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CHAPTER 7

HYDROLOGY
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CHAPTER 7

HYDROLOGY

7.10 Introduction

This chapter presents a description of the hydrologic considerations for permitting of the Crandall Canyon Mine operations. The information in this chapter was provided by the staff of GENWAL Resources, Inc. and by various consultant firms as noted under specific sections. Conclusions drawn herein are based upon detailed field reconnaissance and spring/seep surveys of the area, limited exploratory drilling and published hydrologic information on the area.

7.11 General Requirements

This chapter presents a description of:

- o existing hydrologic resources,
- o proposed operations and the potential impacts to the hydrologic resources,
- o methods of compliance with design criteria and performance standards, and
- o hydrologic reclamation plans for the Crandall Canyon Mine operations.

7.12 Certification

All maps, plans and cross-sections presented in this chapter which deal with the design of facilities or the determination of watershed characteristics have been certified by a professional engineer.

7.13 Inspection

Impoundments included in the runoff control plan will be inspected as described in Section 5.14 of this application.

7.20 Environmental Description

This section presents a description of the hydrologic resources within the Crandall Canyon Mine permit area and the South Crandall Lease area and the U-68082 lease mod area. Refer to Appendix 3-20, "Final Environmental Assessment, Modification of Federal Coal Lease UTU-68082, U.S. Forest Service" for additional information regarding hydrology in the lease mod area.

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7.21 General Requirements

This section presents a description of the hydrologic resources within the Crandall Canyon Mine permit area and the South Crandall Lease area and the U-68082 lease mod area.

7.22 Cross Sections and Maps

Figures 7-1 through 7-12 and Plates 7-1 through 7-17 of this chapter depict existing surface and groundwater occurrences within and adjacent to the Crandall Canyon Mine permit area and the South Crandall Lease area and the U-68082 lease mod area. These figures also illustrate the topography, streams, springs, wells, water monitoring locations, and other hydrologic design information pertinent to the Crandall Canyon Mine and the South Crandall Lease area and the U-68082 lease mod area. Refer to 7-63 for a detailed map of the Little Bear Canyon watershed showing mining projection, geology and location of seeps below the Castle Gate sandstone where cover is less than 600' above the coal seams.

Plates 7-14 and 7-15 have been updated to show the groundwater and surface water rights within and adjacent to the South Crandall lease area and the U-68082 lease mod area. Plates 7-12 (seep and spring) and 7-16 (stream monitoring) have also been updated relative to the South Crandall lease area and the U-68082 lease mod area. Note that Plate 7-13 has been deleted from the MRP.

7.2 Sampling and Analysis

All water samples are collected and analyzed according to methods in either the "Standard Methods for the Examination of Water and Waste Water" or the 40 CFR parts 136 and 434.

7.24 Baseline Information

(It should be noted that the Dellenbach fee tract is included in the currently approved permit area. All current data for hydrologic, geologic, and climatologic information applies to the Dellenbach tract.) Baseline hydrologic information for the South Crandall Lease area is summarized in Appendix 7-58. Baseline hydrologic information for seeps, springs, and streams in the U-68082 lease mod area are summarized in Appendix 7-64.

In response to concerns for the possible effect of mining on certain seeps in the Little Bear drainage, GENWAL commits to preparing a map identifying and showing the general location of vegetation in the area that could potentially be affected by mining in Little Bear Canyon, and will also prepare a detailed map of the vegetation associated with the spring/seep sites (LBA7, LB7A, LB7B, LB7C, LB5A and LB12) in Little Bear Canyon. This mapping will be done in the 2005 field season. This information will then be added to the MRP as an appendix.

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7.24.1 Groundwater Information

This section is a comprehensive view of the groundwater hydrology for the Crandall Canyon Mine permit and surrounding area and the the South Crandall Lease area and the U-68082 lease mod area.

Scope

This section presents discussions of groundwater conditions within and adjacent to the permit area, which consists of lease areas SL 062648 and U 054762, State leases ML21568 and ML21569, UTU-68082 and the South Crandall Lease area, UTU-78953 and the U-68082 lease mod area (Plate 7-12). Conclusions drawn herein are based upon detailed seep and spring surveys of the area, limited exploratory drilling, results of stream monitoring, and the results of groundwater investigations conducted by others in the region of the mine.

Methodology

Seep and spring surveys were conducted in 1985, 1987, and 1989 through 1993, within an area that extended approximately one mile north, west, and south of the boundaries of the permit area. Springs and seeps in the South Crandall Lease area were monitored again during 2003. Seeps, springs, and streams in the U-68082 lease mod area were monitored again during 2004. The study area for the survey was bounded by Huntington Creek on the east, the east-west ridge between the North Fork of Horse Canyon and the South Fork of Huntington Creek on the north, Bald Ridge and Bald Mountain in Scad Valley to the west, and Mill Fork on the south.

An aerial reconnaissance of the survey area was initially conducted to provide an indication of spring locations and site accessibility. The area was then traversed on foot to allow springs and seepage points to be precisely located, examined, and sampled. Geologic conditions at all seeps and springs were noted in the field, including lithologic and structural controls and the geologic formation from which the seepage issued. Signs of usage were also noted. The flow rate was visually estimated and (if sufficient water was present) a sample of the water was collected. The temperature of the water issuing from the spring was measured at the site. All samples were subsequently analyzed in the field for pH and specific conductance.

Hydrologic characteristics of the North Horn, Price River, Castlegate, Blackhawk Formation and Star Point Sandstone are reviewed in this section. Locations of seeps and springs monitored during 1985, 1987,1989 through 1993, and during 2003, and during 2004 are shown on Plate 7-12. The geologic occurrence and use of seeps and springs are found in Appendix 7-16. Flow rate and temperature measurements appear in Appendix 7-17. Specific conductivity and pH measurements are found in Appendices 7-18 and 7-19 respectively. Field water-quality measurements are summarized in Appendix 7-20. Laboratory analytical reports for groundwater collected from the eight quarterly sampled seep/spring locations are also contained in Appendix 7-20. Hydrologic baseline information from the South Crandall Lease area is summarized in Appendix 7-58. Hydrologic baseline from the U-68082 lease mod area is summarized in Appendix 7-64.

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Seep and spring surveys were conducted in the area around the IBC (Federal Right-of Way UTU-77975)area during 1987, 1989 and 1990. No seeps or springs were identified in the IBC area. The area was resurveyed by Gary Gray and Erik Petersen in 1998.

Regional Groundwater Hydrology

Six formations outcrop in the Mine Permit Area (Plate 6-1). According to Doelling (1972), the Masuk Shale Member of the Mancos Shale (Km on Plate 6-1) is a light gray to blue-gray marine sandy shale in the mine vicinity. This unit is exposed at the mouth of Crandall Canyon and in adjacent areas along Huntington Creek. The Masuk Shale Member yields water locally to seeps and springs but does not serve as a regionally important aquifer (Danielson et al., 1981).

The Star Point Sandstone (Ksp) is predominantly a light-gray massive sandstone with minor interbedded layers of shale and siltstone near its base (Doelling, 1972). In the vicinity of the mine, the Star Point Sandstone is 350 to 450 feet thick. The Star Point Sandstone yields water to several minor and some major springs where fractured and jointed.

The Blackhawk Formation (Kb) is the principal coal-bearing unit in the region (Doelling, 1972). This formation consists of interbedded layers of sandstone, siltstone, shale, and coal, and reaches a thickness of about 1000 feet in the mine area. The principal coal seam (the Hiawatha seam) is present at the base of the formation. The formation yields water to springs and coal mines when fractured. At GENWAL the water has been encountered within the Starpoint Sandstone approximately 50-100 feet below the contact point with Hiawatha seam.

The Price River Formation overlies the Blackhawk Formation and consists of the tan to brown cliff-forming Castlegate Sandstone (Kc) and the slope forming Upper Price River Member (Kpr). Fluvial sandstones of the Castlegate are massive and medium- to coarse-grained. In the area of the mine, the Castlegate is approximately 200 feet thick. The Castlegate yields water locally to seeps and springs, but does not serve as an important regional aquifer because it is commonly drained within short distances from its recharge area due to deeply incised canyons (Danielson et al., 1981).

The Upper Price River Member (Kpr) consists predominantly of friable calcareous sandstones interbedded with pebbly conglomerates and shales. It forms steep receding slopes and reaches a maximum thickness of about 600 feet in the mine areas (Doelling, 1972). This formation yields water locally to seeps and springs (Danielson et al., 1981). However, like the Castlegate Sandstone, deeply incised canyons in the area prevent the Upper Price River Member from being an important regional aquifer.

The uppermost formation that outcrops within the permit area is the North Horn Formation (Tkn). This formation consists of interbedded limestones, sandstones, and shales (Doelling, 1972). Due to the presence of low-permeability strata in the formation, downward vertical migration of groundwater is limited. Consequently, springs in the North Horn Formation are formed where

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perched groundwater is forced to flow laterally in the subsurface until the formation intersects the land surface, forming a spring.

Investigations by Danielson et al. (1981) indicated that most, if not all, groundwater in the region is derived from snow melt. Recharge tends to be limited in areas underlain by the Price River Formation and older rocks (relative to recharge in areas underlain by younger rocks) due to slope steepness and relative imperviousness (both of which promote runoff rather than infiltration of snow melt).

Detailed potentiometric surface data are not available for the region surrounding the permit area. However, the deeply incised canyons interrupt the flow of groundwater in much of the area. Danielson et al. (1981) suggest that groundwater generally moves from high areas of recharge to low areas of drainage, principally along stream channels.

The predominant chemical constituents in most springs in the region are calcium and bicarbonate (Danielson et al., 1981). Dissolved solids concentrations generally range from about 50 to 750 milligrams per liter. Regionally, the concentrations of major dissolved constituents in water from individual geologic units is highly variable, due to the complex lithologic nature of the area (Danielson et al., 1981).

Mine Plan Area Aquifers

Results of the initial seep and spring inventories conducted in the study area were submitted previously to DOGM (EarthFax Engineering, 1985a, 1985b). All data associated with subsequent seep and spring inventories are located within this MRP. Locations of the seeps and springs discovered during the inventories are shown on Plate 7-12. Data collected during the inventories are included in Appendices 7-16 through 7-20. Data from the 2003 inventories in the South Crandall Lease area are presented in Appendix 7-58.

Approximately 60% of all the seeps and springs found during the early-season surveys had flows of one gallon per minute or less (Appendix 7-17). These flows typically decreased by the time of the late-season surveys, with most of the low-flow sources issuing only as seeps or being dry. The majority of seeps and springs issue from bedding planes separating porous sandstones or fractured zones from underlying low-permeability siltstone and shale beds.

The primary exception to the above generality is flow from seeps and springs along the western edge of UTU-68082 which discharge from the North Horn Formation, alluvium covering the North Horn Formation, or from Tufa deposits in Upper Joes Valley. Flow from most of these seeps and springs is attributed to discharge from the Joes Valley fault zone.

The occurrence of groundwater at Trail Mountain (Lines, 1985) is very similar to that at Crandall Canyon. The major water bearing unit at both mines is the Blackhawk-Star Point aquifer. The Trail Mountain Mine is overlain by perched aquifers in the Blackhawk, Castlegate, Price River, and North Horn Formations; these perched aquifers are separated by unsaturated zones (Lines, 1985). Seep and spring survey results at Crandall Canyon and at the South Crandall Lease area also reveal the presence of perched aquifers in the same formations. As at Trail Mountain, this perching

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occurs where more-permeable strata (aquifers) overlie less-permeable strata (aquitards and aquicludes) (Lines, 1985; Appendix 7-16).

The distribution of seeps and springs among the formations present at both the Trail Mountain (Lines, 1985) and Crandall Canyon (Appendix 7-16) mines is very similar. At both mine areas the largest percentage of seeps and springs are found in the North Horn and Price River Formations. Similarly, in both mine areas the smallest percentage of seeps and springs are found in the Castlegate Sandstone Formation and Blackhawk Formation. Some springs and seeps discharge from the Star Point Sandstone in the South Crandall Lease area. Little Bear Spring, which is a developed spring that provides municipal water to nearby towns, discharges from a fracture system in the Star Point Sandstone.

Because of its importance as a municipal water supply source and its proximity to proposed mining areas, Little Bear Spring has been extensively studied. Several hydrologic studies have been performed since 1977 to investigate the recharge source for Little Bear Spring. These studies have agreed that the spring flow is supported by a fault/fracture system. Since Little Bear Spring lies more than 300 feet below the level of the mineable coal seams and past mining encountered the fault/fracture system without significant inflow of water, there is general consensus among the Castle Valley Special Service District (CVSSD), mine operators, scientific community, and the regulatory agencies that adverse effect to the spring are unlikely. (Forest Service, BLM Joint Decision Notice/Finding of No Significant Impact, Coal Lease Application UTU-78953)

Several studies have been done that suggest a northerly component of flow feeding Little Bear Spring. These studies include:

(i) Vaughn Hansen Associated, *Water Quality and Hydrologic Study in Vicinity of Huntington Creek Mine No. 4 and Little Bear Spring*, Prepared for Swisher Coal Company, August1977.

(ii) Hydro-Sciences, Inc., *Ground Water Hydrology in the Vicinity of the Huntington No. 4 Mine,* Prepared for ARCO Coal Company, December 19, 1980.

(iii) Beaver Creek Coal Company, *Huntington Canyon No. 4 Mining and Reclamation Plan,* Prepared for UDOGM, 1983.

(iv) Utah Geological and Mineral Survey, *Effects of Coal Mining at Huntington Canyon No. 4 Mine on Little Bear Spring, Emery County,* Prepared for Castle Valley Special Services District, Job No. 84-005, January 21, 1984.

(v) Vaughn Hansen Associated, *Hydrologic Conditions in Huntington Canyon No. 4 Mine,* 1984.

These referenced studies are available for review at the Division's Public Information Center.

Other studies indicate that the Little Bear Spring may possibly be fed by fault/fracture system which intercepts surface water in Mill Fork Canyon southwest of the South Crandall Lease area. These scientific investigations include an investigation of the Little Bear Spring groundwater system and the groundwater systems encountered in the Crandall Canyon Mine (Appendix 7-52), a solute and isotopic investigation of groundwater from Little Bear Spring and the Star Point Sandstone and Blackhawk Formation groundwater systems the Crandall Canyon Mine (Appendix 7-53), an

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investigation of the hydraulic conductivity of the Star Point Sandstone in the vicinity of the Crandall Canyon Mine (Appendix 7-54), an investigation of the alluvial groundwater system in Mill Fork Canyon with implications for recharge to Little Bear Spring (Appendix 7-55), an investigation of the potential for Little Bear Spring recharge in Mill Fork Canyon (Appendix 7-56), and a fluorescent dye-tracing study that conclusively demonstrates the hydraulic connection between the stream/alluvial groundwater system in Mill Fork Canyon and Little Bear Spring (Appendix 7-57). Sunrise Engineering also performed a series of investigations using a proprietary geophysical technique that demonstrated a hydraulic connection between Little Bear Spring and the surface drainage in Mill Fork Canyon. These investigations are included as Appendix 7-59, Appendix 7-60, Appendix 7-61, and Appendix 7-62.

While the flow mechanisms conveying water to Little Bear Spring are not completely understood, additional hydrologic studies performed since the Mill Fork EA was written have indicated that adverse impacts to the spring are not expected due to the vertical separation between the coal seams and flow. (Forest Service, BLM Joint Decision Notice/Finding of No Significant Impact, Coal Lease Application UTU-78953)

The low flow rates from most of the seeps and springs emitting from the Blackhawk Formation (Appendices 7-16, ~~and~~ 7-17, and 7-58) result from the low hydraulic conductivity of the formation where it remains unfractured. Laboratory permeability data from a core sample taken in T17S-R6E-Sec27 at Trail Mountain indicate an average horizontal hydraulic conductivity of 1.3×10^{-2} feet per day, and an average vertical hydraulic conductivity of 3.8×10^{-3} feet per day for sandstone units of the Blackhawk Formation (Lines, 1985).

Shale and siltstone samples of the Blackhawk Formation have maximum horizontal and vertical hydraulic conductivities of only 1.0×10^{-7} and 1.2×10^{-6} feet per day, respectively (Lines, 1985). These low hydraulic conductivities of the shales and siltstones indicate that these finer-grained sediments within the Blackhawk serve as barriers to the downward migration of water. As a result, water recharge into the Blackhawk, either from adjacent formations, snow melt, or rainfall is allowed to percolate vertically through sandstone beds until a siltstone/shale bed is encountered at which time the water is forced to travel laterally along the bedding plane to the surface.

Similarly, the majority of the seeps and springs in the Castlegate, Star Point and North Horn Formations observed in the field surveys in Crandall Canyon also issue from bedding planes. Due to the presence of these vertical permeability barriers, the aquifers in the North Horn, Price, River, Castlegate, as well as in the upper portions of the Blackhawk Formations are perched, with no direct communication to the underlying regional Star Point aquifer. Consequently, any dewatering of the perched Star Point aquifer resulting from mining the Hiawatha Coal of the Blackhawk Formation has little potential of affecting seeps and springs in the area (Lines, 1985).

Most of the seeps and springs in and around the state lease areas, and the UTU-68082 leases principally drain perched aquifers in the North Horn and Price River Formations (Appendix 7-16). The North Horn and Price River Formation perched aquifers lie 470 to over 2410 feet above the top of the Hiawatha Coal Seam. These aquifers exist along bedding planes and are perched with no direct hydraulic connection to the existing or proposed mine workings in the Hiawatha coal bed.

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As a result, mine dewatering is anticipated to have minimal, if any effects on these seeps and springs.

Lesser numbers of seeps and springs drain the perched aquifers in the Blackhawk Formation and lie approximately 420 or more feet above the potentiometric surface of the regional Star Point aquifer. With no direct communication to the underlying regional aquifer these water sources should not be affected by mine dewatering, if it occurs.

Elevations of perched aquifers overlying the Hiawatha Coal Seam are evidenced by the occurrence of seeps and springs (Plate 7-12). The locations of seeps and springs suggest that perched aquifers may be present in the following areas:

Approx. Elev.	**Location**	**Geologic Formation**
10,160 feet	Sec. 12,T16S,R6E, SE	North Horn
9,440 feet	Sec. 12,T16S,R6E, NE	Price River - base
8,720 feet	Sec. 1,T16S,R6E, NW	Blackhawk - top
9,920 feet	Sec. 2,T16S,R6E, SW, NW SW	North Horn
10,240 feet	Sec. 2,T16S,R6E, SW	North Horn
10,480 feet	Sec. 35T,15S,R6E, SE	North Horn
10,240 feet	Sec. 35T,15S,R6E, NW	North Horn - base
9,280 feet	Sec. 31T,15S,R7E, SW	Price River
9,680 feet	Sec. 25T,15S,R6E,S ½	Castlegate

Seeps and springs northwest of the permit area discharge from the North Horn Formation or alluvium covering the North Horn Formation in Upper Joe's Valley. In contrast to other seeps and springs in the study area, flows from many of these water sources increased substantially between the spring/early summer surveys and the fall surveys (Appendix 7-17). This anomalous water flow trend is attributed to three factors:

First is the groundwater recharge from the Joe's Valley Fault Zone. These water sources lie in two linear positions parallel to the fault zone. Those springs occurring in the valley bottom directly east or immediately contiguous to Indian Creek, and those springs on the west hillslope above Indian Creek which also follows the trace of the fault zone.
Secondly, recharge from water in the colluvium and alluvium on the west-facing slope of East Mountain flows downhill toward Upper Joe's Valley and discharges into the valley alluvium. The relatively late arrival (mid-summer) of this water is due to the lag time created as this snow melt-derived water travels through the soil to the valley floor.

Thirdly, the seeps and springs in Upper Joe's Valley lie in a different drainage basin than those in the rest of the study area, a drainage basin which has a contrasting flow pattern to that present in the Huntington Creek tributaries on the east-facing slopes of East Mountain.

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According to the approved current mine plans for the UTU-68082 (LBA No. 9) area (which is bounded at the east margin of the LBA by the north and south trending Joes Valley Fault Zone) mining will not occur within approximately 1000 feet of the fault zone.

During the period of March and April 1987, a monitoring well (MW-1) was installed at the Crandall Canyon Mine in the location indicated in Plate 7-13. MW-1 provides less than 1 gpm of water and is used to supplement the water withdrawn from Crandall Creek for in-mine usage. MW-1 was drilled using air-rotary methods to a total depth of 375 feet, and encountered Star Point Sandstone through its entire depth (Figure 7-1).

The driller indicated that the formation was relatively homogenous except in the zone from 290 to 335 feet, where the sandstone became coarser. It is from this zone that the well is producing water, with water first being encountered at a depth of about 315 feet. The static water level, approximately one week after completion of the well, was at a depth of 186.1 feet below ground surface, indicating the presence of a significant upward pressure component (approximately 130 feet) within the saturated zone.

After completion of the well, a slug test was performed on the well to determine the approximate hydraulic characteristics of the Star Point Sandstone at the mine site. This test was performed by inserting approximately 10 feet of drill stem below the water surface and allowing the water level to stabilize over a period of 3.75 hours. Although water level recovery was measured during this period, the data are not adequate for slug-test analysis since the drill stem was present within the zone of influence of the injection test, thus displacing additional water during the recovery period.

Following stabilization of the water level, the drill stem was rapidly removed from below the water level and the resulting recovery to static conditions was measured for a period of more than 2 hours. Data collected from this test have been provided to the Division in a letter addressed to Mr. Dave Cline from Richard B. White of EarthFax Engineering, Inc. and dated April 30, 1987. Data collected for the first 700 seconds of the test are provided in Figure 7-2.

In-mine monitoring wells MW-4 and MW-5 were installed, completed, and developed in January, 1992. Monitoring well MW-3 is located in an area that was sealed in 1979 and is now inaccessible. Water-level data collected in January, 1992 from MW-2, MW-4, and MW-5 were used to produce the potentiometric surface map depicted on Plate 7-13. Slug tests were also performed on MW-4 and MW-5. (See Appendix 7-24).

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The slug test data were analyzed using a method developed by Bouwer and Rice (1976). According to this method:

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2L} \ln\frac{1}{t} \frac{Y_o}{y_t} \qquad (7\text{-}1a)$$

where K = hydraulic conductivity (feet per day)
r_c = radius of the casing (feet)
r_w = radius of the well
L = length of the screened section (feet)
t = time since test began (seconds)
y_o = maximum drawdown during test of drawdown immediately following slug injection or withdrawal (feet)
y_t = drawdown at time t (feet)

$$\ln(R_e/r_w) = \left[\frac{1.1}{\ln(H/r_w)} + \frac{C}{L/r_w}\right]^{-1}$$

where H = depth from static water level to the base of the producing zone
C = a dimensionless coefficient as a function of L/r_w obtained from Figure 3 of Bower and Rice (1976, p.426)

For the slug test conducted at MW-1,

r_c = r_w = 0.25 ft (hole radius of 3 inches)
L = 335-290 = 45 ft (length of the producing zone according to the driller's records)
H = 335-187 = 148 ft (distance between the static water level and the base of the producing zone
y_o = 2.50 ft (see Figure 7-2)
y_t = 2.10 ft at t = 400 s (see Figure 7-2)

$$\ln(R_e/r_w) = \left[\frac{1.1}{\ln(148/0.25)} + \frac{6.6}{45/0.25}\right]^{-1} = 4.8$$

By means of equation (7-1a) and these data, a hydraulic conductivity of 0.1 foot per day was calculated. Assuming that the 45-foot producing zone accounts for the entire thickness of the aquifer at the location of MW-1, this value converts to a transmissivity of 4.5 square feet per day.

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Slug tests from MW-4 and MW-5 were analyzed using the same equation and the hydraulic conductivity for MW-4 was determined to be 0.6 foot per day (2.3 square feet per day) and 2.5 foot per day (13.0 square feet per day) for MW-5. The data sheets for MW-4 and MW-5 slug tests are included in Appendix 7-24. These determined transmissivities are similar to those measured by Lines (1985) from pumping tests performed in the Star Point Sandstone near Trail Mountain approximately 10 miles southwest of Crandall Canyon.

According to Danielson et al. (1981), the flow of groundwater in the region is generally from high-elevation recharge areas toward major canyons. In most locations, the piezometric surface in the Star Point Sandstone is below the mine floor. Minor inflow to the existing mine workings has been from the roof, even though the floor of the mine within the western third of the mine area is below the elevation of Crandall Creek. Most groundwater inflow into the mine occurs from sandstone paleochannels in the mine roof, especially where these sandstone rocks are fractured. In the westernmost portion of the Crandall Canyon Mine, the piezometric surface in the Star Point is at or slightly above the elevation of the mine floor. In these areas, minor amounts of groundwater weeps into the mine from fractured sandstone in the mine floor. In addition, as noted above, the depth to groundwater at the mouth of the mine (at MW-1) is approximately 186 feet below ground surface. Thus, it is reasonable to assume that groundwater within the Star Point Sandstone beneath the mine does not discharge into Crandall Creek.

Although the regional stratigraphic dip is to the west (see Chapter 6), the local strata generally dip to the southeast. As shown on Plate 7-13, the direction of groundwater flow in the Star Point Sandstone beneath the mine is generally eastward, from East Mountain to Huntington Canyon.

In the area of Trail Mountain (located approximately 10 miles southwest of Crandall Canyon) the hydraulic gradient of groundwater in the Star Point Sandstone varies from about 0.11 foot per foot in the recharge area near the ridge line to about 0.03 foot per foot in the discharge area in Straight Canyon (Lines, 1985). Due to the similarity of the geologic conditions in the two areas (Waddell et al., 1981), similar hydraulic gradients are expected in the East Mountain recharge area and Huntington Canyon discharge area, respectively.

Usage of most seeps and springs within the survey area is confined to deer, elk, and other wildlife and limited seasonal usage by livestock. Flowing surface water within each watershed does contribute to downstream water users such as industry, domestic water supplies, and recreation (i.e., cold water fisheries). As would be expected, wildlife usage of the springs is most abundant where flows are greatest and the sources are most accessible. Little Bear Spring has been developed for municipal use by adjacent municipalities.

Data indicate that the specific conductance of water issuing from springs in June generally increased with increasing stratigraphic depth. This is in agreement with the findings of Danielson et al, (1981). Springs issuing from the Price River Formation typically had a specific conductance, during the June survey, that varied from 150 to 450 umhos/cm at 25°C while those issuing from the Blackhawk Formation and Star Point Sandstone had a specific conductance varying from 500 to 1000 umhos/cm at 25°C.

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The pH of water issuing from springs in the survey area showed no trends within or between formations. Values varied from 6.80 to 8.57, averaging 7.74. Hence, spring water in the study area is slightly alkaline.

In those springs with sufficient water to sample, pH generally increased slightly between June and October. Increases normally amounted to 0.1 to 0.5 pH unit. Specific conductance showed no consistent pattern between the June and October data, with approximately as many increases as decreases between June and October.

Water temperatures vary widely at the site. In general, water temperatures are lowest in springs issuing from fractures and highest in springs issuing from shallow colluvium over bedrock. Lower water temperatures generally occurred in the springs with relatively low specific conductances.

Appendix 7-42 contains water quality results for selected springs from 1988 through 1991. These water quality analyses generally have included pH, temperature, conductivity or TDS, total manganese (as Mn), and either total or dissolved iron (as Fe). Baseline discharge and water quality data from the South Crandall Lease area is included in Appendix 7-58. Baseline discharge and water quality data from the U-68082 lease mod area is included in Appendix 7-64.

Groundwater Development and Mine Dewatering

Water Supply

A few of the seeps or springs inventoried during the spring/seep surveys have been developed for beneficial use. No water wells used for consumption by humans or animals, other than MW-1, are known to exist within the study area of the spring inventory. However, groundwater which reaches the surface water within each watershed does contribute to downstream water users in Huntington Creek who have the water allocated for industry, domestic water supplies, agriculture, and recreation (i.e., cold water fisheries). Little Bear Spring has been developed as a municipal water source for adjacent municipalities.

Appendix 7-1 contains a listing of groundwater rights (and their associated seeps and springs) in and adjacent to the permit area (within a 1-mile perimeter boundary). This data was obtained from the files of the Utah Division of Water Rights. Locations of these water rights are denoted in Plate 7-14. Appendix 7-1 also shows what groundwater right corresponds to the seeps and springs observed in the field inventories.

Mine Dewatering

An underground water budget (amended August 23, 1994) appears in Appendix 7-21. Based on the water budget, current underground use of water for the mine equipment averages 14.3 gpm throughout the year. Infiltration along the mine floor and sumps totals 10 gpm and evaporation due to mine ventilation equals 50 to 60 gpm. Coal moisture content accounts for 68.5 gpm. The combined approximate total equals 150 gpm. The quantity of mine inflow that is lost to evaporation and infiltration are estimates based on experience at other mines, and the infrequent need to

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discharge into Crandall Creek. Additional water depletion analysis for Fish and Wildlife Service is provided in Chapter 3.

Although worst-case estimates of mine inflow are greater than the present inflow rate, the actual inflow rate to be encountered is unknown. In order to effectively treat mine inflow an additional sump and pump house will be built in the southeastern corner of Lease ML-21569 (Appendix 7-22). This new sump will be equipped with a Worthington pump capable of pumping 150 gpm at 400 psi. This proposed sump will serve as the primary treatment facility for mine inflow, as well as the active water supply for mining operations. The existing sump will be maintained as a secondary water treatment facility. If discharge is required, water to be discharged will be initially treated in the proposed sump in Lease ML-21569, then pumped to the secondary (presently existing) sump, prior to discharge into Crandall Creek.

In the event mine inflow rates exceed the capacity of these treatment facilities to treat the mine inflow to meet the discharge limit criteria outlined in the NPDES Permit (UPDES Permit No. UT0024368, authorizing two discharge points), GENWAL commits to modifying these treatment facilities and/or constructing additional facilities in order to ensure compliance with the UPDES Permit. Treatment facilities to be considered include enlargement and/or construction of additional underground sumps and/or surface settling ponds. If excessive water volumes are encountered the use of flocculants and gel-logs will be considered as stopgap measures until more permanent treatment facilities are in-place.

Make-up water for in-mine use is pumped from Crandall Creek into the main mine sump at no more than 75 gallons per minute (pump capacity). At its lowest recorded flow, at the lower flume, a minimum of 100 gallons per minute remains within Crandall Creek even when the mine is withdrawing water for in-mine use.

The majority of natural water inflow is occurring in the old mine workings (Leases U054762 and SL-062648). According to GENWAL personnel, natural mine inflow accounts for less than 400,000 gallons per year of the total water used in-mine. Only negligible mine inflow has been encountered in Lease UTU-68082 and State Lease ML-21569. Currently, water used in mining operations is being pumped to State Lease SL-21569 from the sump in the old mine workings. All inflow water is used in underground mining operations.

Effects of Mining Operation On Groundwater

Mine dewatering (resulting in removal of water from the aquifers) is the primary mechanism by which the groundwater system may be impacted. As previously stated, it is believed that the water emitting from seeps and springs in State Leases ML-21568 and ML-21569, as well as areas within and adjacent to UTU-68082 (LBA No.9) and groundwater supporting springs and seeps in the South Crandall Lease area (UTU-78953), originate from perched aquifers with no direct communication with the regional Star Point aquifer. Although groundwater discharging from Little Bear Spring travels through a fracture system in the Star Point Sandstone, it is believed that the fracture system is the conveyance system for the the groundwater. Groundwater migrating through the pore spaces in the Star Point Sandstone near the spring likely does not contribute any significant quantity of

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groundwater to the spring. This conclusion is based on the very low hydraulic coductivity of unfractured Star Point Sandstone described in a subsequent section (see also Appendix 7-54). Thus, dewatering resulting from mining the Hiawatha Coal of the Blackhawk Formation has little potential for impact on the regional aquifer or for a diminution of flow from Little Bear Spring. This observation is in agreement with conditions present at Trail Mountain as reported by Lines (1985).

Laboratory permeability data reported by Lines (1985) on cores collected from the Blackhawk Formation indicate that the hydraulic conductivity of shale and siltstone units of this formation is typically four to six orders of magnitude lower than the hydraulic conductivity of the sandstone units. The relatively higher hydraulic conductivity of the sandstones of the Blackhawk Formation compared with the siltstones and shales indicates that the finer-grained sediments of the formation serve as barriers to the downward movement of water. As water recharges the Blackhawk Formation (either through snow melt, rainfall, or subsurface seepage from an adjacent formation) it percolates downward within the sandstone beds. However, upon reaching a less-permeable siltstone or shale layer, the water is forced to flow laterally to the surface, issuing at the interface between two units of contracting hydraulic conductivity.

Notable exceptions to the above generality concerning the Blackhawk Formation are present at springs that issue from fractured sandstone within the formation. Examples of this phenomenon are present in springs SP-53 through SP-58 (Plate 7-12), where flow rates greater than 100 gallons per minute have been measured. Travertine deposits are common at these springs, which suggests that the recharge area for these springs is dominated by calcium carbonate. In areas, the upper portion of the Blackhawk Formation may serve more as a conveyance body rather than a significant source of water to these springs.

Results of slug tests on MW-1, MW-4 and MW-5 indicate that the Star Point Sandstone in the Crandall Canyon area has a hydraulic conductivity of 0.1 to 2.5 ft/day. Based on an average hydraulic conductivity of 1.0 ft/day, an average hydraulic gradient of 0.025 ft/ft (see Plate 1-8), an average Star Point porosity of 0.14 (Lines, 190\85) and the modified Darcy equation (Freeze and Cherry, 1979), the average linear velocity of groundwater flowing through the Star Point Sandstone beneath Lease #UTU-68082 and adjacent areas is approximately 0.2 ft/day.

Results of slug tests performed on the in-mine Star Point Sandstone wells MW-2, MW-6A, MW-7, and MW-6 by Mayo and Associates in 1997 (Appendix 7-54) indicated an average hydraulic conductivity of unfractured Star Point Sandstone of approximately 0.005 ft/day. Using information from these wells, the calculated average linear velocity of groundwater moving through the Star Point Sandstone is even less than 0.2 ft/day..

It is of note that laboratory permeability data provided by Lines (1985) from core samples collected approximately 10 miles south of Crandall Canyon indicate that the Star Point Sandstone has an average horizontal hydraulic conductivity of 2.3×10^{-2} ft/day and an average vertical hydraulic conductivity of 8.8×10^{-3} feet per day. With the range of slug test results at the mine and the lower values reported by Lines (1985), the velocity presented above is considered to be a maximum.

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The potentiometric surface of the Star Point aquifer directly underlying the Hiawatha Seam (the coal bed mined at Crandall Canyon) is shown on Plate 7-13. The water table rises to the northwest under East Mountain at an average angle of 3 degrees, and lies from 50 to 115 feet below the Hiawatha coal seam. This regional water table is 150 feet below ground surface in the area of the mine portal, and up to 2220 feet below the surface under East Mountain in Sec. 2,T.16S.,R.6E.

Mitigation and Control Plan

Based on information presented in the preceding section, only minimal impacts on groundwater resources in the permit area may result. A probable hydrologic consequences determination that includes the South Crandall Lease area is included as a portion of this chapter and is located in Appendix 7-15. Installation of the main bypass culvert will not alter the Probable Hydrologic Consequences.

Mitigation for potential disruption to the Little Bear Spring will be accomplished though the construction of a water treatment plant which will provide replacement water for the spring. Construction of this water treatment plant will be done under the provisions of a water replacement agreement between GENWAL Resources, Inc. and the Castle Valley Special Service District who maintain culinary water rights to Little Bear springs. A copy of this water replacement agreement is included in Appendix 7-51. With construction of this water treatment plant an uninterrupted supply of culinary water will be assured irrespectively of whether mining can be conclusively shown to have affected Little Bear Spring. This is in compliance with special stipulation #17 of federal lease UTU-78953 (see Appendix 1-13).

Currently, treatment of mine water prior to discharge into Crandall Creek includes the use of two underground sumps. Discharge to Crandall Creek has occurred only 5 times prior to 1994 (UPDES Permit - Appendix 5-14).

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7.24.2 Surface Water Information

Scope

This section presents discussion of surface water conditions within and adjacent to the permit area (lease areas SL062648 and U 054762, state leases ML21568 and ML21569, and UTU-68082) and in the South Crandall Lease area (UTU-78953) and the U-68082 lease mod area. Conclusions drawn herein are based upon a field reconnaissance of the area and a review of published hydrologic information.

Methodology

The U.S. Geological Survey established a gaging station at the mouth of Crandall Creek in 1978. The gaging station was maintained through water year 1984. Data collected from this station were obtained from the Water Resource Division of the USGS in Salt Lake City and used to determine seasonal variations in flows in areas adjacent to the mine plan area. Additional information is provided from Parshall flumes and instantaneous stream flow measurements by GENWAL in Blind Canyon, Horse Canyon, Indian Creek, Crandall Canyon, No Name Canyon, Little Bear Canyon, and several unnamed drainages in the South Crandall Lease area (Appendix 7-23, 7-58).

Regional Surface Water Hydrology

The region (including the existing permit area, the U-68082 lease mod area and the South Crandall Lease area) is drained by a combination of ephemeral, intermittent and perennial streams. Two watersheds within the permit area have both intermittent and perennial sections within the stream drainage: Crandall Canyon and Horse Canyon. Two additional perennial streams occur adjacent to the permit area: Indian Creek (which drains to Joe's Valley Reservoir) and Huntington Creek. There are no perennial drainages in the South Crandall Lease area, although the Forest Service considers the Little Bear drainage a "perennially functioning stream".

Crandall Creek is an east-flowing tributary of Huntington Creek, one of the major tributaries of the San Rafael River. Huntington Creek had annual flows near the city of Huntington ranging from 25,000 to 150,000 acre-feet during the period of October 1931 through September 1973, averaging 65,000 acre-feet per year (Waddell et al., 1981). Variations in the annual flow of Huntington Creek near Huntington are depicted on Figure 7-6. Approximately 50 to 70 percent of stream flow in the mountain streams of the region occurs during May through July (Waddell et al., 1981). Stream flow during this late spring/early summer period is the result of snow melt runoff.

Horse Canyon is also an east-flowing tributary of Huntington Creek. Instantaneous flow measurements collected during 1991 indicate that peak flow occurred during May and June with approximately 2500 gpm at station H-1 (see Plate 7-16). Minimal flow was observed during August, September, and October at approximately 15 gpm. No flow was observed at station HS-5 (located on the south fork of Horse Canyon near the fork) during September of 1992. Additionally, the main

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channel of Horse Canyon was observed to be dry approximately 340 feet above the fork. Stream flow and temperature measurements for Horse Canyon can be found in Appendix 7-23.

The quality of water in Huntington Creek and other similar streams in the area varies significantly with distance downstream. Waddell et al. (1981) found that concentrations of dissolved solids varied from 125 to 375 milligrams per liter in reaches of major streams above major diversions to 1600 to 4025 milligrams per liter in reaches below major irrigation diversions and population centers. The major ions at the upper sites were found to be calcium, magnesium, and bicarbonate, whereas sodium and sulfate became more dominant at the lower sites. They attributed these changes to (a) diversion of water containing low dissolved solids concentrations, (b) subsequent irrigation and return drainage from moderate to highly saline soils, (c) groundwater seepage, and (d) inflow of sewage and pollutants from population centers.

Average annual sediment yields within the Huntington Creek drainage basin range from approximately 0.1 acre-feet per square mile in the headwaters area to about 3.0 acre-feet per square mile near the confluence with the San Rafael River (Waddell et al., 1981). Increases in sediment yield with increasing distance downstream is generally the result of the water contacting increasing amounts of shale and sandstone in the downstream direction (Waddell et al., 1981).

Periodic instantaneous stream flow measurements for Indian Creek, collected by the U.S. Forest Service, are found in Appendix 7-44. These measurements were collected in Sec. 17,T.17S.,R.6E., during the period of July 1970 through April 1977. During seep and spring inventories conducted in the area by GENWAL in October and November of 1989, 1990, and 1991, the upper portion of Indian Creek was observed to be dry at elevations above 9120 feet in Sec. 34,T.15S.,R6.6E.

Observations of drainages located along the west facing slope of East Mountain in T15S R6E Section 35 W1/2 have been made during the seep and spring surveys from 1985 to 1990. The drainages have been found to be dry during all fall seep and spring surveys. Flow was observed during the fall 1991 survey; however, flow was not measured due to the existing field conditions (rain and melting snow) that would mask any natural perennial flow or lack of flow. Appendix 7-48 contains additional information concerning hydrologic conditions for the UTU-68082 (LBA No. 9) areas.

Mine Plan Area Surface Hydrology

The permit area (including the South Crandall Lease area and the U-68082 lease mod area) is drained by a combination of ephemeral, intermittent, and perennial streams. The watersheds are steep (with average slopes often exceeding 50 percent) and well vegetated (with percent covers also often exceeding 50 percent).

Within the South Crandall Lease area, no perennial streams have been identified. Based on the discharge data for these drainages (Appendix 7-58), the drainages in the South Crandall Lease would be considered ephemeral or intermittent. There are no perennial streams in the U-68082 lease mod area (see Appendix 7-64). The reaches of No Name Canyon creek would all be considered

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ephemeral or intermittent. The Forest Service considers parts of the Little Bear Canyon drainage as a "perennially functioning stream".

Flow measurements collected at the U.S. Geological Survey gaging station at the mouth of Crandall Creek can be found in Appendix 7-2. Flow measurements from a flume in Blind Creek, and estimated in Horse Creek are contained in Appendix 7-23. The Crandall Creek data are summarized in Figures 7-7 (monthly flow volumes) and 7-8 (monthly maximum and minimum flow rates) for the period of record (October 1978 - September 1984). Data collection from the Crandall Canyon gaging station was discontinued by the USGS in 1984.

As noted in Figures 7-7 and 7-8, the flow data for Crandall Creek are not complete for the winter months in most years, because of freezing conditions. Assuming an average flow of 30 acre-feet per month for the period of missing record, the average annual flow for the six-year period of data contained in Appendix 7-2 was 2740 acre-feet.

According to Figure 7-8, maximum flow rates in Crandall Creek normally occur in the months of May or June, while minimum recorded flows occurred during the months of September through November. During the period of record, the maximum recorded daily flow rate has been 88 cubic feet per second (on May 30, 1983). The minimum recorded daily flow rate was 0.28 cfs (on several days in September 1981). Lower minimum flows may have occurred during the winter months when data are lacking.

Plan and profile views of Crandall Creek adjacent to the surface facilities are shown on Plate 7-1. Selected cross sections are provided on Plate 7-2. As noted, Crandall Canyon is steep, with channel slopes normally exceeding 5 percent. The channel bottom is approximately 10 feet wide and side slopes are steep (generally greater than 100 percent).

Surface water-quality data collected from Crandall Creek by GENWAL are contained in Appendix 7-3 and summarized in Table 7-5A. These data, collected between June 1983 and November 1985, indicate that the dominant ions in Crandall Creek are calcium and bicarbonate. Total dissolved solids concentrations in the stream have varied from 180 to 286 milligrams per liter, with lower concentrations normally occurring during the high-flow season. Total suspended solids concentrations in Crandall Creek have varied during the period of record from <0.5 to 5.0 milligrams per liter (see Appendix 7-3). As expected, the highest suspended solids concentrations generally occur during periods of highest stream flow.

Parshall flumes were installed by GENWAL in Blind Canyon in July 1991 and in Crandall Canyon in May 1988. Locations of the lower and upper Crandall Canyon flumes (CF-1 and CF-1, respectively), and Blind Canyon flume (BF) are shown on Plate 7-16. Charts and tabulated flow data collected from the flumes are presented in Appendix 7-23.

Periodic instantaneous stream flow measurements collected in 1991 by GENWAL in Blind Canyon, Horse Canyon, and the north and south branches of Crandall Creek appear in Appendix 7-23. These measurements were collected from the locations shown on Plate 7-16. When the area was accessible, these measurements were collected monthly from January through June, bi-monthly

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from July through September, and monthly from October through December. During seep and spring surveys performed in the area by GENWAL in October 1989, the South Fork of Horse Canyon was observed to be dry above the forks (Plate 7-16). Blind Canyon was observed to be dry in October 1989 above the midpoint between stations B-2 and B-3 (Plate 7-16). See also Appendix 7-23 for additional evaluations on flow through September 1992.

Water quality data collected by the U.S. Forest Service from Indian Creek are summarized in Appendix 7-45.

Water quality and discharge data for streams in the South Crandall Lease area are presented in Appendix 7-58. Water quality and discharge data for seeps, springs, and streams in U-68082 lease mod area are presented in Appendix 7-64.

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Table 7-5A
Concentrations of Selected Constituents in Crandall Creek

Constituent	Maximum (mg/1)	Date	Minimum (mg/1)	Date	Mean (mg/1)
Upper Station[a] 60 Samples					
Total Diss. Solids	320	11/24/87	180	4/08/85	255
Total Susp. Solids	1472	5/16/84	0	7/17/86	59.3
pH[b]	8.28	10/29/86	6.75	1/14/84	7.78
Total Iron	0.34	6/28/83	<0.05	Several	0.06
Diss Iron	<0.05	Several	<0.05	Several	<0.05
Total Manganese	0.03	Several	<0.01	Several	0.01
Lower Station[a] 52 Samples					
Total Diss. Solids	323	1/29/86	165	11/07/84	259
Total Susp. Solids	1468	5/16/84	0	7/17/86	57.8
pH[b]	8.66	11/20/86	6.95	11/01/84	7.75
Total Iron	0.25	6/28/83	<0.05	Several	<0.05
Diss Iron	<0.05	Several	<0.05	Several	<0.05
Total Manganese	0.03	Several	<0.01	Several	0.01

(a) See Figure 7-8
(b) In standard pH units solids concentrations generally occur during period of highest flow.

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Analytical results are for samples collected from 1971 through 1978. Samples were collected from Sec. 17,T.17S.,R6E.

Laboratory analytical results of water samples collected by GENWAL at the Crandall and Blind Canyon flume locations appear in Appendix 7-3. Crandall Canyon water quality data have been collected from July 1983 to 1991. Blind Canyon water quality data represent the period of November 1990 to 1991.

Surface water-quality data contained in Appendix 7-3 indicate that the dominate constituents in Crandall Creek are calcium and bicarbonate. Total dissolved solids concentrations in the stream have generally varied from 200 to 300 milligrams per liter, with lower concentrations in the streams have generally varied from 200 to 300 milligrams per liter, with lower concentrations normally occurring during the high-flow season. The highest suspended solids concentrations generally occur during periods of highest flow and are a result of overgrazing in the upper Crandall Canyon Watershed.

Blind Canyon Drainage Study

In consultation with the Division of Oil, Gas and Mining, Utah State Lands, the Manti-La Sal National Forest, the U.S. Forest Service Intermountain Research Station, and the U.S. Bureau of Land Management, GENWAL Resources Inc. committed to participating in a scientific study in which the pillars beneath the unnamed drainage in Blind Canyon in Utah State Lands (T15S-R6E-Sec 36) will be retreat-mined to determine effects of retreat-mining produced subsidence on watershed erosion and stream flow. This study would monitor the actual effects of mining as proposed in Section 36. The U.S.F.S. Intermountain Research Station's research proposal appears in Appendix 7-25. This research proposal has been developed during close communication between the Intermountain Research Station and GENWAL Resources Inc. (Appendix 7-25). GENWAL Resources Inc. has committed to help finance the U.S.F.S. Intermountain Research Station's study, and perform subsidence monitoring, collection of Blind Canyon water quality and discharge data, as well as provide additional field support.

The approximate number and locations of cross-sections to be measured by the Intermountain Research Station personnel, and the current profile of the Blind Canyon Drainage from the Western Section Line of T15S-R6E-S36 to Route 31 appear on Plate 7-17. The locations and number of cross-sections may be modified by the researchers as ground conditions dictate. A final drainage profile and actual cross-section locations will be provided to DOGM when they are known. In addition to the cross-sections depicted on Plate 7-17, approximately 25 cross-sections in Crandall Canyon will be measured to serve as a control.

A timetable of research and mining to be conducted is found in Appendix 7-26. This timetable was developed in consultation with the U.S.F.S. Intermountain Research Station's Principal Investigator, to ensure that baseline data will be collected prior to retreat mining subsidence within the study area. As part of an agreement between GENWAL Resources Inc. and the above-referenced parties, pre- and post-mining erosion calculations for the Blind Canyon drainage have been calculated to determine the maximum worst-case amount of increased erosion that could occur as a result of

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retreat mining. These calculations appear in Appendices 7-27 through 7-38. An overview of the erosion calculations is presented in Appendix 7-39. Final results of these calculations are presented in Appendix 7-38. Drawings applicable to the erosion calculations appear in Plates 7-8, 7-9, 7-10, 7-11, and 7-12.

Appendix 7-38 results indicate a worst-case erosion volume exiting State Lease ML-21569 (T15S-R6E-S36) that could potentially be transported onto Manti-La Sal National Forest land to be 0.145 ac-ft (one time event). Appendix 7-37 presents the pre-and post-SEDROUTE outputs. An increase of 0.006 ac-ft (annually) is calculated. This value is the sum of potential headcutting (Appendix 7-38) and SEDROUTE calculations (Appendix 7-37). In order to calculate a worst-case erosion value the following have been assumed:

1) all potentially erodible material is transported down the Blind Canyon drainage off of State Section 36 onto Manti-La Sal National Forest Service land,

2) headcutting erosion is calculated on rills (A, B, C, and D) (Plate 7-9), all ephemeral drainages,

3) headcutting is calculated for drainage "E" (Appendix 7-9), a drainage reach that also exhibits ephemeral flow, and

4) erosion is calculated at the eastern edge of Section 36 (stations 14.5 through 19) (Plate 7-9), over an area where a barrier pillar exists and erosion is extremely unlikely. Drainage erosion between stations 14.5 and 19 is extremely unlikely given the absence of a nick-point produced by retreat-mining (downward hydraulic jump), from which erosion can advance from in an upstream direction resulting in erosion. The more likely occurrence is for all but the smallest sizes of suspended sediment (colloidal) to be deposited upstream of station 14.5, and not reach Manti-La Sal Forest Service land further downstream.

The Manti-La Sal National Forest Service desires an equal or greater amount of sediment to be trapped elsewhere in the Manti-La Sal National Forest to offset potential increases of sedimentation on Forest Service land that could result from retreat-mining of State Section 36. As discussed with the U.S.F.S. Research Station personnel, and officials of the Manti-La Sal National Forest Service, erosion control measures cannot be implemented within the Blind Canyon drainage, on the State of Utah or Manti-La Sal National Forest Service lands, due to potential impacts on the U.S.F.S. Intermountain Research Station's study.

Consultations with Manti-La Sal National Forest Service personnel have resulted in identification of a site, Nuck Woodward Canyon where an erosion enhancement procedure can be conducted to reduce an equal or greater amount of sediment entering Huntington Creek. The enhancement procedure consists of graveling approximately 1/2 mile of the U.S.F.S road from the intersection of Route 31 to the trailhead area of the Nuck Woodward Canyon. An agreement whereby GENWAL donates $15,000 to the Manti-La Sal Forest to fund the Forest Service graveling of this road is provided in Appendix 7-49. This mutually agreed upon action by GENWAL Resources

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Inc. and the Manti-La Sal National Forest, satisfies the U.S.F.S.'s "Net Beneficial Impact Policy." Additionally, GENWAL commits to remediating any adverse effects of retreat mining.

Thin-section microscopy and x-ray diffraction analyses of shales obtained from Crandall Canyon Mine overburden reveal the presence of a variety of bentonitic (swelling) clays. Moreover, carbonate cementation characteristics observed in thin-section and at outcrops, as well as groundwater analytical results, suggest pore-fluid chemistry conditions promote sealing of subsidence fractures (Appendix 7-41). This appendix also references a U.S. Forest Service study which indicates physical closure of subsidence fractures. The Crandall Canyon Mine overburden mineralogy, as well as physical closure of tension fractures, will aid in the protection of perched aquifers and surface waters.

SURFACE WATER DEVELOPMENT AND CONTROL

Water Supply

No extensive surface water development has occurred in the mine permit area or adjacent areas. GENWAL has historically pumped water from the stream near the sedimentation pond and from the sediment pond for use underground. GENWAL agrees to not pump from Crandall Creek at a rate that will cause the instream flow to decrease below 0.30 cfs. For the purpose to this determination, flow rates were measured using the flume at the "Lower Stream Station" indicated on Plate 7-7. No other points of development are known to exist on Crandall Creek or adjacent streams in the immediate vicinity of the mine plan area.

Appendix 7-1 presents a listing of surface water rights within the permitted and adjacent areas as obtained from the files of the Utah Division of Water Rights. Listing of these rights are noted on Plate 7-15 and summarized in Table 7-6.

Only one water-supply intake is known to exist on Crandall Creek. This intake is located immediately upstream from the sedimentation pond and is operated by GENWAL to obtain water for use at the mine. A search of records on file with the Utah Division of Water Rights and an examination of physical conditions along Crandall Creek and Huntington Creek indicate that no other water-supply intakes exist within one mile of the confluence of the two streams. It should be noted that an underground monitoring well (MW-1) drilled in 1987, currently serves as a water supply well for the mine. The use of this well supplements Crandall Creek for in-mine process water.

7.24.3 Geologic Information

Geologic information required for Sections 724.310 and 724.320 is provided in Chapter 6 and in this chapter under Sections 7.24.1 and 7.24.2.

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7.24.4 Climatological Information

General

The Air Pollution Control Plan has been approved with conditions by the Department of Health letter of February 3, 1992. An amended Letter of Intent to Modify GENWAL's existing Air Pollution Control Plan was submitted to the Executive Secretary of the Division of Air Quality in September, 1995. Fugitive dust control measures to be used in connection with the GENWAL Mine facility are included within the remainder of this Section. The addition of the culvert expansion and a proposed increase in coal production has been included in the amended letter of intent.

The climatological information presented below is believed to be applicable to the South Crandall Lease area and the U-68082 lease mod area.

EXISTING ENVIRONMENT

Precipitation

Monthly Averages

Jan.	2.90"	Feb.	2.18"	Mar.	2.53"
Apr.	0.72"	May	1.67"	June	0.19"
July	0.96"	Aug.	2.29"	Sept.	0.32"
Oct.	0.40"	Nov.	2.66"	Dec.	3.18"

Yearly Average: 20.00"

Mean Monthly: 1.75"

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TABLE 7-6

Surface Water Rights in the Crandall Canyon Mine Permit Area & Adjacent Areas

W.U. Claim No.	Owner	Claim Allotment	Use	Period of Use	Source
93-134	U.S. Forest Service	(d)	Stockwater	Jun 21 to Sept 30	Stream
93-175	U.S. Forest Service	(a)	Stockwater	July 6 to Sept 25	Stream
93-181	U.S. Forest Service	(b)	Stockwater	July 1 to Aug 30	Stream
93-182	U.S. Forest Service	(d)	Stockwater	May 21 to Aug 30	Stream
93-183	U.S. Forest Service	(a)	Stockwater	July 6 to Aug 25	Stream
93-184	UT State Lands&Forestry	(c)	Stockwater	Jan 1 to Dec 31	Stream
93-188	U.S. Forest Service	(d)	Stockwater	June 21 to Aug 30	Stream
93-190	U.S. Forest Service	(d)	Stockwater	June 21 to Sept 10	Stream
93-191	U.S. Forest Service	(a)	Stockwater	July 6 to Sept 25	Stream
93-192	U.S. Forest Service	(d)	Stockwater	June 21 to Sept 30	Stream
93-193	U.S. Forest Service	(E)	Stockwater	July 1 to Sept 30	
93-197	U.S. Forest Service	(d)	Stockwater	June 21 to Sept 30	Stream
93-198	U.S. Forest Service	(e)	Stockwater	July 1 to Sept 10	Stream
93-199	Pacificorp DBA UP&L	(j)	Stockwater	Jan 1 to Dec 31	Stream
93-201	U.S. Forest Service	(e)	Stockwater	July 1 to Sept 30	Stream
93-219	Huntington Clev. Irr. Co.	(i)	Varied*	Jan 1 to Dec 31	Stream
93-258	UT State Lands&Forestry	(c)	Stockwater	Jan 1 to Dec 31	Stream
93-336	U.S. Forest Service	(a)	Stockwater	July 6 to Sept 25	Stream
93-377	U.S. Forest Service	(f)	Stockwater	June 1 to Sept 30	Stream
93-383	UT State Lands&Forestry	(c)	Stockwater	Jan 1 to Dec 31	Stream
93-483	U.S. Forest Service	(a)	Stockwater	July 6 to Sept 25	Stream
93-606	U.S. Forest Service	(a)	Stockwater	June 6 to Sept 25	Stream
93-1180	U.S. Forest Service	(d)	Stockwater	June 21 to Sept 30	Stream
93-1590	U.S. Forest Service	(g)	Stockwater	June 21 to Sept 30	Stream
93-1673	U.S. Forest Service	(h)	Stockwater	June 6 to Sept 20	Stream

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TABLE 7-6 (continued)

Surface Water Rights in the Crandall Canyon Mine Permit Area & Adjacent Areas

(a) Part of water right WUC 93-1403 on Crandall Canyon Allotment
(b) Part of water right WUC 93-507 on Horse Creek Allotment
(c) Part of water right WUC 93-500
(d) Part of water right WUC 93-116 on Gentry Mountain Allotment
(e) Part of water rights WUC 93-193, -198, -201, -1410, -1411, -1412, -1413, and -1414 on Crandall Canyon Allotment
(f) Part of water right WUC 93-377 on Little Joe's Valley Allotment
(g) Part of water right WUC 93-1588 on Trail Mountain Allotment
(h) Part of water rights WUC 93-985, -1632, and -1677 on Joe's Valley Allotment
(i) Part of water right WUC-93-219, a7941
(j) Claims 199, 1183

* Irrigation, stockwatering, domestic, power, industrial

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Temperature

Summer Range: +32 to +90 Degrees Fahrenheit
Winter Range: -10 to +40 Degrees Fahrenheit

Evaporation

Potential evapotranspiration of 18 to 21 inches per year.

Wind

Average direction of prevailing winds from west and northwest. The average velocity of prevailing winds representative of the proposed mine plan area is 12 miles per hour as determined by the Utah State Climatological office.

EFFECTS OF MINING OPERATION ON AIR QUALITY

Estimate of Uncontrolled Emissions

The estimate of uncontrolled particulate emissions was determined by GENWAL and submitted to the State of Utah Department of Health for a coal production rate of 3,500,000 tons per year.

Description of Control Measures

Refer to Appendix 4-7 for measures that will be specifically committed to, for implementation. The air quality approval order authorizes the increase in coal production with the conditions noted therein.

A description of the controls and design features associated with the yard expansion can be found in Chapter 5 under section 5.26.

Climatological and Air Quality Monitoring

GENWAL does not require a continuous monitoring plan for the limited amount of dust, particuate emissions or diesel exhaust. (See State of Utah, Division of Health recommendations for monitoring letter included as Appendix 4-7).

7.24.5 Supplemental Information

Because GENWAL has an existing and approved permit it is not anticipated that any additional information will be required for the PHC.

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7.24.6 Survey of Renewable Resource Lands

All renewable resource survey information is included in the Subsidence Control Plan in Section 5.25.

7.24.7 Alluvial Valley Floors

The permit area is located in a narrow V-shaped canyon with upland areas and steep hillslopes. The mine and permit area and the South Crandall Lease area and the U-68082 lease mod area are covered by a thin veneer of colluvial deposits and residual soils. The only alluvial materials are associated with the immediate stream channel which is less than 20 feet wide. These alluvial deposits are discontinuous as many portions of the stream are located directly on bedrock. As a result, the area is not underlain by an alluvial valley floor.

The area occupied by the surface facilities is a steep, narrow canyon hillslope and v-shaped narrow canyon bottom. No agricultural activities have been conducted in the area in the past nor will they be in the future due to the limited width of alluvium along the stream (less than 20 feet), to restrictive climatic conditions, and the limiting physical properties of the alluvial materials. Hence, the Crandall Creek area adjacent to the surface facilities is not an alluvial valley floor. This negative determination was also determined by the U.S. Soil Conservation Service (see Appendix 7-12).

7.25 Baseline Cumulative Impact Area Information

Sufficient information was provided by GENWAL during the initial permitting of the Crandall Canyon Mine for the Division to develop a Cumulative Hydrologic Impact Assessment (CHIA).

Geologic Information pertaining to Little Bear Spring

The Little Bear Spring is located close to the southern boundary of the South Crandall Lease area. This spring is an important source of culinary water for many residents of Emery County. In order to ensure that the spring would be protected from the effects of mining in the South Crandall lease area. the Forest Service and the BLM required a number of detailed hydrology studies to ascertain the source of the spring. Based on the result of these studies the federal government has concluded that the potential for mining this lease to alter the flow of Little Bear Spring is low and has issued a Finding of No Significant Impact (FONSI) regarding the proposal to conduct mining operations within the lease. The following studies were required by the Forest Service and BLM prior to leasing action and are included in this MRP as appendices in Chapter 7. Each report includes an extensive discussion of the geology of the South Crandall tract as relates to the occurrence of ground-water, aquifers, and recharge sources of the Little Bear Spring.

App 7-51 Little Bear Spring Water Replacement Agreement
App 7-52 Supplemental Hydrogeologic information for LBA 11
App 7-53 Summary of New Isotopic Information for LBA 11
App 7-54 Results of In-Mine Slug Tests
App 7-55 Investigation of Alluvial Ground Water System In Mill Fork Canyon

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App 7-56 Investigation of Potential for Little Bear Spring Recharge
App 7-57 Determination of Recharge Location of Little Bear Spring (Dye Tracing)
App 7-58 Summary of Hydrologic Baseline Information, South Crandall Lease
App 7-59 Little Bear Spring Study (Initial study, 1998) AquaTrack
App 7-60 Little Bear Spring Study (Expanded Study, 1999) AquaTrack
App 7-61 Mill Fork Resistivity Study, 2001 AquaTrack
App 7-62 Little Bear Spring (2nd Expanded Study, 2001) AquaTrack

7.26 Modeling

No hydrologic model has been prepared or conducted at this site, nor is any planned.

7.27 Alternative Water Source Information

GENWAL recognizes the fact that the Division of Wildlife Resources, the U.S. Forest Service, the Division of Oil, Gas & Mining, and the State Engineer consider all seeps and springs to be important to wildlife and downstream users. If, during the monitoring of the springs, it is determined that over the course of time a spring has been dewatered, GENWAL will notify the Division of Wildlife Resources, the Division of Oil, Gas and Mining, the U.S. Forest Service, the State Engineer, and any affected downstream users. A determination as to the probable cause of diminished flow will **be** made and if mining activities are found to be the cause, work will begin on an acceptable mitigation plan involving the use of guzzlers or other replacement measures acceptable to GENWAL, DOGM, the U.S. Forest Service, the State Engineer, and affected downstream users. The Utah Division of State Lands and Forestry will also be conferred with in formulating any mitigation plans that will affect the lands in the State Leases.

These replacement measures will be designed in cooperation with the Division of Wildlife Resources, the Division of Oil, Gas and Mining and the U.S. Forest Service and placed in the area of the effected spring. No other sources of water, other than the springs located by the seep and spring survey, are known to exist in the mine plan area. GENWAL owns shares in the Huntington-Cleveland Irrigation Company that can be transferred if required, to meet the demands of an alternate water supply. A copy of the water share certificate which would be used as an alternative water source is included in Appendix 7-14.

Mitigation for potential disruption to the Little Bear Spring will be accomplished though the construction of a water treatment plant which will provide replacement water for the spring. Construction of this water treatment plant will be done under the provisions of a water replacement agreement between GENWAL Resources, Inc. and the Castle Valley Special Service District who maintain culinary water rights to Little Bear springs. A copy of this water replacement agreement is included in Appendix 7-51. With construction of this water treatment plant an uninterrupted supply of culinary water will be assured irrespectively of whether mining can be conclusively shown to have affected Little Bear Spring. This is in compliance with special stipulation #17 of federal lease UTU-78953 (see Appendix 1-13).

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7.2 Probable Hydrologic Consequences Determination

The Probable Hydrologic Consequences (PHC) is included as a separate document in Appendix 7-15. Installation of the culvert expansion project does not change the conclusions presented in the current PHC.

7.29 Cumulative Hydrologic Impact Assessment

The Division has prepared a Cumulative Hydrologic Impact Assessment (CHIA) for this operation in the initial permit. A complete PHC is provided in Appendix 7-15 to aid in the determination as to whether a new CHIA is required for this renewal.

7.30 Operation Plan

7.31 General Requirements

This section describes the groundwater and surface water protection plan and water quality monitoring program implemented within the existing permit area and to be implemented for the refuse disposal site. The purpose of the groundwater and surface water protection plan is to minimize the potential for water pollution and changes in water quality and flow for surface and groundwater within and adjacent to disturbed areas. The purpose of the water quality monitoring program is to identify the potential impacts of coal mining operations on the hydrologic balance.

7.31.1 Hydrologic Balance Protection

Surface and Groundwater Protection Plan

GENWAL has included a plan to protect the surface and groundwater in the area of the mine facilities, topsoil storage site and refuse disposal site. The plan will ensure protection of the ground water and surface water resources of the sites by handling earth and refuse materials in a manner that prevents or controls, using the best technology currently available, the discharge of pollutants to the hydrologic system. Additionally, the GENWAL commits to handle acid- and toxic-forming materials, if encountered in the future, in a manner that will minimize acid- and toxic-forming discharge to surface or groundwater. The design details of the water protection plans are presented in Section 7.42 of this application.

In order to prevent material damage to the hydrologic balance and to protect the hydrologic systems possibly associated with the Joes Valley fault system, GENWAL plans to drill ahead before mining in the Incidental Boundary Change area adjacent to the Joes Valley fault in T. 16 S., R. 6 E. Sections 3 and 10.

When mining in the longwall gate entry nears the fault (between 200-300 feet away), an underground drill will be used to drill west toward the fault to determine its location. The drill will drill horizontally toward the fault up to 50 feet ahead of the entry face. If the fault is not

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encountered, the continuous miner will advance about 30-40 feet toward the fault, leaving at least 10 feet of coal between the entry and the end of the hole. The drill will again drill ahead. This sequence will continue until either water or fault gouge is encountered in the hole or the entry has been developed to its maximum extent (providing no fault was detected). If the fault is encountered prior to reaching the bleeder entries, then mining will stop and the bleeder entries will be relocated. At least 10 feet of solid coal will be left between the face of the entry and the fault.

Other indicators have been experienced during mining up next to Joe's Valley Fault. Any of these indicators being present will affect the above mining sequence. The indicators, which we have experienced are severe rib rashing in some cases; in others the ribs will stand up showing no rib rash. Severe water pressures have never been encountered. Large flows of water have occurred from cracks in the roof, but these flows have been associated with sand channels rather than the fault.

One horizontal hole will be drilled in the 10, 11 12 13 and 14th west panels. Should water be encountered by the drill hole, entry development would terminate at that point. Although large amounts of water and high pressure have not been previously encountered by mining near the fault, an emergency plan to handle water inundation from the fault has been developed. The plan consists of the following actions:

1. Pull equipment back from face
2. Erect two Kennedy stoppings at least 2 feet apart
3. Place appropriate sized de-water pipe w/valve at bottom of stoppings
4. Pump quick drying cement into the space between the stopping
5. After minimum drying time, close water valve

As a secondary measure of precaution, no longwall mining will take place in the 22 degree angle of draw projected from the Joes Valley fault. Therefore no subsidence from mining operations will intersect the fault or fault zone. Any hydrologic conditions specific to the Joes Valley Fault will not be impacted through mining or subsidence based on accessibility of the sites. Water monitoring reports will be submitted to the Division on a quarterly basis, and a summary report will be submitted yearly with the Annual Report for the mine.

All test and measurement instruments are operated, maintained and calibrated in accordance with the manufacturers instructions. The results of all field measurements are recorded and initialed by the sampler. When laboratory measurements are required, a specific set of sample bottles are pre-ordered from the laboratory. Bottles received from the laboratory are clean, pre-acidified and color-coded. Once the sample bottles are filled, they are individually labeled with water-proof, smudge-proof labels, placed in ice chests with ice packs and returned to the laboratory as soon as possible to insure proper holding times are met.

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7.31.21 Groundwater Monitoring Plan

As noted in Section 7.24.1 only four springs were found during the June 1985 seep and spring survey within the area of potential subsidence with flow rates of one to two gallons per minute (SP-16, SP-17, SP-30, SP-36). By the time of the fall survey, all seeps and springs with the area of potential subsidence except SP-30 and SP-36 had dried up. Spring SP-30 was found to be dry during 1986 and in subsequent years to the present. The flow from SP-30 originally measured in 1985 is most likely attributable to higher than normal precipitation during 1983-1985. SP-30 occurs as diffuse seepage from the Blackhawk Formation above the mine portals and is collected in a diversion pipe to avoid problems at the portal face. Flow at SP-36 issues from a sandstone-shale contact within the Blackhawk Formation and showed evidence of use by elk and deer. All major springs (flows of at least five gallons per minute) found during the June 1985 survey were located outside of the area of potential subsidence at that time.

The Federal Lease #UTU-68082 and State Leases have since been added to the permit area, and the area of potential subsidence has therefore expanded. Additional spring and seep surveys were conducted in 1987, 1989, through 1993. The proposed groundwater monitoring program described below is based on the results of those surveys and is designed to evaluate impacts from the entire permit area, including the State Leases and Lease #UTU-68082 (LBA 9). A table clarifying the groundwater monitoring program is shown in Table 7-10 at the end of Chapter 7 text.

Previous to August 1994, groundwater monitoring for the Crandall Canyon Mine area included collection of water quality and quantity data from eleven springs as well as points of significant inflow to the underground workings. Based on the permit modification to include UTU-68082 (LBA #9), GENWAL conducts the monitoring of fourteen seeps and springs:

SP-30 and SP-36 are monitored to determine potential impacts in the immediate vicinity of the mine. SP-58 is monitored as an indicator of long-term changes in groundwater issuing from the Blackhawk Formation in a area that will not be affected by mining operations. The magnitude of these changes will be useful when interpreting changes at SP-30 and SP-36.

SP2-24, SP2-9, SP-47A, and SP1-3 are monitored since a water right has been filed on the springs by the U.S. Forest Service. Springs SP1-19 and SP1-22 are monitored as indicators of the water supply in the upper reaches of Blind Canyon and the North Fork of Crandall Canyon.

SP1-33, SP1-47, and SP2-1 are monitored as an indicator of changes in groundwater emanating near the western border of East Mountain, contiguous to Joe's Valley Fault.

SP1-9 (also SP1-19 mentioned above is located within this state lease) located in Lease ML-21569 and SP1-24 in lease ML-21568 are monitored to evaluate the effects of potential subsidence in the state leases. Plate 7-12 shows the location of each spring.

Samples were collected from each of the fourteen seeps/springs listed above, plus seeps SP2-14 and SP2-23, during the spring of 1994 and analyzed for both quantity and quality. Based on the information collected during 1994 and the past seep and spring surveys, springs SP-36, SP-58, SP2-9, SP2-24, SP1-33, and SP1-9 are monitored quarterly for quantity and quality. The remaining springs (SP-30, SP2-1, SP1-47, SP1-24, SP1-19, SP-47A, SP1-3, and SP1-22) are monitored for quantity and

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field chemical parameters only. Springs SP2-14 and SP2-23 have been removed from the list of springs to be monitored due to extremely low or no flow over the past few years and SP2-9, which is contiguous to these two springs, is a good indicator of the water quality and quantity for that area of the mine permit. Monitoring at the fourteen seeps/springs will continue on a quarterly basis.

Following reclamation the samples will be collected semiannually until the surety bond is released. At least one of these samples will be collected during the low-flow period (normally the fourth quarter). These samples are collected as close as possible to the point of issuance of the springs. Samples are analyzed according to the list of parameters in Table 7-4 which includes, flow, pH, conductivity or TDS, total iron, and total manganese as required by R645-301-724.1.

Samples collected during the low-flow period of the year (fourth quarter) will be analyzed according to the list of parameters contained in Table 7-5 (as requested in guidelines from DOGM) in the years 1990, 1995, 2000, and at 5-year intervals thereafter until the surety bond is released.

Even though SP-30 has been dry since the original measurement in 1985, monitoring at SP-30 will continue. By continuing to monitor SP-30, flow trends, as they relate to precipitation patterns, can be observed. Substitution of another spring in the vicinity was considered and dismissed due primarily to the long term monitoring correlation stated above and because there exists a lack of flowing springs in the vicinity of old mine workings. Additionally, when the physiographic location of the mine portal is compared with similar locations in adjacent canyons (ie; Blind Canyon, Horse Canyon, Little Bear, and Mill Fork) there are an apparent absence of springs on these mid to upper south facing hill slopes (Plate 7-12). The apparent absence of seeps and springs in these areas is primarily related to the geologic nature and limiting hydrologic characteristics of the Blackhawk Formation in its upper strata.

In conjunction with the South Crandall Lease (UTU-78953) and the SITLA/PacifiCorp sublease GENWAL will monitor four springs. The monitoring plan for the South Crandall Lease is described below. Monitoring site locations are shown on Plate 7-18. The monitoring protocols for each of the monitored springs are presented in Table 7-10.

The monitoring plan for springs includes springs in the Castlegate Sandstone, Blackhawk Formation, and Star Point Sandstone. As demonstrated in the PHC, it is believed that the potential for diminution of flow or degradation of the water quality of springs discharging from the Price River or North Horn Formations is remote.

Little Bear Spring will be regularly monitored to verify that impacts to not occur and to document the relationship between climatic variability and discharge from the spring. Quarterly water quality sampling at the spring will occur and the samples will be analyzed for the parameters listed in Table 7-4. Discharge from the spring is monitored by the Castle Valley Special Service District.

Springs LB-7, LB-7A, LB-7B, AND LB-7C discharge near the contact of the Blackhawk Formation and Castlegate Sandstone in Little Bear Canyon. Spring LB-12 discharges from the Blackhawk Formation near the bottom of Little Bear Canyon. These springs will be monitored quarterly for flow and field water-quality parameters. NOTE: multiple seam mining beyond spring site LB-7 in Little Bear Canyon is contingent upon a monitoring plan approved by the Division in concurrence with the Forest Service at least two years prior to mining in that area.

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It should be noted that access to Little Bear Canyon can be hazardous. When ice or snow is present it can become unsafe to traverse the cliffs, and steep, rugged slopes in the canyon. It can also be dangerous to wade across Huntington Creek when stream flows are high. In consideration of these difficulties, a diligent attempt will be made each quarter to monitor the springs at times when conditions permit. However, there will likely be times when these springs are not accessible for monitoring.

Spring LB-5A discharges from a sandstone channel in the upper Blackhawk Formation overlying proposed mining areas. To monitor for potential impacts to groundwater systems in the Blackhawk Formation, LB-5A will be monitored quarterly for Table 7-4 parameters including flow and field water-quality parameters.

Spring SP-79 discharges from the Star Point Sandstone in the northeast portion of the proposed South Crandall Lease area. To monitor for potential impacts to Star Point Sandstone groundwater systems (stratigraphically below the mined coal seam) quarterly monitoring of this spring will occur. SP-79 will be monitored according to Table 7-4 parameters including flow and field water-quality parameters.

SP-18 and SP-22 are located in the Shingle Canyon (aka No Name Canyon) area in th northeast part of the permit area. SP-18 issues from the contract between the Blackhawk formation and the Star Point sandstone near the confluence of the drainage. SP-22 is located higher in right fork of Shingle Creek in the Blackhawk above the elevation of the coal seam to be mined. These springs will be monitored to verify that effects of mining in the U-68082 lease modification area. These springs will be monitored for flow and field parameters quarterly.

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TABLE 7-4

Abbreviated Groundwater Analysis List

Field Measurements:

Water level or flow
pH
Specific conductance (umhos/cm)
Temperature (°C)

Laboratory Measurements:

Total dissolved solids
Total hardness (as $CaCO_3$)
Total Alkalinity
Bicarbonate (as HCO_3)
Carbonate (as CO_3)
Calcium (as Ca)
Chloride (as Cl)

Dissolved iron (as Fe)
Total Iron (as Fe)
Magnesium (as Mg)
Total Manganese (as Mn)
Potassium (as K)
Sodium (as Na)
Sulfate (as SO_4)

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TABLE 7-5

Extended Groundwater Analysis List

Field Measurements:

Water level or flow
pH
Specific conductance (umhos/cm)
Temperature (°C)

Laboratory Measurements:

Total dissolved solids
Total hardness (as $CaCO_3$)
Total Alkalinity
Acidity
Aluminum (as Al)
Arsenic (as As)

Barium (as Ba)
Bicarbonate (as HCO_3)
Baron (as B)
Carbonate (as CO_3)
Cadmium (as Cd)(Dissolved)
Calcium (as Ca)(Dissolved)

Chloride (as Cl)
Copper (as (Cu)(Dissolved)
Dissolved Iron (as Fe)
Total Iron (as Fe)

Lead (as Pb)(Dissolved)
Magnesium (as Mg)(Dissolved)
Dissolved Manganese
Total Manganese (as Mn)
Molybdenum (as Mo)(Dissolved)

Nitrogen-Ammonia (as NH_3)
Nitrite (as NO_2)
Nitrate (as NO_3)
Potassium (as K)(Dissolved)
Phosphate (as PO_4)

Selenium (as Se)(Dissolved)
Sodium (as Na)(Dissolved)
Sulfate (as SO_4)
Zinc (as Zn)

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All samples are preserved as soon as practicable after collection. Samples are collected and analyzed according to the methodology in the current edition of "Standard Methods for the Examination of Water and Wastewater" or the methodology in 40 CFR Parts 136 and 434.

On a quarterly basis an inventory will be conducted of the active portion of the mine to identify the location and geologic occurrence of mine inflows that exceed three gallons per minute. In consultation with DOGM, certain of these inflows (if they occur) will be selected for continued monitoring. Previously, only one such inflow existed, flowing from the roof of the mine from an exploratory hole (DH-1) that was vertically drilled from within the permit area at the location shown on Plate 3-2 (listed as "DRILL HOLE"). Flow from this hole was originally controlled with a valve. However, the overlying perched aquifer no longer produces a flow sufficient to monitor.

After selection of the inflow points to be monitored, data will be collected on a quarterly basis and analyzed according to Table 7-4. Samples collected during the low-flow period (normally the fourth quarter) will be analyzed according to Table 7-5 in the years 1990, 1995, 2000, and at 5-year intervals thereafter. Monitoring and sampling of the selected mine inflow points will continue, according to this schedule, in safely accessible portions of the mine.

Water rights apparently have been filed for two additional springs in the area surrounding the lease areas (93-1407 and 93-1408 on Plate 7-14). As noted in Section 7.24.1 the source at 93-1407 was not discovered until the fall of 1990. Until this time it was surmised to exist as only a seep (similar to 93-1408 (SP-47). Since its discovery GENWAL has committed to monitoring and sampling SP-1407 (SP-47a) in the groundwater monitoring plan submitted with the Right-of-Way application. Source 93-1408 existed as a seep in June but was dry in October, 1985. Hence, it was decided not to monitor 93-1408 on a long-term basis since it does not flow at a sufficient rate to permit sample collection. SP-47 was observed to be dry in October, 1989 and in June of 1990.

GENWAL installed monitoring wells near the mine portal (MW-1), and in the East Mains near their junction with the North Mains (MW-2) (Plate 7-13). Monitoring well MW-3 is located in an area sealed in 1979, and is now inaccessible. Monitoring wells MW-4 and MW-5 were installed in January 1992. These locations were chosen in areas where access will be maintained as long as possible.

Each underground monitoring well was drilled using air-rotary techniques (see Appendix 7-46 for completion diagrams). MW-1 was drilled to a total depth of 375 feet (Figure 7-1). As 6 5/8-inch diameter steel casing was cemented within a 10-inch diameter hole to a depth of 100 feet. A 6-inch diameter open hole completion exists from 100 to 375 feet. MW-2 was drilled to a total depth of 134 feet. Four-inch casing was set to 5 feet. A 3-inch open hole completion exists from 5 to 134 feet. Drilling of a larger diameter hole at greater depth was precluded by the inability of a larger drill rig to mobilize underground.

Monitoring well MW-4 was drilled to a depth of 111.5 feet. The hole has a 5" casing set to a depth of 4 feet, and a 1.5 inch PVC casing for the remainder, with a slot screen in the bottom 10 feet. MW-5 was drilled to a depth of 116.8 feet. It has a 5" casing to a depth of 4 feet, and a 2 inch PVC casing for the remainder, with a slot screen in the bottom 40 feet.

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After drilling, each hole was surged with air to remove fines that had accumulated in the holes. Surging continued until the water discharging from the holes was visibly clear. A cap was placed over the surface casing to allow closure of each well when not in use.

Construction and initial sampling of the underground monitoring wells was completed in June, 1989 and June, 1992. Lithologic/completion logs of the wells have been submitted to DOGM along with the results of analyses of the first samples collected from the wells. An interpretation of the hydrogeology of the Star Point Sandstone beneath the mine appears in Section 7.24.1.

Water-level measurements and water-quality samples will be collected from the monitoring wells on a quarterly basis following completion during the first two years following completion of the in-mine wells and in the years 1990, 1995, 2000 and in 5-year intervals thereafter. During the operational period of the mine, water-quality samples collected from all wells will be analyzed according to the list provided in Table 7-4. Monitoring will continue according to this schedule in accessible wells until two years after the completion of surface reclamation activities.

Each monitoring well will be pumped prior to sampling to purge it of stagnant water standing in the hole. In the case of M-1, purging will be accomplished using a submersible pump. A bailer will be used for purging and sampling MW-2, MW-4 and MW-5. In each case, purging will continue until at least 3 times the volume of water standing in the well has been pumped. Samples will be collected directly from the discharge line of the pump. Samples will be preserved and stored in accordance with U.S. Environmental Protection Agency guidelines.

Groundwater monitoring data collected from the area will be submitted to DOGM on a quarterly basis. On an annual basis, a report will be submitted to DOGM summarizing all data collected during the year and containing an analysis of the mine water balance, accounting for mine inflows, outflows, consumptive uses, and sump storage (a copy of the annual report will also be given directly to the Price office of the U.S. Forest Service).

After the completion of mining activities and during the post-mining/reclamation period, water-level and quality samples will be collected annually from the designated springs and MW-1 until the termination of bonding. In-mine wells will be inaccessible following reclamation. Samples will be collected during the latter portion of the summer to represent low-flow conditions. Samples thus collected will be analyzed for the parameters listed in Table 7-4. A report will be submitted to DOGM on an annual basis summarizing the results and assessing mining impacts and system recovery since mining ceased.

7.31.22 Surface Water Monitoring Plan

Two 36-inch Parshall flumes were installed in July 1985 on Crandall Creek (one upstream from the surface facilities and one downstream (see Plate 7-16). A 12-inch Parshall flume has been installed in Blind Canyon to monitor possible effects of mining in State Lease ML-21569. These flumes are equipped with Stevens Type-F water-level recorders to allow the collection of continuous flow data. Charts will be changed and the flumes inspected on a monthly basis. Flume location and stream monitoring stations are shown on Plate 7-16.

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Water quality samples will be collected from the flume locations quarterly, and analyzed according to the list contained in Table 7-8. In the years 1990, 1995, 2000 and every fifth year thereafter the samples collected during the low-flow period (normally fourth quarter) will be analyzed according to Table 7-9. All samples will be analyzed for total and dissolved constituents according to the indicated lists. Sampling and analysis will be conducted quarterly until the surface areas are reclaimed, at which time sampling will be conducted semiannually until the surety bond is released. For perennial streams, those samples will be collected during high-flow (normally second quarter) and low-flow (normally fourth quarter) periods. Discharges from the sedimentation pond will be analyzed in accordance with the NPDES permit for the facility.

Stream flow observations made during drilling operations as well as seep and spring surveys suggest that large portions of the south fork of Horse Creek, and both the north and south forks of Crandall Creek have only ephemeral and intermittent flows within State Leases ML-21568 and ML-21569 and portions of UTU-68082. Plate 7-16 shows the points of transition between perennial and intermittent flow for Horse Creek, Blind Creek, the north and south forks of Crandall Creek, and Indian Creek. Blind Creek has been determined to be intermittent.

Stream channel monitoring stations have been established along both the north and south forks of Crandall Creek, and the south branch of Horse Creek to determine what stream reaches exhibit perennial flow. Stream flow and water temperature were measured twice monthly from May through July, and monthly during the remainder of 1991 when the area was accessible. Stream monitoring results are found in Appendix 7-23. Stream monitoring was again done on September 28, 1992. These results are also contained in Appendix 7-23. Stream monitoring ceased at the end of 1992.

To provide for proper monitoring of Indian Creek (in Upper Joe's Valley) a 36-inch Parshall flume was installed. This flume is equipped with a Stevens Type-F water-level recorder to allow the collection of continuous flow data. Charts will be changed and the flumes inspected on a monthly basis. The location of this flume is depicted on Plate 7-16. Because of its higher elevation and limited access this flume is typically operational from June 1 through November 1 of any given year. If seasonal variations and access allow, this station will be operated for longer periods.

Water quality samples will be collected from the Indian Creek flume location quarterly (weather permitting), and analyzed according to the list contained in Table 7-8. In the years 1995, 2000 and every fifth year thereafter the samples collected during the low-flow period (normally fourth quarter) will be analyzed according to Table 7-9. All samples will be analyzed for total and dissolved constituents according to the indicated lists. When flumes or other monitoring devices are no longer required, they will be removed and the affected areas will be restored.

No retreat mining will be conducted within the designated stream channel buffer zones. Horse Canyon is located hydraulically upgradient and north of the UTU-68082 (LBA No. 9) north boundary line. Current mine plans show that because of limited coal height that neither development mining or retreat mining will occur beneath Horse Canyon and the stream channel buffer zones. Since mining has already occurred under Blind Canyon, Crandall Canyon, and beneath the upper reaches of the left fork (South Fork) tributary of Horse Canyon, any adverse effects to the respective

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streams should manifest as reduced stream flow and a continuous high volume inflow into the mine workings. If it is found that stream flows in Blind Canyon and Crandall Canyon have been impacted by mining, then a decision to monitor Horse Canyon on a continuous basis will be made.

In conjunction with the South Crandall Lease (UTU-78953) and the SITLA/PacifiCorp sublease GENWAL will monitor four creeks. The monitoring plan for the South Crandall Lease is described below. Monitoring site locations are shown on Plate 7-18. The monitoring protocols for each of the monitored creeks are presented in Table 7-10.

Little Bear Canyon Creek will be monitored quarterly for Table 7-8 parameters including flow and field water-quality parameters. The creek will be monitored approximately 100 feet above the confluence with Huntington Creek (Plate 7-18). Based on the range of discharge anticipated at the creek (see Appendix 7-58) discharge measurements at Little Bear Canyon Creek will likely be performed using a 90° v-notch weir or a portable 3-inch Parshall flume.

The ephemeral drainage in SW 1/4 of Section 4 T16S R7E will be monitored quarterly for Table 7-8 parameters including flow and field water-quality parameters. No discharge was observed in this drainage during drought conditions in 2003. If flow occurs in this drainage, the discharge will be measured using appropriate portable discharge measuring devices.

Monitoring station IBC-1 monitors the drainage located along the border of Sections 5 and 6, T16S, R7E. This drainage will be monitored quarterly for Table 7-8 parameters including flow and field water-quality parameters. Discharge in this drainage has been meager (Appendix 7-58) and discharge will likely be measured using a stopwatch and a calibrated bucket. The potential for impacts to this drainage are considered remote because only a small region in the extreme northwestern portion of the South Crandall Lease area is drained by this drainage. However, to verify that no impacts to this drainage occur, and to document the effects of climatic variability on stream discharge in the region, this creek will be monitored.

The creek in Section 5 T16S, R7E will be monitored quarterly for Table 7-8 parameters including flow and field water-quality measurements. This creek drains most of the northeastern portion of the South Crandall Lease area, where the initial mining in the lease area will occur. Additionally, the upper forks of this drainage will be monitored for flow and field water-quality measurements will be performed. Flow at each of the monitoring sites on this drainage has been meager. Thus, flow measurements will likely be performed using a stopwatch and a calibrated bucket.

In conjunction with mining in the U-68082 lease modification area GENWAL will monitor surface flow in Shingle Canyon (aka No Name Canyon), for flow and field parameters quarterly. This site is located immediately down stream from the confluence of the right and left forks of the canyon, and is shown on Plate 7-18.

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TABLE 7-8

Abbreviated Surface Water Analysis List

Field Measurements:

Water level or flow
pH
Specific conductance (umhos/cm)
Temperature (°C)
Dissolved oxygen (ppm)

Laboratory Measurements:

Total dissolved solids
Total suspended solids
Total settleable solids
Total hardness (as $CaCO_3$)
Total Alkalinity
Bicarbonate (as HCO_3)

Carbonate (as CO_3)
Calcium (as Ca)
Chloride (as Cl)
Dissolved Iron (as Fe)
Total Iron as (Fe)
Magnesium (as Mg)

Dissolved Manganese
Total Manganese (as Mn)
Potassium (as K)
Sodium (as Na)
Sulfate (as SO_4)
Oil and Grease
Cation - Anion balance

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TABLE 7-9

Extended Surface Water Analysis List
(Baseline Parameters)

Field Measurements:
Flow
pH
Specific conductance (umhos/cm)
Temperature (°C)
Dissolved oxygen (ppm)

Laboratory Measurements:

Total dissolved solids
Oil and Grease
Cation - Anion balance
Total suspended solids
Total settleable solids
Total hardness (as $CaCO_3$)
Total Alkalinity

Acidity as ($CaCO^3$)
Aluminum (as Al)
Arsenic (as As)
Bicarbonate (as HCO_3)
Boron (as B)
Carbonate (as CO_3)

Cadmium (as Cd)
Calcium (as Ca)
Chloride (as Cl)
Copper (as Cu)(Dissolved)
Dissolved iron (as F)
Total iron as (Fe)
Lead (as Pb)(Dissolved)
Magnesium (as Mg)(Dissolved)

Dissolved Manganese
Total Manganese (as Mn)
Molybdenum (as Mo)(Dissolved)
Nitrogen-Ammonia (as NH_3)
Nitrite (as NO_2)

Nitrate (as NO_3)
Potassium (as K)(Dissolved)
Phosphate (as PO_4)
Selenium (as Se)(Dissolved)
Sodium (as Na)(Dissolved)

Sulfate (as SO_4)
Zinc (as Zn)(Dissolved)

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Table 7-10 Water Monitoring Program

Ground Water

Springs

1	SP-30	No Side Lower Crandall	Flow and field parameters quarterly
2	SP-36	No Side Lower Crandall	Flow, field parameters, and Table 7-4 parameters quarterly
3	SP-58	Forks of Crandall Crk.	Flow, field parameters, and Table 7-4 parameters quarterly
4	SP2-24	Top of East Mountain	Flow, field parameters, and Table 7-4 parameters quarterly
5	SP2-9	Top of East Mountain	Flow, field parameters, and Table 7-4 parameters quarterly
6	SP47A	Pt No of Crandall Mine	Flow and field parameters quarterly
7	SP1-3	Top of East Mountain	Flow and field parameters quarterly
8	SP1-19	Top of East Mountain	Flow and field parameters quarterly
9	SP1-22	Top of East Mountain	Flow and field parameters quarterly
10	SP1-33	Upper Joe's Valley	Flow, field parameters, and Table 7-4 parameters quarterly
11	SP1-47	Upper Joe's Valley	Flow and field parameters quarterly
12	SP2-1	Upper Joe's Valley	Flow and field parameters quarterly
13	SP1-9	Top of East Mountain	Flow, field parameters, and Table 7-4 parameters quarterly
14	SP1-24	Top of East Mountain	Flow and field parameters quarterly
15	LB-5A	Little Bear Canyon	Flow, field parameters, and Table 7-4 parameters quarterly
16	LB-7	Little Bear Canyon	Flow, field parameters quarterly
17	LB-7A	Little Bear Canyon	Flow, field parameters quarterly
18	LB-7B	Little Bear Canyon	Flow, field parameters quarterly
19	LB-7C	Little Bear Canyon	Flow, field parameters quarterly
20	LB-12	Little Bear Canyon	Flow, field parameters quarterly
21	SP-79	Huntington Canyon trib.	Flow, field parameters, and Table 7-4 parameters quarterly
22	Little Bear Spring		Flow, field parameters, and Table 7-4 parameters quarterly
23	SP-18	Shingle Canyon	Flow, field parameters quarterly.
24	SP-22	Shingle Canyon	Flow, filed parameters quarterly.

In-Mine Monitoring Wells

1	DH-1	Main North (Dry)	Flow, field parameters, and Table 7-4 parameters quarterly
2	DH-2	In Sealed Area	Flow, field parameters, and Table 7-4 parameters quarterly
3	MW-1	At Portals	Flow, field parameters, and Table 7-4 parameters quarterly
4	MW-2	At Mouth of Main East	Flow, field parameters, and Table 7-4 parameters quarterly
5	MW-3	In Sealed Area	Flow, field parameters, and Table 7-4 parameters quarterly
6	MW-4	In Sealed Area	Flow, field parameters, and Table 7-4 parameters quarterly
7	MW-5	Destroyed	Flow, field parameters, and Table 7-4 parameters quarterly
8	MW-6	Main South (DEEP)	Flow, field parameters, and Table 7-4 parameters quarterly
9	MW-6a	Main South (No of Dike)	Flow, field parameters, and Table 7-4 parameters quarterly
10	MW-7	Main West	Flow, field parameters, and Table 7-4 parameters quarterly
11	MW-8	Main South (So of Dike)	Flow, field parameters, and Table 7-4 parameters quarterly

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Table 7-10 Water Monitoring Program (continued)

Surface Water

Streams

1 Upper Flume Crandall Creek	Flow, field parameters, and Table 7-8 parameters quarterly
2 Lower Flume Crandall Creek	Flow, field parameters, and Table 7-8 parameters quarterly
3 Horse Canyon Creek	Flow, field parameters, and Table 7-8 parameters quarterly
4 Blind Canyon Creek	Flow, field parameters, and Table 7-8 parameters quarterly
5 Indian Creek	Flow, field parameters, and Table 7-8 parameters quarterly
6 IBC-1	Flow, field parameters, and Table 7-8 parameters quarterly
7 Section 4 Creek	Flow, field parameters, and Table 7-8 parameters quarterly
8 Section 5 Creek (lower)	Flow, field parameters, and Table 7-8 parameters quarterly
9 Section 5 Creek (Upper Right Fork)	Flow and field parameters quarterly
10 Section 5 Creek (Upper Left Fork)	Flow and field parameters quarterly
11 Little Bear Creek	Flow, field parameters, and Table 7-8 parameters quarterly
12 Shingle Creek	Flow, Field parameters quarterly.

UPDES

1 001 – Sed Pond Discharge	Flow, field parameters, and UPDES parameters per occurrence
2 002 – Mine Water Discharge	Flow, field parameters, and UPDES parameters monthly

Note: See Plate 7-18 for Locations

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Baseline water quality samples will be collected quarterly from the stream monitoring station below the forks in Horse Canyon at location H-1 (Plate 7-16) and analyzed according to the list contained in Table 7-8. Instantaneous flow estimates will be made for stations H-1, HS-5, and HN-1 during the spring and summer water quality sampling event. This monitoring will continue for a period of three years at which time the need for continued monitoring of Horse canyon will be evaluated.

Surface-water monitoring data will be submitted to DOGM on a quarterly basis. At the end of each calendar year, an annual summary will be submitted. This annual summary will analyze and describe variations in flows and quality during the year and will include tables, graphs, hydrographs, etc. as appropriate.

If available data (testing within 24 hours of proposed discharge) indicate that the water in the pond meets the effluent limitations contained in R614-301-751 and any applicable UPDES permits, this water will be pumped directly to Crandall Creek. Any direct discharges will be monitored at the beginning and end of pumping from the pond. The pump inlet will be placed on a floating spring to avoid pulling excess sediment into the discharge table during pumping. Water will be pumped from below the water surface to avoid introduction of oil to the discharge water.

During the post-operational period, surface-water data will be collected from the upper and lower stations shown in Plate 7-7 and the inflow to the sedimentation pond as indicated on Plate 5-16. Flow data will be collected continuously from the flumes at the upper and lower Crandall Creek stations and twice annually (during the high- and low-flow seasons) from the sedimentation pond inflow during the post-mining period. In addition, water-quality samples will be collected from each station during the high- and low-flow seasons following mining. These samples will be analyzed for the parameters listed in Table 7-8. Data thus collected will be submitted to DOGM on a quarterly basis.

The post-mining reports will contain not only the laboratory and field data but also an assessment of current impacts from mining on surface-water systems and the amount of recovery of the system since mining. Surface-water monitoring following mining will continue until the termination of the bonding period.

7.31.3 Acid- and Toxic- Forming Materials

As discussed in Section 5.28.30, waste rock is not produced during mining operations. When incidental quantities of rock are encountered, the rock is left in the mine and will not be removed at any time in the future; thus, no negative effects are expected from the acid-forming potential of strata which overlie and underlie the Hiawatha seam. However, to further characterize the acid-forming potential of strata immediately above and below the Hiawatha seam, GENWAL collected additional roof- and floor-rock samples from three locations within the current mine workings (including the state lease and Lease #UTU-68082 areas). These new data also show the materials to be non-acid/non-toxic forming. Analytical results from these three sets of samples are contained in Appendix 6-2.

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The presence of acid- or toxic-forming materials has been determined by laboratory testing (as defined in "Guidelines for Management of Topsoil and Overburden for Underground and Surface Coal Mining"). These data are contained in Appendix 6-2. If waste material is generated it will be tested for acid- or toxic-forming materials on a yearly basis or prior to disposal. If such material is identified, it will be stored in an enclosed area (i.e. dumpster) or within a containment (bermed) area until such time as it can be disposed of.

7.31.4 Transfer of Wells

Before final bond release, exploratory or monitoring wells will be sealed in a safe and environmentally sound manner in accordance with Sections 7.38 and 7.65.

7.31.5 Discharges

The Applicant will not discharge into the underground mine, unless specifically approved by the Division and/or meets the approval of MSHA. Discharges will be limited to the following:

1. Water
2. Coal processing waste
3. Fly ash from a coal-fired facility
4. Sludge from an acid-mine-drainage treatment facility
5. Flue-gas desulfurization sludge
6. Inert materials used for stabilizing underground mines
7. Underground development waste.

7.31.51 Gravity Discharges

The angle at which the coal bed is inclined from the horizontal (dip) prevents any gravity discharge of water from the surface entries.

7.31.6 Stream Buffer Zones

The disturbed area is drained by ephemeral "streams" which are tributaries to Crandall Creek. The undisturbed drainages will enter Crandall Canyon above and below the culvert. Stream buffer zones will be maintained above and below the culvert. Portions of the road lie within 100' of Crandall Creek. The sediment pond outslope is contiguous to Crandall Creek, a perennial stream at the mine facility area.

Crandall Creek water quality is protected from the impacts of the mine by the use of revegetation, silt fences and/or straw bales, and rip-rapped channels. In addition, buffer zone signs have been installed to indicate the area beyond which no disturbance shall take place. For additional information concerning stream buffer zone protection see pages 3-9 and 3-10 of this permit.

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7.31.7 Cross Sections and Maps

Cross sections and maps, as required for R645-301-731.700, are presented within this application.

7.31.8 Water Rights and Replacement

In the event that the monitoring program identifies an impact to the water source in the permit and adjacent areas, the replacement of water rights will be addressed as described in Section 7.27 of this application.

7.3 Sediment Control Measures

The sediment control measures for the Crandall Canyon Mine operations are discussed in Section 7.42 of this application. This includes design, operation and maintenance of applicable siltation structures, sedimentation pond, diversions, and road drainage, as required.

7.33 Impoundments

There are no permanent impoundments associated with GENWAL's operations. Temporary impoundments of water collected for runoff control will occur in the sediment ponds and containment berms. The design of these structures is presented in Section 7.42 and 7.43 of this application.

7.34 Discharge Structures

Discharge from the sediment ponds is conveyed by a 18-inch CMP culvert (principal spillway) and an open channel concrete lined emergency spillway. The outlets of these spillways are protected by riprap. This design complies with R645-301-744.

7.35 Disposal of Excess Spoil

No significant excess spoil has been or will be developed by operating the underground mine. The only anticipated excess material will be from the sediment ponds. This limited volume of material will be removed from the ponds transported to an approved refuse disposal site, disposed of underground or sold with the coal.

7.36 Coal Mine Waste

Any refuse will be disposed of in accordance with the designs presented in Chapter 5 and Section 7.46 of this application.

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7.37 Noncoal Mine Waste

Noncoal mine waste will be stored and final disposal of noncoal waste will comply with R645-301-747.

7.38 Temporary Casing and Sealing of Wells

Each well which has been identified in the approved permit application to be used to monitor ground water conditions will comply with R645-301-748 and be temporarily sealed before use. Drilling and Sealing of such wells will be done according to the procedure described in Chapter 6, Section 6.41.

7.40 Design Criteria and Plans

7.41 General Requirements

The runoff control plans for the Crandall Canyon Mine facilities includes the diversion of the undisturbed runoff from areas contributing to the facilities, the collection of all runoff from disturbed areas associated with the sites and the containment and treatment of this disturbed runoff through the use of sediment ponds, strawbales, silt fence, riprap, mulches and revegetation.

7.42 Sediment Control Measures

7.42.10 General Requirements

Appropriate sediment control measures will be designed, constructed and maintained using the best technology currently available to:

1. Prevent, to the extent possible, additional contributions of sediment to stream flow or to runoff outside the permit area.

2. Meet the effluent limitations under R645-301-751.

3. Minimize erosion to the extent possible.

Sediment control measures include practices carried out within and adjacent to the disturbed area. The sedimentation storage capacity of practices in and downstream from the disturbed areas will reflect the degree to which successful mining and reclamation techniques are applied to reduce erosion and control sediment. Sediment control measures consist of the utilization of proper mining and reclamation methods and sediment control practices, singly or in combination. Sediment control methods include, but are not limited to:

1. Retaining sediment within disturbed areas;

2. Diverting runoff away from disturbed areas;

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3. Diverting runoff using protected channels or pipes through disturbed areas so as not to cause additional erosion;

4. Using straw dikes, riprap, check dams, mulches, vegetative sediment filters, dugout ponds and other measures that reduce overland flow velocities, reduce runoff volumes or trap sediment;

5. Treating with chemicals/paving;

6. For the purposes of UNDERGROUND COAL MINING AND RECLAMATION ACTIVITIES, treating mine drainage in underground sumps.

7.42.20 Siltation Structures

7.42.21 General Requirements

Additional contributions of suspended solids and sediment to stream flow or runoff outside the permit area will be prevented to the extent possible using the best technology currently available.

Alternate Sediment Control Areas and Small Area Exemptions

The Alternate Sediment Control Areas (ASCAs) at the Crandall Canyon Mine are shown on Plates 7-5 and Plate 2-3. Previously 8 areas existed as ASCA's or Small Area Exemptions (SAE's). However, under this proposed culvert expansion 3 of the eight areas will be eliminated from the MRP. They are SAE 1, SAE 3, and ASCA 4. ASCA's 2, 5, 6, 7, and 8 will remain. Three new ASCAs (ASCA 9, 10 and 11) will be added due to the culvert expansion project.

ASCA-2 (consisting of 0.34 acre) exists at the northwest corner of the site. This area was initially constructed as a substation pad and associated access road. Because the substation has not been installed and may not be installed in the future, SAE-2 was reclaimed. Of the total area, 0.15 acre received final reclamation treatment and 0.19 acre received interim reclamation treatment (see Chapter 5, Plate 7-16 and Plate 7-5C). An additional 0.90 acres of undisturbed area drains onto ASCA-2 from above.

ASCA-2 was reclaimed (interim and final) as outlined in Section 525.300. A 12-inch CMP culvert was installed to act as a discharge into UD-1. A silt fence and strawbale dike have been placed to trap the sediment and prevent erosion.

ASCA-5, ASCA-6, ASCA-7 and ASCA-11 consist of the topsoil stockpiles that are located on the north and south side of the access road east of the mine site in the areas indicated on Plate 2-3. Disturbed areas associated with the topsoil stockpiles are 0.20 acres, 0.22 acres, 0.62 acres and 0.65

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acres for ASCA-5, ASCA-6, ASCA-7, and ASCA-11, respectively. All topsoil stockpiles have been protected from erosion by a combination of dikes, silt-fencing, berms, and a vegetative cover. ASCA-11 is the lower-north side topsoil stockpile area which will be used to store soil material from the culvert expansion project.

ASCA-8 consists of the Forest Service parking area west of the mine surface facilities (see Plate 7-16). This parking area was constructed by GENWAL for the Forest Service during the latest surface expansion. Although it is not part of the surface facilities, it is a disturbed area within the permit boundaries.
Sedimentation control will, therefore be provided. The disturbed area associated with ASCA-8 is 0.29 acre.

Sedimentation control for ASCA-8 will be provided by a silt fence installed in accordance with Figure 7-12 between the parking area and Crandall Creek. The silt fence will be periodically inspected and repaired as required to ensure that its integrity is maintained.

ASCA 9 & 10 are the pad slope areas at both ends of the culvert expansion project. The drainage from these areas can not be directed to the sediment pond and are too close to the creek to construct separate sediment ponds. Therefore GENWAL will use alternate sediment control methods such as silt fences, straw bale dikes and vegetative filters. Once vegetation has been successful and lasting GENWAL will submit evidence supporting a request for Small Area Exemption.

ASCA-11 is the new topsoil storage area located at the mouth of Crandall Canyon immediately across the road from the existing topsoil pile, ASCA-7. The topsoil storage area is bounded by the Crandall Canyon road on the southwest, the bluffs of Huntington Creek on the east and a sloping hillside onthe northwest. A silt fence will be constructed below the downstream toe of the stockpile to prevent sediment loss and treat runoff. The topsoil pile will cover an area of approximately 0.65 acres. The pile will be constructed using end-dump trucks and a front-end loader and will be blended into the existing hillside. The pile will be revegetated in accordance with the approved interim reclamation seed mix specified in Chapter 3 under 3.31 Disturbance and Interim Stablization.

7.42.22 Sedimentation Pond

Design

The sedimentation pond located in Crandall Canyon has been redesigned to control the additional storm runoff from the pad extension and from the designated undisturbed drainage areas above the pad extension associated with the proposed culvert expansion. The topography and watershed boundaries are shown on Plate 7-5 and 7-5C. Cross sections of the pond design are shown on Plate 7-3.

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Runoff- and Sediment-Control Facilities

Results of analyses to determine the required size and hydraulics of the sedimentation pond are included in Appendix 7-4. Details of the sedimentation pond required for compliance with 30 CFR 77.216-1 and 30 CFR 77.216-2 are contained in Appendix 7-8. Permanent disposal of the sediment removed during cleanout will be in accordance with Section 535.

Prior to any discharges through the decant system on the sedimentation pond, a sample will be collected to determine total suspended solids, settleable solids, total dissolved solids, oil and grease, total iron, total manganese concentrations, and pH. The sample will be collected by opening the gate valve on the dewatering device, allowing water to flow from the pond through the primary spillway for a sufficient time to collect a sample of the water, and then immediately shutting the gate valve to prevent further dewatering. This sample will then be submitted to a laboratory for analyses of the indicated parameters.

After receipt of analytical results from the laboratory, if the pH and concentrations of total suspended solids, settleable solids, total dissolved solids, oil and grease, total iron, and total manganese are within the acceptable limits, water will be discharged from the pond through the dewatering device. If the parameters of concern are not within the acceptable limits, no water will be discharged through the device.

During discharge of water to Crandall Creek from the sedimentation pond, samples of the water will be collected at the discharge point at the beginning and end of the discharge time. These samples will be sent to a laboratory following the discharge period for analyses of total suspended solids, settleable solids, total dissolved solids, total iron, total manganese, oil and grease, and pH. Analytical results will be submitted to the Division with the subsequent quarterly report.

The emergency spillway discharges onto the boulder-covered slope adjacent to the sedimentation pond. Boulders that cover this slope were blasted from the cut above the pond during construction of the mine-access road. Due to the large size of the boulders, laboratory size-fraction analyses could not be conducted. However, the boulders are visually estimated to range in size up to at least 10 feet in diameter. It is further estimated that approximately 80 percent of the coarse rock on the slope is finer than 8 feet in diameter, 30 percent is finer than 5 feet in diameter, and 10 percent is finer than 3 feet in diameter.

The blasted rock has an approximate thickness of 15 to 20 feet at the top of the slope and 5 to 6 feet at the bottom of the slope. The soil that underlies the rock is a silty sand. Size-fraction

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analyses presented by Delta Geotechnical Consultants (1982) indicate that this soil is 70 percent sand ans 30 percent silt and clay (the latter being minus 200 mesh).

The emergency spillway is lined wuth riprap and a filter blanket to reduce erosion potential. A concrete cutoff has also been installed immediately downstream of the inlet. The concrete cutoff ensures that the emergency spillway will not erode during a discharge event. Grading of the riprap, filter blanket, and embankment materials are shown in Figure 7-10. The spillway will discharge directly onto the boulder-covered slope. Due to the extreme thickness of the boulders snd cobbles on the slope, additional erosion protection below the emergency splillway will not be required.

All new fill required to modify the mebankment will be placed in 6-inch lifts. This new fill will be compacted in place by repeated passes of a front-end loader or equivalent prior to placing the next lift. Compaction will continue until the density of the material is at least 90 percent of Proctor density (as determined by sandcone density tests in the field).

As included in the original design, the interior of the pond will be lined with a 12-inch thick local, compacted clay to reduce seepage from the pond and, thereby increase the stability of the embankment. The clay liner will be placed in 66-inch lifts and compacted during placement by at least four passes of a front-end loader or equivalent. The initial layer will be disk-harrowed into the bottom of the pond to completion.

After pond cleanout, the thickness of the clay liner will be sampled by means of a bucket auger at 8 locations. Three holes will be placed along the ingress/egress route and five additional holes will be randomly selected fro the remaining pond area. If any of the holes penetrates less than 10 inches of clay, additional clay will be compacted into the deficient areas of the pond.

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Flow conditions in Crandall Creek adjacent to the sedimentation pond were examined to determine if flood flows may erode the downstream toe (see Appendix 7-5). As noted, the peak flow from the 100-year, 24-hour precipitation event will encroach 0.6 foot above the toe of the embankment. Thus, a riprap protective layer (with a median rock diameter of 12.5 inches) was placed along the lower 2.0 feet of the embankment as shown in Plate 7-4. Placement of this riprap will serve an incidental purpose of increasing the stability of the dam by placing additional weight on the downstream toe (Figure 7-10).

Following construction of the sedimentation pond as designed herein, all disturbed areas associated with pond construction (with the exception of the interior of the pond) will be revegetated with the temporary seed mixture. This mixture was developed in consultation with Lynn Kunzler of the Division and Walt Nowak of the U.S. Forest Service. This mixture provides rapid growth species, sod-forming species, and species that are compatible with other plants.

Seeding will be done in the late fall, just prior to the first heavy snowfall of the year (Plummer et al., 1968). Seeding will be accomplished by hydroseeder. Mulch will be placed after seeding. The mulch, which consists of two tons of straw or grass hay per acre of disturbed area, will be spread over the area to be planted by hydromulcher.

Following seeding, the revegetated outslopes of the pond will be inspected during normal pond inspections to determine the effectiveness of the seeding. Straw-bale dikes will be added as necessary to control excessive gullying on the dam face. These dikes will be installed as noted by Figure 7-11.

7.42.30 Diversions

Diversion UD-1 was placed along the western edge of the site at the location shown on Plate 7-5A to divert water from a 95-acre undisturbed watershed around the yard area. Analyses and design information associated with this and other diversions associated with the site are contained in Appendix 7-4.

Two additional diversions were designed to convey water from undisturbed areas away from the disturbed site. One (UD-2) was constructed in the northwest portion of the site along the proposed substation pad. The other was constructed in the northeastern portion of the site to convey water away from the portal area. Details of diversion design are presented in Appendix 7-4.

Existing and proposed culverts in the mine yard were examined to determine their adequacy with respect to passing the peak flow. Details of these designs are provided in Appendix 7-4.

Similarly, ditches within the disturbed area are designed to pass the peak flow from the 10-year, 6-hour storm. Typical cross sections and design calculations are contained in Appendix 7-4 for these ditches. Ditches have been evaluated for adequacy in passing the 10 year-24 hour storm and found to be of adequate size (see Appendix 7-4).

A berm was placed around the proposed power substation to prevent runoff water that accumulates thereon from flowing across the remainder of the site. A small channel on the

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substation pad collects water from the pad and adjacent undisturbed areas. A stilling basin was placed at the downstream end of this diversion to trap sediment prior to discharging into UD-1.

Proposed Expansion Area Surface Water Drainage and SedimentControl

Water on the extended mining pad associated with the proposed culvert expansion comes from two sources. The pad itself and two watershed areas located in undisturbed terrain to the south of the proposed pad. Runoff from the pad and watersheds will be collected and controlled by the use of drainage ditches and culverts. All runoff diverted through the drainage ditches and culverts will eventually go into a sediment pond. The watersheds are shown on Plate 7-5 and 7-5A. The location of drainage ditches and culverts can be also be found on plate 7-5.

All diversion ditches have been designed to have a triangular channel with a minimum depth of one foot and side slopes of 1H:1V. During the periods of peak flow at least 3" of the channel depth will be freeboard. The calculations associated with drainage ditch design can be found in Appendix 7-4.

7.42.40 Road Drainage

All of GENWAL's roads have been designed, located and constructed as required by the regulations R645-301-742.410 through R645-301-742-423.5.

7.43 Impoundment

There are no permanent impoundments associated with the GENWAL facilities. Temporary impoundments of water collected for runoff control will occur in the sediment pond. The physical design of the sediment pond are certified designs as required in R645-301-512 and are presented in Section 5.33 and Appendix 7-4 of this application. The sediment pond does not meet the criteria for MSHA regulations. The hydrologic design for the sediment pond is presented in Section 7.42.20 and Appendix 7-4. On cessation and reclamation of mining and disposal activities, the sediment pond will be removed.

7.44 Discharge Structures

The sediment pond is equipped with a decant, a riser pipe (cmp) principle overflow and a rip-rapped open-channel emergency spillway. Sediment pond details are covered under Section 7.42.20 and in Appendix 7-4.

7.45 Disposal of Excess Spoil

No significant excess spoil will be developed by the underground mine. In the event spoil is generated during the mining operations, this will be transported to an approved disposal site. The handling of these materials will comply with R645-301-745.

7.46 Coal Mine Waste

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The disposal and placement of any refuse materials will be conducted in accordance with the plans presented in Chapter 5 of this application.

7.47 Disposal of Noncoal Mine Waste

Garbage

Solid waste generated from mining activities, such as garbage and paper products, is disposed of in large trash "dumpsters" located near the portal. A contract garbage hauling service, empties the contents of the dumpsters on a weekly basis and hauls the garbage to an approved dump or landfill.

Unusable Equipment

All salvageable mining equipment is sold to local scrap dealers: items such as broken bolts, worn out engine parts, and items which might be recycled. Any machinery or large parts are placed in a stockpile near the material storage area for periodic salvage by local scrap dealers. No mining equipment will be merely abandoned.

Petroleum Products

Oil and grease wastes are collected in tanks and returned to distributors for refining or used as heating fuel. In case of spills, a spill control plan has been developed and is located at the mine site.

7.48 Casing and Sealing of Wells

Following completion of reclamation, the monitoring wells for the mine site will be plugged and abandoned in accordance with R645-301-631 and R645-301-748. This will prevent the potential for disturbance to the hydrologic balance.

7.50 Performance Standards

All coal mining and reclamation operations will be conducted to minimize disturbance to the hydrologic balance within the permit and adjacent areas, to prevent material damage to the hydrologic balance outside the permit area and support approved postmining land uses in accordance with the terms and conditions of the approved permit and the performance standards of R645-301 and R645-302. For the purpose of SURFACE COAL MINING AND RECLAMATION ACTIVITIES, operations will be conducted to assure the protection or replacement of water rights in accordance with the terms and conditions of the approved permit and the performance standards of R645-301 and R645-302.

The following sections, 7.51 through 7.55 provide a commitment to meet the requirements of the applicable laws. Specific plans for accomplishing compliance are provided under the applicable, referenced sections of this Mining and Reclamation Plan.

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7.51 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 limitations for coal mining promulgated by the U.S. Environmental Protection Agency set forth in 40 CFR Part 434.

7.52 Sediment Control Measures

Sediment control measures will be located, maintained, constructed and reclaimed according to plans and designs given under R645-301-732, R645-301-742 and R645-301-760. Refer to sections 7.32, 7.42 and 7.60 of this plan.

7.52.10 Siltation Structures

Siltation structures and diversions will be located, maintained, constructed and reclaimed according to plans and designs given under R645-301-732, R645-301-742 and R645-301-763. Refer to sections 7.32, 7.42 and 7.63 in this plan.

7.52.20 Road Drainage

Roads will be located, designed, constructed, reconstructed, used, maintained and reclaimed according to R645-301-732.400, R645-301-742-400, and R645-301-762. Refer to sections 7.32, 7.40 and 7.62 in this plan.

7.52.21 Erosion Control or Prevention

Control or prevent erosion, siltation and the air pollution attendant to erosion by vegetating or otherwise stabilizing all exposed surfaces in accordance with current, prudent engineering practices.

7.52.22 Suspended Solids

Control or prevent additional contributions of suspended solids to steam flow or runoff outside the permit area.

7.52.23 Effluent Standards

Neither cause nor contribute to, directly or indirectly, the violation of effluent standards given under R645-301-751. Refer to section 7.51 in this plan.

7.52.24 Surface and Groundwater Systems

Minimize the diminution to, or degradation of, the quality or quantity of surface and groundwater systems.

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7.52.25 Normal Water Flow

Refrain from significantly altering the normal flow of water in streambeds or drainage channels.

7.53 Impoundments and Discharge Structures

Impoundments and discharge structures will be located, maintained, constructed and reclaimed to comply with R645-301-733, R645-301-734, R645-301-743 and R645-301-745 and R645-301-760. Refer to sections 7.33, 7.34, 7.43, 7.45 and 7.60 in this plan.

7.54 Disposal of Excess Spoil, Coal Mine Waste and Noncoal Mine Waste

Disposal areas for excess spoil, coal mine waste and noncoal mine waste will be located, maintained, constructed and reclaimed to comply with R645-301-735, R645-301-736, R645-301-745, R645-301-746, R645-301-747 and R645-301-760. Refer to sections 7.35, 7.36, 7.45, 7.46 7.47 and 7.60 in this plan.

7.55 Casing and Sealing of Wells

All wells will be managed to comply with R645-301-748 and R645-301-765. Water monitoring wells will be managed on a temporary basis according to R645-301-738. Refer to sections 7.38, 7.48, and 7.65 in this plan.

7.60 Reclamation

Sealing of Mine Openings

The Applicant has drilled from the Hiawatha seam upwards to the Blind Canyon seam as described in Chapter 6. The drilling occurred in areas that pillar extraction will occur and no provisions were made to seal the bore hole.

Temporary sealing of the portals, if needed, will be accomplished by the construction of protective barricades or other covering devices, fenced and posted with signs indicating the hazardous nature of the opening. Permanent closure plans will include sealing the portals as per the request of the U.S.G.S. (See Section 5.29).

Upon cessation of mining operations all drift openings to the surface from underground will be backfilled, regraded and reseed as per Section 5.40 of this plan. Prior to final sealing of any openings, the U.S.G.S. will require an on site inspection and a submission of formal sealing methods for approval. The formal sealing methods will be presented as a plan including cross sections demonstrating the measures taken to seal or manage mine openings will comply with R645-301-529.

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Removal of Surface Structures

All waste material generated from the removal of the structures will be removed from the property and sold as scrap or disposed of in the appropriate approved state land fill. The only structures to remain after the mining operation will be the sedimentation system and all necessary diversions required to insure routing of disturbed area drainage to the pond and diversions to maintain the integrity of the pond until the requirements are met. The diversion ditch is shown on Plate 5-16.

Upon cessation of mining operations, the water supply well (MW-1) will be permanently abandoned in accordance with regulations promulgated by the Utah Division of Water Rights. This will include filling of the well with a neat cement grout in accordance with the regulations.

Disposition of Dams, Ponds and Diversions

Upon final cessation of mining the area will be reclaimed. Upon completion of the reclamation earthwork the sediment pond will be cleaned out and the material disposed of in the approved method. Once it is determined that the pond is no longer required for sediment control of the reclaimed area and Phase I reclamation has been deemed complete, the pond will be cleaned out again. The pond will only be reclaimed after vegetation has been established on the site and Phase I reclamation has been approved. The material in the pond should only be topsoil that has eroded from the reclaimed site, (care will be taken not to mix the pond liner with this topsoil). This topsoil will be stockpiled and allowed to dry at the edge of the pond. Once the topsoil has been dried, the sediment pond will be reclaimed and the topsoil spread on top of the pond area.

Recontouring

All areas affected by surface operations will be graded and restored to approximate original contour that is compatible with natural surroundings and postmining land use. For approximate contours prior to GENWAL's surface disturbance refer to the topography south of the road on Plate 5-20. The final regraded contours can be found on Plate 5-17.

Removal or Reduction of Cut Slopes & Highwalls

Backfilling and grading will proceed so as to eliminate the cutslopes and highwalls. This can be done by recontouring as per Section 5.40 of this Plan. The portals will be backfilled with soil and two rows of solid concrete blocks placed across each entry and then backfilled to the surface and recontoured as shown on Plate 5-17. The cut slope above the coal stockpile will be backfilled with material from the culvert expansion project.

Terracing and Erosion Control

No terracing will be done. All final grading, preparation of overburden before replacement of topsoil will be done along the contour to minimize erosion and instability unless this operation becomes hazardous to equipment operators in which case the grading, preparation and placement in a direction other than generally parallel to the contour will be used.

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Final Reclamation

All areas affected by surface operations will be graded and restored to approximate original contour. All final grading will be done along the contour to minimize erosion and instability unless this operation becomes hazardous to the equipment operators. Backfilling and grading will proceed so as to eliminate the cut slopes and highwalls. Refer to Plates 5-16 and 5-17. Backfilling and grading will be done according to the reclamation timetable as originally submitted.

If possible, the topsoil will be redistributed in the late fall (late September or early October) just prior to the seeding to keep the seedbed free of weeds and annual grasses. Should weeds and annual grasses become established before seeding, they will be removed prior to seeding, refer to Chapters 2 and 3 for additional information.

Typical cross sections and topographic maps which adequately represent the existing land configuration of the area affected by surface operations are shown on Plates 3-7, 3-8 and 3-9 for existing ground as well as Plate 5-20 for premining topography and the geotextile-covered area. Postmining reclamation cross sections and surface topography will be as near to premining as is possible and practical, as noted on Plate 5-17.

A reclamation map showing post construction interim reclamation areas and final reclamation accompanies this document as Plates 7-16 and 5-17. Slope rounding on Plate 5-3 has been revised to meet the required slope of 1.5:1 at the specified reclaimed cross sections. Two distinct areas showing post construction interim reclamation and final reclamation can be found on Plates 7-5.

Reclamation hydrology is discussed in Appendix 7-4.

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CHAPTER 7

FIGURES

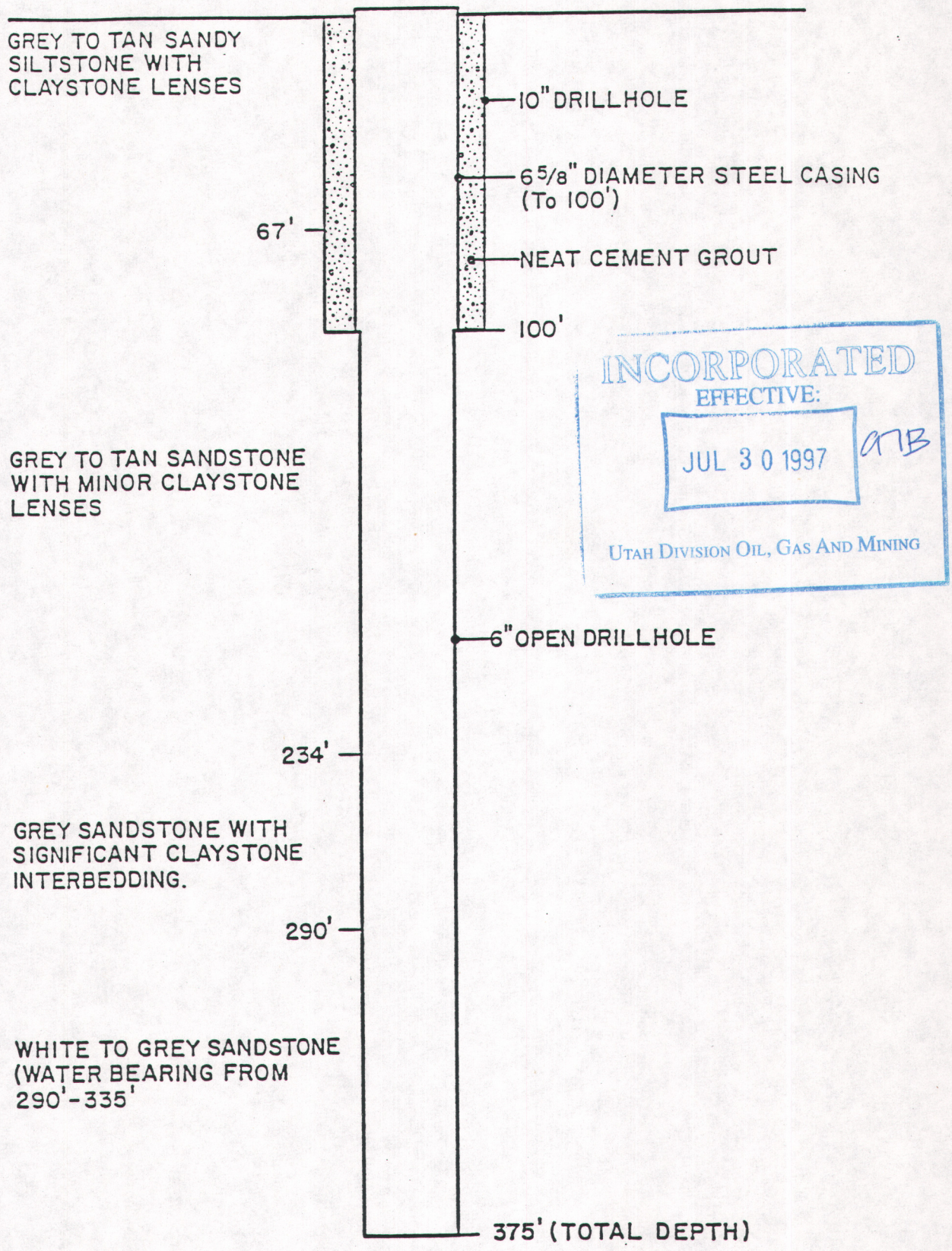

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Figure 7-1. Well completion and lithologic log for MW-1.

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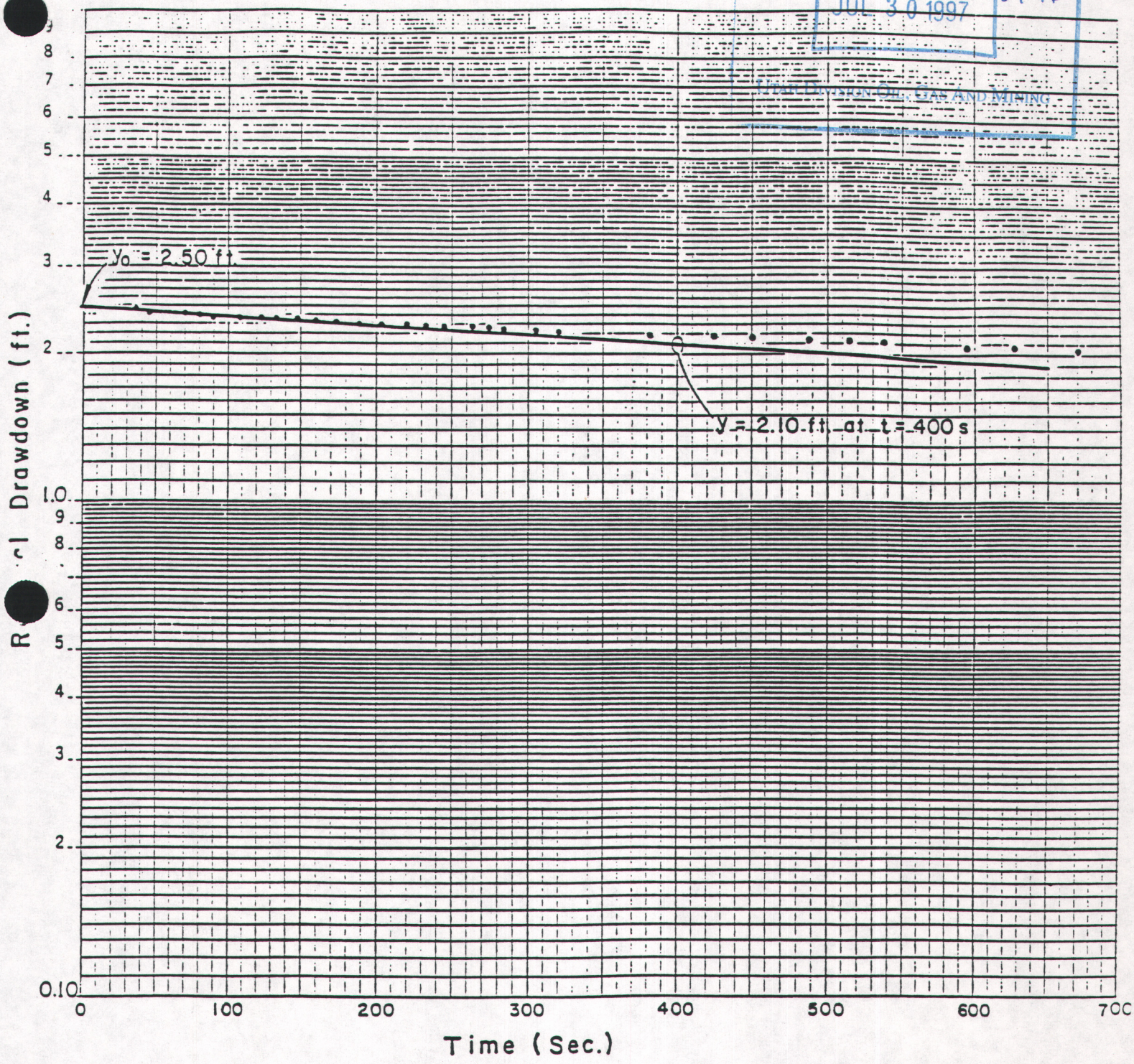

Figure 7-2. Results of slug withdrawal test in MW-1.

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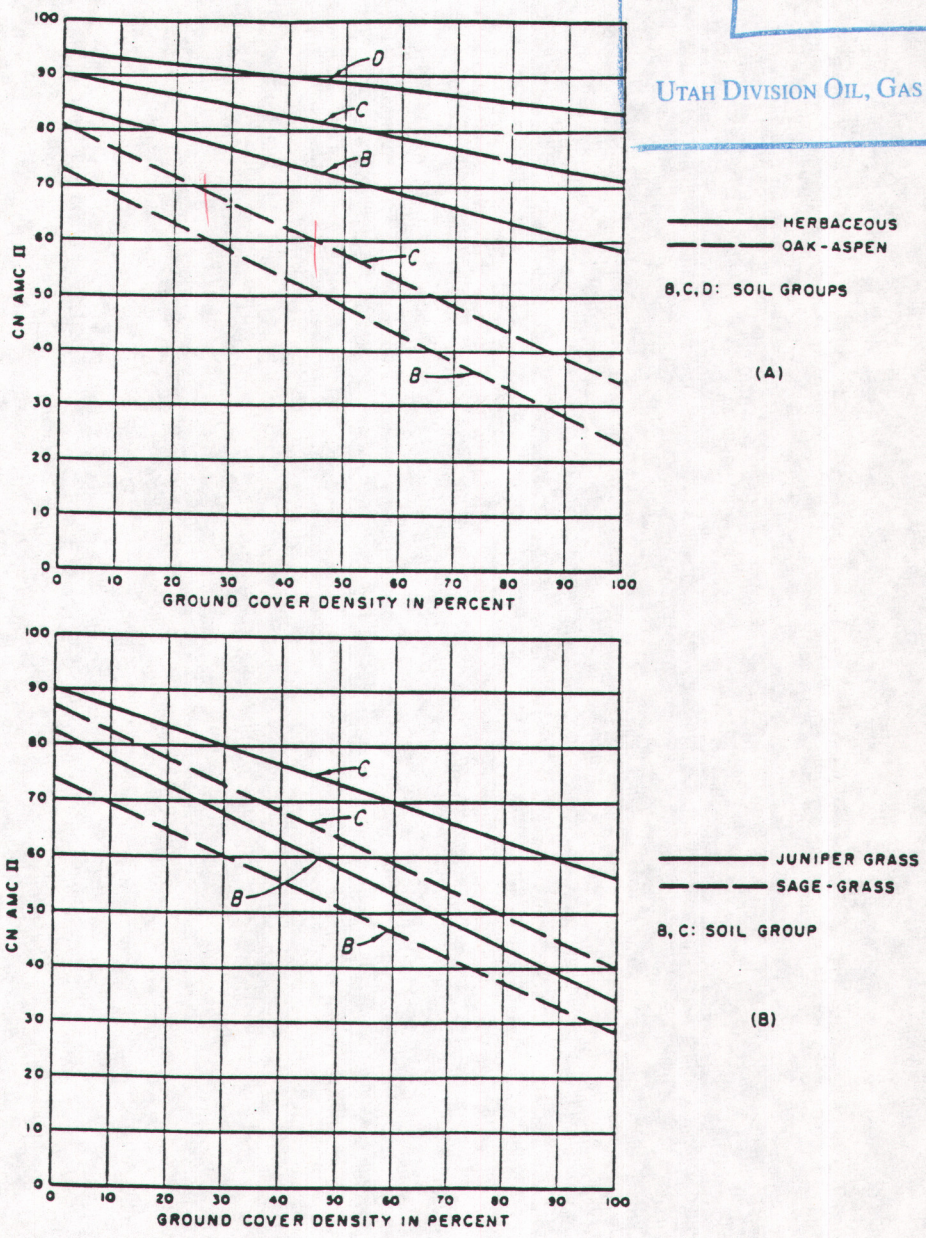

Figure 7-3. Runoff curve numbers for forest-range in the western U.S. (from U.S. Bureau of Reclamation, 1977).

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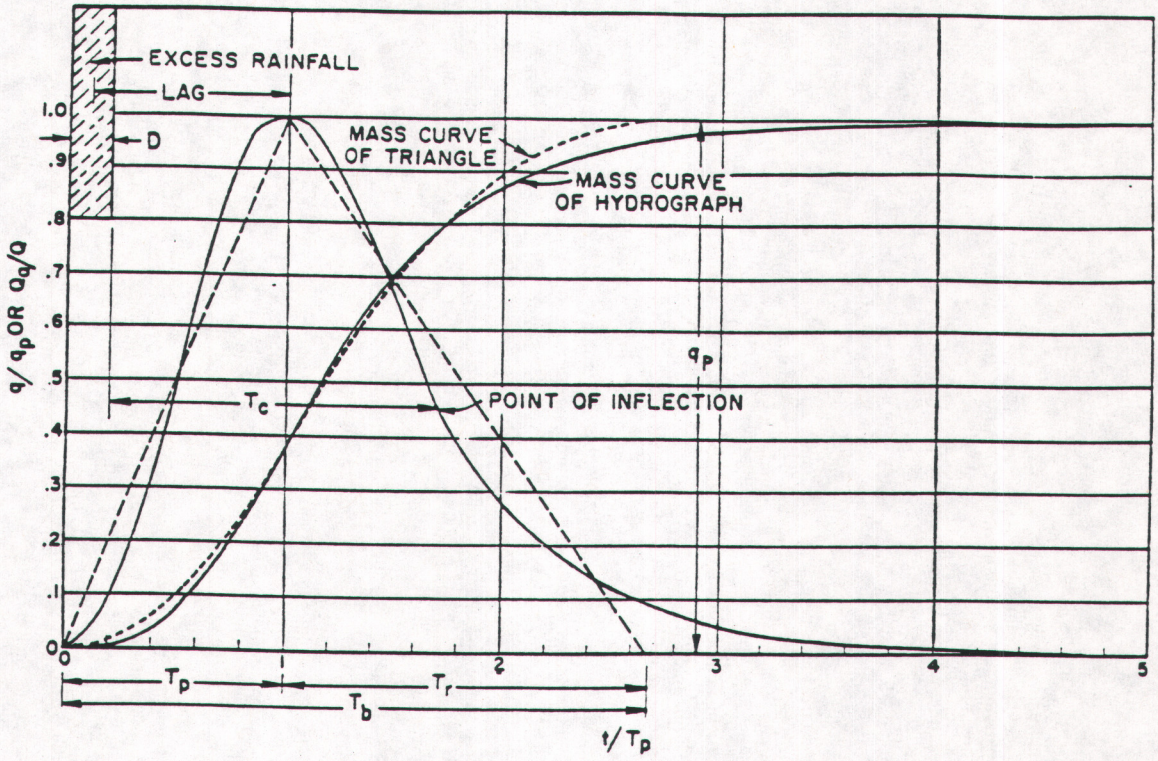

Figure 7-4. Curvilinear and triangular unit hydrographs (from U.S. Soil Conservation Service, 1972).

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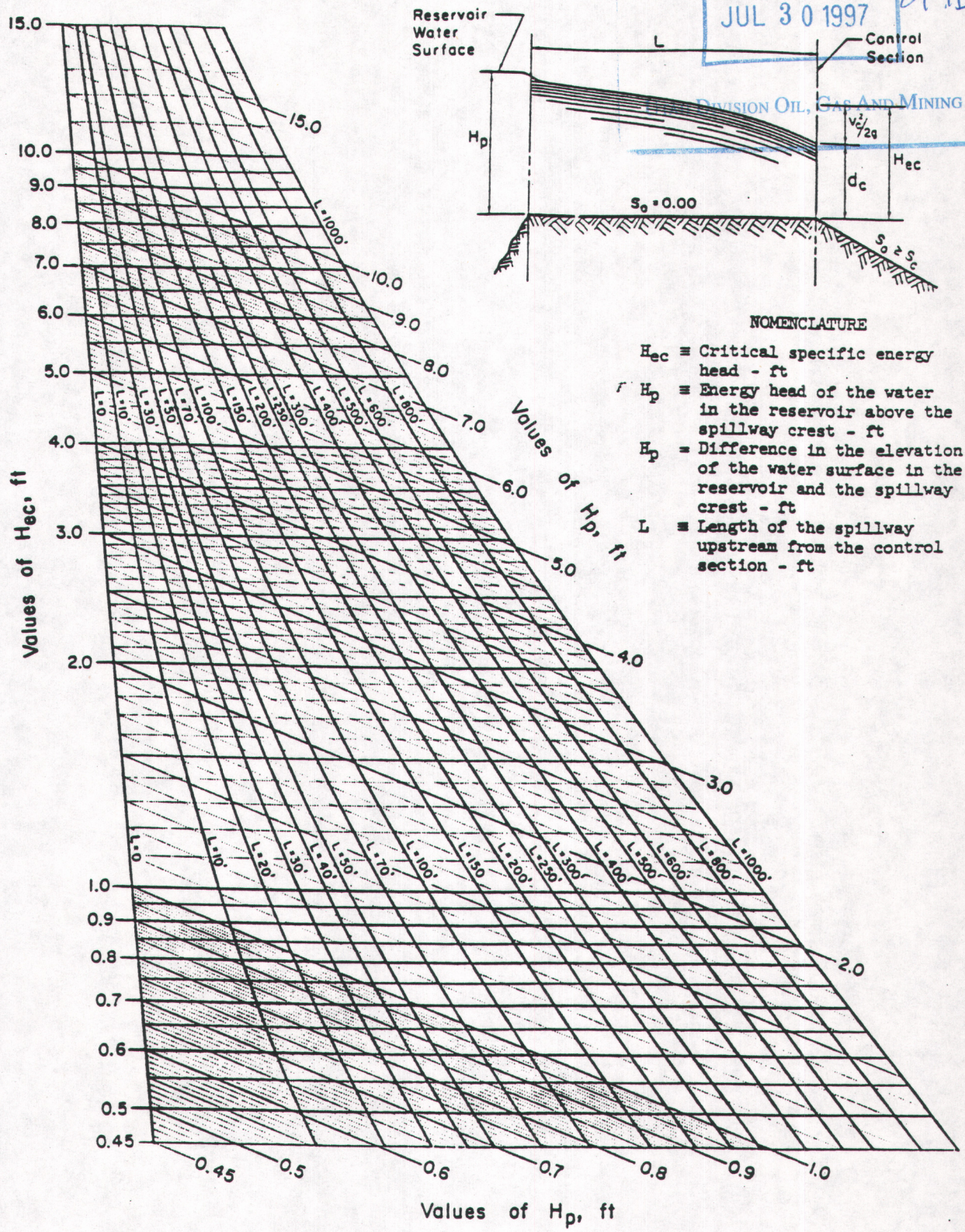

NOMENCLATURE

H_{ec} ≡ Critical specific energy head - ft

H_p ≡ Energy head of the water in the reservoir above the spillway crest - ft

H_p = Difference in the elevation of the water surface in the reservoir and the spillway crest - ft

L ≡ Length of the spillway upstream from the control section - ft

Figure 7-5. Head relationships for selected broad-crest weirs (from U.S. Soil Conservation Service, 1968)

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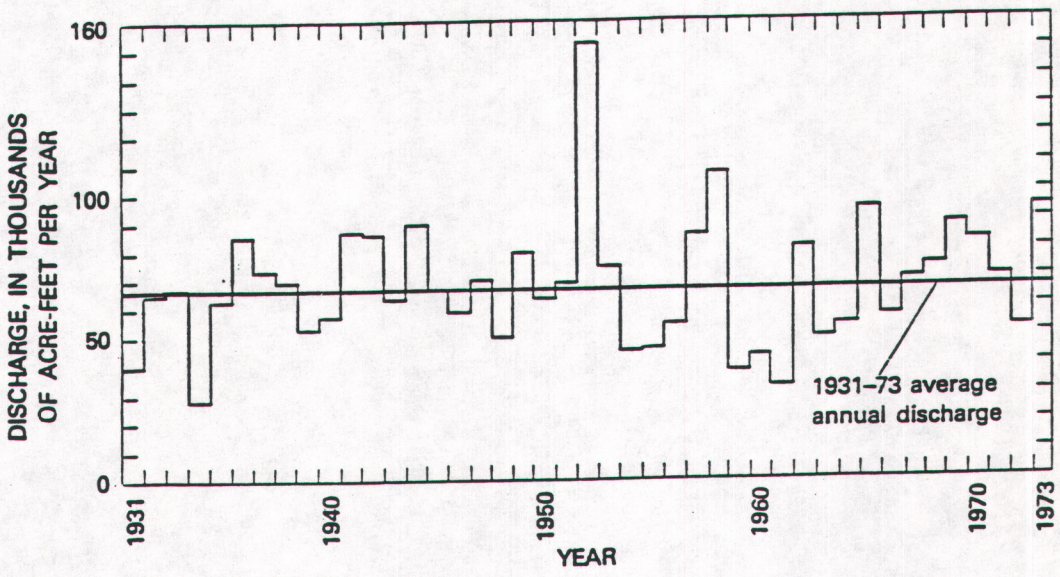

Figure 7-6. Annual discharge of Huntington Creek (from Waddell et al., 1981).

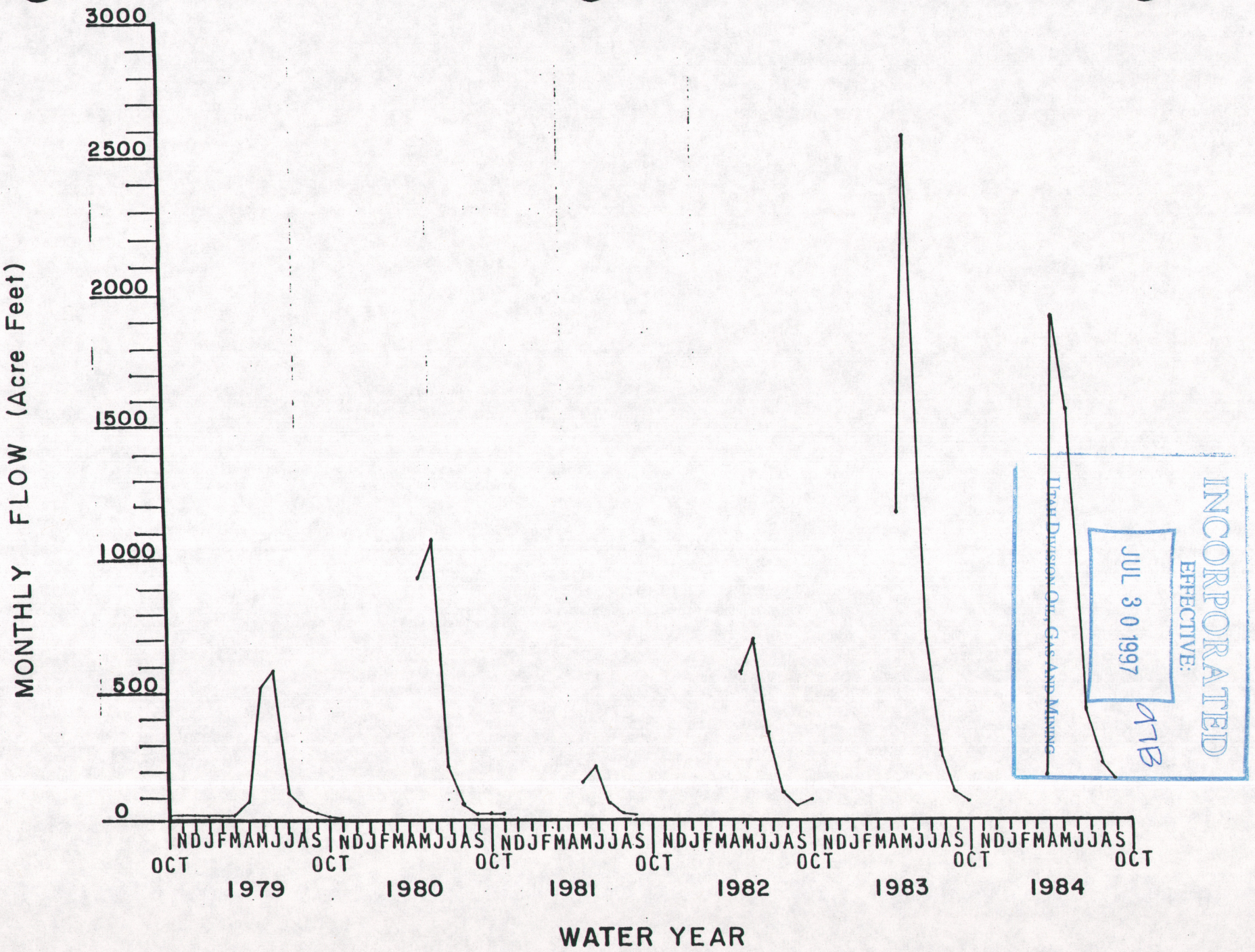

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Figure 7-7. Monthly flow of Crandall Creek near Huntington.

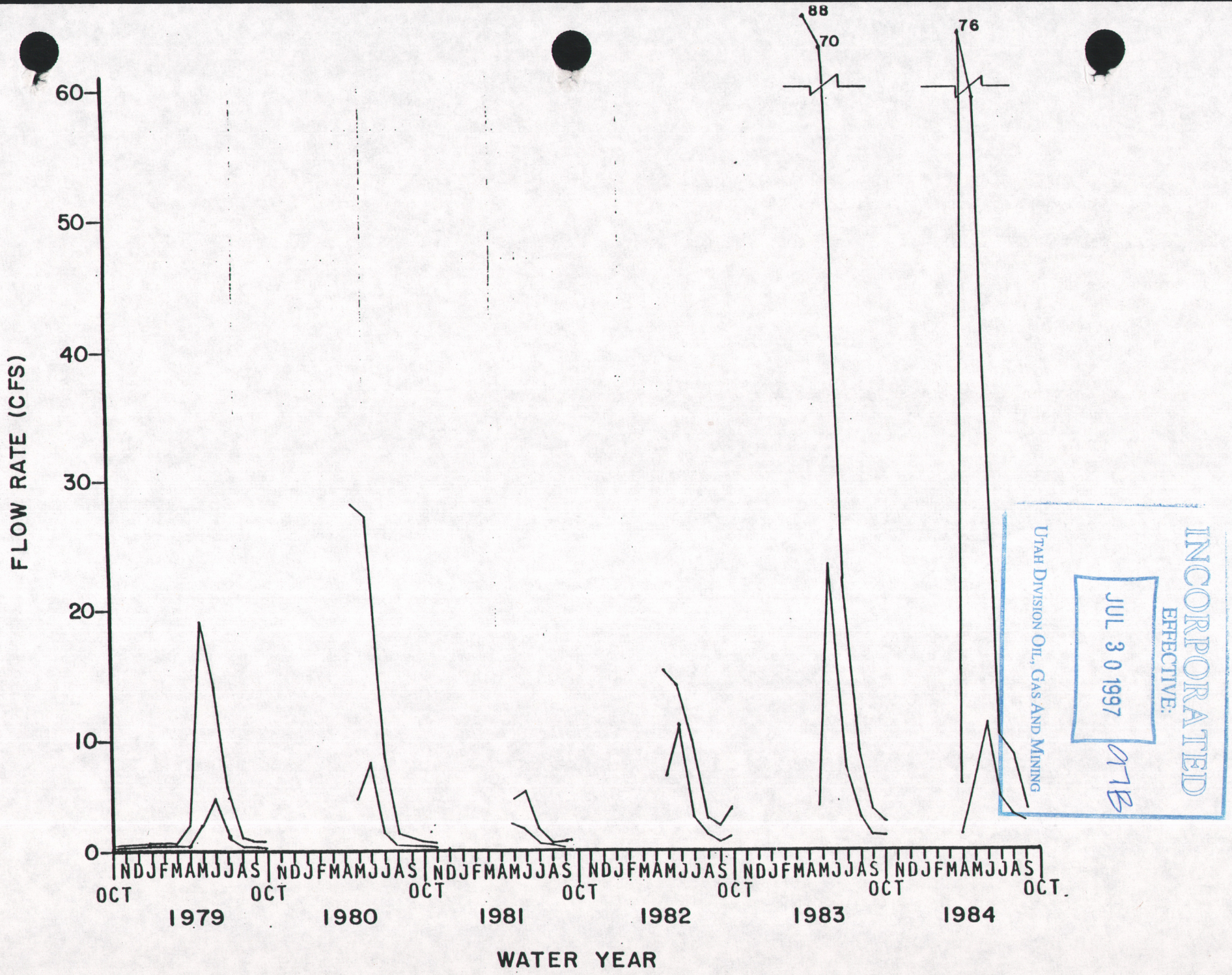

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Figure 7-8. | Maximum and minimum daily flows of Crandall Creek near Huntington.

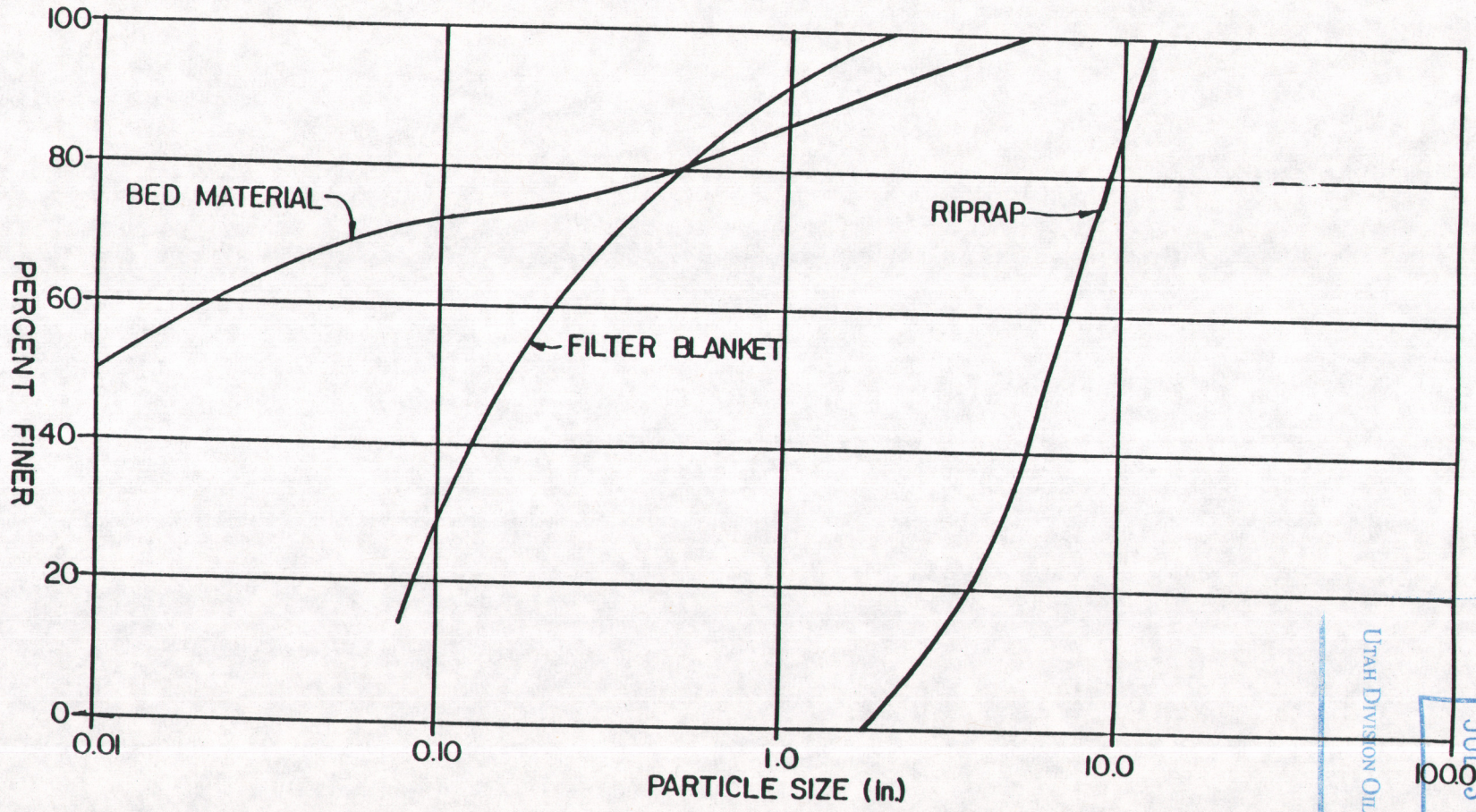

Figure 7-10. Gradation of embankment, filter, and riprap materials.

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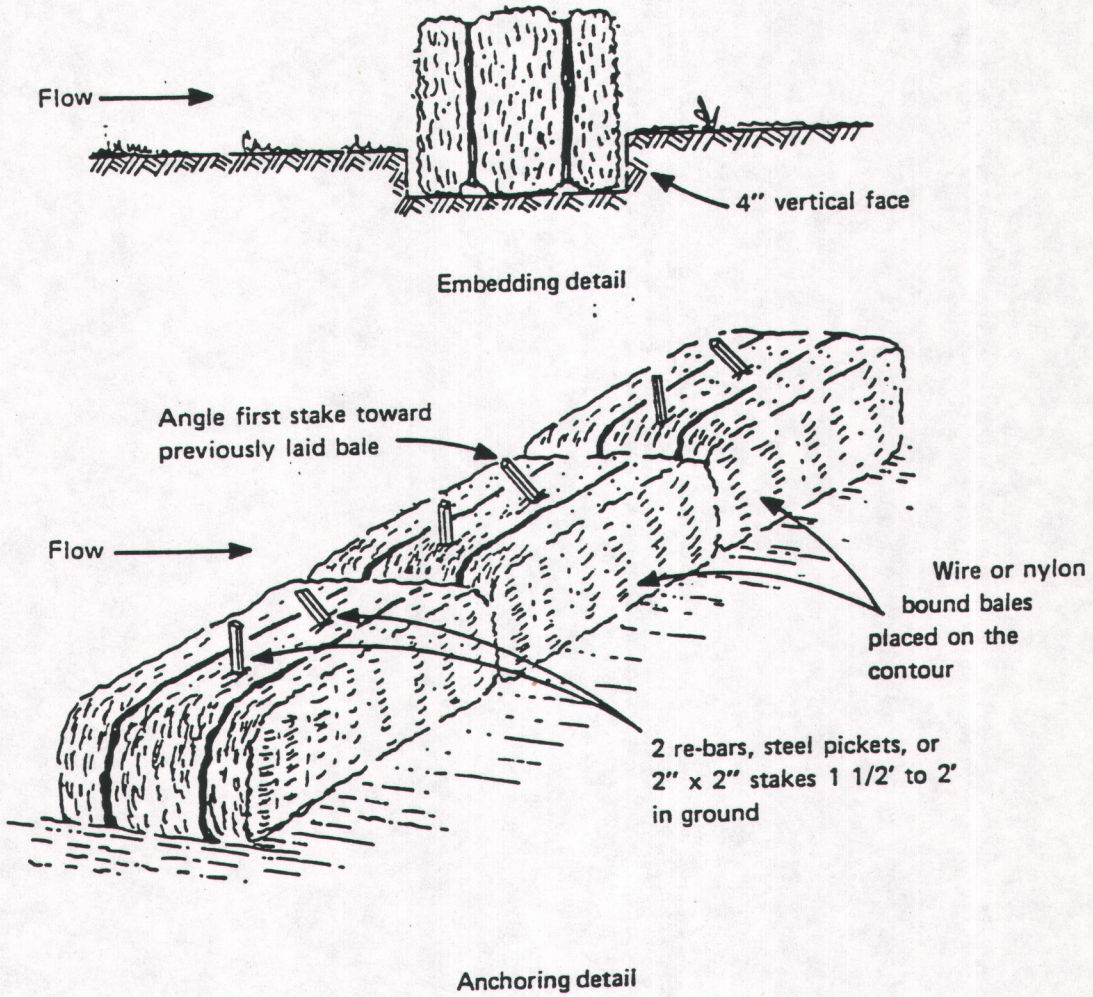

Figure 7-11. Typical straw-bale dike.

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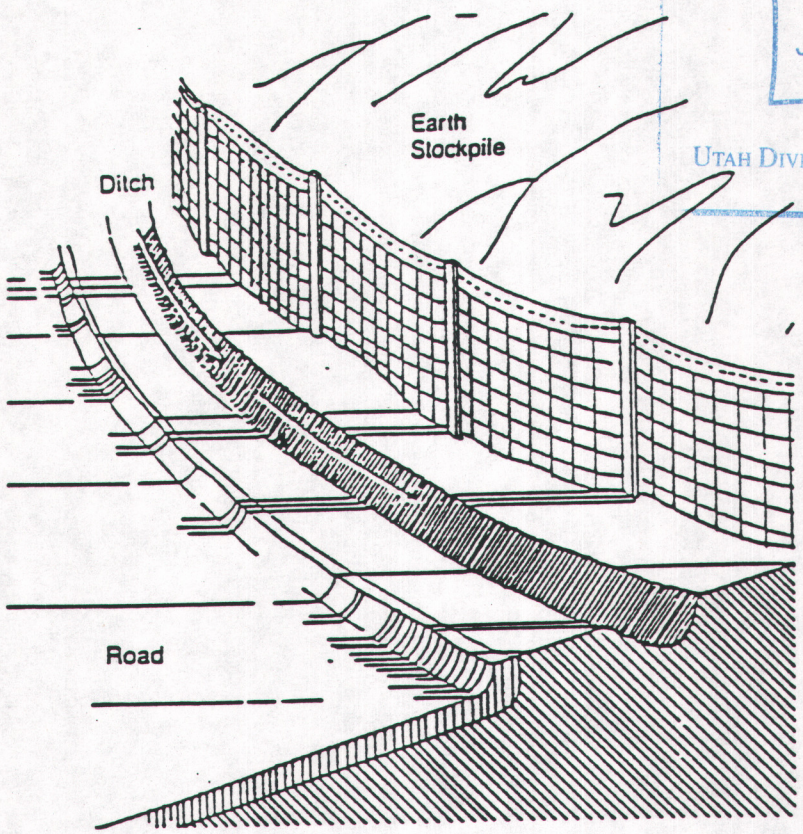

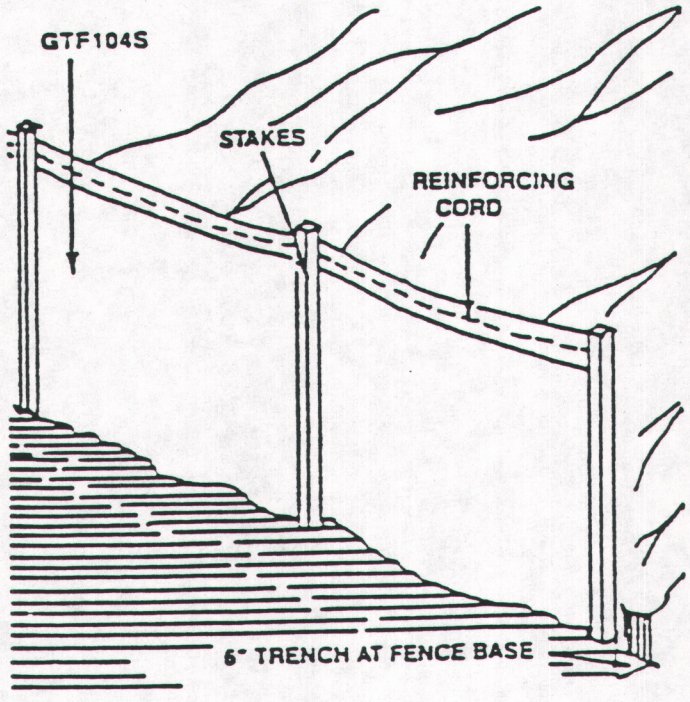

Figure 7-12.. Typical silt fence installation.

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