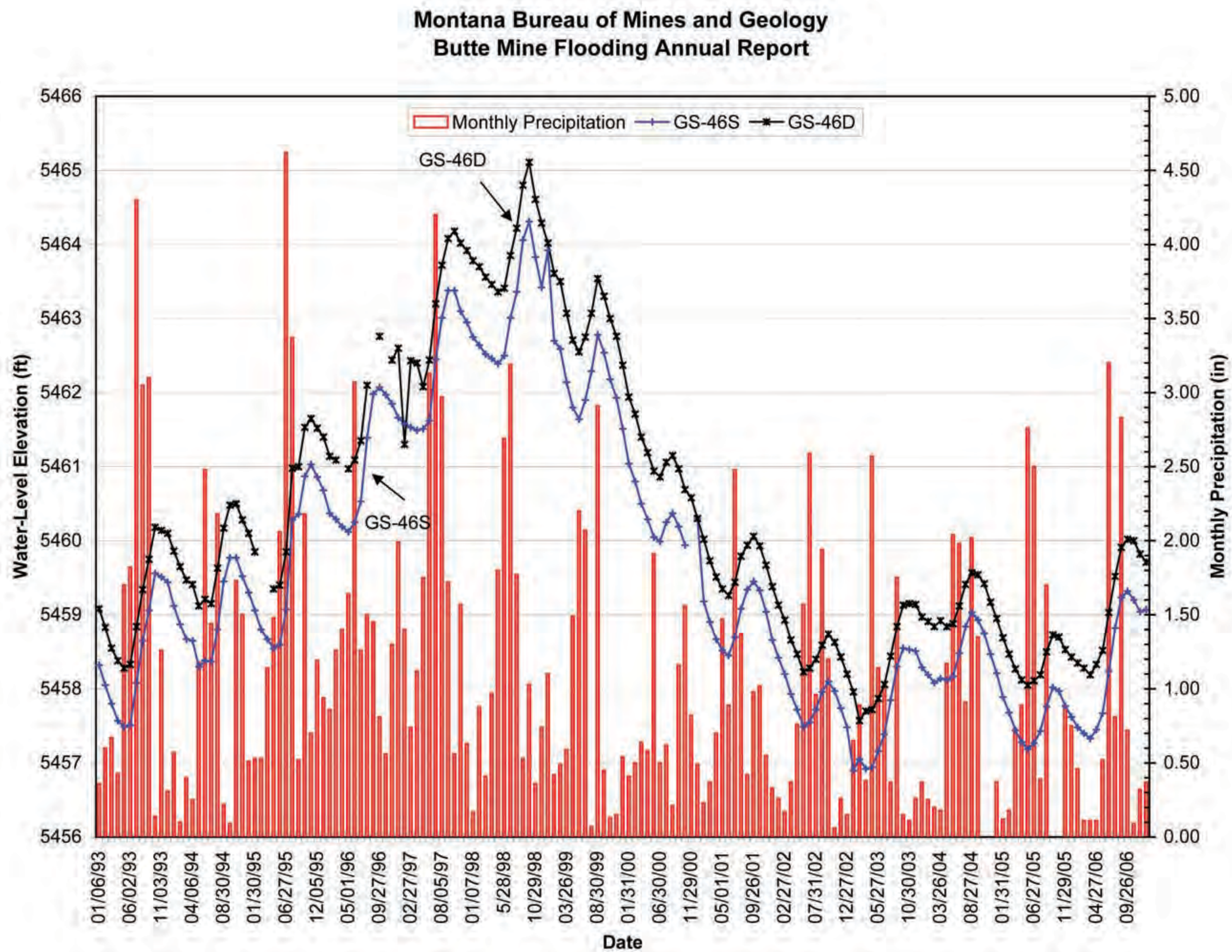


Figure 2-20. Water-level hydrographs for GS-46S and GS-46D wells.

The BMF05-series wells were installed in late 2005 and early 2006. These wells were installed to replace the domestic wells that were part of the post RI/FS monitoring program. The domestic wells were monitored from 1997 through 2002; however, it was felt that dedicated monitoring wells would be more reliable for the long-term monitoring program and would not be influenced by household usage. The location of these wells is shown on figure 2-17. The wells were located to provide coverage throughout the same area covered by the domestic wells and to provide information to the south of the Berkeley Pit-active mine area. This area is important to better define the groundwater divide between the Butte Mine Flooding alluvial aquifer and Butte Priority Soils. Pressure transducers were installed in the spring of 2006 in each well for continuous water-level monitoring. Water levels had a net rise in all four wells for 2006, with increases varying between 1-ft and 2-ft.

Figure 2-21 shows daily average water levels based upon data collected from the pressure transducers. The transducers record water-level changes every hour; the data is then converted to daily averages to reduce the size of the data set. Each well has an overall upward water-level trend that levels off in the fall and early winter with the exception of well BMF05-4. The water level continued to rise throughout the fall and winter in this well. While the data from the continuous monitoring shows an upward trend it is hard to establish the relationship that water-level changes have with precipitation events. Figure 2-22 is a hydrograph based upon monthly water levels and monthly precipitation totals. As more data becomes available it will be easier to correlate water-level changes to precipitation events.

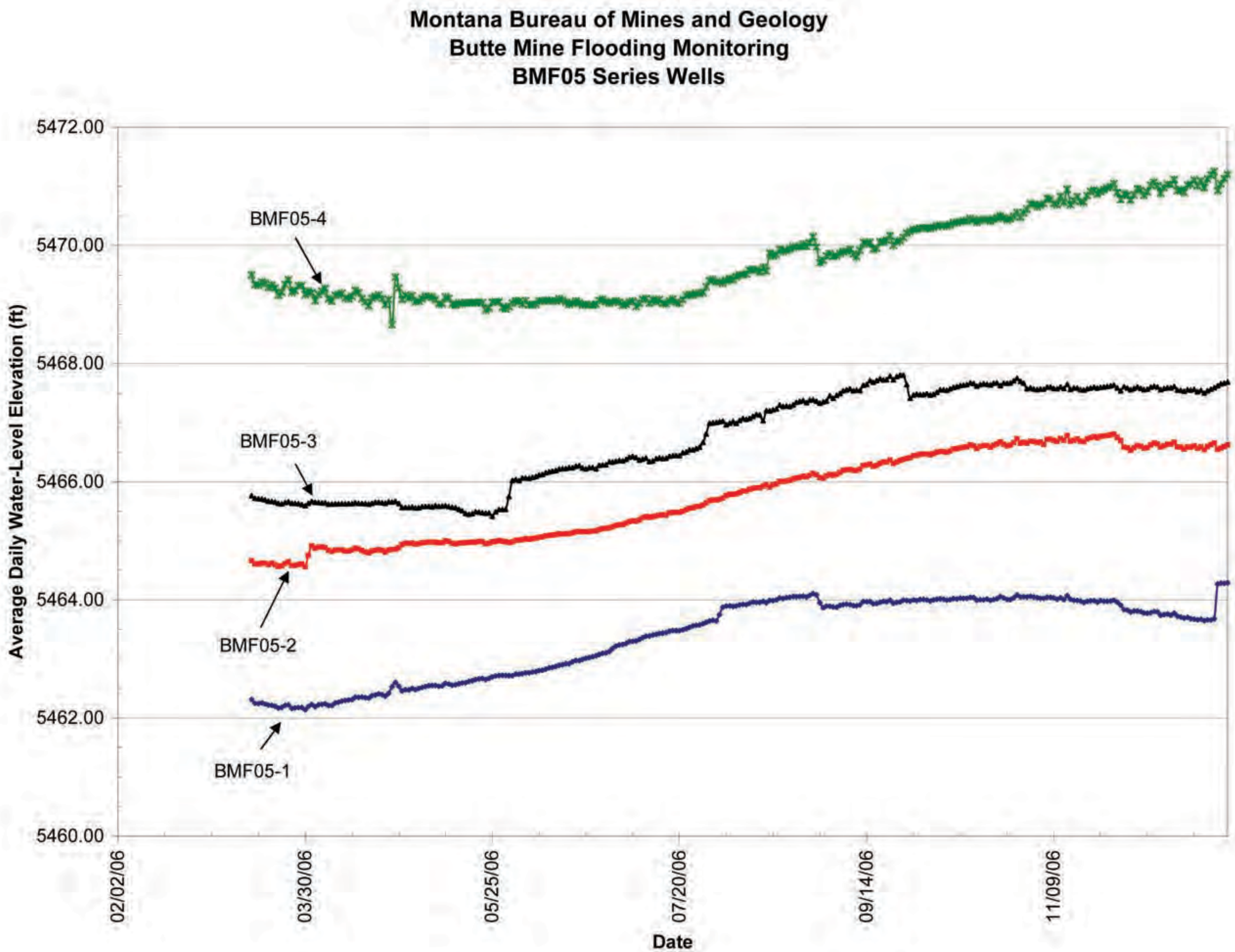


Figure 2-21. Average daily water-levels for BMF05 series wells.

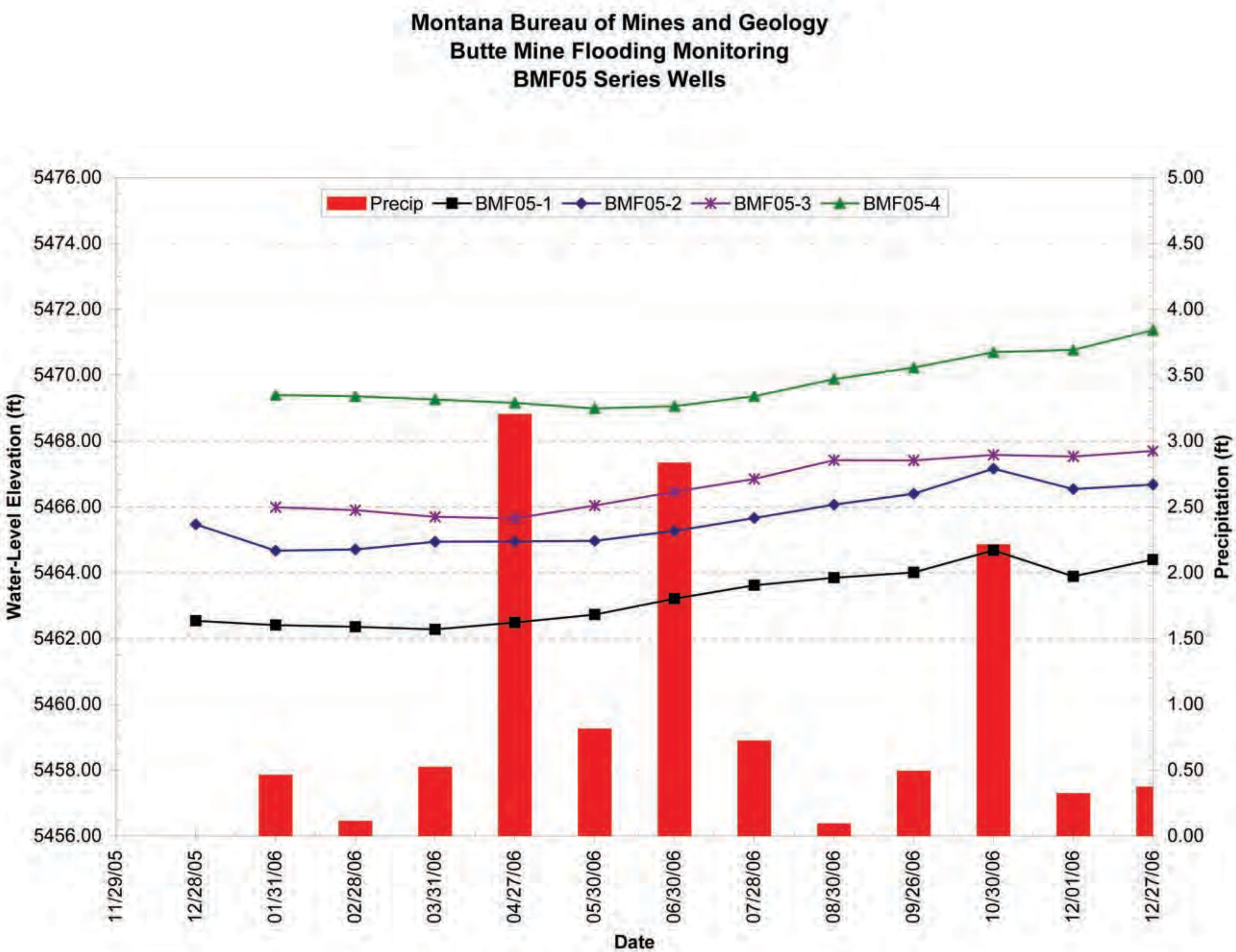


Figure 2-22. Monthly water-levels versus precipitation, BMF05 series wells.

Section 2.1.4.1 GS and BMF05-Series Wells Water Quality

Water-quality samples were collected during the spring (May) sample event from GS-series wells as part of the 2006 BMFOU monitoring. The poor water quality in GS-41S and GS-41D reflects their proximity to the Parrot tailings area; concentrations of dissolved constituents are extremely high. Data collected in 2006 confirms upward trends in many of the dissolved constituents.

The concentration of several dissolved constituents continues to exceed MCLs in Well GS-44S at the north end of Clark Park. Cadmium concentrations continue to increase to levels above the MCL in 2005 and 2006, after being below it for the previous two years. Well GS-44D continues to exhibit concentrations greater than MCLs, but overall concentrations have decreased by as much as 50 percent over the period of record and several were approaching the MCL. Wells GS-46S and D, northeast of Clark Park continued to exhibit good water quality in 2006 and show little or no change in trend, with the exception of uranium (GS-46S) which exceeds the MCL in both the 2005 and 2006 sample results.

Quarterly water-quality samples were collected from the BMF05 wells during 2006 to begin establishing baseline conditions for these four sites. Well BMF05-1 is extremely contaminated with a pH less than 5.50 and extremely elevated concentrations of iron, manganese, cadmium, copper and zinc. Table 2.1.4.2 shows the mean values for the elevated constituents and the appropriate MCL or SMCL standard.

Table 2.1.4.2 Mean concentrations of analytes that exceed water-quality standards, well BMF05-1.

Analyte	Mean Concentration	MCL (mg/L)	SMCL (mg/L)
pH	5.02		6.5-8.5
Iron	6.82		0.30
Manganese	123.		0.05
Aluminum	0.348		0.05-0.2
Cadmium	0.236	0.005	
Copper	3.2		1
Zinc	51.6		5
Sulfate	1,561		250

Based upon the location of this well (Fig. 2-17), adjacent to the historic Silver Bow Creek channel and down gradient from MR's concentrator, it is not surprising that the groundwater in the area is contaminated with mining related type wastes. Contaminant concentrations are similar to those in well AMC-5 located to the north.

Concentrations are above standards for nitrate in well BFM05-2; pH in well BMF05-3; and pH and manganese in well BMF05-4. However, all of the concentrations are only slightly above the standards.

Section 2.2 East Camp Underground Mines

Monitoring of water levels in the seven East Camp underground mines continued. Their locations are shown on figure 2-23. During the year 2006, water levels rose between 7.5 and 9-ft in the mines, slightly higher than last year, but similar to 2004. The Berkeley Pit water level rose 7.69-ft, which is 0.66-ft more than last year (Table 2.2.1). Figure 2-24 shows the annual water level changes graphically for these sites. The net 2006 water-level change between the mine shafts and Berkeley Pit were very comparable.

Table 2.2.1 Annual water-level changes in East Camp mines, in feet.

Year	Berkeley Pit	Anselmo	Kelley	Belmont (1)	Steward	Granite Mountain	Lexington(2)	Pilot Butte
1982			1,304.00	117.00	85.00			
1983			877.00	1,054.00	1,070.00			
1984			262.00	269.00	274.00			
1985			122.00	121.00	123.00			
1986		56.00	96.00	102.00	101.00			
1987		77.00	84.00	77.00	79.00	67.00		
1988		53.00	56.00	53.00	52.00	57.00	8.10	
1989		29.00	31.00	31.00	29.00	31.00		
1990		32.00	33.00	34.00	33.00	34.00		
1991	12.00	29.00	33.00	30.00	29.00	31.00		
Change Years 1-10*	***12.00***	***276.00***	***2,898.00***	***1,888.00***	***1,875.00***	***220.00***	***8.10***	
1992	25.00	22.00	24.00	24.00	23.00	25.00		
1993	26.00	24.00	25.00	26.00	25.00	26.00		
1994	27.00	25.00	26.00	25.00	25.00	27.00		
1995	29.00	28.00	27.00	18.00	28.00	30.00		
1996	18.00	16.00	19.00	4.15	18.00	18.00	1.19	3.07
1997	12.00	13.58	16.09	15.62	14.80	15.68	12.79	18.12
1998	17.08	13.23	14.73	13.89	14.33	14.24	13.71	11.26
1999	12.53	11.07	11.52	12.15	11.82	11.89	10.65	11.61
2000	16.97	14.48	14.55	15.66	14.60	15.09	14.01	14.11
2001	17.97	16.43	11.77	16.96	16.48	16.35	15.95	16.59
Change Years 11-20	**201.74**	**184.45**	**188.69**	**170.64**	**190.62**	**199.12**	**68.30**	**74.76**
2002	15.56	11.60	13.15	13.02	12.60	12.82	12.08	11.33
2003	13.08	13.05	13.94	13.74	13.44	14.23	2.75	14.05
2004	7.68	7.31	7.86	7.54	7.48	7.67		7.53
2005	7.03	7.10	7.37	7.17	7.00	6.98		6.97
2006	7.69	7.70	8.29	7.74	7.99	7.92		8.61
Change Years 21-25	**51.04**	**46.76**	**50.61**	**49.21**	**48.51**	**49.62**	**14.83**	**48.49**
Net Change*	***264.78***	***505.81***	***3,136.72***	***2,107.35***	***2,114.68***	***468.84***	***91.23***	***12325***

(1) Mine shaft collapsed in 1995; a replacement well was drilled adjacent to the mine, into mine workings, in 1997. Since the well was drilled into the Belmont Mine workings, it is assumed that this water level is reflective of the Belmont Mine.

(2) No water-level measurements since February 2003, due to obstruction in shaft at 366-ft below surface.

(*)Total change is the measured change in water level. Access or obstructions have prevented continuous water-level measurements at some sites.

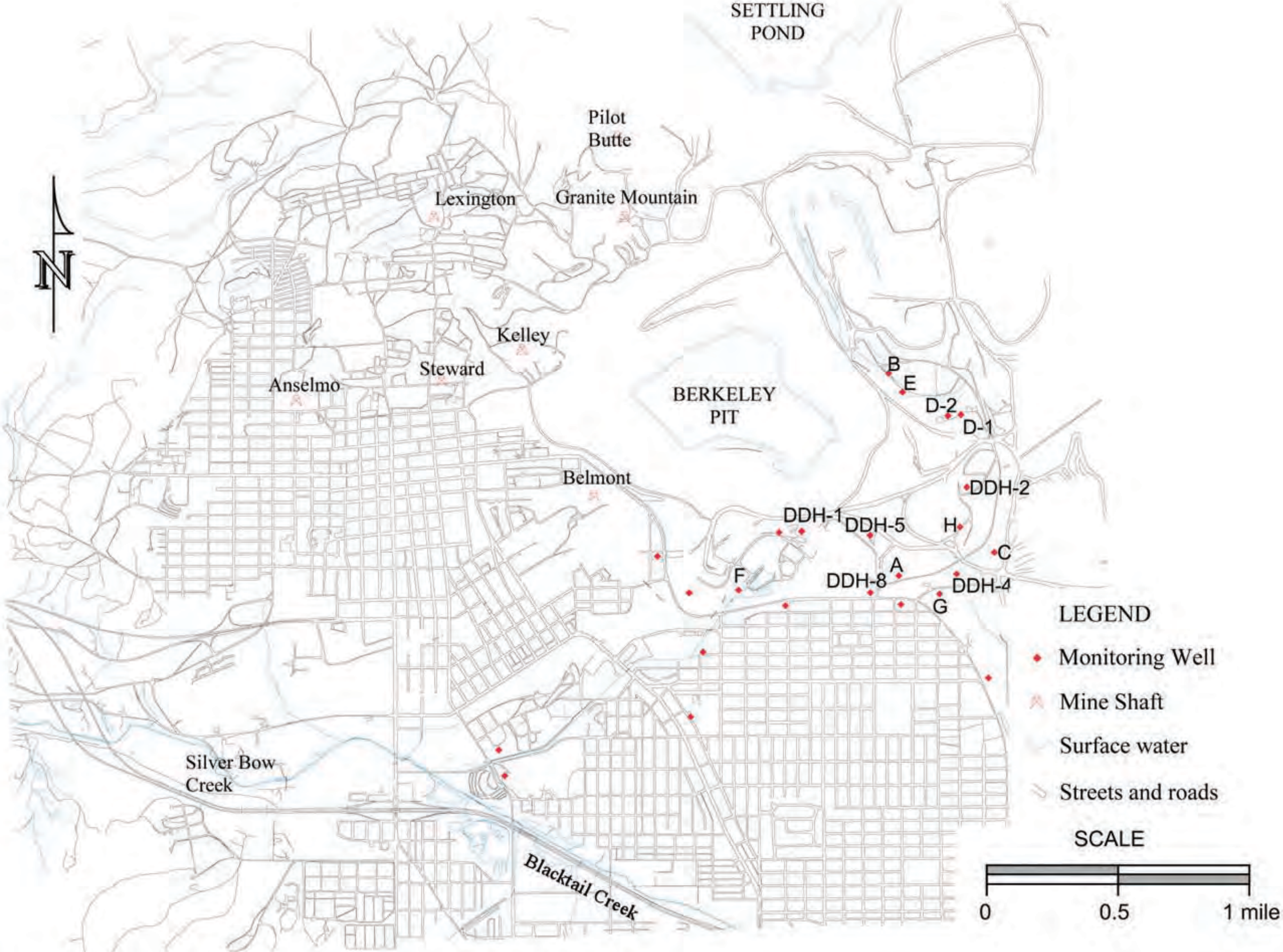


Figure 2-23. East Camp Mines and Bedrock Wells Location Map

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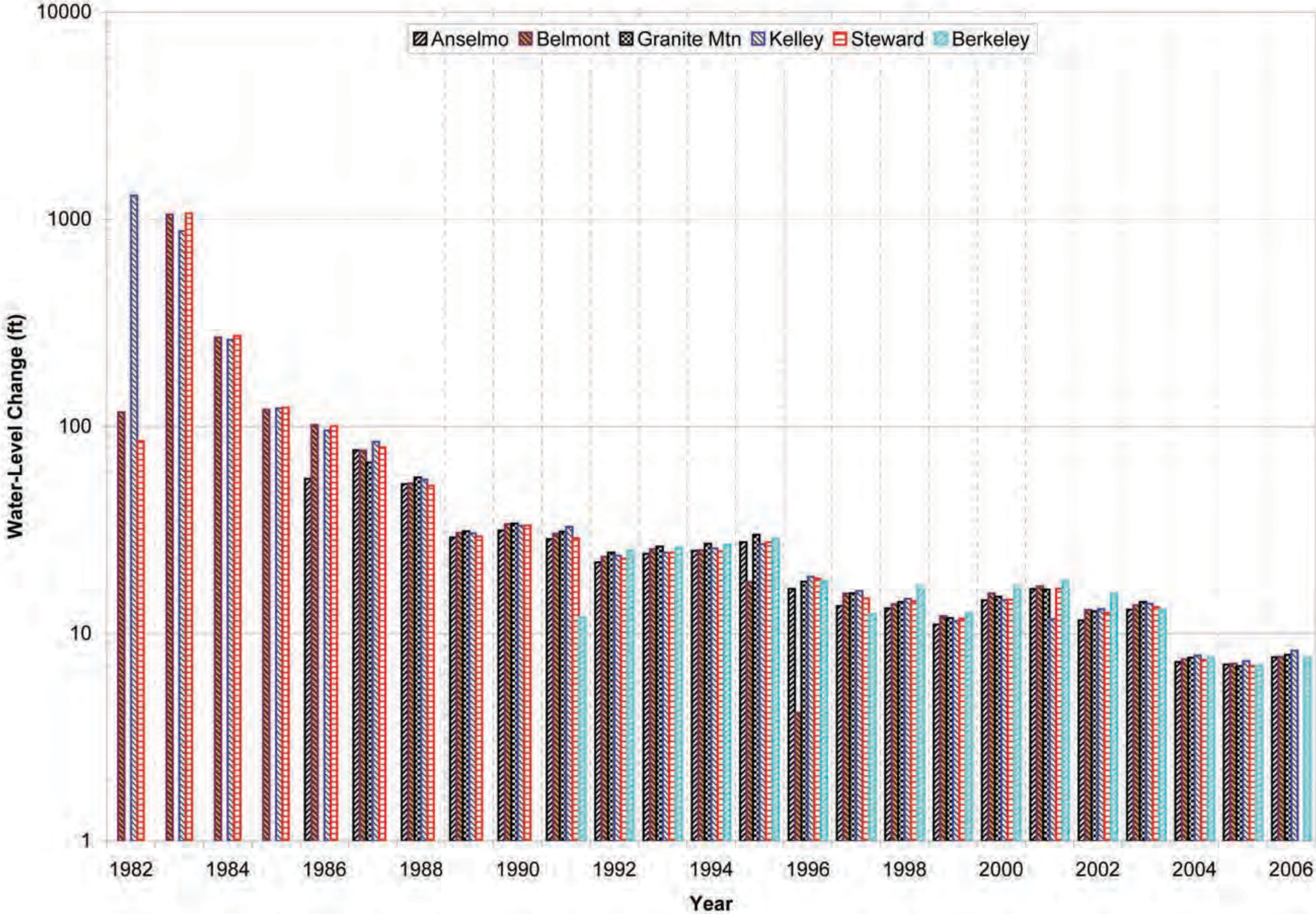


Figure 2-24. East Camp mines annual water-level changes.

Figure 2-25 is a hydrograph based upon water levels for the Anselmo Mine and Kelley Mine. There are no obvious variations in water levels on this figure; however, when water levels are plotted from 1995 through 2006, several changes are noticeable (fig. 2-26). The removal of HSB drainage water from discharging into the pit in April 1996 resulted in a flattening of the line, while the July 2000 addition of the HSB drainage water, following MR's suspension of mining, resulted in an increased slope of the line. The slope of the line, or rate of rise, shown on fig. 2-26 flattened out throughout 2006, corresponding to the removal of the HSB drainage water and its subsequent treatment. The HSB treatment plant came on-line during late November 2003.

Figure 2-27 shows monthly water-level changes in the Berkeley Pit through 2006. Water-level changes seen over the last 6 months of 2000, following the addition of HSB drainage water, continued through 2003. However, water-level increases were much less from 2004-2006 as a result of the decreased inflow of water into the pit. A similar trend was seen in all the East Camp underground mines. Water levels remain the highest in the sites farthest from the Berkeley Pit. This continues to confirm that water is flowing towards the pit, thus keeping the pit the low point in this system.

Figure 2-28 is a plot of selected mine-shaft water-levels versus precipitation. There is no apparent influence on water levels in the underground mines from monthly precipitation. It is obvious that the rise in water levels is a function of historic mine-dewatering activities and the void areas in the underground mine workings and Berkeley Pit and is not a function of precipitation. Based upon volume estimates of the underground mines and December 2006 water-level elevations, almost 85 percent of the underground workings are flooded. However, since approximately 12 percent of the underground workings are above the CWL elevation of 5410-ft, only 3 to 4 percent of the underground workings remain to be flooded.

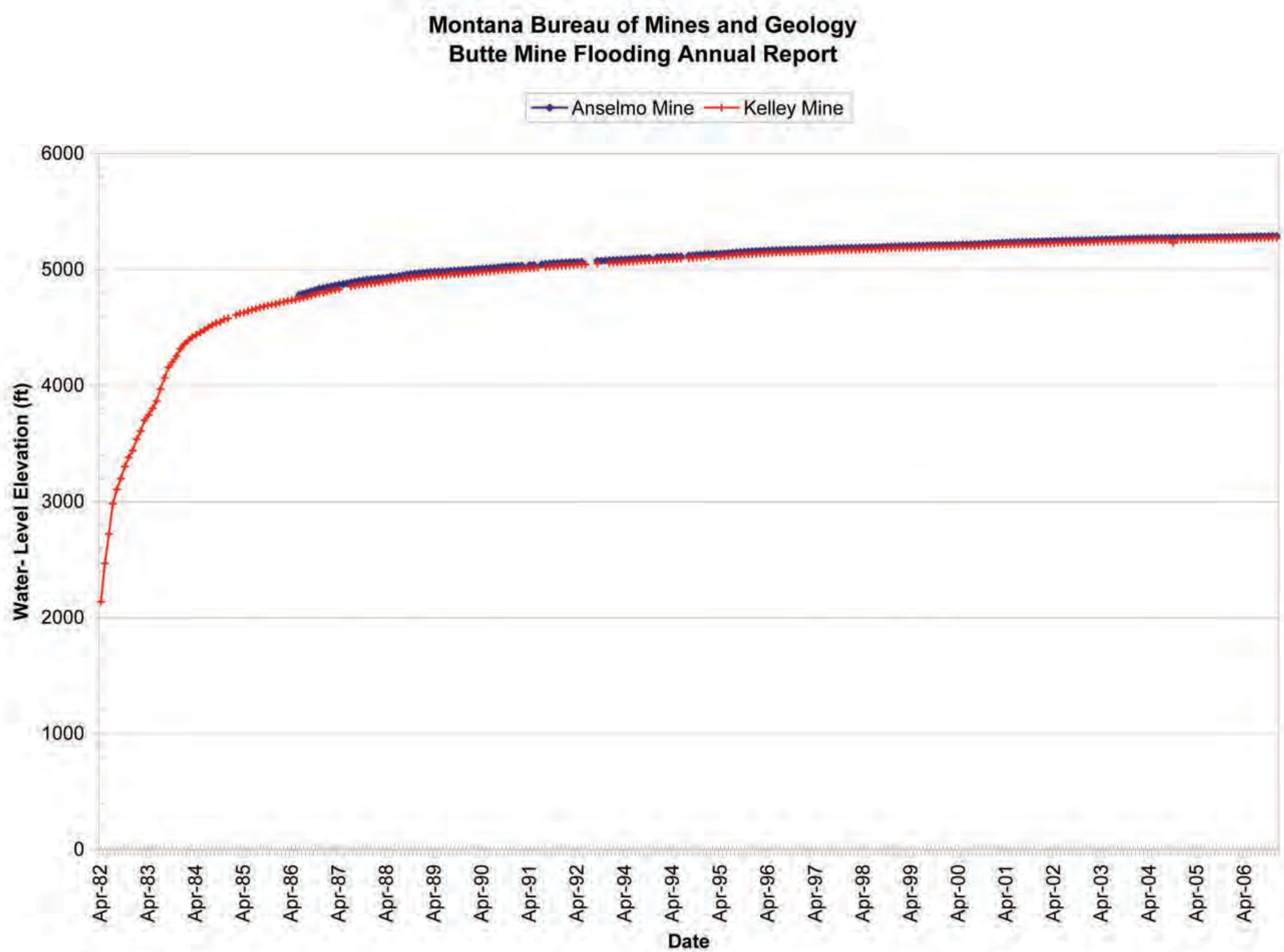


Figure 2-25. Water-level hydrographs for the Anselmo Mine and Kelley Mine.

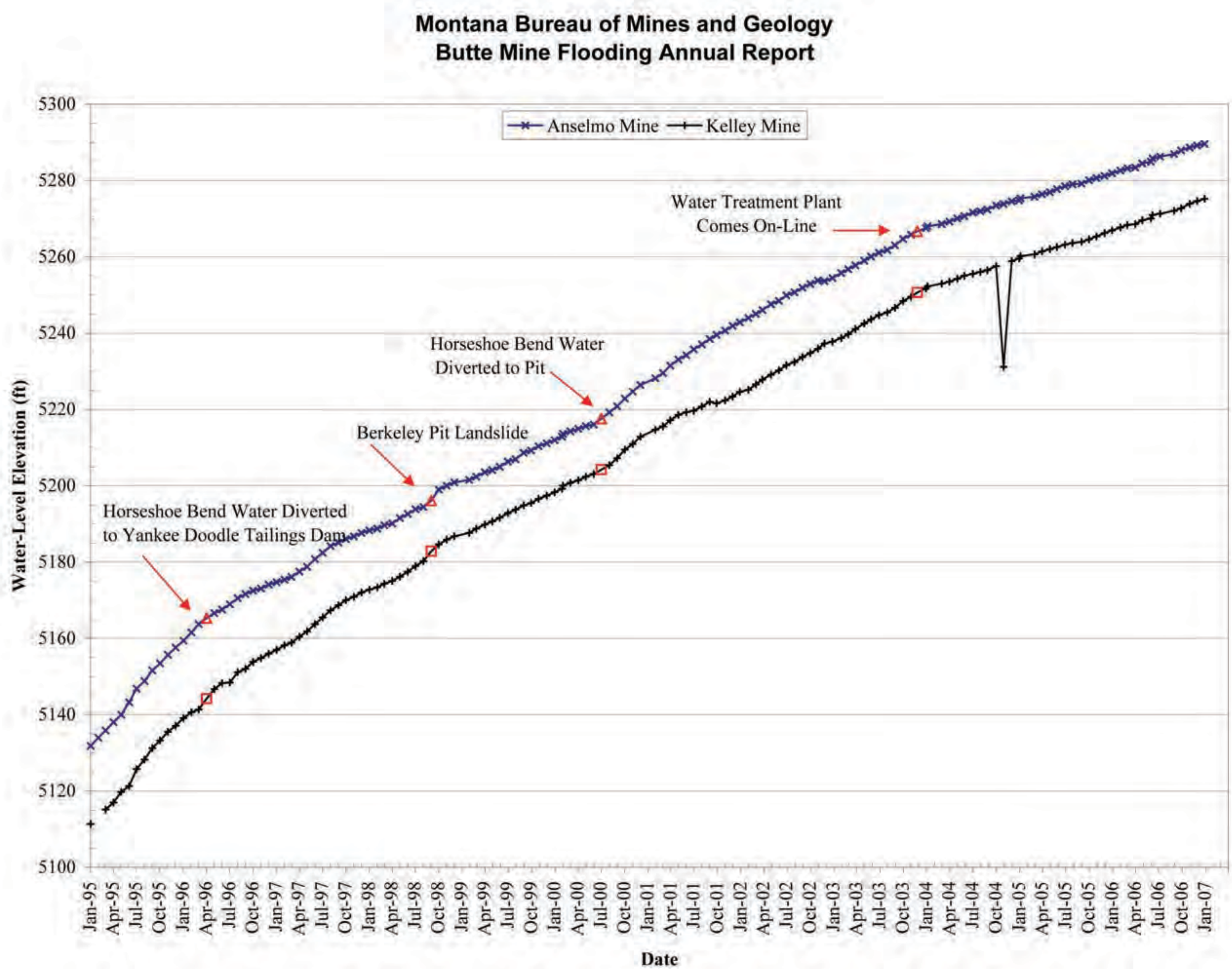


Figure 2-26. Water-level hydrograph, 1995-2006, Anselmo Mine and Kelley Mine.

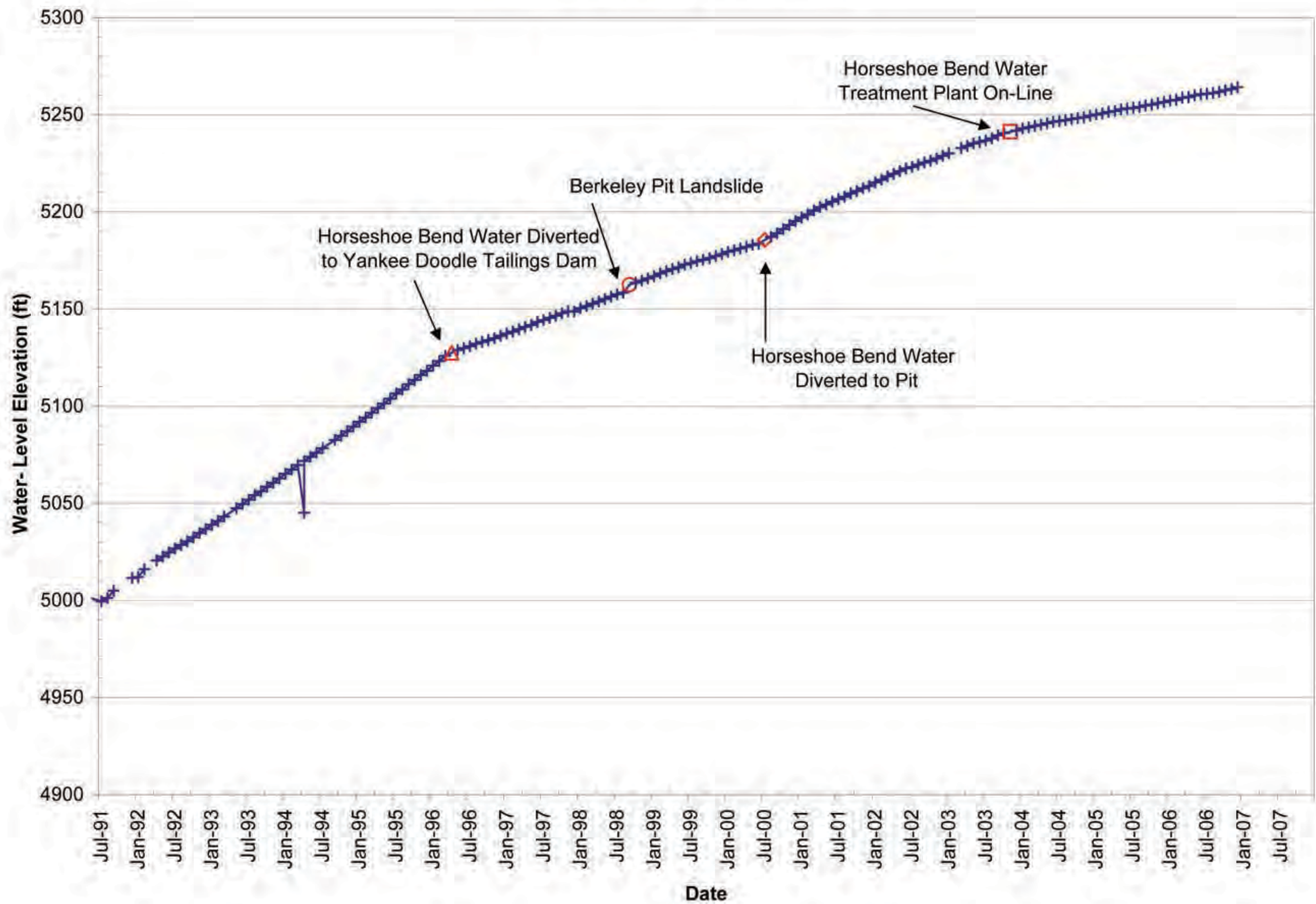


Figure 2-27. Water-level hydrograph for the Berkeley Pit.

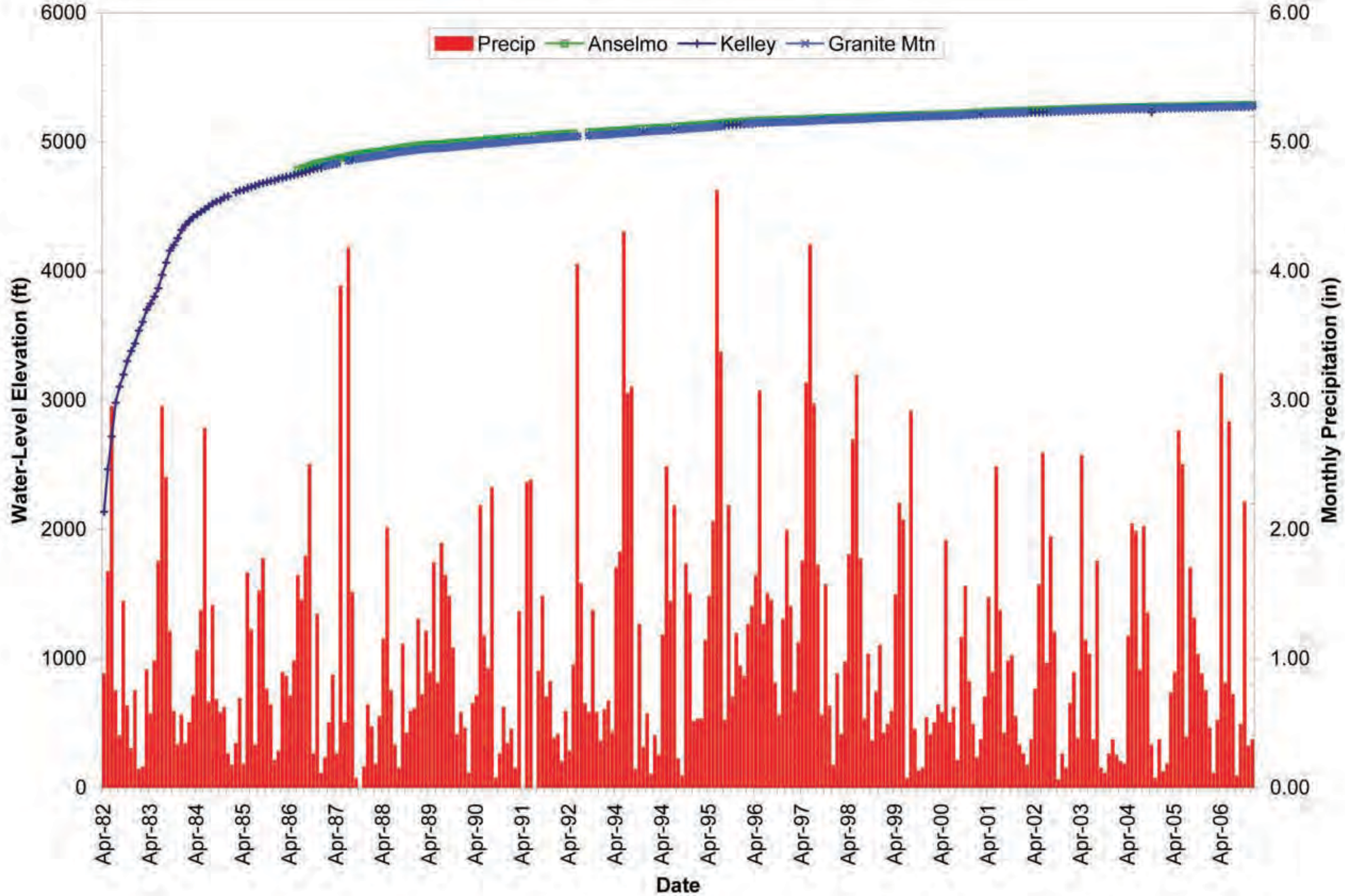


Figure 2-28. Water-level hydrographs for selected East Camp Mines, with monthly precipitation.

Section 2.2.1 Water Quality

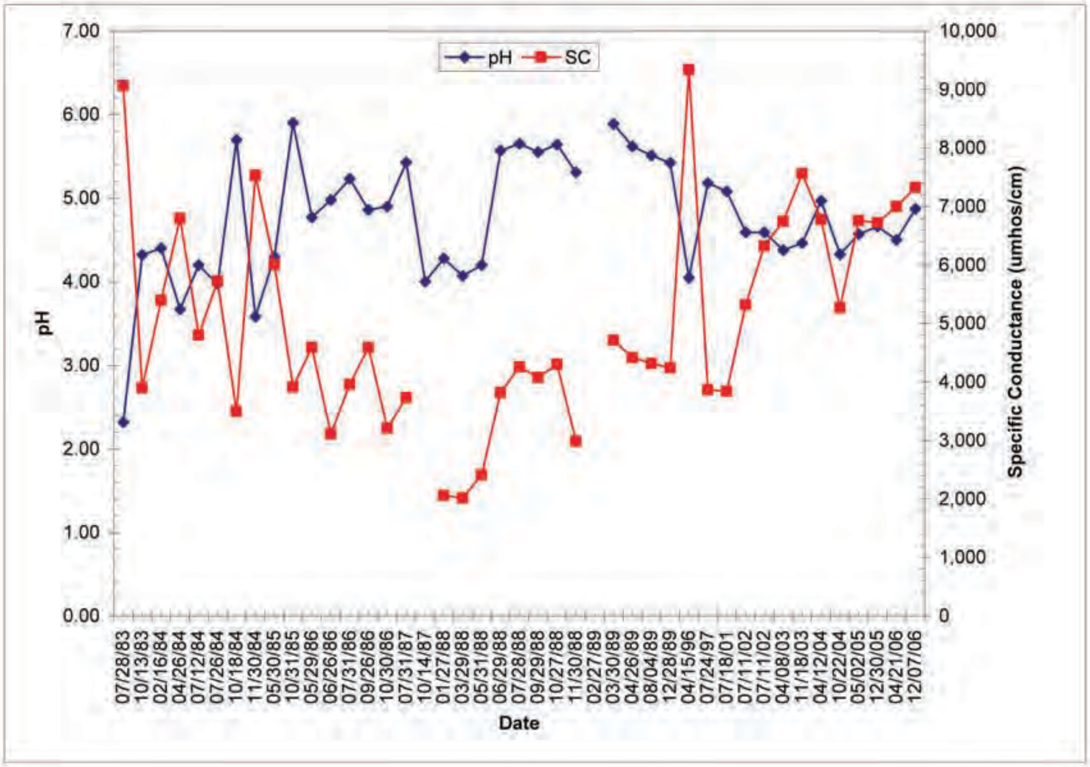
Earlier reports discussed the lack of appreciable change in water quality within the East Camp mines until 2002 when several of the shafts exhibited significant departure from previous trends. Data from the 2006 sampling indicate that the changes in concentration are sustained for yet another year. Again, most notable is the elevated concentration of metals, arsenic, and sulfate in the Kelley shaft; the exception being that of dissolved copper which continues to decrease in concentration. The relationship between the concentration of zinc (increasing) and copper (decreasing) should be explored, but requires a great deal more sampling than the current effort. The Anselmo and Steward Mines were sampled once during 2006 at two different depths (100-ft and ~500-ft below the water surface at the Anselmo and 100-ft and ~1000-ft below the surface at the Steward). Kelly Mine samples were collected twice during 2006 and from two different depths (100-ft and ~1000-ft below the water surface) to better document water-quality conditions. (Data shown in figures are from samples collected 100-ft below the water surface.)

Kelley: iron, sulfate, arsenic, and aluminum increased to near historic concentrations in 2003-2004, decreasing slightly in 2005 and 2006; copper concentration remains very low (fig. 2-29). There were slight increases with depth for iron, manganese, arsenic, and zinc in the spring 2006 samples; while the differences in the fall samples were less pronounced.

Anselmo: the concentration trend for iron and arsenic concentrations remain elevated but less than 2004 concentrations; zinc and cadmium show large fluctuations, with an overall downward trend (fig. 2-30). Copper concentrations remain very low (<20 ug/L). Concentrations did not vary with sample depth.

Steward: the iron and arsenic concentrations in the Steward shaft remain high, following the upward trend of recent years. The trend has been downward for zinc and copper (fig. 2-31); however zinc concentrations remain well above standards. Concentrations did not vary with sample depth.

Montana Bureau of Mines and Geology
Butte Mine Flooding Monitoring
Kelley Mine



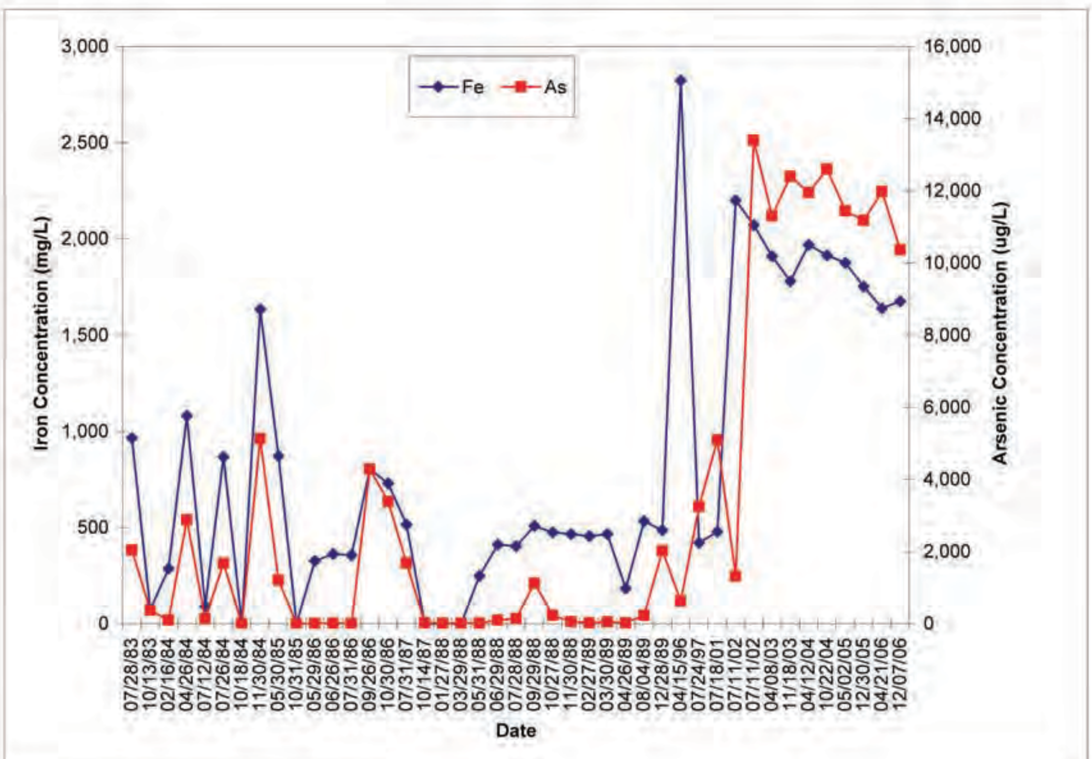


Figure 2-29. Kelley Mine water quality changes over time.

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Butte Mine Flooding Monitoring
Anselmo Mine

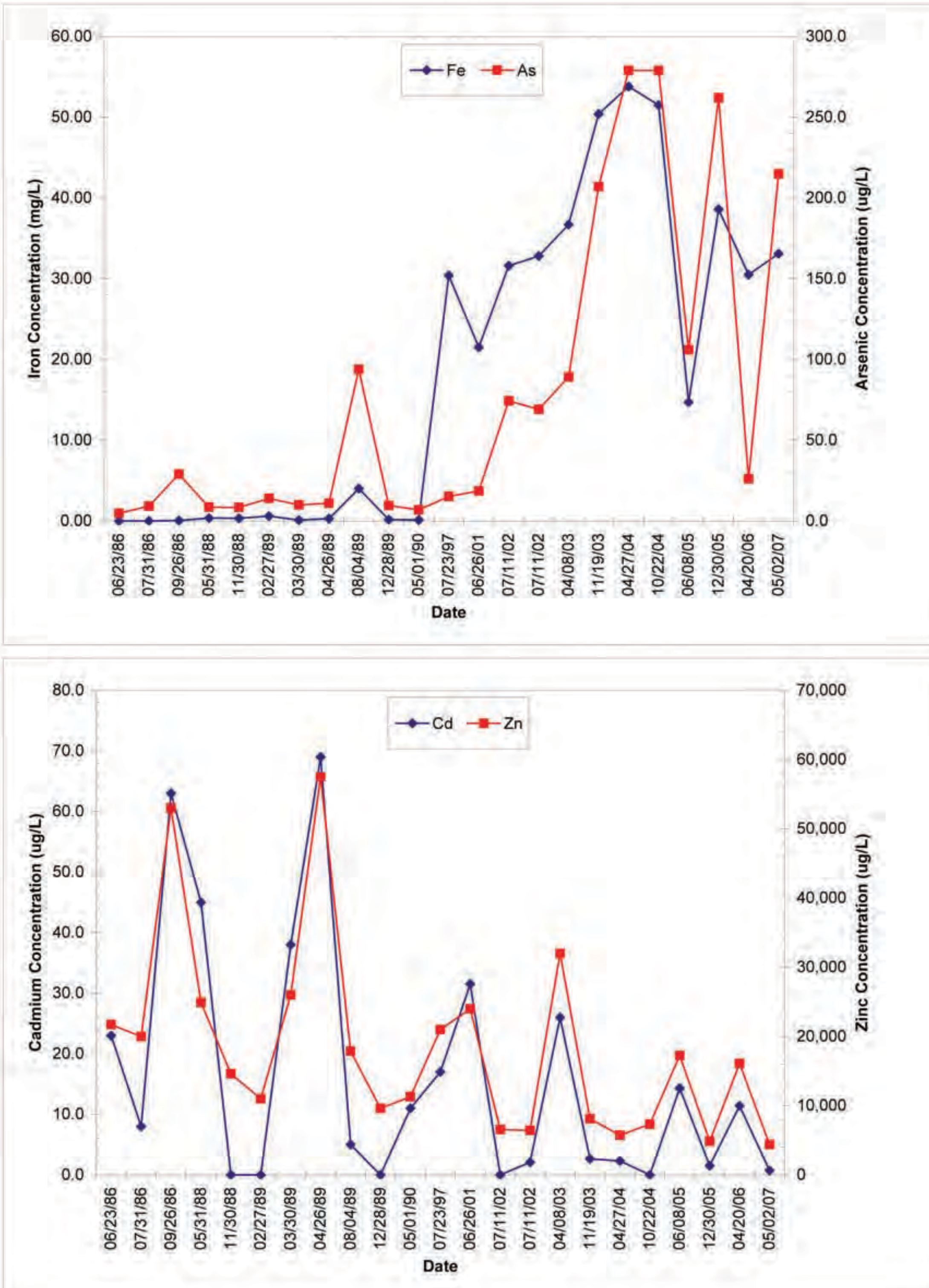

Figure 2-30. Anselmo Mine water quality changes over time.

Montana Bureau of Mines and Geology
Butte Mine Flooding Monitoring
Steward Mine

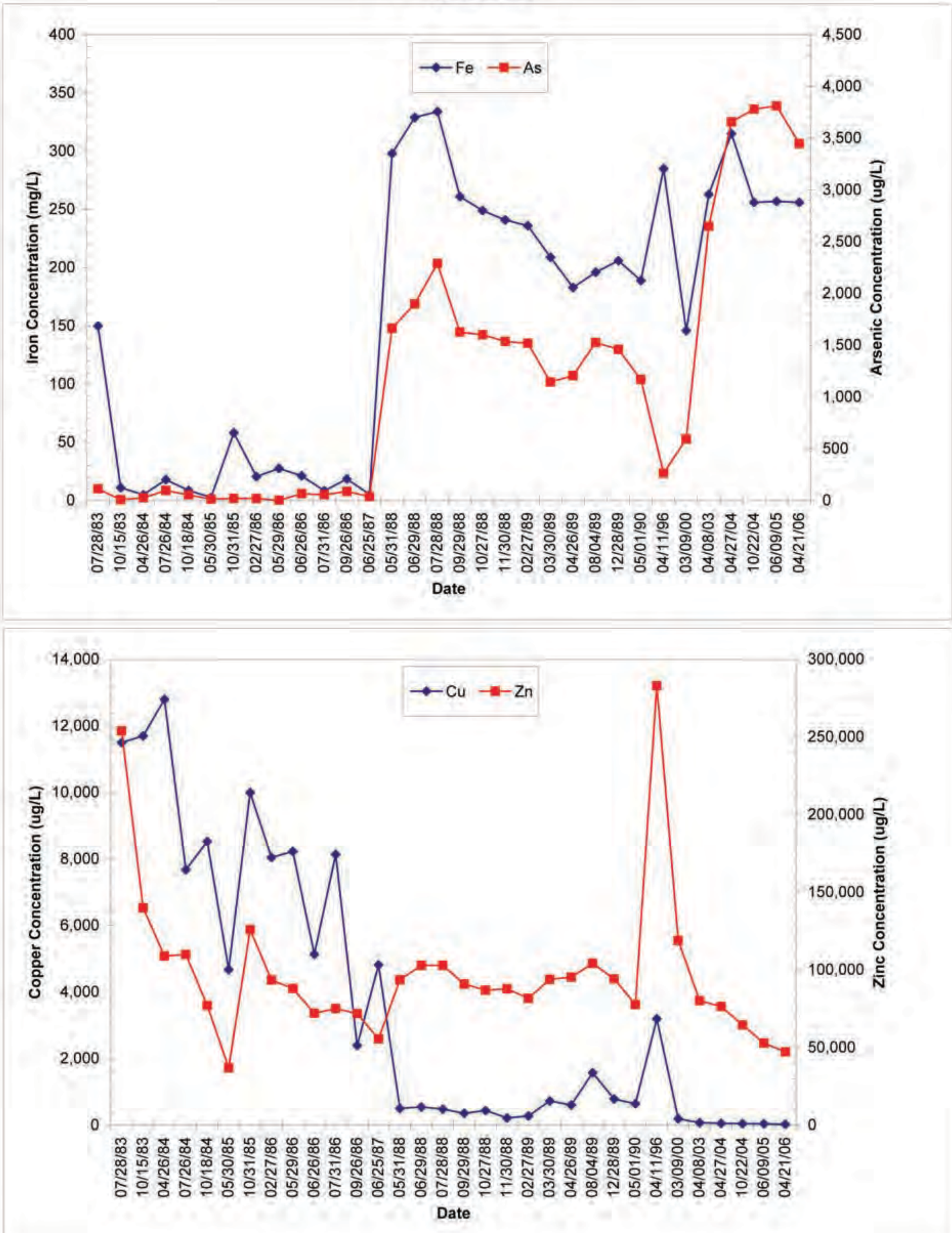

Figure 2-31. Steward Mine water quality changes over time.

Section 2.2.2 RI/FS Bedrock Monitoring Wells

Monitoring of the 9 RI/FS and ROD-installed bedrock wells continued. Monitoring-well locations are shown on figure 2-23. Water levels continue to rise in wells A, C, D-1, D-2, G, and J at rates similar to those in the East Camp Mine system. Water levels in well E continue to follow patterns identified in earlier reports, while water levels in well F decreased slightly. Table 2.2.1.1 contains yearly water-level changes and figure 2-32 shows these changes graphically.

Table 2.2.1.1 RI/FS bedrock well annual water-level change, in feet.

Year	Well A	Well B	Well C	Well D-1	Well D-2	Well E	Well F	Well G	Well H	Well J
1989										
1990										
1991	33.18		22.38	24.20	22.68	1.73				
1992	39.22	8.78	26.53	27.89	25.04	0.47	-1.92			
1993	27.95	8.68	21.72	24.41	24.51	-0.37	1.09			
1994	25.65	7.90	23.88	25.12	25.21	0.27	0.11			
1995	28.69	13.41	29.55	26.99	27.50	0.44	1.65	28.74	30.37	
1996	19.31	14.56	26.22	18.77	18.92	0.48	-0.11	22.40	18.72	
1997	14.44	12.35	19.25	13.62	13.68	-0.64	1.41	15.67	3.76	
1998	15.96	11.30	16.68	16.41	16.39	0.44	1.03	15.56	154	
Change Years 1-10	**204.4**	**76.98**	**186.21**	**177.41**	**173.93**	**2.82**	**3.26**	**82.37**	**68.29**	
1999	11.21	5.11	12.44	12.18	12.03	-0.78	-1.80	12.00	P&A	1.99
2000	15.12	8.20	13.39	14.66	15.79	-2.68	-2.49	12.84	P&A	16.19
2001	18.33	9.08	16.86	19.81	18.61	-3.58	-0.61	16.56	P&A	18.81
2002	15.16	1.73	14.41	14.69	14.76	-3.37	-0.73	14.84	P&A	15.29
2003	12.75	8.70	13.20	13.69	13.72	-2.66	1.16	12.71	P&A	13.48
2004	7.60	4.46	8.71	7.90	7.83	-1.12	0.32	8.31	P&A	7.58
2005	5.82	-7.00	6.76	5.56	6.08	-2.51	-0.73	5.95	P&A	7.03
2006	7.44	5.82	6.81	3.56	3.20	-0.83	1.22	6.39	P&A	6.72
Change Years 11-18	**93.43**	**36.10**	**92.58**	**92.05**	**92.02**	**-17.53**	**-3.66**	**89.69**	**0.00**	**87.09**
Net Change*	**297.83**	**113.08**	**278.79**	**269.46**	**265.95**	**-14.71**	**-0.40**	**172.06**	**68.29**	**87.09**

Table 2.2.1.1 RI/FS bedrock well annual water-level change, in feet. (cont.)

Year	DDH-1	DDH-2	DDH-4	DDH-5	DDH-8
1989	29.53			34.83	30.48
1990	36.24	30.99	5.44	27.61	35.96
1991	27.03	28.20	39.81	27.01	28.96
1992	28.25	26.09	37.66	21.07	26.16
1993	24.33	24.16	26.88	24.40	24.46
1994	25.00	25.65	28.34	19.78	15.97
1995	27.66	28.74	28.80	26.10	--
1996	18.53	18.97	20.24	12.41	55.68
1997	13.33	14.09	14.32	15.89	13.38
1998	15.03	16.20	16.25	16.50	16.50
∗Changes Years 1-10	**244.93**	**213.09**	**217.74**	**235.60**	**247.55**
1999	11.66	12.00	11.88	4.82	15.50
2000	14.64	16.11	14.77	P&A	10.42
2001	18.14	18.78	18.52	P&A	18.93
2002	14.63	14.80	13.14	P&A	13.64
2003	13.05	13.90	NA	P&A	14.49
2004	7.08	7.89	NA	P&A	7.90
2005	4.87	5.89	NA	P&A	57.52
2006	6.30	6.75	NA	P&A	6.03
Change Years 11-18	**90.37**	**96.12**	**58.31**	**4.82**	**144.43**
Net Change∗	**335.30**	**309.21**	**276.05**	**240.42**	**391.98**

(∗)Total change is the measured change. Access or obstructions prevented continuous water-level measurements at some sites. P&A B well plugged and abandoned due to integrity problems. Well J was drilled as a replacement for well H.

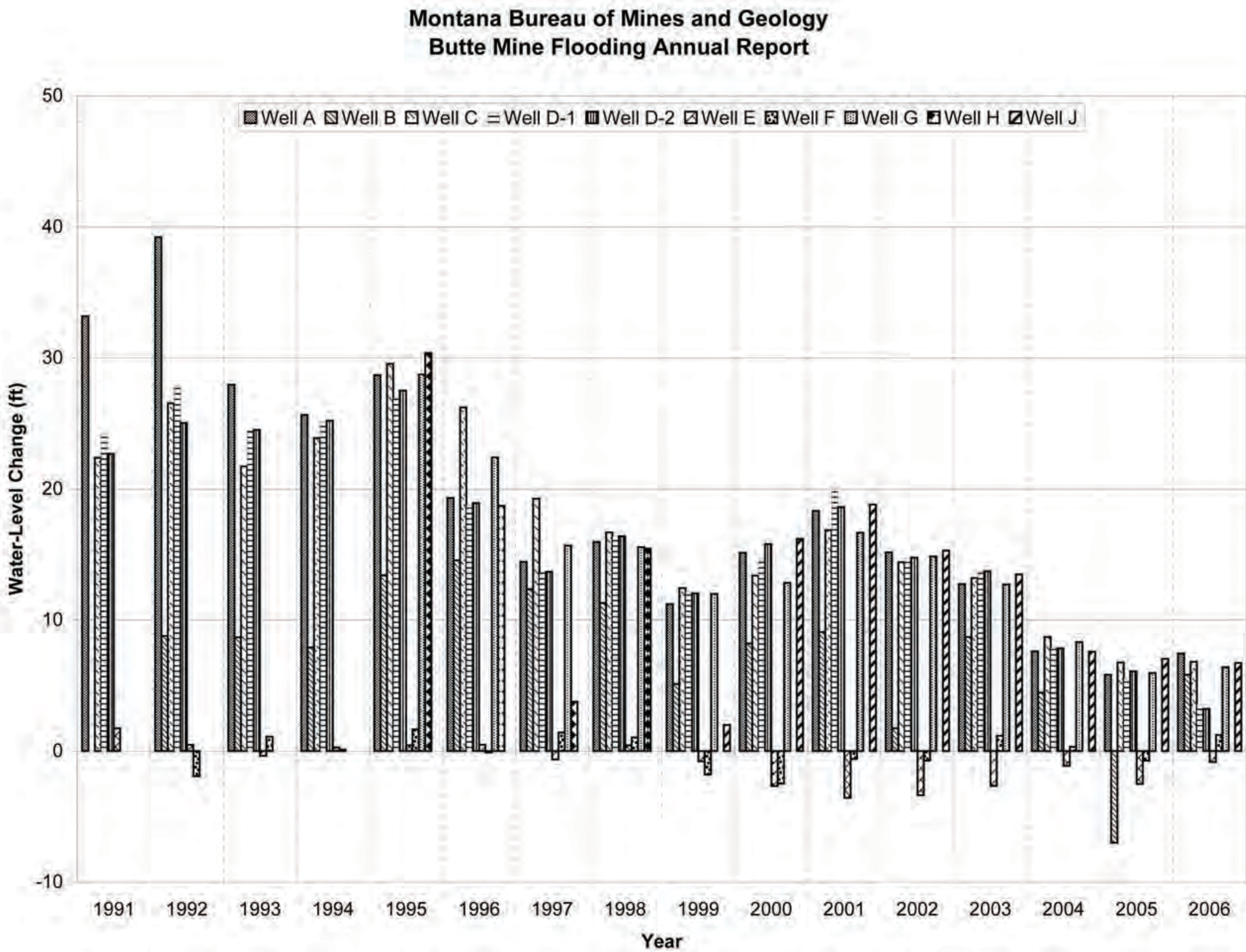

Figure 2-32. RI/FS bedrock wells annual water-level change.

The monitoring program contained in the 2002 CD specified that water levels be monitored on a continuous basis in bedrock wells A, B, C, and G. Water-level transducers were installed in each of these wells and set to collect water-level data every hour. This detailed level of monitoring allows recording of changes in water levels not seen when only one water-level measurement is taken monthly. This increased level of monitoring allows greater interpretation of water-level changes caused by either natural (i.e., earthquakes or slumps) or man-induced (i.e., pumping) occurrences.

While there were two events that occurred during 2005 that affected water levels in the East Camp bedrock system, the July 25th magnitude 5.6 earthquake and MR's December pumping test, the only activities in 2006 that influenced the rising ground water levels were those caused by MR's continued exploration work associated with future mine expansion. Those activities were twofold: 1) pumping tests in January and October-November; and 2) the back filling and grouting of Pittsmont mine workings.

MR ran a moderate length pumping test from January 5th through January 23, 2006, pumping at a rate of approximately 1000 gallons per minute. Figures 2-33a and 2-33b show the water level drawdown in the bedrock system associated with this testing. Bedrock wells D-1 and J are in close proximity to the Pittsmont shaft while wells A, C and G (figure 2-33b) are farther away. The wells closest to the pumping site respond almost instantaneously to the start and stop of pumping; while the wells farther away (A, C, G) show a more gradual drawdown and recovery. There were no long-term influences on water levels in the bedrock system from this pumping test.

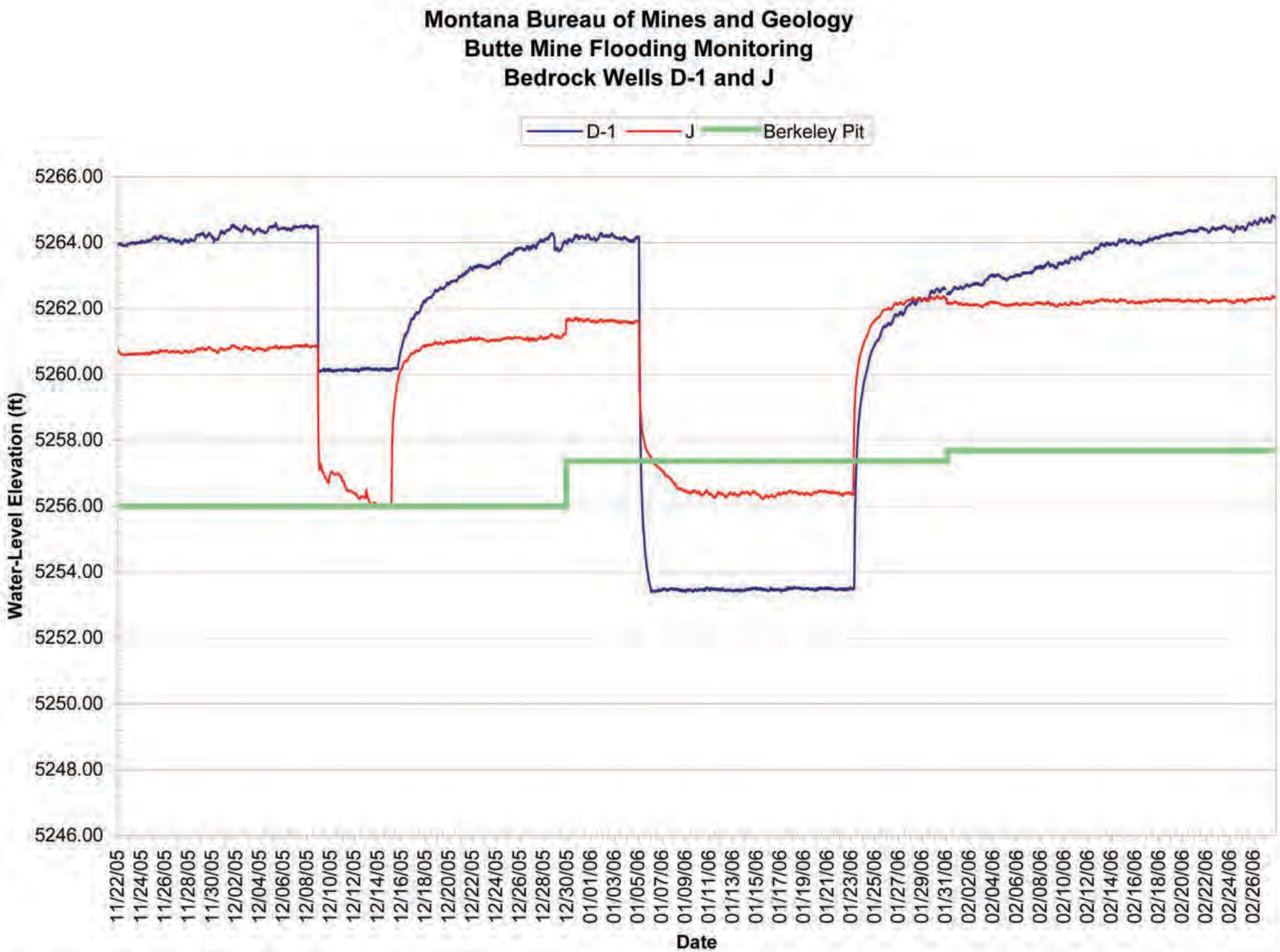

Figure 2-33a. Hydrograph showing influence of December 2005 and January 2006 pumping test on East Camp bedrock water-levels.

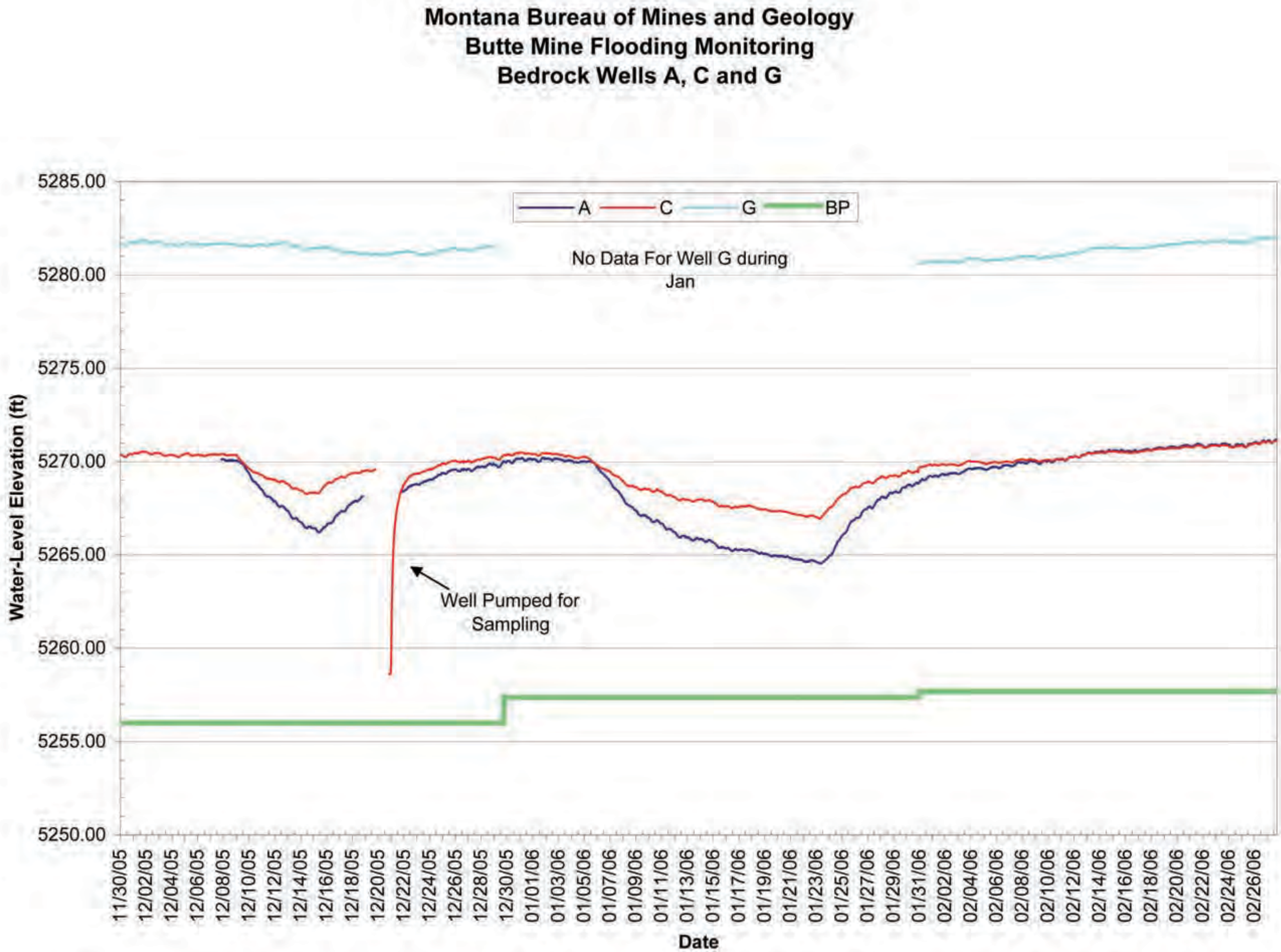

Figure 2-33b. Hydrograph showing the influence of December 2005 and January 2006 pumping test on East Camp bedrock water-levels.

The second pumping test took place from October 13th through November 4, 2006. Between this test and the January 2006 test, MR back-filled the Pittsmont #3 shaft and a portion of its workings with sand tailings from the concentrator and injected grout into the 800 level of the Pittsmont workings to seal the Pittsmont #3 shaft and associated workings from the Berkeley Pit. Figures 2-34a and 2-34b show the influence, or lack of, on bedrock wells from the October pumping. The MBMG measured drawdown of over 90-ft during this test.

Well D-2, which is located a short distance to the northwest of the Pittsmont #3 shaft showed a water-level decline similar to previous tests. This well is also located on the east side of the area where the grouting took place. Water-levels showed an almost immediate response at the start of pumping; however the period of recovery was much longer than during earlier tests (figure 2-34a). (It should be noted that monitoring was moved from well D-1 to D-2 between the January and October tests, however, these wells are close to each other with D-2 being completed at a slightly deeper depth. The historic water-level trend between these wells has been similar and the response to the pumping tests should be similar.) The length of time necessary for water-levels to recover increased due to the apparent lack of recharge from areas to the west.

The water-level response in wells J (figure 2-34a) and A, C, and G (figure 2-34b) was quite different during the October-November pumping test. These wells which are located farther away from the Pittsmont #3 shaft showed a gradual water-level decline beginning shortly after the start of the tests in December and January (2-33b) and a rise beginning at the test's end. No water-level response during the October-November test is noticeable on the graphs for any of these wells until several days into the test and again near the end of the test in well J. These water-level changes are very minor, but may show a small amount of connection between this well and the Pittsmont #3 shaft. All three of these wells are on the other side of the zone MR tried to isolate during their grouting operations. Based upon the lack of drawdown seen in these wells it appears the grouting was successful in these areas.

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Bedrock Wells D-2 and J

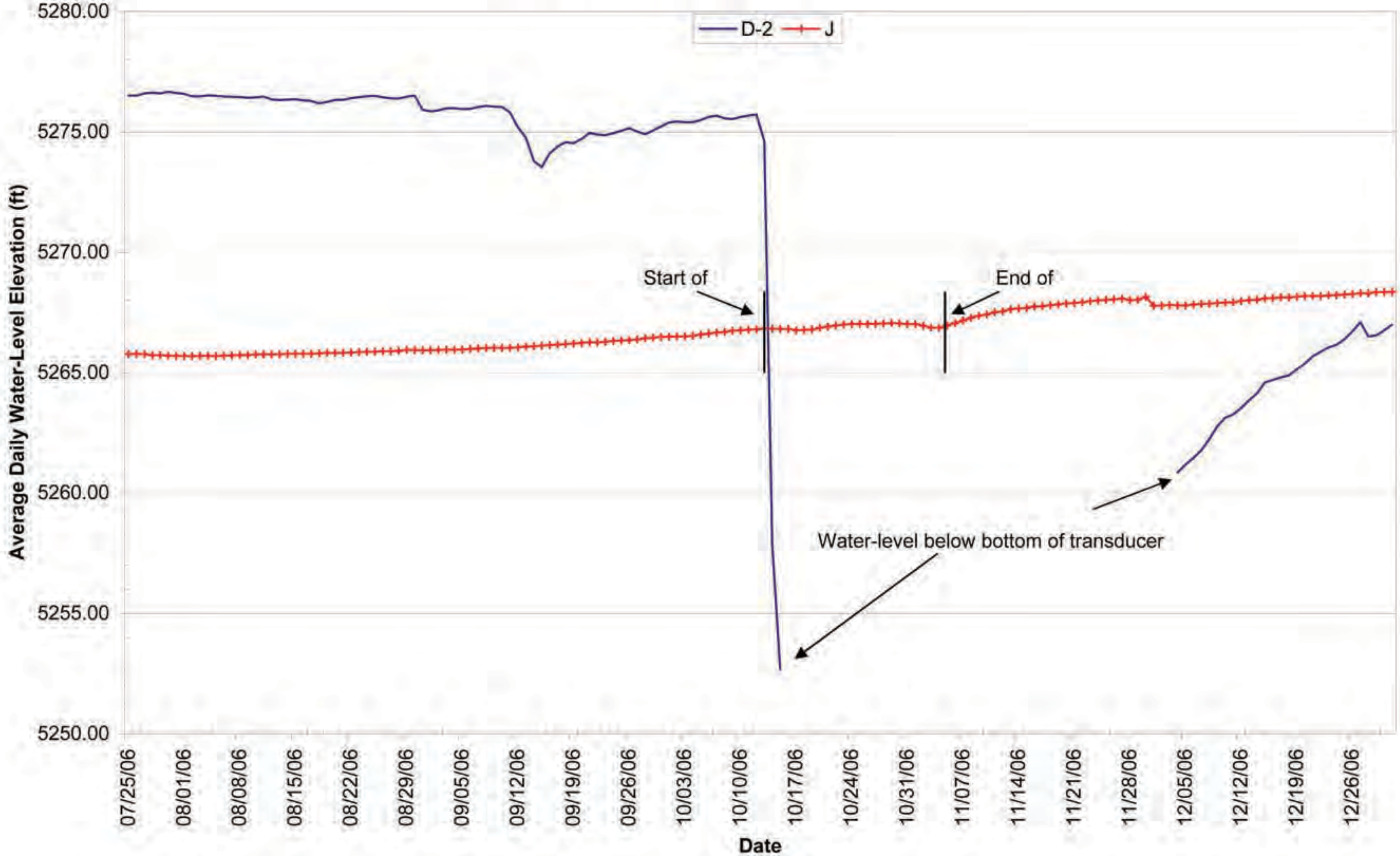

Figure 2-34a. Hydrograph showing influence of October-November 2006 pumping test on bedrock water-levels, wells D-2 and J.

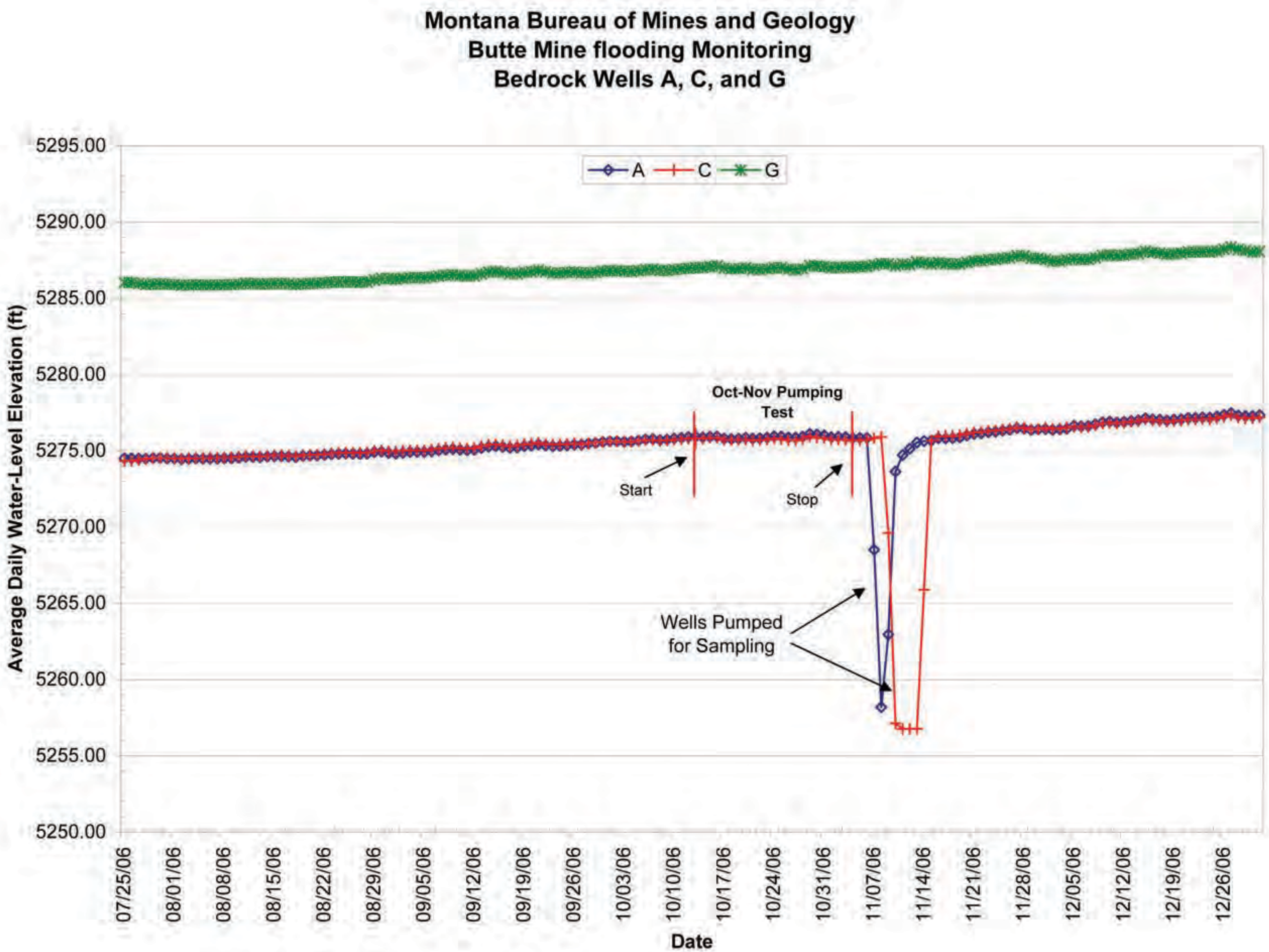

Figure 2-34b. Hydrograph showing the influence of October-November 2006 pumping test on East Camp bedrock wells A, C, and G.

The back filling of the Pittsmont #3 shaft mentioned above was the other activity that influenced water levels in the East Camp bedrock system during 2006. Figure 2-35 shows the water-level increase observed in well D-1 by the addition of the sand tailings in the Pittsmont shaft and associated workings. Well D-1 is located to the northwest of the shaft and adjacent to workings from this mine. The fill material was allowed to flow into the mine from the surface at the shaft collar until the void area was filled. The tailings were injected from May 18th to June 2nd. A corresponding increase in water-levels occurred during that time in this well.

Water levels in the bedrock aquifer, which had been affected by historic underground mine dewatering, are responding to the cessation of pumping and show no apparent relationship to precipitation through 2006. Instead, physical changes that affect the flow of water into the Berkeley Pit and underground mines, e.g. the 1996 HSB water diversion and the 2000 addition of the HSB drainage flow, are the major influences on water-level increases. Figure 2-36 is a hydrograph for well A showing monthly water levels and monthly precipitation totals with 1996, 2000 and 2003 HSB operational changes identified. The void areas in the mines and Berkeley Pit control the annual rate of rise in this system.

Water levels measured in well J since its completion in 1999 have been in the same range as those in other surrounding bedrock wells, and are shown on figure 2-37. Historic water levels for well H are shown on this figure with a linear projection of water levels included. Water levels for well J plot very closely to those projected for well H, verifying that well J was completed in the same bedrock zone as well H. However, beginning in April 2004, the water level for well J plots below the projected water level for well H. This is a result of the filling rate slowing from the diversion and treatment of water from the HSB drainage. The projected water level for well H does not take into account the removal of HSB water from the pit.

The water-level change in well B was about one-half the rate of that of the above bedrock wells and Berkeley Pit over a number of years, until November 2002. Due to a water-level decline during November and December, the 2002 rate of water-level rise was only 11 percent of that of the Berkeley Pit. The 2003 and 2004 water-level increases were closer to 60% that of the other bedrock wells; however, as a result of the influence of the July 2005 earthquake and water-quality sampling on this well, the water level had a net 7-ft decline for 2005. The 2006 water-level increase was about 75% that of the Berkeley Pit, indicating there were no long term effects in water levels from the 2005 earthquake. Hydrographs for wells A and B, showing monthly water-level elevations are shown on figure 2-38.

Water levels in wells E and F do not follow the trends seen in the other bedrock wells (fig. 2-39). Water levels in these two wells are considerably higher than those in the other bedrock wells, indicating a lack of dewatering and interconnection to historic mining activities.

Water-level monitoring continues to confirm that the flow of water in the affected bedrock aquifer is towards the Berkeley Pit. The potentiometric-surface map (fig. 2-40) for the East Camp bedrock aquifer shows the flow of water from all directions is towards the pit. While there were short-term influences on water levels in a number of these wells, the overall direction of groundwater flow did not change.

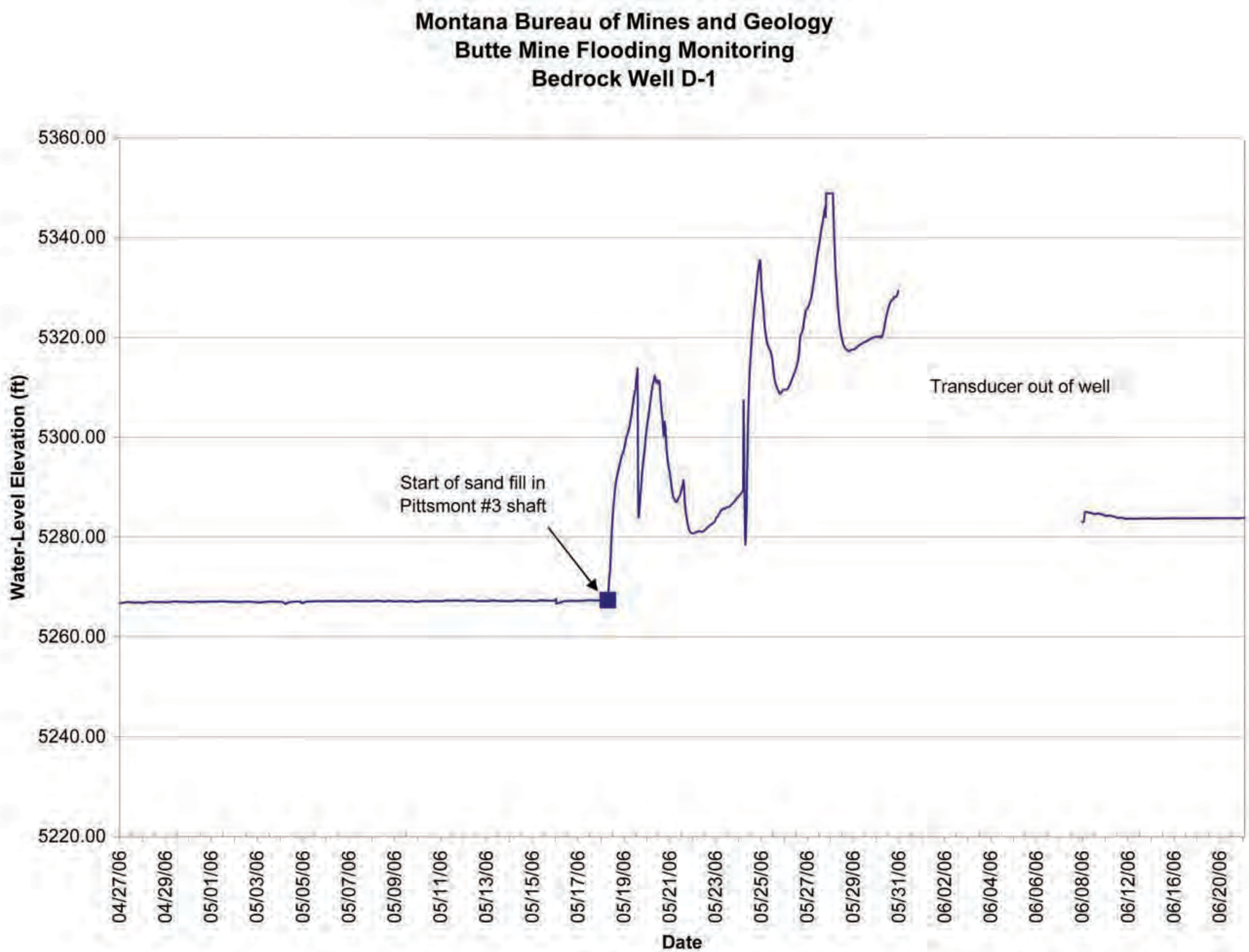

Figure 2-35. Hydrograph of well D-1 showing influence of Pittsmont #3 shaft back filling.

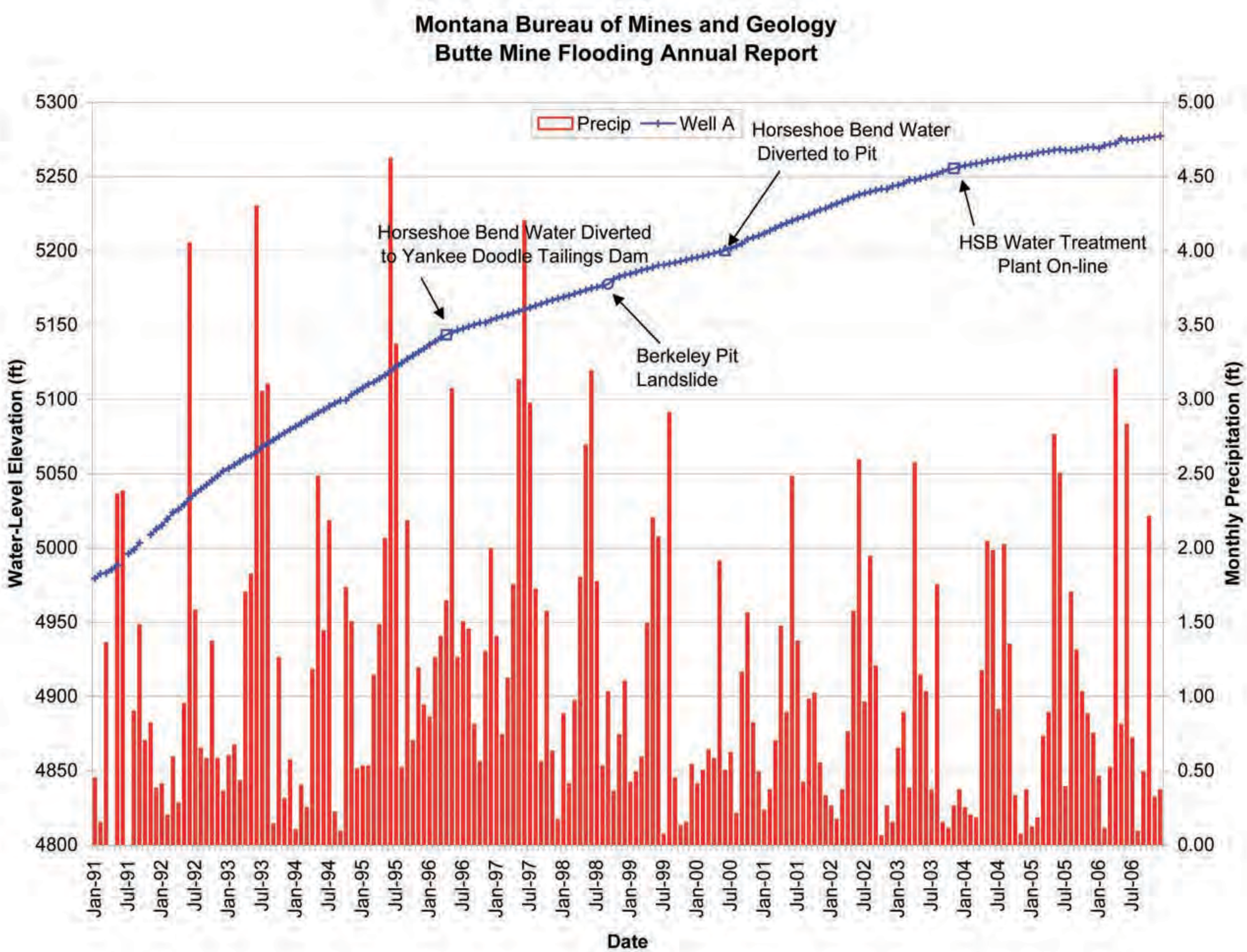

Figure 2-36. Water-level hydrograph for bedrock well A.

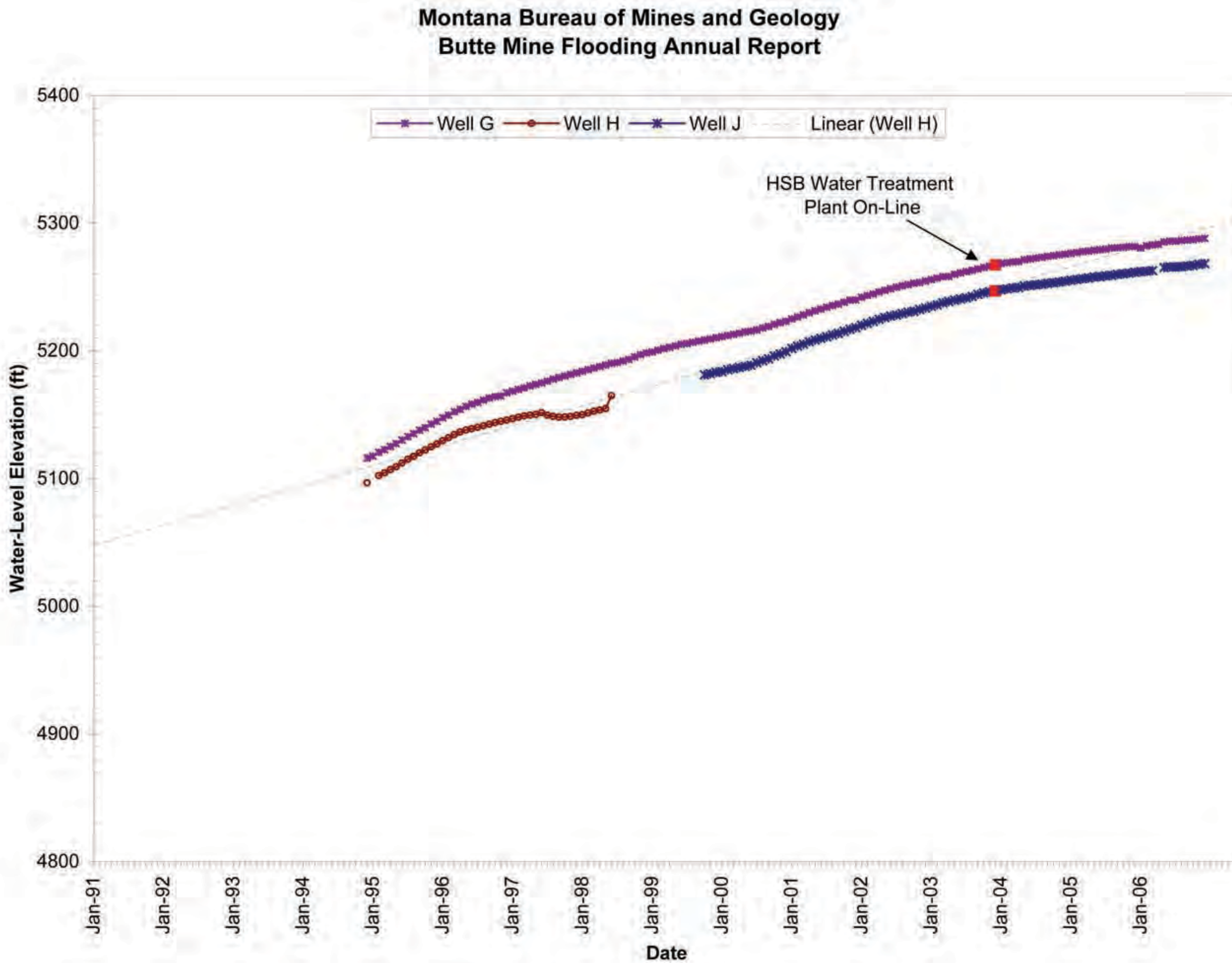

Figure 2-37. Water-level hydrographs for bedrock wells G, H, and J.

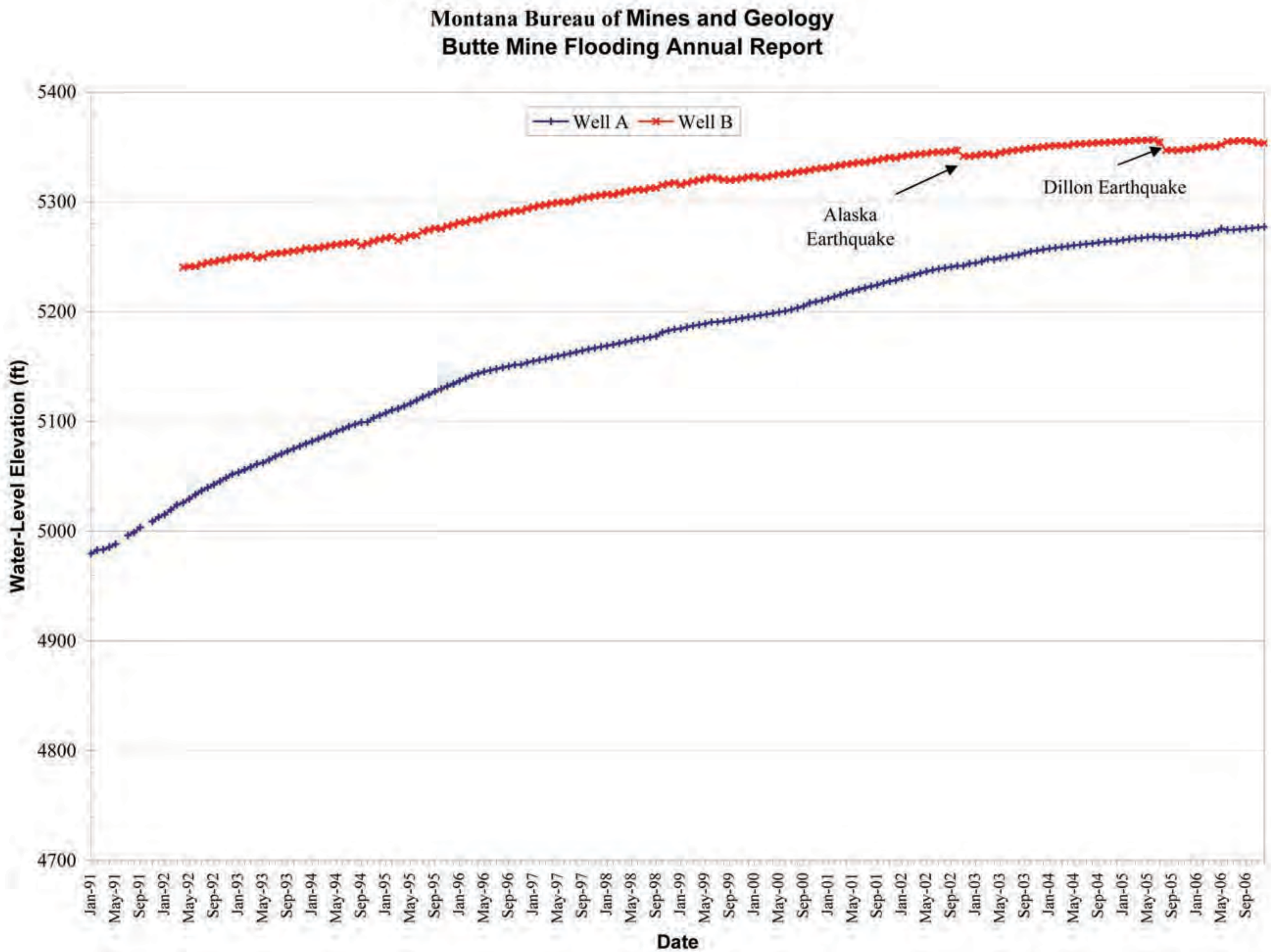

Figure 2-38. Water-level hydrograph for bedrock wells A and B.

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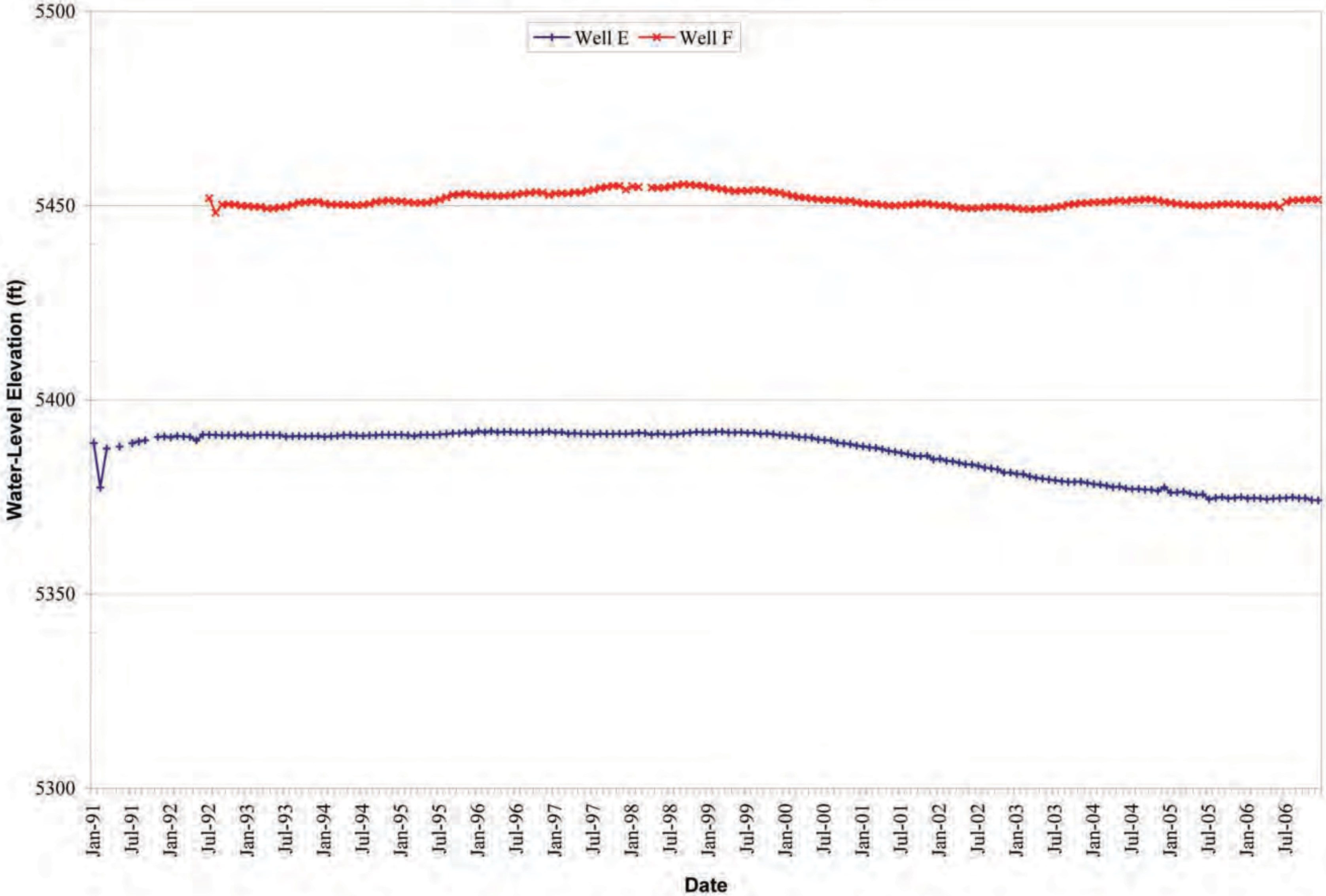

Figure 2-39. Water-level hydrograph for bedrock wells E and F.

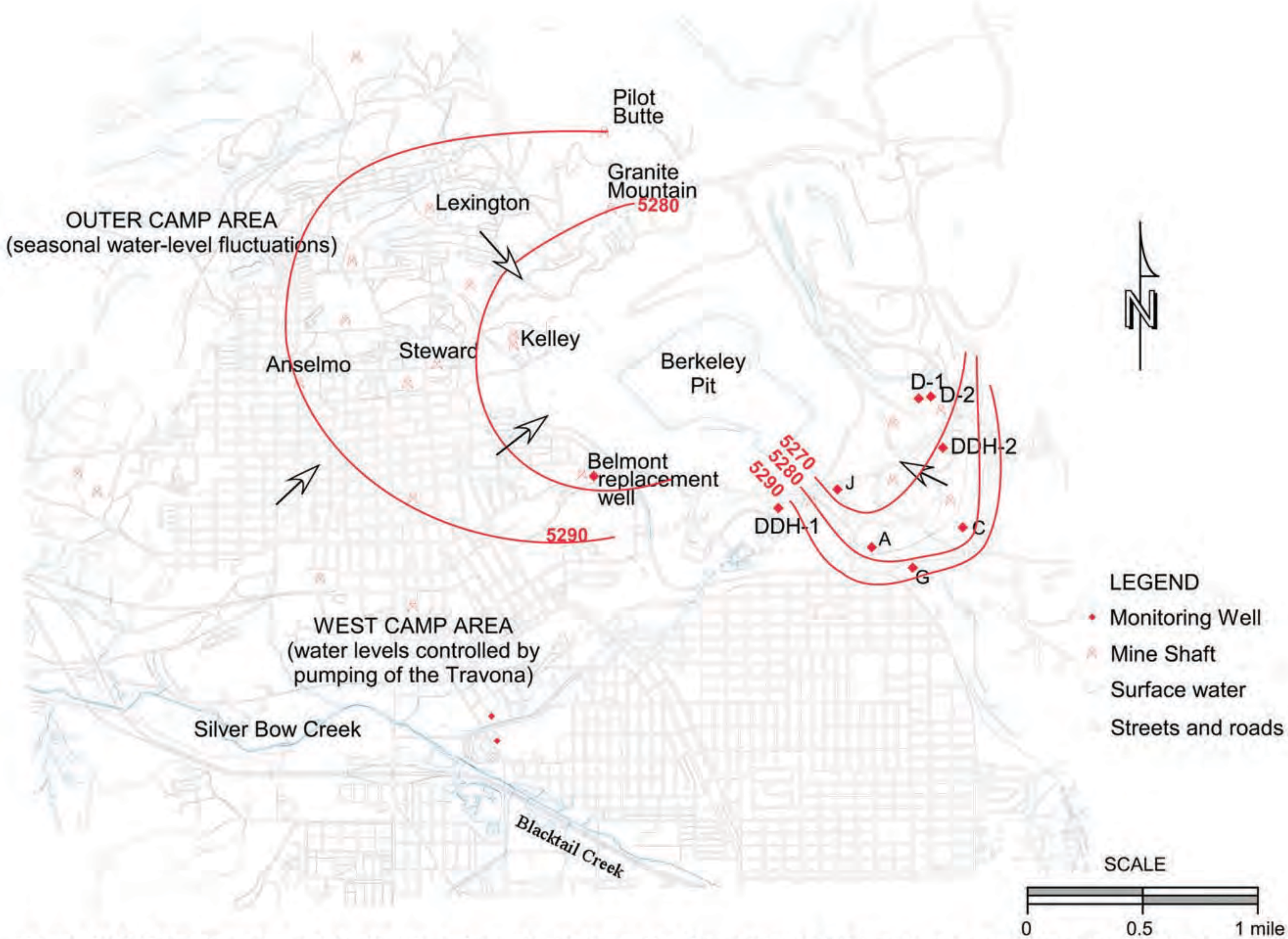

Figure 2-40. Potentiometric map for the East Camp bedrock aquifer, December of 2006; arrows indicate direction of ground-water flow (contour interval is 10 feet).

Section 2.2.2.1 RI/FS Bedrock Well Water Quality

Water quality in the East Camp bedrock wells has shown little change in recent years. Data collected in 2006 indicate only slight change for most wells. Table 2.2.1.1.1 summarizes the water-quality trends over the past few years; as noted in previous reports, the status of well B changed with respect to MCLs due to the change in the water-quality standard of arsenic from 18 ug/L to 10 ug/L. In most wells, there was little change in the concentration of dissolved constituents. Arsenic is the only MCL exceeded in the bedrock wells, while iron, manganese, zinc and sulfate are the SMCL's exceeded.

While a majority of sites exceed one or more secondary standards, the levels of concentrations between wells can vary considerably. Figure 2-41a shows iron and arsenic concentrations for the six bedrock wells sampled in 2006. As can be seen on figure 2-41a iron concentrations vary from less than 1 mg/L to greater than 350 mg/L; while arsenic concentrations vary from less than 2 ug/L to greater than 1350 ug/L.

Bedrock well J was installed into an area where workings from the Pittsmont Mine intersect the Berkeley Pit; the well is completed approximately 40-ft above workings from the Pittsmont Mine that extend to the pit. Water quality in this well has been very poor since its installation. This is not unexpected considering the close proximity of this well to the pit. Figure 2-41b is a comparison of selected trace metal concentrations for well J, the 1-ft deep Berkeley Pit sample and bedrock well A, which is located farther south. While the water quality is similar between the pit and well J, concentrations in well A are orders of magnitude less. This helps confirm the observations made by monitoring water levels that bedrock ground water flow is towards the pit and no contamination is leaving the site.

Table 2.2.1.1.1 Exceedences and recent trends for East Camp bedrock wells, 1989 through 2006.

Well Name	Exceedences (1 or more)	Concentration Trend	Remarks
A	Y	Unchanged	arsenic (MCL), iron, manganese, sulfate (SMCL)
B	Y	Unchanged	arsenic (MCL), iron, manganese, sulfate (SMCL)
C	Y	Unchanged	pH, iron, manganese, sulfate (SMCL)
D-1	Y		no longer sampled, replaced by well D-2
D-2	Y	Upward	arsenic (MCL), iron, manganese, sulfate, zinc (SMCL)
E	Y	Variable	sampled every two years, no 2006 sample
F	Y	Unchanged	sampled every two years, no 2006 sample
G	Y	Unchanged	pH, iron, manganese, sulfate (SMCL)
J	Y	Unchanged	very poor quality water

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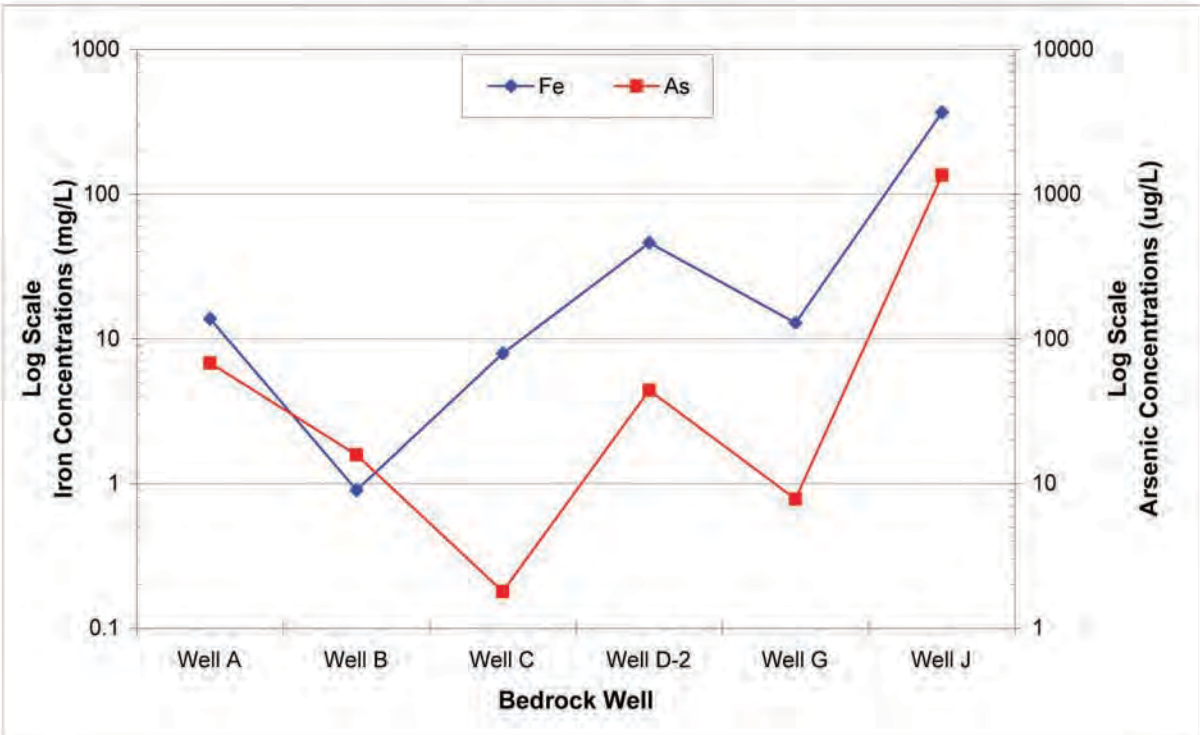

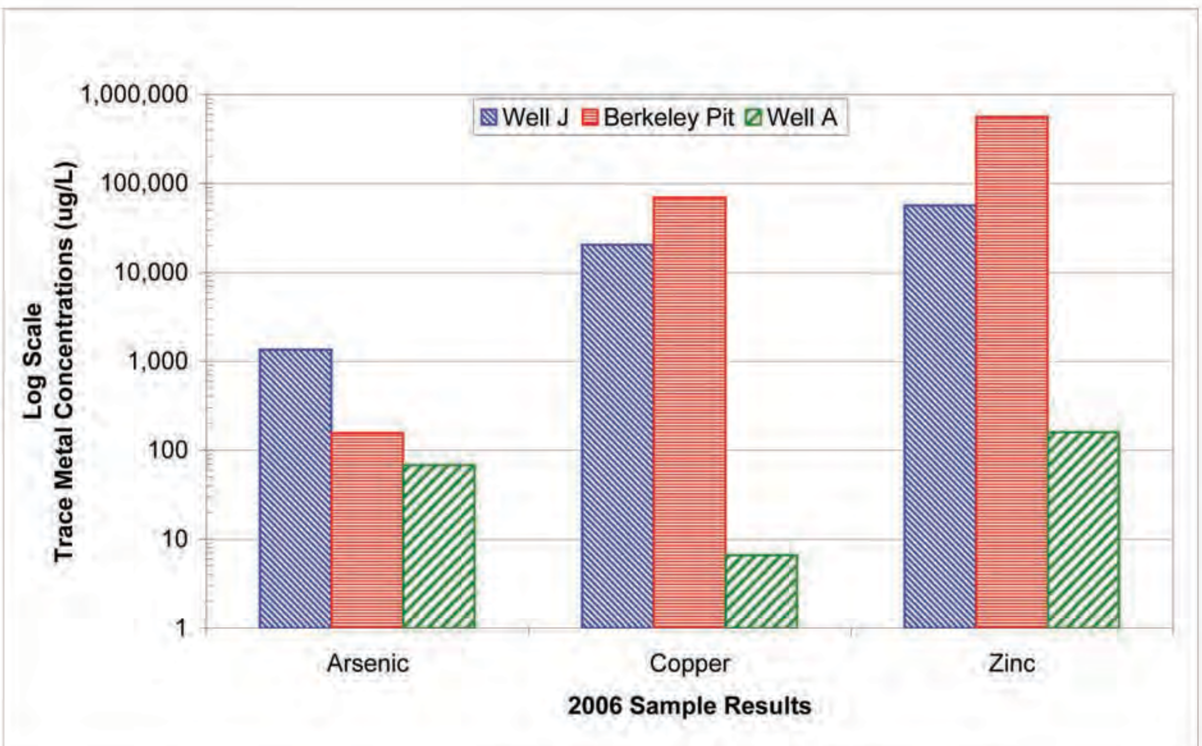

Figure 2-41a (top). Bedrock wells iron and arsenic concentration, 2006.
Figure 2-41b (bottom). Selected trace metal comparisons between bedrock well J, the Berkeley Pit 1-ft sample and bedrock well A.

Section 2.2.3 DDH Series Wells

Water-level monitoring of the DDH series wells continued. Water levels have continued to rise in these wells, following previous trends with the exception of well DDH-8. The water-level rise in wells DDH-1 and DDH-2 ranged from 6.3 to 6.7-ft in 2006. The rates of rise are consistent with those of the RI/FS bedrock wells and East Camp mine shafts. Figure 2-42 shows a hydrograph for well DDH-2 showing water-level increases. Once again, precipitation does not show any affect on water-level rise. Well DDH - 8 had an unexplained water-level increase during August 2005. Its water level rose over 52-ft during the month. During this time the 2-inch PVC casing was removed and a submersible pump was installed to test the water for possible irrigation use. The water level rise began prior to the well pumping and continued after its completion. Nothing out of the ordinary was noted during the pumping to account for the abnormal water-level change. During the remainder of the year water-level changes were similar to those of the other DDH series wells. The water-level rise in this well during 2006 was similar (6-ft) to the other bedrock wells, however, the water-level elevation is over 50-ft higher that the other bedrock wells due to the unexplained 2005 increase. It is important to note that the DDH wells were not installed for monitoring purposes, they are old exploration holes that extend several thousand feet below ground surface and have various size casings installed. Due to completion uncertainties and the drilling techniques it is not unexpected to have problems occur with these wells. In the past, another well (DDH-6) had to be plugged and abandoned due to casing integrity problems.

No water-quality samples were collected from these wells, as they are used only for water-level monitoring.

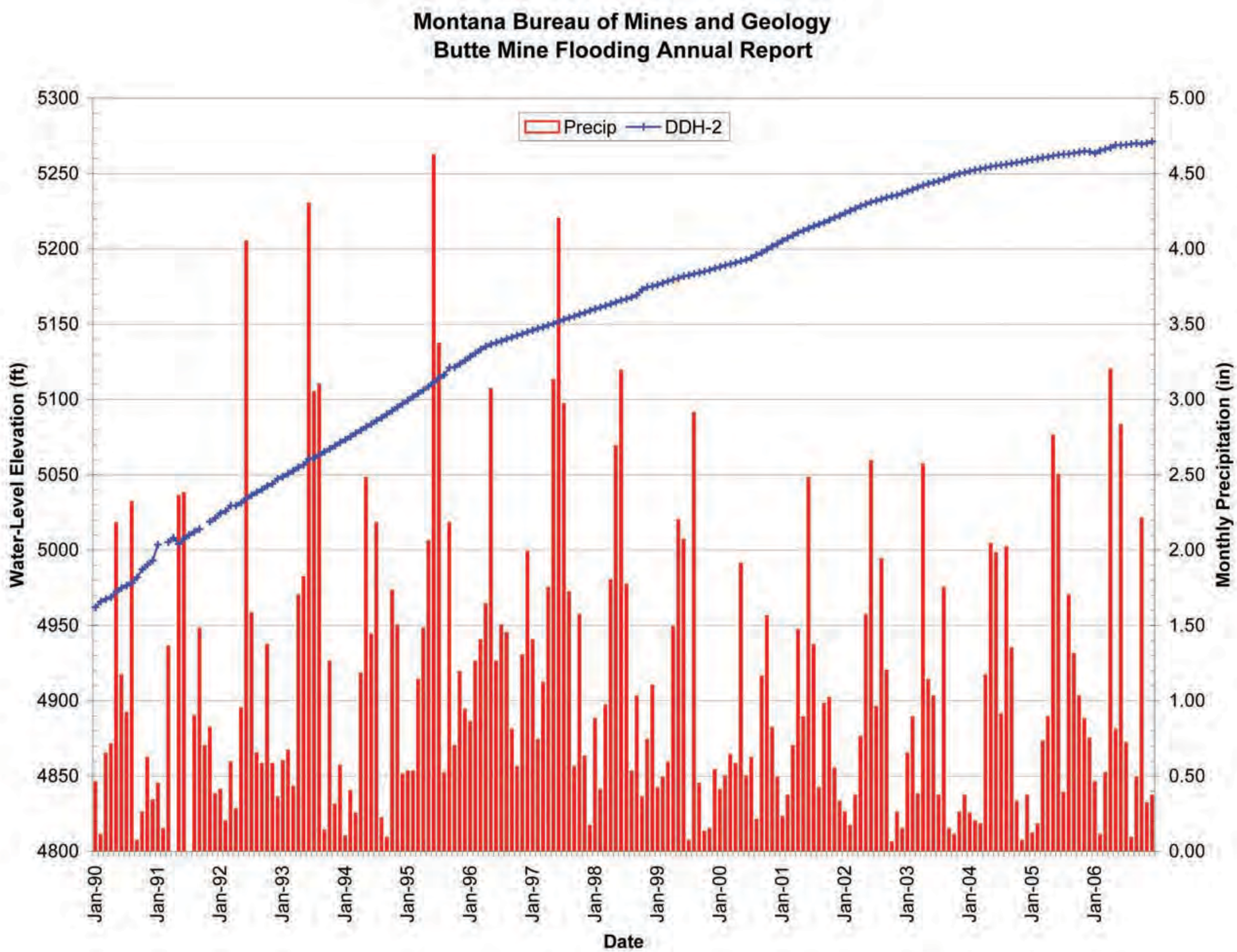

Figure 2-42. Water-level hydrographs for bedrock well DDH-2.

Section 2.3 Berkeley Pit and Horseshoe Bend Drainage

The Berkeley Pit water-level elevation was surveyed each month to coincide with monthly water-level monitoring in wells and mine shafts. Figure 2-43a is a hydrograph showing the pit's water-level rise over time; while figure 2-43b is a hydrograph showing water-levels changes since 1995.

The overall trend is similar to that of previous years. There are four noticeable changes on figure 2-43b which show the influence of physical changes on water-level rise. The first change represents a decrease in the filling rate (seen as a change in slope on the graph) when the HSB drainage diversion occurred in April of 1996; the second is an almost instantaneous water-level rise from the September 1998 landslide; the third depicts an increased filling rate (seen as a change in slope on the graph) following MR's June 2000 suspension of mining and the subsequent inflow of water from the HSB drainage to the pit; and the fourth shows the decrease in filling rate as a result of the HSB water-treatment plant coming on-line in November 2003 and the diversion of HSB drainage water away from the pit. From April 1996 through June 2000, water from the HSB drainage was diverted and incorporated into the mining and milling process. Following the June 2000 suspension of mining, water from the HSB drainage was again allowed to flow into the Berkeley Pit. The volume of water allowed to enter the pit exceeded 3.2 billion gallons from July 2000 through November 2003 when the water-treatment plant became operable. This represents an average flow of 1,820 (gpm) during the period of mine suspension. The overall Berkeley Pit water-level rise for 2006 was 7.69-ft compared to 7.03-ft in 2005, 7.68-ft in 2004 and 13.08-ft in 2003.

The 2002 CD contains a stipulation that the water level in the Berkeley Pit remain below those of other East Camp monitoring sites, referred to as the points of compliance. The CD identified 4 mines and 4 bedrock monitoring wells as the points of compliance. They are shown in Table 2.3.1 along with their December 2006 water-level elevation and the distance below the CWL. The Berkeley Pit water-level elevation is included with this table as a reference only. Based upon this information the current compliance point is the Pilot Butte Mine, which is located to the north of the pit.

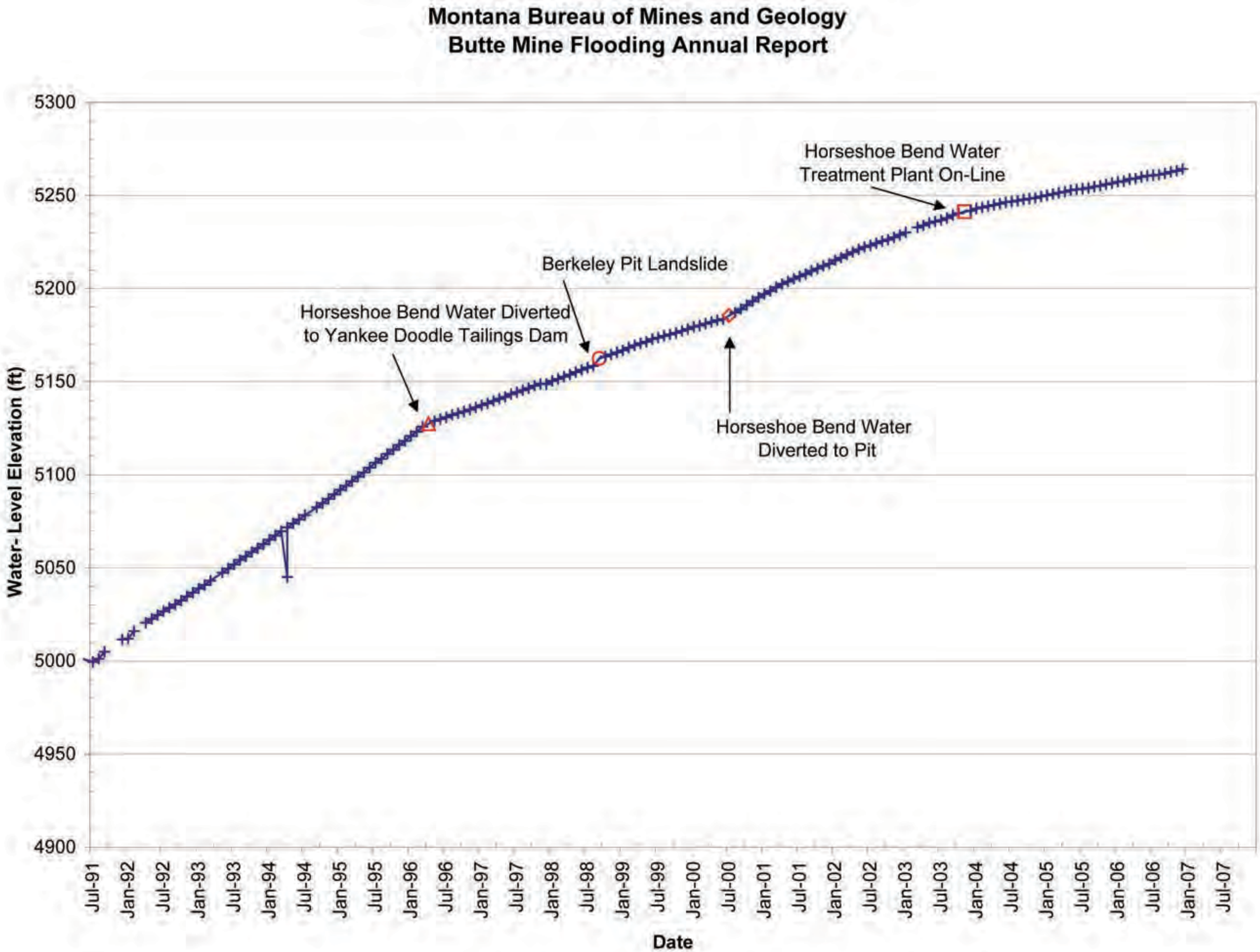

Figure 2-43a. Water-level hydrograph for the Berkeley Pit.

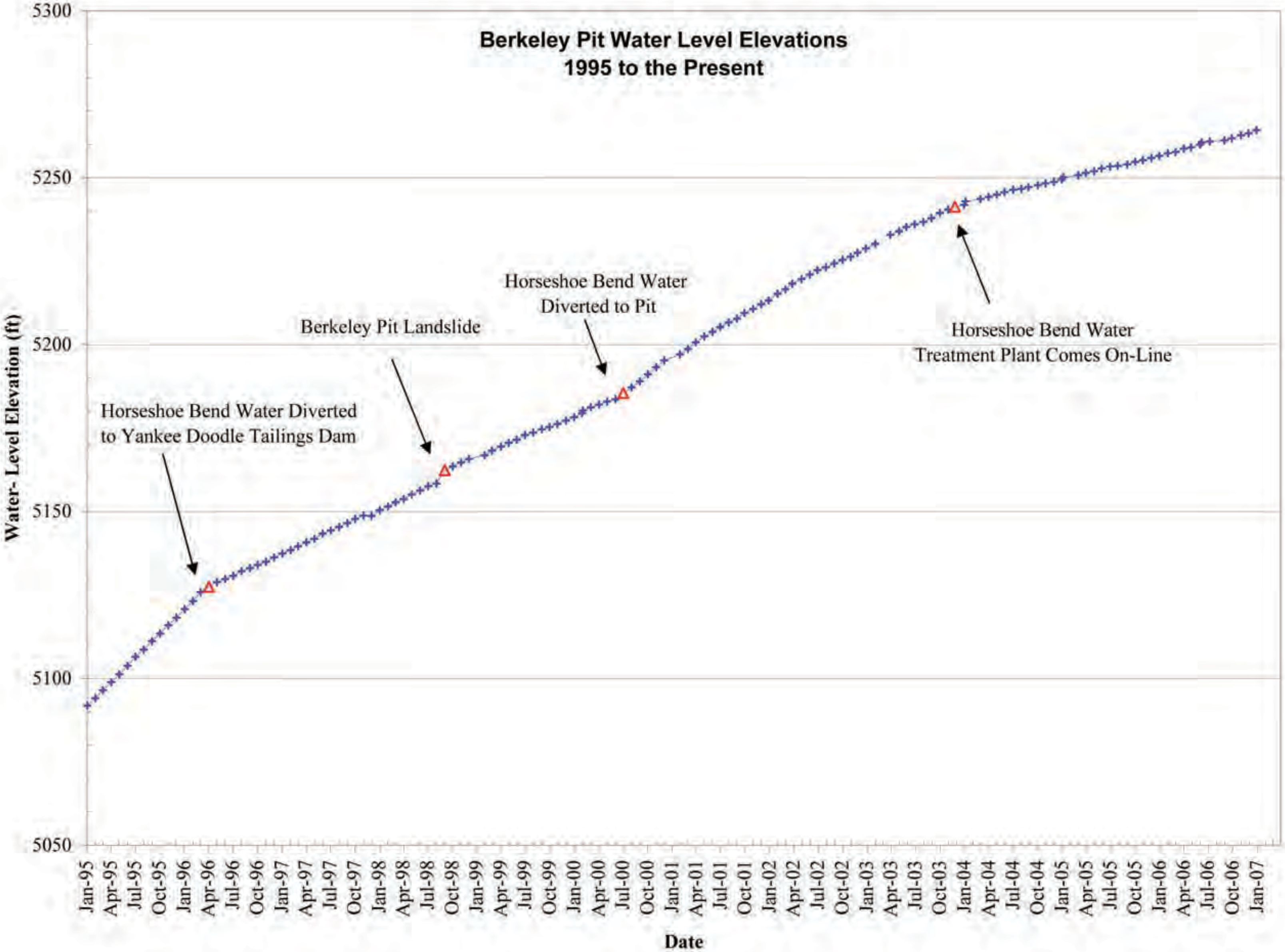

Figure 2-43b. Water-level hydrograph of Berkeley Pit, 1995-2006.

Table 2.3.1. East Camp Points of Compliance and Depth Below CWL, December 2006.

Point of Compliance	December 2006 Water-Level Elevation (ft)	Depth Below CWL (ft)
Anselmo Mine	5289.61	120.39
Granite Mountain Mine	5279.94	130.06
Pilot Butte Mine	5290.03	119.97
Kelley Mine	5275.22	134.78
Belmont Well #2	5276.02	133.98
Well A	5277.33	132.67
Well C	5277.16	132.84
Well G	5288.10	121.90
Berkeley Pit (not a compliance point)	5264.28	145.72

Flow monitoring of the Horseshoe Bend drainage continued throughout 2006. As discussed in previous reports, the 90^0 V-notch weir was relocated upstream in the HSB drainage to accommodate infrastructure changes associated with the water-treatment plant construction. Construction activities affected flow monitoring at times from April through October 2002, however, there have been no major disruptions of monitoring activities since then. Ice build-up on the holding pond and bio-fouling of the transducer used to measure flow are on-going problems associated with monitoring at this site. However, more frequent site visits to clean the transducer and note gauge height readings have helped to minimize problems. The average daily flow rate was 2,814 gpm for 2006, an increase of almost 800 gpm from last year and almost 1,600 gpm more than 2004. A total of 1.34 billion gallons of water flowed through this site for treatment in the HSB water treatment plant. Figure 2-44 shows the daily average flow rate from July 2000 through December 2006.

Flows measured at the HSB Falls flume averaged 978 gpm for the year, an increase of more than 450 gpm from 2005 and more than 800 gpm from 2004. This flow is approaching the historic flow rates of 1,000 gpm or more reported by MR. Figure 2-45 shows both historic flow rates when MR operated this site and current flow rates since the MBMG began monitoring. The increased flow from this site accounts for more than one-half the total flow increase seen for the entire HSB drainage; the remaining increases most likely coming from a combination of other seeps in the drainage.

Based upon the flow data recorded during both the 2000-2003 mine suspension and flows since then, the operation of the Yankee Doodle Tailings Dam as a disposal area for mill tailings is very important in the flow of water from the HSB drainage.

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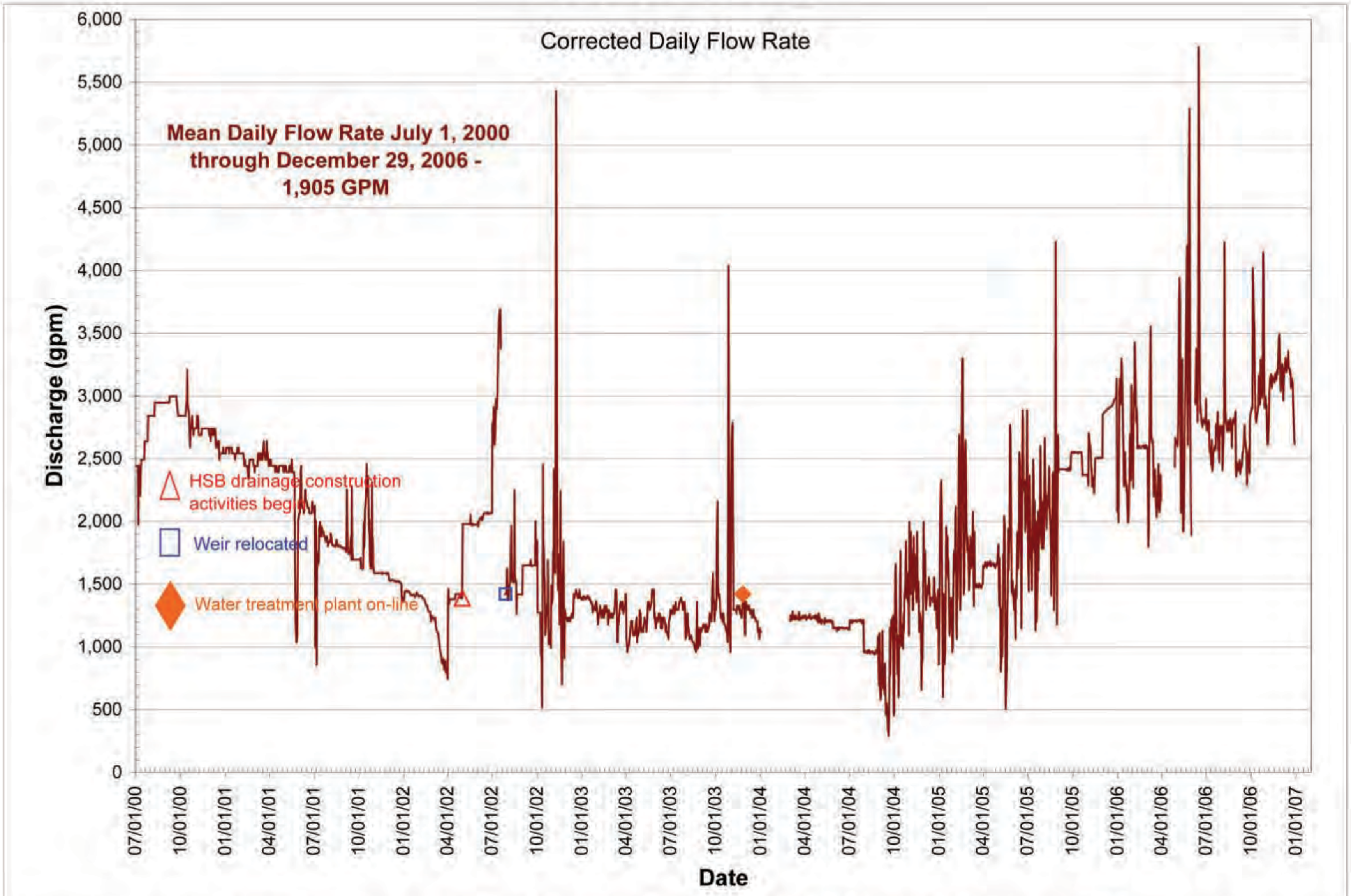


Figure 2-44. Horseshoe Bend drainage flow rate, July 2000 through December 2006.

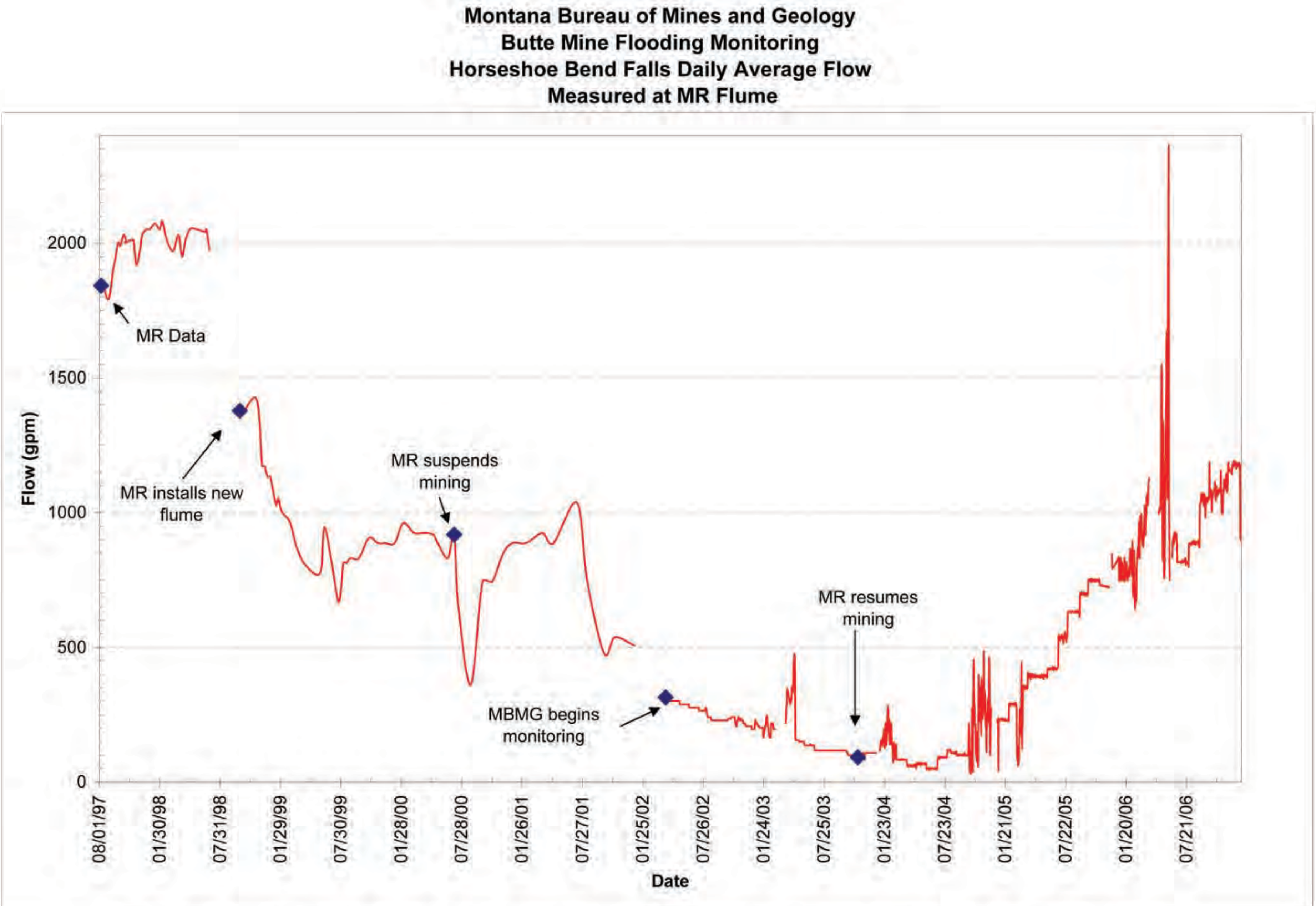


Figure 2-45. Horseshoe Bend Falls long-term daily average flow rates, includes both MR and MBMG data.

Section 2.3.1 Berkeley Pit and Horseshoe Bend Drainage Water Quality

Water-quality sampling of the Berkeley Pit occurs twice per year and is timed to replicate spring and fall conditions within the pit water column, in an effort to determine if turnover occurs within the water column. Samples are collected at a minimum of three depths. In addition to collecting samples for inorganic analysis, a vertical profile throughout the upper portion (0-300-ft) of the water is performed that measures in-situ physical parameters. The physical parameters measured are: pH, specific conductance, temperature, oxidation-reduction-potential, and dissolved oxygen. Turbidity is measured periodically.

Water-quality samples are collected monthly from the Horseshoe Bend drainage at the weir used for flow monitoring. This site is just upstream of the influent pond associated with the HSB water treatment plant. Therefore, this water is representative of the water entering the plant for treatment.

Section 2.3.1.1 Berkeley Pit Water-Quality Sampling and Monitoring Overview

It took 19 months (April 1982-November 1983) for the flooding underground mine waters to reach the elevation of the bottom of the Berkeley Pit, however, water had been accumulating in the pit bottom from contaminated surface water sources that were diverted into the pit in 1982 and again in 1983 for containment. The first water samples were collected from the pit in the fall of 1984. These samples and the 1985 samples were collected using a helicopter that hovered above the water surface (figure 2-46a). A point source bailer was lowered from the helicopter into the pit water. Sampling in 1986 (figure 2-46b) and 1987 used a helicopter to ferry in boats which were used for sample collection. Much more accurate sampling and vertical profiling of the pit water column were accomplished during these events. By the summer of 1991 the water-level within the pit reached a point that old haul roads could safely be re-opened, allowing sample crews to drive to the water's edge. Since that time samples have been collected from a temporarily installed stationary platform (figure 2-46c) or boats, which allowed the collection of high quality data.

MR purchased a pontoon boat in 1996 for use in their waterfowl monitoring program. They have allowed the MBMG use of this boat for monitoring and sampling activities since (figure 2-46d).

Figure 2-46a. 1985 Berkeley Pit sampling event.

Figure 2-46b. 1986 Berkeley Pit sampling event.

Figure 2-46c. MBMG sampling platform being located in the Berkeley Pit, 1991.

Figure 2-46d. MR pontoon boat is used for Berkeley Pit sampling. Boat is docked next to pump station used for pumping pit water to precipitation plant for copper recovery. (Photo courtesy of Daryl Reed, DEQ.)

Section 2.3.1.2 Berkeley Pit Water Chemistry

Currently the Berkeley Pit is approximately 850-ft deep, consisting of roughly 37 billion gallons of low pH, high saline water. Since flooding of the Berkeley Pit commenced in 1982, the MBMG has been the primary agency that has consistently collected, analyzed, and interpreted the data. Prior to 2001, water-quality samples were collected when deemed necessary, i.e. during the RI/FS investigation, with records going back as far as November 1984. Water quality in the Berkeley Pit has been monitored on a bi-annual basis since the spring of 2001, as per terms of the 2002 CD. This report focuses primarily on the data collected since that time, as it is consistent and precise data. Data collected prior to 2001, though accurate, is not as consistent as the semi-annual monitoring which began in 2001, and is for the most part excluded from this report. Records dating back to November 1984 are published and can be found on the online MBMG Ground-Water Information Center website (GWIC 2007). A recent publication by Gammons and Duaime (2006) focuses on the long-term changes in the limnology and geochemistry of the Berkeley Pit Lake System.

Throughout the years, changes in water quality in the Berkeley Pit may be linked to a number of factors such as seasonal changes, occurrence of landslides, MR copper recovery operations, dumping of high density sludge into the Berkeley Pit from the HSB water treatment plant, and the diversion of HSB water into and away from the pit surface water. The following sections attempt to determine the factors associated with some of the recent water-quality changes.

2.3.1.3 Physical Parameters

Physical parameters of pH, specific conductance (SC), oxidation reduction potential (ORP), and temperature were measured in-situ using Hydrolab multi-parameter sampling equipment from 0 -300-ft. Equipment constraints prevented deeper in-situ depth measurements. Seasonal changes in physical parameters for the 2006 sampling season can be found in figure 2-47, and long-term (2001-2006) changes can be found in figure 2-48.

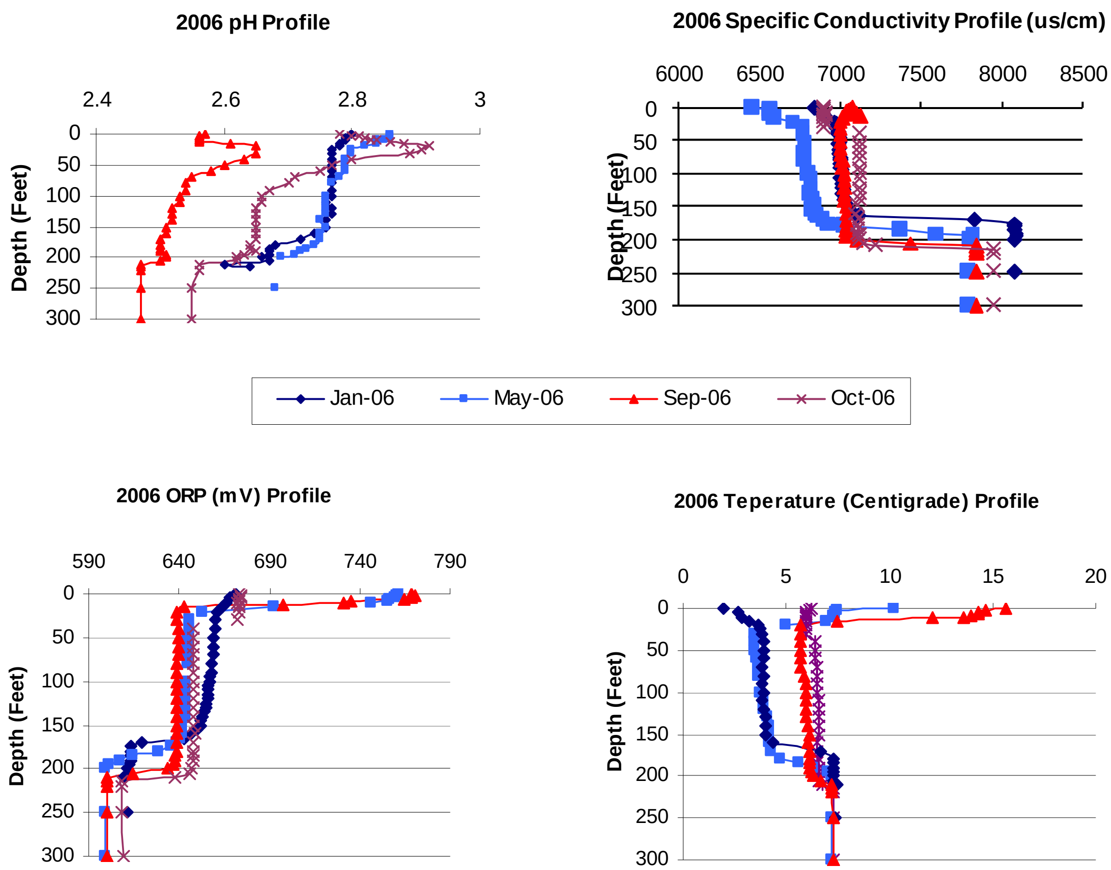


Figure 2-47. 2006 Seasonal depth profiles for the Berkeley Pit Lake System.

The diagram in the upper-left shows pH profiles as a function of depth, whereas the diagram in the upper-right illustrates SC depth profiles. The lower-left diagram is a depth profile of oxidation-reduction potential, and temperature profiles are given in the lower right diagram of the figure. A total of four profiling events occurred in 2006, all of which are illustrated above.

Data collected in the fall are shown for five years: 2001, 2003, 2004, 2005, and 2006. All data were collected by members of the MBMG. Both 2001 and 2003 data represent a time when HSB water was being diverted into the Berkeley Pit, and is a representation of the three year period when HSB water was allowed to collect in the Berkeley Pit. In November 2003, the lime treatment plant began to capture and treat HSB water, and the 2004, 2005, and 2006 events represent one, two, and three-year post

HSB diversion intervals respectively.

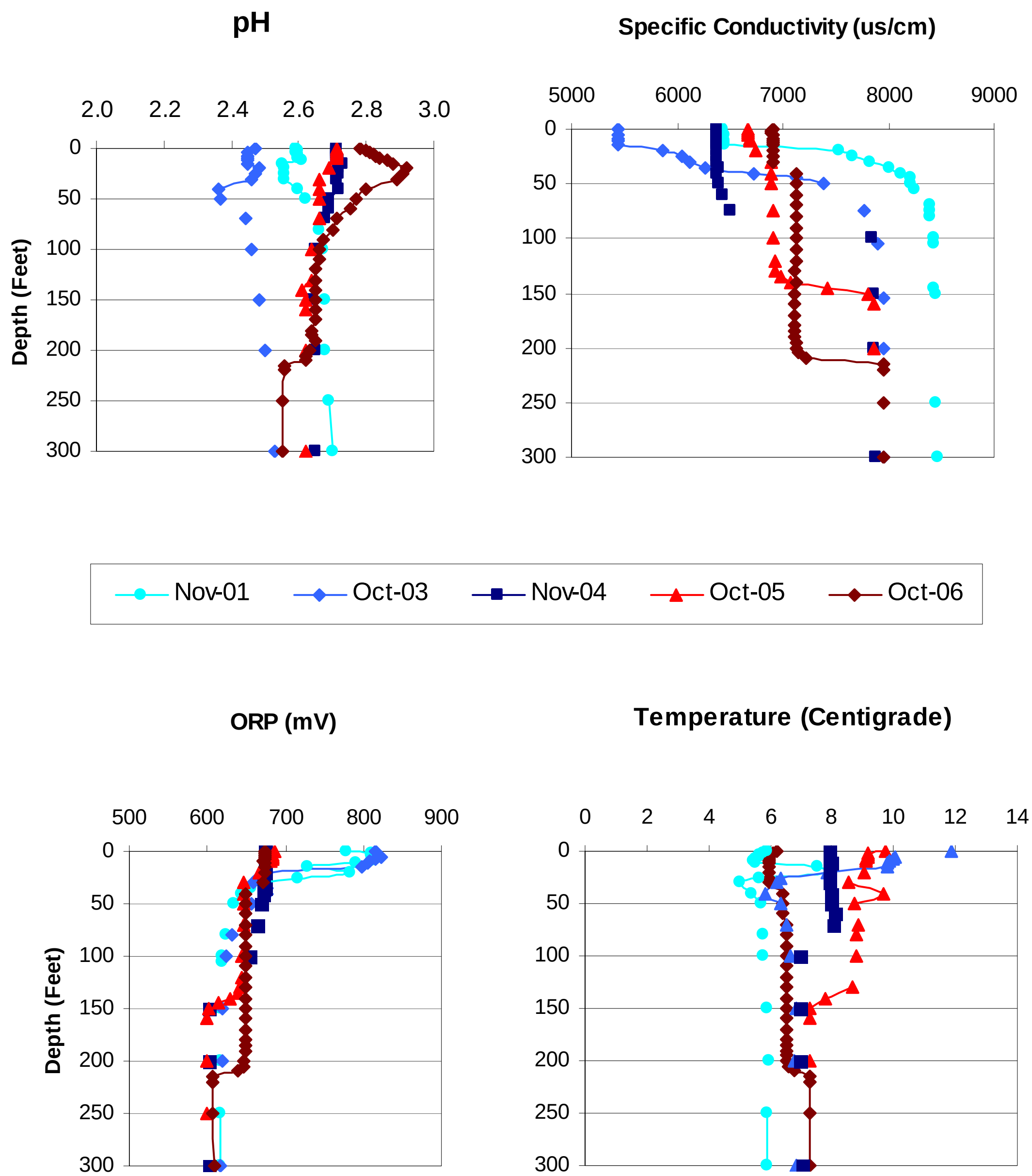


Figure 2-48. Long-term changes in depth profiles for selected parameter in the Berkeley Pit Lake. All data from all years are representative of fall sampling events, and were collected by the MBMG.

As a general rule, pH in the Berkeley Pit remains between 2.4 and 2.8. At depth, little change has been noted over the years. In recent years, pH in surface-waters has shown a slightly increasing trend. A possible explanation for this occurrence may be the impacts of high density sludge on pit surface waters from the HSB treatment plant. Since November 2003, pH neutralizing sludge has been discarded into the Berkeley Pit as a waste product from the treatment plant at a rate of 265,000 gallons per day. Though this volume is small (~180 gpm) compared to that of the Berkeley Pit, a cumulative impact may be starting to occur. Of course, pH values > 2.8 have been observed before, but only when HSB (pH value ~3.0) water was infiltrating the pit surface waters. Currently, HSB water has not entered the Berkeley Pit for 3 plus years.

Temperature profiles suggest three thermally-stratified zones in the Berkeley Pit. The first and second zones are delineated by the thermocline, a thermally-stratified boundary which is seasonal and dependent upon ambient air temperatures. A thermocline is defined as a 1°C difference for every 3-ft. of vertical change in the water column. The second boundary, the chemocline, is an area of density stratification which formed when HSB water was allowed to collect on top of the more dense Berkeley Pit water. The chemical differences between the two waters prevented mixing, and HSB water pooled on top of Berkeley Pit water, and the boundary between them is coined the chemocline. The formation of these two boundaries forms three zones, the epilimnion (upper most layer), metalimnion (middle layer), and the hypolimnion (bottom layer). The relationships between these layers can be observed in seasonal depth profiles.

Seasonal temperature profiles (figure 2-47) suggests that a thermocline exists during the summer and winter months. During winter, colder air temperatures influence the shallow waters, creating a column of water which is colder than the water below it. Inversely, warmer air temperatures in the summer create thermal stratification with warmer waters on top of colder. During early spring and late fall, the effects of air temperature create water temperature in the shallow epilimnion that are constant with the metalimnion waters, and mixing between the first two zones is possible. Also apparent in the thermal profile, below the seasonal thermocline, is the chemocline present at a depth > 150-ft. In recent years, the chemocline has been a permanent layer, though recent changes in pit water management may alter the fate of this layer.

In recent years, the depth of the chemocline has been dropping. This trend is noticed in all depth profiles, and is a direct result of MR's copper recovery operation. Water is pumped from depth (currently >300-ft) in the pit to the precipitation plant where the copper is removed through the copper cementation process. The iron rich water is then returned to the pit. This action is resulting in some interesting water-quality changes which are worth noting. The effects of the copper cementation process are best observed in the specific conductivity profile (figure 2-48). Prior to January 2004 the depth of the chemocline, though variable, remained above 50-ft below water surface. Since that time, the copper-recovery process has drawn down the chemocline at an average rate of 60-ft per year. This rate is increasing as the diameter of the pit walls narrow. As of October 2006, the depth of chemocline was 215-ft, and at the current rate, the chemocline will disappear in 2 years time. Currently, it is unknown what will happen to the water chemistry as a result. Frequent turn-over events are a possibility, which could worsen water quality.

Additionally, depth profiles of specific conductance and oxidation reductions potential appear to show surface waters more saline and reducing with time. Physical parameters (SC and ORP) of surface waters are approaching that of the deeper waters. If homogenous conditions were to be reached and the chemocline eliminated, top to bottom turn-over could occur, and oxygen may be introduced into deeper Berkeley Pit waters. This could further affect the water quality of the entire system.

2.3.1.4 Chemical Parameters

Interesting changes in the chemistry of the Berkeley Pit have occurred as a result of copper recovery activities and diversion of HSB water away from the Berkeley Pit since 2004. Water-quality samples for chemical analysis were collected by the MBMG at three depths on a bi-annual basis, and results were published on the MBMG online database entitled Ground-water Information Center (GWIC 2007). This database contains a large amount of data pertaining to the water quality of the Berkeley Pit. This section discusses some of the recent water-quality changes in chemical parameters that have been observed.

The copper-recovery process extracts water at depth (>300-ft below the water surface) below the chemocline, where copper concentrations are higher than shallower depths. This water is then passed over scrap iron where the copper plates onto the iron through a process known as oxidative-reductive ion exchange. Dissolved iron replaces the copper in solution, and this iron rich, low copper water is discharged to the surface water of the pit. The chemistry of these waters is illustrated in Table 2.3.1.4.1. Influent and effluent samples from the copper-precipitation process were taken in October of 2006, and are represented in the table as precip-in and precip-out respectively. Influent samples are consistent with the depth in which they were extracted from (~ 700-ft below surface (fbs)). Effluent samples, as a result of the ion exchange process are lower in copper concentrations and higher in iron concentrations.

Table 2.3.1.4.1 Water composition which currently represent the Berkeley Pit Lake System.

	pH	SC	Ca	Mg	Na	K	Fe	Mn	Al	Cu	Zn	As	SO_4
Precip-in	2.97	7,850	449	504	76	7	949	239	268	162	608	0.07	8,946
Precip-out	3.21	7,959	441	493	77	7	1,222	235	265	17	605	0.07	9,870
BP Surface	2.78	6,903	459	498	75	9	538	246	255	72	565	0.12	7,459
BP 700 fbs	3.05	7,959	438	492	75	7	924	232	263	158	594	0.06	8,218

All data shown in this table are from the October 2006 sampling event. All data are in mg/L except pH (standard units) and SC (us/cm@25^{o}C).

Currently, the copper precipitation process is recycling deep Berkeley Pit water to shallow Berkeley Pit water at an approximate rate of 10,000 gpm. This process has been in operation since 2004, and has had significant impacts on the chemistry of the surface water. Figure 2-49 represents time-series plots for the major ions in solution at all depths. Concentrations of Al, Fe, Mg, Mn, and Zn have all increased significantly in the surface samples, a trend not observed at other depths, with the exception of iron. Iron concentrations decreased at 100-ft in May-05 and at the 200-ft level in Oct-06; observations which correspond well with the location of the chemocline. As the chemocline dropped below a certain depth, iron concentrations at that depth decrease by 50%, a trend recorded at both the 100-ft and 200-ft levels. This trend was not observed at 700-ft, which remains well below the chemocline.

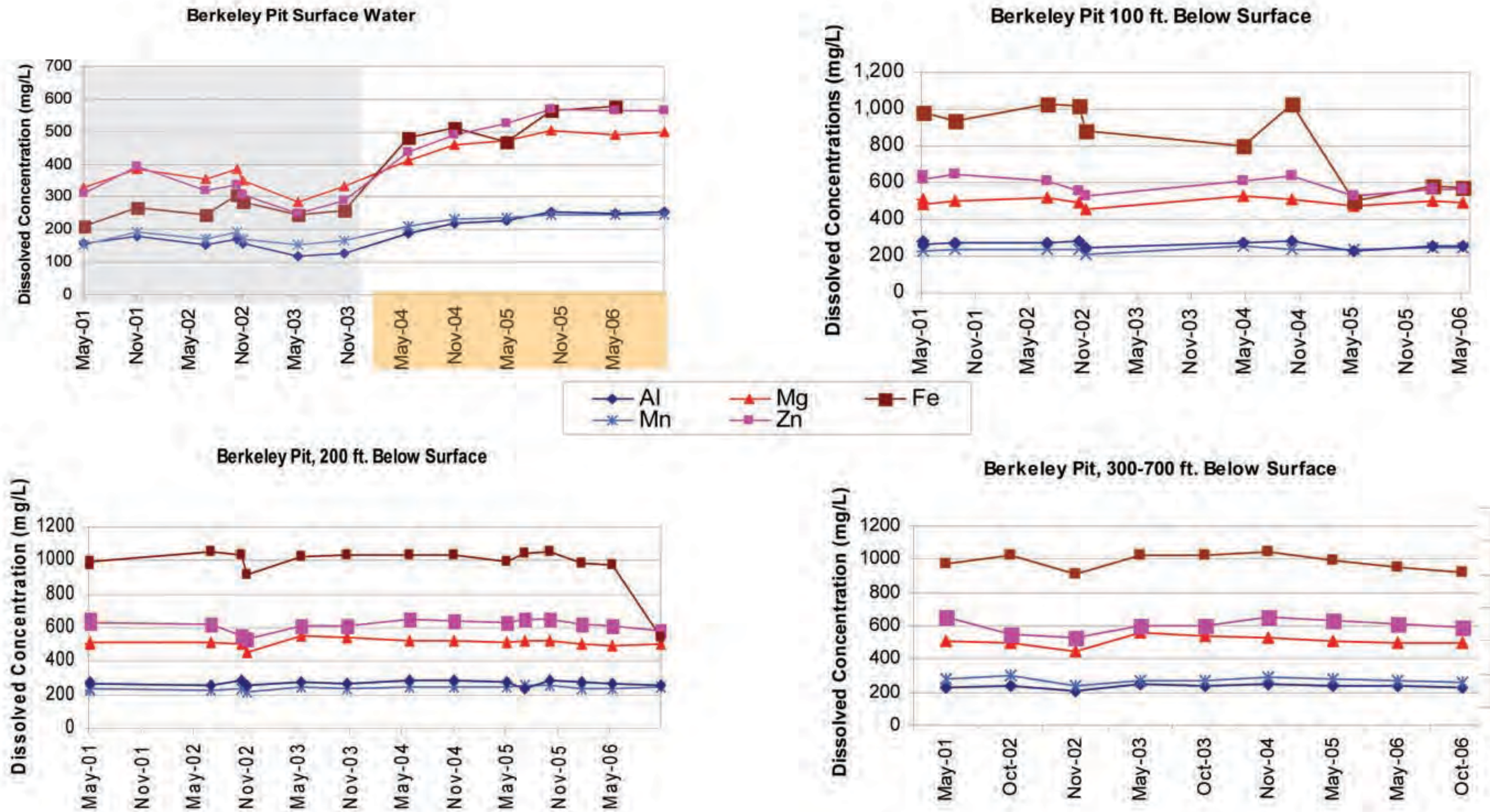
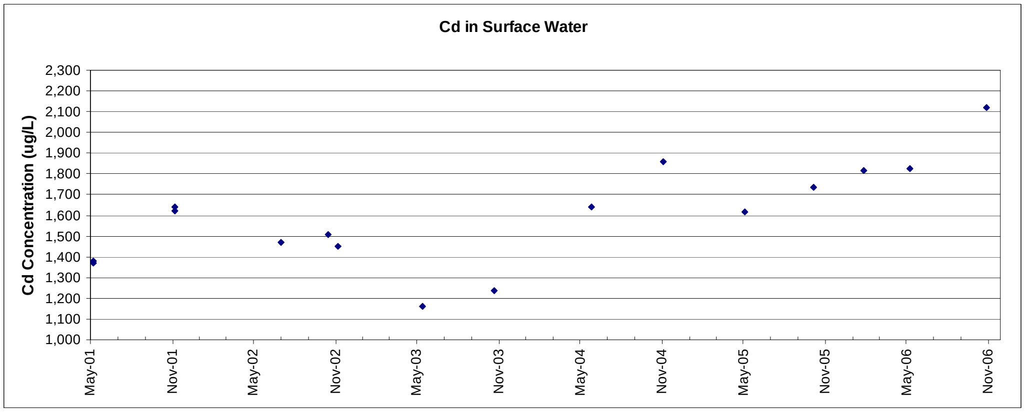
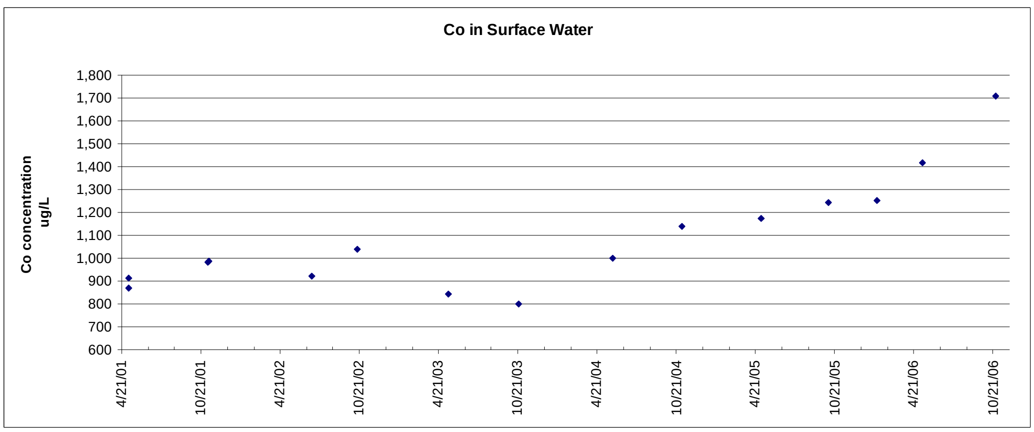


Figure 2-49. Long-term changes in dissolved concentrations of Al, Fe, Mn, Mg, and Zn at four depths in the Berkeley Pit Lake. The shaded green area in the surface-water show the period when Horseshoe Bend was diverted into the Berkeley Pit. The dates highlighted in brown show the period of copper-recovery.

Figure 2-50 shows the increasing trends of three other elements in the pit surface water. Dissolved concentrations of Cd, Co, and U all appear to increase significantly with time. Again, these increases appear to be a result Horseshoe Bend diversion and copper-recovery.





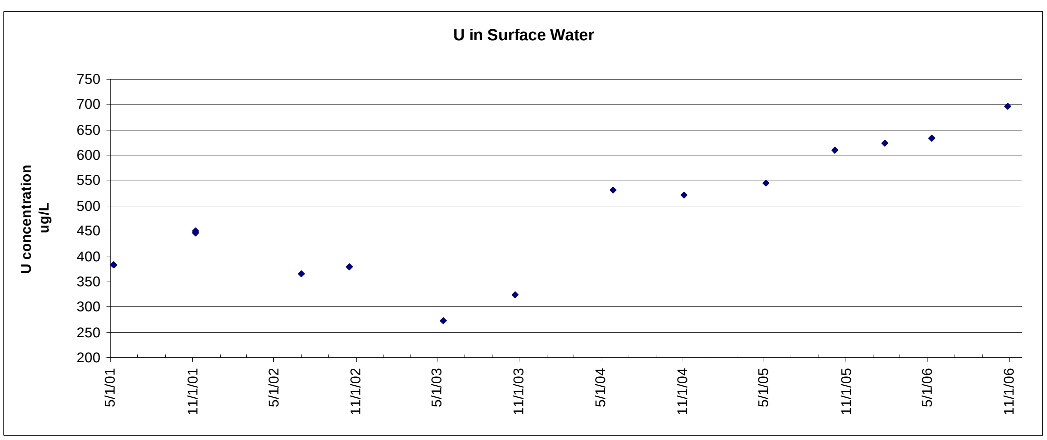
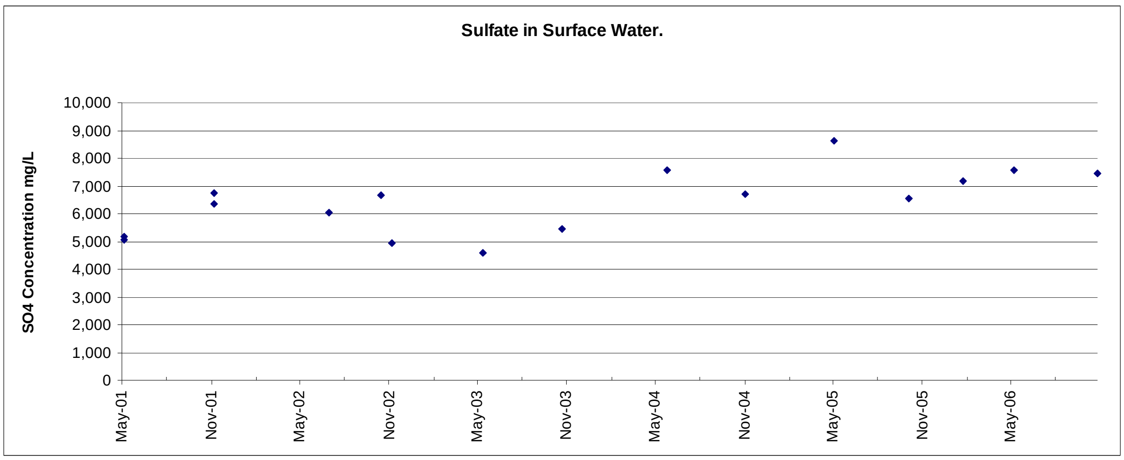


Figure 2-50. Change in the concentration of selected solutes in the Berkeley Pit surface water.

Trends for copper and sulfate concentrations in surface water appear to be remaining stable over time although copper concentrations in effluent samples from the copper cementation process are much lower than ambient surface water conditions (17 ppm vs. 72 ppm respectively). Sulfate concentrations in effluent samples are much higher than ambient surface water conditions and therefore, the inverse trend would be expected.



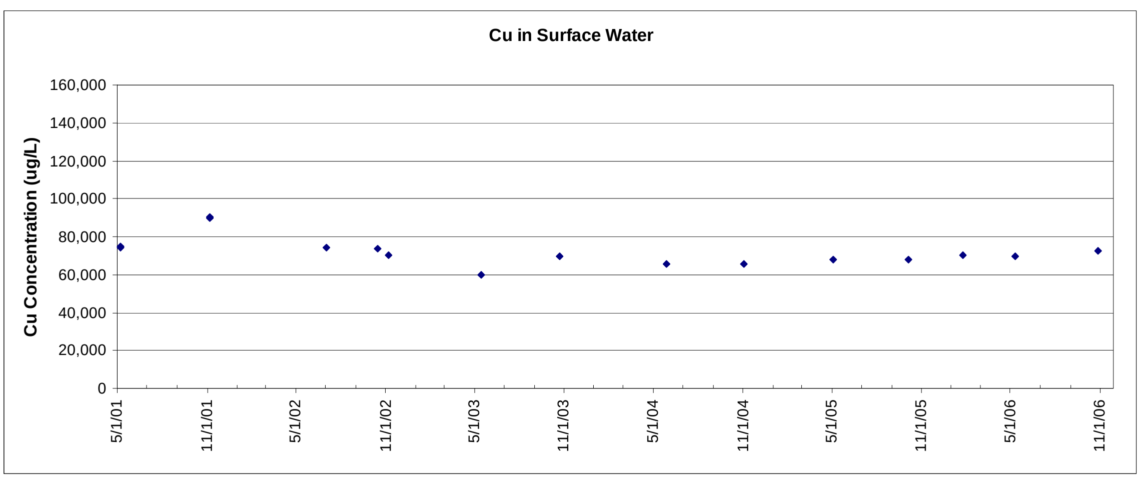


Figure 2-51. Change in the concentration of selected solutes in the Berkeley Pit surface water.

Copper concentrations in both the surface water and at depth appear to be at saturation. The stability of copper, both above and below the chemocline, is an interesting occurrence. The geochemistry of aqueous copper, copper complexes and the effects of water-rock interaction with regards to copper have not been studied in the Berkeley Pit, and may warrant further investigation. At this time, the effects of return water from the precipitation plant has had an insignificant impact on pit's surface water with respect to copper, despite the high volume of low copper water being recycled since it began again in early 2004. Sulfate is most likely at saturation in the Berkeley Pit; complexation and dissolution reactions of metal-sulfates are the most reasonable explanation for the stability of dissolved sulfate.

Arsenic concentrations, unlike any other dissolved constituent, have shown decreasing trends over time. Figure 2-52 portraits trends in arsenic at four depths on eleven sampling events. Data collected in the spring are shown for five years, 2001, 2003, 2004, 2005, and 2006. One sample in 2002 was collected in the summer months. Data obtained in the fall are shown for five years, 2001, 2002, 2003, and 2004, and 2005. All data collected in 2001, 2002, and 2003 are representative of the time when HSB water was allowed to pool on top of Berkeley Pit water. Data given for 2004, 2005, and 2006 were collected when HSB was diverted away from the pit and copper recovery was taking place. Data at the 240-700-ft level for the May 2004 sampling event is missing.

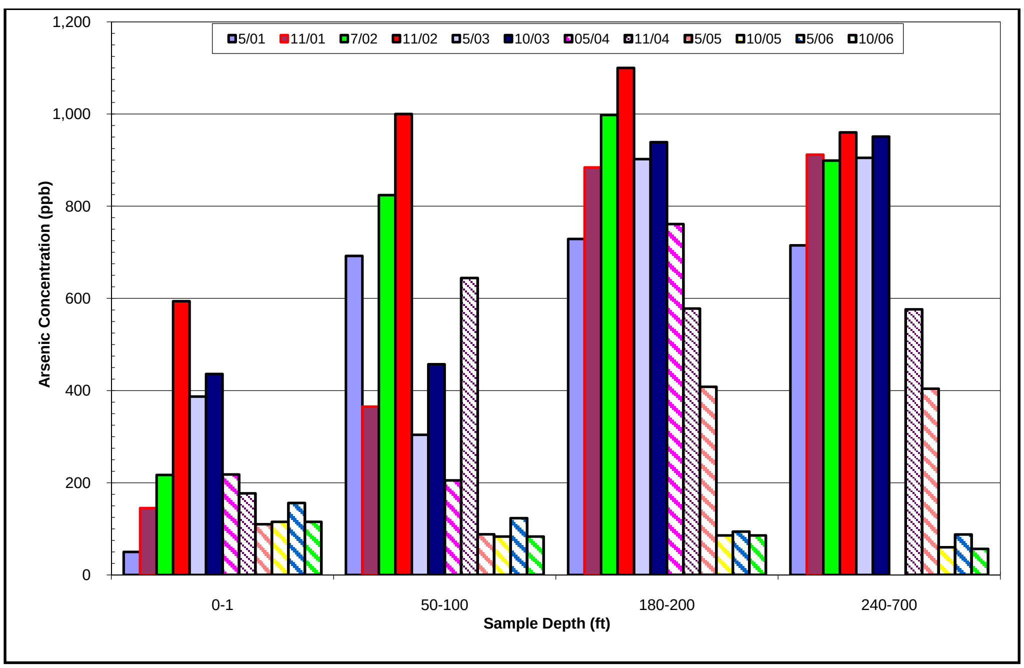


Figure 2-52. Recent changes in the concentration of arsenic at four depths. Both spring and fall sampling events are represented in this figure.

Arsenic concentrations reached their maximum values during the later period of mine suspension. Following the resumption of mining and the diversion of HSB water away from the pit, arsenic concentrations in the surface water began to decrease (May 2004 sampling event) , and a decrease in arsenic concentrations at all depths are shown in later sampling events.

Arsenic behavior in the Berkeley Pit may be inversely related to iron behavior. Long-term arsenic and iron trends are shown in figures 2-53. Green shaded areas represent the times when HSB water was diverted into the Berkeley Pit. The red line on each graph represents the major landslide on the SE wall of the Berkeley Pit where 1.3 M cubic yards of material slid into the lake. The brown shaded areas (on the x-axis) represent times when the copper-recovery was in operation.

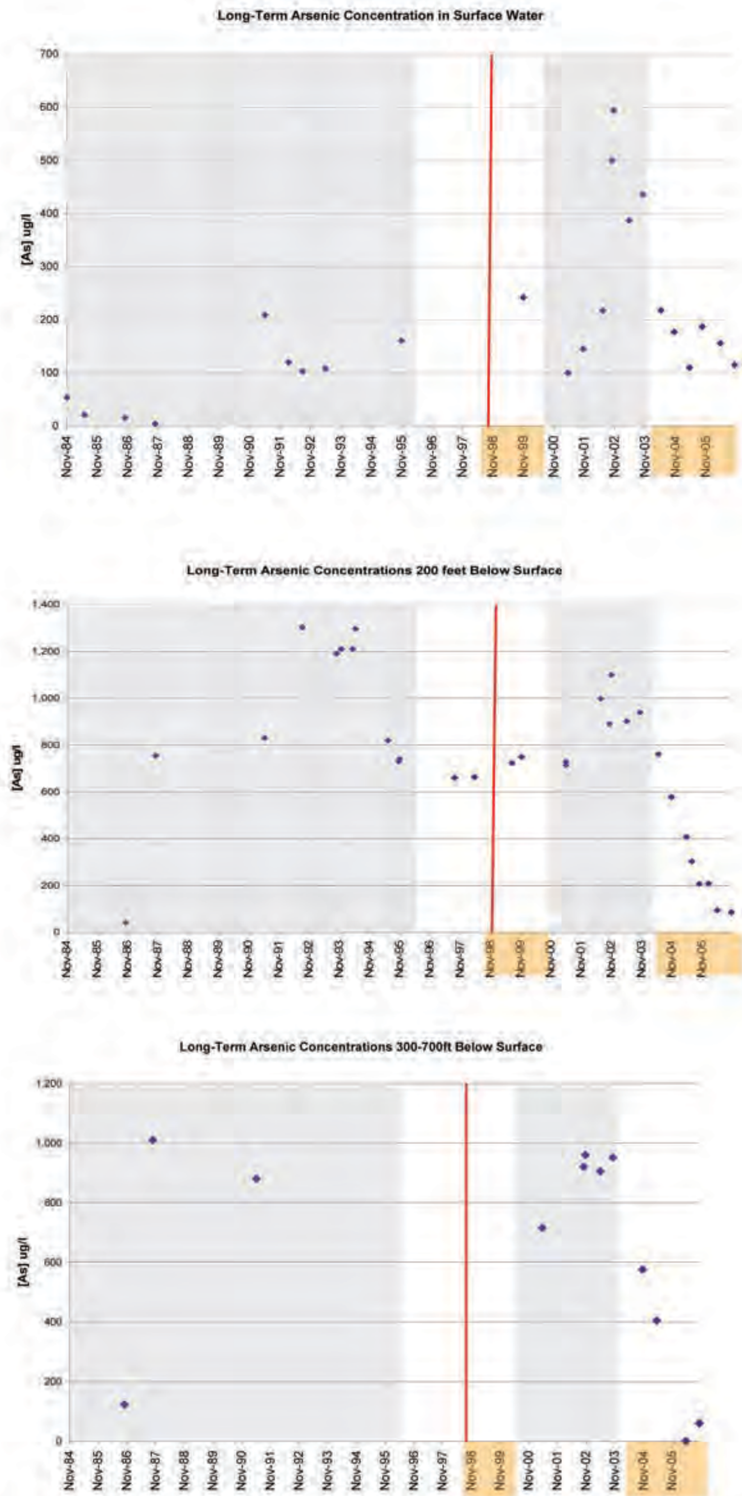
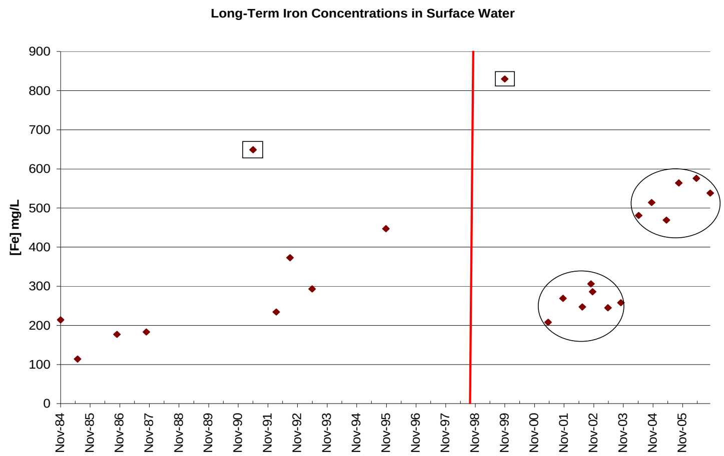
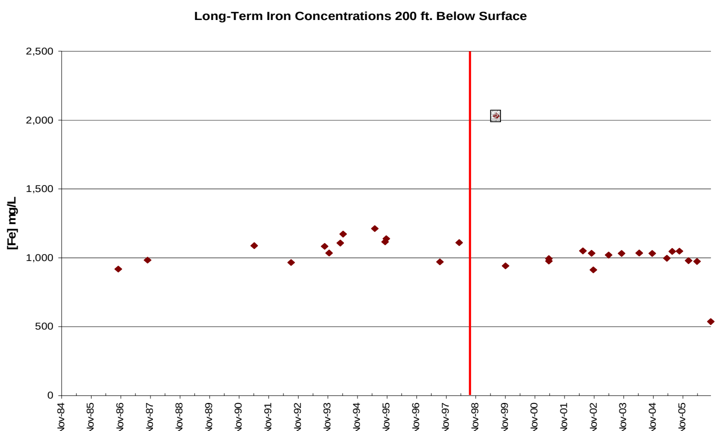


Figure 2-53. Long-term changes in the concentration of arsenic at three depths, surface, 200 fbs, and 300-700 fbs. The areas shaded green show times when Horseshoe Bend was diverted into the Berkeley Pit. The dates which are highlighted (brown) are those periods where copper recovery was in operation. The red line marks the date of the landslide.

In recent years arsenic appears to be sharing an inverse relationship with iron, and can be a possible explanation for the decrease in arsenic. Arsenic is known to adsorb onto many Fe-complexes such as hydrous ferric oxides (HFO) and schwertmannite ($Fe_{16}O_{16}(OH)_{12}(SO_4)_2$. When HSB was being diverted into the pit (2000-2003), iron concentrations in the surface water were low and consistent with HSB water (figure 2-54). As a result, less iron complexes were formed resulting in more arsenic being released into the water as a result of the dissolution of existing complexes. After 2004, iron concentrations increased, which may have resulted in the increase of Fe-As complexation. Concentrations of arsenic decreased as a result of increased attachment sites onto Fe-complexes. The constant circulation of deep iron-rich water to the surface, may explain the decrease in arsenic noticed at all depths over time. This explanation is also supported by the physical change in the coloration of the pit's surface-waters, as many who frequently view the pit comment on how the water appears to be getting "redder" over time. This change in coloration supports the explanation given above, as most Fe-complexes are red in appearance.

The possibility of iron-sulfate precipitates complexing with arsenic is a possibility, though more experimentation has to be conducted to further test this hypothesis. Studies are planned for the 2007 sampling season with the scope of further understanding the behavior of these elements.





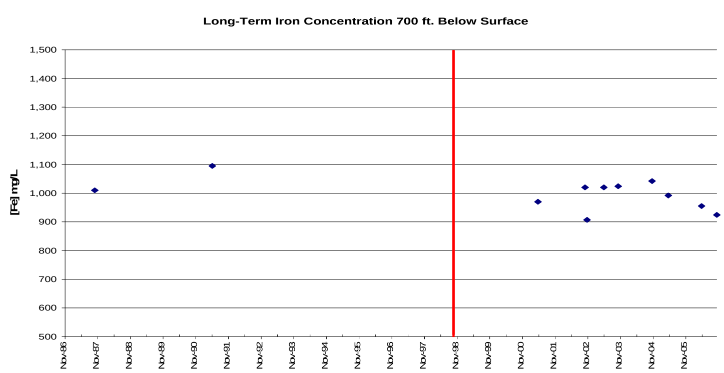


Figure 2-54. Long-term changes in the concentration of iron at three depths; surface, 200 fbs, and 300-700 fbs.

The shaded areas show times when Horseshoe Bend was diverted into the Berkeley Pit. The dates which are highlighted (on the x-axis) are those periods where Copper recovery was in operation. The red line marks the date of the landslide. Data points outlined with squares show times when Fe concentrations were unusually high, and may be the result of turn-over in the Berkeley Pit. The circled shaded area show trends in dissolved iron when HSB was diverted into the Berkeley Pit and the area outlined in blue show Fe trends post copper-recovery.

Section 2.3.2 Horseshoe Bend Water Quality

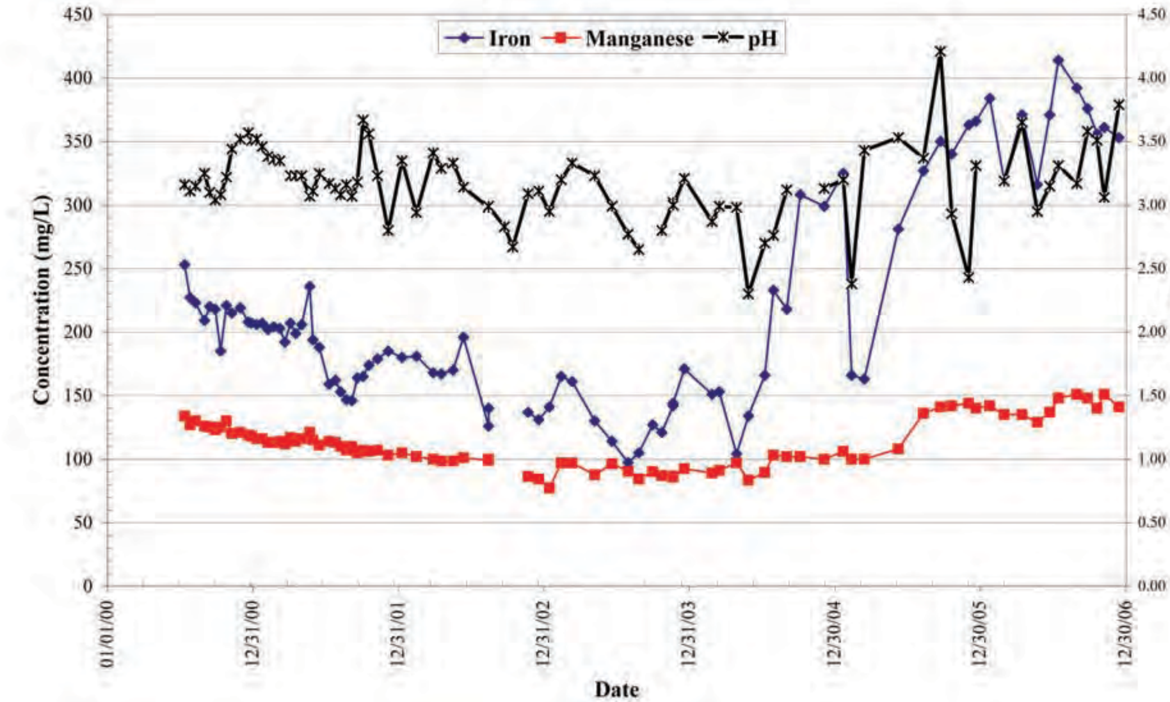
Monitoring of the HSB drainage began in July 2000 following MR's temporary suspension of mining. Similar to the changes seen in flow rates during the period of mine suspension, concentrations decreased in a number of metal concentrations. When mining resumed in the fall of 2003 and flow rates began to increase throughout 2004-2006, concentrations of a number of metals began to increase also (figure 2-55). However, copper concentrations increased slightly during 2005 before falling over the last year. This is in contrast to the trend observed for zinc.

The water quality of the HSB drainage continues to be slightly better than that of the Berkeley Pit (table 2.3.2.1).

Table 2.3.2.1 Selected chemistry from the Berkeley Pit and Horseshoe Bend.

Area	Sample Date	pH (S.U.)	SO_4 (mg/L)	Al (ug/L)	Cu (ug/L)	Pb (ug/L)	Zn (ug/L)
Berkeley							
Surface	10/26/06	2.78	7,459	254,534	72,298	29.6	564,578
HSB	10/19/06	3.51	5,377	229,123	38,411	<20	317,641

Montana Bureau of Mines and Geology
Butte Mine Flooding Monitoring



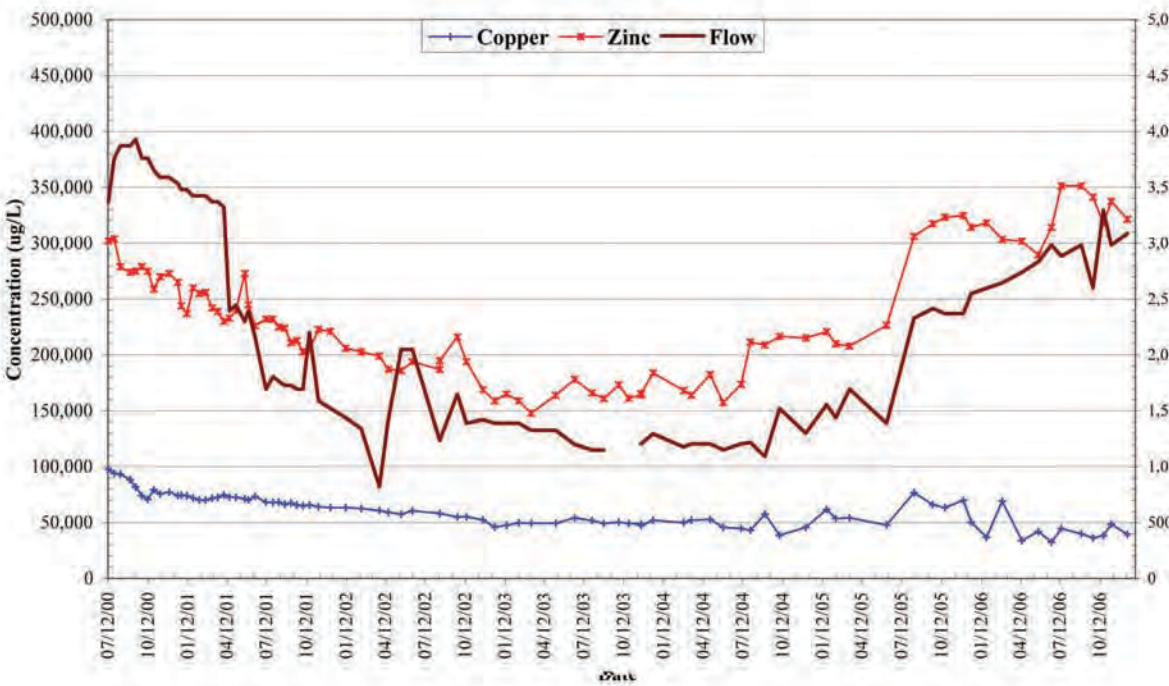


Figure 2-55. Horseshoe Bend water quality comparisons of selected constituents, 2000-2006.

SECTION 3.0 WEST CAMP SYSTEM

Water-level monitoring continued during 2006 in the three mine shafts and six monitoring wells (fig. 3-1) that comprise the West Camp system. ARCO diverted the water pumped from the West Camp to the Lower Area One wetlands demonstration site during March 2002. Pumping occurred almost continuously throughout 2006, with pumping rates about thirteen percent higher than 2005. There were small water-level decreases throughout the system, as a result of the increased pumping rates.

Section 3.1 West Camp Underground Mines

Water levels in the West Camp Mine system continue to be controlled by pumping facilities located at the BMF-96-1D and BMF-96-1S site. ARCO had a special well drilled for dewatering (pumping) purposes in the fall of 1997; which is referred to as the West Camp Pumping Well (WCPW). Pumping activities were transferred from the Travona Mine to this site on October 23, 1998. The pump and pipeline at the Travona Mine were left intact, however, allowing it to serve as a backup pumping system.

The West Camp pumping system operated almost continuously during 2006, with the exception of several short periods caused by power outages and for maintenance. The pumping rates were greater than those of the past three years. A total of 290 acre-ft of water was pumped compared to 258 acre-ft pumped in 2005 and 255 acre-ft in 2004. Table 3.1.1 shows the annual amount of water pumped in acre-ft, the change in acre-ft from the previous year, and the percent change from 1996 (the first full year of continuous pumping). Figure 3-2 shows the amount of water pumped annually and the percent of average annual precipitation since 1982.

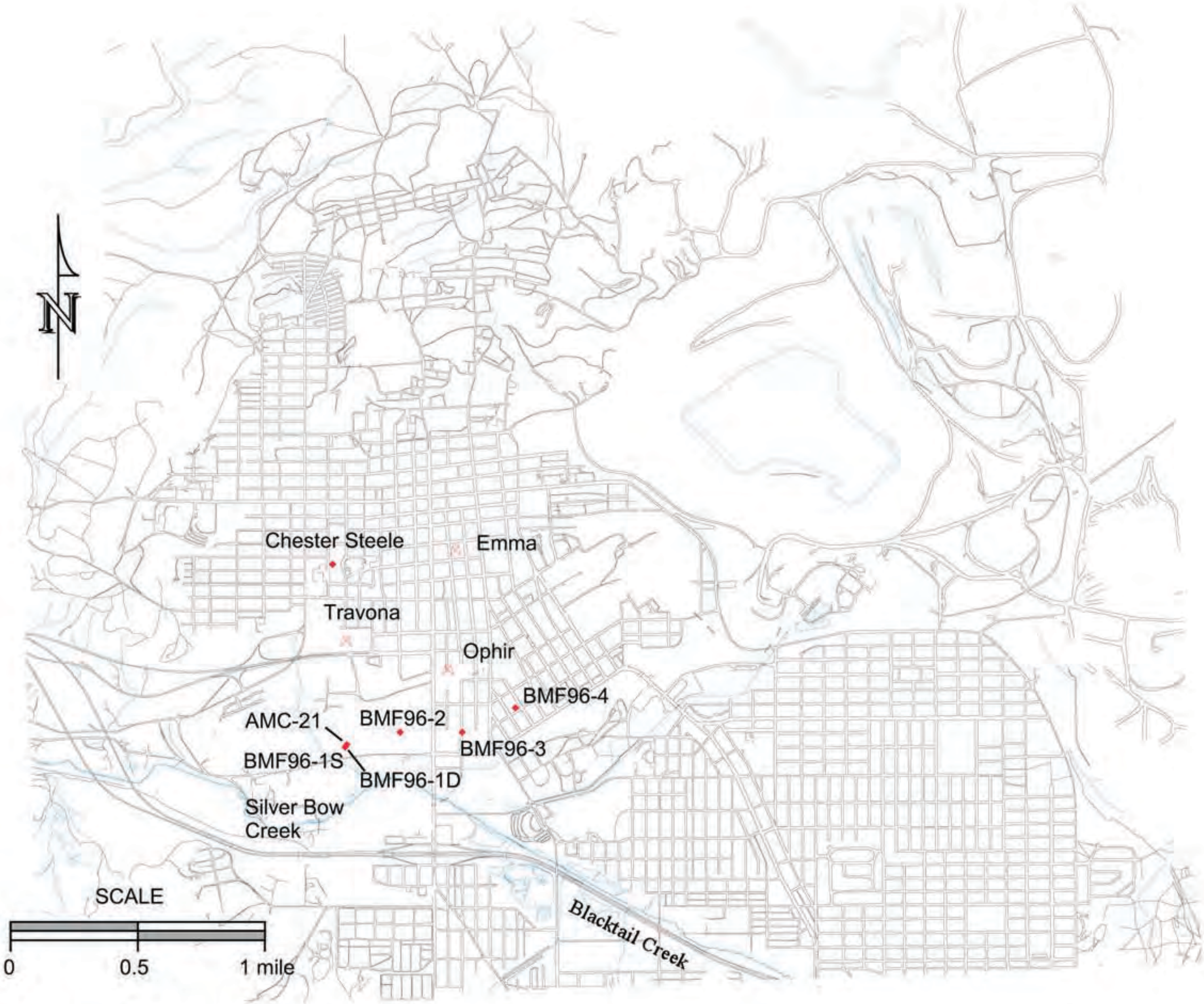


Figure 3-1. West Camp Monitoring Sites Location Map.

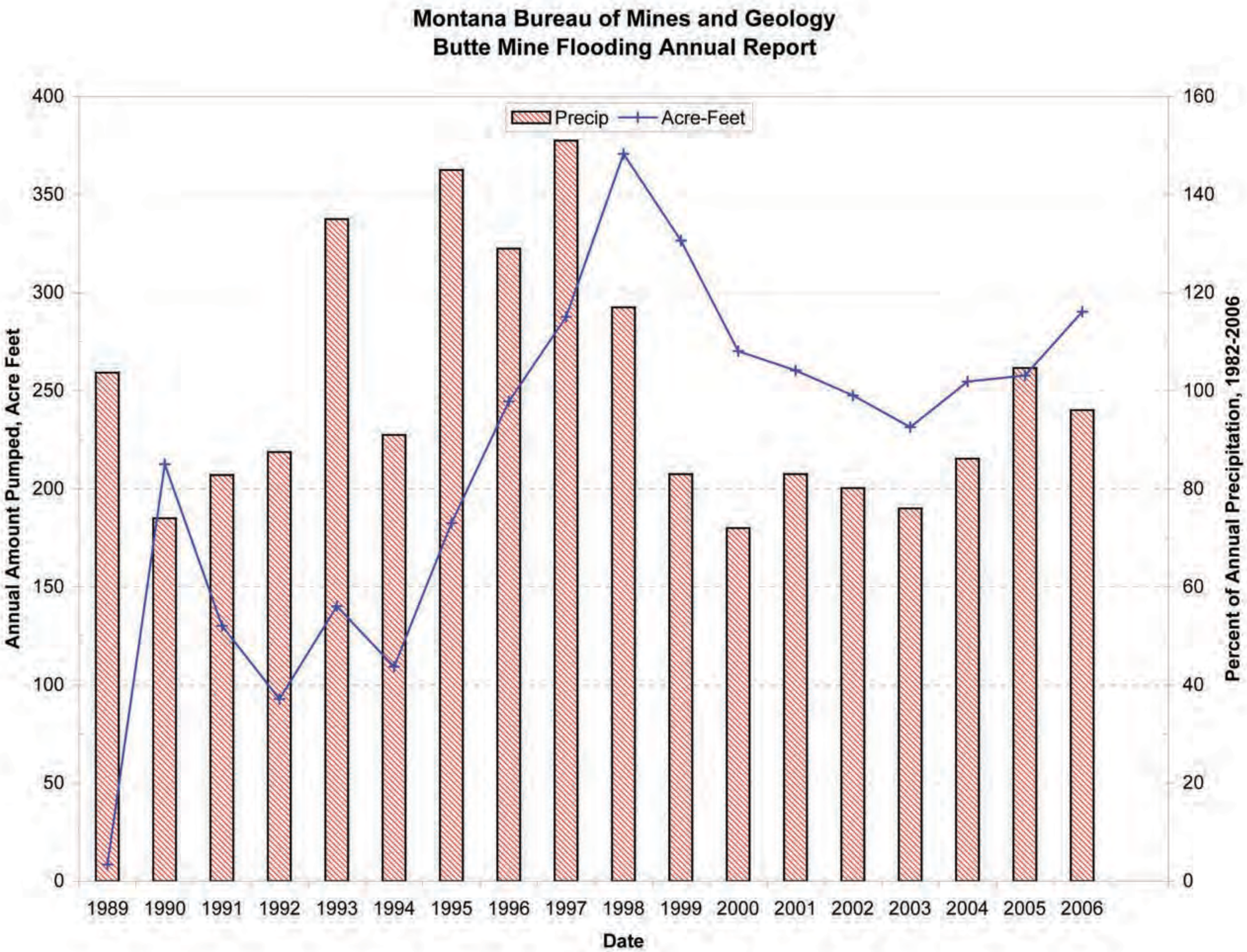


Figure 3-2. Annual amount of water pumped from the West Camp system.

Table 3.1.1 Annual quantity of water pumped from the West Camp, in acre-feet.

Year	Total Amount Pumped (Acre ft)	Change From Prior Year (Acre ft)	Percent Change From 1996
1989	8.50		
1990	212.54	+204.04	
1991	130.16	-82.38	
1992	92.82	-37.34	
1993	140.18	+47.36	
1994	109.31	-30.87	
1995	182.54	+73.23	
1996	244.56	+62.02	
1997	287.70	+43.14	118
1998	370.72	+83.02	152
1999	326.56	-44.16	134
2000	270.20	-56.36	110
2001	260.37	-9.83	106
2002	247.66	-12.71	101
2003	231.43	-16.23	95
2004	254.70	+23.26	104
2005	257.82	+3.12	105
2006	290.33	+32.51	113

All three mines had a net water-level decrease between 1.3 and 1.7-ft during 2006. Water-level changes in the West Camp mines reflect changes in pumping rates in the WCPW and precipitation amounts. Figure 3-3 shows annual water-level changes for the West Camp sites. Water levels are more than 11-ft below the West Camp action level of 5,435-ft stipulated in the 1994 ROD.

Water-level elevations for the three West Camp mines are shown on figure 3-4. Water levels in these mines are almost identical and continue to follow the trends of previous years. Pumping rates and the amount of water pumped are the most important controls on water levels.

Section 3.2 West Camp Monitoring Wells

Water levels declined in two of the five BMF96 West Camp wells, while rising in the other three wells during 2006. Well BMF96-1D, which was completed into the Travona Mine workings, had water-level changes (decreases) similar to the West Camp mines. These changes are shown in table 3.1.2 and on figure 3-3.

Table 3.1.2 Annual water-level changes for the West Camp sites, in feet.

Year	Travona	Emma	Ophir	Chester Steele	BMF 96-1D	BMF 96-1S	BMF 96-2	BMF 96-3	BMF 96-4
1982	4.30								
1983	2.00								
1984	55.90								
1985	61.90								
1986	36.10								
1987	49.70	14.20							
1988	15.69	6.60		16.42					
1989	5.67	-		1.79					
1990	-18.42	18.66		-5.77					
1991	13.88	13.52		-8.28					
Change Years 1-10*	**226.72**	**15.66**		**4.16**					
1992	7.21	6.79		-11.20					
1993	1.01	0.93		-1.11					
1994	4.24	4.26	4.00	5.36					
1995	-0.98	-1.00	-0.96	12.72					
1996	-3.72	-3.76	-3.56	6.14	-1.50	-5.41	0.00	-2.85	
1997	7.29	7.28	7.22	14.82	7.20	7.36	2.13	-0.19	-0.80
1998	-7.31	-7.88	-7.20	-2.51	-7.35	-5.63	-2.00	-0.26	-5.88
1999	-0.97	-0.47	-1.03	-5.37	-0.82	-0.61	-1.15	-0.38	-1.76
2000	5.56	5.61	5.53	-4.64	5.70	1.45	-1.13	-0.07	1.86
Change Years 11-20	**-10.68**	**10.06**	**2.48**	**29.82**	**1.45**	**-1.14**	**1.08**	**-3.65**	**-5.18**
2001	1.65	-1.70	-1.52	15.61	-1.78	1.70	3.23	0.10	1.40
2002	1.33	1.74	1.51	6.35	2.03	-0.62	-2.06	-0.21	-0.93
2003	1.45	0.95	0.87	12.94	0.56	0.96	-0.01	0.00	0.54
2004	-1.06	-0.72	0.73*	-4.22	-0.72	1.03	1.41	0.33	-0.31
2005	0.39	0.22	-1.30	-11.35	0.03	-1.42	-0.23	0.18	-0.47
2006	-1.62	-1.49	-1.33	4.76	-1.15	0.65	0.59	-0.31	0.20
Change Years 21-25	**0.49**	**0.70**	**0.48**	**-4.22**	**0.75**	**0.60**	**-0.30**	**-0.01**	**-0.97**
Net Change*	**237.89**	**26.42**	**2.96**	**29.76**	**2.20**	**-0.54**	**0.78**	**-3.66**	**-6.15**

Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements.

*Vandalism to Ophir Mine monitoring point resulted in no water levels being obtained for the last quarter of 2004

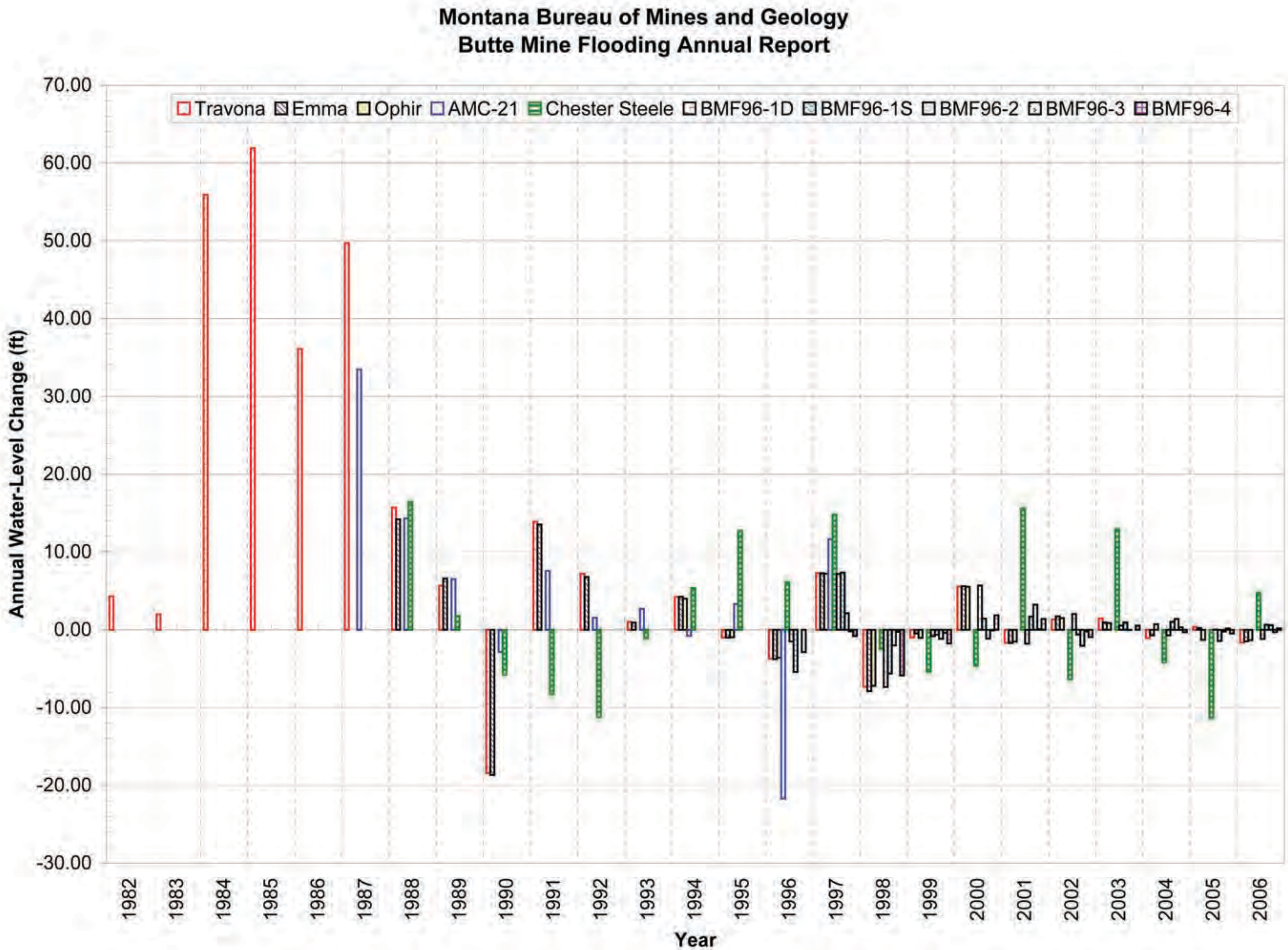


Figure 3-3. Annual water-level change for West Camp sites.

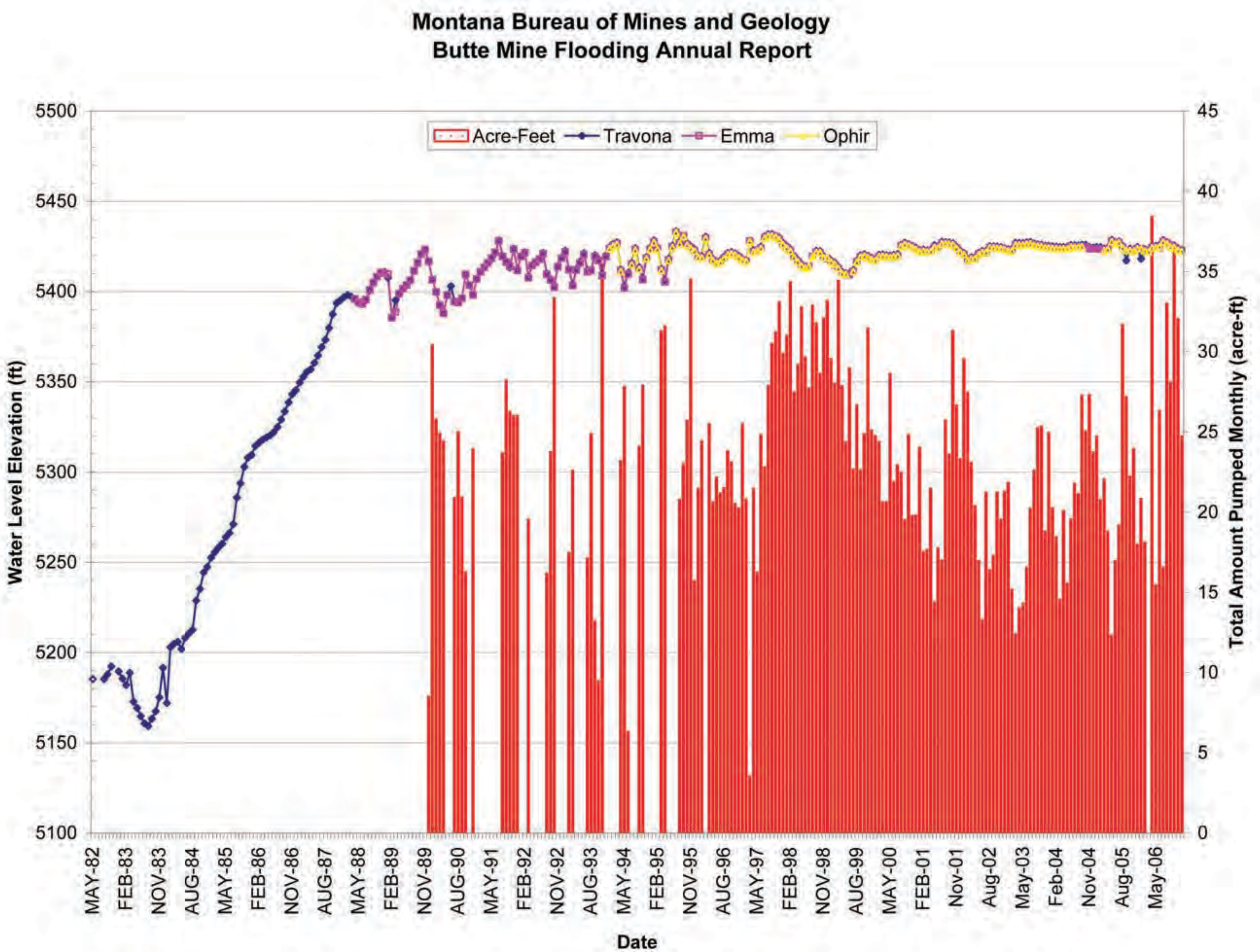


Figure 3-4. West Camp water-level hydrographs and total amount of water pumped monthly.

Figure 3-5 contains water-level hydrographs for wells BMF96-1D, BMF96-1S and BMF96-4. Water levels in wells BMF96-1D and BMF96-4 respond similarly to one another, reflecting the influence pumping has on the system. This is an important trend since well BMF96-4 was not completed into mine workings. It is, however, in the area of the historic 1960's flooding problems that led the Anaconda Company to install well AMC-21 for control of water levels in the West Camp. (See Duaime, et al, 1998 for a greater discussion of historic flooding problems in the West Camp System). There is a lag time between the responses seen in these two wells, which is most likely because well BMF96-4 was not completed into mine workings. During periods of continued water-level change in wells BMF96-1D and BMF96-4, there appears to be a similarity in water-level change in well BMF96-1S. Well BMF96-1S is located adjacent to well BMF96-1D, but was completed at a much shallower depth in the weathered bedrock of the Missoula Gulch drainage. This well also shows a response to pumping in the WCPW. There was no change in longer-term trends in any of these wells from those described in the previous reports.

Water levels in wells BMF96-2 and BMF96-3 are 20 to 50-ft higher than those in wells BMF96-1D and BMF96-4, and when plotted with the other BMF96 wells, initially appeared to show very little change (fig. 3-6). Since 2002, water levels in these two wells appear to follow trends similar to the other wells. When these wells are plotted separately (fig. 3-7a), there is considerable variation in monthly water levels, and water levels in both wells respond similarly. Monthly precipitation is shown on this figure and water levels are seen to respond very quickly to precipitation events. Although these wells were completed at depths of 175-ft below ground surface, their water levels are less than 20-ft below ground surface. Water-level trends during 2006 in these wells for the most part were similar to those seen the previous several years. Figure 3-7b is a hydrograph for these two wells for the period 2002-2006 to better show recent water-level changes. Water levels rise not only with precipitation, but with infiltration from snow melt, which is shown by the early season (March) water-level increases. During the last half of 2001, an unexplained water-level increase of several feet occurred in well BMF96-2; this was not seen in other wells. This trend did not continue in 2002 or beyond; the water level in well BMF96-2 has followed that of well BMF96-3 ever since.

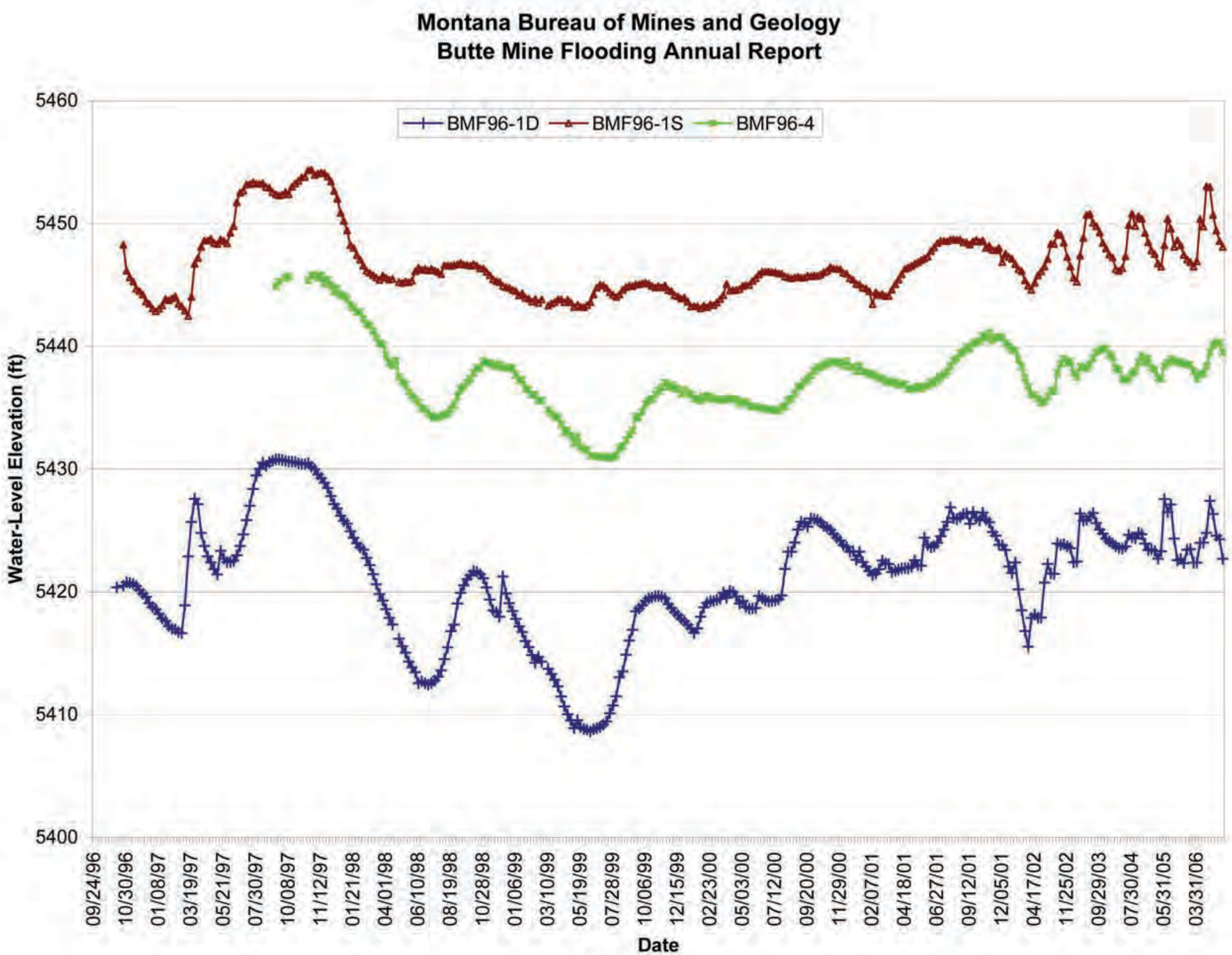


Figure 3-5. Water-level hydrographs for West Camp BMF96-1D, BMF96-1S, and BMF96-4 wells.

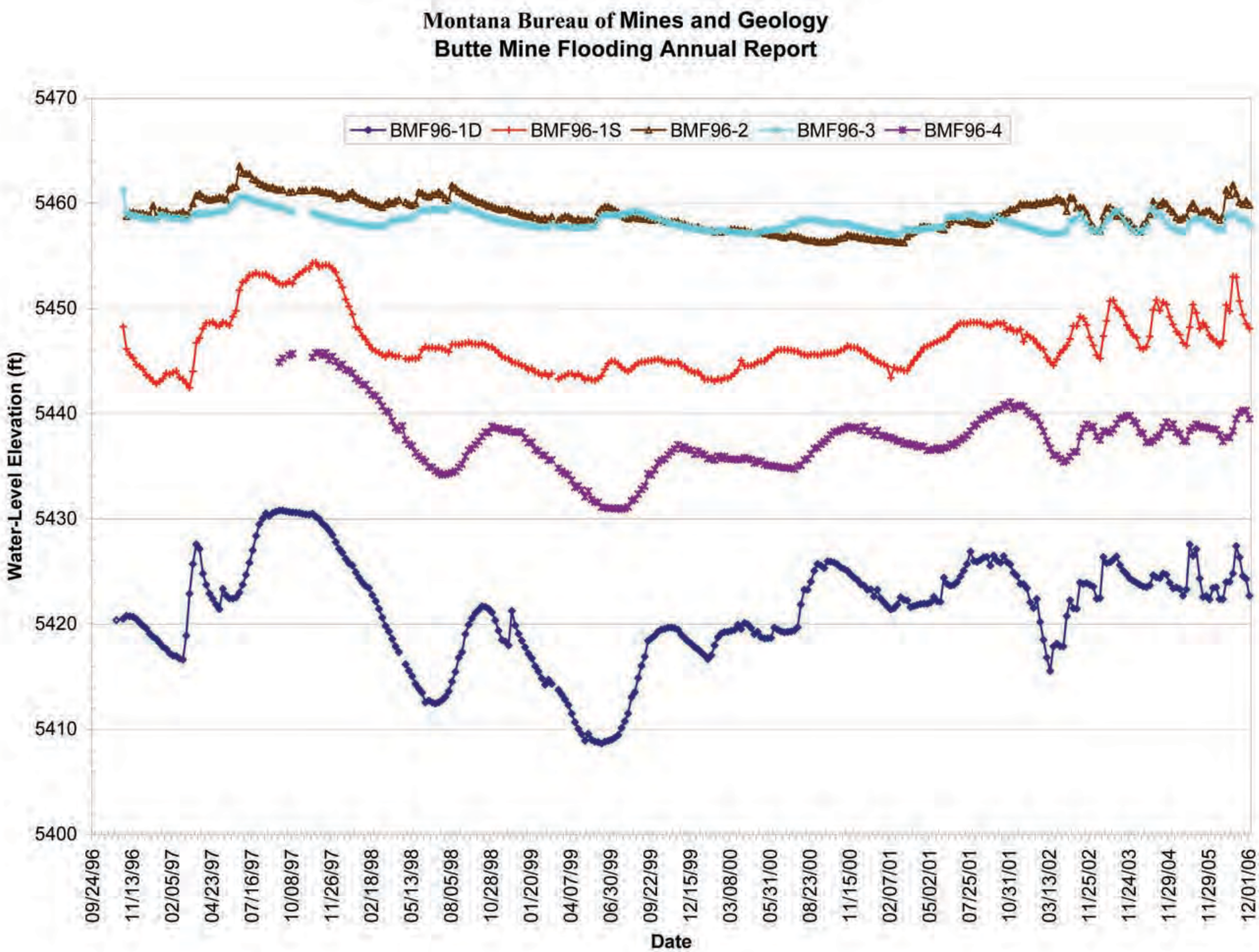
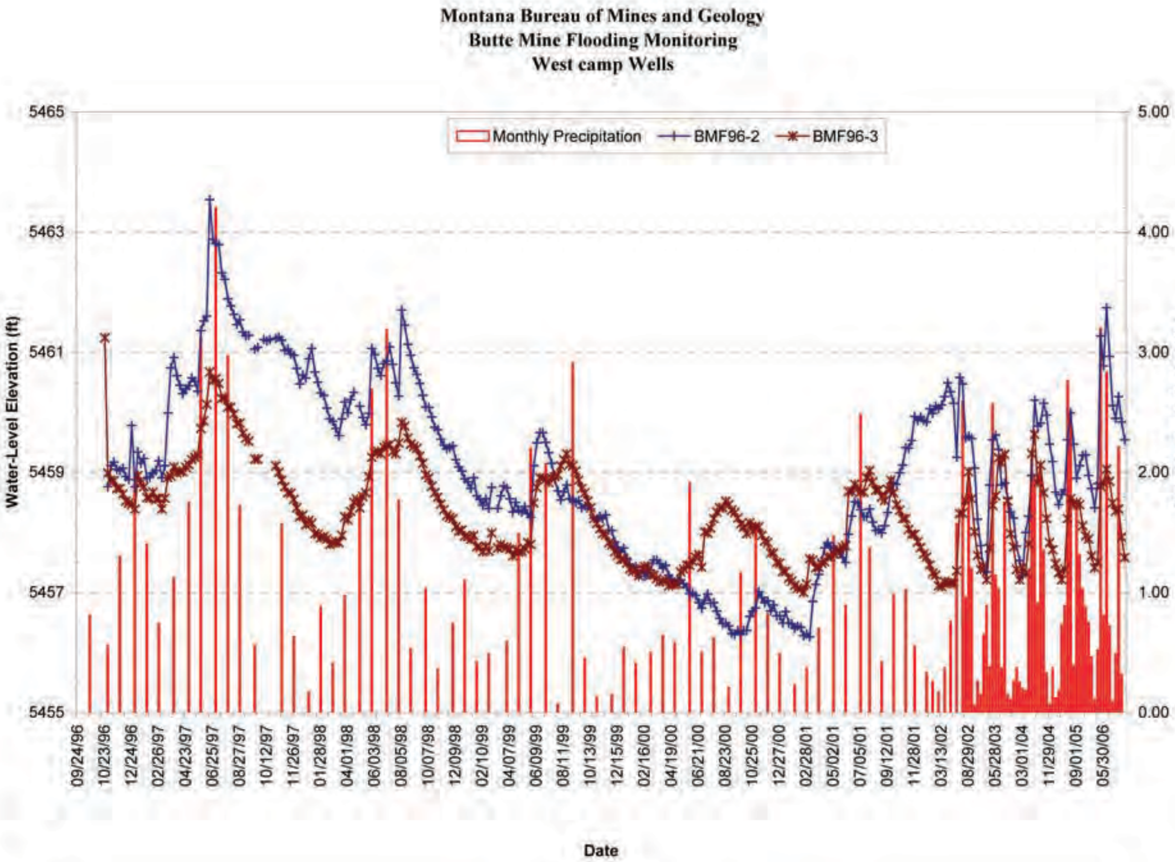


Figure 3-6. Water-level hydrographs for BMF96 series wells.



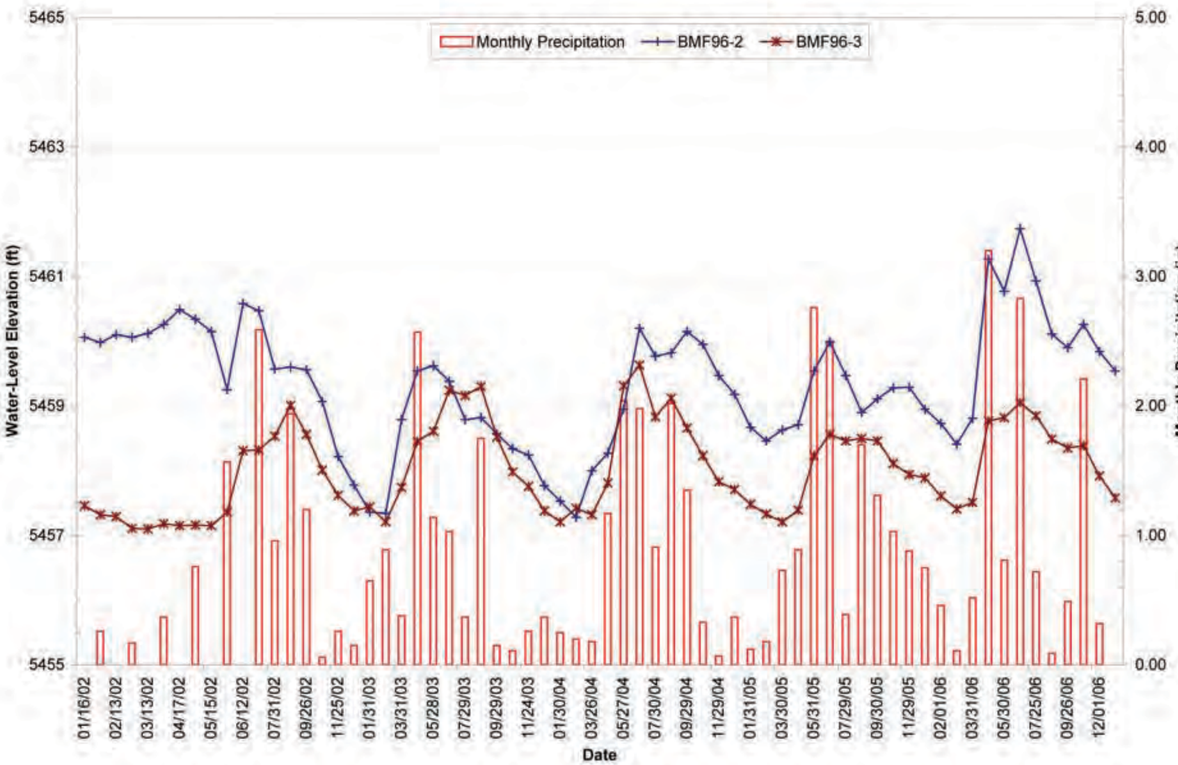


Figure 3-7a (top). Water-level hydrographs for wells BMF96-2 and BMF96-3.
Figure 3-7b (bottom). Water-level hydrographs for wells BMF96-2 and BMG96-3, 2002-2006.

Section 3.2.1 West Camp Mines and Monitoring Wells Water Quality

Water-quality data for the West Camp monitoring system in 2006 are again limited to BMF96-04 and the three West Camp mines (Travona, Emma, and Ophir). These four sites were sampled during the spring sample event only.

With the exception of arsenic (100 ug/L in the Travona Mine and about 25 ug/L in the Emma Mine), the concentrations of most dissolved constituents are similar in the West Camp (fig. 3-8a and 3-8b); a slight trend toward decreasing concentrations continues in 2006. The concentrations of most dissolved metals in the Ophir Mine are low and continued to exhibit a slight downward trend through 2006 (fig. 3-9).

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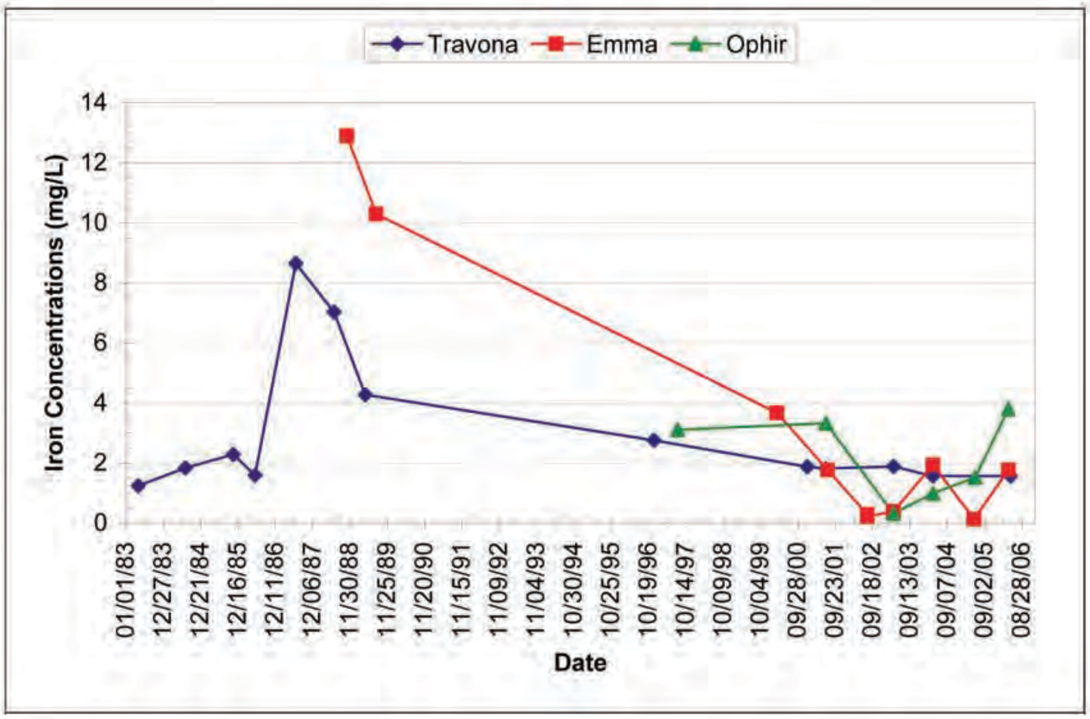

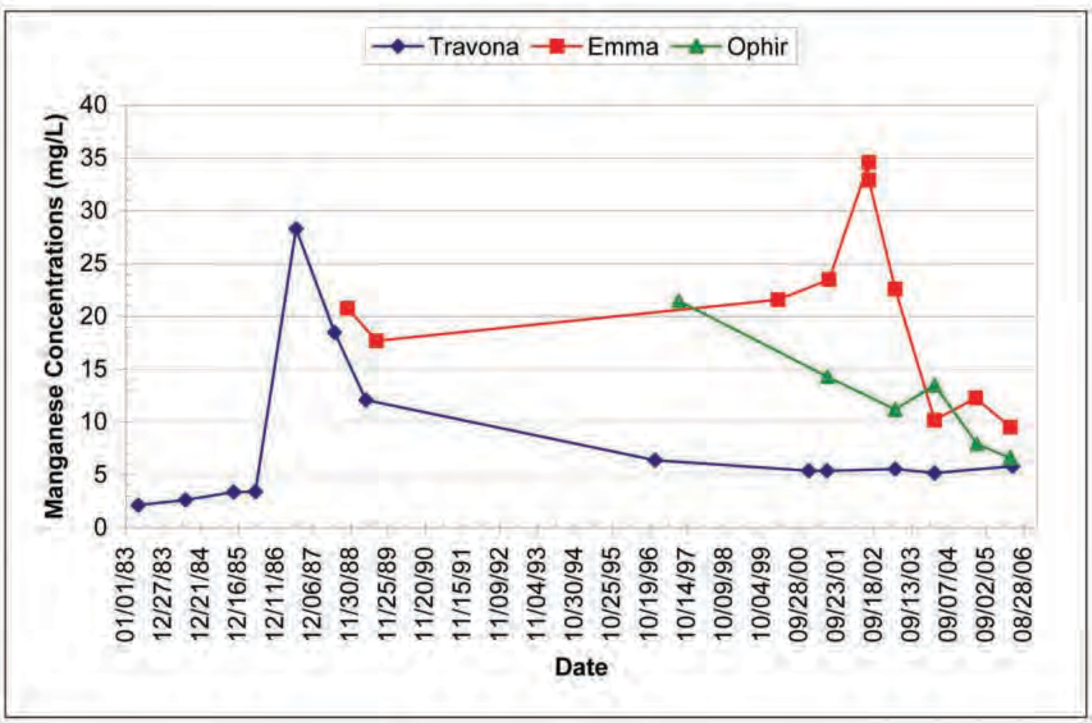

Figure 3-8a. Selected water chemistry for West Camp Mines.

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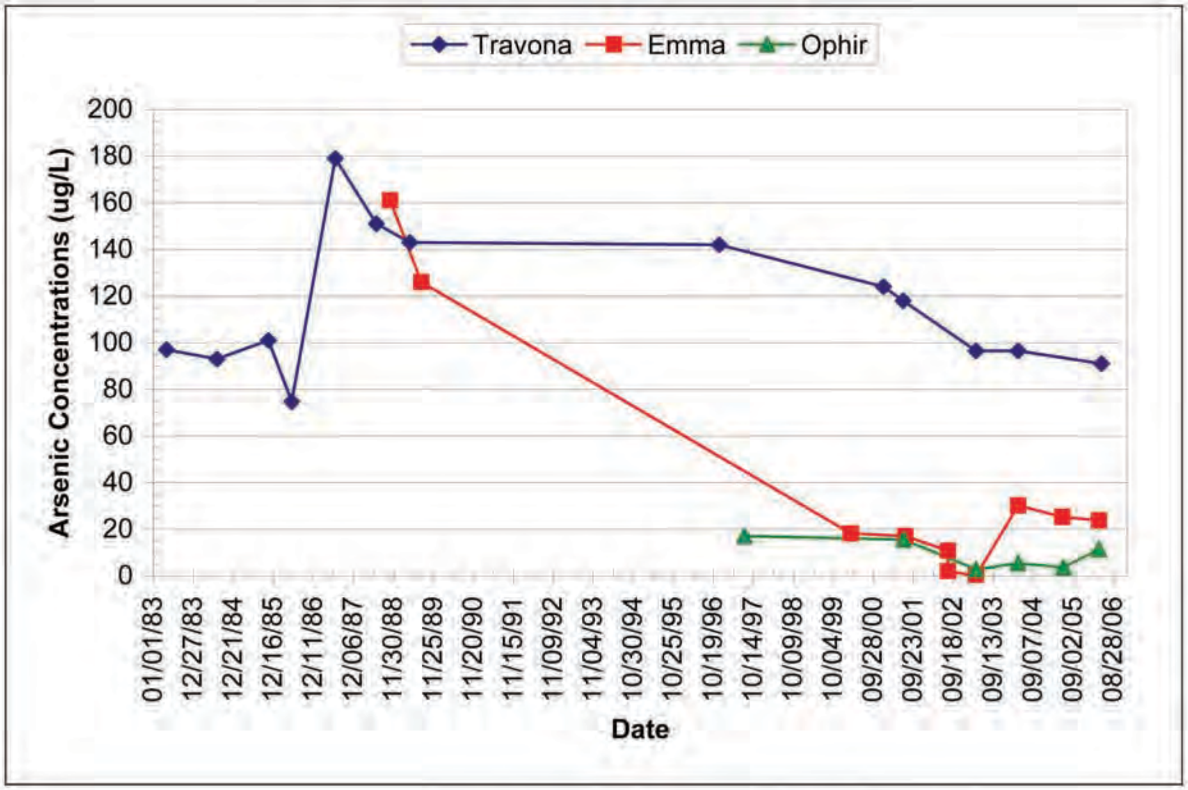

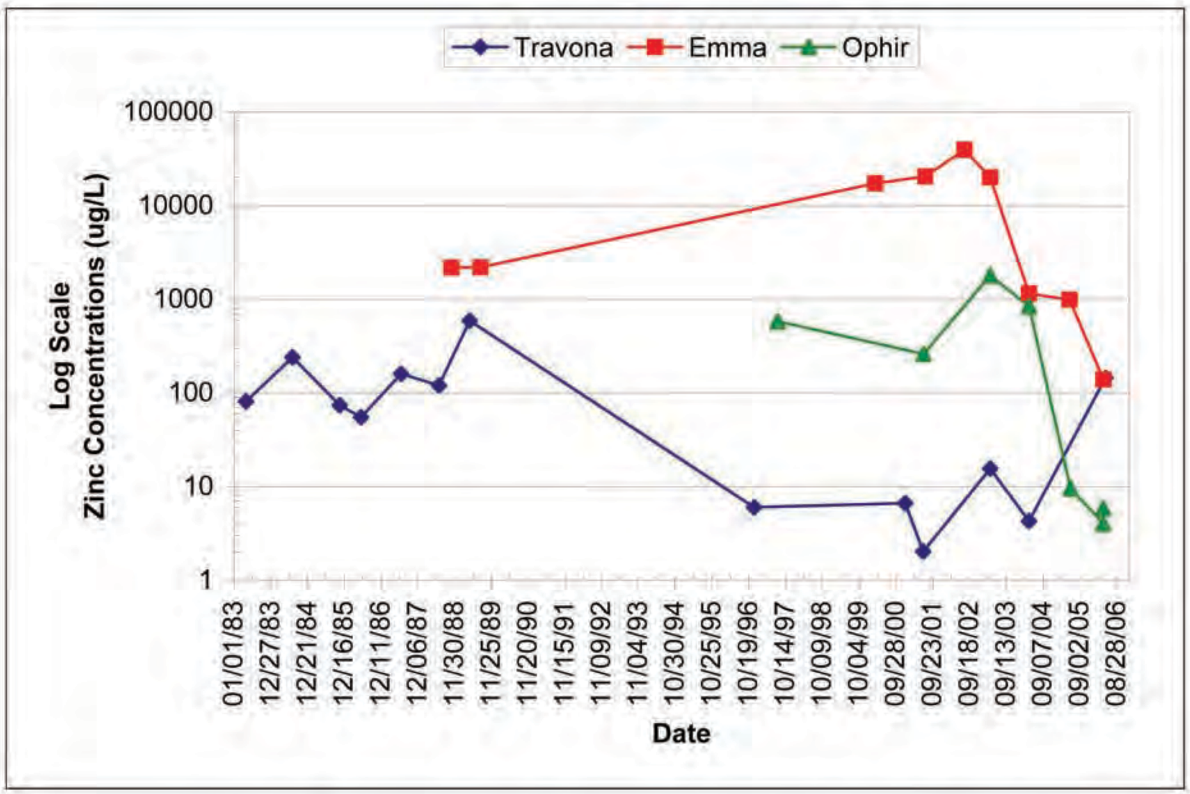

Figure 3-8b. Selected water chemistry for West Camp Mines.

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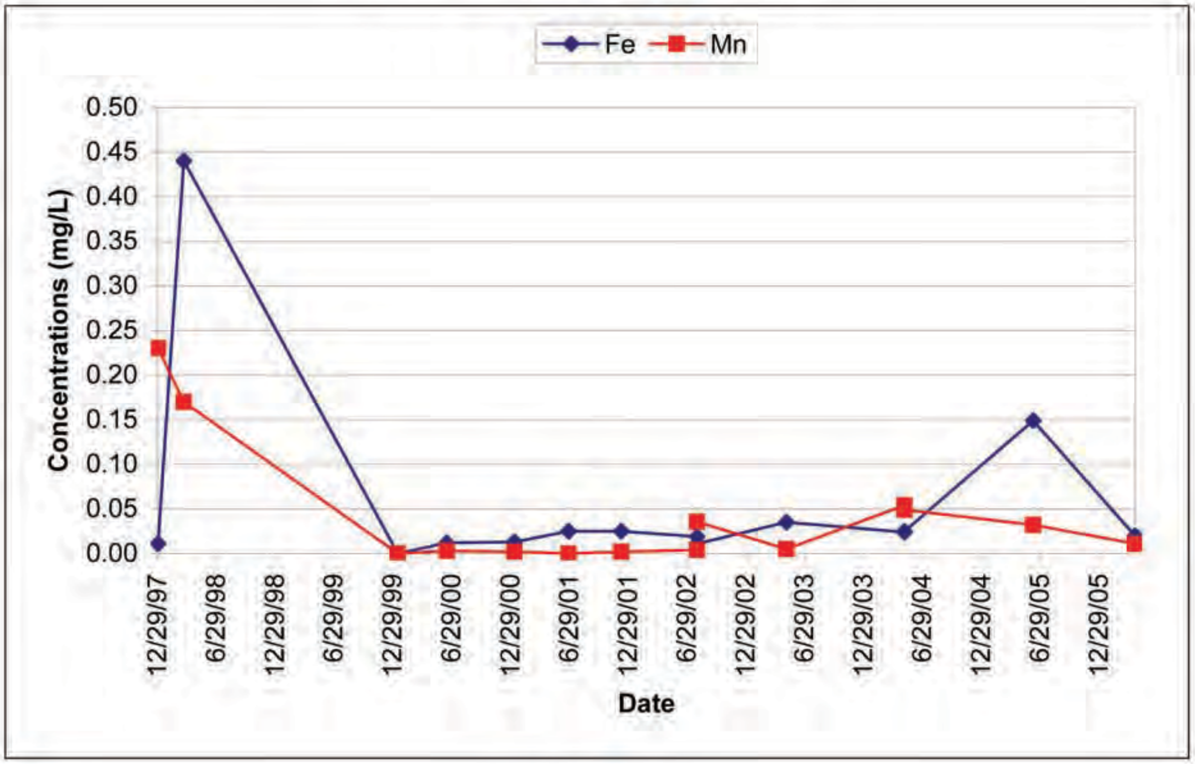

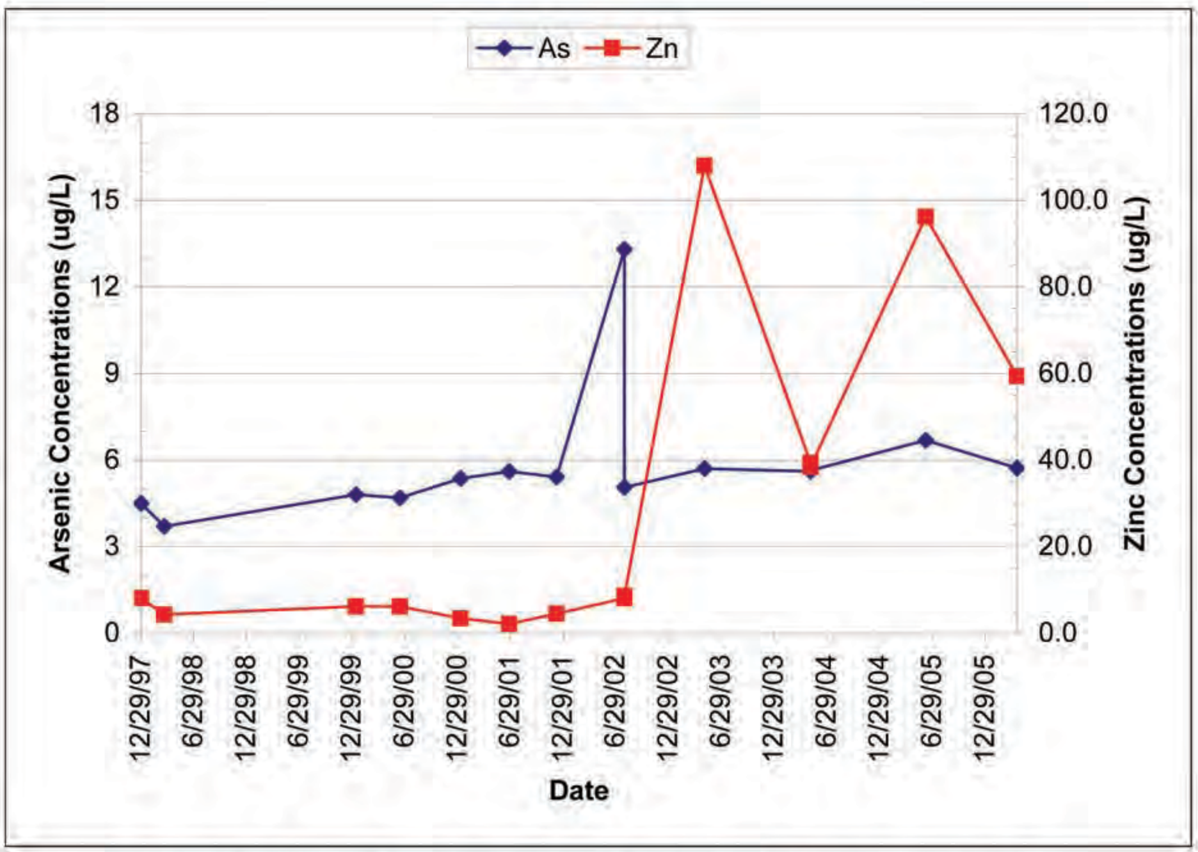

Figure 3-9. Selected water chemistry for West Camp well BMF96-4.

SECTION 4.0OUTER CAMP SYSTEMS

The Outer Camp System consists of the Orphan Boy Mine, Marget Ann Mine, well S-4 and the Montana Tech well (fig. 4-1). It is believed that water levels in the Outer Camp System are at or near pre-mining condition, as these mines had not operated for many years prior to ARCO's suspension of underground mining. It is also believed the few interconnections that existed between these mines and other Butte Hill mines had been sealed off decades earlier by the placement of bulkheads.

Section 4.1 Outer Camp System Water Levels

Outer Camp water levels rose in 2003 for the first time in 5 years; however, water levels declined in all but one site during 2004 and at all sites in 2005. This trend reversed itself in 2006 with water levels rising at all four locations. The net rise for 2006 varied between 4-ft and 9-ft. Table 4.1.1 contains yearly water-level change data, while figure 4-2 shows these changes graphically.

Table 4.1.1 Annual water-level changes for the Outer Camp sites, in feet.

Year	Orphan Boy	Marget Ann	Well S-4	MT Tech Well
1987	2.40			
1988	2.14			
1989	3.83	-3.56	-3.56	
1990		-1.34	-4.23	
1991				
1992	1.41			
1993	5.49			0.36
1994	-0.72	4.66		2.51
1995	5.44	12.41		6.48
1996	-0.96	10.44	18.41	-1.47
Change Years 1-10	**20.43**	**22.61**	**10.62**	**7.88**
1997	7.56	14.50	16.42	7.76
1998	-2.79	0.59	2.17	-2.72
1999	-1.94	-2.87	-2.32	-1.57
2000	NA	-4.71	-4.08	-4.24
2001	NA	-1.49	-1.59	-1.79
2002	NA	-2.99	-3.13	-3.64
2003	NA	1.09	2.23	2.76
2004	-7.67	-2.18	-3.07	0.23
2005	-0.56	-3.01	-2.85	-1.97
2006	4.51	8.66	7.18	5.44
Change Years 11-20	**-0.89**	**7.59**	**10.96**	**0.26**
Total Change*	**19.54**	**30.20**	**21.58**	**8.14**

Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements.

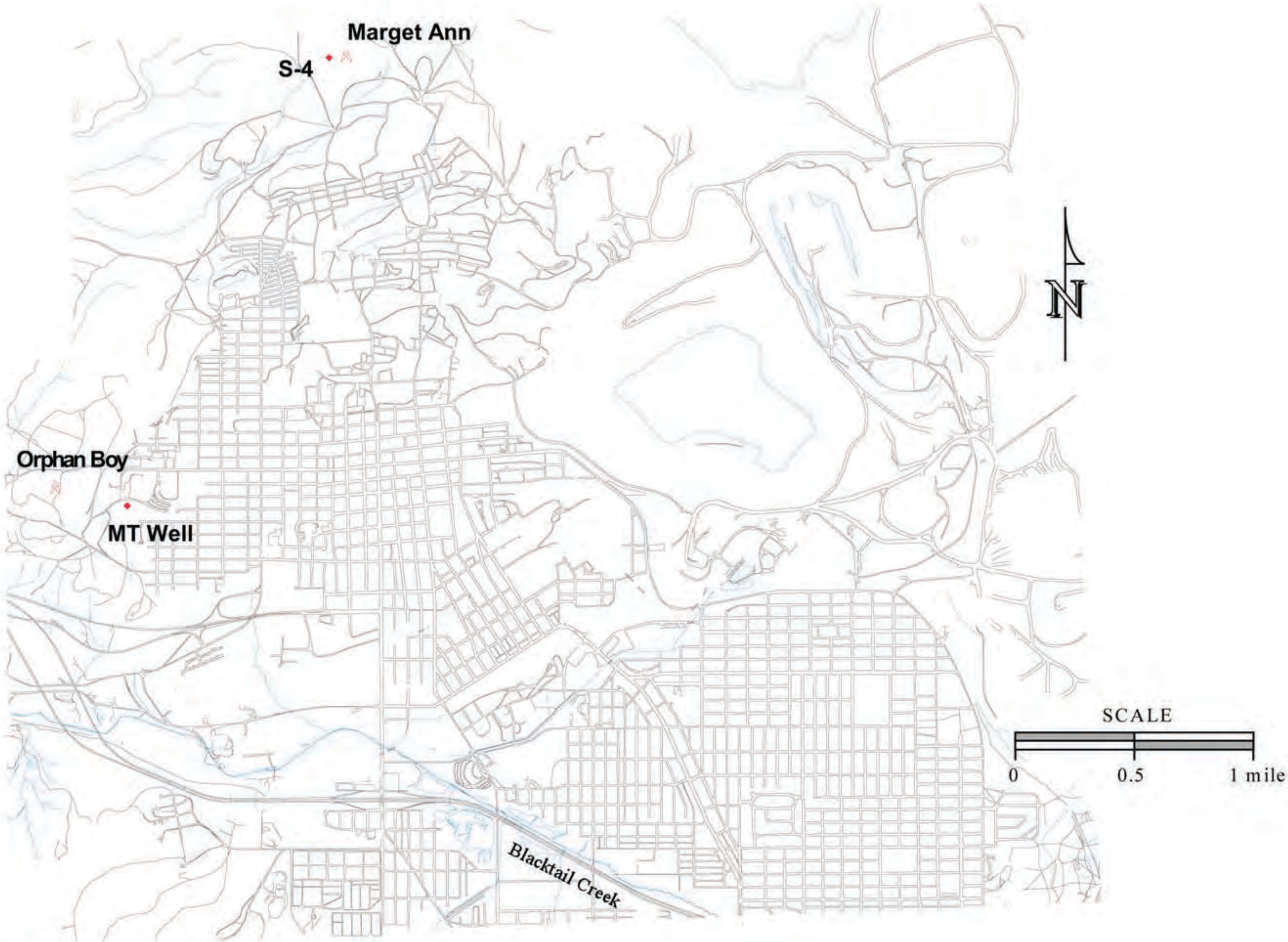

Figure 4-1. Outer Camp Monitoring Sites Location Map.

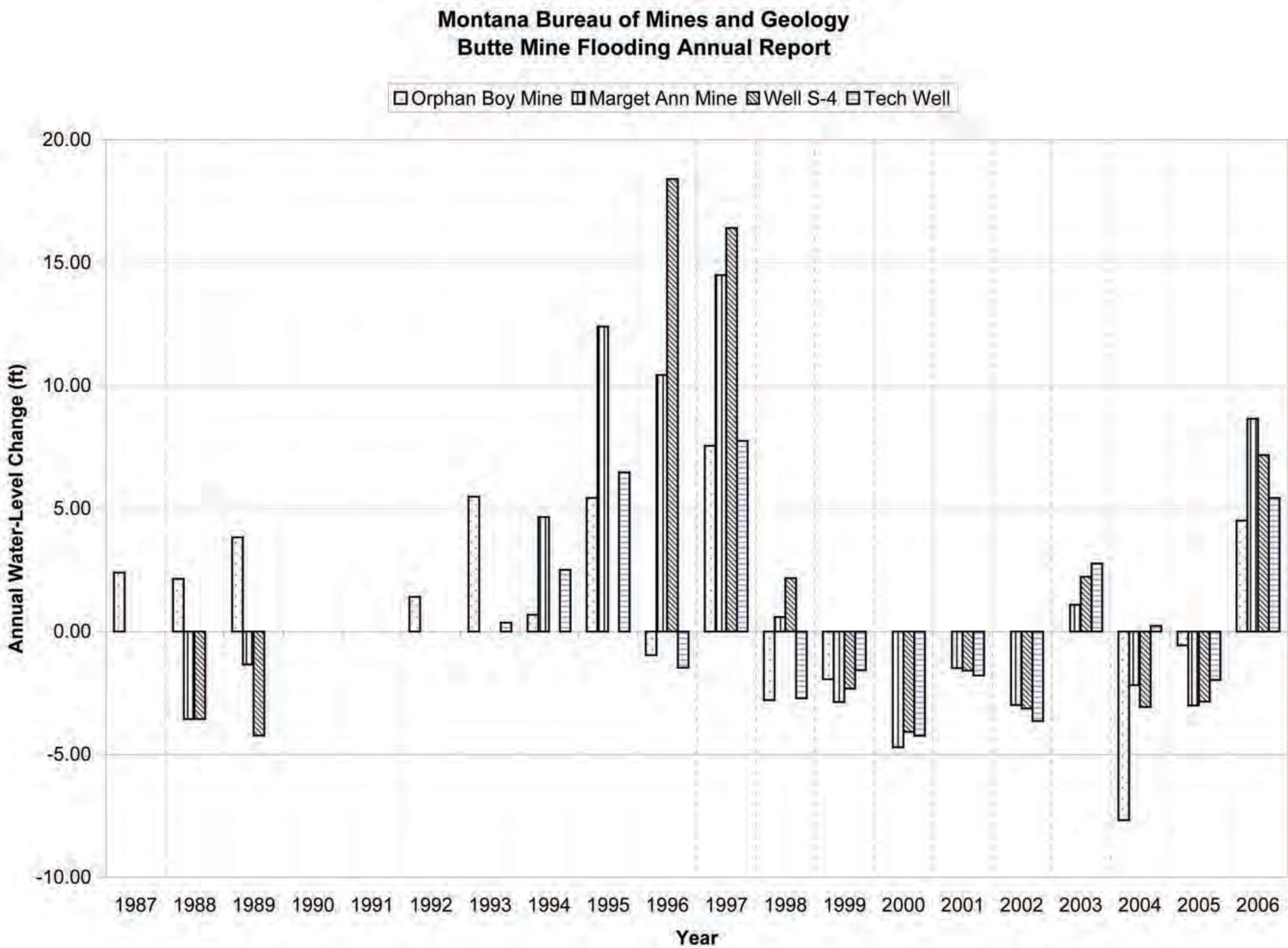

Figure 4-2. Outer Camp sites annual water-level change.

Figure 4-3 shows water levels for the Orphan Boy Mine and the Montana Tech well, along with monthly precipitation amounts. Water levels in the Montana Tech well showed a similar response to precipitation events from 2001 through 2005, rising in the spring and declining throughout the winter. However, the 2005 water-level rise was less than the previous two years although precipitation amounts were higher. The 2006 water-level response was similar in the spring, with water levels beginning to rise in April; however, a corresponding decline in the fall did not occur. Instead water levels continued to rise into the late fall-early winter before leveling off. Water levels had a net increase between 4.5-ft and 5.5-ft at these two sites.

Water levels in the Marget Ann Mine and well S-4 increased between 7.1-ft and 8.6-ft during 2006. This is only the second yearly rise in the last eight years. Figure 4-4 shows water-level hydrographs for these two sites with monthly precipitation totals shown. Water levels from 1994 through 1998 showed a consistent increase regardless of precipitation amounts. From 1999 through 2002, water levels declined, with little apparent influence from precipitation. Water levels in the Marget Ann Mine and well S-4 increased throughout 2003. The initial 2003 water-level rise occurred shortly after a substantial amount of precipitation in the spring (April) of 2003 and continued to rise regardless of precipitation trends the remainder of the year. During 2004 and 2005, water levels declined steadily throughout the year regardless of precipitation events. This trend reversed itself in 2006 with water levels rising in the spring (April), before leveling off in the late fall-early winter. This is the same trend observed in the MT Tech well and Orphan Boy Mine.

Water levels in all four of the Outer Camp sites have a net increase since monitoring began. The increases vary from over 8-ft at the MT Tech well to just over 30-ft at the Marget Ann Mine.

Section 4.2 Outer Camp Water Quality

Water-quality samples were collected from three locations within the Outer Camp System during 2006, those being the Orphan Boy Mine, Orphan Girl Mine, and the Green Lake seep. The Orphan Girl mine is not part of the regular monitoring network; however, the opportunity to sample this site arose due to construction work in the shaft, so a one-time sample was collected. The other two sites were sampled twice each. Figure 4-5 shows selected water chemistry for the Orphan Boy Mine. Water-quality trends have been downward for the most part, the exception being zinc, which increased the past several years. However, these increases coincide with a change in sampling procedures at this site. The 1987 and 1988 samples were collected by bailing a sample from the shaft; while the 2005 and 2006 samples were collected by installing a pump into the shaft and pumping for several hours prior to sampling. It is possible that the change in sampling technique is responsible for the apparent water-quality changes.

Water quality in the Outer Camp is of better quality than that of either the East Camp or West Camp bedrock systems. This is most likely a combination of different geology and equilibrium being reached as a result of the workings in this area being flooded for a longer period of time.

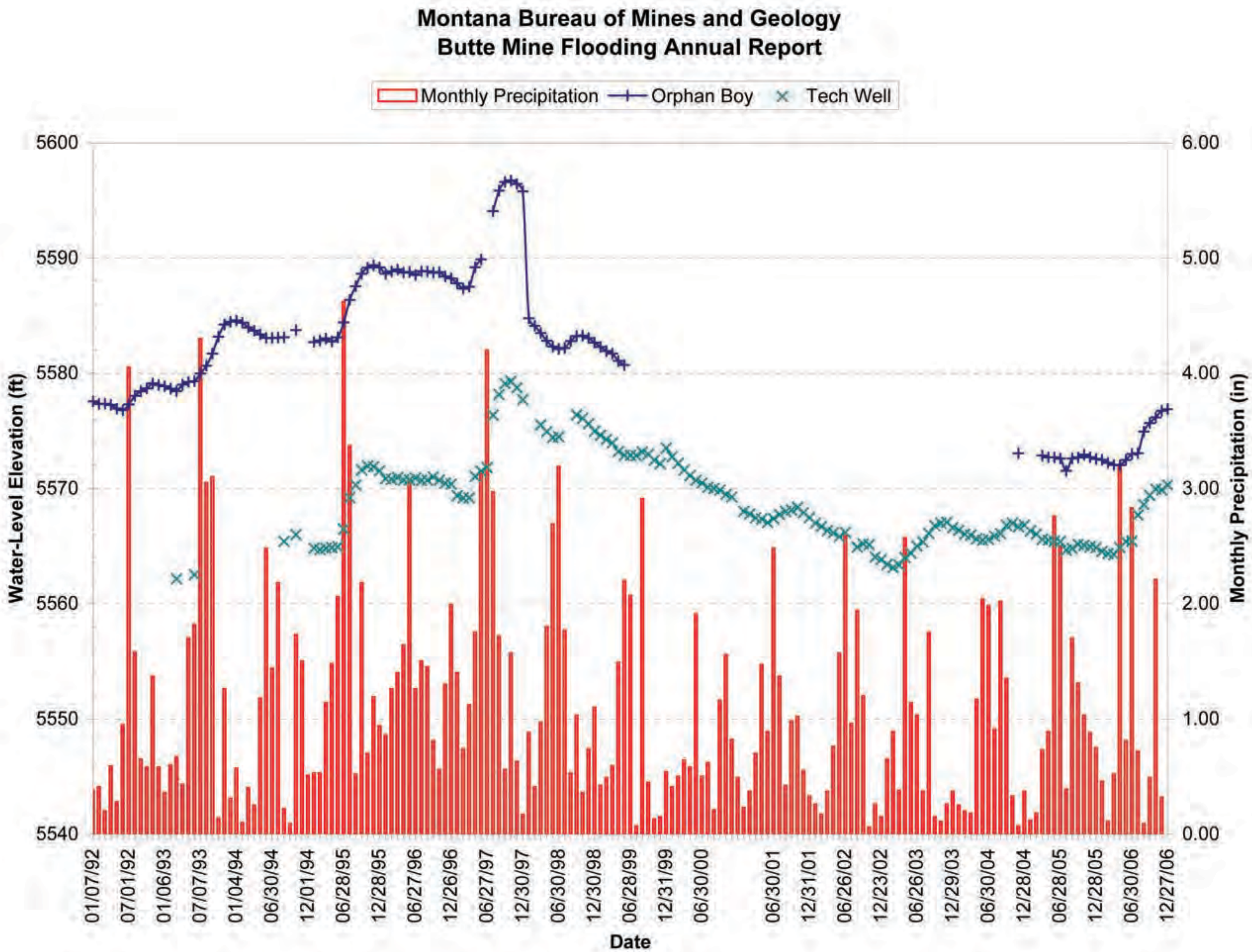

Figure 4-3. Water-level hydrograph of the Orphan Boy Mine and Montana Tech wells.

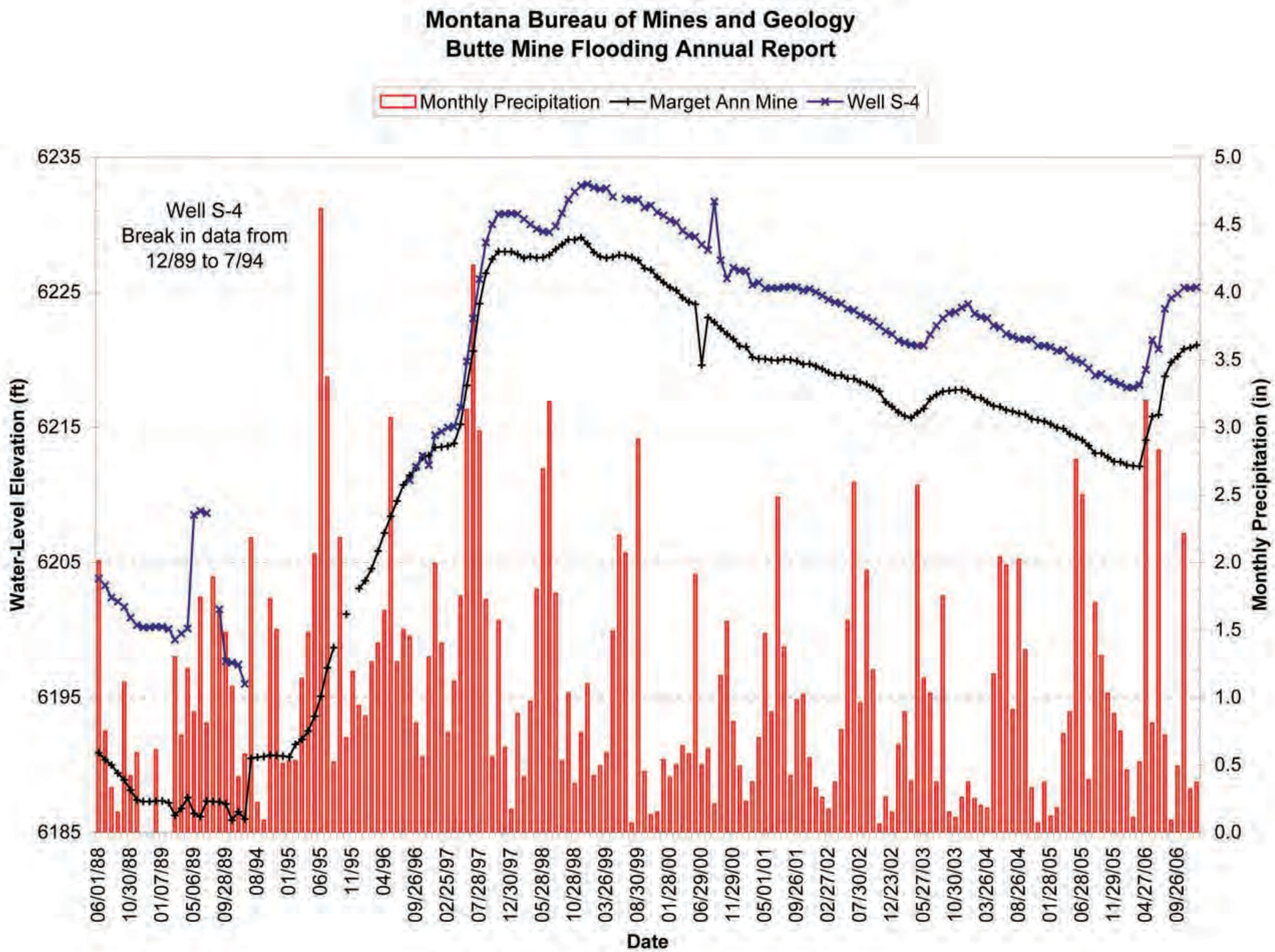

Figure 4-4. Water-level hydrograph for Marget Ann Mine and well S-4.

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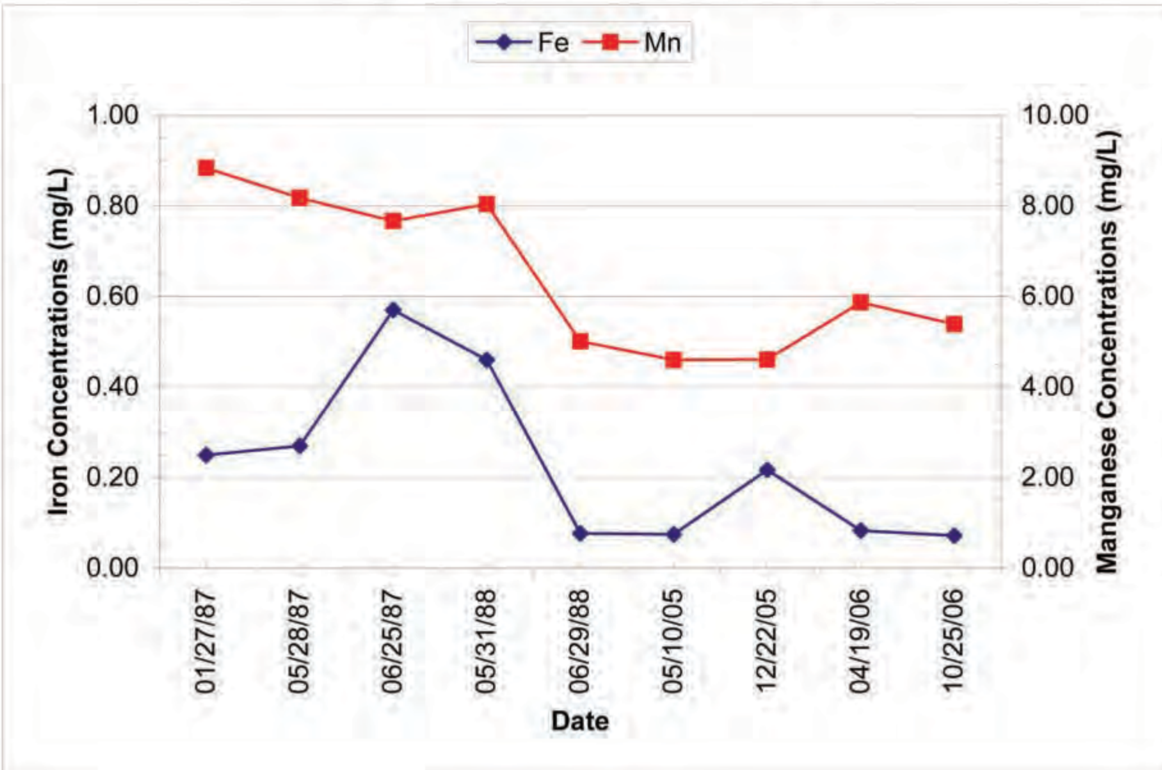
Butte Mine Flooding Monitoring



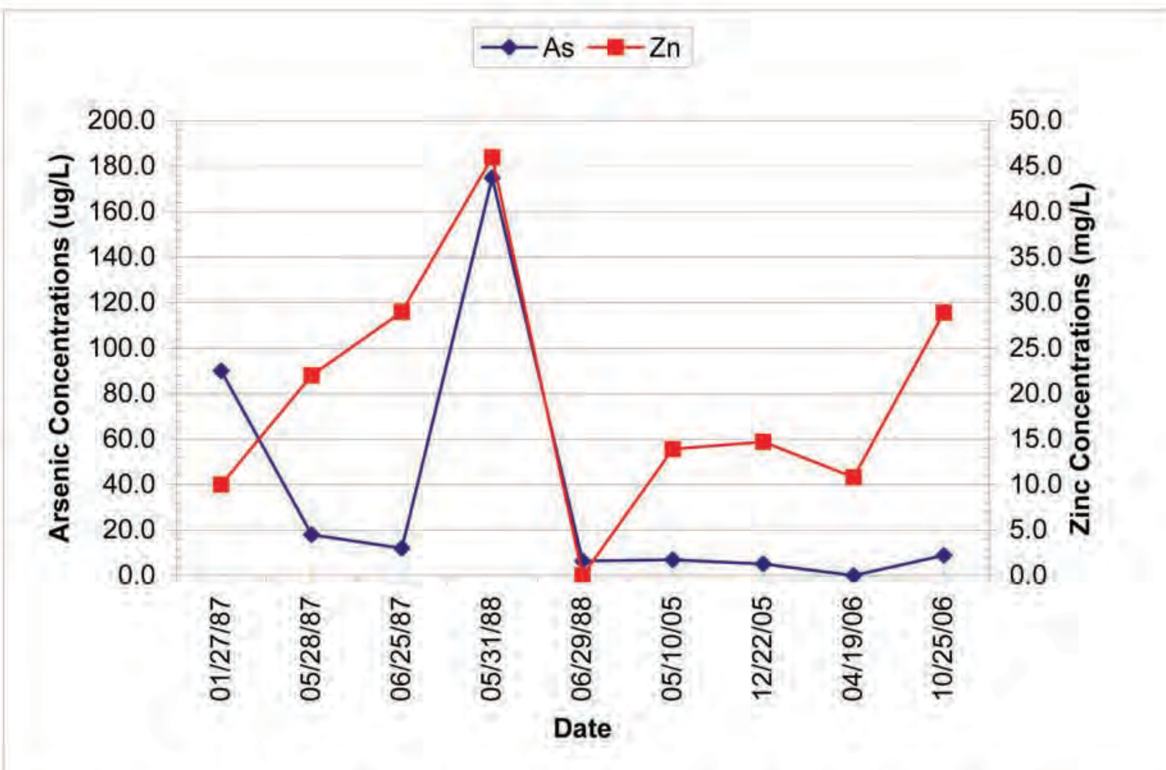


Figure 4-5. Selected water chemistry for Orphan Boy Mine.

SECTION 5.0 PARK WELLS

The locations of the park monitoring wells are shown on figure 5-1. The Hebgen Park and Parrott Park wells are both part of the monitoring program specified in the 2002 CD. The Belmont Well #1 has been added to this group of wells as it is also a bedrock well located within the East Camp system, and is part of the CD monitoring program.

Section 5.1 Park Wells' Water Levels

Annual water-level changes are listed in Table 5.1.1 and shown on figure 5-2. The yearly water-level changes in Belmont Well #1 since 1997 have been much greater than those seen in the other two wells, with the exception of two years. Regardless of whether the change is a rise or fall in water-levels, the magnitude of the change is typically much greater is this well; water levels have varied anywhere from 10 to 50-ft in a year compared to 7-ft or less in the other wells. Since monitoring began at these sites, water levels have rise between 4-ft and 30-ft in the Hebgen and Parrot Park wells, while falling more than 80-ft in the Belmont Well #1.

Table 5.1.1 Annual water-level change for miscellaneous wells, in feet.

Year	Hebgen [1]	Parrott	Belmont Well #1	Year	Hebgen[1]	Parrott	Belmont Well #1
1983				1993	6.27	1.39	
1984				1994	-0.25	5.96	
1985				1995	NA	2.67	
1986				1996	2.75	-1.50	-0.74
1987				1997	4.22	4.75	15.05
1988	1.54	1.43		1998	-0.62	-0.33	-15.13
1989	-2.18	0.42		1999	-2.93	-5.34	14.80
1990	-1.90	5.23		2000	-6.07	1.50	-8.11
1991	3.09	-6.10		2001	0.37	5.47	-0.41
1992	-1.40	0.63		2002	-0.41	-3.27	-24.08
Change Years 1-10	**-0.85**	**1.61**	**---**	**Change Years 11-20**	**3.33**	**11.30**	**-18.62**

Year	Hebgen(1)	Parrott	Belmont Well #1	Year	Hebgen(1)	Parrott	Belmont Well #1
2003	1.25	3.52	-54.19	2013			
2004	-0.12	-1.12	-39.79	2014			
2005	-2.19	6.76	-5.01	2015			
2006	2.86	6.95	35.07	2016			
2007				2017			
2008				2018			
2009				2019			
2010				2010			
2011				2021			
2012				2022			
Change Years 21-24	**1.80**	**16.11**	**-63.92**				
Net Change* Years 1-24	**4.28**	**29.02**	**-82.54**				

(1) Hebgen Park Well B No data from 06-1992 to 01-1993, 01-1995 to 09-1996, and 01-1998 to 01-1999.

(*)Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements.

NA- no access.

P&A- well plugged and abandoned.

Water-level responses during 2006 at the Hebgen Park well (fig. 5-3) were similar to those seen in prior years. Water levels begin to rise during the late spring and continue through the fall, which coincides with both summer precipitation and lawn watering of the park. Precipitation, or the lack of, does not appear to influence water levels once they begin to rise in the spring. Since the water-level rise extends into the fall and early winter, it is probable that a portion of the increase in water level is due to lawn watering in addition to precipitation. The water level in this well increased almost 3-ft during 2006. Since monitoring began at this site, water levels have increased over 4-ft.

The water-level hydrograph for the Parrott Park well is shown on figure 5-4, along with monthly precipitation totals. Water levels declined during most of 2002 before leveling off and rising during December of 2002. The 2003 water levels and trends were similar to those of 2000 and 2001; however 2004 water levels did not show the same level of response to precipitation. Water levels declined for most of 2004 before rising almost 3.5-ft the last two months of the year. The rise that occurred the last 2 months of 2004 is not related to either precipitation events or lawn irrigation. Water levels at this site continued to rise throughout 2005 and 2006 regardless of precipitation trends. The greater than 6-ft water-level rise for 2006 is unlike any other site (with the exception of Belmont Well #1) outside the East Camp bedrock system.

Figure 5-1. East Camp park monitoring wells location map.

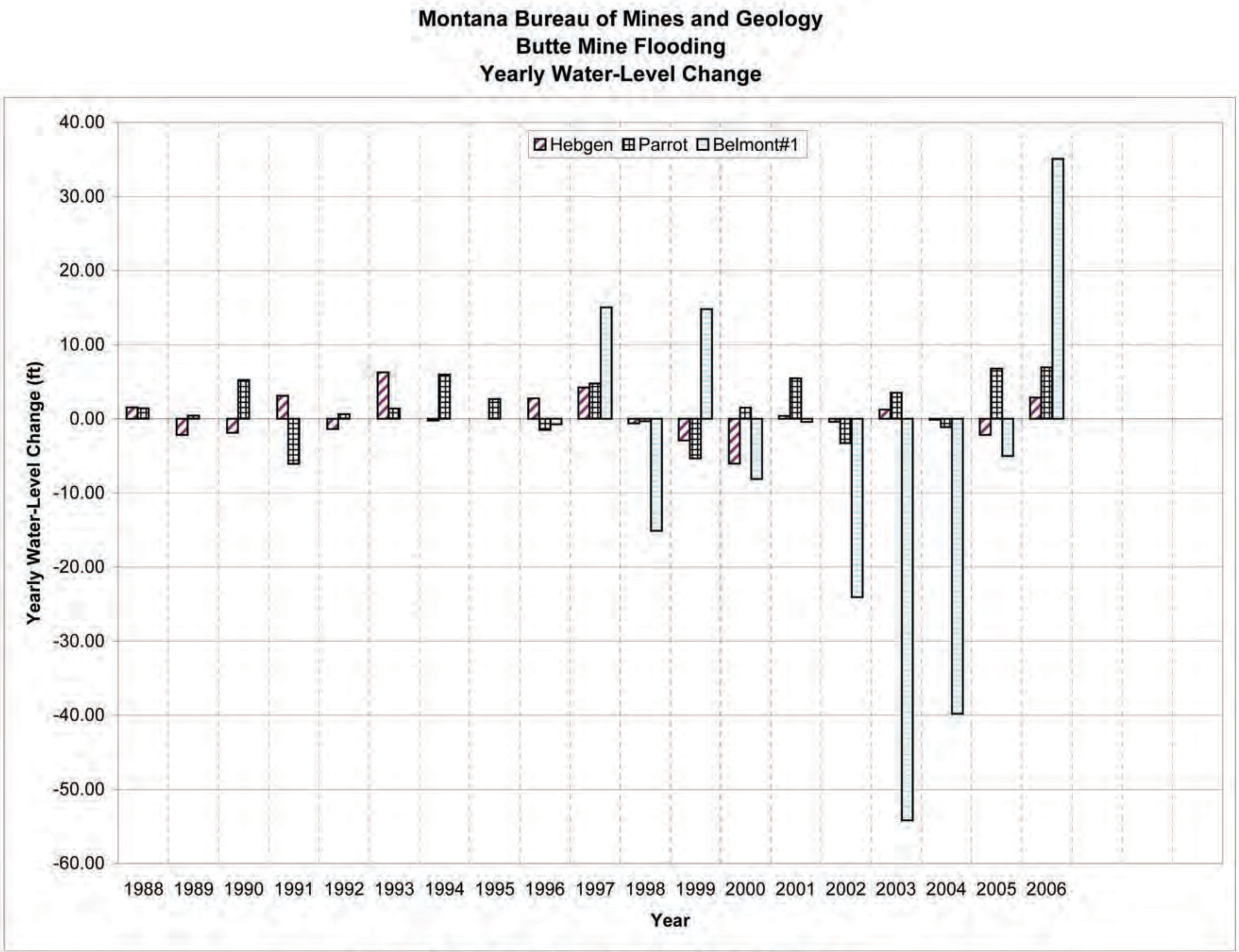


Figure 5-2. Park wells annual water-level changes.

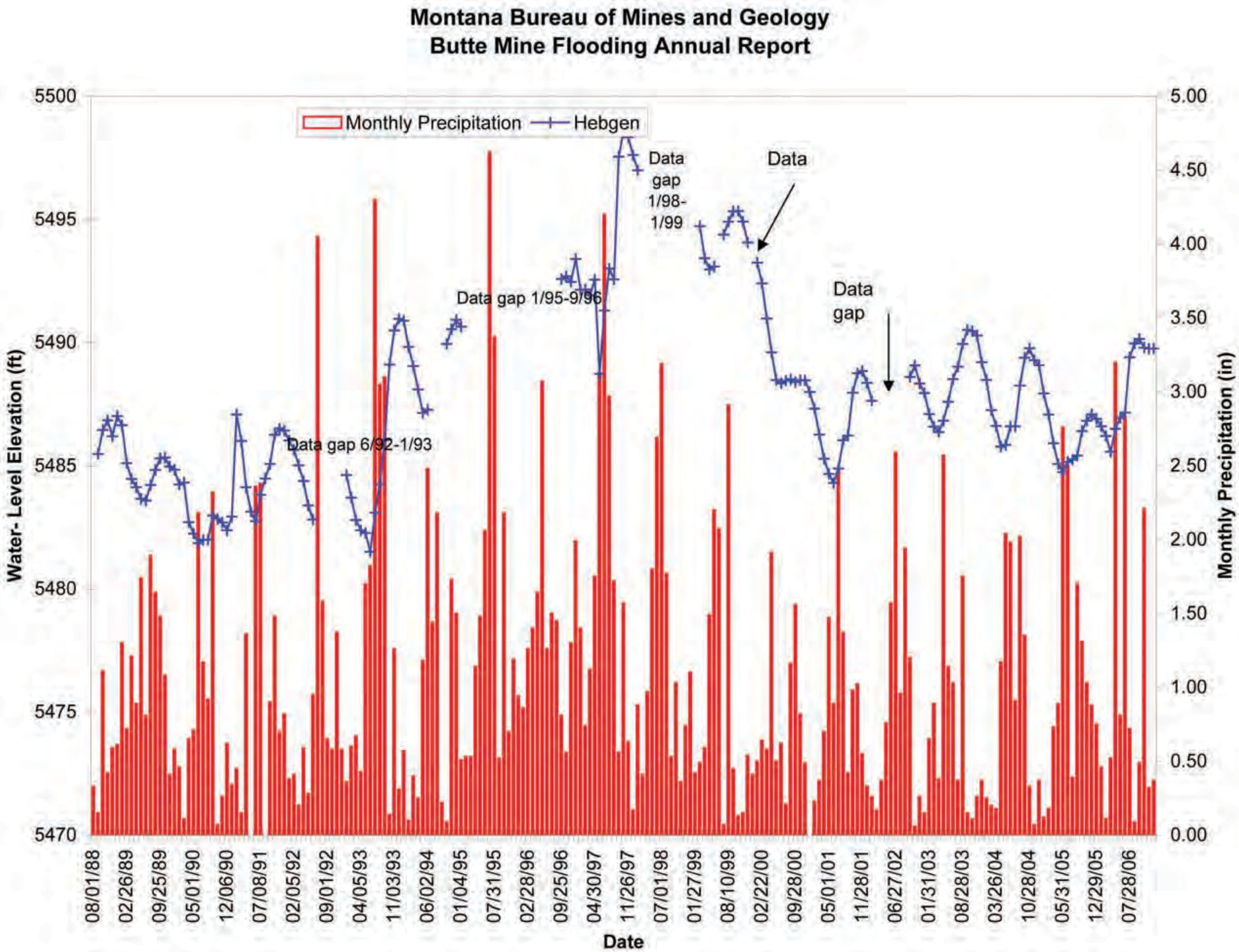


Figure 5-3. Water-level hydrograph for the Hebgen Park Well.

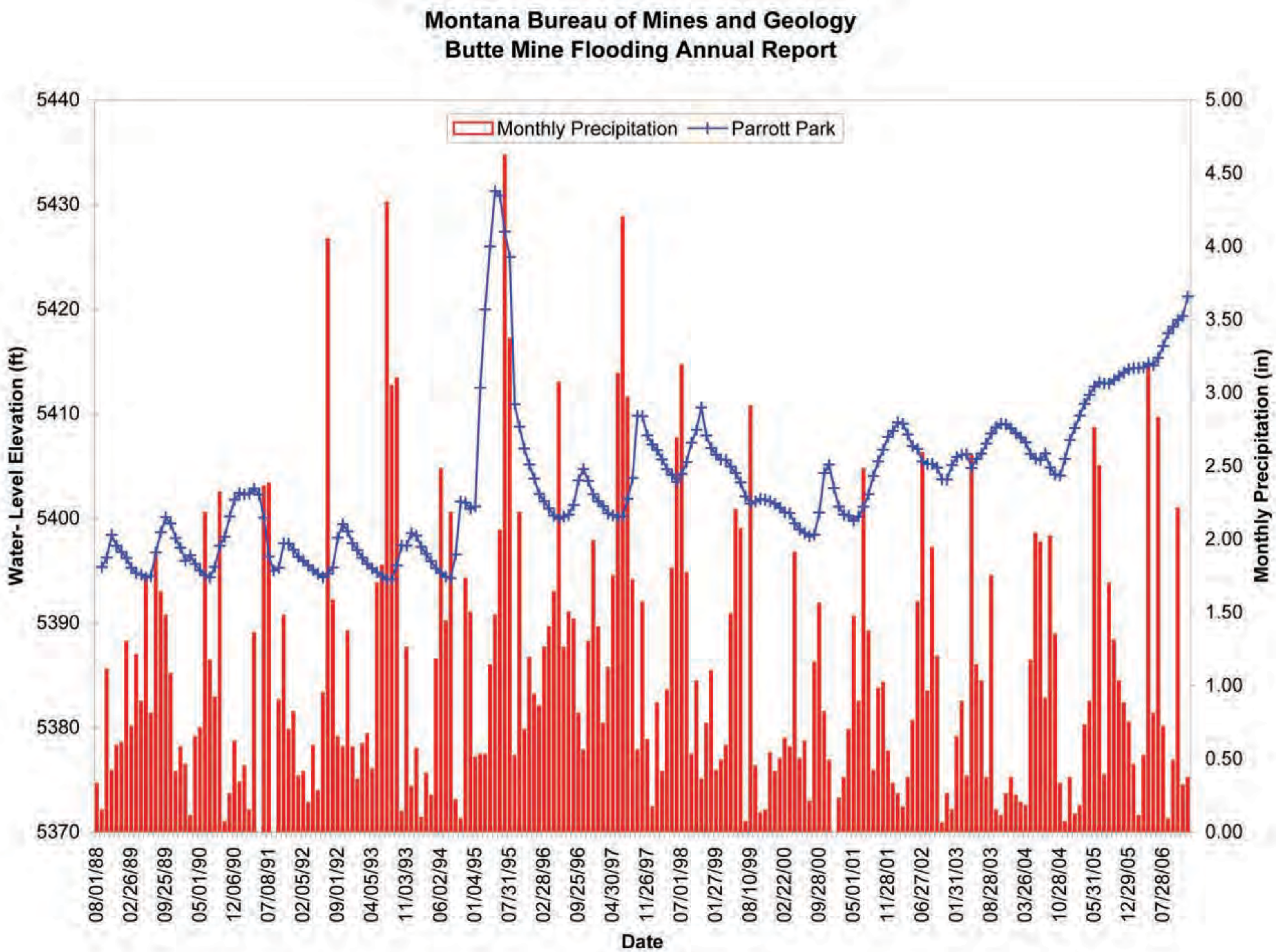


Figure 5-4. Water-level hydrograph for Parrott Park well.

Figure 5-5 is a water-level hydrograph for both the Parrott and Hebgen Park wells which shows the recent water-level trends. The water-level increases seen in the Parrott well coincides with a water-level decline and stabilization in the Hebgen well.

The Belmont Well #1 was originally drilled as a replacement well for monitoring the water level in the Belmont Mine. However, during well completion a collapse in the borehole prevented the casing from being installed to the proper depth. Instead of abandoning this well after a new replacement well was drilled it was kept as a monitoring site since its water level differed from that of the deeper bedrock (mine) system. Water-level changes in this well differ from those seen in any other bedrock well (figure 5-6). From 2002 through 2005 water levels declined more than 120-ft, before rising 35-ft in 2006. It initially appears there may be a response to precipitation and or lawn irrigation when water levels and precipitation are compared during certain periods since 2003 (figure 5-6); however, when a closer look is taken of the graph the water-level increases are 10-ft, 20-ft or more. This amount of rise is much more than would be expected from both precipitation and lawn irrigation even in a bedrock system with low permeability. It is possible that since this well was drilled into the underground mine workings and then collapsed that a fracture opened up allowing water to drain through the collapsed portion of the borehole into the mine workings for several years. Over time the collapsed portion of the borehole has lost permeability through the swelling of clays and water is no longer draining into the underground workings. The resulting water-level rise is related to the gradual rise back to pre-2002 water levels. The water level in this well is 150-ft or more above the water level in the underground mines in this area. This well has been equipped with a pressure transducer to record more frequent water-level changes. Figure 5-7 is a hydrograph for this well from the fall of 2003 through 2006.

Section 5.2 Park Wells' Water Quality

Water-quality samples were collected only from the Parrot Park well during 2006. Figure 5-8a shows concentration trends for cadmium and copper over time for this site, while figure 5-8b shows zinc concentrations over time. Cadmium concentrations exceed the MCL limits while arsenic concentrations are just below the 10 ug/L MCL.

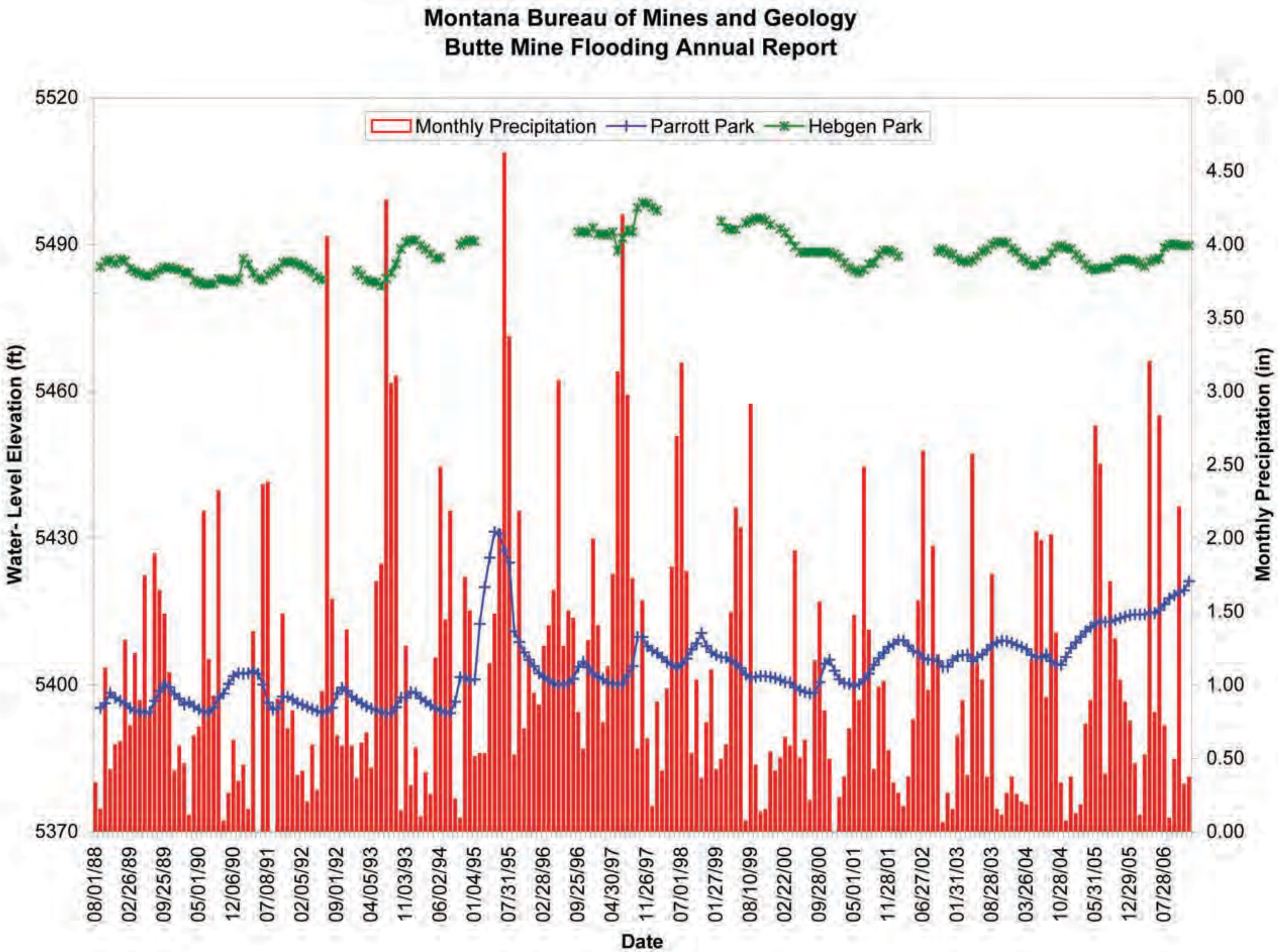


Figure 5-5. Water-level hydrograph for Parrott and Hebgen Park wells.

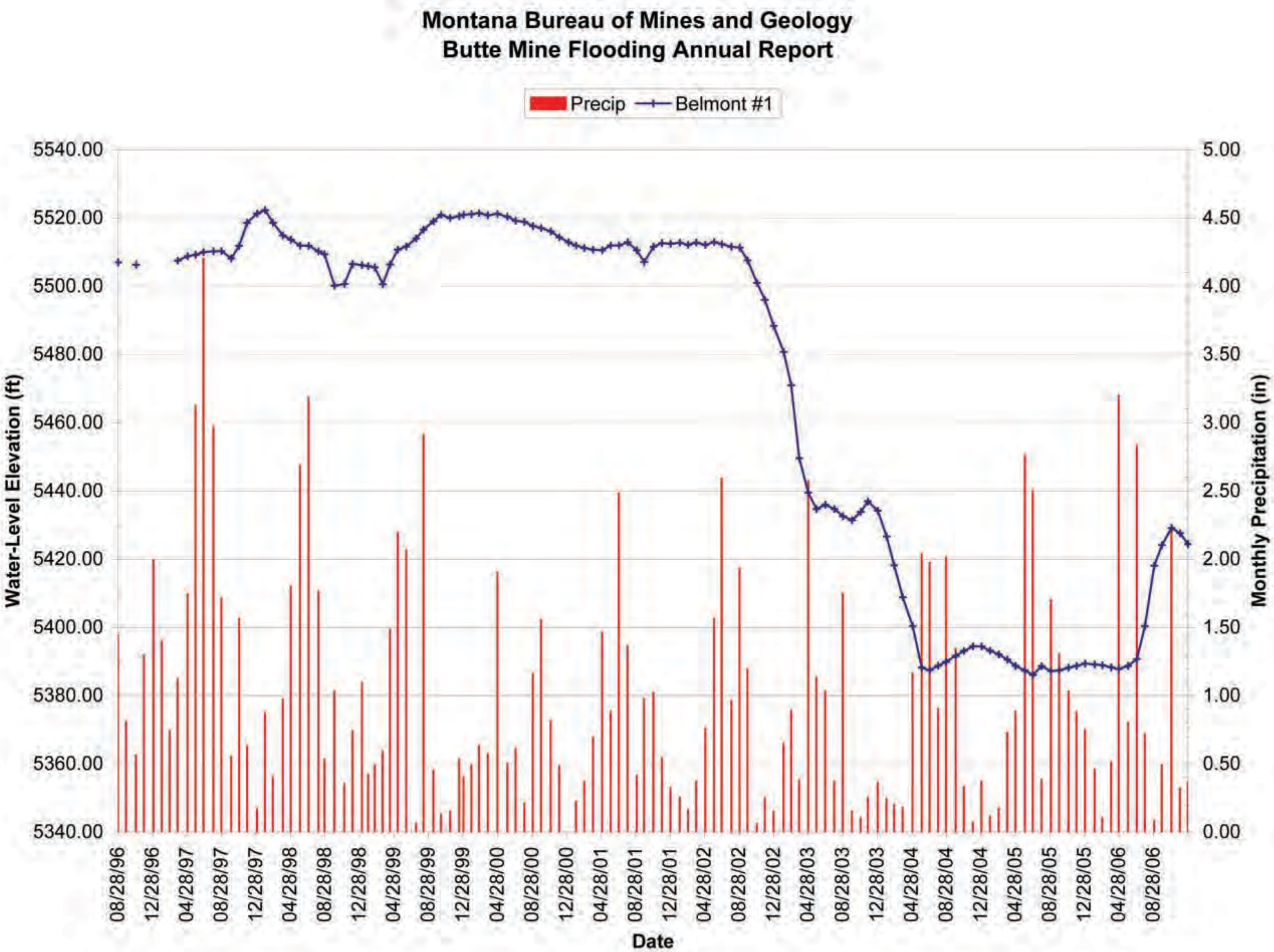


Figure 5-6. Water-level hydrograph for Belmont Well #1.

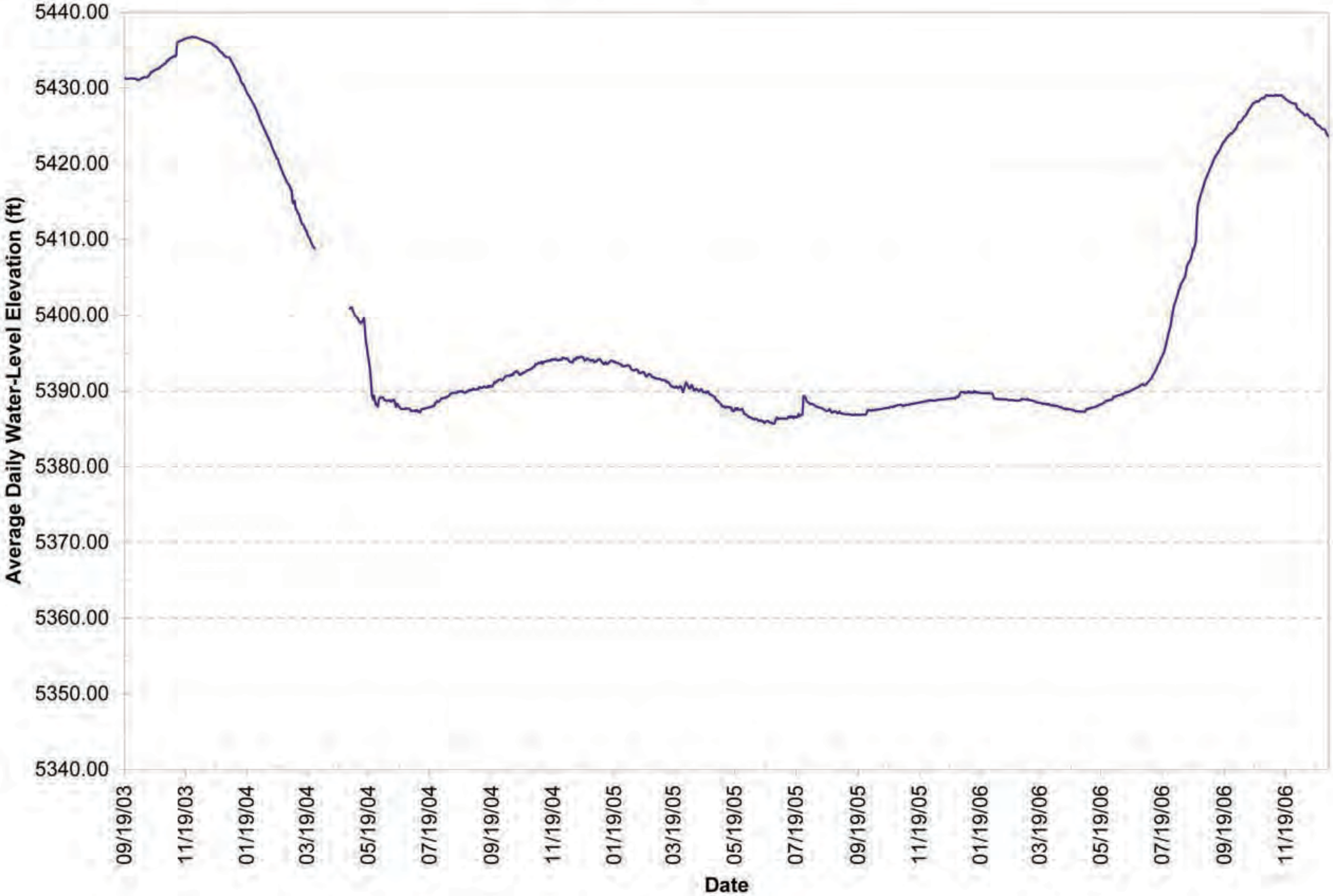


Figure 5-7. Average daily water-level elevations hydrograph for the Belmont Well #1.

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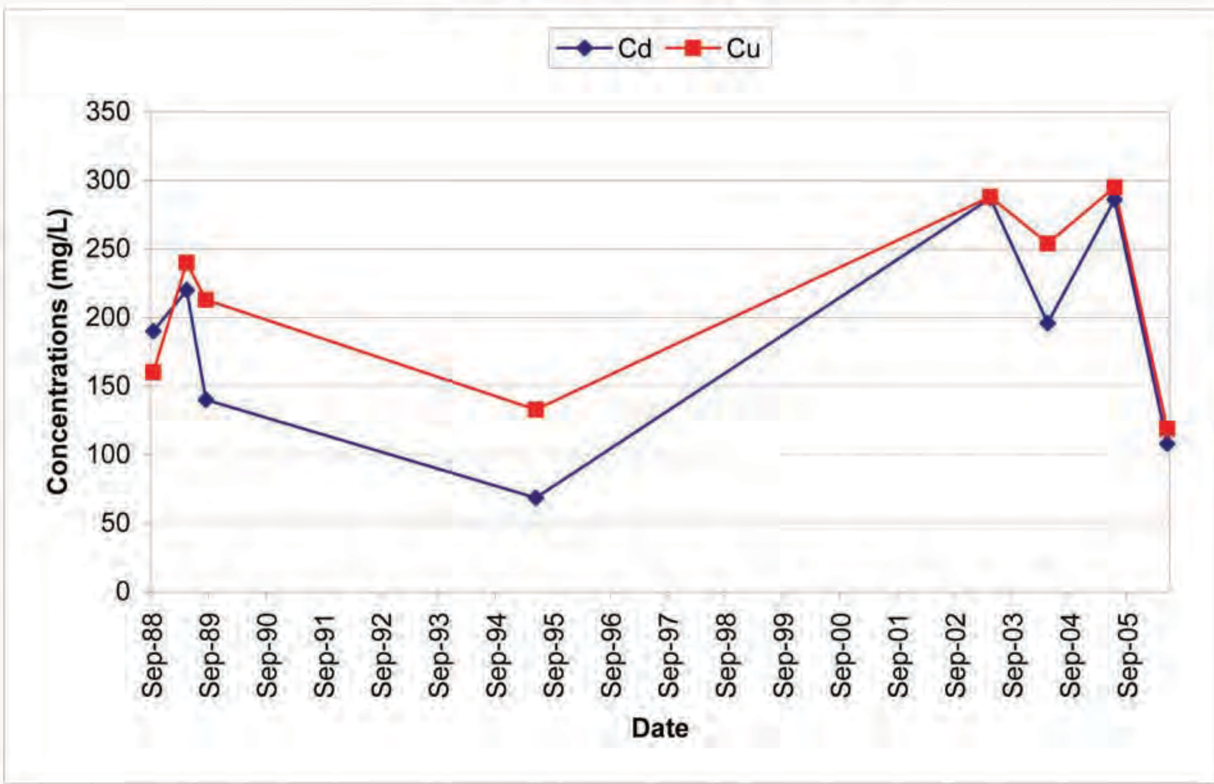

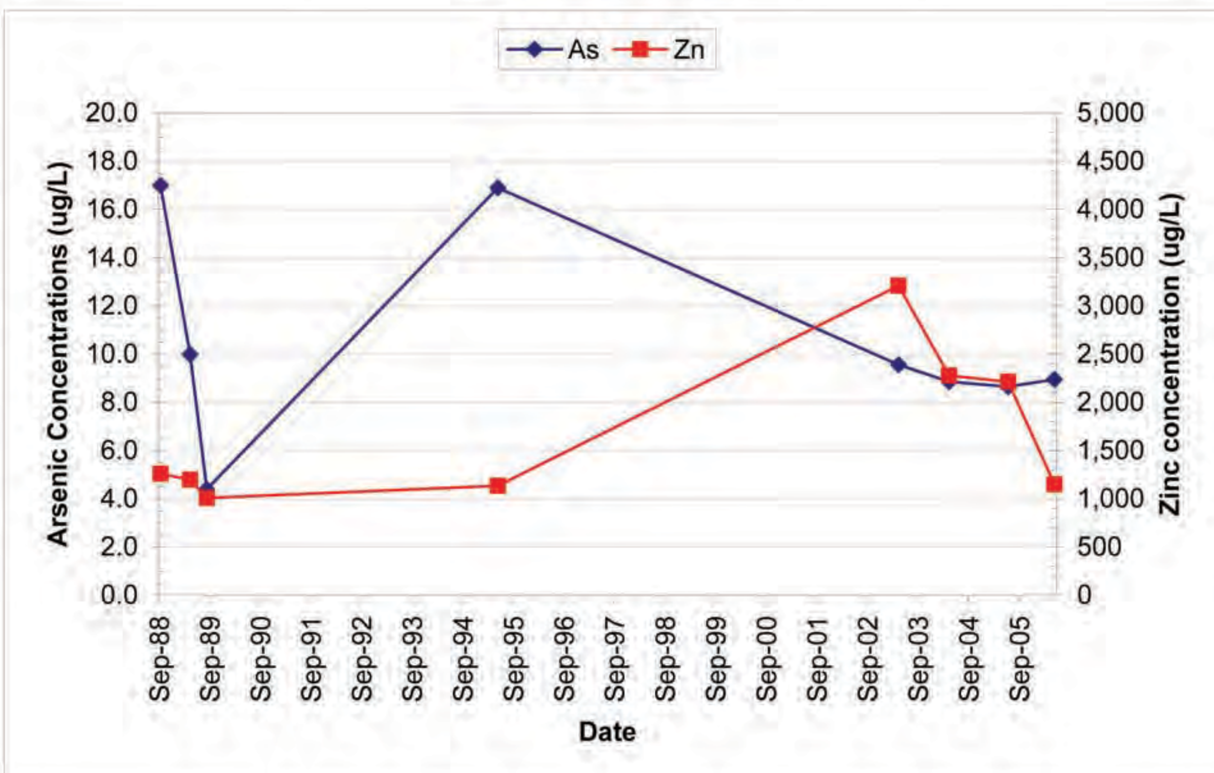

Figure 5-8a (top). Cadmium and copper concentrations for the Parrot Park well.
Figure 5-8b (bottom). Arsenic and zinc concentrations for the Parrot Park well.

SECTION 6.0 REVIEW OF THE BERKELEY PIT MODEL

The Berkeley Pit water-level model was updated based upon actual 2006 water-level measurements and HSB flows as measured in the water-treatment plant. The model incorporates monthly water-level rise information from July 1996 through December 2006.

Based upon the 2006 model update, it is projected that the critical water level (CWL) of 5,410-ft will be reached at the Anselmo Mine in **November 2021**, 5 months later than predicted in the 2005 model (June 2021). The model update includes the surface water inputs from storm water diversions in the Kelley Mine area, the addition of sludge from the HSB water-treatment plant, and previous models infilling rates adjusted for the diversion of HSB water away from the pit. The HSB drainage water that was flowing into the pit from June 2000 through November 17, 2003 is now being diverted to the HSB water-treatment plant for treatment and is being used in MR's mining operations. No major additions into or withdrawals of water were made from the Berkeley Pit during 2006; the consistent filling rate and operational activities led to the slight adjustment in filing rate projections.

The treatment technology and plant-construction time frame for Berkeley Pit water are based upon the schedule listed in the EPA 1994 ROD, and included in the 2002 CD for the Butte Mine Flooding Operable Unit (EPA, 1994). Based upon the current water-level projections, a review of the HSB treatment plant design and operation would begin in November 2017. Any necessary upgrades would have to be completed by November 2019.

SECTION 7.0CONCLUSIONS AND SUMMARY

Water-level trends in the alluvial monitoring system within the active mine area were similar to those of 2003 and before, with water levels declining in wells north of the Pittsmont Dump. This reverses the trend seen in 2004 and 2005 of water levels increasing in a majority of the wells in this area. Water levels rose in a majority of the wells south of the Pittsmont dump, following trends that began in 2003.

Precipitation events still have little or no influence on water levels in the LP-series alluvial wells near the Berkeley Pit and leach pads. Water-level variations in these wells have a greater response to mining activities than precipitation events.

Water levels in a majority of the alluvial monitoring wells located outside the mine area show a response to seasonal precipitation events. The response time varies from immediate to a two- to three-month lag time. The decrease in annual precipitation in the Butte Basin since 1999 was considered a good explanation for the overall water-level decrease seen in a number of monitoring wells, however, water levels increased in all of these wells (AMC and GS series) in 2003 and a majority of them in 2004 before decreasing in 2005. The 2003 water-level increase occurred although precipitation levels were less than previous years. The increases were greater in wells nearest the mine site and water levels rose the most from late summer through the remainder of the year. While this period of time coincides with MR's mine start-up activities, no direct link was found between start-up activities and water-level changes. However, a relationship between filling of the MR concentrator Ecology/Emergency Pond and water-level increases in several AMC wells was apparent. Water-level increases in 2006 were consistent in the alluvial monitoring network, similar to 2003-2004 trends.

The increased water-level changes in the East Camp bedrock system are independent of precipitation, and are a result of the 1982 cessation of long-term mine dewatering activities. No notable precipitation influence was seen in any of the bedrock wells or underground mines water levels. However, the continued diversion of HSB drainage water away from the Berkeley Pit did have an influence on East Camp bedrock water levels. The water-level rise for 2006 (based upon wells A and G) was about 40-50 percent that of 2002-2003 when HSB water was flowing into the pit. Water levels in the bedrock system were affected in varying degrees by MR Central Zone exploration activities (grouting, pumping tests etc), however, no long-term impacts were noted.

The date the East Camp system water level is predicted to reach the CWL elevation of 5,410-ft was changed from June 2021 to November 2021, or 5 months later than that predicted in 2005. The CWL date is assumed to be the date the 5,410-foot elevation would be reached at the Anselmo Mine. The Anselmo Mine is the anticipated compliance point in order to keep the Berkeley Pit the lowest point in the East Camp bedrock-mine system. This will ensure that all water in the historic underground mine system will continue to flow towards the Berkeley Pit.

The pumping of ground water in the West Camp System continues to control water levels in this system. The volume of water pumped during 2006 was 13 percent more than 2005 resulting in water-level decreases of a foot or more throughout this system; water levels are now over 11-ft below the maximum-allowable level.

Monitoring wells in the alluvial aquifers associated with the Mine Flooding Operable Unit continue to show a wide range of water-quality concentrations, both spatially and temporally. As is the case for the last few years, the AMC-series wells show a wide variation and few trends with respect to the concentration of dissolved constituents. The LP-series wells show a continuation of recent trends in most wells for most constituents.

In several cases, chemistry data from the East Camp mines show a strong departure from historic trends, particularly with respect to iron concentrations. What was possibly a sampling or analytical problem is likely a real change in the chemistry of water in the underground workings.

Recent data from the West Camp monitoring sites generally indicate a continuation of recent trends in water quality. Although concentrations of several dissolved constituents trend upward, they are generally well below values observed during initial flooding. Data from the Emma shaft continue to show departure from recent trends and a notable difference in water quality compared to the Travona Mine.

Results of the 2006 monitoring program continue to show that the current monitoring (water-level and water-quality) is adequate for ensuring that contaminated bedrock ground water is flowing into the Berkeley Pit, and that West Camp water levels are being sufficiently controlled by West Camp pumping operations. These are two of the main environmental concerns associated with the flooding of Butte's historic underground mines and the Berkeley Pit.

ACKNOWLEDGEMENTS

The information contained in this report represents the work of many companies and agencies over the past 25 years. Numerous individuals have been responsible for actual data collection. Their dedication and creativity in monitoring and sampling of mine waters provided the information that all future work and evaluations relied upon.

The State of Montana, Department of Environmental Quality and the U.S. Environmental Protection Agency have provided funding for the MBMG to conduct monitoring and sampling activities and preserve continuity between various studies. This support has been invaluable; while their realization that flexibility is needed in the monitoring program has allowed modifications in monitoring as conditions change.

The continued cooperation of Montana Resources and British Petroleum/Atlantic Richfield Company is greatly appreciated, while representatives of New Butte Mining continue to allow access to their properties for monitoring purposes. Special appreciation is extended to the property owners who allowed access to their property for the installation of the new alluvial monitoring wells: Gilman Construction, Continental Public Land Trust, Butte School District #1, and Race Track Volunteer Fire Department.

Special recognition is given to Mike Kerschen, MBMG, for his dedication to monitoring and sampling tasks, and to Peggy Delaney, MBMG, for assisting with the preparation of this report.

Errors and omissions remain the authors' responsibility

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