APPENDIX 7-56

INVESTIGATION OF POTENTIAL FOR LITTLE BEAR SPRING RECHARGE

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Investigation of the Potential for Little Bear Spring Recharge in Mill Fork Canyon, Emery County, Utah

GENWAL Resources, Inc., Huntington, Utah

23 February 2001

Mayo and Associates, LC
Consultants in Hydrogeology

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Executive Summary

Little Bear Spring is located in the central Wasatch Plateau region, approximately 12 miles northwest of Huntington, Utah. Discharge rates from Little Bear Spring are unusually large relative to other springs in the Wasatch Plateau, ranging from about 200 to nearly 500 gpm. Discharge from Little Bear Spring, while being responsive to climate and season, is resistant to even prolonged periods of drought. Because of the large quantities of water that consistently discharge from Little Bear Spring, it has been utilized as a culinary water supply for many years. Castle Valley Special Service District currently utilizes the spring to supply drinking water to the towns of Huntington, Cleveland, and Elmo.

Because of the proximity of Little Bear Spring to current and proposed coal mining areas, considerable attention has been given to the hydrogeologic conditions in the vicinity of the spring. Mayo and Associates (1999) suggested that recharge to Little Bear Spring occurs through surface water and/or alluvial groundwater losses in Mill Fork Canyon. Water Technology and Research (1999) performed a geophysical investigation of Little Bear Spring that is in overall agreement with this conclusion. There is currently a general consensus in the local scientific community that Little Bear Spring is likely recharged from the south, probably in Mill Fork Canyon.

Previous investigations (Huntington No. 4 Mine MRP, Mayo and Associates, 1999) have demonstrated that there is commonly no flow in Mill Fork Creek in the vicinity of the fracture system from which Little Bear Spring discharges. The Mill Fork stream channel at the confluence with Huntington Creek is, likewise, commonly dry during much of the year. This condition is anomalous relative to the adjacent Wasatch Plateau drainages both above and below Mill Fork. In nearly all years, discharge persists throughout the year in the Horse Canyon, Blind Canyon, Crandall Canyon, Little Bear Canyon, and Rilda Canyon drainages.

The predicted water yield from Mill Fork Canyon was evaluated using two independent methods to determine if there is sufficient available water in the basin to sustain Little Bear Spring.

Using a comparative basin analysis approach, the discharge from Mill Fork Canyon was compared with the Crandall Canyon discharge. A surrogate basin was used for analysis in order to determine what a typical drainage basin (without a major diversion from the drainage as occurs in Mill Fork) should produce in terms of its annual water yield. The use of Crandall Canyon discharge as a surrogate for Mill Fork was based on the fact that the surface areas of the two adjoining basins are essentially identical (within less than 2%). The aspects, vegetation, and elevation distributions of the two drainages are likewise very similar.

It was determined that, while there is no baseflow discharge in Mill Fork Creek below the fracture system, a baseflow discharge of about 300 gpm persists throughout the year in

Crandall Creek. The alluvial groundwater flowing in Crandall Canyon is not included in this baseflow estimate. An obvious question follows this determination – why is there no baseflow in upper Mill Fork and where did the water go? The assumption that the water that is lost from upper Mill Fork canyon is recharging Little Bear Spring (which has a baseflow discharge of about 300 gpm) is entirely consistent with all of the available data.

The Utah Division of Water Resources (1975) has predicted that up to 4 inches of runoff can be expected from drainage basins in the vicinity of Mill Fork Canyon. Using a conservative estimate of 3.5 inches of runoff, it is calculated that upper Mill Fork should yield about 800 acre-feet of runoff per year, or an average discharge rate of about 500 gpm. This conclusion is in good agreement with that determined using the comparative basin approach.

A conceptual model of groundwater recharge to Little Bear Spring in Mill Fork Canyon has been developed. During the fall and winter months, recharge to the spring occurs as alluvial groundwater is intercepted by the Star Point Sandstone fracture system where it intersects the bottom of the stream channel. During the high-flow season, surface water also contributes to the recharge of Little Bear Spring both directly (through nearby stream losses) and as a result of overall increases in the amount of groundwater flow in the alluvial sediments. This recharge model satisfies all of the physical constraints that must be met for the model to be accepted.

To summarize, it is determined that the upper Mill Fork drainage *is* capable of sustaining the discharge at Little Bear Spring. Moreover, it is difficult to explain the lack of flow in the Mill Fork drainage without taking recharge to Little Bear Spring into account.

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Little Bear Spring is located in the central Wasatch Plateau region, approximately 12 miles northwest of Huntington, Utah (Figure 1). Discharge rates from Little Bear Spring are unusually large relative to other springs in the Wasatch Plateau, ranging from about 200 to nearly 500 gpm. Discharge from Little Bear Spring, while being responsive to climate and season, is resistant to even prolonged periods of drought (Figure 2; Table 1). During the severe regional drought of the early 1990s, discharge from Little Bear Spring was continuously greater than 200 gpm (Figure 2).

Because of Little Bear Spring's large discharge rate and good reliability, it has been utilized as a culinary water supply for many years. Castle Valley Special Service District currently utilizes the spring to supply drinking water to the towns of Huntington, Cleveland, and Elmo.

Considerable attention has been given to the hydrogeologic conditions in the vicinity of the spring due to the proximity of the spring to current and proposed coal mining areas. Particular attention has been given to identifying the recharge mechanism and location for the spring because of concerns regarding the potential for mining-related impacts. Mayo and Associates (1999) concluded that recharge to Little Bear Spring occurs through surface water

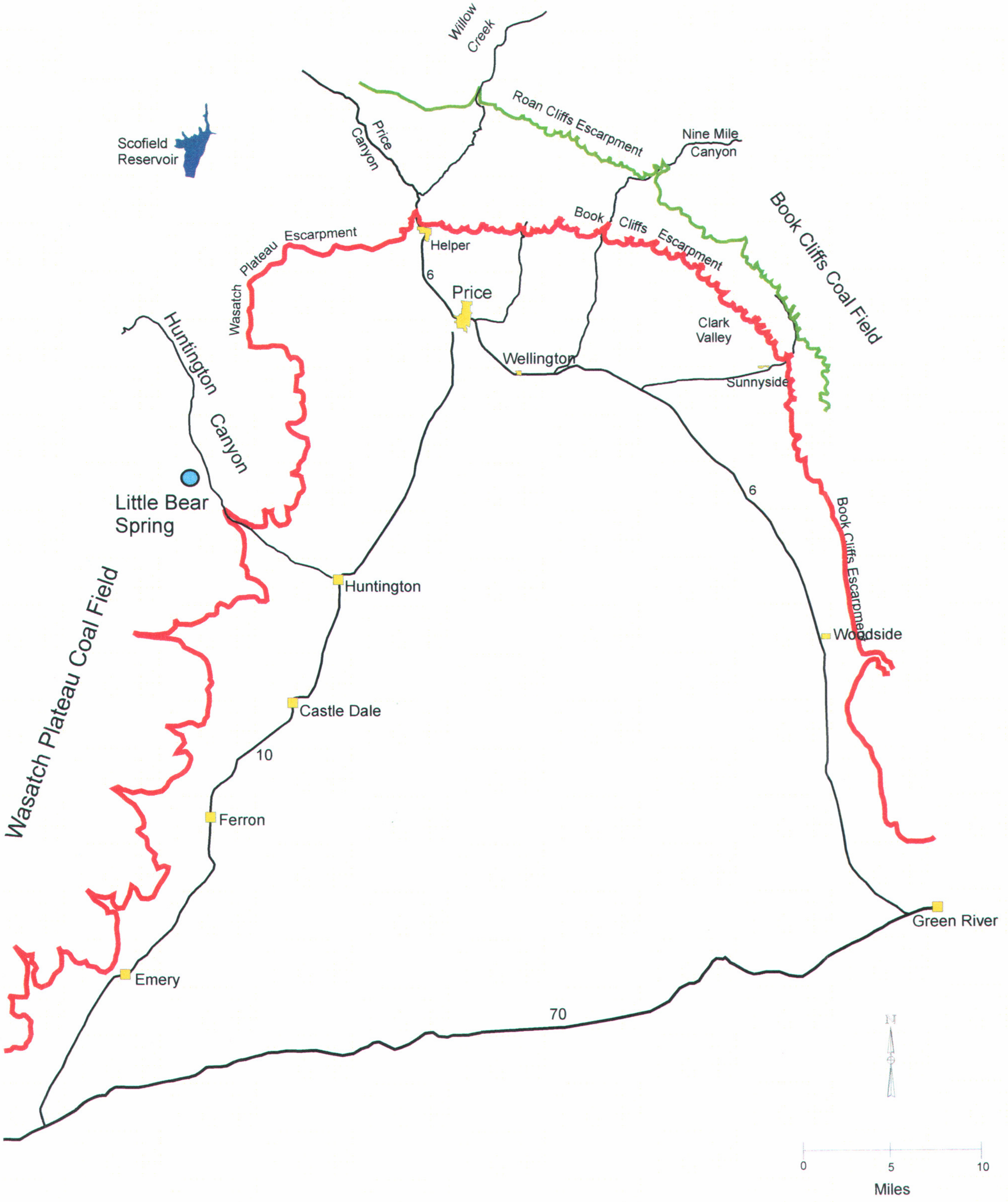

Figure 1 Location map of the Little Bear Spring area.

Mayo & Associates
Fig1 - Regional Map.cdr 13 Jul 99

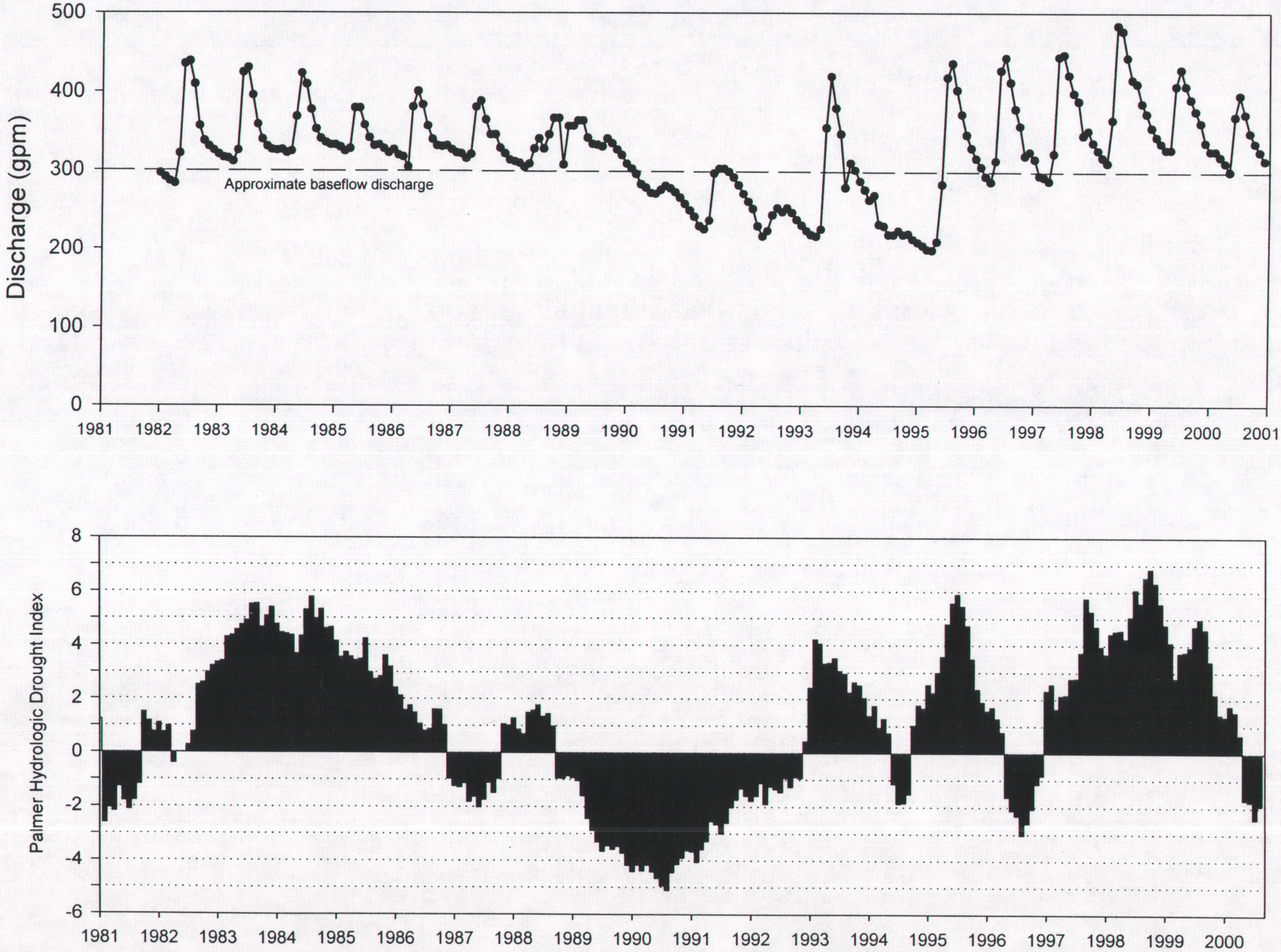

Figure 2 Discharge hydrograph for Little Bear Spring and a plot of the Palmer Hydrologic Drought Index for Utah Region 4.

Table 1 Monthly discharge data for Little Bear Spring (data provided by Castle Valley Special Service District).

LITTLE BEAR SPRING AVERAGE MONTHLY FLOW (gpm)

Year	Jan Avg Flow	Feb Avg Flow	Mar Avg Flow	Apr Avg Flow	May Avg Flow	Jun Avg Flow	Jul Avg Flow	Aug Avg Flow	Sep Avg Flow	Oct Avg Flow	Nov Avg Flow	Dec Avg Flow	Yearly Average
1982	296	291	286	283	321	435	438	409	356	337	330	325	342
1983	320	316	315	311	325	424	430	395	358	339	330	326	349
1984	325	326	322	324	368	423	409	377	352	340	335	332	353
1985	332	329	324	227	379	379	357	341	331	332	327	322	332
1986	326	319	317	304	380	400	383	356	339	331	330	331	343
1987	326	322	321	315	320	380	388	364	345	345	328	321	340
1988	313	311	309	304	308	327	340	327	345	366	366	307	327
1989	256	356	363	363	341	333	332	330	340	334	326	319	333
1990	308	302	295	282	278	271	270	275	280	277	272	265	281
1991	257	249	241	229	225	236	296	302	302	298	291	281	267
1992	270	260	251	229	216*	223*	243	252	247	252	246	237	244
1993	230	223	218	216	225	354	419	379	346	278	309	300	291
1994	286	275	262	268	231	229	218	218	223	218	219	212	238
1995	208	204	199	198	209	282	418	436	402	371	345	328	300
1996	315	304	292	285	312	427	443	412	378	356	318	323	347
1997	314	293	291	286	321	444	447	421	398	388	344	350	358
1998	335	325	316	309	364	484	477	443	415	410	385	372	386
1999	354	342	334	326	326	407	428	407	390	375	360	335	365
2000	324	324	317	309	298	368	395	371	347	334	323	312	
2001													

Note * Discovered a broken pipe at the lower spring which decreased the flow

Mo. Totals	5695	5671	5573	5368	5531	6603	7131	6815	6494	6281	5761	5586	5796.92
Monthly Ave.	299.7	298.5	293.3	282.5	291.1	347.5	375.3	358.7	360.8	348.9	320.1	310.3	322.05

and/or alluvial groundwater losses in Mill Fork Canyon. Water Technology and Research (WTR; 1999) performed a geophysical investigation of Little Bear Spring that is in general agreement with this conclusion.

The purpose of this investigation is to determine if the Mill Fork drainage can sustain the discharge of Little Bear Spring. Specific objectives are 1) to determine if the annual water yield from the upper Mill Fork drainage is sufficient to sustain the discharge at Little Bear Spring in addition to any surface water discharge from the basin, and 2) to evaluate the physical mechanism whereby surface water from Mill Fork Creek and/or alluvial groundwater may recharge the fracture system that discharges at Little Bear Spring.

Including this introduction, this report contains the following sections:

- Introduction
- Background
- Methods of Study
- Climate
- Geologic and Physiographic Setting
- Water Budget
- Conceptual Recharge Model for Little Bear Spring
- Conclusions

2. Background

Mayo and Associates (1999) investigated groundwaters and surface waters in the vicinity of Little Bear Spring and the surrounding area. This investigation included an evaluation of the potential coal mining impacts to Little Bear and other springs in the area. Mayo and Associates concluded that mining-related impacts to water quality or water quantity at the spring were unlikely. Based on several lines of evidence they also concluded that Little Bear Spring does not originate from the groundwater systems surrounding the coal seams. The evidence included groundwater age dating (the Star Point Sandstone groundwater in the mine is nearly 20,000 years old while Little Bear Spring water is modern), groundwater stable isotopic compositions, potentiometric data, groundwater discharge characteristics and rates, and chemical information.

Previous investigations concluded that the Little Bear Canyon drainage does not receive sufficient precipitation to sustain the discharge from Little Bear Spring (Vaughn Hansen Associates, Beaver Creek Coal Company, Huntington #4 Mine MRP, 1977). They suggested that the recharge location for Little Bear Spring must originate from outside the Little Bear Canyon drainage. Mayo and Associates (1999) concluded that the most likely recharge mechanism for Little Bear Spring was from surface-water or alluvial groundwater losses in a major drainage south of the spring, most likely in Mill Fork Canyon. The fracture system from which Little Bear Spring discharges intersects the bottom of Mill Fork Canyon approximately 1.5 miles southwest of the spring.

WTR (1999), using a proprietary geophysical technique, concluded that the primary recharge to Little Bear Spring originates from the southwest along the same trend as the fracture system from which the spring emanates. They further concluded that Little Bear Spring was likely recharged from losses in Mill Fork Creek.

Although several recharge mechanisms and locations for Little Bear Spring have been proposed through the years, there is now a general consensus among the local scientific community that recharge to the spring most likely occurs to the south or southwest of the spring (Conference on Little Bear Spring at the Manti-La Sal National Forest office, Price, Utah, 26 October 2000).

At the October 2000 meeting, it was concluded that additional data should be collected to verify the conclusion that Little Bear Spring could be recharged from surface water or alluvial groundwater losses in Mill Fork Canyon. Specifically, it was determined that a water budget analysis should be performed to verify that the annual water yield from the upper Mill Fork drainage is sufficient to sustain both the discharge at Little Bear Spring and any surface water flowing out of the drainage.

3. Methods of Study

The hydrology and hydrogeology of the study area have been evaluated by analyzing: 1) surface water and groundwater discharge data, 2) climatological data, and 3) geologic and topographic information. Specific methods of investigation are described below.

3.1 Maps and reports

Existing published and unpublished hydrologic, hydrogeologic, and geologic reports and maps were obtained and reviewed.

3.2 Compilation of historic stream flow data

Historic discharge data for streams in the region were obtained from GENWAL Resources and compiled into electronic format. Additional data were obtained from the Utah Division of Oil, Gas and Mining on-line database and from the U.S. Environmental Protection Agency on-line database (STORET). Historic and recent discharge data for Little Bear Spring were obtained from the Castle Valley Special Service District.

3.3 Stream gauging in Mill Fork Canyon

Prior to the 2000 conference, stream flow measurements were taken on both the main and upper left forks of Mill Fork Creek on 8-9 October 1998. The upper left forks were gauged from approximately the eastern edge of section 13, T16S R6E to the confluence with the main fork near spring MF-3. The main fork was gauged from just above spring MF-7 to the confluence with Huntington Creek. All stream flow measurements were made using a calibrated bucket and a stopwatch. Temperature and electrical conductivity were recorded at each gauging station. Additionally, water samples were collected at each site for stable isotopic analysis.

On 3-4 November 2000, stream flow measurements were again performed on both the main and upper left forks of Mill Fork Creek. Stream flow measurements were made with either a 90º v-notch weir or with a calibrated bucket and stopwatch.

3.4 Drainage basin area calculations

Surface areas for the Mill Fork and Crandall Canyon drainages were calculated from the Rilda Canyon USGS 7.5 minute topographic map. Drainage basin areas were digitized and the areas were electronically determined using AutoCAD™ software.

4. Climate

Precipitation in Crandall Canyon near the mine portal (at an elevation of about 8000 feet) averages 20 inches per year (Crandall Canyon Mine, MRP). The average monthly precipitation at the mine is shown in Figure 3. Because precipitation in the area is highly influenced by topography, regions at significantly higher elevations likely receive more precipitation, whereas the lower-lying areas likely receive less. Most of the precipitation in the area occurs as winter snow between November and March. Significant thunderstorms often occur during the monsoon season in August.

Temperatures in the Crandall Canyon area commonly range from 32 to 90°F (0 to 32°C) in the summer months and from –10 to 40°F (-23 to 4.4°C) during the winter months.

Potential evapotranspiration is 18 and 21 inches per year in the Crandall Canyon area (Crandall Canyon Mine MRP). Potential evapotranspiration is defined as the water loss that will occur if at no time there is a deficiency of water in the soil for the use of plants or

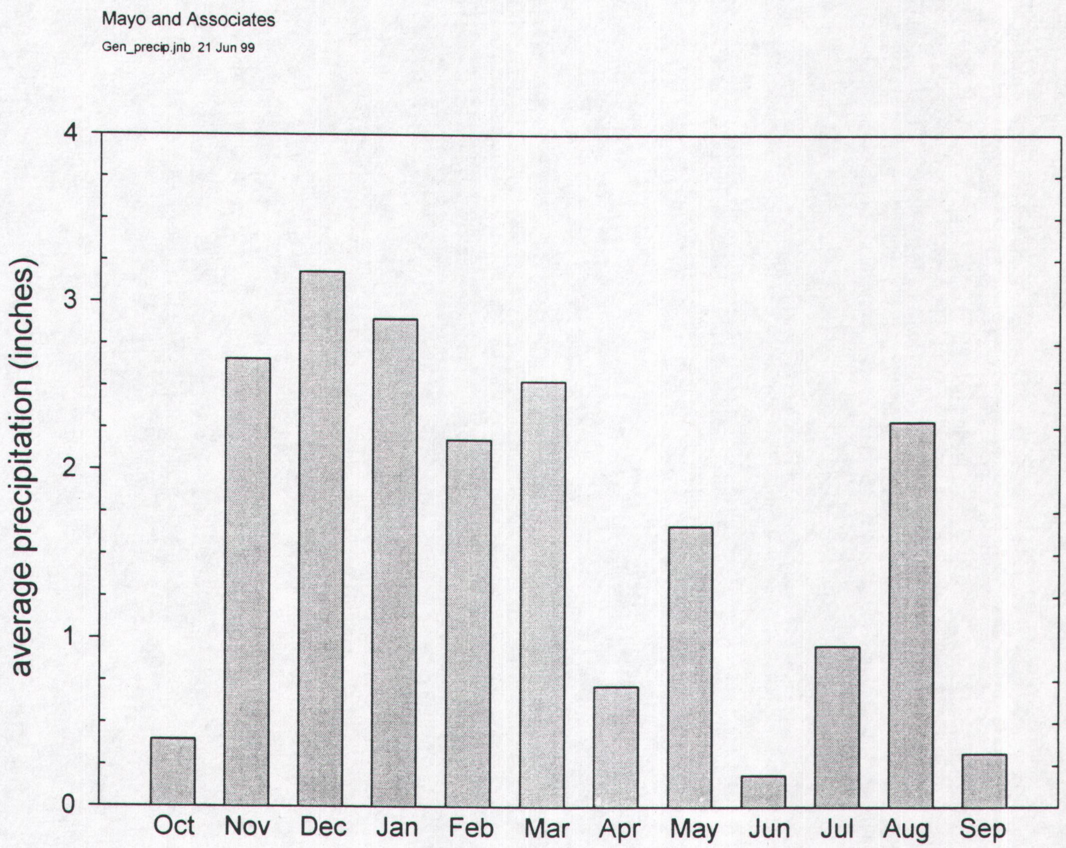

Figure 3 Average monthly precipitation at the Crandall Canyon #1 Mine.

evaporation at the ground surface. Because this condition is not always met, the actual evapotranspiration rate is commonly lower than the potential rate.

The average direction of the prevailing winds is from the west and northwest at an average velocity of 12 mph.

It is believed that climatic conditions in the Mill Fork and Little Bear drainages (at similar elevations) are likely similar to those in the Crandall Canyon area.

A plot of the Palmer Hydrologic Drought Index (PHDI) for Utah Division 4 is shown in Figure 2. The PHDI (NCDC, 1997; Karl, 1986; Guttman, 1991) indicates the long-term climatic trends for the region. The PHDI is a monthly value calculated by the National Climatic Data Center (NCDC) that indicates the severity of a wet or dry spell. The PHDI is based on climatic and hydrologic parameters such as temperature, precipitation, evapotranspiration, soil water recharge, soil water loss, and runoff. Because the PHDI takes into account parameters that affect the balance between moisture supply and moisture demand, the index is a useful tool for evaluating the long-term relationship between climate and groundwater recharge and discharge.

The PHDI is useful for determining if variations in spring or stream discharges are the result of climatic variability or whether they are the result of other factors.

5. Geologic and Physiographic Setting

Seven bedrock formations crop out in the study area. In descending order these formations are the Flagstaff Limestone, North Horn Formation, Price River Formation, Castlegate Sandstone, Blackhawk Formation, Star Point Sandstone, and the Masuk Member of the Mancos Shale. These formations are shown on a geologic map in Figure 4 and on an east-west geologic cross-section in Figure 5. Little Bear Spring discharges from the Panther Tongue of the Star Point Sandstone, which is separated from the overlying coal seams of the Blackhawk Formation by more than 300 feet of mostly low-permeability rock (Beaver Creek Coal Company, 1991).

Geophysical studies conducted in Mill Fork Canyon (Sunrise Engineering, 2001) indicate that an appreciable alluvial system occurs in Mill Fork Canyon. Alluvial thickness measured in the vicinity of the Star Point Sandstone fracture system ranged from about 30 to 45 feet. It was observed that the near-surface sediments in the stream channel in this area consist primarily of clean sand with some gravel and boulders. There was an overall lack of fine-grained material observed in the stream channel. The makeup of the deeper alluvial sediments has not been investigated.

Mayo and Associates (1999) indicated that vertical downward migration of near-surface recharge water through the bedrock formations does not occur in the Little Bear Spring area. This is evidenced by the extremely old Star Point Sandstone groundwaters below the coal mine (nearly 20,000 years old) and the lack of seasonal variations in wells completed in the

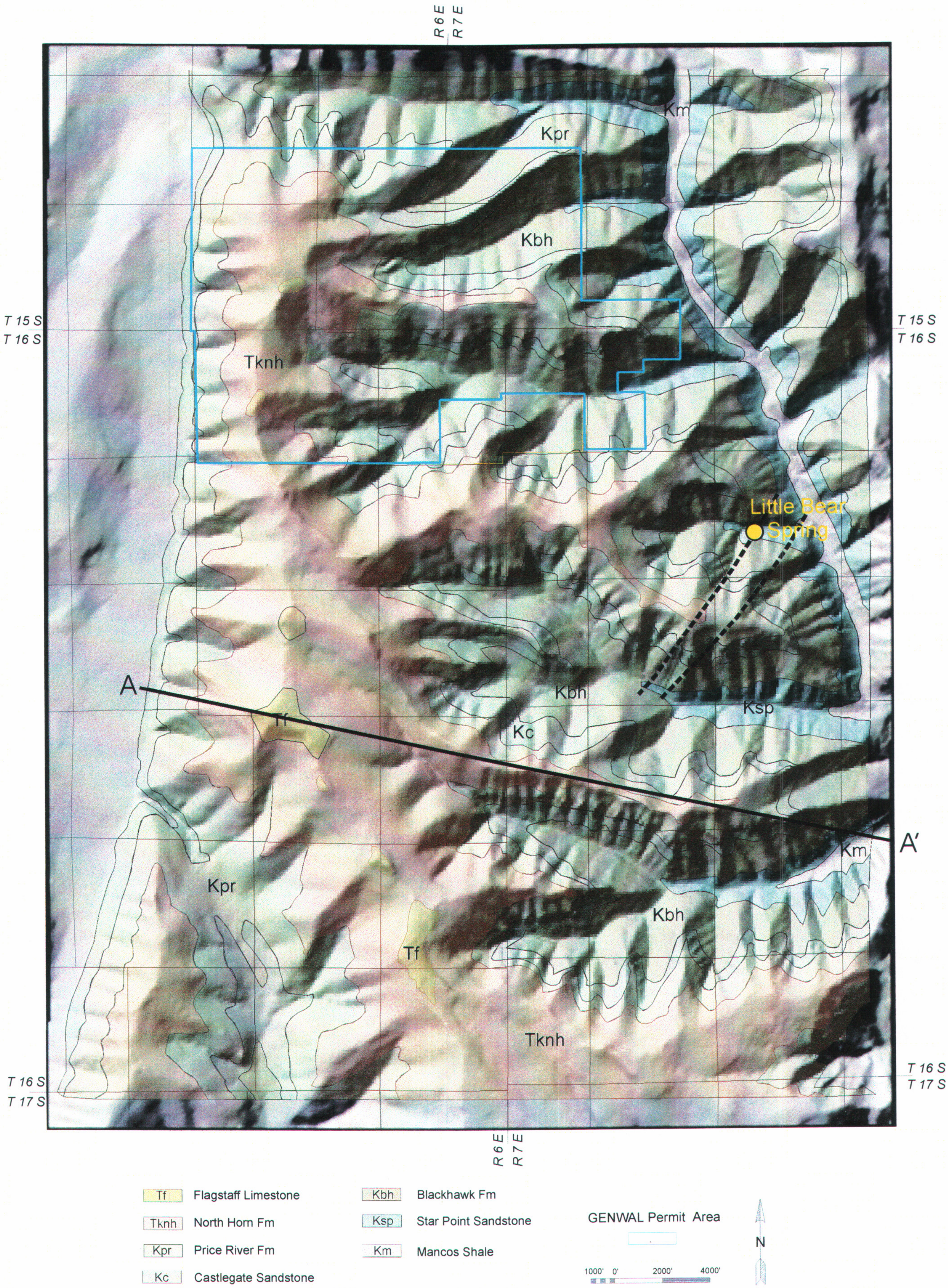

Figure 4 Geologic map of the Little Bear Spring area.

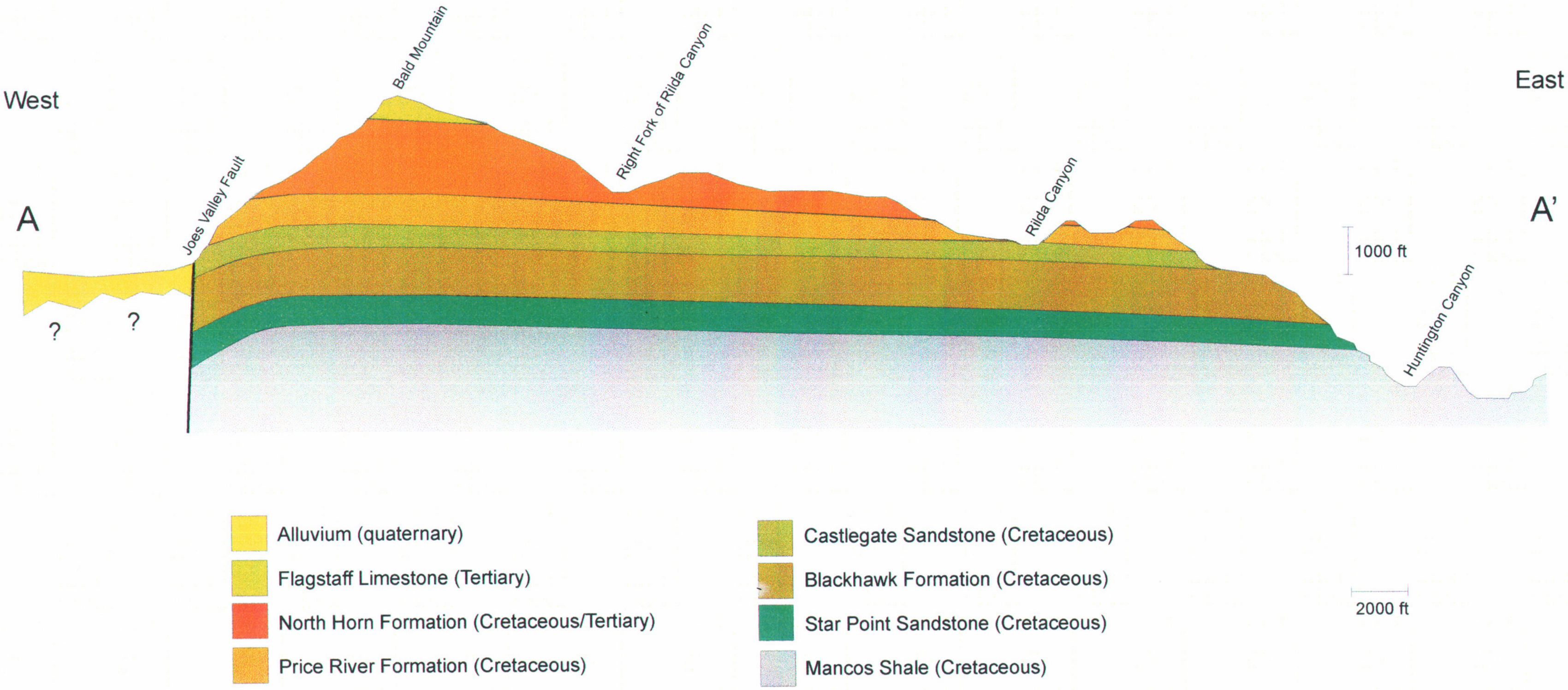

Figure 5 Generalized cross-section A-A'. Cross-section location is shown on Figure 4.

Star Point Sandstone. Likewise, groundwater inflow rates in the mine do not show seasonal variation. In contrast, all of the 23 springs and streams sampled for groundwater age dating had a modern origin (i.e. recharged in the past 50 years). Little Bear Spring shows pronounced seasonal and climatic fluctuations in discharge rate (Figure 2). The annual discharge peak usually occurs during May or June (Table 1). Because of the inability of groundwater to migrate downward in appreciable quantities, the most likely recharge location for Little Bear Spring is where the Star Point Sandstone is exposed at the surface.

Previous investigations examined the nature of surface water discharge in Mill Fork Canyon (Huntington No. 4 Mine, MRP; Mayo and Associates, 1999). The Results of the October 1998 stream gauging at Mill Fork canyon are shown on Figures 6 and are listed in the appendix. The stream gauging locations are shown on Figure 7. Also shown on Figure 7 are the locations of the upper and lower water monitoring stations monitored by the Huntington No. 4 Mine. The results of the stream monitoring indicate that there is usually no flow in Mill Fork canyon in the vicinity of the fracture system from which Little Bear Spring discharges. The Mill Fork stream channel at the confluence with Huntington Creek is likewise commonly dry during much of the year. The only reach of the stream below the fracture system that contained any water during the November 2000 stream survey (27 gpm) occurred at a bedrock high located near the base of the Star Point Sandstone. Within less than a half mile downstream, this meager discharge had infiltrated into the alluvial sediments and surface flow ceased. The general lack of water in the middle and lower reaches of Mill Fork Canyon is anomalous when compared to the adjacent drainages both above and below

Mill Fork. In nearly all years, discharge persists throughout the year in the Horse Canyon, Blind Canyon, Crandall Canyon, Little Bear Canyon, and Rilda Canyon drainages.

6. Water Budget

The annual water yield from Mill Fork Canyon has been evaluated using two independent methods: 1) a comparative basin analysis using Crandall Canyon as a surrogate for Mill Fork Canyon, and 2) an area-based projected yield investigation. The results of the water yield determinations using these two methods are described below.

6.1 Comparative basin analysis

Using a comparative basin approach, the discharge from Mill Fork Canyon is compared with the Crandall Canyon discharge. A surrogate basin was used for this analysis in order to establish the approximate magnitude of the annual water yield that would be anticipated from Mill Fork Canyon were there no major surface-water or groundwater diversions from the drainage (i.e., recharge to Little Bear Spring). This approach is favorable because 1) the physical characteristics of the upper Crandall Canyon drainage are in most respects remarkably similar to those of the adjacent upper Mill Fork drainage (Figure 8), and 2) there is a large amount of available historical discharge data from the Crandall Canyon drainage.

It is apparent in Figure 8 that the overall physical characteristics of the upper Mill Fork drainage and the upper Crandall Canyon drainage are very comparable. The area of the upper Mill Fork drainage (above the intersection of the fracture zone) was calculated as 4.29 square miles. The area of the Crandall Canyon drainage above the GENWAL Resources upper flume was calculated as 4.36 square miles, which is less than 2% greater than that of upper Mill Fork. Likewise, the elevation distribution of the surface area is similar between the two basins, with the Mill Fork drainage having only slightly less surface area in the highest elevation zones (Figure 8). The aspects of the two adjoining drainages are also comparable and there are no apparent differences in the surrounding land topography that might result in orographic variations in precipitation. Vegetation in both drainages is similar, with dense conifer or aspen forests dominating the north-facing slopes, while the south facing slopes are much less heavily vegetated.

Discharge hydrographs for the Mill Fork drainage are shown in Figure 9. In Figure 10, the discharge from the upper Mill Fork drainage (4-3W) is plotted together with the discharge from upper Crandall Creek (UPF-1). Based on the similarities between these two basins, it is anticipated that the annual water yield from these drainages should be similar. However, as shown in Figure 10, both the baseflow and springtime peak flows from the basins are strikingly disparate. Upper Crandall Creek has a historic baseflow discharge of about 300 gpm that persists throughout the year (Figure 10). The alluvial groundwater flowing in Crandall Canyon is not included in this baseflow estimate. In contrast, there is no baseflow discharge in Mill Fork Creek in the vicinity of the fracture system from which Little Bear Spring discharges. An obvious question follows this observation – why is there no baseflow discharge in upper Mill Fork Creek, and where did the water go?

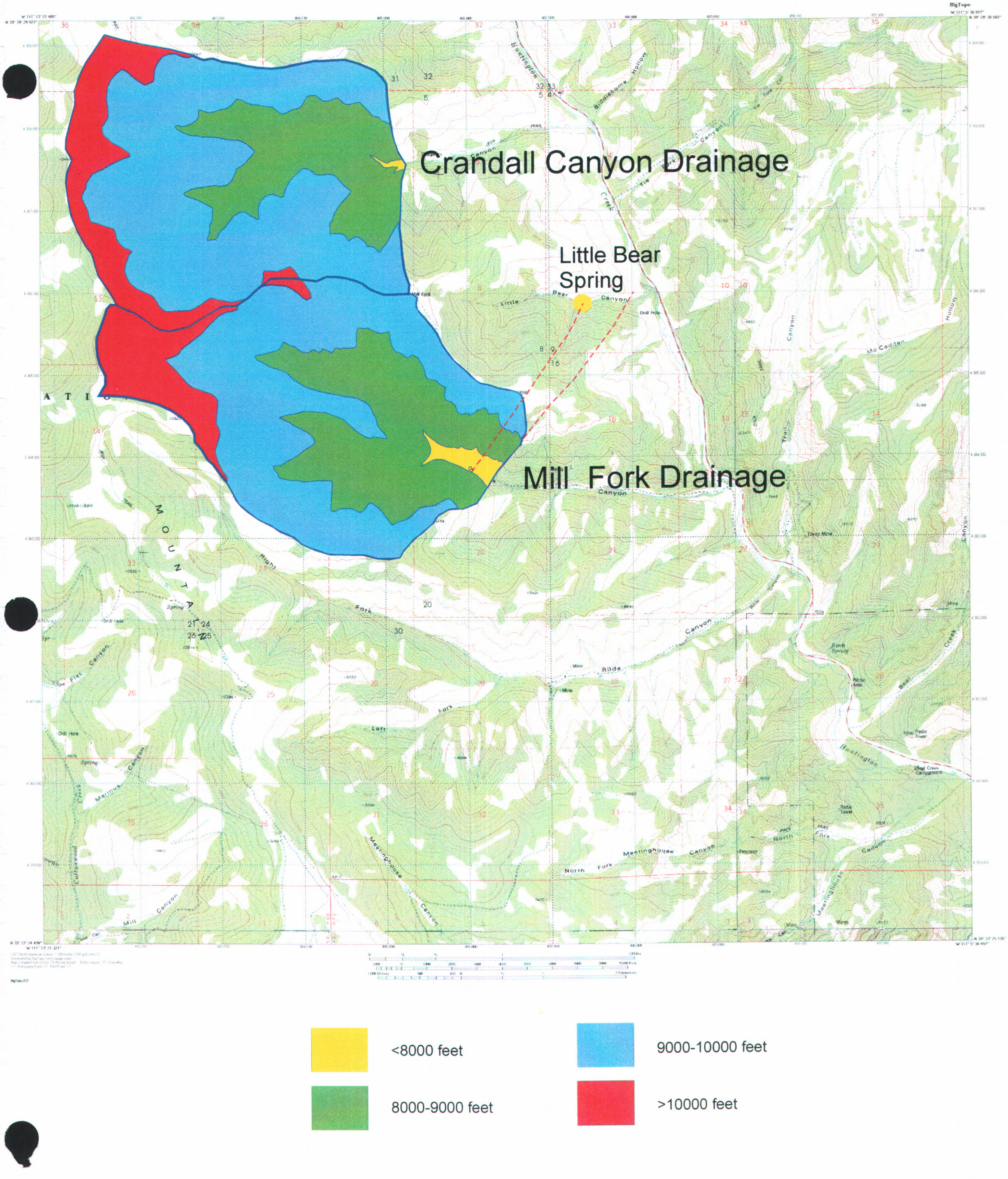

Figure 8 Comparison of Mill Fork and Crandall Canyon drainages.

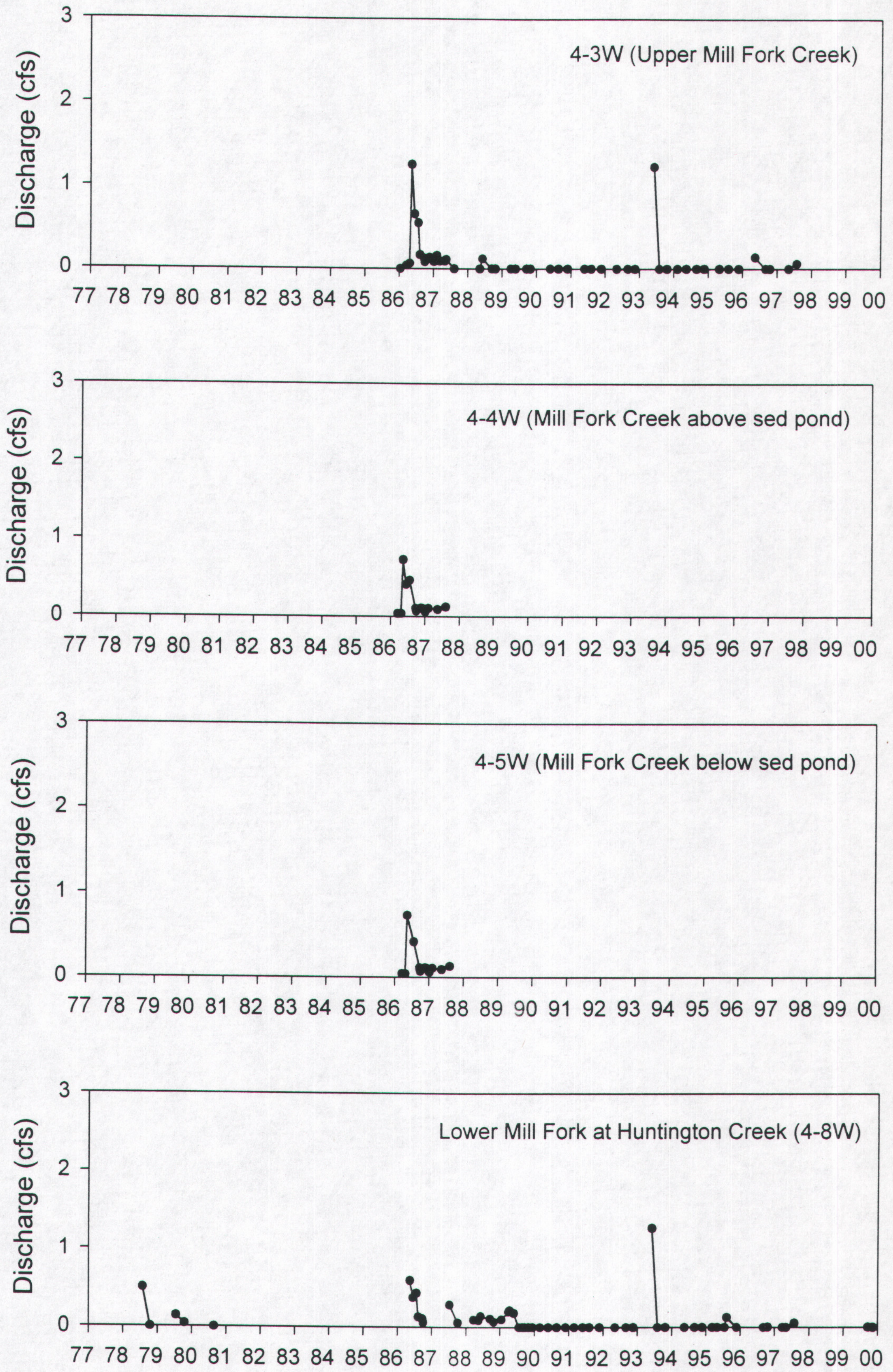

Figure 9 Discharge hydrographs showing available data for Mill Fork Creek (1978-2000).

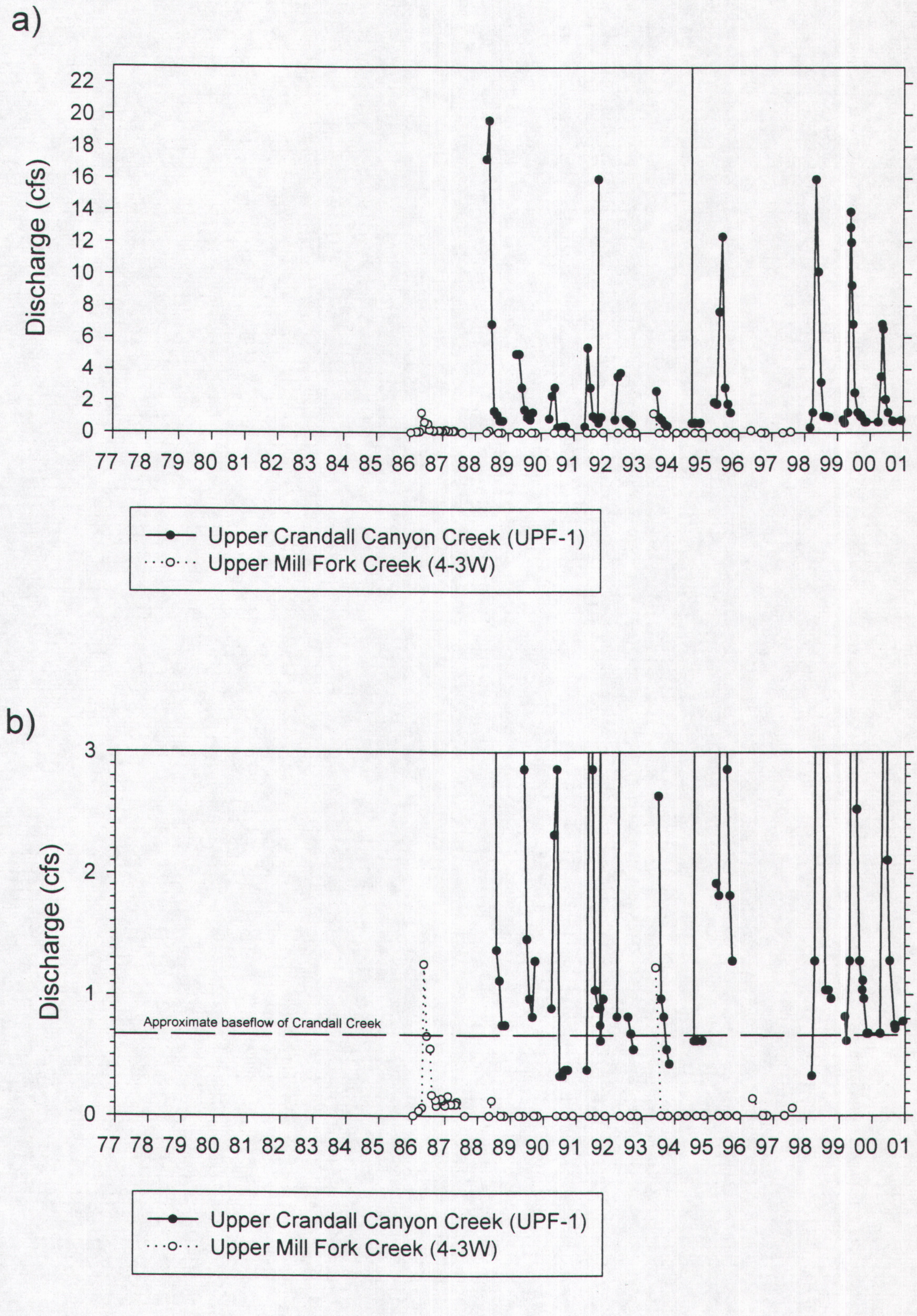

Figure 10 Discharge hydrographs for upper Mill Fork Creek and upper Crandall Canyon Creek. a) plot showing relative magnitudes of yearly discharges from the creeks, b) enlargment of lower range of graph to compare baseflow discharge rates.

The upper Mill Fork Drainage should produce approximately 300 gpm of baseflow discharge during normal water years. The fact that there is none suggests that approximately 300 gpm of discharge during baseflow conditions have been removed from the basin. That this water is recharging Little Bear Spring is entirely consistent with all of the available data.

6.2 Area-based projected yield

A determination of the annual water yield for upper Mill Fork Canyon has also been made using empirical data on basin yield provided by the Utah Division of Water Resources (1975). The Utah Division of Water Resources (1975) has predicted that up to 4 inches of runoff can be expected from drainage basins similar to and in the vicinity of Mill Fork Canyon.

It should be noted that Crandall Canyon, which is physically similar to Mill Fork, has historically had annual yields that are significantly greater than 4 inches per year. During 1998, for example (a relatively wet year for which daily average discharge data for the ice-free period are available), upper Crandall Creek discharged approximately 1,525 acre-feet, which equates with a yield of 6.56 inches per year as expressed over the 4.36 square mile drainage. During that same year, the discharge from Little Bear Spring totaled 623 acre-feet, which equates with a yield in upper Mill Fork Canyon of only 2.72 inches. This suggests that even after recharging Little Bear Spring, there is a significant surplus of water in the drainage.

Using a conservative estimate of 3.5 inches of runoff for the upper Mill Fork drainage, it is calculated that on average the drainage should yield about 800 acre-feet of runoff per year from the 4.29 square miles of the drainage. This equates with an average discharge rate from upper Mill Fork Canyon of about 500 gpm, which exceeds the yearly average discharge rate from Little Bear Spring (about 322 gpm) by more than 50%. Given the fact that only relatively small amounts of surface water leave Mill Fork Canyon during the year, the conclusion that much of the annual yield of the upper Mill Fork drainage provides recharge to Little Bear Spring seems reasonable. This conclusion is in good agreement with the comparative basin analysis result discussed previously.

7. Conceptual recharge model for Little Bear Spring

Based on the findings of this and previous investigations, a conceptual model for the recharge of Little Bear Spring in Mill Fork Canyon has been developed. The conceptual model is graphically depicted in Figure 11. A regional geologic cross-section along the trace of the Star Point Sandstone fracture system is shown on Plate 1. Recharge to Little Bear Spring occurs as alluvial groundwater in Mill Fork Canyon is intercepted by the Star Point Sandstone fractures where they intersect the base of the alluvial deposits. During the low-flow season, the spring is sustained primarily by losses of alluvial groundwater into the fracture system. During the high-flow season in the springtime and early summer, surface water also contributes to the recharge of Little Bear Spring both directly (through stream losses near the fractures) and as a result of overall increases in the amount of groundwater flow in the alluvial sediments.

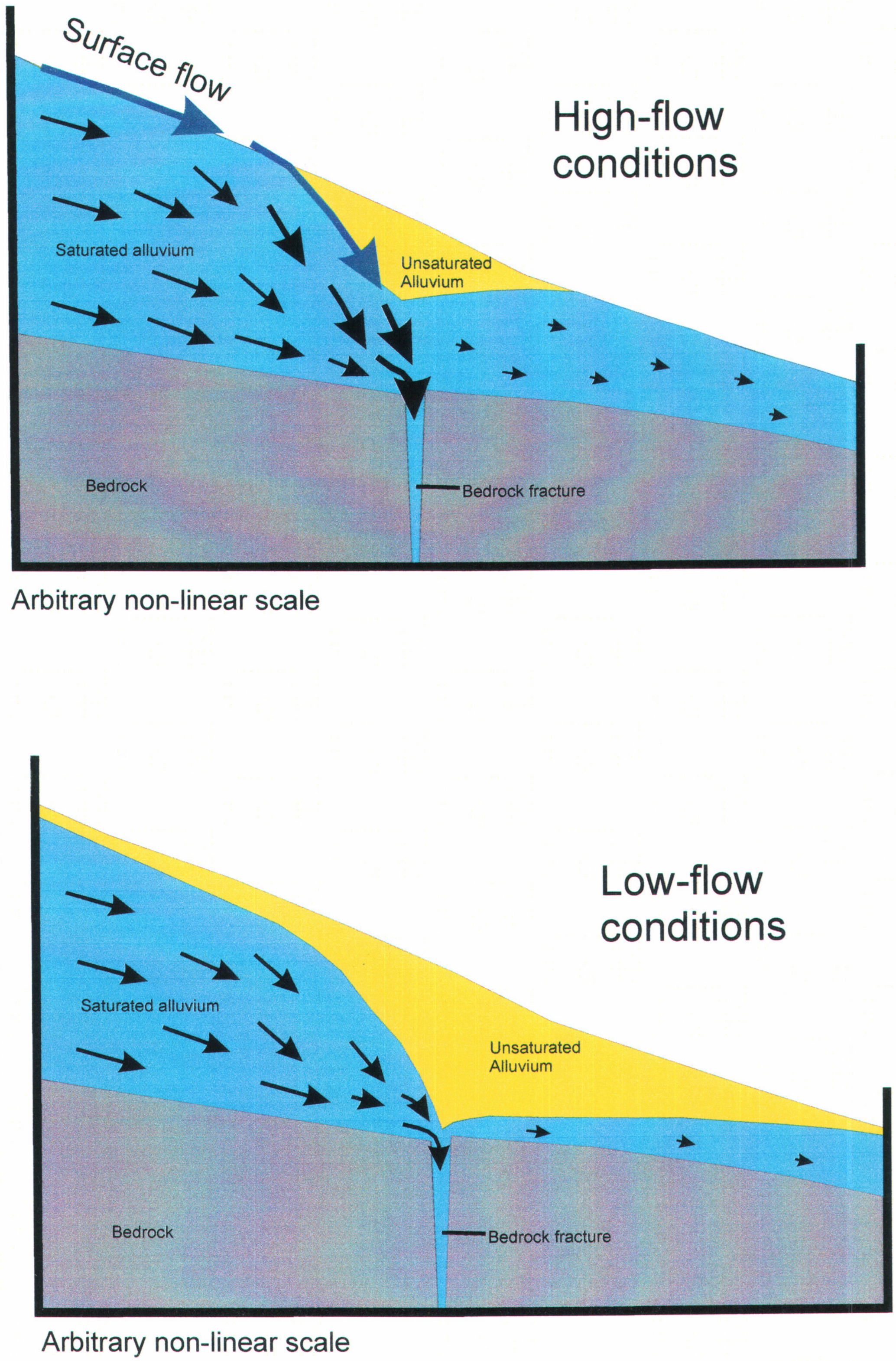

Figure 11 Cartoon showing the conceptual recharge model for Little Bear Spring.

There are several constraints that must be satisfied in order for any proposed recharge model for Little Bear Spring to be accepted. Each of these constraints is listed in Table 2 below.

Table 2 Acceptability constraints for the proposed Little Bear Spring recharge model.

Constraint	Proposed Mill Fork recharge model
There must be sufficient available water in the basin to supply at least 200 gpm of recharge continuously to the spring.	As discussed above, the upper Mill Fork drainage is believed to have more than adequate capacity to sustain Little Bear Spring. Moreover, it is difficult to explain the lack of baseflow in the drainage without taking Little Bear Spring recharge into account.
The recharge location must be located topographically above the elevation of Little Bear Spring (about 7475 feet) to provide the driving head to cause the spring to discharge.	The fracture system from which Little Bear Spring discharges intersects the Mill Fork drainage at an elevation of approximately 7710 to 7790 feet.
The water recharging Little Bear Spring must be of modern origin as evidenced by the modern water encountered in Little Bear Spring (Mayo and Associates, 1999).	Surface waters in the region have been demonstrated to discharge modern water (Mayo and Associates, 1999). Groundwater discharge into the Mill Fork drainage was sampled in three locations (MF-3, MF-7, and MF-20). All of these groundwaters were found to be of modern origin.
The recharge water must respond to season and climate.	Surface waters in the region have been demonstrated to respond to season and climate. The alluvial groundwater system in Mill Fork Canyon is also responsive to climate and season.
The chemical quality of the recharge water must be of similar or higher quality relative to Little Bear Spring discharge water.	The water quality in Mill Fork Canyon is of the same chemical type and approximate TDS concentration as that discharging from Little Bear Spring (Mayo and Associates, 1999)
Because of the inability of recharge water to migrate downward through the relatively impermeable bedrock formations in the region, the recharge will most likely occur where the Star Point Sandstone outcrops at the surface	The fracture system from which Little Bear Spring discharges intersects the bottom of the alluvial deposits in the Star Point Sandstone.

As described above, the proposed recharge location and mechanism is able to satisfy all of the required constraints.

8. Conclusions

- The upper Mill Fork drainage *is* capable of sustaining the discharge at Little Bear Spring. Moreover, it is difficult to explain the lack of flow in the Mill Fork drainage without taking recharge to Little Bear Spring into account.

- The proposed model of recharge to Little Bear Spring satisfies all of the physical constraints required for the model to be accepted.

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Appendix 1 Mill Fork stream gauging results.

Station #	Flow (gpm) November 2000	Flow (gpm) October 1998	Cond October 1998	Elev. (ft)
Mill-1	0.0	31.7	370	8720
Mill-2	0.0	61.4	450	8650
Mill-3	18.5	54.0	450	8490
Mill-4	---	74.3	460	8440
Mill-5	31.5	115.2	460	8340
Mill-6	12.0	115.2	450	8200
Mill-7	0.0	106.0	430	8060
Mill-8	0.0	72.4	430	7980
Mill-9	0.0	47.9	410	7910
Mill-10	0.0	0.0	---	7900
Mill-11	0.0*	40.0	430	7850
Mill-12	0.0	44.4	430	7820
Mill-13	0.0	28.6	420	7780
Mill-14	0.0	12.4	410	7680
Mill-15	0.0	0.0	---	7640
Mill-16	---	2.0	480	7400
Mill-17	26.6	144.2	540	7340
Mill-18	0.0	114.2	540	7040
L Mill-1	0.0	48.0	340	8420
L-Mill-2	0.0	34.3	340	8200
L-Mill-3	0.0	25.5	340	8080

* Spring MF-3 was discharging at 18.7 gpm during November 2000, but the flow had all infiltrated before Mill-11

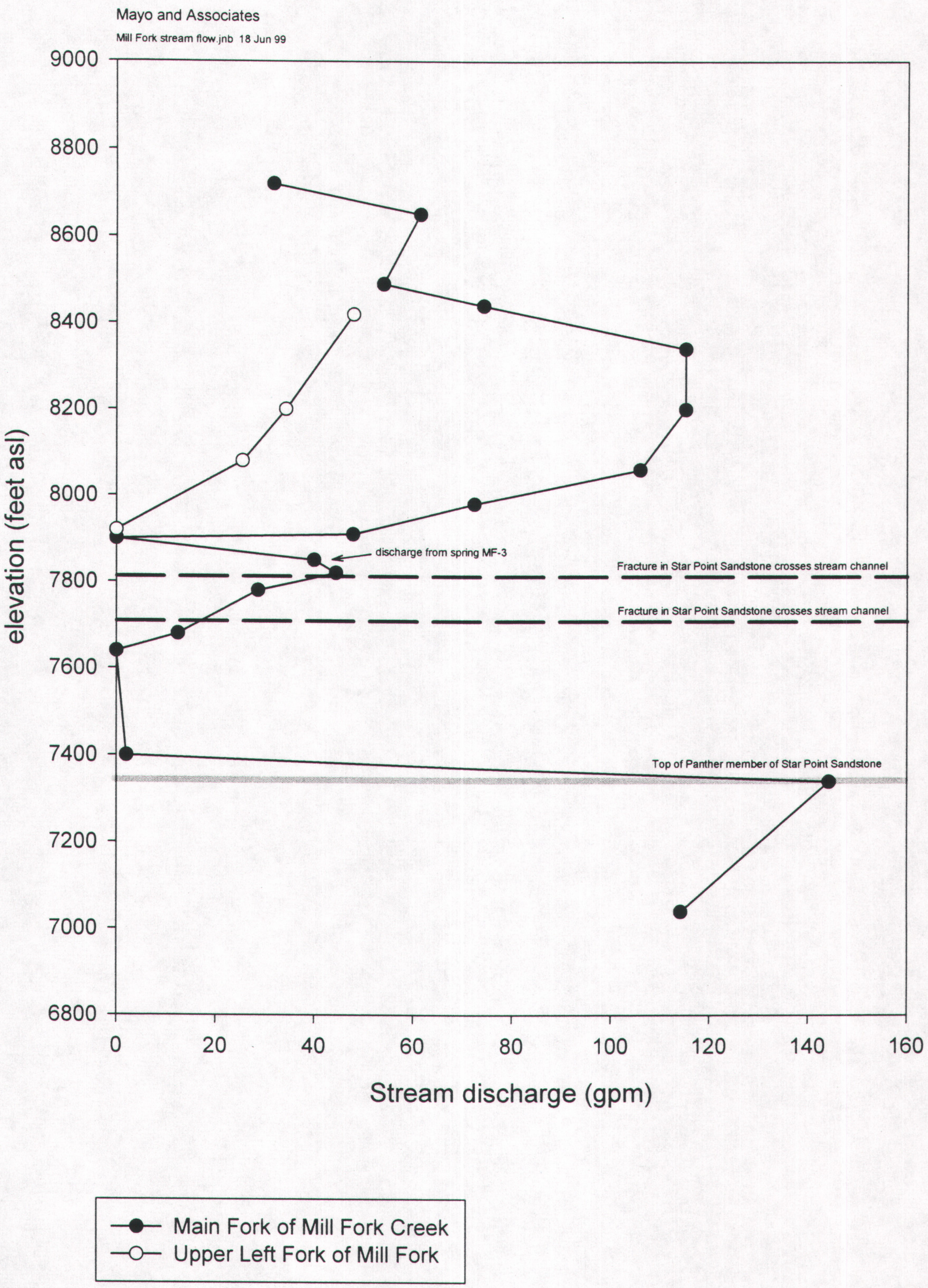
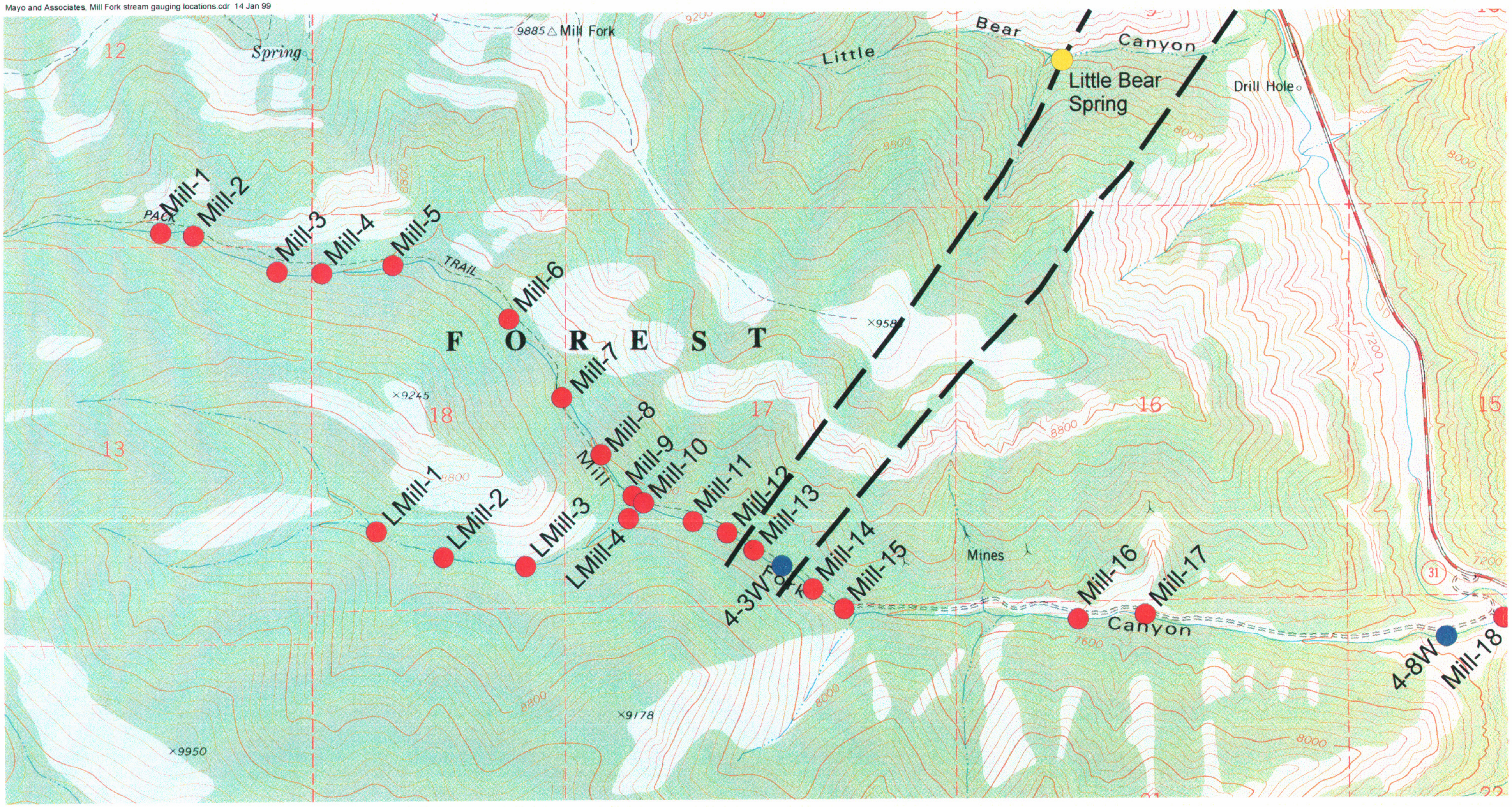


Figure 6 Streamflow measurements from Mill Fork Creek, 8-9 October 1998.

Mayo and Associates, Mill Fork stream gauging locations.cdr 14 Jan 99



Mayo and Associates 1998 stream gauging location

Huntington No. 4 Mine water monitoring location

N

2,000 feet

Figure 7 Stream gauging and monitoring stations on Mill Fork Creek.