Cottonwood Mine
C/015/019
Deer Creek Mine
C/015/018
Des-Bee-Dove Mine
C/015/017

Volume 9 Hydrologic Section

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April 08, 2005

R645-301-700 HYDROLOGIC SECTION

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R645-301-700 HYDROLOGIC SECTION

R645-301-710 INTRODUCTION

This application provides a detailed description of the hydrology, including groundwater and surface water quality and quantity, of the land within the permit and surrounding area (see Figures HF-1A and 1B).

Since 1979 detailed data on the hydrology of the land within the permit and surrounding area have been collected, compiled, and analyzed by PacifiCorp and several government agencies. Information collected by PacifiCorp is the result of exploratory drilling, field investigations, geologic mapping, aerial photography, spring surveys, groundwater tests, monitoring of numerous wells and stream stations, climatological monitoring, and investigations by independent consultants. The data collection program is part of a complete Hydrologic Monitoring Program which has been approved by the State of Utah, Division of Oil, Gas and Mining (DOGM) and the Office of Surface Mining (OSM). All data collected have been and will continue to be submitted to OSM, DOGM, United States Forest Service (USFS), and the Bureau of Land Management (BLM) each year in the annual Hydrologic Monitoring reports.

PacifiCorp has a policy of close cooperation with many agencies and has invited, encouraged, and permitted numerous agencies to conduct investigations and experiments within and adjacent to the permit area. The resulting information produced by these investigations is quite extensive and has been utilized throughout this application.

R645-301-711 GENERAL REQUIREMENTS

711.100 Existing hydrologic resources as given under R645-301-720

711.200 Proposed operations and potential impacts to the hydrologic balance as given under R645-301-730

711.300 The methods and calculations utilized to achieve compliance with hydrologic design criteria and plans given under R645-301-740

711.400 Applicable hydrologic performance standards as given under R645-301-750

711.500 Reclamation activities as given under R645-301-750

R645-301-712 CERTIFICATION

All cross sections, maps, and plans required by R645-301-722 as appropriate and R645-301-731.700 will be prepared and certified according to R645-301-512.

R645-301-713 INSPECTION

Impoundments will be inspected as described under R645-301-514.300.

R645-301-720 ENVIRONMENTAL DESCRIPTION

R645-301-721 GENERAL REQUIREMENTS

The existing pre-mining hydrologic resource of the East Mountain property is subdivided into the following sections.

A. Existing Groundwater Resources

1. Regional and Permit Area Groundwater Hydrology
2. Regional and Permit Area Geology
3. Regional and Permit Area Groundwater Characteristics

4. Springs and Seeps
5. Groundwater Quality
6. Chemical Evolution of Groundwater
7. Isotopic Compositions of Snow and Groundwater: δ^2H and $\delta^{18}O$
8. Groundwater Ages (^3H and ^{14}C)
9. Groundwater Occurrence
10. Mine Dewatering
11. Groundwater Rights and Users
12. North Emery Water Users Association (NEWUA) Rilda Canyon Springs

B. Existing Surface Resources

1. Regional and Permit Area Surface Water Hydrology
2. Surface Water Quality
3. Soil Loss and Sediment Yield

A. *EXISTING GROUNDWATER RESOURCES*

1. Regional Groundwater Hydrology

The characteristics and usefulness of a groundwater resource are dependent upon the geology of the water-bearing strata and on the geology and hydrology of the recharge area. Groundwater movement and storage characteristics are dependent on the characteristics of the substratum. To facilitate an understanding of groundwater of the East Mountain property, a discussion of pertinent regional geologic features is presented below.

2. Regional Geology

The East Mountain property is located in the central portion of the Wasatch Plateau Coal Field in Emery County, Utah. Generally, this area is a flat-topped mesa surrounded by heavily vegetated slopes which extend to precipitous cliffs dropping steeply to the valley below. Relief of up to 2,500 feet is measured from Castle Valley lowland to the plateau above. The following discussion summarizes the structural geology and stratigraphy of the region and the permit areas located within the East Mountain property.

Strata in the East Mountain permit area are gently down-folded in the area of the Straight Canyon Syncline which is present in the central portion of the property (see Maps HM-1 and HM-4). The bearing of the Straight Canyon Syncline is approximately N30^{O}E and the structure plunges to the southwest. Dips in the syncline range from two to six degrees with the north limb dipping the steepest.

In the area south of the Straight Canyon Syncline the coal seam dips gently in a northwest direction toward the syncline; however, to the northwest of the Straight Canyon Syncline both the Hiawatha and Blind Canyon seams dip in a southeast direction at three to five degrees.

The strata within the property have been offset by a series of north-south trending normal fault zones. Generally, the faults are nearly vertical and do not have significant amounts of fault gouge or drag associated with them. One of the major faults present in the region, the Pleasant Valley Fault, has been intersected in both the Deer Creek and Wilberg mines.

The Pleasant Valley Fault consists of two parallel fractures about 150 feet apart. The fault's total displacement (where it was intersected in the Deer Creek Mine) to the north is 150 feet with its downthrown side on the east. The displacement diminishes to less than one foot where it was intersected in the Wilberg Mine near the south end of the property.

Another north-south trending fault, the Deer Creek Fault, is present to the east of the Pleasant Valley Fault. It limits the eastward development of the Wilberg/Cottonwood and Deer Creek mines. The displacement of the Deer Creek Fault ranges from 100 to 170 feet with the east block being downthrown.

A northeast-southwest trending fault system, the Roans Canyon Graben, is present along the axis of the Straight Canyon Syncline. The system contains up to six normal faults having displacements ranging from a few feet to over 150 feet. Coal deposits present to the north of the fault have been accessed through rock tunnels driven from the 3rd North section of the Deer Creek Mine.

The rock formations exposed in the East Mountain area range from Upper Cretaceous to Tertiary in age (see Figure HF-2). The formations, in ascending order, are the Masuk Shale member of the Mancos Shale, Star Point Sandstone, Blackhawk, Castlegate Sandstone Sandstone, Upper Price River, North Horn, and Flagstaff Limestone. The coal deposits are restricted to the lower portion of the Blackhawk Formation.

The Masuk Shale is the upper member of the Mancos Shale and consists of light to medium gray marine mudstones. Usually this formation weathers readily, forming slopes which are often covered by debris. It is generally devoid of water.

Overlying and intertonguing with the Masuk Shale is the Star Point Sandstone. In the East Mountain area the Star Point consists of three or more cliff-forming massive sandstones totaling about 400 feet in thickness. Generally, the sandstones are fine to medium-grained and moderately well-sorted. The upper contact of the Star Point Sandstone is usually quite abrupt and readily identifiable on the outcrop. Even though the Star Point Formation exists throughout the entire East Mountain property, the low permeability and lack of recharge limit its usefulness as a water producing aquifer. Permeability and the limiting factors of recharge, i.e., very little outcrop exposure and limited vertical groundwater migration caused by the mudstone layers of the North Horn and Blackhawk formations, will be discussed in detail in the section entitled REGIONAL GROUNDWATER CHARACTERISTICS. Locally, the Star Point Sandstone exhibits aquifer characteristics. These are isolated occurrences where regional faults have created secondary permeability and have been intersected by major canyons with perennial streams. An example is Little Bear spring located in Huntington Canyon.

The Blackhawk Formation consists of alternating mudstones, siltstones, sandstones, and coal. Although coal is generally found throughout the Blackhawk Formation, the economic seams are restricted to the lower 150 feet of the formation. The sandstones contained within the Blackhawk Formation are fluvial and increase in number in the upper portions of the formation. Many of the tabular sandstone channels form local perched water tables. The total thickness of the Blackhawk Formation in the East Mountain area is about 750 feet.

The Castlegate Sandstone Sandstone, the lower member of the Price River Formation, generally caps the escarpment which surrounds the eastern limit of the property. The Castlegate Sandstone consists of about 250 feet of coarse-grained, light gray, fluvial sandstones; pebble conglomerates; and subordinate zones of mudstones.

The Upper Price River Formation, which overlies the Castlegate Sandstone, is about 350 feet thick and forms slopes which extend upward from the Castlegate Sandstone escarpment. Although some mudstones are present, fine-grained, poorly sorted sandstones dominate the Upper Price River Formation.

The North Horn Formation is about 850 to 900 feet thick in the East Mountain area. Mudstones dominate the rock types present and are generally gray to light brown in color. Localized, lenticular sandstone channels are present throughout the formation. The sandstone beds are more common near the upper and lower contacts of the formation.

The Flagstaff Formation is the youngest formation exposed in the permit area and consists of white to light gray lacustrine limestone. An erosional remnant of 100 to 150 feet of this formation remains, forming a cap on the highest plateaus.

3. Regional Groundwater Characteristics

Waters entering the groundwater system are mostly from snow melt. The amount of water which enters the groundwater system is highly variable from one site to another. The low surface relief on the top of East Mountain encourages the infiltration of melting snow. Conversely, the many areas with steep slopes have a much more limited infiltration opportunity. All of the geologic formations which surface in the area have relatively low permeability which further reduces the amount of water entering the groundwater system. Probably less than five percent of the annual precipitation recharges the groundwater supply (Price and Arnow, 1974; U. S. Geological Survey, 1979).

Geology controls the movement of groundwater. Because of the low permeability of the consolidated sedimentary rocks in the East Mountain area, groundwater movement is primarily "through fractures, through openings between beds, and, in the case of the Flagstaff Limestone, through solution openings" (Danielson et al., 1981, p. 25).

The majority of the groundwater which infiltrates the Flagstaff Limestone flows down vertical fractures which intersect sandstone channel systems in the North Horn Formation. The majority of the groundwater reaching this point intersects the surface in springs located in the North Horn Formation. Very little recharge intersects the Price River Formation and Castlegate Sandstone; consequently, they are not water saturated where intersected in the numerous drill holes penetrating those units. The remaining water then flows downdip (to the southeast) from the northern reaches of East Mountain until it intersects the northeast trending Roans Canyon Fault Graben. In-mine long-hole drilling completed to test the hydrology of this fault system has shown that the system acts as an imperfect aquiclude to prevent further southeast migration of water. The system acts as an aquiclude because swelling bentonitic clays along the fault prohibit most of the water from penetrating across the fault. Most of the recharge south of the Roans Canyon Fault System comes from the snow melt directly above. The same mode of water migration occurs there as to the north; but, when the water intersects the sandstone channels, it migrates toward the canyons which surround and dissect the permit area.

Data have been collected from numerous coal exploration drill holes, from within the mine workings, from surface drainages, and from the springs in the area. The data have identified two separate isolated aquifer systems on the East Mountain property; the first is localized perched water tables in the North Horn Formation, and the second is a combination of localized perched water tables in the Blackhawk Formation and the Star Point Sandstone which exhibits some limited potential as a regional aquifer. Stratigraphy is the main controlling factor restricting groundwater movement and development of regional and perched aquifer systems within the East Mountain property. The following is a description of the various formations and how they influence the groundwater systems. The description is in descending order, which parallels the general groundwater flow (see Figure HF-3).

a. Flagstaff Limestone

This formation displays a strong joint pattern which permits good groundwater movement both vertically and horizontally through the formation.

b. North Horn Formation

This formation is comprised of a variety of rock types which range from highly calcareous sandstone to mudstone. Its permeability is variable.

Lenticular sandstone channels are oftentimes present in the upper and lower portions of the formation. Water which percolates down fractures from the overlying Flagstaff Limestone works its way into the sandstones, forming the perched water tables. The actual lateral extent, or correlation, between the perched water tables has not been identified; and it is not practical to do so because the tables are limited in extent and variable in stratigraphic location. Many springs have been identified where the sandstone channels intersect the land surface.

The lower two-thirds (upper Cretaceous in age) of the formation is generally highly bentonitic mudstone which is impermeable. It is likely that this material is acting as an aquiclude, preventing adequate recharge from reaching the Upper Price River Formation or Castlegate Sandstone below. (The bentonitic mudstone will be discussed in detail in the PHC.) The mudstones present swell when they come in contact with water. Therefore, vertical migration of water along fractures through this material is limited because the fractures are sealed by the swelling clays.

The depth of the aquifers in the North Horn Formation is variable due to the rugged topography. The localized perched water tables may either intersect the surface of the ground or be covered by as much as 1,000 feet of overburden. They are located at least

1,400 feet above the coal seam to be mined. Communication of water between the perched aquifers in the North Horn Formation and the water flowing into the mine is limited in quantity and occurs very slowly. The monitoring of the numerous springs located on East Mountain gives PacifiCorp the ability to assess any effects that mining might have on the North Horn Formation perched aquifers.

With the data available it is not possible to compile a piezometric map of the water-bearing strata in the North Horn Formation because the channels are discontinuous and not interconnected.

c. Upper Price River Formation

The Upper Price River Formation is comprised predominantly of sandstone but commonly contains mudstone beds between the point bar deposits. It is generally void of water because it lacks adequate recharge.

d. Castlegate Sandstone

The formation is thought to be fairly permeable but, where it has been intersected by drill holes, has never been found to be water-saturated. It is oftentimes dry or slightly damp in some zones. It is void of significant water because it lacks adequate recharge.

e. Blackhawk Formation

The Blackhawk Formation contains only perched or limited aquifers which exist within the strata overlying the coal seams and the upper portion of the Star Point Sandstone Formation. The perched aquifers exist as fluvial channels (ancient river systems) which overlie and scour into the underlying strata (refer to Maps HM-2 and HM-3). The locations of the channels shown on Maps HM-2 and HM-3 are based on data collected from in-mine mapping and numerous drill holes, both in-mine and surface, that have been completed on the property. These channel systems were part of a deltaic depositional setting active during and after the coal-forming peat accumulation. The largest influx of water encountered during the mining process occurs beneath the fluvial channels. The sandstone channels are mainly composed of a fine- to medium-grained sand with similar characteristics to the Star Point Sandstone Formation. The semi-permeable and porous nature of the channels allows an effective route for water transport. Other constituents of the Blackhawk Formation (i.e., mudstone, carbonaceous mudstone, coal seams, and interbedded mudstones/siltstone and sandstones) generally act as aquicludes which impede vertical groundwater flow to the lower stratigraphic units. In areas other than where faulting and fracturing have created secondary permeability, the migration of water from the perched aquifers-sandstone channel systems of the Blackhawk Formation to the Star Point Sandstone Formation is limited. Extensive mining in the Cottonwood/Wilberg complex, which produces coal from the Hiawatha seam, is stratigraphically located on top of the upper member of the Star Point Formation Sandstone. Only minor quantities of groundwater have been produced from the Star Point Sandstone Formation. The coal seams of the Blackhawk Formation are effective in impeding vertical groundwater movement. In many areas in the mine where roof coal was left in place because of abundant thickness or as an additional effort to support the immediate roof, production of groundwater occurred only when roof support was installed or when a roof failure occurred exposing the overlying sandstone channel systems. Listed below are hydrologic characteristics of individual rock types reported by the USGS, Open File 84-067.

Lithology: Sh, shale; Slt, siltstone; Ss, sandstone; f, fine grained; m, medium grained.
Hydraulic conductivity: I, impermeable to water even at a pressure of 5,000 pounds per square inch.

Geologic unit	Lithology	Depth below land surface (feet)	Porosity (percent)	Hydraulic conductivity (feet per day) Horizontal	Vertical
Blackhawk	Ss, f	1,521	14	$1.5x10^{-2}$	$3.7x10^{-3}$
Formation	Slt	1,545	3	$9.3x10^{-8}$	$1.2x10^{-7}$
	Sh	1,786	2	I	I
	Ss, f	1,792	14	$1.1x10^{-2}$	$3.9x10^{-3}$
	Sh	2,170	4	$1.1x10^{-8}$	---
	Slt	2,265	2	$2.0x10^{-7}$	$2.2x10^{-6}$
Star Point	Ss, m	2,466	17	$3.1x10^{-2}$	$1.1x10^{-2}$
Sandstone	Ss, m	2,493	11	$1.5x10^{-2}$	$6.6x10^{-3}$

The majority of the water flowing into the mines comes from within the limited fluvial channel aquifers; however, water is also transmitted into the mine workings by way of faults, joints or fractures, and in-mine drill holes (see Figure HF-4). The Des-Bee-Dove permit area is an exception. The Deer Creek Fault, which separates Deer Creek and Wilberg/Cottonwood mines from Des-Bee-Dove, forms an aquiclude to the water migration to the east. Since 1978 the water flowing into the mine workings has been measured. The measurement locations in the Deer Creek Mine are shown on Map HM-2, in the Wilberg/Cottonwood Mine on Map HM-3. Many locations within the mines have been monitored in the past, but a limited number of accessible long-term water monitoring locations now exists because most water-producing areas of the mines are dewatered and stop flowing shortly after initial mining in the area.

In several locations in the Deer Creek and Wilberg/Cottonwood mines, such as retreated longwall panels, water is being produced but cannot be measured because the workings are inaccessible. The water entering these areas flows into numerous low areas in the mine which act as temporary sumps. The water is then pumped to the main sump located near the mine portal. Because the pumping system in the mine is ever changing (i.e., portable pumps being moved to various locations within the mine as the need arises), it is not possible to collect meaningful data from specific areas of the mine that can be compared with data collected from years or even months past. PacifiCorp commits to monitoring long term areas of water production if measuring devices can be installed and maintained to collect accurate information over a long term period. When mine entries are sealed, access to long-term monitoring sites may be lost, in which case monitoring will cease.

The most accurate measurement of water flowing into the mine workings is achieved by measuring the total water leaving the mine, which is done and reported annually in the Hydrologic Monitoring Report. The total amount of water leaving the mine includes metered discharge water as well as estimated water which evaporates from the mine workings.

Based on current data, several observations have been made concerning the Blackhawk water-bearing strata. The sandstone, which is semi-permeable and porous, affords an effective route of water transport; while relatively impervious shale in the Blackhawk Formation prevents significant downward movement of the percolating water. Of the water-producing areas, those closest to the active mining face exhibit the greatest flows. As mining advances the area adjacent to the active face continues to be excessively wet, and previously mined wet areas experience a decrease in flow. It appears that the water source is being dewatered since mined out areas of the mine do not continue to produce water indefinitely. The water source must be either of limited extent, e.g., a perched aquifer, or have a limited recharge capacity. In an attempt to quantitatively evaluate saturated sandstone channels, a dripping channel in the 6th West area of the Deer Creek Mine was investigated (site 6W X 20; Figure 10, refer to Mayo & Associates report, Hydrologic Support Information No. 11). The channel, located near a minor fault with very limited displacement, has the dimensions of >2,000 feet in length, 150 feet in width and a maximum thickness of 25 feet. An array of up-hole monitoring wells was installed across the width of the channel. The wells were 15 to 25 feet deep and were open along their entire depth. Each well was equipped with a shutoff valve and pressure gauge. The idea was to conduct a pump test by letting selected wells gravity drain and simultaneously measuring pressure change in nearby wells. Because a maximum of about 2 psi was recorded in the well (i.e. (5 feet of water) we were unable to conduct the test. What the well did demonstrate was that the sandstone channel was not fully saturated and it was a perched, unconfined groundwater system.

To evaluate the amount of potential drawdown and recovery rates due to dewatering of intersected groundwater, PacifiCorp installed a series of groundwater monitoring wells south and north of the Roans Canyon Fault system in Cottonwood Canyon (see Appendix C for detailed information). The wells will be situated down gradient from future mining north of the Roans Canyon Fault and will allow long-term, year around access. Monitoring of these wells will be incorporated in PacifiCorp's hydrologic monitoring program.

Although much of the water transfer within the Blackhawk Formation is through fractures or faults, data indicate that recharge to the Blackhawk is limited because of the above confining formations and many of the fractures become sealed by swelling bentonitic clays which stop or limit the water transfer, confirmation of which exists along the numerous faults and fractures over the area. Very few springs are found within the Blackhawk except along the extensive faults in the Wasatch Plateau. A measurable flow of water along a fault existed at only one location in the Wilberg/Cottonwood Mine -- along the Pleasant Valley Fault in Main West, Wilberg. This location produced an estimated average flow of 5 gpm from the time it was encountered to 1980 when the flow stopped. The fractures sealed readily because of the ability of the shaley layers to swell and decompose to form an impervious clay, preventing significant downward percolation, collection, or conveyance of water along faults in the Blackhawk Formation. Significant quantities of groundwater were also encountered in the Deer Creek Mine, 4th South area, where development entries intersected fractures/faults associated with the Roans Canyon Fault system. As with other areas where groundwater has been intercepted, the flow from the 4th South/2nd Right area has decreased rapidly, from approximately 2000 gpm in March 1990 to approximately 120 gpm in December 1990. Exploratory drilling was utilized in the development entries to locate and map the extent of the water producing fracture. The water producing zone was isolated utilizing an inflatable packer and a pressure gauge was installed to monitor the head differential. Pressure readings recorded were similar to those of Roans Canyon Fault crossing at 3rd North, with readings varying from 80-90 pounds per inch. This would calculate out to approximately 200 feet of head. The amount of overburden in the area where the water producing fracture was encountered is approximately 1800-2000 feet. In reviewing the dewatering curve and the initial head differential, groundwater produced from the interception of the water producing fracture was a function of storage and recharge to the fault is limited. To monitor the potential impact of mine dewatering PacifiCorp installed a series of wells in both the Deer Creek and Cottonwood/Wilberg mines (see HM-2 and HM-3). These wells were incorporated in the hydrologic monitoring program in 1989. (See Figures HF-43 and HF-44 for historical information. Well development information was detailed in the 1989 Annual Hydrologic Monitoring Report and in Volume 9 - Hydrologic Support Information). Only the wells in the Deer Creek Mine along the axis of the Straight Canyon Syncline revealed a change which could possibly be related to mine dewatering. Monitoring of these wells will continue and data collected will be utilized to document potential impacts related to dewatering and to determine the rate of recovery once mining has been terminated. In addition to the in-mine monitoring PacifiCorp installed a series of surface wells to monitor the potential impacts outside the permit area (see Appendix C). To evaluate the effects on the surface springs and surface drainage systems PacifiCorp maintains an extensive monitoring program. Data collected is reported annually in the Hydrologic Monitoring reports.

Long-term water producing areas do exist within the current mine workings. Four types of occurrences have been recognized and will be monitored by the applicant (see Figure HF-4) and include 1) structural rolls with overlying fluvial channels, 2) Pleasant Valley and Roans Canyon Fault systems, 3) fractures and joints (lineaments), and 4) surface and in-mine drill holes.

f. Star Point Sandstone

The Star Point Sandstone Formation overlies and intertongues with the Masuk Shale. The formation is approximately 150 to 200 feet in thickness and consists of at least three upward coarsening sandstone units. Mudstone units of the Masuk Shale are present above the lower two sandstone members of the Star Point Sandstone Formation due to the interfingering nature of the contact between the two units.

The Star Point Sandstone Formation, which immediately underlies the Hiawatha Coal Seam, exhibits some characteristics of an aquifer but experiences little recharge. Studies conducted by the USGS indicate that the Star Point Sandstone Formation is of low permeability, thus limiting its usefulness as a water-producing aquifer. Most of the water discharge from the Star Point Formation is where it has been intersected by the major canyons in the plateau or where faulting has caused secondary permeability. Drill holes completed in the Deer Creek and Wilberg/Cottonwood mines defined the piezometric gradient in the lower Blackhawk Star Point Formation System and confirmed the groundwater flow to conform with the topographic relief and structural features, i.e., regional dip, Straight Canyon Syncline, and regional faulting (see Figure HF-5). This, plus the fact that the Star Point Formation is only slightly to moderately permeable, allows only limited flow of groundwater through the formation.

Water in most of the Blackhawk-Star Point aquifer is confined under pressure between shale and siltstone beds within the aquifer (USGS Lines, Open File Report 84-067). Water is released from storage from confined aquifers mainly by compression of the sandstones and less permeable, confining beds as pressure in the aquifer declines. The quantity of water that can be released from storage is dependent on the storage coefficient, which is about $1x10^{-6}$ per foot of thickness for most confined aquifers (Lohman, 1971, p. 8). Data collected by PacifiCorp on the Roans Canyon Fault System in 1988, 3rd North fault crossing, confirmed the USGS storage coefficient estimations, with values ranging from $1.6x10^{-4}$ to $7.0x10^{-6}$. Transmissivity values computed for pump tests conducted by the USGS on Trail Mountain on non-fully penetrating wells in the Blackhawk-Star Point aquifer ranged from 0.7 to 100 ft^2

/day with a majority of the two results ranging from 1 to 10 ft^2 /day. The computed transmissivity of 100 ft^2 /day was greater than the laboratory data (listed early in this section) and was believed to be due to secondary permeability in the form of fractures. Transmissivity results ranging from 0.7 to 10 ft^2 /day are indicative of the low permeability rock in most of the cretaceous and tertiary strata within the Wasatch Plateau.

g. Structural Hydrologic Features

Four important structural hydrologic features, the Roans Canyon Fault Graben, the Straight Canyon Syncline, Deer Creek Fault, and the Mill Fork Fault Graben, have been identified within the East Mountain permit area (see Map HM-1).

A hydrogeologic investigation of the Roans Canyon Fault Graben was completed during 1988 in order to develop plans for management of groundwater inflow during and after the construction of three parallel rock tunnels which were completed in 1990. The fault crossing is located in the 3rd North section of the Deer Creek Mine (see Map HM-2). Five (5) test wells were developed in order to conduct the investigation. Selected intervals in the boreholes were tested for hydraulic properties with straddle packers. In addition, three (3) short-term and one long-term constant rate flow tests were performed to measure aquifer parameters. The packer test and flow and recovery test data were analyzed to determine static pressures and gradients through the fault system and to determine transmissivity, hydraulic conductivity, and storage coefficient for each zone tested.

The investigation defined two major hydrogeologic units which are fractured, well-sorted, medium-grained, friable, oxidized channel sandstones. The first sandstone unit is located approximately 350 feet, the second about 650 feet, horizontally from the southern bounding fault (see Map HM-2). The sandstone units are likely of limited vertical thickness but may have more extensive lateral continuity. The two sandstones are heavily oxidized and iron-stained along fractures, and in places the sandstone is totally oxidized for several feet adjacent to the fracture. The oxidation, at a depth of 1400 feet below land surface, indicates that oxygenated water was infiltrating rapidly from the surface through fractures, suggesting that there was good hydraulic connection between the channel sandstones at the depth of the rock tunnels and the recharge at the surface, primarily though fractures. The oxidation of the strata most likely occurred shortly after the initial ground movement. In reviewing other areas where the Roans Canyon Fault system was intersected (longwall development entries off of 4th South, Deer Creek Mine), the close proximity of Meetinghouse Canyon is a major factor in controlling the amount of oxidation which has occurred. In the 4th South area, where longwall development entries intersected a sympathetic fault associated with the Roans Canyon Fault, in-mine drilling was utilized to project and locate the fracture system along with defining the southern boundary of the Roans Canyon Fault system so that mine plans could be adjusted to minimize inflow of groundwater. No oxidation was detected during this investigation or along the intercepted sympathetic fault as was the case in the 3rd North fault crossing. Additional evidence for the lack of rapid influx from the surface, the monitoring of a horizontal hole (TW-10) drilled across the fault for hydrologic testing, has failed to show any seasonal variation in either quality or quantity (see 1991 Annual Hydrologic Report).

Aquifer test results indicated both horizontal and vertical components to the groundwater flow directions. The horizontal gradient measured between two of the test wells, which were

300 feet apart, was approximately 0.038 psi/ft or 0.089 ft/ft. The vertical gradient measured between two of the wells, which were 58 feet apart vertically where they penetrated the first water producing sandstone unit, was approximately 0.069 psi/ft or 0.159 ft/ft, approximately twice the horizontal gradient. Test results indicated the horizontal flow component is the result of flow in the graben from the west toward the east where the graben intersects the canyon walls and, presumably, the groundwater system discharges. The vertical flow component is controlled by the Star Point Sandstone Formation which underlies the entire graben. The average hydraulic conductivity measured for the fractured sandstone was 15 gallons per day per square foot (gpd/ft^2). The results are within the expected range for this type of aquifer. The average storage coefficients measured at $5x10^{-5}$ (unitless) indicate that the two major sandstone units are confined.

The groundwater flow in the graben occurs primarily in the fractures of the two major water-producing zones with lesser flow quantities in the fractured siltstone units. Virtually no flow occurs in the mudstone between the siltstone and sandstone. The south boundary fault of the graben creates a hydrologic barrier to flow into the mine area south of the graben whereas the north boundary fault does not have a thick fault gouge zone like the one associated with the southern fault, but, from drilling observations, it is also suspected to be a barrier to groundwater flow.

A pressure grout program was utilized to minimize the long-term groundwater inflow from the water-producing zones encountered during slope development. The grouting program consisted of drilling a series of boreholes prior to water-producing zone interception and forcing fast-setting grout material into the fractures. Experience with pressure grouting indicates that as much as seventy-five to ninety-five percent (75-95%) of the groundwater inflow was effectively stopped. Tunnel inflow rates range from 50 to 75 gallons per minute.

One factor addressed during the dewatering and grouting evaluation was the influence of the tunnels and prior dewatering on the flow from the surface springs located in the vicinity of the Roans Canyon Fault Graben (see HM-5). Several of the major springs on the East Mountain property are located along the trace of the northernmost fault of the graben including Elk Spring, 89-60, Sheba Springs, and 79-10. Assuming the worst case scenario in which grouting was not applied or was ineffective, a maximum drawdown of approximately ten (10) feet at the surface of the graben was calculated using the groundwater model (see Volume 9 Hydrologic Support Information for complete details on the Roans Canyon hydrologic research project). Given the preexisting dominant vertical flow direction documented during the hydrologic testing of the fault system and the fact that the springs do not appear to be associated with aquifers encountered during the hydrologic investigation of the Roans Canyon Fault system, it is unlikely that the tunnels would exert a measurable influence on the springs. Major springs which occur along the Roans Canyon fault trace are formed when water infiltrates the surface and migrates vertically along fractures which intersect sandstone channel systems in the North Horn Formation. The groundwater then flows downdip (to the southeast) from the northern reaches of East Mountain until it intersects the Roans Canyon Fault system. Drilling of the hydrologic test holes prior to crossing the Roans Canyon Fault system confirmed the presence of significant amounts of clay filled fault gouge which prevents further southeast migration of groundwater. Groundwater in the fault system was isolated to fluvial channel systems in the Blackhawk Formation at a pressure of approximately 80 to 90 psi (see Volume 9 - Hydrologic Support

Information). This is equivalent to approximately 200 feet of head at the location of the fault crossing. Overburden in this area was in excess of 1400 feet and with maximum pressure readings of 80-90 psi indicated that the fault system was not fully saturated. Drawdown tests and subsequent dewatering of test hole TW-10 have shown that the long-term sustained yield is less than two percent of the initial discharge rates. As discussed earlier, PacifiCorp utilized a pressure grout program to minimize the long-term groundwater inflow from the water producing zones encountered during the slope development. To monitor the potential impacts of the Roans Canyon slope development, PacifiCorp developed TW-10 into a long-term water site with quality and quantity measurement on a quarterly basis. Along with in-mine monitoring, major springs associated with the Roans Canyon Fault are included in the East Mountain Monitoring Program.

Another area associated with the Roans Canyon fault system where groundwater was intercepted is in longwall development entries driven west from 4th South Mains (see Map HM-2, Section 7, Township 17 South, Range 6 East). Development entries intersected an unknown sympathetic fault with approximately 2.5 feet of displacement (2nd Right off 4th South). Initial groundwater inflow rates were estimated at approximately 2000 gpm. At that time development was terminated and a hydrogeologic program was developed to determine the extent and bearing of the fracture system. In-mine horizontal drilling was utilized to project the fracture system as well as to isolate the water zone for aquifer testing. Inspection of the sympathetic fault and drill hole information indicated that the geology differed from that of the 3rd North area in that little or no oxidation had occurred to surrounding strata. The aquifer test utilized inflatable packers to isolate the zone to flow and pressure characteristics. Test results indicated that the fracture zone had similar hydrologic properties to the Roans Canyon system tested in 3rd North, maximum pressure recorded was 90 psi (indicating a relatively low head differential), and flow rates from the fracture zone diminished over time. A permanent monitoring site was established using a two-foot rectangular weir to measure the intercepted groundwater. Flow from this area has diminished rapidly from approximately 2000 gpm in April to 125 gpm in March of 1991, further confirming PacifiCorp's hydrologic model that the majority of intercepted groundwater is in the form of storage and not from recharge. As a result of significant inflows associated with the fracture system, mine plans were adjusted based on the projection of the fracture so that the potential for additional interception of groundwater would be reduced.

The Straight Canyon Syncline is the second structurally related hydrologic feature within the permit boundary. It parallels and lies adjacent to the Roans Canyon Fault Graben (see Map HM-1). Dips in the syncline range from two to six degrees with the north limb dipping the steepest. In the area south of the Straight Canyon Syncline the coal seam dips gently in a northwest direction toward the syncline; however, to the northwest of the Straight Canyon both the Hiawatha and Blind Canyon seams dip in a southeast direction at three to five degrees. The dip and strike of the coal seams can be better visualized on Maps CE-10693-EM and CE-10694-EM in the geologic section. The groundwater tends to migrate to the lowest portion. Wet conditions have been experienced where mining has taken place in the base of the syncline. Structure and gradient studies have indicated that groundwater migrates downdip and, due to hydrologic characteristics of the Blackhawk Formation, becomes perched along hydrologic boundaries, as in the case of East Mountain property, the Roans Canyon system. The groundwater intercepted in the western development entries off 4th South in Deer Creek Mine has been influenced by the Straight Canyon Syncline as well as the Roans Canyon system, but the hydrologic significance of the syncline is much less than that of the Roans Canyon system.

The third feature is the Deer Creek Fault. Mining in the Deer Creek and Wilberg mines to the west of the Deer Creek Fault had intersected wet strata while the Des-Bee-Dove Mine to the east had dry strata, indicating that the fault forms an aquiclude to water migration to the east.

The fouth feature is the Mill Fork Fault Graben located in the northwestern portion of the permit boundary. A fault system referred to as the Mill Fork Canyon Graben is projected to intersect the western portion of Federal Coal Lease U-06039 (refer to map HM-9). The Mill Fork Canyon Graben was intersected and crossed to the north of the Rilda Canyon in the Beaver Creek No. 4 Mine and consisted of a series of faults with a total displacement of approximately thirty (30) feet. Beaver Creek No. 4 Mine was a relatively dry mine with only a few isolated roof drippers associated with the Mill Fork Fault system. PacifiCorp has conducted extensive exploration programs to delineate the Mill Fork Graben including a series of close spaced drill holes in the Right Fork of Rilda Canyon. Drilling was conducted on approximately 250 foot centers across the projected Mill Fork Graben from previously completed drill holes EM-158 and EM-56. No structural discontinuities were identified during drilling. Groundwater encountered during drilling was restricted to minor quantities from the alluvial/colluvial fill (estimated at 2 - 5 GPM) near the alluvial/bedrock interface.

h. Alluvial Aquifers

Utah Regulations require that the presence of alluvial valley floors in or adjacent to the mine project area be identified. The regulations define an alluvial valley floor as "unconsolidated stream-laid deposits holding streams with water availability sufficient for sub-irrigation or flood irrigation agricultural activities but does not include upland areas which are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion, deposits formed by unconcentrated runoff or slope wash together with talus, or other mass-movement accumulations, and wind blown deposits." The alluvial valley floor is therefore determined to exist if:

1. Unconsolidated stream-laid deposits holding streams are present, and
2. There is sufficient water to support agricultural activities as evidenced by:
   a. The existence of flood irrigation in the area in question or its historical use;
   b. The capability of an area to be flood irrigated, based on stream-flow, water yield, soils, water quality, topography, and regional practices; or
   c. Subirrigation of the lands in question, derived from the groundwater system of the valley floor.

Scope: The purpose of this section of the report is to examine the potential existence of alluvial valley floors in and adjacent to the areas to be affected by surface operations associated with the permit areas. It is divided into three parts. First, a general description of the surface operations and site disturbances associated with the permit areas is presented. Next, discussions of the characteristics of geomorphology and irrigation are presented. Finally, the conclusions of the alluvial valley floor determination are summarized.

Site Description: Surface facilities associated with the permit area will consist of the portal area and associated facilities: for Deer Creek Mine - Deer Creek and Rilda (proposed) canyons; for Des-Bee-Dove - unnamed drainage associated with Grimes Wash; and for Wilberg/Cottonwood - Grimes Wash.

The climate of the general area is semi-arid to arid and continental. Daily minimum temperatures recorded at the East Mountain weather station in winter range from the average low of -6.3° F to the maximum record low of -15.2° F, and daily maximum temperatures in summer range from the average high of 84.7°F to the maximum record high of 89.3° F.

Temperatures in the region tend to be inversely related to elevation. Average annual precipitation recorded for a 10-year period (1981-90) at the East Mountain weather station averaged 14.15 inches. Approximately fifty percent of the annual precipitation falls during the winter as snow with most of the remainder coming as summer thunderstorms.

Alluvial Valley Floor Characteristics: In this section of the report the various criteria for determining the existence of an alluvial valley floor are examined in relation to the overall permit and adjacent areas.

Geomorphic Criteria: Alluvial deposits in and adjacent to the mine permit area have been mapped and reported in Doelling's "Wasatch Plateau Coal Fields, 1972." The report indicated that alluvia in the area are found solely along Huntington Creek below the Rilda Canyon confluence in the Huntington drainage system, in the Cottonwood drainage system along lower Cottonwood Creek and at the mouth of the North Fork of Cottonwood Creek, and in the Joe's Valley drainage.

Flood Irrigation: Flood irrigation near the project area is currently (and has historically been) confined to the alluvial areas of Huntington Creek approximately one mile below the confluence of Deer Creek and Huntington Creek. In the Cottonwood drainage system flood irrigation is currently, and historically, confined to the alluvial areas of lower Cottonwood Creek. No flood irrigation has historically been practiced on the narrow alluvium land upstream in the canyons opening to lower Cottonwood and Huntington Canyon creeks. The historic lack of flood irrigation in these steep, narrow canyons suggests that such activities are not feasible in the region. In addition, the topography is very steep and consequently not conducive to agricultural activities.

Water quality of Cottonwood and Huntington creeks is good. A detailed review of the surface water quality has been presented previously in this report and is updated each year in the annual Hydrologic Monitoring Report.

Subirrigation: Some subirrigation of vegetation does occur on the alluvial valley floors. The subirrigated species (mainly cottonwoods and willows) are found along the channels of Cottonwood Creek and in the Joe's Valley drainage above the reservoir and along the channels of Rilda Canyon and Huntington Creek. This suggests that subirrigation is confined to the channel areas where the water table is near the surface.

Alluvial Valley Floor Identification: Based on the foregoing analysis, the narrow canyons associated with the permit area cannot be considered to have an alluvial valley floor due to insufficient alluvium and the very limited area for supporting an agriculturally useful crop. The valley floor of Huntington Creek below the confluence with Deer Creek, however, can be classified as an alluvial valley floor due to the presence of both flood irrigation and limited subirrigation on the alluvium.

Potential Impacts of Alluvial Valley Floors: Very little potential exists for the mine operations to impact the Cottonwood and Huntington Creek alluvial valley floor due to the location of the operations in comparison to the alluvial deposits. All surface disturbances in the portal area will be protected by sediment control facilities and have been designed and constructed according to R645 standards in an environmentally sound manner.

The hydrologic monitoring program will help determine the actual impact of surface activities and aid in selecting mitigating measures, if necessary; however, it is believed that the overall permit area and associated activities will have no significant hydrologic impacts on the alluvial valley floor along Cottonwood and Huntington creeks. Details concerning the monitoring program are outlined in section R645-301-731.

4. Springs And Seeps

The 1979 water reconnaissance program of East Mountain Springs was initiated with an aerial survey of East Mountain properties via helicopter. During the survey the locations of 102 possible springs were plotted on aerial photographs. Subsequent field work confirmed the locations of forty-eight (48) springs producing measurable amounts of water. The remaining sightings proved to be minor seeps, dry or runoff from other springs. Between the time PacifiCorp began monitoring springs on East Mountain and 1991, the number of springs identified increased from less than fifty (50) to nearly eighty (80). Each spring site on East Mountain has been studied to determine the geologic circumstances that cause the springs to occur. The mode of occurrence for each spring has been tabulated on the "Springs Geologic Conditions Inventory" sheets located in the annual Hydrologic Monitoring reports. The springs on East Mountain originate in several different ways (see Table HT-1 and Map HM-5); however, many springs share the same mode of occurrence and, in some cases, are related.

The most frequent occurrences of springs are those located about 150 to 350 feet below the top of the North Horn Formation (see Figure HF-6). The drill hole data show a predominance of fluvial siltstone and sandstone at that stratigraphic interval. These sedimentary rocks represent many isolated fluvial systems which are water-bearing. The springs are formed where the fluvial channels intersect the land surface. Because the fluvial channels within this zone are generally not interconnected, the springs are not interrelated but share the same mode of occurrence.

Numerous springs located in the lower portion of the North Horn Formation occur when water flowing through fluvial sandstones which are underlain by a thin zone of impervious mudstone at the base of the North Horn Formation intersect the land surface. The surface drill hole data indicate that impervious mudstone units occur at the upper and lower portion of the North Horn Formation. Even though these individual mudstone layers are discontinuous, the occurrence of this type of strata exists throughout the East Mountain Property. As part of Volume 9 - Hydrologic Support Information, logs of representative holes from the East Mountain exploration programs are included to document the occurrence of this type of strata (additional drill hole data are located at PacifiCorp's Salt Lake or Huntington offices). The springs related to this mode of occurrence are not generally interrelated because they are fed by waters flowing through isolated fluvial channel sandstones and siltstones.

Several springs are located along the Roans Canyon Fault Graben. Generally, the springs are located within the North Horn Formation along the fault zone. Few springs are located in the area below the base of the North Horn Formation below where the impervious mudstone is located, supporting the fact that water percolating down a fracture or fault is stopped from further downward travel when it reaches the impervious clay zone which forms a seal along the fracture. Many of the largest springs on East Mountain are located along this fault system. Because the fault system is located along the trough of the Straight Canyon Syncline, water from both the north and the south flows toward the fault where it is allowed to migrate to the land surface. The springs located along this fault zone are generally interrelated.

A few springs are located within both the Flagstaff and Price River formations; however, their occurrence is insignificant in comparison to springs located in the North Horn Formation.

Generally springs with discharges exceeding 50 gpm are associated with faulting where permeability has been increased by fracturing. The discharge of the springs varies directly with the amount of precipitation and also varies seasonally. Discharge is greatest during the snow melt period, normally from late April through the month of June. Following periods of groundwater recharge the discharge recedes fairly rapidly at first, then gradually, indicating a double porosity effect. At the end of the water year the remaining discharge is only twenty to thirty percent (20-30%) of the peak discharge. Annual variations and historical comparisons are depicted in the annual Hydrologic Monitoring reports.

5. Groundwater Quality

Groundwater chemical quality is very good in strata above the Mancos Shale. The USGS reports a range in dissolved solids from 50 to 750 mg/l for samples from 140 springs in the region issuing from the Star Point Sandstone Formation and overlying formations (Danielson et al., 1981). Danielson et al. (1981) identified the regional trends of decreasing water quality from north to south and west to east across the Wasatch Plateau. Waters percolating through the underlying Mancos Shale quickly deteriorate, with total dissolved solids concentrations frequently exceeding 3000 mg/l.

Additional studies by PacifiCorp have confirmed the primary findings of the USGS concerning regional trends in quality. Originally, decreasing quality from north to south was believed to depict the groundwater flow direction, and the quality decreased as a function of the time it traveled through the strata. The time travel component is probably an important factor. In 1985 a surface exploration program identified the existence of an area of residual heat from an ancient burn on the outcrop throughout the southern portion of East Mountain. The high temperature was also explored within the mine and a portion of reserves were lost because of the situation. It is now theorized that the high temperature water dissolved the mineral constituents of the formations, thereby altering the water chemistry. The quality also decreases vertically because of the influence of marine sediments along with the trend of decreasing quality from north to south.

An examination of Figure HF-7 indicates that a relationship exists between elevation and the total dissolved solids concentration of the springs and the surface streams. A distinct relationship exists with respect to surface and water emanating from the springs. The data indicate that concentrations of dissolved materials increase with diminishing elevation for both surface streams and springs. The change in quality is a function of the differences in the chemical character of geologic formations which outcrop at different elevations (see Table HT-2 for East Mountain springs water quality).

To more closely identify springs which are related, water samples are analyzed to determine the percentage of cations and anions in solution. These percentages have been graphically represented as cation-anion diagrams in the annual Hydrologic Monitoring reports. The purpose of the diagrams is to identify groups of related springs by water chemistry. The diagrams clearly show the similarity of water quality of springs originating in the same geologic formation. To better visualize this concept, the cation-anion diagrams are presented by the geologic formation in which they originate. A general pattern for the Flagstaff and Price River formations can be recognized for each year in which the cation/anions were analyzed. A consistent pattern for the North Horn is less obvious due to the complex geology of the formation itself. One aspect the cation-anion diagrams demonstrate is that, even though the quality varies slightly from individual sites as well as from different formations, seasonal variations do not exist.

PacifiCorp began in-mine quality monitoring in 1977. With the collection of numerous samples throughout the extent of the mine workings, the quality has remained relatively constant (see Maps HM-2 and HM-3). As with the springs the quality varies from individual sites, but quality from the individual sites remains constant versus time (see Figure HF-8). The overall quality collected from each mine is shown in Table HT-3.

The predominant dissolved chemical constituents of the groundwater from both surface springs and samples collected in the mine are calcium, bicarbonate, magnesium, and sulfate. Concentrations of magnesium are normally about one-half the concentration of calcium. Sulfate concentrations are typically higher in water from springs issuing from the Star Point Formation-Blackhawk aquifer zone or confined aquifers intersected by mine workings. As mentioned earlier, water quality degrades from the north to the south and also vertically.

PacifiCorp contracted Mayo & Associates to conduct comprehensive study to characteristize the hydrology and hydrogeology of the East and Trail mountains (refer to Volume 9 - Hydrologic Support Information No.11). The hydrogeology of the PacifiCorp leases were evaluated by analyzing: 1) solute and isotopic composition of surface and groundwaters, 2) surface and groundwater discharge data, 3) piezometric data, and 4) geologic information.

As a part of this investigation water samples from 13 springs, 2 wells, 9 in-mine groundwater discharge locations, the portal of the abandoned Oliphant Mine, and 6 snow sites were collected and analyzed for solute and isotopic composition during 1996 and 1997.

Isotopic samples for δ^2H, $\delta^{18}O$, and ^3H analyses were collected, sealed, and preserved in appropriate glass or HDPE plastic bottles. Dissolved inorganic carbon and SO_4^{-2} for $\delta^{13}C$, $\delta^{34}S$, and ^{14}C analysis were precipitated with $BaCl_2$□$2H_2O$. Stable isotopic analyses for δ^2H, $\delta^{18}O$, $\delta^{13}C$, and $\delta^{34}S$ compositions and unstable ^{14}C contents were performed by Geochron Laboratories, Cambridge, Massachusetts. The ^3H analyses were performed by the Tritium Laboratory, University of Miami, Florida using electrolytic enrichment and low level counting methods. Laboratory reporting sheets for isotopic analyses are included in Hydrologic Support Information No. 11 as Appendix A.

6. Chemical Evolution Of Groundwater

a. Chemical Reactions

Solute compositions of groundwaters are the result of interactions between groundwaters and bedrock lithologies and between groundwaters and atmospheric and soil gases. The general reactions responsible for the chemical evolution of groundwaters in the vicinity of the PacifiCorp lease area and inside the coal mines are described below:

Groundwater acquires most of its $CO_{2(g)}$ in the soil zone where the partial pressures of CO_2 greatly exceeds atmospheric levels. This CO_2 combines with water to form carbonic acid according to

$$CO_{2(g)} + H_2O = H_2CO_3 \qquad (1)$$

Carbonic acid dissociates into H^+ and HCO_3^- as

$$H_2CO_3 = HCO_3^- + H^+ \qquad (2)$$

The H^+ ions temporarily decrease the pH of the water but are quickly consumed by the dissolution of carbonate minerals that are abundant in the soil zone and in most aquifers. Carbonate mineral dissolution is represented as

$$\underset{\text{(dolomite)}}{2H^+ + CaMg(CO_3)_2} = Ca^{2+} + Mg^{2+} + 2HCO_3^-\text{, and} \qquad (3)$$

$$\underset{\text{(calcite)}}{H^+ + CaCO_3} = Ca^{2+} + HCO_3^- \qquad (4)$$

The net effect of reactions 2 through 4 is to increase the pH and the Ca^{2+}, Mg^{2+}, and HCO_3^- contents of waters. Dissolution of small amounts of gypsum, which is present in many formations in the region, can elevate the Ca^{2+} and SO_4^{2-} contents in the absence of additional $CO_{2(g)}$ and H^+ according to

$$\underset{\text{(gypsum)}}{CaSO_4 \cdot 2H_2O} = Ca^{2+} + SO_4^{2-} + 2H_2O \qquad (5)$$

Elevated Na^+ concentrations may result from either the dissolution of small amounts of very soluble halite or from ion exchange on clay particles or on sodium zeolites. Halite dissolution will increase the overall solute concentration (i.e. TDS) and will yield equal Na^+ and Cl^- contents when the solute compositions are reported in the meq L^{-1} units. Ion exchange will not directly elevate the overall solute content, but will result in increased Na^+

concentrations at the expense of reduced Ca^{2+} and/or Mg^{2+} concentrations. Halite dissolution may be represented as

$$NaCl = Na^+ + Cl^-, \qquad (6)$$

and ion exchange may be represented by reactions involving the sodium zeolite analcime,

$$2NaAlSi_2O_6 \cdot H_2O + Ca^{2+} = Ca(AlSi_2O_6)_2 \cdot H_2O + 2Na^+, \qquad (7)$$

$$2NaAlSi_2O_6 \cdot H_2O + Mg^{2+} = Mg(AlSi_2O_6)_2 \cdot H_2O + 2Na^+, \qquad (8)$$

or clay mineral exchange which may be represented as

$$Ca^{2+} + Na\text{-clay} = 2Na^+ + Ca\text{-clay} \qquad (9)$$

$$Mg^{2+} + Na\text{-clay} = 2Na^+ + Mg\text{-clay} \qquad (10)$$

b. Groundwater Solute Compositions

Solute compositions of groundwater from 96 springs, 4 french drains, 5 wells and 46 in-mine sampling locations were analyzed as part of this investigation (Spring and well locations are shown on Figure 9, refer to Hydrologic Support Information No. 11). In-mine sampling locations for the Blind Canyon seam in the Deer Creek Mine and for the Hiawatha seam in the Trail Mountain and Cottonwood/Wilberg Mines are show in Figures 10 and 11, respectively (refer to Hydrologic Support Information No. 11).

Mean solute compositions for each spring and well have been calculated for the high-flow and low-flow conditions (refer to Hydrologic Support Information No. 11: Table 1). The highest discharge from springs generally occurs in July and records with sampling dates in May, June, or July are included in the high flow mean. The low flow mean is calculated using records with dates from August to April. In Table 1 (refer to Hydrologic Support

Information No. 11) groundwaters issuing from the North Horn Formation are classified as either low or high SO_4^{2-} water.

A two-tailed paired t-test comparing the mean high flow and low flow solute concentrations of spring and well waters organized by formation was performed (Table 2, refer to Hydrologic Support Information No. 11). If the t-test values is <0.05 there is a statistical probability that the means of the two populations are different at the 95% confidence interval. Table 2 (refer to Hydrologic Support Information No. 11) shows that there is not a statistical difference in the high and low flow solute compositions of groundwater issuing from most formations. Exceptions include TDS, Ca^{2+}, and SO_4^{2-} in alluvial groundwater systems and Cl^- in low sulfate North Horn Formation groundwater. The calculated statistical difference in K^+ in high sulfate North Horn Formation groundwater is not considered valid because the difference is the result of a single sample from spring EMS79-19.

The mean solute compositions of groundwaters issuing from each bedrock source, (regardless of discharge rates) are listed in Table 3 (refer to Hydrologic Support Information No. 11) and are illustrated on a trilinear diagram (refer to Hydrologic Support Information No. 11: Figure 12). The solute compositions of groundwater issuing from each spring, well, and in-mine sampling location are illustrated as Stiff diagrams on Figures 13 and 14 (refer to Hydrologic Support Information No. 11).

Most groundwater discharging from springs in the study area is of the Ca^{2+}-HCO_3^- or Ca^{2+}-Mg^{2+}-HCO_3^- type. The solute compositions of these waters are due to the dissolution of carbonate minerals in the presence of soil zone CO_2 (Eqs. 1-4). Most groundwaters have Na^+

concentrations 2 to 3 times as great as Cl^- when concentrations are expressed as meq L^{-1} (refer to Hydrologic Support Information No. 11: Table 3). Na:Cl ratios appreciably greater than 1 are interpreted to be the result of ion exchange of Ca^{2+} and Mg^{2+} for Na^+ on clays (Eqs. 9 and 10). Ion exchange appears to be particularly prevalent in the Blackhawk, Price River, and high SO_4^{2-} North Horn spring waters. Two types of groundwater issue from the North Horn Formation. The more predominant of the two waters is a Ca^{2+}-Mg^{2+}-HCO_3^- type water with low TDS (refer to Hydrologic Support Information No. 11: Table 3). The second is a Ca^{2+}-HCO_3^--SO_4^{2-} type water which has an elevated TDS as well as elevated Ca^{2+} and SO_4^{2-} concentrations (refer to Hydrologic Support Information No. 11: Table 3). The elevated solute concentrations are interpreted to result from the dissolution of gypsum (Eq. 5). This second group includes waters with SO_4^{2-} concentrations greater than about 50 mg L^{-1}. The distinction between low and high SO_4^{2-} water was determined from an ordered ranking of SO_4^{2-} concentrations (refer to Hydrologic Support Information No. 11: Figure 15).

The Ca^{2+}-HCO_3^--SO_4^{2-} waters issue from two sections of the North Horn Formation. As shown in Figure 16a (refer to Hydrologic Support Information No. 11), high SO_4^{2-} waters are found in springs that issue within 50 feet of the base of the North Horn and between 550 and 600 feet from the base of the formation. Sulfate concentrations do not correlate with discharge rates (refer to Hydrologic Support Information No. 11: Figures 16b and 16c). Although detailed stratigraphic information describing the North Horn Formation is not available, the solute data suggest that there are two gypsiferous sequences in the formation that represent evaporative depositional conditions. Low SO_4^{2-} waters discharge from springs located stratigraphically throughout the formation including from the two sections identified above.

What the distribution of high SO_4^{2-} spring waters means is that flow paths within the North Horn Formation are short and that there is little vertical communication of waters. If water were being communicated vertically, solute concentrations, especially Ca^{2+} and SO_4^{2}, would be more uniform in the formation.

In-mine roof drip waters and spring waters issuing from the Blackhawk Formation have elevated TDS contents relative to all other groundwater in the study area (refer to Hydrologic Support Information No. 11: Table 3). The elevated TDS is largely the result of elevated Ca^{2+}, Mg^{2+}, Na^{+}, and SO_4^{2-} concentrations (refer to Hydrologic Support Information No. 11: Table 3, Figure 12). These elevated concentrations are the result of a series of interrelated and cascading mineral dissolution and precipitation reactions. Sources of elevated SO_4^{2-} include the dissolution of evaporative gypsum (Eq. 5), associated with the swamp environments, and the oxidation of pyrite. Gypsum dissolution also elevates the concentration of Ca^{2+} which in turn results in the precipitation of calcite due to the common ion effect. Ca^{2+} and Mg^{2+} are also removed from groundwater by ion exchange on clays and in coal deposits on the Na^{+} zeolite analcime (Eqs. 7-10). The removal of Ca^{2+} and Mg^{2+} triggers the dissolution of additional calcite and dolomite (Eqs. 3 and 4).

Five in-mine samples collected from the Wilberg Mine have very elevated TDS (refer to Hydrologic Support Information No. 11: Table 3; Figure 14). These samples have a mean TDS of about 1,500 mg L^{-1}, which is about 1,000 mg L^{-1} greater than the mean of the other 40 in-mine samples. The samples were collected near an ancient coal burn that has greatly affected their solute compositions.

7. Isotopic Compositions Of Snow And Groundwater: Δ^2h And Δ^{18}

The δ^2H and $\delta^{18}O$ composition of a water molecule falling as precipitation is determined by the temperature at which nucleation of the water droplet occurs. The stable isotopic compositions of waters are usually analyzed relative to the Meteoric Water Line (MWL). The MWL is empirically derived from the worldwide plotting locations of coastal zone precipitation and is defined by the equation $\delta^2H = 8\ \delta^{18}O + 10$ (refer to Hydrologic Support Information No. 11: Appendix B for further discussion of the MWL). Relative to the MWL, precipitation that forms under cooler conditions will plot more negative than precipitation which forms under warmer conditions.

In addition to the nucleation temperature of the water molecule, several other factors may affect the isotopic composition of recharge water. These factors include rainout and orographic effects and the sublimation of snow prior to the springtime snowmelt. Sublimation often causes the isotopic composition of snow to be considerably more negative than the compositions of waters in streams and issuing from springs.

Except for unusual conditions such as geothermal heating above abut 100°C, the δ^2H and $\delta^{18}O$ composition of a groundwater is set at the time of recharge and is not affected by subsurface conditions such as residence time and mineral dissolution and precipitation reactions. In other words, the recharge and flow history of a groundwater can be evaluated independently of the solute content of the water.

The δ^2H and $\delta^{18}O$ composition of both in-mine groundwaters and groundwaters from springs and wells in the lease area are listed in Table 4 and are plotted on Figure 17 (refer to Hydrologic Support Information No. 11). All groundwaters in the study area plot near the meteoric water line (MWL) indicating a meteoric recharge origin (i.e. rain and snow; refer to Hydrologic Support Information No. 11: Figure 17). The groundwaters have stable isotopic compositions considerably more positive than snow samples (refer to Hydrologic Support Information No. 11: Table 4). We attribute the differences in the isotopic compositions of snow and groundwater samples to evaporation effects prior to groundwater recharge.

In many groundwater investigations of coal mining areas in the Wasatch Plateau and the Book Cliffs we have found that in-mine groundwaters have isotopic compositions which are distinct from spring and stream waters and which have more negative plotting locations. Although considerable scatter occurs in the δ^2H and $\delta^{18}O$ data from the study area and the data do not fit such a pattern, some preliminary conclusions may be made.

Groundwaters from wells, springs and in-mine samples collected from Trail Mountain tend to have more negative isotopic compositions than do similar samples collected from East Mountain (refer to Hydrologic Support Information No. 11: Figure 17). Such differences may be the result orographic effects associated with the morphology of the lease area and its positioning along the eastern edge of the Wasatch Plateau.

8. Groundwater Ages (^3H and ^{14}C)

The concept of groundwater age is difficult to define because water arriving at a well or spring seldom travels via pure piston flow. Instead it is usually a mixture of water molecules that recharged at different locations and at different times, thus water has no unique age. It is, therefore, best to think of a groundwater age as the *mean residence time* of the water molecules sampled at the well or spring.

In this investigation, two unstable isotopes, tritium (^3H) and carbon-14 (^{14}C), have been used to evaluate mean residence times. Tritium is a qualitative tool indicating if groundwater has a component of water that recharged since about 1954. Groundwater that recharged prior to about 1954 will contain essentially no tritium. Carbon-14 provides information regarding the number of years that have elapsed since the groundwater became isolated from soil zone gases and near-surface waters. Like tritium, ^{14}C can indicate if groundwater has a component that recharged since the 1950s. Groundwaters with ^{14}C contents greater than about 50 pmc contain anthropogenic (human-induced) carbon associated with atmospheric nuclear weapons testing. It is not uncommon for groundwater issuing from a spring or occurring in a well to be a mixture of old (i.e. containing no ^3H) and younger groundwaters.

Groundwater ages have been calculated for 13 springs, 9 in-mine locations, 2 Star Point Sandstone wells, and the Oliphant Mine discharge (refer to Hydrologic Support Information No. 11: Table 5). All springs waters, except for spring 18-4-1(Trail Mountain), contain anthropogenic carbon and appreciable amounts of ^3H and are, therefore, modern. These springs issue from alluvial systems, the North Horn Formation, the Price River Formation, the Castlegate Sandstone, and Blackhawk Formation.

Spring 18-4-1 issues from the Blackhawk Formation-Castlegate Sandstone contact at the down plunge end of the Straight Canyon Syncline (refer to Hydrologic Support Information No. 11: Figure 13). The spring water does not contain water which recharged since 1954; however, the water was likely recharged less than a few hundred years ago as is indicated by its ^{14}C content.

Most groundwaters collected inside the Cottonwood/Wilberg Mine contain essentially no tritium (refer to Hydrologic Support Information No. 11: Table 5) and have mean ^{14}C ages ranging from 2,000 to 12,000 years. Roof drip waters associated with faults (i.e., 1.5N X 29, 6W X 20, and MN-ME) contain waters 2,000 to 7,000 years old and are not in hydraulic communication with the surface (refer to Hydrologic Support Information No. 11: Table 5).

A water sample from drill hole TW-10, which intercepts groundwater in the Roans Canon Fault in the Deer Creek mine, contains anthropogenic carbon, appreciable amounts of ^{3}H, and was thus recharged less than 50 years ago. The drill hole intercepted the fault in late 1988 and the initial discharge rate was about 80 gpm. Within about two years the drip rate stabilized at about 4 to 6 gpm. ^{3}H and ^{14}C data indicate that, unlike other mine roof drips and fault waters, the discharge at TW-10 is in hydraulic communication with the surface. However, discharge from TW-10 does not exhibit seasonal fluctuations indicating that the hydrodynamics of this system are buffered. This buffering may be due to a tortuous flow path, which means a longer travel time, or the mixing of modern recharge water with older water. It is possible that the initial water intercepted by the drill hole was of similar old age as other waters encountered in the mine. Prior to intercepting the fault, the fault may have been full and rejected recharge may have occurred. The small, stabilized drip rate, 3-4 gpm, suggests that the impact to near-surface waters is limited. Groundwater associated with the Roans Canyon Fault, which is intercepted by TW-10, is further discussed in Section 6.3.2.2 (refer to Hydrologic Support Information No. 11).

Isotopic samples were also collected from gob areas in the Cottonwood and Deer Creek Mines (refer to Hydrologic Support Information No. 11: Figures 10 and 11; Table 4). The gob waters have mean ^{14}C residence times of 8,000 to 12,000 years (refer to Hydrologic Support Information No. 11: Table 5), and they contain approximately 1 TU of ^{3}H. These gob areas received most of their water from fault drainage and a small fraction of their water from process water return flows. The process water was pumped from nearby creeks and is likely responsible for the small ^{3}H contents.

A groundwater sample collected from the Oliphant Mine portal (refer to Hydrologic Support Information No. 11: T-18; Figure 9) has a mean ^{14}C residence time of 7,000 years. The Oliphant Mine is sealed and it is unknown if the discharge water issues from the mine roof or mine floor.

Two wells completed in the Star Point Sandstone, CCCW-1S and TM-3, have mean groundwater residence times of 1,000 and 6,000 years, respectively. These two wells are both completed in the Spring Canyon tongue and appear to be located on approximately the same flow line. CCCW-1S is up gradient and TM-3 is down gradient. Assuming that the two wells intercept groundwater along the same flow line, travel times can be calculated using the method described by Mooke (1980):

$$\Delta T = 8270 \ln (a_{k+1}^{14}/a_k^{14}) \qquad (11)$$

$$\Delta T = 5{,}300 \text{ years}$$

where:

ΔT = travel time (in years)

a_{k+1}^{14} = ^{14}C activity of up-gradient sample

a_k^{14} = ^{14}C activity of down-gradient sample

Assuming the travel time of 5,300 years and a distance of 4 miles, the calculated flow velocity is approximately 0.25 feet per year.

9. Groundwater Occurrence

Groundwater naturally discharges, in greatly varying quantities, from most formations exposed in Trail and East Mountains. Approximately 75% of the identified springs issue from the North Horn Formation, which comprises nearly the entire plateau surface of East and Trail Mountains. No springs have been identified which discharge from the Star Point Sandstone or the Mancos Shale.

Within the mines, groundwater issues from short-lived roof drips, the mine floors in some locations in the Trail Mountain, Deer Creek, Cottonwood, and Wilberg mines, and from the mine roof and mine floor after encountering some faults. Confined groundwater occurs in monitoring wells in the Star Point Sandstone that have been installed in the mines and elsewhere. Groundwater discharge is generally not associated with the Mancos Shale.

a. Spring Discharge Characteristics

More than 100 spring hydrographs were analyzed as part of this investigation. Approximately 75% of the springs discharge from the North Horn Formation. The remainder discharge from creek bottom alluvial systems, the Flagstaff Limestone, the Price River Formation, the Castlegate Sandstone, and the Blackhawk Formation. No springs have been identified which discharge from the Star Point Sandstone or Mancos Shale within the lease area. Because of the great number of springs for which discharge data are available, hydrographs for only selected representative springs are presented and discussed here. The maximum flow rates for some springs are probably greater than those reported due to the inaccessibly of many springs until mid-July, after the peak of the snowmelt.

b. Alluvial Springs

(1) Rilda Canyon

The North Emery Water Users Association (NEWUA) Rilda Canyon collection system captures groundwater in a series of french drains (refer to Hydrologic Support Information No. 11: Figure 9) in the shallow alluvium in Rilda Canyon (Meters 1-4). Flow meters were first installed in the piping system in September 1990 and monthly monitoring of these meters has occurred since that time. Meter 2 contains flow from the combined discharge from Side Canyon and from the vicinity of South Spring. Meter 3 measures flow from the central portion of the collection system near Rilda Canyon Creek. Previous to 1995, Meter 4 recorded flow from the north side of Rilda Canyon Creek. In 1995, flow from Meter 4 was combined with flow from Meter 3, and monitoring of Meter 4 was discontinued.

It is apparent from the NEWUA meter discharge hydrographs (refer to Hydrologic Support Information No. 11: Figure 18) that flow in this alluvial groundwater system is highly dependent upon seasonal recharge. Springtime maximum flows as great as about 180 gpm have been recorded at Meter 4 while the base flow discharge at Meter 4 has been a low as 1.5 gpm. The decline in discharge from Meter 2, which has the lowest flows of the NEWUA meters (<20 gpm) from 1990 to 1991 is believed to be the result of maintenance problems with the piping system.

PacifiCorp performed a pump-test during November 1990 in the vicinity of the Rilda Canyon collection system. The results of this testing suggested that at least 90% of the flow to the system could be accounted for by drainage directly from the shallow alluvial sediments (non-bedrock derived). The remaining <10% was believed to be derived from bedrock discharge. However, it was later learned that the thickness of saturated alluvium upgradient from the wells was thicker than that assumed at the time of the testing. If the greater thickness of saturated alluvium is used in the pump-test equations, a value greater than 90% is calculated for the percentage of flow attributable to alluvial discharge.

Because discharge data for individual meters in the Rilda Canyon collection system are only available since the end of 1990, the effects of long-term climatic fluctuations cannot be determined.

(2) Cottonwood Canyon Alluvium

In an attempt to determine the nature of the alluvial groundwater system in Cottonwood Canyon, PacifiCorp carried out a detailed hydrogeologic investigation in 1994. The investigation included construction of monitoring wells, geophysical surveys, and detailed geologic mapping. The results of the geologic mapping, drilling, and resistivity studies indicated that the maximum alluvial thickness in the canyon bottom ranges from 40 to 70 feet. The alluvial sediments consist primarily of lateral and terminal glacial moraine deposits. Below the northwest corner of Section 24, the alluvial deposits are fluvial in origin. Nested monitoring wells were installed in the alluvium in Cottonwood Canyon and in the underlying Spring Canyon member of the Star Point Sandstone. The hydrographs for these wells (refer to Hydrologic Support Information No. 11 Section 6.4) indicate that the alluvial deposits, which respond to seasonal variations in precipitation, are hydraulically isolated from groundwaters in the underlying Spring Canyon sandstone. The springs discharging near the base of Cottonwood Canyon (e.g. Roans Canyon Spring, Cottonwood Spring) are fed by shallow alluvial systems and are not related to bedrock groundwater systems in the Star Point Sandstone. In 1996, as a part of this investigation, stable and unstable isotopic data were collected from the alluvial groundwater system in Cottonwood Canyon at Roans Spring. The ^{14}C and ^{3}H compositions of this water (refer to Hydrologic Support Information No. 11: Table 5) indicate that it is of modern origin and is not related to the deep groundwater systems encountered within the mines. The interception of groundwaters within the mine workings, therefore, does not adversely impact groundwater flow rates in the alluvial springs in Cottonwood Canyon.

c. Formation Springs

(1) Flagstaff Limestone Springs

Although the Flagstaff Limestone occurs in the highest elevations of the plateau where precipitation is the greatest, only 5 springs have been identified which discharge from the limestone in the mine lease area. Spring discharges respond to both seasonal recharge and climatic factors. Hydrograph recession characteristics indicate that these springs are dependent on annual recharge events. For example, Spring 79-35 had a maximum discharge of about 20 gpm in 1979, but has gone completely dry at least three times since then (refer to Hydrologic Support Information No. 11: Figure 19a). Both climatic and seasonal effects are also illustrated in the Sheba Spring hydrograph (refer to Hydrologic Support Information No. 11: Figure 19b). The limited number of springs reflects the character of the rock. In the lease area the limestone is relatively thin (<100 feet) and groundwater can only flow in the few fractures which are interconnected. Springs occur where the width of the limestone outcrops is greatest.

(2) North Horn Formation Springs

Seventy-two springs have been identified as discharging from the North Horn Formation. Springs respond to annual recharge from snowmelt events and exhibit a wide range of discharge rates (refer to Hydrologic Support Information No. 11: Figures 19c and 19d). It is not uncommon for these springs to discharge more than 20 gpm during the springtime and to discharge less than 5 gpm during the late fall. The discharge from Elk Spring (refer to Hydrologic Support Information No. 11: Figure 19c) increased from 24 gpm in November 1994 to 600 gpm the following July 1995.

Discharge from most North Horn Formation springs is also dependent on long-term climatic trends. Substantial declines in peak flow discharges are observed in most hydrographs in the late 1980s and spikes in peak flow discharge occurred in the springtime 1994 and 1996 (refer to Hydrologic Support Information No. 11: Figure 19c).

(3) Price River Formation Springs

Thirteen springs have been identified as discharging from the Price River Formation. Although considerably fewer in number than North Horn Formation springs, these springs have similar discharge characteristics as do North Horn Formation springs. Long-term discharge data are only available for one Price River Formation spring. Seasonal variability is apparent in the hydrograph for Spring 82-52 (refer to Hydrologic Support Information No. 11: Figure 19f) and by comparing maximum and minimum measured discharges of several other springs:

Spring	*n*	*Years of Record*	*Maximum (gpm)*	*Minimum (gpm)*	*Variability Factor*
Spring 79-24	5	1979-88	60	0.7	86
Spring 79-40	11	1979-95	15	0.1	150
Spring 80-41	12	1980-95	14	0.4	35
Spring 80-44	10	1980-93	40	0.5	80
Spring 80-45	5	1980-85	12	0.5	24
Spring 80-49	5	1980-94	43	12.0	4
Spring 82-51	7	1980-95	15	3.0	5
Spring 82-52	46	1982-95	80	.2	400
Spring 89-60	6	1989-95	3	1.0	3
Jerk Water	10	1982-86	3	2.0	2

where n is the number of measurements, and the variability factor is the maximum measured discharge divided by the minimum measured discharge. Springs with a high variability factor generally are more responsive to seasonal recharge than are springs with a lower variability factor.

(4) Blackhawk Formation-Castlegate Sandstone Contact Springs

Seven springs have been identified which discharge from near the Castlegate Sandstone-Blackhawk Formation contact. Limited discharge data are available for two of these (Springs 91-72 and 91-73). Hydrographs for these springs are shown on Figures 19g and 19h (refer to Hydrologic Support Information No. 11). Maximum and minimum measured discharges are listed below:

Spring	*n*	*Years of Record*	*Maximum (gpm)*	*Minimum (gpm)*	*Variability Factor*
Spring 91-72	10	1991-96	9.2	4.9	1.9
Spring 91-73	8	1991-96	2.3	1.0	2.3

Although the data are limited, the data suggest that the discharges from these springs are somewhat seasonally dependent. Sufficient discharge data is not available to determine the response of these springs to long-term climatic trends.

(5) Blackhawk Formation springs

Only 2 springs (Spring 80-50 and 84-57) have been identified which discharge from the Blackhawk Formation. Only four flow measurements are available from two springs and seasonal discharge data are not available. The discharges measured from these springs are low, averaging only 1.6 gpm.

d. In-mine groundwater

PacifiCorp has monitored significant groundwater inflows into each of its mines since 1979. Groundwater encountered within mine openings occurs by three main mechanisms. These mechanisms include: 1) drainage from overlying sandstone channels which are penetrated by roof-bolts and by vertical boring, or which are exposed during mining, 2) interception of water bearing faults and major fracture systems which transmit water from either overlying or underlying horizons, and 3) upward leakage from the underlying Spring Canyon Member of the Star Point Sandstone.

(1) Sandstone channel groundwater

Numerous sandstone channels directly overlie coal-bearing horizons (refer to Hydrologic Support Information No. 11: Figures 20 and 21). These channels may be several miles long, up to 1000 feet wide and are commonly 25 to 30 feet thick. These channels have varying degrees of water saturation, which results in wet and dry regions of the mine.

It is common in wet portions of the mines for roof-drip groundwater to be encountered at the mining-face during mining operations. Most roof-drips typically are short lived, persisting for only a few weeks before the flow completely ceases. Thus, the roof-drips appear to dry up behind the mining operations. The discharges from these short-lived inflows into the mine are typically not recorded. In other portions of the mines, the coal seam and adjacent rocks are completely dry.

Occasionally, areas with greater, more persistent inflows are encountered. These sources are usually associated with faults or large sandstone channels that contain greater quantities of water. Such fault-channel systems are discussed below.

Typical hydrographs of roof drips that have not dried up immediately are shown on Figure 22 (refer to Hydrologic Support Information No. 11). Carbon-14 ages of 6,500 and 12,000 years (refer to Hydrologic Support Information No. 11: Table 5) have been determined for groundwaters issuing from locations TMA X 32 and 2S X 11, respectively. The discharge declines of the hydrographs typically follow an exponential decay, with the greatest flow occurring immediately after the source is completely exposed and then falling off rapidly. The tail end of the discharge hydrograph typically trails off gradually, with slowly decreasing rates of discharge. Near the end of the discharge recession, the discharge hydrograph may appear nearly flat. Occasionally, a hydrograph may show a marked increase in discharge after the initial peak has passed. This is usually due to a change in the geometry of the system due to mining activities in the vicinity of the discharge.

In an attempt to quantitatively evaluate saturated sandstone channels, a dripping channel in the 6th West area of the Deer Creek Mine was investigated (site 6W X 20; Figure 10). The channel, located near a minor fault with very limited displacement, has the dimensions of >2,000 feet in length, 150 feet in width and a maximum thickness of 25 feet. An array of up-hole monitoring wells was installed across the width of the channel. The wells were 15 to 25 feet deep and were open along their entire depth. Each well was equipped with a shutoff valve and pressure gauge. The idea was to conduct a pump test by letting selected wells gravity drain and simultaneously measuring pressure change in nearby wells. Because a maximum of about 2 psi was recorded in the well (i.e. ~5 feet of water) we were unable to conduct the test. What the well did demonstrate was that the sandstone channel was not fully saturated and it was a perched, unconfined groundwater system. Water issuing from the channel has a mean ^{14}C age of 2,000 years (refer to Hydrologic Support Information No. 11: Table 5). The perched, unconfined groundwater system evaluated in the 6th West area is consistent with the commonly observed roof drip conditions.

(2) Fault water

Groundwater has been encountered in 3 faults in the PacifiCorp mines. These include the Pleasant Valley Fault in the both the Deer Creek Mine and Cottonwood/Wilberg Mine, the Roans Canyon Fault, and the Left Fork Graben in the Deer Creek Mine. The groundwater flow regimes associated with each of these faults are described below.

(a) Pleasant Valley Fault

The Pleasant Valley Fault is a north-south trending fault, which is exposed in both the Wilberg and Deer Creek Mines (refer to Hydrologic Support Information No. 11: Figure 5). The fault was first encountered in the early 1970s by Peabody Coal Co. during the construction of rock slopes and has been encountered in at least 4 different locations in the Wilberg Mine. When the fault was first crossed during mining, groundwater discharge primarily occurred as floor upwelling in the Wilberg mine and as roof drips in the Deer Creek Mine. The discharge rate was small and never exceeded 50 gpm in any location. PacifiCorp□s initial monitoring location in the Wilberg Mine discharged 50 gpm. Within 2 or 3 months, the flow from the fault had diminished greatly and the sampling point became only a puddle on the floor. Groundwater discharge rates from other locations on the Pleasant

Valley Fault are also small but are more constant. Groundwater discharging from Pleasant Valley Fault sampled as part of this investigation is of ancient origin.

Three samples of fault-related groundwater were collected as part of this investigation for radiocarbon dating (6W X 20 and MN-ME in the Deer Creek Mine, and 1.5N X 29 Fault in the Wilberg Mine; refer to Hydrologic Support Information No. 11: Table 5). The recession hydrograph for MN-ME (refer to Hydrologic Support Information No. 11: Figure 23) shows that discharge has steadily declined from about 0.5 to 0.2 gpm over 4 years. Groundwater issuing from 6W X 20, MN-ME and 1.5N X 29 have ^{14}C ages of 2,000, 7,000 and 4,500 years, respectively (refer to Hydrologic Support Information No. 11: Table 5).

(b) Roans Canyon Fault

The Roans Canyon fault system forms a graben which trends in a northeasterly direction through the middle of Trail Mountain and northern East Mountain (refer to Hydrologic Support Information No. 11: Figure 5). The fault is parallel with and adjacent to the axis of the Straight Canyon Syncline. The Roans Canyon Fault was first encountered in the Deer Creek Mine in a series of horizontal drill holes completed in 1985. A second series of horizontal drill holes penetrated the fault system in 1989. The purpose of these drill holes was to evaluate the porosity of the fault system and to evaluate the potential for dewatering of the fault ahead of mining operations. Limited lateral communication along the fault system was suggested by the fact that discharge from drill holes located only 200 feet apart did not significantly affect the discharge rates of the individual holes.

The fault was first encountered in a mine opening in 1st Right in January 1990. Substantial groundwater inflows of several hundred gallons per minute occurred in each of the entries.

The water discharging from the fault was entirely from the roof and appeared to be related to a large, overlying sandstone channel. A small sympathetic fault with less than 5 feet of offset associated with the Roans Canyon Fault was subsequently encountered in the 2nd Right entries in April 1990. Peak discharge from was estimated at 5,000 gpm. The last measurement of discharge from the fault zone (from an established monitoring point in 1989) collected in March 1991 was 150 gpm. Currently, the discharge from the fault zone is believed to be less than 150 gpm. The large discharge rate from the Roans Canyon Fault had a profound effect on the discharge rate from the Deer Creek Mine (refer to Hydrologic Support Information No. 11: Figure 24).

Groundwater from the Roans Canyon Fault was encountered with a series of test wells including TW-10, a 1,100 foot long horizontal hole drilled into the fault system in the Deer Creek Mine (refer to Hydrologic Support Information No. 11: Figure 10). It was apparent during drilling that groundwater issuing from TW-10 was from a sandstone channel that had been highly fractured. Ubiquitous iron oxide in the fractured sandstone indicated that water in the fracture had been in good communication with atmospheric gases. Although TW-10 is under considerable cover (1,200 feet), it is located near the cliff faces. The cliff face rocks are extremely fractured and open to recharge water. The average temperature of groundwater from TW-10 is 7.7°C while the average temperature of other groundwaters in the Deer Creek Mine is 11.8°C. The cooler temperature of water from TW-10 relative to other in-mine groundwaters is attributed to the location of TW-10 near cliff faces.

The discharge rate from TW-10 has declined from about 80 gpm in 1989 to about 5-6 gpm in 1997 (refer to Hydrologic Support Information No. 11: Figure 23). Groundwater sampled from this location in 1996 contained anthropogenic ^{14}C and had a ^{3}H content of 20.8 TU (refer to Hydrologic Support Information No. 11: Table 5). These data indicate that groundwater now discharging from TW-10 is in hydraulic communication with recent recharge water. Discharge from TW-10 does not exhibit seasonal fluctuations indicating that the hydrodynamics of this system are buffered. This buffering may be due to a tortuous flow path, which means a longer travel time, or the mixing of modern recharge water with older water. It is possible that the initial water intercepted by the drill hole was of similar old age as other waters encountered in the mine. Prior to intercepting the fault, the fault may have been full and rejected recharge may have occurred.

In an attempt to determine whether groundwaters discharging from the Roans Canyon Fault deeper within the mine, away from the cliff face, are tied to active, modern groundwater systems, a sample of the longwall gob water (3S Seals) in the Deer Creek Mine was collected and analyzed for isotopic composition. It is important to note, however, that this water is a composite sample of groundwater discharging from the fault and other in-mine sources, and a small percentage of Huntington Creek water used as process water in mining operations. The ^{14}C age of this sample is 12,000 years, with a tritium content of 0.9 TU (refer to Hydrologic Support Information No. 11: Table 5). We believe that the small component of tritium in the water is derived from the creek water. Therefore, we conclude that the groundwater in the Roans Canyon Fault deep within the mine, away from cliff faces, is of ancient origin and is likely not related to overlying shallow groundwater systems.

e. Well hydrographs

Historic water-level monitoring information is available for 16 wells from the study area. These wells monitor groundwater levels in alluvial systems, the Blackhawk Formation, and the Star Point Sandstone.

(1) Alluvial system wells

(a) Cottonwood Canyon

PacifiCorp currently monitors three wells completed in alluvium in Cottonwood Canyon. These include CCCW-1A, CCCW-2A, and CCCW-3A (refer to Hydrologic Support Information No. 11: Figure 9). Well screen intervals and gravel pack intervals are:

Well	Screen interval (ft)	Gravel pack (ft)
CCCW-1A	96 ▯ 126	40-136
CCCW-2A	96-126	42-136
CCCW-3A	51 ▯ 81	83-101

Hydrographs for each of these wells (refer to Hydrologic Support Information No. 11: Figure 25) show responses to annual precipitation. The somewhat muted hydrograph responses may be the result of depth of the screened intervals.

(b) Rilda Canyon

Seven shallow wells were constructed in alluvium in Rilda Canyon in the mid 1980s (refer to Hydrologic Support Information No. 11: Figure 9). Hydrographs for these wells, identified as P-1 through P-7, are shown in Figure 26 (refer to Hydrologic Support Information No. 11). All of the wells show the effects of annual precipitation. The hydrographs for P-1 and P-5 show less response to seasonal precipitation than do the other hydrographs. Well P-1 is located downgradient and is likely affected by the discharge from a series of upgradient springs. Well P-5 is located in the creek bottom near the NEWUA collection system. Previous researchers have suggested that the smaller hydraulic fluctuations observed in these wells are likely due to the situation of the wells in the narrow creek bottom above bedrock highs where alluvial groundwater is forced to flow near the surface.

(c) Blackhawk Formation Wells

Only 1 well, CCCW-3SU, monitors groundwater levels in the lower Blackhawk Formation. The well head is situated atop alluvial deposits in the bottom of Cottonwood Canyon (refer to Hydrologic Support Information No. 11: Figure 9). The well hydrograph (refer to Hydrologic Support Information No. 11: Figure 25) suggests that the formation responds to annual precipitation. However, we attribute the seasonal responses to hydraulic communication between overlying alluvial sediments and the well gravel-pack. The hydrograph response is similar to hydrographs in nearby alluvial system wells and the distance from the base of the alluvial deposits to the top of the gravel-pack zone is only 27 feet. We believe that the water level fluctuations are due to the seasonal groundwater fluctuations in the creek-bottom alluvium.

(d) Star Point Sandstone Wells

Six monitoring wells have been completed in the Star Point Sandstone from the surface. The locations of the wells are shown on Figure 9 (refer to Hydrologic Support Information No. 11:, and each well is described below).

(i) Well CCCW-

1SWell CCCW-1S is located in Cottonwood Canyon near the axis of the Straight Canyon Syncline (refer to Hydrologic Support Information No. 11: Figure 9). The well has a total depth of 720 feet, and is screened between 655 to 705 feet in the Spring Canyon Member. There is approximately 475 feet of potentiometric pressure in water in the well and the potentiometric level declined slightly, approximately 10 feet, between early 1993 and early 1995. Since then the water level in the well has remained relatively constant (refer to Hydrologic Support Information No. 11: Figure 25). The well hydrograph does not respond to seasonal recharge.

(ii) Well CCCW-3S L

Well CCCW-3SL is located in Cottonwood Canyon (refer to Hydrologic Support Information No. 11: Figure 9). The well has a total depth of 730 feet, and is screened between 680 and 730 feet in the Spring Canyon Member. The well is part of a multiple completion well with CCCW-3SU. There is approximately 80 feet of potentiometric pressure in water in the well and the potentiometric level declined slightly, approximately 5 feet, between early 1993 and early 1994. Since then the water level in the well has remained relatively constant (refer to Hydrologic Support Information No. 11: Figure 25). The well hydrograph does not respond to seasonal recharge.

(iii) TM-1B

Well TM-1B is located in Cottonwood Canyon stratigraphically below the portal of the Trail Mountain Mine (refer to Hydrologic Support Information No. 11: Figure 9). The well has a total depth of 500 feet, and is screened between 380 and 460 feet in the Panther Tongue. There is approximately 350 feet of potentiometric pressure in water in the well. The potentiometric level has remained constant and the well hydrograph does not respond to seasonal recharge (refer to Hydrologic Support Information No. 11: Figure 25).

(iv) TM-3

Well TM-3 is located at the south end of the Trail Mountain Lease in Straight Canyon (refer to Hydrologic Support Information No. 11: Figure 9). A hydrograph for this well is shown in Figure 27a (refer to Hydrologic Support Information No. 11). The well has a total depth of 560 feet, and is screened between 505 and 555 feet in the Spring Canyon Member. When first completed in September 1993, the well flowed freely at the surface and maintained a constant shut-in pressure of 64 psi (approximately 150 feet) for several years. The well was opened in December 1996 and allowed to free flow at approximately 20 gpm for one week to facilitate chemical and isotopic sampling. After the sampling, the well was again shut in and the hydraulic head has decreased steadily since that time. On 22 August 1997, the water level had declined to 75 feet below land surface.

Although the cause of the reduction of hydraulic head is problematic, it is likely that the decrease is the result of depressurization of the Spring Canyon Member in the vicinity of the well. Mining operations in the Hiawatha seam in the southern portion of the Trail Mountain Mine are currently located approximately 0.5 miles northeast of well TM-3. In the Trail Mountain Mine the Hiawatha seam is located directly on the Spring Canyon Member.

Approximately 200 to 300 gpm of groundwater upwells from the Spring Canyon Member to the mine floor in the current mining area. Because the current mining area is located up dip of well TM-3, mining is likely the cause of the depressurization.

Prior to mining, the elevation of the potentiometric level in TM-3 was 6900 feet. The top of the Spring Canyon Member is exposed in Cottonwood Creek 1.7 miles southeast of TM-3 at an elevation of 6500 feet. Because the Spring Canyon Member crops out below the potentiometric level reflected by TM-3, there is a hydrodynamic potential for water to discharge from the Spring Canyon Member to Cottonwood Creek. However, we believe that very little, if any, groundwater discharges to Cottonwood Creek from this horizon and therefore depressurization of the Spring Canyon Member will not decrease flow in Cottonwood Creek. Two lines of evidence support this conclusion. First, natural groundwater discharge would be indicated by springs in the Spring Canyon Member; however no springs have been identified in this unit in the vicinity of Cottonwood Creek. Second, we have calculated a maximum potential discharge of 1 gpm based on the assumptions described below. This discharge rate was calculated using Darcy□s law:

$$Q = K I A,$$

where,

Q = discharge rate

K = hydraulic conductivity

I = gradient

A= cross sectional area.

PacifiCorp (1994) calculated a hydraulic conductivity of 4.3×10^{-6} feet sec^{-1} for the Spring Canyon Member from a recovery test conducted on well TM-3. A gradient of 0.05 was calculated from the difference between the pre-mining elevation of the potentiometric level in TM-3 (6900 feet) and the outcrop elevation of the Spring Canyon Member in Cottonwood Creek (6450 feet) divided by the distance separating these two points (9000 feet). A cross sectional area of 10,000 ft^2 was calculated using the thickness of the Spring Canyon Member (100 feet) and a 100-foot exposure width.

(v) Well EM-31

Well EM-31 is located in Cottonwood Canyon (refer to Hydrologic Support Information No. 11: Figure 9). The well head is located on alluvial deposits just above the Trail Mountain Mine portals. The thickness of the alluvium at the well head is 20 feet. A 20-foot thick layer of sandstone and a 10-foot thick sequence of interbedded siltstone and mudstone underlie the alluvium. The well has a total depth of 280 feet. Although the well casing is perforated from 190 to 250 feet, the gravel-pack zone extends from 50 feet to 280 feet which provides opportunity for vertical communication between saturated horizons. The hydrograph of EM-31 (refer to Hydrologic Support Information No. 11: Figure 27b) shows that the well responds subtly to annual precipitation and long-term climatic cycles. We believe that these hydraulic responses are due in large part to hydraulic communication between the gravel-pack zone and shallow, overlying groundwater systems. The Star Point Sandstone, in other locations, does not respond to annual precipitation or climatic trends.

(vi) Well EM-47

Well EM-47 is located in Rilda Canyon (refer to Hydrologic Support Information No. 11: Figure 9). The well head is located in alluvial deposits near Rilda Canyon Creek. The well has a total depth of 300 feet, and is screened between 210 and 270 feet in the Spring Canyon Tongue. Water levels in the well respond to annual precipitation events, and since about 1986 there has been a general decline in water levels (refer to Hydrologic Support Information No. 11: Figure 27b). The annual responses are attributed to well completion problems rather than to fluctuations in water levels in the Spring Canyon Member. The coarse gravel-pack interval in this well is from 50 to 300 feet. The gravel used was 0.25 to 0.375 inches in diameter. The thickness of the alluvium at the surface is 25 feet, and the bedrock underlying the alluvium is a continuous sandstone layer that extends to a depth of 70 feet. Thus there is only 25 feet of sandstone separating the gravel-pack from the surface alluvium. The general decline in water surface elevation since about 1986 may be the result of climatic variability.

f. In-mine piezometers

(1) Deer Creek Mine

In late 1989 four piezometers were constructed in the Deer Creek Mine to monitor groundwater levels in the lower portion of the Blackhawk Formation and in the Spring Canyon Member of the Star Point Sandstone beneath the mine workings. The piezometers designated DCP-1 through DCP-4, and are all located in the 3rd North/1st West Mains area (refer to Hydrologic Support Information No. 11: Figure 10). Each of the wells has a 20-foot surface casing and is open for 150 feet below that. Thus, each of the wells are open to Blackhawk Formation sandstones and claystones located above the Hiawatha seam, the Hiawatha coal seam, and the Spring Canyon Member of the Star Point Sandstone. What this means is that water levels represent composite hydraulic heads and are not necessarily representative of the Spring Canyon Member or the lower Blackhawk Formation.

Two of the piezometers (DCP-1 and DCP-4) had initial static water levels which rose to the bottom of the mine workings (Blind Canyon seam), and two of the piezometers (DCP-2 and DCP-3) had initial static water levels which rose to the middle of the lower portion of the Blackhawk Formation. Between mid-1990 and mid-1993 a transient potentiometric level decline occurred in Wells DCP-1, DCP-3, and DCP-4 (refer to Hydrologic Support Information No. 11: Figure 28). Mine workings containing DCP-2 and DCP-4 were sealed in late 1991, workings containing DCP-3 were sealed in late 1993, and data collection ended. By early 1997 the potentiometric level in DCP-1 recovered to the initial static level. There are two possible causes of the transient response. The potentiometric decline approximately coincides with the Roans Canyon Fault dewatering. However, it is difficult to envision a correlative mechanism. The fault drained a sandstone channel located above Blind Canyon

Seam and the piezometers are located below the seam 0.3 to 1 mile southwest of the fault. If the decline were related to fault dewatering, there is not a mechanism for piezometric recovery.

The transient response is most likely related to mining along the Straight Canyon Syncline in an area located down dip and to the west of the piezometers and not to depressurization and subsequent repressurization of the Spring Canyon Member. During mining, considerable floor water was encountered. Upon completion of mining, the area was sealed and flooded. We believe that the piezometric decline was the result of the down gradient depressurization and recovery in the lower portion of the Blackhawk Formation.

(2) Cottonwood Mine piezometers

In late 1989 four piezometers (WCP-1 through WCP-4) were constructed in the Cottonwood Mine to monitor groundwater levels in the Spring Canyon Member of the Star Point Sandstone (refer to Hydrologic Support Information No. 11: Figure 11). Each of the wells has a 10-foot surface casing and is open holes for 60 to 130 feet below that. Thus, each of the wells is open to Spring Canyon Member and interbedded clays separating the Spring Canyon Member from the Storrs Member. Well WCP-1 is also open to the upper portion of the Storrs Tongue. The workings containing the piezometers were progressively sealed starting in late 1989 to late 1990 and data are not available after that. Potentiometric levels in wells WCP-2, WCP-3, and WCP-4 show no seasonal variations. Water levels increased slightly in WCP-3 and WCP-4 (refer to Hydrologic Support Information No. 11: Figure 29). The potentiometric record for WCP-1 suggests some fluctuation in the hydraulic head in the well. However, it is believed that the fluctuations in head are the result of a malfunctioning pressure transducer and are not representative of actual conditions in the formation. The pressure transducer was replaced in early 1990. Seasonal variations in potentiometric levels are not observed.

g. Steady state recharge-discharge rates in-mine groundwaters

The fact that in-mine groundwaters do not have infinite ^{14}C ages means that there must at some time have been some hydraulic communication between the near-surface and in-mine (deep) groundwater systems. We believe that this communication most likely occurred during a cooler, wetter climatic cycle, when more water was available for groundwater recharge.

An alternative way to view the deep groundwater regime is that the groundwater is in constant flux and that the rate of groundwater movement is slow. If we make the assumption that the water discharging in the mine from deep systems is in equilibrium with its recharge, it is possible to calculate an estimate of the steady-state throughput of the system. These calculations are based on an estimate of the total volume of water in storage in the system being drained, and the calculated radiocarbon age of the water. In the nearby Bear Canyon Mine we calculated a steady state recharge-discharge rate of 1.2 gpm for a sandstone channel containing about 1 billion gallons of water. The 3,250-foot long channel, located above the Blind Canyon seam, contained groundwater with a mean residence time of 1,500 years. These types of calculations give an approximation of the *maximum* flux of water through the system *if* deep systems were currently in hydraulic communication with adjacent active systems. However, we believe that the actual flux of groundwater through these systems is generally less than that calculated because we do not believe that the deep systems are currently in communication with the near-surface systems. Similar steady state recharge-discharge rate calculations for the Roans Canyon and Pleasant Valley faults, and typical sandstone channels located above the mined coal seams are shown below:

(1) Faults

(a) Roans Canyon Fault/Straight Canyon Syncline

The largest single influx of water into the mine, about 5×10^9 gallons, was from the Roans Canyon Fault/Straight Canyon Syncline. Carbon-14 ages are not available directly from groundwaters issuing from the fault/syncline. However, water from longwall gob areas (3S Seals and MW Seals), which contain mostly Roans Canyon Fault/Straight Canyon Syncline discharge water, have ^{14}C ages of 8,000 and 12,000 years (refer to Hydrologic Support Information No. 11: Table 5). Based on these data a range of values for steady state recharge-discharge conditions are:

$$\frac{5 \times 10^9 \text{ gallons (storage capacity)}}{8{,}000 \text{ years } (4.2 \times 10^9 \text{ minutes; residence time})} = 1.23 \text{ gpm}$$

$$\frac{5 \times 10^9 \text{ gallons (storage capacity)}}{12{,}000 \text{ years } (6.3 \times 10^9 \text{ minutes; residence time})} = 0.79 \text{ gpm}$$

(b) Pleasant Valley Fault:

Only small discharges have been measured from the Pleasant Valley fault. A more reasonable estimate of the discharge from the Pleasant Valley fault is 25 gpm for 20 years. Groundwater ^{14}C ages of 4,500 to 7,000 years have been calculated for sites 1.5N X 29 (Wilberg Mine) and MN-ME (Deer Creek Mine), respectively (refer to Hydrologic Support

Information No. 11: Table 5). Based on these data a range of values for steady state recharge-discharge conditions are:

$$\frac{2.6 \text{ x } 10^8 \text{ gallons (storage capacity)}}{7{,}000 \text{ years } (3.7 \text{ x } 10^9 \text{ minutes; residence time})} = 0.07 \text{ gpm}$$

$$\frac{2.6 \text{ x } 10^8 \text{ gallons (storage capacity)}}{4{,}500 \text{ years } (2{,}4 \text{ x } 10^9 \text{ minutes; residence time})} = 0.11 \text{ gpm}$$

(c) Sandstone Channels

Drip rate data and ^{14}C ages are available for three sandstone channels. The channels have been monitored at locations 2S X 11 (Cottonwood Mine), TMA X 32 (Cottonwood Mine) and UG-3 (Trail Mountain Mine). Additional groundwater storage data and the ^{14}C groundwater age is available from 6W X 20 (Deer Creek Mine). Steady state recharge-discharge rate calculations are shown below:

(i) 2S X 11 (Cottonwood Mine):

The roof drip (refer to Hydrologic Suport Information No. 11: Figure 22a) shows a gradual decline from about 0.11 gpm in 1984 to about 0.06 gpm in 1996. The hydrograph recession suggests the drip will dry flow for about 30 total years. Based on a mean drip rate of 0.06 gpm the total discharge will be 9.5 x 10^6 gallons.

$$\frac{9.5 \text{ x } 10^6 \text{ gallons (storage capacity)}}{12{,}000 \text{ years } (6.3 \text{ x } 10^9 \text{ minutes; residence time})} = 0.002 \text{ gpm}$$

Assuming the drip at 2S X 11 only represented 10% of the total volume of water in the channel the steady state recharge-discharge rate would be 0.02 gpm. If the drip only represented 1% of the total volume of water in the channel the steady state recharge-discharge rate would be 0.2 gpm.

$$\frac{2.6 \times 10^6 \text{ gallons (storage capacity)}}{6{,}500 \text{ years } (3.4 \times 10^9 \text{ minutes; residence time})} = 0.001 \text{ gpm}$$

(ii) TMA x 32 (Cottonwood Mine):

The roof drip (refer to Hydrologic Support Information No. 11: Figure 22d) shows a decline from about 10 gpm in October 1994 to 2 gpm in April 1996. The hydrograph recession suggests that the drip will flow for 5 years or less and the average drip rate will be 1 gpm or less. Based on a mean drip rate of 1 gpm the total discharge will be 2.6×10^6 gallons.

Assuming the drip at TMA X 32 only represented 10% of the total volume of water in the channel the steady state recharge-discharge rate would be 0.01 gpm. If the drip only represented 1% of the total volume of water in the channel the steady state recharge-discharge rate would be 0.1 gpm.

(iii) UG-3 (Trail Mountain Mine):

Reliable hydrograph data are not available for UG-3. Monitoring by PacifiCorp first occurred in May 1990 when a flow of 25 gpm was measured. In mid-1995 the drip had declined to about 5 gpm. Assuming a drip life of 20 years and a mean drip rate of 5 gpm the total discharge will be 5.3×10^7 gallons.

$$\frac{5.3 \times 10^7 \text{ gallons (storage capacity)}}{5{,}500 \text{ years } (2.9 \times 10^9 \text{ minutes; residence time})} = 0.018 \text{ gpm}$$

Assuming the drip at UG-3 only represented 10% of the total volume of water in the channel the steady state recharge-discharge rate would be 0.18 gpm. If the drip only represented 1% of the total volume of water in the channel the steady state recharge-discharge rate would be 1.8 gpm.

h. Groundwater Model: Active/Inactive Zones

The overall pattern of groundwater flow and surface water-groundwater interactions in the mine lease area can be described by a fairly simple conceptual model involving both active and inactive groundwater flow regimes (refer to Hydrologic Support Information No. 11: Figure 30). Active regime groundwater flow systems contain abundant ^3H, have excellent hydraulic communication with the surface and thus are dependent on annual recharge events and are affected by short term climatic variability. Groundwater in these systems circulates shallowly and has short flow paths. The active regime includes alluvial groundwater, all of the Flagstaff Limestone, near-surface exposures of all other bedrock formations except, perhaps, the Mancos Shale. The "near surface" extends about 500 to 1,000 feet into cliff faces and is controlled by fracturing, weathering, and the surface exposures of fluvial channel sands. Further into the cliff faces the discontinuous character of the channel sands prevents active groundwater flow.

Inactive groundwater flow regimes contain old groundwater (i.e. 2,000 to 12,000 years), have very limited hydraulic communication with the surface and with other active groundwater flow systems, and are not influenced by either annual recharge events or short term climatic variability. Groundwater in these systems tends to occur in sandstone channels in the North Horn, Price River, and Blackhawk Formations which are not in direct hydraulic communication with the surface (i.e. greater than about 500 to 1,000 feet from cliff faces). These sandstone channels are vertically and horizontally isolated from each other and when encountered in mine workings are usually drained quickly. The blanket sands of the Star Point Sandstone are also largely in the inactive zone. For the most, part faults encountered in mine workings are part of the inactive regime.

A report by the U.S. Geological Survey (Lines, 1985) states that there exists a regional aquifer in the lower Blackhawk Formation and Star Point Sandstone in the Wasatch Plateau. Lines also postulates that the regional aquifer is recharged by the downward migration of groundwaters from overlying perched groundwater systems in the North Horn and Price River Formations. For several reasons, we believe that these ideas are incorrect. Groundwaters encountered within mine openings in the lowermost Blackhawk Formation occur primarily within discontinuous sandstone channels. It is not uncommon for some of these channels to be completely dry, while others are partially or completely filled with water. Between these sandstone channels, the surrounding shales and claystones of the

Blackhawk Formation are usually dry. The discontinuous nature of the saturated sediments in the lowermost Blackhawk Formation, and the unconfined conditions under which these groundwaters exist do not support the idea of a deep, regional system with groundwater flowing from areas of recharge to areas of discharge. Additionally, the radiocarbon and tritium age dating of waters from the lower Blackhawk Formation (refer to Hydrologic Support Information No. 11: Section 5.4) indicates that, while the groundwaters from the shallow perched groundwater systems are modern (post-1954), groundwaters from the Blackhawk Formation and Star Point Sandstone are thousands of years old. Because the mine workings do not intercept the Star Point Sandstone, less is known about the continuity of groundwater systems there. However, groundwaters in the Star Point Sandstone are thousands of years old (refer to Hydrologic Support Information No. 11: section 5.4) and occur in laterally discontinuous sandstone tongues bounded by nearly impermeable shale units of the Mancos Shale. Because of the lateral discontinuity of these tongues, regional groundwater flow regimes cannot develop.

We believe that the presence of swelling clays and impermeable shales in the rocks in the unsaturated zone between the overlying perched systems and the Blackhawk Formation effectively prohibit downward vertical migration of waters from the perched systems. Lines (1985) analyzed cores taken from well (D-17-6)27bda-1 and found the hydraulic conductivities of the shales and siltstones to be very low (i.e. 10^{-7} to 10^{-8} ft/day). One shale sample was found to be effectively impermeable even when a hydraulic pressure of 5,000 psi was applied.

Because there are no areally extensive groundwater regimes in the lower Blackhawk Formation or Star Point Sandstone within the lease area, it is not possible to draw meaningful potentiometric surface maps of these systems. Lines (1985) also reported that water was likely leaking from the Joes Valley Reservoir downward into the lower Blackhawk / Star Point aquifer in Straight Canyon. We believe that this is incorrect. Groundwater collected from well TM-3, which is completed in the Star Point Sandstone, in Straight Canyon just below the reservoir has a radiocarbon age of 6,000 years, while water in Joes Valley Reservoir is of modern origin. Water levels in TM-3 do not respond to seasonal fluctuations in the water level in Joes Valley Reservoir, indicating that there is little or no hydraulic communication between the reservoir and water in the Star Point Sandstone. Groundwater was sampled at UG-3 in the lower Blackhawk Formation in the Trail Mountain Mine. This water has a radiocarbon age of 5,500 years, which is likewise not consistent with water from the reservoir.

i. Conclusions From Mayo & Associates Hydrologic Investigation

1. The δ^2H and $\delta^{18}O$ compositions demonstrate that all groundwaters are of meteoric origin (i.e. snow and rain).
2. Active and inactive groundwater regimes occur in the mine lease area.
3. The active regime includes alluvial groundwater, groundwater in the Flagstaff Formation, and all near surface exposures of the other bedrock formations except, perhaps, the Mancos Shale. The near surface extends about 500 to 1,000 feet into cliff faces. Groundwaters in the active regime contain abundant ^3H and anthropogenic ^{14}C.

4. Comparison of long-term discharge hydrographs with precipitation records demonstrates that active regime groundwaters: 1) are in direct hydraulic communication with the surface, 2) are recharged by modern precipitation, and 3) have large fluctuations in spring discharge rates which can be attributed to seasonal and climatic variability. High-flow/low-flow discharge rates vary as greatly as 600 gpm to nearly dry; however, most high flow rates are less than 50 gpm.
5. Despite the seasonal variability in discharge rates, the solute concentrations of active region groundwaters do not exhibit significant seasonal variability.
6. The inactive regime includes groundwater in sandstone channels in the North Horn, Price River, and Blackhawk Formations which are not in direct hydraulic communication with the surface (i.e. greater than about 500 to 1,000 feet from cliff faces). Mine workings are largely part of the inactive regime. The sandstone channels are vertically and horizontally isolated from each other and when encountered in mine workings are usually drained quickly. Coal seams are hydraulic barriers to groundwater flow. The blanket sands of the Star Point Sandstone are also largely in the inactive zone. Except where exposed near cliff faces, faults encountered in mine workings are part of the inactive regime. Except near cliff faces, faults are not conduits for vertical hydraulic communication between otherwise hydraulically isolated pockets of groundwater.
7. Inactive region groundwater systems contain old groundwater (i.e. 2,000 to 12,000 years), and are not influenced by annual recharge events or short term climatic variability.
8. In-mine inactive regime groundwaters occur in nearly stagnant, isolated zones which have extremely limited hydraulic communication with other inactive regime

groundwaters in the vicinity of mine workings and with near-surface active regime groundwaters as evidenced by the following:

a) Groundwaters discharging into mine openings have ^{14}C ages ranging from 2,000 to 12,000 years

b) Roof drip rates rapidly decline when water is encountered in the mine indicating that the saturated zone above the coal seam is not hydraulically continuous and has a limited vertical and horizontal extent.

c) Unsaturated conditions have been identified in boreholes drilled vertically into sandstone channels located above coal seams.

9. The fact that inactive region groundwaters encountered in mine openings do not have an infinite age means that, at some time, there has been some hydraulic communication with the surface. This communication is extremely limited as illustrated by calculated steady state recharge-discharge rates of faults and sandstone channels in the inactive zone which range from 0.001 to 1.23 gpm.

10. Groundwater in the Star Point Sandstone is part of the inactive regime as evidenced by the 6,000 year ^{14}C age of the sample from well TM-3. In the down dip direction along the axis of the Straight Canyon Syncline, potentiometric pressures in the Spring Canyon member results in upwelling of groundwater into Hiawatha seam mine openings. Such upwelling may locally reduce the pressure in the Spring Canyon member.

11. Areally extensive groundwater regimes in the lower Blackhawk Formation and Star Point Sandstone do not exist within the lease area. Therefore, it is not meaningful to create piezometric surface maps of these systems.

12. Streamflow is dependent on snow melt, precipitation and thunderstorm activity. There is no apparent hydraulic communication between streamflow and groundwater encountered in mine openings.
13. The groundwater discharging into the Rilda Canyon alluvial collection system is of modern origin and is closely tied to seasonal recharge. This is evidenced by its modern radiocarbon and ^{3}H contents and by the discharge hydrographs. The alluvial groundwater is not related to the groundwater encountered in the mines.
14. The groundwater discharging in Cottonwood Canyon near Cottonwood Spring and Roans Spring discharges from glacial deposits and is of modern origin. The radiocarbon and ^{3}H contents of this water indicate a modern origin. The water in the shallow glacial deposits is not related to the groundwater encountered in the mines.

10. Mine Dewatering

Water encountered within the Deer Creek and Wilberg/Cottonwood mines (Des-Bee-Dove is a dry mine) has generally been confined to the perched aquifer systems and fractures-faults associated with the Blackhawk Formation as discussed earlier. Water enters the mines through various avenues including roof leakers (drippers) from overlying fluvial sandstone channels, bolt holes, tension cracks in the overlying strata, longwall caved areas, and where fractures or faults have been intersected by the mine workings. Excess water not utilized in the mining operation or for domestic use is either pumped to storage areas or discharged from the mine under approved UPDES permits (see Appendix B for UPDES permit information). A complete description of the quality and quantity is reported in the annual Hydrologic Monitoring reports and also in the PHC section (R645-301-728).

11. Groundwater Rights And Users

Nine springs have been developed in Huntington Canyon to provide for domestic, industrial, and commercial water needs. Currently, Huntington City utilizes two springs in Huntington Canyon, Big Bear Canyon Springs and little Bear Canyon Springs. The North Emery Water Users Association also utilizes springs in Huntington Canyon to provide for domestic and industrial water needs in areas outside of Huntington City. The Association is currently utilizing water from three springs in Rilda Canyon as well as from four other springs in the general area (see Map HM-1).

Some of the springs on East Mountain have been developed for watering livestock by installing troughs, and Elk Springs has limited use as a culinary water source for cabins in the area. See Table HT-4 for a summary of the springs within the permit area, their location, and any claims placed on the water they produce.

a. North Emery Water Users Association

Of concern to PacifiCorp is the proximity of proposed mining activities in Rilda Canyon to the Rilda Canyon Springs which currently serve as a culinary water source to the North Emery Water Users Association (NEWUA) serving some 410 connections. Due to the importance of these springs, a separate discussion is provided herein describing the nature of NEWUA's Rilda Canyon Springs and the sources of the waters issuing from them. The structural geologic setting is described, followed by an analysis of spring flow quality and quantity.

Although no significant north-south trending faults are known to exist in the Rilda Canyon area west of the Pleasant Valley fault zone, other physical features in the area indicate that the major springs issuing from the Star Point Sandstone Formation in the Rilda, Mill Fork, and Little Bear canyon bottoms are fault or fracture related (see Maps HM-4 and HM-6 for spring locations). A noteworthy feature related to the occurrence of the principal Star Point Formation springs is the location of each spring with regard to a known fault or the location with regard to the linear orientation of significant north-south trending side drainage channels. As illustrated on Map HM-7, Little Bear Spring is directly in line with the western edge of the graben identified in Beaver Creek Coal Company's Huntington No. 4 Mine. The Rilda Canyon Springs lie directly in line with a north-south trending side canyon to the south as well as one to the north. From examination of topographic features of the area under a stereoscope, it appears that the linear relationship of side drainage channels (or lineament) can be traced through Mill Fork Canyon to the north, intersecting the northeast-southwest trending graben (encountered by Beaver Creek Coal) near the northern ridge of Mill Fork Canyon. Two separate geophysical techniques were employed in Rilda Canyon to assist interpreting the occurrence and movement of groundwater. First, Very Low Frequency Electromagnetic Analysis (VLFEM) and second, Resistivity-induced Polarization were utilized to verify the existence of fracture zones in line with the lineament traced from Rilda into Mill Fork Canyon.

The VLFEM study consisted of two transects in an east-west direction across the Rilda Canyon Spring area, one along the road that bypasses the springs and one along the road bypassing the springs to the south. Data from the east-west transect are shown on

Figure HF-9B. In both transects, a significant subsurface anomalous condition was encountered in the vicinity of the springs and directly in line with the north and south canyons. In addition to the east-west transect, three north-south transects were conducted in order to delineate possible fracture zones parallel to the stream. Data from the north-south transect are illustrated in figures HF-9D through 9E and locations of the transect are shown on Figure HF-9F. Analysis of the north-south transect shows an anomalous area, which might indicate the existence of a fault or fracture in the westernmost transect as shown on Figure HF-9C. This anomalous area was also evident on the resistivity-IP survey which will be discussed below. The two transects which were conducted lower in the canyon do not show strong evidence of any anomalous areas (see figures HF-9D and 9E).

VLFEM surveys conducted in Rilda Canyon were performed by Hansen Allen & Luce (HA&L) of Salt Lake City, Utah. Survey procedures utilized by HA&L consisted of selecting a transmitter station which provides a field approximately parallel to the traverse direction, i.e., approximately perpendicular to the expected strike of a conductor. VLFEM transmitter stations are located at several points around the globe. They broadcast at frequencies close to 20,000 Hz, which is low compared to the normal broadcast band. Data was collected utilizing a hand held instrument manufactured by Corne Geophysical Limited on fifty-foot intervals along the transect with two readings collected at each location: 1) field strength, and 2) dip angle (in degrees from a horizontal plane). It should be stressed that data collected during VLF surveys are very sensitive to sharp changes in topography and natural and manmade metallic material such as fences, pipelines, etc. In Rilda Canyon very little manmade materials exist except for wire fence which surrounds the NEWUA spring collection area shown on Figure HF-9B. Pipelines used to collect and transport the spring water in Rilda Canyon are constructed of PVC and are considered to have little or no adverse impact on the data that was collected. It should also be stressed that the VLF data should only be considered one facet of the hydrologic investigation conducted in Rilda Canyon and not the sole source of hydrologic interpretation.

PacifiCorp contracted Geowestern to conduct a Resistivity-Induced Polarization (I.P.) Survey in Rilda and Mill Fork canyons in the summers of 1989 and 1992. (Refer to Volume 9 - Hydrologic Support Information.) The intent of the survey was to identify fractures in the strata and the depth of alluvium in Rilda Canyon by contrasting areas of Resistivity and I.P. response. As with the VLFEM data, resistivity-IP assisted in the hydrologic interpretation and was utilized to plan the location and depth of wells constructed for hydrologic drawdown conducted in November 1990.

Resistivity-I.P. surveys have been utilized for many years to map out subsurface occurrences of groundwater or mineralization. Because groundwater within the Wasatch Plateau tends to be concentrated along fractures, Resistivity-I.P. surveys can effectively identify fractures, faults included. Where strata are present at depths having highly contrasting resistivity or I.P. response, displacement along a fault can be detected by the offset of the depth to the contrasting beds. Where faults are present within a survey area but the strata is fairly uniform in resistivity and I.P. response, no displacement will be recognized in the data collected but the fault plane itself will most likely be easily detected. The latter scenario is normally the case within our property; therefore, the surveys will identify water-filled fractures and faults but will not always differentiate between the two. Most of the anomalies identified will be fractures, and differentiating between faults and fractures requires additional geologic data provided by field mapping or published data.

The Resistivity-I.P. Survey was conducted on nine separate lines, five in Rilda Canyon and one in Mill Fork Canyon (see Map HM-7). Three of the lines (longitudinal) were along roads in the canyon bottoms in both Rilda and Mill Fork canyons. Six lines were transverse, across Rilda Canyon, and were designed to identify the depth of alluvial fill in the canyon bottom.

The resistivity survey used the pole-dipole configuration with station intervals of fifty (50) feet on longitudinal lines and twenty (20) feet on transverse lines. Resistivity and I.P. values were measured at separate intervals of 100, 200, 300, and 400 feet on each of the longitudinal lines and 20, 40, 60, and 80 feet on the transverse lines. These separations in data collection allowed the recovery of data that revealed conditions up to 400 feet in depth on both the longitudinal and transverse lines. The I.P. survey used the time-domain method and reflects areas where the ground has a greater electrical capacitance, a condition normally caused by disseminated sulfides which, on our property, would most likely be minor amounts of pyrite along fractures.

Rapid changes in the resistivity or I.P. response of the surveys are almost always associated with fractures in a geologic setting such as we have and can follow a distinct trend at depth which allows the determination of the angle of dip of the fracture. The Resistivity-I.P. Survey identified several anomalies indicating fractures and/or faults. The fractures which cause the anomalies dip steeply in a westerly direction or are vertical. The degree of dip associated with each fracture is shown on Map HM-7. Each of the anomalous areas representing fractures was examined in the field and on aerial photographs to determine the significance of the anomalies. The geophysical data was then compared with geologic data collected in the field and from publicly available reports, making it possible to locate a fault graben (Mill Fork Graben) system trending in a northeast direction which cuts across the western portion of our northern reserves (see Map HM-9). The southernmost fault of the graben was intersected in ARCO's Beaver Creek #4 Mine in Mill Fork Canyon and has a displacement of about twenty (20) feet down on the northwest side. Where it crosses the northern end of East Mountain, the fault has been mapped to have a displacement of thirty (30) feet down on the northwest side. All other faults in the graben system have a relative displacement which is up on the northwest side.

Several anomalies to the southeast of the Mill Fork Graben were identified by the Resistivity-I.P. Survey. No displacement is identified on any of them. The anomalies are on the same geologic trend as areas mined in the ARCO Beaver Creek #4 Mine where no faults exist; therefore, in all probability they are water saturated fractures having no vertical displacement.

The transverse lines (R-3 through R-5, and R-7 through R-9) were designed to provide data regarding the depth of the alluvium in the canyon bottom. The alluvial/bedrock contact is identifiable on the profiles and provides important information on the hydrology of the springs located in the canyon. The alluvial floor is up to seventy (70) feet thick as indicated by resistivity profiles R-3 through R-5 and drill hole information obtained from P-6 and P-7 (see Figure HF-10).

b. Description Of Newua Spring Collection System

The NEWUA spring system consists of a series of collection lines extending westward up Rilda Canyon and southward up a small side drainage as shown on Map HM-8 enclosed. The NEWUA spring system is metered at four locations. Meter 1 (Side Canyon Spring) is located at the downstream end of a collection line which enters Rilda Canyon from the South. Meter 2 (Side Canyon Spring plus South Spring) is located near the bottom of the main east-west trending collection line which lies to the south of Rilda Canyon Creek at a point just upstream (west) of the main spring collection box. Meter 2 records combined flows from both the Side Canyon (Meter 1) as well as additional inflows which enter the system below Meter 1 known as South Spring. Meter 3 (North Spring) records flows for the east-west central collection line which was constructed through the central portions of the valley near Rilda Canyon Creek. Meter 4 (North Spring) collects data from the north collection line located on the north side of Rilda Canyon Creek. During the Rilda Canyon road re-alignment project completed in 1995, flow from the north collection line (Meter 4) was combined with east-west central line (Meter 3), thereby eliminating Meter 4.

In addition to the main spring collection lines there are two flumes in the vicinity which monitor flow rates within Rilda Canyon Creek. The upper flume, RCF-2, is located adjacent to the extreme west end of the spring collection system monitored by Meter 4. Flume RCF-3 is located in Rilda Canyon Creek adjacent to spring collection Meter 2.

Seven shallow wells have been located in the area surrounding the spring collection system to monitor groundwater level fluctuations through time. The locations of the wells are shown on Map 1. Wells 1 through 5 are relatively shallow wells which were constructed prior to 1990. Wells 6 and 7 are larger wells which were completed in 1990 replaced wells P-2 and P-3, respectively, in order to obtain more complete groundwater data through aquifer testing.

c. Quantity

Through the cooperative efforts of PacifiCorp and NEWUA, flow meters were installed in September 1990 to isolate individual spring areas for quantity and quality (see Map HM-8). Individual flow rates for meters 2-3 (flow from Meter 1 is included in Meter 2) are reported in the Annual Hydrologic Report.

The seasonal variation of the monthly average flow from all NEWUA's Rilda Canyon Springs is shown in Figure HF-11. With the installation of the flow meters, individual spring contribution to the total flow can be plotted over time.

PacifiCorp contracted Hansen, Allen & Luce (HA&L) to conduct a hydrologic test in Rilda Canyon. The overall purpose of the hydrologic testing was to determine to the degree possible 1) general hydrologic conditions associated with the NEWUA springs, including the general direction of groundwater movement; 2) the potential origin of waters feeding the NEWUA springs; and 3) a determination of general aquifer characteristics, including transmissivity. Earlier reports (April 1983 and March 1984) prepared by Vaughn Hansen Associates identified the source of water from the North Spring to originate from two general sources. The earlier report concluded that the source of water originated from a north-south trending subsurface anomaly which may be a strike slip fault located immediately downstream of the main North Spring area. The latter, using additional data collected, concluded that there also appears to be an east-west trending anomaly which intersects the north-south anomaly just north of the North Spring. Water collected in the east-west anomaly from surface and/or fault sources located higher in the canyon may issue forth at the North Spring as the water comes in contact with the north-south trending anomaly. It was believed at the onset of the project that the source of water (whether from the north-south trending anomaly or from sources farther up the canyon) could be determined by pumping strategically placed wells near the sources of water.

Upon initiation of the project PacifiCorp and HA&L met to determine the most efficient method of proceeding with the proposed pumping tests. It was mentioned that because of the proximity of Well P-6 to the main spring collection area, pumping Well P-7 might produce clearer test results. Pumping P-6 would have an impact upon the main spring collection system; however, any attempts to determine the source of spring water could be masked by the influence of the drawdown cone. That is, by pumping P-6 both sources of recharge to the North Spring would be drawn upon, thereby making the attempt at isolation more difficult.

Soon after initiation of the project it was decided that the most complete data could be obtained by pump testing P-7 because of its location upgradient of the main spring collection area. If P-7 could be pumped sufficiently, the potential source of recharge water feeding the North Spring from the alluvial canyon fill west of the spring could be reduced without affecting water recharging the springs from the north-south trending anomaly or fault system. The level of impact due to pumping P-7 would then be an indicator of the general source of water issuing from the NEWUA springs.

The purpose of the pump test performed on P-7 was to pump the well to its maximum potential for a period of time sufficient to note and record impacts upon the NEWUA springs or other wells located in the vicinity. The amount of pumping and the level of impact on the local systems was used subsequent to the test to help document the source of water discharging into the NEWUA spring collection system. A pump test was run on P-7 continuously from 4:00 p.m. on November 13 through 12:30 p.m. on November 20, 1990. Throughout this period records were kept related to pumping conditions and flow rate discharging P-7, water levels in wells P-1 through P-7, and spring flows recorded at NEWUA spring collection meters 1 through 4. Well P-3 was dry throughout the test.

d. Aquifer Characteristics

The local groundwater system in the vicinity of the NEWUA springs consists of an unconfined alluvial valley fill aquifer as well as bedrock and fracture systems. Resistivity data provided by PacifiCorp indicate that the total maximum depth of alluvium ranges from 50 to 73 feet at the three locations where cross sections were taken. The locations of the resistivity cross sections within Rilda Canyon are shown on Map HM-7. The width of the unconfined aquifer varies due to the influence of side drainages which also feed the area.

Water moving throughout Rilda Canyon appears to originate from at least three sources (Vaughn Hansen Associates, 1983, Hydrologic Support Information: Rilda Canyon Pump Test and personnel communication with governmental agencies). The first and most obvious source is through the alluvial valley fill, the second is through an east-west trending fault which is believed to lie to the north of the canyon floor, and the third is potentially through a north-south trending fault which bisects the canyon just west of the NEWUA spring collection system. More is mentioned about water quality from these sources later in this document. Springs within Rilda Canyon are believed to indicate and verify the locations of changes in geologic structure.

Examples of local geologic structures and their impact on hydrology have been verified historically through stream and spring flow observations. The canyon drainage west (or above) the interface with the upper contact of the Star Point Sandstone Formation is generally a discharging stream section. When alluvial waters come in contact with the more impermeable members of the upper Star Point Sandstone Formation formation, they are often forced to the surface, creating springs. Local NEWUA springs confirm a recharging stream section. When these more impermeable formations are crossed, the stream once more becomes a losing stream until subsurface waters again come in contact with the more impermeable members of the Star Point Sandstone Formation and underlying Mancos Shale formations. Some sections of the stream within Rilda Canyon gain flow, thereby evidencing the locations where subsurface water is forced to the surface by the tighter formations.

Data collected during and following the pump test of P-7 were used to provide estimates of local valley fill aquifer characteristics. For these analyses data from both pumped Well P-7 and from observation Well P-6 during both the drawdown and recovery portions of the test were used. Well P-6 was used as an observation well over other local wells because 1) it is the closest to the pumped well, 2) it is up gradient from the north-south trending anomaly associated with the spring, 3) it showed the most response to pumping, and 4) the data were more consistent than other data collected.

In order to analyze the data in an acceptable fashion, the data sets were broken into three separate portions. The first data set has been termed the "initial" data set and includes time and drawdown data from P-7 for the beginning period of the test where the flow rate was recorded to be equal to 8.22 gpm. The "intermediate" data set includes data subsequent to that time when the flow rate was increased to an average value over time of 16.4 gpm. The third data set includes data taken during the "recovery" portion of the test after the pump in P-7 was shut off.

Three basic analytical methods; the Cooper-Jacob, Theis, and Neuman methods, were used to estimate aquifer transmissivity for the data contained herein. Each method, along with applicable data, is discussed separately in the following sections.

(1) Cooper-Jacob Drawdown and Recovery Analyses

(a) Drawdown Methods

The Cooper-Jacob straight line method of analysis utilizes a semi-log plot for the display and analysis of the data as shown on Figure HF-12. The data shown on the plot entitled "PacifiCorp P-7 Initial Data Q=8.22 gpm" have three general slopes. The first few data points are usually ignored in a pump test because they reflect initial drawdown anomalies generally due to evacuation of the well drill stem or casing. The next set of data, beginning at two minutes and running through 100 minutes, show a good aquifer response and an associated transmissivity of approximately 35,650 gpd/ft. The plot, however, shows that a change in the slope of the data occurred at about 100 minutes. Such a change in grade generally indicates the presence of a boundary condition which, in the case of Rilda Canyon, reflects the bedrock of the canyon walls. Generally under such conditions the slope of the curve after the time in which the boundary was encountered will double (see Figure HF-13).

The slope of the straight line for the latter part of the data shows a transmissivity on the order of 21,100 gpd/ft, a forty percent decrease. Based upon this data it is believed that the initial transmissivity of the alluvial valley is on the order of 35,000 gpd/ft for the initial period of pumping, during which time the aquifer is unaffected by distant barriers. After a barrier influences groundwater hydrology, the transmissivity reduces to the estimated 21,100 gpd/ft.

Intermediate data provide similar data. The barrier effects discussed occurred within the first 100 minutes of pumping, before data was collected for this data set; therefore, the majority of the impacts due to the barrier already will have been accounted for although some effects should occur due to an increased pumping rate. With this in mind, the straight line Cooper-Jacob analysis produces a transmissivity of 17,550 gpd/ft, as shown in Figure HF-14. Although slightly less, this value is similar in nature and magnitude to that found for the last half of the initial data set.

An analysis of the intermediate data was also made by using data collected from P-6 located approximately 500 feet to the east of P-7. The analysis shown in Figure HM-15 indicates that the long-term transmissivity for this data set is in the rage of 23,800 gpd/ft. Again, this is in the general range of estimates already made above.

(b) Recovery Methods

Straight line methods of analysis are also used for well recovery data which is taken after the pump is shut off. In the case of P-7 the recovery curves are shown as Figures HM-16 and HM-17. Immediately after pumping ceases in a well, water levels recover at an abnormally high rate in a similar fashion to what occurred during the first two minutes of the pumping test as shown in Figure HM-12. By taking the next set of data, a straight line can be fit to obtain an approximation of long-term transmissivity on the order of 13,700 gpd/ft, as shown in Figure HF-16. Although this estimate is a little low compared to the estimate given above, it is of the same order of magnitude.

Short-term transmissivity is checked for the recovery data by the fitting of a straight line through the low end of the data. The transmissivity under short-term pumping is estimated at 35,900 gpd/ft, which matches very well the 35,650 gpd/ft estimate made by utilizing the Cooper-Jacob straight line drawdown analysis discussed above.

(c) Theis Drawdown Analysis

The Theis method of solution utilizes a log-log plot of drawdown versus time as shown on Figure HM-18. The solution is achieved by matching a well function curve to the data as shown. It should be noted that the data utilizing this method of solution does not readily show the boundary condition which was identified by the Cooper-Jacob solution method. There is a slight curvature of the data at about the 100-minute time mark as shown on the plot; however, without other methods it is unlikely that a boundary condition would have been identified for this data set. Since the solution does not identify a boundary condition, the solution reached is a mix of both short- and long-term transmissivities. An analysis using this approximation method (resulting in an average transmissivity) results in an estimate of 28,450 gpd/ft.

A check of the estimate can be made by averaging transmissivities for both the initial short-term and intermediate long-term data sets obtained using the Cooper-Jacob method.

The average of 35,650 and 21,100 gpd/ft is 28,380 gpd/ft, which is within one-half of a percent of the estimate given above using the Theis method.

An analysis of the intermediate data shown on Figure HM-19 shows that the estimated long-term transmissivity using the Theis method is on the order of 17,900 gpd/ft, which can be compared to the 17,550 gpd/ft estimate made using the Cooper-Jacob method. The estimates indicated are within two percent of each other, again showing good correlation.

(d) Neuman Drawdown Analysis

The third method of analysis is based upon unconfined aquifer solutions as determined by Neuman. His analysis utilizes two basic curve types. The "Type A" curve is characteristic of that shown on Figures HM-20 and HM-21 where the curve is a power curve asymptotic to the horizontal line. "Type B" curves bend in the opposite direction, i.e., they start relatively flat and turn upward as one moves to the right on the plot. Slight trends toward both the "Type A" and "Type B" curves can be seen on Figure HM-20. A "Type A" curve could be fit to the data between times 1 and 30, and a "Type B" curve could be fit to the data between times 30 and 1000; however, because the data is influenced by the presence of a boundary condition (as discussed above) and because the Neuman solution does not identify boundary conditions in its methodology, such an analysis would provide inaccurate results. As a compromise, an average solution is attempted by analyzing the data based upon the complete data set wherein an estimate of 13,150 gpd/ft is obtained. Although lower than some of the earlier estimates made, this estimate again has the same relative order of magnitude.

The intermediate data set was also analyzed using the Neuman approach as shown in Figure HM-21. From the data it is seen that this solution predicts a low value of transmissivity. It is believed that the other predictions of transmissivity given above are more accurate and reliable than this estimate because of the reasons discussed in the previous paragraph.

Aquifer transmissivities as determined by the methods listed above range from a low of 6,100 gpd/ft to a high of 35,900 gpd/ft. As a summary of values determined, the following table is provided. The table contains a column identified as "Credibility of Results" which is intended to be a guide to the numbers given. A high credibility rating indicates that the method basically accounts for conditions believed to exist within Rilda Canyon. A medium credibility indicates that the numbers are within the range expected but that the solution may not be as accurate as another method. A low credibility indicates that, for these conditions, the solution does not appear to fully account for identified field conditions. As outlined in the table, it is believed that long-term transmissivities are on the order of 20,000 gpd/ft and short-term transmissivities are on the order of 35,000 gpd/ft. The variation in results appears to be due to boundary effects created by the canyon walls. If used for further analyses, the short-term transmissivity estimates should govern.

SUMMARY OF CALCULATED TRANSMISSIVITIES

Analysis Used	Data Type	Well Data Used	Estimated Transmissivity (gpd/ft)		Credibility of Results		
			Short-Term	Long-Term	High	Medium	Low
Cooper-Jacob	Drawdown	P-7	35,650	17,550-21,000	XXX		
Cooper-Jacob	Drawdown	P-6		23,600	XXX		
Cooper-Jacob	Recovery	P-7	35,900	13,700	XXX	XXX	
Theis	Drawdown	P-7	28,450	17,900	XXX	XXX	
Neuman	Drawdown	P-7	13,150	6,100			XXX

e. Quality

Initial water quality investigations (sampling consisted of wells P-1 through P-5 and three spring collection areas) conducted by West Appa Coal Company in the fall of 1982 indicated two distinct classes of groundwater (primarily defined by sulfate concentrations). Illustrated on Figures HF-22, 23, and 24 are the percent reacting values for major cations and anions for the five piezometers and three spring collection areas as determined from samples collected on September 16, October 15, and December 6, 1982, respectively. As illustrated on the figures, there are two distinct groupings of data from the various sources with regard to sulfate concentrations and total dissolved solids (TDS) concentrations. In general, the Side Canyon Spring, the South Spring collection zone, and well P-4 contain groundwater higher in TDS and sulfate concentrations than do the North Spring collection zone, wells P-2 and P-5.

Differences in the above-referenced groupings of data reflect differences in the groundwater source or the origin of groundwater for the various springs issuing within the Rilda Springs area. The Side Canyon Spring is located at or near the base of the Blackhawk Formation. The higher sulfate concentrations and TDS concentrations from the spring are characteristic of waters associated with the Blackhawk Formation. The similarity in water quality between the Side Canyon Spring and the South Spring collection area, Meter 2, would indicate that South Spring waters are also primarily of Blackhawk origin. The slightly better quality of South Spring water over the Side Canyon Spring water indicates that some of the South Spring water is derived from waters moving within the fracture zone of the Star Point Sandstone Formation.

As illustrated by TDS concentrations on Figures HF-22, 23, and 24, waters issuing from the North Spring collection area are of a better quality than waters from the Side Canyon and South Spring collection areas. Waters issuing from the North Spring originate primarily from water moving within the alluvial valley sediments and fracture systems of the Star Point Sandstone Formation and are not derived from the Blackhawk Formation.

Additional water quality sampling conducted by PacifiCorp during 1990 confirmed the early results obtained by West Appa. In summary, water quality of the springs does not generally correlate well with waters originating from the south as measured by Meter 1 (Side Canyon) and Meter 2 (South Spring), nor do they correlate well with surface waters monitored within Rilda Canyon. The water appears to be more highly correlated with waters moving toward the NEWUA springs from the west. Water movement from the west is most likely through three source mechanisms. The first and most obvious water source is through the alluvial valley aquifer into which local wells have been drilled. The next sources may be through faulting and fracturing systems within Rilda Canyon or through the north-south anomaly which passes through the west end of the spring collection system, as discussed above. The waters originating through faulting, fracturing, and Rilda Canyon alluvial valley fill appear to have different water quality characteristics than those of the southern springs. Detailed annual water quality analysis of the individual springs will be submitted in the Annual Hydrologic Report.

f. Water Source

In the report originally prepared by Vaughn Hansen Associates in April of 1983 for West Appa Coal Company, it was noted that the water appeared to be originating from the north along a north-south oriented anomaly in the vicinity of the main north spring. In a later response to an OSM Completeness Review for West Appa Coal Company in March of 1984 it was noted that additional data seemed to indicate that a portion of the flow may originate from sources to the west which move into an east-west oriented anomaly or fracture, then intersect the north-south anomaly before discharging as spring water.

g. Piezometric Surface

Water level data collected at each of the wells or piezometers within Rilda Canyon has been compiled to indicate the general orientation and direction of groundwater within the vicinity of the NEWUA springs as shown on Map HM-8. Note from the map that the general direction of groundwater continues to be to the east along the axis of Rilda Canyon with flow contributions being received by the drainage entering from the south. Water table gradients for the area are dependent upon the time of year as well as overall groundwater recharge characteristics. For example, from the map it can be found that the average slope of the monitored water table lying between wells P-7 and P-5 was 4.3 percent in November 1990. At the same time the average water table gradient increases downgradient of P-5 where it was found to be 6.4 percent. The fact that the water table gradient increases downstream of P-5 still tends to confirm the presence of the north-south anomaly reported earlier for the area. A check of water table gradients during high flow periods shows larger values than were noted in the latter part of 1990. Analysis of historic data shows that, although flow patterns are relatively unchanged during high flow periods, the water table gradient above P-5 may have been as high as 7.4 percent in 1987.

h. Groundwater Quantity Based On Pump Test Results

An approximation of the total groundwater flow moving eastward down Rilda Canyon was made using data collected from the resistivity studies completed by PacifiCorp and from data collected at local area wells. The flow approximation was made by applying the general flow equation Q=VA. The area of groundwater flow was determined using the inferred cross sectional area identified in the resistivity study as "R-3" (see Map HM-7) for the canyon adjacent to P-7. The velocity of groundwater movement was determined from the relationship between hydraulic permeability and groundwater gradient, V=ki. Permeability was determined from the estimate for short-term transmissivity obtained using the methods discussed earlier. It was felt that under flow conditions uninfluenced by man, the short-term transmissivity is most representative of natural conditions. Using these relationships, the estimated amount of groundwater moving down Rilda Canyon was determined for both high and low flow conditions.

Based on historic data, low flow conditions were found to dominate during the period of the 1990 pump test; however, it has been noted by PacifiCorp employees that a rise in water level occurs within Rilda Canyon wells each year as the groundwater aquifer responds to snow melt runoff. Historical data reproduced in Figure HF-25 for wells 1 through 5 shows seasonal and annual water level fluctuations. Note the relative change in water level between wells. Little overall variation is noted except for P-3 which shows changes over time totaling approximately thirteen to fourteen (13-14) feet. Changes recorded in P-3 are likely greater than those indicated by Figure HF-25 because P-3 is only thirty-eight (38) feet deep and water levels have been known to drop below the bottom of the well. A comparison of water level variations between P-3 and adjacent P-7 indicates that the total water level fluctuation may be as much as twenty-two (22) feet.

<u>Low Flow</u>. The first condition analyzed was based upon the relatively low flow condition found in November 1990. Using the relationship Q=VA as discussed above, the total alluvial valley aquifer flow in the area of P-7 was estimated to be approximately 151 gpm. Subtracting an average pumped volume of 16.4 gpm from P-7, an estimated flow of 135 gpm bypassed P-7 and continued downstream toward the NEWUA spring collection system. Impacts noted upon the NEWUA spring system as a result of pumping P-7 appear to be confined to a reduction in flow from the springs on the order of ten percent. Before pumping began, total combined spring flows were approximately 85 gpm. During the later stages of pumping, just prior to termination of the test, spring flows had reduced to approximately 77.5 gpm, indicating a reduction in flow of 7.5 gpm during the pump test. Additional reductions in flow will probably occur as flows continue to stabilize.

<u>High Flow</u>. High flow conditions were estimated by adding to the 151 gpm base flow calculated for the November 1990 period the additional flow which would move down the canyon given a twenty-two (22) foot rise in water level which would occur during a wet year. The additional flow projected to occur during wet years was estimated by 1) measuring the cross sectional area which would result from a twenty-two (22) foot rise in the water table and 2) by applying the flow relationship Q=kiA. As indicated earlier, the water table gradient (i) used in this equation was found to be greater in 1987 than during the November

1990 test. Based on these assumptions, increased water levels measured during the high flow period of 1987 resulted in an estimated alluvial valley aquifer flow rate of 372 gpm.

B. EXISTING SURFACE RESOURCES

Presented within this section of the report is the regional hydrologic setting as well as the site specific description of hydrologic surface water characteristics of the permit area.

1. Regional And Permit Area Surface Water Hydrology

The PacifiCorp permit area is located in the headwater region of the San Rafael River Basin (see Figure HF-26). The surface drainage system of the permit area is divided into two major drainages. The southwest portion forms part of the Cottonwood Creek drainage, and the northeast portion contributes to the Huntington Creek drainage (see Map HM-1). The Huntington Creek drainage covers seventy-three percent (73%) of the East Mountain leases held by PacifiCorp; the remaining twenty-seven percent (27%) is within the Cottonwood drainage system.

Huntington and Cottonwood creeks drain about 300 square miles of the Wasatch Plateau in central Utah. Altitude changes rapidly across the Wasatch Plateau with steep canyon sides and high mountain peaks. Altitudes range from 6,000 to 10,700 feet. Average precipitation generally increases with altitude and ranges from ten (10) inches near the town of Huntington to thirty (30) inches in the upper reaches of Huntington and Cottonwood creeks. Most of the precipitation occurs during winter months in the form of snow.

Water use upstream from Castle Valley (the monoclinal valley containing most of the agricultural land noted in Figure HM-27) is primarily for stock watering and industrial purposes (coal mining and electrical power generation). Within Castle Valley, agriculture and power production utilize nearly all of the inflowing water (Mundorff, 1972) with minimum flows in the gaged streams occasionally approaching zero. Transbasin diversions occur throughout the area.

In general, the chemical quality of water in the headwaters of the San Rafael River Basin is excellent, with these watersheds providing most of the domestic water needs to the people below; however, quality rapidly deteriorates downstream as the streams cross shale formations (particularly the Mancos Shale in and adjacent to Castle Valley) and receive irrigation return flows from lands situated on Mancos-derived soils (Price and Waddell, 1973). Dissolved solids concentrations range from about 100 to 600 mg/l in the mountain regions and from 600 to 6000 mg/l in Castle Valley.

Huntington Creek above the USGS stream gaging station (0318000) near the town of Huntington drains approximately 190 square miles. Storage reservoirs regulate runoff from fifty-four square miles in the upper part of Huntington Creek. The average channel gradient of Huntington Creek above Huntington is about 100 feet per mile (1.9 percent). Danielson et al. (1981) estimate the average annual precipitation on the Huntington Creek drainage to be on the order of twenty-six (26) inches. The average discharge at the USGS gage near Huntington is approximately ninety-six (96) cubic feet per second (70,000 acre-feet per year). The USGS estimates that "during most years, about 65 percent of the annual discharge at the Huntington Creek station (09318000) occurs during the snowmelt period (April-July)" (Danielson et al., 1981, p. 110). For example, the monthly distribution of flows for Huntington Creek near Huntington for the water year 1978, corrected for the influence of

Electric Lake Dam, is shown on Figure HF-28. The annual peak flows recorded for the USGS station near Huntington are plotted on Figure HM-29. While the majority of stream flows are due to snow melt, thunderstorms of high intensity are common in the area during the summer months. A review of the discharge records for Huntington Creek near Huntington shows that twenty-two of seventy-one (31 percent) measured annual peak flows occurred during July, August, or September. The largest annual peak flows have been caused by thunderstorms. Of the measured annual peak flows on Huntington Creek near Huntington, eight annual events have been greater than 1600 cfs (about a 10-year return period), all of which occurred during July, August, or September. The peak discharge of record was 2500 cfs on August 2 or 3, 1930.

Cottonwood Creek above Straight Canyon drains approximately 21.9 square miles. The average channel gradient of Cottonwood Creek above Straight Canyon is 300 feet/mile (5.7 percent). Only a short period of record (October 1978 to present) is available for the USGS stream gaging station (09324200) on Cottonwood Creek above Straight Canyon. Danielson et al. (1981) estimate the average annual precipitation to be on the order of twenty-two (22) inches, or 26,000 acre-feet, on the Cottonwood Creek drainage above Straight Canyon. Danielson et al. (1981) also estimate that only two percent of the precipitation on Cottonwood Creek above Straight Canyon leaves the basin as stream flow compared to thirty percent for Huntington Creek above Huntington. The suggested reasons for the wide difference in percent of precipitation contributing to stream flow are: 1) Cottonwood Creek Basin has a greater proportion of area with southern exposure with more gradual slopes than Huntington Creek Basin and 2) possible subsurface movement of water through fractures associated with the Joe's Valley Fault. For example, the monthly distribution of flows for

Cottonwood Creek above Straight Canyon for the water year 1979 is shown on Figure HM-30. About seventy percent of the total discharge at the Cottonwood Creek station above Straight Canyon for the water year 1979 occurred during the snow melt period (April-July).

Sixty years of data are available for the gaging station on Cottonwood Creek near Orangeville (09324500). The drainage area above Orangeville contributing to Cottonwood Creek is approximately 208 square miles. Cottonwood Creek has an average discharge near Orangeville of about ninety-five (95) cfs, or 69,000 acre-feet per year. The maximum and minimum discharges of record on Cottonwood Creek near Orangeville are 7,220 cfs (August 1, 1964) and 1.2 cfs (April 8, 1966), respectively.

The mine permit area is drained by four major drainage systems, Grimes Wash, Deer Creek, Meetinghouse, and Rilda canyons. Listed below is the individual breakdown for each individual permit area including stream classification.

MINE PERMIT AREAS	DRAINAGE SYSTEM	STREAM CLASSIFICATION
Deer Creek	Grimes Wash	Ephemeral
	Deer Creek	Ephemeral
	Meetinghouse	Ephemeral
	Rilda	Ephemeral-Perennial
	Mill Fork	Ephemeral-Intermittent
Wilberg/Cottonwood	Grimes Wash	Ephemeral
Des-Bee-Dove	Deer Creek	Ephemeral

PacifiCorp has observed that all of the streams emanating from within the permit boundary with the exception of Rilda Canyon Creek and Mill Fork Canyon cease flowing in the fall or winter, suggesting that they are not perennial but ephemeral. Rilda Canyon Creek is considered perennial below the springs located along the western border of Section 28, Township 16 South, Range 7 East, Mill Fork Canyon is intermittent from Section 21, Township 16 South, Range 7 East to the confluence of Huntington Canyon. Most of the streams in the permit area are spring fed. PacifiCorp has monitored all of the surface waters since 1979 (except Rilda and Mill Fork canyons initiated in 1989 and 1997 respectfully) and will continue to monitor them in the future. The data collected is included in each annual Hydrologic Monitoring Report.

a. Permit Area Watershed Characteristics

All of the streams within the permit boundary are ephemeral except for Rilda Canyon and Mill Fork Canyon, as mentioned earlier. Elevations in the permit area range from approximately 7000 feet to near 10,400 feet. General land slopes in the permit area range from near vertical along the Castlegate Sandstone escarpment to less than four percent. Vegetative cover consists of sagebrush, juniper, and grasses on the south-facing slopes and dense conifer and aspen complexes on the north-facing slopes.

Water sources within the mine plan area include springs and seeps, which were discussed earlier in the Existing Groundwater Resources section of this report. There are no major water bodies located within or immediately adjacent to the mine plan area.

b. Water Quality And Quantity

PacifiCorp maintains an extensive surface monitoring program to evaluate both quantity and quality of the two major drainage systems which incorporate the permit area. The following will be divided by major drainage systems.

(1) Huntington Creek Drainage System

(a) Huntington Creek

Huntington Creek is comprised of many smaller tributary systems that feed the main stream. Deer Creek, Meetinghouse, and Rilda canyon creeks are the only tributaries to Huntington Creek that emanate from within the permit area.

Huntington Creek flow data are recorded on a continuous basis by UP&L at two locations; one station is located near the Huntington Power Plant, the other below Electric Lake which is about twenty-two miles upstream from the Huntington Plant. Flow records are maintained by UP&L in order to determine water entitlements and reservoir storage allocation for the various users on the river.

The UP&L station near the plant was established in the fall of 1973. Prior flow records were obtained from the USGS station located about one mile downstream from UP&L's existing station. The USGS station was established in 1909 and discontinued in 1970 after determination of available water supply for the Electric Lake Dam. The dam was completed in December 1973, and water storage commenced shortly afterward.

The calculated natural flow rates, which consider actual flow recorded at the plant, plant diversions, Electric Lake storage, and lake evaporation along with yearly comparisons, are reported annually in the Hydrologic Monitoring Report.

Huntington Creek water quality information is compiled on a monthly basis for stations above and below the Huntington Plant, while samples for Huntington Creek below Electric

Lake and the Right Fork are taken quarterly. The location of water quality sampling stations on Huntington Creek that were considered for this report are listed below (refer to Map HM-1).

a). Below Electric Lake+*

b). Above the Forks+*

c). Below the Power Plant Diversion*

d). Below the Power Plant*

\+ Not listed on map due to scale

* The sites listed above are not considered part of PacifiCorp's Hydrologic Monitoring Program but will be included in the annual report as long as data is available.

In addition to the sites monitored by Huntington Plant-Environmental Service, three sites were added on Huntington Creek near the Deer Creek confluence in conjunction with the Deer Creek discharge permit (see PHC section).

Specific water quality data as well as yearly comparisons are reported annually in the Hydrologic Monitoring Report. This practice will continue throughout the life of the permit. In general, the water shows a gradual increase in concentration of dissolved minerals as the flow proceeds down Huntington Canyon. The values at the station below Electric Lake do not express the actual natural drainage water quality characteristics because of the lake effect, but it appears that the surface flow in Huntington Canyon is of very high quality in the upper reaches with some natural degradation occurring as the flow proceeds to the canyon mouth.

(b) Deer Creek

Deer Creek is a tributary of Huntington Creek and flows from the same canyon in which the Deer Creek Mine is located. Three permanent runoff sampling sites were established in 1980 to monitor the characteristics of Deer Creek and are sampled according to the following flow and sampling schedule (see Hydrologic Monitoring Schedule Appendix A).

a). Locations:

(1). Above the Mine - DCR01

(2). @ Permit Boundary - DCR04

(3). @ Huntington Confluence - DCR06 (see Map HM-1)

b). Flow information is collected during the first or second week of each month.

c). Water samples will be collected and analyzed quarterly (one sample at low flow and high flow) during the first or second week of the quarter. Parameters analyzed are those listed in the DOGM Guidelines for Surface Water Operational Quality. Field measurements, including pH, specific conductivity, and temperature, will be performed monthly in conjunction with quantity measurements.

As stated above, flow information is collected monthly throughout the year with the use of two Parshall flumes (see Map HM-1). Hydrographs comparing yearly flows are reported in the annual Hydrologic Monitoring Report and also as Figures 31A-C.

In accordance with the Hydrologic Monitoring Plan baseline quality analysis was performed in 1986 and 1991 (refer to respective Annual Hydrologic reports). Baseline analysis will be repeated once every five (5) years. Quality samples collected from Deer Creek at the sites above the Deer Creek Mine and below the Mine are summarized in Tables HT-5A and 5B. It is apparent from the tables that the quality of the Deer Creek run-off degradates slightly from the upper to the lower sampling point. The quality of the lower sampling point is thought to be affected by the Mancos Shale which causes the increase in TDS.

(c) Meetinghouse Canyon Creek

Meetinghouse Canyon Creek is a tributary of Huntington Creek and is monitored according to the following schedule (see Hydrologic Monitoring Schedule included herein).

a). Location: South Fork of Meetinghouse Canyon (see Map HM-1).

b). Flow information is collected during the first or second week of each month.

c). Water samples will be collected and analyzed quarterly (one sample at low flow and high flow) during the first or second week of the quarter. Parameters analyzed are those listed in the DOGM Guidelines for Surface Water Operational Quality. Field measurements, including pH, specific conductivity, and temperature, will be performed monthly in conjunction with quantity measurements. Data regarding flow in Meetinghouse Canyon Creek is presented in the annual Hydrologic Monitoring Report.

As stated above, flow information is collected monthly throughout the year with the use of a Parshall flume (see Map HM-1). Hydrographs comparing yearly flows are reported in the annual Hydrologic Monitoring Report and also as Figure HF-32.

In accordance with the Hydrologic Monitoring Plan baseline quality analysis was performed in 1986 and 1991 (refer to respective Annual Hydrologic reports). Baseline analysis will be repeated once every five (5) years. Quality sampling was initiated in 1986; results of the samples collected are presented in Table HT-6 and in the Hydrologic Monitoring Report.

(d) Rilda Canyon Creek

Rilda Canyon Creek is a tributary of Huntington Creek and is monitored according to the following schedule (see Hydrologic Monitoring Schedule included herein).

a). Locations:

(1). Right Fork of Rilda - RCF1*
(2). Left Fork of Rilda - RCLF1 (Field data only)
(3). Left Fork of Rilda - RCLF2 (Field data only)
(4). Rilda Canyon - RCF2 (Field data only)
(5). Rilda Canyon - RCF3
(6). Rilda Canyon - RCW4 (see Map HM-1)

* During mining of the North Rilda Leases, an additional site has been added upstream of RCF1 (adjacent to drill hole EM-163) to monitor surface/groundwater flow relationships. Flow will be measured yearly during base flow conditions.

b). Flow information is collected during the first or second week of each month.

c). Water samples will be collected and analyzed quarterly (one sample at low flow and high flow) during the first or second week of the quarter. Parameters analyzed are those listed in the DOGM Guidelines for Surface Water Operational Quality. The program was initiated in June 1989. Field measurements, including pH, specific conductivity, temperature, and dissolved oxygen, will be performed at the perennial stream locations, i.e., RCF3 and RCW4, monthly in conjunction with quantity measurements. Data regarding flow in Rilda Canyon Creek is presented in the annual Hydrologic Monitoring Report.

As stated above, flow information is collected monthly throughout the year with the use of three Parshall flumes and one V-notch weir (see Map HM-1). Hydrographs comparing yearly flows are reported in the annual Hydrologic Monitoring Report and also as Figure HF-33.

In accordance with the Hydrologic Monitoring Plan baseline quality analysis will be for a two-year period, 1989-90 (refer to the respective Annual Hydrologic reports). Baseline analysis will be repeated once every five (5) years. Quality sampling was initiated in 1989; results of the samples collected are presented in Table HT-7 and in the Hydrologic Monitoring Report.

(e) Mill Fork Canyon Creek

Mill Fork Canyon Creek is a tributary of Huntington Creek and was included in PacifiCorp's monitoring program starting in 1997. Monitoring of Mill Fork will be conducted according to the following schedule (see Hydrologic Monitoring Schedule included herein).

a.) Locations:

(1). Above old mines – MFA01
(2). Mill Fork Canyon Culvert – MFB02 (see Map HM-1).

b.) Flow information is collected during the first or second week of each month.

c.) Water samples will be collected and analyzed quarterly (one sample at low flow and high flow) during the first or second week of the quarter.

Parameters analyzed are those listed in the DOGM Guidelines for Surface Water Operational Quality. The program was initiated in 1997. Field measurements, including pH, specific conductivity, temperature will be performed quarterly in conjunction with quantity measurements. Data regarding flow in Mill Fork Canyon Creek is presented in the annual Hydrologic Monitoring Report.

As stated above, flow information is collected monthly throughout the year (Vol. 9 - Hydrologic Section: Map HM-1). Hydrographs comparing annual flows are reported in the annual Hydrologic Monitoring Report.

Historical monitoring data collected by Beaver Creek Coal Company - No. 4 Mine and the United States Geological Survey (site No. 76 Open File Report 81-539) has been incorporated in PacifiCorp's hydrologic database. Operational water quality monitoring was conducted during 1997 and 1998 (refer to Quarterly Hydrologic submittals). Baseline quality analysis was initiated in November 1998. In accordance with the Hydrologic Monitoring Plan, baseline quality analysis will be conducted for a two-year period, fourth quarter 1998 – fourth quarter 2000 (refer to respective Annual Hydrologic reports). Thereafter, baseline analysis will be repeated once every five- (5) years.

(2) Creek Drainage System Cottonwood

The southern portion of East Mountain is intersected by Cottonwood Creek and its associated tributaries, including Cottonwood Canyon Creek and Grimes Wash. The Cottonwood Creek drainage is about equal in size to the Huntington drainage, with total discharge from each drainage about 70,000 acre feet per year. The major cultural feature on Cottonwood Creek is the Joe's Valley Reservoir, located about twelve miles west of the town of Orangeville. The 63,000 acre foot reservoir was constructed by the U.S. Bureau of Reclamation and provides storage water for irrigation, industrial, and municipal needs in the Emery County area.

(a) Cottonwood Canyon Creek

An extensive baseline study conducted on Cottonwood Canyon Creek to determine water characteristics prior to mining at the proposed Cottonwood Mine began in 1979. A property acquisition in 1981 resulted in mine plan changes; therefore, the baseline study was terminated as of January 1, 1984. As agreed upon with DOGM, UP&L will continue to monitor the flow and water quality field measurements at the USGS flume location on monthly basis (see Figure HF-34).

The Cottonwood Canyon is a major drainage system where evidence of glaciation exists. From the headwaters to Section 24, Township 17 South, Range 6 East, the canyon is characterized by U-shaped valleys with associated lateral and terminal moraine deposits. Lateral moraine deposits most commonly occur at the intersection with side canyons. Terminal moraine deposits occur at the northwest corner of Section 24 and from this point to near the confluence with Straight Canyon the canyon can be characterized as a V-shaped valley with little evidence of glaciation.

Based on data collected by PacifiCorp, Cottonwood Canyon Creek is an ephemeral stream from its headwaters to Section 24, Township 17 South, Range 6 East and intermittent from that point to its confluence with Cottonwood Creek at Straight Canyon. The stream becomes intermittent near the intersection of Roans Canyon just below the terminal moraine deposits discussed above. During drought conditions which have been experienced since 1985, flow in Cottonwood Canyon is limited to flow emanating from the Roans Canyon Spring located in Section 24 near the confluence with Roans Canyon (see HM-1 for location of the spring). Prior to the drought, flow occurred along the entire reach of Cottonwood Canyon and had to be forged to access the Mill Canyon dugway located in Section 2. Along with Roans Canyon Spring, another spring referred to as Cottonwood Spring is also associated with the alluvial (glacial) deposits. Cottonwood Spring is located in the canyon bottom within the area of terminal moraine deposits at an elevation higher than that of Roans Spring. With normal precipitation, especially in the form of winter snowpack, runoff would saturate the alluvial deposits and a portion of groundwater would discharge at the location of Cottonwood Spring. During the period of the drought recharge to the alluvial deposits has been limited and the level of groundwater has been reduced to a point below the elevation of the Cottonwood Spring. To verify the extent of the alluvial deposits and to define the hydrologic characteristics, PacifiCorp conducted a hydrologic research project in 1992 which included a series of resistivity lines and the drilling of three surface sites (see Appendix C for complete details). At each of the surface sites two wells were completed (except for CCCW-2), one in the alluvial deposits and one in the Spring Canyon member of the Star Point Sandstone Formation Formation. Wells completed in the alluvial deposits will be utilized to compare the well hydrographs to those of Cottonwood Canyon Creek and the Star Point Sandstone Formation. Monitoring data is included in the Annual Hydrologic Monitoring Reports.

(b) Grimes Wash

Grimes Wash is a tributary of Cottonwood Creek and flows in the same canyon in which the Wilberg/Cottonwood Mine is located. Three permanent runoff sampling sites were established in 1980 and are sampled as listed below (see Hydrologic Monitoring Schedule included herein).

a). Locations:

(1). Right Fork - GWR01

(2). Left Fork - GWR02

(3). Below the Mine - GWR03 (see Map HM-1)

b). Flow information is collected during the first or second week of each month.

c). Water samples will be collected and analyzed quarterly (one sample at low flow and high flow) during the first or second week of the quarter. Parameters analyzed are those listed in the DOGM Guidelines for Surface Water Operational Quality. Field measurements, including pH, specific conductivity, and temperature, will be performed monthly in conjunction with quantity measurements.

As stated above, flow information is collected monthly throughout the year with the use of two Parshall flumes (see Map HM-1 for flume locations). Hydrographs comparing yearly flows are shown in the Hydrologic Monitoring Report and also as Figures 35A-C.

In accordance with the Hydrologic Monitoring Plan baseline quality analysis was performed in 1986 and 1991 (refer to respective Annual Hydrologic reports). Baseline analysis will be repeated once every five (5) years. Quality samples collected in Grimes Wash are shown in Tables HT-8A-C. The Grimes Wash drainage quality is influenced by two factors: 1) Under normal conditions the Right Fork contributes a relatively high amount of suspended solids during spring runoff due to the fact that it is a south facing canyon dominated by argillaceous sediments; 2) Mancos Shale/Star Point Sandstone Formation interface seeps and springs elevate the TDS at the Below the Mine location.

2. Soil Loss - Sediment Yield

Sediment load concentrations in the area of the permit vary dramatically depending on the percentage of disturbed areas, ruggedness of the terrain, geologic formations present, the amount of precipitation the area receives, and stream flow volume.

As part of the U.S. Geological Survey water monitoring program in Utah coal fields (Open File Report #81-359), fourteen water samples associated with the permit area were collected between August 1978 and September 1979 at gaging station 09318000 on Huntington Creek to determine suspended-sediment concentrations and loads. Three samples each were collected at gaging stations 09317919, 09317920, and 09324200 in Crandall and Tie Fork canyons and on Cottonwood Creek. Five additional samples were collected by project personnel from these and other streams in the study area. Representative suspended-sediment concentrations and loads of streams in the study area are listed below.

		Suspended sediment		
Stream	Site No.	Concentration Date	Loads (mg/L)	(tons per day)
Huntington Creek (gaging station 09318000)	88	8-13-78	104	27.00
		11-17-78	72	2.50
		6-13-79	114	66.00
		8-7-79	44	15.00
Crandall Canyon (gaging station 09317919)	51	8-12-78	49	0.14
		11-18-78	60	0.08
		6-14-79	15	0.41
		8-6-79	56	0.15
Tie Fork Canyon (gaging station 09317920)	67	8-13-78	12	0.03
		11-18-78	57	0.12
		6-14-79	38	0.68
		8-6-79	66	0.17
Bear Creek	81	10-25-78	8,860	1.90
Deer Creek	87	6-14-79	609	3.10
Cottonwood (gaging station 09324200)	104	8-15-78	5	0.003
		11-19-78	130	0.20
		8-5-79	63	0.09

As indicated from the samples collected by the USGS, the suspended-sediment concentrations varied widely among the drainages analyzed. The relatively low concentrations of suspended sediment were attributed to well established channels, low flow periods, and a scarcity of roads. Higher concentrations appeared to be associated with the activities of man and erosion of large exposures of the Mancos Shale formation in the lower reaches of the drainages. Sediment concentrations generally increased with increased stream discharge. Note that the highest values at all of the locations occurred during the spring runoff period, but not enough data were available to compute daily sediment discharge.

PacifiCorp has collected samples on a quarterly basis from the streams within and adjacent to the permit area. Samples taken at periods of both high and low flow have been tested for total suspended solids (TSS) to identify stream stability and are reported annually in the Hydrologic Monitoring Report. Tables HT-5 through HT-8 show the TSS results for streams monitored by PacifiCorp.

Runoff from disturbed areas is diverted through sediment control facilities or protected from abnormal erosion. Each sediment control facility is sized according to calculated annual sediment accumulations (see Operational section of the individual permit applications for specific information on sediment yields from disturbed areas). Water discharged from the sediment pond facilities is monitored according to the stipulations set forth in the UPDES permits (see Appendix B).

R645-301-723 SAMPLING AND ANALYSIS

Water quality sampling and analysis of samples collected by PacifiCorp will be done according to the "Standard Methods for the Examination of Water and Wastewater." Refer to Appendix A for sample documentation and analytical methods and detection limits.

R645-301-724 BASELINE INFORMATION

PacifiCorp maintains an extensive groundwater and surface monitoring program to characterize pre-mining and any mining-related impacts both to quality and quantity. As an integral part of the permit application, an annual Hydrologic Monitoring Report is prepared by PacifiCorp and submitted to appropriate government agencies. Baseline information for the East Mountain property will be divided into the following categories: 1) Groundwater and 2) Surface Water.

1) Groundwater

The characteristics of the groundwater resource are dependent upon the geology of the water-bearing strata and on the geology and hydrology of the recharge area. Groundwater movement and storage characteristics are dependent on the characteristics of the substratum. To characterize the baseline quality and to document the existence of seasonal variations, PacifiCorp developed a groundwater monitoring program which includes sampling both surface springs and in-mine groundwater sources. The program was initiated during a period from 1977 through 1979. Routine monitoring continues to support the quality data collected during the initial phase. In general, data from the springs and in-mine sources are representative of the groundwater quality in the geologic strata from which the groundwater sources issue. Cation-anion diagrams have been utilized to depict the groundwater characteristics and to monitor quality trends. Results of the data collected have shown that in both the surface springs and in-mine groundwater sources variations in quality from individual sources do exist, but the quality from the individual sources remains consistent with time. Spring water is mostly calcium-bicarbonate with some magnesium and sulfate. As discussed in the General Requirement Section - R645-301-711, quality decreases with increasing downward vertical movement and from north to south with sulfate becoming a major constituent. Cation-anion diagrams have been included in the Annual Hydrologic Reports to support the lack of seasonal variation. A copy of the 1991 quality information is included in Volume 9 - Hydrologic Support Information, Baseline Section (additional information concerning groundwater quality can be found in the Annual Hydrologic reports).

2) Surface Water

The East Mountain permit area is drained by five major drainage systems: Cottonwood Canyon Creek, Grimes Wash, Deer Creek, Meetinghouse, and Rilda canyons. PacifiCorp has documented that all of the streams emanating from within the permit area with the exception of Rilda Canyon Creek cease flowing in the fall or winter, suggesting that they are not perennial but ephemeral. Flow in the drainage is a combination of snow melt and springs. Most of the runoff occurs during the months of April through July. Even though the drainage systems are ephemeral, except for the lower reaches of Rilda Canyon, variations in quality does exist. Total dissolved solids increase gradually in concentration as flow proceeds from the upper plateau areas to the confluence of the major drainages of Huntington and Cottonwood Canyons. Surface waters in the mine permit area are predominantly bicarbonate, calcium, and magnesium in the upper reaches with sulfate becoming a major constituent in the lower reaches. The increase in sulfate concentration is due to the influence of the Mancos Shale, a marine shale which outcrops in the lower reach of each of the drainage systems. Seasonal total suspended solids variations also occur with the highest concentrations occurring during the initial runoff period. A yearly summary sheet for each drainage is included in Volume 9 - Hydrologic Support Information, Baseline Section.

R645-301-724.100 GROUNDWATER INFORMATION

A detailed description of the ownership of existing wells, springs, and other groundwater resources, including seasonal quality and quantity of groundwater and usage, is given in sections R645-301-721 and 722.

R645-301-724.200 SURFACE WATER INFORMATION

A detailed description of all surface water bodies, i.e., streams and lakes, including quality, quantity, and usage is given in section R645-301-722.

R645-301-724.300 GEOLOGIC INFORMATION

Applicable geologic information can be referenced in the Geologic section of the PAP.

R645-301-724.400 CLIMATOLOGICAL INFORMATION

PacifiCorp operates a network of weather stations, including two at low elevations (Hunter and Huntington power plants) and two at high elevations (Electric Lake and East Mountain).

A. PRECIPITATION

The climate of the permit area has been described by the U.S. Geological Survey, which states that it is semi-arid to subhumid and precipitation generally increases with altitude. The average annual precipitation ranges from about ten (10) inches in the lowest parts of the permit area (southeast) to more than twenty-five (25) inches in the highest parts (northwest). PacifiCorp's weather station, located in Section 26, Township 17 South, Range 7 East, has provided data which shows that the summer precipitation in the form of thundershowers averages about the same as the winter precipitation in the form of snowfall. Because much of the summer precipitation runs off without infiltration, the winter precipitation has the greatest impact on groundwater.

Precipitation amounts have been and will continue to be recorded at the Hunter and Huntington power plants, at Electric Lake Dam, and on East Mountain. Precipitation data can be found in the annual Hydrologic Monitoring Report (see Table HT-9 for East Mountain data).

B. TEMPERATURES

Air temperatures vary considerably both diurnally and annually throughout the permit area Midsummer daytime temperatures in lower areas commonly exceed 100° F, and midwinter nighttime temperatures throughout the area commonly are well below 0° F. The summer temperatures are accompanied by large evaporation rates. Although not recorded, there probably also is significant sublimation of the winter snowpack, particularly in the higher plateaus which are unprotected from dry winds common to the region. Temperature information is collected at the UP&L weather stations at each power plant, at Electric Lake, and on East Mountain. These data will continue to be included in the annual Hydrologic Monitoring Report (see Table HT-9 for East Mountain data).

C. WINDS

The winds in the area are generally variable. The wind rose presented in Figure HF-36 displays the variability for the Meetinghouse Ridge area for January to December 1978.

R645-301-724.600 SURVEY OF RENEWABLE RESOURCES LANDS

Information describing the existing groundwater resources, including descriptions of permit area aquifers and areas of recharge can be found in section R645-301-721. Impacts related to mine subsidence can be found in section R645-301-728.

R645-301-724.700 ALLUVIAL VALLEY FLOORS

Utah Regulations require that the presence of alluvial valley floors in or adjacent to the mine project area be identified. The regulations define an alluvial valley floor as "unconsolidated stream-laid deposits holding streams with water availability sufficient for sub-irrigation or flood irrigation agricultural activities but does not include upland areas which are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion, deposits formed by unconcentrated runoff or slope wash together with talus, or other mass-movement accumulations, and wind blown deposits." The alluvial valley floor is therefore determined to exist if:

1. Unconsolidated stream-laid deposits holding streams are present, and
2. There is sufficient water to support agricultural activities as evidenced by:

a. The existence of flood irrigation in the area in question or its historical use;

b. The capability of an area to be flood irrigated, based on stream-flow, water yield, soils, water quality, topography, and regional practices; or

c. Subirrigation of the lands in question, derived from the groundwater system of the valley floor.

A. SCOPE

The purpose of this section of the report is to examine the potential existence of alluvial valley floors in and adjacent to the areas to be affected by surface operations associated with the permit areas. It is divided into three parts. First, a general description of the surface operations and site disturbances associated with the permit areas is presented. Next, discussions of the characteristics of geomorphology and irrigation are presented. Finally, the conclusions of the alluvial valley floor determination are summarized.

B. SITE DESCRIPTION

Surface facilities associated with the permit area will consist of the portal area and associated facilities: for Deer Creek Mine - Deer Creek and Rilda (proposed) canyons; for Des-Bee-Dove - unnamed drainage associated with Grimes Wash; and for Wilberg/Cottonwood - Grimes Wash.

The climate of the general area is semi-arid to arid and continental. Daily minimum temperatures recorded at the East Mountain weather station in winter range from the average low of -6.3° F to the maximum record low of -15.2° F, and daily maximum temperatures in summer range from the average high of 84.7° F to the maximum record high of 89.3° F.

Temperatures in the region tend to be inversely related to elevation. Average annual precipitation recorded for a 10-year period (1981-90) at the East Mountain weather station averaged 14.15 inches. Approximately fifty percent of the annual precipitation falls during the winter as snow with most of the remainder coming as summer thunderstorms.

C. ALLUVIAL VALLEY FLOOR CHARACTERISTICS

In this section of the report the various criteria for determining the existence of an alluvial valley floor are examined in relation to the overall permit and adjacent areas.

D. GEOMORPHIC CRITERIA

Alluvial deposits in and adjacent to the mine permit area have been mapped and reported in Doelling's "Wasatch Plateau Coal Fields, 1972." The report indicated that alluvia in the area are found solely along Huntington Creek below the Rilda Canyon confluence in the Huntington drainage system, in the Cottonwood drainage system along lower Cottonwood Creek and at the mouth of the North Fork of Cottonwood Creek, and in the Joe's Valley drainage.

E. FLOOD IRRIGATION

Flood irrigation near the project area is currently (and has historically been) confined to the alluvial areas of Huntington Creek approximately one mile below the confluence of Deer Creek and Huntington Creek. In the Cottonwood drainage system flood irrigation is currently, and historically, confined to the alluvial areas of lower Cottonwood Creek. No flood irrigation has historically been practiced on the narrow alluvium land upstream in the canyons opening to lower Cottonwood and Huntington Canyon creeks. The historic lack of flood irrigation in these steep, narrow canyons suggests that such activities are not feasible in the region. In addition, the topography is very steep and consequently not conducive to agricultural activities.

Water quality of Cottonwood and Huntington creeks is good. A detailed review of the surface water quality has been presented previously in this report and is updated each year in the annual Hydrologic Monitoring Report.

F. SUBIRRIGATION

Some subirrigation of vegetation does occur on the alluvial valley floors. The subirrigated species (mainly cottonwoods and willows) are found along the channels of Cottonwood Creek and in the Joe's Valley drainage above the reservoir and along the channels of Rilda Canyon and Huntington Creek. This suggests that subirrigation is confined to the channel areas where the water table is near the surface.

G. ALLUVIAL VALLEY FLOOR IDENTIFICATION

Based on the foregoing analysis, the narrow canyons associated with the permit area cannot be considered to have an alluvial valley floor due to insufficient alluvium and the very limited area for supporting an agriculturally useful crop. The valley floor of Huntington Creek below the confluence with Deer Creek, however, can be classified as an alluvial valley floor due to the presence of both flood irrigation and limited subirrigation on the alluvium.

H. POTENTIAL IMPACTS OF ALLUVIAL VALLEY FLOORS

Very little potential exists for the mine operations to impact the Cottonwood and Huntington Creek alluvial valley floor due to the location of the operations in comparison to the alluvial deposits. All surface disturbances in the portal area will be protected by sediment control facilities and have been designed and constructed according to R645 standards in an environmentally sound manner.

The hydrologic monitoring program will help determine the actual impact of surface activities and aid in selecting mitigating measures, if necessary; however, it is believed that the overall permit area and associated activities will have no significant hydrologic impacts on the alluvial valley floor along Cottonwood and Huntington creeks. Details concerning the monitoring program are outlined in section R645-301-731.

R645-301-725 BASELINE CUMULATIVE IMPACT AREA INFORMATION

Hydrologic and geologic data required to assess the probable cumulative impacts of the coal mining and reclamation activities are presented in the Hydrologic (including the Annual Hydrologic Reports), Operational, and Reclamation sections of the permit applications.

R645-301-728 PROBABLE HYDROLOGIC CONSEQUENCES (PHC) DETERMINATION

Probable hydrologic consequence determinations are based on extensive investigations conducted to determine existing groundwater and surface water resources along with ongoing hydrologic research and comprehensive monitoring programs including hydrologic and subsidence. Data utilized to arrive at the conclusions presented in this section were discussed earlier (see Section R645-301-721), and specific information pertaining to impacts to the hydrologic balance will be discussed under the appropriate section.

A. DESCRIPTION OF THE MINING OPERATION

The PacifiCorp mine permit areas are located in the central portion of the Wasatch Plateau Coal Field in Emery County, Utah. Generally, this area is a flat-topped mesa surrounded by heavily vegetated slopes which extend to precipitous cliffs leading to the valley below. Much data has been collected regarding the geology and the hydrology of the East Mountain property. In all, over 120 drill holes have been completed from the surface, over 500 from within the mines; and a comprehensive hydrologic data collection program is ongoing, all of which have provided data used in this PHC. The most applicable data have been included in this document. For a review of additional data it is suggested that the reader refer to the annual Hydrologic Monitoring Report.

B. GEOLOGY

A detailed description of the geology (structure and stratigraphy) has been presented in a previous section and will not be duplicated here. (Refer to R645-301-721).

C. MINING METHODS

Mining of the East Mountain permit area will be conducted entirely by underground mining methods consisting of continuous miner and longwall techniques (Des-Bee-Dove area permit has been and will be mined utilizing continuous miners exclusively). Two mineable coal seams exist within the property. In ascending order they are the Hiawatha and Blind Canyon. Each of the separate permit areas (Deer Creek, Des-Bee-Dove, and Wilberg/Cottonwood) have mined or will mine both of the seams (see operational plans of each separate permit application).

The chemical and physical properties of the overburden have been identified and described in the Geologic section of the permit application.

Because mining is limited to underground mining techniques, only minor amounts of overburden directly in contact with the seam, either roof or floor, will be removed during mining operations.

D. SURFACE WATER SYSTEM

A detailed description of the regional and permit area surface water resources has been presented in previous sections and will not be duplicated here. (Refer to R645-301-722). In general, the surface drainage system on East Mountain is divided into two major drainages; the southwest portion forms part of the Cottonwood Creek drainage, and the northeast portion contributes to the Huntington Creek drainage. The Huntington Creek drainage covers seventy-three percent (73%) of the East Mountain leases held by PacifiCorp. Both of these perennial streams are located adjacent to but not within the permit boundaries. PacifiCorp has observed that all of the streams emanating from within the permit boundary, with the exception of Rilda Canyon Creek and Mill Fork Canyon, cease flowing in the fall or winter, suggesting that they are not perennial but ephemeral. The upper reaches of Rilda and Mill Fork canyons are ephemeral. Rilda Canyon Creek is considered perennial below the springs located along the western border of Section 28, Township 16 South, Range 7 East, Mill Fork Canyon is intermittent from Section 21, Township 16 South, Range 7 East to the confluence of Huntington Canyon Most of the streams are spring fed. PacifiCorp has monitored all of the surface waters since 1979 (except for Rilda and Mill Fork canyons, 1989 and 1997 respectfully) and will continue to monitor them in the future. The data collected is included in each annual Hydrologic Monitoring Report.

Impacts to surface water due to the underground operations of Deer Creek, Des-Bee-Dove, and Wilberg/Cottonwood are minor, both in terms of quality and quantity. Due to the type of mining and relatively small areas of surface disturbance, surface water impacts are limited. Through the use of sedimentation ponds and the diversion of runoff from undisturbed areas around the surface facilities, impacts to surface waters are negligible. (See Appendix B for UPDES permit information.) One impact associated with the Deer Creek and Wilberg/Cottonwood operations is mine dewatering. A detailed analysis of the associated impacts is described in the Hydrologic Balance section below.

E. HYDROLOGIC BALANCE - SURFACE WATER SYSTEM

As mentioned previously in this report, the major drainages conveying runoff away from the mine permit areas are streams in Deer Creek, Grimes Wash, Meetinghouse, and Rilda canyons. With the exception of the very headwater regions of these drainage basins, mining and, therefore, subsidence will not occur beneath the major stream channels of these canyons. In the majority of cases, cracking due to subsidence is not anticipated to extend to the surface; therefore, surface runoff patterns will not be significantly affected. Data collected by PacifiCorp over a ten-year period concerning subsidence and surface drainages has not detected any surface stream impacts. Consequently, subsidence should not cause significant impacts to the surface water system. Surface facilities are located in the following canyons:

Deer Creek Mine:	Deer Creek Canyon Rilda Canyon
Des-Bee-Dove mines:	Unnamed drainage associated with Grimes Wash Canyon
Wilberg/Cottonwood mines:	Grimes Wash Canyon

Natural tributary flows are diverted around surface facilities. Surface runoff from disturbed areas is detained in sedimentation ponds prior to release. All discharge from the sedimentation ponds is sampled in accordance with the stipulations in the UPDES permits (see Appendix B).

Underground coal mines in the Wasatch Plateau Coal Field typically intersect groundwater from strata surrounding the coal seam. Both Deer Creek and Wilberg/Cottonwood mines have intersected quantities of water in excess of operational needs and therefore have discharged intercepted groundwater. Dewatering of Deer Creek and Wilberg/Cottonwood has had only a minor impact on surface quality and quantity on a regional basis; however, on a site specific basis the flow in Deer Creek and Grimes Wash has increased from pre-mining conditions. During periods of high runoff changes in quality are insignificant; however, in low flow conditions some degradation is likely due to the fact that the mine discharge waters are higher in TDS than the surface waters. It is difficult to assess the degradation because it is not known from where or how much of the water discharged from the mine would naturally have been discharged into the receiving streams by natural groundwater flow. The section below will describe the dewatering of Deer Creek and Wilberg/Cottonwood and related surface impacts.

1. Deer Creek

Excess water not utilized in the mining operation or for domestic use is either pumped to storage areas or discharged from the mine. (Quality and quantity is reported in the Annual Hydrologic Report.) The locations of the main sump areas within the mine are shown in Figure HF-37. The largest volume of water is stored in the western part of Main West, which has not been actively mined for several years.

In-line flow meters are utilized to record the amount of water discharged from the mine, after which it passes through underground sedimentation sumps (see Figure HF-38). Prior to December 1990 all of the water discharged from Deer Creek was piped directly to PacifiCorp's Huntington Power Plant. As of November 16, 1990, the State of Utah-Department of Health granted PacifiCorp a temporary discharge permit under a bypass agreement . Based on negotiations with the Department of Health, PacifiCorp conducted investigations to determine the impact to surface waters as the result of discharging mine water to Deer Creek and to the main receiving stream of Huntington Creek (refer to Hydrologic Support Information No. 3 for a complete analysis). On June 1, 1994, Department of Health granted PacifiCorp a site specific permit which included discharge from the Deer Creek Mine. Excess water not utilized in the mining operation or for domestic use is either pumped to storage areas or discharged to the Huntington Plant or Deer Creek drainage in accordance with stipulations of UPDES Permit Number UT-0023604-02 (see Appendix B for UPDES permit information).

2. Wilberg/Cottonwood

PacifiCorp notified the Division of temporary cessation of coal mining operations at the Cottonwood/Wilberg Mine effective May 29, 2001. Coal mining at the Cottonwood/Wilberg Mine ceased as of March 15, 2001. All portal were sealed according MSHA specifications on May 28, 2001. During normal operations, excess water not utilized in the mining operation or for domestic use is either pumped to storage areas or discharged into the Left Fork of Grimes Wash in accordance with stipulations of UPDES Permit Number UT-0022986-01 (see Appendix B for UPDES permit information). During temporary cessation, Trail Mountain Access intake portal was designed as a drain. PacifiCorp applied to the Division of Water Quality to relocate UPDES 0022896 outfall 001 from Grimes Wash to Cottonwood Canyon. Approval was granted July 30, 2001.

In each case the receiving stream or canyon where the discharge occurs (discharge to the Left Fork of Grimes Wash, Miller Canyon and Cottonwood Canyon Creek) is classified as intermittent/ephemeral. In most instances the flow from Miller Canyon does not reach the intermittent receiving stream of Cottonwood Canyon Creek. The impact associated with the discharge from either location is negligible based upon limited quantities discharged. Quality of water discharged by location is shown in Table HT-10.

In addition to water chemistry sampling, bioassay tests were conducted at outfall 001 from 1988 through 1992 using guidelines, "Methods for Measuring the Acute Toxicity of Effluent to Freshwater and Marine Organisms," EPA-600/4-85-013 (Rev. March 1985). Each test included a 48-hour static toxicity test using Ceriodaphnia sp. and an acute 96-hour static replacement toxicity test using fathead minnows five (5) days of age. These tests were utilized to determine aquatic characteristics of the intercepted groundwater and mine water discharged from both locations. All of the tests passed the guidelines established by the EPA.

F. MITIGATION AND CONTROL PLANS

Runoff from disturbed areas is diverted through sediment control facilities or protected from abnormal erosion. Any mine discharge will be routed through the underground sediment pond and reservoir in the old workings or specialized sump areas and will be monitored in accordance with UPDES permit standards and state and federal regulations. (See Appendix B for UPDES permit information.)

The effects of the mining operation on the surface water system will be analyzed through the surface water monitoring plan described below. In the event that monitoring shows that the surface water system is being adversely affected by mining activities, additional steps will be taken to rectify said impacts in cooperation with local, state, and federal regulatory agencies.

G. SURFACE MONITORING PLAN

A hydrologic surface monitoring program, initiated in 1979 (sites in Meetinghouse, Mill Fork, and Rilda canyons were added in 1986, 1997, and 1989, respectively), has been underway at each of the surface monitoring stations shown on Map HM-1. Stations were established to monitor water quality and quantity above and below the mine permit areas. The parameters for laboratory analyses are those established by DOGM in "Guidelines for Surface Water Quality" (see Appendix A). Once baseline data have been collected (two-year period), the surface sites described in the hydrologic monitoring schedule in Appendix A will continue to be monitored quarterly (when accessible) throughout the operational phase of the mine. The quarterly monitoring during the mine operational phase will include flow and quality to delineate seasonal variation and assess changes in water quality.

Future data may show that modifications of the monitoring schedule are justified. Any changes to the monitoring schedule (frequency or parameters) will be made only with the approval of DOGM. Results of all water quality data will be submitted to that agency quarterly, with an annual summary.

Post-mining monitoring of surface water will continue at representative stations determined with the aid and approval of DOGM. Representative surface water stations will be monitored biannually during high and low flow conditions. Monitoring will continue until the release of the reclamation bond or until an earlier date to be determined after appropriate consultation with local, state, and federal agencies.

H. GROUNDWATER SYSTEM

Detailed descriptions of the regional and permit area groundwater resources have been presented in previous sections and will not be duplicated here (refer to R645-301-722). In general, the majority of all natural groundwater discharge points located on the East Mountain property are in the form of seeps and springs. UP&L has mapped approximately eighty (80) springs ranging in discharge from <1 gpm to as high as 450 gpm (see Map HM-4).

PacifiCorp has collected an extensive database of information pertaining to the groundwater quality and quantities of the East Mountain region and adjacent areas. Included in the database is long-term quality and flow information both for springs and for groundwater intercepted by mining. In addition to the studies completed by PacifiCorp, Mayo & Associates was contracted in 1996 to conduct comprehensive study to characteristize the hydrology and hydrogeology of the East and Trail mountains (refer to Volume 9 - Hydrologic Support Information No.11). The hydrogeology of the PacifiCorp leases were elevated by analyzing: 1) solute and isotopic composition of surface and groundwaters, 2) surface and groundwater discharge data, 3) piezometric data, and 4) geologic information.

The following is summary of the conclusion of this study (refer to Volume 9 Hydrologic Support Infomation No. 11 for complete details):

1. Conclusions From Mayo & Assiociates Hydrologic Investigation

1. The δ^2H and $\delta^{18}O$ compositions demonstrate that all groundwaters are of meteoric origin (i.e. snow and rain).
2. Active and inactive groundwater regimes occur in the mine lease area.
3. The active regime includes alluvial groundwater, groundwater in the Flagstaff Formation, and all near surface exposures of the other bedrock formations except, perhaps, the Mancos Shale. The near surface extends about 500 to 1,000 feet into cliff faces. Groundwaters in the active regime contain abundant ^3H and anthropogenic ^{14}C.
4. Comparison of long-term discharge hydrographs with precipitation records demonstrates that active regime groundwaters:

   1) are in direct hydraulic communication with the surface

   2) are recharged by modern precipitation, and 3) have large fluctuations in spring discharge rates which can be attributed to seasonal and climatic variability. High-flow/low-flow discharge rates vary as greatly as 600 gpm to nearly dry; however, most high flow rates are less than 50 gpm.
5. Despite the seasonal variability in discharge rates, the solute concentrations of active region groundwaters do not exhibit significant seasonal variability.
6. The inactive regime includes groundwater in sandstone channels in the North Horn, Price River, and Blackhawk Formations which are not in direct hydraulic communication with the surface (i.e. greater than about 500 to 1,000 feet from cliff

faces). Mine workings are largely part of the inactive regime. The sandstone channels are vertically and horizontally isolated from each other and when encountered in mine workings are usually drained quickly. Coal seams are hydraulic barriers to groundwater flow. The blanket sands of the Star Point Sandstone are also largely in the inactive zone. Except where exposed near cliff faces, faults encountered in mine workings are part of the inactive regime. Except near cliff faces, faults are not conduits for vertical hydraulic communication between otherwise hydraulically isolated pockets of groundwater.

7. Inactive region groundwater systems contain old groundwater (i.e. 2,000 to 12,000 years), and are not influenced by annual recharge events or short term climatic variability.

8. In-mine inactive regime groundwaters occur in nearly stagnant, isolated zones which have extremely limited hydraulic communication with other inactive regime groundwaters in the vicinity of mine workings and with near-surface active regime groundwaters as evidenced by the following:

   a) Groundwaters discharging into mine openings have ^{14}C ages ranging from 2,000 to 12,000 years

   b) Roof drip rates rapidly decline when water is encountered in the mine indicating that the saturated zone above the coal seam is not hydraulically continuous and has a limited vertical and horizontal extent.

   c) Unsaturated conditions have been identified in boreholes drilled vertically into sandstone channels located above coal seams.

9. The fact that inactive region groundwaters encountered in mine openings do not have an infinite age means that, at some time, there has been some hydraulic

communication with the surface. This communication is extremely limited as illustrated by calculated steady state recharge-discharge rates of faults and sandstone channels in the inactive zone which range from 0.001 to 1.23 gpm.

10. Groundwater in the Star Point Sandstone is part of the inactive regime as evidenced by the 6,000 year ^{14}C age of the sample from well TM-3. In the down dip direction along the axis of the Straight Canyon Syncline, potentiometric pressures in the Spring Canyon member results in upwelling of groundwater into Hiawatha seam mine openings. Such upwelling may locally reduce the pressure in the Spring Canyon member.

11. Areally extensive groundwater regimes in the lower Blackhawk Formation and Star Point Sandstone do not exist within the lease area. Therefore, it is not meaningful to create piezometric surface maps of these systems.

12. Streamflow is dependent on snow melt, precipitation and thunderstorm activity. There is no apparent hydraulic communication between streamflow and groundwater encountered in mine openings.

13. The groundwater discharging into the Rilda Canyon alluvial collection system is of modern origin and is closely tied to seasonal recharge. This is evidenced by its modern radiocarbon and ^{3}H contents and by the discharge hydrographs. The alluvial groundwater is not related to the groundwater encountered in the mines.

14. The groundwater discharging in Cottonwood Canyon near Cottonwood Spring and Roans Spring discharges from glacial deposits and is of modern origin. The radiocarbon and ^{3}H contents of this water indicate a modern origin. The water in the shallow glacial deposits is not related to the groundwater encountered in the mines.

The USGS has conducted extensive studies to determine the regional groundwater system for the central Wasatch Plateau Coal Field. The studies indicate a regional aquifer exists in the coal-bearing sequence of the Blackhawk and the underlying Star Point Sandstone Formation formations. The studies have also concluded that several isolated or perched aquifers existed above the Blackhawk-Star Point Formation aquifer. PacifiCorp agrees with conclusions of the USGS studies concerning the perched aquifers above the coal-bearing sequence of the Blackhawk Formation but has some reservations about the significance of the Blackhawk-Star Point Formation aquifer which will be discussed below. The majority of the groundwater is discharged from the perched aquifers which occur along the base of the North Horn Formation in the form of seeps and springs (see Map HM-4, Figure HF-6, and Table HT-1). Several other perched aquifers exist mainly along the formational contacts with the North Horn Formation, including the upper contact with the Flagstaff Limestone and the lower contact with the Price River Formation.

The majority of the groundwater recharge on East Mountain comes from the winter snowpack which melts and infiltrates into the surface of East Mountain. The water flows down vertical fractures which intersect sandstone channel systems in the North Horn and Blackhawk formations. The majority of the groundwater reaching this point intersects the surface in springs located in the North Horn Formation. Very little recharge intersects the Price River Formation and Castlegate Sandstone sandstones; consequently, they are not water saturated where intersected in the numerous drill holes penetrating those units. The remaining water then flows downdip (to the southeast) from the northern reaches of East Mountain until it intersects the northeast trending Roans Canyon Fault Graben. In-mine long-hole drilling completed to test the hydrology of this fault system has shown that the system acts as an imperfect aquiclude to further southeast migration of water. Figure HF-5C shows the hydrologic gradient measured by the drill holes completed across the fault system. The system acts as an aquiclude because swelling clays along the fault prohibit most of the water from penetrating across the fault. Most of the recharge south of the Roans Canyon Fault System comes from the snow melt directly above. The same mode of water migration occurs there as to the north; but, when the water intersects the sandstone channels, it migrates toward canyons which surround and dissect the permit area.

Several vertical drill holes completed in the Deer Creek and Cottonwood mines were developed into water monitoring holes to test the piezometric gradient of the Star Point-Blackhawk aquifer (see Figures HF-5A and HF-5B). Data collected from the holes identify the hydrologic gradient.

The hydrogeologic characteristics of the coal-bearing Blackhawk and overlying formations effectively limit the extent of impacts to the hydrologic system. Impacts to water quality are negligible and may be slightly beneficial. As discussed previously, two separate aquifers-water bearing zones occur on the East Mountain property: 1) perched aquifers associated mainly with the North Horn Formation, and 2) Blackhawk-Star Point Formation, which exhibits limited potential as a property wide, water saturated zone. The following hydrologic balance section will segregate the two zones and describe the significance and possible impacts to each zone.

I. HYDROLOGIC BALANCE - GROUNDWATER

Mining within the East Mountain permit area will have negligible impact on the regional hydrologic balance, but there could be some possible local impact. This section discusses the possible mining-related impact on the hydrologic balance due to A) subsidence - perched aquifer systems, B) mining in the Rilda Canyon area - NEWUA springs, and C) interception of groundwater by mine workings.

1. Subsidence: Perched Aquifer Systems Above The Mine Horizon

As discussed earlier, most of the groundwater in the permit area discharges in the form of seeps and springs. Springs issuing from the perched groundwater in the Flagstaff Limestone and the North Horn and Price River formations will only be impacted by mining activities if fracturing from subsidence reaches upward into these formations and is not sealed by swelling or fracture filling from plastic mudstones. As shown in Figure HF-6 and Table HT-1, the majority of springs on the East Mountain property are associated with the North Horn Formation. As discussed in the regional groundwater characteristics section, the North Horn Formation is comprised of a variety of rock types which range from highly calcareous sandstone to mudstone. Lenticular sandstone channels are oftentimes present in the upper and lower portion of the formation. Water which percolates down fractures from the overlying Flagstaff Limestone works its way into the sandstones, forming the perched water tables. The actual lateral extent, or correlation, between the perched water tables has not been identified; and it is not practical to do so because the tables are limited in extent and variable in stratigraphic location. Many springs have been identified where sandstone channels intersect the land surface (refer to Table HT-1 for Mode of Occurrence. A Spring

Geologic Conditions Inventory sheet has been completed for each spring inventoried on the East Mountain Property and can be found in Volume 9 - Hydrologic Support Information).

The lower two-thirds (upper Cretaceous in age) of the formation is generally highly bentonitic mudstone which is impermeable. It is likely that this material is acting as an aquiclude, preventing adequate recharge from reaching the Price River Formation or Castlegate Sandstone Sandstone below. The mudstones present appear to swell when they come in contact with water; therefore, vertical migration of water along fractures through this material is limited because the fractures are sealed by the swelling clays. To identify and verify the existence of these bentonitic-plastic type mudstones, PacifiCorp conducted a special surface drilling program in 1989 to determine the rock strength and lithologic characteristics of the overburden on the East Mountain property. The entire sequence of the formations which are present on the East Mountain property, from the Flagstaff through the Star Point Sandstone Formation, was penetrated using two drill holes, identified as EM-136C and EM-137C (see Maps HM-2, 3, and 4). Drill hole EM-136C penetrated the Flagstaff Limestone and the upper 200 feet of the North Horn Formation. Hole EM-137C penetrated the lower portion of the North Horn Formation through the upper Star Point Sandstone Formation (refer to Hydrologic Support Information: No.8). Previous East Mountain surface exploration programs have experienced swelling and caving problems associated with plastic mudstone zones located in the upper and lower portions of the North Horn Formation. Regional as well as property wide drilling, along with limited-accessible outcrop data, has shown that even though projecting the lateral extent of individual lithologic units is not practical, the basic lithologic characteristics of the North Horn Formation are consistent on regional and permit area bases. Drilling of EM-136C and 137C confirmed existence of soft, plastic type mudstones which form an aquiclude, preventing significant recharge to the lithologic units below the North Horn Formation. Field investigations have shown that even along major fault systems, i.e., Pleasant Valley and Roans Canyon, vertical migration is interrupted by the lithologic characteristics of the North Horn Formation, forming springs along the fault traces. Examples of springs of this type are shown on Table HT-1 and Map HM-4.

The depth of the aquifers in the North Horn Formation is variable due to the rugged topography. The localized perched water tables may either intersect the surface of the ground or be covered by as much as 1,000 feet of overburden. They are located at least 1,400 feet above the coal seam to be mined. Communication of water between the perched aquifers in the North Horn Formation and the water flowing into the mine is limited in quantity and occurs very slowly.

To identify any mining related impacts to the perched aquifer systems above the mine horizon PacifiCorp monitors a significant number of springs which have been undermined or will be undermined within the next five years (see Hydrologic Monitoring Schedule and Map HM-5). A field verification meeting will be held each year with the government agencies involved to determine if changes in the springs monitored are required. Each year in the annual Hydrologic Monitoring Report spring flow rates are compared to East Mountain climatology as to how closely spring discharge follows local annual precipitation or to verify any mining related impacts.

Data collected by PacifiCorp continue to show the relationship between the variation in groundwater discharge quantity and precipitation. Hydrologic monitoring completed on the East Mountain property has failed to identify any changes in the quantity or quality of groundwater discharge from the springs which have been undermined.

2. Mining In The Rilda Canyon Area-Newua Springs

As discussed in R645-301-721, North Emery Water Users Association (NEWUA), a major concern to PacifiCorp is the proximity of proposed mining activities in Rilda Canyon to the Rilda Canyon springs.

PacifiCorp contracted Hansen, Allen & Luce (HA&L) to conduct a hydrologic test in Rilda Canyon. (Refer to Volume 9 - Hydrologic Support Information, Rilda Canyon Pump Test.) The findings from this test were then compared to the proposed Wellhead Protection Program criteria to determine the appropriate mitigation measures. The local groundwater system in the vicinity of the NEWUA springs consists of an unconfined alluvial valley fill aquifer as well as bedrock and fracture systems. Resistivity data provided by PacifiCorp indicate that the total maximum depth of alluvium ranges from 50 to 73 feet at the three locations where cross sections were taken. The locations of the resistivity cross sections within Rilda Canyon are shown on Map HM-7 The width of the unconfined aquifer varies due to the influence of side drainages which also feed the area.

Water moving throughout Rilda Canyon appears to originate from at least three sources. The first and most obvious source is through the alluvial valley fill, the second is through an east-west trending fault which is believed to lie to the north of the canyon floor, and the third is potentially through a north-south trending fault which bisects the canyon just west of the NEWUA spring collection system. Springs within Rilda Canyon are believed to indicate and verify the locations of changes in geologic structure.

Examples of local geologic structures and their impact on hydrology have been verified historically through stream and spring flow observations. The canyon drainage west (or above) the interface with the upper contact of the Star Point Sandstone Formation is generally a discharging stream section. When alluvial waters come in contact with the more impermeable members of the upper Star Point Sandstone Formation formation, they are often forced to the surface, creating springs. Local NEWUA springs confirm a recharging stream section. When these more impermeable formations are crossed, the stream once more becomes a losing stream until subsurface waters again come in contact with the more impermeable members of the Star Point Sandstone Formation and underlying Mancos Shale formations Some sections of the stream within Rilda Canyon gain flow, thereby evidencing the locations where subsurface water is forced to the surface by the tighter formations.

Data collected during and following the pump test of Well P-7 were used to provide estimates of local valley fill aquifer characteristics. For these analyses data from both pumped P-7 and from observation Well P-6 during both the drawdown and recovery portions of the test were used.

Aquifer transmissivities as determined by the methods described in R645-301-721 range from a low of 6,100 gpd/ft to a high of 35,900 gpd/ft. As a summary of values determined, the following table is provided. The table contains a column identified as "Credibility of

Results" which is intended to be a guide to the numbers given. A high credibility rating indicates that the method basically accounts for conditions believed to exist within Rilda Canyon. A medium credibility indicates that, for these conditions, the solution does not appear to fully account for identified field conditions. As outlined in the table, it is believed that long-term transmissivities are on the order of 20,000 gpd/ft and short-term transmissivities are on the order of 35,000 gpd/ft. The variation in results appears to be due to boundary effects created by the canyon walls. If used for further analyses, the short-term transmissivity estimates should govern.

SUMMARY OF CALCULATED TRANSMISSIVITIES

Analysis Used	Data Type	Well Data Used	Estimated Transmissivity (gpd/ft)		Credibility of Results		
			Short-Term	Long-Term	High	Medium	Low
Cooper-Jacob	Drawdown	P-7	35,650	17,550-21,000	XXX		
Cooper-Jacob	Drawdown	P-6		23,600	XXX		
Cooper-Jacob	Recovery	P-7	35,900	13,700	XXX	XXX	
Theis	Drawdown	P-7	28,450	17,900	XXX	XXX	
Neuman	Drawdown	P-7	13,150	6,100			XXX

a. Groundwater Quantity Based On Pump Test Results

An approximation of the total groundwater flow moving eastward down Rilda Canyon was made using data collected from the resistivity studies completed by PacifiCorp and from data collected at local area wells. The flow approximation was made by applying the general flow equation Q=VA. The area of groundwater flow was determined using the inferred cross sectional area identified in the resistivity study as "R-3" (see Map HM-7) for the canyon adjacent to P-7. The velocity of groundwater movement was determined from the relationship between hydraulic permeability and groundwater gradient, V=ki. Permeability was determined from the estimate for short-term transmissivity obtained using the methods discussed earlier. It was felt that under flow conditions uninfluenced by man, the short-term transmissivity is most representative of natural conditions. Using these relationships, the estimated amount of groundwater moving down Rilda Canyon was determined for both high and low flow conditions.

Based on historic data, low flow conditions were found to dominate during the period of the 1990 pump test; however, it has been noted by PacifiCorp employees that a rise in water level occurs within Rilda Canyon wells each year as the groundwater aquifer responds to snow melt runoff. Historical data reproduced in Figure HF-25 for wells 1 through 5 shows seasonal and annual water level fluctuations. Note the relative change in water level between wells. Little overall variation is noted except for P-3 which shows changes over time totaling approximately thirteen to fourteen (13-14) feet. Changes recorded in P-3 are likely greater than those indicated by Figure HF-25 because P-3 is only thirty-eight (38) feet deep and water levels have been known to drop below the bottom of the well. A comparison of water level variations between P-3 and adjacent P-7 indicates that the total water level fluctuation may be as much as twenty-two (22) feet.

Low Flow. The first condition analyzed was based upon the relatively low flow condition found in November 1990. Using the relationship Q=VA as discussed above, the total alluvial valley aquifer flow in the area of P-7 was estimated to be approximately 151 gpm. Subtracting an average pumped volume of 16.4 gpm from P-7, an estimated flow of 135 gpm bypassed P-7 and continued downstream toward the NEWUA spring collection system. Impacts noted upon the NEWUA spring system as a result of pumping P-7 appear to be confined to a reduction in flow from the springs on the order of ten percent. Before pumping began, total combined spring flows were approximately 85 gpm. During the later stages of pumping, just prior to termination of the test, spring flows had reduced to approximately 77.5 gpm, indicating a reduction in flow of 7.5 gpm during the pump test. Additional reductions in flow will probably occur as flows continue to stabilize.

As stated above, not all the water moving down Rilda Canyon in the alluvial valley aquifer was collected through pumping of P-7. In order to obtain an estimate of the total possible impact should the entire alluvial aquifer be eliminated as a source of water, a straight line extrapolation was made of pumped flows versus decreased spring flows. A straight line extrapolation of the data in this fashion should be considered an approximation only, not an accurate method of determining precise impacts. At an average pump rate of 16.4 gpm at P-7, NEWUA spring flows decreased by approximately ten percent. Assuming all alluvial valley recharge bypassing P-7 was eliminated as a potential source of water, the estimated impact to the NEWUA springs (using the straight line extrapolation method) could be approximately 69 gpm. The estimated spring impact based in percent would then be 69 gpm over an uninfluenced flow rate of 85 gpm or eighty-one percent. Using this methodology, the remaining nineteen percent of the flow contributing to the NEWUA springs appears to be coming from other sources.

<u>High Flow</u>. High flow conditions were estimated by adding to the 151 gpm base flow calculated for the November 1990 period the additional flow which would move down the canyon given a twenty-two (22) foot rise in water level which would occur during a wet year. The additional flow projected to occur during wet years was estimated by 1) measuring the

cross sectional area which would result from a twenty-two (22) foot rise in the water table and 2) by applying the flow relationship Q=kiA. As indicated earlier, the water table gradient (i) used in this equation was found to be greater in 1987 than during the November 1990 test. Based on these assumptions, increased water levels measured during the high flow period of 1987 resulted in an estimated alluvial valley aquifer flow rate of 372 gpm.

Data shows that total NEWUA spring flow during high flow periods is typically on the order of 400 gpm (see Figure HF-11). If all alluvial flow entered the springs, then the total impact to the springs resulting from the loss of said flow would be on the order of ninety-three percent (372 gpm/400 gpm). An alternate method of approximating the potential impact is through the use of the same impact ratio as was determined from the low flow pump test completed on P-7. Using this method, the total expected decrease in spring flows during high flow periods would be approximately 170 gpm, or a forty-three percent decrease (170 gpm expected decrease/400 gpm total spring flow).

b. Wellhead Protection Program

The State of Utah has been required by the federal government under the Federal Safe Drinking Water Act to establish a Wellhead Protection Program to protect groundwater that supply drinking water to public water supply systems. Included in this classification is the NEWUA spring collection system within Rilda Canyon. During the time frame of the NEWUA springs investiagation, (1989-90), the wellhead protection rules were in draft form and were being considered for adoption by the Utah Safe Drinking Water Committee. The wellhead protection rules were adopted by the Utah Safe Drinking Water Committee and referred to as the *"DRINKING WATER SOURCE PROTECTION"* rules, R309-113, on July

26, 1993. Delineation of protection zones and management areas remained unchanged from the draft guidelines listed in Table HT-11 . A brief summary of the proposed draft rules is included as Table HT-11 (refer to Vol. 9 - Hydrologic Section).

Based upon information contained in the table, it appears that the property included within Zone 1, a 100-foot radius around the NEWUA spring collection system, should be owned by the water supplier and be fenced. In addition, Zone 1 should be protected against anthropogenic sources of contamination. The "Master List of Potential Anthropogenic Sources of Contamination in Utah" as given in R449-113-8.1 includes coal companies within the designation, "Concrete, asphalt, tar and coal companies." Note the designation difference between new and existing sources in the table just discussed in that "new sources" indicates a definitive action whereas "existing sources" indicates that the action "should" be done. This distinction implies that existing facilities will be treated with more latitude than new facilities. It appears that this wording has been added to take into account the many possible configurations of public water supplies wherein little can be done to modify or correct long standing conditions.

Because the area has a characteristically high groundwater velocity, the criteria identified by zones 2 and 3 in the table do not apply. For example, a 250-day travel time for water found within the alluvial aquifer (using a permeability of 167 ft/day as estimated by the pump test results) would be 7.9 miles. Since the criteria require that the zone not extend beyond the natural hydrologic boundaries, the zone is reduced to the limit or extent of the canyon in which the NEWUA springs are located. Using this criteria, the north and south limits would include the land to the ridgeline of Rilda Canyon. The west boundary line would be placed at a two mile radius from the NEWUA spring collection system, and the east boundary would be located along the contour line 100 feet lower in elevation from the groundwater source. A map showing the approximate groundwater protection zone boundary as defined by the preliminary draft regulation is presented in Figure HF-41. It should be noted that this boundary is only an approximation of the two mile radial zone as defined in the regulation, and refinement will be needed as the regulation is further defined.

As of the date of this report it is anticipated that public water suppliers will be required to prepare Drinking Water Source Protection plans between December 31, 1993 and December 31, 1996 according to the following schedule.

Population Served by the Public Water Supplier	Drinking Water Source Protection plan due by
Over 10,000 (all wells)	December 31, 1993
3,300 to 10,000 (all wells)	December 31, 1994
Less than 3,300 (all wells)	December 31, 1995
All springs and others	December 31, 1996

These plans will require the submittal of mapping and hydrogeologic information capable of demonstrating the potential impacts from contamination sources. At a minimum they will require 1) the delineation of the protection zone, 2) the inventory of potential contamination sources, 3) a control assessment of each contamination source, 4) land management strategies to be used to control the contamination source, and 5) an implementation schedule and resource evaluation.

c. Spring Impacts

Impacts noted on NEWUA springs during the pump test completed in November 1990 were found to be in the range of approximately ten percent. The impacts are based upon the pump test, water level data collected from P-7, other local piezometers, and spring discharge data. Continued pumping beyond the length of the test completed will likely result in additional declines beyond those noted during the seven-day test. The impacts to the springs based upon varying local conditions and flow patterns have been reviewed as a result of this reporting effort. Some of the changes which could potentially occur to the local groundwater system, thereby impacting local springs, are discussed below.

(1) Total Elimination of Alluvial Flow
In the event that all alluvial aquifer flow from the west up Rilda Canyon was eliminated as a spring recharge source, impacts to the NEWUA springs may be more severe than forty-two of the ninety-three percent estimate made through the use of pumping test data. Impacts to the NEWUA springs would be most severe in the event that local alluvial water provides the majority of the head driving the spring collection system during peak periods. Based on the large fluctuations noted in Well P-3 this appears to be the case. Other flows, including those related to faults and fractures, may provide a relatively constant base flow to the spring collection system; however, the majority of impact potential to the springs at this time appears to be related to alluvial recharge.

(2) Elimination of Other Sources
Other sources of spring recharge water include faults and fractures as well as alluvial flow in the side canyon located adjacent to the NEWUA springs to the south. Should recharge waters feeding the faults originate from areas proposed to be mined and mining diverts the

water from its natural course, impacts to the springs could be cumulative with those resulting from a reduction of alluvial flow as discussed above. Obviously, under these conditions the impacts will be greater than those estimated herein based upon alluvial flow near P-7 alone.

With the exception of P-3, little seasonal variation was noted in the water level within the wells shown in Figure HF-25. The variation noted in P-3 is insufficient, however, to account for the total flow variation measured in the NEWUA springs between high and low flow years. High and low flow alluvial recharge from the main canyon area was estimated earlier to be approximately 372 and 151 gpm, respectively. The increase in alluvial recharge is then the difference between the two values, which is 221 gpm; however, the increase in spring discharge between high and low flows has been reported to be approximately 320 gpm, thirty-one percent higher than the total alluvial flow increase originating from the main canyon area. This may indicate that the remaining portion of NEWUA spring flows come from either other "non alluvial" sources or additional alluvial flow from the south tributary.

Overall Impact Potential. PacifiCorp conducted a pump test project in Rilda Canyon to determine the groundwater characteristics and source. As documented by the pump test, the major source of groundwater to the Rilda Canyon Springs is from the alluvial deposits (refer to Volume 9 - Hydrologic Support Information, Rilda Canyon Pump Test). The majority of the recharge to the alluvial deposits is from the north fork of Rilda Canyon. As shown on Map HM-1, most of the recharge area exists to the west of the East Mountain permit boundary. As previously outlined, the potential impacts to the Rilda Canyon Springs if the groundwater source is eliminated, a worst case scenario. Little impact to spring flow may actually occur unless geologic conditions change as a result of mining. Subsidence could potentially result in the development of cracking or fracturing of the subsurface geologic stratum above the mine workings. Local recharge crossing these hypothetically subsided areas could be lost from the spring recharge system, thereby directly affecting local spring flows. Mining below the left fork of the Rilda Canyon drainage will consist of first mining only (main entry development) which will minimize the potential impacts related to subsidence (refer to Deer Creek mine plan in Volume 4 of the Deer Creek PAP). Mitigation for the loss of spring flow has been based on the elimination of the alluvial recharge which is unlikely to occur based upon the projected extent of the mine compared to the recharge area. Mitigation efforts based on the worst case scenario have been outlined in the following section. The mitigation alternative will become part of the PAP-Volume 9 once it has been agreed upon.

(3) Mitigation

It is apparent from the study completed that, should mining operations intersect or divert (through subsidence) water contributing to either the Rilda Canyon alluvial valley aquifer or the fault and fracture system feeding waters to the spring, flows in the NEWUA springs will decrease. Complete interruption of the water sources feeding the alluvial aquifer will have a severe impact upon the spring system. In addition, a decrease in flow from water sources entering the springs from fault and fracture systems will result in additional impacts. PacifiCorp cooperated with NEWUA in developing a comprehensive mitigation plan. The agreement was signed on April 7, 1994. As part of the agreement PacifiCorp constructed a water treatment plant and storage system loacted near the confluence of Meetinghouse and Huntington canyons. The mitigation alternative information is found in Appendix D of this volume.

3. Interception Of Groundwater By Mine Workings

As previously discussed in this section, the Blackhawk Formation consists of interbedded layers of sandstone and mudstone separated by various mineable and non-mineable coal seams. The sandstone beds-fluvial channel systems are generally massive while the mudstone layers are fine textured and have a tendency to swell when wet and decompose into an impervious clay. Because of the aquiclude formed by mudstone layers in the North Horn Formation, recharge to the Blackhawk Formation is limited, even along major fault systems. Due to the lithologic characteristics of the Blackhawk, both vertical and horizontal migration is constricted.

The interception of groundwater varies and is dependent on several factors. One of the most significant is that when the mine enters virgin country, a significant amount of water is liberated. In virtually all cases the amount of water which flows into the mine exceeds the recharge and, in time, the water inflow decreases in volume. If new areas are not mined, the discharge from the mine will decrease accordingly. As reported in the annual Hydrologic Monitoring reports, flow rates for individual areas including fault zones normally decrease to less than ten percent of the initial flow rate. (Historical information can be found in the annual Hydrologic Monitoring reports.) Following are two recent examples of this. One is TW-10, a drill hole completed across the Roans Canyon Fault zone in the Deer Creek Mine during 1988, which produced approximately 80 gpm during aquifer testing. Once the hole was opened and allowed to discharge the flow rate decreased rapidly and as of early 1991 had stabilized at approximately 4 gpm. Two, as discussed previously, large volumes of water were intersected in Deer Creek Mine, 2nd Right off 4th South (see HM-2) when development workings intersected small sympathetic faults-fractures associated with the Roans Canyon fault system. Initial inflows exceeded 2000 gpm, by far the largest volume of water ever intersected by PacifiCorp operations. Groundwater inflow rates decreased rapidly to approximately 125 gpm as of early 1991.

Long-term monitoring of water producing zones in both Deer Creek and Wilberg/Cottonwood mines has established that once base flow has been reached, the flow is consistent over time. Monitoring has not indicated any seasonal or yearly variations (see annual Hydrologic Monitoring reports for in-mine long-term flow information).

As pointed out by Theis (1957, p. 3), water discharged from a well or, in this case, underground mines, must be balanced by 1) an increase in recharge to the groundwater system, 2) a decrease in natural discharge from the system, or 3) a decrease of groundwater in storage, or by a combination of all of these. As hydrologic studies have shown and monitoring of intercepted groundwater has verified, recharge into the underground workings is limited even in areas of faults and fractures. Based on the hydrologic characteristics of the Blackhawk and the underlying Star Point Formation (low porosity and hydraulic conductivities) and data from surface hydrologic monitoring, decrease in the natural discharge of the system is considered to be only a minor factor; therefore, groundwater intercepted in the permit area is believed to be from storage. One factor which verifies this conclusion is rapid dewatering of intercepted groundwater with no apparent change in the surface hydrological system. As the USGS pointed out in Open File 81-539 and monitoring by PacifiCorp has shown, the majority of surface flow is due to the runoff from the winter snowpack and not from groundwater recharge. It is possible that over a long period of time the groundwater system of the Cottonwood and Huntington Creek drainage systems could be impacted from a slight reduction in recharge; but this is more than offset by the interception of the groundwater, especially in terms of quality, which will be discussed later.

a. Mining Below The Right Fork Of Rilda Canyon

A portion of the Right Fork area of Rilda Canyon lies within the North Rilda Canyon area of the Deer Creek Mine. Due to the environmental sensitivity of the Right Fork area (specifically the sub-surface hydrologic alluvial system and associated surface riparian vegetation zone), a complete analysis of a proposed "no-subsidence / long term stability" design of the 5^{th} North Mains development within the area of the Right Fork of North Rilda Canyon has been conducted addressing the long term ground stability and subsidence protection of the area with regards to proposed mining. All pre-mining and post-mining conditions have been evaluated based on the best geologic and engineering information currently available (refer to Volume 11 of the Deer Creek Mine MRP: R645-301-500 Engineering Section: Appendix 1).

Selection of the Right Fork stream crossing area was based on the results of an extensive surface exploration program conducted in the Right Fork of Rilda Canyon (refer to maps HM-9 and HM-10, Volume 9 of the Deer Creek MRP). A series of six drill holes were completed in 1997 to document coal seam characteristics, structural geology and hydrologic conditions. Drilling was conducted on approximately 250 foot centers across the projected Mill Fork Graben from previously completed drill holes EM-158 and EM-56. No structural discontinuities were identified during drilling. Groundwater encountered during drilling was restricted to minor quantities from the alluvial/colluvial fill (estimated at 2 - 5 GPM) near the alluvial/bedrock interface. Based on the results of the 1997 surface exploration conducted in the Right Fork of Rilda Canyon, a meeting was held in October 1997 with DOGM, USFS, and BLM to discuss the re-location of the 4/5th North intersection to maximize the overburden in the Right Fork stream crossing. The 5th North Mains were re-located approximately 800 feet west of the original projection, increasing the overburden from 120 to approximately 200 feet. A fault system referred to as the Mill Fork Canyon Graben is projected to intersect the western portion of Federal Coal Lease U-06039 (refer to map HM-9). The Mill Fork Canyon Graben was intersected and crossed north of the North Rilda Area permit extension in the Beaver Creek No. 4 Mine and consisted of a series of faults with a total displacement of approximately thirty (30) feet. Beaver Creek No. 4 Mine was a relatively dry mine with only few isolated roof drippers associated with the Mill Fork Fault system. In reviewing the exploration data and in-mine information from the development of the 5th North Mains, it appears that the eastern fault of the Mill Fork Graben diminishes to the south from where it was intercepted in the Beaver Creek No. 4 Mine located north of Mill Fork Canyon. If mining intersects faulting related to the Mill Fork Graben during development, permanent seals will be installed to control groundwater if present.

b. Depletion Of Storage

Three main areas-types of groundwater depletion occur within the permit area and will be discussed separately, 1) fluvial sandstone channel systems, 2) faults and fractures, and 3) structural low areas.

(1) Fluvial Sandstone Channel Systems

Up until early 1990 the majority of the intercepted groundwater was confined to dewatering or perched fluvial sandstone systems. The sandstone channels (ancient river systems) overlie and scour into the underlying strata (refer to Maps HM-2 and HM-3). The locations of the channels shown on HM-2 and HM-3 are based on data collected from in-mine mapping and numerous drill holes, both in-mine and surface, that have been completed on the property. These channel systems were part of a deltaic depositional setting active during and after the coal-forming peat accumulation. The largest influx of water originates from the roof when mining advances beneath sandstone top. The sandstone, which is semi-permeable and porous, affords an effective route of water transport. Mudstone, siltstone, and interbedded materials generally act as aquicludes which impede water flow unless fracturing of the formation has allowed for secondary permeability. Of the water producing areas, those closest to the active mining face exhibit the greatest flows. As mining advances, the area adjacent to the active face continues to be excessively wet and previously mined wet areas experience a decrease in flow. Data collected from 1978 through 1990 indicate a ninety percent reduction in water flows from roof sampling sites over a five-month period (or less) as the mining face is advanced (review annual Hydrologic Monitoring reports). It has also been noted that the outermost entries of a multiple entry system remain wet for a longer period of time than the inner entries. It appears that the water source is being dewatered since excavated areas of the mine do not continue to produce water indefinitely. The water source must be either of limited extent, i.e., a perched aquifer, or have a limited recharge capacity, i.e., poor horizontal and vertical permeability. Figure HF-42 depicts an idealized view of the dewatering process.

To monitor and to quantify the effects of dewatering the perched aquifers overlying the coal seams and on the Star Point Sandstone Formation, PacifiCorp installed a series of holes both in the Deer Creek and Cottonwood/Wilberg mines. These holes are located in main development entries and are shown on maps HM-2 and HM-3 (hole development information can be found in Volume 9 - Hydrologic Support Information). Holes in the Cottonwood/Wilberg Mine were developed in the upper member of the Star Point Sandstone Formation - Spring Canyon. Pressure transducers were installed and monitored on a continuous basis to quantify the impacts to the Star Point Sandstone Formation due to dewatering of the isolated perched aquifers above the Hiawatha Seam. As shown in Figure HF-44 the water elevations remained constant over time with no apparent evidence of an impact-cone of depression due to dewatering of the perched aquifers. In the Deer Creek Mine a series of holes was developed in the lower portion of the Blackhawk and upper member of the Star Point Sandstone Formation. These holes are located along the axis of the Straight Canyon Syncline and are in close proximity to the Roans Canyon Fault system (see HM-2). Monitoring of these wells has shown a decline of between two to seven feet in elevation thought to be related to interception of groundwater in the development entries off 4th South, Deer Creek Mine. Mining in the 4th South area was completed in May of 1992 and seals were installed in 4th South between crosscuts 24 and 25 (see Figure HF-45). This area will be allowed to flood and water production from the sealed area will be monitored as a long-term study area. In addition to monitoring the water production from the 4th South sealed area, PacifiCorp will continue to monitor in-mine wells for any potential impacts of dewatering and will document the recovery rates. To develop an possible area of influence-cone of depression on a regional basis, PacifiCorp installed a series of groundwater monitoring wells in Cottonwood Canyon downgradient of future mining north of the Roans Canyon Fault system(see Appendix C).

(2) Faults And Fractures

Another source of intercepted groundwater is faults and fractures, especially in the Deer Creek Mine. As discussed in the regional and permit area geology (see R645-301-721) the strata within the property have been offset by a series of north-south trending fault zones. Generally, the faults are nearly vertical and do not have significant amounts of fault gouge or drag associated with them. One of the major faults present in the region, the Pleasant Valley Fault, has been intersected in both the Deer Creek and Wilberg mines.

The Pleasant Valley Fault consists of two parallel fractures about 150 feet apart. The fault's total displacement (where it was intersected in the Deer Creek Mine) to the north is 150 feet with its downthrown side on the east. The displacement diminishes to less than one foot where it was intersected in the Wilberg Mine near the south end of the property. Where the fault has been intersected by mine workings, groundwater inflow has been insignificant.

Another north-south trending fault, the Deer Creek Fault, is present to the east of the Pleasant Valley Fault. It limits the eastward development of the Wilberg/Cottonwood and Deer Creek mines and also forms an aquiclude preventing water migration to the east. The displacement of the Deer Creek Fault ranges from 100 to 170 feet with the east block being downthrown.

A northeast-southwest trending fault system, the Roans Canyon Graben, is present along the axis of the Straight Canyon Syncline. The system contains up to six normal faults having displacements ranging from a few feet to over 150 feet. Coal deposits present to the north of the fault have been accessed through rock tunnels driven from the 3rd North section of the Deer Creek Mine.

Several hydrogeologic investigations of the Roans Canyon Fault Graben have been completed to characterize its hydrologic significance. In 1988 a comprehensive hydrogeologic investigation was conducted to develop plans for management of groundwater inflow during and after the construction of three parallel rock tunnels which were completed in 1990. The fault crossing is located in the 3rd North section of the Deer Creek Mine (see Map HM-2). Five (5) test wells were developed in order to conduct the investigation. Selected intervals in the boreholes were tested for hydraulic properties with straddle packers. In addition, one long-term and three (3) short-term constant rate flow tests were performed to measure aquifer parameters. The packer test and flow and recovery test data were analyzed to determine static pressures and gradients through the fault system and to determine transmissivity, hydraulic conductivity, and storage coefficient for each zone tested.

The investigation defined two major hydrogeologic units which are fractured, well-sorted, medium-grained, friable, oxidized channel sandstones. The first sandstone unit is located approximately 350 feet, the second about 650 feet, horizontally from the southern bounding fault (see Map HM-2). The sandstone units are likely of limited vertical thickness but may have more extensive lateral continuity. The two sandstones are heavily oxidized and iron-stained along fractures, and in places the sandstone is totally oxidized for several feet adjacent to the fracture. The oxidation, at a depth of 2000 feet below land surface, indicates that oxygenated water is infiltrating rapidly from the surface through the fractures, suggesting that there is good hydraulic connection between the channel sandstones at the depth of the rock tunnels and the recharge at the surface, primarily through fractures.

Aquifer test results indicated both horizontal and vertical components to the groundwater flow directions. The horizontal gradient measured between two of the test wells, which were 300 feet apart, was approximately 0.038 psi/ft or 0.089 ft/ft. The vertical gradient measured between two of the wells, which were 58 feet apart vertically where they penetrated the first water producing sandstone unit, was approximately 0.069 psi/ft or 0.159 ft/ft, approximately twice the horizontal gradient. Test results indicated the horizontal flow component is the result of flow in the graben from the west toward the east where the graben intercepts the canyon walls and, presumably, the groundwater system discharges. The vertical flow component is controlled by the Star Point Sandstone Formation which underlies the entire graben. The average hydraulic conductivity measured for the fractured sandstone was 15 gallons per day per square foot (gpd/ft^2). The results are within the expected range for this type of aquifer. The average storage coefficients measured at $5x10^{-5}$ (unitless) indicate that the two major sandstone units are confined.

The groundwater flow in the graben occurs primarily in the fractures of the two major water-producing zones with lesser flow quantities in the fractured siltstone units. Virtually no flow occurs in the mudstone between the siltstone and sandstone. The south boundary fault of the graben creates a hydrologic barrier to flow into the mine area south of the graben whereas the north boundary fault does not have a thick fault gouge zone like the one associated with the southern fault, but, from drilling observations, it is also suspected to be a barrier to groundwater flow.

A pressure grout program was utilized to minimize the long-term groundwater inflow from the water-producing zones encountered during slope development. The grouting program consisted of drilling a series of boreholes prior to water-producing zone interception and forcing fast-setting grout material into the fractures. Experience with pressure grouting indicates that as much as seventy-five to ninety-five percent (75-95%) of the groundwater inflow was effectively stopped. Tunnel inflow rates range from 50 to 75 gallons per minute. PacifiCorp utilizes one of the holes developed for hydrologic testing as a long-term monitoring point (see Map HM-2). Data collected from this site confirm the test results, that the groundwater flow would diminish rapidly until a base is reached. The base from this site is approximately five percent of initial flow.

One factor addressed during the dewatering and grouting evaluation was the influence of the tunnels and prior dewatering on the flow in the surface springs located in the vicinity of the Roans Canyon Fault Graben. A maximum drawdown of approximately ten (10) feet at the surface of the graben was calculated using the groundwater model. Given the preexisting dominant vertical flow direction and the fact that the springs do not appear to be associated with aquifers of concern to this investigation, it is unlikely that the tunnels or the recommended dewatering systems would exert a measurable influence on the springs. As part of PacifiCorp's hydrologic monitoring program, major springs associated with the Roans Canyon Fault Graben, i.e., Elk Spring, Sheba Springs, and 79-10, are monitored for flow on a monthly basis. Monitoring has not indicated any mining related impacts but confirms climatological effects.

Another area associated with the Roans Canyon fault system where groundwater was intercepted is in longwall development entries driven west from 4th South Mains (see Map HM-2, Section 7, Township 17 South, Range 6 East). Development entries intersected an unknown sympathetic fault with approximately 2.5 feet of displacement (2nd Right off 4th South). Initial groundwater inflow rates were estimated at approximately 2000 gpm. At that time development was terminated and a hydrogeologic program was developed to determine the extent and bearing of the fracture system. In-mine horizontal drilling was utilized to project the fracture system as well as to isolate the water zone for aquifer testing. The aquifer test utilized inflatable packers to isolate the zone to flow and pressure characteristics. Test results indicated that the fracture zone had similar hydrologic properties to the Roans Canyon system tested in 3rd North, maximum pressure recorded was 90 psi (indicating a relatively low head differential), and flow rates from the fracture zone diminished over time. A permanent monitoring site was established using a two-foot rectangular weir to measure the intercepted groundwater. Flow from this area has diminished rapidly from approximately 2000 gpm in April to 125 gpm in March of 1991, further confirming PacifiCorp's hydrologic model that the majority of intercepted groundwater is in the form of storage and not from recharge. As a result of significant inflows associated with the fracture system, in-mine horizontal drilling was utilized to project the extent and bearing of the fracture system in advance of mining the development entries off of 4th South, Deer Creek Mine. As a result of drilling, mine plans were adjusted based on the projection of the fracture so that the potential for additional interception of groundwater would be reduced. The 4th South area was sealed as of June 1992 and a metering system was installed to monitor the long-term water production from a longwall mined area (see Figure HF-45, seal configuration and metering system). Information on water production will be reported in future Annual Hydrologic reports.

(3) Structural Low Areas

The geologic structure of the area is fairly simple. The strata are gently downfolded in the area of the Straight Canyon Syncline which is present in the northern portion of the property (see Maps CE-10693-EM and CE-10694-EM in the Geologic Section). Dips in the syncline range from two to six degrees with the north limb dipping the steepest.

In the area south of the Straight Canyon Syncline the coal seam dips gently in a northwest direction toward the syncline; however, to the northwest of the Straight Canyon both the Hiawatha and Blind Canyon seams dip in a southeast direction at three to five degrees. The dip and strike of the coal seams can be better visualized on Maps CE-10693-EM and CE-10694-EM in the geologic section. The groundwater tends to migrate to the lowest portion. Wet conditions have been experienced where mining has taken place in the base of the syncline. Structure and gradient studies have indicated that groundwater migrates downdip and, due to hydrologic characteristics of the Blackhawk Formation, becomes perched along hydrologic boundaries, as in the case of East Mountain property, the Roans Canyon system. The groundwater intercepted in the western development entries off 4th South in Deer Creek Mine has been influenced by the Straight Canyon Syncline as well as the Roans Canyon system, but the hydrologic significance of the syncline is much less than that of the Roans Canyon system.

Mitigation efforts utilized by PacifiCorp include in-depth hydrologic investigations to evaluate the permit area as well as regional hydrologic regime, modifications to the mine plans, and a comprehensive Hydrologic Monitoring Program. As mentioned previously, groundwater intercepted in Deer Creek Mine related to the Roans Canyon Fault System was hydrologically evaluated and, as a result, changes in the plan were instituted to reduce the potential for intercepting groundwater. (See previous section for details.) Hydrologic monitoring is utilized to determine changes in both quality and quantity.

c. Quality

The mines in the coal fields of the Wasatch Plateau tend to act as interceptor drains. The groundwater that is brought to the surface has a lower dissolved solids content than would have existed were the water to continue its downward movement through shale layers, dissolving increased amounts of salt with distance (Southeastern Utah Association of Governments, 1977; Vaughn Hansen Associates, 1979; Danielson et al., 1981).

Additional studies by PacifiCorp have confirmed the primary findings of the USGS concerning regional trends in quality. Originally, decreasing quality from north to south was believed to depict the groundwater flow direction, and the quality decreased as a function of the time it traveled through the strata. The time travel component is probably an important factor. But in 1985 a surface exploration program identified the existence of an area of residual heat from an ancient burn on the outcrop throughout the southern portion of East Mountain. The high temperature was also explored within the mine and a portion of reserves were lost because of the situation. It is now theorized that the high temperature water dissolved the mineral constituents of the formations, thereby altering the water chemistry.

The quality also decreases vertically because of the influence of marine sediments as well as along the trend of decreasing quality from north to south.

d. Post Mining

The monitoring of in-mine water sources has shown that the long-term water flow from a given area is much less than ten percent (10%) of the initial flow from the area. Most of the current inflow into the mine workings is from areas where water storage has not been depleted. After the storage has been depleted, the flow will reduce to roughly equal the recharge rate which is expected to be less than ten percent (10%) (data presented earlier in this report) of the current discharge rate. The current discharge rate from all PacifiCorp mines combined is approximately 1000 to 1500 gpm; therefore, the post-mining discharge rate is expected to be approximately 100 to 150 gpm. For verification purposes, PacifiCorp has monitored selected areas of the mine to formulate discharge recession curves over time, enabling a better understanding of the ratio of initial discharge rates and long-term post mining discharge values (discharge recession curves from long-term in-mine water sources can be found in Volume 9 - Hydrologic Support Information, In-Mine Discharge Recession Curves). There is no reason to assume that the post-mining discharge water quality will differ from that currently being discharged (see Groundwater Quality section). The cumulative effect of discharge water on the receiving stream will be insignificant based on data collected from Deer Creek and in comparison to flow differential.

Because the permit area is divided between the Huntington Creek Drainage Basin and the Cottonwood Creek Drainage Basin, seventy-three percent and twenty-seven percent, respectively, the amount of interbasin water transfer that occurs must be considered.

PacifiCorp will install seals as a mitigation effort to minimize interbasin transfer. The average annual flows of Huntington and Cottonwood creeks are 96.3 and 95.1 cfs, respectively (USGS Open File reports #81-539 and #81-141). The current discharge rate from PacifiCorp's total permit areas ranges from 1000 to 1500 gpm, less than two percent of either of the creeks' average flows. Because a limited portion of the Deer Creek Mine workings (less than twenty-seven percent) intersects water that would normally migrate toward the Cottonwood Basin but is discharged out Deer Creek Canyon, the interbasin water transfer from the Cottonwood drainage to Huntington Creek will probably never exceed one percent (<1%) of the average annual discharge of either system.

Water intersected by the Cottonwood/Wilberg Mine workings currently comes from areas underlying both Cottonwood and Huntington Creek drainages. Mining in the 2nd North region undermined areas of the Huntington Creek drainage and previously mined areas of the Deer Creek Mine. Water normally intercepted by the Deer Creek workings migrated down into the Cottonwood workings. As discussed previously PacifiCorp will install seals as a mitigation effort to minimize interbasin transfer. An example of this type of mitigation effort is Cottonwood Mine's installation of a set of seals in 2nd North (March 1993) as soon as the reserves were extracted from that portion of the mine (refer to Figure HF-46). Mining in 8th and 9th Left longwall panels in the Cottonwood Mine occurred beneath the area previously mined by the Deer Creek Mine (8th-10th Right longwall panels). During development in Cottonwood 9th and 10th Left in-mine drilling was utilized to define the extent of water and roof lithology characteristics. Data from the drilling project indicated that a portion of the abandoned Deer Creek Mine workings was flooded. Drill holes shown on Figure HF-46 were utilized to drain the water from the Deer Creek workings prior to longwall production.

Subsequent fracturing as a result of mining the 9th Left longwall panel drained the remaining portion of stored water. Quantity and quality of intercepted groundwater will be documented in the Annual Hydrologic Monitoring Reports.

Of all the portals in PacifiCorp's permit areas, the Trail Mountain Access portals is at the lowest elevation for the Hiawatha Seam (Cottonwood Mine) and the main intake portal in Deer Creek Canyon for the Blind Canyon seam (refer to HM-2 and HM-3 for mine floor elevation contours and portal elevations). To prevent uncontrolled post mine discharges, PacifiCorp will install hydrologic seals at the Trail Mountain Access portals and in 7th West off 3rd South, refer to HM-3. Installation of the hydrologic seals will prevent post mine discharge at the Trail Mountain Access portals and minimize post mine discharge at the Miller Canyon portals. PacifiCorp notified the Division of temporary cessation of coal mining operations at the Cottonwood/Wilberg Mine effective May 29, 2001. Coal mining at the Cottonwood/Wilberg Mine ceased as of March 15, 2001. All portal were sealed according MSHA specifications on May 28, 2001. During temporary cessation, Trail Mountain Access intake portal was designed as a drain. PacifiCorp applied to the Division of Water Quality to relocate UPDES 0022896 outfall 001 from Grimes Wash to Cottonwood Canyon. Approval was granted July 30, 2001.

Groundwater resources of the Miller Canyon area are limited to a series of seeps located near the formational contact between the Blackhawk and Star Point Sandstone formations and the gravity discharge from the old mine workings. The source of the groundwater seeps is from the winter snowpack which melts and infiltrates the lower Blackhawk Formation through vertical fractures. The groundwater flows down vertically until it intersects mudstone layers above and below the Hiawatha seam. Groundwater flow continues horizontally downdip through the permeable sandstone channels located above the Hiawatha seam and the upper member of the Star Point Sandstone Formation until it intersects the land surface in the form of seeps. Flow from the seeps is insufficient for quantity and quality determination. During reclamation, to facilitate post mine gravity discharge from the portals, french drains were installed to prevent slope failure due to saturation of the fill. Field investigations conducted in May 1999 identified minor seeps at portals two and three, and discharge from portal one was estimated at less than 3 gpm. Flow from portal area reaches the canyon floor, but dissipates within 100 feet from the portal area.

Based on the mine elevation contours and installation of the hydrologic seals in the Cottonwood Mine, post mine discharge for the East Mountain property is projected to occur at the intake portal of the Deer Creek Mine located in Deer Creek Canyon. Deer Creek Mine reclamation plan includes installation of french drain system in the intake portal to accommodate post mine discharge. Further hydrologic monitoring will identify the potential for discharge at each location, and PacifiCorp commits to conducting hydrologic assessment of potential impacts.

R645-301-729 CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT (CHIA)

The Division will provide an assessment of the probable cumulative hydrologic impacts of the proposed coal mining and reclamation operation and all anticipated coal mining and reclamation operations upon surface and groundwater systems in the cumulative impact area.

R645-301-730 OPERATION PLAN

R645-301-731 GENERAL REQUIREMENTS

PacifiCorp has submitted a plan to minimize disturbance to the hydrologic balance, to prevent material damage, and to support approved post-mining land use (see Operational and Reclamation plans of the individual PAP's).

R645-731-100 HYDROLOGIC BALANCE PROTECTION

A. GROUNDWATER PROTECTION

Although the analysis of the overburden samples tested has shown that no toxic or hazardous materials are present, groundwater quality will be protected by handling earth materials and runoff in a manner that minimizes infiltration to the groundwater system.

B. SURFACE WATER PROTECTION

Surface water quality will be protected by handling earth materials, groundwater discharges, and runoff in a manner that minimizes the potential for pollution.

R645-731-200 WATER MONITORING

A. GROUNDWATER

Groundwater within the East Mountain permit area will be monitored according to the schedules in Appendix A.

PacifiCorp has conducted baseline and operational monitoring of springs and in-mine water sources in and adjacent to the permit area. The springs located within or immediately adjacent to areas overlying coal to be mined in the next five (5) years or areas overlying previously mined areas will be monitored (except that the discharge recession curve springs will be monitored in the future regardless of their position relative to mining). The data collected have provided information useful in the understanding of potential hydrologic consequence of mining.

1. East Mountain Springs

Water samples will be collected and analyzed during the months of July and October. Parameters analyzed are those listed in the "DOGM Guidelines for Groundwater Water Quality" (see Appendix A).

2. In-Mine

Two water samples will be collected and analyzed per mine quarterly. Parameters analyzed are those listed in the "DOGM Guidelines for Groundwater Water Quality" (see Appendix A).

Intercepted groundwater sampling sites, (either roof drippers or contribution from the floor), will be established according to the Special Condition Stipulation in the Deer Creek permit renewal, (February 6, 1996); *"If during entry development, sustained quantities of groundwater are encountered which are greater than 5 gpm from a single source in an individual entry, and which continue after operational activities progress beyond the area of groundwater production, PacifiCorp must monitor these flows for quality and quantity under the approved monitoring plan".* In addition to the standard plan described above, if mining encounters significant quantities of groundwater which issues from a fault zone, PacifiCorp will; quantify the volume, sample for water quality according to the approved monitoring plan (baseline parameters for two year period), conduct isotopic sampling using a systematic approach (phase 1: tritium analysis, phase 2: depending the results of the tritium sampling, perform carbon age dating).

3. Waste Rock Wells

One water sample will be collected and analyzed per location quarterly. Parameters analyzed are those listed in the "DOGM Guidelines for Groundwater Water Quality" (see Appendix A).

B. SURFACE WATER

PacifiCorp has conducted baseline monitoring of surface waters within and adjacent to the permit area. Water samples will be collected and analyzed quarterly (one sample at low flow and high flow) during the first or second week of the quarter. Parameters analyzed are those listed in the "DOGM Guidelines for Surface Water Quality." Long-term monitoring sites have been equipped with Parshall style flumes to facilitate monitoring. Locations of all surface monitoring sites and sampling schedules can be found in Appendix A.

R645-301-731.300 ACID AND TOXIC-FORMING MATERIALS

Refer to Waste Rock Permit applications.

R645-301-731.500 DISCHARGES

Refer to Mine Dewatering R645-301-721 and UPDES information in Appendix B.

R645-301-731.600 STREAM BUFFER ZONES

Mining related activities will not occur within 100 feet of a perennial or intermittent streams unless the Division authorizes such activities.

As mentioned in the PROBABLE HYDROLOGIC CONSEQUENCES DETERMINATION section, (728: Hydrologic Balance - Surface Water System), the drainages conveying runoff away from the North Rilda areas are streams in Rilda, and Mill Fork canyons. Second mining, ie. longwall extraction, room & pillar, of the North Rilda area will be limited to the ridge separating Rilda and Mill Fork canyons and subsidence will not occur beneath the stream channels of these canyons. First mining, ie. mainline, gateroad development, will occur below the right fork of Rilda Canyon. For a complete analysis of the proposed "no subsidence" design of the 4/5th North Mains development within the Right Fork of Rilda and the long-term stability analysis, refer to the Engineering Section R645-301-500 Appendix 1. To protect the alluvial/colluvial system of the Right Fork of Right Fork of Rilda Canyon, a stream buffer zone was established based on the extent of the riparian zone and the angle of draw from the Hiawatha Seam, the lowest seam to be mined. The riparian zone within the right fork of Rilda Canyon was delineated by field observation, aerial photography, and map contour analysis. The extent of the identified zone is based on the contact of the alluvial/colluvial fill with the canyon's side slopes. The angle of draw was calculated from the Hiawatha Seam horizon/elevation @ 15 degrees to the point of intersection on the surface. The stream buffer zone delineates the area restricted from full extraction mining. The referenced 15 degree angle of draw is an industry/agency accepted standard used for delineation of surface influence protection from mining areas considered for full extraction mining. Mining experience at Energy West's Deer Creek, Cottonwood, and Trail Mountain mines has provided a sound, scientific basis for using the 15^{o} angle of draw mentioned above (refer to Annual Subsidence Reports of the Deer Creek MPR).

R645-301-731.700 CROSS SECTION AND MAPS

731.710-720 and 750 A water supply intake system known as "North Emery Water Users Association - Rilda Canyon Springs" is located in Section 28, Township 16 South, Range 7 East (refer to Map HM-9 within this volume, a detailed drawing of the collection system is provided in Volume 9 - Hydrologic Section Map HM-8). The intake system consists of a series of french drains collecting near surface alluvial water as a supply source for culinary water (for complete description of the NWEUA system refer to R645-721 “Existing Groundwater Resources”). No surface disturbance is planned within the boundaries of the North Rilda Area. Accordingly, it will not be necessary to divert, collect, convey, store, or discharge water from disturbed areas.

Mine Sites: All disturbed area drainage will flow into an approved sediment control device. Maps showing water diversion, collection, conveyance, treatment, storage, and discharge can be found in the Operational section of the individual PAP's.

730 Water Monitoring Location Map - See HM-1.

R645-301-731.800 WATER RIGHTS AND REPLACEMENT

In order to fulfill the requirements to restore the land affected by applicant's mining operations to a condition capable of supporting the current and post-mining land uses stated herein, the applicant will replace water determined to have been lost or adversely affected as a result of applicant's mining operations if such loss or adverse impact occurs prior to final bond release. The water will be replaced from an alternate source in sufficient quantity and quality to maintain the current and post-mining land uses.

R645-301-732 - 764 SEDIMENT CONTROL

Information pertaining to sediment control can be found in the Operational plans of the individual PAP's.

R645-301-748, 755, 765 CASING AND SEALING OF WELLS

Each water well will be cased, sealed, or otherwise managed, as approved by the Division.

R645-301-751 WATER QUALITY STANDARDS AND EFFLUENT LIMITATIONS

Discharges of water from areas disturbed by coal mining and reclamation operations will be made in compliance with all Utah and federal water quality laws and regulations and with effluent imitations for coal mining promulgated by the EPA set forth in 40CFR Part 434 (see Appendix B for UPDES permit information).

Cottonwood Mine
C/015/019
Deer Creek Mine
C/015/018
Des-Bee-Dove Mine
C/015/017

Volume 9 Hydrologic Section

Appendices

Replace Appendix A
Entire Section

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April 8, 2005

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HYDROLOGIC MONITORING PROGRAM
DEER CREEK, WILBERG/COTTONWOOD, DES-BEE-DOVE
and TRAIL MOUNTAIN MINES

I. MONITORING LOCATIONS

A. Surface Water Hydrology (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1, Deer Creek Volume 12 R645-301-700: Hydrologic Monitoring Map MFS1851D Mill Fork Lease for East Mountain locations listed below / Trail Mountain Mine: Volume 3 Plate 7-1 and Plate 7-2 for Trail Mountain locations listed below)

1. Cottonwood Creek Drainage System

a. ***Cottonwood Canyon Creek*** (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1 or Trail Mountain Mine Permit Volume 3 Plate 7-1)

(1) SW-1 - Above Trail Mtn. Mine
(Approximately 5000 feet upstream from the inlet culvert for the disturbed area.) 2150 feet South, 2000 feet East of the Northwest corner of Section 24, Township 17 South, Range 6 East.

(2) SW-2 - Below Trail Mtn. Mine
(Approximately 200 feet downstream from the outlet culvert for the disturbed area.) 1300 feet South, 1750 feet West of the Northeast corner of Section 25, Township 17 South, Range 6 East.

(3) CCC01 - USGS Flume:
(Approximately 7800 feet downstream from the outlet culvert for the disturbed area.)1500 feet North, 200 feet East of the Southwest corner of Section 31, Township 17 South, Range 7 East.

(4) SW-3 - Below Trail Mtn. Mine
(Approximately 3800 feet above confluence with Straight Canyon) 2400 feet South, 2400 feet East of the Northeast corner of Section 6, Township 18 South, Range 6 East.

b. ***Unnamed Drainage off Straight Canyon*** (refer to Trail Mountain Mine Permit Volume 3 Plate 7-1)
   (1) T-19
   (Approximately 200 feet upstream from the from confluence with Straight Canyon) 2500 feet South, 1100 feet East of the Northeast corner of Section 3, Township 18 South, Range 6 East.

c. ***Grimes Wash*** (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1)
   (1) GWR01 - Right Fork:
   (Approximately 1500 feet upstream from the inlet culvert for the disturbed area.) 550 feet North, 1500 feet West of the Southwest corner of Section 22, Township 17 South, Range 7 East.
   (2) GWR02 - Left Fork:
   (Approximately 50 feet upstream from the inlet culvert for the disturbed area.) 200 feet South, 2350 feet East of the Northwest corner of Section 27, Township 17 South, Range 7 East.
   (3) GWR03 - Below the mine:
   (Approximately 500 feet downstream from the outlet culvert below the disturbed area.) 1770 feet South, 1820 feet West of the Northeast corner of Section 27, Township 17 South, Range 7 East.

d. ***Indian Creek*** (refer to Deer Creek Volume 12 R645-301-700: Hydrologic Monitoring Map MFS1851D)
   (1) ICA - Indian Creek Above
   (Approximately 2500 feet northwest of the Mill Fork permit boundary) 400 feet North, 2350 feet West of the Southwest corner of Section 3, Township 16 South, Range 6 East.
   (2) ICF - Indian Creek Flume
   (Approximately 2100 feet west of the Mill Fork permit boundary) 300 feet North, 3400 feet West of the Southwest corner of Section 10, Township 16 South, Range 6 East.

(3) ICD - Indian Creek Ditch
(Approximately 1600 feet west of the Mill Fork permit boundary, irrigation ditch for Upper Joes Valley) 240 feet North, 2850 feet West of the Southwest corner of Section 15, Township 16 South, Range 6 East.

(4) ICB - Indian Creek Below
(Approximately 3700 feet west of the Mill Fork permit boundary, junction of Indian Creek and FDR040) 70 feet North, 120 feet West of the Southwest corner of Section 16, Township 16 South, Range 6 East.

2. Huntington Creek Drainage System

a. ***Huntington Creek*** (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1)

(1) HCC01 - Above Deer Creek Confluence:
1400 feet north, 2200 feet west of the southeast corner of Section 36, Township 16 South, Range 7 East.

(2) HCC02 - Below Deer Creek Confluence:
300 feet north, 300 feet west of the southwest corner of Section 31, Township 16 South, Range 8 East.

(3) HCC03 - Below Huntington Power Plant:
2500 feet north, 1500 feet east of the southeast corner of Section 6, Township 17 South, Range 8 East.

(4) HCC04 - @ Research Farm*
800 feet north, 200 feet east of the southwest corner of Section 5, Township 17 South, Range 8 East.
*Not listed on map due to scale.

b. ***Deer Creek*** (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1)

(1) DCR01 - Above the mine:
(Approximately 600 feet upstream from the mine facility.) 200 feet North, 800 feet West of the Southeast corner of Section 10, Township 17 South, Range 7 East.

(2) DCR04 - Near C1/C2 Belt Intersection: (Approximately 5,000 feet downstream from the mine facility.) 300 feet North, 2000 feet East of the Southeast corner of Section 2, Township 17 South, Range 7 East.

(3) DCR06 - @ Huntington Creek Confluence: (Approximately 15,000 feet downstream from the facility) 1400 feet north, 1100 feet east of the southeast corner of Section 36, Township 16 South, Range 7 East.

c. ***Meetinghouse Canyon - South Fork*** (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1) (Approximately 200 feet upstream from the north and south convergence.) 800 feet North, 1500 feet East of the Southwest corner of Section 35, Township 16 South, Range 7 East.

d. ***Rilda Canyon*** (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1)

(1) RCF-1 - Rilda Canyon - Right Fork: (Approximately 4000 feet upstream from the Right and Left fork convergence.) 400 feet South, 200 feet West of the Northeast corner of Section 30, Township 16 South, Range 7 East.

(2) RCLF1 - Rilda Canyon - Left Fork, below Rilda Canyon Portals: (Approximately 200 feet upstream from the Right and Left fork convergence.) 2400 feet North, 2100 feet West of the Southeast corner of Section 29, Township 16 South, Range 7 East.

(3) RCLF2 - Rilda Canyon - Left Fork, above Rilda Canyon Portals: (Approximately 1600 feet upstream from the Right and Left fork convergence.) 1600 feet North, 2300 feet West of the Southwest corner of Section 29, Township 16 South, Range 7 East.

(4) RCF2 - Rilda Canyon - Above NEWUA springs: 2500 feet South, 400 feet West of the Northeast corner of Section 29, Township 16 South, Range 7 East.

(5) RCF3 - Rilda Canyon - Below NEWUA springs: 2550 feet South, 1000 feet East of the Northeast corner of Section 28, Township 16 South, Range 7 East.

(6) RCW4 - Rilda Canyon: (Approximately 1000 feet upstream from the confluence with Huntington Creek.) 850 feet North, 1900 feet West of the Southeast corner of Section 26, Township 16 South, Range 7 East.

e. ***Mill Fork Canyon*** (refer to Deer Creek Volume 12 R645-301-700: Hydrologic Monitoring Map MFS1851D)

(1) MFA01 - Mill Fork Canyon - Above Old Mine: (Approximately 2000 feet above old mine portals @ end of USFS development road.) 100 feet North, 1500 feet West of the Southeast corner of Section 17, Township 16 South, Range 7 East.

(2) MFB02 - Mill Fork Canyon - Above Huntington Creek Confluence: (Approximately 200 feet above confluence with Huntington Creek @ culvert outfall.) 100 feet South, 1900 feet East of the Northwest corner of Section 22, Township 16 South, Range 7 East.

(3) MFU03 - Mill Fork Canyon - Above Mill Fork Fault Crossing: (Approximately 700 feet upstream of projected Mill Fork Fault crossing) 1150 feet North, 1700 feet East of the Southwest corner of Section 17, Township 16 South, Range 7 East.

3. Reclamation Monitoring:
Following stage 1 final reclamation backfilling and grading monitoring will be conducted at points immediately above and below the last sediment pond(s).

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HYDROLOGIC MONITORING PROGRAM
DEER CREEK, WILBERG/COTTONWOOD, DES-BEE-DOVE
and TRAIL MOUNTAIN MINES

B. Groundwater Hydrology

1. **East Mountain Springs** (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine Permit : Volume 9 maps HM-4 and HM-5)

Burnt Tree *	80-41
Elk Spring *	80-43
Sheba Springs *	80-44*
Ted's Tub	80-46*
79-2	80-47
79-10 *	80-48
79-15	80-50
79-23 *	82-51
79-24	82-52*
79-26 *	84-56*
79-28 (Flag Lake)	89-60(Alpine Spring)
79-29 *	89-61
79-32	89-65
79-34	89-66
79-35 *	89-67
79-38	89-68
79-40	Rilda Canyon-(Meters 2&3)

* Recession Study Springs (Flow August & September)

2. **Trail Mountain Springs** (refer to Trail Mountain Mine Permit Volume 3 Plate 7-1)

T-6	T-14
T-8	T-15
T-9	T-16
T-10	T-18 (Oliphant Mine Discharge)

3. **East Mountain Springs - Mill Fork Area** (refer to Deer Creek Permit Volume 12 R645-301-700: Hydrologic Monitoring Map MFS1851D)

EM-216	MFR-30
JV-9	RR-5
JV-34	RR-15
MF-7	RR-23A
MF-10	SP1-26
MF-19B	SP1-29
MF-213	UJV-101
MF-219	UJV-206
MFR-10	EMPOND
Grants Spring	Little Bear Spring

3. **Piezometric Data**
   a. Surface
      (1) Rilda Canyon (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1)
         P1
         P5
         P6
         P7
         EM-47
      (2) Cottonwood Canyon Creek
         East Mountain (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1)
         EM-31
         CCCW-1A
         CCCW-1S
         CCCW-2A
         CCCW-3A
         CCCW-3S U
         CCCW-3S L

Trail Mountain (refer to Trail Mountain Mine Permit Volume 3 Plate 7-1)
TM-1B
TM-3

b. Underground: In-Mine
   (1) Deer Creek Mine (Refer to Annual Hydrologic Reports for Locations : Map HM-2)

4. In-Mine Water Locations
   a. Deer Creek Mine (Refer to Annual Hydrologic Reports for Locations : Map HM-2)
   b. Wilberg/Cottonwood Mines (Refer to Annual Hydrologic Reports for Locations : Map HM-3)
   c. Trail Mountain Mine (Refer to Annual Hydrologic Reports for Locations : PLATE 7-3)

5. Waste Rock Wells (refer to Deer Creek, Wilberg/Cottonwood, Des-Bee-Dove Mine: Volume 9 Map HM-1)
   a. Deer Creek
   b. Cottonwood

C. UPDES Monitoring Locations

a. ***Deer Creek Mine***
UPDES UT0023604
001- Sediment Pond
002- Mine Discharge

b. ***Des-Bee-Dove Mines***
UPDES UTG040022
001- Sediment Pond

c. ***Wilberg/Cottonwood Mines***
UPDES UT0022896
001- Mine Discharge @ Cottonwood Canyon (TMA)
002- Sediment Pond Discharge @ Cottonwood Canyon
003- Sediment Pond @ Mine Facilities
004- Mine Discharge @ Miller Canyon
005- Sediiment Pond Discharge @ Waste Rock Site

d. ***Trail Mountain Mine***
UPDES UT0023728
001- Sediment Pond
002- Mine Discharge

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HYDROLOGIC MONITORING PROGRAM
DEER CREEK, WILBERG/COTTONWOOD, DES-BEE-DOVE
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II. MONITORING SCHEDULE (see enclosed monitoring table)

A. Field Measurements

Field Measurements collected during quality sampling: Listed below are the sites which will be monitored by PacifiCorp - Energy West in accordance with the guidelines established by DOGM; i.e.,

- Date and Time
- Flow
- pH
- Temperature
- Conductivity
- Dissolved oxygen (perennial streams only)

Surface Monitoring

Surface monitoring locations will be field monitored quarterly for all field parameters, except Indian Creek - monitoring to be conducted during baseflow only.

1. **Cottonwood Canyon Creek**
   a. Cottonwood Canyon Creek
      (1) SW-1
      (2) SW-2
      (3) Cottonwood Canyon Creek - USGS Flume
      (4) SW-3
   b. Grimes Wash
      (1) GWR01
      (2) GWR02
      (3) GWR03
   c. Indian Creek
      (1) ICA
      (2) ICF
      (3) ICD
      (4) ICB
   d. Straight Canyon
      (1) T-19 (Unnamed Side Drainage)

2. Huntington Canyon Drainage

a. Deer Creek
   (1) DCR01
   (2) DCR04
   (3) DCR06

b. Huntington Creek
   (1) HCC01
   (2) HCC02
   (3) HCC04

   Flow in Huntington Creek is measured only at HCC01 by Utah Power, and will be reported in the Annual Hydrologic Report.

c. Meetinghouse Canyon - South Fork: MCH01

d. Rilda Canyon
   (1) RCF1*
   (2) RCLF 1
   (3) RCLF 2
   (4) RCF2
   (5) RCF3
   (6) RCW4

   * Baseline flow will be measured adjacent to EM-163

e. Mill Fork Canyon
   (1) MFA01
   (2) MFB02
   (3) MFU03

Groundwater Monitoring

1. East Mountain Springs (see monitoring location list)
2. Trail Mountain Springs (see monitoring location list)
3. East Mountain Springs - Mill Fork Area (see monitoring location list)

   East/Trail Mountain Springs will be field monitored during the months of July and October. In addition, the East Mountain Recession Study Springs (denoted by asterisks in the Monitoring Location section) and Trail Mountain Springs will be field monitored for flow only from July through October. T-18: Oliphant Mine Discharge, will be collected and analyzed quarterly. Rilda Canyon Springs - NEWUA (meters 2 & 3) will be field monitored monthly depending upon access.

3. In-Mine
    a. Deer Creek
    b. Wilberg/Cottonwood
    c. Trail Mountain

    In-mine locations will be field monitored quarterly for all field parameters except pH, conductivity, and dissolved oxygen.

4. Piezometric Wells
    a. Surface

    Piezometric surface wells will be field monitored for level only on a monthly basis depending upon access.

    (1) Rilda Canyon (see Map HM-1 for locations)
        P1
        P5
        P6
        P7
        EM-47
    (2) Cottonwood Canyon Creek (see Map HM-1 for locations)
        EM-31
        CCCW-1A
        CCCW-1S
        CCCW-2A
        CCCW-3A
        CCCW-3S U
        CCCW-3S L
        TM-1B
        TM-3

5. Waste Rock Wells
    a. Deer Creek
    b. Cottonwood

UPDES Monitoring

1. Deer Creek
2. Des-Bee-Dove
3. Wilberg/Cottonwood
4. Trail Mountain

UPDES sites will be monitored as speicfied in the individual permits.

Reclamation Monitoring

Surface Water Resources: (see enclosed monitoring table)
Surface monitoring locations will be field monitored monthly for flow and all field parameters quarterly until bond release.

Ground Water Resources: (see enclosed monitoring table)

Springs: East/Trail Mountain Springs will be field monitored during the months of July and October.
Rilda Canyon Springs NEWUA (meters 2 & 3) will be field monitored monthly for flow depending upon access. East/Trail Mountain Springs (including Rilda Springs and T-18 [Oliphant Mine]) monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.

Wells: Piezometric surface wells (Rilda Canyon and Cottonwood Canyon including TM-3 in Straight Canyon): will be field monitored for level only on a monthly basis depending upon access. Piezometric surface well monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.
Waste Rock Wells and TM-1B: will be field monitored for level only on a quarterly basis. Monitoring will be conducted until sealing during Phase I reclamation.

UPDES: Sites will be monitored as specified in the individual permits

B. Quality Sampling (Laboratory Measurements)

1. **Surface Water Hydrology:** Water samples will be collected and analyzed quarterly (one sample at low flow and high flow) during the first or second week of the quarter, except for Indian Creek - quality samples will be collected during baseflow only. Parameters analyzed are those listed in the DOGM Guidelines for Surface Water Quality (see Table #1). Quarterly sampling was initiated during March 1988 and will continue throughout the year; i.e., June, September, and December. Baseline analysis was performed in 2001 and will be repeated every five years thereafter.

a. **Cottonwood Creek Drainage**

(1)Cottonwood Canyon Creek
- (a) SW-1
- (b) SW-2
- (c) SW-3

(2)Grimes Wash
- (a)GWR01
- (b)GWR02
- (c)GWR03

(3) Indian Creek
- (a) ICA
- (b) ICD
- (c) ICB

(4) Straight Canyon
- (a) T-19

b. **Huntington Creek Drainage**

(1) Deer Creek
- (a) DCR01
- (b) DCR04
- (c) DCR06

(2) Huntington Creek
- (a) HCC01
- (b) HCC02
- (c) HCC04

(3) Meetinghouse Canyon - South Fork: MCH01

(4) Rilda Canyon
 (a) RCF1
 (b) RCF3
 (c) RCW4
(5) Mill Fork Canyon
 (a) MFA01
 (b) MFB02
 (c) MFU03

Reclamation Monitoring - Surface Water Hydrology: Water samples will be collected and analyzed quarterly (one sample at low flow and high flow) during the first or second week of the quarter. Parameters analyzed are those listed in the DOGM Guidelines for Surface Water Quality (see Table #1). Sampling will be conducted on a quarterly basis until bond release. Baseline analysis will be performed on the 5^{th} and 9^{th} years following reclamation. In no case will baseline sampling time frame exceed 5 years converting from operational to reclamation monitoring.

2. Groundwater Hydrology

a. East/Trail Mountain Springs: Water samples will be collected and analyzed during the months of July and October. Rilda Canyon Springs (NEWUA: Meters 2 & 3) and T-18 (Oliphant Mine Discharge) will be monitored for quarterly for quality. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2).
b. In-Mine: Two water samples will be collected and analyzed per mine quarterly. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2).
c. Wells: TM-1B will be sampled quarterly. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2).
d. Waste Rock Wells: One water sample will be collected and analyzed per location quarterly. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2).

Baseline analysis was performed in 2001 and will be repeated every five years thereafter.

Reclamation Monitoring - Groundwater Hydrology:

a. East/Trail Mountain Springs: Water samples will be collected and analyzed during the months of July and October. Rilda Canyon Springs (NEWUA: Meters 2 & 3) will be monitored quarterly for quality. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2). East/Trail Mountain Springs (including Rilda Springs and T-18 [Oliphant Mine Discharge]) monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.

b. In-Mine: Two water samples will be collected and analyzed per mine quarterly until the mine is sealed or the sites become inaccessible. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2).

c. Wells: Well TM-1B will be sealed during Phase I reclamation. Quarterly sampling will continue until sealing. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2).

d. Waste Rock Wells: Waste rock wells will be sealed during Phase I reclamation. One water sample will be collected and analyzed per location quarterly until well sealing. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2).

e. Post Reclamation Monitoring: PacifiCorp commits to conduct annual surveys to identify new discharge locations within and below sealed portals. If discharge occurs, one water sample will be collected and analyzed per location quarterly. Parameters analyzed are those listed in the DOGM Guidelines for Groundwater Water Quality (see Table #2). Baseline analysis will be performed on the 5th and 9th year.

3. UPDES Monitoring Sites

a. Deer Creek Mine
b. Des-Bee-Dove Mines
c. Wilberg/Cottonwood Mines
d. Trail Mountain Mine

UPDES sites will be monitored as speicfied in the individual permits.

III. ANNUAL REPORTS

All data collected regarding the hydrology of East/Trail Mountain will be summarized by the applicant in an annual Hydrologic Monitoring Report. Copies of the report will be submitted to the; U.S. Forest Service; and the Utah State Division of Oil, Gas and Mining. In addition, any raw data collected will be submitted to the Utah State Division of Oil, Gas and Mining on a quarterly basis.

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HYDROLOGIC MONITORING PROGRAM

TABLE 1
SURFACE WATER (UPDES Monitoring) BASELINE, OPERATIONAL, POSTMINING WATER QUALITY PARAMETER LIST

Field Measurements:

	*	-	Water Level or Flow
	*	-	pH
	*	-	Specific Conductivity (umhos/cm)
	*	-	Dissolved Oxygen (ppm) (Perennial Streams Only)
	*	-	Temperature

Laboratory Measurements: (mg/l)

#	*	-	Total Settleable Solids (UPDES Only)
#	*	-	Total Suspended Solids
	*	-	Total Dissolved Solids
	*	-	Total Hardness ($CaCO_3$)
		-	Acidity ($CaCO_3$)
		-	Aluminum (Al) - Dissolved
		-	Arsenic (As) - Dissolved
		-	Boron (B) - Dissolved (Waste Rock Sites Only)
	*	-	Carbonate ($CaCO_3$)
	*	-	Total Alkalinity/Bicarbonate ($CaCO_3$)
		-	Cadmium (Cd) - Dissolved
	*	-	Calcium (Ca) - Dissolved
	*	-	Chloride (Cl^-)
		-	Copper (Cu) - Dissolved
	*	-	Iron (Fe) - Total & Dissolved
		-	Lead (Pb) - Dissolved
	*	-	Magnesium (Mg) - Dissolved
	*	-	Manganese (Mn) - Total & Dissolved
		-	Molybdenum (Mo) - Dissolved
		-	Nitrogen: Ammonia (NH_3) - reported as N
		-	Nitrite (NO_2) - reported as N
		-	Nitrate (NO_3^-) - reported as N
	*	-	Potassium (K) - Dissolved
	*	-	Oil & Grease (UPDES & Above & Below Mine Sites Only)
		-	Ortho Phosphate (PO_4^{-3}) - reported as P
		-	Selenium (Se) - Dissolved (Waste Rock Sites Only)
	*	-	Sodium (Na) - Dissolved
	*	-	Sulfate (SO_4^{-2})
		-	Zinc (Zn) - Dissolved
	*	-	Cation-Anion Balance

Construction * Operational - Baseline

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HYDROLOGIC MONITORING PROGRAM

TABLE 2
GROUND WATER BASELINE, OPERATIONAL, POSTMINING WATER QUALITY PARAMETER LIST

Field Measurements:

*	-	Water Level or Flow
*	-	pH
*	-	Specific Conductivity (umhos/cm)
*	-	Temperature

Laboratory Measurements: (mg/l)

*	-	Total Dissolved Solids
*	-	Total Hardness ($CaCO_3$)
	-	Acidity ($CaCO_3$)
	-	Aluminum (Al) - Dissolved
	-	Arsenic (As) - Dissolved
	-	Boron (B) - Dissolved (Waste Rock Sites Only)
*	-	Carbonate (CO_3^{-2})
*	-	Total Alkalinity/Bicarbonate ($CaCO_3$)
	-	Cadmium (Cd) - Dissolved
*	-	Calcium (Ca) - Dissolved
*	-	Chloride (Cl^-)
	-	Copper (Cu) - Dissolved
*	-	Iron (Fe) - Total & Dissolved
	-	Lead (Pb) - Dissolved
*	-	Magnesium (Mg) - Dissolved
*	-	Manganese (Mn) - Total & Dissolved
	-	Molybdenum (Mo) - Dissolved
	-	Nitrogen: Ammonia (NH_3) - reported as N
	-	Nitrite (NO_2) - reported as N
	-	Nitrate (NO_3^-) - reported as N
*	-	Potassium (K) - Dissolved
	-	Ortho Phosphate (PO_4^{-3}) reported as P
	-	Selenium (Se) - Dissolved (Waste Rock Sites Only)
*	-	Sodium (Na) - Dissolved
*	-	Sulfate (SO_4^{-2})
	-	Zinc (Zn) - Dissolved
*	-	Cation-Anion Balance

* Operational - Baseline

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HYDROLOGIC MONITORING PROGRAM

WATER SAMPLE DOCUMENTATION

The following information will be included on the lab sheets:

1. Sample time and date
2. Individual taking sample
3. Field parameters (except in-mine)
   - Temperature
   - Flow
   - pH (units)
   - Conductivity (umhos/cm)
   - Dissolved Oxygen (PPM), depending on location
4. Precipitation date if applicable
5. Date and time each parameter is analyzed at the lab

ANALYTICAL METHOD AND DETECTION LIMIT

Parameter	MRL	UNITS	Method
Acidity	5	mg/l $CaCO_3$	D1067-92
Alkalinity, Bicarbonate	5	mg/l $CaCO_3$	SM 2320 B
Alkalinity, Carbonate	5	mg/l $CaCO_3$	SM 2320 B
Alkalinity, Total	5	mg/l $CaCO_3$	SM 2320 B
Aluminum	0.03	mg/l	EPA 200.7
Anions	----	meq/l	-------------
Arsenic	.01	mg/l	EPA 200.7
Barium	0.02	mg/l	EPA 200.7
Boron	0.01	mg/l	EPA 200.7
Cadmium	0.001	mg/l	EPA 200.7
Calcium	0.03	mg/l	EPA 200.7
Cations	----	meq/l	-------------
Chloride	1	mg/l	EPA 300.0
Chromium	0.001	mg/l	EPA 200.7
Conductivity	---	umhos/cm	SM2510-B
Copper, Drinking Water	0.01	mg/l	EPA 220.1
Copper, Waste Water	0.01	mg/l	EPA 200.7
Fluoride	0.05	mg/l	EPA 300.0
Hardness, Total	----	mg/l $CaCO_3$	SM2340-B
Iron	0.05	mg/l	EPA 200.7
Iron, Dissolved	0.03	mg/l	EPA 200.7
Lead, Drinking Water	0.001	mg/l	EPA 239.2
Lead, Waste Water	0.01	mg/l	EPA 200.7
Magnesium	0.01	mg/l	EPA 200.7
Manganese	0.002	mg/l	EPA 200.7
Mercury	.0002	mg/l	EPA 245.1
Molybdenum	0.005	mg/l	EPA 200.7
Nickel	0.001	mg/l	EPA 200.7
Nitrogen, Ammonia	0.1	mg/l	EPA 350.3
Nitrogen, Nitrate	0.05	mg/l	EPA 300.0
Nitrogen, Nitrite	0.05	mg/l	EPA 300.0
Oil & Grease	2	mg/l	EPA 413.1
Oxygen, Dissolved	----	mg/l	EPA 360.1
pH	----	Units	EPA 150.1
Phosphorus, Ortho	0.05	mg/l	EPA 300.0
Phosphorus, Total	0.05	mg/l	SM 4500P, B & E
Potassium	0.14	mg/l	EPA 200.7
Selenium	0.02	mg/l	EPA 200.7
Silver, Total	0.002	mg/l	EPA 200.7
Sodium	0.01	mg/l	EPA 200.7
Solids, Settleable	0.1	ml/l	EPA 160.5
Solids, Total Dissolved	30	mg/l	EPA 160.1
Solids, Total Suspended	5	mg/l	EPA 160.2
Sulfate	1	mg/l	EPA 300.0
Sulfide	1	mg/l	EPA 376.1
Turbidity	0.1	NTU	EPA 180.1
Zinc, Total	0.004	mg/l	EPA 200.7
Zinc, Dissolved	0.004	mg/l	EPA 200.7

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HYDROLOGIC MONITORING PROGRAM

DEER CREEK/COTTONWOOD-WILBERG/DES-BEE-DOVE/TRAIL MOUNTAIN MINES

SURFACE HYDROLOGY - OPERATIONAL SAMPLING (Table 1)

Drainage System	Drainage	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cottonwood Creek Drainage System	*Cottonwood Canyon Creek*	SW1	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		SW2	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		CCC01	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field
		SW3	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
	Grimes Wash	GWR01	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		GWR02	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		GWR03	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
	Joes Valley Indian Creek	ICA	Based Flow Monitoring Only (October or November)									Operational		
		ICF	Based Flow Monitoring Only (October or November)									Field		
		ICD	Based Flow Monitoring Only (October or November)									Operational		
		ICB	Based Flow Monitoring Only (October or November)									Operational		
	Straight Canyon	T-19	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
Huntington Drainage System	*Deer Creek*	DCR01	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		DCR04	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		DCR06	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
	Huntington Creek	HCC01	Flow *	Flow *	Operational*	Flow *	Flow *	Operational*	Flow *	Flow *	Operational*	Flow *	Flow *	Operational*
		HCC02			Operational*			Operational*			Operational*			Operational*
		HCC04			Operational*			Operational*			Operational*			Operational*
			* Flow in Huntington Creek is measured @ HCC01 by Utah Power, and will be reported in the Annual Hydrologic Report											
	Meetinghouse Canyon	MCH01	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
	Rilda Canyon	RCF1*	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		RCLF1	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field
		RCLF2	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field
		RCF2	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field
		RCF3	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		RCW4	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
			* Baseline flow will be measured adjacent to EM-163											
	Mill Fork Canyon	MFA01	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		MFB02	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		MFU03	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational

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HYDROLOGIC MONITORING PROGRAM

DEER CREEK/COTTONWOOD-WILBERG/DES-BEE-DOVE/TRAIL MOUNTAIN MINES

GROUNDWATER HYDROLOGY - OPERATIONAL SAMPLING (Table 2)

Groundwater Type

Groundwater Type	Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Springs	*East Mountain*	*(Includes Mill Fork Springs)*							Operational	Flow *	Flow *	Operational		
										* Recession Springs				
	East Mountain-Rilda Canyon		Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
	Trail Mountain								Operational	Flow	Flow	Operational		
	Oliphant	T-18			Operational			Operational			Operational			Operational
In-Mine	*Cottonwood*				Operational			Operational			Operational			Operational
	Deer Creek				Operational			Operational			Operational			Operational
	Trail Mountain				Operational			Operational			Operational			Operational
Wells	*Cottonwood Waste Rock Well*				Operational			Operational			Operational			Operational
	Cottonwood Canyon Wells		Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level
	(includes Straight Canyon TM-3)													
	Deer Creek Waste Rock Well				Operational			Operational			Operational			Operational
	Deer Creek In-Mine Well				Level			Level			Level			Level
	Rilda Canyon Wells		Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level
	Trail Mountain (TM-1B)		Level	Level	Operational	Level	Level	Operational	Level	Level	Operational	Level	Level	Operational

UPDES SAMPLING - (Table 1)

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mine Water Discharge	*Cottonwood*	TMA	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
		Miller	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Deer Creek	DCD	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Trail Mountain	TMD	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
Sediment Pond Discharge	*Cottonwood*	2 Outfalls	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Deer Creek	1 Outfall	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Des-Bee-Dove	1 Outfall	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Trail Mtn	1 Outfall	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational

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HYDROLOGIC MONITORING PROGRAM

DEER CREEK/COTTONWOOD-WILBERG/DES-BEE-DOVE/TRAIL MOUNTAIN MINES

SURFACE HYDROLOGY - BASELINE SAMPLING (Table 1) - 2006

Drainage System	Drainage	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cottonwood Creek Drainage System	*Cottonwood Canyon Creek*	SW1	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		SW2	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		CCC01	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field
		SW3	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
	Grimes Wash	GWR01	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		GWR02	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		GWR03	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
	Joes Valley Indian Creek	ICA	Based Flow Monitoring Only (October or November)									Baseline		
		ICF	Based Flow Monitoring Only (October or November)									Field		
		ICD	Based Flow Monitoring Only (October or November)									Baseline		
		ICB	Based Flow Monitoring Only (October or November)									Baseline		
	Straight Canyon	T-19	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
Huntington Drainage System	*Deer Creek*	DCR01	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		DCR04	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		DCR06	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
	Huntington Creek	HCC01	Flow *	Flow *	Baseline*	Flow *	Flow *	Baseline*	Flow *	Flow *	Baseline*	Flow *	Flow *	Baseline*
		HCC02			Baseline*			Baseline*			Baseline*			Baseline*
		HCC04			Baseline*			Baseline*			Baseline*			Baseline*
			* Flow in Huntington Creek is measured @ HCC01 by Utah Power, and will be reported in the Annual Hydrologic Report											
	Meetinghouse Canyon	MCH01	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
	Rilda Canyon	RCF1*	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		RCLF1	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field
		RCLF2	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field
		RCF2	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field	Flow	Flow	Field
		RCF3	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		RCW4	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
			* Baseline flow will be measured adjacent to EM-163											
	Mill Fork Canyon	MFA01	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		MFB02	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
		MFU03	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline

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ENERGY WEST MINING COMPANY

HYDROLOGIC MONITORING PROGRAM

DEER CREEK/COTTONWOOD-WILBERG/DES-BEE-DOVE/TRAIL MOUNTAIN MINES

GROUNDWATER HYDROLOGY - BASELINE SAMPLING (Table 2) - 2006

Groundwater Type			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Springs	*East Mountain*	*(Includes Mill Fork Springs)*							Baseline	Flow *	Flow *	Baseline		
										* Recession Springs				
	East Mountain-Rilda Canyon		Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline	Flow	Flow	Baseline
	Trail Mountain								Baseline	Flow	Flow	Baseline		
	Oliphant	T-18			Baseline			Baseline			Baseline			Baseline
In-Mine	*Cottonwood*				Baseline			Baseline			Baseline			Baseline
	Deer Creek				Baseline			Baseline			Baseline			Baseline
	Trail Mountain				Baseline			Baseline			Baseline			Baseline
Wells	*Cottonwood Waste Rock Well*				Baseline			Baseline			Baseline			Baseline
	Cottonwood Canyon Wells		Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level
	(includes Straight Canyon TM-3)													
	Deer Creek Waste Rock Well				Baseline			Baseline			Baseline			Baseline
	Deer Creek In-Mine Well				Level			Level			Level			Level
	Rilda Canyon Wells		Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level
	Trail Mountain (TM-1B)		Level	Level	Baseline	Level	Level	Baseline	Level	Level	Baseline	Level	Level	Baseline

UPDES SAMPLING - (Table 1)

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mine Water Discharge	*Cottonwood*	TMA	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
		Miller	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Deer Creek	DCD	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Trail Mountain	TMD	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
Sediment Pond Discharge	*Cottonwood*	3 Outfalls	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Deer Creek	1 Outfall	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Des-Bee-Dove	1 Outfall	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational
	Trail Mtn	1 Outfall	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational	Operational

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HYDROLOGIC MONITORING PROGRAM

DEER CREEK/COTTONWOOD-WILBERG/DES-BEE-DOVE/TRAIL MOUNTAIN MINES

SURFACE HYDROLOGY - RECLAMATION SAMPLING (Table 1)

Drainage System	Drainage	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*Cottonwood Creek Drainage System**	*Cottonwood Canyon Creek*	SW1			Operational			Operational			Operational			Operational
		SW2			Operational			Operational			Operational			Operational
		CCC01			Field			Field			Field			Field
		SW3			Operational			Operational			Operational			Operational
	Grimes Wash	GWR01			Operational			Operational			Operational			Operational
		GWR02			Operational			Operational			Operational			Operational
		GWR03			Operational			Operational			Operational			Operational
	Joes Valley	ICA	Based Flow Monitoring Only (October or November)									Operational		
	Indian Creek	ICF	Based Flow Monitoring Only (October or November)									Field		
	Indian Creek	ICD	Based Flow Monitoring Only (October or November)									Operational		
		ICB	Based Flow Monitoring Only (October or November)									Operational		
	Straight Canyon	T-19			Operational			Operational			Operational			Operational
*Huntington Drainage System**	*Deer Creek*	DCR01			Operational			Operational			Operational			Operational
		DCR04			Operational			Operational			Operational			Operational
		DCR06			Operational			Operational			Operational			Operational
	Huntington Creek	HCC01			Operational**			Operational**			Operational**			Operational**
		HCC02			Operational**			Operational**			Operational**			Operational**
		HCC04			Operational**			Operational**			Operational**			Operational**
			*** Flow in Huntington Creek is measured @ HCC01 by Utah Power, and will be reported in the Annual Hydrologic Report*											
	Meetinghouse Canyon	MCH01			Operational			Operational			Operational			Operational
	Rilda Canyon	RCF1***			Operational			Operational			Operational			Operational
		RCLF1			Field			Field			Field			Field
		RCLF2			Field			Field			Field			Field
		RCF2			Field			Field			Field			Field
		RCF3			Operational			Operational			Operational			Operational
		RCW4			Operational			Operational			Operational			Operational
			**** Baseline flow will be measured adjacent to EM-163*											
	Mill Fork Canyon	MFA01	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		MFB02	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
		MFU03	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational

** Analyzed for Baseline Parameters During the Fifth (5) and Ninth (9) Year After Final Reclamation*

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HYDROLOGIC MONITORING PROGRAM

DEER CREEK/COTTONWOOD-WILBERG/DES-BEE-DOVE/TRAIL MOUNTAIN MINES

In no case will baseline sampling time frame exceed 5 years converting from operational to reclamation monitoring.

GROUNDWATER HYDROLOGY - RECLAMATION SAMPLING (Table 2)

Groundwater Type

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Springs	**East Mountain (Includes Mill Fork Springs)**								Operational			Operational		
	Spring monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.													
	East Mountain-Rilda Canyon		Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational	Flow	Flow	Operational
	Rilda Spring monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.													
	Trail Mountain								Operational			Operational		
	Oliphant	**T-18**			Operational			Operational			Operational			Operational
	Spring monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.													
In-Mine	**Deer Creek/Cottonwood/Trail Mtn. samples will be collected and analyzed quarterly until the mine is sealed or the sites become inaccessible**													
	Oliphant Mine discharge monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.													
Wells	**Cottonwood Waste Rock Well**				Operational			Operational			Operational			Operational
	Cottonwood Waste Rock Well will sealed during Phase I reclamation. One water sample will be collected and analyzed per location quarterly until well sealing													
	Cottonwood Canyon Wells* (includes Straight Canyon TM-3)		Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level
	Cottonwood Canyon well monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.													
	Deer Creek Waste Rock Well				Operational			Operational			Operational			Operational
	Deer Creek Waste Rock Well will sealed during Phase I reclamation. One water sample will be collected and analyzed per location quarterly until well sealing													
	Rilda Canyon Wells*		Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level	Level
	Rilda Canyon well monitoring will be conducted until permit area reduction approval or unless otherwise approved by the Division.													
	Trail Mountain (TM-1B)		Level	Level	Operational	Level	Level	Operational	Level	Level	Operational	Level	Level	Operational

TM-1B well will sealed during Phase I reclamation. One water sample will be collected and analyzed per location quarterly until well sealing
** Monitored monthly subject ot access*

UPDES SAMPLING - (Table 1)

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
*Mine Water Discharge***	*Cottonwood*	TMA	As Needed Basis According to UPDES Permit Stipulations											
		Miller	As Needed Basis According to UPDES Permit Stipulations											
	Deer Creek	DCD	As Needed Basis According to UPDES Permit Stipulations											
	Trail Mountain	TMD	As Needed Basis According to UPDES Permit Stipulations											

***** After Portal Sealing, PacifiCorp Will Monitor Down Dip For Development Of Groundwater Seeps/Springs Until Bond Release***

Sediment Pond Discharge	*Cottonwood*	2 Outfalls	As Needed Basis According to UPDES Permit Stipulations
	Deer Creek	1 Outfall	As Needed Basis According to UPDES Permit Stipulations
	Des-Bee-Dove	1 Outfall	As Needed Basis According to UPDES Permit Stipulations
	Trail Mtn	1 Outfall	As Needed Basis According to UPDES Permit Stipulations

Cottonwood Mine
C/015/019
Deer Creek Mine
C/015/018
Des-Bee-Dove Mine
C/015/017

Volume 9 Hydrologic Section

Map HM-9

Replace

Clean Copy (1)

April 8, 2005

Cottonwood Mine
C/015/019
Deer Creek Mine
C/015/018
Des-Bee-Dove Mine
C/015/017

Volume 9 Hydrologic Section

Map HM-10

Replace

Clean Copy (1)

April 8, 2005

Cottonwood Mine
C/015/019
Deer Creek Mine
C/015/018
Des-Bee-Dove Mine
C/015/017

Volume 9 Hydrologic Section

Map HM-11

Remove

April 8, 2005

Deer Creek Mine
C/015/018

Volume 12 Mill Fork Lease

R645-301-700 Hydrology
Appendix A

Remove Entire Section
and Insert Reference Page

Clean Copy (1)

April 8, 2005

DEER CREEK MINE

VOLUME 12

MILL FORK LEASE

R645-301-700
HYDROLOGY

APPENDIX A

*** REFER TO VOLUME 9 APPENDIX A FOR A COPY OF THE APPROVED HYDROLOGIC MONITORING PROGRAM***