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ANALYSIS OF ACID ROCK DRAINAGE IN THE MIDDLE REACH OF THE RED RIVER, TAOS COUNTY, NEW MEXICO

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INTERIM REPORT

FOR

MOLYCORP INC.

QUESTA DIVISION

VAIL ENGINEERING, INC.

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ANALYSIS OF ACID ROCK DRAINAGE IN THE MIDDLE REACH OF THE RED RIVER, TAOS COUNTY, NEW MEXICO - INTERIM REPORT

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1 INTRODUCTION

1.1 Foreword

This report presents interim results of an on-going study aimed at identifying the sources and fate of acid rock drainage from natural and mine-disturbed areas along the middle reach of the Red River, Taos County, New Mexico. Recently, a comprehensive study program has been initiated by Molycorp under the time extension request for Development of a Closeout Plan. The interim results presented here will be updated and included in the comprehensive water and load balance study, which was proposed under this study program (RGC, 2000a) and is due for submittal on December 15, 2000.

In this report the term acid rock drainage (ARD) is used generically to represent all contaminants (in particular sulfate) which are generated during the process of oxidation of mineralized rock.

1.2 Background

At the present time, the water quality in Red River through the mine area is very high and in compliance with the New Mexico State Stream Standards for a Cold Water Fishery. Occasional exceedances of the Standards in the past, have generally been the result of run-off from intense thunderstorms over the hydro-thermal scar areas upstream of the mine area (Smolka and Tague, 1998) and from high concentrations of natural acid rock drainage products during very low river flow periods.

Prior analyses of the flow and acid rock drainage accretions to Red River have focused primarily on the surface flows in the river (e.g. Slifer, 1996; Vail, 1989; Allen et al., 1999). A notable increase in sulfate and metal concentrations in the Red River along the mine reach was observed which was attributed to acid rock drainage from the mine area (Slifer, 1996; Allen et al., 1999).

However, recent analyses have shown that there is a significant ground water flow in the alluvial aquifer along the Red River valley and that this aquifer transports a significant portion of the contaminant load originating upstream of the mine area. Most of this underground flow is discharged to the river surface flow in the Columbine Park area, i.e. along the lower reaches of the mine area. This groundwater flow significantly contributes to the ARD loading to the Red

River and needs to be included in any load and source determination of acid rock drainage (ARD) for the middle reach of the Red River (including reach along Molycorp's Questa mine).

This report summarizes results of a flow and sulfate load balance analysis, which considers both the surface flow and ground water flow in the middle reach of the Red River basin. It will be shown that much of the ARD loading to the Red River originates from mineralized areas located upstream of the mine and transported to the mine area via groundwater flow. The results of this analysis suggest that earlier studies, which neglected groundwater flow in their analysis, are significantly in error and likely have overestimated the ARD contributions from the mine area to the Red River.

1.3 Study Objectives

The objectives of the present study can be summarized as follows:

- Develop water balance for middle reach of Red River System;
- Develop sulfate load balance for Red River System
- Assess Impact of Questa Mine Operation on Sulfate Loading.

1.4 Organization of Report

Section 2 summarizes the methods and results of the field investigation which provides the basis for subsequent analyses. Section 3 summarizes the methods and results of the flow and sulfate balance, including supporting analyses on the runoff yield from the middle Red River basin and properties of the alluvial aquifer system. Section 4 discusses the impact of natural versus mining-related acid rock drainage on the Red River and the impact of long-term climatic conditions on contaminant yields. Section 5 summarizes the major findings of this interim study.

2 FIELD INVESTIGATION

The field investigation focused on the middle reach of the Red River between the town of Red River and the Ranger Station (Figure 1). Vail Engineering has performed regular stream water quality surveys since 1988. These earlier surveys are described in more detail in Vail (1989 and 1993). This report summarizes the results of the most recent river survey conducted on October 13, 1999.

2.1 Methods

2.1.1 Period of Observation

The stream survey was conducted on October 13, 1999 representing low flow conditions typical for this time of year. This observation period was selected for several reasons:

- ARD accretions have the most pronounced effect on the water quality in the Red River during fall and winter (due to the absence of dilution by spring runoff);
- Stream flows show very little diurnal variation allowing accurate stream flow measurements and determination of accretions between stations;

No significant precipitation events or large day-to-night temperature fluctuations (which could cause cyclic freezing and thawing of the river flows) were observed prior to and during the sampling event.

2.1.2 Sampling Stations

The number of stream water sampling stations was significantly increased from those used in earlier surveys (USDHEW, 1966; USEPA 1971; Smolka and Tague, 1986 & 1988) in order to allow a more detailed determination of where and to what extent Acid Rock Drainage (ARD) is being discharged to Red River. The initial Molycorp survey conducted by Scott Vail in 1988 sampled the main stream of Red River at 15 locations. In subsequent years additional stations were added at locations where further definition of the accretions was desired. Surveys in recent years resulted in water sample collection from the River at 23 stations. In addition water samples have been collected from more than 20 side flows such as springs and wells which were tributary to or in the surface or ground water flow path.

Figure 4 shows the locations of the various sampling stations along the Red River used during the most recent survey on October 13th 1999. The locations of the sampling stations were selected to provide data which would reflect the change in the water quality of Red River past each significant segment such as individual hydro-thermal scar areas, major drainage areas, mine waste rock deposits, significant springs and mill water diversion points.

2.1.3 *Water Quality Sampling and Analyses*

All stream surveys were conducted from station to station in a downstream direction and all stations along the river were sampled on the same day. This procedure was followed to determine the extent practical the changes in the same section of the flow as it proceeded downstream (average flow velocities in the river between the town of Red River and the Ranger Station vary from about 0.75 to 1.5 miles per hour resulting in a total travel time of approximately 8 hours for this reach).

All river samples were collected from near mid stream to obtain a well-mixed, representative sample (there are many hidden ARD seeps along the river and concentrations may travel downstream for a considerable distance before the flow is completely mixed). Many locations were checked by taking conductivity readings across the stream cross section before the site was selected as a sampling station. Suspended ARD constituents tend to settle out and concentrate in the lower portion of placid sections of the stream flow. Samples were collected at the lower end of turbulent water areas to insure representative sampling.

All sample locations were approached in an upstream direction. Wading upstream of the sampling point was avoided as such might stir up settled precipitates. Sample bottles were held by the base and filled with the bottle mouth pointing upstream.

Sample bottles were permanently marked with the Station Number prior to filling. Sample bottles were placed in ice chests immediately after filling. Ice was added to the chests when either the river water or ambient air temperature was significantly above freezing.

Field conductivity, pH and temperature measurements were taken simultaneously with the collection of the water samples and from the same spot. The conductivity readings were reviewed at that time to note any erratic or unusual changes. Field conductivity measurements were taken with a HACH Model 44600 temperature compensating conductivity meter. Field pH measurements were made with a water proof temperature compensating pH meter.

The conductivity and pH meter probes were soaked in distilled water for about an hour prior to the first sample collection and the probes were kept moist during the survey period. It was found that rinsing the conductivity and pH meters with distilled water after each reading resulted in a much longer time for stabilization and more erratic readings. When this was done, the meters had to adjust all the way from a near zero conductivity of the distilled water to the high conductivity of the river water. The probes were kept moist in the water from the previous sample station while traveling to the next point. Before taking the next reading the probes were thoroughly rinsed in the water then being sampled. To avoid sudden large changes in the readings, we generally collected samples and made conductivity measurements of springs and other side flows on a separate run. The probes were rinsed with distilled water after each sample location where high conductivities were observed.

The probes were rinsed in distilled water at the end of each survey and instrument calibration was periodically checked with standard solutions. Experience has shown that these procedures resulted in a high degree of precision and consistency in the conductivity readings.

Ice was added to the sample bottle chests, chain of custody records were completed and instructions were given to the analytical laboratory. The samples were shipped to CDS Laboratory in Durango, Colorado (now Acculabs, Inc.) a certified laboratory with several branches in the western states. The samples were filtered and preserved upon arrival in the laboratory (i.e. within 20 hours after collection).

2.1.4 Stream Flow Measurements

Streamflow measurements in the Red River were taken in parallel to the water quality sampling. At each station a suitable transect with a relatively uniform streambed was selected and measurements of depth to bottom and flow velocity were taken to compute the total flow. The measurements were carried out by Larry Kuck, who measured stream flows for the USGS for 20 years, using standard USGS procedures except that the depth and velocity measurements were taken at closer than normal intervals (at 0.3 to 0.5 ft) across the main part of the flow channel to obtain higher precision. The streamflow measurements are estimated to be within 5% of actual flow.

The flows of all larger tributaries (e.g. Columbine Creek) were also measured. Small spring flows were measured or determined by visual estimates. No active diversions of river water (for mill water supply or irrigation) took place immediately prior to or during the October 13 1999 survey.

2.2 Results and Discussion

Figure 2 shows the pH, conductivity (EC), sulfate and stream flow as a function of distance from station 1. In general, stream pH shows a general decline in the downstream direction whereas EC and sulfate show a gradual increase. However, several deviations from this pattern are observed:

- a pH depression and sulfate gain is observed in the reach between stations 1 and 3 (near town of Red River) and stations 6 and 6A (below Hansen Creek);
- the water quality improves markedly between stations 10 and 10A, because of Columbine Creek inflow;
- a pH depression and sulfate gain is again observed in the reach between stations 11A and 11C as a result of large ground to surface water discharge.

With the exception of Columbine Creek (measured flow ~5.27 cfs) and Bear Creek there are no significant surface inflows to the Red River in the study reach. In other words, any gains in stream flow (accretion) are a result of groundwater discharge into the Red River.

The October 13 stream flow measurements indicated gains of 1.32 cfs from Station 10A to 11A (300' above Thunder Bridge), 1.69 cfs from Station 11A to 11B (300' below Thunder Bridge and 3.02 cfs from Station 11B to 13 (c. Figure 2). Additional flow measurements taken on October 15th were in good agreement with the October 13th readings indicating gains of 1.5, 1.75 and 3.67 cfs for the same reaches. No measurement was taken on October 13 at Station 11C (above Goat Hill Culvert and below Spring 39). The October 15th measurement indicated that there was a large gain on this date between Stations 11B (above Spring 39) and 11C.

The observed changes in stream water quality in the Red River (with the exception of the observed dilution immediately downstream of the Columbine and Bear Creek inflows) are a result of these groundwater discharges into the river.

The water quality trends observed on October 13th 1999 are consistent with earlier stream surveys during similar runoff conditions conducted by Vail in 1989 and bi-annually since 1996 and other investigators (Slifer, 1996; Allen et al., 1999). Slifer (1996) and Allen et al. (1999) suggested that the deterioration in water quality (pH depression and sulfate gains) in the reach of the Molycorp mine is a result of acidic seepage originating from the waste rock piles on Molycorp property. However, no water balance or constituent load balances were presented in support of this hypothesis. In the following section a detailed water and sulfate load balance model is developed in an attempt to explain the observed changes in water quality (specifically sulfate) in the Red River along the entire middle reach of the Red River (including the reach along the Molycorp mine).

3 WATER AND LOAD BALANCE ANALYSIS

3.1 Approach

A water and sulfate load balance was developed for the middle reach of the Red River to explain the observed accretions in river flows and associated changes in stream water quality. The approach can be briefly summarized as follows:

1) Calculate incremental yields between successive stations using empirical runoff relationship for the Red River basin;
2) Estimate groundwater discharges from the alluvial aquifer to the Red River between successive stations as the difference between calculated incremental yield and observed increase in river flow (accretion) in that segment of the Red River;
3) Calculate sulfate concentrations in the underflow at various stations assuming initial best guess of source concentration in the alluvial aquifer;
4) Compare calculated and measured sulfate loadings at various stations in the Red River;
5) repeat steps 3) and 4) by adjusting initial source concentration (within observed range) and estimates of groundwater to surface water discharges until a satisfactory match of observed and calculated sulfate loads is obtained.

Section 3.2 outlines the methods used to estimate incremental yields for the middle reach of the Red River. Section 3.3 summarises the hydraulic and water quality data for the alluvial aquifer of the middle Red River basin (providing realistic bounds for groundwater flows and sulfate concentrations). Finally, the water and sulfate load balance analyses are presented in sections 3.3 and 3.4, respectively.

3.2 Estimating Yield to Middle Reach of Red River

Yield refers to the portion of precipitation falling on a basin that subsequently contributes flow to the local surface and groundwater flow. In other words, it is the portion of precipitation not evaporated. Within the Red River basin, virtually all of the yield (not captured by the underground mine) initially drains towards the valley of the Red River. After arriving in the valley, this water flows out of the basin via two routes: i) surface flow along the channel of the Red River; and, ii) groundwater flow through the deep alluvium filling the Red River valley. Interchanges between the surface flows and groundwater flows take place as these waters move in the downstream direction.

The surface and groundwater components of the total yield both have significant flow rates at most locations along the middle reach of the Red River. The magnitude of the groundwater component can rival the surface component during the winter months and other low-flow periods. Accordingly, both components had to be accounted for in reconstructing the water and chemical load balances of the river. Neglect of the groundwater component would have led to serious misinterpretations regarding the locations and magnitudes of the primary sources of chemical loading within the Red River basin.

This section of the report examines the surface and groundwater components as an aggregate value (i.e., the total yield moving through the valley). Later sections describe the various means of separating the yield into its surface and groundwater components. To reconstruct the water and load balances, it was necessary to estimate the magnitude of the yield at a number of key locations along the middle reach of the Red River from a point just upstream of the Town of Red River to a point opposite the Questa Ranger Station. The technique selected for doing this is known as Regional Analysis. The premise of this technique is that yield is empirically related to the physical and climatic characteristics of the basin that generated the yield. For example, elevation tends to explain a significant amount of the variation in yield within a mountainous region (i.e., the higher the elevation, the greater is the yield). The starting point for the Regional Analysis was a runoff study prepared by the U.S. Geological Survey (USGS) for the Sangre de Cristo Mountains (Hearne and Dewey, 1988). This study included a method for estimating average annual yields at ungaged locations. The flows predicted by the USGS method can be considered to represent natural conditions (i.e., conditions in which the flow regime has not been significantly influenced by human activities).

The USGS study on its own could not provide all the information on hydrology that was required to reconstruct the water and chemical load balances for the Red River. To prepare these balances, it was necessary to determine the flows in the Red River on the specific dates on which the water quality surveys were conducted. This required that supplemental analyses be conducted. One analysis was required to examine seasonal changes in the yield of the Red River basin while another was needed to examine the influence of the mining operation on the hydrology of the Red River. The subsections below review the USGS estimation technique and describe the supplemental hydrologic analyses that were carried out.

3.2.1 *Prediction of Average Annual Natural Yield*

In the late 1980's, the USGS conducted a hydrologic analysis of the portion of the Rio Grande Basin above Embudo, New Mexico. This basin encompasses a wide range of geologic and hydrologic settings. A number of different techniques had to be employed to establish the runoff generated by these diverse settings. For the Sangre de Cristo Mountains, the USGS chose to assess yield using a multiple regression between runoff, drainage area and mean winter precipitation. The regression was developed using the data from 16 basins monitored by the USGS network of streamflow gaging stations. The basins were selected on three criteria. They:

1) had a period of record that spanned most of the period 1950 to 1980; 2) had no unmeasured diversions upstream of the gaging station; and, 3) overlay crystalline rock. The groundwater passing below the gaging station was assumed to be negligible and, accordingly, the measured flow at the gaging station was assumed to represent the total water yield of the basin (Hearne and Dewey, 1988).

The regression equation developed by the USGS is:

$$Q = 7.62 \times 10^{-5} A^{0.977} P^{3.596}$$

where: Q = average annual yield (ft^3/s);

A = drainage area (mi^2); and,

P = average October to April precipitation (inches).

Mean winter precipitation tends to increase with increasing elevation. Accordingly, the above equation is an implicit function of elevation. The equation explains a considerable amount of the variation in the yield observed amongst the 16 USGS basins, based on the high correlation coefficient that was achieved ($r^2 = 0.96$).

A slight modification had to be introduced to the above equation before it could be applied to the Red River study. The modification was brought about because the equation was originally intended for application to an entire basin and not its component subbasins. For the Red River study, it was necessary to estimate the yield at a large number of locations along the middle reach of the Red River, which meant that yields had to be assessed for the intervening subbasins between the locations. The equation could not be used directly to assess the yield of these individual basins because it does not preserve continuity. In other words, the computed yields from the subbasins would add up to a different value than would be computed if the equation was applied to the Red River basin as a whole. This is a consequence of using drainage area in the equation with an exponent different from one. This situation was easy to remedy because the regression analysis computed an exponent for drainage area that was nearly equal to one (i.e., 0.977). Accordingly, to preserve continuity, the USGS equation was modified by adjusting the exponent to equal one. The predictions made by the modified equation are only slightly different than obtained from the original equation. The modified equation is written as follows:

$$Q = 7.62 \times 10^{-5} A P^{3.596}$$

where the definitions of the variables are the same as given above. The equation is presented in graphical format in the middle plot of Figure 3. The vertical axis of this plot presents values of unit yield expressed in inches (i.e., yield divided by area) while the horizontal axis presents the mean winter precipitation, also in inches. To validate the relationship, the data from various USGS streamflow gaging stations in the Red River basin were compared against the results of the modified equation (see bottom plot of Figure 3). As can be seen, the modified relationship provides reasonably accurate estimates of annual yield for the Red River.

To assess the annual yields at key locations along the middle reach, the Red River basin above the Ranger Station was subdivided into a number of subbasins (see Figure 4). These subbasins were then further subdivided into elevational bands with 1000 ft increments. This additional subdivision was introduced because the main input variable to the prediction equation, namely winter precipitation, exhibits a strong dependency on elevation. The upper plot on Figure 3 presents the adopted relationship between mean winter precipitation and elevation. It was derived from NOAA isopluvial precipitation charts and from the data of long-term precipitation records at several climate stations in the region.

To compute average yields, the modified equation was applied to each elevational band within each subbasin. The predicted yields were then accumulated in a downstream order to predict the average annual yields at specific points along the Red River. Two plots were created to demonstrate the results of applying the modified equation to the middle reach of the Red River. These plots are shown together on Figure 5a. Both plots effectively show the same information; they are graphs of average annual yield versus distance upstream from the Ranger Station. Their one difference is the units used to express yield. The top plot presents yield as a long-term average flow rate in ft^3/s while the bottom plot expresses yield as a percentage of the flow at the Ranger Station. As can be seen, the average yield upstream of the town of Red River is estimated to be about 46.5% of the flow at the Ranger Station. The locations of the water quality monitoring stations are marked on the horizontal axis of the bottom plot.

3.2.1 Prediction of Seasonal Natural Yields

The above subsection presented a method for assessing the long-term average annual yield at any location along the middle reach of the Red River. As such, it does not completely fulfill the objective of this section of the report, namely to develop a technique that predicts the yields in the river on specific dates. The complete technique involves several more steps which will be addressed below in this subsection and the next. However, the results presented above illustrate the main feature of the adopted technique. In essence, the technique assumes that, for specific times of the year, the relative contributions from each subbasin remain sensibly constant throughout a wide range of flows. For example, if a given subbasin is known to contribute 5% of the total basin flow during October average flow conditions, then it is assumed to also contribute 5% of the total flow during October for a severe drought, or during a wet year.

The discussion above outlines an approximate method of estimating flows along the middle reach of the Red River given an observed flow at the Ranger Station. The accuracy of the method can be improved by recognizing that the yields from the various elevational bands change on a seasonal basis. For instance, most of the yield from the areas of higher elevation result from the melt of the winter snowpack, which occurs during the months of May, June and July. Conversely, there is very little yield from the higher elevations during the winter months when the ground is frozen. Snowmelt from low elevation areas generally occurs earlier than from high elevation areas. In June, approximately 70% of the flow past the Ranger Station originates from above the Town of Red River. In March this same area produces a smaller contribution of 62% of the flow at the Ranger Station. Average monthly flows at the Ranger Station range from about 140 ft^3/s in June to 16.5 ft^3/s in January.

The average monthly yield of the of the total basin above the Ranger station was determined by the USGS 1913-1995 stream flow records. The estimation of average monthly yields of the sub-basins was determined by intensive analysis. Essentially, an analysis was made of how the yield varies throughout the year within each 1000 ft elevational band. The analysis for each band was guided by the well-known observation that low elevation areas melt earlier than high elevation areas. The set of developed monthly yield patterns were also based on analysis of the average monthly runoff hydrographs at a number of USGS streamflow gaging stations. Differences between the predicted and observed patterns were noted and adjustments were made to the elevational yield patterns to attempt to improve the fit. This process was repeated many times until an adequate fit between predicted and observed patterns was achieved. Figure 5b shows the resulting monthly average yield patterns for the various elevational bands. These patterns show the expected trend of the progressively later peaks being associated with increasing elevation.

Based on these seasonal yield patterns, predictions were made of the average monthly yield along the middle reach of the Red River for each month of the year. Figure 6 shows the average monthly yield along this reach for the months of March and October, or the months typically chosen to conduct the water quality surveys along the river. For comparison purposes, the line representing the average annual yield has also been drawn on this figure. Table 1 summarizes all the calculated average monthly yields for all intervening sub-basins between the water quality monitoring points in the middle reach of the river.

3.2.2 Allowance for Influence of Mine Development

This section describes adjustments to the natural yields that had to be undertaken to account for the influence of the mining operation on the flows in the river and to make estimates of yield for a specific date, corresponding to the date of one of the spring or fall water quality monitoring surveys.

The mine has had two types of influences on the flows in the Red River. Firstly, a large portion of the yield generated by the mine area has been intercepted and diverted to the tailings impoundment some 8 miles to the west. This diversion is the result of the following activities that have taken place:

- alteration of the Sulphur Gulch drainage pattern by developing the open pit;
- connection of the open pit and the old underground mine via adits and shafts that were daylighted during development of the open pit;
- connection of the new and old underground mine workings by a borehole;
- capture and diversion of drainage from upper Capulin Canyon to Goathill Gulch;
- creation of the caved zone, which effectively diverted surface and groundwater flows from the Goathill Gulch to the underground mine workings;
- diversion of mine dewatering flows to the tailings impoundment via the tailings slurry pipeline; and,
- creation of a groundwater capture zone by development of the underground and surface mine workings and by dewatering these mine workings.

The second influence on the flow regime of the Red River is a result of the abstractions made for the mill water supply. Abstractions are obtained both directly from the river and from wells developed in the river alluvium.

Different means were adopted to handle these two influences. To deal with the diversion of mine site yield to the tailings impoundment, the estimated yields from the areas captured by the open pit and caved area were subtracted from the natural yields predicted for the river.

Allowance for the abstraction of water from the river was more involved. It required the following data to be assembled:

- the observed flow at the USGS streamflow gaging station near the Questa Ranger Station for the date of interest ($Q_{\text{Ranger, Observed}}$);
- the total quantity of water abstracted from the surface of the river and from the wells developed in the river alluvium on the date of interest (Q_{Abstract});
- an estimate of the change in storage within the river alluvium due to the well pumpage ($Q_{\Delta S}$); and,
- the estimated average monthly yield for the Ranger Station for the month of interest ($Q_{\text{Ranger, Yield}}$).

From these data the following ratio was computed:

$$(Q_{\text{Ranger, Observed}} + Q_{\text{Abstract}} + Q_{\Delta S}) / Q_{\text{Ranger, Yield}}$$

This ratio is an estimate of the naturalized flow at the Ranger Station divided by the long-term average monthly yield at the Ranger Station. The term "naturalized" means that the influence of the mine development has been removed from the observed flow value (i.e., the river abstractions and the change in storage within the river alluvium have been added to the observed flow). Once this ratio was computed, it could be used to estimate the natural yields all along the middle reach of the Red River for the specific date of interest. This was accomplished by scaling the predicted average monthly yields by the ratio. For example, if the date of interest was in the month of October, then all the monthly yields for the month of October (see Figure 6) would be adjusted by the ratio. The resulting values would represent the natural yield of the Red River for the specific date of interest (e.g., October 13, 1999).

Finally, these natural yields had to be adjusted to represent actual conditions within the river. This was done by subtracting the abstractions of mill water supply from the natural yields and by accounting for any estimated change in storage within the river alluvium.

It should be noted that the analysis above tacitly assumes that the USGS streamflow gage monitors essentially the entire yield of the Red River at the Ranger Station (i.e., very little groundwater passes beneath the gage). In reality, a small unknown portion of the Red River yield passes beneath the gaging station in the river alluvium and, therefore, escapes measurement. Small increases in sulfate concentration below the Ranger Station down to Eagle Rock Lake support this notion. The stream flow balance calculations included an allowance for this probable small groundwater flow.

3.3 Groundwater Flow in Red River Alluvial Aquifer

The existence of large alluvial basins in the Columbine Park and in the mill area has been recognized for many years. Monitor and extraction wells drilled by Molycorp along the valley in the mine area, supply wells at US Forest Service campgrounds, wells in the vicinity of the town of Red River and geological interpretations all suggest that this basin extends continuously, with considerable depth and cross sectional area, from below the Ranger Station to above the Town of Red River. The depth of the basin below the river level is on the order of 100 feet and the width varies from a few hundred feet to over 1,000 feet. A significant portion of the basin fill is predominantly composed of highly permeable alluvial flood flow deposits of boulders and gravel.

Figure 7a shows the approximate extent of the alluvial aquifer in vicinity of the mine area. The various monitoring and extraction wells completed in the alluvial aquifer over the years by Molycorp are also shown. Figure 7b shows a cross-section through the alluvial aquifer along the mine area, as interpreted from existing borehole information. Molycorp has utilized this alluvial aquifer since start-up of milling operations in 1965 to extract groundwater for its milling operation. Extraction rates have varied significantly over the years depending on mill demand but typically averaged 6-7 cfs for periods of full production. All four extraction wells (Mill wells No. 1 and 1A in the mill yard area and Columbine wells No. 1 and 2 in the Columbine Park area, see Figure 7a,b) are capable of producing in excess of 2000 gpm for sustained periods of times.

A good understanding of the groundwater system in the Red River basin is essential in interpreting stream water quality in the Red River due to the interaction of surface and groundwater flows. In the following we review hydraulic and water quality data pertaining to the alluvial aquifer system.

3.3.1 *Analysis of Pump Test Data*

Two pump tests have been carried out to date to estimate the transmissivity of the alluvial aquifer of the middle Red River basin (Gsi/Water, 1996; Souder Miller & Associates, 2000). In October 1996, Gsi/Water performed a constant rate pump test in the Columbine well No 2, located in the Columbine Park area (Figure 7a). The well was pumped at a rate of about 2000 gpm for a duration of 15 days while monitoring the drawdown in the pumping well and several monitoring wells in the area. Using the distance-drawdown relationship after 6 and 15 days of pumping an aquifer transmissivity of about 200,000 gpd/ft and a storage coefficient of 0.44 was obtained (Gsi Water, 1996). Well losses at the pumping well were assumed to be negligible in the analysis of the distance-drawdown plot.

The pump test data suggested significant recharge of river water to the valley aquifer during the pump test. The observed drawdown in monitoring wells in vicinity of the Red River (e.g. P5 a & b & c) showed consistently lower drawdowns (after correction for distance from pumping well) than those wells located at greater distance from the river (i.e. Columbine well No. 1, P1, P3 and Cabin Well). The transmissivity values calculated from time-drawdown curves for the latter group of monitoring wells (i.e. those not influenced by river recharge) were somewhat greater (i.e. T=250,000 to 280,000) than the estimate from the distance-drawdown plot. The discrepancy is likely due to the fact that well losses and recharge effects were not accounted for in the distance-drawdown estimate.

On May 9th-10th 2000, Souder, Miller & Associates carried out a pump and recovery test in the mill yard area. Mill well No 1 was pumped at a constant rate of about 2800 gpm for 24 hours (see SMA, 2000 for details) and the drawdown monitored in two observation wells (Mill well No. 1A and Old Mill Well, see Figure 7a for locations). After completion of the pump test the recovery of groundwater levels were monitored for a period of four days.

The maximum drawdown (after 24 hours) were 4.9 ft in Mill Well 1A and 4.6 ft in the Old Mill Well (at a distance of 325 ft and 285 ft from the pumping well, respectively). The later time data (100-1000 min) showed a significant increase in the rate of drawdown suggesting boundary effects. Using the Cooper-Jacob straight line method for the early time-drawdown data (10-100 min), transmissivity values of 600,000 gpd/ft and 660,000 gpd/ft were obtained for the Mill Well 1A and the Old Mill Well, respectively (SMA, 2000). Analysis of the recovery data suggested slightly higher transmissivity values for the alluvial basin (T=740,000 and 700,000 gpd/ft using Mill Well 1A and Old Mill Well data, respectively).

The transmissivity values obtained for the mill area are in general agreement with those obtained for the Columbine Park area and suggest that the aquifer is highly transmissive. Using these transmissivity values the capacity for groundwater flow in the alluvial aquifer can be estimated. The ground water table in the basin slopes downstream at an average gradient that is approximately the same as the river gradient. This averages about 2% downstream of the mill area to about 2.7% between the mill and the Town of Red River. Based on an estimated cross-sectional area of 42,000 ft^2 in the mill yard and Columbine Park area, the groundwater flow capacity in these two basins would be in the order of 7 cfs. The actual flows in the two basins would be somewhat less depending on the amount of drawdown at any given point in time.

3.3.2 Influence of Pumping on Groundwater Levels and Spring Flows

Water levels have been monitored by Molycorp on a monthly basis since November 1995 in several monitoring wells screened in the alluvial aquifer along the mine reach. Figure 8 shows the observed groundwater levels in monitoring wells MMW 10A,B, C and MMW-11 (lower panel). These monitoring wells are located in the Red River reach between the mill yard area (about 5600 ft upstream) and the Columbine Park area (about 3000 ft downstream) (see Figure 7a for location). The monthly volumes pumped from the mill area wells, the Columbine wells and the combined total volume (as reported in Molycorp files) are shown for comparison (Figure 8, lower panel).

Figure 8 demonstrates the influence that pumping of the alluvial aquifer has on groundwater levels in these monitoring wells. During the shutdown period (1992 to mid November 1996) no groundwater was pumped from the alluvial aquifer and the groundwater levels were relatively constant (close to the river level). Since restart of the mill and pumping in mid-1996 the groundwater levels have decreased significantly (by as much as 15 ft in these observation wells). Note that the monitoring wells shown here are at a significant distance from the pumping wells hence there is a delay of several weeks between changes in pumping rates and resulting changes in the groundwater levels. Monitoring wells closer to the extraction wells (e.g. MMW-13 and the P series wells) respond much sooner and have experienced water level drawdowns as high as 70 ft during periods of extended pumping (not shown).

Based on our estimates of the area of the basins and assuming an effective porosity of 0.30 an average basin water level change of 1 foot in one month would result in about 0.37 cfs going into or out of storage in the mill well basin, 0.48 cfs in the Columbine Well Basin and 0.43 cfs in the basin between the Mill area and Columbine Park. These figures would decrease gradually with a decline in the water tables since such would result in a smaller surface area.

Figure 8 also illustrates the recharge of river water to the alluvial aquifer during periods of peak flow spring runoff (typically May and June, see Table 1). For example, in the spring of 1997 the groundwater levels in MMW-10 and MMW-11 increased sharply by 17-18 ft from mid-May to mid-June. This recharge correlates closely with the high flow period of the Red River (monthly average flows in the Red River for these two months at the Ranger Station were 170 and 227 cfs, respectively).

Assuming a potential storage volume of 0.43 cfs per foot of increase in groundwater levels (see above) this water level increase would represent an increase in storage in excess of 7 cfs. This high recharge during the snow melt flood period is likely a result of the flood flows scouring the river bottom down to clean sands, gravel and boulders. After the flood period the river flow velocities decrease and silts are deposited over the river bottom. This results in a substantial reduction in the seepage rate. The river bottom is further sealed in the following months by clays washed down from the upstream hydro-thermal scar areas and by the aluminum precipitate that forms in the river. In the late fall, winter and spring months the river bottom is generally tightly sealed and the seepage is very small (i.e. less than can be detected by river flow measurements).

There are limiting factors, however, on how high the basin water levels can rise. When the ground water level exceeds the river level there is a discharge from the ground water to the surface flow (e.g. at Portal Springs and Cabin Springs, see location map in Figure 8). Groundwater discharge at these springs explains the near constant water levels during the spring runoff in 1996 (Figure 8). The fact that Portal Springs and Cabin Springs do not flow during periods of continuous pumping (these springs were only "discovered" during the shut-down period) supports the hypothesis that these springs represent discharge points of the alluvial aquifer system for periods of high water levels.

The change in storage in the alluvial aquifer basin, if significant, needs to be accounted for in the water balance analysis. The changes in water levels in the alluvial aquifer were examined over a period of a few weeks preceding the October 1999 river survey. However, very little change in the ground water levels was observed during this low flow period requiring no significant adjustments of groundwater flows in this area.

3.3.3 Alternative Determinations of Groundwater Flows

The pumping test conducted by Souder Miller & Associates in the mill yard area indicated a basin transmissivity in excess of 600,000 gallons per day. The aquifer water depth in these areas is on the order of 100 feet indicating an average formation permeability (k) of 6,000 gpd/ft^2 which is equivalent to 0.28 cm/sec.

It is estimated that the basin aquifer between the mill area and Columbine Park has an average width of 500 feet, and an average depth of 67 feet. The ground water gradient (I) along this reach averages 2.2%. Based on the simple Darcy equation $Q = k*I*A$, if the permeability was 6,000 gpf/ft^2, the basin would transport a flow of 6.8 cfs. The basin aquifer in the mill and Columbine Park area has a significantly larger cross sectional area.

During the fall of 1997 milling was in process and there was considerable pumpage which resulted in a declining trend in the ground water level in the mill area and along the reach between the mill area and Columbine Park. Milling operations were suspended on December 1, 1997 and pumpage was substantially reduced with the result that water levels immediately started to rise in the mill area. As the mill area water level rose such resulted in an increasing discharge downstream. Approximately 13 days after the reduction in pumpage, the ground water level in the vicinity of MMW-13 started to rise, and approximately 8 days later a rising water level was noted in the vicinity of monitoring wells MMW-10A, B and C. Milling and an associated increase in pumpage was resumed on January 6, 1998 with a resulting decline in the water level in the mill area. After approximately the same time delays as noted above, a resumption of the declining ground water levels was observed at MMW-13 and MMW-10.

The distance from the mill area to the vicinity of monitoring well MMW-13 is approximately 3,000 feet and it is another 2,600 feet down to the vicinity of MMW-10. This indicates that the absolute flow velocity ($q=Q/A$) down stream along the reach was on the order of 280 feet per day. The Darcy velocity would be equivalent to the absolute velocity multiplied by the porosity. Assuming the typical porosity value of 28% for the coarse sand and gravel formation, the indicated Darcy velocity would be 78 feet per day. The equation for Darcy Velocity is V_d= permeability X slope. At a hydraulic gradient of 2.2%, the permeability of the basin aquifer based on the indicated flow velocity, would be on the order of 26,600 gpd/ft^2 or 1.25 cm/sec. It is probable that the indicated flow velocity is representative of the velocity in the more permeable sections of the aquifer and therefore the average permeability would be somewhat less, but still sufficient to transport the flows indicated by the flow balance analysis.

3.3.4 Groundwater Quality in Alluvial Aquifer

Table 2 shows recent water quality data for selected monitoring wells screened in the alluvial aquifer in the middle reach of the Red River basin (modified from RGC, 2000c). The alluvial groundwater on the north side of the valley aquifer is generally acidic (pH~4-5) and shows elevated concentrations of sulfate (~1000-1500 mg/l) and other metals (AL, Zn, Fe, Mn etc.). Note that acidic conditions and high sulfate concentrations exist already upstream of the mine area (e.g. Red River private well and Straight Creek well). However, the water quality on the south side of the valley aquifer shows much less impact of acidic drainage (e.g. see Junebug and

Elephant Rock Campground wells upstream of the mine area and Mill and Columbine wells in the mine area).

The large differences in ground water quality can be explained by the spatial distribution of source areas upstream of the mine (RGC, 2000c). Figure 9 shows the extent of hydrothermal scars in the middle reach of the Red River. These scar areas represent mineralized areas where rates of erosion exceed the tolerance level for the maintenance of natural self-sustaining vegetation (RGC, 2000c). Areas outside alteration scar areas are also underlain by mineralized rock, and metals concentrations in the rocks of these adjacent areas may be as great as or exceed, the values underlying scar areas. Thus, the extent of naturally mineralized rock in the Red River basin far exceeds the extent of the scar areas (RGC, 2000c). It is readily apparent that the mineralized area (the source for scar development) is predominantly to the north of the Red River.

RGC (2000c) discuss the migration of natural ARD from these mineralized watersheds into the Red River. Highly acidic runoff from the scar areas and underlying mineralized rock is flowing at surface and in the subsurface towards the Red River. At the confluence with the flow in the main Red River valley this naturally contaminated ground water will be deflected downriver and be forced into a flow stream which hugs the north wall of the alluvial basin. Mixing with the main alluvial basin flow therefore will occur only over a substantial flow length down the Red River (RGC, 2000c). Thus, the ground water flow and quality distribution along the flanks of the Red River alluvium is influenced by vertical zoning in the side channel discharges and by horizontal zoning within the main alluvial channel.

This conceptual model is consistent with the water quality observed in the alluvial basin. For example, Elephant Rock and June Bug Campground wells located on the south side of the basin, show much better water quality than the Straight Creek well which is located on the north side at the mouth of a major scar watershed.

The water quality of Cabin Springs and Portal Springs is consistent with the water quality in the alluvial groundwater sampled further upstream. This observation supports the contention that these springs are fed by the alluvial groundwater system during periods of high groundwater levels.

Note that the alluvial groundwater is much more acidic and has a much higher total dissolved solids content (including sulfate and metals) than the Red River water (c. Figure 2 and Table 2). Hence even small discharges of groundwater into the Red River can result in detectable depressions in pH and increases in total dissolved solids (including sulfate and metals) in the stream water. In the following sections the contributions of this acidic groundwater to streamflow were estimated using a series of mixing calculations. The non-reactive constituent sulfate was selected for this analysis, since it mixes conservatively and shows very large concentration differences between the Red River (80-180 mg/l) and the alluvial groundwater (200-1500 mg/l).

3.4 Flow and Load Balance Analysis

3.4.1 Methods

The flow and load balance analysis was carried out using a spreadsheet model (Table 3). The model is subdivided into stream reaches (i.e. catchment areas between two successive sampling stations) and two flow compartments representing surface flow and underflow (in the alluvial aquifer of the Red River basin), respectively. The sum of the surface and groundwater flows and mass loads are shown on the right hand side of the model (Table 3). This flow represents the total adjusted yield and is calculated from the regional analysis of strteamflow in the area (see section 3.2.2). For each flow component a flow (in cfs) and a sulfate concentration (in mg/l) is specified. The product of the flow and sulfate concentration represents the sulfate load (in pounds/hr) for any particular flow component.

Each stream reach was subdivided into areas contributing significant ARD (elevated sulfate concentrations) and all remaining areas not contributing ARD (very low sulfate concentrations). For the reaches upstream of the mine all catchment areas with significant hydrothermal scars were assumed to be contributing ARD to the Red River. However, initial results from a recent background study in these watersheds with prominent scars suggest that the areas contributing ARD are significantly greater than the erosional scars (RGC, 2000c). This finding was represented in this interim analysis by assuming ARD contributions from the entire watershed area containing scars. This area roughly coincides with the zone of mineralized rock in the middle reach of the Red River basin (RGC, 2000c).

Figure 9 shows the areal extent of the hydrothermal scars in the middle reach of the Red River as determined from aerial photography. It can be seen that most the hydrothermal scars are located on the north side of the Red River. Hence, in most stream reaches it was sufficient to subdivide the catchment area into "North" and "South" areas with the former yielding a high sulfate load and the latter yielding a very low sulfate load (with the notable exception of Junebug scar on the south side of the Red River).

For the reaches along the mine property the same approach was used, i.e. sulfate yields were calculated separately for the catchment areas north and south of the Red River. No attempt was made in this interim analysis to determine the sulfate loads for various potential sources of ARD on the mine site (i.e. mineralized rock, erosional scars, mine disturbed areas including mine rock piles etc.). Most of the mine-disturbed areas are in mineralized rock and/or erosional scars and it would be difficult, if not impossible, to separate the various sources with any degree of confidence at this time. However, a comprehensive characterization and modeling study has been initiated by Molycorp under the time extension request for Development of a Closeout Plan to further define these sources and quantify their contributions to the loading to the Red River (see RGC, 2000a).

The water yields from the various source areas were calculated using the procedure outlined in section 3.2.2. Where applicable, the following additional sources and sinks were included in the flow and load balance spreadsheet (c. Table 3):

- Surface inflows (e.g. Pioneer Creek in the stream reach between station 1 and 3)
- Groundwater storage (e.g. in stream reaches between stations 8, 8A and 10);
- Groundwater Abstractions (e.g. in mill area between stations 7 and 8);
- Seepage from the Red River to the alluvial aquifer (e.g. in stream reach between stations 8 and 8A); and
- Underflow from the alluvial aquifer to the Red River (e.g. in stream reach of town of Red River between stations 1 and 3).

No adjustments were necessary for the October 1999 survey with respect to surface water abstractions (i.e. neither mill diversion nor irrigation diversions were operated during the observation period).

The flows of the point sources and sinks (river inflows, groundwater pumpage etc.) were measured directly or obtained from pumping/run time records. The effects of groundwater storage in the alluvial aquifer were estimated based on water level readings in the various monitoring wells in the area. The cumulative flow in the alluvial aquifer (middle column of Flow Balance Spreadsheet) represents the difference between the adjusted calculated total flow and the observed surface flow. Finally, the only remaining unknown, i.e. exchange of water between the Red River and the alluvial aquifer (either seepage to the aquifer or underflow to the Red River), were calculated from the flow balance assuming conservation of mass.

In order to calculate sulfate yields and solve the sulfate load balance, sulfate concentrations had to be assigned to all flow components. First, all sulfate concentrations of flow balance components known from measurement (e.g. individual Red River stations, surface inflows, pumping wells etc.) were input into the model (and held constant). Next, source concentrations for all ARD contributing areas and non-contributing areas upstream of the mine were back-calculated from the total load at Station 7. The sulfate concentration for non-contributing areas was assumed to be 20 mg/l (as observed in runoff from non-mineralized areas). The sulfate concentration for the various ARD-contributing areas was estimated by apportioning the total sulfate load increase from town of Red River to just upstream of the mine to the various areas in proportion to the elevation and areal extent of its prominent scar. Those source concentrations were also not varied during calibration of the model.

It is recognized that there is probably some variation in the relative amount of acid rock drainage between the various hydro-thermal scar areas. There is however insufficient data at the present time to establish a basis for assessment of this variation. Although this may result in some error in the calculated loading and concentrations in the ground water flow for specific reaches upstream of the mine area, these discrepancies balance out to result in the correct total loading at Station 7.

For all remaining sulfate concentrations, initial probable values were assigned to all remaining and the flow and load balance model was solved iteratively by adjusting these source input concentrations and flow estimates (within a plausible range). The model input variables were adjusted until the calculated flows and sulfate concentrations at the various stations matched the measured values.

Note that the flow and load balance model essentially consists of a series of mass balance calculations for each stream reach (i.e. between each sampling station). Within each stream reach, mass balance of flow and sulfate load has to be achieved to obtain a calibrated solution. The overall flow and load balance provides a check on the calibrated solution. In working with this model it was found that there is a surprisingly small amount of latitude for the making of adjustments while keeping tentative values within a reasonable and probable range and that this latitude becomes smaller as you approach the final balance. The tentative final balance was then carefully reviewed to verify that all developed values are within a reasonable and probable range and within a range that is consistent with values determined by other methods of calculations.

3.4.2 Results

3.4.2.1 Flow Balance for October 13, 1999

Figure 10 shows the cumulative total yield (i.e. surface and groundwater flow combined) for the Red River basin between the town of Red River and the Ranger Station. The incremental yields between each station were calculated using the procedure described in section 3.2.2. Note that the measured river flow at the Ranger Station on October 13, 1999 was very close to the calculated average October basin yield. In other words, flow conditions were typical for October and did not require significant additional adjustments to reflect higher or lower than average flow conditions. The following observations can be made:

- A large increase in yield is observed between stations 1 and 3; this yield represents groundwater flow from the large Bitter Creek catchment area;

- A large increase in yield to the Red River between stations 10 and 10A due to the inflow of Columbine Creek (the only significant surface inflow to the Red River during this survey); and
- A steady increase in yield over the remaining reaches commensurate with the increase in catchment area downstream; there is a small decrease in specific yield (yield per river mile) downstream due to the fact that catchment areas further upstream have a higher proportion of high-elevation country, which produce higher yields (c. section 3.2.2).

Figure 11 shows the calculated total yield for the middle Red River basin adjusted for Molycorp's water abstractions and changes in groundwater storage (see section 3.2.2 for details). The main adjustments for the October 13 survey represent pumpage of groundwater from the extraction wells in the mill yard area (between stations 7 and 8) and the Columbine Park area (between stations 10A and 11. The effects of change in groundwater storage on the total yield were minimal.

Figure 12 shows the observed surface flow in the Red River on October 13th 1999. Note that stream flow measurements could not be taken at all stations (time constraints and lack of suitable river channel for accurate measurements of streamflow). The stream flows at stations not measured directly were calculated using the flow and sulfate load balance model and assessing changes in surface water quality (see section 3.4.1).

Figure 13 compares the calculated adjusted yield for the middle Red River basin to the measured surface flow in the Red River for October 13, 1999. The difference between the calculated adjusted yield and the observed surface flow (i.e. the area in purple) represents the groundwater flow in the alluvial aquifer underlying the Red River.

A direct comparison of surface flows and groundwater flows is provided in Figure 14. The arrows connecting the surface flow and groundwater flow charts represent the exchanges between those two flow regimes. Arrows directing towards the surface water chart represent discharge of groundwater to surface water (termed "underflow to Red River" in spreadsheet model, Table 3). Arrows directing towards the groundwater water chart represent recharge of river water to the alluvial aquifer (termed "seepage" in spreadsheet model, Table 3). Arrows connecting from the outside to the respective chart represent flows contributing from the catchment areas ("area drainage") or point sources and sinks (surface inflows such as creeks or seeps; well pumpage etc.). The widths of all arrows were scaled in proportion to the calculated flux of any given flow path.

The following conclusions can be drawn from the flow balance analysis:

- A large increase in groundwater flow was computed downstream of station 1; the majority of this flow enters from the large Bitter Creek watersheds (Bitter Creek had no surface flow on

October 13, 1999); this large groundwater flow then discharges to the Red River over the next couple of miles;

- In the mine reach upstream of Columbine Creek, a significant decrease in surface flow and a commensurate increase in groundwater flow was computed; this recharge to groundwater is a result of the ground water table in the mill area being well below the river level which results in high seepage from the river to the GW;
- The total groundwater flow in the alluvial aquifer upstream of the mine is in the order of 5 cfs and peaks at about 6.8 cfs in the mill yard area; downstream of the Columbine Park area the alluvial groundwater flow is reduced greatly by pumpage and discharge of groundwater to surface water; downstream of the mine area (at station 13A and below) the alluvial groundwater flow is only an estimated 0.7 cfs.

The stream survey on October 13, 1999 was conducted at a time of typical late fall stream conditions. The measured flow at the Ranger Station was 25.37 cfs. The measured surface flow at Station 10A (below Columbine Creek) was 18.80 cfs and at Station 12 (Goat Hill Camp Ground) it was 24.00 cfs – a gain of 5.20 cfs. The calculated normal accretion at this time for the drainage area between Stations 10A and 12 is 0.34 cfs. The surface flow gain of 5.20 cfs could not possibly be from the contiguous drainage area. Even the corresponding calculated yield of the entire mine area upstream of Station 12 is only on the order of 1.0 cfs (with adjustment for higher infiltration rates from mine-disturbed areas). Of this approximately 0.7 cfs is captured by the underground mine. The nominal amount of mill pumpage during this period (2.72 cfs) was sufficient to offset any accretions from the mine area in excess of that captured by the underground mine. In other words the 5.2 cfs surface flow gain could not originate from the mine area. The only plausible source for the gain is the discharge to the surface of the basin ground water aquifer flow entering the mine area. This is consistent with the flow balance analysis for October 13, 1999 which indicates that the calculated yield of the Red River basin above the mine area was 20.79 cfs which exceeded the measured surface flow at Station 7 by 5.42 cfs.

The large groundwater discharge observed in the Columbine Park area on October 13th 1999 is consistent with earlier stream flow surveys conducted by Vail Engineering since 1996. Table 4 summarizes all stream flow surveys, which were conducted by Vail Engineering from April 1996 to March 2000. In all surveys a significant apparent discharge of groundwater to the Red River was observed in the Columbine Park area. A direct comparison to the October 1999 data is not always possible because of mill surface diversions and/or not all monitoring stations being surveyed. Nevertheless, a general increase in surface water flows in the Columbine Park area of 3.3. to 6.3 cfs has been observed in all surveys which can only be attributed to groundwater to surface water discharge.

Our analysis clearly indicates that the observed gains in Red River streamflow in the lower reaches of the mine far exceed the possible gains from the incremental catchment areas along these reaches (including the incremental mine areas). In fact, the analysis suggests that much of this gain has to be attributed to catchment areas upstream of the mine. Based on the flow analysis a total of about 5.4 cfs enters the mine area from upstream areas (at station 7) whereas only about 0.7 cfs is leaving the mine area as groundwater flow.

The large computed flows of groundwater in the alluvial aquifer (5-6 cfs) are consisted with independent estimates of groundwater flow in the alluvial aquifer basin (see section 3.3.4). Using aquifer transmissivity values determined from pump test data in the mill yard area (sections 3.3.3) and assuming plausible ranges of cross-sectional area and hydraulic gradient the groundwater flow in the alluvial aquifer was estimated to be in the order of 6-7 cfs (see section 3.3.4)

In the following section it will be shown that the large discharge of alluvial groundwater to surface water in the lower mine reach (below Columbine Park) has a significant impact on the water quality in the Red River.

3.4.2.2 Calibrated Sulfate Concentrations

The calibrated source concentrations for ARD contributing areas upstream of the mine (predominantly from the north) ranged from as low as 99 mg/l for the reach between stations 1 and 3 to as high as 2272 mg/l for the reach between stations 5 and 6 (Table 3). The high source concentrations were computed for reaches where the scar area represents a relatively large fraction of the total ARD contributing area (e.g. Hansen Creek and Straight Creek). Conversely, low source concentrations were computed for reaches where the scar area represents a relatively small fraction of the total ARD contributing area (in particular Bitter Creek).

The calibrated source concentrations for the mine reach varied from as low as 770 mg/l for the reach between stations 7 and 8 to as high as 2813 mg/l. for the reach between stations 8A and 10 (Table 3). These computed source concentrations are not significantly greater than those in the mineralized areas upstream of the mine and are consistent with observed sulfate concentrations observed in the respective reaches of the mine (Table 3).

The calibrated sulfate concentrations for the alluvial groundwater ("underflow") ranged from 123 mg/l (between stations 3 and 4) to 600 mg/l (between stations 10A and 11) (Table 3). Note that these calibrated concentrations represent average concentrations in the aquifer. The model assumes complete mixing in the alluvial aquifer along each reach and does not explicitly account for the significant variability in sulfate concentrations observed across the valley. The range of calibrated concentrations lies well within the observed range of sulfate concentrations in the alluvial aquifer (Table 3).

3.4.2.3 Sulfate Balance for October 13, 1999

Figures 15 and 16 summarize the results of the sulfate load balance model. Figure 15 shows sulfate loads (cumulative loads in pounds/hour) for the surface flow (Red River) and groundwater flow (alluvial aquifer) separately, with arrows linking the two flow components indicating fluxes related to seepage or groundwater discharge. Figure 16 shows the total sulfate load in the Red River system. The arrows leading into the charts from the margins indicate sinks and sources of sulfate to and from surface flow and groundwater flow, respectively. Again, the widths of all arrows were scaled in proportion to the calculated flux of any given flow path.

The following conclusions can be drawn from the sulfate balance analysis:

- The majority of the total sulfate loading to the Red River system occurs upstream of the mine from the north-side drainages with prominent scars (Bitter Creek, Hottentot Creek, Straight Creek and Upper and Lower Hansen Creek); sulfate loading from the mine area is comparatively small and limited to the upper reaches (above Columbine Park);
- Essentially all loading upstream of the mine occurs directly to groundwater; most of that load is then transferred to the Red River in the mine area via groundwater to surface water discharge; the total load entering the mine area from upstream sources is 530 pounds/hour, roughly equally divided between surface flow and groundwater flow; the much smaller flows in the alluvial aquifer (compared to surface flows in the Red River) are off-set by the much higher sulfate concentrations (~214 mg/l in aquifer versus 78 mg/l in stream);
- Most of the sulfate load entering the Red River occurs as a result of return flow of groundwater (with elevated sulfate concentrations) from the alluvial aquifer to the stream; the largest single increase in the sulfate load of the Red River occurs in the lower mine reach (between stations 11 and 11C); much of this sulfate load can be attributed to source areas upstream of the mine;

Perhaps the most critical value to be determined for the sulfate load balance model is the average concentration of the groundwater in the alluvial aquifer (underflow) at Station 7 (above the mine area). The groundwater flow at this station has been established with high confidence by the computed yield less the surface flow and this has been adequately supported by independent analyses (see section 3.3.2).

In the fall of 1999 two observation wells were established at the extreme east end of the mine area, i.e. MMW-17A in alluvium and MMW-17B in bedrock. At the time of the river survey on October 13, 1999 the sulfate concentration in MMW-17B was 450 mg/l On this date the ground water level was below the level of the bottom of MMW-17A and no water sample was available. Earlier in the year when there were higher water levels; the concentrations in MMW-17A and MMW-17B were approximately the same.

However, the monitoring wells MMW-17A and MMW-17B are located at the far north side of the ground water basin. It is evident that most of the acid rock drainage in the ground water basin is concentrated along the north side of the basin. In consideration of this the concentration in MMW- 17B was not considered to be representative of the average ground water quality across the full basin section at this point.

Mill well No. 1 is located in the far south part of the underground basin and Mill Well 1A is located near the center of the basin. On October 13, 1999 the sulfate concentration in Well No.1 was 145 mg/l and in Well No.1A was 283 mg/l. There is no apparent significant inflow or outflow to the ground water basin between the east end of the mine area down to the mill well area. The mill wells at times pump a substantial portion of the ground water flow and therefore area probably representative of the average ground water quality.

Based on sensitivity analyses, the average concentration of the two mill wells (214 mg/l) was finally selected for the estimated concentration of the average ground water flow at Station 7. This figure resulted in calculations of downstream loadings that fit well with the loadings indicated by the actual downstream flow and concentration measurements and produced results that were consistent with other analysis and calculations. A fence of monitoring wells has been proposed in this reach of the Red River to more accurately determine the water quality variations across the alluvial groundwater channel and to estimate more accurately the contaminant load entering the mine area via groundwater (RGC, 2000a).

The sulfate load balance model clearly indicates that much of the sulfate loading to the Red River is originating from natural sources upstream of the mine area transported into the mine area via the alluvial groundwater system. The analysis also shows that pumping of groundwater from this alluvial aquifer (at the mill yard area and Columbine Park) has a beneficial effect on Red River water quality in removing some of this sulfate load (and other contaminants originating from ARD) from the alluvial aquifer before it can discharge into the Red River. The implications of mine operation on Red River water quality are discussed in more detail in section 4.2.

4 DISCUSSION

4.1 Assessment of Natural ARD Contributions

The flow and sulfate balance analysis clearly demonstrates that much of the sulfate load in the middle Red River basin is generated from natural sources upstream of the mine. A flow and sulfate load balance was also carried out assuming there had been no mining in this reach of the middle reach of the Red River. As a first approximation it was assumed that the sulfate yield from the ARD-contributing areas on the mine site would be equal to those calibrated for the ARD contributing areas upstream of the mine. This appears to be conservative in that other analysis and observations indicate that the altered rock areas in and below the mine area produce a relative higher amount of acid rock drainage or produce higher concentrations of metals (RGC, 2000c). The same climate conditions as observed for October 13, 1999 were assumed for this analysis.

Figures 17 and 18 show the results of the sulfate balance with the effects of mine operation removed. The analysis indicates that there would be significant water and sulfate gains along the mine reach in particular from the major side drainages, i.e. Sulphur Gulch and Goathill Gulch. Both drainages originate in and used to drain large, mature scar areas. The total sulfate loading to the middle reach of the Red River basin under natural conditions (mine operation removed) was computed to be about 825 pounds/hour.

The calculated sulfate load balance shown in Figure 18 is an estimate of what natural sources would contribute today (i.e. under current climate and runoff conditions). This sulfate load is not necessarily equivalent to pre-mining conditions (e.g. in 1965) because climate and runoff conditions vary over time and were very different in the late 60s and early 70' compared to those observed for October 13, 1999. As discussed in more detail in section 4.3 the sulfate yield (and similarly yields of other contaminants related to ARD) strongly depends on climate and runoff conditions and have to be taken into account when comparing contaminant yields to the Red River.

A more detailed determination of pre-mining conditions and natural ARD loading to the Red River from the mine area will be made as part of the on-going background study (see RGC, 2000a) and comprehensive water and load balance study (see RGC, 2000b) for the middle Red River basin.

4.2 Impact of Mine Operations

The effect of current mining operation on the Red River system was evaluated by comparing the reconstructed sulfate load balance for “no mining” (Figure 18) to actual conditions observed on October 13, 1999 (Figure 16). Figure 19 shows the total sulfate balance (in surface and groundwater combined) for actual conditions and "no mining" conditions. Figure 19 illustrates that the mining operation has reduced the total sulfate load to the Red River, mainly because (i) pumping of the alluvial aquifer (for process water) removes a significant sulfate load from the alluvial aquifer and (ii) much of the contaminated drainage from Sulphur Gulch and Goathill Gulch is now captured in the underground workings.

It should be pointed out that this comparison was carried out for fall low-flow conditions. During periods of high runoff (i.e. snowmelt runoff and in particular thundershower events) the natural loading without mining would have been much greater than under current conditions because of the much higher surface yields introduced to the Red River from Sulphur Gulch and Goat Hill Gulch (these drainages are now cut-off and are captured in the underground mine).

The results of the sulfate load balance model are consistent with observed changes in stream water quality over time. During most of the years from 1966 through 1991 Molycorp's mill was operated at or near full capacity and large quantities of water (6-7 cfs) were pumped from the ground water. Such pumpage removed substantially more acid rock drainage from the stream system than what entered the stream surface and ground water flow through the mine area. This resulted in a water quality through and downstream of the mine area that was much better than would have prevailed under natural non-mine conditions.

During the years 1992 through most of 1996 Molycorp suspended mining and milling operations and there was very little pumpage of the mill and Columbine wells. As a result most of the acid rock drainage in the ground water flow entering the mine area, and that generated in the mine area, was discharged to the river surface water flow in the Columbine Park area. This resulted in a substantially poorer quality of water in that area than had prevailed in prior years. Even during this period, the downstream river water quality was better than it would have been under natural ("no-mining") conditions. The better than natural water quality during this period was due to the elimination of the large quantities of acid rock drainage from the mineralized mine area and in particular the large Sulfur and Goat Hill Gulch scar areas. These drainages are now being captured by the under ground mine and are being treated and used for mill process water.

From 1996 to the present, Molycorp's mining and milling has been at substantially less than capacity and there has been only a nominal amount of pumpage. This nominal amount of pumpage however has generally been sufficient to remove as much acid rock drainage from the river system as was discharged from the mine area. As a result, during this 1996 to 1999 period, the total amount of acid rock drainage in the ground and surface water flow leaving the mine area, was approximately the same as the total amount of acid rock drainage that entered the mine area. In other words, there was no significant net increase in sulfate loading to the Red River system through the mine area. Under natural non-mine conditions the amount of acid rock drainage leaving the mine area would have been significantly higher because of the significant natural additions from Sulfur Gulch, Goat Hill Gulch and other mineralized areas.

4.3 Comparison with Previous Water Quality Surveys

A comparison of recent stream water quality surveys (including this October 13, 1999 survey) with older surveys carried out by the US Department of Health and Welfare in November 1965 (USDHEW, 1966) and the US EPA in November 1970 suggests that the water quality in the Red River has deteriorated over time. The increase in ARD derived contaminants such as sulfate in the Red River has led some investigators to believe that the ARD load from the mine area, and the mine rock piles in particular, is increasing over time (e.g. Allen et al., 1999). The flow and sulfate load balance model presented above was applied to these surveys to get a better understanding for the cause of this change in Red River water quality.

Figure 20 shows the calibrated flow balance for the 1970 and 1999 surveys. The flow conditions varied very significantly in those two years with much lower surface and groundwater flows observed in the middle Red River basin in 1970 compared to 1999 (Figure 20). Note that these differences were observed consistently for reaches upstream of the mine and along the mine reach. Note also that significant surface flows were diverted at that time for milling in addition to pumping groundwater from the aquifer. As a result of very low groundwater flows there was also a very low groundwater to surface water discharge in the Columbine Park area relative to what was observed in 1999.

This difference is in great part due to the smaller flows in surface and groundwater in 1970 compared to 1999. However, the flow and load balance model also indicated that source concentrations from the ARD contributing areas must have been significantly lower than they currently are. The on-going background study will attempt to shed further light on the physical and geochemical controls on sulfide oxidation and ARD production in the naturally mineralized areas.

Figure 21 shows the calibrated sulfate balance for the 1970 and 1999 surveys. Very substantial differences were also observed for the sulfate loading in those two years with significantly (more than 3 times) smaller loads computed for 1970 compared to 1999. It should be emphasized that the lower sulfate loads in 1970 were observed upstream of the mine. In other words, different runoff conditions caused a lower ARD yield to the Red River from natural sources, i.e. the mineralized areas and erosional scars located upstream of the mine. The already favorable conditions were further improved by pumpage for milling operations, which extracted virtually all sulfate load carried into the mine area as groundwater flow in the alluvial aquifer.

The much lower sulfate loading in 1970 is in great part due to the smaller flows in surface and groundwater in 1970 compared to 1999. However, the flow and load balance model also indicated that source concentrations from the ARD contributing areas must have been significantly lower than they currently are. The on-going background study (RGC, 2000a) will attempt to shed further light on the physical and geochemical controls on sulfide oxidation and ARD production in the naturally mineralized areas.

A similar flow and sulfate load balance analysis was carried out for the November 1965 survey done by USDHEW (not shown here). The results indicate that the 1965 runoff conditions and sulfate loads were very similar to those in 1970 (not shown here). Again, climatic conditions and resulting differences in sulfate yield from the naturally mineralized areas can explain the much reduced sulfate loads to the Red River basin compared to current conditions.

The large differences in sulfate loadings (and sulfate concentrations) over the years are directly related to long-term changes in climate conditions. Drought conditions in the region prevailed over most of the period from 1950 through 1968. During this period precipitation at the Town of Red River averaged 15% less than normal. Conversely during the period 1979 through 1994, the average Town of Red River precipitation was 15% above normal. The difference in the yield of Red River was even more pronounced -15% below average (39.8 cfs) during the 1953 - 1964 period and 24 % above average (57.8 cfs) during the 1979 - 1994 period.

The sulfate concentrations observed in the Red River indicate that the difference in antecedent precipitation resulted in an even larger variation in the relative amounts of ARD products discharged to the river. Such is evidenced by the following:

SO^4 Concentration in Red River **Above** the Mine Area

Date	mg/l SO^4
November 4, 1965	47
November 4, 1970	60
October 13, 1994	93
November 9, 1995	83
November 5, 1996	96
November 3, 1997	94

In consideration of the above, it is not surprising that the sulfate concentrations in the river at the Ranger Station were considerably higher in recent years than they were in 1965 and 1970.

The exceptionally good water quality observed in the 1965 survey reflects the highly unusual meteorological conditions preceding the survey date. Snow fall during the preceding winter and spring months was considerably above average and there were exceptionally large amounts of rainfall in July and September. These conditions resulted in an above average November high quality surface flow from drainage of the snow melt and shallow surface runoff. In the antecedent years however precipitation was considerably below normal. Other data indicate that a large portion of the ARD from the hydro-thermal scars is by ground water flow which reaches the river over a period of several years. The analysis of the survey data shows that at the time of the November 1965 survey there was a relatively low amount of ARD and that the valley basin aquifer total flow was significantly less than average. These conditions resulted in an exceptionally high quality of water in Red River at above the mine area as well as at the Ranger Station. In addition it is probable that by November 1965 most of the drainage from the Sulphur Gulch hydro-thermal scar area had been cut off by the open pit excavation.

In 1970, current year and antecedent precipitation was slightly less than normal and although the surface water quality above the mine area was very good, the flow balance analysis indicates that there was a fairly large amount of ARD being transported by the basin aquifer. The exceptionally high water quality prevailing in the surface flow in and downstream of the mine area was primarily due to the fact that Molycorp's mill was in full production and a major portion of basin aquifer flow was being pumped out for mill supply. As a result there was only a small amount of ground to surface water discharge in the Columbine Park area.

Starting in 1979 and thereafter annual precipitation significantly increased and resulted in significant increases in the ARD concentrations in both the surface and basin aquifer water entering the mill area and a significant increase in the basin aquifer flow. The surface water quality through and below the mine area however continued to be good during most of the time until 1992 because of the large amount of mill pumpage from the basin aquifer.

During periods in 1986 and 1988 the pumpage was substantially reduced as a result of a prolonged labor strike and shutdown for conversion to underground mining operations. Unfortunately it was during these periods when the NMED Smolka-Tague river surveys were conducted. The somewhat poorer river water quality was reflected by these and Molycorp's November 1988 surveys.

The mine was shut down at the end of 1991 until near the end of 1996 and there was very little pumpage during this period. As a result the full natural ground to surface water discharge was prevalent in Columbine Park and Portal and Cabin Springs resumed their natural flow. This resulted in a significant increase in ARD concentrations in the downstream surface flow. These concentrations however were commensurate with or below the concentrations that would have occurred had the mine not been in existence during this prevailing high precipitation period. The better than natural water quality during this period was due to the elimination of the ARD drainage from Sulphur Gulch and most of Goat Hill Gulch.

Mining operations were resumed in November 1965 and have continued at a reduced level and with only a nominal amount of pumpage since that time. The amount of pumpage however has been sufficient to offset nearly all of the natural mine area ARD drainage and the mine related drainage if any. As a result since 1995 there has been little if any increase in ARD loading in the combined surface and basin aquifer flow through the mine area and the surface water quality has been significantly better than it would have been naturally.

The water quality in Red River varies substantially with time due to differences in both short and long term meteorological conditions. Valid comparisons of the results of river surveys cannot be made without taking such into consideration.

5 CONCLUSIONS

Prior analyses of the flow and acid rock drainage accretions to Red River have focused primarily on the surface flows in the river (e.g. Slifer, 1996; Vail, 1989; Allen et al., 1999). A notable increase in sulfate and metal concentrations in the Red River along the mine reach was observed which was attributed to acid rock drainage from the mine area (Slifer, 1996; Allen et al., 1999). However, these previous studies have ignored the presence of ARD contaminated groundwater (from upstream sources) which is discharged to the Red River along the mine reach.

A detailed flow and sulfate load balance study has been carried out using actual observations of stream flow and water quality at 23 stations along the middle Red River collected on October 13, 1999. Both surface flow and groundwater flow were explicitly accounted for in this load model.

The following conclusions are drawn from the analyses set forth in this study:

(a.) There is a large alluvial aquifer in the Red River Valley that extends continuously from below the Ranger Station to above the Town of Red River. This aquifer transports a large portion of the Red River Basin water yield from above the mine area into the mine area. From October to April the ground water flow entering the mine area comprises approximately 25% of the total ground and surface water flow into the mine area.

(b.) A major portion of the natural acid rock drainage from above the mine area enters the ground water flow and is transported therein downstream to the mine area. The hydro-thermal scars and altered rock areas contain significant quantities of pyrite (Fe S2). When precipitation falls on such areas, sulfuric acid is generated. The acid leaches minerals from the rocks and such is transported to the river (i.e. acid rock drainage). The sulfate concentrations in Red River are well below stream standards. Nevertheless, the sulfate concentrations and loads can be used as an indicator of the acid rock drainage. The average sulfate concentration in the ground water flow entering the mine area is approximately three times of that in the surface flow (~220 vs 75 mg/l). Much higher sulfate concentrations are observed in the natural ARD plume flowing along the north side of the alluvial aquifer. About half of the total sulfate load from natural sources enters the mine area with the groundwater flow.

(c.) In the mine area and particularly in the Columbine Park area, a major portion of the ground water flow and sulfate loading is discharged to the river surface flow. This discharge accounts for the major portion of the increase in the sulfate loading in the surface flow that occurs through the mine area.

(d.) Large quantities of water are being pumped from the ground water aquifer for milling of ore and transport of tailings to the tailings ponds. This pumpage reduces the amount of the high acid rock drainage laden ground water that is discharged to the surface flow in the mine area. During most of the years from 1966 through 1991 Molycorp's mill was operated at or near full capacity and large quantities of water (6-7 cfs) were pumped from the ground water. Such pumpage removed substantially more contaminants from the stream system than what entered the stream flow and ground water flow through the mine area. This resulted in a water quality through and downstream of the mine area that was much better than would have prevailed under natural no-mining conditions.

(e.) Analysis of a detailed river survey made on October 13, 1999 indicated the following sulfate gains in the combined surface and groundwater flows

Above Town Red River	Gain 12.37 cfs @ 17 Avg Mg/L = 47 Net #/hr SO4
Town Red River to Mine Area	Gain 8.42 cfs @ 255 Avg Mg/L = 483 Net #/Hr SO4
MINE AREA Station 7-13	**Gain 4.51 cfs @ 26 Avg Mg/L = 26 Net #/Hr SO4**
Below Mine Area to RS	Gain 0.79 cfs @ 383 Avg Mg/L = 68 Net #/Hr SO4

In other words, the majority of sulfate load to the Red River was generated in the mineralized areas upstream of the mine area. Only a very small fraction of the sulfate load was generated along the mine reach.

(f.) For thousands of years prior to the development of the open pit and present under ground mine, there have been significant amounts of acid rock drainage to Red River from the hydrothermal scars and altered rocks of Sulfur and Goat Hill Gulch areas. Because of the capture by the present underground mine of both the natural and mine related acid rock drainage from these areas, the total acid rock drainage from the mine area to the Red River flow system is significantly less at the present time than it would be under natural (no-mining) conditions.

(g.) There is a substantial variation from year to year in the amounts of flow and acid rock drainage from both the mine area and the non-mine areas. This is due to the variation in both the short and long term amounts of precipitation. Except for the variation resulting from the change in precipitation; the stream flow data does not give evidence of any increase in the amount of acid rock drainage in the mine area during the past several years or evidence that such an increase is likely in the future.

The analysis presented in this report raises serious doubts about the validity of earlier studies, which did not take into account the importance of groundwater flow (and associated contaminant loading from upstream natural sources) on Red River water quality. The failure to account for this groundwater load from upstream sources has resulted in a significant overestimation of the contaminant load attributed to the mine area.

6 CLOSURE

This report has been prepared for Molycorp Inc., Questa Division by Vail Engineering. Robertson GeoConsultants Inc. provided assistance in the preparation of this interim report.

Respectively Submitted
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Tables

Table 1. Monthly Incremental Water Flows Along Red River.

Reach	Estimated Average Yield (ft3/s)												
	North Side												
	O	N	D	J	F	M	A	M	J	J	A	S	Annual
Above Zwergle	7.958	5.719	4.203	4.029	4.116	4.553	11.764	40.346	51.132	24.703	14.801	10.640	17.727
Zwergle to 1	3.780	2.877	2.155	1.944	2.045	2.586	6.774	16.545	18.149	8.452	5.917	4.409	7.288
1 to 3	4.338	3.036	2.205	2.027	2.111	2.570	8.019	20.234	20.478	7.789	5.760	4.535	8.006
3 to 4	0.243	0.202	0.160	0.136	0.146	0.211	0.481	0.804	0.794	0.416	0.361	0.262	0.406
4 to 5	0.196	0.162	0.128	0.109	0.117	0.168	0.390	0.664	0.656	0.336	0.289	0.212	0.330
5 to 6B	0.118	0.102	0.082	0.069	0.074	0.113	0.228	0.331	0.325	0.200	0.181	0.128	0.188
6B to 6A	0.173	0.146	0.116	0.099	0.106	0.155	0.349	0.560	0.551	0.296	0.260	0.189	0.289
6A to 7	0.109	0.101	0.084	0.069	0.074	0.119	0.218	0.232	0.221	0.181	0.176	0.120	0.164
7 to 8	0.401	0.347	0.279	0.234	0.252	0.377	0.812	1.197	1.171	0.681	0.612	0.438	0.655
8 to 8A	0.059	0.056	0.047	0.038	0.041	0.067	0.113	0.101	0.096	0.097	0.097	0.065	0.084
8A to 10	0.028	0.026	0.022	0.018	0.019	0.032	0.048	0.043	0.041	0.046	0.046	0.030	0.038
10 to 9	4.831	3.539	2.544	2.413	2.470	2.825	7.084	23.772	28.410	14.020	8.467	6.207	10.268
9 to 11	0.014	0.013	0.011	0.009	0.009	0.016	0.020	0.017	0.016	0.024	0.024	0.015	0.018
11 to 11B	0.012	0.011	0.009	0.008	0.008	0.014	0.019	0.016	0.016	0.020	0.020	0.013	0.016
11B to 11A	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.002	0.004	0.004	0.003	0.003
11A to 12	0.202	0.187	0.156	0.128	0.138	0.220	0.392	0.411	0.394	0.336	0.327	0.224	0.300
12 to 13	0.024	0.022	0.019	0.015	0.016	0.027	0.037	0.033	0.031	0.040	0.040	0.027	0.032
13 to 14	0.235	0.220	0.182	0.149	0.163	0.255	0.489	0.526	0.502	0.392	0.380	0.263	0.362
14 to 15	0.027	0.024	0.020	0.017	0.018	0.029	0.038	0.032	0.032	0.044	0.044	0.029	0.034
15 to 16	0.015	0.013	0.011	0.009	0.010	0.016	0.018	0.015	0.015	0.025	0.025	0.016	0.018

Reach	Estimated Average Yield (ft3/s)												
	South Side												
	O	N	D	J	F	M	A	M	J	J	A	S	Annual
Above Zwergle													
Zwergle to 1													
1 to 3	1.598	1.180	0.848	0.801	0.822	0.947	2.368	7.819	9.282	4.604	2.789	2.049	3.382
3 to 4	0.129	0.121	0.101	0.082	0.089	0.142	0.261	0.272	0.259	0.215	0.210	0.143	0.195
4 to 5	0.253	0.193	0.143	0.129	0.135	0.174	0.432	1.077	1.161	0.561	0.391	0.291	0.476
5 to 6B	0.100	0.088	0.072	0.060	0.064	0.098	0.199	0.271	0.264	0.169	0.155	0.109	0.159
6B to 6A	0.012	0.011	0.009	0.008	0.008	0.014	0.019	0.016	0.016	0.020	0.020	0.013	0.016
6A to 7	0.499	0.384	0.285	0.258	0.268	0.345	0.819	2.123	2.338	1.176	0.799	0.589	0.952
7 to 8	0.325	0.246	0.181	0.165	0.171	0.215	0.508	1.424	1.590	0.800	0.526	0.388	0.63
8 to 8A	0.027	0.025	0.021	0.017	0.018	0.030	0.043	0.038	0.036	0.044	0.044	0.029	0.0357
8A to 10	0.271	0.231	0.184	0.156	0.167	0.245	0.526	0.845	0.850	0.489	0.418	0.300	0.451
10 to 9													
9 to 11	0.007	0.006	0.005	0.004	0.004	0.007	0.008	0.006	0.006	0.011	0.011	0.007	0.008
11 to 11B	0.006	0.005	0.004	0.004	0.004	0.006	0.007	0.006	0.006	0.010	0.010	0.006	0.007
11B to 11A	0.031	0.028	0.024	0.020	0.021	0.035	0.049	0.043	0.041	0.051	0.051	0.033	0.041
11A to 12	0.169	0.150	0.124	0.103	0.110	0.171	0.320	0.404	0.393	0.284	0.266	0.185	0.258
12 to 13	0.020	0.018	0.015	0.013	0.013	0.022	0.030	0.026	0.025	0.033	0.033	0.022	0.026
13 to 14	0.518	0.412	0.313	0.276	0.292	0.392	0.929	2.040	2.173	1.101	0.808	0.596	0.949
14 to 15	0.020	0.019	0.016	0.013	0.014	0.023	0.035	0.031	0.030	0.034	0.034	0.023	0.028
15 to 16	0.009	0.008	0.007	0.006	0.006	0.010	0.013	0.011	0.011	0.015	0.015	0.010	0.012

Table 2. Water Quality Results for alluvial aquifer in middle reach of Red River (modified from RGC, 2000).

Station	Date	pH	TDS	SO4	Fe	Mn	Cu	Zn	Al	Co	Mo	Ni	Cd	Cr	F	Pb
a) Monitoring Wells																
Red River Private Well (PWRR)	12-May-00	6.5	3,010	1,270	7.6	5.0	7.6	0.3	<0.06	0.04	0.01	0.10	<0.0005	N/A	1.9	N/A
Straight Creek Well (RR WWTP wel	13-Apr-00	N/A	1,300	910	36.0	5.6	0.01	2.1	34	0.10	<0.1	0.27	0.002	0.240	1.3	0.003
Junebug Campground (GW-8)	08-Nov-94	N/A	193	61	0.13	0.08	<0.0028	0.25	<0.028	<0.0046	<0.02	<0.0167	<0.0039	<0.0037	N/A	<0.001
Elephant Rock Campground (GW-9)	08-Nov-94	N/A	173	50	0.10	0.01	0.005	0.11	<0.028	<0.0046	<0.02	<0.0167	<0.0039	<0.0037	N/A	<0.0009
Mill Well 1	01-Sep-97	5.7	400	285	<0.2	0.8	<0.25	<0.25	0.7	0.02	<0.02	0.04	<0.005	N/A	0.8	<0.02
Mill well 1A	01-Sep-97	4.6	555	370	<0.2	1.1	<0.25	0.4	5.1	<0.02	<0.02	0.05	<0.005	N/A	1.2	<0.02
MMW 24	12-Jan-00	4.79	3,300	1,800	0.22	14	1.4	2.7	53	0.23	<0.1	0.51	0.02	<0.01	41	<0.006
MMW 10A	03-Feb-00	4.32	2,800	1,800	<0.1	24	0.88	4	64	0.23	<0.1	0.56	0.044	<0.01	26	<0.009
MMW 10C	03-Feb-00	4.81	990	620	<0.1	9.8	0.24	2.2	19	0.066	<0.1	0.23	0.018	<0.01	13	<0.006
MMW 8B	04-Feb-00	5.66	2,200	1,400	<0.1	0.66	0.018	0.65	1.9	<0.01	<0.1	0.12	0.0057	<0.01	1.7	<0.003
P1	08-Feb-00	4.68	1,700	1,100	<0.1	16	0.31	6.1	28	0.018	<0.1	0.69	0.046	<0.01	25	<0.006
P-2	08-Feb-00	4.86	1,200	780	<0.1	13	0.27	3.2	21	0.71	<0.1	0.39	0.025	<0.01	19	<0.006
P-3	08-Feb-00	4.96	1,200	790	<0.1	7.8	0.17	4.2	16	<0.01	<0.1	0.51	0.032	<0.01	17	<0.003
P-4b	08-Feb-00	4.59	1,900	1,100	<0.1	21	0.5	5.3	36	0.13	<0.1	0.63	0.043	<0.01	23	<0.009
P-5b	07-Feb-00	4.49	2,000	1,300	<0.1	26	0.62	4.9	46	0.2	<0.1	0.56	0.038	<0.01	24	<0.009
P-5c	07-Feb-00	4.63	1,900	1,200	<0.1	21	0.85	6.2	33	0.031	<0.1	0.86	0.056	<0.01	28	0.015
Columbine No. 1	01-Sep-97	6.00	495	340	0.5	0.8	<0.25	1.04	2.2	<0.02	<0.02	0.15	0.008	N/A	4.64	<0.02
Columbine No. 2	01-Sep-97	6.20	435	280	0.4	0.5	<0.25	0.74	1.4	<0.02	<0.02	0.1	<0.005	N/A	3.32	<0.02
b) Springs																
Cabin Springs	15-Jun-00	4.40	1,900	1,900	<0.1	27	0.68	4.7	48	0.21	<0.1	0.55	0.036	<0.01	28	<0.015
Portal Spring	15-Jun-00	4.60	920	820	<0.1	7.7	0.22	1.6	16	0.036	<0.1	0.19	0.016	<0.01	8	<0.003

all values are in mg/L (except pH)

Table 3. Calibrated flow and sulfate load balance model - October 13, 1999.

File: 99NORTH&SOUTH **RED RIVER ANALYSIS ACTUAL CONDITIONS OCT 13, 1999 VAIL ENGINEERING** Revised 7/03/00

2000STUDY	**SURFACE FLOW**		**#/HOUR**	**UNDERFLOW**			**TOTAL SURFACE & UNDERFLOW**			LINE #
Station	**CFS**	**Mg/L SO4**	**SO4**	**CFS**	**Mg/L SO4**	**#/Hr. SO4**	**CFS**	**Mg/L SO4**	**#/Hr SO4**	NOTES
1	**9.64**	**17**	**37**	**2.73**	**17**	**10**	**12.37**	**17**	**47**	1
PIONEER	1.20	29	8	0.00	0	0	1.20	29	8	2
MALLETTE	0.07	32	1	0.00	0	0	0.07	32	1	3
AREA South	0.00	20	0	0.48	20	2	0.48	20	2	4
AREA North			0	4.54	99	101	4.54	99	101	5
UF to River	2.09	190	89	-2.09	190	-89	0.00	0	0	6
3	**13.00**	**46**	**134**	**5.66**	**19**	**24**	**18.66**	**38**	**158**	7
AREA South	0.00	0	0	0.14	759	24	0.14	759	24	8
AREA North			0	0.34	1570	120	0.340	1570	120	9
UF to River	1.50	123	41	-1.50	123	-41	0.00	0	0	10
4	**14.50**	**54**	**176**	**4.64**	**121**	**126**	**19.14**	**70**	**302**	11
AREA South	0.00	0	0	0.16	263	9	0.16	263	9	12
AREA North			0	0.37	1124	93	0.370	1124	93	13
UF to River	0.25	172	10	-0.25	172	-10	0.00	0	0	14
5	**14.75**	**56**	**186**	**4.92**	**198**	**219**	**19.67**	**92**	**404**	15
AREA South		0	0	0.11	20	0	0.11	20	0	16
AREA North			0	0.16	2272	81	0.159	2272	81	17
UF to River	0.25	172	10	-0.25	172	-10	0.00	0	0	18
6	**15.00**	**58**	**195**	**4.93**	**262**	**290**	**19.93**	**108**	**486**	19
AREA South		0	0	0.01	20	0	0.01	20	0	20
AREA North			0	0.21	872	41	0.209	872	41	21
UF to River	0.52	536	63	-0.52	536	-63	0.00	0	0	22
6A	**15.52**	**74**	**258**	**4.63**	**259**	**269**	**20.15**	**116**	**527**	23
AREA South		0	0	0.53	20	2	0.53	20	2	24
AREA North			0	0.11	20	0	0.11	20	0	25
Seepage	-0.50	74	-8	0.50	74	8	0.00	0	0	26
UF to River	0.35	250	20	-0.35	250	-20				27
7	**15.37**	**78**	**269**	**5.42**	**214**	**261**	**20.79**	**113**	**530**	28
AREA south	0.00	0	0	0.34	20	2	0.34	20	2	29
AREA north				0.35	770	61	0.35	770	61	
Pumpage-Mill Wells		0	0	-2.00	214	-96	-2.00	214	-96	30
Seepage	-1.20	78	-21	1.20	78	21	0.00	0	0	31
To Storage	0.00	0	0	0.00	0	0				32
8	**14.17**	**78**	**248**	**5.31**	**207**	**247**	**19.48**	**113**	**496**	33
AREA south	0.00	0	0	0.03	20	0	0.03	20	0.13	34
AREA north	0.00	0	0	0.11	1775	44	0.110	1775	44	35
Seepage	-0.41	78	-7	0.41	78	7	0.00	0	0	36
Fr Storage	0.00	0	0	0.19	207	9	0.19	207	9	37
8A	**13.76**	**78**	**241**	**6.05**	**226**	**307**	**19.81**	**123**	**548**	38
AREA south	0.00	0	0	0.29	20	1	0.29	20	1	39

Table 3. Calibrated flow and sulfate load balance model - October 13, 1999.

File: 99NORTH&SOUTH	RED RIVER ANALYSIS			ACTUAL CONDITIONS OCT 13, 1999			VAIL ENGINEERING		Revised 7/03/00	
2000STUDY	SURFACE FLOW		#/HOUR	UNDERFLOW			TOTAL SURFACE & UNDERFLOW			LINE #
Station	CFS	Mg/L SO4	SO4	CFS	Mg/L SO4	#/Hr. SO4	CFS	Mg/L SO4	#/Hr SO4	NOTES
AREA north				0.07	2813	44	0.07	2813	44	
Fr Storage	0.00	0	0	0.19	226	10	0.19	226	10	40
Seepage	-0.30	78	-5	0.30	78	5	0.00	0	0	41
UF to River	0.07	450	8	-0.07	450	-8				42
10	13.53	80	243	6.83	235	360	20.36	132	604	43
COL CREEK	5.27	9	11	0.00	0	0	5.27	9	11	44
AREA south	0.00	0	0	0.00	0	0	0.00	0	0	45
AREA north	0.00	0	0	0.00	0	0	0.00	0	0	46
UF to River	0.00	0	0	0.00	0	0				47
10A	18.80	60	254	6.83	235	360	25.63	107	614	48
AREA south	0.00	0	0	0.01	20	0	0.01	20	0.06	49
AREA north			0	0.01	20	0	0.01	20	0.03	50
Pumpage-Columbine Wells			0	-0.72	440	-71	-0.72	440	-71	51
UF to River	0.105	600	14	-0.105	600	-14	0.00		0	52
11	18.91	63	268	6.02	203	275	24.93	97	543	53
AREA south	0.01	20	0.06	0.00	0	0.00	0.01	20	0.06	54
AREA north	0.01	20	0.03	0.00	0	0.00	0.01	20	0.03	55
Fr Storage		0	0	0.00	0.00	0	0.00	0	0	56
UF to River	1.195	97	26	-1.195	97	-26	0.00		0	57
11A	20.12	65	294	4.83	230	249	24.95	97	543	58
AREA south	0.00	20	0.00	0.00	20	0	0.00	20	0.00	59
AREA north	0.03	20	0.13	0.00	0	0	0.03	20	0.13	60
Seepage	0.00	0	0	0.00	0	0	0.00		0	61
UF to River	1.66	315	118	-1.66	315	-118	0.00		0	62
11B	21.81	84	412	3.17	185	131	24.98	97	543	63
AREA south	0.09	20	0	0.00	20	0	0.09	20	0	64
AREA north	0.10	510	11	0.00	0	0	0.10	510	11	65
Seepage	0.00	0	0	0.00	0	0	0.00		0	66
UF to River	1.55	175	61	-1.55	175	-61	0.00		0	67
11C	23.55	92	485	1.62	194	71	25.17	98	555	68
AREA south	0.01	20.00	0.04	0.00	20	0	0.01	20	0.04	69
AREA north	0.07	20.00	0.31	0.00	0	0	0.07	20	0.31	70
Seepage	0.00	0	0	0.00	0	0	0.00		0	71
UF to River	0.37	125	10	-0.37	125	-10	0.00		0	72
12	24.00	92	495	1.25	215	60	25.25	98	556	73
AREA south	0.03	20	0	0.00	20	0	0.03	20	0.13	74
AREA north	0.02	20	0	0.00	0	0	0.02	20	0.09	75
Seepage	0.00	0	0	0.00	0	0	0.00		0	76
UF to River	0.78	157	27	-0.78	157	-27	0.00		0	77
13	24.83	94	523	0.47	312	33	25.30	98	556	78

Table 3. Calibrated flow and sulfate load balance model - October 13, 1999.

File: 99NORTH&SOUTH **RED RIVER ANALYSIS ACTUAL CONDITIONS OCT 13, 1999 VAIL ENGINEERING** Revised 7/03/00

2000STUDY	**SURFACE FLOW**		**#/HOUR**	**UNDERFLOW**			**TOTAL SURFACE & UNDERFLOW**			LINE #
Station	**CFS**	**Mg/L SO4**	**SO4**	**CFS**	**Mg/L SO4**	**#/Hr. SO4**	**CFS**	**Mg/L SO4**	**#/Hr SO4**	NOTES
AREA south	0.00	0.00	0	0.00	0	0	0.00	0	0	79
AREA north	0.10	1550	35			0	0.10	1550	35	80
Seepage	0.00	0	0	0.00	0	0	0.00		0	81
UF to River	0.13	164	5	-0.13	164	-5	0.00		0	82
13A	**25.06**	**100**	**563**	**0.34**	**369**	**28**	**25.40**	**104**	**591**	83
Bear Creek	0.52	20	2	0.00	20	0	0.52	20	2	84
AREA north	0.10	1000	22	0.00	1000	0	0.10	1000	22	85
Seepage	0.00	0	0	0.00	0	0	0.00		0	86
UF to River	0.11	200	5	-0.11	200	-5	0.00		0	87
14	**25.79**	**102**	**592**	**0.23**	**450**	**23**	**26.02**	**105**	**615**	88
AREA south	0.00	20	0	0.01	20	0	0.01	20	0.04	89
AREA north	0.00	0	0	0.00	20	0	0.00	20	0	90
Seepage	-0.60	102	-14	0.60	102	14	0.00		0	91
UF to River	0.00	0	0	0.00	0	0	0.00		0	92
14A	**25.19**	**102**	**579**	**0.84**	**196**	**37**	**26.03**	**105**	**615**	93
AREA south	0.00	0	0			0	0.00	0	0	94
AREA north	0.03	1200	8	0.00	1200	0	0.03	1200	8	95
Seepage	0.00	0	0	0.00	0	0	0.00		0	96
UF to River	0.13	200	6	-0.13	200	-6	0.00		0	97
15	**25.35**	**104**	**593**	**0.71**	**195**	**31**	**26.06**	**107**	**624**	98
AREA	0.01	104	0.23			0	0.01	20	0	99
0	0.02	104	0.47	0.00	146	0	0.02	146	1	100
Seepage	-0.01	0	0	0.01	0	0	0.00		0	101
UF to River	0.00	0	0	0.00	0	0	0.00		0	102
16	**25.37**	**104**	**593**	**0.72**	**192**	**31**	**26.09**	**107**	**624**	103
										104

SUMMARY

Above Town Red River	GAIN abv 1 12.37 CFS	@17 Avg Mg/L	47 Net #/Hr SO4
Town RR to Mine Area	GAIN 1-7 8.42 CFS	@255 Avg Mg/L	483 Net #/H SO4
MINE AREA	GAIN 7-13 4.51 CFS	@ 26 Avg Mg/L	26 Net #/H SO4
Below Mine Area to RS	GAIN 13-16 0.79 CFS	@383 Avg Mg/L	68 Net #/H SO4
TOTAL	Above RS 26.09CFS	@106 Avg Mg/l	624 Net #/Hr SO4

Table 4. Summary of stream flow measurements in Middle Red River.

BOLD FIGURES INDICATE PROBABLE DIMINISHED FLOW AS RESULT OF MILL SURFACE DIVERSION

Station	Date	4/2/96	10/8/96	10/11/96	10/15/96	10/18/96	11/4/96	11/14/96	11/15/96	3/13/97	3/14/97	7/21-2/97	8/4/97
1	Abv Town RR											28.3	42.9
4	Junebug CG												
6A	Blw Hansen												
7X	Abv Mill		10.92	10.62	9.77	9.74	11.29	9.53	9.65	10.69	10.64	35	47.35
8	Blw Mill						11.64	**6.08**		**7.88**	**7.48**	34.13	54.02
10 By subtraction	Abv Col -Computed 10A-9		10.85	**8.17**	**5.64**	**5.95**	11.64	**6.31**	**5.45**	**7.13**	**6.98**	33.26	50.56
10A	Blw Col Ck		12.97	**10.34**	**7.74**	**8.05**	13.64	**8.31**	**7.53**	**9.61**	**9.71**	42.8	60.1
11	@ Lower Brg		11.42	**9.98**	**6.93**	**7.37**	13.49	**7.96**	**8.75**	**11.1**	**9.42**	39	**55.8**
11A	Abv Thund Brg	16.75				**12.15**			**10.45**				
11B	Blw Thund Brg	17.25					18.21	**12.24**		**14.76**	**13.7**		
11C	Abv Goat Hill									**14.9**	**12.13**	45.35	63.4
12	@Goat Hill CG				**10.55**	**10.09**	**16.79**	**11.29**	**13.87**				
13	Abv Capulin											46.9	**56.28**
16	@Ranger Sta	24		12.9	**10.74**	**10.6**	**15.62**	**11.93**	**11.32**	**13.2**	**12.24**	56	61.7
	RS+So, Dtch	26.4		14.23	**12.84**	**12.8**	**16.92**	**13.23**	**12.62**	**14.5**	**12.54**	59.76	65.46
9	Columbine Ck		2.12	2.17	Est 2.10	Est 2.10	Est 2.00	Est 2.00	2.08	2.48	2.73	9.54	9.54
										Est 1.3	Est 1.3	3.76	3.76
	South Ditch			1.33	Est 1.30	Est 1.3	Est 1.3	Est 1.3	Est 1.3				
APPARENT GROUND TO SURFACE DISCHARGE					3.62	4.78	4.57	4.28	6.34			0.08	
					*Sta 12-11	'Sta 11A-11	'Sta 11B-11	*Sta 11B-11	12-10A				
										5.29	3.66	6.35	3.30
								Revised 2/7/00		Sta 11C-10A	11B-11	11C-11	11C-10A

Table 4. Summary of stream flow measurements in Middle Red River.

Station	Date	8/5/97	8/18/97	8/19/97	9/9/97	11/3/97	11/4/97	3/9/98	3/10/98	4/30/98	5/1/98	10/20/98	10/21/98	10/13/99
1	Abv Town RR			21.96	15.66		8.61		3.9	29.4			9.18	9.64
4	Junebug CG			26.58	22.08		14.4		15.1		39.0		12.89	15.58
6A	Blw Hansen			27.1	19.99		15.86		13.46		43.7		15.37	
7X	Abv Mill			28.77	20.05	12.05		8.80		34.9		14.91	14.75	15.57
8	Blw Mill			26.12	**16.76**	**9.98**		7.93		36.5				
10 By subtraction	Abv Col -Compute					**10.26**		7.96		**28.45**		13.82		13.54
10A	Blw Col Ck			31.85	20.37	**14.43**		10.49		**39.45**		17.58		18.81
11	@ Lower Brg	51.7		29.89	19.51	**14.07**		14.2		**40.00**		18.31		
11A	Abv Thund Brg													20.12
11B	Blw Thund Brg													21.81
11C	Abv Goat Hill			36.38	25.35	**17.33**		17.5		**43.8**		20.87		24.83
12	@Goat Hill CG													
13	Abv Capulin	55.3		35.94	24.14	19.66		18.71		**43.21**		24.28		
16	@Ranger Sta	57.7	40.21	38.91	27.93	23.64		18.13	18.62	**52**	63	21.38	20.81	24.93
	RS+So, Dtch	61.65	42.81	41.51	29.6	25		18.13		52		23.34		25.98
9	Columbine Ck		6.56		5.04		4.17		2.53		11.0		3.76	
		3.95	2.6		1.67		1.36		0		0		1.96	
	South Ditch	0.15	0.042	Hansen	0.04	@Hwy			3.82	4.83				Pione
		0.24	0.103	Bear Ck	0.11									Mallet
APPARENT GROUND TO		0.034	0.026		0.06									
SURFACE DISCHARGE								3.3		4.35		3.29		6.02
								Sta 11C-11		Sta 11C-10A		Sta 11C-10A		Sta 11C-10A
		3.60		6.49	5.84	3.26								
		13-11		11C-11	11C-11	11C-11								

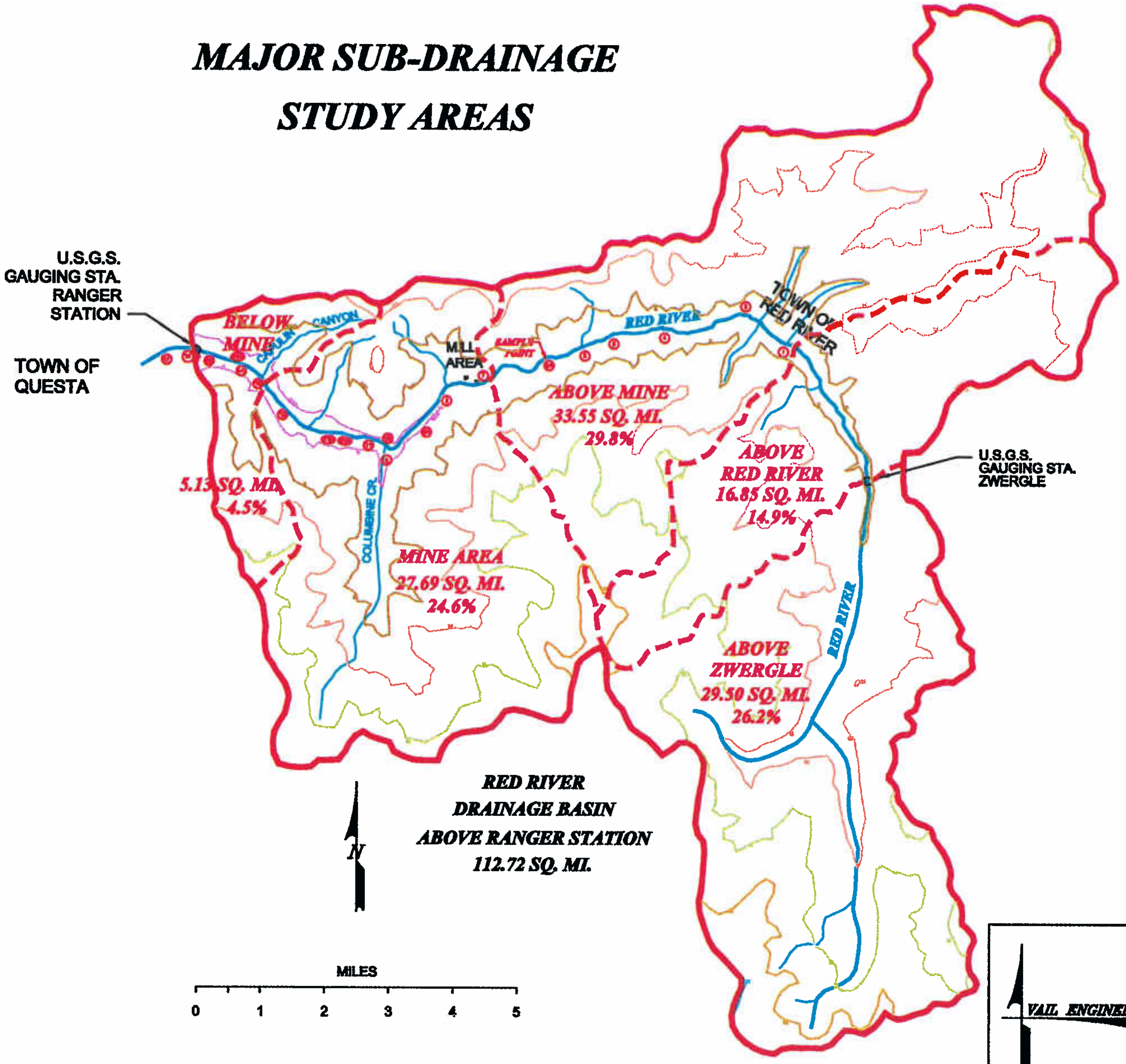
BOLD FIGURES INDICATE PROBABLE DIMINISHED FLOW AS RESULT OF MILL SURFACE DIVERSION

Table 4. Summary of stream flow measurements in Middle Red River.

Station	Date	10/14/99	10/15/99	3/15/2000	3/16/00	3/17/00
1	Abv Town RR	9.94		6.30	5.92	
			Sta 3	8.50		
4	Junebug CG	13.68		10.02	8.32	
			Sta 5	10.60		
6A	Blw Hansen	15.52		11.39		
7X	Abv Mill	14.36	15.65	9.31	10.19	6.78
8	Blw Mill		12.72			6.50
10	Abv Col -Compute		11.00		9.03	6.76
By subtraction						
10A	Blw Col Ck		16.27		11.87	9.66
11	@ Lower Brg					9.80
11A	Abv Thund Brg		17.78		13.20	8.92
11B	Blw Thund Brg		19.53		14.26	12.15
11C	Abv Goat Hill		23.41		16.06	13.66
12	@Goat Hill CG		21.7			
13	Abv Capulin		23.2		17.95	16.54
				Sta 14	14.40	13.86
16	@Ranger Sta	24.93	24.31	14.68	**18**	**14-18**
	RS+So, Dtch	25.98	25.36	Larry	**FROM USGS DAT**	
9	Columbine Ck	5.27		2.84		
		1.05				
	South Ditch	er Ck	1.2	0	0.51	0
		te Ck	0.07	dry		
APPARENT GROUND TO SURFACE DISCHARGE			7.14		4.19	4.00
			Sta 11C-10A		Sta 11C-10A	ta 11C-10A
		REV	2/7/00			

Figures

MAJOR SUB-DRAINAGE STUDY AREAS



RED RIVER
DRAINAGE BASIN
ABOVE RANGER STATION
112.72 SQ. MI.

VAIL ENGINEERING, INC.

1588 SAN MATEO LANE
SANTA FE, NEW MEXICO
87505

MOLYCORP, INC.

RED RIVER DRAINAGE BASIN
MAJOR SUB-DRAINAGE AREAS

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
		June 2000	June 2000	1"= 4000'	Fig.1

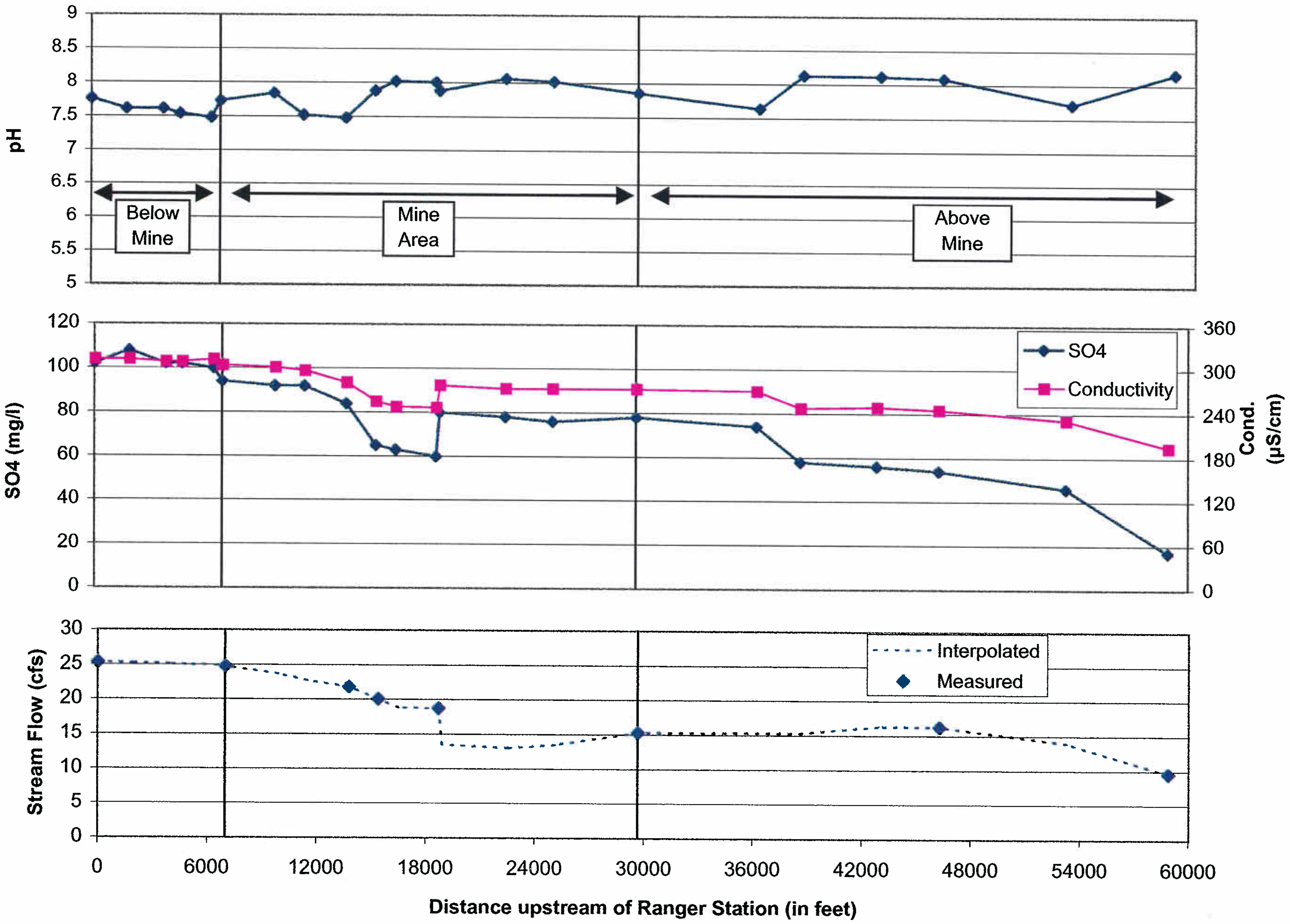


Figure 2. Stream survey parameters measured on October 13, 1999.

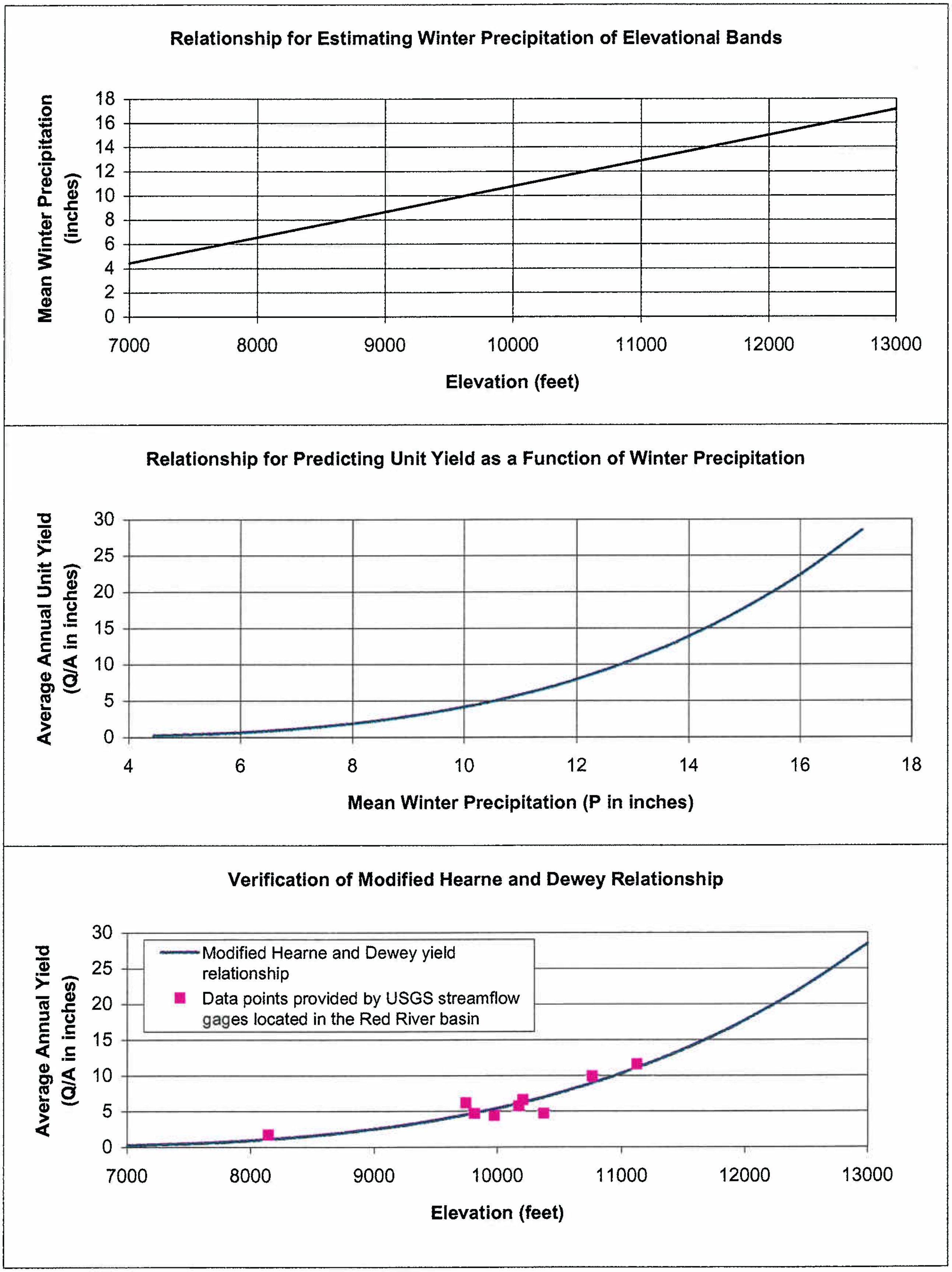
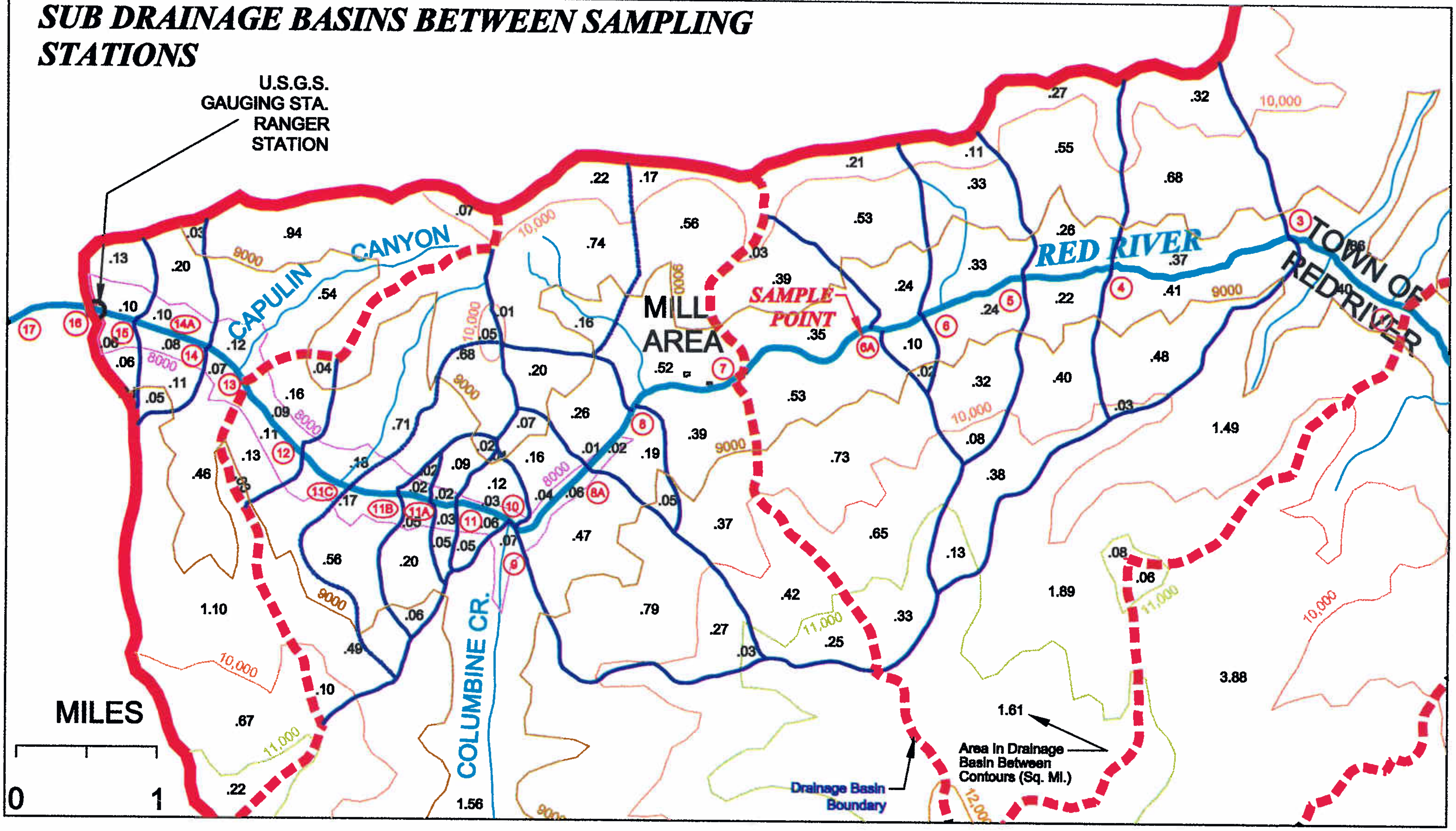


Figure 3 Modified Hearne and Dewey Relationship

SUB DRAINAGE BASINS BETWEEN SAMPLING STATIONS



VAIL ENGINEERING, INC.
[illegible] SAN MATEO LANE
SANTA FE, NEW MEXICO
87505

MOLYCORP, INC.
QUESTA DIVISION

RED RIVER DRAINAGE BASIN
SUB DRAINAGE BASINS

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
hdflow	RV	JUNE 2000	JUNE 2000	1" = 2000' H	4

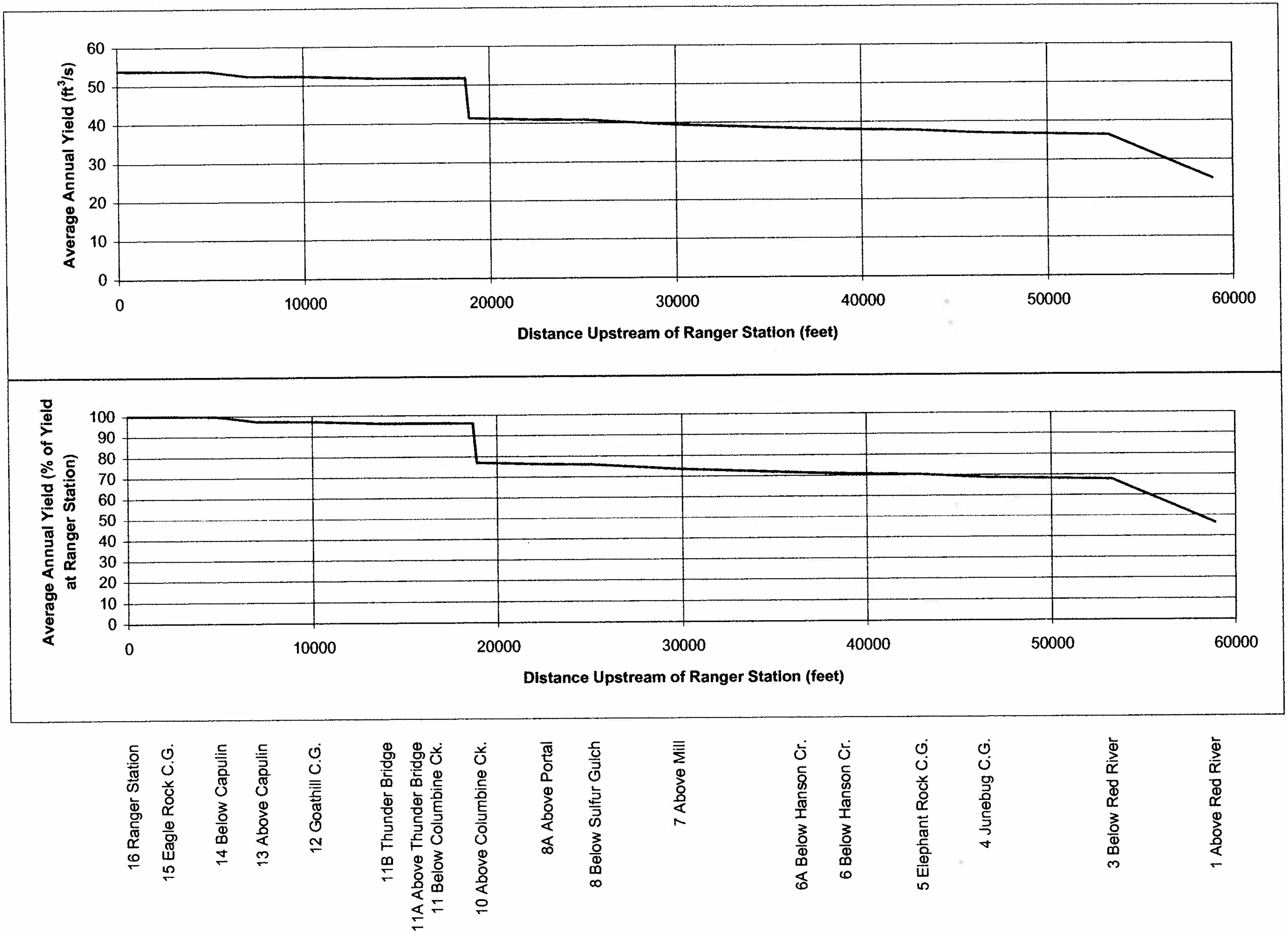
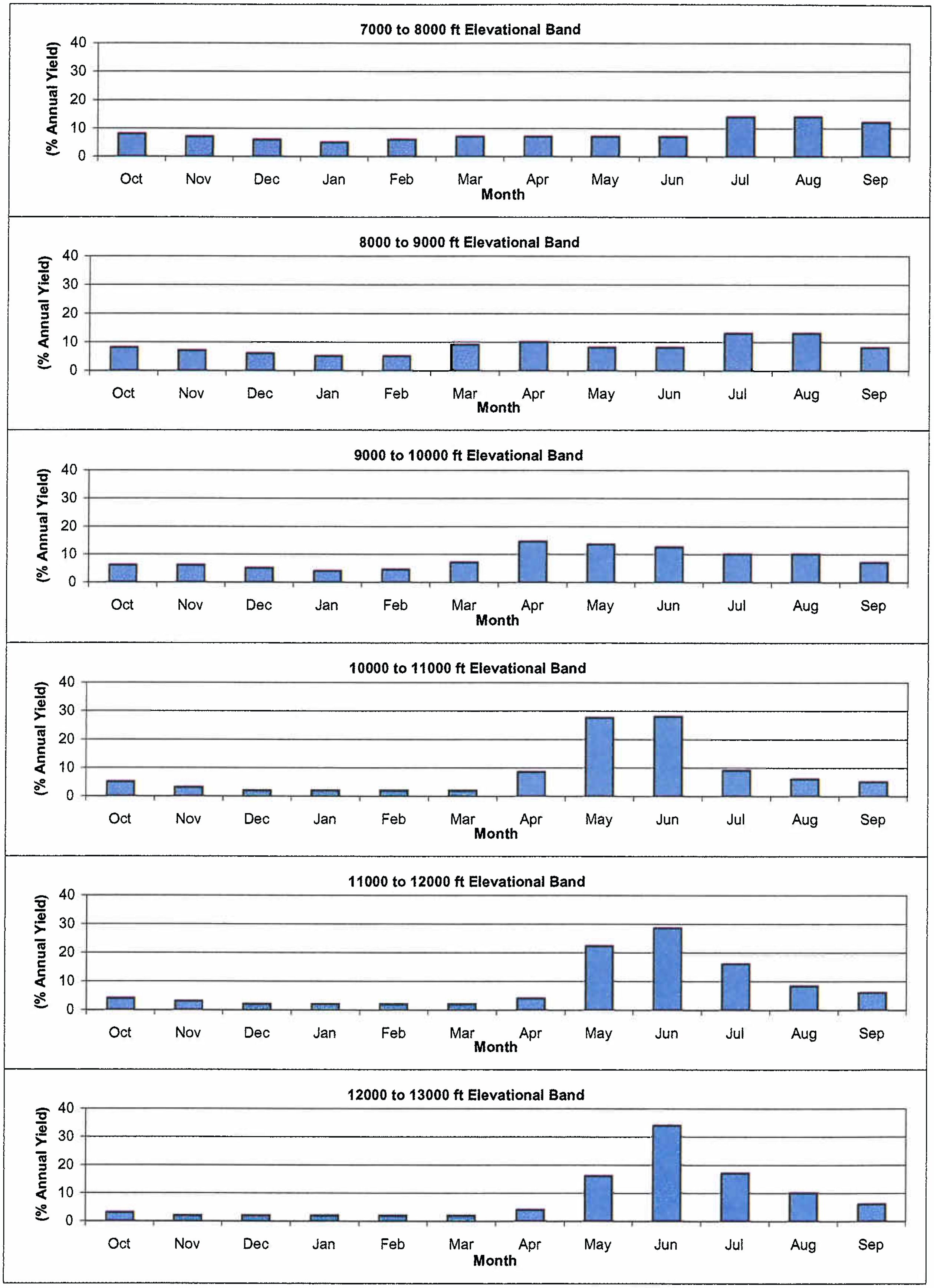


Figure 5a Estimated Average Annual Natural Yield Along Middle Reach



7000 to 8000 ft Elevational Band

8000 to 9000 ft Elevational Band

9000 to 10000 ft Elevational Band

10000 to 11000 ft Elevational Band

11000 to 12000 ft Elevational Band

12000 to 13000 ft Elevational Band

Figure 5b Estimated Average Monthly Yields for Elevational Bands

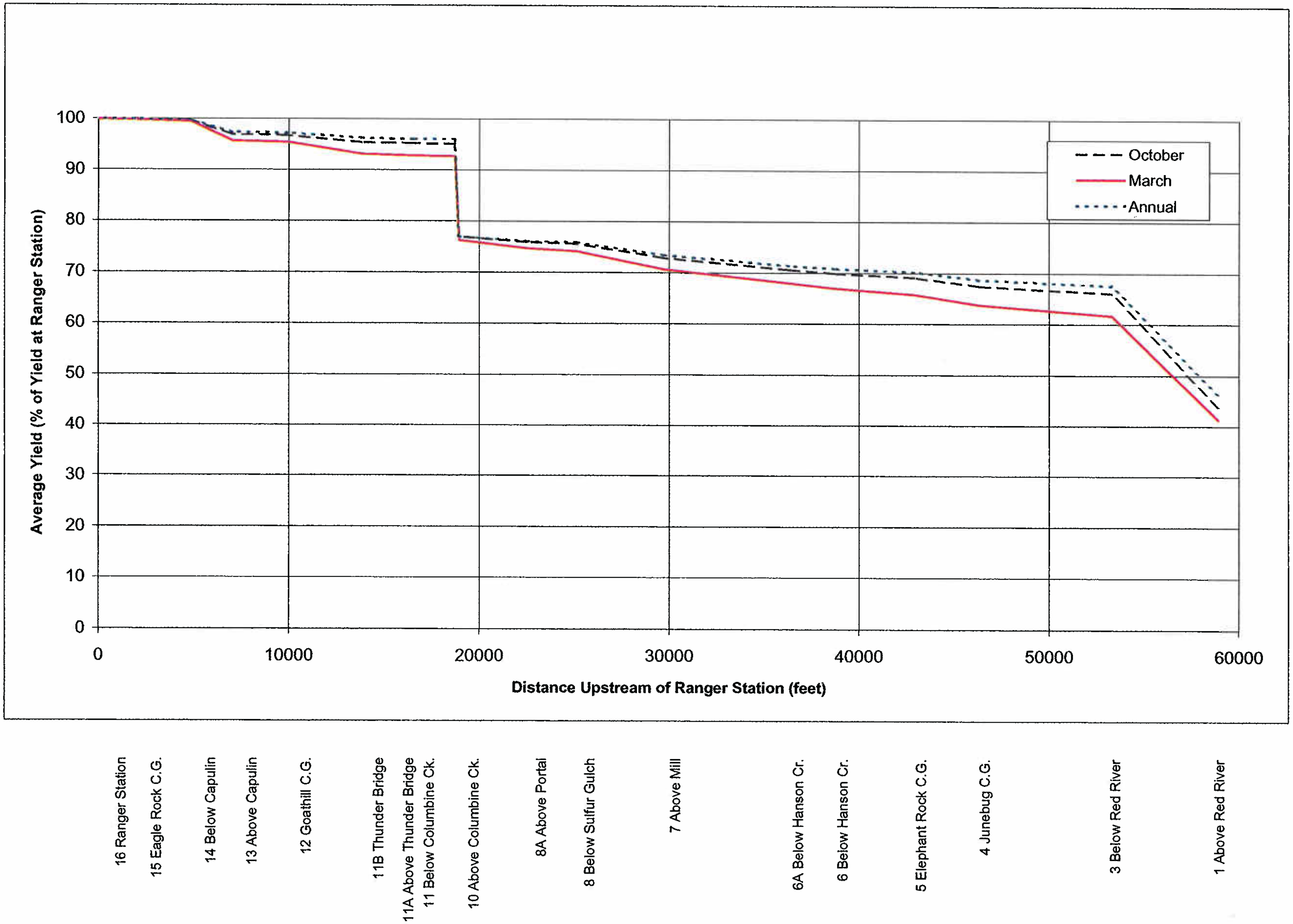
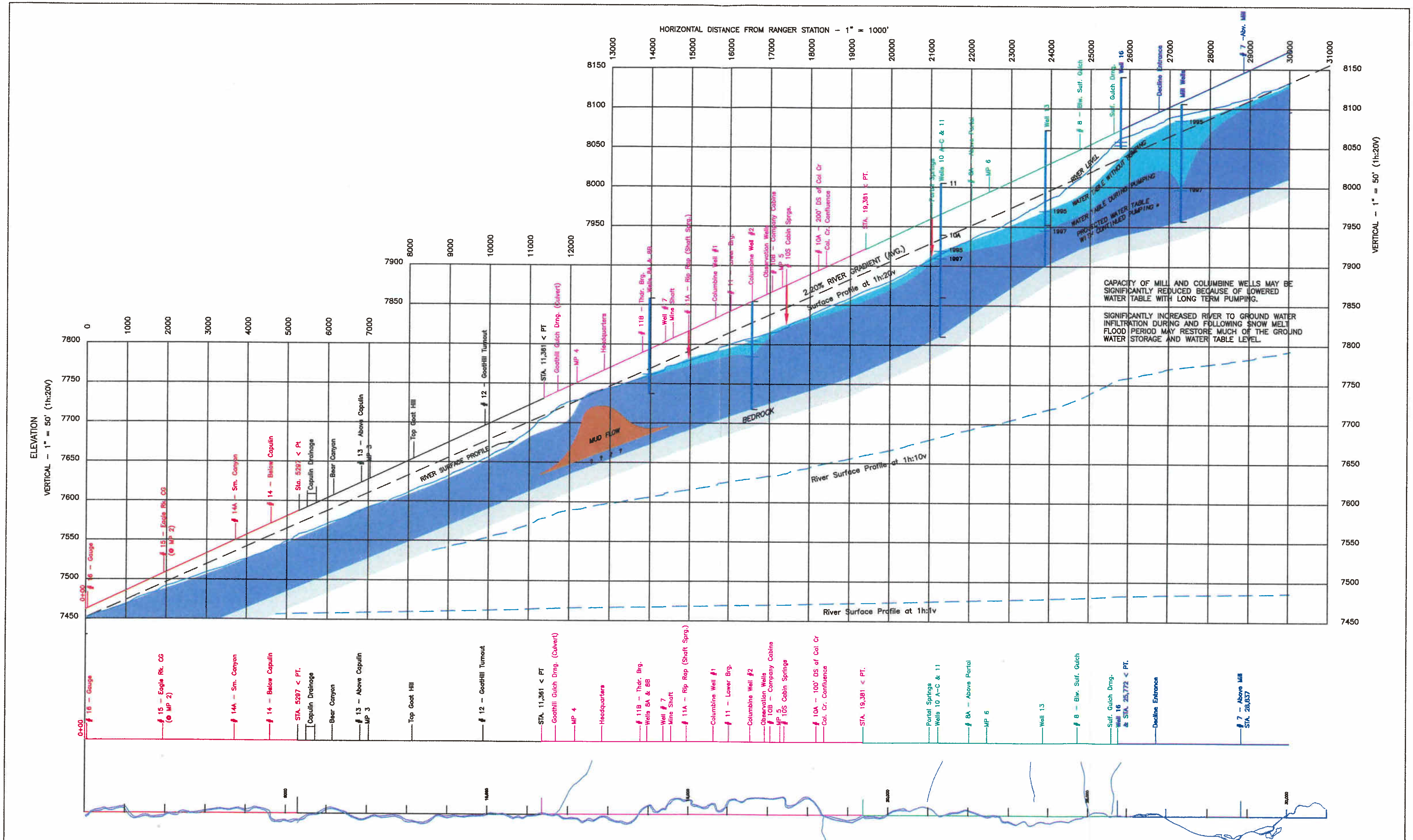


Figure 6 Estimated Average Monthly Natural Yield Along Middle Reach



CAPACITY OF MILL AND COLUMBINE WELLS MAY BE SIGNIFICANTLY REDUCED BECAUSE OF LOWERED WATER TABLE WITH LONG TERM PUMPING.

SIGNIFICANTLY INCREASED RIVER TO GROUND WATER INFILTRATION DURING AND FOLLOWING SNOW MELT FLOOD PERIOD MAY RESTORE MUCH OF THE GROUND WATER STORAGE AND WATER TABLE LEVEL.

FIGURE 7b. PROFILE OF RED RIVER AND GROUND WATER TABLE

RIVER ELEVATION DATA FROM 1964 AERIAL PHOTOGRAPHY

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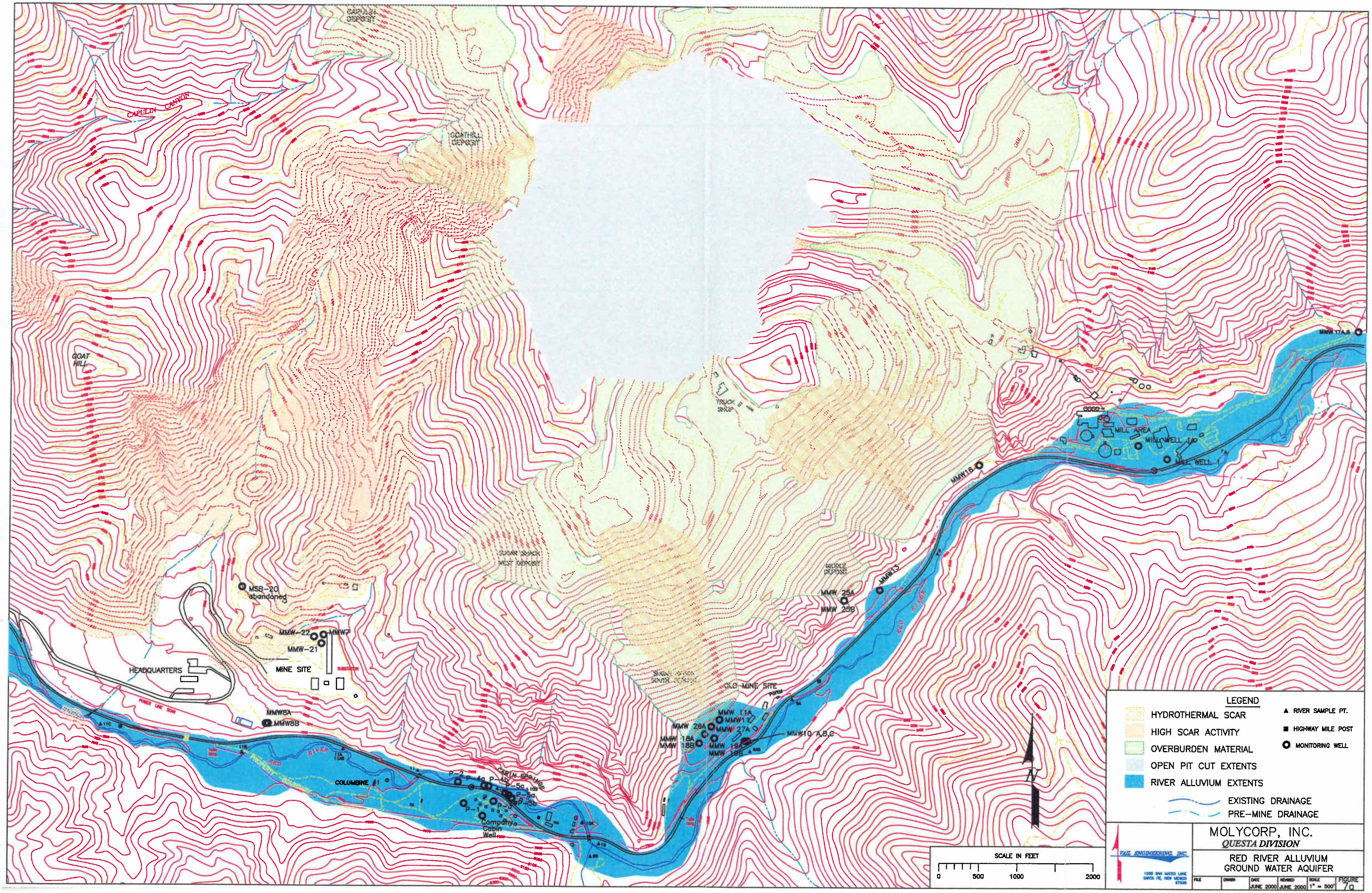
RED RIVER PROFILE

FILE	DESIGN	DATE	REVISED	SCALE – H	SCALE – V
RIVPROF		JUNE 2000	JUNE 2000	1"=1000'	1"=50'



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QUESTA DIVISION

RED RIVER ALLUVIUM
GROUND WATER AQUIFER

FILE	DRAWN	DATE	REVISED	SCALE	FIGURE
		JUNE 2000	JUNE 2000	1" = 500'	7a

FIGURE 9. HYDROTHERMAL SCAR AREAS
PERCENTAGE BY REACH

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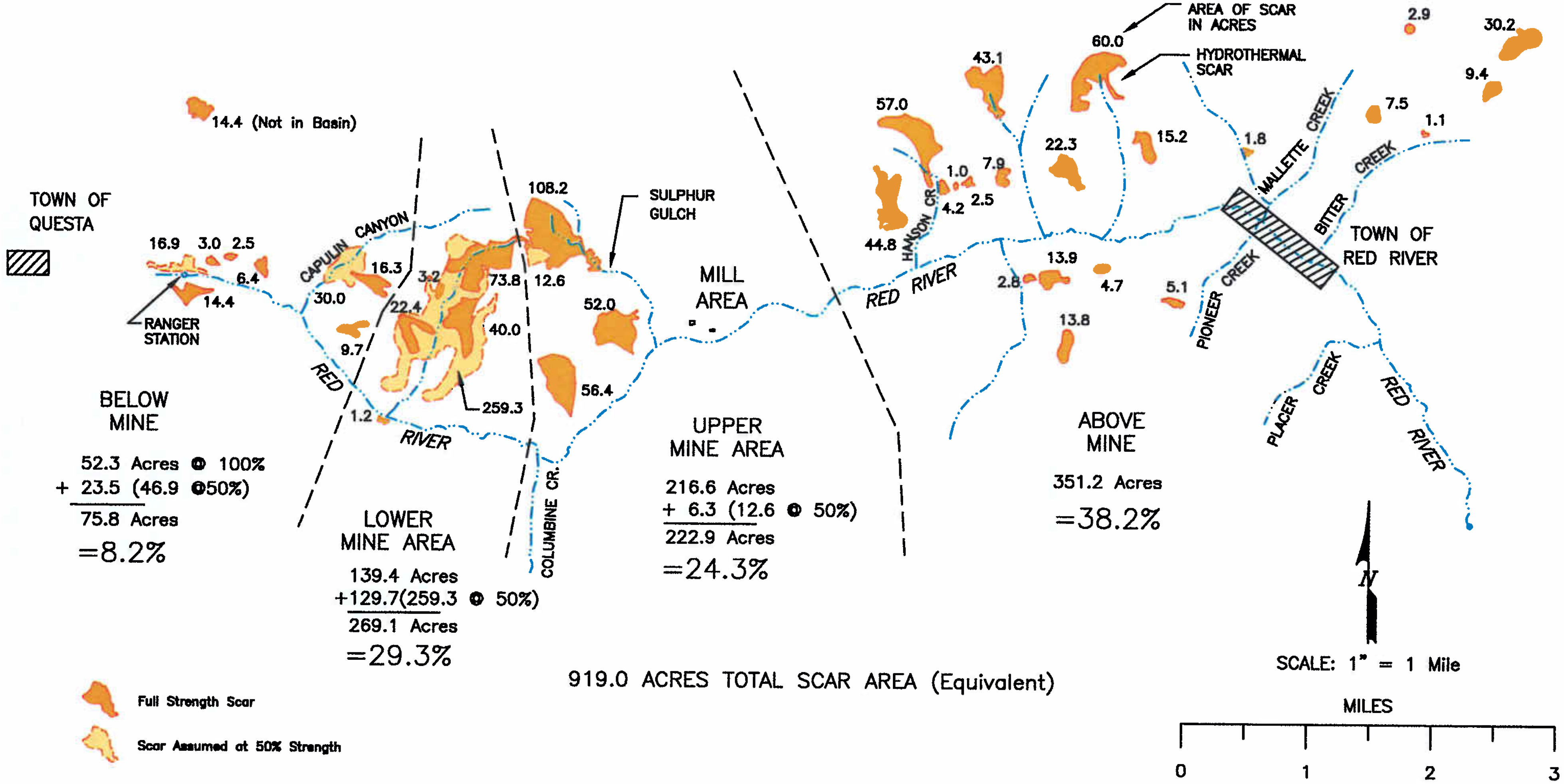

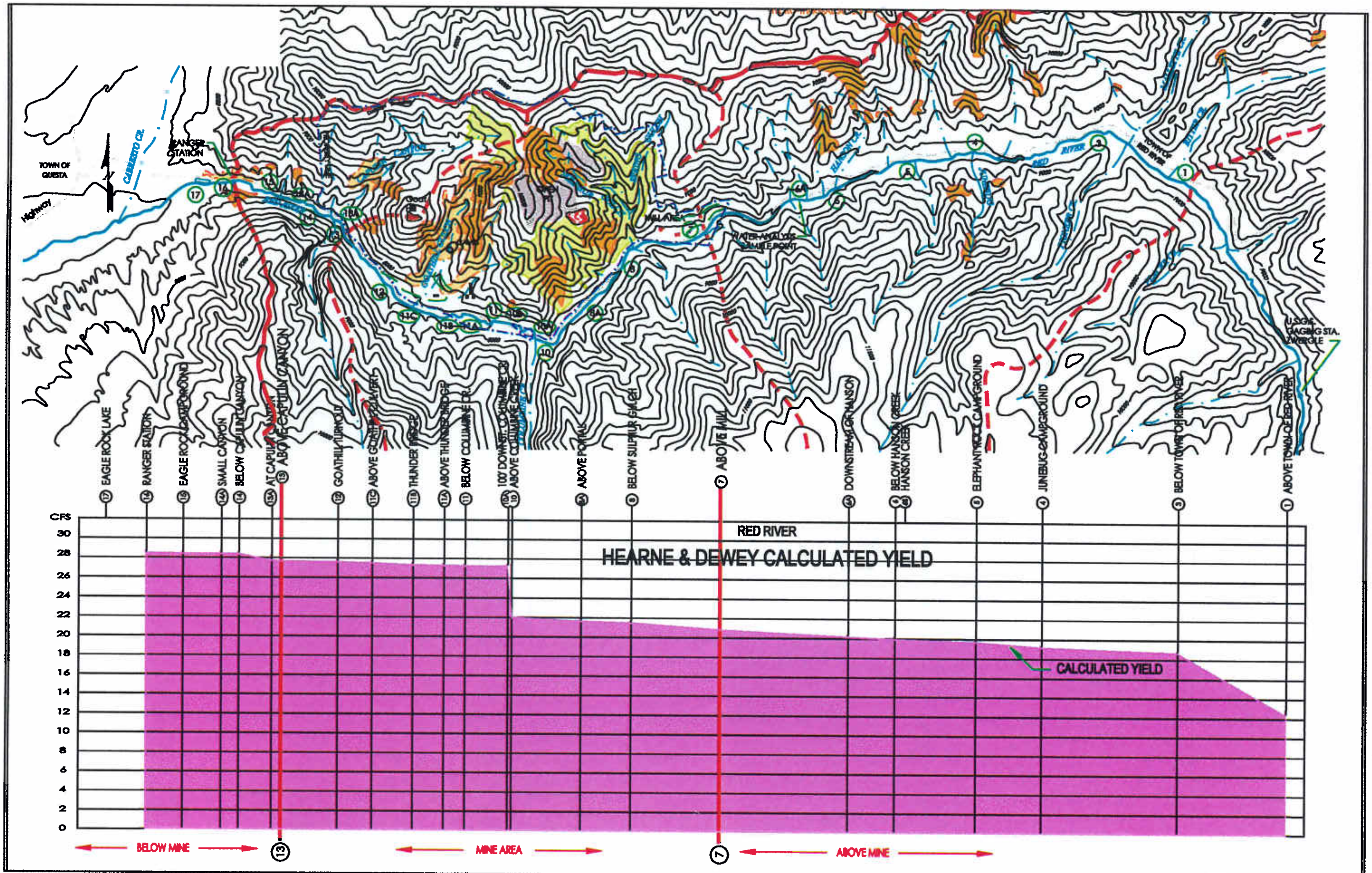

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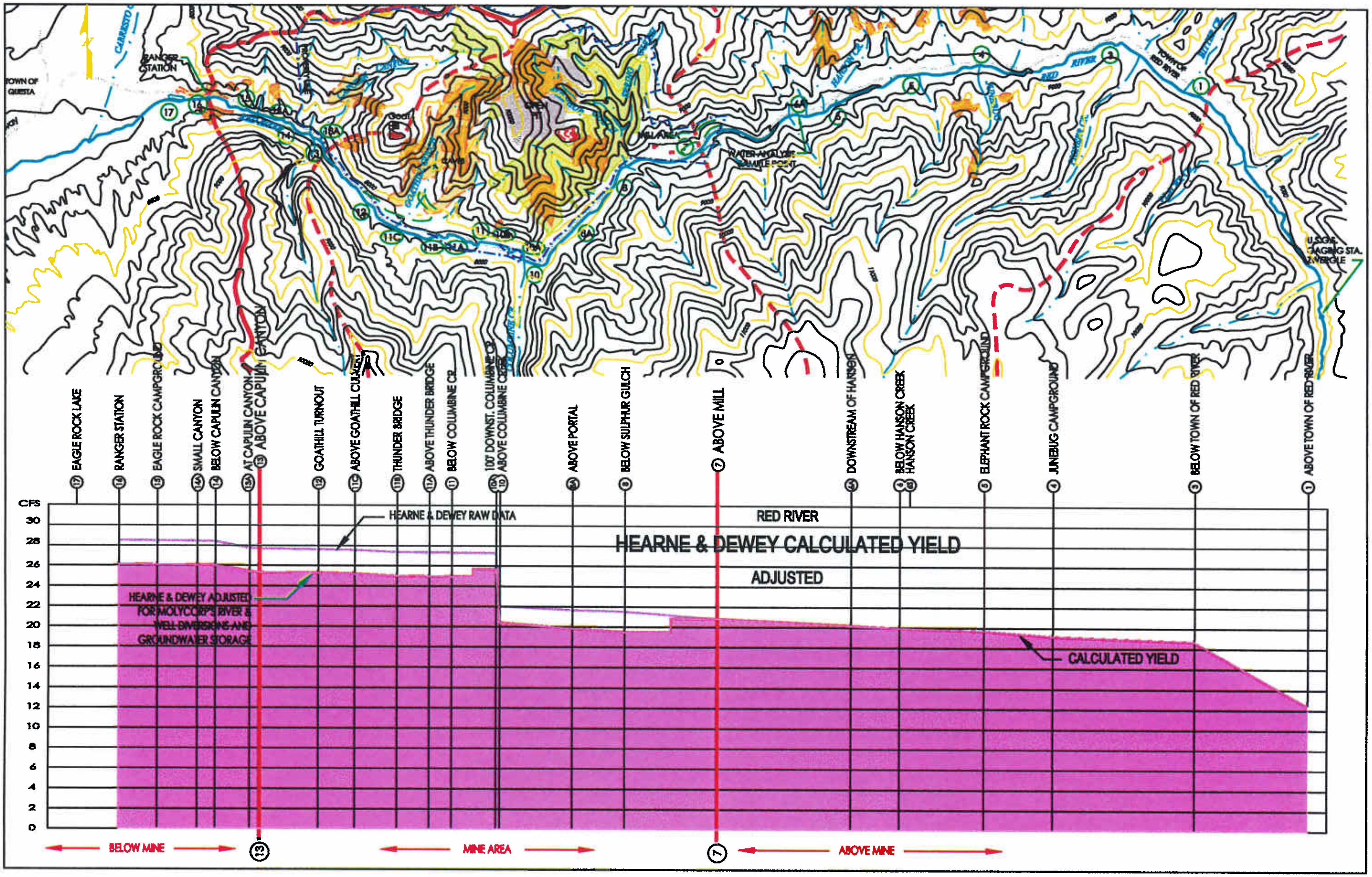
HEARNE & DEWEY CALCULATED YIELD
OCTOBER, 1999

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
hdyield		JUNE 2000	JUNE 2000		10



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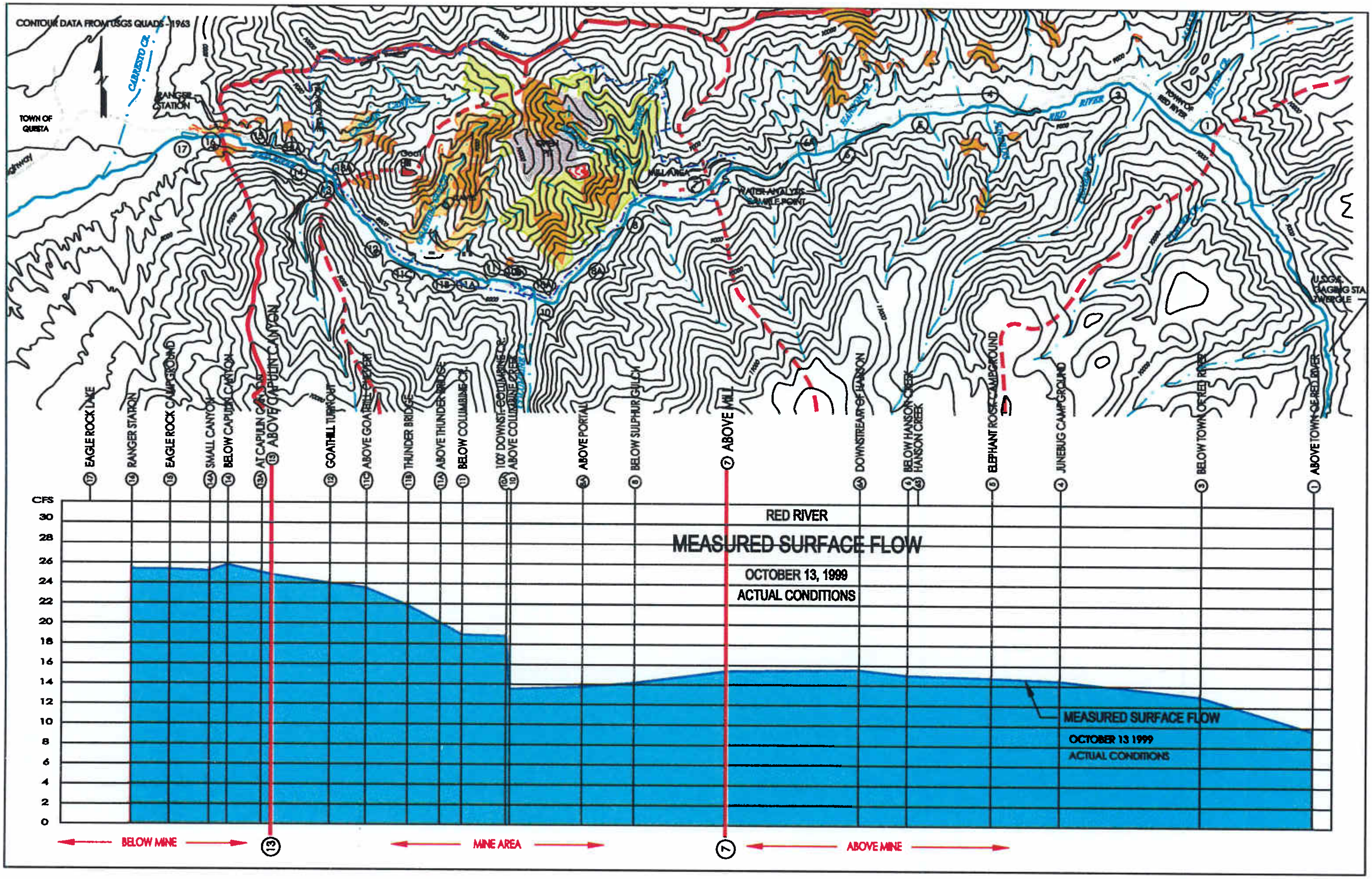
87505

MOLYCORP, INC.
QUESTA DIVISION

HEARNE & DEWEY ADJUSTED YIELD
OCTOBER, 1999

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
hdyield		JUNE 2000	JUNE 2000		11

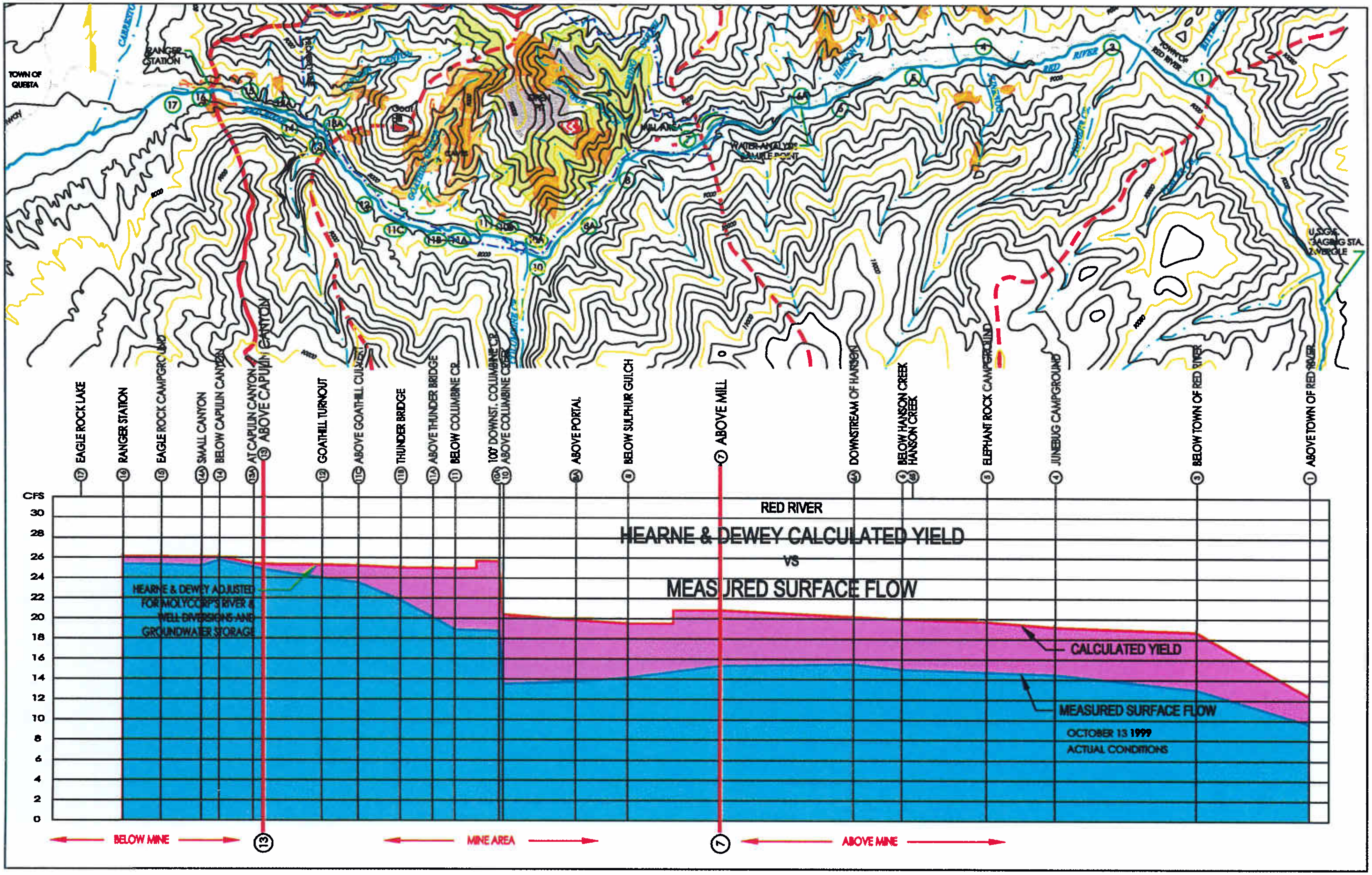


VAIL ENGINEERING, INC.
1600 SAN MATEO LANE
SANTA FE, NEW MEXICO
87505

MOLYCORP, INC.
QUESTA DIVISION

MEASURED SURFACE FLOW
OCTOBER 13, 1999

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
		JUNE 2000	JUNE 2000		12



VAIL ENGINEERING, INC.
1508 SAN MATEO LANE
SANTA FE, NEW MEXICO
87505

MOLYCORP, INC.
QUESTA DIVISION

HEARNE & DEWEY vs. MEASURED
OCTOBER 13, 1999

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
		JUNE 2000	JUNE 2000		13

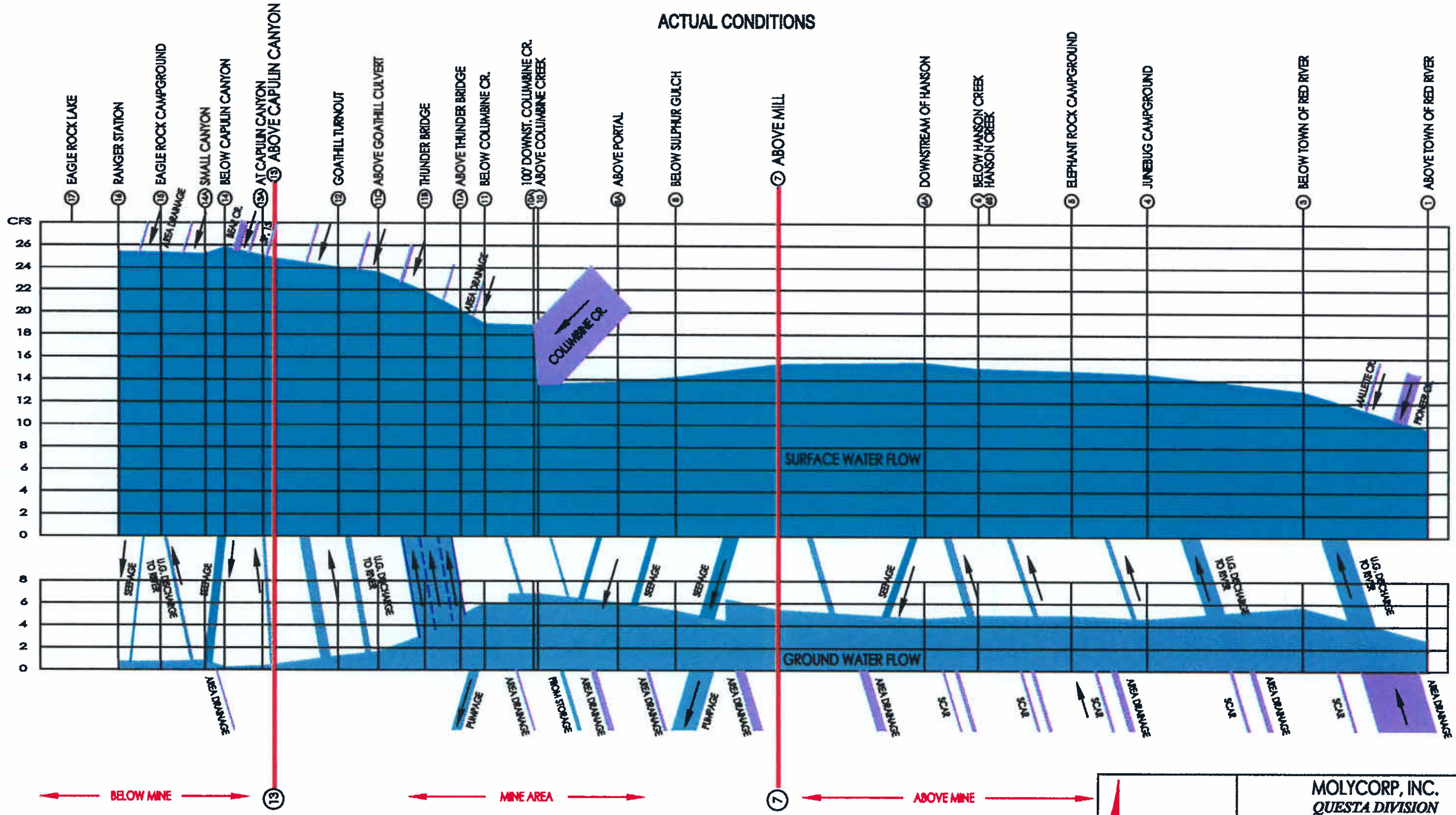
RED RIVER

FLOW BALANCE

GROUNDWATER & SURFACE WATER

OCTOBER 13, 1999

ACTUAL CONDITIONS



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[illegible]

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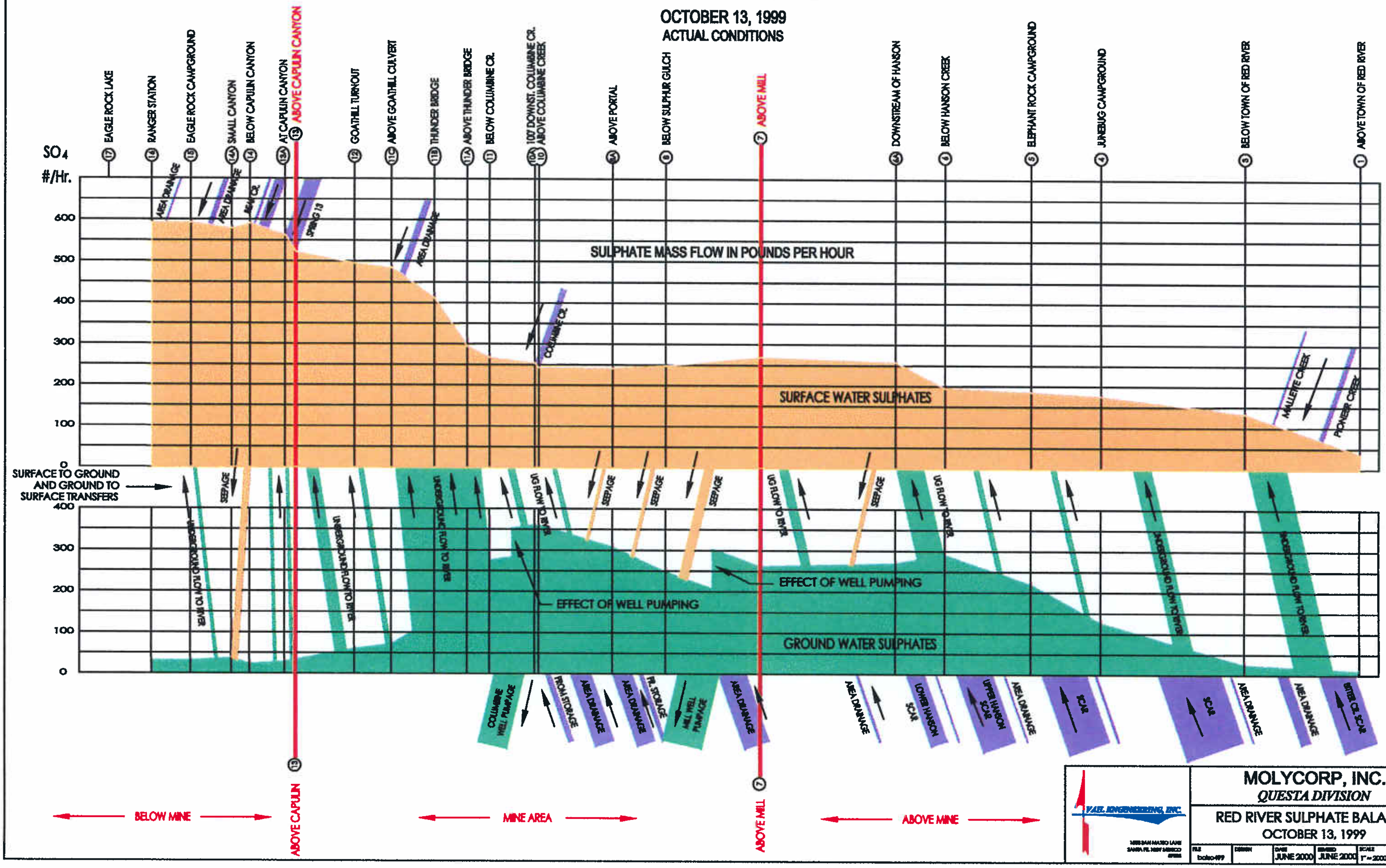
QUESTA DIVISION

RED RIVER FLOW BALANCE
OCTOBER 13, 1999

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
	RW	JUNE 2000	JUNE 2000	1" = 2000' H	14

RED RIVER
SULPHATE BALANCE
GROUNDWATER & SURFACE WATER
OCTOBER 13, 1999
ACTUAL CONDITIONS



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RED RIVER SULPHATE BALANCE
OCTOBER 13, 1999

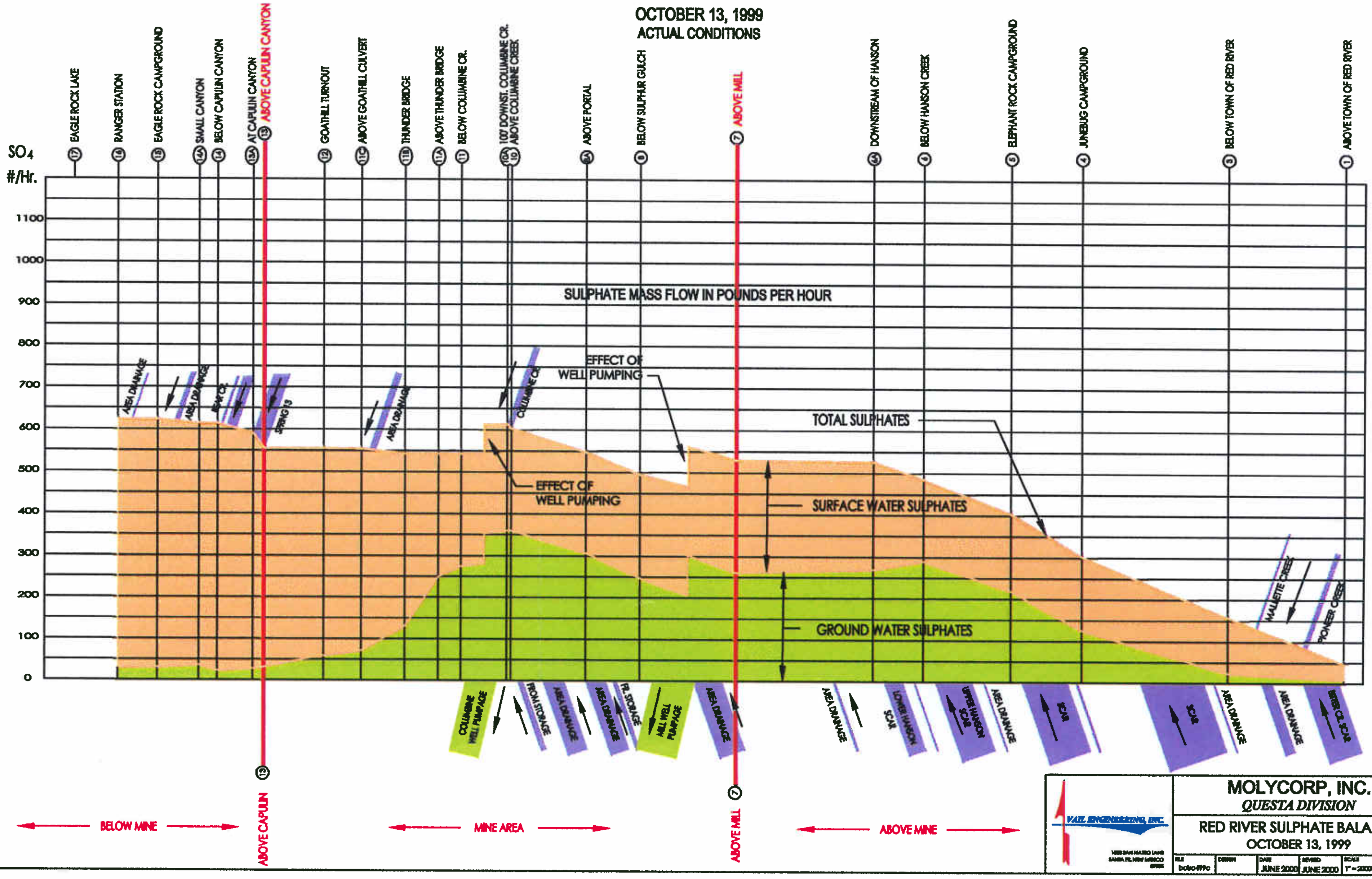
FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
balso499		JUNE 2000	JUNE 2000	1" = 2000' H	15

RED RIVER

SULPHATE BALANCE

GROUNDWATER & SURFACE WATER

OCTOBER 13, 1999
ACTUAL CONDITIONS



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MOLYCORP, INC.
QUESTA DIVISION

RED RIVER SULPHATE BALANCE
OCTOBER 13, 1999

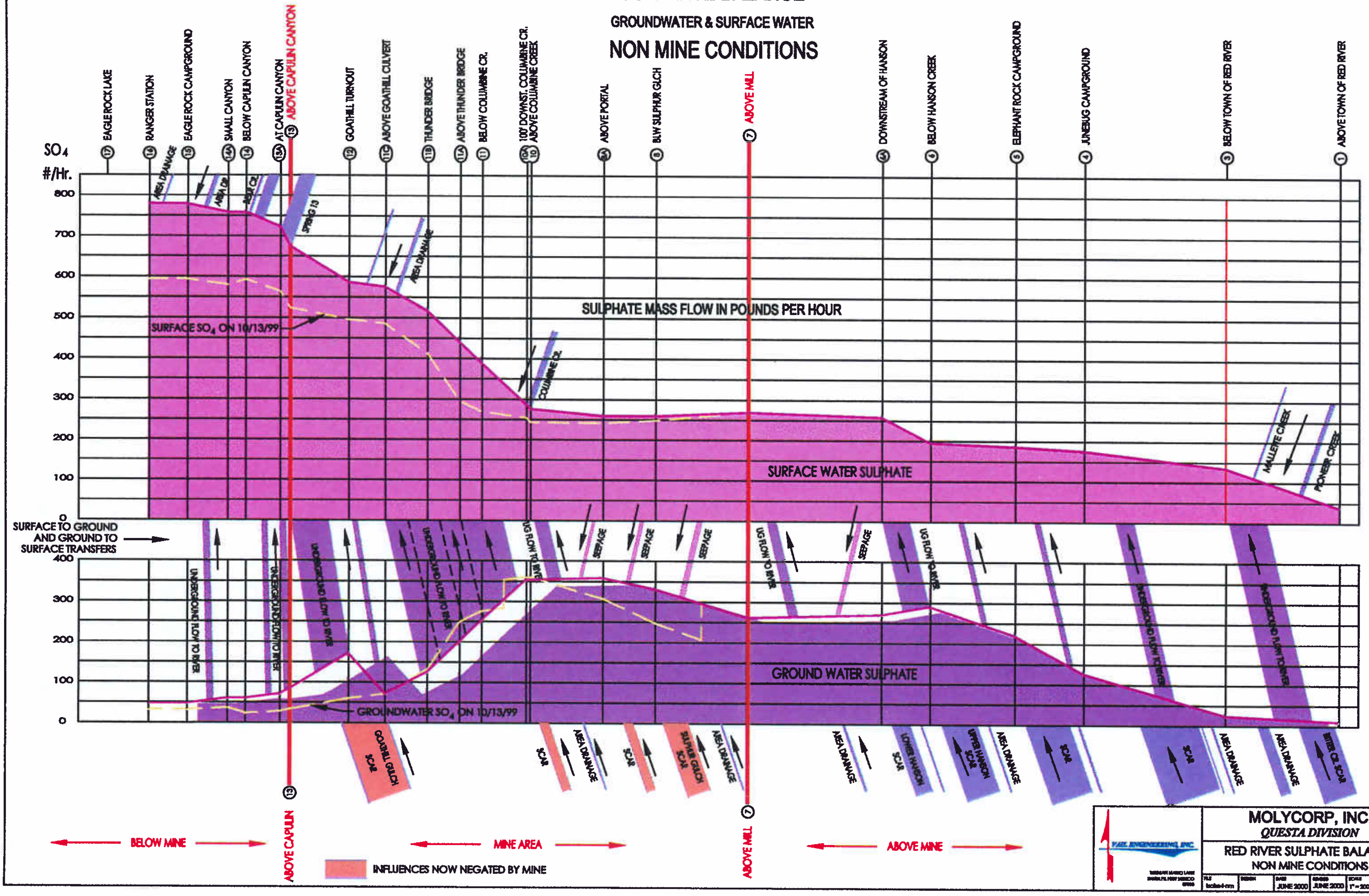
FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
balso499c		JUNE 2000	JUNE 2000	1" = 2000' H	16

RED RIVER

SULPHATE BALANCE

GROUNDWATER & SURFACE WATER

NON MINE CONDITIONS



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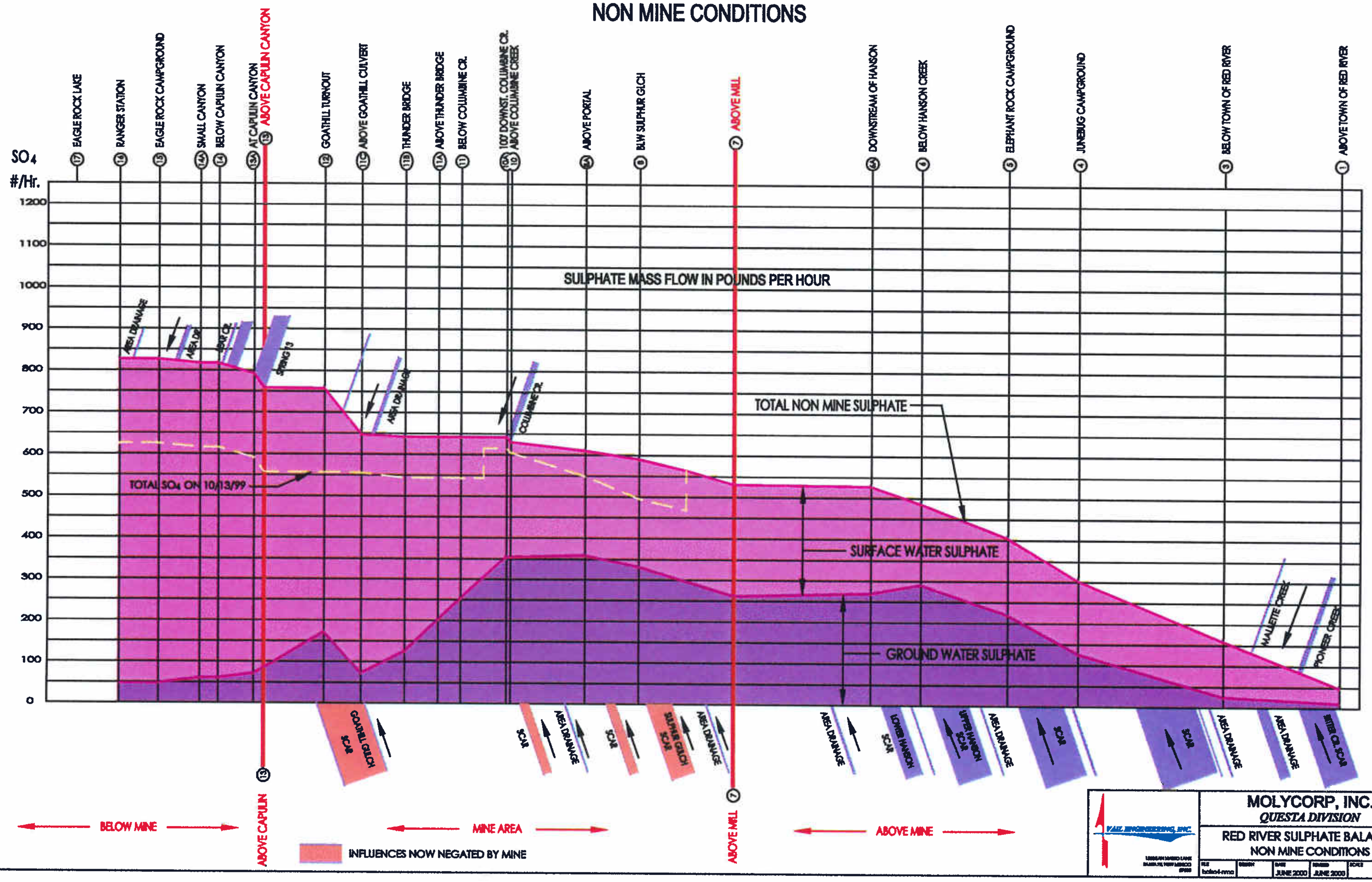
MOLYCORP, INC.
QUESTA DIVISION

RED RIVER SULPHATE BALANCE
NON MINE CONDITIONS

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
[illegible]		JUNE 2000	JUNE 2000	1" = 200' H	17

RED RIVER
SULPHATE BALANCE
GROUNDWATER & SURFACE WATER
NON MINE CONDITIONS



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QUESTA DIVISION

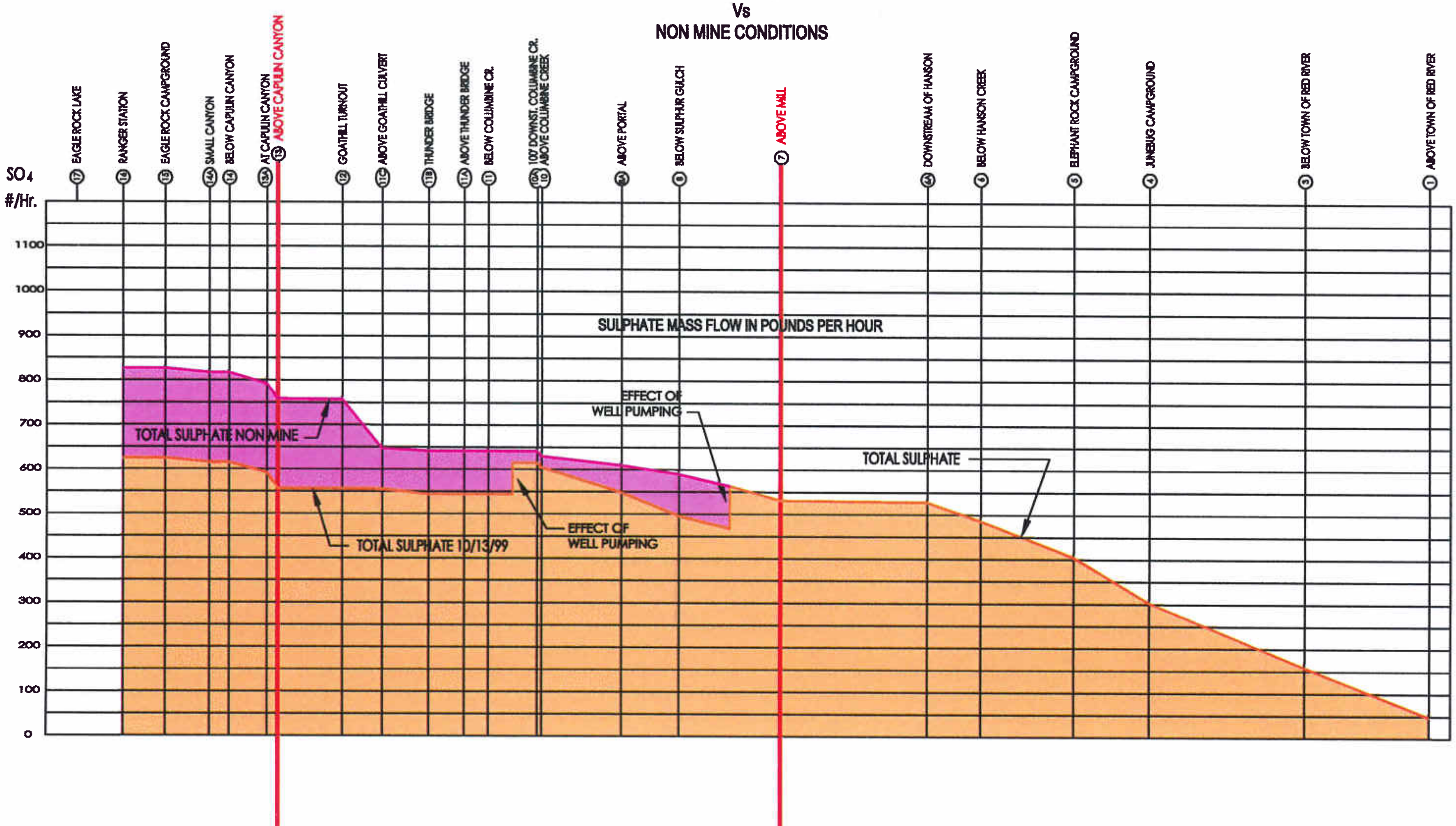
RED RIVER SULPHATE BALANCE
NON MINE CONDITIONS

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
balso4-nmc		JUNE 2000	JUNE 2000		18

RED RIVER

TOTAL SULPHATE

OCTOBER 13, 1999
Vs
NON MINE CONDITIONS



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1[illegible] SAN MATEO LANE
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[illegible]

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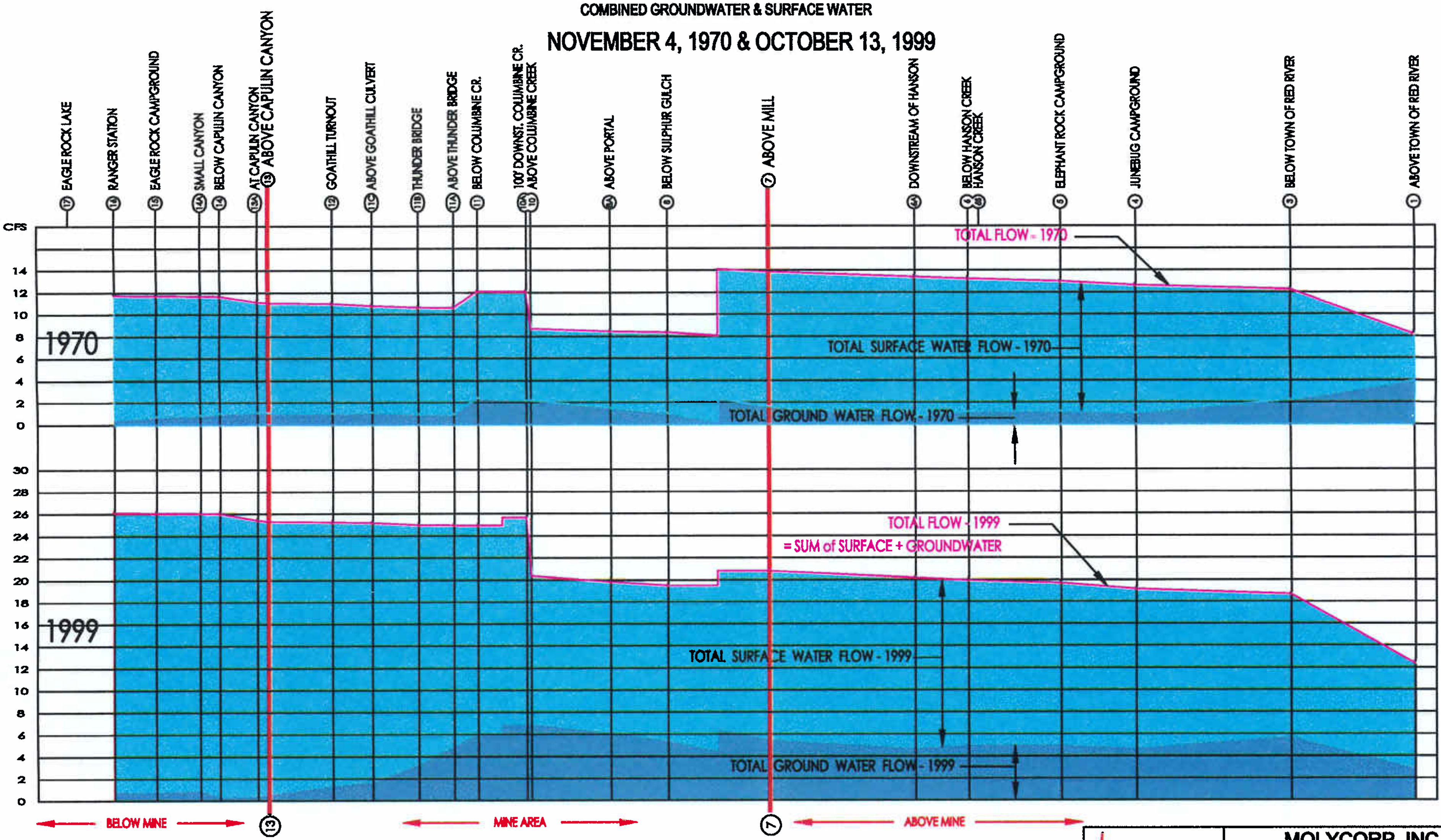
QUESTA DIVISION

RED RIVER TOTAL SULPHATE
1999 vs NON MINE

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
bales4both		JUNE 2000	JUNE 2000	1" = 2000' H	19

RED RIVER
FLOW BALANCE
COMBINED GROUNDWATER & SURFACE WATER
NOVEMBER 4, 1970 & OCTOBER 13, 1999



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[illegible]

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QUESTA DIVISION

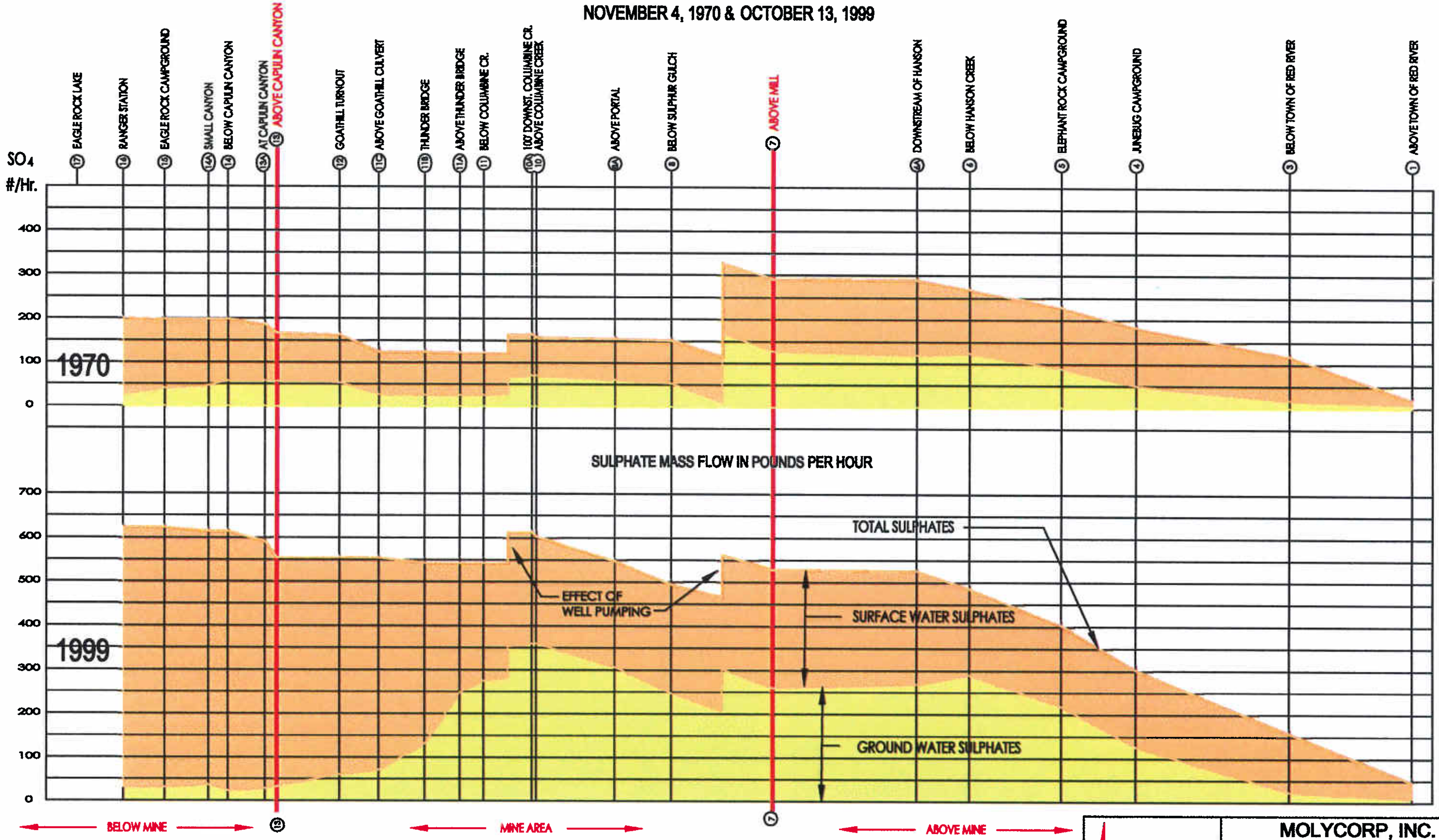
RED RIVER FLOW BALANCE
NOVEMBER 4, 1970 vs OCTOBER 13, 1999

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
balflow70	RW	JUNE 2000	JUNE 2000	1" = 2000' H	20

RED RIVER

SULPHATE BALANCE

COMBINED GROUNDWATER & SURFACE WATER
NOVEMBER 4, 1970 & OCTOBER 13, 1999



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[illegible] SAN MATEO LANE
SANTA FE, NEW MEXICO
[illegible]

MOLYCORP, INC.
QUESTA DIVISION

RED RIVER SULPHATE BALANCE
NOVEMBER4, 1970 & OCTOBER 13, 1999

FILE	DESIGN	DATE	REVISED	SCALE	FIGURE
pdso4-70spd		JUNE 2000	JUNE 2000	1" = 2000' H	21