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CHAPTER 7

HYDROLOGY

R645-301-700

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HYDROLOGY

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CHAPTER 7

R645-301-700. HYDROLOGY

711. GENERAL REQUIREMENTS

711.100 – 711.500 Contents

This chapter provides a description of the hydrology and hydrogeology of the proposed Coal Hollow Mine permit and adjacent area. Specifically, this permit section includes descriptions of existing hydrologic resources according to R645-301-720, proposed operations and potential impacts to the hydrologic balance according to R645-301-730, methods and calculations utilized to achieve compliance with the hydrologic design criteria and plans according to R645-301-740, applicable hydrologic performance standards according to R645-301-750, and reclamation activities according to R645-301-760.

This information is presented in subsequent sections of this chapter and in Appendix 7-1. Appendix 7-1 includes a comprehensive characterization of groundwater and surface-water systems in the proposed Coal Hollow permit and adjacent areas, recommendations for groundwater and surface-water monitoring, and the results of a field investigation regarding the potential for alluvial valley floors in the proposed Coal Hollow Mine permit and adjacent area. It should be noted that Appendix 7-1 may be updated periodically in the future as additional hydrologic and hydrogeologic data become available.

712 CERTIFICATION

All cross sections, maps, and plans have been prepared per R645-301-512. Compliance with this section has been completed and certifications are available on all Drawings. The cross sections and maps that are included in this permit application and are required to be certified have been prepared by or under the direction of a qualified, registered, professional engineer or a professional geologist, with assistance from experts in related fields such as hydrology, geology and landscape architecture.

713 INSPECTION

Impoundments will be inspected as described under R645-301-514.300. Designs for proposed impoundments in the proposed Coal Hollow permit area are shown in Drawings 5-25 through 5-31 and Appendices A5-1 and A5-2. No impoundments or sedimentation

ponds meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) exist or are planned within the proposed Mine Permit Area.

A professional engineer or specialist experienced in the construction of impoundments will inspect impoundments. Inspections will be made regularly during construction, upon completion of construction, and at least yearly until removal of the structure or release of the performance bond. The qualified registered professional engineer will promptly, after each inspection, provide to the Division, a certified report that the impoundment has been constructed and maintained as designed and in accordance with the approved plan and the R645 Rules. The report will include discussion of any appearances of instability, structural weakness or other hazardous conditions, depth and elevation of any impounded waters, existing storage capacity, any existing or required monitoring procedures and instrumentation and any other aspects of the structure affecting stability. A copy of the report will be retained at or near the mine site.

720 ENVIRONMENTAL DESCRIPTION

721 GENERAL REQUIREMENTS

The existing, pre-mining hydrologic resources within the permit and adjacent areas that may be affected by coal mining and reclamation operations are described in Appendix 7-1 and are summarized below.

Groundwater Resources

A spring and seep survey of the proposed Coal Hollow Mine permit and surrounding area has been conducted by Petersen Hydrologic, LLC. The locations of springs and seeps in the proposed permit and adjacent area are shown on Drawing 7-1. Seasonal discharge and field water quality measurements for springs and seeps in the proposed Coal Hollow Mine permit and adjacent area have been submitted electronically to the Utah Division of Oil, Gas and Mining Utah Coal Mining Water Quality Database (UDOGM, 2007). Baseline discharge and water quality data for groundwater resources in the proposed Coal Hollow Mine permit and adjacent area are have also been submitted electronically to the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality Database (UDOGM, 2007). Locations of baseline monitoring stations are shown on Drawing 7-2. Locations of water rights in and adjacent to the proposed Coal Hollow Mine permit area are shown on Drawing 7-3. Water rights data from the proposed Coal Hollow Mine permit and adjacent area are detailed in Appendix 7-3. A plot showing potentiometric levels in alluvial groundwater systems in the proposed Coal Hollow Mine permit and adjacent area is presented in Drawing 7-13.

There are no domestic water supply springs or wells in the proposed permit area. However, wells and springs that provide water for domestic and livestock use are located on and adjacent to the proposed permit area (Drawing 7-2). Some lands east of and

adjacent to the proposed Coal Hollow Mine permit area have historically been irrigated using water from alluvial springs; However, no irrigation of these lands is currently occurring nor has it occurred in at least the past 10 years. Additionally, limited irrigation of lands occurs east of the proposed Coal Hollow permit area using surface waters derived from runoff from the adjacent Paunsaugunt Plateau area. Irrigation of these lands is largely limited to years with appreciable precipitation and stream runoff.

Groundwater discharge occurs from springs and seeps in the upland areas of the Paunsaugunt Plateau east of the permit area (Tilton, 2001; Appendix 6-3). However, these springs discharge from rock strata that are topographically and stratigraphically up-gradient of and considerable distances from the proposed Coal Hollow Mine permit area. Consequently, groundwater systems in these areas will not be impacted by mining activities and these are not considered further here.

Groundwater resources in the Tropic Shale and underlying Dakota Formation in the permit and adjacent area are not appreciable. During drilling activities in the proposed Coal Hollow Mine permit and adjacent area, appreciable groundwater inflows were not encountered in the Tropic Shale. Other than a single seep (SP-37; Drawing 7-1) which discharges at a rate of less than 0.05 gpm from an apparent fracture system in a sandy horizon along the eastern margin of lower Sink Valley, no springs or seeps with measurable discharge have been identified in the Tropic Shale. The lack of appreciable groundwater discharge in the Tropic Shale is a result of the poor water transmitting properties of the marine shale unit. While sandstone units occur stratigraphically higher in the Tropic Shale in the surrounding area, in areas proposed for surface mining, the unit present consists of a fairly uniform sequence of soft shale, silty shale, and claystone with minor siltstone horizons. Competent sandstone strata in the Tropic Shale overlying proposed mining areas was not observed during drilling. The Tropic Shale acts as a barrier impeding downward migration of groundwater in the proposed Coal Hollow Mine permit and adjacent area where it is present. The unit also forms a basal confining layer for alluvial groundwater systems in the proposed permit area.

Groundwater discharge from the Dakota Sandstone in the permit and adjacent area is also meager. The Dakota Formation consists of shaley strata interbedded with lenticular, fine- to medium-grained sandstone and coal. Because of the pervasiveness of interbedded low-permeability horizons in the formation and the vertical and lateral discontinuity of sandstone horizons, the potential for vertical and horizontal movement of groundwater is limited. While no springs discharge from the Dakota Formation in the permit area, a spring with a discharge of about 1 gpm and displaying little seasonal variability in discharge (SP-4; Drawing 7-1) discharges from an apparent fault zone in the Dakota Formation approximately 1.1 miles south of the proposed Coal Hollow permit area. Additionally, two seeps with discharges of less than 0.05 gpm (SP-27 and SP-34; Drawing 7-1) seep from the Dakota Formation in lower Sink Valley more than ½ mile south of the proposed Coal Hollow Mine permit area. The results of slug testing performed on wells screened in the Smirl coal seam indicate relatively low values of hydraulic conductivity for the coal seam (Table 7-8). In much of the proposed mining

area, the coal seam is dry (UDOGM, 2007). Thus, appreciable migration of groundwater through the Smirl coal seam is not anticipated.

No water wells are known to exist in the Tropic Shale or Dakota Formation in the proposed Coal Hollow Mine permit and adjacent area, demonstrating the inability of these formations to transmit useful quantities of water to wells. Groundwaters from the Tropic Shale and Dakota Formation do not contribute measurable baseflow to streams in the proposed permit and adjacent area (at least at the surface in stream channels).

Natural groundwater discharge in the permit and adjacent area occurs primarily from alluvial sediments. Alluvial discharge occurs both as discrete springs and seeps (Drawing 7-1) and also locally as diffuse seepage to the surface. Groundwater discharge areas in the proposed Coal Hollow Mine permit and adjacent area are shown on Drawing 7-4 (see also photograph section). The area of most appreciable alluvial groundwater discharge occurs in central Sink Valley in the northwest quarter of Section 29, T39S, R5W (see Drawing 7-4; groundwater discharge area A). The alluvial groundwater system in this area exists under artesian conditions, resulting from the presence of a considerable thickness of sloping, low permeability clayey sediments overlying coarser, water-bearing alluvial sediments at depth (See cross-section Y – Y' in Drawing 6-9). The artesian alluvial groundwater system in Sink Valley is likely recharged via mountain-front-recharge along the flanks of the Paunsaugunt Plateau to the east and north of the proposed Coal Hollow Mine permit area. This artesian alluvial groundwater system that exists along the eastern margins of Sink Valley is likely continuous from near mountain-front recharge areas southward along the eastern margins of Sink Valley to the lower portion of Sink Valley. Discharge from the alluvial groundwater systems in and adjacent to the proposed Coal Hollow Mine permit area occurs primarily in two areas (Drawing 7-4). In the northwest quarter of Section 29, T39S, R5W, considerable natural discharge from the alluvial groundwater system occurs through springs and seeps (Drawing 7-4; groundwater discharge area A). Minor discharge from several flowing artesian wells also occurs in this area. The artesian alluvial groundwater system in eastern Sink Valley also likely provides recharge to the clayey alluvial sediments in the southwestern portion of the valley in the proposed Coal Hollow Mine permit area. Discharge from the alluvial groundwater system in groundwater discharge area A area results in decreases to the amount of water in storage in the alluvial groundwater system and also decreases in artesian hydraulic pressure in the aquifer.

Appreciable discharge from the alluvial groundwater system also occurs in lower Sink Valley in the northwest quarter of Section 32, T39S, R5W (see Drawing 7-4; groundwater discharge area B). Sink Valley constricts markedly in this area, which forces shallow alluvial groundwaters flowing down the valley to discharge at the land surface as springs, seeps, and diffuse discharge to the surface (i.e., there is a significant decrease in the cross-sectional area of the alluvial sediments). Groundwater discharge in this area occurs from diffuse seepage to the surface and also as discharges to two springs and several small seeps (Drawing 7-1).

Much of the alluvial groundwater in Sink Valley likely ultimately leaves the valley via evapotranspiration. This conclusion is based on the observation that there is very rarely any discharge of surface water (at least at the surface in the channel) in Sink Valley Wash below Sink Valley (See site SW-9; Drawing 7-2; UDOGM, 2007). The clayey, low-permeability sediments present at the surface over most of Sink Valley also impede appreciable infiltration of precipitation and snow melt waters into the deeper subsurface. Hence, groundwater recharge to the lower half of the Sink Valley sediments (including the proposed Coal Hollow Mine permit area) likely occurs primarily via horizontal migration of alluvial groundwaters from up-gradient areas.

Flowing artesian groundwater conditions are also observed in monitoring wells screened near the base of the alluvial sediments in the northwest corner of Section 32 T39S, R5W. It is probable that the artesian alluvial groundwater system in Section 29, T39S, R5W is continuous with that in the northwest corner of Section 32. It should be noted that within the proposed Coal Hollow permit area, artesian conditions were not observed in monitoring wells. While the thickness of the alluvial sediments in the artesian groundwater system east of the proposed Coal Hollow permit area range up to 150 feet thick, the thickness of alluvium overlying areas with mineable coal in the proposed Coal Hollow permit area generally does not exceed about 50 feet and in many locations it is considerably thinner.

Natural discharge of alluvial groundwater in the Robinson Creek drainage area is meager. This condition is largely due to the presence of the elevated ridge of impermeable Tropic Shale bedrock associated with the Sink Valley Fault that dissects and effectively isolates the alluvium east of the fault from that west of the fault (See Drawing 6-1). Because of the low permeability of the Tropic Shale, this condition apparently forces alluvial groundwater east of the Tropic Shale ridge to flow to the south toward Sink Valley that would otherwise report to the Robinson Creek drainage. During high flow conditions in the alluvial groundwater system east of the Tropic Shale ridge, minor amounts of groundwater "overtop" the bedrock ridge and drain via surface flow over the Tropic Shale bedrock, where it either recharges shallow alluvial sediments to the west of the fault or is lost to evapotranspiration. The influence of the Tropic Shale ridge is readily evident in field observations, with marked differences in vegetation and soil moisture being apparent on opposite sides of the ridge. During low-flow conditions, discharge from the overtopping of the bedrock ridge has generally not been observed. Isolated areas of soil wetness and shallow perched alluvial groundwater systems that exist west of the bedrock ridge in the northeast corner of Section 30 and the southeast corner of Section 19, T39S, R5W are likely sourced via this mechanism.

Seepage of alluvial groundwater into the deeply incised lower Robinson Creek stream channel occurs near the contact with the underlying Dakota Formation in the southeast quarter of Section 19, T39S, R5W. This water is likely related to saturated alluvial deposits underlying the Robinson Creek stream channel. The alluvial groundwater emerges near where the saturated alluvial sediments intersect the mostly impermeable Dakota Formation bedrock in the base of the stream channel. It is noteworthy that the location of the emergence of alluvial water in the channel has varied somewhat over time.

The Robinson Creek stream channel above this location is almost always dry (except for in direct response to torrential precipitation events or during the springtime runoff season during wet years. This seepage of alluvial water in the Lower Robinson Creek channel is typically about 5 to 10 gpm or less and is routinely monitored at monitoring station SW-5 (Drawing 7-2).

Information on water quality for groundwaters and surface-waters has been uploaded into the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality Database (UDOGM, 2007) and is summarized and described in Appendix 7-1.

Appreciable spatial variability exists in water quality in groundwaters and surface waters in the proposed Coal Hollow permit and adjacent area. Stiff diagrams depicting solute compositions and overall water quality for groundwaters and surface waters in the proposed Coal Hollow Mine permit and adjacent area are shown on Drawing 7-5. Important water quality characteristics for groundwaters are summarized below.

Groundwater Source	**Chemical type**	**TDS (mg/L)**
Alluvial groundwaters, coarse-grained system east of proposed permit area	Calcium-magnesium-bicarbonate	380 mg/L to 500 mg/L typically, Little seasonal variability
Alluvial groundwaters in south sink valley	Variable, magnesium-bicarbonate sulfate, calcium-magnesium-bicarbonate	450 mg/L to 3,600 typically, Highly variable based on season and climate for shallow systems, less variability in deeper system
Dakota Formation, fault groundwater system south of proposed permit area	Sodium-bicarbonate	500 mg/L to 600 mg/L typically, Little seasonal variability

It is apparent that the overall water quality of alluvial groundwater degrades from the artesian groundwater system east of the proposed Coal Hollow permit area to the non-artesian shallow alluvial groundwater systems located in the more distal portions of Sink Valley. These changes are due to groundwater interaction with soluble minerals in the primarily Tropic Shale-derived sediments that make up the shallow alluvial materials in the proposed permit area.

Surface Water Resources

Surface water resources in the proposed Coal Hollow Mine permit and adjacent area are described in Appendix 7-1 and are summarized below.

Surface waters in the proposed Coal Hollow Mine permit and adjacent area are tributary to Kanab Creek. Surface waters in the northern portion of the proposed permit and adjacent area drain into the Robinson Creek and upper Kanab Creek drainages. Surface waters in the southern portion of the proposed permit and adjacent area drain into the Sink Valley Wash drainage which is tributary to Kanab Creek about 6 miles below the proposed Coal Hollow Mine permit area. Surface water drainages in the permit and surrounding areas are shown on Drawing 7-6. Surface water baseline monitoring stations are shown on Drawing 7-2. Locations of surface-water water rights in and adjacent to the proposed Coal Hollow Mine permit and adjacent area are shown on Drawing 7-3. Water rights data from the proposed Coal Hollow Mine permit and adjacent area are detailed in Appendix 7-3.

Information on water quality for groundwaters and surface-waters has been uploaded into the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality Database (UDOGM, 2007) and is summarized and described in Appendix 7-1.

Surface waters in Kanab Creek are used for stock watering and crop irrigation in the irrigable lands adjacent to Kanab Creek west of the proposed Coal Hollow Mine permit area. Discharge in Kanab Creek measured near the town of Alton (SW-1) is seasonally dependent and largely influenced by upstream water use. Discharge in Kanab Creek monitored at SW-1 typically ranges from 10 cfs or less during the springtime runoff period to 1 cfs or less during the summertime.

Discharge in Lower Robinson Creek drainage is meager. Other than during the springtime runoff event in wet years or during torrential precipitation events, flow has not been observed at monitoring stations SW-4 and SW-101 (Drawing 7-2). Discharge at the lower monitoring site on Lower Robinson Creek (SW-5; Drawing 7-2) is meager. The small discharge occasionally present at SW-5 is derived from the seepage of alluvial groundwater into the Lower Robinson Creek stream channel between monitoring sites SW-101 and SW-5

Tributaries to the Sink Valley Wash drainage in the proposed Coal Hollow Mine permit and adjacent areas include (from north to south) Water Canyon, an unnamed drainage south of Water Canyon in Section 21 T39S, R5W, and Swapp Hollow (Drawing 7-6). Discharge rates in these drainages are highly seasonally dependent (UDOGM, 2007; Appendix 7-1). Discharges in the Water Canyon and Swapp Hollow drainages are intermittent or perennial in nature with discharge peaks occurring during the springtime runoff season and much lower flows occurring during the late summer and fall months. Discharge in the unnamed drainage in Section 21 T39S, R5W is ephemeral.

The water quality and discharge characteristics of surface waters in the proposed Coal Hollow Mine permit and adjacent area are presented in UDOGM (2007) and described in Appendix 7-1. Solute compositions of stream waters are also depicted graphically as Stiff diagrams in Drawing 7-5. The solute compositions of surface waters in the proposed Coal Hollow Mine permit and adjacent area are summarized below.

Source	Chemical type	TDS (mg/L)
Robinson Creek/Dry Fork	Calcium-magnesium-bicarbonate	300 mg/L typical
Lower Robinson Creek	Variable, magnesium-sulfate-bicarbonate	300 – 3,000 mg/L typical, dependent on discharge
Swapp Hollow	Calcium-magnesium-bicarbonate	250-350 mg/L typical
Kanab Creek	Magnesium-calcium-bicarbonate-sulfate during high flow, variable during low-flow, variability likely due largely to interaction with Tropic Shale soils and irrigation return flows	500-1,300 mg/L typical, Variable dependent on season and irrigation use
Sink Valley Wash	Magnesium-calcium-bicarbonate	600 -1,500 mg/L typical, variable dependent on discharge

Considerable seasonal variability in the solute compositions of stream waters in Kanab Creek in the proposed Coal Hollow Mine permit and adjacent area is also evident in Drawing 7-5 and in Appendix 7-1. During low-flow conditions, interactions between stream waters and Tropic Shale or Tropic Shale-derived alluvial sediments likely result in increased TDS concentrations. Return flow from irrigated fields and interactions with soils rich in soluble minerals also likely contribute to increased TDS concentrations in the summertime. During the spring runoff season, high surface-water flows that originate from the adjacent upland areas dominate the flow in the channel. The TDS concentrations of Kanab Creek waters during high-flow conditions are thus lower than during the low-flow season. Much less seasonal variability in solute content in surface water flows from the mountain stream in Swapp Hollow (Drawing 7-5; Appendix 7-1). This condition is likely attributable to the fact that the stream in Swapp Hollow, which originates on geologic formations overlying the Tropic Shale, has considerably less contact with the Tropic Shale than does Kanab Creek. Additionally, there are no known irrigation diversions or returns above the stream monitoring point (SW-8; Drawing 7-2) in Swapp Hollow.

722 CROSS SECTIONS AND MAPS

722.100 A map showing the locations of springs and seeps in the proposed Coal Hollow Mine permit and adjacent area is presented in Drawing 7-1. A map showing potentiometric levels in alluvial groundwater systems in the proposed Coal Hollow and adjacent areas is presented in Drawing 7-13. It is important to note that the alluvial groundwater potentiometric contours depicted in Drawing 7-2 are not representative of a laterally or vertically continuous groundwater system. Within the proposed Coal Hollow Mine permit and adjacent area, appreciable portions of the alluvial sediments are not saturated. Additionally, perched groundwater conditions are present in many locations in the alluvium in the area. In other words, the alluvial groundwater systems in the proposed Coal Hollow Mine permit and adjacent area are not a single, interconnected aquifer. Rather, there exist several areas of saturated alluvium, which may or may not be in good hydraulic communication with adjacent areas. Consequently, it is not possible or meaningful to construct a true potentiometric contour map in the strict sense. Consequently, it is not appropriate to evaluate regional potentiometric trends over large distances or to infer precise groundwater flow directions or hydraulic gradients in the alluvial groundwater system based on Drawing 7-2. The alluvial groundwater system potentiometric map presented in Drawing 7-2 is useful for evaluating approximate local potentiometric conditions general saturation trends.

722.200 Location of surface water bodies

Within the proposed Coal Hollow Mine permit and adjacent area, no significant natural ponds or lakes occur. The locations of springs and streams are shown in Drawing 7-1. Many small earthen impoundments and ponds have been created to store surface-water runoff and spring discharge water for stock watering and irrigation use. The locations of ponds and associated conveyance ditches are shown on Drawing 7-7.

722.300 Baseline monitoring stations

Baseline monitoring stations are shown on Drawing 7- 2. A map showing the locations of monitoring wells in the proposed Coal Hollow permit and adjacent area is presented in Drawing 7-12. Drawings 7-2 and 7-12 also show monitoring stations from which baseline hydrologic data were collected in previous studies. Monitoring station locations, elevations, and other details are presented in Table 7-1.

722.400 Location of water wells

Water well locations are shown in Drawing 7-2 and Drawing 7-12. Well construction details and locations are presented in Table 7-2.

722.500 Contour map(s) of disturbed area(s)

Surface contours representing the existing land surface configuration of the proposed permit area (including potentially disturbed areas) are shown on Drawing 5-1 and the post mining land configuration is shown on 5-35. Cross sections with both these landforms are shown on Drawing 5-36. The premining landform, with exception of the Facilities area and Lower Robinson Creek, are from an aerial flight that was limited to a five foot contour interval. Therefore, contours have been interpolated down to a 2 foot level using the available aerial flight information. This interpolation provides accuracy for the Division to make the necessary determinations. The Facilities area and portions of Lower Robinson Creek are actual survey data to the accuracy of 2 foot contours.

723 SAMPLING AND ANALYSIS

Water quality sampling and analyses have been and will be conducted according to the "Standard Methods for the Examination of Water and Wastewater" or EPA methods listed in 40 CFR Parts 136 and 434. Information regarding laboratory analytical methods utilized in performing water quality analyses at the analytical laboratories has been submitted to the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality Database (UDOGM, 2007).

724 BASELINE INFORMATION

Baseline groundwater, surface-water, geologic, and climatologic data are described in Appendix 7-1 and summarized below.

724.100 Groundwater Information

The location of wells and springs in the proposed Coal Hollow Mine permit and adjacent area are shown on Drawings 7-1 (Spring and seep survey map), 7-2 (Baseline monitoring locations), and 7-12 (Monitoring well location map). Groundwater rights in and around the proposed Coal Hollow Mine permit area are shown on Drawing 7-3 and tabulated in Appendix 7-3.

Seasonal quality and quantity of groundwater and usage is presented in Appendix 7-1 and UDOGM (2007). Baseline discharge and water quality data have been submitted electronically to the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality (UDOGM, 2007).

Baseline monitoring of groundwater resources in and around the proposed Coal Hollow permit area have been carried out by several entities. Previous hydrologic studies of the region have been made in the Alton Coal Field area by Goode (1964, 1966), Sandberg (1979), Cordova (1981), and Plantz (1983). Selected hydrologic data collected in conjunction with these studies have been incorporated into the hydrologic analysis and baseline data included in this permit application.

During the 1980's, extensive monitoring of groundwater resources in the proposed permit and surrounding areas was performed by Utah International, Inc. Utah International Inc.'s groundwater monitoring activities included the construction of numerous groundwater monitoring wells, aquifer testing activities, and the performance of discharge, water level, and field and laboratory water quality monitoring of springs, seeps, and wells. These baseline monitoring activities were performed as part of a proposed coal mine permitting action in the Alton Coal Field. Ultimately, the proposed coal mining action did not proceed. Relevant monitoring information from the Utah International, Inc. baseline monitoring activities have been included as supplemental baseline data included in this permit application.

Commencing in the 2nd quarter of 2005, regular quarterly baseline monitoring of groundwater resources has been commissioned by Alton Coal Development, LLC. Baseline monitoring of springs, seeps, and groundwater wells in and around the proposed Coal Hollow Mine permit area have been routinely performed. Data collected in the baseline monitoring activities have been submitted electronically to the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality Database (UDOGM, 2007).

During December 2006 and January 2007 an extensive drilling and monitoring well construction program was implemented. This hydrogeologic program included the installation of 30 groundwater monitoring wells in and adjacent to the proposed Coal Hollow Mine permit area. The focus of the drilling program was to characterize the stratigraphy and hydrogeologic properties of alluvial groundwater systems in and adjacent to proposed mining areas. Aquifer characterization of the alluvial groundwater system was also performed using pump testing and slug testing techniques. Investigative methods utilized and the results of the analysis of the data are described in Appendix 7-1.

724.200 Surface Water Information

The locations of streams, stock watering ponds, and conveyance ditches in the proposed Coal Hollow Mine permit and adjacent area are shown on Drawing 7-7. Surface-water rights in and adjacent to the proposed Coal Hollow Mine permit area are shown on

Drawing 7-3 and tabulated in Appendix 7-3. Surface-water discharge rates and water quality data have been submitted electronically to the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality Database (UDOGM, 2007). Additional surface-water information is provided in Appendix 7-1.

It is not anticipated currently that discharge from the proposed Coal Hollow Mine will be necessary. Where necessary, alluvial groundwater that may be intercepted by mining will be placed in drains and diverted away from disturbed areas and discharged (i.e., as groundwater dewatering). However, a Utah UPDES discharge permit will be obtained so that if discharge of mine water becomes necessary, it can be discharged in accordance with the UPDES discharge permit. The exact locations of mine water discharge points will be established upon issuance of the UPDES discharge permit. Any mine discharge water will be placed in either the Lower Robinson Creek drainage or the Sink Valley Wash drainage. Both of these drainages are tributary to Kanab Creek.

As described in R645-301-728.320, acid drainage is not expected from the proposed mining operation. This is due to the pervasiveness of carbonate minerals in the mine environment which will neutralize any acid produced.

Seasonal quality and quantity of groundwater and usage is described herein and in Appendix 7-1. Baseline discharge and water quality data have been submitted electronically to the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality (UDOGM, 2007).

Baseline monitoring of surface-water resources in and around the proposed Coal Hollow permit area have been carried out by several entities. Previous hydrologic studies of the have been made in the Alton Coal Field area by Goode (1964, 1966), Sandberg (1979), Cordova (1981), and Plantz (1983). Selected hydrologic data collected in conjunction with these studies have been incorporated into the baseline data as part of this permit application.

During the 1980's, extensive monitoring of surface water resources in the proposed permit and surrounding areas was performed by Utah International, Inc. Utah International Inc.'s groundwater monitoring activities included the operation of continuous recording stations on selected streams, and the performance of routine surface-water discharge measurements and field and laboratory water quality analyses. These baseline monitoring activities were performed as part of a proposed coal mine permitting action in the Alton Coal Field. Ultimately, the proposed coal mining action did not proceed. Relevant monitoring information from the Utah International, Inc. baseline monitoring activities have been included as supplemental baseline data as part of this permit application.

Commencing in the 2nd quarter of 2005, regular quarterly baseline monitoring of surface-water resources has been commissioned by Alton Coal Development, LLC. Baseline monitoring of surface-waters in and around the proposed Coal Hollow permit area,

including surface-water discharge measurements and field and laboratory water quality analyses, have been routinely performed.

All surface waters in the proposed Coal Hollow Mine permit and adjacent area are tributary to the Kanab Creek drainage. Surface-water monitoring stations from which baseline data have been collected are shown on Drawing 7-2 and include the following:

Sink Valley Wash drainage

SW-8 (Swapp Hollow above proposed mining areas), SW-7 (unnamed drainage in Section 21, T39S, R5W), RID-1 (irrigation diversion of water from Water Canyon drainage above proposed mining areas), SW-6 (headwaters of unnamed tributary to lower Sink Valley Wash), and SW-9 (Sink Valley Wash below proposed mining areas).

Lower Robinson Creek drainage

SW-4 (Robinson Creek above proposed mining areas), SW-101 (Lower Robinson Creek near proposed mining areas), and SW-5 (Lower Robinson Creek below proposed mining areas).

Kanab Creek drainage

SW-1 (Kanab Creek near Alton, Utah; above proposed mining areas), SW-3 (Kanab Creek above proposed mining areas), and SW-2 (Kanab Creek below Lower Robinson Creek and below proposed mining areas)..

724.300 Geologic Information

Geologic information in sufficient detail to determine the probable hydrologic consequences of mining and determine whether reclamation as required by R645 can be accomplished is given in Chapter 6 of this permit application package and in Appendix 7-1.

724.400 Climatological Information

Climatological information, including temperature and precipitation data, have been routinely measured and recorded at the Alton, Utah weather station (420086) since 1928. The station is located in the town of Alton, approximately two miles north of the proposed Coal Hollow Mine permit area. Climatological data collected at the Alton station for the 77 year period from 1928 to 2005 are summarized in Table 7-3. Climatological data from the proposed Coal Hollow Mine permit and adjacent area are plotted in Drawing 7-8.

An automated weather station was installed in the proposed Coal Hollow Mine permit area in December 2005. The station is configured to continuously monitor and record temperature, wind velocity, and wind direction data. The station is also configured to continuously measure and record precipitation, although the tipping rain-gauge is not operative during winter months. Climate data from the proposed Coal Hollow Mine and adjacent area are also presented in Appendix 7-6.

724.411 Seasonal precipitation

Precipitation data from the Alton, Utah weather station indicates average annual precipitation of 16.38 inches per year. Doelling (1972) reports average annual precipitation in the Alton Coal Field area ranging from 9 to 20 inches annually with slightly higher increments likely in the higher parts of the plateau (Doelling, 1972). There are generally two annual wet periods in the region. During the wintertime, cyclonic storms bring precipitation (mainly snowfall) to the region. During the summertime, storms originating from convection of air from the Gulf of Mexico or the Pacific Ocean bring rains to the region. Of the two annual wet cycles, the summer rainfall is most reliable. Average monthly precipitation at the Alton station ranges from a low of 0.57 inches in June to a maximum of 1.80 inches in February. Daily temperature and precipitation data recorded at the Coal Hollow Project weather station during 2006 and early 2007 are presented in Appendix 7-6.

The Palmer Hydrologic Drought Index (PHDI; NCDC, 1997) indicates long-term climatic trends for the region. The PHDI is a monthly value generated by the National Climatic Data Center (NCDC) that indicates the severity of a wet or dry spell. The PHDI is computed from climatic and hydrologic parameters such as temperature, precipitation, evapotranspiration, soil water recharge, soil water loss, and runoff. Because the PHDI takes into account parameters that affect the balance between moisture supply and moisture demand, the index is a useful for evaluating the long-term relationship between climate and groundwater recharge and discharge. A plot of the PHDI for Utah Region 4 (which includes the proposed Coal Hollow Mine permit and surrounding area) is shown in Drawing 7-9. It is apparent in Drawing 7-9 that the region has experienced cyclical periods of drought and wetness since 1980. Baseline hydrologic monitoring performed by Utah International, Inc in 1987 and 1988 occurred during a period of near normal wetness. Recent baseline hydrologic monitoring conducted in 2005 and 2006 occurred during a period of moderate to severe wetness, with 2005 being wetter than 2006.

724.412 Wind direction and velocity

Wind data have been collected at the Coal Hollow Project weather station since December 2005. Monthly wind data from the Coal Hollow Project weather station are available from January 2006 through March 2006, and from November 2006 through May 2007. Monthly wind data are plotted as wind rose diagrams, which depict the average direction and velocity of prevailing winds, in Appendix 7-1. Based on recent data from the Coal Hollow Project weather station, it is apparent that the predominant wind direction in the proposed Coal Hollow Mine permit area (during the months for which data are available) are from the northeast, with secondary peaks from the north and south-southwest (Appendix 7-1). Surface winds recorded at the Coal Hollow Project weather station averaged about 6.4 miles per hour. Tabulated hourly wind data from the

Coal Hollow Project weather station are maintained on file at Alton Coal Development, LLC.

Wind data have also been collected historically at nearby locations by governmental and other entities. The regionally predominant direction of winds in the region is southwest through west. Secondary peaks are from southeast and northwest. Surface winds in the area average approximately 8 miles per hour. Higher wind speeds are associated with fronts and storms and generally occur during the springtime.

724.413 Seasonal temperature ranges

Temperature data from the region are summarized in Table 7-3. Temperatures in the permit area vary greatly. Temperature data from the Alton station (1928-2005) indicate that monthly average low temperatures are below freezing for the 6-month period from November to April. Monthly average minimum temperatures range from a low of 15.1 °F during January to a high of 49.8 °F in July. Monthly average maximum temperatures range from a low of 39.5 °F in January to a high of 82.6 °F in July. Daily maximum and minimum temperature data collected at the Coal Hollow Project weather station during 2006 and the first quarter of 2007 are presented in Appendix 7-6 and plotted in Drawing 7-8. The maximum temperature recorded during this period was 93.3 °F in July 2006. The minimum temperature recorded during this period was -7.3 °F in January 2007.

724.500 Supplemental Information

Other than the possible short-term diminution in discharge rates from alluvial groundwater systems, including the potential short-term diminution of discharge rates from some springs and seeps in Sink Valley, adverse impacts to the hydrologic balance, either on or off the permit area are not expected to occur. It is not anticipated that acid- and toxic-forming materials will cause significant contamination of groundwater or surface-water supplies. Any discharges of mine waters to surface-water systems will be regulated under and meet the criteria of a UPDES discharge permit. The mining and reclamation plan has been designed to minimize the potential for disturbance or disruption of the hydrologic balance and to protect groundwater and surface-water resources in the area.

If substantial alluvial groundwater inflows into mining areas occur as mining progresses in close proximity to alluvial springs and seeps in the eastern ¼ of Section 30, T39S, R5W and the northwest ¼ of Section 29, T39S, R5W or in close proximity to coarse-grained alluvial sediments in the artesian groundwater system along the eastern side of Sink Valley, Alton Coal Development, LLC will evaluate hydrogeologic conditions at the time such may occur. It should be noted that very large discharges into mine workings are not anticipated based on the results of recent drilling and aquifer testing performed in these areas (see Appendix 7-1). Based on the hydrogeologic conditions encountered, where necessary Alton Coal Development, LLC will use a suitable technique to minimize

groundwater inflow rates into the mine, which may include the use of bentonite or natural clay filled cutoff walls or other means where appropriate to protect groundwater resources up-gradient of mining activities. The potential for success of such protective measures in minimizing drainage of alluvial deposits up-gradient of proposed mining areas is believed to be good, given that the thickness of the alluvium in these areas is generally on the order of about 20 to 50 feet and these sediments are directly underlain by essentially impermeable Tropic Shale in proposed mining areas. It is important to note that while temporary impacts to groundwater discharge rates from alluvial springs and seeps could possibly occur, these impacts will likely be short-lived. This conclusion is based on the fact that individual mine pits in most instances will remain open for no more than about 60 to 120 days. After mine pits are backfilled and reclaimed, the potential for appreciable continued drainage of up-gradient alluvial groundwater through the backfilled pits in that area is low. When mining is complete in an area, seasonal recharge to alluvial groundwater systems will gradually replenish groundwater to the alluvial groundwater system. Large-scale dewatering of the alluvial groundwater system, such that appreciable compaction of the aquifer skeleton could occur, is not anticipated (see Appendix 7-1).

If diminution of discharge rates from seeps and springs does occur as a consequence of mining and reclamation activities, any lost water will be replaced according to all applicable Utah State laws and regulations using the water replacement source specified in R645-301-727. The quantity and quality of replacement water detailed in R645-301-727 will be suitable for the existing premining uses and approved postmining land uses.

It should be noted that the proposed Coal Hollow Mine plan calls for the permanent diversion of a reach of the Lower Robinson Creek stream channel approximately 2,000 feet in length in the southeast ¼ of Section 19, T39S, R5W. Details of the proposed diversion are given in Chapter 5, Section 527.220 of this MRP. If this action results in diminution of groundwater or surface-water resources, where required a suitable mitigation for this potential impact will be designed and implemented in consultation with the Division of Oil, Gas and Mining.

If excess groundwater were to be encountered during mining operations such that it could not be adequately managed or discharged in compliance with the Utah UPDES discharge permit (which is considered unlikely), Alton Coal Development, LLC may when necessary and with the approval of the Utah Division of Oil, Gas and Mining construct supplemental containment and settlement ponds in which mine discharge waters may be held for treatment (where necessary) and subsequent discharge through UPDES discharge points in compliance with the UPDES discharge permit.

724.600 Renewable Resource Lands

Not applicable

724.700 Alluvial Valley Floor Determination

A field investigation has been performed in the proposed Coal Hollow Mine permit and adjacent area to provide to the Division the information required to make an evaluation regarding the existence of a probable alluvial valley floor in the proposed Coal Hollow Mine permit and adjacent area. The results of this field investigation and related information is provided in Appendix 7-1.

A report detailing the findings of a previous field investigation performed by Water Engineering & Technology, Inc., entitled "Geomorphological and sedimentological characteristics of Sink Valley, Kane County, Utah" is included as Appendix 7-4.

725 BASELINE CUMULATIVE IMPACT AREA INFORMATION

Appendix 7-1 contains the results of a comprehensive investigation of groundwater and surface-water systems in the proposed Coal Hollow Mine permit and adjacent area. Appendix 7-1 also includes information regarding the probable hydrologic consequences of coal mining in the proposed Coal Hollow Mine permit area and recommendations for hydrologic monitoring. Appendix 7-1 also includes the results of a field investigation performed in the proposed Coal Hollow Mine permit and adjacent area to provide to the Division of Oil, Gas and Mining the information required to make an evaluation regarding the existence of a probable alluvial valley floor in the proposed Coal Hollow Mine permit and adjacent area. This Information together with the information submitted herein can be used to assess the probable cumulative hydrologic impacts of coal mining and reclamation operations in the proposed Coal Hollow Mine permit and adjacent area as required by R645-301-729.

R645-301-726 Modeling

No numerical models have been created for the permit area nor are any planned.

727 ALTERNATIVE WATER SOURCE INFORMATION

This section provides information on the alternative water source that will be used to replace water from groundwaters or surface waters should they be impacted by mining and reclamation activities in the proposed Coal Hollow Mine permit and adjacent area. The alternative water source is a water production well located in Section 29, T39S, R5W. The well is identified as Y-61 in baseline monitoring information. The location of Y-61 is shown on Drawings 7-2 and 7-12. The well is located on private land about ½ mile east of the adjacent boundary of the proposed Coal Hollow Mine permit area. The well was drilled in November 1980 and is 150 feet in total depth. The well is screened in the Sink Valley artesian alluvial groundwater system in strata comprised chiefly of gravels and coarse sands. The well is cased with solid steel casing from the surface to a

depth of 112 feet and screened with 6.625-inch well screen from 112 to 142 feet depth, with a borehole diameter of 8.625 feet.

Water quality data from the proposed alternative water source (Y-61) have been submitted electronically to the Utah Division of Oil, Gas and Mining Utah Coal Mining Water Quality Database (UDOGM, 2007). The hydrogeologic characteristics of the alluvial groundwater system in which Y-61 is screened are described in Appendix 7-1. It is anticipated that the quantity and quality of water produced from Y-61 will be suitable for the existing premining uses and approved postmining land uses.

It should be noted that the proposed water replacement source, water well Y-61, produces water from the coarse-grained alluvial groundwater system in Sink Valley. Nearby springs that could potentially be impacted by mining and reclamation activities are supported by the same alluvial groundwater system. However, while modest decreases in the artesian hydraulic pressures in the alluvial groundwater system could potentially result in diminution of spring flows, water well Y-61 is 150 feet deep and will be equipped with an electric well pump giving it the capacity to produce groundwater from the alluvial system even if the hydraulic head in the area were to be diminished such that artesian flow conditions temporarily ceased to exist.

Alton Coal Development, LLC has entered into an agreement with the town of Alton, Utah to transfer the point of diversion for water rights totaling 50 acre-feet per year to the water well Y-61 for use as an alternative water source for the proposed Coal Hollow Mine. Alton Coal Development, LLC has also entered into a verbal agreement with the property owner to allow access and use of the well with a written agreement pending.

728 PROBABLE HYDROLOGIC CONSEQUENCES (PHC) DETERMINATION

This section describes the probable hydrologic consequences of surface coal mining in the proposed Coal Hollow Mine permit area. This determination is based on data presented herein and on information provided in Appendix 7-1. This mining and reclamation plan has been designed to minimize potential adverse impacts to the hydrologic balance. It should be noted that this PHC and also Appendix 7-1 may be updated periodically as required as additional hydrogeologic information and mining data become available in the future.

728.310 Potential adverse impacts to the hydrologic balance

Other than the possible short-term diminution in discharge rates from alluvial groundwater systems, including the potential short-term diminution of discharge rates from some springs and seeps in Sink Valley, appreciable adverse impacts to the hydrologic balance, either on or off the permit area are not expected to occur. The basis for this determination is discussed below.

As discussed in Section 721 above, minimal groundwater resources exist in the Tropic Shale, which directly overlies the coal reserves in proposed mining areas. Groundwater in the Tropic Shale does not provide measurable baseflow discharge to streams in the area. The lack of appreciable groundwater flow in the Tropic Shale is a result of the poor water transmitting properties of the marine shale unit. Consequently, it is anticipated that little groundwater will be encountered in the Tropic Shale in mining areas. Thus, the potential for adverse impacts to the hydrologic balance resulting from mining through the Tropic Shale in the proposed Coal Hollow Mine permit area is minimal.

Similarly, as described in Section 722 above, groundwater resources in the Dakota Formation underlying the coal seam to be mined are not appreciable. This condition is fundamentally a result of the heterogeneity of the rock strata in the Dakota Formation which impedes the ability of the formation to transmit groundwaters significant distances vertically or horizontally. The presence of the essentially impermeable Tropic Shale on top of the Dakota Formation also minimizes the potential for vertical recharge to the Dakota Formation. Mining operations will remove the overlying Tropic Shale rock strata from the Dakota Formation in addition to the Smirl coal seam deposit at the top of the Dakota Formation in mined areas. However, because the pre-mining hydraulic communication between the Tropic Shale and the underlying Dakota Formation in planned mining areas is believed to be minimal, the removal of the Tropic Shale overburden and Smirl coal seam from the Dakota Formation, followed by the rapid backfilling of pit areas with low-permeability fill materials should not result in adverse impacts to the hydrologic balance in the Dakota Formation (i.e., the post-mining degree

of hydraulic communication between the Dakota Formation and the overlying low-permeability backfill material will be similar to that of the pre-mined condition).

It should be noted that the first water-bearing strata underlying the coal seam to be mined in the proposed Coal Hollow Mine permit area from which appreciable quantities of groundwater can be produced is the Navajo Sandstone. The Navajo Sandstone aquifer is of regional significance in that it provides groundwater of good quality to domestic, agricultural, and municipal wells regionally and provides baseflow to springs and streams. The Navajo Sandstone does not crop out in the proposed Coal Hollow Mine permit and adjacent area. The formation is effectively isolated from proposed mining areas by more than 1,000 feet of rock strata of the Dakota and Carmel Formations (which includes large thicknesses of low-permeability shales and siltstones). The Navajo Sandstone aquifer will not be impacted by proposed mining operations. It should be noted that some previously proposed mining operations in the Alton Coal Field have proposed drilling and pumping of large amounts of groundwater from high-capacity production wells in the Navajo Sandstone aquifer for operational use. No such wells are planned in the proposed Coal Hollow Mine permit and adjacent area.

Of primary importance to the hydrologic balance in the proposed Coal Hollow Mine permit and adjacent area are alluvial groundwater systems. As discussed in Section 722 and in Appendix 7-1, alluvial groundwater systems in the area support springs, seeps, diffuse groundwater discharge, and a limited number of wells. The bulk of the alluvial groundwater flux through the area occurs in alluvial sediments that include coarse-grained and finer-grained sediments near the eastern margins of Sink Valley, east of the proposed Coal Hollow Mine permit area. Lesser quantities of alluvial groundwater migrate through finer-grained alluvial sediments (predominantly clays, silts, and sands) in the western portions of Sink Valley and in the Lower Robinson Creek drainage within the proposed Coal Hollow Mine permit area. Discharges from alluvial groundwater systems in Sink Valley do not contribute measurable quantities of baseflow to streams (at least at the surface in the stream channel). Alluvial groundwater systems in the Lower Robinson Creek area are much less extensive than the alluvial groundwater systems in Sink Valley. Other than the re-emergence of alluvial groundwater flowing beneath the Lower Robinson Creek stream channel where the stream channel exists directly on bedrock substrate, discharge from the alluvial groundwater system as springs or seeps in Lower Robinson Creek is generally not observed. Perched groundwater conditions exist locally in the alluvial groundwater system in the Lower Robinson Creek drainage.

In the general sense, surface coal mining activities in the proposed Coal Hollow Mine permit area have the potential to impact groundwater systems primarily through three mechanisms:

1) Where water-bearing strata in proposed mining areas are mined through, groundwater systems within these strata will obviously be directly intercepted,
2) Where groundwater flow paths through mine openings are interrupted, groundwater flow in down-gradient areas could be diminished, and

3) Where mine openings intercept permeable strata, groundwater resources in up-gradient areas could potentially be diminished if appreciable quantities of groundwater were to be drained from up-gradient areas.

The potential for the occurrence of each of these potential impacts are described in the following.

Direct Interception of Groundwater Resources

As discussed above, groundwater resources in the relatively impermeable Tropic Shale in the proposed permit area are meager. Consequently, it is improbable that direct interception of appreciable groundwater in the Tropic Shale will occur. Additionally, because Tropic Shale groundwater systems generally do not support discharges to springs or provide baseflow to streams, the potential interception of limited quantities of groundwater in the Tropic Shale will not adversely impact the hydrologic balance. Similarly, groundwater resources in the Dakota Formation (including within the Smirl coal seam) are meager. While the Smirl coal seam will be extracted through mining operations, the underlying strata of the Dakota Formation will not be disturbed. Consequently, adverse impacts to groundwater systems in the Dakota Formation through direct interception of groundwater resources are not anticipated.

Alluvial groundwater systems in planned mining areas in the proposed Coal Hollow Mine permit area will be directly intercepted by the mine openings. It is not anticipated that the direct interception of shallow alluvial groundwater will adversely impact the overall hydrologic balance in the region. This is because no springs, seeps or other important groundwater resources have been identified in proposed mine pit areas (Drawing 7-1). In the pre-mining condition, any diffuse groundwater discharge to the ground surface that occurs is primarily lost to evapotranspiration and does not contribute appreciably to the overall hydrologic balance in the area.

Diminution of down-gradient groundwater resources

Where groundwater flow paths that convey groundwater to down-gradient areas exist in areas that will be mined, there is the potential that diminution of down-gradient groundwater resources could occur. In the proposed Coal Hollow Mine permit area, it is considered unlikely that appreciable diminution of down-gradient resources will occur as a result of mining and reclamation activities. The basis of this conclusion is presented below.

Groundwater resources in the Tropic Shale are meager and groundwater flow rates are very slow through the marine shale unit. Groundwater systems in the Tropic Shale do not support appreciable spring or seep discharge nor do they provide measurable baseflow to streams down-gradient of mining areas. Consequently, the potential for adverse impacts

to the hydrologic balance as a result of mining through Tropic Shale is considered minimal.

Similarly, groundwater resources in the Dakota Formation are meager. The potential for lateral and vertical migration of groundwater through the formation is limited by the pervasiveness of low-permeability shaley strata in the formation and the lateral discontinuity of permeable strata. Groundwater systems in the Dakota Formation do not support appreciable spring or seep discharge nor do they provide measurable baseflow to streams down-gradient of mining areas. Additionally, with the exception of the relatively low-permeability Smirl coal seam located at the top of the formation, groundwater systems in Dakota Formation rock strata below the coal seam will not be disturbed by mining and reclamation activities. Consequently, the potential for adverse impacts to the hydrologic balance as a result of mining through Dakota Formation strata is considered minimal. It should be noted that spring SP-4 discharges at about 1 gpm approximately 1.1 miles south of the proposed Coal Hollow Mine permit area from an apparent fault/fracture system in the Dakota Formation that may be related to the Sink Valley Fault. It is unlikely that appreciable migration of groundwater through the Sink Valley Fault system in the relatively impermeable Tropic Shale or shallow alluvium in the proposed Coal Hollow Mine permit area occurs. Consequently, it is considered unlikely that mining and reclamation activities in the proposed Coal Hollow Mine permit area will cause a diminution of discharge from spring SP-4.

Alluvial groundwater systems in proposed mining areas area supported primarily by clays, silts, and fine-grained sands. In proposed mining areas in Sink Valley, appreciable coarse grained alluvial sediments were not encountered in drill holes or back-hoe excavations. Significant layers of clean coarse alluvium, which could rapidly convey significant amounts of groundwater were likewise not observed. The results of slug testing performed on wells in and adjacent to proposed mining areas likewise suggest that the potential for rapid migration of groundwaters through alluvial sediments in proposed mining areas is low (Tables 7-8 and 7-9). These data and observations suggest that the flux of groundwater migrating through the alluvial sediments in proposed mining areas in Sink Valley (that could support down-gradient groundwater systems) is not large. Much of the groundwater migrating through the alluvial sediments in proposed mining areas (in the East ¼ of Section 30, T39S, R5W) likely leaves the groundwater system through diffuse discharge to the land surface and is lost evapotranspiration and does not contribute to the overall hydrologic balance in the area. In Sink Valley, a preferential pathway for alluvial groundwaters through deep coarse-grained alluvial sediments likely exists along the east side of Sink Valley. While the thickness of the alluvium in proposed mining areas in Sink Valley generally does not exceed 50 feet (and in many locations is much less), the alluvial sediments along the eastern side of Sink Valley adjacent to proposed mining areas range from about 120 to 140 feet. Of the total flux of groundwater through the alluvial groundwater systems in Sink Valley, most of the flux is likely through this coarse-grained portion of the system. The percentage of the total flux that migrates through clayey and silty alluvial sediments in proposed mining areas along the western flanks of Sink Valley is likely much less.

It should be noted that highly permeable strata were encountered from about 60 to 75 feet depth just above the bedrock interface at the SS well cluster (monitoring well SS-75; Table 7-2). This well is screened in an area of burned or eroded coal (the coal is absent) and consequently, mining will not occur at this location. The coal seam is present at the nearby C9 cluster area. Were mining operations to intercept this highly permeable zone, substantial groundwater inflows into the mine openings could occur. Consequently, prior to surface mining in this area, the boundary between the competent coal seam and the area of burned or eroded coal will be more precisely defined by drilling or other suitable techniques such that mine openings can be designed to avoid these areas of potentially large groundwater inflows.

As discussed in Section 722 above, alluvial groundwater from Sink Valley discharges to several springs and seeps and as diffuse discharge to the ground surface in the northwest ¼ of Section 32, T39S, R5W (see Drawing 7-4; groundwater discharge area B). This groundwater discharge is likely a result of the constriction in Sink Valley in this area and the corresponding decrease in the cross-sectional area of the alluvial sediments in the valley, which forces groundwater to discharge at the surface. Most of the groundwater discharge in this area is likely derived from the up-gradient alluvial groundwater systems in the eastern portion of the valley (i.e., the coarse-grained portion of the alluvial groundwater system), which is situated east of the proposed Coal Hollow Mine permit area. This conclusion is based on 1) the substantially larger cross-sectional area of the alluvium in the deeper eastern portion of the valley relative to that in proposed mining areas near the western margins of the valley, 2) the higher hydraulic conductivity of the sediments in the coarse-grained part of the alluvial system, and 3) the lack of other apparent discharge mechanisms for the coarse-grained system further downstream in Sink Valley Wash (i.e., there are no significant alluvial springs or seeps further downstream in Sink Valley Wash and the system apparently does not contribute measurable baseflow to Sink Valley Wash further downstream (at least at the surface in the stream channel, as evidenced by the lack of baseflow in the wash monitored at SW-9).

Because most of the alluvial groundwater discharge supporting springs and seeps in this area is likely not derived from groundwater systems that underlie planned mining areas in the proposed Coal Hollow Mine permit area, it is considered unlikely that discharges from the springs and seeps in northwest ¼ of Section 32 T39S, R5W will be appreciably diminished as a result of the proposed mining and reclamation activities. While considered unlikely, some temporary impacts to discharge rates from springs and seeps in this area are possible. In particular, it should be noted that mining in the southernmost portions of the proposed Coal Hollow Mine permit area has a somewhat greater potential to decrease groundwater discharge rates at spring SP-6, which is located about 600 feet below the southernmost proposed mining areas (Drawing 7-2). SP-6 is an alluvial seep which has been impounded with an earthen dam from which measurable discharge is generally not present.

It is critical to note that individual mine pits in this area will remain open for short lengths of time, generally no more than about 60 to 120 days. Mining operations in the vicinity near the alluvial groundwater discharge area in the northwest ¼ of Section 32

T39S, R5W are planned to be completed in about 1 year. Thus, any potential impacts to discharge rates from down-gradient groundwater systems will be short-lived. Following the backfilling and reclamation of mine openings, the potential for interception or re-routing of alluvial groundwater away from the groundwater discharge area in northwest ¼ of Section 32 T39S, R5W will be negligible. As stated above, most of the flux through the Sink Valley alluvial groundwater system that supports springs and seeps in the area occurs in the eastern portion of the valley, which will not be impacted by mining and reclamation activities. Consequently, long-term impacts to discharge rates from springs and seeps in this area are not anticipated. It should also be noted that if increased quantities of groundwater were to be encountered in mine workings in lower Sink Valley such that the water would need to be discharged to surface drainages, the mine water will ultimately be discharged to the Sink Valley Wash drainage (i.e., the water will remain in its drainage basin).

Alluvial groundwater systems in the Lower Robinson Creek area are much less extensive than the alluvial groundwater system in Sink Valley. Perched groundwater conditions exist locally in the alluvial groundwater system in the Lower Robinson Creek drainage. Other than the re-emergence of alluvial groundwater flowing beneath the Lower Robinson Creek stream channel where the stream channel exists directly on bedrock substrate, discharges from the alluvial groundwater system as springs or seeps in Lower Robinson Creek are not observed. Consequently, mining operations in the Lower Robinson Creek drainage will likely not result in diminution of down-gradient groundwater resources.

It should be noted that the proposed Coal Hollow Mine plan calls for the permanent diversion of a reach of the Lower Robinson Creek stream channel approximately 2,000 feet in length in the southeast ¼ of Section 19, T39S, R5W. Details of the proposed diversion are given in Chapter 5, Section 527.220 of this MRP. If this action results in diminution of groundwater or surface-water resources, where required a suitable mitigation for this potential impact will be designed and implemented in consultation with the Division of Oil, Gas and Mining.

If any Utah State appropriated water rights are impacted by mining and reclamation operations in the proposed Coal Hollow Mine, these will be replaced according to all applicable Utah State laws and regulations using the designated water replacement source described in Section 727 above.

Draining of up-gradient groundwater resources

Where surface mining occurs adjacent to up-gradient groundwater systems, there is a potential that draining of groundwater from the up-gradient groundwater system into the mine voids could occur. This condition could occur if a sufficiently large and permeable stratum were to be intercepted that is in good hydraulic communication with the up-gradient groundwater system through which appreciable quantities of water could be transmitted.

To more fully evaluate the potential for draining of up-gradient groundwater resources, a field investigation was performed during the winter of 2006-2007 that was designed to facilitate the characterization of the alluvial groundwater system in the proposed Coal Hollow Mine permit and adjacent area. Specifically, this program was designed 1) to better define the vertical and lateral extent of permeable, coarse-grained sediments in the alluvial groundwater system, 2) to characterize the water bearing and water transmitting properties of alluvial sediments, and 3) to evaluate the degree of hydraulic communication between the coarse-grained portion of the alluvial system in Sink Valley and the clayey alluvial sediments in proposed mining areas.

This field investigation included 1) the drilling and installation of 30 monitoring wells, 2) the performance of a 28-hour pumping and recovery test on alluvial production well Y-61 with contemporaneous measuring of water levels in the monitoring well network and contemporaneous measuring of spring discharge rates at three alluvial springs, and 3) the slug testing of 20 monitoring wells to determine approximate values of hydraulic conductivity. The results of the field investigation including analysis of the data collected in the investigation are presented in Appendix 7-1 and are summarized below.

Other than occasional pebbles or small rocks, coarse-grained sediments (i.e., gravels and coarse sands) were not encountered in the drilling of wells along the eastern margins of proposed mining areas in Sink Valley (C1, C2, C3, and C4 well clusters). Rather, the sediments encountered in the drilling of these wells were dominated by clays and silts with subordinate amounts of fine-grained sand. Similarly, coarse-grained deposits were not encountered in well clusters C6, C7, C8, and C9. There was no indication during drilling of any appreciable thickness of highly permeable strata through which groundwater could rapidly be transmitted (although it should be noted that the presence of thin sand layers are difficult to identify in wet auger drilling returns). Similarly, appreciable amounts of high-permeability coarse-grained alluvial sediments were not noted in alluvial sediments investigated in backhoe excavated pits and erosional escarpments in Sink Valley.

The hydraulic heads measured in alluvial monitoring wells near proposed mining areas in Sink Valley (C2, C3, C4, C7, C8, and C9) did not indicate artesian pressures. Rather, marked upward or downward vertical hydraulic gradients were not observed in any of these areas and water levels were consistently within several feet of the ground surface.

The results of pump-testing in the alluvial groundwater system demonstrate that the springs in the northwest ¼ of Section 29, T39S, R5W are in direct hydraulic communication with the coarse-grained alluvial groundwater system in which the pumping well Y-61 is screened. Discharge rates (or water levels at Sorensen Spring) measured at each of the four springs (SP-8, SP-14, SP-20, and Sorensen spring) monitored during the 28-hour pumping test responded to pumping at the well. Monitoring wells at clusters C2, C3, and C4 near the easternmost proposed mining areas also showed small, muted responses, with declines measured in water levels during the 28-hour test ranging from about 0.05 to 0.10 feet. Other monitoring wells in proposed

mining areas did not respond measurably to pumping at Y-61. It should be noted that after the pumping well was turned off at the end of the 28-hour pumping test, spring discharge rates and water levels in alluvial monitoring wells recovered to approximate pre-testing levels.

The results of slug testing of wells in the proposed Coal Hollow Mine and adjacent area are presented in Table 7-8. Using these hydraulic conductivity values together with measured thicknesses of saturated alluvial sediments determined during drilling, and hydraulic gradient values determined from water levels measured in monitoring wells, rates of estimated groundwater inflows to mine openings have been calculated using Darcy's Law (Table 7-9).

Darcy's Law may be expressed as.

$$Q = KIA$$

Where	Q	=	groundwater discharge rate
	K	=	hydraulic conductivity
	I	=	hydraulic gradient
	A	=	cross-sectional area

The values listed in Table 7-9 are reported as inflow rates per 100 lineal feet of mine openings oriented perpendicular to the groundwater flow direction. Calculations at individual locations are adjusted for the thickness of the saturated alluvium at that location. For all calculations in Table 7-9, a gradient of 0.10 has been used, which is considered a conservative estimate for the alluvial groundwater system in the vicinity of the planned Coal Hollow Mine workings. It is important to note that while values for saturated aquifer thickness and local hydraulic gradient in the alluvial groundwater system can be determined relatively precisely, hydraulic conductivity values determined from slug testing methods are generally considered as order-of-magnitude estimates. Consequently, the information from Table 7-9 should be used for general purposes only. The estimated groundwater inflow rates presented in Table 7-9 suggest that copious, unmanageable amounts of alluvial groundwater will likely not be encountered.

As surface mining operations advance toward the alluvial groundwater discharge area in the northwest ¼ of Section 29, T39S, R5W (See Drawing 7-4; groundwater discharge area A), the information in Table 7-9 suggests that groundwater inflow rates in this area will be modest, generally on the order of a few tens of gallons per minute or less per 100 lineal feet of mine opening. However, it should be noted that, as discussed above, if mine openings in this area were to intersect a substantial thickness of coarse-grained alluvial material that was in good hydraulic communication with the coarse-grained alluvial system located along the eastern margins of Sink Valley, substantially greater rates of groundwater inflow could occur. Based on the information in Tables 7-8 and 7-9, this is not considered likely.

As mining operations advance toward the alluvial groundwater discharge area in the northwest ¼ of Section 29, T39S, R5W (See Drawing 7-4; groundwater discharge area A) and groundwater discharge from up-gradient alluvial groundwater systems occurs, there is the potential that discharge rates from alluvial springs in this area could be diminished. The magnitude of this potential impact will be largely dependent on the drainage rate and volume of groundwater that may be drained from the up-gradient alluvial groundwater system.

The potential for diminution of discharge from alluvial springs near proposed mining areas near the northwest ¼ of Section 29, T39S, R5W will be minimized because:

1) As mining progresses toward the groundwater discharge area in the northwest ¼ of Section 29, T39S, R5W (see Drawing 7-4, groundwater discharge area A), groundwater inflows into mine openings and discharge rates from the nearby alluvial springs will be closely monitored. If groundwater inflow rates into mine openings are excessive, where necessary Alton Coal Development, LLC will use a suitable technique to minimize groundwater inflow rates into the mine. These techniques may include the use of bentonite or natural clay filled cutoff walls or other means where appropriate to isolate and protect groundwater resources up-gradient of mining activities, and

2) Individual mine pits in the proposed Coal Hollow Mine will remain open for short lengths of time, generally no more than about 60 to 120 days. Consequently, any potential impacts to spring discharge rates in the alluvial groundwater system in this area will likely be short-lived. Because the alluvial groundwater recharge areas are located well up-gradient of proposed mining areas (mountain-front recharge) and will not be impacted, recharge to the alluvial system should continue uninterrupted, it is anticipated that water levels in the artesian groundwater system should recover from any mining-related declines in hydraulic head subsequent to the completion of mining in the area.

Groundwater discharge from the springs in the northwest ¼ of Section 29, T39S, R5W (See Drawing 7-4; groundwater discharge area A) do not contribute any measurable baseflow discharge to streams in the area. This conclusion is based on the lack of any baseflow discharge in streams down-gradient of this area in Sink Valley (see monitoring data for SW-6 and SW-9). Rather, most of this discharge is likely ultimately lost to evapotranspiration as the water migrates across the low-permeability, near-surface clayey sediments in Sink Valley. Consequently, the potential temporary diminution of discharge from alluvial springs in the northwest ¼ of Section 29, T39S, R5W would not result in appreciable adverse impacts to the surrounding hydrologic balance.

If any Utah State appropriated water rights are impacted by mining and reclamation operations in the proposed Coal Hollow Mine, these will be replaced according to all

applicable Utah State laws and regulations using the designated water replacement source described in Section 727 above.

728.320 Presence of acid-forming or toxic-forming materials

Chemical information on the acid- and toxic-forming potential of earth materials naturally present in the proposed permit area are presented in Appendix 6-2. Chemical information on the low-sulfur Smirl coal seam proposed for mining is presented in Appendix 6-1 (confidential binder). Based on laboratory analytical data, it is apparent that acid-forming and toxic-forming materials that could result in the contamination of surface-water or groundwater supplies in the proposed Coal Hollow Mine permit and adjacent area are generally not present.

Selenium was not detected in any of the samples from the proposed Coal Hollow Mine permit area. Likewise, concentrations of water-extractable boron were also low, being less than 3 mg/kg in all samples analyzed. The pH of groundwaters in and around the proposed Coal Hollow Mine permit area are moderately alkaline (UDOGM, 2007). Data in Appendix 6-2 likewise indicate moderately alkaline conditions in sediments in the proposed permit area. The solubility of dissolved trace metals is usually limited in waters with alkaline pH conditions. Consequently, high concentrations of these metal constituents in groundwaters and surface waters with elevated pH levels are not anticipated. Additionally, most of the materials that will be handled as part of mining and reclamation activities in the proposed Coal Hollow Mine area are of low hydraulic conductivity (i.e. clays, silts, shales, siltstones, claystones, etc.). Consequently, it is anticipated that groundwater seepage volumes through low-permeability backfill and reclaimed land surfaces in reclaimed mine pit areas and excess spoils storage areas will not be large. Additionally, reclaimed areas will be regraded, sloped, and otherwise managed to minimize the potential for land erosion, to restore approximate surface-water drainage patterns, and also to minimize the potential for ponding of surface waters on reclaimed areas (other than "roughening" or "gouging" of some areas to enhance reclamation). Thus, the potential for interactions between large amounts of disturbed earth materials and groundwaters and surface waters, which could result in leaching of chemical constituents into groundwater and surface-water resources, will be minimized.

Additionally, the mining plan calls for the emplacement of 40 inches of suitable cover material over backfilled areas made up of material types which could appreciably impact vegetation (materials with elevated SAR ratios or other physical or chemical characteristics that could adversely impact vegetation).

The neutralization potential greatly exceeded the acid potential in all samples analyzed, with the neutralization potential commonly exceeding the acid potential by many times, suggesting that acid-mine-drainage will not be a concern at the proposed Coal Hollow Mine. Acid-forming materials in western coal mine environments often consist of sulfide minerals, commonly including pyrite and marcasite, which, when exposed to air and water, are oxidized causing the liberation of H^+ ions (acid) into the water. Oxidation of

sulfide minerals may occur in limited amounts in the mine pits where oxygenated water encounters sulfide minerals. However, the acid produced by pyrite oxidation is quickly consumed by dissolution of abundant, naturally occurring carbonate minerals (Appendix 6-2). Dissolved iron is readily precipitated as iron-hydroxide in well aerated waters, and consequently excess iron is not anticipated in mine discharge water.

Other acid-forming materials or toxic-forming materials have not been identified in significant concentrations nor are such suspected to exist in materials to be disturbed by mining.

Because of the overall low-permeability of the rock strata and sediments surrounding the mine workings (primarily the shales and claystones of the lower Tropic Shale), the potential for seepage of mine water outward into adjacent stratigraphic horizons is low. Additionally, because the floors of the mine pits need to be accessible in order to extract the coal, the mining operations will be carried out in such a manner that the accumulation of large amounts of water in the mine pits will be avoided.

728.331 Sediment yield from the disturbed area.

Erosion from disturbed areas will be minimized through the use of silt fences and other sediment control devices. Surface runoff occurring on disturbed areas will be collected and treated as necessary to remove suspended matter. Four diversion ditches along with four sediment impoundments are proposed for the permit area. In addition, miscellaneous controls such as silt fence and berms are also proposed for specific areas. The proposed locations for these structures are shown on Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

The smallest practicable area, consistent with reasonable and safe mine operational practices will be disturbed at any one time during the mining operation and reclamation phases. This will be accomplished through progressive backfilling, grading, and prompt revegetation of disturbed areas. The backfilled material will be stabilized by grading to promote a reduction of the rate and volume of runoff in accordance with the applicable requirements. The excess spoil and fill above approximate original contour will be graded to a maximum 3h:1v slope and revegetated to minimize erosion.

Cut ditches will be established on the shoulders of all primary roads to control drainage and erosion. Cut and fill slopes along the primary roads will be minimal and are not expected to cause significant erosion. In locations where there are culvert crossings (i.e. Lower Robinson Creek), the fills slopes will be stabilized by utilizing standard methods such as grass matting or straw wattles. The location and details for roads can be viewed on Drawings 5-3 and 5-22 through 5-24.

Through the implementation of these sediment control measures, it is anticipated that sediment yield from disturbed areas in the proposed Coal Hollow Mine permit area will be minimized.

728.332 Impacts to important water quality parameters

As discussed above, appreciable quantities of groundwater are not anticipated to be intercepted in the Tropic Shale overlying proposed mining areas. Consequently, discharge of Tropic Shale groundwaters from mining areas is not anticipated. Because of the very low hydraulic conductivity of the marine Tropic Shale unit which immediately overlies the coal in proposed mining areas, the lateral migration of appreciable amounts of groundwater outward from proposed mine pit areas is not anticipated. Therefore, no impacts to important water quality parameters in surrounding groundwater and surface-water resources that could result from the interception of Tropic Shale groundwaters is anticipated.

Similarly, appreciable quantities of groundwater are not expected to emanate from the Dakota Formation in the mine floor into the mine openings. This conclusion is based on the fact that 1) vertical and horizontal groundwater flow in the Dakota Formation is impeded by the presence of low-permeability shales that encase the interbedded lenticular sandstone strata in the formation (i.e., the formation is not a good aquifer), 2) appreciable natural discharge from the Dakota Formation in the surrounding area to springs or streams is not observed, supporting the conclusion that the natural flux of groundwater through the formation is meager, and 3) mining will commence near the truncated up-dip end of the formation, minimizing the potential for elevated hydraulic head in the Dakota Formation. The results of slug testing performed on wells screened in the Smirl coal seam indicate relatively low values of hydraulic conductivity for the coal seam (Table 7-8). In much of the proposed mining area, the coal seam is dry. Thus, large inflows of groundwater from the coal seam into mine workings are not anticipated. Likewise, the potential for seepage out of mine pits through the coal seam is minimal. Consequently, impacts to important water-quality parameters in the Dakota Formation potentially resulting from mining operations are not anticipated, nor are impacts to important water-quality parameters in surrounding groundwater and surface-water systems anticipated as a result of interactions with intercepted Dakota Formation groundwater.

The water quality of groundwaters in the alluvial groundwater system up-gradient of mining operations will likely not be impacted by mining and reclamation activities in the proposed Coal Hollow Mine. Were alluvial groundwaters intercepted by mine openings allowed to flow into the mine pits, there would be the potential for substantially increased TDS concentrations as the water interacts with the marine Tropic Shale and the Smirl coal seam. This occurrence will be avoided.

As groundwater naturally migrates through the shallow, fine-grained alluvial sediments in the proposed Coal Hollow Mine permit and adjacent area (most evident in Sink

Valley), the quality of the water is naturally degraded (see Appendix 7-1). In the distal portions of Sink Valley, most notably concentrations of magnesium, sulfate, and bicarbonate are elevated in the alluvial groundwater.

The potential for TDS increases associated with interaction of waters with the Tropic Shale can be minimized by avoiding contact where practical between water sources and earth materials containing soluble minerals. Where possible, groundwater that will be encountered in alluvial sediments along the margins of mine pit areas will be routed through pipes, ditches or other conveyance methods away from mining areas via gravity drainage so as to prevent or minimize the potential for interaction with sediments disturbed by mining operations (including contact with the mined coal seam). If diverted alluvial groundwater were allowed to interact extensively with the Tropic Shale bedrock or Tropic Shale-derived alluvial sediments, similar increases in magnesium, sulfate, bicarbonate, and TDS concentrations would be anticipated. Consequently, where intercepted groundwaters will be routed around disturbed areas through pipes or well-constructed and maintained ditches, it is anticipated that detrimental impacts to important water quality parameters in these waters will be minimal.

The pumping and discharging of mine water from mine pits at the proposed Coal Hollow Mine permit area is not anticipated. The impoundment of substantial quantities of water within the mine pits would likely result in degradation of groundwater quality and is also not compatible with the proposed surface mining technique (the coal extraction operations occur at the bottom of the mine pit and thus they cannot be performed in flooded mine pits). As discussed above, the only likely foreseeable source of appreciable quantities of groundwater is from the alluvial groundwater systems overlying the low-permeability Tropic Shale in proposed mining areas. Where this alluvial groundwater is encountered in mining areas, it will be diverted away from mine workings prior to significant interaction with sediments in disturbed areas. Any discharge from the mine pits that does occur will be regulated under a Utah UPDES discharge permit.

As discussed above, acid mine drainage is not anticipated at the proposed Coal Hollow Mine permit area. This is due primarily to the relatively low sulfur content of the coal (see Appendix 6-1; confidential binder) and rock strata in the permit and adjacent area, and to the pervasiveness of carbonate minerals in the soil and rock strata which neutralize the acidity of the water if it occurs. If sulfide mineral oxidation and subsequent acid neutralization via carbonate dissolution were to occur, increases in TDS, calcium, magnesium, sulfate, and bicarbonate concentrations (and possibly also sodium concentrations via ion-exchange with calcium or magnesium on exchangeable clays) would be anticipated.

As described in Chapter 5, Section 532, surface runoff that occurs on disturbed areas will be treated through sedimentation ponds or other sediment-control devices and particulate matter will be allowed to settle prior to the discharging of the water to the receiving water, thus controlling suspended solids concentrations.

At any mining operation there is the potential for contamination of soils, surface-water and groundwater resources resulting from the spillage of hydrocarbons. Diesel fuels, oils, greases, and other hydrocarbons products will be stored and used at the mine site for a variety of purposes. A spill Prevention Control and Countermeasure Plan will be implemented that will help minimize any potential detrimental impacts to the environments.

Spill control kits will be provided on all mining equipment and personnel will be trained to properly control spills and dispose of any contaminated soils in an appropriate manner.

Based on these findings, it is concluded that the potential for mining and reclamation activities in the proposed Coal Hollow Mine permit area to cause detrimental impacts to important water quality parameters is minimal.

728.333 Flooding or streamflow alteration

As described above, appreciable groundwater inflow from the Tropic Shale and Dakota Formation into mine pits at the proposed Coal Hollow Mine are not anticipated. Appreciable groundwater inflows are anticipated only from the relatively thin, overlying alluvial groundwater systems. The thicknesses of the alluvium adjacent to mine openings in the proposed mining areas is generally less than 40 to 50 feet. The hydraulic conductivity of the predominantly clayey and silty alluvial sediments are low, and consequently, very large or sudden groundwater inflows into mine openings are not anticipated. Where appreciable alluvial groundwater is encountered adjacent to mine openings, it will be routed away from mining areas through ditches of other conveyance mechanisms. Consequently, discharge of mine water from the mine pits is not anticipated. The rates of alluvial groundwater drainage that could occur will likely not be of a magnitude that could potentially cause flooding or streamflow alteration in either the Sink Valley Wash or Lower Robinson Creek drainages.

If excess groundwater were to be encountered during mining operations such that it could not be adequately managed or discharged in compliance with the Utah UPDES discharge permit (which is considered unlikely), Alton Coal Development, LLC may when necessary construct supplemental containment and settlement ponds in which mine discharge waters may be held for treatment (where necessary) and subsequent discharge through UPDES discharge points in compliance with the UPDES discharge permit, minimizing the potential for flooding or streamflow alteration in areas adjacent to mining.

It should be noted here that the principal surface-water drainages in and adjacent to the proposed Coal Hollow Mine permit area are in many locations not stable in their current configurations (see photograph section). These stream drainages are currently actively eroding their channels during precipitation events, resulting in rapid down-cutting and deep entrenchment of stream channels, the formation of unstable near-vertical erosional escarpments adjacent to stream channels (which occasionally spall off into the stream

channel) , aggressive headward erosion of stream channels and side tributaries, and the transport of very large quantities of sediment associated with torrential precipitation events. These processes are currently actively ongoing in the proposed permit and adjacent area and the upper extents of these erosional processes are in many locations migrating upward in stream channels, resulting in ever-increasing lengths of unstable stream channels. This condition is reportedly a result of land management practices in the late 1800's or early 1900's.

The surface-water drainages adjacent to the proposed Coal Hollow Mine permit area have large discharge capacities (lower Sink Valley Wash, Lower Robinson Creek, and Kanab Creek). These drainages periodically convey very large amounts of precipitation water associated with torrential precipitation events. The anticipated discharge rates from alluvial groundwater drainage and the maximum reasonably foreseeable amount of mine discharge water that could potentially be required to be discharged from mine pits is much less than that periodically occurring during major torrential precipitation events. While the addition of modest amounts of sediment-free water into these stream channels has the potential to cause minor increases in channel erosion, the magnitude of this potential impact is inconsequential relative to that occurring during torrential precipitation events.

Most precipitation waters falling on disturbed areas will be contained in diversion ditches and routed to sediment impoundments that are designed to impound seasonal water and storms. Sediment control facilities will be designed and constructed to be geotechnically stable. This will minimize the potential for breaches of sediment control structures, which if they occur could result in down-stream flooding and increases in stream erosion and sediment yield. Emergency spillways will be part of the impoundment structures to provide a non-destructive discharge route should capacities ever be exceeded.

Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

Following reclamation, stream channels will be returned to a stable state to the extent possible given the currently highly unstable state of natural drainage channels in the area. Stream channels will be designed to withstand anticipated storm events, thus minimizing the potential of flooding in the reclaimed areas.

The potential for flooding or streamflow alteration resulting from mining and reclamation activities at the proposed Coal Hollow Mine permit area is considered minimal.

728.334 Groundwater and surface water availability

Groundwater use in the proposed Coal Hollow Mine permit and adjacent area is generally limited to stock watering and domestic use in Sink Valley. Some limited use of spring discharge water for irrigation has occurred in Sink Valley, although such irrigation is not occurring presently nor has it occurred in at least the past 10 years. The areas of

groundwater use in the proposed Coal Hollow Mine permit and adjacent area are located in the northwest ¼ of Section 29, T39S, R5W (see Drawing 7-4; groundwater discharge area A), and in the northwest ¼ of Section 32, T39S, R5W (see Drawing 7-4; groundwater discharge area B). The likely future availability of groundwater in each of these areas is discussed below.

Groundwater discharge area A (Northwest ¼, Section 29, T39S, R5W)

Groundwater use in area A occurs from several alluvial springs and seeps that are used for stock watering and limited domestic use. As described in Section 728.311 above, short-term diminution in discharge rates from springs in northwest ¼ of Section 29, T39S, R5W are possible as mining operations advance toward these springs. This potential impact is associated with the possible drainage of up-gradient alluvial groundwater into mine openings as mining advances toward groundwater discharge area A. Because individual mine pits will typically remain open for less than about 60 to 120 days before subsequently being backfilled and reclaimed, the potential for long-term drainage of alluvial groundwater into the mine voids is negligible, and thus any potential decreases in alluvial discharge in groundwater discharge area A is anticipated to be short-lived.

If groundwater inflow rates into mine openings in this area are excessive, such that appreciable impacts to the springs and seeps in groundwater discharge area A are likely, where necessary Alton Coal Development, LLC will use a suitable technique to minimize groundwater inflow rates into the mine voids. These techniques may include the use of bentonite or natural clay filled cutoff walls or other means where appropriate to isolate and protect groundwater resources up-gradient of mining activities. Consequently, the potential that groundwater could become unavailable in this area is minimal. Additionally, if alluvial groundwater resources were to become unavailable in this area due to mining and reclamation activities in the proposed Coal Hollow Mine permit area, groundwater will be replaced according to all applicable State laws and regulations using the replacement water source described in Section 727 above.

It should be noted that the proposed water replacement source, water well Y-61, produces water from the coarse-grained alluvial groundwater system in Sink Valley. Nearby springs that could potentially be impacted by mining and reclamation activities are supported by the same alluvial groundwater system. However, while modest decreases in the artesian hydraulic pressures in the alluvial groundwater system could potentially result in diminution of spring flows, water well Y-61 is 150 feet deep and will be equipped with an electric well pump providing the capability to produce groundwater from the alluvial system even if the hydraulic head in the alluvial groundwater system were to be diminished such that artesian flow conditions temporarily ceased to exist.

Groundwater discharge area B (Northwest ¼, Section 32, T39S, R5W)

Groundwater use in groundwater discharge area B occurs at alluvial springs and seeps located southeast of the proposed Coal Hollow Mine permit area that are used for stock watering and limited domestic use. As described in Section 728.311 above, although some temporary and short-lived diminution in discharge rates from springs in northwest ¼ of Section 29, T39S, R5W is possible, this potential impact is not considered likely.

In the event that alluvial groundwater resources were to become unavailable in this area due to mining and reclamation activities in the proposed Coal Hollow Mine permit area, groundwater will be replaced according to all applicable State laws and regulations using the replacement water source described in Section 727 above.

Surface-water availability

Surface-water use in the proposed Coal Hollow Mine permit and adjacent area occurs in the Sink Valley Wash drainage and in Lower Robinson Creek. Surface waters in the Sink Valley Wash drainage (primarily from Water Canyon via an irrigation diversion and from Swapp Hollow; appreciable discharge in Sink Valley Wash below Section 29 T39S, R5W is usually absent) are utilized for both stock watering and limited irrigation use. Stream water in the Sink Valley Wash drainage is derived from runoff from the adjacent Paunsaugunt Plateau area. Because the surface water in the drainage originates from areas up-gradient areas located large distances from proposed mining areas, and because the stream channel is entirely outside the permit area and will not be impacted by mining and reclamation activities, there is essentially no probability that surface water availability in the Sink Valley Wash drainage could become unavailable as a result of mining and reclamation activities.

Discharge in Lower Robinson Creek immediately above the proposed Coal Hollow Mine permit area typically occurs only in direct response to significant precipitation or snowmelt events. Thus, surface-water availability is currently limited in this drainage prior to any mining activities.

Seepage of alluvial groundwater into the deeply incised lower Robinson Creek stream channel occurs near the contact with the underlying Dakota Formation in the southeast quarter of Section 19, T39S, R5W. This water is likely related to saturated alluvial deposits directly underlying the Robinson Creek stream channel and emerges near where the saturated alluvial sediments intersect the mostly impermeable Dakota Formation bedrock in the base of the stream channel. It is noteworthy that the location of the emergence of alluvial water in the channel has varied somewhat over time. This seepage of alluvial water is usually about 5 - 10 gpm or less and is routinely monitored at monitoring station SW-5 (Drawing 7-2).

It should be noted that the proposed Coal Hollow Mine plan calls for the permanent diversion of a reach of the Lower Robinson Creek stream channel approximately 2,000

feet in length in the southeast ¼ of Section 19, T39S, R5W. Details of the proposed diversion are given in Chapter 5, Section 527.220 of this MRP. If this action results in diminution of the meager discharge of surface water in the drainage below the planned diversion, where required a suitable mitigation for this potential impact will be designed and implemented in consultation with the Division of Oil, Gas and Mining.

The information presented above suggests that the potential for significant impacts to groundwater and surface-water availability resulting from mining and reclamation activities in the proposed Coal Hollow Mine permit and adjacent systems in the region is low.

728.340 Whether mining and reclamation activity will result in contamination, diminution or interruption of State-appropriated waters

State appropriated water rights in the proposed Coal Hollow Mine permit and adjacent area are shown on Drawing 7-3 and tabulated in Appendix 7-3.

Appropriated groundwaters include alluvial springs and seeps in the northwest ¼ of Section 29, T39S, R5W (groundwater discharge area A), springs and seeps in the northwest ¼ of Section 32, T39S, R5W (groundwater discharge area B). State appropriated surface waters include reaches of Sink Valley Wash east of the proposed Coal Hollow Mine permit area, and reaches of Lower Robinson Creek.

The potential for mining and reclamation activities at the proposed Coal Hollow Mine permit area to result in contamination, diminution or interruption of State-appropriated water in the proposed Coal Hollow Permit and adjacent area are described in detail in Sections 728.310, 728.320, 728.332, and 728.334.

With the possible exception of short-term diminution in discharge rates from springs and seeps in the northwest ¼ of Section 29, T39S, R5W, Contamination, diminution, or interruption of State-appropriated waters in the proposed Coal Hollow Mine permit and adjacent area are not anticipated. It should be noted that if groundwater inflow rates into mine openings in this area are excessive, such that appreciable impacts to the springs and seeps in groundwater discharge area A are likely, where necessary Alton Coal Development, LLC will use a suitable technique to minimize groundwater inflow rates into the mine voids. These techniques may include the use of bentonite or natural clay filled cutoff walls or other means where appropriate to isolate and protect groundwater resources up-gradient of mining activities, minimizing the potential for diminution of discharge rates from these springs.

Additionally, it should be noted that the proposed Coal Hollow Mine plan calls for the permanent diversion of a reach of the Lower Robinson Creek stream channel approximately 2,000 feet in length in the southeast ¼ of Section 19, T39S, R5W. Details of the proposed diversion are given in Chapter 5, Section 527.220 of this MRP. If this

action results in diminution of the meager discharge of surface water in the drainage below the planned diversion, where required a suitable mitigation for this potential impact will be designed and implemented in consultation with the Division of Oil, Gas and Mining.

In the event that any State appropriated waters were to be contaminated, diminished, or interrupted due to mining and reclamation activities in the proposed Coal Hollow Mine permit area, groundwater will be replaced according to all applicable State laws and regulations using the replacement water source described in Section 727 above.

730 OPERATION PLAN

Coal mining in the proposed Coal Hollow Mine permit area will occur using surface mining techniques. 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. 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.

In order to maximize the use and conservation of the coal resource, coal will be recovered using large hydraulic backhoes or front end loaders and off-road trucks. Mined coal will be hauled to a central coal processing area for crushing and placement into a stockpile. Coal from the stockpile will be transferred into a bin and loaded into over the road trucks for transport.

The plan, with Drawings, cross sections, narrative, descriptions, and calculations indicates how the relevant requirements will be met. The lands subject to coal mining and reclamation operations over the estimated life of the operations are identified and briefly described. All appropriate information is located in the subsequent sections and Drawings 5-1 through 5-39 and Appendices A5-1 through A5-3.

731 GENERAL REQUIREMENTS

Operations will be conducted to assure 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.

Groundwater and Surface-Water Protection

To protect the hydrologic balance, coal mining and reclamation operations will be conducted to handle earth materials and runoff in a manner that minimizes acid, toxic, or other harmful infiltration to the groundwater system. Additionally, excavations, and disturbances will be managed to prevent or control discharges of pollutants to the groundwater.

Products including chemicals, fuels, and oils used in the mining process will be stored and used in a manner that minimizes the potential for these products entering groundwater systems. Concrete oil and fuel containments will be constructed as shown on Drawings 5-3 and 5-8.

The wash bay at the mine site will include a closed circuit water recycle system. This system will eliminate and store water impurities and reroute water back through the wash bay for cleaning equipment, thus minimizing water consumption the potential for contamination of groundwater resources. Details for this structure can be viewed on Drawings 5-3, and 5-8.

As mining operations approach springs and seeps in the northwest ¼ of Section 29, T39S, R5W (See Drawing 7-4; groundwater discharge area A), there is the potential for drainage of up-gradient into mine openings to cause short-lived diminution of discharge from these springs. If groundwater inflow rates into mine openings in this area are excessive, such that appreciable impacts to the springs and seeps in groundwater discharge area A are likely, where necessary Alton Coal Development, LLC will use a suitable technique to minimize groundwater inflow rates into the mine voids. These techniques may include the use of bentonite or natural clay filled cutoff walls or other means where appropriate to isolate and protect groundwater resources up-gradient of mining activities, minimizing the potential for diminution of discharge rates from these springs.

The mine will replace loss of water identified for protection in this MRP that are impacted by mining and reclamation operations.

To protect the hydrologic balance, coal mining and reclamation operations will be conducted to handle earth materials and runoff in a manner that minimizes acidic or toxic drainage, prevents to the extent possible, additional contributions of suspended solids to streamflow outside the permit area and otherwise prevents water pollution. Runoff and sediment control measures are described in detail in Chapter 5 of this MRP. The mine will maintain adequate runoff- and sediment-control facilities to protect local surface waters.

Discharge of mine water that has been disturbed by coal mining and reclamation operations is not anticipated. However, any discharges of water from areas disturbed by coal mining and reclamation operations that do occur 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. Discharge of mine waters will be regulated by a Utah UPDES discharge permit.

Water pollution associated with mining and reclamation activities within the permit areas will be controlled by:

- Construction of berms and/or diversion ditches to control runoff from all facilities areas.
- Roads will be constructed with ditches to capture runoff
- Diversion ditches will be constructed as necessary around active mining and reclamation areas to capture runoff from those areas.

- Sedimentation impoundments will be constructed to control discharges
- In areas where impoundments or diversions are not suitable to the surrounding terrain, silt fence or straw bales will be utilized to control sediment discharge from the permit area.

In order to accomplish these objectives, watershed analysis of the permit and adjacent areas has been completed and specific designs are established for each water pollution control structure. Primary control structures include four sediment impoundments, four diversion ditches and miscellaneous berms. The locations of these structures can be viewed on Drawing 5-3. The detailed analysis for these structures and specific designs can be viewed on Drawings 5-25 through 5-34. In addition, a geotechnical analysis of the impoundments to ensure stability can be viewed in Appendix 5-1. The watershed and structure sizing analysis can be viewed in Appendix 5-2. In addition to these primary structures, temporary diversions and impoundments may also be implemented, as necessary, in mining areas to further enhance pollution controls.

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. 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. Storm water and snow melt that occurs within the facilities area will be routed to an impoundment that will contain sediment. This impoundment will have a drop-pipe spillway installed that will allow removal of any oil sheens that may result from parking lots or maintenance activities by using absorbent materials to remove the sheen. Details for this impoundment can be viewed on Drawings 5-28.

There are four sediment impoundments proposed for the permit area. These structures will be constructed using a combination of dozers and backhoes. The structures have been designed to contain the required storm events as specified in Appendix 5-2. The structures will have sediment removed as necessary to ensure the required capacities. Details for these structures can be viewed on Drawings 5-25, 5-26 and 5-28 through 5-32. Calculations and supporting text can be viewed in Appendix 5-2.

Four diversion ditches along with four sediment impoundments are proposed for the permit area. In addition, miscellaneous controls such as silt fence and berms are also proposed for specific areas. The proposed locations for these structures are shown on Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

The smallest practicable area, consistent with reasonable and safe mine operational practices will be disturbed at any one time during the mining operation and reclamation phases. This will be accomplished through progressive backfilling, grading, and prompt revegetation of disturbed areas.

There are no other coal processing waste banks, dams or embankments proposed within the permit area.

Diesel fuels, oils, greases, and other hydrocarbons products will be stored and used at the mine site for a variety of purposes. A spill Prevention Control and Countermeasure Plan will be implemented that will help minimize any potential detrimental impacts to the environments.

Products including potentially hazardous chemicals, fuels, and oils used in the mining process will be stored and used in a manner that minimizes the potential for these products to contaminate surface-water resources. Concrete oil and fuel containments will be constructed as shown on Drawings 5-3 and 5-8.

The wash bay at the mine site will include a closed circuit water recycle system. This system will eliminate and store water impurities and reroute water back through the wash bay for cleaning equipment, thus minimizing water consumption the potential for contamination of surface-water resources. Details for this structure can be viewed on Drawings 5-3, 5-8, and Appendix 5-4. .

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. The specific plan for road locations and design are presented in R645-301-534. The location and details for roads can be viewed on Drawings 5-3 and 5-22 through 5-24.

Roads will be located, designed, constructed, reconstructed, used, maintained and reclaimed to control or prevent additional contributions of suspended solids to stream flow or runoff outside the permit area; Neither cause nor contribute to, directly or indirectly, the violation of effluent standards given under R645-301-751; minimize the diminution to or degradation of the quality or quantity of surface- and ground-water systems; and refrain from significantly altering the normal flow of water in streambeds or drainage channels. No acid- or toxic-forming substances will be used in road surfacing.

All roads will be removed and reclaimed according to Drawings 5-35 and 5-36. The estimated timetable for removing these roads is shown on Drawing 5-38. Cut ditches will be established on the shoulders of all primary roads to control drainage and erosion. Cut and fill slopes along the primary roads will be minimal and are not expected to cause significant erosion. In locations where there are culvert crossings (i.e. Lower Robinson Creek), the fills slopes will be stabilized by utilizing standard methods such as grass matting or straw wattles.

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.

Wells constructed for monitoring groundwater conditions in the proposed Coal Hollow Mine permit and adjacent area, including exploration holes and boreholes used for water wells or monitoring wells, will be designed to prevent contamination of groundwater and surface-water resources and to protect the hydrologic balance. A diagram depicting typical monitoring well construction methods is shown in Drawing 7-11. Monitoring wells will include a protective hydraulic seal immediately above the screened interval, an

annular seal plugging the borehole above the hydraulic seal to near the ground surface, and a concrete surface seal extending from the top of the hydraulic seal to the ground surface which is sloped away from the well casing to prevent the entrance of surface flows into the borehole area. Well casings will protrude above the ground surface a sufficient height so as to minimize the potential for the entrance of surface water or other material into the well. A steel surface protector with a locking cover will be installed at monitoring wells to prevent access by unauthorized personnel. Where there is potential for damage to monitoring wells, the wells will be protected through the use of barricades, fences, or other protective devices. These protective devices will be periodically inspected and maintained in good operating conditions. Monitoring wells will be locked in a closed position between uses.

When no longer needed for monitoring or other use approved by the Division upon a finding of no adverse environmental or health and safety effects, or unless approved for transfer as a water well under R645-301-731.100 through R645-301-731.522 and R645-301-731.800, each well will be capped, sealed, backfilled, or otherwise properly managed, as required by the Division in accordance with R645-301-529.400, R645-301-631.100, and R645-301-748. Permanent closure measures will be designed to prevent access to the mine workings by people, livestock, fish and wildlife, machinery and to keep acid or other toxic drainage from entering ground or surface waters.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

Permanent closure and abandonment of water wells greater than 30 feet in depth will be in accordance with the requirements of "Administrative Rules for Water Well Drillers", State of Utah, Division of Water Rights or other applicable state regulations. Abandonment of wells will be performed by a licensed water well driller. The wells to be abandoned will be completely filled using neat cement grout, sand cement grout, unhydrated bentonite, or bentonite grout, or other materials approved by the Utah State Engineer's office. Alternatively, the well may be abandoned using a different procedure upon approval from the Utah State Engineer's office.

Abandonment materials will be introduced at the bottom of the well or required sealing interval and placed progressively upward to the top of the well. The casing will be severed a minimum of 2 feet below the ground surface. A minimum of 2 feet of compacted native material will be placed above the abandoned well upon completion.

Within 30 days of the completion of well abandonment procedures, a report will be submitted to the State Engineer by the responsible licensed driller giving data related to the abandonment of the well. This shall include the name of the licensed driller or other person(s) performing abandonment procedures, name of well owner at the time of abandonment, the address or location of the well by section, township, and range, abandonment materials and equipment used, water right or file number covering the well, the final disposition of the well, and the date of completion.

Exploration holes and boreholes will be backfilled, plugged, cased, capped, sealed, or otherwise managed to prevent acid or toxic contamination of water resources and to minimize disturbance to the prevailing hydrologic balance. Exploration holes and boreholes will be managed to ensure the safety of people, livestock, fish and wildlife, and machinery.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

If any exploration boreholes are to be used as monitoring wells or water wells, these will meet the provisions of R645-301-731 and be managed according to the following.

Boreholes will be backfilled to within 1 foot of the land surface with concrete or other materials approved by the Division as necessary to prevent contamination of groundwater or surface-water resources or to protect the prevailing hydrologic balance. The upper approximately 1 foot will be backfilled with native materials to facilitate reclamation (see Drawing 6-11). Exploration holes and boreholes that may be uncovered during mining and reclamation activities will be permanently closed unless approved for water monitoring or otherwise managed in a manner approved by the Division.

If mining and reclamation activities result in the contamination, diminution, or interruption of State appropriated groundwater or surface-water sources, replacement water will be provided using the alternate water source described in R645-301-727.

731.200 Water Monitoring

This section describes the hydrologic monitoring plan. Locations of surface-water and groundwater monitoring sites are indicated on Drawing 7-10. Hydrologic monitoring protocols, sampling frequencies, and sampling sites are described in Table 7-4. Groundwater and surface-water monitoring locations are listed in Table 7-5. Operational field and laboratory hydrologic monitoring parameters for surface water are listed in Table 7-6, and for groundwater in Table 7-7. The hydrologic monitoring parameters have been selected in consultation with the Division's directive Tech-006, *Water Monitoring Programs for Coal Mines.*

The groundwater and surface-water monitoring plan is extensive and includes 54 monitoring sites. The monitoring plan is designed to monitor groundwater and surface-water resources for any potential impacts that could potentially occur as a result of mining and reclamation activities in the proposed Coal Hollow Mine permit and adjacent area. Each of the sampling locations and their monitoring purpose are described below.

Streams

Kanab Creek will be monitored at sites SW-3 (above the permit area), and SW-2 (below the permit area). Lower Robinson Creek will be monitored at sites SW-4 (above the permit area), SW-101 (within the permit area), and SW-5 (below the permit area above the confluence with Kanab Creek). The irrigation water near SW-4 will also be monitored at site RID-1. Swapp Hollow creek will be monitored above the permit area at site SW-8. Sink Valley Wash will be monitored at SW-6 (a small tributary to the wash immediately below the permit area) and at SW-9, located in the main drainage below the permit area. All of these locations, with the exception of RID-1) will be monitored for discharge and water quality parameters specified in Table 7-6 quarterly, when reasonably accessible. Additionally, Lower Robinson Creek will be monitored at site BLM-1, which is near the location of alluvial groundwater emergence in the bottom of the stream channel. BLM-1 and RID-1 will be monitored for discharge and field water quality parameters.

Springs

Eight springs from alluvial groundwater area A will be monitored including SP-8, SP-14, SP-16, SP-19, SP-20, SP-22, SP-24 and Sorensen Spring. Spring SP-8 is a developed spring in area A that provides culinary water for the Swapp Ranch house. SP-8 will be monitored for discharge and operational laboratory water quality measurements quarterly when reasonably accessible. Springs SP-14, SP-16, SP-19, SP-20, SP-22, SP-24 and Sorensen Spring springs will be monitored for discharge and field water quality measurements quarterly when reasonably accessible.

Springs SP-4 and SP-6, and SP-33, which are located in Sink Valley below the proposed mining area, will also be monitored. SP-6 is an area of diffuse seepage above an earthen impoundment in the wash immediately below the permit area. Spring SP-33 is a developed spring that discharges into a pond below the permit area and provides culinary water to two adjacent cabins. Each of these Springs SP-6 and SP-33 will be monitored for discharge and operational laboratory water quality measurements quarterly when reasonably accessible. SP-4 discharges from a fault/fracture system in the Dakota Formation near the canyon margin in Sink Valley Wash below the permit area. Spring SP-4 will be monitored for discharge and field water quality measurements quarterly when reasonably accessible. Spring SP-3 discharges from pediment alluvium in the upland area above Sink Valley Wash more than a mile from the permit area. It is extremely unlikely that discharge rates or water quality at this spring could be impacted as a result of mining-related activities in the mine permit area. However, this spring will be monitored for discharge and field water quality measurements quarterly, primarily to provide background data from springs in the region.

Wells

Wells Y-98 (Robinson Creek alluvium above the permit area), Y-45 (coal seam well in Swapp Hollow above permit area), Y-102 (flowing alluvial well in alluvial groundwater discharge area A), Y-36 (coal seam well in Sink Valley above the permit area), Y-38 (coal seam well in Sink Valley permit area), Y-61 (alluvial well at the Sorenson Ranch), and C5-130 (new monitoring well in alluvial groundwater discharge A) will be monitored quarterly when reasonable accessible. Well Y-61 will be monitored for groundwater operational laboratory water quality parameters to monitor groundwater quality in alluvial groundwater discharge area A. The other wells will be monitored for water level only.

Additionally, 19 newly constructed monitoring wells constructed in the Sink Valley alluvial groundwater system will be monitored quarterly. These include C2-15, C2-28, C2-40, C3-15, C3-30, C3-40, C4-15, C4-30, C4-50, C7-20, C9-15, C9-25, C9-40, LS-28, LS-60, LS-85, SS-15, SS-30, and SS-75. All of these wells will be monitored quarterly for water level. Additionally, wells LS-85 and SS-30 will be monitored for groundwater operational laboratory water quality measurements.

Additionally two wells in the Lower Robinson Creek alluvium will be monitored for water level and groundwater operational laboratory chemistry. These include UR-70 located above proposed mining locations in the Lower Robinson Creek drainage, and LR-45, located below proposed mining areas adjacent to Lower Robinson Creek. It should be noted that LR-45 is located near a proposed sediment pond impoundment. Consequently, if this well becomes unsuitable for monitoring, an alternate location will be used to monitor the Lower Robinson alluvial groundwater system in this area.

Wells C0-18 and C0-54 are located near the initial proposed mining areas in the Lower Robinson Creek drainage. These will be monitored for water level quarterly.

It should be noted that many of the wells specified for monitoring in this monitoring plan will at some point be destroyed or rendered inoperable as the mine workings precede through the area. These wells will be monitored until such a time as they are destroyed or become inoperable.

Groundwater and surface-water monitoring will continue through the post-mining periods until bond release. The monitoring requirements, including monitoring sites, analytical parameters and the sampling frequency may be modified in the future in consultation with the Division if the data demonstrate that such a modification is warranted.

731.600 Stream Buffer Zones

Any perennial or intermittent streams in the mine area will be protected by 100 foot stream buffer zones on either side of these streams. Coal mining and reclamation operations will not cause or contribute to the violation of applicable Utah or federal water

standards and will not adversely affect the water quality and quantity or other environmental resources of the stream.

Temporary or permanent stream channel diversion will comply with R645-301-742-300. It should be noted that the proposed Coal Hollow Mine plan calls for the permanent diversion of a reach of the Lower Robinson Creek stream channel approximately 2,000 feet in length in the southeast ¼ of Section 19, T39S, R5W. Details of the proposed diversion are given in Chapter 5, Section 527.220 of this MRP. If this action results in diminution of the meager discharge of surface water in the drainage below the planned diversion, where required a suitable mitigation for this potential impact will be designed and implemented in consultation with the Division of Oil, Gas and Mining.

The areas surrounding the streams that are not to be disturbed will be designated as buffer zones, and will be marked as specified in R645-301-521.260.

731.700 Cross sections and Maps

The locations of springs and seeps identified in the proposed Coal Hollow Mine permit and adjacent area are shown in Drawing 7-1. The locations of baseline hydrologic monitoring locations are shown on Drawing 7-2. The locations of water rights in the proposed Coal Hollow permit and adjacent area are provided on Drawing 7-3. Cross-sections depicting the stratigraphy and hydrostratigraphy of the proposed Coal Hollow Mine permit and adjacent area are presented in Chapter 6, Drawing 6-2. Designs for proposed impoundments in the proposed Coal Hollow permit area are shown in Drawings 5-25 through 5-31

731.800 Water Rights and Replacement

Alton Coal Development, LLC commits to replace the water supply of an owner of interest in real property who obtains all or part of his or her supply of water for domestic, agricultural, industrial, or other legitimate use from the underground or surface source, where the water supply has been adversely impacted by contamination, diminution, or interruption proximately resulting from the surface mining activities. Baseline hydrologic information required in R645-301-624.100 through R645-301-624.200, R645-301-625, R645-301-626, R645-301-723 through R645-301-724.300, R645-301-724.500, R645-301-725 through R645-301-731, and R645-301-731.210 through R645-301-731.223 will be used to determine the extent of the impact of mining upon ground water and surface water.

732 Sediment Control Measures

Sediment control measures have been designed, constructed and maintained to prevent additional contributions of sediment to streamflow or to runoff outside the permit area.

732.100 Siltation Structures

Siltation structures within the permit area are described in Section 732.200

732.200 Sedimentation Ponds

Four diversion ditches along with four sediment impoundments are proposed for the permit area. In addition, miscellaneous controls such as silt fence and berms are also proposed for specific areas. The proposed locations for these structures are shown on Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

Sedimentation ponds have been designed in compliance with the requirements of R645-301-356.300, R645-301-356.400, R645-301-513.200, R645-301-742.200 through R645-301-742.240, and R645-301-763.

No sedimentation ponds or earthen structures which will remain open are planned.

The sedimentation plan has been designed to comply with the MSHA requirements given under R645-301-513.100 and R645-301-513.200.

732.300 Diversions

The runoff control plan is designed to isolate, to the maximum degree possible, runoff from disturbed areas from that of undisturbed areas. Where possible, this has been accomplished by allowing up-stream runoff to bypass the disturbed area, and routing any runoff from undisturbed areas which enters the disturbed area into a sediment control system.

Four diversion ditches along with four sediment impoundments are proposed for the permit area. In addition, miscellaneous controls such as silt fence and berms are also proposed for specific areas. The proposed locations for these structures are shown on Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

732.400 Road Drainage

All roads will be constructed, maintained and reconstructed to comply with R645-301-742.400. Road drainage facilities include diversion ditches, culverts, containment berms, and/or water bars. Specific plans for road drainage, road construction, and road maintenance are presented in Chapter 5, Section 534 of this MRP.

A description of measures to be taken to obtain division approval for alteration or relocation of a natural drainage way will be presented to the Division when necessary.

A description of measures to be taken to protect the inlet end of a ditch relief culvert will be submitted to the Division when necessary.

All road drainage diversions will be maintained and repaired to operational condition following the occurrence of a large storm event. Culvert inlets and outlets will be kept clear of sediment and other debris.

733 IMPOUNDMENTS

733.100 General Plans

A professional engineer experienced in the design and construction of impoundments with assistance from a geotechnical expert has used current, prudent, engineering practices to design the proposed impoundments. The plans have been certified and a detailed geotechnical analysis has been provided. The certifications and drawings can be viewed in Drawings 5-25 through 5-31 and Appendices A5-1 and A5-2.

Details for each proposed water impoundment within the proposed permit area will be submitted upon final facility design. Each general plan will be prepared and certified as described under R645-301-512, contain maps and cross sections, contain a narrative that describes the structure, contains the results of a survey as described under R645-301-531, contain the preliminary hydrologic and geologic information required to assess the hydrologic impact of the structure and contain a certification statement which includes a schedule setting forth the dates when any detailed design plans for structures that are not submitted with the general plan to the Division.

733.200 Permanent and Temporary Impoundments

All impoundments have been designed and constructed using current, prudent engineering practices and have been designed to comply with the requirements of R645-301-512.240, R645-301-514.300, R645-301-515.200, R645-301-533.100 through R645-

301-533.600, R645-301-733.220 through R645-301-733.226, R645-301-743.240, and R645-301-743.

No impoundments or sedimentation ponds meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) exist or are planned within the proposed Mine Permit Area. Should impoundments and sedimentation ponds meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) become necessary, compliance with the requirements of MSHA, 30 CFR 77.216 will be met.

734 Discharge Structures

Discharge structures will be constructed and maintained to comply with R645-301-744.

The proposed impoundments are designed to temporarily store water from storm events and snow melt. Long term standing water in the impoundments is anticipated to be seasonal and sediment will be removed as necessary to provide the required storage capacities. Emergency spillways have been included in the designs to provide a non-destructive discharge route should the capacities ever be exceeded. Surveys of these impoundments will be regularly conducted to ensure that design capacities are available.

Storm water and snow melt that occurs within the facilities area will be routed to an impoundment that will contain sediment. This impoundment will have a drop-pipe spillway installed that will allow removal of any oil sheens that may result from parking lots or maintenance activities by using absorbent materials to remove the sheen. Details for this impoundment can be viewed on Drawings 5-28.

735 Disposal of Excess Spoil

Areas designated for the disposal of excess spoil and excess spoil structures will be constructed and maintained to comply with R645-301-745.

Details of proposed excess spoil disposal plans are presented in Chapter 5, Section 535 of this MRP and are summarized below.

A geotechnical analysis has been completed for the proposed excess spoil structure. This analysis estimates the long-term safety factor to be 1.7 to 1.8 based on the proposed design. Following proper construction practices of building the structure in maximum four foot lifts and meeting 90% compaction based on the standard Procter will ensure that the structure will be stable under all conditions of construction. This construction will occur only in the designated excess spoil area as shown on Drawing 5-3 and 5-35. The fill will be placed with end dump haul trucks and lifts will be constructed using dozers. High precision GPS systems will be regularly utilized to check grades and appropriate lift thickness. The geotechnical analysis for this structure can be viewed in Appendix 5-1.

The excess spoil is planned to be placed in an area where natural grades range from 0 to 5%. This is one of the most moderately sloping locations in the Permit Area. Stability of this structure is estimated to be 1.7 to 1.8 based on the Appendix 5-1.

Geotechnical borings were completed in the foundation of the proposed disposal area. Laboratory analysis of these borings has also been completed. Details of this analysis can be viewed in Appendix 5-1.

Permanent slopes for the proposed excess spoil will not exceed 3h:1v (33 percent), therefore no keyway cuts have been proposed in the design. Appendix 5-1 details the stability analysis for the proposed structure.

Excess spoil will not be disposed of in underground mine workings.

Horizontal lifts will not exceed four feet in thickness unless otherwise approved by the Division. The lifts will be concurrently compacted to meet 90% of the standard Procter. The geotechnical analysis (Appendix 5-1), provides information showing that these construction standards will provide mass stability and will prevent mass movement during and after construction. The excess spoil will be graded to provide drainage similar to original flow patterns. Topsoil and subsoil as designated in Chapter 2 will be removed and separated from other materials prior to placement of spoil.

A description of the character of the bedrock and any adverse geologic conditions in presented in Appendix 5-1.

Spring and seep survey information is provided on Drawing 7-1. There are no springs or seeps identified in the excess spoil area.

There are no historical underground mining operations in the proposed excess spoil area. There are also no future underground operations proposed.

There are no rock chimneys or drainage blankets proposed.

A stability analysis including strength parameters, pore pressures and long-term seepage conditions is presented together with all supporting data in Appendix 5-1.

Neither rock-toe buttresses nor key-way cuts are required under R645-301-535.112 or R645-301-535.113.

No valley fills or head-of-hollow fills are proposed.

No durable rock fills are proposed.

No disposal of waste on preexisting benches is planned

The excess spoil structure and fill above approximate original contour are the only alternative specifications proposed. A geotechnical analysis has been completed for this proposal and can be viewed in Appendix 5-1. All other mined areas will be restored to approximate original contour.

736 Coal Mine Waste

Areas designated for disposal of coal mine waste and coal mine waste structures will be constructed and maintained to comply with R645-301-746.

No structures for the disposal of coal mine waste are planned.

737 Noncoal Mine Waste

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

Noncoal mine waste, including but not limited to grease, lubricants, paints, flammable liquids, garbage, machinery, lumber and other combustible materials generated during coal mining and reclamation operations will be placed and stored in a controlled manner in a designated portion of the permit area or state-approved solid waste disposal area.

Topsoil storage areas and handling can be viewed on Drawing 2-2. Spoil placement and the excess spoil structure can be viewed on Drawings 5-3, 5-17, 5-18, 5-19, 5-35 and 5-36.

Only sizing of the coal is proposed. This process will not produce any waste.

Final disposal of noncoal mine wastes will be in a designated disposal site in the permit area or a State-approved solid waste disposal area. Disposal sites in the permit area will be designed and constructed to ensure that leachate and drainage from the noncoal mine waste area does not degrade surface or underground water. Wastes will be routinely compacted and covered to prevent combustion and wind-borne waste. When the disposal is completed, a minimum of two feet of soil cover will be placed over the site, slopes, stabilized, and revegetation accomplished in accordance with 244.200 and R645-301-353 through R645-301-357. Operation of the disposal site will be conducted in accordance with all local, Utah, and Federal requirements.

At no time will any noncoal mine waste be deposited in a refuse pile or impounding structure, nor will any excavation for a noncoal mine waste disposal site be located within eight feet of any coal outcrop or coal storage area.

Notwithstanding any other provision to the R645 Rules, any noncoal mine waste defined as "hazardous" under 3001 of the Resource Conservation and Recovery Act (RCRA) (Pub. L. 94-580, as amended) and 40 CFR Part 261 will be handled in accordance with the requirements of Subtitle C of RCRA and any implementing regulations.

Debris, acid-forming, toxic-forming materials and materials constituting a fire hazard will be identified and disposed of in accordance with R645-301-528.330, R645-301-537.200, R645-301-542.740, R645-301-553.100 through R645-301-553.600, R645-301-553.900, and R645-301-747. Appropriate measures will be implemented to preclude sustained combustion of such materials.

Plans do not include using dams, embankments or other impoundments for disposal of coal, overburden, excess spoil or coal mine waste.

738 Temporary Casing and Sealing of Wells

Wells constructed for monitoring groundwater conditions in the proposed Coal Hollow Mine permit and adjacent area, including exploration holes and boreholes used for water wells or monitoring wells, will be designed to prevent contamination of groundwater and surface-water resources and to protect the hydrologic balance. A diagram depicting typical monitoring well construction methods is shown in Drawing 7-11. Monitoring wells will include a protective hydraulic seal immediately above the screened interval, an annular seal plugging the borehole above the hydraulic seal to near the ground surface, and a concrete surface seal extending from the top of the hydraulic seal to the ground surface which is sloped away from the well casing to prevent the entrance of surface flows into the borehole area. Well casings will protrude above the ground surface a sufficient height so as to minimize the potential for the entrance of surface water or other material into the well. A steel surface protector with a locking cover will be installed at monitoring wells to prevent access by unauthorized personnel. Where there is potential for damage to monitoring wells, the wells will be protected through the use of barricades, fences, or other protective devices. These protective devices will be periodically inspected and maintained in good operating conditions. Monitoring wells will be locked in a closed position between uses.

When no longer needed for monitoring or other use approved by the Division upon a finding of no adverse environmental or health and safety effects, or unless approved for transfer as a water well under R645-301-731.100 through R645-301-731.522 and R645-301-731.800, each well will be capped, sealed, backfilled, or otherwise properly managed, as required by the Division in accordance with R645-301-529.400, R645-301-631.100, and R645-301-748. Permanent closure measures will be designed to prevent access to the mine workings by people, livestock, fish and wildlife, machinery and to keep acid or other toxic drainage from entering ground or surface waters.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

Permanent closure and abandonment of water wells greater than 30 feet in depth will be in accordance with the requirements of "Administrative Rules for Water Well Drillers", State of Utah, Division of Water Rights or other applicable state regulations. Abandonment of wells will be performed by a licensed water well driller. The wells to be abandoned will be completely filled using neat cement grout, sand cement grout, unhydrated bentonite, or bentonite grout, or other materials approved by the Utah State Engineer's office. Alternatively, the well may be abandoned using a different procedure upon approval from the Utah State Engineer's office.

Abandonment materials will be introduced at the bottom of the well or required sealing interval and placed progressively upward to the top of the well. The casing will be severed a minimum of 2 feet below the ground surface. A minimum of 2 feet of compacted native material will be placed above the abandoned well upon completion.

Within 30 days of the completion of well abandonment procedures, a report will be submitted to the State Engineer by the responsible licensed driller giving data related to the abandonment of the well. This shall include the name of the licensed driller or other person(s) performing abandonment procedures, name of well owner at the time of abandonment, the address or location of the well by section, township, and range, abandonment materials and equipment used, water right or file number covering the well, the final disposition of the well, and the date of completion.

Exploration holes and boreholes will be backfilled, plugged, cased, capped, sealed, or otherwise managed to prevent acid or toxic contamination of water resources and to minimize disturbance to the prevailing hydrologic balance. Exploration holes and boreholes will be managed to ensure the safety of people, livestock, fish and wildlife, and machinery.

If any exploration boreholes are to be used as monitoring wells or water wells, these will meet the provisions of R645-301-731

Boreholes will be backfilled to within 1 foot of the land surface with concrete or other materials approved by the Division as necessary to prevent contamination of groundwater or surface-water resources or to protect the prevailing hydrologic balance. The upper approximately 1 foot will be backfilled with native materials to facilitate reclamation (see Drawing 6-11). Exploration holes and boreholes that may be uncovered during mining and reclamation activities will be permanently closed unless approved for water monitoring or otherwise managed in a manner approved by the Division.

740 DESIGN CRITERIA AND PLANS

741 GENERAL REQUIREMENTS

742 SEDIMENT CONTROL MEASURES

742.100 General Requirements

742.110 Design

Appropriate sediment control measures will be designed, constructed and maintained using best technology currently available to prevent to the extent possible, contributions of sediment to stream flow or to runoff outside the permit area; meet the effluent limitations under R645-301-751; and minimize erosion to the extent possible.

Four diversion ditches along with four sediment impoundments are proposed for the permit area. In addition, miscellaneous controls such as silt fence and berms are also proposed for specific areas. The proposed locations for these structures are shown on Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

Sedimentation ponds have been designed in compliance with the requirements of R645-301-356.300, R645-301-356.400, R645-301-513.200, R645-301-742.200 through R645-301-742.240, and R645-301-763.

No sedimentation ponds or earthen structures which will remain open are planned.

The sedimentation plan has been designed to comply with the MSHA requirements given under R645-301-513.100 and R645-301-513.200.

Sediment control methods may include retaining sediment within disturbed areas, diverting runoff away from disturbed areas, diverting runoff using protected channels or pipes through disturbed areas so as not to cause additional erosion; 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; treating with chemicals.

Four diversion ditches along with four sediment impoundments are proposed for the permit area. In addition, miscellaneous controls such as silt fence and berms are also proposed for specific areas. The proposed locations for these structures are shown on

Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

742.200 Siltation Structures

Siltation structures have been designed in compliance with the requirements of R645-301-742.

Miscellaneous controls such as silt fence and berms are proposed for specific areas. The proposed locations for these structures are shown on Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

742.210 General Requirements

Additional contributions of suspended solids and sediment to streamflow or runoff outside the permit area will be prevented to the extent possible using the best technology currently available. Additional contributions of suspended solids and sediment to streamflow or runoff outside the permit area will be prevented to the extent possible using the best technology currently available. Siltation structures for an area will be constructed before beginning any coal mining and reclamation operations in that area and, upon construction, will be certified by a qualified registered professional engineer to be constructed as designed and as approved in the reclamation plan. Any siltation structures which impounds water will be designed, constructed and maintained in accordance with R645-301-512.240, R645-301-514.300, R645-301-515.200, R645-301-533.100 through R645-301-533.600, R645-301-733.220 through R645-301-733.224, and R645-301-743.

742.220 Sedimentation Ponds.

Sedimentation ponds, when used will be used individually or in series; be located as near as possible to the disturbed area and out of perennial streams unless approved by the Division; and be designed, constructed, and maintained to provide adequate detention time to allow the effluent from the ponds to meet Utah and federal effluent limitations; Contain or treat the 10-year, 24-hour precipitation event unless a lesser design event is approved by the Division based on terrain, climate, or other site-specific conditions and on a demonstration that the effluent limitations of R645-301-751 will be met; provide a nonclogging dewatering device adequate to maintain the detention time required under R645-301-742.221.32. Minimize, to the extent possible, short circuiting; Provide periodic sediment removal sufficient to maintain adequate volume for the design event; Ensure against excessive settlement; Be free of sod, large roots, frozen soil, and acid- or toxic-forming coal processing waster and be compacted properly.

Four diversion ditches along with four sediment impoundments are proposed for the permit area. The proposed locations for these structures are shown on Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

Sedimentation ponds have been designed in compliance with the requirements of R645-301-356.300, R645-301-356.400, R645-301-513.200, R645-301-742.200 through R645-301-742.240, and R645-301-763.

No sedimentation ponds or earthen structures which will remain open are planned.

The sedimentation plan has been designed to comply with the MSHA requirements given under R645-301-513.100 and R645-301-513.200.

No sedimentation ponds meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) are planned.

In the future, any sedimentation ponds that may be constructed meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) will comply with all the requirements of that section, and will have a single spillway or principal and emergency spillways that in combination will safely pass a 100-year, 6-hour precipitation event or greater event as demonstrated to be necessary by the Division.

Sedimentation ponds not meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) will provide a combination of principal and emergency spillways that will safely discharge a 25-year, 6 hour precipitation event or greater event as demonstrated to be needed by the Division. Such ponds may use a single open channel spillway if the spillway is: Of nonerodible construction and designed to carry sustained flows; or Earth- or grass-lined and designed to carry short-term infrequent flows at non-erosive velocities where sustained flows are not expected.

The proposed impoundments are designed to temporarily store water from storm events and snow melt. Long term standing water in the impoundments is anticipated to be seasonal and sediment will be removed as necessary to provide the required storage capacities. Emergency spillways have been included in the designs to provide a non-destructive discharge route should the capacities ever be exceeded. Surveys of these impoundments will be regularly conducted to ensure that design capacities are available.

742.230 Other Treatment Facilities

Other treatment facilities will be designed to treat the 10-year, 24-hour precipitation event unless a lesser design event is approved by the Division based on terrain, climate, other site-specific conditions and a demonstration by the operator that the effluent limitations of R645-301-751 will be met.

Other treatment facilities will be designed in accordance with the applicable requirements of 645-301-751.

742.300 Diversions

742-310 General Requirements

All diversions have been designed to minimize adverse impacts to the hydrologic balance within the permit and adjacent areas, to prevent material damage outside the permit area and to assure the safety of the public.

The diversion and its appurtenant structures will be designed, located, constructed, maintained and used to be stable; provide against flooding and resultant damage to life and property; prevent, to the extent possible using the best technology currently available, additional contributions of suspended solids to streamflow outside the permit area; and comply with all applicable local, Utah, and federal laws and regulations.

Temporary diversions will be removed when no longer needed to achieve the purpose for which they were authorized. The land disturbed by the removal process will be restored in accordance with R645-301 and R645-302. Before diversions are removed, downstream water-treatment facilities previously protected by the diversion will be modified or removed, as necessary, ,to prevent overtopping or failure of the facilities. A permanent diversion or a stream channel reclaimed after the removal of a temporary diversion will be designed and constructed so as to restore or approximate the premining characteristics of the original stream channel including the natural riparian vegetation to promote the recovery and enhancement of the aquatic habitat.

742.320 Diversion of Perennial and Intermittent Streams.

All specifications required to meet the requirements for such a diversion have been included in this diversion design with the exception of R645-301-742.322. R645-301-742.322 specifies that the design capacity of the diversion be at minimum the capacity of the natural channel immediately above and below the diversion. Due to the excessive erosion that has occurred in the natural channel, this diversion is not designed to this excess capacity and instead is designed beyond the capacity standard set forth in R645-301-742.323 (100 year, 6 hour). Appendix 5-2 details the analysis/specifications for this diversion and Drawings 5-20 and 5-21 show the details of this design.

742.323

The requirements of R645-301-742.312.2 will be met when the temporary and permanent diversion for perennial and intermittent streams are designed so that the combination of channel, bank and floodplain configuration is adequate to pass safely the peak runoff of a

10-year, 6-hour precipitation event for a temporary diversion and a 100-year, 6-hour precipitation event for a permanent diversion.

Mine development work will include a permanent diversion of Lower Robinson Creek away from the mining area. This diversion has been designed for a flow capacity of a 100 year, 24 hour storm event. The sides will be graded to a 3h:1v slope and rip-rap will be appropriately placed to minimize erosion of the channel beyond current channel conditions. All specifications required to meet the requirements for such a diversion have been included in this diversion design with the exception of R645-301-742.322. R645-301-742.322 specifies that the design capacity of the diversion be at minimum the capacity of the natural channel immediately above and below the diversion. Due to the excessive erosion that has occurred in the natural channel, this diversion is not designed to this excess capacity and instead is designed beyond the capacity standard set forth in R645-301-742.323 (100 year, 6 hour). Appendix 5-2 details the analysis/specifications for this diversion and Drawings 5-20 and 5-21 show the details of this design.

742.324

The design and construction of all stream channel diversions of perennial and intermittent streams have been certified by a qualified registered professional engineer as meeting the performance standards of R645-301 and R645-302 and any design criteria set by the division.

742.330 Diversion of Miscellaneous Flows.

Miscellaneous flows, which consist of all flows except for perennial and intermittent streams, may be diverted away from disturbed areas if required or approved by the Division. Miscellaneous flows will include ground-water discharges and ephemeral streams.

The design, location, construction, maintenance, and removal of miscellaneous flows will meet all of the performance standards set forth in R645-301-742.310.

The requirements of R645-301-742.312.2 will be met when the temporary and permanent diversions for miscellaneous flows are designed so that the combination of channel, bank and floodplain configuration is adequate to pass safely the peak runoff of a 2-year, 6-hour precipitation event for a temporary diversion and a 10-year, 6-hour precipitation event for a permanent Diversion.

742.400 Road Drainage

742.410 All Roads

The design and construction of reconstruction of roads will incorporate appropriate limits for surface drainage control, culvert placement, culvert size, and any necessary design criteria established by the Division.

No part of any road will be located in the channel of an intermittent or perennial stream unless specifically approved by the Division in accordance with applicable parts of R645-301-731 through R645-301-742.300.

Roads will be located to minimize downstream sedimentation and flooding.

All roads used for transporting coal or spoil outside the active mining area are classified as primary roads and all other roads outside the active mining area are classified as ancillary roads; see Drawing 5-3 for location of Primary Roads.

All roads will be maintained on an as needed basis using motor graders, water trucks for dust suppression, and other equipment as necessary. Crushed stone and/or gravel will be used as a surface course for primary roads outside the active mining area, and may be used as needed for ramps and travelways within the pit. Should the roads be damaged by a catastrophic event, such as an earthquake or a flood, repairs will be made as soon as possible after the damage has occurred or the road will be closed and reclaimed.

Cut ditches will be established on the shoulders of all primary roads to control drainage and erosion. Cut and fill slopes along the primary roads will be minimal and are not expected to cause significant erosion. In locations where there are culvert crossings (i.e. Lower Robinson Creek), the fills slopes will be stabilized by utilizing standard methods such as grass matting or straw wattles.

The location and details for roads can be viewed on Drawings 5-3 and 5-22 through 5-24.

742.420 Primary Roads

To minimize erosion, a primary road will be located, insofar as practical, on the most stable available surfaces.

Stream fords by primary roads will not be utilized unless they are specifically approved by the Division as temporary routes during periods of construction.

Planned primary roads have been located on the most stable surfaces available. Stream fords by primary roads have not been planned.

Two primary haul roads are planned within the permit area. The first road extends from the coal unloading area to the first series of pits along the west side of the property. This road will be utilized for access to pits 1 through 15 (pits shown on Drawing 5-10). This road will be approximately 2,600 feet in length and will be utilized mainly during the first two years of mining. There will be three culverts installed along this road all sized for a 100 year, 24 hour storm event. The first culvert will be across a tributary of Lower Robinson Creek and will be a 36 inch corrugated steel pipe. The second culvert is the main crossing over Lower Robinson Creek and is a 96 inch corrugated steel pipe. Both of these culverts have been sized based on analysis of the Lower Robinson Creek watershed. This analysis can be viewed in Appendix 5-1. The third culvert is crossing over a diversion ditch that will route water mainly from disturbed areas along the south side of Lower Robinson Creek to a sediment impoundment. This culvert will be a 24 inch corrugated steel pipe appropriately sized for the maximum flows expected in the diversion.

The second road extends from an intersection with the first road, located just south of the Lower Robinson Creek crossing, and proceeds south to approximately pit 25. This road is approximately 2,500 feet in length and will be used for the south pits 16 through 30. There is one culvert crossing along this road to cross a diversion ditch. This culvert will be a 24 inch culvert sized for maximum anticipated flows in the diversion.

742.423 Drainage Control

Primary roads will be designed, constructed or reconstructed and maintained to have adequate drainage control, using structures such as bridges, ditches, cross drains, and ditch relief drains. The drainage control system will be designed to pass the peak runoff safely from a 10-year, 6-hour precipitation event, or an alternative event of greater size as demonstrated to be needed by the Division.

Drainage pipes and culverts will be constructed to avoid plugging or collapse and erosion at inlets and outlets.

Drainage ditches will be designed to prevent uncontrolled drainage over the road surface and embankment. Trash racks and debris basins will be installed in the drainage ditches where debris from the drainage area may impair the functions of drainage and sediment control structures.

Natural stream channels will not be altered or relocated without the prior approval of the Division in accordance with R645-301-731.100 through R645-301-731.522, R645-301-731.600, R645-301-731.800, R645-301-742.300, and R645-301-751.

Except as provided in R645-301-742.422, drainage structures will be used for stream channel crossings, made using bridges, culverts or other structures designed, constructed and maintained using current, prudent engineering practice.

The primary roads are designed on the most practicable, stable surfaces.

The following specifications apply to the Primary roads:

1) Roads will be approximately 80' in width
2) Approximately a 2% crown
3) Approximately one foot deep cut ditches along shoulders for controlling storm water
4) 18" of crushed rock or gravel for road surfacing
5) Cut and fill slopes of 1.5 h:1v
6) Minimum fill over each culvert will be 2 times diameter of culvert
7) 6 foot berms placed as necessary along fills

The ancillary roads will have similar specifications except surfacing will occur only as needed and may be narrowed to a 40 foot road width.

The location and details for roads can be viewed on Drawings 5-3 and 5-22 through 5-24.

743 IMPOUNDMENTS

743.100 General Requirements

Temporary and permanent impoundments meeting the Class B or C criteria for dams in the U.S. Department of Agriculture, Natural Resources Conservation Services Technical Release No. 60. Earth Dams and Reservoirs will comply with the Minimum Emergence Spillway Hydrologic Criteria, table in TR-60 and the requirements of this section.

Impoundments meeting the criteria of MSHA, 30 CFR 77.216(a) will comply with the requirements of 77.216 and R645-301-512.240, R645-301-514.300, R645-301-515.200, R645-301-533.100 through R645-301-533.600, R645-301-733.220 through R645-301-733.224, and R645-301-743. The plan required to be submitted to the Division as part of the permit application.

The design of impoundments will be prepared and certified as described under R645-301-512. Impoundments will have adequate freeboard to resist overtopping by waves and by sudden increases in storage volume. Impoundments meeting the NRCS Class B or C criteria for dams in TR-60 will comply with the freeboard hydrograph criteria in the "Minimum Emergency Spillway Hydrologic Criteria" table in TR-60.

Impoundments will include either a combination of principal and emergency spillways or a single spillway as specified in 743.131 which will be designed and constructed to safely

pass the design precipitation event or greater event specified in R645-301-743.200 or R645-301-743.300

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

A professional engineer experienced in the design and construction of impoundments with assistance from a geotechnical expert has used current, prudent, engineering practices to design the proposed impoundments. The plans have been certified and a detailed geotechnical analysis has been provided. The certifications and drawings can be viewed in Drawings 5-25 through 5-31 and Appendices A5-1 and A5-2

A professional engineer or specialist experienced in the construction of impoundments will inspect impoundments. Inspections will be made regularly during construction, upon completion of construction, and at least yearly until removal of the structure or release of the performance bond. The qualified registered professional engineer will promptly, after each inspection, provide to the Division, a certified report that the impoundment has been constructed and maintained as designed and in accordance with the approved plan and the R645 Rules. The report will include discussion of any appearances of instability, structural weakness or other hazardous conditions, depth and elevation of any impounded waters, existing storage capacity, any existing or required monitoring procedures and instrumentation and any other aspects of the structure affecting stability. A copy of the report will be retained at or near the mine site.

The MRP does not contemplate construction of any impoundments meeting the NRCS Class B or C criteria for dams in TR-60, or the size or other criteria of 30 CFR Sec. 77.216. If such impoundments become necessary, they will be examined in accordance with 30 CFR Sec. 77.216-3. Impoundments not meeting the NRCS Class B or C Criteria for dams in TR-60, or subject to 30 CFR Sec. 77.216, will be examined at least quarterly. A qualified person designated by Alton Coal Development LLC will examine impoundments for the appearance of structural weakness and other hazardous conditions.

If any examination or inspection of an impoundment discloses that a potential hazard exists, the person who examined the impoundment will promptly inform the Division of the finding and of the emergency procedures formulated for public protection and remedial action. If adequate procedures cannot be formulated or implemented, the Division will be notified immediately.

744 DISCHARGE STRUCTURES

Discharge from sedimentation ponds, permanent and temporary impoundments, coal processing waste dams and embankments, an diversion sill be controlled, by energy dissipaters, riprap channels and other devices, where necessary to reduce erosion to prevent deepening or enlargement of stream channels, and to minimize disturbance of the hydrologic balance.

Discharge structures will be designed according to standard engineering design procedures.

The proposed impoundments are designed to temporarily store water from storm events and snow melt. Long term standing water in the impoundments is anticipated to be seasonal and sediment will be removed as necessary to provide the required storage capacities. Emergency spillways have been included in the designs to provide a non-destructive discharge route should the capacities ever be exceeded. Surveys of these impoundments will be regularly conducted to ensure that design capacities are available.

744 Disposal of Excess Spoil

744.100 General Requirements

Excess spoil will be placed in designated disposal areas within the permit area, in a controlled manner to minimize the adverse effects of leachate and surface water runoff from the fill on surface and ground waters; ensure permanent impoundments are not located on the completed fill. Small depressions may be created if approved by the Division if they are needed to retain moisture or minimize erosion, create and enhance wildlife habitat or assist revegetation, and if they are not incompatible with the stability of the fill; and adequately cover or treat excess spoil that is acid- and toxic-forming with nonacid nontoxic material to control the impact on surface and ground water is accordance with R645-301-731.300 and to minimize adverse effects on plant growth and the approved postmining land use.

If the disposal area contains springs, natural or manmade water courses or wet weather seeps, the fill design will include diversions and underdrains as necessary to control erosion, prevent water infiltration into the fill and ensure stability.

Details of proposed excess spoil disposal plans are presented in Chapter 5, Section 535 of this MRP and are summarized below.

A geotechnical analysis has been completed for the proposed excess spoil structure. This analysis estimates the long-term safety factor to be 1.7 to 1.8 based on the proposed design. Following proper construction practices of building the structure in maximum four foot lifts and meeting 90% compaction based on the standard Procter will ensure that the structure will be stable under all conditions of construction. This construction will occur only in the designated excess spoil area as shown on Drawing 5-3 and 5-35. The fill will be placed with end dump haul trucks and lifts will be constructed using dozers. High precision GPS systems will be regularly utilized to check grades and appropriate lift thickness. The geotechnical analysis for this structure can be viewed in Appendix 5-1.

The excess spoil is planned to be placed in an area where natural grades range from 0 to 5%. This is one of the most moderately sloping locations in the Permit Area. Stability of this structure is estimated to be 1.7 to 1.8 based on the Appendix 5-1.

Geotechnical borings were completed in the foundation of the proposed disposal area. Laboratory analysis of these borings has also been completed. Details of this analysis can be viewed in Appendix 5-1.

Permanent slopes for the proposed excess spoil will not exceed 3h:1v (33 percent), therefore no keyway cuts have been proposed in the design. Appendix 5-1 details the stability analysis for the proposed structure.

Excess spoil will not be disposed of in underground mine workings.

Horizontal lifts will not exceed four feet in thickness unless otherwise approved by the Division. The lifts will be concurrently compacted to meet 90% of the standard Procter. The geotechnical analysis (Appendix 5-1), provides information showing that these construction standards will provide mass stability and will prevent mass movement during and after construction. The excess spoil will be graded to provide drainage similar to original flow patterns. Topsoil and subsoil as designated in Chapter 2 will be removed and separated from other materials prior to placement of spoil.

A description of the character of the bedrock and any adverse geologic conditions in presented in Appendix 5-1.

Spring and seep survey information is provided on Drawing 7-1. There are no springs or seeps identified in the excess spoil area.

There are no historical underground mining operations in the proposed excess spoil area. There are also no future underground operations proposed.

There are no rock chimneys or drainage blankets proposed.

A stability analysis including strength parameters, pore pressures and long-term seepage conditions is presented together with all supporting data in Appendix 5-1.

Neither rock-toe buttresses nor key-way cuts are required under R645-301-535.112 or R645-301-535.113.

No valley fills or head-of-hollow fills are proposed.

No durable rock fills are proposed.

No disposal of waste on preexisting benches is planned

The excess spoil structure and fill above approximate original contour are the only alternative specifications proposed. A geotechnical analysis has been completed for this proposal and can be viewed in Appendix 5-1. All other mined areas will be restored to approximate original contour.

745.200 Valley Fills and Head-of-Hollow Fills

Valley fills and head-of-hollow fills are not anticipated in the proposed Coal Hollow Mine permit area.

745.300. Durable Rock Fills.

Durable rock fills are not anticipated in the proposed Coal Hollow Mine permit area.

745.400. Preexisting Benches.

The disposal of excess spoil through placement on preexisting benches is not anticipated in the proposed Coal Hollow Mine permit area.

746. COAL MINE WASTE

746.100. General Requirements.

No coal mine waste is anticipated.

746.200. Refuse Piles.

Not applicable

746.300. Impounding structures.

Not applicable

746.330. Drainage control.

Not applicable.

746.400. Return of Coal Processing Waste to Abandoned Underground Workings.

Not applicable

747. DISPOSAL OF NONCOAL WASTE

Noncoal mine waste, including but not limited to grease, lubricants, paints, flammable liquids, garbage, machinery, lumber and other combustible materials generated during coal mining and reclamation operations will be placed and stored in a controlled manner in a designated portion of the permit area or state-approved solid waste disposal area.

Topsoil storage areas and handling can be viewed on Drawing 2-2. Spoil placement and the excess spoil structure can be viewed on Drawings 5-3, 5-17, 5-18, 5-19, 5-35 and 5-36.

Only sizing of the coal is proposed. This process will not produce any waste.

Final disposal of noncoal mine wastes will be in a designated disposal site in the permit area or a State-approved solid waste disposal area. Disposal sites in the permit area will be designed and constructed to ensure that leachate and drainage from the noncoal mine waste area does not degrade surface or underground water. Wastes will be routinely compacted and covered to prevent combustion and wind-borne waste. When the disposal is completed, a minimum of two feet of soil cover will be placed over the site, slopes, stabilized, and revegetation accomplished in accordance with 244.200 and R645-301-353 through R645-301-357. Operation of the disposal site will be conducted in accordance with all local, Utah, and Federal requirements.

At no time will any noncoal mine waste be deposited in a refuse pile or impounding structure, nor will any excavation for a noncoal mine waste disposal site be located within eight feet of any coal outcrop or coal storage area.

Notwithstanding any other provision to the R645 Rules, any noncoal mine waste defined as "hazardous" under 3001 of the Resource Conservation and Recovery Act (RCRA) (Pub. L. 94-580, as amended) and 40 CFR Part 261 will be handled in accordance with the requirements of Subtitle C of RCRA and any implementing regulations.

Debris, acid-forming, toxic-forming materials and materials constituting a fire hazard will be identified and disposed of in accordance with R645-301-528.330, R645-301-537.200, R645-301-542.740, R645-301-553.100 through R645-301-553.600, R645-301-553.900, and R645-301-747. Appropriate measures will be implemented to preclude sustained combustion of such materials.

Plans do not include using dams, embankments or other impoundments for disposal of coal, overburden, excess spoil or coal mine waste.

Placement and storage of noncoal mine waste within the permit area will ensure that leachate and surface runoff do not degrade surface or ground water.

Final disposal of noncoal mine waste within the permit area will ensure that leachate and drainage does not degrade surface or underground water.

748. Casing and Sealing of Wells.

Wells constructed for monitoring groundwater conditions in the proposed Coal Hollow Mine permit and adjacent area, including exploration holes and boreholes used for water wells or monitoring wells, will be designed to prevent contamination of groundwater and surface-water resources and to protect the hydrologic balance. A diagram depicting typical monitoring well construction methods is shown in Drawing 7-11. Monitoring wells will include a protective hydraulic seal immediately above the screened interval, an annular seal plugging the borehole above the hydraulic seal to near the ground surface, and a concrete surface seal extending from the top of the hydraulic seal to the ground surface which is sloped away from the well casing to prevent the entrance of surface flows into the borehole area. Well casings will protrude above the ground surface a sufficient height so as to minimize the potential for the entrance of surface water or other material into the well. A steel surface protector with a locking cover will be installed at monitoring wells to prevent access by unauthorized personnel. Where there is potential for damage to monitoring wells, the wells will be protected through the use of barricades, fences, or other protective devices. These protective devices will be periodically inspected and maintained in good operating conditions. Monitoring wells will be locked in a closed position between uses.

When no longer needed for monitoring or other use approved by the Division upon a finding of no adverse environmental or health and safety effects, or unless approved for transfer as a water well under R645-301-731.100 through R645-301-731.522 and R645-301-731.800, each well will be capped, sealed, backfilled, or otherwise properly managed, as required by the Division in accordance with R645-301-529.400, R645-301-631.100, and R645-301-748. Permanent closure measures will be designed to prevent access to the mine workings by people, livestock, fish and wildlife, machinery and to keep acid or other toxic drainage from entering ground or surface waters.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

Permanent closure and abandonment of water wells greater than 30 feet in depth will be in accordance with the requirements of "Administrative Rules for Water Well Drillers", State of Utah, Division of Water Rights or other applicable state regulations. Abandonment of wells will be performed by a licensed water well driller. The wells to be abandoned will be completely filled using neat cement grout, sand cement grout, unhydrated bentonite, or bentonite grout, or other materials approved by the Utah State Engineer's office. Alternatively, the well may be abandoned using a different procedure upon approval from the Utah State Engineer's office.

Abandonment materials will be introduced at the bottom of the well or required sealing interval and placed progressively upward to the top of the well. The casing will be severed a minimum of 2 feet below the ground surface. A minimum of 2 feet of compacted native material will be placed above the abandoned well upon completion.

Within 30 days of the completion of well abandonment procedures, a report will be submitted to the State Engineer by the responsible licensed driller giving data related to the abandonment of the well. This shall include the name of the licensed driller or other person(s) performing abandonment procedures, name of well owner at the time of abandonment, the address or location of the well by section, township, and range, abandonment materials and equipment used, water right or file number covering the well, the final disposition of the well, and the date of completion.

Exploration holes and boreholes will be backfilled, plugged, cased, capped, sealed, or otherwise managed to prevent acid or toxic contamination of water resources and to minimize disturbance to the prevailing hydrologic balance. Exploration holes and boreholes will be managed to ensure the safety of people, livestock, fish and wildlife, and machinery.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

If any exploration boreholes are to be used as monitoring wells or water wells, these will meet the provisions of R645-301-731

Boreholes will be backfilled to within 1 foot of the land surface with concrete or other materials approved by the Division as necessary to prevent contamination of groundwater or surface-water resources or to protect the prevailing hydrologic balance. The upper approximately 1 foot will be backfilled with native materials to facilitate reclamation (see Drawing 6-11). Exploration holes and boreholes that may be uncovered during mining and reclamation activities will be permanently closed unless approved for water monitoring or otherwise managed in a manner approved by the Division.

750 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. Mining 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.

751. Water Quality Standards and Effluent Limitations.

Discharges of water from areas disturbed by coal mining and reclamation operations will be made in compliance with all Utah and federal water quality laws and regulations and with effluent limitations for coal mining promulgated by the U.S. Environmental Protection Agency set forth in 40 CFR Part 434.

752. 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.

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.

Four diversion ditches along with four sediment impoundments are proposed for the permit area. The proposed locations for these structures are shown on Drawing 5-3. Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

Sedimentation ponds have been designed in compliance with the requirements of R645-301-356.300, R645-301-356.400, R645-301-513.200, R645-301-742.200 through R645-301-742.240, and R645-301-763.

No sedimentation ponds or earthen structures which will remain open are planned.

The sedimentation plan has been designed to comply with the MSHA requirements given under R645-301-513.100 and R645-301-513.200.

No sedimentation ponds meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) are planned.

In the future, any sedimentation ponds that may be constructed meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) will comply with all the requirements of that section, and will have a single spillway or principal and emergency spillways that in combination will safely pass a 100-year, 6-hour precipitation event or greater event as demonstrated to be necessary by the Division.

Sedimentation ponds not meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) will provide a combination of principal and emergency spillways that will safely discharge a 25-year, 6 hour precipitation event or greater event as demonstrated to be needed by the Division. Such ponds may use a single open channel spillway if the spillway is: Of nonerodible construction and designed to carry sustained flows; or Earth- or grass-lined and designed to carry short-term infrequent flows at non-erosive velocities where sustained flows are not expected.

The proposed impoundments are designed to temporarily store water from storm events and snow melt. Long term standing water in the impoundments is anticipated to be seasonal and sediment will be removed as necessary to provide the required storage capacities. Emergency spillways have been included in the designs to provide a non-destructive discharge route should the capacities ever be exceeded. Surveys of these impoundments will be regularly conducted to ensure that design capacities are available.

Precipitation waters falling on disturbed areas will be contained in diversion ditches and routed to sediment impoundments that are designed to impound seasonal water and storms. Sediment control facilities will be designed and constructed to be geotechnically stable. This will minimize the potential for breaches of sediment control structures, which if they occur could result in down-stream flooding and increases in stream erosion and sediment yield.

Details associated with these structures can be viewed on Drawings 5-25 through 5-34 and Appendix 5-2.

752.200. 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 and to achieve the following:

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;

Control or prevent additional contributions of suspended solids to stream flow or runoff outside the permit area;

Neither cause nor contribute to, directly or indirectly, the violation of effluent standards given under R645-301-751;

Minimize the diminution to or degradation of the quality or quantity of surface- and ground-water systems; and

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

753. 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, R645-301-745 and R645-301-760.

A professional engineer experienced in the design and construction of impoundments with assistance from a geotechnical expert has used current, prudent, engineering practices to design the proposed impoundments. The plans have been certified and a detailed geotechnical analysis has been provided. The certifications and drawings can be viewed in Drawings 5-25 through 5-31 and Appendices A5-1 and A5-2.

There are four sediment impoundments proposed for the permit area. These structures will be constructed using a combination of dozers and backhoes. The structures have been designed to contain the required storm events as specified in Appendix 5-2. The structures will have sediment removed as necessary to ensure the required capacities.

Sediment control facilities have been designed and constructed to be geotechnically stable. This will minimize the potential for breaches of sediment control structures, which if they occur could result in down-stream flooding and increases in stream erosion and sediment yield.

Impoundments will be inspected as described under R645-301-514.300. Designs for proposed impoundments in the proposed Coal Hollow permit area are shown in Drawings 5-25 through 5-31 and Appendices A5-1 and A5-2. No impoundments or sedimentation ponds meeting the size or other qualifying criteria of MSHA, 30 CFR 77.216(a) exist or are planned within the proposed Mine Permit Area.

A professional engineer or specialist experienced in the construction of impoundments will inspect impoundments. Inspections will be made regularly during construction, upon completion of construction, and at least yearly until removal of the structure or release of the performance bond. The qualified registered professional engineer will promptly, after each inspection, provide to the Division, a certified report that the impoundment has been constructed and maintained as designed and in accordance with the approved plan and the R645 Rules. The report will include discussion of any appearances of instability, structural weakness or other hazardous conditions, depth and elevation of any impounded

waters, existing storage capacity, any existing or required monitoring procedures and instrumentation and any other aspects of the structure affecting stability. A copy of the report will be retained at or near the mine site.

The proposed impoundments are designed to temporarily store water from storm events and snow melt. Long term standing water in the impoundments is anticipated to be seasonal and sediment will be removed as necessary to provide the required storage capacities. Emergency spillways have been included in the designs to provide a non-destructive discharge route should the capacities ever be exceeded. Surveys of these impoundments will be regularly conducted to ensure that design capacities are available.

754. 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.

Excess Spoil

Excess spoil will be placed in designated disposal areas within the permit area, in a controlled manner to minimize the adverse effects of leachate and surface water runoff from the fill on surface and ground waters; ensure permanent impoundments are not located on the completed fill. Small depressions may be created if approved by the Division if they are needed to retain moisture or minimize erosion, create and enhance wildlife habitat or assist revegetation, and if they are not incompatible with the stability of the fill; and adequately cover or treat excess spoil that is acid- and toxic-forming with nonacid nontoxic material to control the impact on surface and ground water is accordance with R645-301-731.300 and to minimize adverse effects on plant growth and the approved postmining land use.

If the disposal area contains springs, natural or manmade water courses or wet weather seeps, the fill design will include diversions and underdrains as necessary to control erosion, prevent water infiltration into the fill and ensure stability.

Details of proposed excess spoil disposal plans are presented in Chapter 5, Section 535 of this MRP and are summarized below.

A geotechnical analysis has been completed for the proposed excess spoil structure. This analysis estimates the long-term safety factor to be 1.7 to 1.8 based on the proposed design. Following proper construction practices of building the structure in maximum four foot lifts and meeting 90% compaction based on the standard Procter will ensure that the structure will be stable under all conditions of construction. This construction will occur only in the designated excess spoil area as shown on Drawing 5-3 and 5-35. The fill will be placed with end dump haul trucks and lifts will be constructed using dozers.

High precision GPS systems will be regularly utilized to check grades and appropriate lift thickness. The geotechnical analysis for this structure can be viewed in Appendix 5-1.

The excess spoil is planned to be placed in an area where natural grades range from 0 to 5%. This is one of the most moderately sloping locations in the Permit Area. Stability of this structure is estimated to be 1.7 to 1.8 based on the Appendix 5-1.

Geotechnical borings were completed in the foundation of the proposed disposal area. Laboratory analysis of these borings has also been completed. Details of this analysis can be viewed in Appendix 5-1.

Permanent slopes for the proposed excess spoil will not exceed 3h:1v (33 percent), therefore no keyway cuts have been proposed in the design. Appendix 5-1 details the stability analysis for the proposed structure.

Excess spoil will not be disposed of in underground mine workings.

Horizontal lifts will not exceed four feet in thickness unless otherwise approved by the Division. The lifts will be concurrently compacted to meet 90% of the standard Procter. The geotechnical analysis (Appendix 5-1), provides information showing that these construction standards will provide mass stability and will prevent mass movement during and after construction. The excess spoil will be graded to provide drainage similar to original flow patterns. Topsoil and subsoil as designated in Chapter 2 will be removed and separated from other materials prior to placement of spoil.

Coal Mine Waste

Not applicable

Noncoal Mine Waste

Noncoal mine waste, including but not limited to grease, lubricants, paints, flammable liquids, garbage, machinery, lumber and other combustible materials generated during coal mining and reclamation operations will be placed and stored in a controlled manner in a designated portion of the permit area or state-approved solid waste disposal area.

Topsoil storage areas and handling can be viewed on Drawing 2-2. Spoil placement and the excess spoil structure can be viewed on Drawings 5-3, 5-17, 5-18, 5-19, 5-35 and 5-36.

Only sizing of the coal is proposed. This process will not produce any waste.

Final disposal of noncoal mine wastes will be in a designated disposal site in the permit area or a State-approved solid waste disposal area. Disposal sites in the permit area will be designed and constructed to ensure that leachate and drainage from the noncoal mine waste area does not degrade surface or underground water. Wastes will be routinely compacted and covered to prevent combustion and wind-borne waste. When the disposal is completed, a minimum of two feet of soil cover will be placed over the site, slopes, stabilized, and revegetation accomplished in accordance with 244.200 and R645-301-353 through R645-301-357. Operation of the disposal site will be conducted in accordance with all local, Utah, and Federal requirements.

At no time will any noncoal mine waste be deposited in a refuse pile or impounding structure, nor will any excavation for a noncoal mine waste disposal site be located within eight feet of any coal outcrop or coal storage area.

Notwithstanding any other provision to the R645 Rules, any noncoal mine waste defined as "hazardous" under 3001 of the Resource Conservation and Recovery Act (RCRA) (Pub. L. 94-580, as amended) and 40 CFR Part 261 will be handled in accordance with the requirements of Subtitle C of RCRA and any implementing regulations.

Debris, acid-forming, toxic-forming materials and materials constituting a fire hazard will be identified and disposed of in accordance with R645-301-528.330, R645-301-537.200, R645-301-542.740, R645-301-553.100 through R645-301-553.600, R645-301-553.900, and R645-301-747. Appropriate measures will be implemented to preclude sustained combustion of such materials.

Plans do not include using dams, embankments or other impoundments for disposal of coal, overburden, excess spoil or coal mine waste.

Placement and storage of noncoal mine waste within the permit area will ensure that leachate and surface runoff do not degrade surface or ground water.

Final disposal of noncoal mine waste within the permit area will ensure that leachate and drainage does not degrade surface or underground water.

755. 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.

Wells constructed for monitoring groundwater conditions in the proposed Coal Hollow Mine permit and adjacent area, including exploration holes and boreholes used for water wells or monitoring wells, will be designed to prevent contamination of groundwater and surface-water resources and to protect the hydrologic balance. A diagram depicting typical monitoring well construction methods is shown in Drawing 7-11. Monitoring wells will include a protective hydraulic seal immediately above the screened interval, an

annular seal plugging the borehole above the hydraulic seal to near the ground surface, and a concrete surface seal extending from the top of the hydraulic seal to the ground surface which is sloped away from the well casing to prevent the entrance of surface flows into the borehole area. Well casings will protrude above the ground surface a sufficient height so as to minimize the potential for the entrance of surface water or other material into the well. A steel surface protector with a locking cover will be installed at monitoring wells to prevent access by unauthorized personnel. Where there is potential for damage to monitoring wells, the wells will be protected through the use of barricades, fences, or other protective devices. These protective devices will be periodically inspected and maintained in good operating conditions. Monitoring wells will be locked in a closed position between uses.

When no longer needed for monitoring or other use approved by the Division upon a finding of no adverse environmental or health and safety effects, or unless approved for transfer as a water well under R645-301-731.100 through R645-301-731.522 and R645-301-731.800, each well will be capped, sealed, backfilled, or otherwise properly managed, as required by the Division in accordance with R645-301-529.400, R645-301-631.100, and R645-301-748. Permanent closure measures will be designed to prevent access to the mine workings by people, livestock, fish and wildlife, machinery and to keep acid or other toxic drainage from entering ground or surface waters.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

Permanent closure and abandonment of water wells greater than 30 feet in depth will be in accordance with the requirements of "Administrative Rules for Water Well Drillers", State of Utah, Division of Water Rights or other applicable state regulations. Abandonment of wells will be performed by a licensed water well driller. The wells to be abandoned will be completely filled using neat cement grout, sand cement grout, unhydrated bentonite, or bentonite grout, or other materials approved by the Utah State Engineer's office. Alternatively, the well may be abandoned using a different procedure upon approval from the Utah State Engineer's office.

Abandonment materials will be introduced at the bottom of the well or required sealing interval and placed progressively upward to the top of the well. The casing will be severed a minimum of 2 feet below the ground surface. A minimum of 2 feet of compacted native material will be placed above the abandoned well upon completion.

Within 30 days of the completion of well abandonment procedures, a report will be submitted to the State Engineer by the responsible licensed driller giving data related to the abandonment of the well. This shall include the name of the licensed driller or other person(s) performing abandonment procedures, name of well owner at the time of abandonment, the address or location of the well by section, township, and range, abandonment materials and equipment used, water right or file number covering the well, the final disposition of the well, and the date of completion.

Exploration holes and boreholes will be backfilled, plugged, cased, capped, sealed, or otherwise managed to prevent acid or toxic contamination of water resources and to minimize disturbance to the prevailing hydrologic balance. Exploration holes and boreholes will be managed to ensure the safety of people, livestock, fish and wildlife, and machinery.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

If any exploration boreholes are to be used as monitoring wells or water wells, these will meet the provisions of R645-301-731

Boreholes will be backfilled to within 1 foot of the land surface with concrete or other materials approved by the Division as necessary to prevent contamination of groundwater or surface-water resources or to protect the prevailing hydrologic balance. The upper approximately 1 foot will be backfilled with native materials to facilitate reclamation (see Drawing 6-11). Exploration holes and boreholes that may be uncovered during mining and reclamation activities will be permanently closed unless approved for water monitoring or otherwise managed in a manner approved by the Division.

760. RECLAMATION

761. GENERAL REQUIREMENTS

Before abandoning a permit area or seeking bond release, the mine will ensure that all temporary structures are removed and reclaimed, and that all permanent sedimentation ponds, diversions, impoundments and treatment facilities meet the requirements of R645-301 and R645-302 for permanent structures, have been maintained properly and meet the requirements of the approved reclamation plan for permanent structures and impoundments. The mine will renovate such structures if necessary to meet the requirements of R645-301 and R645-302 and to conform to the approved reclamation plan.

762. ROADS

A road not to be retained for use under an approved postmining land use will be reclaimed immediately after it is no longer needed for coal mining and reclamation operations, including restoring the natural drainage patterns, and reshaping all cut and fill slopes to be compatible with the postmining land use and to complement the drainage pattern of the surrounding terrain.

The post mining land configuration is shown on 5-35.

763. SILTATION STRUCTURES

763.100.

Siltation structures will be maintained until removal is authorized by the Division and the disturbed area has been stabilized and revegetated. In no case will the structure be removed sooner than two years after the last augmented seeding.

All impoundments will be reclaimed at the end of operations. The estimated timeline for removal of these structures are shown on Drawing 5-38. Expected removal is year four of the mining and reclamation process. In areas where soils are not stabilized following the removal of these sediment impoundments, silt fence will be appropriately installed and maintained to provide sediment control until stable conditions are met.

763.200.

When the siltation structure is removed, the land on which the siltation structure was located will be regraded and revegetated in accordance with the reclamation plan and R645-301-358, R645-301-356, and R645-301-357.

No permanent sedimentation ponds are planned.

764. STRUCTURE REMOVAL

The application will include the timetable and plans to remove each structure, if appropriate.

All impoundments will be reclaimed at the end of operations. The estimated timeline for removal of these structures are shown on Drawing 5-38. Expected removal is year four of the mining and reclamation process. In areas where soils are not stabilized following the removal of these sediment impoundments, silt fence will be appropriately installed and maintained to provide sediment control until stable conditions are met.

The facilities will be fully reclaimed at the end of mining operations. The final contour for this area can be viewed on Drawing 5-35.

The reclamation sequence and final landform can be viewed on Drawings 5-35 and 5-38.

765. PERMANENT CASING AND SEALING OF WELLS

Wells constructed for monitoring groundwater conditions in the proposed Coal Hollow Mine permit and adjacent area, including exploration holes and boreholes used for water wells or monitoring wells, will be designed to prevent contamination of groundwater and surface-water resources and to protect the hydrologic balance. A diagram depicting typical monitoring well construction methods is shown in Drawing 7-11. Monitoring wells will include a protective hydraulic seal immediately above the screened interval, an

annular seal plugging the borehole above the hydraulic seal to near the ground surface, and a concrete surface seal extending from the top of the hydraulic seal to the ground surface which is sloped away from the well casing to prevent the entrance of surface flows into the borehole area. Well casings will protrude above the ground surface a sufficient height so as to minimize the potential for the entrance of surface water or other material into the well. A steel surface protector with a locking cover will be installed at monitoring wells to prevent access by unauthorized personnel. Where there is potential for damage to monitoring wells, the wells will be protected through the use of barricades, fences, or other protective devices. These protective devices will be periodically inspected and maintained in good operating conditions. Monitoring wells will be locked in a closed position between uses.

When no longer needed for monitoring or other use approved by the Division upon a finding of no adverse environmental or health and safety effects, or unless approved for transfer as a water well under R645-301-731.100 through R645-301-731.522 and R645-301-731.800, each well will be capped, sealed, backfilled, or otherwise properly managed, as required by the Division in accordance with R645-301-529.400, R645-301-631.100, and R645-301-748. Permanent closure measures will be designed to prevent access to the mine workings by people, livestock, fish and wildlife, machinery and to keep acid or other toxic drainage from entering ground or surface waters.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

Permanent closure and abandonment of water wells greater than 30 feet in depth will be in accordance with the requirements of "Administrative Rules for Water Well Drillers", State of Utah, Division of Water Rights or other applicable state regulations. Abandonment of wells will be performed by a licensed water well driller. The wells to be abandoned will be completely filled using neat cement grout, sand cement grout, unhydrated bentonite, or bentonite grout, or other materials approved by the Utah State Engineer's office. Alternatively, the well may be abandoned using a different procedure upon approval from the Utah State Engineer's office.

Abandonment materials will be introduced at the bottom of the well or required sealing interval and placed progressively upward to the top of the well. The casing will be severed a minimum of 2 feet below the ground surface. A minimum of 2 feet of compacted native material will be placed above the abandoned well upon completion.

Within 30 days of the completion of well abandonment procedures, a report will be submitted to the State Engineer by the responsible licensed driller giving data related to the abandonment of the well. This shall include the name of the licensed driller or other person(s) performing abandonment procedures, name of well owner at the time of abandonment, the address or location of the well by section, township, and range, abandonment materials and equipment used, water right or file number covering the well, the final disposition of the well, and the date of completion.

Exploration holes and boreholes will be backfilled, plugged, cased, capped, sealed, or otherwise managed to prevent acid or toxic contamination of water resources and to minimize disturbance to the prevailing hydrologic balance. Exploration holes and boreholes will be managed to ensure the safety of people, livestock, fish and wildlife, and machinery.

If a water well is exposed by coal mining and reclamation operations, it will be permanently closed unless otherwise managed in a manner approved by the Division.

If any exploration boreholes are to be used as monitoring wells or water wells, these will meet the provisions of R645-301-731

Boreholes will be backfilled to within 1 foot of the land surface with concrete or other materials approved by the Division as necessary to prevent contamination of groundwater or surface-water resources or to protect the prevailing hydrologic balance. The upper approximately 1 foot will be backfilled with native materials to facilitate reclamation (see Drawing 6-11). Exploration holes and boreholes that may be uncovered during mining and reclamation activities will be permanently closed unless approved for water monitoring or otherwise managed in a manner approved by the Division.

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Table 7-1 Baseline monitoring station locations and details.

Site	UTM location, Z12, NAD 27		Elevation (approx)	Drainage basin	Geologic Formation	Uses
Springs						
SP-3	4136009	372028	6882	lower Sink Valley Wash	Pediment alluvium	Wildlife, contritubes to stream flow
SP-4	4136427	371531	6700	lower Sink Valley Wash	Dakota/fault ?	Stock watering
SP-5	4137820	373080	7215	Sink Valley	Pediment alluvium	None apparent
SP-6	4137977	371717	6829	Sink Valley	Alluvium	Stock watering, wildlife
SP-8	4139231	371861	6920	Sink Valley	Alluvium	Domestic, stock watering, wildlife, irrigation historically
SP-14	4139790	372023	6985	Sink Valley	alluvium	Stock watering, wildlife
SP-15	4139660	371960	6980	Sink Valley	alluvium	Stock watering, wildlife
SP-16	4139656	372035	6980	Sink Valley	alluvium	Stock watering, wildlife
SP-17	4139559	372236	6970	Sink Valley	alluvium	None apparent
SP-18	4139486	372196	6965	Sink Valley	alluvium	None apparent
SP-19	4139384	372256	6960	Sink Valley	alluvium	Stock watering
SP-20	4139325	372014	6940	Sink Valley	alluvium	Stock watering, wildlife, irrigation historically
SP-21	4139289	371980	6940	Sink Valley	alluvium	Wildlife
SP-22	4139423	371863	6940	Sink Valley	alluvium	Wildlife
SP-23	4139382	371838	6935	Sink Valley	alluvium	Wildlife
SP-24	4139356	371822	6920	Sink Valley	alluvium	Wildlife
SP-25	4139322	371798	6920	Sink Valley	alluvium	wildlife
SP-26	4139211	371717	6920	Sink Valley	alluvium	Stock watering, wildlife
SP-27	4137416	371645	6800	Sink Valley	Dakota Formation	None apparent
SP-28	4137718	371896	6790	Sink Valley	alluvium	Wildlife
SP-29	4137853	371885	6800	Sink Valley	alluvium	Wildlife
SP-30	4137787	371852	6800	Sink Valley	alluvium	None apparent
SP-31	4137764	371830	6800	Sink Valley	alluvium	None apparent
SP-32	4137864	371810	6800	Sink Valley	alluvium	Stock watering, wildlife
SP-33	4137543	371788	6785	Sink Valley	alluvium	Domestic, stock watering, wildlife
SP-34	4135632	371512	6660	lower Sink Valley Wash	colluvium/Dakota	None apparent
SP-35	4139747	372051	6980	Sink Valley	alluvium	Drinking water for camper/trailer
SP-36	4139979	371830	6970	Sink Valley	alluvium	None apparent
SP-37	4138266	372316	6885	Sink Valley	alluvium/fracture?	Stock watering, wildlife
Streams						
SW-1	4143476	370429	6930	Kanab Creek	---	---
SW-2	4139065	368782	6644	Kanab Creek	---	---
SW-3	4141433	369896	6797	Kanab Creek	---	---
SW-7	4140667	373803	7228	Swapp Hollow (adjacent)	---	---
SW-8	4138970	373869	7212	Swapp Hollow	---	---
SW-6	4138093	371677	6834	Sink Valley Wash	---	---
SW-9	4135632	371485	6624	Lower Sink Valley Wash	---	---
SW-4	4141366	373381	7213	Robinson Creek	---	---
SW-5	4139453	369169	6677	Robinson Creek	---	---

Site	UTM location, Z12, NAD 27		Elevation (approx)	Drainage basin	Geologic Formation	Uses
SW-101	4140303	371304	6891	Robinson Creek	---	---
RID-1 (irrigation)	4141391	373420	7220	Robinson Creek	---	---
SW-10	4135431	371689	6650	Unnamed trip to Sink Valley	---	---
Lamb Canal	4140670	369678	6751	Kanab Creek	---	---
Wells						
Y-102 (A5)	4139571	371917	6950	Sink Valley	Alluvium	Monitoring well
Y-45	4139436	372942	7044	Swapp Hollow	Coal	Monitoring well
Y-61	4139433	372226	6962	Sink Valley	Alluvium	Monitoring well (pumping)
Y-59	4139375	372321	6973	Sink Valley	Alluvium	Monitoring well
Y-63	4137634	371896	6790	Sink Valley Wash	Alluvium	Monitoring well
Y-36	4139447	372147	6965	Sink Valley	Coal	Monitoring well
Y-38	4138615	371318	6871	Sink Valley	Coal	Monitoring well
Y-98 (A1)	4140999	373288	7177	Robinson Creek	Alluvium	Monitoring well
Y-99 (A2)	4140538	372371	7055	Robinson Creek	Coal	Monitoring well
Alluvial trenches						
SVT-01	4138309	371600	6836	Sink Valley	Allvuium	---
SVT-02	4138512	371543	6844	Sink Valley	Allvuium	---
SVT-03	4138743	371485	6856	Sink Valley	Allvuium	---
SVT-04	4139107	371378	6869	Sink Valley	Allvuium	---
SVT-05	4139189	371594	6882	Sink Valley	Allvuium	---
SVT-06	4139150	371595	6881	Sink Valley	Allvuium	---

Table 7-2 Monitoring well details.

Well	Date drilled	Screened formation	Collar elevation (feet)	Depth (feet)	Depth to bedrock (feet)	Screened interval From (feet)	Screened interval To (feet)
C0-18	Jan-07	*Lower Robinson alluvium*	6864.14	22	---	12	22
C0-54	Jan-07	Dakota Formation above coal	6862.59	54	40	47	54
C1-24	Jan-07	Lower Robinson alluvium	6949.19	26.5	24	16.5	26.5
C2-15	Jan-07	Sink Valley alluvium	6920.28	15	---	5	15
C2-28	Dec-06	Sink Valley alluvium	6919.81	28	---	17	27
C2-40	Dec-06	Sink Valley alluvium	6919.58	40	40	20	40
C3-15	Dec-06	Sink Valley alluvium	6890.41	15	---	5	15
C3-30	Dec-06	Sink Valley alluvium	6890.77	30	---	10	20
C3-40	Dec-06	Sink Valley alluvium	6890.73	40	38	20	40
C4-15	Dec-06	Sink Valley alluvium	6873.92	15	---	5	15
C4-30	Dec-06	Sink Valley alluvium	6873.91	30	---	10	30
C4-50	Dec-06	Sink Valley alluvium	6873.52	50	47	30	50
C5-130	Jan-07	Sink Valley alluvium	6938.92	130	123.5	90	130
C6-15	Jan-07	Lower Robinson alluvium	6897.63	15	11	5	15
C7-10	Jan-07	Sink Valley alluvium	6873.77	10	---	10	15
C7-20	Jan-07	Sink Valley alluvium	6872.89	20	19	15	20
C8-25	Jan-07	Sink Valley alluvium	6859.70	27	20	7	27
C9-15	Jan-07	Sink Valley alluvium	6846.77	15	---	5	15
C9-25	Jan-07	Sink Valley alluvium	6846.36	26	---	16	26
C9-40	Jan-07	Sink Valley alluvium	6846.94	42	39	22	42
SS-15	Jan-07	Lower Sink Valley alluvium	6831.57	15	---	5	15
SS-30	Jan-07	Lower Sink Valley alluvium	6830.47	29	---	19	29
SS-75	Jan-07	Lower Sink Valley alluvium	6832.06	75	75	54	74
UR-70	Jan-07	Upper Robinson alluvium	7005.14	70	62	50	70
LR-29	Jan-07	Dakota Formation (uppermost)	6803.10	29	20	19	29
LR-45	Jan-07	Lower Robinson alluvium	6798.41	42	41.5	21	41
LS-15	Jan-07	Lower Sink Valley alluvium	6810.28	15	---	4	14
LS-28	Jan-07	Lower Sink Valley alluvium	6810.23	28	---	17	27
LS-60	Jan-07	Lower Sink Valley alluvium	6810.35	60	---	39	59
LS-85	Jan-07	Lower Sink Valley alluvium	6810.53	87	---	64	84
Y-36	Dec-79	Smirl coal seam (Dakota Formation)	6956.97	230	155	194	214
Y-38	Nov-79	Smirl coal seam (Dakota Formation)	6860.85	105	50	71	86
Y-45	Aug-80	Smirl coal seam (Dakota Formation)	7043.55	352	40	314	330
Y-59	Dec-80	Sink Valley alluvium	6959.06	110	---	50	110
Y-61	Nov-80	Sink Valley alluvium	6962.10	150	145	112	142

Well	Date drilled	Screened formation	Collar elevation (feet)	Depth (feet)	Depth to bedrock (feet)	Screened interval From (feet)	To (feet)
Y-63	Nov-80	Lower Sink Valley alluvium	6789.34	51	34	Open hole	Open hole
Y-98 (A1)	Jul-86	Upper Robinson alluvium	7173.50	86	83.5	36.6	86
Y-99 (A2)	Jul-86	Upper Robinson alluvium	7055.54	22	20	5.1	13.2
Y-102 (A4	Jul-86	Sink Valley alluvium	6950.06	86	84.0	43.7	62.94

Table 7-3 Monthly climate summery for Alton, Utah weather station (420086), 1/1/1928 - 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average max. temperature (°F)	39.5	42.1	47.9	57.7	67.2	76.7	82.6	80.4	73.9	63.1	49.9	41.8	60.2
Average min. temperature (°F)	15.1	17.5	21.8	28.0	34.8	42.0	49.8	48.9	41.8	33.0	23.0	16.8	31.0
Average total precipitation (in.)	1.79	1.8	1.54	1.05	0.85	0.57	1.40	1.76	1.49	1.40	1.23	1.52	16.38
Average total snowfall (in.)	21.2	19.5	14.3	4.5	0.6	0.2	0.0	0.0	0.0	1.3	6.6	15.4	83.4
Average snow depth (in.)	7	8	5	1	0	0	0	0	0	0	1	2	2

Table 7-4 Hydrologic monitoring protocols and locations.

Discharge and water level measurements

Protocol	Applies to	Parameter	Frequency
A	Streams	Discharge	Quarterly
B	Springs	Discharge	Quarterly
C	Monitoring wells	Water elevation	Quarterly

Water quality

Protocol	Applies to	Parameters	Table	Frequency
1	Streams	Operational field and laboratory water quality measurements	7-6	Quarterly
2	Streams	Field water quality measurements only	7-6	Quarterly
3	Springs	Operational field and laboratory water quality measurements	7-7	Quarterly
4	Springs	Field water quality measurements only	7-7	Quarterly
5	Monitoring wells	operational field and laboratory water quality measurements	7-7	Quarterly
6	Monitoring wells	Field water quality measurements only	7-7	Quarterly

Table 7-5 Hydrologic monitoring locations.

Site	Protocols	Comments
Streams		
BLM-1	A, 2	Lower Robinson Creek adjacent to mined areas
RID-1	A, 2	Irrigation ditch in Robinson Creek
SW-2	A, 1	Kanab Creek below Robinson Creek
SW-3	A, 1	Kanab Creek above permit area
SW-4	A, 1	Lower Robinson Creek above permit area
SW-5	A, 1	Lower Robinson Creek above Kanab Creek
SW-6	A, 1	Sink Valley Wash at permit boundary
SW-8	A, 1	Swapp Hollow Creek above permit area
SW-9	A, 1	Sink Valley Wash below permit area
SW-101	A, 2	Lower Robinson Creek in permit area
Springs		
Sorensen Spring	B,4	Developed alluvial spring in Sink Valley at Sorensen ranch
SP-3	B, 4	Spring in upland pediment alluvium south of permit area
SP-4	B, 3	Developed spring in Sink Valley Wash 1 mile below permit area
SP-6	B, 3	Seep in Sink Valley below permit area
SP-8	B, 3	Developed alluvial spring in Sink Valley at Dames ranch
SP-14	B, 4	Alluvial spring in Sink Valley
SP-16	B, 4	Alluvial spring in Sink Valley
SP-19	B, 4	Alluvial spring in Sink Valley
SP-20	B, 4	Alluvial spring in Sink Valley
SP-22	B, 4	Alluvial spring in Sink Valley
SP-23	B, 4	Alluvial spring in Sink Valley
SP-33	B, 3	Developed spring in lower Sink Valley alluvium
Wells		
Y-36	C	Coal well in Sink Valley above permit area
Y-38	C	Coal well in Sink Valley in permit area
Y-45	C	Coal seam well in Swapp Hollow above permit area
Y-61	C, 5	Water well in Sink Valley artesian alluvial groundwater system above permit area
Y-63	C	Monitoring well in lower Sink Valley Alluvium below mining areas
Y-98	C	Alluvial well in Robinson Creek above permit area
Y-102	C	Alluvial well in upper Sink Valley in permit area
C0-18	C	Alluvial monitoring well in Lower Robinson Creek drainage
C0-54	C	Monitoring well in Lower Robinson Creek drainage near coal seam
C1-24	C	Alluvial monitoring well in Lower Robinson Creek drainage

Site	Protocols	Comments
C2-15	C	Monitoring well in Sink Valley alluvium
C2-28	C	Monitoring well in Sink Valley alluvium
C2-40	C	Monitoring well in Sink Valley alluvium
C3-15	C	Monitoring well in Sink Valley alluvium
C3-30	C	Monitoring well in Sink Valley alluvium
C3-40	C	Monitoring well in Sink Valley alluvium
C4-15	C	Monitoring well in Sink Valley alluvium
C4-30	C	Monitoring well in Sink Valley alluvium
C4-50	C	Monitoring well in Sink Valley alluvium
C5-130	C	Monitoring well in Sink Valley artesian alluvial groundwater system above permit area
C7-20	C	Monitoring well in Sink Valley alluvium
C9-15	C	Monitoring well in Sink Valley alluvium
C9-25	C	Monitoring well in Sink Valley alluvium
C9-40	C	Monitoring well in Sink Valley alluvium
LR-45	C, 5	Monitoring well in Lower Robinson Creek alluvium below mine area
LS-28	C	Monitoring well in Sink Valley Alluvium below mining areas
LS-60	C	Monitoring well in Sink Valley Alluvium below mining areas
LS-85	C, 5	Monitoring well in artesian Sink Valley Alluvium below mining areas
SS-15	C	Monitoring well in Sink Valley Alluvium below mining areas
SS-30	C, 5	Monitoring well in Sink Valley Alluvium below mining areas
SS-75	C	Monitoring well in burned coal area material
UR-70	C, 5	Monitoring well in Lower Robinson Creek alluvium above mine area

Table 7-6 Surface water operational water quality monitoring

FIELD MEASUREMENTS	REPORTED AS
pH	pH units
Specific Conductivity	µs/cm @ 25°C
Dissolved Oxygen	mg/L
Temperature	°C
LABORATORY MEASUREMENTS	
Total Dissolved Solids	mg/L
Total Suspended Solids	mg/L:
Bicarbonate	mg/L
Carbonate	mg/L
Calcium (dissolved)	mg/L
Chloride	mg/L
Iron (total)	mg/L
Iron (dissolved)	mg/L
Magnesium (dissolved)	mg/L
Manganese (total)	mg/L
Manganese (dissolved)	mg/L
Potassium (dissolved)	mg/L
Sodium (dissolved)	mg/L
Sulfate	mg/L
Oil and grease	mg/L
Cations	meq/l
Anions	meq/l
Cation/Anion Balance	%

Table 7-7 Groundwater operational water quality monitoring.

FIELD MEASUREMENTS	REPORTED AS
pH	pH units
Specific Conductivity	µs/cm @ 25°C
Temperature	°C
LABORATORY MEASUREMENTS	
Total Dissolved Solids	mg/L
Carbonate	mg/L
Bicarbonate	mg/L
Calcium (dissolved)	mg/L
Chloride	mg/L
Iron (total)	mg/L
Iron (dissolved)	mg/L
Magnesium (dissolved)	mg/L
Manganese (total)	mg/L
Manganese (dissolved)	mg/L
Potassium (dissolved)	mg/L
Sodium (dissolved)	mg/L
Sulfate	mg/L
Cations	meq/L
Anions	meq/L
Cation/Anion Balance	%

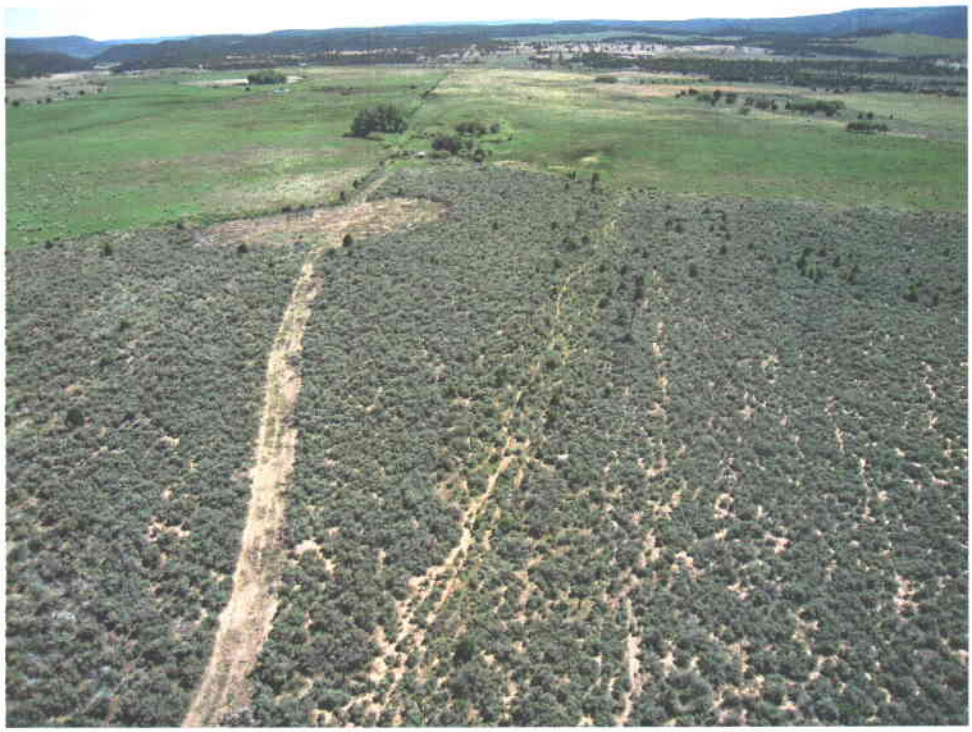
Table 7-8 Slug testing and pump testing results.

Well	Screened formation	Hydraulic conductivity (cm/sec)	Data source	Method
Sink Valley Alluvium				
Coarse upper-central coarse artesian system				
Y-61	Sink Valley alluvium (artesian system)	6.0×10^{-2}	Utah International	Pump test (Jacob; 1946)
Shallow clayey alluvium				
C2-15	Sink Valley alluvium	1.0×10^{-6}	Petersen	Slug test (Hvorslev; 1951)
C3-15	Sink Valley alluvium	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
C4-15	Sink Valley alluvium	6.0×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C7-20	Sink Valley alluvium	8.3×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C8-25	Sink Valley alluvium	3.8×10^{-7}	Petersen	Slug test (Hvorslev; 1951)
C9-15	Sink Valley alluvium	2.5×10^{-5}	Petersen	Slug test (Hvorslev; 1951)
SS-15	Lower Sink Valley alluvium	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
Middle and lower Sink Valley sandy, silty, clayey alluvium				
C2-28	Sink Valley alluvium	5.3×10^{-3}	Petersen	Slug test (Hvorslev; 1951)
C2-40	Sink Valley alluvium	1.5×10^{-3}	Petersen	Slug test (Hvorslev; 1951)
C3-30	Sink Valley alluvium	5.8×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C3-40	Sink Valley alluvium	4.7×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C4-30	Sink Valley alluvium	9.4×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C4-50	Sink Valley alluvium	1.5×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C9-25	Sink Valley alluvium	1.1×10^{-3}	Petersen	Slug test (Hvorslev; 1951)
C9-40	Sink Valley alluvium	9.3×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
SS-30	Lower Sink Valley alluvium	2.1×10^{-5}	Petersen	Slug test (Hvorslev; 1951)
Lower Sink Valley coal burned area				
SS-75	Lower Sink Valley alluvium	High ($>10^{-2}$)	Petersen	Slug test (Hvorslev; 1951)
Robinson Creek drainage alluvium				
Upper Robinson Creek drainage coarse alluvium				
Y-98 (A1)	Upper Robinson alluvium	3.2×10^{-2}	Utah International	Slug test (Bouwer and Rice; 1976)
Lower Robinson Creek drainage clayey alluvium				
C0-18	*Lower Robinson alluvium*	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
C1-24	Lower Robinson alluvium	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
C0-54	Alluvium/Dakota Formation above coal	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
Smirl Coal Seam				
Y-36	Smirl coal seam (Dakota Formation)	1.0×10^{-5}	Utah International	Slug test (Hvorslev; 1951)
Y-38	Smirl coal seam (Dakota Formation)	6.3×10^{-5}	Utah International	Slug test (Hvorslev; 1951)

Table 7-9 Estimated rates of groundwater inflows based on drilling and slug testing results.

	Saturated alluvial thickness (feet)	Hydraulic conductivity; Clayey alluvium (cm/sec)	Clayey alluvium thickness (feet)	Hydraulic conductivity; Silty alluvium (cm/sec)	Silty alluvium thickness (feet)	Hydraulic conductivity; Coal burn (cm/sec)	Coarse alluvium thickness (feet)	Hydraulic gradient	Discharge per 100 linear feet over saturated thickness (gpm)
Lower Robinson Creek									
C0 area	34	$< 1 \times 10^{-6}$	34	NA	0	NA	0	0.10	< 1
C1 area	6	$< 1 \times 10^{-6}$	6	NA	0	NA	0	0.10	< 1
Sink Valley									
C2 area	40	1.0×10^{-6}	10	5.3×10^{-3}	30	NA	0	0.10	24
C3 area	38	$< 1 \times 10^{-6}$	10	9.4×10^{-4}	28	NA	0	0.10	1.7
C4 area	47	6.0×10^{-4}	10	9.4×10^{-4}	30	NA	0	0.10	6.0
C6 area	0	NA	0	NA	0	NA	0	0.10	<1
C7 area	11	8.3×10^{-4}	11	NA	0	NA	0	0.10	1.3
C8 area	13	3.8×10^{-7}	13	NA	0	NA	0	0.10	<1
C9 area	31	2.5×10^{-5}	10	1.1×10^{-3}	21	NA	0	0.10	3.4
SS area	70	$< 1 \times 10^{-6}$	15	2.1×10^{-5}	40	$> 1 \times 10^{-1}$	15	0.10	> 220

View looking north at groundwater discharge area B in Sink Valley.
Note that proposed mining locations are north and west of Area B.



View looking southwest at groundwater discharge area A in Sink Valley.
Note that proposed mining locations are west of Area A.

View looking east in Lower Robinson Creek drainage in proposed mining area (in foreground).

View looking south down Sink Valley Wash below proposed mining areas.

View looking north at Tropic Shale ridge
and Sink Valley Fault.

APPENDIX 7-1

Petersen Hydrologic, LLC report

Investigation of Groundwater and Surface-Water Systems in the 630-Acre Proposed Coal Hollow Mine permit And Adjacent Area; Probable Hydrologic Consequences of Coal Mining; Recommended Monitoring Plan; Potential Alluvial Valley Floor Information; Kane County, Utah

12 June 2007

Alton Coal Development, LLC
Huntington, Utah

PETERSEN HYDROLOGIC, LLC
CONSULTANTS IN HYDROGEOLOGY

Investigation of Groundwater and Surface-Water Systems in the 630-Acre Proposed Coal Hollow Mine permit And Adjacent Area; Probable Hydrologic Consequences of Coal Mining; Recommended Monitoring Plan; Potential Alluvial Valley Floor Information; Kane County, Utah

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Alton Coal Development, LLC
Huntington, Utah

Prepared by:

Erik C. Petersen, P.G.
Senior Hydrogeologist
Utah P.G. No. 5373615-2250

PETERSEN HYDROLOGIC
CONSULTANTS IN HYDROGEOLOGY

2695 N. 600 E.
LEHI, UTAH 84043
(801) 766-4006
PETERSEN@RELIA.NET

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Investigation of Groundwater and Surface-Water Systems in the 630-Acre Proposed Coal Hollow Mine Permit and Adjacent Area; Probable Hydrologic Consequences Of Coal Mining; Recommended Monitoring Plan; Potential Alluvial Valley Floor Information; Kane County, Utah

NOTE: *This report provides a hydrologic and hydrogeologic characterization of groundwater and surface water systems in the proposed Coal Hollow Mine permit and adjacent area. The report is based on information available at the time the analysis was performed. By design, the hydrologic conditions will be continuously monitored in the future. As additional hydrologic and hydrogeologic data become available, this report will be periodically updated to reflect the new information.*

1.0 Introduction

Alton Coal Development, LLC is currently making application for a Utah State coal mining permit from the Utah Division of Oil, Gas and Mining (UDOGM) to mine coal at the proposed Coal Hollow Mine permit area. The proposed Coal Hollow Mine permit area is located on private lands in the Alton Coal Field of south-central Utah, approximately three miles south of the town of Alton, Utah (Figure 1).

The requirements of the mining and reclamation plan (MRP) include, among other things, a description of geologic conditions and groundwater and surface-water resources in the proposed permit and adjacent area, and a determination of the probably hydrologic consequences of coal mining. This document is a report of an investigation of geologic, hydrogeologic, and hydrologic conditions in the proposed Coal Hollow Mine permit and adjacent area and is provided as supplemental information in support of the Coal Hollow Mine MRP.

Including this introduction, this report contains the following sections:

1. Introduction
2. Historical Overview
3. Methods of Study
4. Climate
5. Physiography
6. Geology
7. Presentation of Data
8. Solute and Isotopic Chemistry
9. Groundwater Systems
10. Surface-Water Systems
11. Probable Hydrologic Consequences Determination
12. Proposed Hydrologic Monitoring Plan
13. Alluvial Valley Floor Information
14. References Cited

2.0 Historical Overview

The Alton Coal Field is located adjacent to the highlands of the Paunsaugunt Plateau, mostly in Kane County, Utah. Historical mining operations in the Alton Coal Field have been limited, with the total production from the field from all mines being less than 50,000 tons (Doelling, 1972). Coal mining in the Alton Coal Field began in the late 1920's with the most significant mining activity commencing in the period following World War II. The most important mines in the field were the Smirl and Alton Coal Mines, both located

approximately two miles south of the town of Alton. Mining in the Alton Coal Field ended in 1969 with the closure of the Smirl Mine.

Beginning in 1960, coal leasing of large tracts of land in the Alton Coal Field was carried out by Nevada Electric Investment Co. and the Utah Construction on Mining Company. As part of these leasing activities, extensive drilling and mapping of the coal deposits in the field occurred (Doelling, 1972).

In the 1980's, a large-scale coal mining operation was proposed in the Alton Coal field by Utah International, Inc. Coal from this mine was to have been the primary energy source for a proposed coal-fired power plant about 25 miles northeast of Las Vegas, Nevada. The proposed operation included both a large surface mining operation and a coal slurry preparation plant and slurry pipeline through which coal would be transported to southern Nevada. The proposed slurry line was to have used large quantities of groundwater pumped from the Navajo Sandstone. In conjunction with the planning for this mine (in the 1970's and 1980's), extensive drilling, hydrogeologic characterization, and groundwater and surface-water monitoring activities were carried out. A mining and reclamation plan for the proposed Utah International, Inc. mine was prepared and submitted to the Utah Division of Oil, Gas and Mining that was subsequently determined to be administratively complete. However, due to several factors, the mining and reclamation plan was later withdrawn and the plans for mining did not proceed. The coal leases held by Utah International, Inc. subsequently lapsed and were eventually returned to the governmental agencies.

Alton Coal Development, LLC is currently in the process of securing a Utah State coal mining permit for a 630-acre area for the proposed Coal Hollow Mine on privately held lands in the Alton Coal Field (Figure 1). Current mining plans call for the production of about 2 million tons of coal per year using surface mining techniques. It should be noted that the size of the proposed mine permit area and the proposed mining extraction rates are many times smaller than those proposed previously. Additionally, while previously proposed mining operations in the Alton Coal Field included the planned drilling and pumping of large amounts of groundwater from high-capacity production wells in the Navajo Sandstone aquifer for operational use, no such wells are planned in the proposed Coal Hollow Mine permit and adjacent area.

3.0 Methods of Study

The methods of study utilized in this hydrogeologic investigation, including data collection methods and investigative techniques are described below.

- Existing published and unpublished maps and reports were obtained and reviewed
- Discharge, water-quality, and potentiometric data were obtained from several sources and compiled into an electronic database for analysis. These included hydrologic data collected in conjunction with United States Geological Survey investigations, data

collected by Utah International, Inc. in the 1980's as part of previous coal mine permitting actions, and data collected during baseline monitoring activities conducted by Alton Coal Development, LLC. As of the time of the writing of this report, Alton Coal Development has collected eight continuous quarters of baseline hydrologic data (2nd Q 2005 – 1st Q 2007). These data have also been submitted electronically into the Utah Division of Oil, Gas and Mining, Utah Coal Mining Water Quality Database.

- A spring and seep survey of the proposed Coal Hollow Permit and adjacent area was commissioned by Alton Coal Development, LLC and carried out by Petersen Hydrologic, LLC. At each location, discharge measurements and field water-quality measurements were performed. Each spring and seep location was also digitally photographed and the site location determined by GPS.

- As part of this investigation, groundwater and surface-water samples were collected from springs, stream, and wells for stable and radiogenic isotopic analysis. Isotopic samples for δ^2H, $\delta^{18}O$, and tritium (^3H) were collected in appropriate sealed glass or HDPE plastic bottles. Samples for $\delta^{13}C$ and ^{14}C analysis were collected in HDPE plastic carboys and subsequently pretreated at the Brigham Young University isotope laboratory using $BaCl_2 \cdot 2H_2O$ to segregate dissolved inorganic carbon.

- Stable isotopic δ^2H and $\delta^{18}O$ analyses were performed by the Brigham Young University Stable Isotopic Laboratory of Provo, Utah. Tritium analyses were performed by the University of Miami Tritium Laboratory using electrolytic enrichment and low-level counting techniques. Carbon-14 analyses were performed by Geochron Laboratories of Cambridge, Massachusetts using conventional counting techniques on the dissolved inorganic carbon sample. Analyses for $\delta^{13}C$ were also performed by Geochron Laboratories.

- Discharge, isotopic, solute chemical, and other data were compiled into electronic format for analysis. Data analysis was performed using graphical, statistical, and computer methods. Solute chemical data were analyzed graphically using Stiff (1951) diagrams and using the computer code WATEQF (Plummer et al., 1976). Groundwater radiocarbon mean residence times were calculated using methods described by Pearson and Hanshaw (1970), Fontes (1980), and Mooke (1980).

- As part of this investigation, thirty monitoring wells were installed during the winter of 2006-2007. Additionally, continuous core drilling was performed at four locations near proposed mining areas in late 2005. Geologic logging of the lithologic and hydrogeologic properties of continuous core samples obtained during the core drilling activities was performed. Samples were collected from auger-drilled boreholes using a driven sampling tube and also directly from the auger return cuttings. Selected representative samples were also analyzed for acid- and toxic-forming potential and physical parameters by Energy Laboratories, Inc. of Billings, Montana.

- Monitoring well ground coordinates and collar elevations were professionally surveyed.

- Newly constructed monitoring wells were professionally developed using surging and bailing techniques.

- Samples for laboratory water quality analysis were collected and analyzed according to standard EPA methods. Laboratory water quality measurements were performed by SGS Mineral Services Division of Huntington, Utah, a Utah state certified analytical laboratory. Information regarding laboratory standard analytical methods and procedures used and laboratory detection limits has been entered into the Utah Division of Oil, Gas and Mining, Utah Coal Mine water quality database (UDOGM, 2007).

- Discharge measurements for springs and seeps were typically performed using a calibrated container and a stopwatch. The measurements were performed by damming and diverting the spring discharge through a pipe. Using an appropriately sized container, time-to-fill measurements were typically performed at least 3 times at each location. An average time-to-fill value was used to calculate the reported discharge measurement.

- Discharge measurements at stream monitoring stations were performed using either a portable 3-inch Parshall flume, electronic current-velocity meter and wading rod, portable 90-degree v-notch weir, or a stopwatch and calibrated container as appropriate. Discharge measurements and calculations were performed using standard U.S. Bureau of Reclamation methods.

- Potentiometric levels were monitored in wells using a Waterline Envirotech, Ltd. Model 500 coaxial water-level indicator.

- Temperature measurements were performed using a Taylor brand electronic digital thermometer. Discharge temperature measurements at springs were performed as close to the spring discharge locations as possible. Stream temperature measurements were performed, where possible, in a shaded, actively flowing portion of the stream.

- Specific conductance measurements were performed using an Extech brand model EC400 conductivity meter with automatic temperature compensation. The instrument was regularly calibrated using traceable ASTM conductivity standard solutions.

- pH Measurements were performed using an Oakton brand Acorn 6 model electronic pH meter with automatic temperature compensation. The instrument was regularly calibrated using traceable ASTM pH standard solutions.

- Dissolved oxygen measurements were performed using a YSI brand model 55 dissolved oxygen meter. The meter was routinely calibrated using atmospheric oxygen calibration methods.

- Slug testing on selected wells in the proposed Coal Hollow Mine and adjacent area was performed. Slug testing was performed by rapidly injecting an appropriate volume of water into the well casing. Water level declines were then monitored electronically using a Solinst brand Levelogger model 3001 pressure transducer/data logger. Slug test analyses were performed using methods described by Hvorslev (1951). Pump testing analysis of pumping well Y-61 were performed by previous researchers using methods described by Jacob (1946).

4.0 Climate

Climatological information, including temperature and precipitation data, have been routinely measured and recorded at the Alton, Utah weather station (420086) since 1928. The station is located in the town of Alton, approximately two miles north of the proposed Coal Hollow Mine permit area. Climatological data collected at the Alton station for the 77 year period from 1928 to 2005 are summarized in Table 2 and plotted in Figure 2.

An automated weather station was installed in the proposed Coal Hollow Mine permit area in December 2005. The station is configured to continuously monitor and record temperature, wind velocity, and wind direction data. The station is also configured to continuously measure and record precipitation, although the tipping rain-gauge is not operative during winter months when snowfall may not be recorded. Climate data from the Coal Hollow Project weather station, including daily maximum and minimum temperature and precipitation for the period January 2006 through May 2007 are presented in Table 3.

Precipitation data from the Alton, Utah weather station indicates average annual precipitation of 16.38 inches per year. Doelling (1972) reports average annual precipitation in the Alton Coal Field area ranging from 9 to 20 inches annually with slightly higher increments likely in the higher parts of the plateau. There are generally two annual wet periods in the region. During the wintertime, cyclonic storms bring precipitation (mainly snowfall) to the region. During the summertime, storms originating from convection of air from the Gulf of Mexico or the Pacific Ocean bring rains to the region. Of the two annual wet cycles, the summer rainfall is most reliable (Doelling, 1972). Average monthly precipitation at the Alton station ranges from a low of 0.57 inches in June to a maximum of 1.80 inches in February.

The Palmer Hydrologic Drought Index (PHDI; NCDC, 1997) indicates long-term climatic trends for the region. The PHDI is a monthly value generated by the National Climatic Data Center (NCDC) that indicates the severity of a wet or dry spell. The PHDI is computed from climatic and hydrologic parameters such as temperature, precipitation, evapotranspiration, soil water recharge, soil water loss, and runoff. Because the PHDI takes into account parameters that affect the balance between moisture supply and moisture demand, the index

is a useful for evaluating the long-term relationship between climate and groundwater recharge and discharge. A plot of the PHDI for Utah Region 4 (which includes the proposed Coal Hollow Mine permit and surrounding area) is shown in Figure 3. It is apparent in Figure 3 that the region has experienced cyclical periods of drought and wetness since 1980. Baseline hydrologic monitoring performed by Utah International, Inc in 1987 and 1988 occurred during a period of near normal wetness. Recent baseline hydrologic monitoring conducted in 2005 and 2006 occurred during a period of moderate to severe wetness, with 2005 being wetter than 2006.

Wind data have been collected at the Coal Hollow Project weather station since December 2005. Monthly wind data from the Coal Hollow Project weather station are available from January 2006 through March 2006, and from November 2006 through May 2007. Monthly wind data are plotted as wind rose diagrams, which depict the average direction and velocity of prevailing winds, in Figure 4. Based on recent data from the Coal Hollow Project weather station, it is apparent that the predominant wind direction in the proposed Coal Hollow Mine permit area (during the months for which data are available) are from the northeast, with secondary peaks from the north and south-southwest (Figure 4). Surface winds recorded at the Coal Hollow Project weather station averaged about 6.4 miles per hour. Tabulated hourly wind data from the Coal Hollow Project weather station are maintained on file at Alton Coal Development, LLC.

Wind data have also been collected historically at nearby locations by governmental and other entities. The regionally predominant direction of winds in the region is southwest through west. Secondary peaks are from southeast and northwest. Surface winds in the area average approximately 8 miles per hour. Higher wind speeds are associated with fronts and storms and generally occur during the springtime.

Temperature data from the region are summarized in Table 2. Temperatures in the permit area vary greatly. Temperature data from the Alton station (1928-2005) indicate that monthly average low temperatures are below freezing for the 6-month period from November to April. Monthly average minimum temperatures range from a low of 15.1 °F during January to a high of 49.8 °F in July. Monthly average maximum temperatures range from a low of 39.5 °F in January to a high of 82.6 °F in July. Daily maximum and minimum temperature data collected at the Coal Hollow Project weather station during 2006 and the first quarter of 2007 are presented in Table 3 and plotted in Figure 5. The maximum temperature recorded during this period was 93.3 °F in July 2006. The minimum temperature recorded during this period was -7.3 °F in January 2007.

5.0 Physiography

The Alton Coal Field is a roughly horseshoe-shaped region that is situated between the Kaiparowits Coal Field to the east, and the Kolob Coal Field to the west. The land surface in the vicinity of the proposed Coal Hollow Mine permit and adjacent area is situated primarily in Sink Valley, which is adjacent to the western escarpment of the Paunsaugunt Plateau.

Topographic relief in the surrounding area exceeds 3,000 feet, ranging from about 9,300 feet on top of the Paunsaugunt Plateau east of the proposed permit area, to about 6,200 feet in the Kanab Creek valley west of the proposed permit area.

Most of the land surface within the proposed permit area is situated on a broad valley fan deposit in Sink Valley that originated from outwash from adjacent upland areas to the east through a series of deeply incised, steep-walled canyons. The portion of the proposed permit area within Sink Valley is typified by broad, gently sloping land surfaces with isolated bedrock outcrops. The land surface within Sink Valley slopes gently to the west, southwest, and south. It is noteworthy that there is a conspicuous lack of a continuous stream channel running through Sink Valley. The region immediately west of Sink Valley is dominated by rolling hills and valleys above the Kanab Creek valley located west of the proposed permit area (Figure 1).

6.0 Geology

The coal to be mined at the Coal Hollow Project area is of Cretaceous age and resides in the Alton Coal Field of south-central Utah. The economic coal seams are located primarily along the western and southern flanks of the Paunsaugunt Plateau.

The geologic history, geology, stratigraphy, and structure of the Alton Coal Field have been described by Doelling (1972) and Tilton (2001) and are summarized below. A map of geologic formations exposed at the surface in the Coal Hollow Project area is shown in Figure 6. A cross-section showing the regional geologic conditions in the Alton Coal Field is presented in Figure 7. A north-south and an east-west cross-section through the proposed Coal Hollow Mine permit and adjacent area are presented in Figure 8.

Geologic History

During the Jurassic, sediment deposition into a slowly subsiding basin occurred, mostly by fluvial or eolian mechanisms. Later, during the Upper Jurassic, the area was intermittently inundated by a shallow, restrictive sea, with the accompanying deposition of sediments eroded from Mesozoic rocks to the south and west. Subsequently, prior to the end of the Lower Cretaceous, a broad uplift centered west of the Paunsaugunt area occurred, resulting in the erosion of the uplifted areas. Subsequently, to the east, the rock sequence down to the Entrada Formation was eroded away. To the west, the rock sequence down to the Carmel was eroded away. After additional erosion of the region occurred, during the latest Cretaceous or earliest Upper Cretaceous, the land subsided and the region was covered with sediments. The source of these sediments lay mostly to the west and perhaps also to the south. As the Cretaceous Interior Seaway migrated westward, rock deposition occurred in fluvial, paludal, lagoonal and perhaps nearshore marine environments during transgressions and regressions of the seaway. This deposition resulted in the formation of the rocks of the Dakota Formation, which include the economic coal seams of the Alton Coal Field. The two principal coal seams of the Dakota Formation were formed during this period, one near the beginning and the other near the end of Dakota time. After the deposition of the Dakota Formation, the area experienced marine

conditions as the Cretaceous Interior Seaway encroached westward toward eastern Iron County, resulting in the deposition of the marine shales of the Tropic Shale. After the subsequent eastward regression of the seaway, nearshore sand deposition occurred, resulting in the deposition of the Straight Cliffs Formation. Deposition of the Wahweap and Formation occurred as floodplains developed and an alternating sequence of sandstones and shales was deposited. Subsidence then ceased for a time and uneven erosion of the region occurred. Subsequent fluvial deposition resulted in the deposition of the Kaiparowits Formation on the erosional surface. Later, in the early Tertiary period, the area subsided and was filled with a lake in which the carbonate sediments of the Claron Formation were deposited. Thereafter, volcanism became active to the west and spread to the margins of the Paunsaugunt. Various agglomerates and volcanic breccias were deposited along the western margin of the plateau. Late in the Tertiary period, the Sevier and Paunsaugunt Fault systems became active. During the Pleistocene, several cinder cones developed which extruded olivine basalts. These include Bald Knoll, Buck Knoll, and others.

Stratigraphy

Stratigraphic units present in the Alton Coal Field area are described in ascending order below. A stratigraphic column showing these geologic formations is shown in Figure 9. A diagrammatic correlation of Cretaceous units in southern and south-central Utah is shown in Figure 10.

Navajo Sandstone (Lower Jurassic)

The Navajo Sandstone is a light gray to tan, locally cross-bedded massive eolian sandstone that underlies the region. Where exposed south of the Alton area, it forms the regionally prominent White Cliffs topographic feature. The Thousand Pockets Tongue of the Navajo Sandstone intertongues with the overlying Carmel Formation. Thickness of the Navajo Sandstone exceeds 1,000 feet in the Paunsaugunt Plateau region. The Navajo Sandstone does not crop out in the Coal Hollow Project area.

Carmel Formation (Upper Jurassic)

The Carmel Formation unconformably overlies the Navajo Sandstone in the region. The Carmel Formation is heterogeneous and consists of limestone, siltstone, sandstone, and gypsum beds. The formation has been subdivided into several members by previous researchers. These include the Wiggler Wash Member, the Winsor Member, the Paria River Member, the Crystal Peak Member, and the Kolob Limestone Member. The thickness of the Carmel Formation ranges from about 650 to 800 feet in the Alton Coal Field area and the formation thickens to the west. The Winsor Member of the Carmel Formation crops out in the bottom of the Kanab Creek drainage in the southernmost portion of the Coal Hollow Project area.

Entrada Sandstone (Upper Jurassic)

The Entrada Sandstone, which may be as thick as 500 feet regionally, is present above the Carmel Formation in the eastern portion of the Alton Coal Field. The formation consists predominantly of siltstone and cross-bedded or fine-grained massive sandstone. The formation is not present in the Coal Hollow Project area.

Dakota Formation (Cretaceous)
The Dakota Formation contains the economic coal seams in the Alton Coal Field. The formation consists of fine- to medium-grained sandstone with interbedded gray shale, carbonaceous shale, and coal. In most locations, shaley strata dominate the formation, comprising about 60 to 75 percent of the formation. The unit characteristically forms ledge and slope topography. In the Coal Hollow Project area the Dakota Formation directly overlies the Carmel Formation. Regionally, the outcrop of the Dakota Formation forms the Gray Cliffs topographic feature. The economic coal seams in the Alton Coal Field are present near the base (Bald Knoll coal zone) and near the top of the formation (Smirl coal zone). Local thinner coal seams that are not of economic importance are present in the center of the formation. The thickness in the western portion of the Alton Coal Field is about 450 feet. In the eastern portion of the Alton Coal Field, the Dakota Formation is about 150 feet thick and rests on the Entrada Sandstone.

Tropic Shale (Cretaceous)
The Tropic Shale consists predominantly of gray and carbonaceous silty shale with a few marine sandstone beds. The formation typically weathers at the surface to a clayey soil that typically forms gentle, vegetated slopes. The Tropic Shale is present (in some locations covered with shallow alluvial or colluvial deposits) at the land surface over most of the Coal Hollow Project area. The formation was deposited in an open-marine offshore environment during the maximum westward transgression of the Cretaceous Western Interior Seaway in the Late Cretaceous (Tilton, 2001). Near the top of the formation, more sandy horizons are interbedded with the mudstone units of the formation. These sandy units together with the sandstone at the base of the overlying Straight Cliffs Formation reflect the initial sand influx onto the marine environment of the Tropic Shale. The thickness of the Tropic Shale in the Alton Quadrangle is about 700 feet.

Straight Cliffs Formation (Cretaceous)
The Straight Cliffs Formation is approximately 1,200 feet thick in the Alton Quadrangle. The formation is comprised predominantly of calcite-cemented sandstone and mudstone, with sandstone composing about 75 percent of the total composition. The sandstones of the Straight Cliffs Formation make up the lower two-thirds of the ledges radiating out from the southern Paunsaugunt Plateau. Four members of the Straight Cliffs Formation have been identified in the Alton Quadrangle by Tilton (2001). These include the Tibbet Canyon Member (orange-gray weathering fine- to medium grained sandstone), the Smoky Hollow Member (interbedded sandstone, mudstone, and thin coal), the John Henry Member (interbedded mudstone and fluvial sandstone), and Drip Tank Member (light-gray cliff forming sandstone). The Straight Cliffs Formation outcrops on the hillsides east and north of the Coal Hollow Project area.

Wahweap and Kaiparowits Formations (Cretaceous)
The Wahweap Formation is composed of alternating sandy shales and thin- to thick-bedded sandstones. The unit contains carbonaceous shale and thin coal beds that are not of economic importance in its lower part. The unit forms step-like topography. Regionally, the Wahweap Formation is separated from the overlying Kaiparowits Formation by an unconformity. Erosion of both the Wahweap and Straight Cliffs Formations prior to the deposition of the Kaiparowits

Formation may have locally reduced the thicknesses of these formations in the vicinity of the Paunsaugunt Plateau. The Kaiparowits Formation is composed of irregular beds of arkosic sandstone. The sandstone is weakly cemented by calcite cement. Because of difficulties identifying mappable boundaries between the Wahweap and Kaiparowits Formations in the Alton Quadrangle, the formations were mapped as an undivided unit (Tilton, 2001). The total thickness of the Wahweap and Kaiparowits Formations in the Alton Quadrangle ranges from about 600 to 800 feet.

Claron Formation (Tertiary)

The Claron Formation (also sometimes known as the Wasatch Formation, although the Utah Geological Survey uses the name Claron Formation) forms the cap rock over much of the Paunsaugunt Plateau. The formation is also present west of the Sevier Fault Zone west and north of the town of Alton. The unit is subdivided into a lower pink (also known as red) member and an upper white member, both consisting mostly of massive, fine-grained crystalline limestone of fluvial and lacustrine origin. Resistance to erosion varies both vertically and horizontally in the Claron Formation, resulting in a series of cliffs and steep joints. This condition, together with the presence of closely spaced joints, produces the unique topography associated with the Claron Formation. The Claron Formation is about 800 thick in the Alton Quadrangle. Also mapped together with the Claron Formation in the Alton Quadrangle is the Cretaceous Canaan Peak Formation. The Canaan Peak is a thin, discontinuous formation consisting primarily of conglomerate and conglomeratic sandstone with some mudstone interbeds sometimes present at the base of the Claron Formation. Thickness of the Canaan Peak Formation locally ranges from 0 to 30 feet.

Brian Head Formation (Tertiary)

The Brian Head Formation consists of interbedded pink and purplish-gray very fine-grained sandstone, friable sandstone, conglomerate, siltstone, mudstone, and limey mudstone in its lower part, and gray to white, fine- to medium-grained sandstone and calcarenite, in part with a volcanically derived clay matrix. The formation includes rocks present above the underlying white member of the Claron Formation and the overlying ash-flow tuff of the Needles Range Group. The unit is not resistant to erosion and has been eroded away from the top of the Paunsaugunt Plateau in the Alton Quadrangle. The formation is present in the rugged hills west of the Sevier Fault Zone near the town of Alton. The unit is about 200 feet thick in the Alton Quadrangle.

Quaternary Deposits

Quaternary deposits present in the area include pediment alluvium, landslide deposits, mass-wasting debris, and alluvium.

The pediment alluvium deposits in the region consist of poorly sorted alluvial and colluvial silt, sand, and gravel deposited on broad pediments. After deposition, the pediment surfaces were abandoned as streams have cut down to lower levels.

Landslide deposits in the area are primarily gravity-transported hummocky deposits of mud, sand, and occasional blocks of sandstone. Most of the landslide deposits originated from the

lower portion of the Straight Cliffs Formation and slid onto the underlying Tropic Shale, although movement within the Tropic Shale has also occurred. A conspicuous series of progressively built landslide deposits is present east of the Alton Amphitheater as a broad, rolling apron below the lowest cliffs of the Straight Cliffs Formation. The thickness of the landslide deposits locally ranges from a few feet to more than 100 feet.

Alluvium deposits in the region consist of unconsolidated clay, silt, sand, and gravel in and near existing drainages. These deposits exist as stream and fan alluvium and terrace deposits. In the headwaters of the mountain streams, the alluvial material consists predominantly of sand and gravel. In downstream areas, the alluvial material consists mostly of mud derived from the Tropic Shale. Alluvial thickness in the Alton Quadrangle typically ranges from a thin covering to about 10 feet or more.

Additionally, an igneous dike consisting of black, fine-grained porphyritic olivine basalt is present northeast of Alton near Kanab Creek.

Structure

Rock strata in the region dip gently toward the north and north-east, generally from 1 to 5 degrees. The Alton Coal Field is bounded on the east by the Paunsaugunt Fault, on the west by the Sevier Fault. Regional displacements on these two faults are about 1,000 to 2,000 feet, and 100 to 800 feet, respectively. Additionally, several faults with lesser displacements have been mapped in the region, including the Sand Pass Fault zone (about 400 feet of offset), the Bald Knoll Fault (about 650 feet of offset), and the Sink Valley Fault. Most local faults in the Alton Quadrangle trend in a northerly or north-westerly direction, are several miles long, and are near vertical. A preminent north- to northwest-trending vertical joint set is present in the Upper Cretaceous sandstone rocks in the region. Stratal dips vary appreciably near the fault zones.

Description of Coal Seam Geology

The coal seams in the Alton Coal Field are located in the Smoky Hollow Member of the Straight Cliffs Formation, and in the Dakota Formation. The coal seam in the Smoky Hollow Member, which occurs within the lower 3 feet of the Member, is only a few inches in thickness and is not of economic importance. Within the Dakota Formation, two regionally important coal zones are present. These include the Smirl coal zone, which is located near the upper formational contact with the Tropic Shale, and the Bald Knoll coal zone, which is located about 200 feet below the Smirl coal zone near the base of the Dakota Formation. Some previous researchers have included the Smirl coal zone as part of the overlying Tropic Shale.

The coal in the Alton Coal Field is reported to have an apparent rank of sub-bituminous B, with an average heating value of about 9,560 Btu, an average sulfur content of 1.0 percent, and an average ash content of 7.2 percent (Tilton, 2001). Doelling (1972) reports that coal in the Alton area is a high-volatile C Bituminous coal. Doelling also reports that a coal sample from the Smirl Mine contained 0.56 percent sulfur: 0.01 percent sulfate, 0.11 percent pyritic sulfur, and 0.44 percent organic sulfur. The sample also contained 18.5 percent moisture and 6.3 percent ash.

Doelling (1972) reported that the Smirl coal zone is 14 to 18 feet thick without splits, while the Bald Knoll coal zone contains several coal seams separated by thin splits, with the thickest seam being 4.8 feet thick. Within the Alton Quadrangle, five small mines and two prospects have been worked. Production from these mines was small, with a total production from all mines of 35,000 and 50,000 tons from the late 1920s to 1969, when the last mine closed. The last operating mine in the Alton Coal Field was the Smirl Mine, which was located about 1.5 miles south of the town of Alton. In its last year of operation, a total of 1,597 tons of coal was produced. The Smirl Mine portal was sealed by the Utah Division of Oil, Gas and Mining in 1992.

7.0 Presentation of Data

Discharge, potentiometric, and water-quality data for springs, streams, and wells in the proposed Coal Hollow Mine permit and adjacent area are presented in Table 4. Baseline monitoring locations are plotted on Figure 11. The results of the spring and seep survey are presented in Appendix B. Monitoring station details are presented in Table 1. The locations of monitoring wells in the proposed Coal Hollow Mine permit and adjacent area are shown in Figure 12. Monitoring well completion data are presented in Table 5. Potentiometric data from monitoring wells in the proposed permit and adjacent area are presented in Table 13. Discharge and water level hydrographs for springs, streams, and wells are presented in Figure 13. Stiff (1951) diagrams depicting solute chemical compositions for groundwaters and surface-waters are shown on Figure 14. Stiff diagrams are a useful analytical tool in evaluating the geochemical compositions of groundwaters and surface-waters. The solute composition (chemical type) of the water is represented by the shape of the diagram. The size of the Stiff diagram is a function of the total dissolved solids (TDS) concentration. Stable and radiogenic isotopic compositions of groundwaters and surface-waters in the proposed Coal Hollow Mine project and adjacent area are presented in Table 6. Hydraulic conductivity measurements determined from slug testing are presented in Table 7. Stable isotopic δ^2H and $\delta^{18}O$ compositions for groundwaters and surface-waters are plotted on Figure 15.

8.0 Solute and Isotope Chemistry

8.1 Solute Chemistry

Groundwaters discharging from alluvial springs and surface waters flowing in streams in upland recharge areas east of the proposed Coal Hollow Mine permit area commonly acquire their solute compositions through a series of well-documented chemical reactions. These are briefly summarized below.

Carbon dioxide gas is produced naturally in the soil at concentrations greatly exceeding atmospheric concentrations by root-zone respiration and also by the decay of organic matter. Recharge water (rain and snow melt), upon entering the soil mantle, reacts with CO_2 to produce carbonic acid according to:

$$CO_2 + H_2O = H_2CO_{3\ (carbonic\ acid)} \qquad \text{(Equation 1)}$$

The produced carbonic acid subsequently dissociates into hydrogen ions (acid) and bicarbonate according to:

$$H_2CO_3 = H^+ + HCO_3^- \qquad \text{(Equation 2)}$$

The H^+ produced from Equation 2 reacts with carbonate minerals pervasive in the rocks of the Alton Coal Field, yielding calcium and magnesium ions and additional bicarbonate ions to the water according to:

$$CaCO_{3\ (calcite)} + H^+ = Ca^{2+} + HCO_3^- \qquad \text{(Equation 3)}$$

and

$$CaMg(CO_3)_{2\ (dolomite)} + 2H^+ = Ca^{2+} + Mg^{2+} + 2\ HCO_3^- \qquad \text{(Equation 4)}$$

Because of the limited solubility of calcite and dolomite in the absence of an additional source of CO_2, waters acquiring their solute compositions through the geochemical evolutionary pathway described in Equations 1 through 4 typically have relatively low TDS concentrations.

Groundwaters or surface waters of the low-TDS calcium–bicarbonate or calcium–magnesium–bicarbonate type upon entering the Tropic Shale or Tropic Shale-derived alluvial sediments can experience appreciable increases in TDS concentration and a change in chemical type due to the dissolution of various soluble minerals present in the Tropic Shale. Although a leaching study of the Tropic Shale sediments has not been performed in this investigation, geochemical reactions potentially occurring in marine shales may include:

$$CaSO_4 \cdot 2H_2O_{\ (gypsum)} = Ca^{2+} + 2H_2O \qquad \text{(Equation 5)}$$

$$Na_2SO_{4\ (thenardite)} = Na^+ + 2SO_4^{2-} \qquad \text{(Equation 6)}$$

$$NaCl_{\ (halite)} = Na^+ + Cl^- \qquad \text{(Equation 7)}$$

$$Na_2SO_4 \cdot 10H_2O_{\ (mirabolite)} = Na^+ + 2SO_4^{2-} + 10H_2O \qquad \text{(Equation 8)}$$

Waters rich in Ca^{2+} resulting from the dissolution of gypsum (Equation 5) may undergo ion exchange on clay minerals present in the Tropic Shale resulting in an increase in Na^+ concentrations at the expense of exchanged Ca^{2+} ions according to:

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

Ion exchange may also occur on zeolite minerals such as the sodium zeolite analcime according to:

$$2NaAlSi_2O_6 \cdot H_2O + Ca^{2+} = Ca(AlSi_2O6)_2 \cdot H_2O + 2Na^+ \quad \text{(Equation 10)}$$

Through reactions 9 and 10, groundwater may evolve chemically into Na^+ - SO_4^{2-} chemical type with elevated TDS concentration. An elevated TDS, Na^+ - SO_4^{2-} chemical type may also result directly from the dissolution of thenardite (Equation 6), a highly soluble mineral potentially present in Tropic Shale sediments. The dissolution of halite (Equation 7), where present, results in elevated Cl^- concentrations and also contributes a corresponding quantity of Na^+.

It is noteworthy that while Ca^{2+} and HCO_3^- concentrations are largely constrained by the solubilities of calcite (Equation 3), Mg^{2+} concentrations are elevated in some groundwaters and surface waters in groundwater discharge area B (Table 4; Figures 14 and 16). The source of the elevated Mg^{2+} remains problematic. The dissolution of soluble magnesium bearing minerals such as epsomite ($MgSO_4 \cdot 7H_2O$) and magnesium chloride ($MgCl_2$) potentially present in the Tropic Shale may be all or in part responsible for the observed Mg^{2+} in the groundwater. Additionally, kinetic restraints inhibiting dolomite precipitation may also contribute to the observed elevated magnesium concentrations (i.e., dolomite is readily dissolved in the presence of CO_2, but is not easily precipitated).

8.2 Isotope Chemistry

8.2.1 Deuterium (δ^2H) and Oxygen-18 ($\delta^{18}O$)

The δ^2H and $\delta^{18}O$ composition of a water molecule falling as precipitation is determined primarily by the temperature at which nucleation of the water droplet occurs. Other effects related to the bulk composition of the water vapor phase, such as cloud rainout and orographic effects, also can affect the stable isotopic composition of precipitation water.

It is useful to analyze stable isotopic δ^2H and $\delta^{18}O$ compositions relative to the meteoric water line (MWL). The MWL is derived empirically from worldwide δ^2H and $\delta^{18}O$ compositions of coastal precipitation waters. Water falling as precipitation in coastal areas will plot along the meteoric water line. Precipitation that forms in cold conditions will plot lower on the MWL relative to precipitation forming under warmer conditions. This relationship is also commonly evident in the plotting locations of waters recharging at different elevations. Waters recharging in high-elevation areas will typically plot lower on the MWL than will waters recharging at lower elevations. A local meteoric water line may be determined by analyzing and plotting the δ^2H and $\delta^{18}O$ compositions of local precipitation waters. In the central Utah coal fields, precipitation waters often plot slightly to the right of the global meteoric water line. The plotting locations of waters which have undergone

evaporation will commonly plot along an evaporation trajectory, migrating progressively higher and to the right of the non-evaporated source water.

In most non-thermal hydrogeologic environments, the stable isotopic δ^2H and $\delta^{18}O$ compositions of groundwaters are set at the time of recharge and are not affected appreciably by interactions with the aquifer skeleton (i.e., mineral dissolution and precipitation reactions and groundwater residence times). Thus, the stable isotopic chemistry of a groundwater can be evaluated independent of the chemical composition of the water. Stable isotopic δ^2H and $\delta^{18}O$ compositions are commonly used to differentiate groundwaters from different sources (i.e., isotopic fingerprinting of waters).

The δ^2H and $\delta^{18}O$ compositions of groundwaters and surface-waters in the proposed Coal Hollow Mine permit and adjacent area are presented in Table 6 and plotted together with the meteoric water line in Figure 15. It is apparent in Figure 15 that the average Kanab Creek surface waters can be differentiated from surface waters in the Swapp Hollow and Water Canyon drainages. Additionally, the stable isotopic compositions of groundwaters in the alluvial groundwater discharge area A (Figure 15) are similar to those of the Swapp Hollow and Water Canyon drainages. The plotting locations for most of the groundwaters in alluvial groundwater area B are also similar to the surface waters in Swapp Hollow and Water Canyon drainages, suggesting a possible groundwater recharge origin for the alluvial groundwater systems in Sink Valley. The plotting locations for spring SP-6 (Table 6) are considerably to the right of the MWL and higher than other alluvial groundwaters, which is consistent with evaporative effects in the relatively stagnant pool associated with the seep at SP-6. The plotting locations for the Dakota Formation/Fault waters (SP-4) are somewhat lower on the MWL, suggesting that the recharge time and/or mechanism for this water may be different from groundwaters in the alluvial groundwater systems in Sink Valley.

Two samples plot considerably to the right of the meteoric water line in Figure 15. The anomalous plotting locations for these samples are most likely attributable to laboratory analytical error.

8.2.2 Radiocarbon (^{14}C) and Tritium (^3H)

Radiocarbon and tritium isotopic information is useful for determining groundwater mean residence times. However, it is important to note that groundwater arriving at groundwater discharge points (i.e. springs or wells) rarely travels via pure piston flow. Rather, it is not uncommon for groundwater molecules discharging at springs or wells to have migrated to the discharge point from several different locations, each having recharged at different times. Consequently, the term "mean groundwater residence time", which is the average age of all of the water molecules sampled, is commonly used when evaluating the age of groundwater.

In this investigation, both tritium and radiocarbon (^{14}C) have been used to estimate the mean residence time of groundwaters. Tritium is used here primarily as a qualitative tool, indicating whether a groundwater has a component of water that recharged since about 1954.

The presence of tritium in a groundwater, which has a half-life of about 12.3 years, is indicative of water that has recharged in about the past 50 years. The radiocarbon (^{14}C) content of a groundwater is used to calculate the number of years that have elapsed since the groundwater became isolated from soil-zone gasses and near-surface groundwaters. Groundwaters with radiocarbon activities greater than about 50 pmc in carbonate-rich terrains are usually indicative of modern groundwater. Groundwaters with radiocarbon activities significantly greater than about 50 pmc indicate the presence of anthropogenic carbon commonly associated atmospheric weapons testing, also suggesting modern origin.

With the exception of the Dakota Formation/fault groundwater at SP-4, all groundwaters analyzed for tritium had concentrations greater than about 2.75 tritium units, indicating a component of modern recharge (Table 6). Groundwater at SP-4 contained no tritium. Surface water from Swapp Hollow (SW-8) was analyzed for tritium to evaluate the tritium content of current mountain-front recharge waters. The tritium content measured at SW-8 (8.07 TU) is appreciably greater than that of the groundwaters discharging down-gradient from springs and wells. For several reasons, calculations of groundwater residence times based on tritium contents are not straightforward. However, this information does suggest that the mean travel time from mountain-front recharge areas to discharge areas in Sink Valley is likely on the order of several years to perhaps a few tens of years (although certainly less than about 50 years). Tritium information from the groundwater discharging from the Dakota Formation/fault system at SP-4 indicates that the groundwater system has been isolated from the surface for at least the past 50 years.

Similarly, radiocarbon data from all alluvial groundwaters sampled in the alluvial groundwater system in Sink Valley indicate modern recharge. Anthropogenic ^{14}C is also present in these groundwaters, confirming a modern recharge origin. Radiocarbon data from the Dakota Formation/fault groundwater at SP-4 indicates a mean groundwater residence time of approximately 1,000 years.

9.0 Groundwater Systems

The depositional history of geologic formations in the proposed permit and adjacent area has resulted in a heterogeneous sequence of rocks that have a profound effect on the movement and availability of groundwater. Within the proposed Coal Hollow Mine permit and adjacent area, groundwater systems in only the Dakota Formation, Tropic Shale, and alluvial sediments are situated such that potential impacts from mining operations could possibly occur. Groundwater systems occurring in the bedrock stratigraphic sequence of the Paunsaugunt Plateau east of the proposed 630-acre Coal Hollow Mine permit area are located large distances laterally and topographically up-gradient of proposed mining areas such that there is no reasonably plausible mechanism whereby groundwater systems in these formations could be impacted by mining activities. Consequently, groundwater systems in these up-gradient areas are not considered further here.

Similarly, it should be noted that the first water-bearing strata underlying the coal seam to be mined in the proposed Coal Hollow Mine permit area from which appreciable quantities of groundwater can be produced is the Navajo Sandstone. The Navajo Sandstone aquifer is of regional significance in that it provides groundwater of good quality to domestic, agricultural, and municipal wells regionally and provides baseflow to springs and streams. The Navajo Sandstone does not crop out in the proposed Coal Hollow Mine permit and adjacent area. The formation is effectively isolated from proposed mining areas by more than 1,000 feet of rock strata of the Dakota and Carmel Formations (which includes large thicknesses of low-permeability shales and siltstones). The Navajo Sandstone aquifer will not be impacted by mining operations at the proposed Coal Hollow Mine permit area and, consequently, is not further evaluated in this investigation.

It is noteworthy that within the proposed Coal Hollow Mine permit and adjacent area, bedrock formations dip gently to the east – northeast, while the surface topography slopes gently in approximately the opposite direction (to the west, southwest, and south).

The minimal groundwater systems in the two bedrock formations potentially impacted by mining operations at the proposed Coal Hollow Mine permit area are described below. It is noteworthy that no water wells are known to exist in either the Tropic Shale or the Dakota Formation in the proposed Coal Hollow Mine permit and adjacent area, demonstrating the inability of these formations to transmit useful quantities of water to wells. Groundwaters from the Tropic Shale and Dakota Formation do not contribute measurable baseflow to streams in the proposed permit and adjacent area (at least water flowing at the surface in stream channels).

9.1 Tropic Shale

The water-bearing and water-transmitting properties of the Tropic Shale are poor. Lithologic data collected during drilling in the lower portion of the Tropic Shale indicates that the Tropic Shale in the proposed mining area is composed primarily of uniform shale or silty shale with high clay content with thin interbeds of clayey siltstone. No appreciable water inflows were encountered during drilling activities in the Tropic Shale in the proposed mining areas and no spring discharge from the formation has been observed within the proposed Coal Hollow Mine permit area. It should be noted that more resistant siltstone and sandstone strata, through which the potential for groundwater migration is greater than in the lower part of the formation, are sometimes present in the upper portion of the Tropic Shale locally. However, in the proposed Coal Hollow Mine permit area, the upper portion of the Tropic has been eroded away, leaving only the lower part in proposed mining areas. Other than a single seep (SP-37; Appendix B) which discharges at a rate of less than about 0.05 gpm from an a sandy horizon along the eastern margin of lower Sink Valley, no springs or seeps with measurable discharge have been identified in the Tropic Shale in the proposed Coal Hollow Mine permit and adjacent area. The lack of appreciable groundwater discharge in the Tropic Shale is a result of the poor water transmitting properties of the marine shale unit. The Tropic Shale acts as a barrier

impeding downward migration of groundwater in the proposed Coal Hollow Mine permit and adjacent area where it is present. The unit also forms a basal confining layer for alluvial groundwater systems in the proposed permit area.

9.2 Dakota Formation

The Tropic Shale in the proposed permit area is underlain by the Dakota Formation, which crops out in the western portion of the proposed permit area and also west of the proposed permit area near Kanab Creek (Figure 6). Recharge to the Dakota Formation through the overlying Tropic Shale is likely negligible due to the poor groundwater transmitting properties of the Tropic Shale discussed above.

Groundwater discharge from the Dakota Sandstone in the permit and adjacent area is meager. The Dakota Formation consists predominantly of shaley strata interbedded with lenticular, fine- to medium-grained sandstone and coal. Because of the pervasiveness of interbedded low-permeability horizons in the formation and the vertical and lateral discontinuity of sandstone horizons, the potential for vertical and horizontal movement of groundwater is limited. Although aquifer-quality sandstone strata may exist within the formation, appreciable groundwater migration through the formation over large distances likely does not occur due to the lenticular, discontinuous nature of these permeable sandstones. Consequently, groundwater discharge from the rocks of the Dakota Formation in the proposed Coal Hollow Mine permit and adjacent area is not appreciable.

While no springs discharge from the Dakota Formation in the permit area, a spring with a discharge of about 1 gpm and displaying little seasonal variability in discharge is present in the southern portion of the study area in Sink Valley Wash (SP-4; Figure 11). This spring discharges from an apparent fault zone in the Dakota Formation. Additionally, two minor seeps with discharges of less than 0.05 gpm (SP-27 and SP-34; Appendix B) seep from the Dakota Formation or colluvial sediments in lower Sink Valley more than ½ mile south of the proposed Coal Hollow Mine permit area.

It should be noted that the results of slug testing performed on wells screened in the Smirl coal seam of the upper Dakota Formation indicate relatively low values of hydraulic conductivity for the coal seam (Table 7). In much of the proposed mining area, the coal seam is dry (UDOGM, 2007). Thus, appreciable influx of groundwater through the Smirl coal seam into proposed mine workings is not anticipated.

9.3 Alluvial Groundwater Systems

Natural groundwater discharge in the permit and adjacent area occurs primarily from alluvial sediments. Alluvial discharge occurs both as discrete springs and seeps (Figure 11; Appendix B) and also locally as diffuse seepage to the surface. The seasonal variability in discharge rates from groundwater systems is depicted in discharge and water-level

hydrographs for springs and wells in Figure 13. Groundwater discharge areas in the proposed Coal Hollow Mine permit and adjacent area are shown on Figure 16. The area of most appreciable alluvial groundwater discharge occurs in central Sink Valley in the northwest quarter of Section 29, T39S, R5W (see Figure 16; groundwater discharge area A). The alluvial groundwater system in this area exists under artesian conditions, resulting from the presence of a considerable thickness (about 60 feet) of low permeability clayey sediments overlying coarser, water-bearing alluvial sediments at depth (See cross-section Y – Y' in Figure 8). The artesian alluvial groundwater system in Sink Valley is likely recharged via mountain-front-recharge along the flanks of the Paunsaugunt Plateau to the east and north of the proposed Coal Hollow Mine permit area. The alluvial groundwater system that exists along the eastern margins of Sink Valley is likely continuous from near mountain-front recharge areas southward along the eastern margins of Sink Valley to the lower portion of Sink Valley.

A 28-hour pump test was performed in January 2007 in the alluvial groundwater system in Sink Valley using Y-61 (Figure 11) as the pumping well. Y-61 is a steel-cased water well (6.625-inch casing) that is 150 feet deep and screened in the coarse alluvial sediments in Sink Valley. During the pumping of Y-61, contemporaneous discharge measurements were made on four nearby alluvial springs and contemporaneous monitoring of water levels in 20 monitoring wells was also performed. A similar pumping test at Y-61 was performed in the 1980's by Utah International, Inc. The purpose of this pump test was:

1. To evaluate the potential hydraulic connection between the coarse grained portion of the alluvial groundwater system and the silty, clayey, and sandy alluvial sediments overlying areas planned for mining at the proposed Coal Hollow Mine, and
2. To characterize the aquifer parameters of the coarse-grained, artesian portion of the alluvial groundwater system that supports springs and flowing artesian wells in the area.

A plot of the pumping drawdown and recovery in well Y-61 is presented in Figure 17. Plots of contemporaneous groundwater potentiometric levels in monitoring wells and discharge rates in nearby alluvial springs are presented in Figure 18. It is evident in Figure 18 that there is good hydraulic communication between the artesian alluvial groundwater system in which Y-61 is screened and the groundwater systems that support nearby springs. Additionally, a more muted potentiometric response was observed in monitoring wells located near the eastern margins of the proposed mining areas (Figure 18). This suggests some degree of hydraulic communication between the artesian alluvial groundwater near Y-61 and the lower permeability alluvial sediments overlying the easternmost extent of proposed mining areas. Responses to pumping at Y-61 were not observed in other wells in the clayey and silty alluvial system near proposed mining areas. The lack of an observed response in potentiometric levels in the more distant wells may indicate a low degree of hydraulic communication between these areas, or alternatively, it may be that the distances from these wells to the pumping well was too great for a potentiometric response to be measured.

The pumping tests performed at Y-61 indicate a relatively high value of hydraulic conductivity for the coarse-grained alluvial groundwater system on the order of 6×10^{-2} cm/sec (Table 7).

In order to more fully characterize the hydrogeologic conditions in the proposed mining areas, 30 monitoring wells were constructed in the area during the winter of 2006-2007. Inspection of drill cuttings and split-spoon samples indicate that the sediments overlying proposed mining areas are dominated by clayey, silty, and some fine-grained sandy sediments. Tropic Shale bedrock underlies the alluvial sediments in all areas proposed for mining. Coarse-grained sediments were generally not observed in proposed mining areas. Stratigraphic information obtained from drilling activities and monitoring well completion information is presented in Tables 5 and 8.

Slug testing of 20 of the newly constructed wells was performed during January 2007. The results of these slug tests are presented in Table 7. Generally, as anticipated, the values of hydraulic conductivity for the clayey, silty, and sandy sediments overlying proposed mining areas are relatively low, and are several orders of magnitude lower than those in the adjacent coarse-grained portion of the alluvial groundwater system in Sink Valley.

Using Darcy's Law, which may be expressed as:

$$Q = KIA$$

Where
- Q = groundwater discharge rate
- K = hydraulic conductivity
- I = hydraulic gradient
- A = cross-sectional area

Order-of-magnitude estimates for groundwater inflow rates into the mine workings at the proposed Coal Hollow Mine were calculated. A conservative value of 0.10 for the hydraulic gradient was utilized in these calculations. These results are presented in Table 8. Based on the inherent degree of uncertainty in slug testing, the calculations presented in Table 8 should be considered as order-of-magnitude estimates.

It is noteworthy that while artesian pressures exist in the coarse-grained portion of the alluvial groundwater system, appreciable vertical hydraulic gradients (either upward or downward) were generally not observed in nested monitoring wells in proposed mining areas.

Discharge from the alluvial groundwater systems in and adjacent to the proposed Coal Hollow Mine permit area occurs primarily in two areas (Figure 16). In the northwest quarter of Section 29, T39S, R5W, considerable natural discharge from the alluvial groundwater system occurs through springs and seeps (Figure 16; groundwater discharge area A). Minor discharge from several flowing artesian wells also occurs in this area. The artesian alluvial groundwater system in eastern Sink Valley also likely provides recharge to the clayey alluvial sediments in the southwestern portion of the valley in the proposed Coal Hollow Mine permit

area. Discharge from the alluvial groundwater system in groundwater discharge area A results in decreases to the amount of water in storage in the alluvial groundwater system and also decreases in artesian hydraulic pressure in the aquifer.

Appreciable discharge from the alluvial groundwater system also occurs in lower Sink Valley in the northwest quarter of Section 32, T39S, R5W (see Figure 16; groundwater discharge area B). Sink Valley constricts markedly in this area, which forces shallow alluvial groundwater flowing down the valley to discharge at the land surface as springs, seeps, and diffuse discharge to the surface (i.e., there is a significant decrease in the cross-sectional area of the alluvial sediments).

Much of the alluvial groundwater in Sink Valley likely ultimately leaves the valley via evapotranspiration. This conclusion is based on the observation that there is very rarely any discharge of surface water (at least at the surface in the channel) in Sink Valley Wash below Sink Valley (See site SW-9; Figure 11; Table 4). The clayey, low-permeability sediments present at the surface over most of Sink Valley also impede appreciable infiltration of precipitation and snow melt waters into the deeper subsurface. Hence, groundwater recharge to the lower half of the Sink Valley sediments (including the proposed Coal Hollow Mine permit area) likely occurs primarily via horizontal migration of alluvial groundwaters from up-gradient areas.

Flowing artesian groundwater conditions are also observed in monitoring wells screened near the base of the alluvial sediments in the northwest corner of Section 32 T39S, R5W (see Figure 16, area B). It is probable that the artesian alluvial groundwater system in Section 29, T39S, R5W is continuous with that in the northwest corner of Section 32. It should be noted that within the proposed Coal Hollow permit area, flowing artesian conditions were not observed in any of the monitoring wells. While the thickness of the alluvial sediments in the artesian groundwater system east of the proposed Coal Hollow permit area ranges up to 150 feet, the thickness of alluvium overlying areas with mineable coal in the proposed Coal Hollow permit area generally does not exceed about 50 feet and in many locations it is considerably thinner.

Natural discharge of alluvial groundwater in the Robinson Creek drainage area is meager. This condition is largely due to the presence of the elevated ridge of impermeable Tropic Shale bedrock associated with the Sink Valley Fault that dissects and effectively isolates the alluvium east of the fault from that west of the fault (Figure 6). Because of the low permeability of the Tropic Shale, this condition forces alluvial groundwater east of the Tropic Shale ridge to flow to the south toward Sink Valley that would otherwise report to the Robinson Creek drainage. During high flow conditions in the alluvial groundwater system east of the Tropic Shale ridge, minor amounts of groundwater "overtop" the bedrock ridge and drain via surface flow over the Tropic Shale bedrock, where it either recharges shallow alluvial sediments to the west of the fault or is lost to evapotranspiration. The influence of the Tropic Shale ridge is readily evident in field observations, with marked differences in vegetation and soil moisture being apparent on opposite sides of the ridge. During low-flow conditions, discharge from the overtopping of the bedrock ridge has generally not been

observed. Isolated areas of soil wetness and shallow perched alluvial groundwater systems that exist west of the bedrock ridge in the northeast corner of Section 30 and the southeast corner of Section 19, T39S, R5W are likely at least partly sourced via this mechanism.

Seepage of alluvial groundwater into the deeply incised lower Robinson Creek stream channel occurs near the contact with the underlying Dakota Formation in the southeast quarter of Section 19, T39S, R5W. This water is likely related to saturated alluvial deposits underlying the Robinson Creek stream channel. The alluvial groundwater emerges near where the saturated alluvial sediments intersect the mostly impermeable Dakota Formation bedrock in the base of the stream channel. It is noteworthy that the location of the emergence of alluvial water in the channel has varied somewhat over time. The Robinson Creek stream channel above this location is almost always dry (except for in direct response to torrential precipitation events or during the springtime runoff season during wet years. This seepage of alluvial water in the Lower Robinson Creek channel is typically about 5 to 10 gpm or less and is routinely monitored at monitoring station SW-5 (Figure 11).

Appreciable spatial variability exists in water quality in groundwaters and surface waters in the proposed Coal Hollow permit and adjacent area. Stiff diagrams depicting solute compositions and overall water quality for groundwaters and surface waters in the proposed Coal Hollow Mine permit and adjacent area are shown in Figure 14. Important water quality characteristics for groundwaters are summarized below.

Groundwater Source	Chemical type	TDS (mg/L)
Alluvial groundwaters, coarse-grained system east of proposed permit area	Calcium-magnesium-bicarbonate	380 mg/L to 500 mg/L typically, Little seasonal variability
Alluvial groundwaters in south sink valley	Variable, magnesium-bicarbonate sulfate, calcium-magnesium-bicarbonate	450 mg/L to 3,600 typically, Highly variable based on location, season, and climate for shallow systems, less variability in deeper system
Dakota Formation, fault groundwater system south of proposed permit area	Sodium-bicarbonate	500 mg/L to 600 mg/L typically, Little seasonal variability

It is apparent that the overall water quality of alluvial groundwater degrades from the coarse-grained artesian groundwater system east of the proposed Coal Hollow permit area to the non-artesian shallow alluvial groundwater systems located in the more distal portions of Sink Valley. These changes are due to groundwater interaction with soluble minerals in the primarily Tropic Shale-derived sediments (described above) that make up the shallow alluvial

materials in the proposed permit area. The effects of evapoconcentration may also contribute to the increased TDS concentrations of these groundwaters.

In the natural condition, alluvial groundwater systems in Sink Valley do not contribute measurably to baseflow in Sink Valley Wash. Rather, most alluvial groundwater in the basin is likely lost to evapotranspiration. Evaporite minerals at the land surface and high-TDS soil conditions that would eventually build up as a result of evapotranspiration process are likely flushed from the system periodically during torrential precipitation events and during the springtime snowmelt event. Consequently, because alluvial groundwater does not contribute appreciably to surface-water flows in the area, if impacts to water quality in the alluvial groundwater system the potential for impacts to important water-quality parameters in the surrounding areas

It is noteworthy that the groundwater that naturally discharges in the northwest ¼ of Section 32, T39S, R5W is of generally poorer quality that that discharge at up-gradient locations in the alluvial groundwater system, suggesting that interaction between the Tropic Shale or Tropic Shale-derived alluvial sediments has occurred.

10.0 Surface-Water Systems

All surface waters in the proposed Coal Hollow Mine permit and adjacent area are tributary to Kanab Creek. Surface waters in the northern portion of the proposed permit and adjacent area drain into the Robinson Creek and upper Kanab Creek drainages. Surface waters in the southern portion of the proposed permit and adjacent area drain into the Sink Valley Wash drainage which is tributary to Kanab Creek about 6 miles below the proposed Coal Hollow Mine permit area. Surface water drainages in the permit and surrounding areas are shown in Figure 19. Surface water baseline monitoring stations are shown on Figure 11. Discharge rates and seasonal variability occurring in surface-water systems in the proposed Coal Hollow Mine permit and adjacent area are depicted in Figure 13.

Surface waters in Kanab Creek are used for stock watering and crop irrigation in the irrigable lands adjacent to Kanab Creek west of the proposed Coal Hollow Mine permit area. Discharge in Kanab Creek measured near the town of Alton (SW-1) is seasonally dependent and largely influenced by upstream water use. Discharge in Kanab Creek monitored at SW-1 typically ranges from 10 cfs or less during the springtime runoff period to 1 cfs or less during the summertime.

Discharge in the Lower Robinson Creek drainage is meager. Other than during the springtime runoff event in wet years or during torrential precipitation events, flow has not been observed at monitoring stations SW-4 and SW-101 (Figure 11). This condition is largely attributable to the relatively small drainage area of the Lower Robinson Creek

drainage, most of which is located at lower elevations along the margins of the Paunsaugunt Plateau (Figure 19). While surface discharge at SW-4 and SW-101 generally only occurs in direct response to precipitation or snowmelt events, a meager discharge at the lower monitoring site on Lower Robinson Creek (SW-5; Figure 13) is often present. The small discharge occasionally present at SW-5 is derived from the seepage of alluvial groundwater into the Lower Robinson Creek stream channel between monitoring sites SW-101 and SW-5

Tributaries to the Sink Valley Wash drainage in the proposed Coal Hollow Mine permit and adjacent areas include (from north to south) Water Canyon, an unnamed drainage south of Water Canyon in Section 21 T39S, R5W, and Swapp Hollow. Discharge rates in these drainages are highly seasonally dependent (Table 4; Figure 13). Discharges in the Water Canyon and Swapp Hollow drainages are intermittent or perennial in nature with sustained discharge peaks occurring in response to seasonal melting of winter snowpack on the adjacent Paunsaugunt Plateau. The more substantial discharges that occur in these drainages are attributable to the relatively larger size of these drainages and that fact that much of the drainage areas is situated in upland portions of the Paunsaugunt Plateau (Figure 19). Surface-water discharges in these streams decline markedly during the summer and fall months as the snowpack wanes and regional temperatures increase. Climatic variability in discharge rates in these streams is also evident (Table 4; Figure 13). It should be noted that during the 2005 season, much greater than normal precipitation occurred and these conditions are reflected in increased discharges in streams in the area (Table 4). Discharge in the unnamed drainage in Section 21 T39S, R5W is ephemeral. Discharge has not been observed in this canyon during the period of baseline monitoring (Table 4).

The water quality and discharge characteristics of surface waters in the proposed Coal Hollow Mine permit and adjacent area are tabulated in Table 4. Solute compositions of stream waters are also depicted graphically as Stiff diagrams in Figure 14. The solute compositions of surface waters in the proposed Coal Hollow Mine permit and adjacent area are summarized below.

Source	Chemical type	TDS (mg/L)
Lower Robinson Creek above proposed permit area (SW-4)	Calcium-magnesium-bicarbonate when present	300 mg/L typical
Lower Robinson Creek near proposed permit area (SW-101; SW-5)	Variable, magnesium-sulfate-bicarbonate	300 – 3,000 mg/L typical, dependent on discharge, TDS can increase appreciably where torrential precipitation water interacts with native sediments.
Swapp Hollow	Calcium-magnesium-bicarbonate	250-350 mg/L typical
Water Canyon (RID-1 diversion)	Calcium-magnesium-bicarbonate	250-280 mg/L typical
Kanab Creek	Magnesium-calcium-bicarbonate-sulfate during high flow, variable during low-flow, variability likely due largely to interaction with Tropic Shale soils and irrigation return flows	500-1,300 mg/L typical, Variable dependent on season and irrigation use
Sink Valley Wash	Magnesium-calcium-bicarbonate	600 -1,500 mg/L typical, variable dependent on discharge
Section 21 draiange	No flow present	No flow present

Considerable seasonal variability exists in the solute compositions of stream waters in Kanab Creek in the proposed Coal Hollow Mine permit and adjacent area (Table 4). During low-flow conditions, interactions between stream waters and Tropic Shale or Tropic Shale-derived sediments likely result in increased TDS concentrations. Return flow from irrigated fields and interactions with soils rich in soluble minerals may also contribute to increased TDS concentrations in the summertime. During the spring runoff season, high surface-water flows that originate from the adjacent upland areas dominate the flow in the channel. The TDS concentrations of Kanab Creek waters during high-flow conditions are thus lower than during the low-flow season. Much less seasonal variability in solute content in surface water flows from the mountain stream in Swapp Hollow and Water Canyon (Table 4). This condition is likely attributable to the fact that the stream in Swapp Hollow, which originates on geologic formations overlying the Tropic Shale, has considerably less contact with the Tropic Shale than does Kanab Creek. Additionally, there are no known irrigation diversions or returns above the stream monitoring point (SW-8; Figure 11) in Swapp Hollow.

11.0 Probable Hydrologic Consequences Determination

This section describes the probable hydrologic consequences of surface coal mining in the proposed Coal Hollow Mine permit area. The mining and reclamation plan has been designed to minimize potential adverse impacts to the hydrologic balance. It should be noted that this PHC may be updated periodically as required as additional hydrogeologic information and mining data become available in the future.

11.1 Potential adverse impacts to the hydrologic balance

Other than the possible short-term diminution in discharge rates from alluvial groundwater systems, including the potential short-term diminution of discharge rates from some springs and seeps in Sink Valley, appreciable adverse impacts to the hydrologic balance, either on or off the permit area are not expected to occur. The basis for this determination is discussed below.

As discussed in Section 721 above, minimal groundwater resources exist in the Tropic Shale, which directly overlies the coal reserves in proposed mining areas. Groundwater in the Tropic Shale does not provide measurable baseflow discharge to streams in the area. The lack of appreciable groundwater flow in the Tropic Shale is a result of the poor water transmitting properties of the marine shale unit. Consequently, it is anticipated that little groundwater will be encountered in the Tropic Shale in mining areas. Thus, the potential for adverse impacts to the hydrologic balance resulting from mining through the Tropic Shale in the proposed Coal Hollow Mine permit area is minimal.

Similarly, as described above, groundwater resources in the Dakota Formation underlying the coal seam to be mined are not appreciable. This condition is fundamentally a result of the heterogeneity of the rock strata in the Dakota Formation which impedes the ability of the formation to transmit groundwaters significant distances vertically or horizontally. The presence of the essentially impermeable Tropic Shale on top of the Dakota Formation also minimizes the potential for vertical recharge to the Dakota Formation. Mining operations will remove the overlying Tropic Shale rock strata from the Dakota Formation in addition to the Smirl coal seam deposit at the top of the Dakota Formation in mined areas. However, because the pre-mining hydraulic communication between the Tropic Shale and the underlying Dakota Formation in planned mining areas is believed to be minimal, the removal of the Tropic Shale overburden and Smirl coal seam from the Dakota Formation, followed by the rapid backfilling of pit areas with low-permeability fill materials should not result in adverse impacts to the hydrologic balance in the Dakota Formation (i.e., the post-mining degree of hydraulic communication between the Dakota Formation and the overlying low-permeability backfill material will be similar to that of the pre-mined condition).

It should be noted that the first water-bearing strata underlying the coal seam to be mined in the proposed Coal Hollow Mine permit area from which appreciable quantities of

groundwater can be produced is the Navajo Sandstone. The Navajo Sandstone aquifer is of regional significance in that it provides groundwater of good quality to domestic, agricultural, and municipal wells regionally and provides baseflow to springs and streams. The Navajo Sandstone does not crop out in the proposed Coal Hollow Mine permit and adjacent area. The formation is effectively isolated from proposed mining areas by more than 1,000 feet of rock strata of the Dakota and Carmel Formations (which includes large thicknesses of low-permeability shales and siltstones). The Navajo Sandstone aquifer will not be impacted by proposed mining operations. It should be noted that some previously proposed mining operations in the Alton Coal Field have proposed drilling and pumping of large amounts of groundwater from high-capacity production wells in the Navajo Sandstone aquifer for operational use. No such wells are planned in the proposed Coal Hollow Mine permit and adjacent area.

Of primary importance to the hydrologic balance in the proposed Coal Hollow Mine permit and adjacent area are alluvial groundwater systems. As discussed in Section 8 above, alluvial groundwater systems in the area support springs, seeps, diffuse groundwater discharge, and a limited number of wells. The bulk of the alluvial groundwater flux through the area occurs in alluvial sediments that include coarse-grained and finer-grained sediments near the eastern margins of Sink Valley, east of the proposed Coal Hollow Mine permit area. Lesser quantities of alluvial groundwater migrate through finer-grained alluvial sediments (predominantly clays, silts, and sands) in the western portions of Sink Valley and in the Lower Robinson Creek drainage within the proposed Coal Hollow Mine permit area. Discharges from alluvial groundwater systems in Sink Valley do not contribute measurable quantities of baseflow to streams (at least at the surface in the stream channel). Alluvial groundwater systems in the Lower Robinson Creek area are much less extensive than the alluvial groundwater systems in Sink Valley. Other than the re-emergence of alluvial groundwater flowing beneath the Lower Robinson Creek stream channel where the stream channel exists directly on bedrock substrate, discharge from the alluvial groundwater system as springs or seeps in Lower Robinson Creek is generally not observed. Perched groundwater conditions exist locally in the alluvial groundwater system in the Lower Robinson Creek drainage.

In the general sense, surface coal mining activities in the proposed Coal Hollow Mine permit area have the potential to impact groundwater systems primarily through three mechanisms:

1) Where water-bearing strata in proposed mining areas are mined through, groundwater systems within these strata will obviously be directly intercepted,
2) Where groundwater flow paths through mine openings are interrupted, groundwater flow in down-gradient areas could be diminished, and
3) Where mine openings intercept permeable strata, groundwater resources in up-gradient areas could potentially be diminished if appreciable quantities of groundwater were to be drained from up-gradient areas.

The potential for the occurrence of each of these potential impacts are described in the following.

11.2 Direct Interception of Groundwater Resources

As discussed above, groundwater resources in the relatively impermeable Tropic Shale in the proposed permit area are meager. Consequently, it is improbable that direct interception of appreciable groundwater in the Tropic Shale will occur. Additionally, because Tropic Shale groundwater systems generally do not support discharges to springs or provide baseflow to streams, the potential interception of limited quantities of groundwater in the Tropic Shale will not adversely impact the hydrologic balance. Similarly, groundwater resources in the Dakota Formation (including within the Smirl coal seam) are meager. While the Smirl coal seam will be extracted through mining operations, the underlying strata of the Dakota Formation will not be disturbed. Consequently, adverse impacts to groundwater systems in the Dakota Formation through direct interception of groundwater resources are not anticipated.

Alluvial groundwater systems in planned mining areas in the proposed Coal Hollow Mine permit area will be directly intercepted by the mine openings. It is not anticipated that the direct interception of shallow alluvial groundwater will adversely impact the overall hydrologic balance in the region. This is because no springs, seeps or other important groundwater resources have been identified in proposed mine pit areas. In the pre-mining condition, any diffuse groundwater discharge to the ground surface that occurs is primarily lost to evapotranspiration and does not contribute appreciably to the overall hydrologic balance in the area.

11.3 Diminution of down-gradient groundwater resources

Where groundwater flow paths that convey groundwater to down-gradient areas exist in areas that will be mined, there is the potential that diminution of down-gradient groundwater resources could occur. In the proposed Coal Hollow Mine permit area, it is considered unlikely that appreciable diminution of down-gradient resources will occur as a result of mining and reclamation activities. The basis of this conclusion is presented below.

Groundwater resources in the Tropic Shale are meager and groundwater flow rates are very slow through the marine shale unit. Groundwater systems in the Tropic Shale do not support appreciable spring or seep discharge nor do they provide measurable baseflow to streams down-gradient of mining areas. Consequently, the potential for adverse impacts to the hydrologic balance as a result of mining through Tropic Shale is considered minimal.

Similarly, groundwater resources in the Dakota Formation are meager. The potential for lateral and vertical migration of groundwater through the formation is limited by the pervasiveness of low-permeability shaley strata in the formation and the lateral discontinuity of permeable strata. Groundwater systems in the Dakota Formation do not support appreciable spring or seep discharge nor do they provide measurable baseflow to streams down-gradient of mining areas. Additionally, with the exception of the relatively low-

permeability Smirl coal seam located at the top of the formation, groundwater systems in Dakota Formation rock strata below the coal seam will not be disturbed by mining and reclamation activities. Consequently, the potential for adverse impacts to the hydrologic balance as a result of mining through Dakota Formation strata is considered minimal. It should be noted that spring SP-4 discharges at about 1 gpm approximately 1.1 miles south of the proposed Coal Hollow Mine permit area from an apparent fault/fracture system in the Dakota Formation that may be related to the Sink Valley Fault. It is unlikely that appreciable migration of groundwater through the Sink Valley Fault system in the relatively impermeable Tropic Shale or shallow alluvium in the proposed Coal Hollow Mine permit area occurs. Consequently, it is considered unlikely that mining and reclamation activities in the proposed Coal Hollow Mine permit area will cause a diminution of discharge from spring SP-4.

Alluvial groundwater systems in proposed mining areas area supported primarily by clays, silts, and fine-grained sands. In proposed mining areas in Sink Valley, appreciable coarse grained alluvial sediments were not encountered in drill holes or back-hoe excavations. Significant layers of clean coarse alluvium, which could rapidly convey significant amounts of groundwater were likewise not observed. The results of slug testing performed on wells in and adjacent to proposed mining areas likewise suggest that the potential for rapid migration of groundwaters through alluvial sediments in proposed mining areas is low (Tables 7 and 8). These data and observations suggest that the flux of groundwater migrating through the alluvial sediments in proposed mining areas in Sink Valley (that could support down-gradient groundwater systems) is not large. Much of the groundwater migrating through the alluvial sediments in proposed mining areas (in the East ¼ of Section 30, T39S, R5W) likely leaves the groundwater system through diffuse discharge to the land surface and is lost evapotranspiration and does not contribute to the overall hydrologic balance in the area. In Sink Valley, a preferential pathway for alluvial groundwaters through deep coarse-grained alluvial sediments likely exists along the east side of Sink Valley. While the thickness of the alluvium in proposed mining areas in Sink Valley generally does not exceed 50 feet (and in many locations is much less), the alluvial sediments along the eastern side of Sink Valley adjacent to proposed mining areas range from about 120 to 140 feet. Of the total flux of groundwater through the alluvial groundwater systems in Sink Valley, most of the flux is likely through this coarse-grained portion of the system. The percentage of the total flux that migrates through clayey and silty alluvial sediments in proposed mining areas along the western flanks of Sink Valley is likely much less.

It should be noted that highly permeable strata were encountered from about 60 to 75 feet depth just above the bedrock interface at the SS well cluster (monitoring well SS-75; Table 5). This well is screened in an area of burned or eroded coal (the coal is absent) and consequently, mining will not occur at this location. The coal seam is present at the nearby C9 cluster area. Were mining operations to intercept this highly permeable zone, substantial groundwater inflows into the mine openings could occur. Consequently, prior to surface mining in this area, the boundary between the competent coal seam and the area of burned or eroded coal will be more precisely defined by drilling or other suitable techniques such that mine openings can be designed to avoid these areas of potentially large groundwater inflows.

As discussed above, alluvial groundwater from Sink Valley discharges to several springs and seeps and as diffuse discharge to the ground surface in the northwest ¼ of Section 32, T39S, R5W (see Figure 16; groundwater discharge area B). This groundwater discharge is likely a result of the constriction in Sink Valley in this area and the corresponding decrease in the cross-sectional area of the alluvial sediments in the valley, which forces groundwater to discharge at the surface. Most of the groundwater discharge in this area is likely derived from the up-gradient alluvial groundwater systems in the eastern portion of the valley (i.e., the coarse-grained portion of the alluvial groundwater system), which is situated east of the proposed Coal Hollow Mine permit area. This conclusion is based on 1) the substantially larger cross-sectional area of the alluvium in the deeper eastern portion of the valley relative to that in proposed mining areas near the western margins of the valley, 2) the higher hydraulic conductivity of the sediments in the coarse-grained part of the alluvial system, and 3) the lack of other apparent discharge mechanisms for the coarse-grained system further downstream in Sink Valley Wash (i.e., there are no significant alluvial springs or seeps further downstream in Sink Valley Wash and the system apparently does not contribute measurable baseflow to Sink Valley Wash further downstream (at least at the surface in the stream channel, as evidenced by the lack of baseflow in the wash monitored at SW-9).

Because most of the alluvial groundwater discharge supporting springs and seeps in this area is likely not derived from groundwater systems that underlie planned mining areas in the proposed Coal Hollow Mine permit area, it is considered unlikely that discharges from the springs and seeps in northwest ¼ of Section 32 T39S, R5W will be appreciably diminished as a result of the proposed mining and reclamation activities. While considered unlikely, some temporary impacts to discharge rates from springs and seeps in this area are possible. In particular, it should be noted that mining in the southernmost portions of the proposed Coal Hollow Mine permit area has a somewhat greater potential to decrease groundwater discharge rates at spring SP-6, which is located about 600 feet below the southernmost proposed mining areas (Figure 11). SP-6 is an alluvial seep which has been impounded with an earthen dam from which measurable discharge is generally not present.

It is critical to note that individual mine pits in this area will remain open for short lengths of time, generally no more than about 60 to 120 days. Mining operations in the vicinity near the alluvial groundwater discharge area in the northwest ¼ of Section 32 T39S, R5W are planned to be completed in about 1 year. Thus, any potential impacts to discharge rates from down-gradient groundwater systems will be short-lived. Following the backfilling and reclamation of mine openings, the potential for interception or re-routing of alluvial groundwater away from the groundwater discharge area in northwest ¼ of Section 32 T39S, R5W will be negligible. As stated above, most of the flux through the Sink Valley alluvial groundwater system that supports springs and seeps in the area occurs in the eastern portion of the valley, which will not be impacted by mining and reclamation activities. Consequently, long-term impacts to discharge rates from springs and seeps in this area are not anticipated. It should also be noted that if increased quantities of groundwater were to be encountered in mine workings in lower Sink Valley such that the water would need to be discharged to surface drainages, the mine water will ultimately be discharged to the Sink Valley Wash drainage (i.e., the water will remain in its drainage basin).

Alluvial groundwater systems in the Lower Robinson Creek area are much less extensive than the alluvial groundwater system in Sink Valley. Perched groundwater conditions exist locally in the alluvial groundwater system in the Lower Robinson Creek drainage. Other than the re-emergence of alluvial groundwater flowing beneath the Lower Robinson Creek stream channel where the stream channel exists directly on bedrock substrate, discharges from the alluvial groundwater system as springs or seeps in Lower Robinson Creek are not observed. Consequently, mining operations in the Lower Robinson Creek drainage will likely not result in diminution of down-gradient groundwater resources.

It should be noted that the proposed Coal Hollow Mine plan calls for the permanent diversion of a reach of the Lower Robinson Creek stream channel approximately 2,000 feet in length in the southeast ¼ of Section 19, T39S, R5W. Details of the proposed diversion are given in Chapter 5, Section 527.220 of this MRP. If this action results in diminution of groundwater or surface-water resources, where required a suitable mitigation for this potential impact will be designed and implemented in consultation with the Division of Oil, Gas and Mining.

If any Utah State appropriated water rights are impacted by mining and reclamation operations in the proposed Coal Hollow Mine, these will be replaced according to all applicable Utah State laws and regulations using the designated water replacement source described in Chapter 7 of the Coal Hollow Mine MRP (Section 727).

11.4 Draining of up-gradient groundwater resources

Where surface mining occurs adjacent to up-gradient groundwater systems, there is a potential that draining of groundwater from the up-gradient groundwater system into the mine voids could occur. This condition could occur if a sufficiently large and permeable stratum were to be intercepted that is in good hydraulic communication with the up-gradient groundwater system through which appreciable quantities of water could be transmitted.

To more fully evaluate the potential for draining of up-gradient groundwater resources, a field investigation was performed during the winter of 2006-2007 that was designed to facilitate the characterization of the alluvial groundwater system in the proposed Coal Hollow Mine permit and adjacent area. Specifically, this program was designed 1) to better define the vertical and lateral extent of permeable, coarse-grained sediments in the alluvial groundwater system, 2) to characterize the water bearing and water transmitting properties of alluvial sediments, and 3) to evaluate the degree of hydraulic communication between the coarse-grained portion of the alluvial system in Sink Valley and the clayey alluvial sediments in proposed mining areas.

This field investigation included 1) the drilling and installation of 30 monitoring wells, 2) the performance of a 28-hour pumping and recovery test on alluvial production well Y-61 with contemporaneous measuring of water levels in the monitoring well network and contemporaneous measuring of spring discharge rates at three alluvial springs, and 3) the slug

testing of 20 monitoring wells to determine approximate values of hydraulic conductivity. The results of the field investigation including analysis of the data collected in the investigation are summarized below.

Other than occasional pebbles or small rocks, coarse-grained sediments (i.e., gravels and coarse sands) were not encountered in the drilling of wells along the eastern margins of proposed mining areas in Sink Valley (C1, C2, C3, and C4 well clusters). Rather, the sediments encountered in the drilling of these wells were dominated by clays and silts with subordinate amounts of fine-grained sand. Similarly, coarse-grained deposits were not encountered in well clusters C6, C7, C8, and C9. There was no indication during drilling of any appreciable thickness of highly permeable strata through which groundwater could rapidly be transmitted (although it should be noted that the presence of thin sand layers are difficult to identify in wet auger drilling returns). Similarly, appreciable amounts of high-permeability coarse-grained alluvial sediments were not noted in alluvial sediments investigated in backhoe excavated pits and erosional escarpments in Sink Valley.

The hydraulic heads measured in alluvial monitoring wells near proposed mining areas in Sink Valley (C2, C3, C4, C7, C8, and C9) did not indicate artesian pressures. Rather, marked upward or downward vertical hydraulic gradients were not observed in any of these areas and water levels were consistently within several feet of the ground surface.

The results of pump-testing in the alluvial groundwater system demonstrate that the springs in the northwest ¼ of Section 29, T39S, R5W are in direct hydraulic communication with the coarse-grained alluvial groundwater system in which the pumping well Y-61 is screened. Discharge rates (or water levels at Sorensen Spring) measured at each of the four springs (SP-8, SP-14, SP-20, and Sorensen spring) monitored during the 28-hour pumping test responded to pumping at the well. Monitoring wells at clusters C2, C3, and C4 near the easternmost proposed mining areas also showed small, muted responses, with declines measured in water levels during the 28-hour test ranging from about 0.05 to 0.10 feet. Other monitoring wells in proposed mining areas did not respond measurably to pumping at Y-61. It should be noted that after the pumping well was turned off at the end of the 28-hour pumping test, spring discharge rates and water levels in alluvial monitoring wells recovered to approximate pre-testing levels.

The results of slug testing of wells in the proposed Coal Hollow Mine and adjacent area are presented in Table 7. Using these hydraulic conductivity values together with measured thicknesses of saturated alluvial sediments determined during drilling, and hydraulic gradient values determined from water levels measured in monitoring wells, rates of estimated groundwater inflows to mine openings have been calculated using Darcy's Law (Table 8).

Darcy's Law may be expressed as.

$Q = KIA$

Where	Q	=	groundwater discharge rate
	K	=	hydraulic conductivity
	I	=	hydraulic gradient
	A	=	cross-sectional area

The values listed in Table 8 are reported as inflow rates per 100 lineal feet of mine openings oriented perpendicular to the groundwater flow direction. Calculations at individual locations are adjusted for the thickness of the saturated alluvium at that location. For all calculations in Table 8, a gradient of 0.10 has been used, which is considered a conservative estimate for the alluvial groundwater system in the vicinity of the planned Coal Hollow Mine workings. It is important to note that while values for saturated aquifer thickness and local hydraulic gradient in the alluvial groundwater system can be determined relatively precisely, hydraulic conductivity values determined from slug testing methods are generally considered as order-of-magnitude estimates. Consequently, the information from Table 8 should be used for general purposes only. The estimated groundwater inflow rates presented in Table 8 suggest that copious, unmanageable amounts of alluvial groundwater will likely not be encountered.

As surface mining operations advance toward the alluvial groundwater discharge area in the northwest ¼ of Section 29, T39S, R5W (See Figure 16; groundwater discharge area A), the information in Table 8 suggests that groundwater inflow rates in this area will be modest, generally on the order of a few tens of gallons per minute or less per 100 lineal feet of mine opening. However, it should be noted that, as discussed above, if mine openings in this area were to intersect a substantial thickness of coarse-grained alluvial material that was in good hydraulic communication with the coarse-grained alluvial system located along the eastern margins of Sink Valley, substantially greater rates of groundwater inflow could occur. Based on the information in Tables 7 and 8, this is not considered likely.

As mining operations advance toward the alluvial groundwater discharge area in the northwest ¼ of Section 29, T39S, R5W (See Figure 16; groundwater discharge area A) and groundwater discharge from up-gradient alluvial groundwater systems occurs, there is the potential that discharge rates from alluvial springs in this area could be diminished. The magnitude of this potential impact will be largely dependent on the drainage rate and volume of groundwater that may be drained from the up-gradient alluvial groundwater system.

The potential for diminution of discharge from alluvial springs near proposed mining areas near the northwest ¼ of Section 29, T39S, R5W will be minimized because:

1) As mining progresses toward the groundwater discharge area in the northwest ¼ of Section 29, T39S, R5W (see Figure 16, groundwater discharge area A), groundwater inflows into mine openings and discharge rates from the nearby alluvial springs will be closely monitored. If groundwater inflow rates into mine openings are

excessive, where necessary Alton Coal Development, LLC will use a suitable technique to minimize groundwater inflow rates into the mine. These techniques may include the use of bentonite or natural clay filled cutoff walls or other means where appropriate to isolate and protect groundwater resources up-gradient of mining activities, and

2) Individual mine pits in the proposed Coal Hollow Mine will remain open for short lengths of time, generally no more than about 60 to 120 days. Consequently, any potential impacts to spring discharge rates in the alluvial groundwater system in this area will likely be short-lived. Because the alluvial groundwater recharge areas are located well up-gradient of proposed mining areas (mountain-front recharge) and will not be impacted, recharge to the alluvial system should continue uninterrupted, it is anticipated that water levels in the artesian groundwater system should recover from any mining-related declines in hydraulic head subsequent to the completion of mining in the area.

Groundwater discharge from the springs in the northwest ¼ of Section 29, T39S, R5W (See Figure 16; groundwater discharge area A) do not contribute any measurable baseflow discharge to streams in the area. This conclusion is based on the lack of any baseflow discharge in streams down-gradient of this area in Sink Valley (see monitoring data for SW-6 and SW-9). Rather, most of this discharge is likely ultimately lost to evapotranspiration as the water migrates across the low-permeability, near-surface clayey sediments in Sink Valley. Consequently, the potential temporary diminution of discharge from alluvial springs in the northwest ¼ of Section 29, T39S, R5W would not result in appreciable adverse impacts to the surrounding hydrologic balance.

If any Utah State appropriated water rights are impacted by mining and reclamation operations in the proposed Coal Hollow Mine, these will be replaced according to all applicable Utah State laws and regulations using the designated water replacement source described in Chapter 7 of the Coal Hollow Mine MRP (Section 727).

11.5 Presence of acid-forming or toxic-forming materials

Chemical information on the acid- and toxic-forming potential of earth materials naturally present in the proposed permit area are presented in the Coal Hollow Mine MRP (Appendix 6-2). Chemical information on the low-sulfur Smirl coal seam proposed for mining is presented in the Coal Hollow Mine MRP (Appendix 6-1; confidential binder). Based on laboratory analytical data, it is apparent that acid-forming and toxic-forming materials that could result in the contamination of surface-water or groundwater supplies in the proposed Coal Hollow Mine permit and adjacent area are generally not present.

Selenium was not detected in any of the samples from the proposed Coal Hollow Mine permit area. Likewise, concentrations of water-extractable boron were also low, being less than 3 mg/kg in all samples analyzed. The pH of groundwaters in and around the proposed Coal Hollow Mine permit area is moderately alkaline (UDOGM, 2007). Data in the Coal Hollow Mine MRP (Appendix 6-2) likewise indicate moderately alkaline conditions in sediments in the proposed permit area. The solubility of dissolved trace metals is usually limited in waters with alkaline pH conditions. Consequently, high concentrations of these metal constituents in groundwaters and surface waters with elevated pH levels are not anticipated. Additionally, most of the materials that will be handled as part of mining and reclamation activities in the proposed Coal Hollow Mine area are of low hydraulic conductivity (i.e. clays, silts, shales, siltstones, claystones, etc.). Consequently, it is anticipated that groundwater seepage volumes through low-permeability backfill and reclaimed land surfaces in reclaimed mine pit areas and excess spoils storage areas will not be large. Additionally, reclaimed areas will be regraded, sloped, and otherwise managed to minimize the potential for land erosion, to restore approximate surface-water drainage patterns, and also to minimize the potential for ponding of surface waters on reclaimed areas (other than "roughening" or "gouging" of some areas to enhance reclamation). Thus, the potential for interactions between large amounts of disturbed earth materials and groundwaters and surface waters, which could result in leaching of chemical constituents into groundwater and surface-water resources, will be minimized.

Additionally, the mining plan calls for the emplacement of 40 inches of suitable cover material over backfilled areas made up of material types which could appreciably impact vegetation (materials with elevated SAR ratios or other physical or chemical characteristics that could adversely impact vegetation).

The neutralization potential greatly exceeded the acid potential in all samples analyzed, with the neutralization potential commonly exceeding the acid potential by many times, suggesting that acid-mine-drainage will not be a concern at the proposed Coal Hollow Mine. Acid-forming materials in western coal mine environments often consist of sulfide minerals, commonly including pyrite and marcasite, which, when exposed to air and water, are oxidized causing the liberation of H^+ ions (acid) into the water. Oxidation of sulfide minerals may occur in limited amounts in the mine pits where oxygenated water encounters sulfide minerals. However, the acid produced by pyrite oxidation is quickly consumed by dissolution of abundant, naturally occurring carbonate minerals (see Coal Hollow Mine MRP; Appendix 6-2). Dissolved iron is readily precipitated as iron-hydroxide in well aerated waters, and consequently excess iron is not anticipated in mine discharge water.

Other acid-forming materials or toxic-forming materials have not been identified in significant concentrations nor are such suspected to exist in materials to be disturbed by mining.

Because of the overall low-permeability of the rock strata and sediments surrounding the mine workings (primarily the shales and claystones of the lower Tropic Shale), the potential for seepage of mine water outward into adjacent stratigraphic horizons is low. Additionally,

because the floors of the mine pits need to be accessible in order to extract the coal, the mining operations will be carried out in such a manner that the accumulation of large amounts of water in the mine pits will be avoided.

11.6 Sediment yield from the disturbed area

Erosion from disturbed areas will be minimized through the use of silt fences and other sediment control devices. Surface runoff occurring on disturbed areas will be collected and treated as necessary to remove suspended matter. Four diversion ditches along with four sediment impoundments are proposed for the permit area. In addition, miscellaneous controls such as silt fence and berms are also proposed for specific areas. The proposed locations for these structures are shown in Chapter 5 of the Coal Hollow Mine MRP (Drawings 5-3, Drawings 5-25 through 5-34, and Appendix 5-2).

The smallest practicable area, consistent with reasonable and safe mine operational practices will be disturbed at any one time during the mining operation and reclamation phases. This will be accomplished through progressive backfilling, grading, and prompt revegetation of disturbed areas. The backfilled material will be stabilized by grading to promote a reduction of the rate and volume of runoff in accordance with the applicable requirements. The excess spoil and fill above approximate original contour will be graded to a maximum 3h:1v slope and revegetated to minimize erosion.

Cut ditches will be established on the shoulders of all primary roads to control drainage and erosion. Cut and fill slopes along the primary roads will be minimal and are not expected to cause significant erosion. In locations where there are culvert crossings (i.e. Lower Robinson Creek), the fills slopes will be stabilized by utilizing standard methods such as grass matting or straw wattles. The location and details for roads can be viewed in Chapter 5 of the Coal Hollow Mine MRP (Drawings 5-3 and 5-22 through 5-24).

Through the implementation of these sediment control measures, it is anticipated that sediment yield from disturbed areas in the proposed Coal Hollow Mine permit area will be minimized.

11.7 Impacts to important water quality parameters

As discussed above, appreciable quantities of groundwater are not anticipated to be intercepted in the Tropic Shale overlying proposed mining areas. Consequently, discharge of Tropic Shale groundwaters from mining areas is not anticipated. Because of the very low hydraulic conductivity of the marine Tropic Shale unit which immediately overlies the coal in proposed mining areas, the lateral migration of appreciable amounts of groundwater outward from proposed mine pit areas is not anticipated. Therefore, no impacts to important water

quality parameters in surrounding groundwater and surface-water resources that could result from the interception of Tropic Shale groundwaters is anticipated.

Similarly, appreciable quantities of groundwater are not expected to emanate from the Dakota Formation in the mine floor into the mine openings. This conclusion is based on the fact that 1) vertical and horizontal groundwater flow in the Dakota Formation is impeded by the presence of low-permeability shales that encase the interbedded lenticular sandstone strata in the formation (i.e., the formation is not a good aquifer), 2) appreciable natural discharge from the Dakota Formation in the surrounding area to springs or streams is not observed, supporting the conclusion that the natural flux of groundwater through the formation is meager, and 3) mining will commence near the truncated up-dip end of the formation, minimizing the potential for elevated hydraulic head in the Dakota Formation. The results of slug testing performed on wells screened in the Smirl coal seam indicate relatively low values of hydraulic conductivity for the coal seam (Table 7). In much of the proposed mining area, the coal seam is dry. Thus, large inflows of groundwater from the coal seam into mine workings are not anticipated. Likewise, the potential for seepage out of mine pits through the coal seam is minimal. Consequently, impacts to important water-quality parameters in the Dakota Formation potentially resulting from mining operations are not anticipated, nor are impacts to important water-quality parameters in surrounding groundwater and surface-water systems anticipated as a result of interactions with intercepted Dakota Formation groundwater.

The water quality of groundwaters in the alluvial groundwater system up-gradient of mining operations will likely not be impacted by mining and reclamation activities in the proposed Coal Hollow Mine. If alluvial groundwaters intercepted by mine openings were allowed to flow into the mine pits, there would be the potential for substantially increased TDS concentrations as the water interacts with the marine Tropic Shale and the Smirl coal seam. This occurrence will be avoided.

As groundwater naturally migrates through the shallow, fine-grained alluvial sediments in the proposed Coal Hollow Mine permit and adjacent area (most evident in Sink Valley), the quality of the water is naturally degraded (Table 4; Figure 14). In the distal portions of Sink Valley, most notably concentrations of magnesium, sulfate, and bicarbonate are elevated in the alluvial groundwater.

The potential for TDS increases associated with interaction of waters with the Tropic Shale can be minimized by avoiding contact where practical between water sources and earth materials containing soluble minerals. Where possible, groundwater that will be encountered in alluvial sediments along the margins of mine pit areas will be routed through pipes, ditches or other conveyance methods away from mining areas via gravity drainage so as to prevent or minimize the potential for interaction with sediments disturbed by mining operations (including contact with the mined coal seam). If diverted alluvial groundwater were allowed to interact extensively with the Tropic Shale bedrock or Tropic Shale-derived alluvial sediments, similar increases in magnesium, sulfate, bicarbonate, and TDS concentrations would be anticipated. Consequently, where intercepted groundwaters will be routed around

disturbed areas through pipes or well-constructed and maintained ditches, it is anticipated that detrimental impacts to important water quality parameters in these waters will be minimal.

The pumping and discharging of mine water from mine pits at the proposed Coal Hollow Mine permit area is not anticipated. The impoundment of substantial quantities of water within the mine pits would likely result in degradation of groundwater quality and is also not compatible with the proposed surface mining technique (the coal extraction operations occur at the bottom of the mine pit and thus they cannot be performed in flooded mine pits). As discussed above, the only likely foreseeable source of appreciable quantities of groundwater is from the alluvial groundwater systems overlying the low-permeability Tropic Shale in proposed mining areas. Where this alluvial groundwater is encountered in mining areas, it will be diverted away from mine workings prior to significant interaction with sediments in disturbed areas. Any discharge from the mine pits that does occur will be regulated under a Utah UPDES discharge permit.

As discussed above, acid mine drainage is not anticipated at the proposed Coal Hollow Mine permit area. This is due primarily to the relatively low sulfur content of the coal and rock strata in the permit and adjacent area, and to the pervasiveness of carbonate minerals in the soil and rock strata which neutralize the acidity of the water if it occurs. If sulfide mineral oxidation and subsequent acid neutralization via carbonate dissolution were to occur, increases in TDS, calcium, magnesium, sulfate, and bicarbonate concentrations (and possibly also sodium concentrations via ion-exchange with calcium or magnesium on exchangeable clays) would be anticipated.

As described in Chapter 5, Section 532, surface runoff that occurs on disturbed areas will be treated through sedimentation ponds or other sediment-control devices and particulate matter will be allowed to settle prior to the discharging of the water to the receiving water, thus controlling suspended solids concentrations.

At any mining operation there is the potential for contamination of soils, surface-water and groundwater resources resulting from the spillage of hydrocarbons. Diesel fuels, oils, greases, and other hydrocarbons products will be stored and used at the mine site for a variety of purposes. A spill Prevention Control and Countermeasure Plan will be implemented that will help minimize any potential detrimental impacts to the environments.

Spill control kits will be provided on all mining equipment and personnel will be trained to properly control spills and dispose of any contaminated soils in an appropriate manner.

Based on these findings, it is concluded that the potential for mining and reclamation activities in the proposed Coal Hollow Mine permit area to cause detrimental impacts to important water quality parameters is minimal.

11.8 Flooding or streamflow alteration

As described above, appreciable groundwater inflow from the Tropic Shale and Dakota Formation into mine pits at the proposed Coal Hollow Mine are not anticipated. Appreciable groundwater inflows are anticipated only from the relatively thin, overlying alluvial groundwater systems. The thickness of the alluvium adjacent to mine openings in the proposed mining areas is generally less than 40 to 50 feet. The hydraulic conductivity of the predominantly clayey and silty alluvial sediments is low, and consequently, very large or sudden groundwater inflows into mine openings are not anticipated. Where appreciable alluvial groundwater is encountered adjacent to mine openings, it will be routed away from mining areas through ditches of other conveyance mechanisms. Consequently, discharge of mine water from the mine pits is not anticipated. The rates of alluvial groundwater drainage that could occur will likely not be of a magnitude that could potentially cause flooding or streamflow alteration in either the Sink Valley Wash or Lower Robinson Creek drainages.

If excess groundwater were to be encountered during mining operations such that it could not be adequately managed or discharged in compliance with the Utah UPDES discharge permit (which is considered unlikely), Alton Coal Development, LLC may when necessary construct supplemental containment and settlement ponds in which mine discharge waters may be held for treatment (where necessary) and subsequent discharge through UPDES discharge points in compliance with the UPDES discharge permit, minimizing the potential for flooding or streamflow alteration in areas adjacent to mining.

It should be noted here that the principal surface-water drainages in and adjacent to the proposed Coal Hollow Mine permit area are in many locations not stable in their current configurations (see photograph section). These stream drainages are currently actively eroding their channels during precipitation events, resulting in rapid down-cutting and deep entrenchment of stream channels, the formation of unstable near-vertical erosional escarpments adjacent to stream channels (which occasionally spall off into the stream channel), aggressive headward erosion of stream channels and side tributaries, and the transport of very large quantities of sediment associated with torrential precipitation events. These processes are currently actively ongoing in the proposed permit and adjacent area and the upper extents of these erosional processes are in many locations migrating upward in stream channels, resulting in ever-increasing lengths of unstable stream channels. This condition is reportedly a result of land management practices in the late 1800's or early 1900's.

The surface-water drainages adjacent to the proposed Coal Hollow Mine permit area have large discharge capacities (lower Sink Valley Wash, Lower Robinson Creek, and Kanab Creek). These drainages periodically convey very large amounts of precipitation water associated with torrential precipitation events. The anticipated discharge rates from alluvial groundwater drainage and the maximum reasonably foreseeable amount of mine discharge water that could potentially be required to be discharged from mine pits is much less than that periodically occurring during major torrential precipitation events. While the addition of modest amounts of sediment-free water into these stream channels has the potential to cause minor increases in channel erosion, the magnitude of this potential impact is inconsequential relative to that occurring during torrential precipitation events.

Most precipitation waters falling on disturbed areas will be contained in diversion ditches and routed to sediment impoundments that are designed to impound seasonal water and storms. Sediment control facilities will be designed and constructed to be geotechnically stable. This will minimize the potential for breaches of sediment control structures, which if they occur could result in down-stream flooding and increases in stream erosion and sediment yield. Emergency spillways will be part of the impoundment structures to provide a non-destructive discharge route should capacities ever be exceeded.

Details associated with these structures can be viewed in Chapter 5 of the Coal Hollow Mine MRP (see Drawings 5-25 through 5-34 and Appendix 5-2).

Following reclamation, stream channels will be returned to a stable state to the extent possible given the currently highly unstable state of natural drainage channels in the area. Stream channels will be designed to withstand anticipated storm events, thus minimizing the potential of flooding in the reclaimed areas.

The potential for flooding or streamflow alteration resulting from mining and reclamation activities at the proposed Coal Hollow Mine permit area is considered minimal.

11.9 Groundwater and surface water availability

Groundwater use in the proposed Coal Hollow Mine permit and adjacent area is generally limited to stock watering and domestic use in Sink Valley. Some limited use of spring discharge water for irrigation has occurred in Sink Valley, although such irrigation is not occurring presently nor has it occurred in at least the past 10 years. The areas of groundwater use in the proposed Coal Hollow Mine permit and adjacent area are located in the northwest ¼ of Section 29, T39S, R5W (see Figure 16; groundwater discharge area A), and in the northwest ¼ of Section 32, T39S, R5W (see Figure 16; groundwater discharge area B). The likely future availability of groundwater in each of these areas is discussed below.

11.9.1 Groundwater discharge area A (Northwest ¼, Section 29, T39S, R5W)

Groundwater use in area A occurs from several alluvial springs and seeps that are used for stock watering and limited domestic use. As described in Section 728.311 above, short-term diminution in discharge rates from springs in northwest ¼ of Section 29, T39S, R5W are possible as mining operations advance toward these springs. This potential impact is associated with the possible drainage of up-gradient alluvial groundwater into mine openings as mining advances toward groundwater discharge area A. Because individual mine pits will typically remain open for less than about 60 to 120 days before subsequently being backfilled and reclaimed, the potential for long-term drainage of alluvial groundwater into the mine voids is negligible, and thus any potential decreases in alluvial discharge in groundwater discharge area A is anticipated to be short-lived.

If groundwater inflow rates into mine openings in this area are excessive, such that appreciable impacts to the springs and seeps in groundwater discharge area A are likely, where necessary Alton Coal Development, LLC will use a suitable technique to minimize groundwater inflow rates into the mine voids. These techniques may include the use of bentonite or natural clay filled cutoff walls or other means where appropriate to isolate and protect groundwater resources up-gradient of mining activities. Consequently, the potential that groundwater could become unavailable in this area is minimal. Additionally, if alluvial groundwater resources were to become unavailable in this area due to mining and reclamation activities in the proposed Coal Hollow Mine permit area, groundwater will be replaced according to all applicable State laws and regulations using the replacement water source described in Section 727 above.

It should be noted that the proposed water replacement source, water well Y-61, produces water from the coarse-grained alluvial groundwater system in Sink Valley. Nearby springs that could potentially be impacted by mining and reclamation activities are supported by the same alluvial groundwater system. However, while modest decreases in the artesian hydraulic pressures in the alluvial groundwater system could potentially result in diminution of spring flows, water well Y-61 is 150 feet deep and will be equipped with an electric well pump providing the capability to produce groundwater from the alluvial system even if the hydraulic head in the alluvial groundwater system were to be diminished such that artesian flow conditions temporarily ceased to exist.

11.9.2 Groundwater discharge area B (Northwest ¼, Section 32, T39S, R5W)

Groundwater use in groundwater discharge area B occurs at alluvial springs and seeps located southeast of the proposed Coal Hollow Mine permit area that are used for stock watering and limited domestic use. As described in Section 728.311 above, although some temporary and short-lived diminution in discharge rates from springs in northwest ¼ of Section 29, T39S, R5W is possible, this potential impact is not considered likely.

In the event that alluvial groundwater resources were to become unavailable in this area due to mining and reclamation activities in the proposed Coal Hollow Mine permit area, groundwater will be replaced according to all applicable State laws and regulations using the replacement water source described in Chapter 7 of the Coal Hollow Mine MRP (Section 727).

11.10 Surface-water availability

Surface-water use in the proposed Coal Hollow Mine permit and adjacent area occurs in the Sink Valley Wash drainage and in Lower Robinson Creek. Surface waters in the Sink Valley Wash drainage (primarily from Water Canyon via an irrigation diversion and from Swapp Hollow; appreciable discharge in Sink Valley Wash below Section 29 T39S, R5W is usually

absent) are utilized for both stock watering and limited irrigation use. Stream water in the Sink Valley Wash drainage is derived from runoff from the adjacent Paunsaugunt Plateau area. Because the surface water in the drainage originates from areas up-gradient areas located large distances from proposed mining areas, and because the stream channel is entirely outside the permit area and will not be impacted by mining and reclamation activities, there is essentially no probability that surface water availability in the Sink Valley Wash drainage could become unavailable as a result of mining and reclamation activities.

Discharge in Lower Robinson Creek immediately above the proposed Coal Hollow Mine permit area typically occurs only in direct response to significant precipitation or snowmelt events. Thus, surface-water availability is currently limited in this drainage prior to any mining activities.

Seepage of alluvial groundwater into the deeply incised lower Robinson Creek stream channel occurs near the contact with the underlying Dakota Formation in the southeast quarter of Section 19, T39S, R5W. This water is likely related to saturated alluvial deposits directly underlying the Robinson Creek stream channel and emerges near where the saturated alluvial sediments intersect the mostly impermeable Dakota Formation bedrock in the base of the stream channel. It is noteworthy that the location of the emergence of alluvial water in the channel has varied somewhat over time. This seepage of alluvial water is usually about 5 - 10 gpm or less and is routinely monitored at monitoring station SW-5 (Figure 11).

It should be noted that the proposed Coal Hollow Mine plan calls for the permanent diversion of a reach of the Lower Robinson Creek stream channel approximately 2,000 feet in length in the southeast ¼ of Section 19, T39S, R5W. Details of the proposed diversion are given in Chapter 5, Section 527.220 of this MRP. If this action results in diminution of the meager discharge of surface water in the drainage below the planned diversion, where required a suitable mitigation for this potential impact will be designed and implemented in consultation with the Division of Oil, Gas and Mining.

The information presented above suggests that the potential for significant impacts to groundwater and surface-water availability resulting from mining and reclamation activities in the proposed Coal Hollow Mine permit and adjacent systems in the region is low.

11.11 Whether mining and reclamation activity will result in contamination, diminution or interruption of State-appropriated waters

State appropriated water rights in the proposed Coal Hollow Mine permit and adjacent area are shown in Chapter 7 of the Coal Hollow Mine MRP (see Drawing 7-3 and Appendix 7-3).

Appropriated groundwaters include alluvial springs and seeps in the northwest ¼ of Section 29, T39S, R5W (groundwater discharge area A), springs and seeps in the northwest ¼ of Section 32, T39S, R5W (groundwater discharge area B). State appropriated surface waters

include reaches of Sink Valley Wash east of the proposed Coal Hollow Mine permit area, and reaches of Lower Robinson Creek.

The potential for mining and reclamation activities at the proposed Coal Hollow Mine permit area to result in contamination, diminution or interruption of State-appropriated water in the proposed Coal Hollow Permit and adjacent area are described in detail in Sections 728.310, 728.320, 728.332, and 728.334.

With the possible exception of short-term diminution in discharge rates from springs and seeps in the northwest ¼ of Section 29, T39S, R5W, Contamination, diminution, or interruption of State-appropriated waters in the proposed Coal Hollow Mine permit and adjacent area are not anticipated. It should be noted that if groundwater inflow rates into mine openings in this area are excessive, such that appreciable impacts to the springs and seeps in groundwater discharge area A are likely, where necessary Alton Coal Development, LLC will use a suitable technique to minimize groundwater inflow rates into the mine voids. These techniques may include the use of bentonite or natural clay filled cutoff walls or other means where appropriate to isolate and protect groundwater resources up-gradient of mining activities, minimizing the potential for diminution of discharge rates from these springs.

Additionally, it should be noted that the proposed Coal Hollow Mine plan calls for the permanent diversion of a reach of the Lower Robinson Creek stream channel approximately 2,000 feet in length in the southeast ¼ of Section 19, T39S, R5W. Details of the proposed diversion are given in Chapter 5, Section 527.220 of this MRP. If this action results in diminution of the meager discharge of surface water in the drainage below the planned diversion, where required a suitable mitigation for this potential impact will be designed and implemented in consultation with the Division of Oil, Gas and Mining.

In the event that any State appropriated waters were to be contaminated, diminished, or interrupted due to mining and reclamation activities in the proposed Coal Hollow Mine permit area, groundwater will be replaced according to all applicable State laws and regulations using the replacement water source described in Chapter 7 of the Coal Hollow Mine MRP (Section 727).

12.0 Proposed Hydrologic Monitoring Plan

This section describes the hydrologic monitoring plan. Locations of surface-water and groundwater monitoring sites are indicated on Figure 18. Hydrologic monitoring protocols, sampling frequencies, and sampling sites are described in Table 9. Groundwater and surface-water monitoring locations are listed in Table 10. Operational field and laboratory hydrologic monitoring parameters for surface water are listed in Table 11, and for groundwater in Table 12. The hydrologic monitoring parameters have been selected in consultation with the Division's directive Tech-006, *Water Monitoring Programs for Coal Mines.*

The groundwater and surface-water monitoring plan is extensive and includes 54 monitoring sites. The monitoring plan is designed to monitor groundwater and surface-water resources for any potential impacts that could potentially occur as a result of mining and reclamation activities in the proposed Coal Hollow Mine permit and adjacent area. Each of the sampling locations and their monitoring purpose are described below.

12.1 Streams

Kanab Creek will be monitored at sites SW-3 (above the permit area), and SW-2 (below the permit area). Lower Robinson Creek will be monitored at sites SW-4 (above the permit area), SW-101 (within the permit area), and SW-5 (below the permit area above the confluence with Kanab Creek). The irrigation water near SW-4 will also be monitored at site RID-1. Swapp Hollow creek will be monitored above the permit area at site SW-8. Sink Valley Wash will be monitored at SW-6 (a small tributary to the wash immediately below the permit area) and at SW-9, located in the main drainage below the permit area. All of these locations, with the exception of RID-1) will be monitored for discharge and water quality parameters specified in Table 11 quarterly, when reasonably accessible. Additionally, Lower Robinson Creek will be monitored at site BLM-1, which is near the location of alluvial groundwater emergence in the bottom of the stream channel. BLM-1 and RID-1 will be monitored for discharge and field water quality parameters.

12.2 Springs

Eight springs from alluvial groundwater area A will be monitored including SP-8, SP-14, SP-16, SP-19, SP-20, SP-22, SP-24 and Sorensen Spring. Spring SP-8 is a developed spring in area A that provides culinary water for the Swapp Ranch house. SP-8 will be monitored for discharge and operational laboratory water quality measurements quarterly when reasonably accessible. Springs SP-14, SP-16, SP-19, SP-20, SP-22, SP-24 and Sorensen Spring springs will be monitored for discharge and field water quality measurements quarterly when reasonably accessible.

Springs SP-4 and SP-6, and SP-33, which are located in Sink Valley below the proposed mining area, will also be monitored. SP-6 is an area of diffuse seepage above an earthen impoundment in the wash immediately below the permit area. Spring SP-33 is a developed spring that discharges into a pond below the permit area and provides culinary water to two adjacent cabins. Each of these Springs SP-6 and SP-33 will be monitored for discharge and operational laboratory water quality measurements quarterly when reasonably accessible. SP-4 discharges from a fault/fracture system in the Dakota Formation near the canyon margin in Sink Valley Wash below the permit area. Spring SP-4 will be monitored for discharge and field water quality measurements quarterly when reasonably accessible. Spring SP-3 discharges from pediment alluvium in the upland area above Sink Valley Wash more than a

mile from the permit area. It is extremely unlikely that discharge rates or water quality at this spring could be impacted as a result of mining-related activities in the mine permit area. However, this spring will be monitored for discharge and field water quality measurements quarterly, primarily to provide background data from springs in the region.

12.3 Wells

Wells Y-98 (Robinson Creek alluvium above the permit area), Y-45 (coal seam well in Swapp Hollow above permit area), Y-102 (flowing alluvial well in alluvial groundwater discharge area A), Y-36 (coal seam well in Sink Valley above the permit area), Y-38 (coal seam well in Sink Valley permit area), Y-61 (alluvial well at the Sorenson Ranch), and C5-130 (new monitoring well in alluvial groundwater discharge A) will be monitored quarterly when reasonable accessible. Well Y-61 will be monitored for groundwater operational laboratory water quality parameters to monitor groundwater quality in alluvial groundwater discharge area A. The other wells will be monitored for water level only.

Additionally, 19 newly constructed monitoring wells constructed in the Sink Valley alluvial groundwater system will be monitored quarterly. These include C2-15, C2-28, C2-40, C3-15, C3-30, C3-40, C4-15, C4-30, C4-50, C7-20, C9-15, C9-25, C9-40, LS-28, LS-60, LS-85, SS-15, SS-30, and SS-75. All of these wells will be monitored quarterly for water level. Additionally, wells LS-85 and SS-30 will be monitored for groundwater operational laboratory water quality measurements.

Additionally two wells in the Lower Robinson Creek alluvium will be monitored for water level and groundwater operational laboratory chemistry. These include UR-70 located above proposed mining locations in the Lower Robinson Creek drainage, and LR-45, located below proposed mining areas adjacent to Lower Robinson Creek. It should be noted that LR-45 is located near a proposed sediment pond impoundment. Consequently, if this well becomes unsuitable for monitoring, an alternate location will be used to monitor the Lower Robinson alluvial groundwater system in this area.

Wells C0-18 and C0-54 are located near the initial proposed mining areas in the Lower Robinson Creek drainage. These will be monitored for water level quarterly.

It should be noted that many of the wells specified for monitoring in this monitoring plan will at some point be destroyed or rendered inoperable as the mine workings precede through the area. These wells will be monitored until such a time as they are destroyed or become inoperable.

Groundwater and surface-water monitoring will continue through the post-mining periods until bond release. The monitoring requirements, including monitoring sites, analytical parameters and the sampling frequency may be modified in the future in consultation with the Division if the data demonstrate that such a modification is warranted.

13.0 Potential Alluvial Valley Floor Information

A field investigation has been performed in the proposed Coal Hollow Mine permit and adjacent area to provide to the Division with the information required to make an evaluation regarding the existence or non-existence of a probable alluvial valley floor in the proposed Coal Hollow Mine permit and adjacent area as specified in R645-321. This information is summarized below below. Additionally, the other information presented in this report and in the Coal Hollow Mine MRP is provided as supplemental information to the division for making this determination. A report entitled "Geomorphological and sedimentological characteristics of Sink Valley, Kane County, Utah" is a report of an extensive field investigation performed in Sink Valley to evaluate the potential for the existence of an alluvial valley floor. This report is included as Appendix 7-4 in Chapter 7 of the Coal Hollow Mine MRP.

The regulatory definition of an alluvial valley floor as described in the U. S. Department of the interior, Office of Surface Mining Reclamation and Enforcement alluvial valley floor identification guidelines (OSM, 1983) defines an alluvial valley floor based on 1) geologic criteria, and 2) water availability criteria. The geologic criteria that must be met in order for a valley to be determined administratively as an alluvial valley floor include the following:

1. A topographic valley with a continuous perennial, intermittent, or ephemeral stream channel running through it; and
2. Within that valley, those surface landforms that are either flood planes or terraces if these landforms are underlain by unconsolidated deposits (streamlaid); and
3. Within that valley, those side-slope areas that can reasonably be shown to be underlain by alluvium and which are adjacent to floor plane or terrace landforms.

Landforms that are specifically excluded from the definition of alluvial valley floors include upland areas, which are defined as those geomorphic features located outside the flood plain and terrace complex, such as isolated higher terraces, alluvial fans, pediment surfaces, landslide deposits, and surfaces covered with residuum, mud flows or debris flows, as well as highland areas underlain by bedrock and covered by residual weathered material or debris deposited by sheetwash, rillwash, or windblown material.

Based on the information presented, it is apparent that Sink Valley does not meet the regulatory definition of an alluvial valley floor for two fundamental reasons:

1. There is no continuous stream channel running through Sink Valley
2. The valley fill in Sink Valley is not streamlaid, but rather was deposited primarily by mudflows, debris flows, and sheetfloods that formed the alluvial fans.

Information needed by the Division to allow initiating of the technical analysis and finding determination are described below.

- Crop production for each landowner adjacent to the proposed Coal Hollow Mine permit area

There are three owners of agricultural land located adjacent to the proposed Coal Hollow Mine permit area. The crop production for each of these landowners is presented below.

Mr. Richard Dame
There has not been any crop production on Mr. Dame's property in the recent past. Agricultural use of the land has been limited to the grazing of a few horses and/or cows on the property from the months of April through November. Irrigation of the land has not occurred in at least the past 10 years. The post-mining land use plan (See Coal Hollow Mine MRP; R645-301-400) suggests that 1.125 animals/month/acre could reasonably be sustained on the property.

Mr. Burton Pugh
There has not been any crop production on Mr. Pugh's property in the recent past. The land is comprised of unirrigated pasture land, meadows, sagebrush/grass, pinyon-juniper, and oak brush communities. The livestock currently sustained on Mr. Pugh's pasture land are mostly cattle, but sometimes horses are kept on the property. The animals are supported in the pastures from April through November of the year. The post-mining land use plan (See Coal Hollow Mine MRP; R645-301-400) suggests that 1.125 animals/month/acre could reasonably be sustained on the property.

Mr. Darlynn Sorensen
Agricultural production on Mr. Sorensen's property includes 154 acres of grass hay that is not irrigated. Typical production from the 154-acre field ranges from about 1,400 to 2,000 80-pound bales of grass hay per year. Rarely, during optimal climatic conditions, up to 6,000 80-pound bales of grass hay have been harvested from the 154-acre field. The production is highly dependent on the amount and timing of precipitation in the region, with increased production occurring during wet years. Approximately 200 cows and calves use the pasture for a short period of time during the year.

- Locations of irrigation diversion structures

The locations of irrigation diversions and ditches are shown in Chapter 7 of the Coal Hollow Mine (Drawing 7-7).

- Mapping of alluvium, stream laid deposits, and the direction of flow of groundwater (in particular near-surface ground water) on or adjacent to the proposed permit area.

The approximate extent of the principal alluvial sediments in the proposed Coal Hollow Mine permit and adjacent area are shown on Figure 21. Directions of groundwater flow in the proposed Coal Hollow Mine permit and adjacent area, including near-surface groundwater flow directions, are also shown on Figure 21.

Stream laid deposits have generally not been identified in the proposed permit and adjacent area. The basis for this observation is described below.

Field investigations in the proposed permit and adjacent area have included

1. the excavation and mapping of shallow sediments in many back-hoe pits and hand-dug excavations, the examination of alluvium in erosional escarpments and exposures at the surface,
2. investigation of the geomorphology of Sink Valley, and
3. the drilling and examination of sediments in more than 30 recently drilled boreholes.

These investigations (which are also discussed in the Coal Hollow Mine MRP) suggest that the sediments in Sink Valley and the Lower Robinson Creek drainage are primarily fan deposits. The shape of fan deposits and their location at the base of the precipitous Paunsaugunt Plateau are consistent with alluvial fan deposition. Soil classification results do not indicate appreciable fluventic soils in the near surface sediments. Sediment transport and deposition in the valley has likely occurred through mudflows, debris flows, and sheet floods. The results of drilling in the alluvial sediments near proposed mining areas indicate that coarse-grained sediments, which would be consistent with sediment transport in significant fluvial systems during high-energy events, are absent in these locations.

Stream terraces and flood plains associated with continuous stream channels are not present in Sink Valley. The deeply incised stream drainage in Lower Robinson Creek likewise is not associated with a broad flood plane or stream terraces. Additionally, the narrow stream valley associated with Lower Robinson Creek is not readily irrigable, nor does the stream valley have any agricultural importance (See OSM, 1983, p. II-1). These findings are generally consistent with the findings of Water Engineering & Technology, Inc., who likewise did not identify stream laid deposits in the Sink Valley area.

Additional information pertinent to the alluvial valley floor determination presented here includes the following:

A map showing the major landforms in Sink Valley and the Lower Robinson Creek area is included as Figure 22.

A longitudinal profile of Sink Valley from the upper Water Canyon drainage to the Sink Valley Wash is included as Figure 23.

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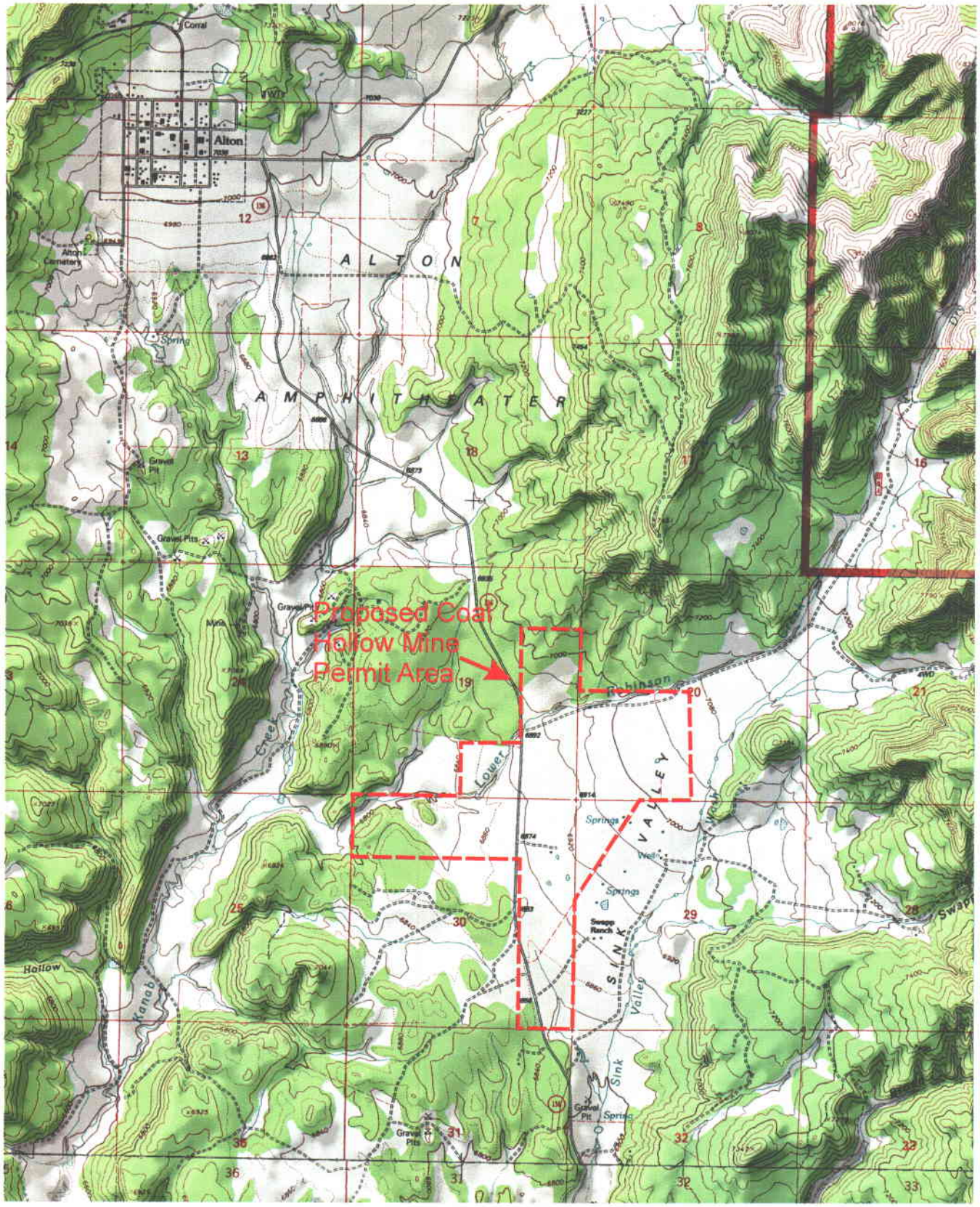


Figure 1 Location map of proposed Coal Hollow Mine permit and adjacent area and the town of Alton, Utah.

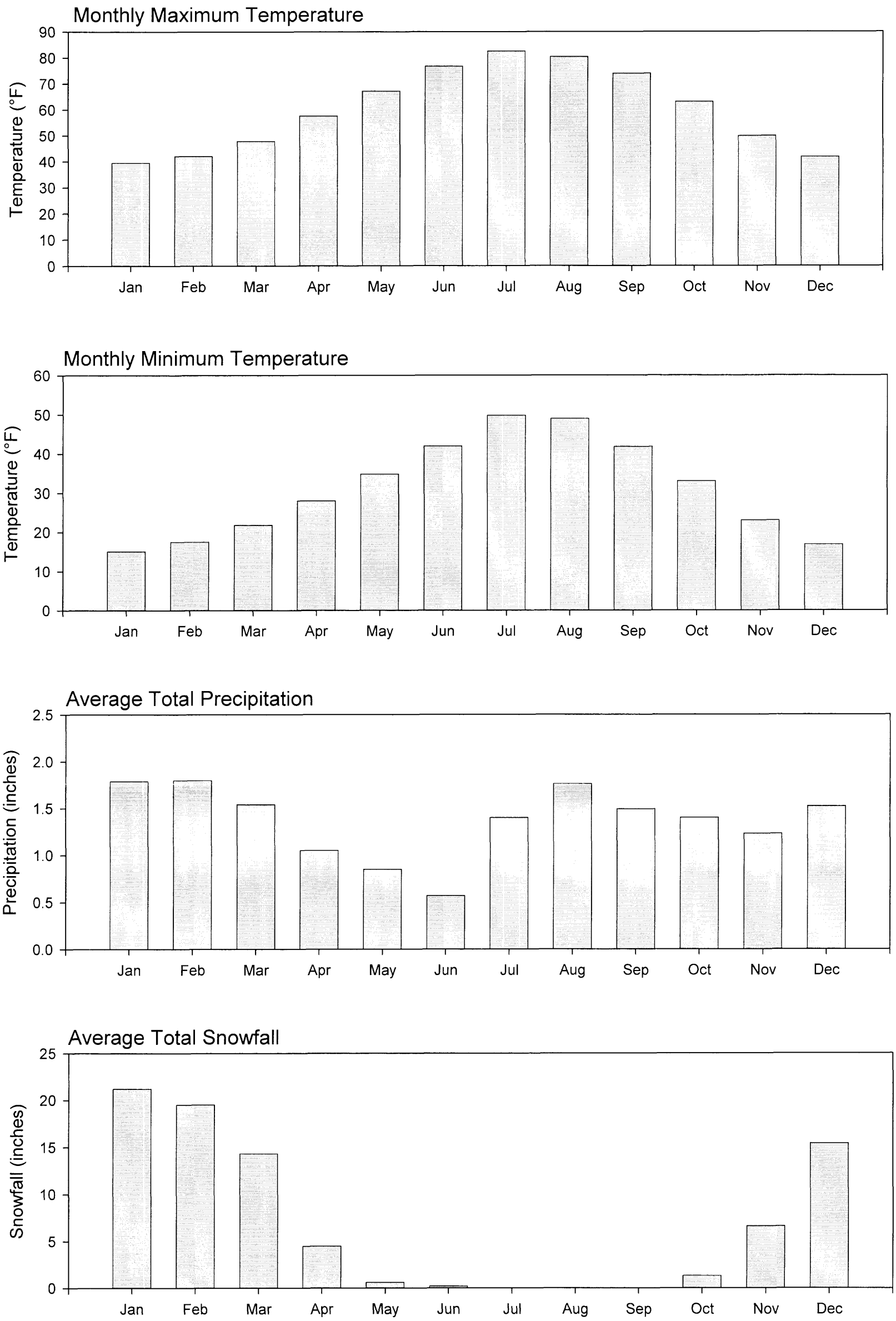
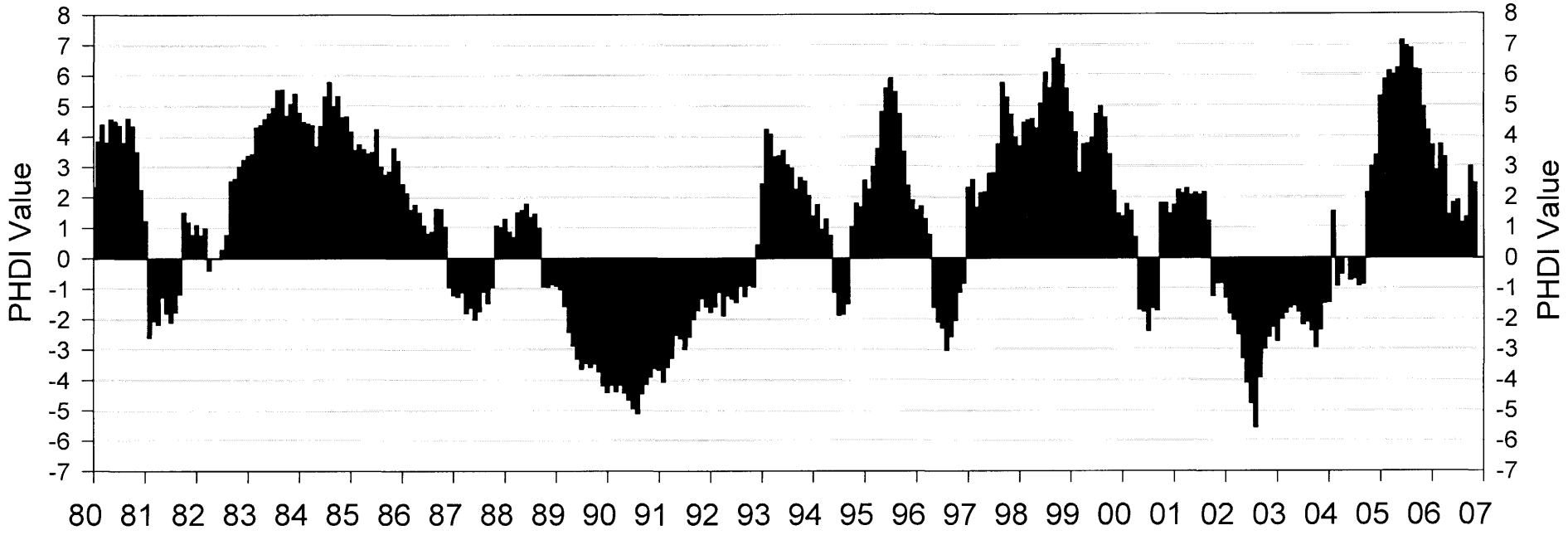
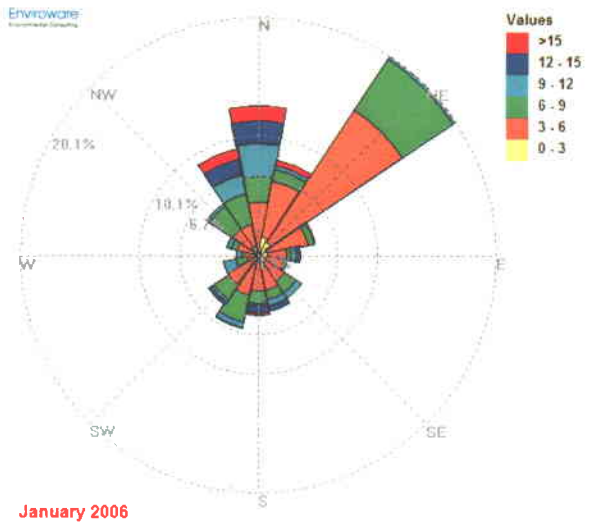


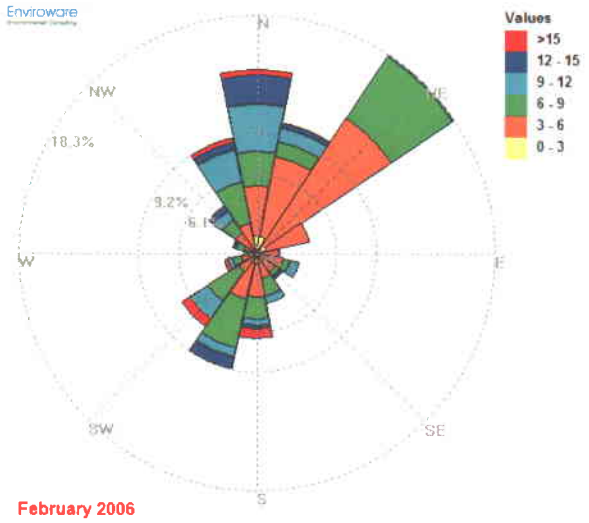
Figure 2 Plots of climatologic information from the Alton, Utah weather station (420086), 1928-2005.



-1 to -2	Mild Drought	1 to 2	Mild Wet Spell
-2 to -3	Moderate Drought	2 to 3	Moderate Wet Spell
-3 to -4	Severe Drought	3 to 4	Severe Wet Spell
-4 to -5	Extreme Drought	4 to 5	Extreme Wet Spell

Figure 3 Plot of Palmer Hydologic Drought Index for Utah Region 4.





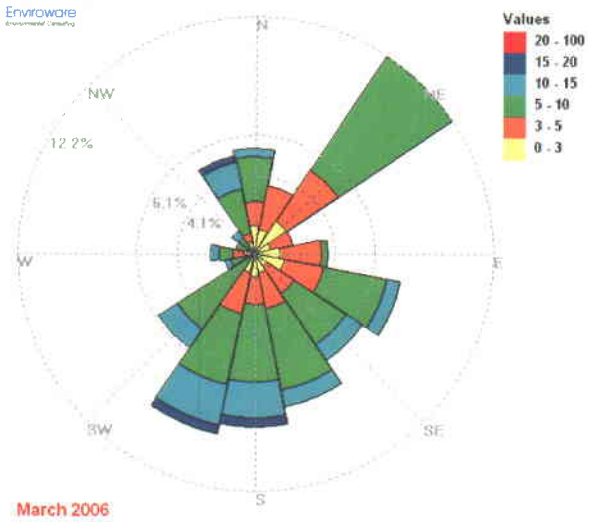
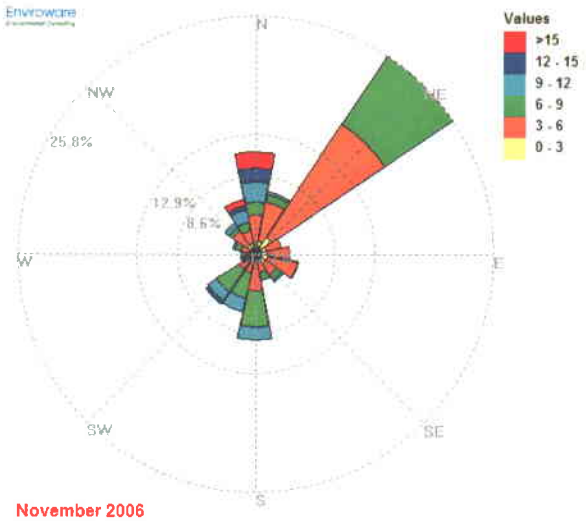


Figure 4 Wind rose diagrams for hourly wind data collected from the Coal Hollow Project weather station.



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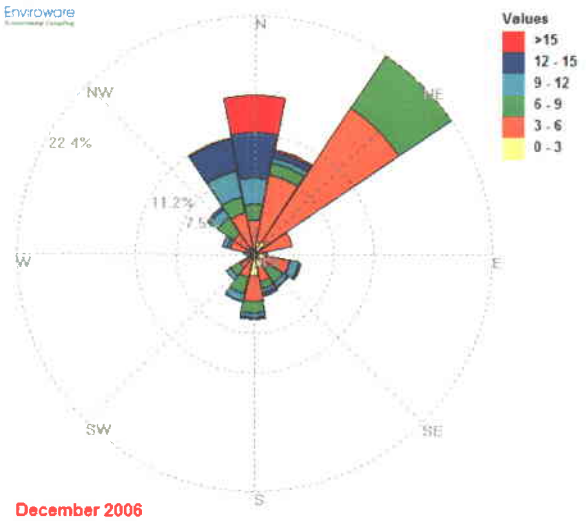

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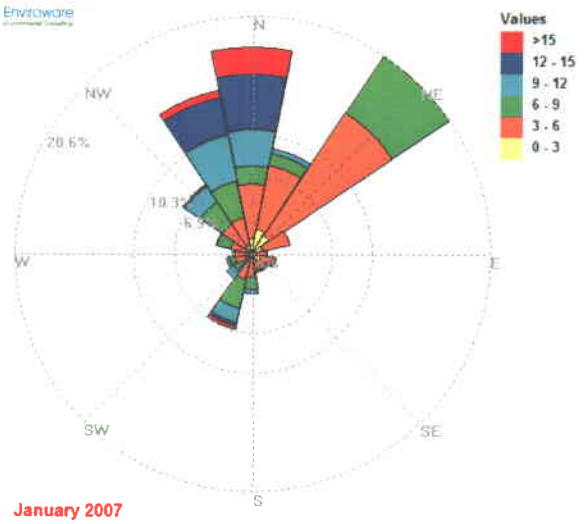

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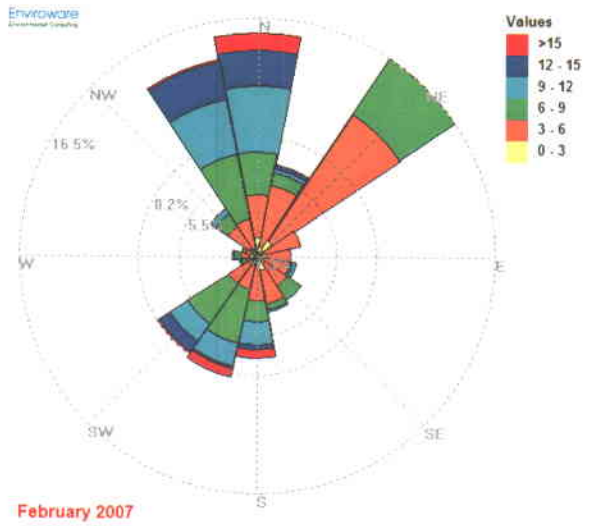
Figure 4 continued.



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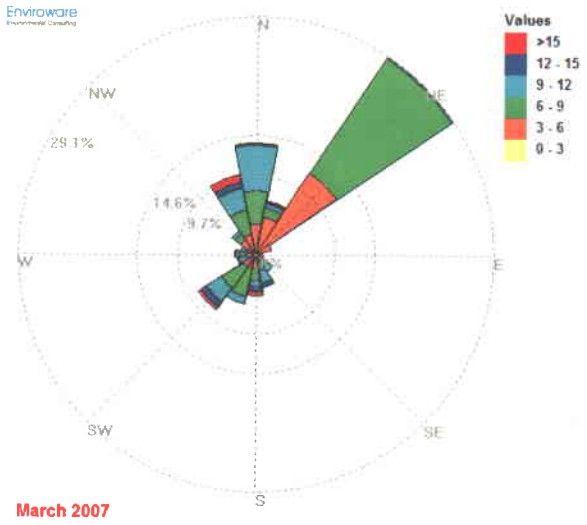

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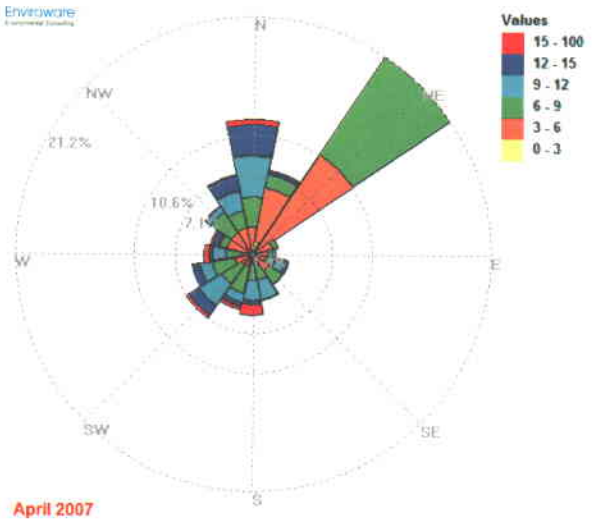

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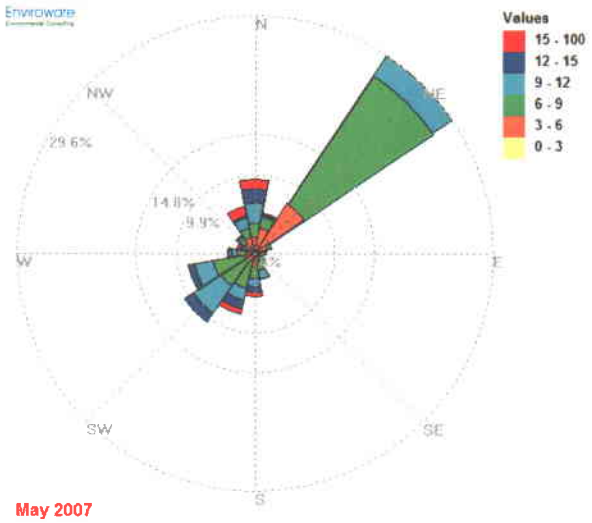
Figure 4 continued.



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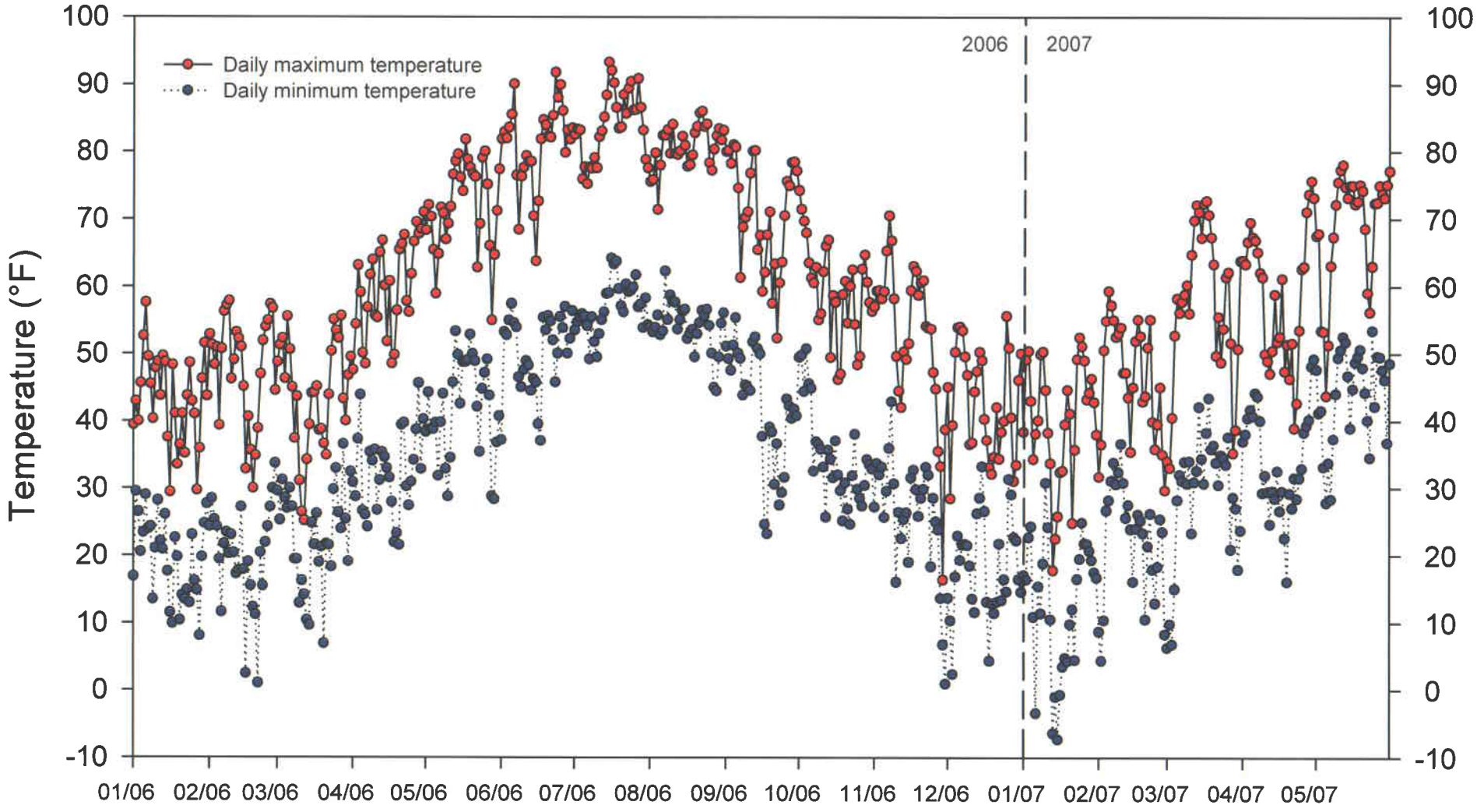
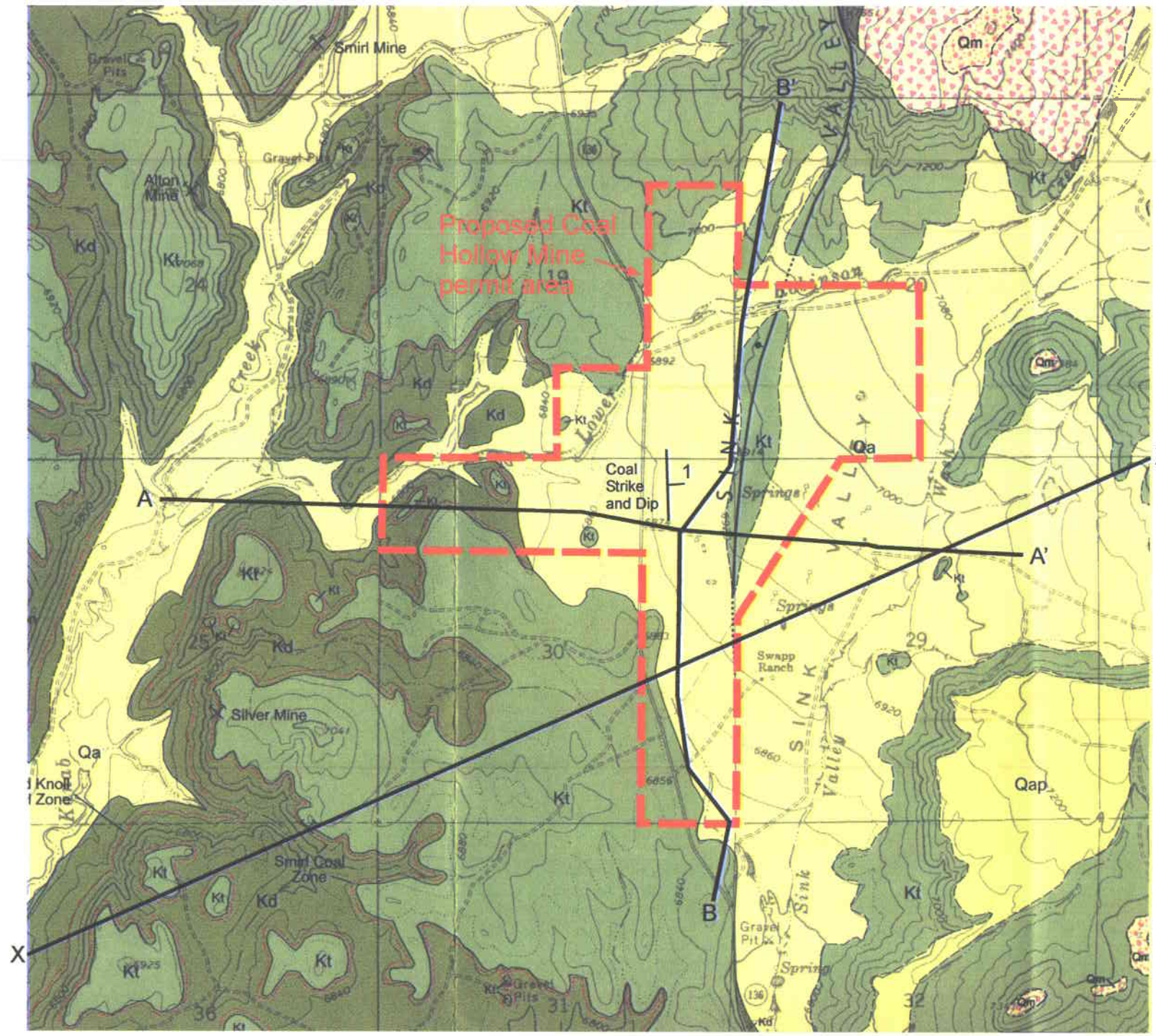


Drawing 5 Plot of daily maximum and minimum temperatures at the Coal Hollow Project weather station, January 2006 - May 2007.



Map Symbols

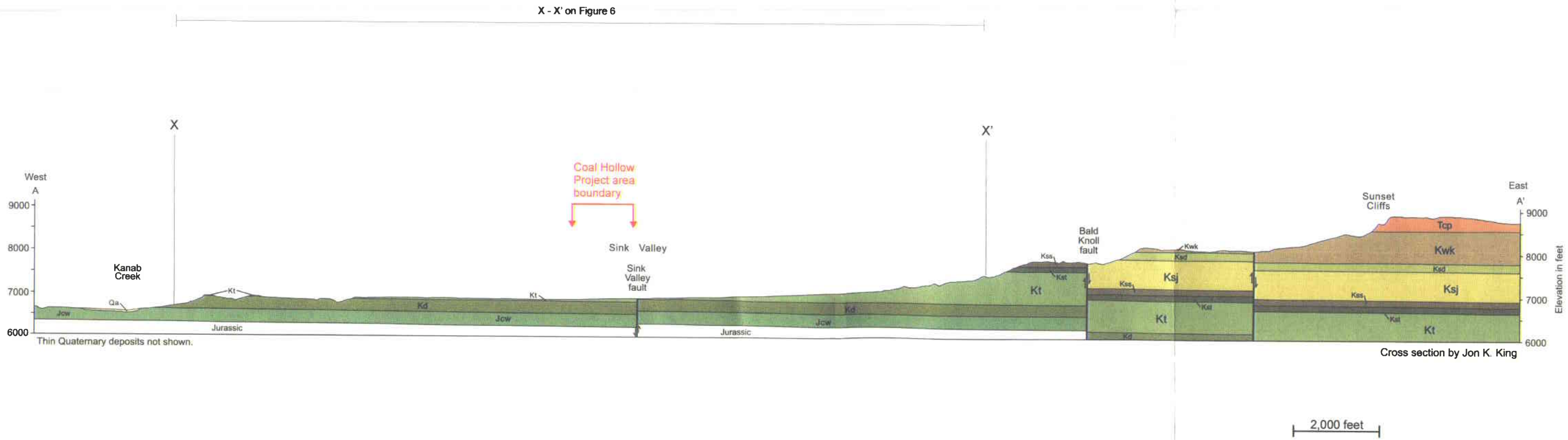
- Contact - *dashed where approximately located*
- Normal Fault - *dashed where approximately located or inferred; dotted where concealed; ball and bar on down-thrown side; X marks the point of reversal of offset on scissor(?) faults; arrows on cross section show offset*
- Strike and dip of bedding
- Strike of vertical joint
- Horizontal joint
- Line of cross section
- Coal zone - approximately located
- Coal mine or prospect

2,000 feet

N

Qa	Alluvium
Qms	Landslide deposits
Qm	Mass-wasting debris
Qap	Pediment alluvium
Qb	Basalt
Tbh	Brian Head Formation
Tcw	White member of Claron Formation
Tcp	Pink member of Claron Formation
Kwk	Wahweap and Kaiparowits Formations (undivided)
Ksd	Drip Tank Member of the Straight Cliffs Formation
Ksj	John Henry Member of the Straight Cliffs Formation
Kss	Smoky Hollow Member of the Straight Cliffs Formation
Kst	Tibbet Canyon Member of the Straight Cliffs Formation
Kt	Tropic Shale
Kd	Dakota Formation
Jcw	Winsor Member of the Carmel Formation

Figure 6
Geologic map of the proposed Coal Hollow Mine permit and adjacent area (after Tilton, 2001).



See Figure 6, geologic map for legend and section location.

Figure 7
Geologic cross-section through the Coal Hollow Project area (from Tilton, 2001).

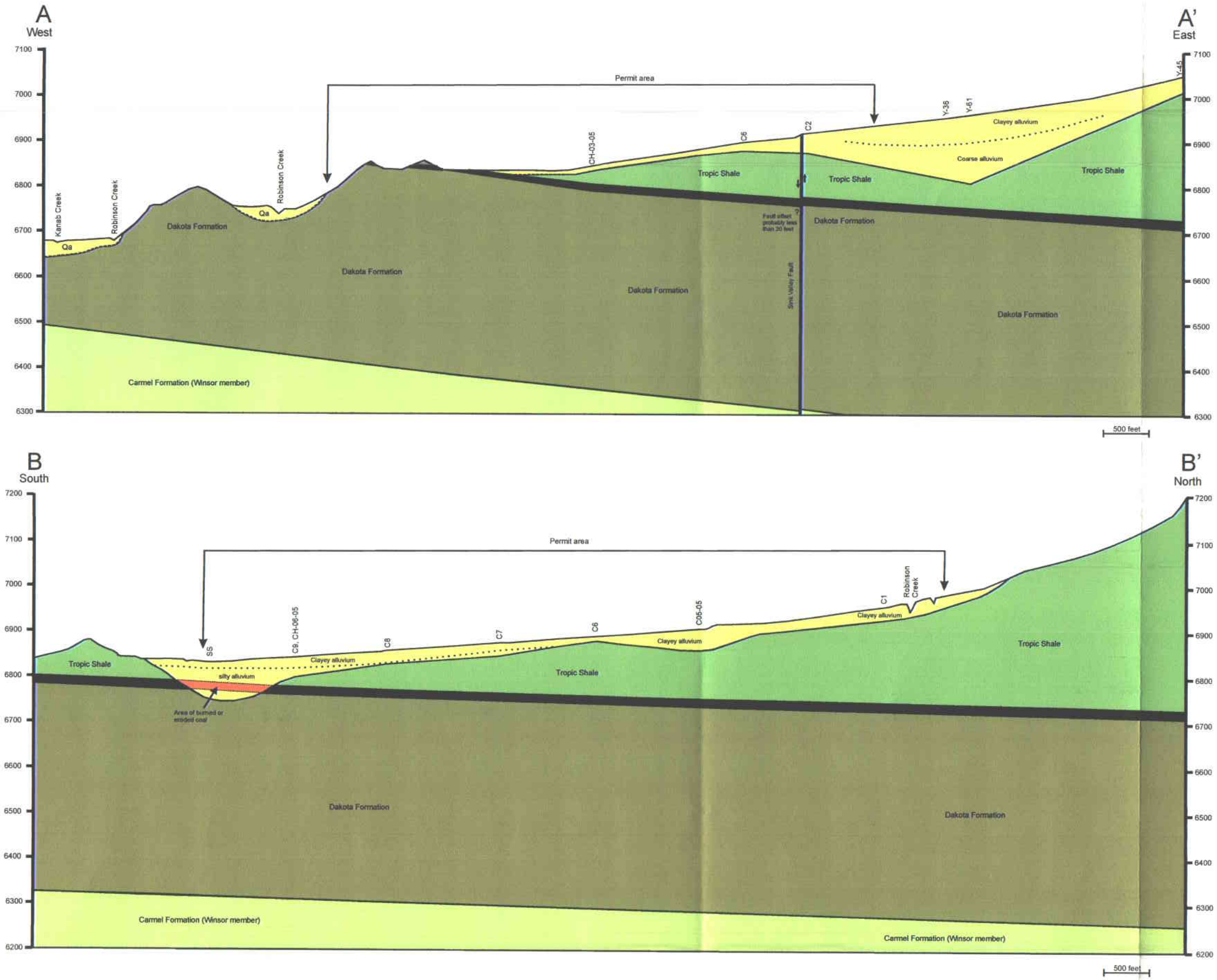
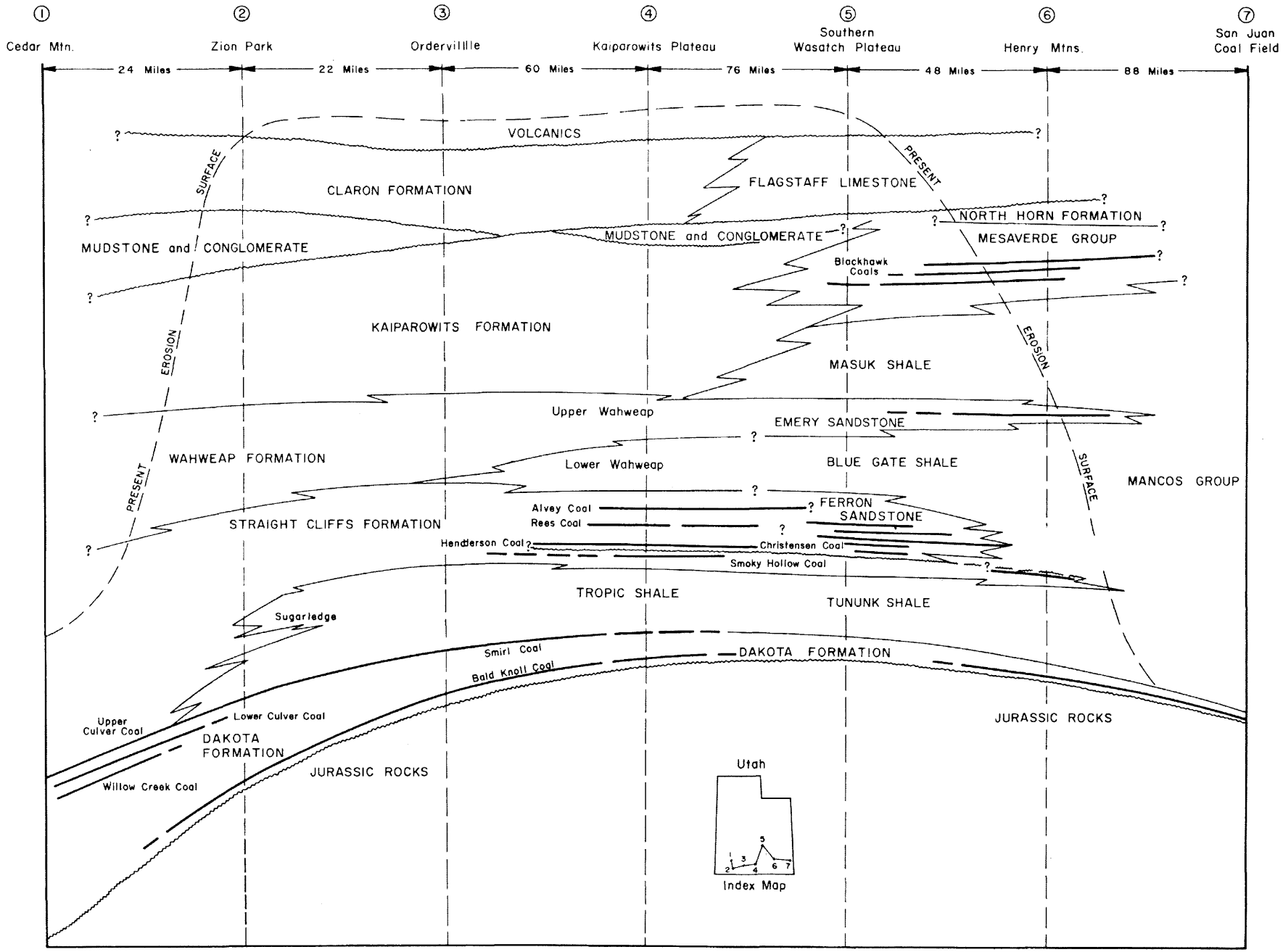


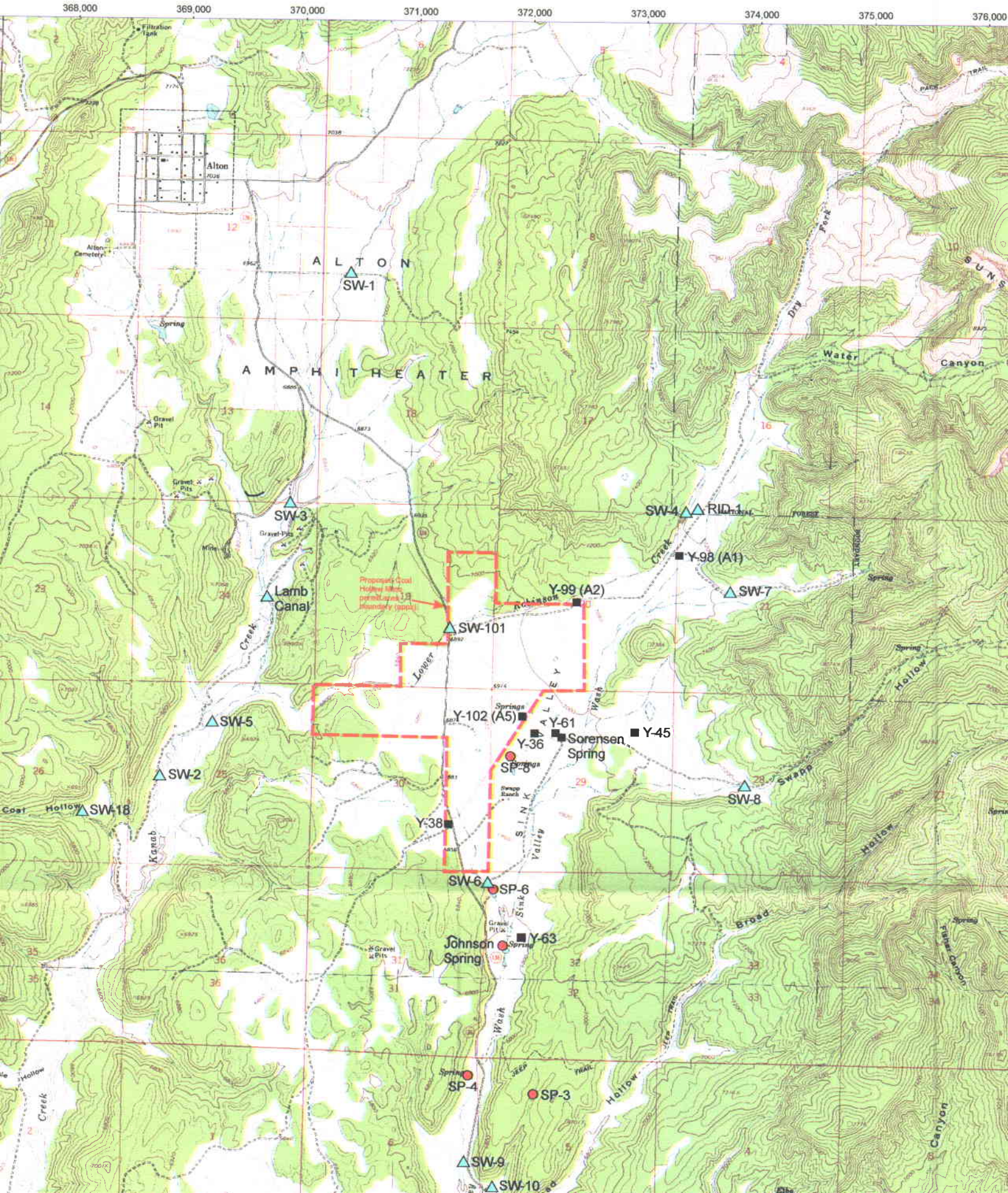
Figure 8
North-south and east-west geologic cross-sections through the proposed Coal Hollow Mine permit and adjacent area.

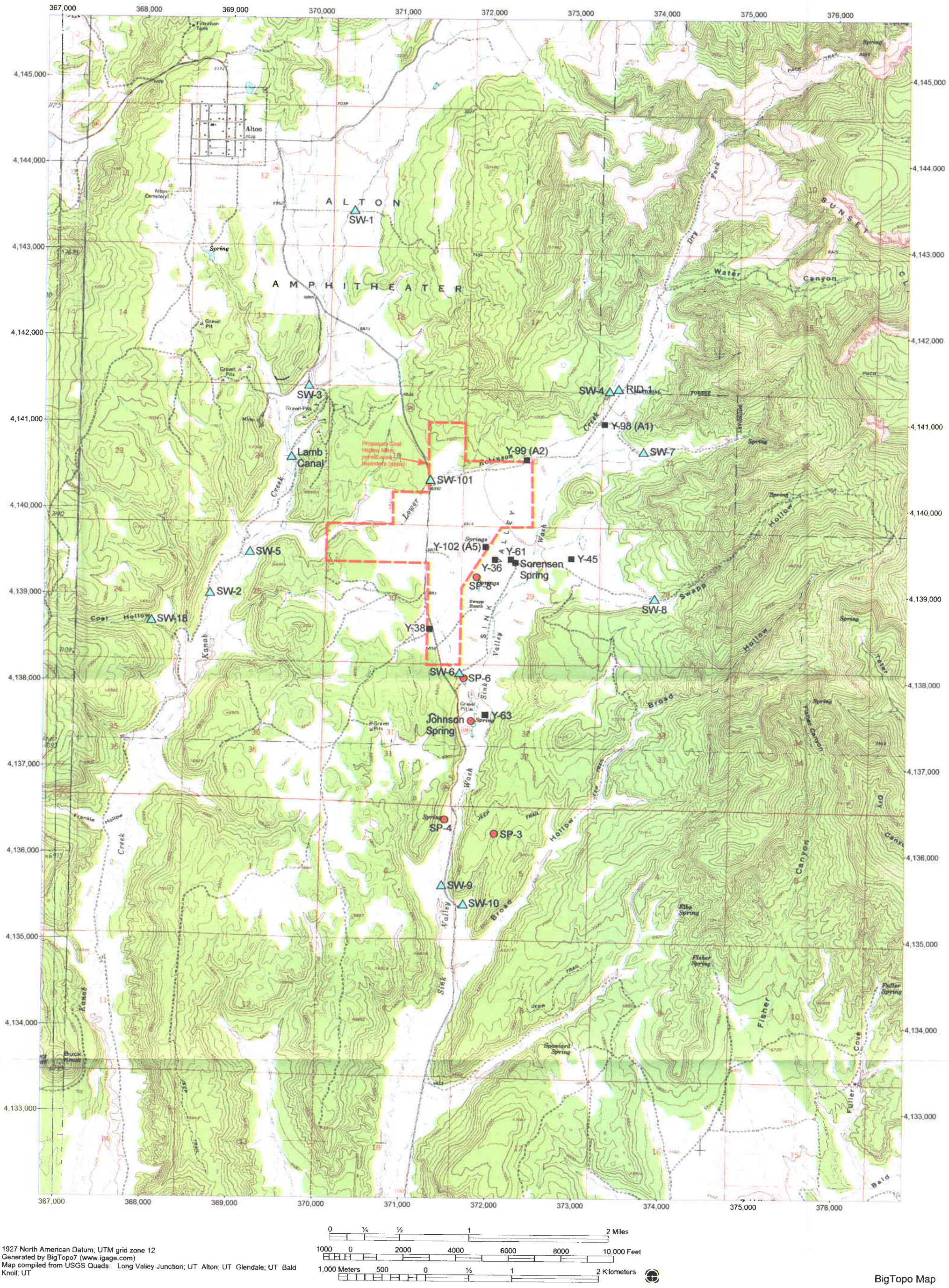
System	Series	Stratigraphic Unit			Thickness (Feet)	Description
Tertiary	Eocene	Claron Formation			1000-1300	Pink, white, and varicolored limestone, cliff former eroding into picturesque slopes and forms, basal conglomerate of exotic quartzite and limestone cobbles and pebbles.
						Unconformity
Cretaceous	Campanian	Kaiparowits Formation			265-700	Dark gray to gray-green arkosic sandstone, friable with weak calcareous cementation.
						Unconformity
	Santonian	Wahweap Formation *Minor Coal*			500-1300	Alternating sandy shale and thin- to thick-bedded resistant sandstone, ledge and slope topography.
	?	Straight Cliffs Formation *Minor Coal*			80-500	Yellow-gray to brown, thick-bedded to massive cliff-forming sandstone with subordinate intervening gray shale, shaley sandstone, *coal* and carbonaceous shale.
	Coniacian					
	?					
	Turonian					
		Tropic Shale			700-1000	Drab gray shale with subordinate thin brown fine-grained sandstone, slope former.
	Cenomanian	Dakota Formation *Major Coal Seams*			150-450	Yellow-gray to brown fine- to medium-grained sandstone alternating with gray shale, sandy shale, carbonaceous shale and *coal*, ledge and slope former creating Gray Cliffs; best *coal* near bottom and top of unit.
						Angular Unconformity
Jurassic	Upper	Entrada Sandstone		Cannonville Member	0-300	White and reddish banded fine-grained sandstone and siltstone, friable and earthy weathering, massive.
				Gunsight Butte Member	0-300	Red-brown and light green siltstone; also red cross-bedded sandstone of the "slickrock" type.
		Carmel Formation		Wiggler Wash Member	0-60	Limestone, red siltstone, white and greenish gypsum.
				Winsor Member	180-250	White, pink, brown sandstone alternating with thin red siltstone and mudstone.
				Paria River Member	55-200	Interbedded light gray and red sandstone, limestone, siltstone, shale, and gypsum.
			Judd Hollow Tongue of Carmel	Thousand Pockets Tongue of Navajo Sandstone	0-60	Yellowish cross-bedded friable but resistant sandstone.
				Crystal Peak Member	120-190	Dark reddish brown and white to light gray fine-grained sandstone, medium-bedded with minor thin gypsiferous or calcareous shales and conglomerate.
				Kolob Limestone	122-350	Gray and tan dense limestone with some thin sandy red shale near the base and thin gypsum near top.
						Unconformity
	Lower	Navajo Sandstone			1000+	Light gray to tan, locally red fine-grained sandstone, massive, exhibiting large-scale aeolian cross-bedding, calcareous and cliff forming.

Figure 9 Generalized geologic section of rock formations in the Alton Coal Field. (from Doelling, 1972).



Drawing 10 Diagrammatic correlation of Cretaceous units in southern Utah (from Doelling, 1972).


368,000
369,000
370,000
371,000
372,000
373,000
374,000
375,000
376,000
Alton
ALTON
SW-1
AMPHITHEATER
SW-3
Lamb Canal
SW-101
SW-4
RID-1
Y-98 (A1)
Y-99 (A2)
SW-7
Y-102 (A5)
Y-61
Y-36
Sorensen Spring
Y-45
SP-5
SW-5
SW-2
SW-18
SW-8
Y-38
SW-6
SP-6
Y-63
Johnson Spring
SP-4
SP-3
SW-9
SW-10
Lower
Creek
Wash
SINK VALLEY
Swapp
Hollow
Broad
Canyon
Water
Dry
Fork
Coal
Kanab
Proposed Coal Hollow Mine permit area boundary (ppa)



1927 North American Datum; UTM grid zone 12
Generated by BigTopo7 (www.igage.com)
Map compiled from USGS Quads: Long Valley Junction; UT Alton; UT Glendale; UT Bald Knoll; UT

0 ¼ ½ 1 2 Miles
1000 0 2000 4000 6000 8000 10,000 Feet
1,000 Meters 500 0 ½ 1 2 Kilometers

BigTopo Map

Figure 11 Baseline monitoring locations.

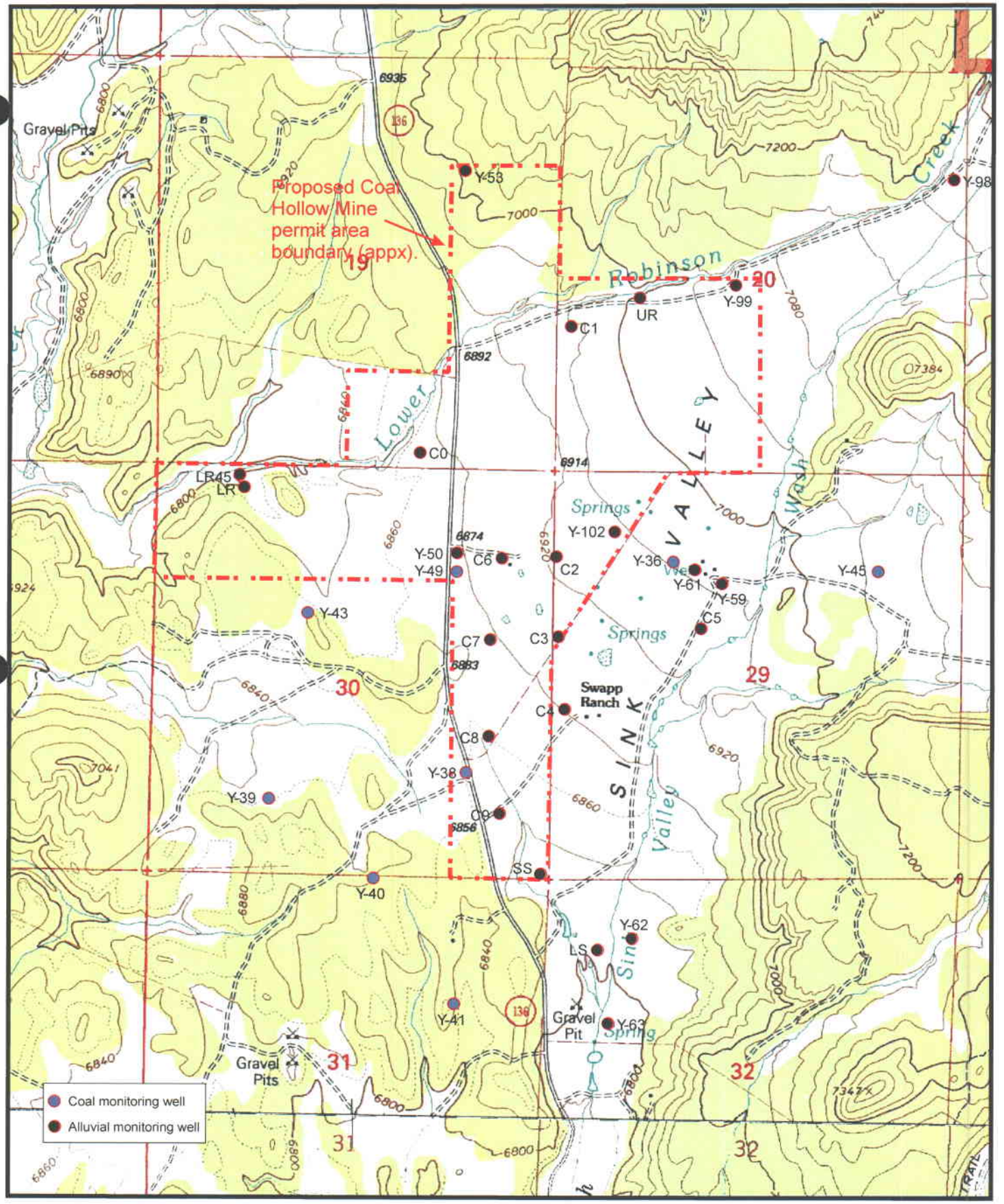
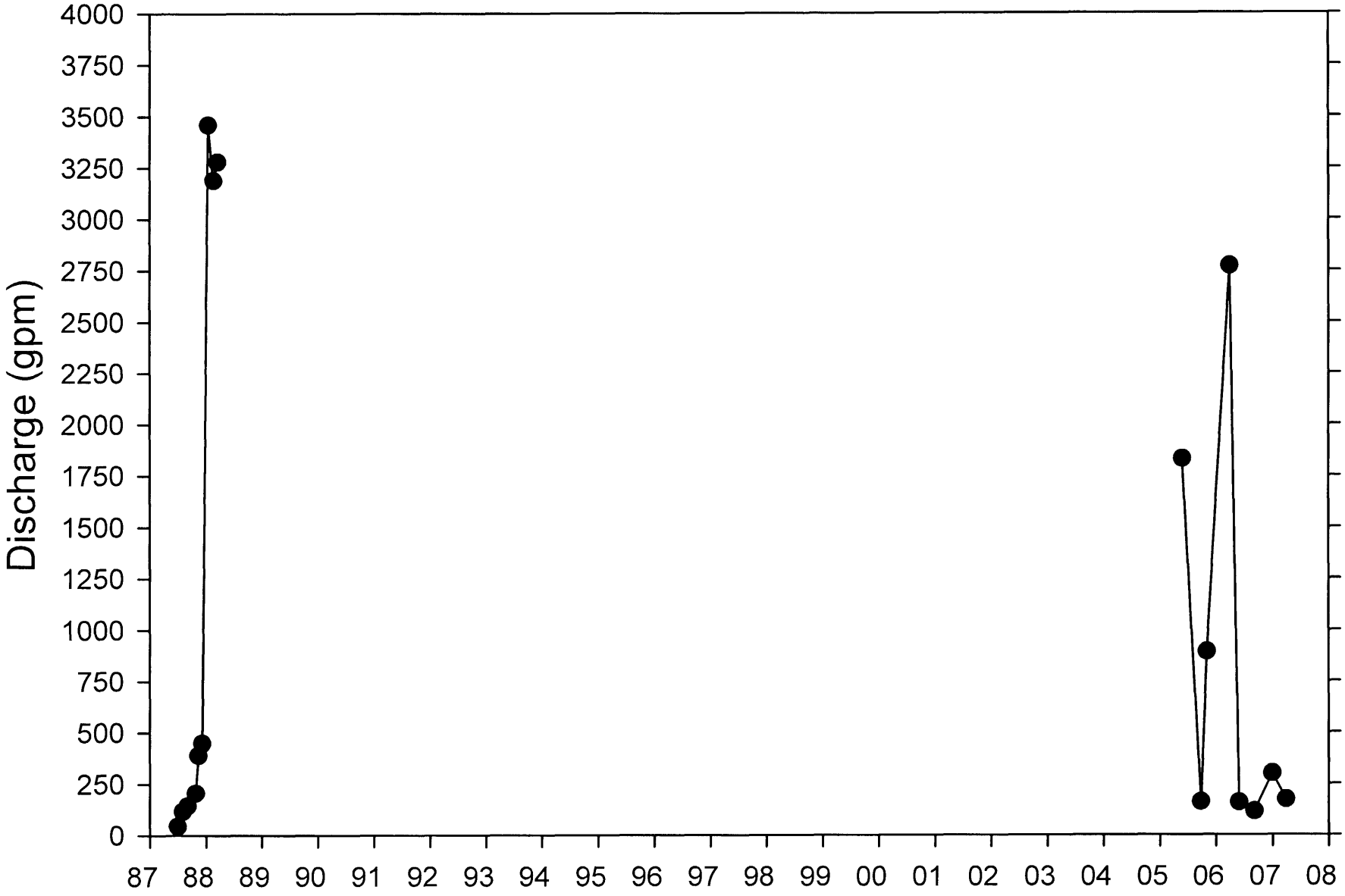


Figure 12 Monitoring well locations

Figure 13

Discharge hydrographs for springs
Discharge hydrographs for streams
Water elevation hydrographs for wells

SW-1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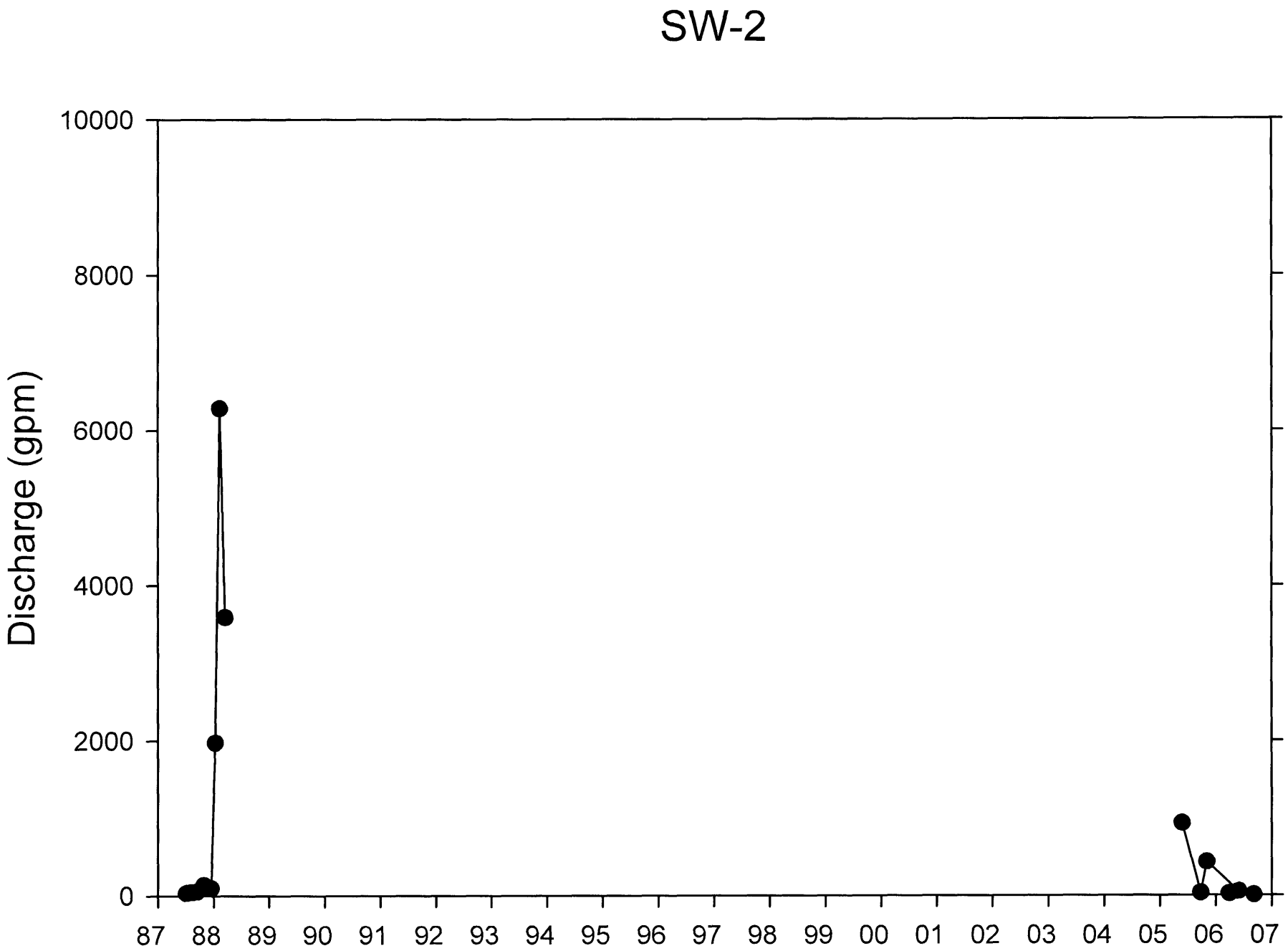
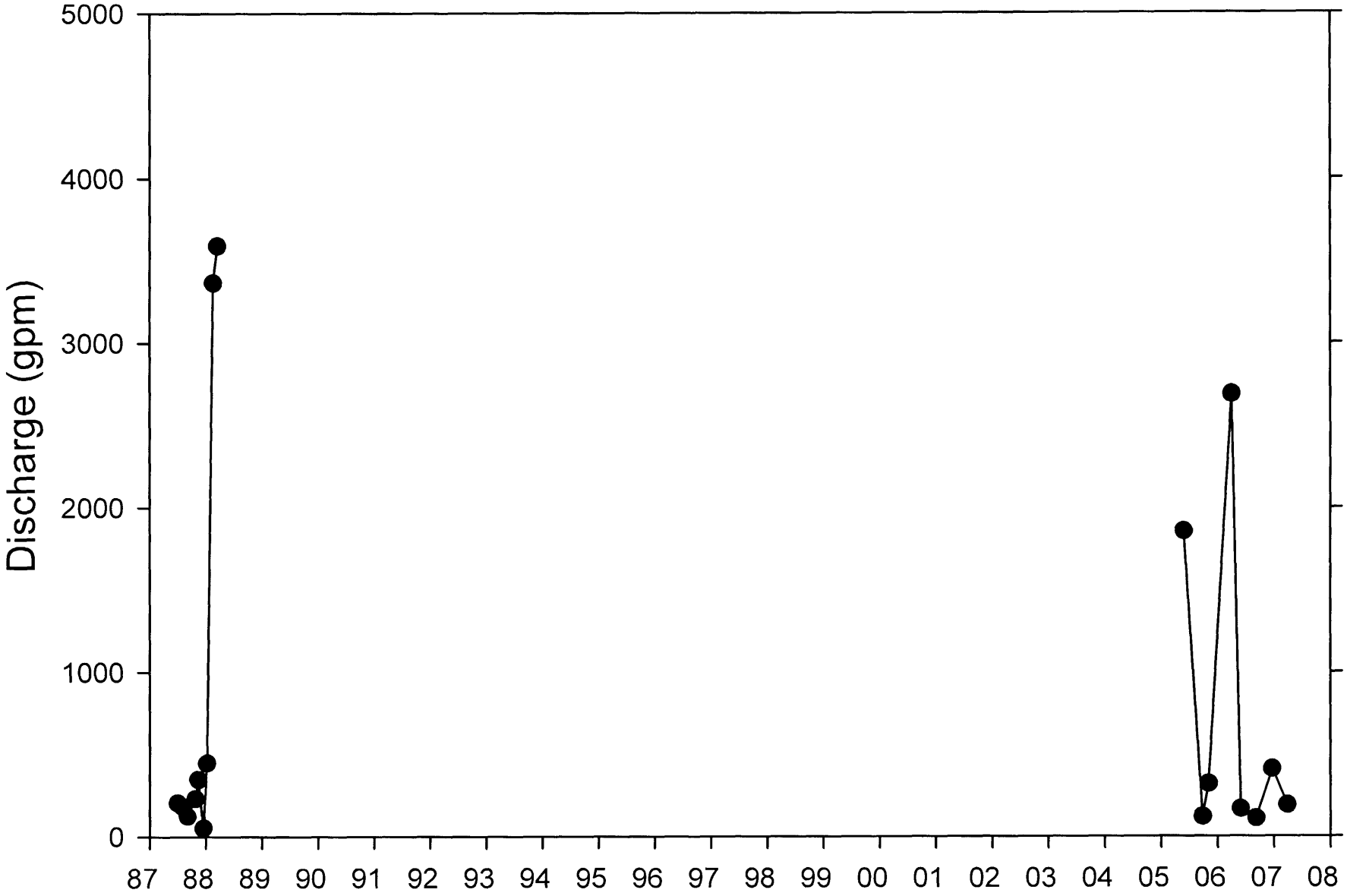
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08


SW-2
Discharge (gpm)
10000
8000
6000
4000
2000
0
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07

SW-3


Discharge (gpm)
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4000
3000
2000
1000
0
87
88
89
90
91
92
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96
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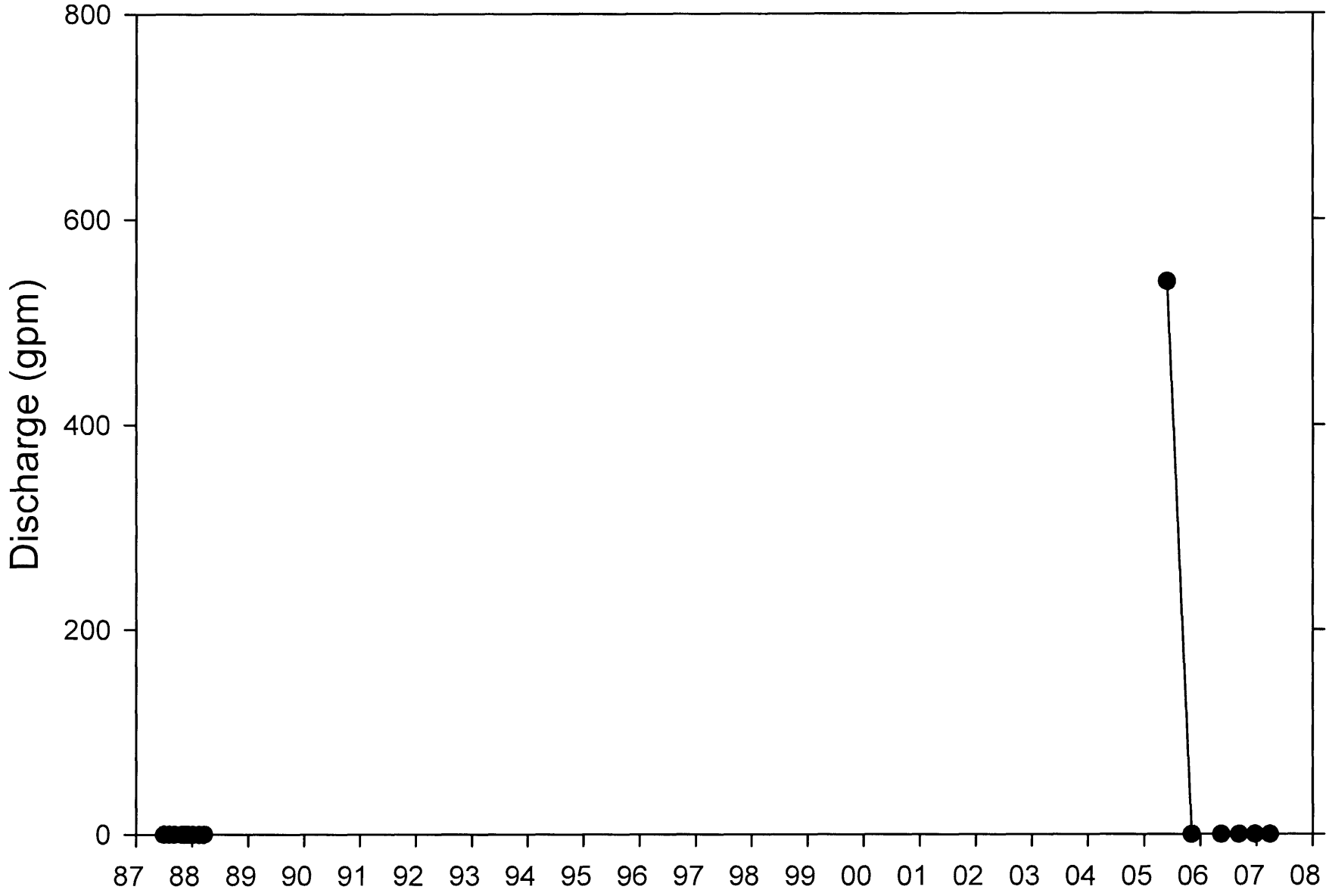
98
99
00
01
02
03
04
05
06
07
08

SW-4


Discharge (gpm)
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600
400
200
0
87
88
89
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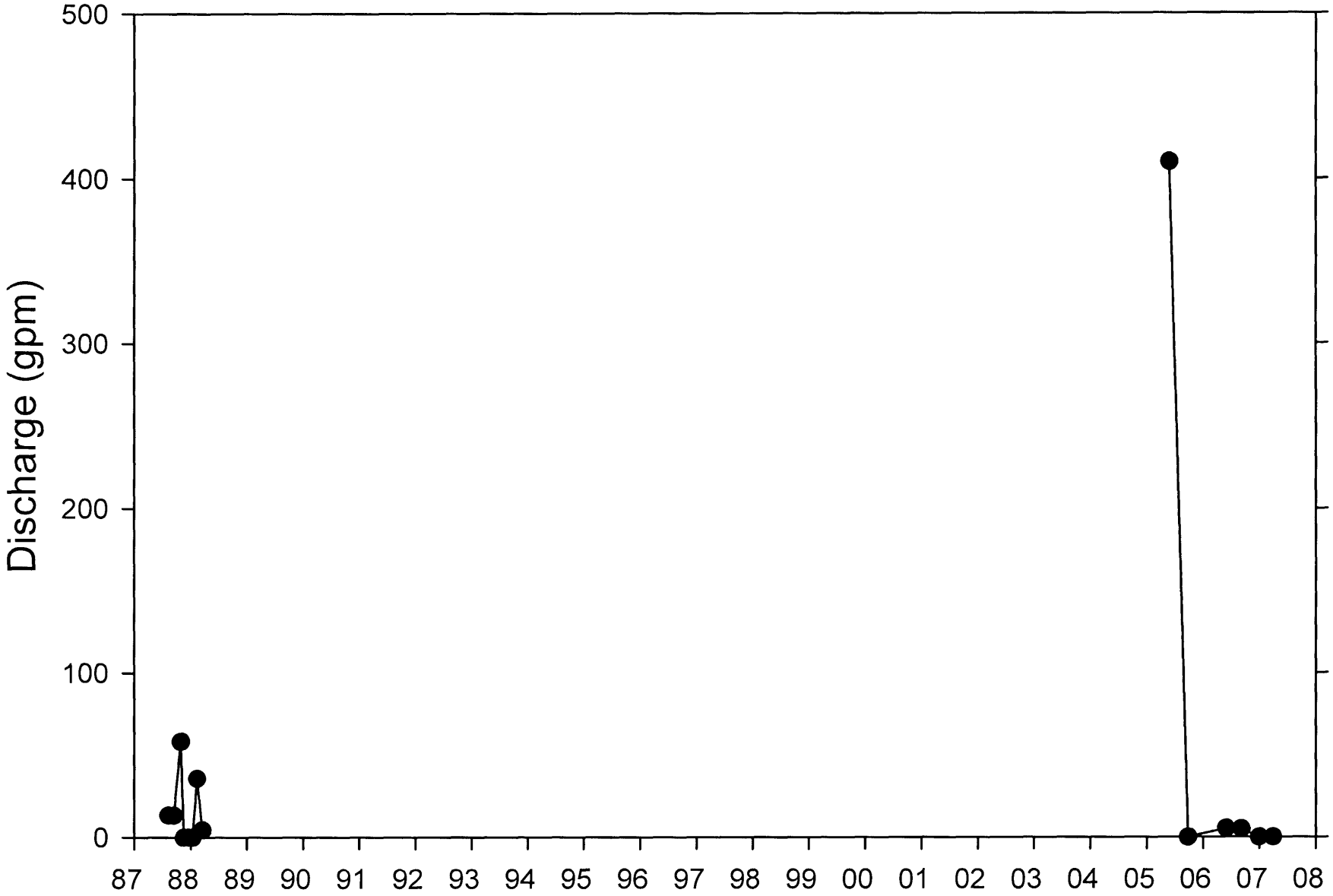
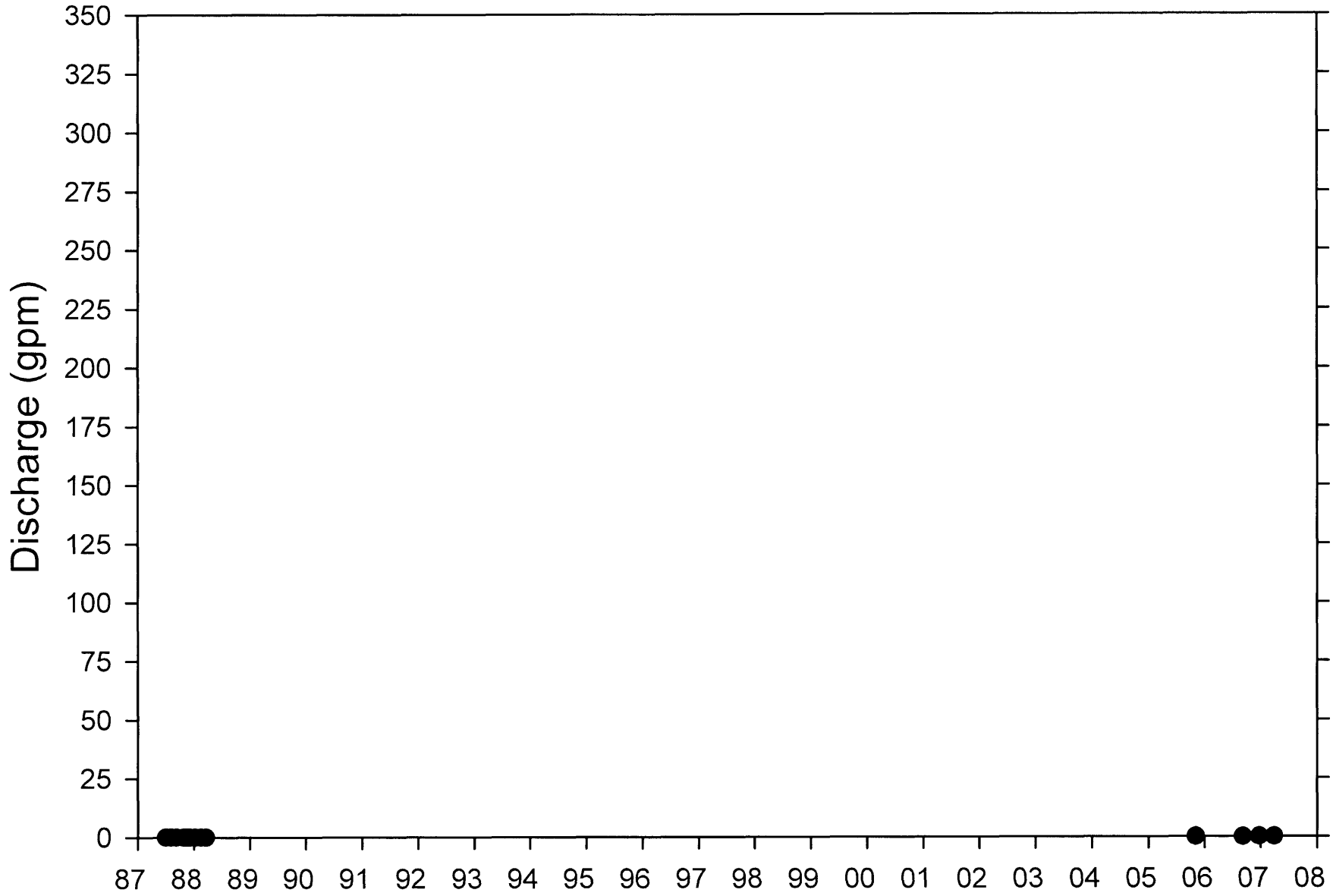
99
00
01
02
03
04
05
06
07
08

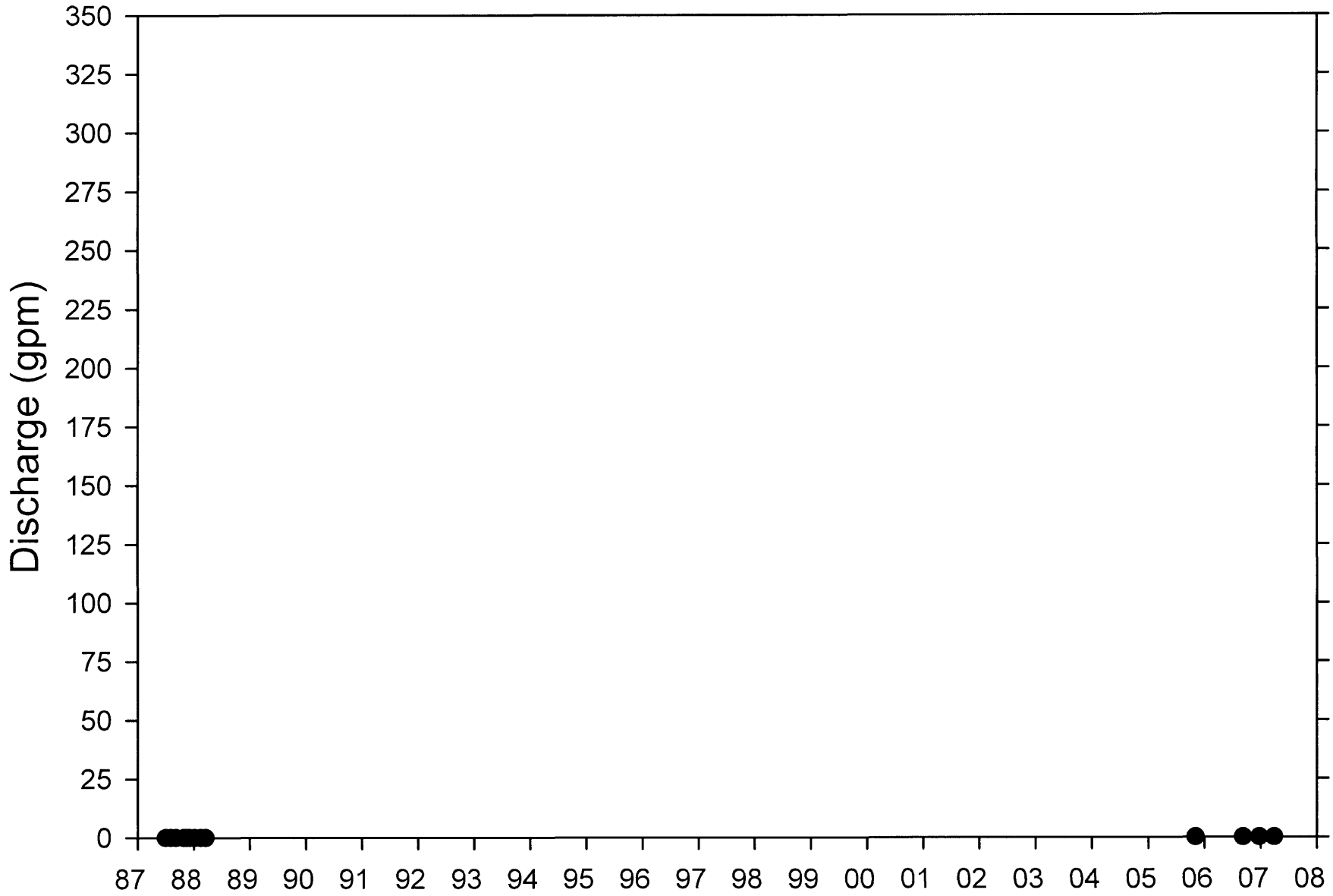
SW-5


Discharge (gpm)
500
400
300
200
100
0
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08

SW-6


Discharge (gpm)
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08

SW-7


Discharge (gpm)
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
87
88
89
90
91
92
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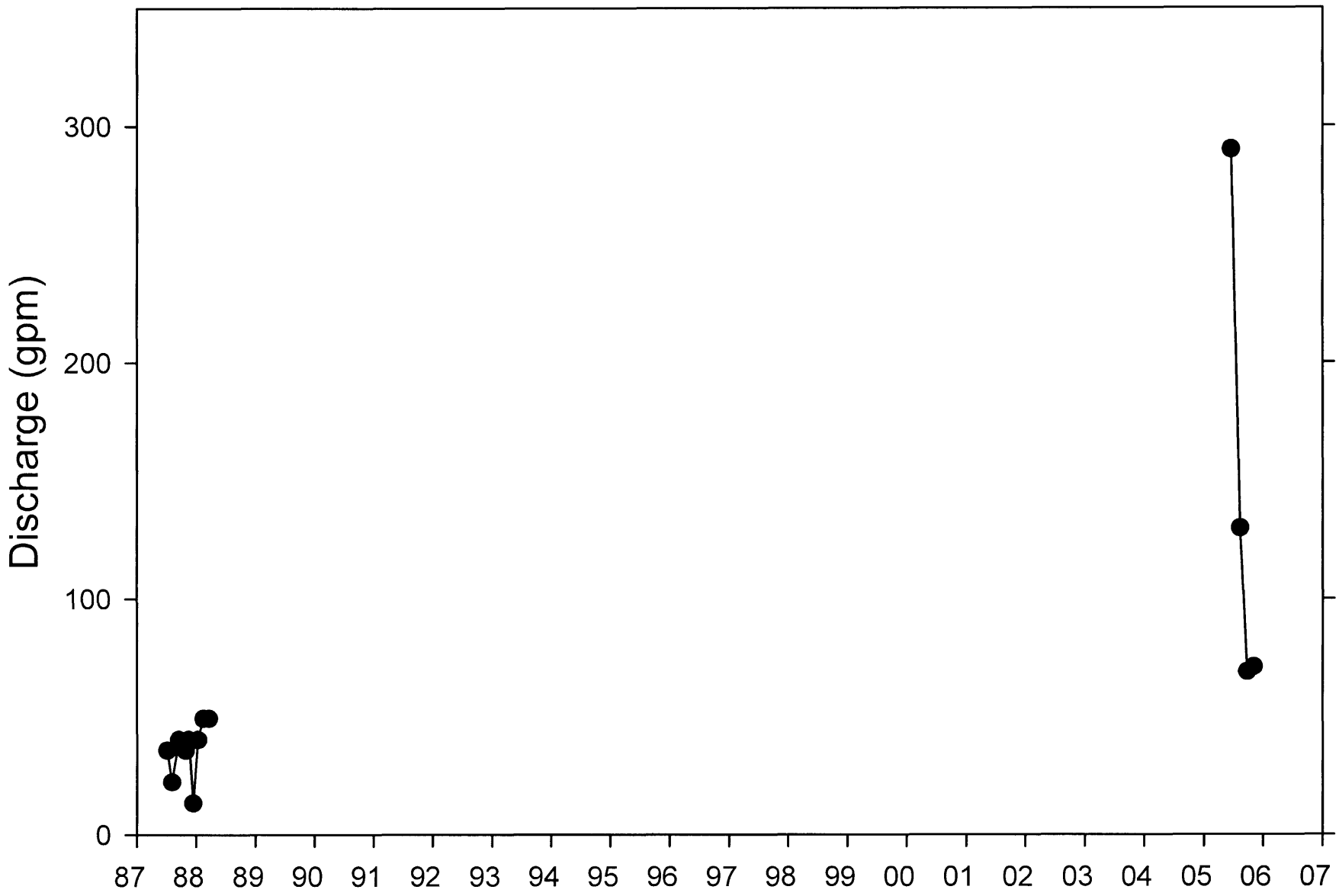
96
97
98
99
00
01
02
03
04
05
06
07
08

SW-8


Discharge (gpm)
300
200
100
0
87
88
89
90
91
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93
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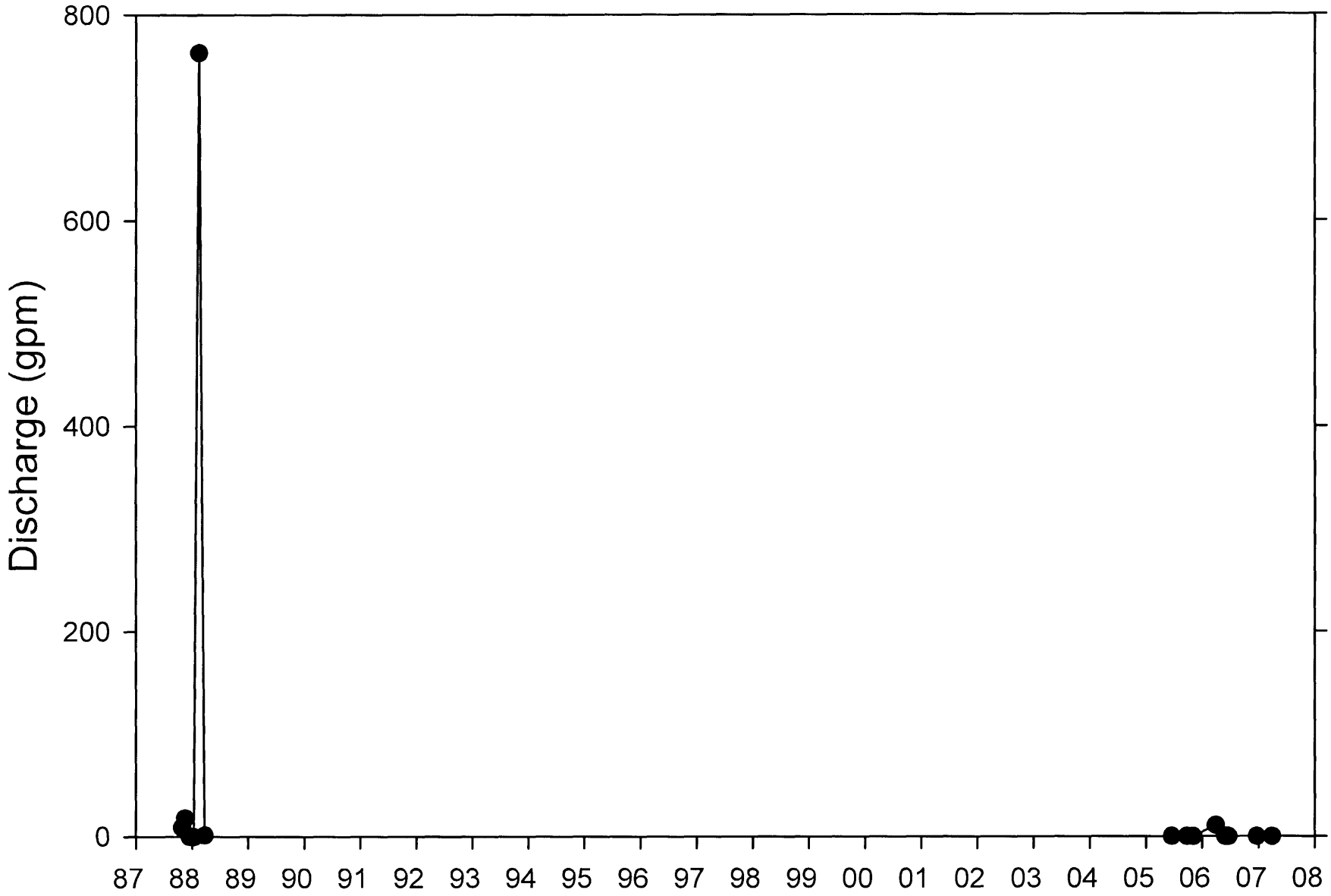
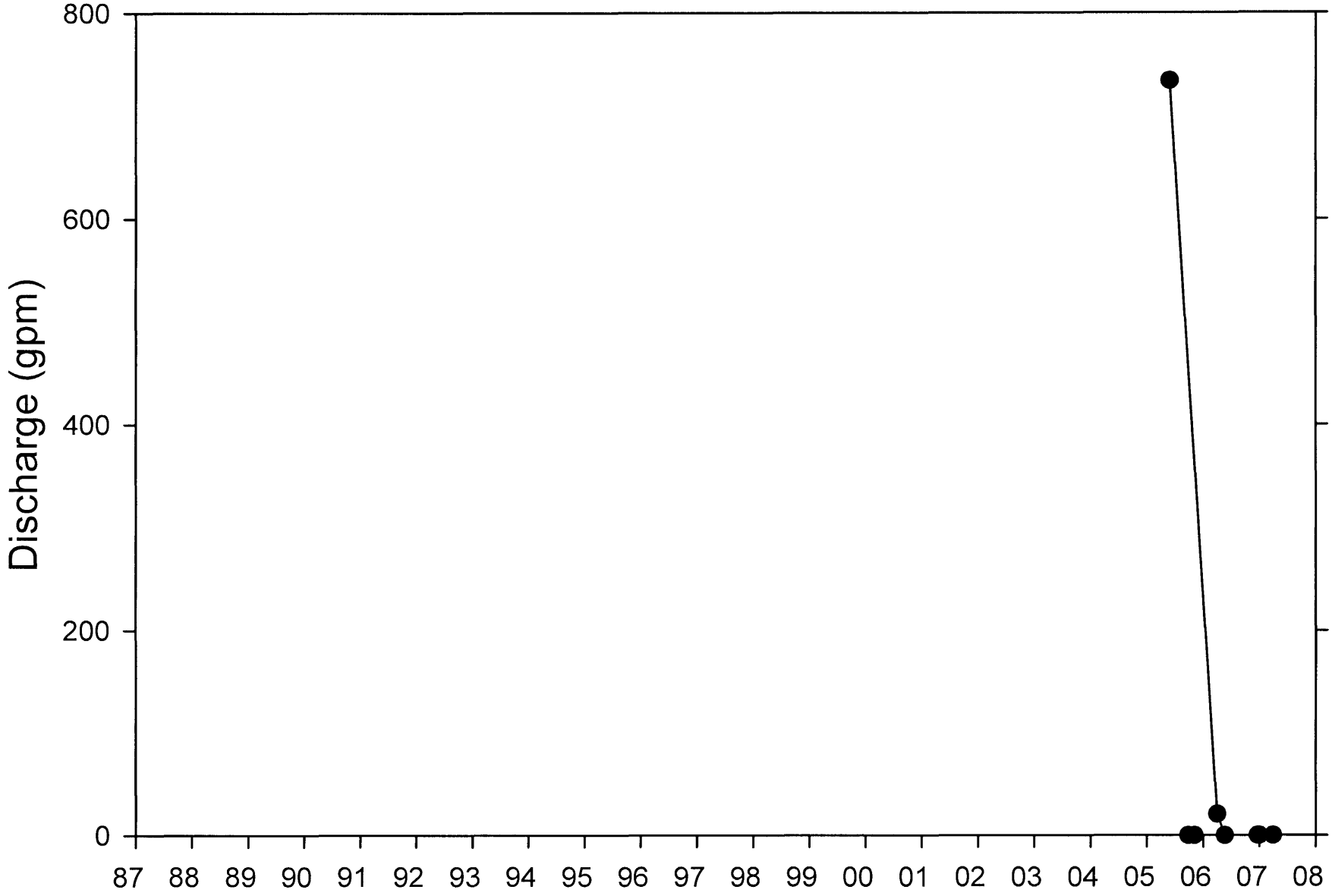
99
00
01
02
03
04
05
06
07

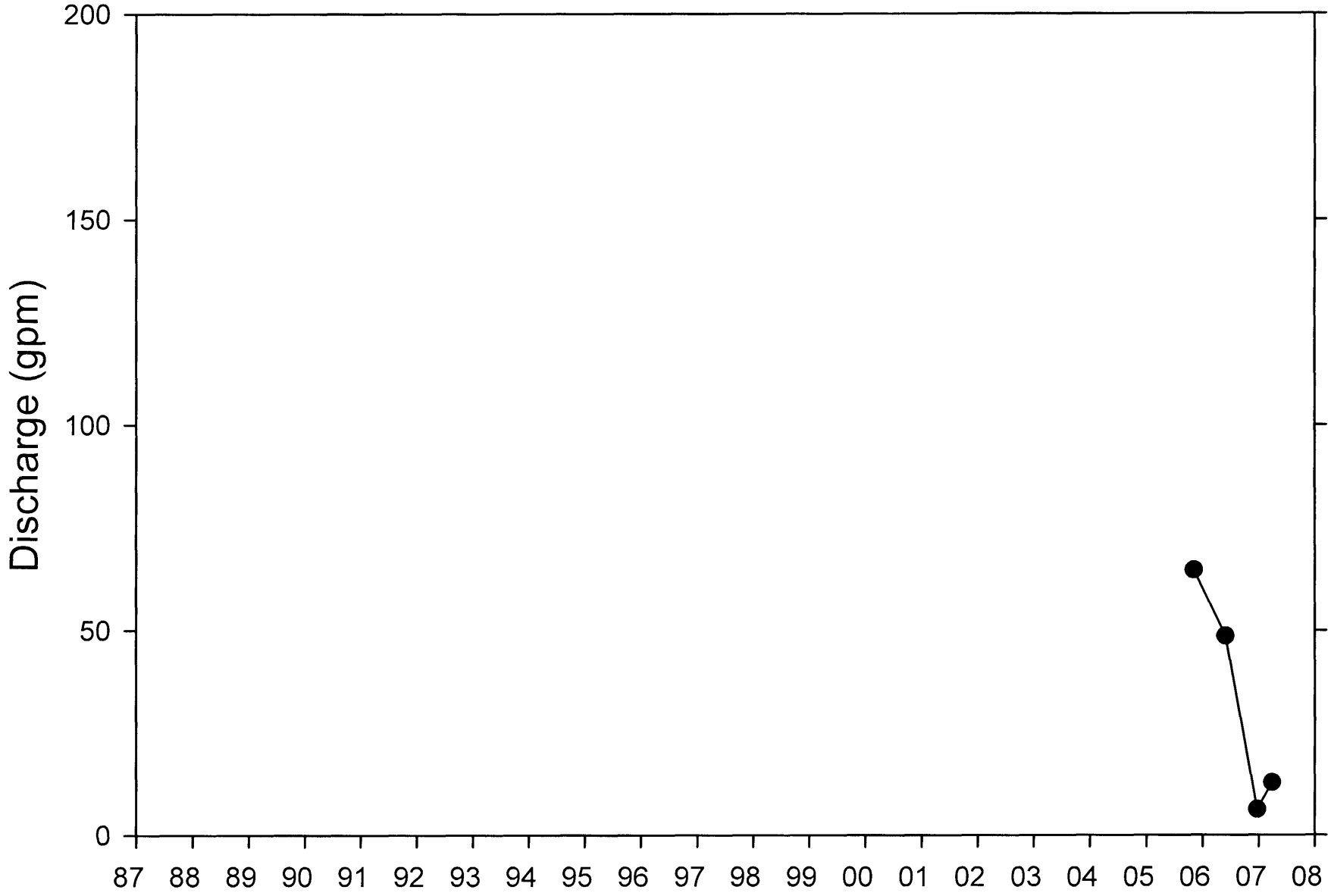
SW-9


Discharge (gpm)
800
600
400
200
0
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08

SW-101


Discharge (gpm)
800
600
400
200
0
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08

RID-1


Discharge (gpm)
200
150
100
50
0
87
88
89
90
91
92
93
94
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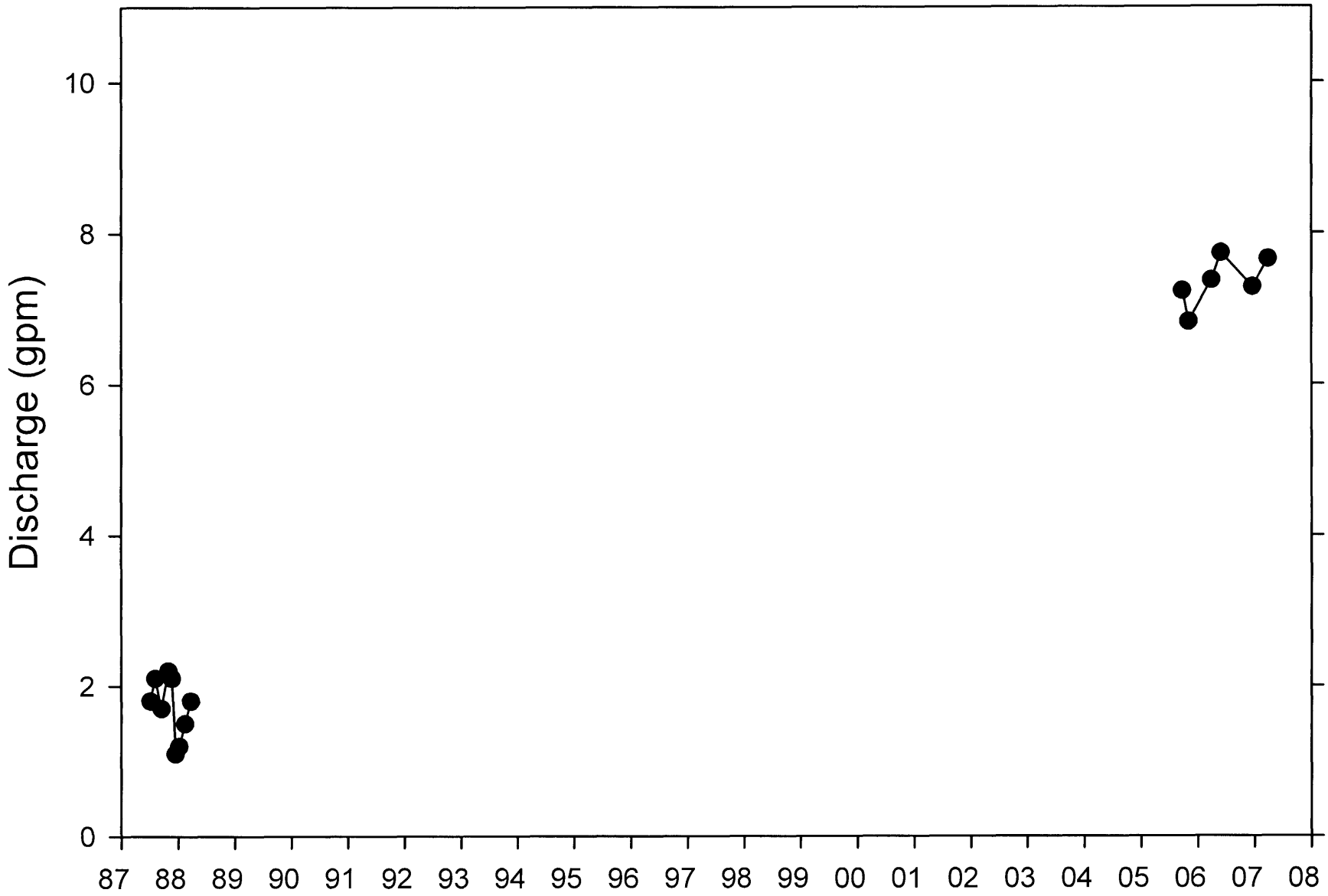
96
97
98
99
00
01
02
03
04
05
06
07
08

SP-3


Discharge (gpm)
0
2
4
6
8
10
87
88
89
90
91
92
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96
97
98
99
00
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02
03
04
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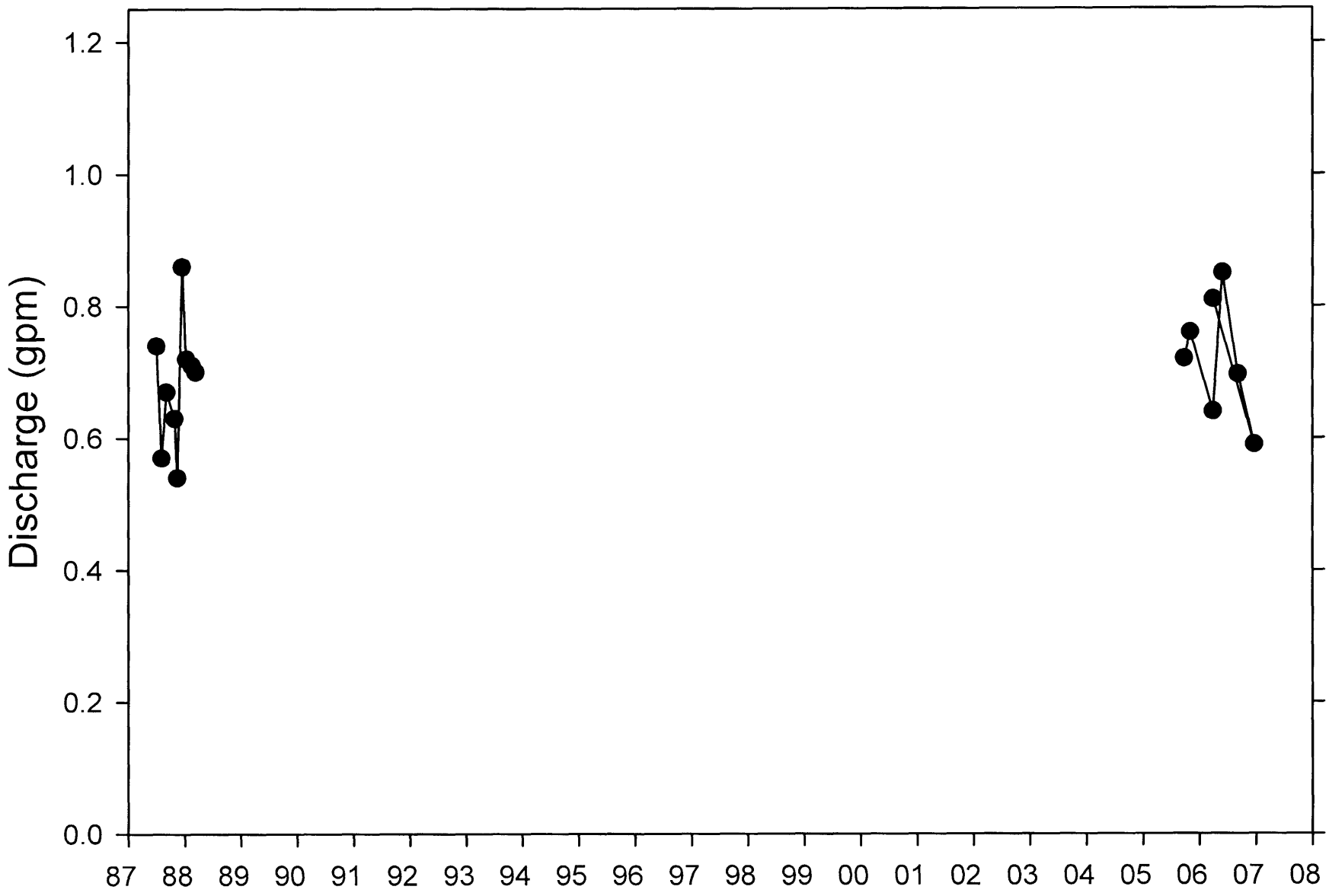
06
07
08

SP-4


Discharge (gpm)
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0.8
0.6
0.4
0.2
0.0
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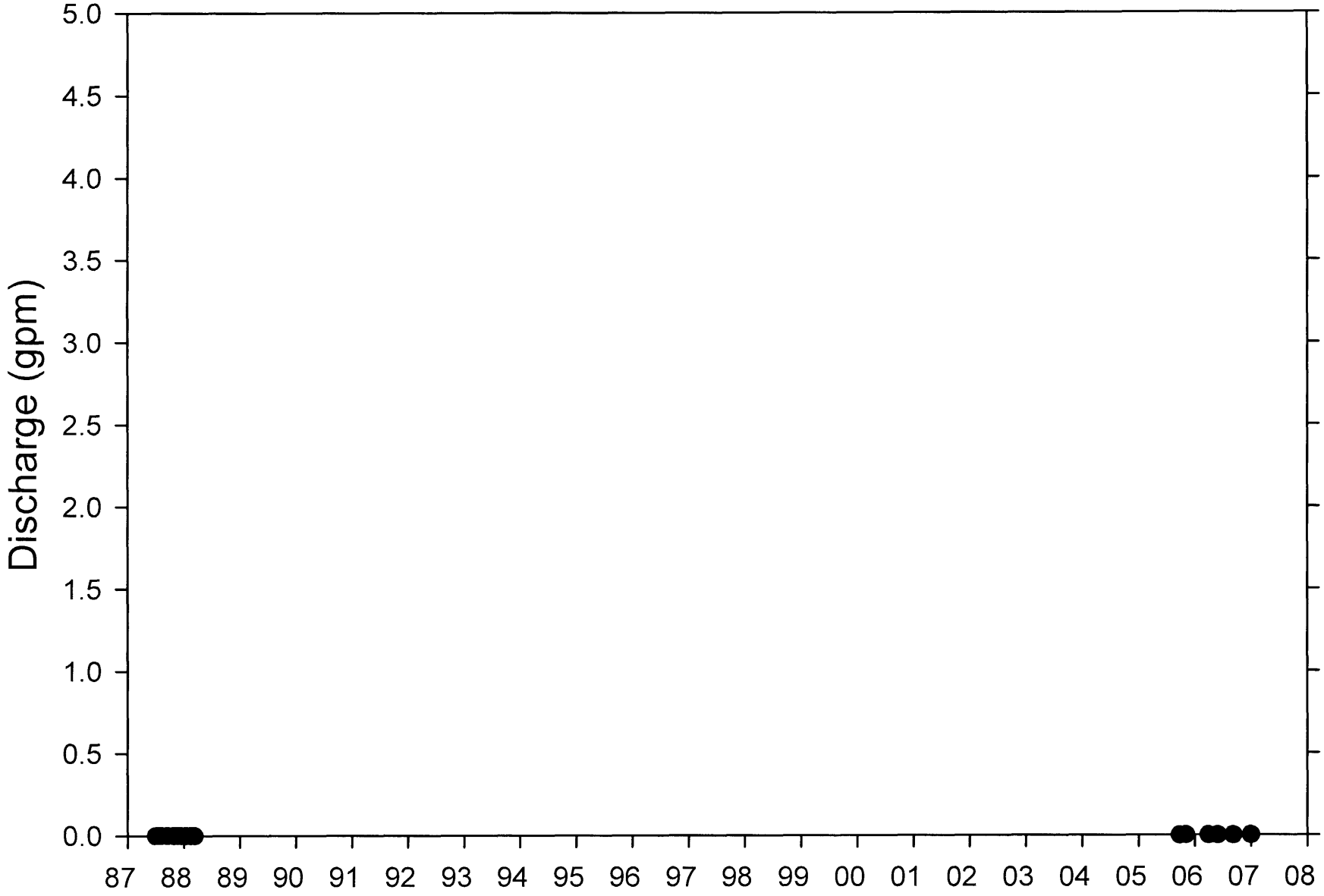
08

SP-6


Discharge (gpm)
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4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
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0.0
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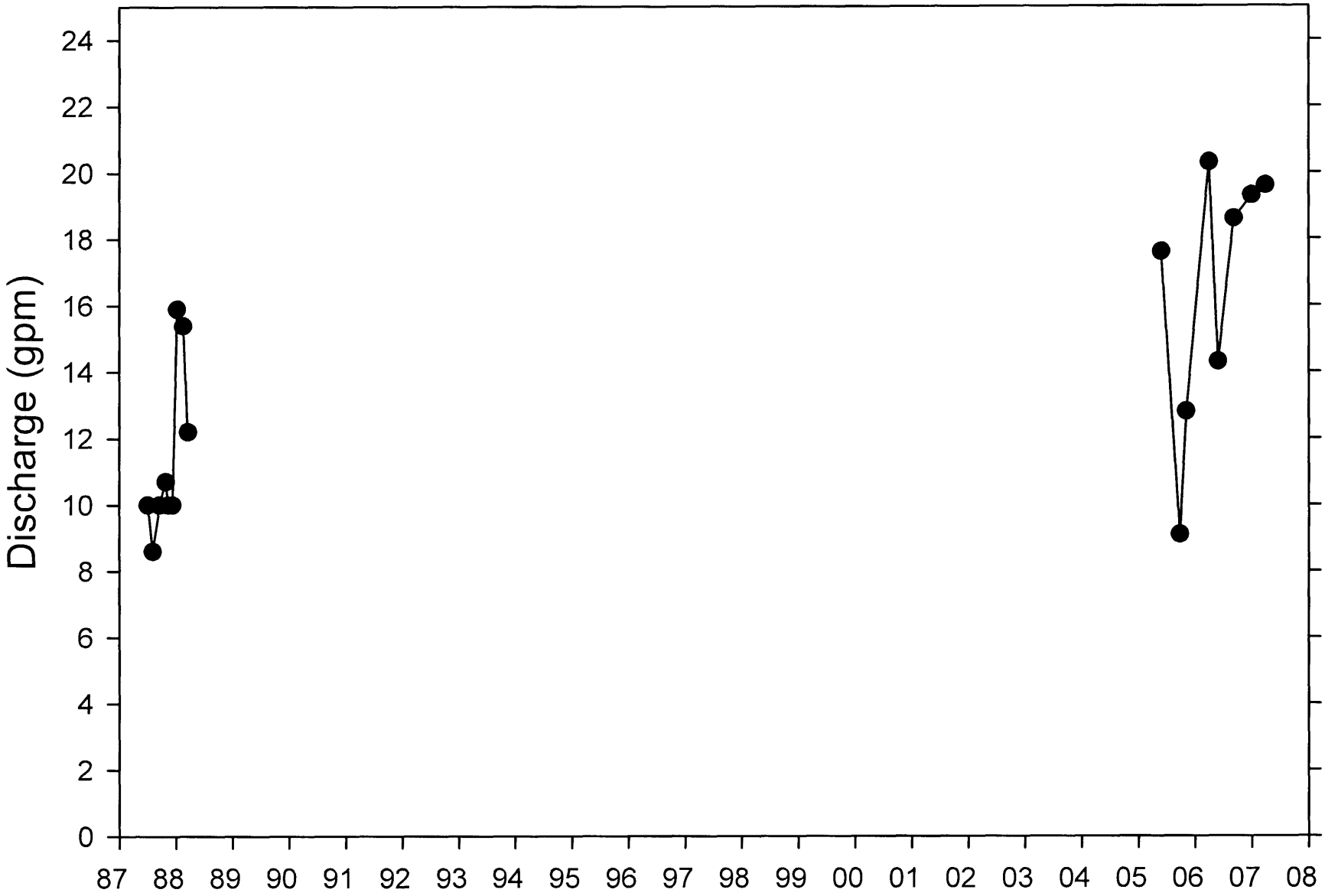
SP-8


Discharge (gpm)
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12
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18
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24
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00
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02
03
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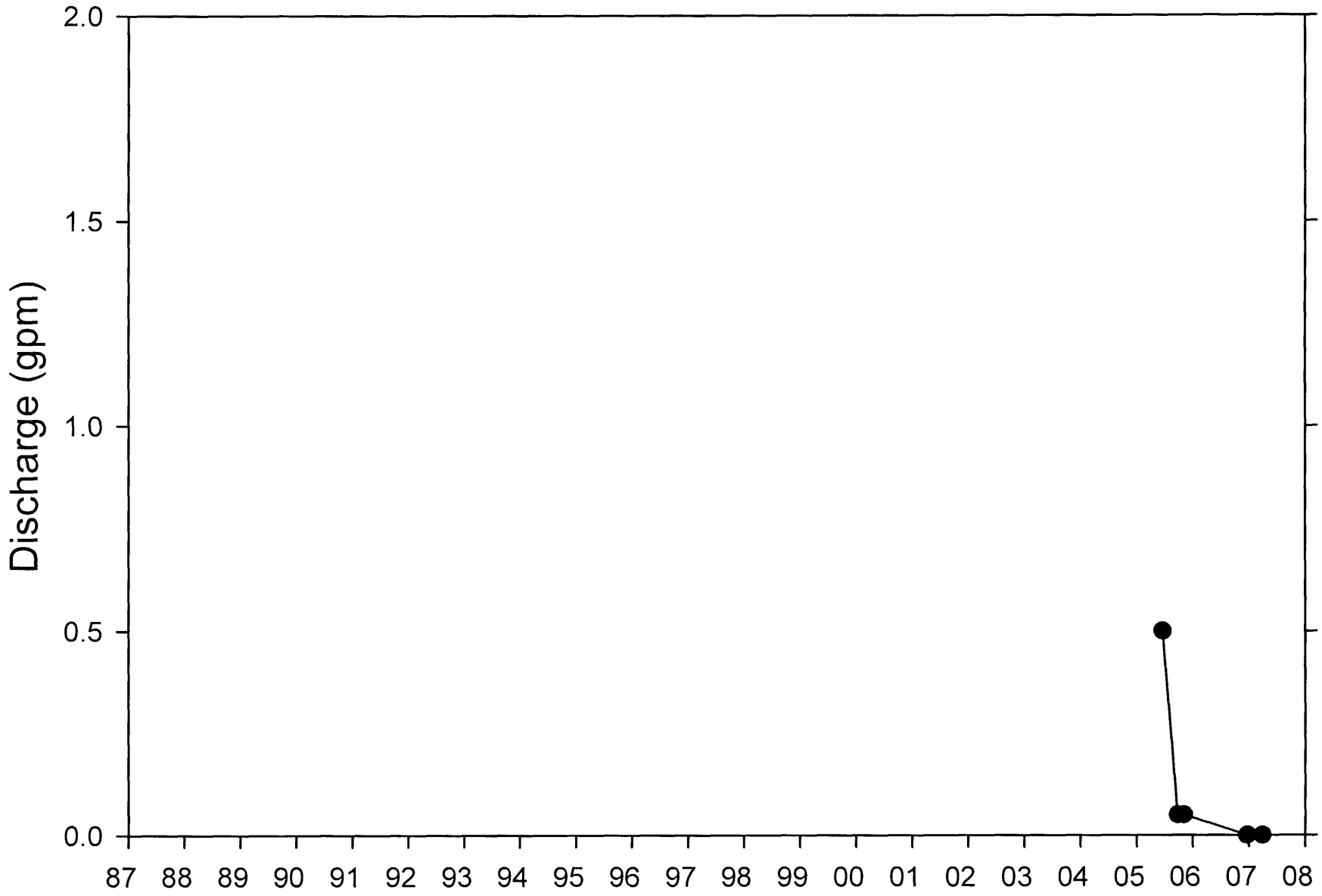
07
08

SP-27


Discharge (gpm)
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1.0
0.5
0.0
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05
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07
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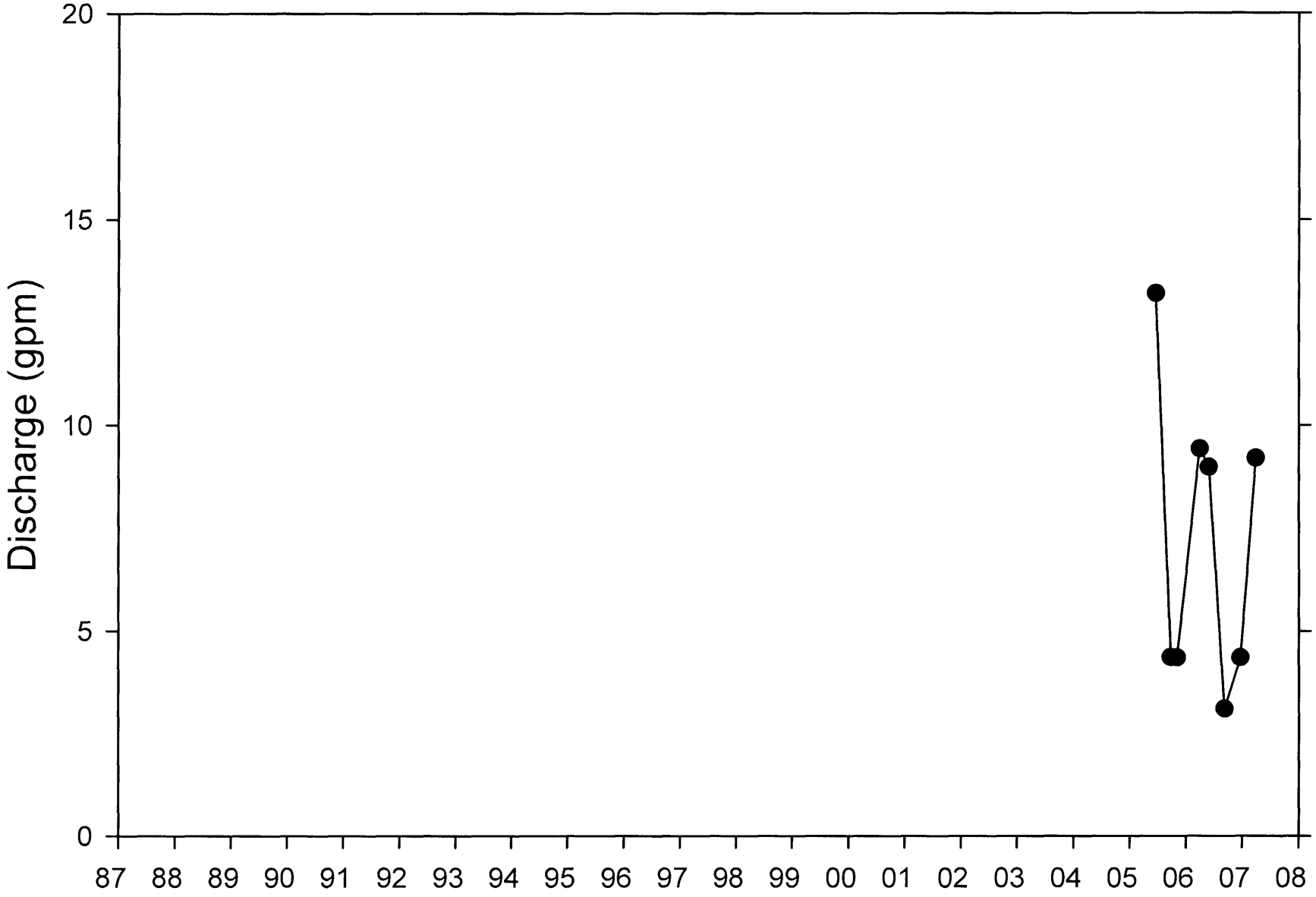
SP-33


Discharge (gpm)
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15
10
5
0
87
88
89
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95
96
97
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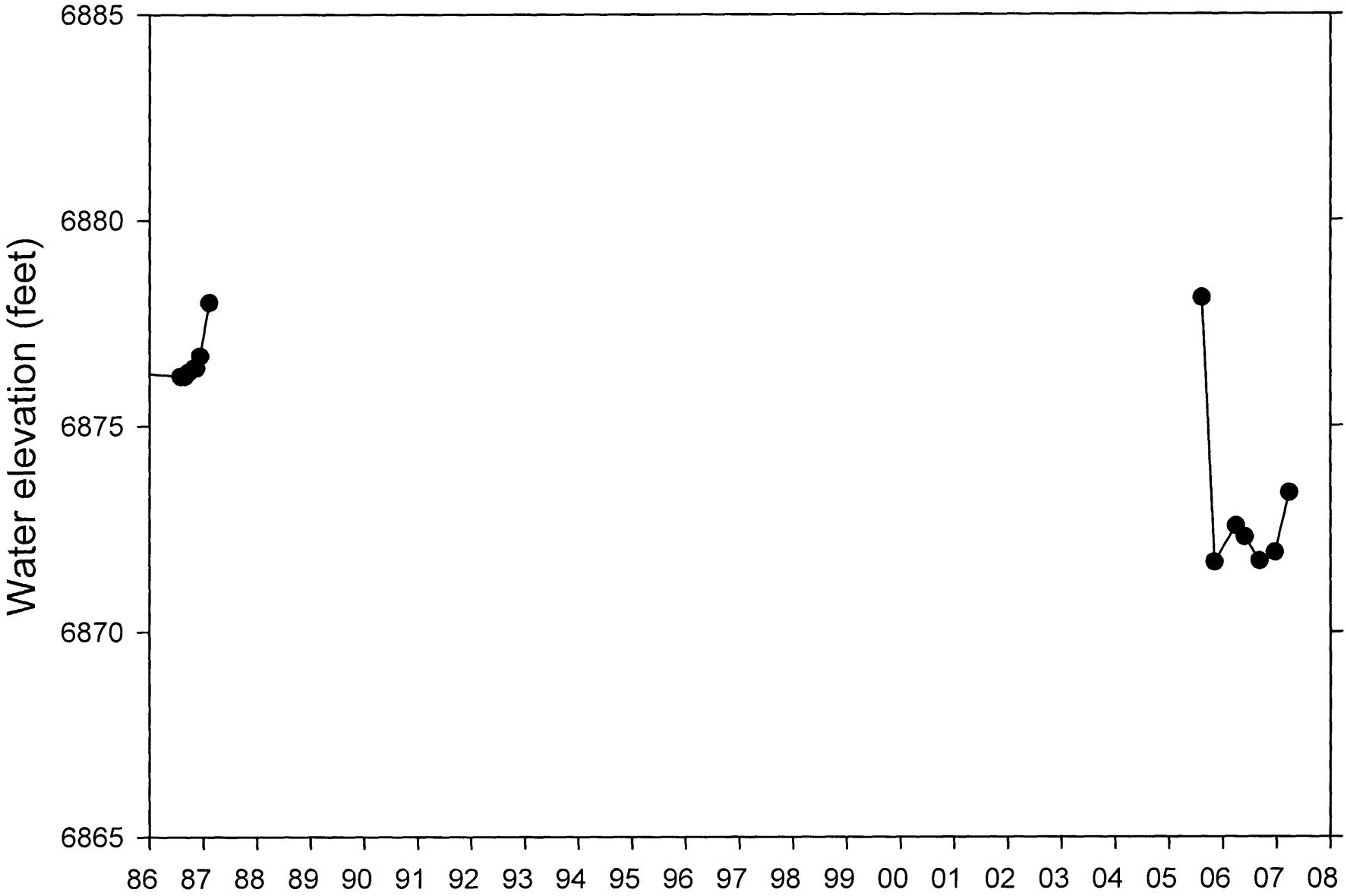
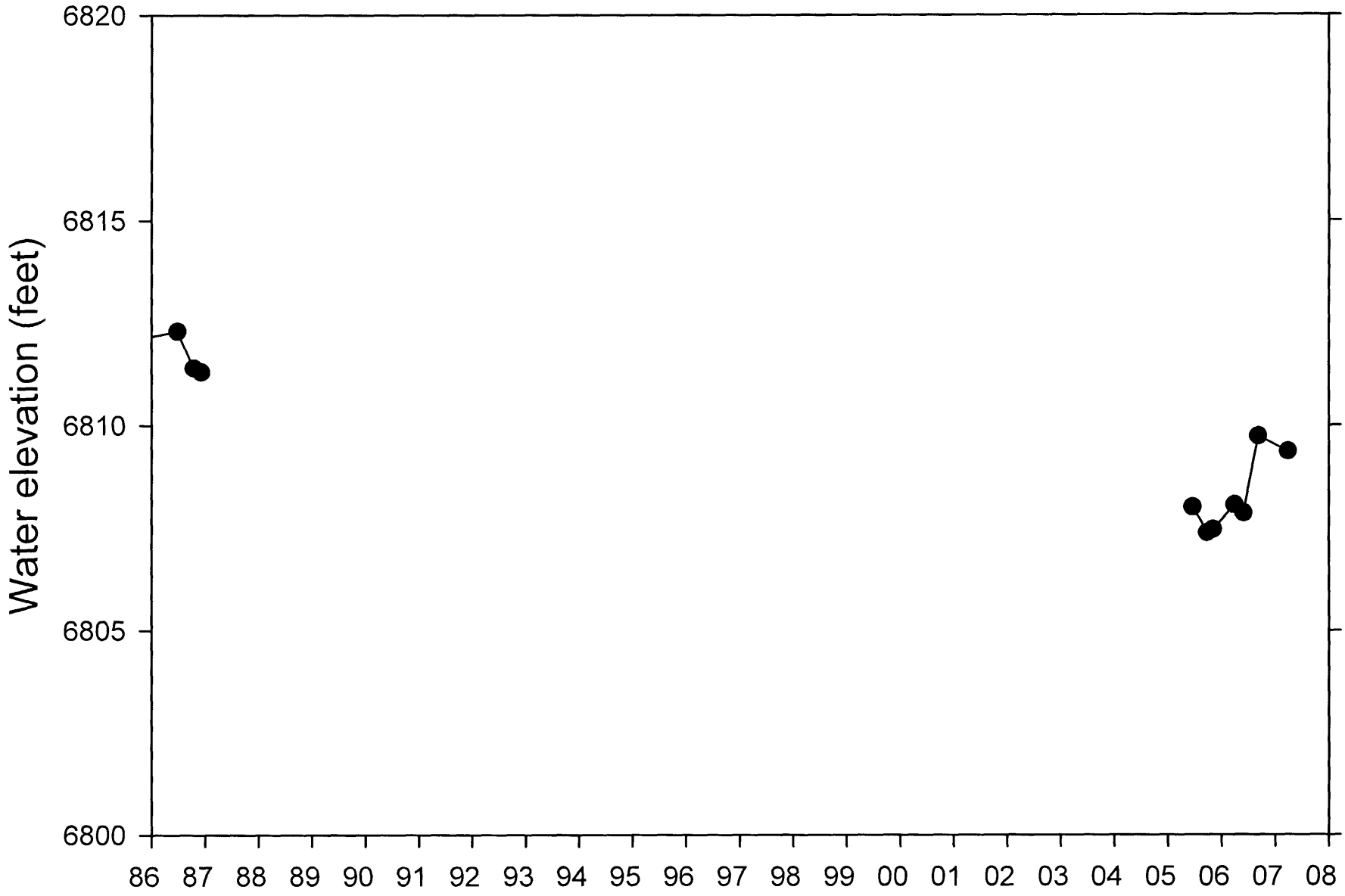
00
01
02
03
04
05
06
07
08

Y-36


Water elevation (feet)
6885
6880
6875
6870
6865
86
87
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02
03
04
05
06
07
08

Y-38


Water elevation (feet)
6820
6815
6810
6805
6800
86
87
88
89
90
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96
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98
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02
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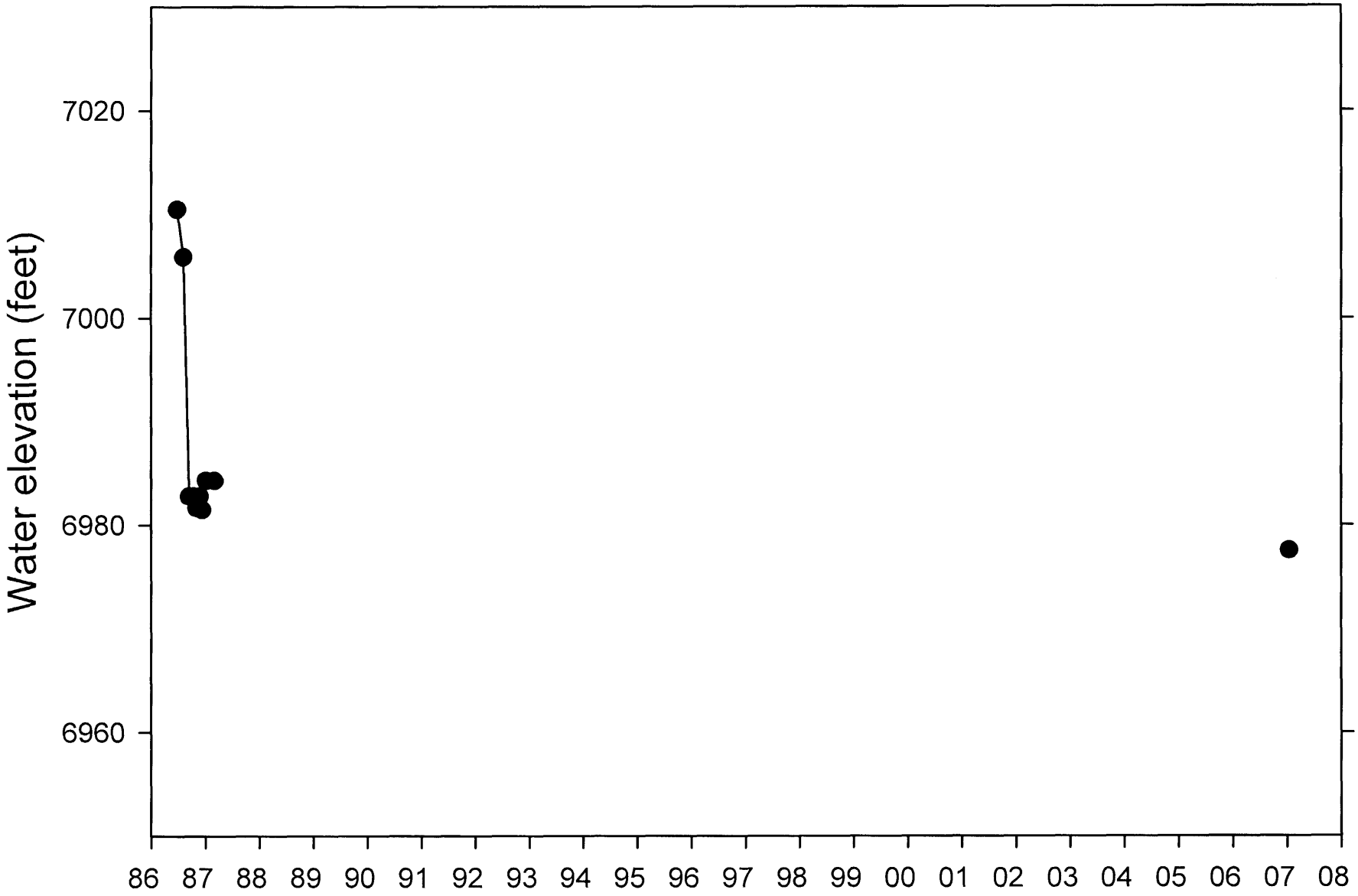
07
08

Y-59


Water elevation (feet)
7020
7000
6980
6960
86
87
88
89
90
91
92
93
94
95
96
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98
99
00
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02
03
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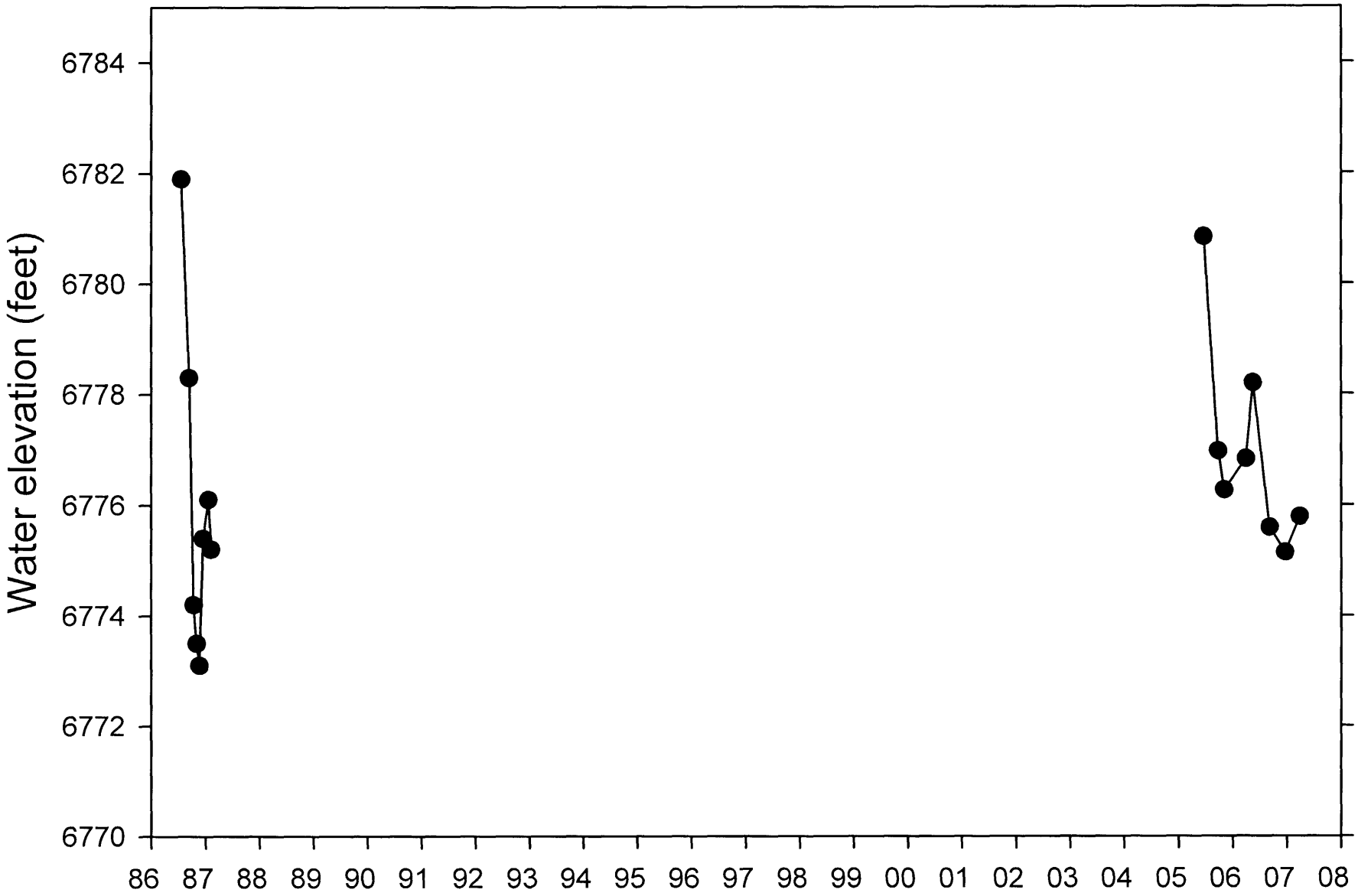
07
08

Y-63


Water elevation (feet)
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6782
6780
6778
6776
6774
6772
6770
86
87
88
89
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95
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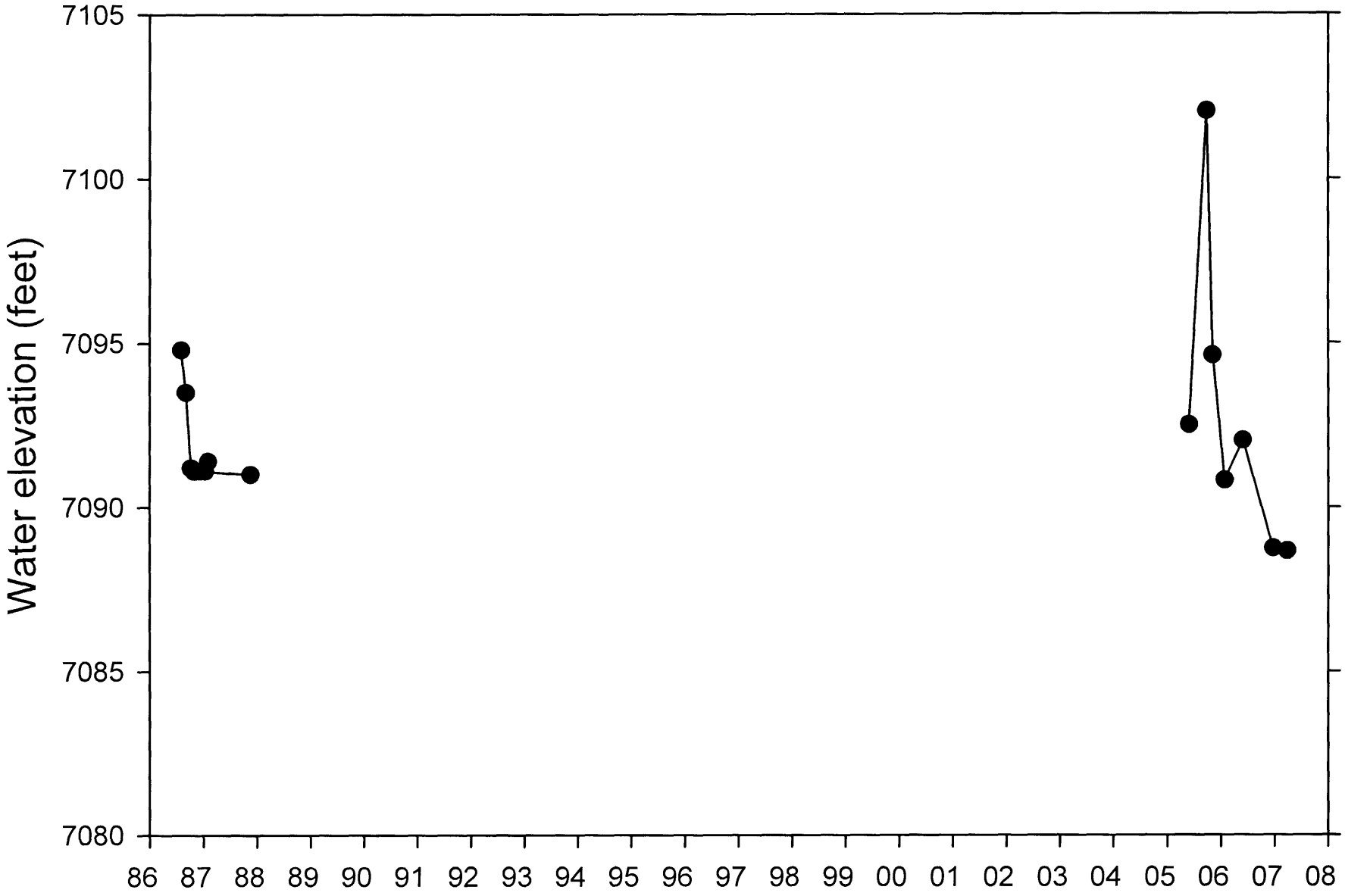
Y-98


Water elevation (feet)
7105
7100
7095
7090
7085
7080
86
87
88
89
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97
98
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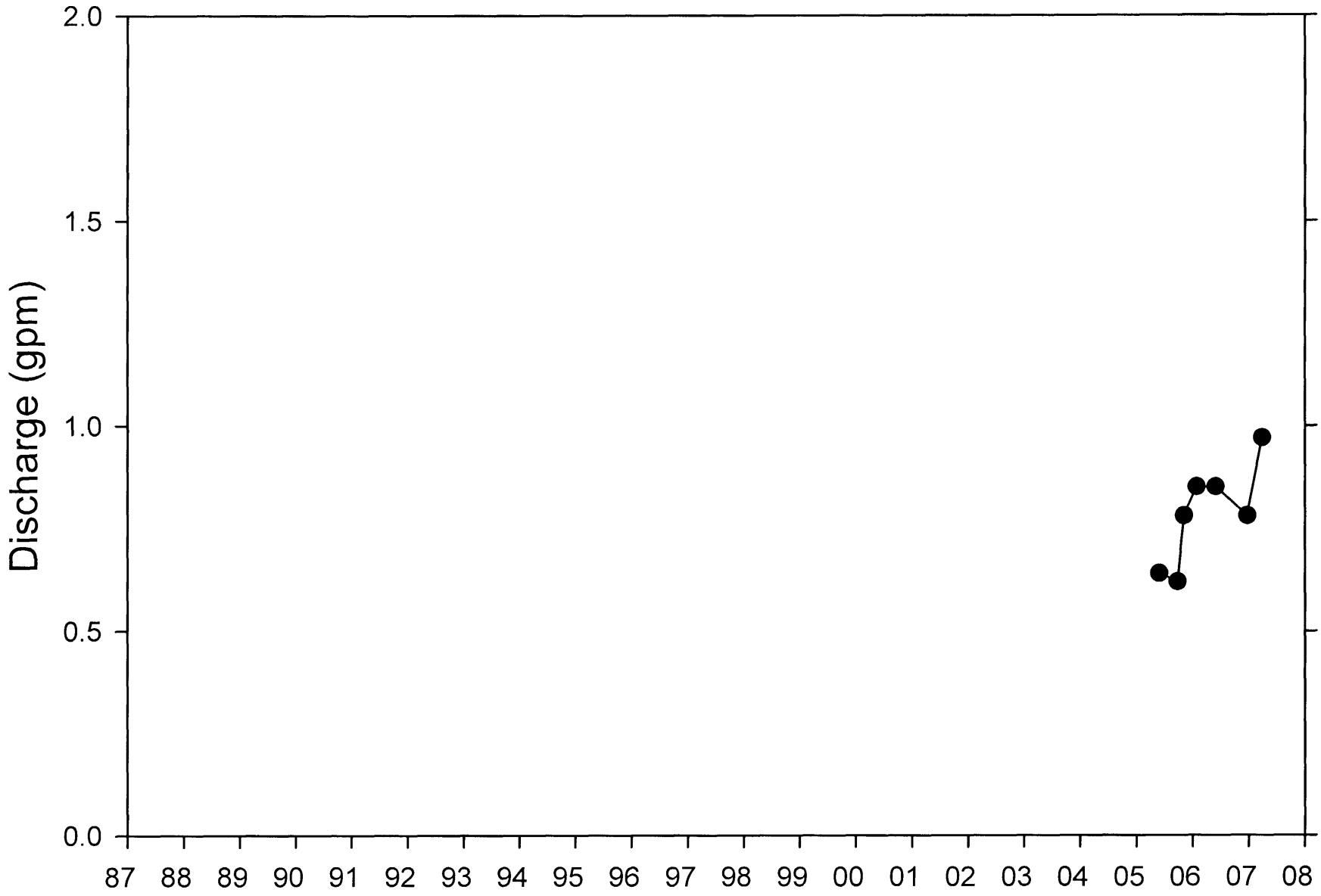
07
08

Y-102


Discharge (gpm)
2.0
1.5
1.0
0.5
0.0
87
88
89
90
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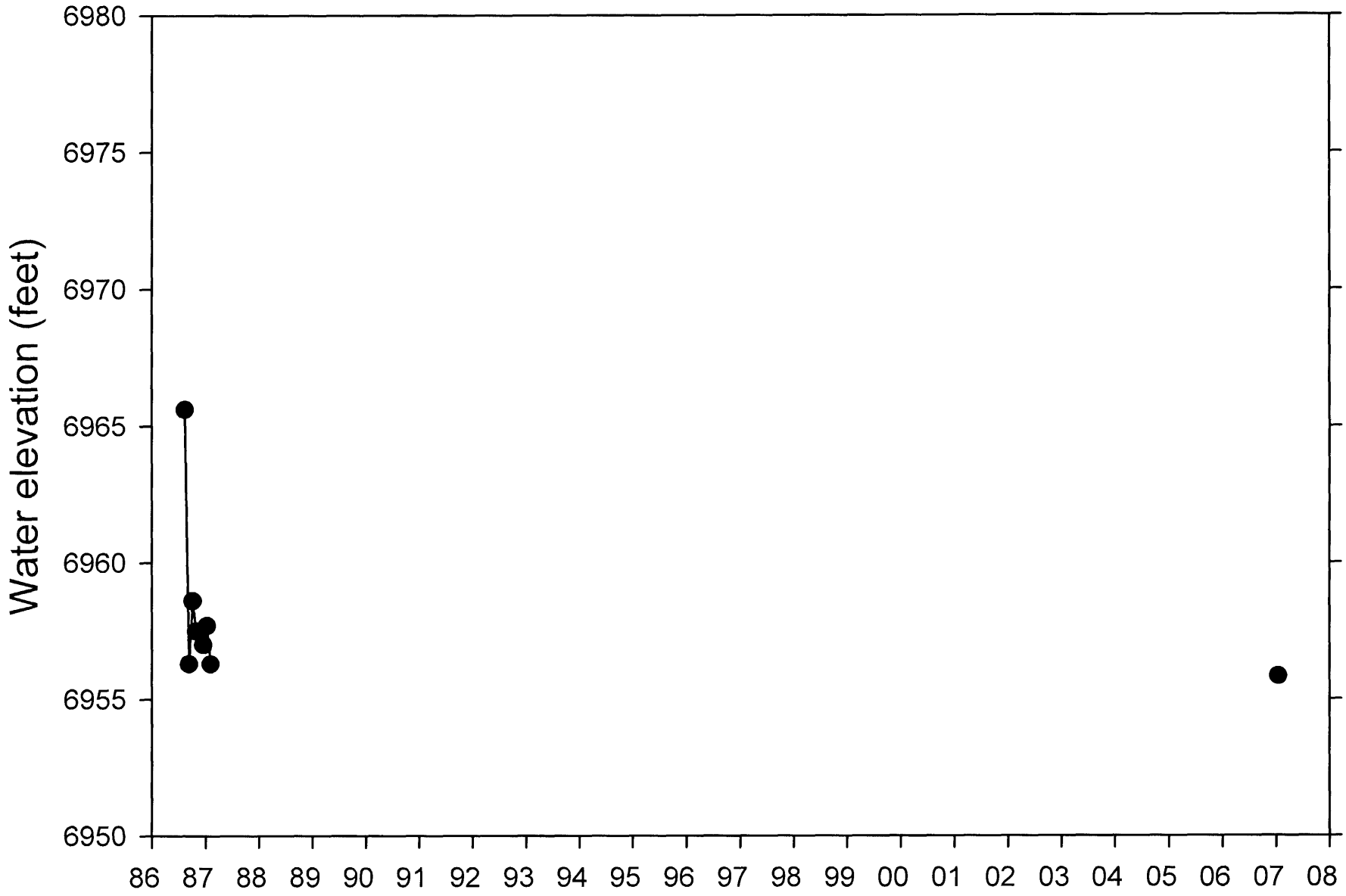
07
08

Y-102


Water elevation (feet)
6980
6975
6970
6965
6960
6955
6950
86
87
88
89
90
91
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06
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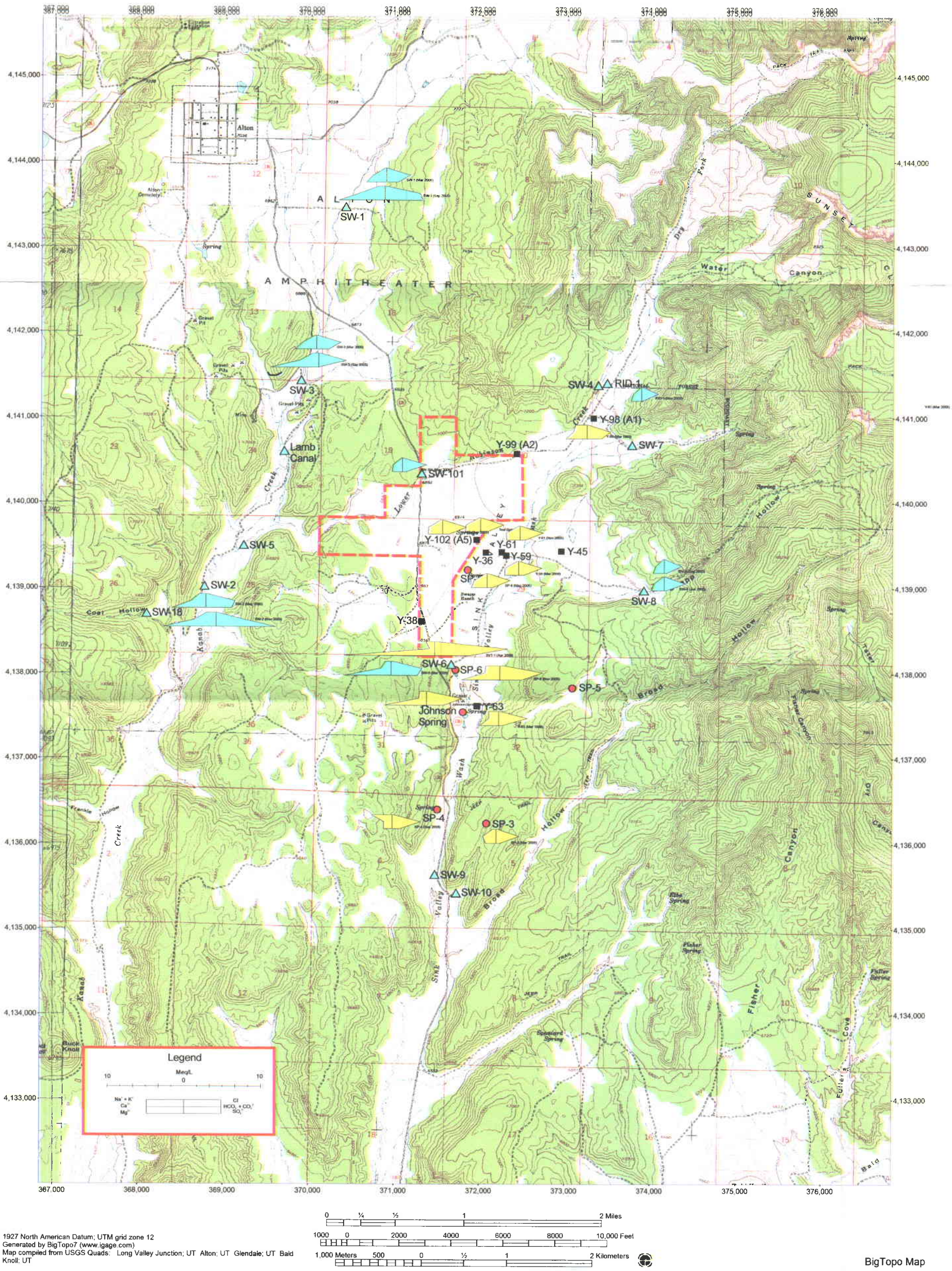
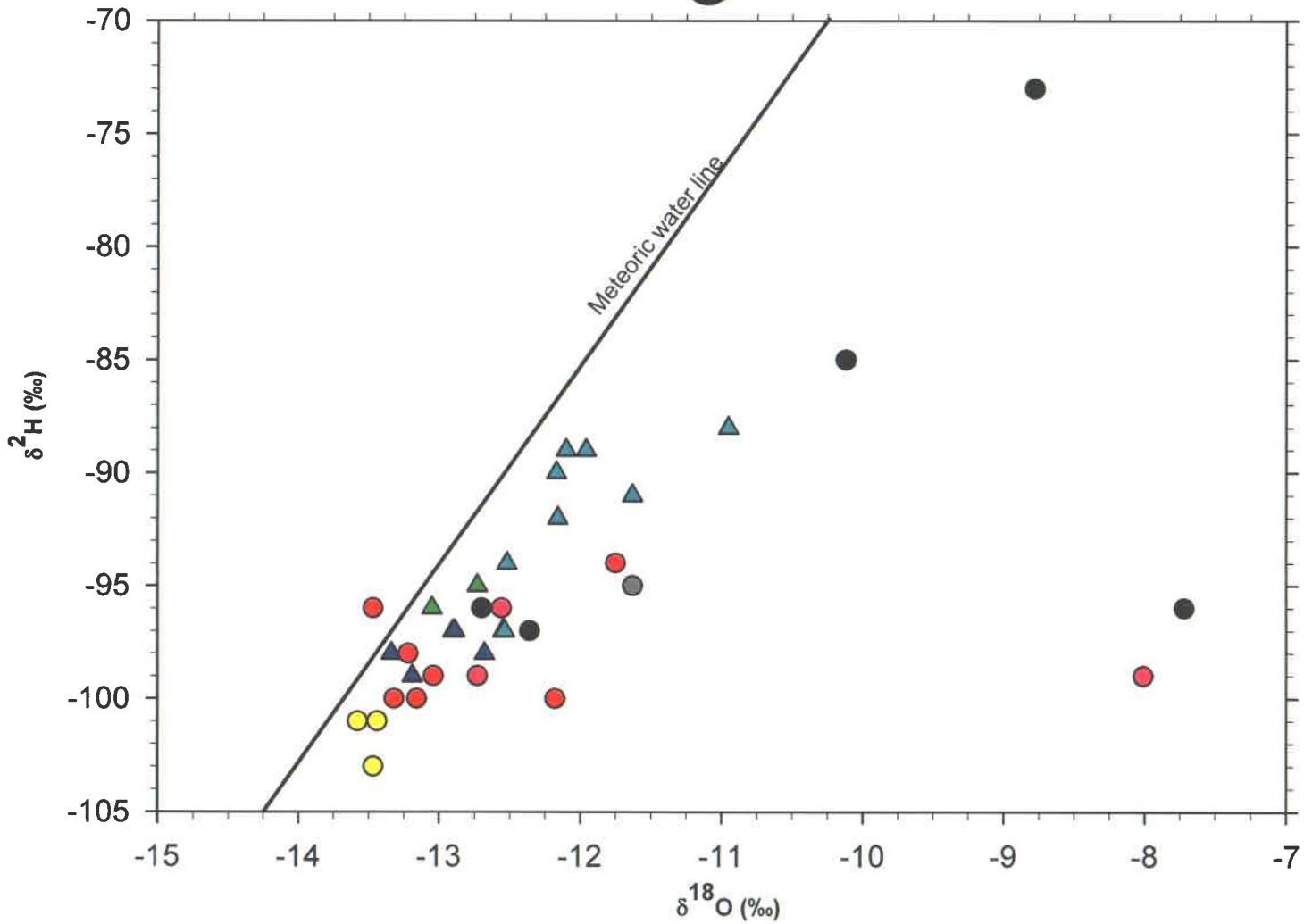


Figure 14 Stiff diagrams for groundwaters and surface waters in the proposed Coal Hollow Mine permit and adjacent area.



Red = Sink Valley alluvial groundwater discharge area A
Black = Sink Valley alluvial groundwater discharge area B
Yellow = Dakota Formation/fault groundwater

Light blue = Kanab Creek
Dark blue = Swapp Hollow and Water Canyon
Green = Lower Robinson Creek drainage

Triangle = surface water
Circle = springs and wells

Figure 15 Plot of δ^2H and $\delta^{18}O$ for groundwaters and surface-waters in the proposed Coal Hollow Mine permit and adjacent area.

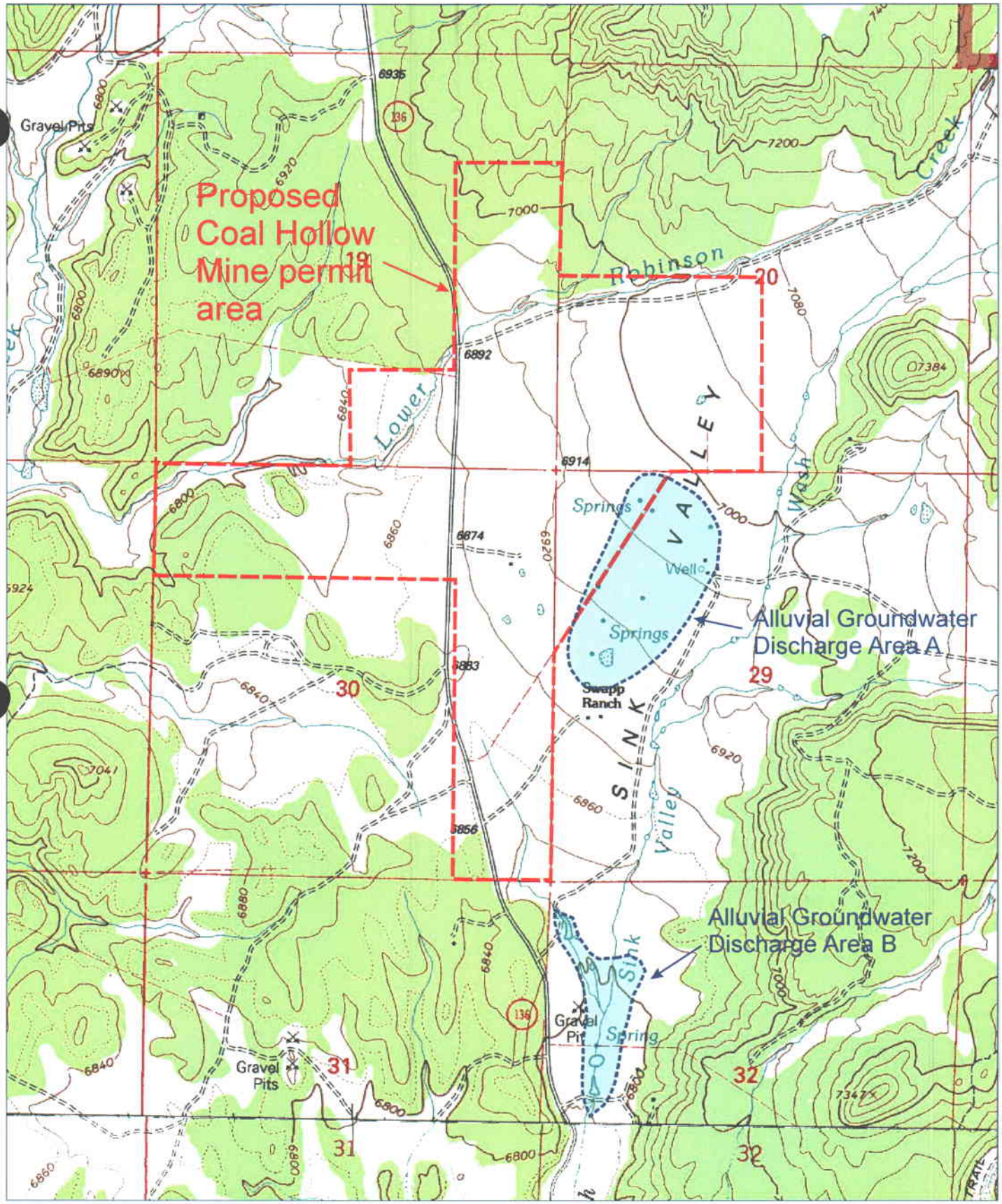


Figure 16 Alluvial groundwater discharge areas.

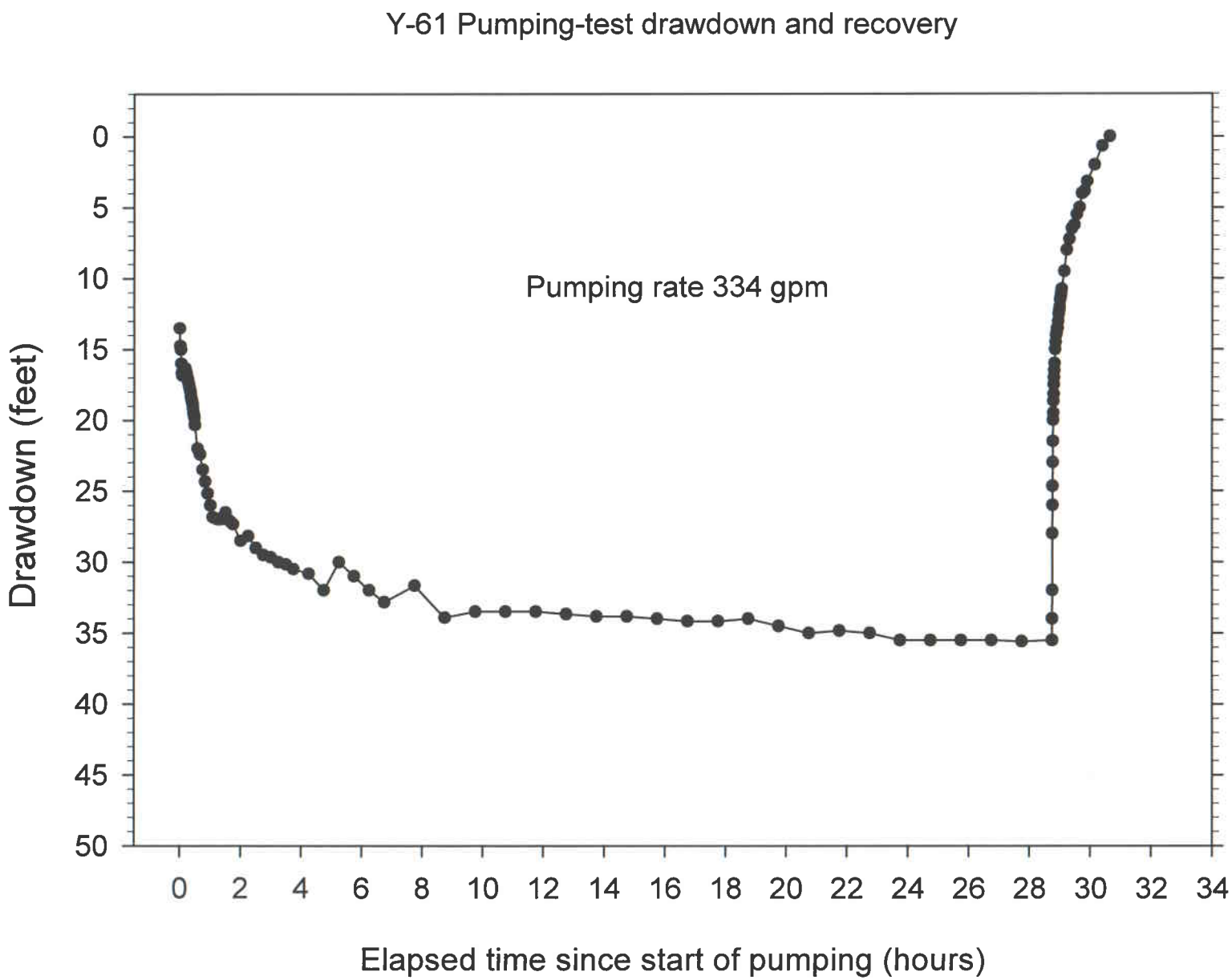
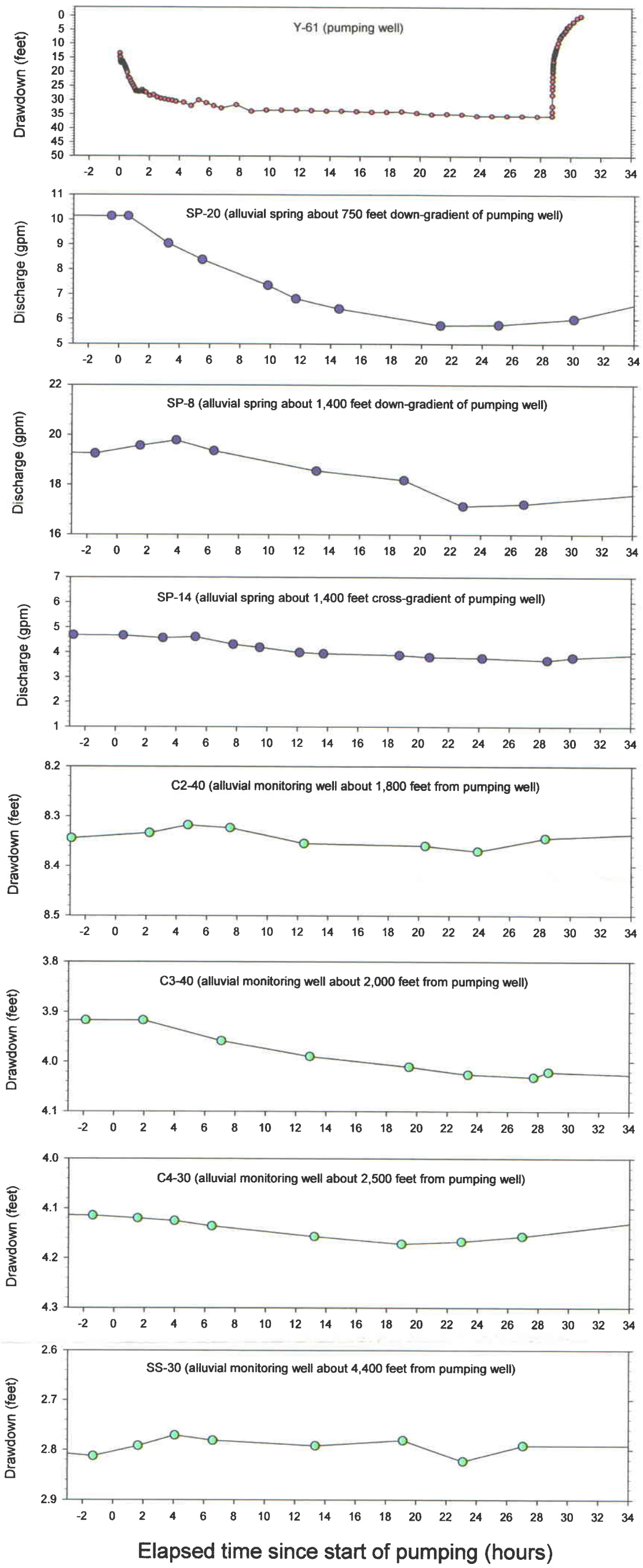
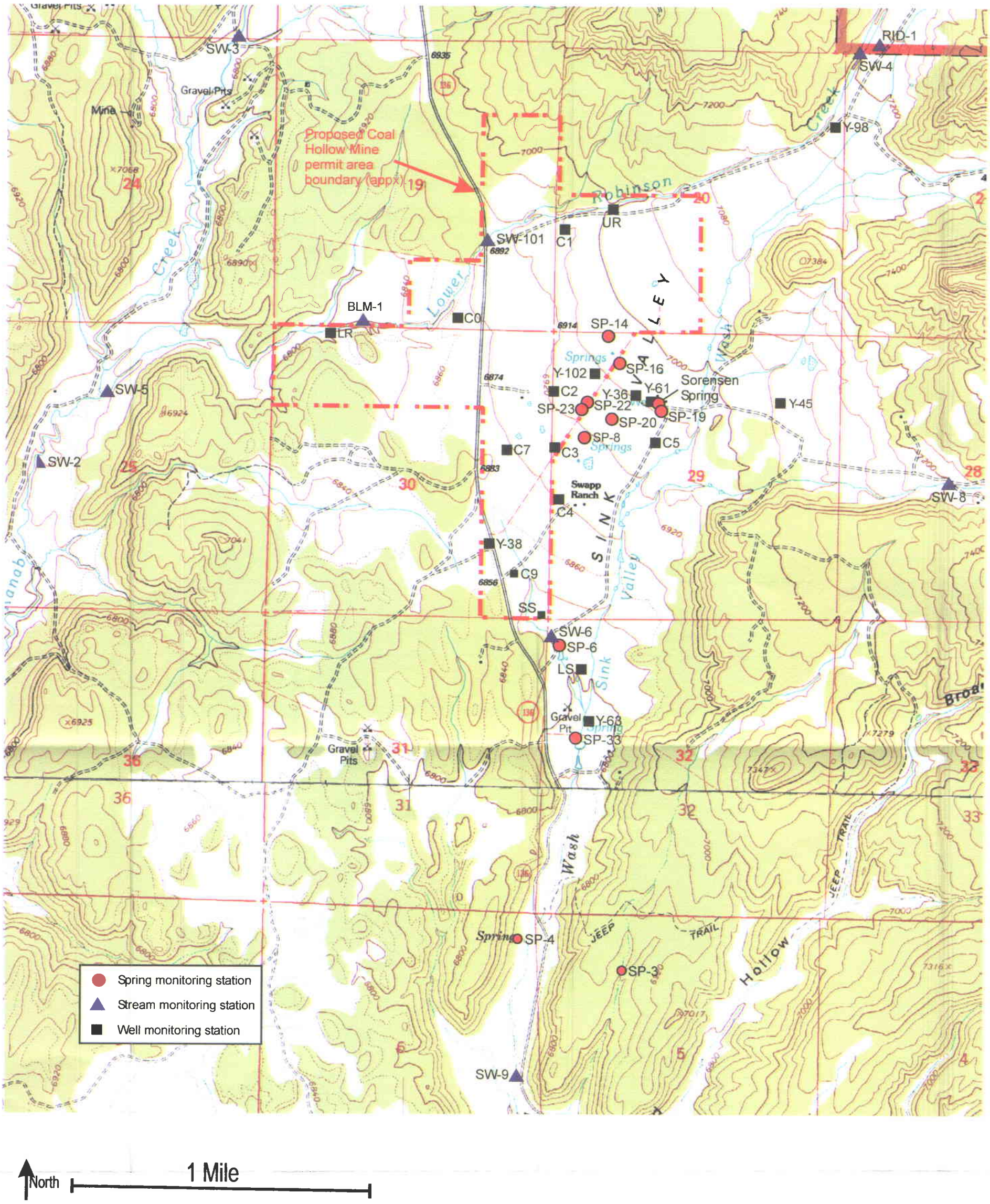


Figure 17 Drawdown and recovery data from pump-test at Y-61.



Pumping well drawdowns plotted in red
Spring discharges in the alluvial groundwater system plotted in blue
Monitoring well drawdowns in the clayey, silty alluvial groundwater plotted in green

Figure 18 Plots of water level responses and spring discharge rates during the pump-test at Y-61.



Faigure 20 Proposed groundwater and surface-water monitoring sites.

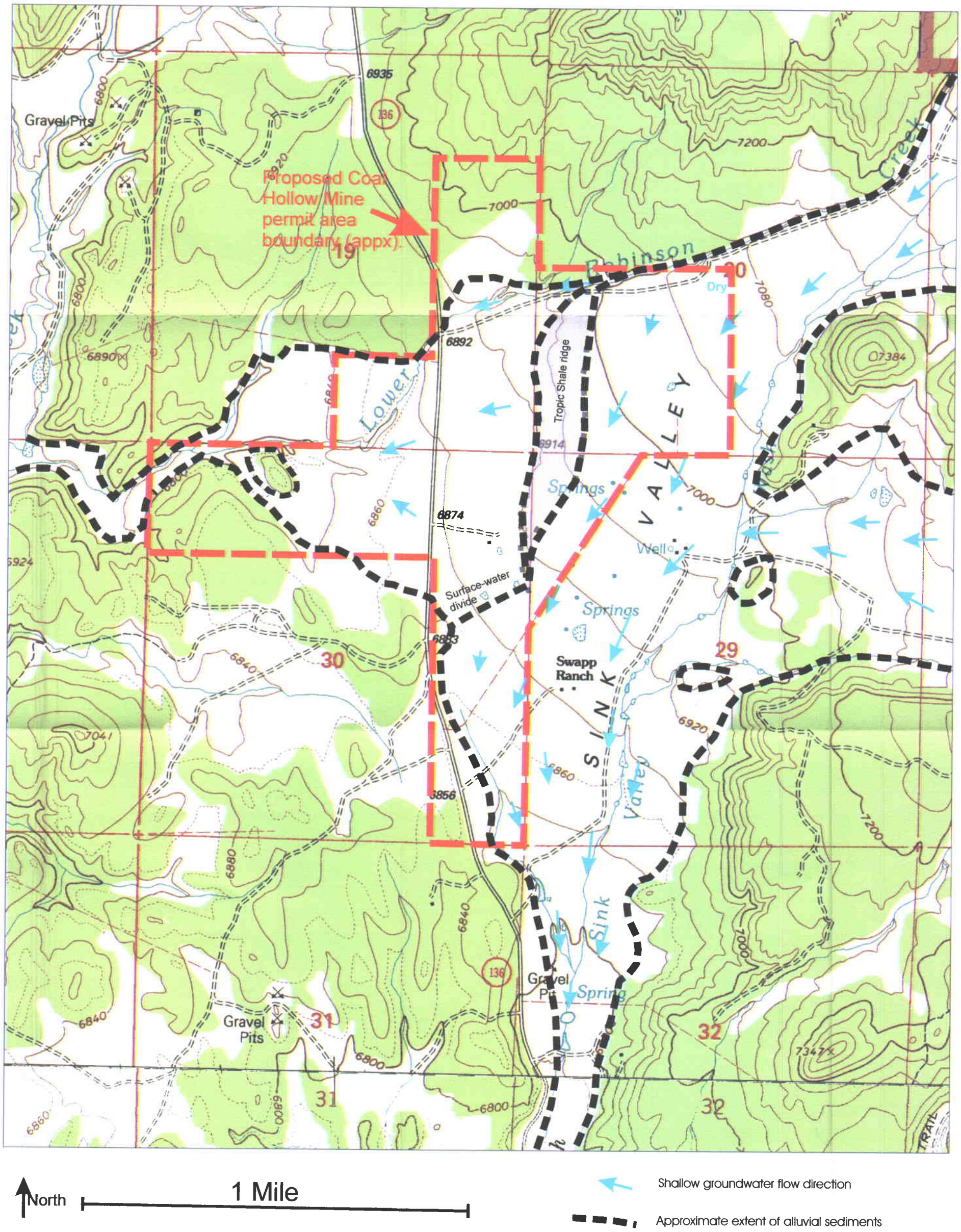


Figure 21 Approximate extent of alluvial sediments and shallow groundwater flow directions in the proposed Coal Hollow Mine permit and adjacent area.

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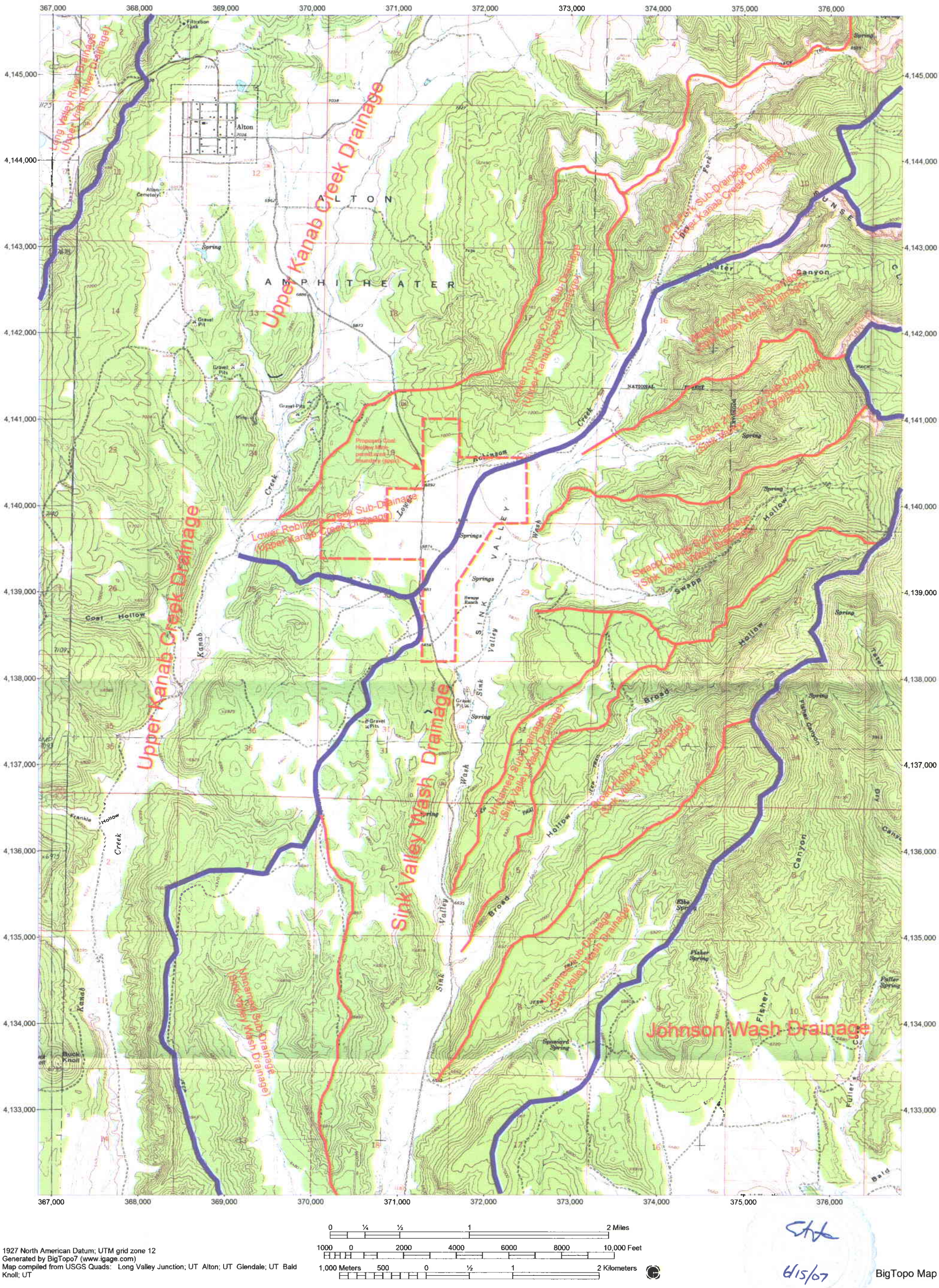

1927 North American Datum; UTM grid zone 12
Generated by BigTopo7 (www.igage.com)
Map compiled from USGS Quads: Long Valley Junction; UT Alton; UT Glendale; UT Bald Knoll; UT

6/15/07

BigTopo Map

Figure 19 Surface water drainages in the proposed Coal Hollow Mine permit and surrounding area.

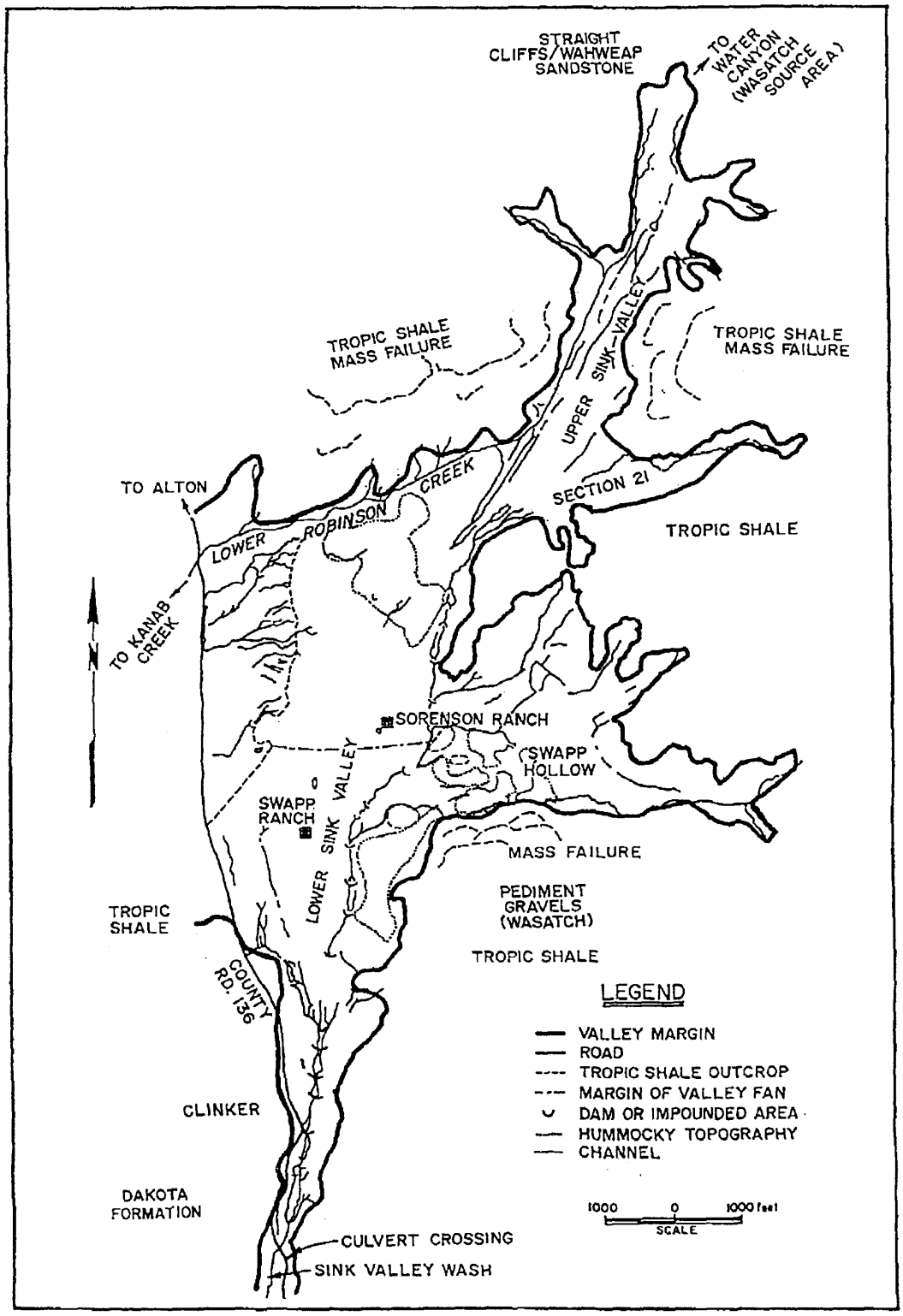

Figure 22 Landforms in the Sink Valley and Lower Robinson Creek area (from Water Engineering & Technology, Inc., 1988).

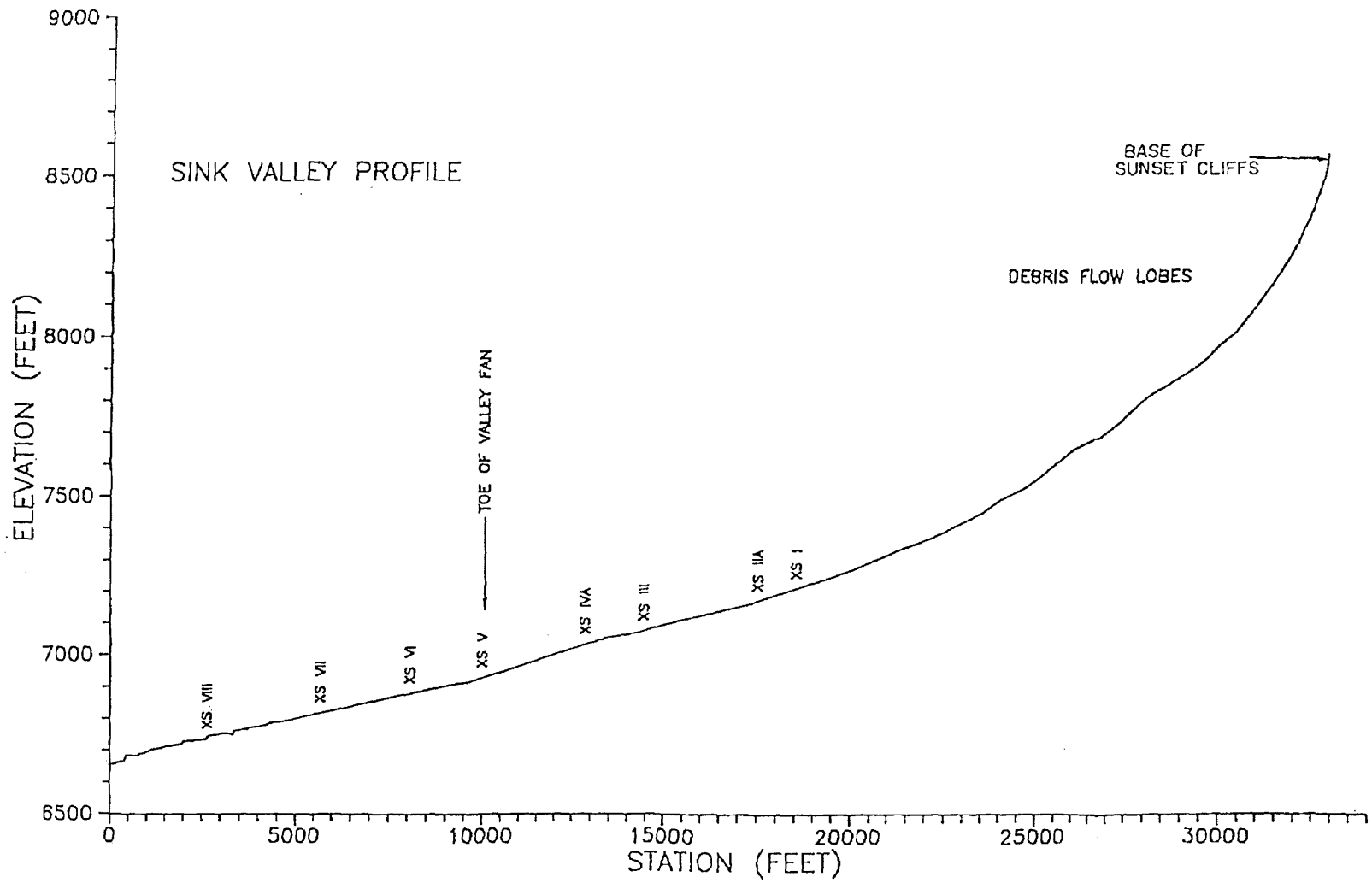

Figure 23 Longitudinal profile of Sink Valley from upper Water Canyon drainage to Sink Valley Wash (from Water Engineering & Technology, Inc., 1988).

Table 1 Baseline monitoring station locations and details.

Site	UTM location, Z12, NAD 27		Elevation (approx)	Drainage basin	Geologic Formation	Uses
Springs						
SP-3	4136009	372028	6882	lower Sink Valley Wash	Pediment alluvium	Wildlife, contritubes to stream flow
SP-4	4136427	371531	6700	lower Sink Valley Wash	Dakota/fault ?	Stock watering
SP-5	4137820	373080	7215	Sink Valley	Pediment alluvium	None apparent
SP-6	4137977	371717	6829	Sink Valley	Alluvium	Stock watering, wildlife
SP-8	4139231	371861	6920	Sink Valley	Alluvium	Domestic, stock watering, wildlife, irrigation historically
SP-14	4139790	372023	6985	Sink Valley	alluvium	Stock watering, wildlife
SP-15	4139660	371960	6980	Sink Valley	alluvium	Stock watering, wildlife
SP-16	4139656	372035	6980	Sink Valley	alluvium	Stock watering, wildlife
SP-17	4139559	372236	6970	Sink Valley	alluvium	None apparent
SP-18	4139486	372196	6965	Sink Valley	alluvium	None apparent
SP-19	4139384	372256	6960	Sink Valley	alluvium	Stock watering
SP-20	4139325	372014	6940	Sink Valley	alluvium	Stock watering, wildlife, irrigation historically
SP-21	4139289	371980	6940	Sink Valley	alluvium	Wildlife
SP-22	4139423	371863	6940	Sink Valley	alluvium	Wildlife
SP-23	4139382	371838	6935	Sink Valley	alluvium	Wildlife
SP-24	4139356	371822	6920	Sink Valley	alluvium	Wildlife
SP-25	4139322	371798	6920	Sink Valley	alluvium	wildlife
SP-26	4139211	371717	6920	Sink Valley	alluvium	Stock watering, wildlife
SP-27	4137416	371645	6800	Sink Valley	Dakota Formation	None apparent
SP-28	4137718	371896	6790	Sink Valley	alluvium	Wildlife
SP-29	4137853	371885	6800	Sink Valley	alluvium	Wildlife
SP-30	4137787	371852	6800	Sink Valley	alluvium	None apparent
SP-31	4137764	371830	6800	Sink Valley	alluvium	None apparent
SP-32	4137864	371810	6800	Sink Valley	alluvium	Stock watering, wildlife
SP-33	4137543	371788	6785	Sink Valley	alluvium	Domestic, stock watering, wildlife
SP-34	4135632	371512	6660	lower Sink Valley Wash	colluvium/Dakota	None apparent
SP-35	4139747	372051	6980	Sink Valley	alluvium	Drinking water for camper/trailer
SP-36	4139979	371830	6970	Sink Valley	alluvium	None apparent
SP-37	4138266	372316	6885	Sink Valley	alluvium/fracture?	Stock watering, wildlife
Streams						
SW-1	4143476	370429	6930	Kanab Creek	---	---
SW-2	4139065	368782	6644	Kanab Creek	---	---
SW-3	4141433	369896	6797	Kanab Creek	---	---
SW-7	4140667	373803	7228	Swapp Hollow (adjacent)	---	---
SW-8	4138970	373869	7212	Swapp Hollow	---	---
SW-6	4138093	371677	6834	Sink Valley Wash	---	---
SW-9	4135632	371485	6624	Lower Sink Valley Wash	---	---
SW-4	4141366	373381	7213	Robinson Creek	---	---
SW-5	4139453	369169	6677	Robinson Creek	---	---

Site	UTM location, Z12, NAD 27		Elevation (approx)	Drainage basin	Geologic Formation	Uses
SW-101	4140303	371304	6891	Robinson Creek	---	---
RID-1 (irrigation)	4141391	373420	7220	Robinson Creek	---	---
SW-10	4135431	371689	6650	Unnamed trip to Sink Valley	---	---
Lamb Canal	4140670	369678	6751	Kanab Creek	---	---
Wells						
Y-102 (A5)	4139571	371917	6950	Sink Valley	Alluvium	Monitoring well
Y-45	4139436	372942	7044	Swapp Hollow	Coal	Monitoring well
Y-61	4139433	372226	6962	Sink Valley	Alluvium	Monitoring well (pumping)
Y-59	4139375	372321	6973	Sink Valley	Alluvium	Monitoring well
Y-63	4137634	371896	6790	Sink Valley Wash	Alluvium	Monitoring well
Y-36	4139447	372147	6965	Sink Valley	Coal	Monitoring well
Y-38	4138615	371318	6871	Sink Valley	Coal	Monitoring well
Y-98 (A1)	4140999	373288	7177	Robinson Creek	Alluvium	Monitoring well
Y-99 (A2)	4140538	372371	7055	Robinson Creek	Coal	Monitoring well
Alluvial trenches						
SVT-01	4138309	371600	6836	Sink Valley	Allvuium	---
SVT-02	4138512	371543	6844	Sink Valley	Allvuium	---
SVT-03	4138743	371485	6856	Sink Valley	Allvuium	---
SVT-04	4139107	371378	6869	Sink Valley	Allvuium	---
SVT-05	4139189	371594	6882	Sink Valley	Allvuium	---
SVT-06	4139150	371595	6881	Sink Valley	Allvuium	---

Table 2 Monthly climate summery for Alton, Utah weather station (420086), 1/1/1928 - 12/31/2005

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average max. temperature (°F)	39.5	42.1	47.9	57.7	67.2	76.7	82.6	80.4	73.9	63.1	49.9	41.8	60.2
Average min. temperature (°F)	15.1	17.5	21.8	28.0	34.8	42.0	49.8	48.9	41.8	33.0	23.0	16.8	31.0
Average total precipitation (in.)	1.79	1.8	1.54	1.05	0.85	0.57	1.40	1.76	1.49	1.40	1.23	1.52	16.38
Average total snowfall (in.)	21.2	19.5	14.3	4.5	0.6	0.2	0.0	0.0	0.0	1.3	6.6	15.4	83.4
Average snow depth (in.)	7	8	5	1	0	0	0	0	0	0	1	2	2

Table 3 Climate data for the Coal Hollow Weather Station, 2006-2007

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
January 2006			
1/1/2006	N/A	39.4	16.9
1/2/2006	N/A	42.9	29.5
1/3/2006	N/A	40.0	26.5
1/4/2006	N/A	45.6	20.5
1/5/2006	N/A	52.6	23.4
1/6/2006	N/A	57.6	29.0
1/7/2006	N/A	49.5	23.9
1/8/2006	N/A	45.5	24.2
1/9/2006	N/A	40.3	13.5
1/10/2006	N/A	47.8	21.1
1/11/2006	N/A	48.8	28.1
1/12/2006	N/A	43.7	22.1
1/13/2006	N/A	49.6	20.9
1/14/2006	N/A	48.7	26.1
1/15/2006	N/A	37.5	17.6
1/16/2006	N/A	29.4	11.5
1/17/2006	N/A	48.3	9.9
1/18/2006	N/A	41.1	22.6
1/19/2006	N/A	33.5	19.8
1/20/2006	N/A	36.4	10.4
1/21/2006	N/A	41.1	14.1
1/22/2006	N/A	35.1	13.4
1/23/2006	N/A	43.7	14.9
1/24/2006	N/A	48.6	12.9
1/25/2006	N/A	42.9	23.1
1/26/2006	N/A	41.0	16.2
1/27/2006	N/A	29.7	14.8
1/28/2006	N/A	35.9	8.1
1/29/2006	N/A	46.3	19.8
1/30/2006	N/A	51.5	24.7
1/31/2006	N/A	43.7	27.7
Month	---	***57.6***	***8.1***
February 2006			
2/1/2006	N/A	52.8	24.3
2/2/2006	N/A	51.3	28.4
2/3/2006	N/A	48.3	25.3
2/4/2006	N/A	50.9	24.3
2/5/2006	N/A	39.3	19.4
2/6/2006	N/A	50.7	11.6
2/7/2006	N/A	56.3	21.7
2/8/2006	N/A	57.2	23.4
2/9/2006	N/A	57.8	20.2

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
2/10/2006	N/A	46.2	23.0
2/11/2006	N/A	49.1	20.4
2/12/2006	N/A	53.2	17.2
2/13/2006	N/A	52.2	17.7
2/14/2006	N/A	51.0	27.2
2/15/2006	N/A	45.1	17.9
2/16/2006	N/A	32.8	2.4
2/17/2006	N/A	40.6	19.1
2/18/2006	N/A	35.6	15.5
2/19/2006	N/A	30.0	12.3
2/20/2006	N/A	34.8	11.2
2/21/2006	N/A	38.9	1.0
2/22/2006	N/A	47.0	20.4
2/23/2006	N/A	51.9	15.5
2/24/2006	N/A	54.0	21.9
2/25/2006	N/A	54.9	24.3
2/26/2006	N/A	57.3	27.2
2/27/2006	N/A	56.8	30.0
2/28/2006	N/A	44.5	33.7
Month	---	***57.8***	***1.0***
March 2006			
3/1/2006	N/A	48.7	29.6
3/2/2006	N/A	51.2	25.2
3/3/2006	N/A	52.3	31.2
3/4/2006	N/A	46.3	28.5
3/5/2006	N/A	55.5	27.0
3/6/2006	N/A	50.6	30.0
3/7/2006	N/A	45.0	27.2
3/8/2006	N/A	37.4	19.4
3/9/2006	N/A	43.6	19.4
3/10/2006	N/A	31.1	12.9
3/11/2006	N/A	26.4	16.2
3/12/2006	N/A	25.1	14.1
3/13/2006	N/A	34.2	10.4
3/14/2006	N/A	39.4	9.6
3/15/2006	N/A	44.1	24.8
3/16/2006	N/A	44.2	21.6
3/17/2006	N/A	45.1	26.2
3/18/2006	N/A	38.6	19.0
3/19/2006	N/A	38.8	21.3
3/20/2006	N/A	36.6	6.9
3/21/2006	N/A	34.9	21.7
3/22/2006	N/A	43.9	21.6
3/23/2006	N/A	50.3	18.3
3/24/2006	N/A	55.1	29.8
3/25/2006	N/A	53.4	32.9
3/26/2006	N/A	52.3	26.4

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
3/27/2006	N/A	55.7	24.0
3/28/2006	N/A	43.3	36.5
3/29/2006	N/A	40.0	25.4
3/30/2006	N/A	46.8	19.1
3/31/2006	N/A	49.5	32.4
Month	***---***	***55.7***	***6.9***
April 2006			
4/1/2006	0.14	47.6	30.9
4/2/2006	0.00	54.4	28.7
4/3/2006	0.00	63.1	37.3
4/4/2006	0.00	59.1	43.9
4/5/2006	0.18	50.1	26.6
4/6/2006	0.10	48.5	26.0
4/7/2006	0.00	56.9	24.2
4/8/2006	0.00	61.7	35.4
4/9/2006	0.00	63.9	34.0
4/10/2006	0.00	55.7	35.7
4/11/2006	0.00	55.4	26.7
4/12/2006	0.00	65.0	31.2
4/13/2006	0.00	66.8	35.3
4/14/2006	0.28	60.1	34.6
4/15/2006	0.12	51.8	33.0
4/16/2006	0.01	60.8	31.5
4/17/2006	0.00	48.5	27.9
4/18/2006	0.00	49.8	21.9
4/19/2006	0.00	56.4	23.3
4/20/2006	0.00	65.4	21.5
4/21/2006	0.00	66.2	39.4
4/22/2006	0.00	67.6	39.7
4/23/2006	0.00	57.8	30.2
4/24/2006	0.00	56.2	27.4
4/25/2006	0.00	61.8	30.9
4/26/2006	0.00	66.6	34.2
4/27/2006	0.00	69.5	38.7
4/28/2006	0.00	67.8	45.6
4/29/2006	0.00	68.5	32.8
4/30/2006	0.00	71.0	40.2
Month	***0.83***	***71.0***	***21.5***
May 2006			
5/1/2006	0.06	68.3	38.3
5/2/2006	0.00	72.1	44.3
5/3/2006	0.00	70.3	38.8
5/4/2006	0.00	65.4	38.8
5/5/2006	0.04	58.9	39.7
5/6/2006	0.00	64.8	31.8
5/7/2006	0.00	71.7	39.8

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
5/8/2006	0.00	70.8	44.0
5/9/2006	0.00	67.0	32.8
5/10/2006	0.00	69.3	28.7
5/11/2006	0.00	71.8	34.5
5/12/2006	0.00	76.6	45.8
5/13/2006	0.00	78.6	53.3
5/14/2006	0.00	79.6	49.8
5/15/2006	0.00	76.2	42.5
5/16/2006	0.16	74.1	48.7
5/17/2006	0.00	81.8	48.8
5/18/2006	0.00	78.8	49.0
5/19/2006	0.00	77.6	52.8
5/20/2006	0.00	76.7	49.9
5/21/2006	0.00	76.3	48.9
5/22/2006	0.00	62.8	42.1
5/23/2006	0.00	69.2	35.4
5/24/2006	0.00	79.1	44.8
5/25/2006	0.00	80.0	47.1
5/26/2006	0.00	75.1	49.2
5/27/2006	0.00	66.0	43.8
5/28/2006	0.00	55.0	28.8
5/29/2006	0.00	64.7	28.3
5/30/2006	0.00	71.2	36.8
5/31/2006	0.00	77.4	40.7
Month	***0.26***	***81.8***	***28.3***
June 2006			
6/1/2006	0.00	81.9	37.2
6/2/2006	0.00	82.9	53.2
6/3/2006	0.00	82.0	52.7
6/4/2006	0.00	83.6	55.0
6/5/2006	0.00	85.5	57.4
6/6/2006	0.00	90.1	54.6
6/7/2006	0.00	76.5	53.9
6/8/2006	0.00	68.4	46.5
6/9/2006	0.00	76.3	45.0
6/10/2006	0.00	77.7	47.6
6/11/2006	0.00	79.4	48.9
6/12/2006	0.00	78.5	48.3
6/13/2006	0.00	78.5	44.5
6/14/2006	0.00	70.4	46.3
6/15/2006	0.01	63.8	45.7
6/16/2006	0.00	72.7	39.5
6/17/2006	0.00	81.9	37.1
6/18/2006	0.00	84.7	55.4
6/19/2006	0.00	83.9	53.5
6/20/2006	0.00	82.3	55.7
6/21/2006	0.00	82.1	54.8

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
6/22/2006	0.00	85.4	52.0
6/23/2006	0.00	91.8	45.8
6/24/2006	0.00	88.0	50.0
6/25/2006	0.00	90.0	55.5
6/26/2006	0.00	86.1	53.8
6/27/2006	0.00	79.9	57.0
6/28/2006	0.00	83.2	50.0
6/29/2006	0.00	81.8	52.2
6/30/2006	0.16	83.5	56.4
Month	***0.17***	***91.8***	***37.1***
July 2006			
7/1/2006	0.00	82.5	53.5
7/2/2006	0.16	83.3	54.7
7/3/2006	0.07	83.2	55.4
7/4/2006	0.00	75.9	55.9
7/5/2006	0.00	77.7	55.6
7/6/2006	0.72	75.2	54.1
7/7/2006	0.02	77.7	49.2
7/8/2006	0.00	77.5	55.5
7/9/2006	0.01	79.1	51.7
7/10/2006	0.03	77.6	49.5
7/11/2006	0.01	82.2	52.9
7/12/2006	0.00	83.1	55.0
7/13/2006	0.00	85.1	56.2
7/14/2006	0.00	88.4	58.9
7/15/2006	0.00	93.3	59.0
7/16/2006	0.03	92.1	64.2
7/17/2006	0.00	90.2	63.3
7/18/2006	0.00	86.5	63.7
7/19/2006	0.00	83.5	59.7
7/20/2006	0.00	83.6	57.1
7/21/2006	0.57	88.5	56.2
7/22/2006	0.02	85.6	60.3
7/23/2006	0.00	89.4	59.2
7/24/2006	0.07	90.5	59.4
7/25/2006	0.04	86.2	59.9
7/26/2006	0.00	86.2	61.7
7/27/2006	0.00	90.9	57.0
7/28/2006	0.10	86.6	57.3
7/29/2006	0.08	83.2	53.9
7/30/2006	0.27	78.8	58.3
7/31/2006	0.45	77.6	54.3
Month	***2.65***	***93.3***	***49.2***
August 2006			
8/1/2006	0.00	75.5	53.9
8/2/2006	0.00	75.8	53.2

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
8/3/2006	0.00	79.8	53.9
8/4/2006	0.17	71.4	55.8
8/5/2006	0.00	78.0	52.8
8/6/2006	0.00	82.4	53.3
8/7/2006	0.00	82.4	62.3
8/8/2006	0.00	83.2	55.1
8/9/2006	0.01	79.7	58.7
8/10/2006	0.00	84.1	57.8
8/11/2006	0.00	79.7	57.7
8/12/2006	0.00	79.6	53.6
8/13/2006	0.00	80.1	55.0
8/14/2006	0.00	82.3	56.4
8/15/2006	0.00	80.9	56.6
8/16/2006	0.00	77.8	52.2
8/17/2006	0.00	78.0	52.9
8/18/2006	0.00	79.5	53.6
8/19/2006	0.00	82.8	49.5
8/20/2006	0.00	83.7	52.9
8/21/2006	0.00	85.7	54.6
8/22/2006	0.00	86.0	56.5
8/23/2006	0.00	83.7	55.6
8/24/2006	0.00	84.1	56.6
8/25/2006	0.00	78.3	54.2
8/26/2006	0.00	77.2	50.1
8/27/2006	0.00	80.3	45.0
8/28/2006	0.00	82.3	44.5
8/29/2006	0.00	83.4	49.5
8/30/2006	0.00	81.7	54.5
8/31/2006	0.00	83.2	56.1
Month	***0.18***	***86.0***	***44.5***
September 2006			
9/1/2006	0.15	80.0	51.1
9/2/2006	0.00	80.2	49.2
9/3/2006	0.00	78.2	47.5
9/4/2006	0.00	81.0	51.2
9/5/2006	0.00	80.7	55.4
9/6/2006	0.06	74.6	50.1
9/7/2006	0.22	61.3	49.3
9/8/2006	0.50	68.8	43.9
9/9/2006	0.02	70.2	45.3
9/10/2006	0.05	71.1	45.0
9/11/2006	0.00	76.8	44.5
9/12/2006	0.00	80.1	51.7
9/13/2006	0.00	80.2	52.5
9/14/2006	0.40	65.4	50.7
9/15/2006	0.00	67.6	49.9
9/16/2006	0.00	59.3	37.7

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
9/17/2006	0.00	62.1	24.6
9/18/2006	0.00	67.6	23.2
9/19/2006	0.00	71.1	39.1
9/20/2006	0.00	57.5	38.4
9/21/2006	0.00	63.3	30.6
9/22/2006	0.00	52.3	36.6
9/23/2006	0.00	60.5	27.5
9/24/2006	0.00	63.6	29.4
9/25/2006	0.00	70.5	31.6
9/26/2006	0.00	75.6	43.3
9/27/2006	0.00	74.9	42.2
9/28/2006	0.00	78.4	40.4
9/29/2006	0.00	78.5	41.8
9/30/2006	0.00	77.1	40.8
Month	***1.40***	***81.0***	***23.2***
October 2006			
10/1/2006	0.00	74.2	49.5
10/2/2006	0.00	71.5	49.8
10/3/2006	0.10	69.7	44.4
10/4/2006	0.00	67.9	50.8
10/5/2006	0.27	63.5	45.6
10/6/2006	0.37	61.3	44.9
10/7/2006	0.00	60.5	32.5
10/8/2006	0.00	62.9	37.0
10/9/2006	0.02	55.0	36.6
10/10/2006	0.31	56.0	35.8
10/11/2006	0.00	62.2	33.2
10/12/2006	0.01	66.0	25.7
10/13/2006	0.00	66.9	35.7
10/14/2006	1.61	49.4	34.3
10/15/2006	0.00	58.7	31.6
10/16/2006	0.00	57.7	37.0
10/17/2006	0.42	46.2	32.0
10/18/2006	0.00	47.0	29.6
10/19/2006	0.00	58.8	25.1
10/20/2006	0.00	60.8	30.8
10/21/2006	0.00	54.6	26.9
10/22/2006	0.00	60.0	24.6
10/23/2006	0.00	62.5	31.9
10/24/2006	0.15	54.4	38.1
10/25/2006	0.09	48.3	29.9
10/26/2006	0.01	49.6	28.5
10/27/2006	0.00	62.6	27.4
10/28/2006	0.00	64.7	30.4
10/29/2006	0.00	60.7	34.3
10/30/2006	0.00	57.6	33.5
10/31/2006	0.00	56.3	32.8

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
Month	***3.36***	***74.2***	***24.6***
November 2006			
11/1/2006	0.00	57.0	27.2
11/2/2006	0.00	59.3	33.7
11/3/2006	0.00	59.4	32.0
11/4/2006	0.00	58.2	33.2
11/5/2006	0.00	59.3	25.7
11/6/2006	0.00	65.3	29.6
11/7/2006	0.00	70.5	35.9
11/8/2006	0.00	66.8	42.9
11/9/2006	0.00	58.2	30.7
11/10/2006	0.00	49.6	16.1
11/11/2006	0.00	44.5	26.4
11/12/2006	0.03	42.0	22.5
11/13/2006	0.00	50.3	25.4
11/14/2006	0.00	49.2	26.4
11/15/2006	0.00	51.5	19.0
11/16/2006	0.00	59.4	31.6
11/17/2006	0.00	63.0	32.7
11/18/2006	0.00	62.3	29.8
11/19/2006	0.00	58.7	25.8
11/20/2006	0.00	60.6	28.5
11/21/2006	0.00	60.9	29.9
11/22/2006	0.00	54.1	33.1
11/23/2006	0.00	53.8	32.0
11/24/2006	0.00	53.7	18.3
11/25/2006	0.00	47.3	28.5
11/26/2006	0.00	44.8	25.0
11/27/2006	0.01	35.5	23.8
11/28/2006	0.20	33.2	13.7
11/29/2006	0.01	16.4	6.8
11/30/2006	0.00	38.8	0.9
Month	***0.25***	***70.5***	***0.9***
December 2006			
12/1/2006	0.00	45.1	13.7
12/2/2006	0.00	28.5	10.4
12/3/2006	0.00	39.4	2.4
12/4/2006	0.00	50.3	16.8
12/5/2006	0.00	53.9	22.9
12/6/2006	0.00	54.0	19.3
12/7/2006	0.00	53.5	21.6
12/8/2006	0.00	49.6	21.7
12/9/2006	0.00	46.9	21.5
12/10/2006	0.12	36.5	18.4
12/11/2006	0.17	36.8	13.6
12/12/2006	0.00	44.4	11.6

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
12/13/2006	0.00	47.4	26.3
12/14/2006	0.00	50.3	28.6
12/15/2006	0.00	49.0	33.3
12/16/2006	0.00	40.3	26.6
12/17/2006	0.20	37.2	13.1
12/18/2006	0.01	33.1	4.4
12/19/2006	0.06	32.1	12.8
12/20/2006	0.00	34.7	11.4
12/21/2006	0.00	42.1	13.1
12/22/2006	0.23	34.3	21.8
12/23/2006	0.00	38.4	13.3
12/24/2006	0.00	40.0	16.4
12/25/2006	0.00	55.6	14.6
12/26/2006	0.00	50.9	31.4
12/27/2006	0.33	40.5	29.1
12/28/2006	0.03	31.1	22.7
12/29/2006	0.00	33.5	22.2
12/30/2006	0.00	46.1	16.4
12/31/2006	0.00	50.0	14.6
Month	***1.15***	***55.6***	***2.4***
January 2007			
1/1/2007	NA	38.4	17.1
1/2/2007	NA	49.1	16.4
1/3/2007	NA	50.4	22.7
1/4/2007	NA	43.0	24.3
1/5/2007	NA	34.3	10.9
1/6/2007	NA	38.1	-3.4
1/7/2007	NA	40.1	15.4
1/8/2007	NA	49.9	11.4
1/9/2007	NA	50.3	18.8
1/10/2007	NA	44.6	30.8
1/11/2007	NA	38.3	24.2
1/12/2007	NA	33.7	10.5
1/13/2007	NA	17.8	-6.4
1/14/2007	NA	22.5	-1.0
1/15/2007	NA	25.8	-7.3
1/16/2007	NA	32.4	-0.7
1/17/2007	NA	32.6	3.5
1/18/2007	NA	39.5	4.8
1/19/2007	NA	44.6	4.3
1/20/2007	NA	41.1	9.8
1/21/2007	NA	24.8	12.0
1/22/2007	NA	35.7	4.5
1/23/2007	NA	49.2	16.5
1/24/2007	NA	52.4	19.5
1/25/2007	NA	51.1	24.9
1/26/2007	NA	49.0	21.8

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
1/27/2007	NA	43.2	21.7
1/28/2007	NA	44.2	20.7
1/29/2007	NA	46.3	19.3
1/30/2007	NA	42.8	17.5
1/31/2007	NA	38.0	16.7
Month	***NA***	***52.4***	***-7.3***
February 2007			
2/1/2007	0	31.7	8.7
2/2/2007	0	36.5	4.4
2/3/2007	0	50.5	10.4
2/4/2007	0	54.9	26.7
2/5/2007	0	59.3	28.2
2/6/2007	0	57.2	31.1
2/7/2007	0	55.0	33.8
2/8/2007	0	52.5	30.6
2/9/2007	0	53.0	32.4
2/10/2007	0	53.9	36.6
2/11/2007	0.32	47.2	30.8
2/12/2007	0.02	47.2	25.6
2/13/2007	0.03	43.5	27.5
2/14/2007	0	35.4	23.9
2/15/2007	0	45.0	16.1
2/16/2007	0	51.9	24.0
2/17/2007	0	55.1	26.1
2/18/2007	0	52.6	25.2
2/19/2007	0.03	42.9	23.3
2/20/2007	0	43.7	10.5
2/21/2007	0	50.9	21.4
2/22/2007	0	55.1	26.2
2/23/2007	0.2	39.9	17.9
2/24/2007	0	35.8	12.9
2/25/2007	0	39.5	18.3
2/26/2007	0	45.0	25.4
2/27/2007	0.08	35.0	23.5
2/28/2007	0.23	29.7	8.3
Month	***0.91***	***59.3***	***4.4***
March 2007			
3/1/2007	0	34.0	6.3
3/2/2007	0	33.0	9.8
3/3/2007	0	40.5	6.8
3/4/2007	0	52.7	15.0
3/5/2007	0	58.2	28.2
3/6/2007	0	56.1	32.0
3/7/2007	0	57.7	31.1
3/8/2007	0	58.8	33.9
3/9/2007	0	60.2	30.7

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
3/10/2007	0	56.0	34.0
3/11/2007	0	64.7	23.3
3/12/2007	0	69.8	30.9
3/13/2007	0	72.1	32.6
3/14/2007	0	71.0	42.1
3/15/2007	0	67.2	34.4
3/16/2007	0	72.3	30.7
3/17/2007	0	72.7	38.3
3/18/2007	0	70.6	43.4
3/19/2007	0	67.3	35.8
3/20/2007	0	63.3	36.4
3/21/2007	0.34	49.7	33.8
3/22/2007	0	55.5	30.5
3/23/2007	0.1	48.7	34.9
3/24/2007	0	53.7	34.5
3/25/2007	0	61.4	33.5
3/26/2007	0	62.1	37.6
3/27/2007	0	51.6	20.9
3/28/2007	0.52	35.2	28.6
3/29/2007	0	38.7	27.0
3/30/2007	0	50.7	17.9
3/31/2007	0	63.8	23.7
Month	***0.96***	***72.7***	***6.3***
April 2007			
4/1/2007	0	63.8	37.0
4/2/2007	0	63.3	38.1
4/3/2007	0	66.6	40.4
4/4/2007	0	69.5	41.7
4/5/2007	0	67.3	40.7
4/6/2007	0	66.8	44.2
4/7/2007	0	65.1	43.7
4/8/2007	0.05	62.0	40.1
4/9/2007	0.01	61.4	29.3
4/10/2007	0	50.0	31.9
4/11/2007	0	48.9	29.5
4/12/2007	0	47.0	24.6
4/13/2007	0.12	50.4	29.6
4/14/2007	0	58.8	28.5
4/15/2007	0	51.7	32.5
4/16/2007	0	52.5	26.6
4/17/2007	0	61.2	29.5
4/18/2007	0	47.4	22.6
4/19/2007	0	51.4	16.1
4/20/2007	0	46.3	29.2
4/21/2007	0	51.6	27.0
4/22/2007	0.34	38.9	31.5
4/23/2007	0.52	42.7	28.4

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
4/24/2007	0.03	53.5	31.5
4/25/2007	0	62.6	32.9
4/26/2007	0	63.0	38.3
4/27/2007	0	71.1	39.3
4/28/2007	0	73.7	40.2
4/29/2007	0	75.7	48.1
4/30/2007	0	73.2	49.2
Month	***1.07***	***75.7***	***16.1***
May 2007			
5/1/2007	0	67.5	47.7
5/2/2007	0	67.8	41.2
5/3/2007	0	53.4	41.5
5/4/2007	0	53.3	33.1
5/5/2007	0.02	43.7	27.8
5/6/2007	0	51.3	33.7
5/7/2007	0	63.1	28.4
5/8/2007	0	67.3	37.3
5/9/2007	0	72.2	44.1
5/10/2007	0	75.5	49.4
5/11/2007	0	77.3	50.6
5/12/2007	0	78.1	52.5
5/13/2007	0	74.8	51.8
5/14/2007	0	73.2	46.7
5/15/2007	0	75.0	38.9
5/16/2007	0	75.0	44.8
5/17/2007	0	72.2	48.8
5/18/2007	0	72.7	49.6
5/19/2007	0	75.1	50.6
5/20/2007	0	74.2	47.9
5/21/2007	0.02	68.6	44.2
5/22/2007	0.10	59.1	40.1
5/23/2007	0.03	56.2	34.5
5/24/2007	0	63.0	53.4
5/25/2007	0	72.4	42.2
5/26/2007	0	72.4	49.6
5/27/2007	0	75.0	49.5
5/28/2007	0	73.8	47.6
5/29/2007	0	73.1	46.1
5/30/2007	0	75.1	36.7
5/31/2007	0	77.1	48.5
Month	***0.17***	***78.1***	***27.8***

** Note: The coal hollow weather station precipitation gauge is not equiped with* a heating unit and consequently precipitation falling during freezing conditions may may not be recorded.

25.2	8.25	1320	8.40																																										
18.4	8.1	1320	6.30																																										
11.2	8.05	1415	8.30	1050	114	142	33	5	430	<5	416	18	0.4	<0.05	<0.001	0.04	0.09	<0.005	<0.01	<0.01	0.27		<0.2	<0.02	0.03		<0.05	<0.02	<0.001	<0.01	<1	4	0.04		0.58	0.01	<0.1		430		867		<0.1
18.9	7.9	1260	7.0																																										
7.5	8	1510	11.3																																										
2.0	6.7	950	13.8	554	89	86	9	3	376	<5	150	8	0.2	0.17	<0.001	0.15	0.03	0.007	0.02	<0.01	1.8		<0.2	<0.02	0.06		<0.05	<0.02	<0.002	<0.01	<1	68	0.04		0.20	<0.02	<0.1		376		575		<0.1
0.0	7.9	735	10.3																																										
3.9	7.8	770	8.4																											0.01															
1.5	7.8	920	9.8	600	78	67	9	2	343	<5	181	7	0.2	0.28	<0.001	0.15	<0.02	<0.005	<0.01	<0.01	2.89		<0.2	<0.02	0.06		<0.05	<0.02	<0.001		<1	118	0.07		0.20	<0.01	<0.1		343		470		0.1
21.9	8.20	813	7.21	578	72.4	82.1	10.4	2.33	299	<5	170	6	0.20	<0.03	<0.010	0.179	0.07	<0.001	<0.001	<0.01	0.77	<0.03	<0.2	<0.01	0.034	0.005	<0.005	<0.001	<0.02	0.005	<2		<0.1					<0.05	303		519	57.9	
12.2	7.9	1962	7.58	1293	146	160	37.9	3.78	609.61	<5.	521	14	0.21	<0.03	<0.01	0.073	0.09	<0.001	<0.001	0.01	<0.05	<0.03	<0.2	<0.01	<0.002	0.043	<0.005	<0.001	<0.02	<0.004	<2.		0.1	<0.02	<0.05	<0.05	<0.05	<0.05	500		1023	4.21	<0.1
8.4	8.24	1551	8.09	1085	124	136	27.4	5.46	560.84	<5.	453	14	0.15	<0.03	<0.01	0.12	0.08	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.011	<0.005	0.002		<0.004	<2.		<0.1					<0.05	460		870	25.1	<0.1
10	8.89	846	8.32	530	77.2	70.2	9.31	2.65	416.97	18.33	154	7	0.2	<0.03	<0.01	0.145	0.04	<0.001	<0.001	<0.01	4.63	<0.03	<0.2	<0.01	0.071	0.007	<0.005	0.001		<0.004	<2.		<0.1		0.06	<0.05	<0.05		353		482	241	0.4
19.2	8.53	1544	7.22	815	104	150	35	4.27	520.6	<5.	485	19	0.32	<0.03	<0.01	0.043	0.1	<0.001	<0.001	<0.01	0.47	<0.03	<0.2	<0.01	0.026	0.002	<0.005	0.001	<0.02	<0.004	<2.	8	<0.1		<0.05	<0.05	<0.05	<0.05	427		877	6.47	<0.1
14.3	8.44	1579	7.93	1292	121.76	168.37	46.32	7.47	542.55	<5.	592	29	0.33	<0.03	<0.01	0.055	0.1	<0.001	<0.001	<0.01	0.52	<0.03	<0.2	<0.01	0.016	0.009	<0.005	<0.001	<0.02	<0.004	<2.	21	<0.1		<0.05	<0.05	<0.05		445		997	12.1	<0.1
0.1	8.76	738	11.2	442	78.38	59.23	7.04	1.7	402.34	<5.	95	4	0.16	<0.03	<0.01	0.199	0.02	<0.001	<0.001	<0.01	0.79	<0.03	<0.2	<0.01	0.025	0.012	<0.005	<0.001	<0.02	<0.004	<2.	27	<0.1	0.11				<0.05	330		440	27.4	<0.1
1.7	8.41	1592	10.99	1238	139	160	36.4	4.13	675.45	<5.	515	21	0.51	<0.03	<0.01	0.12	0.08	<0.001	<0.001	<0.01	0.56	<0.03	<0.2	<0.01	0.067	0.061	<0.005	0.002	<0.02	<0.004	<2.	6	<0.1		<0.05	<0.05	<0.05	<0.05	554		1006	8.51	<0.1
11.3	8.20	2490	8.4																																										
28.2	8.45	2440	6.3																																										
6.8	8.50	1950	9.4	1604	93	211	81	6	382	<5	700	27	0.5	<0.05	<0.001	0.020	0.17	<0.005	<0.01	<0.01	0.13		<0.2	<0.02	0.02		<0.05	<0.02	<0.001	<0.01	<1	<2	<0.02		<0.02	<0.01	<0.1		382		1098		<0.1
15.2	8.2	1910	8.8																				<0.2																					
2.1	8.3	1925	9.1	1474	113	194	58	7	400	<5	796	22	0.3	1.47	0.002	0.050	0.13	<0.005	<0.01	<0.01	10.1		<0.2	<0.02	0.18		<0.05	0.02	<0.002	0.01	<1	484	0.04		0.22	0.02	<0.1		400		1078		0.7
0.5	7.9	1030	11.7	674	86	92	24	3	332	<5	239	8	0.2	0.35	<0.001	0.130	0.03	<0.005	<0.01	<0.01	3.4		<0.2	<0.02	0.06		<0.05	<0.02	<0.001	<0.01	<1	88	0.02		0.22	<0.01	<0.1		332		592		<0.1
0.0	9.1	1500	8.7	1046	112	130	41	4	364	<5	482	16	0.2	0.14	<0.001	0.130	0.08	<0.005	<0.01	<0.01	2.08		<0.2	<0.02	0.08		<0.05	<0.02	<0.001	<0.01	<1	82	0.05		0.13	<0.01	<0.1		364		813		<0.1
0.0	8.3	1270	11.7	876	106	104	29	5	296	<5	428	10	0.3	3.81	0.001	0.150	0.07	<0.005	<0.01	0.01	16		<0.2	<0.02	0.33		<0.05	0.03	<0.001	0.01	<1	3272	0.07		0.12	<0.01	<0.1		296		691		0.5
7.0	8.0	1215	9.5	624	75	73	15	2	318	<5	226	8	0.2	1.77	0.002	0.160	<0.02	<0.005	0.01	0.01	35.5		<0.2	<0.02	0.3		<0.05	<0.02	<0.001	0.02	<1	1168	0.17		0.17	<0.01	<0.1		318		487		2.5
15.8	8.4	1120	8.47	853	87.5	116	42	3.15	360	<5	353	12	0.22	<0.03	<0.010	0.155	0.10	<0.001	0.001	<0.01	16	<0.03	<0.2	<0.01	0.28	0.018	<0.005	0.001	<0.02	<0.004	<2		<0.1					0.88	360		696	>1,000	
15.8	8.35	1120	8.47	853	87.5	116	42	3.15	438.92	<5.	353	12	0.22	<0.03	<0.01	0.155	0.1	<0.001	0.001	<0.01	16	<0.03	<0.2	<0.01	0.28	0.018	<0.005	0.001	<0.02	<0.004	<2.		<0.1					0.88	360	<5.	696	1000	
6.1	8.22	1926	8.24	1625	112	212	94.2	5.24	439	<5	<1	22	0.18	<0.03	<0.010	0.037	0.22	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	0.049	<0.005	<0.001	<0.02	0.053	<2		0.2	<0.02	<0.05	<0.05		<0.05	439		1153	4.75	<0.1
6.1	8.22	1926	8.24	1625	112	212	94.2	5.24	535.24	<5.	<1.	22	0.18	<0.03	<0.01	0.037	0.22	<0.001	<0.001	<0.01	<0.05	<0.03	<0.200:	<0.01	<0.002	0.049	<0.005	<0.001	<0.02	0.053	<2.		0.2	<0.02	<0.05	<0.05	<0.05	<0.05	439		1153	4.75	<0.1
5.9	8.09	1814	7.82	1513	127	183	58.6	7.04	505.97	<5.	821	16	0.17	<0.03	<0.01	0.054	0.18	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.048	<0.005	0.001		<0.004	<2.		<0.1					<0.05	415		1071	7.18	<0.1
8.5	8.69	1855	8.93	1156	113	186	80.8	5.77	508.41	<5.	763	24	0.44	<0.03	<0.01	0.034	0.2	<0.001	<0.001	<0.01	0.12	<0.03	<0.2	<0.01	0.024	0.016	<0.005	0.001	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	417		1048	2.31	<0.1
14.7	8	1959	7.99	1725	123.05	207.19	107.07	6.84	519.39	<5.	892	28	0.49	<0.03	<0.01	0.026	0.24	<0.001	<0.001	<0.01	0.07	<0.03	<0.2	<0.01	0.019	0.014	<0.005	<0.001	<0.02	<0.004	<2.	6	<0.1		<0.05	<0.05	<0.05		426		1160	3.26	<0.1
1.3	8.35	1847	9.65	1511	115	187	93.8	5.46	536.45	<5.	761	24	0.65	<0.03	<0.01	0.044	0.2	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.059	0.059	<0.005	<0.001	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	440		1057	1.37	<0.1
15.7	8.4	1210	8.20																																										
22.1	8.5	1110	6.20																																										
14.9	8.45	1450	8.40	1014	99	147	32	5	368	<5	438	17	0.4	<0.05	<0.001	0.03	0.08	<0.005	<0.01	<0.01	0.2		<0.2	<0.02	<0.01		<0.05	<0.02	<0.001	<0.01	<1	16	0.02		0.30	0.01	0		368		850		<0.1
18.5	8.1	1350	8.2																																										
7.5	8.3	1525	9.4																																										
0.2	7.9	860	11.0	518	63	69	9	3	300	<5	130	6	0.2	0.45	<0.001	0.16	<0.01	<0.005	<0.01	<0.01	5		<0.2	<0.02	0.08		<0.05	<0.02	<0.001	<0.01	<1	158	0.04		0.22	<0.01	0		300		440		<0.1
0.9	8.0	800	10.1																																										
2.1	8.0	780	9.9																																										
5.0	7.9	795	8.3	424	63	49	7	2	286	<5	111	5	0.2	3.05	0.004	0.30	<0.02	<0.005	0.01	0.01	56.8		<0.2	<0.02	0.71		<0.05	0.02	<0.001	0.03	<1	2836	0.10		0.12	<0.01	0		286		358		13.8
12.1	8.26	874	9.2																																							19.6		
12.1	8.26	874	9.22	644	84.1	92.5	12.4	2.47	410.88	<5.	210	7	0.19	<0.03	<0.01	0.17	0.05	<0.001	<0.001	<0.01	0.4	<0.03	<0.2	<0.01	0.033	<0.002	<0.005	0.001	<0.02	<0.004	2		<0.1					0.05	337	<5.	591	19.6	
9.8	8.12	1665	836	1281	110	167	35.7	0.86	477.93	<5.	<1.	16	0.21	<0.03	<0.01	0.01	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004	<2.		0.2	<0.02	<0.05	<0.05	<0.05	<0.05	392		962	7.91	<0.1
9.6	8.33	1519	7.83	1144	125	147	30.1	5.22	507.19	<5.	538	14	0.07	<0.03	<0.01	0.096	0.08	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.008	<0.005	0.001		<0.004	<2.		<0.1					<0.05	416		917	4.06	<0.1
9.5	8.94	878	7.44	554	79.3	74.1	9.94	2.63	348	<5	170	7	0.20	0.05	<0.010	0.143	0.04	<0.001	<0.001	<0.01	2.43	<0.03	<0.2	<0.01	0.049	0.010	<0.005	0.001	<0.02	0.008	<2		0.1	0.3	0.06	<0.05	<0.05		348		503	144	0.2
9.5	8.94	878	7.44	554	79.3	74.1	9.94	2.63	424.29	<5.	170	7	0.2	0.05	<0.01	0.143	0.04	<0.001	<0.001	<0.01	2.43	<0.03	<0.2	<0.01	0.049	0.01	<0.005	0.001		0.008	<2.		0.1		0.06	<0.05	<0.05		348		503	144	0.2
12.4	8.64	1563	8.09	1255	100	156	33.4	4.42	491.34	<5.	554	18	0.3	<0.03	<0.01	0.059	0.1	<0.001	<0.001	<0.01	0.24	<0.03	<0.2	<0.01	0.011	0.002	<0.005	0.002	<0.02	0.006	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	403		892	2.16	<0.1
13.7	8.37	1465	8.11	1257	103.24	170.99	37.73	5.28	436.48	<5.	594	21	0.27	<0.03	<0.01	0.028	0.09	<0.001	<0.001	<0.01	0.2	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	13	<0.1		<0.05	<0.05	<0.05		358		962	6.73	<0.1
0	8.72	819	12.1	570	88	72.31	9.39	2.12	432.82	<5.	146	6	0.18	<0.03	<0.01	0.202	0.03	<0.001	<0.001	<0.01	0.46	<0.03	<0.2	<0.01	0.021	0.011	<0.005	<0.001	<0.02	<0.004	<2.	24	<0.1		0.1	<0.05	<0.05		355		518	13.3	<0.1
0.5	8.63	1503	10.8	1167	124	155	33.3	4.12	562.06	<5.	525	19	0.43	<0.03	<0.01	0.091	0.07	<0.001	<0.001	<0.01	0.23	<0.03	<0.2	<0.01	0.051	0.044	<0.005	0.002	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	461		948	7.07	<0.1
0.3	8.5	490	8.65	286	37	38	7.00	1	228	<5	31	10	0.3	0.07	<0.001	0.22	<0.01	<0.005	<0.01	<0.01	0.19				0.01		<0.05	<0.02	0.001	<0.01	<1	20	<0.02		<0.02	<0.01	0		228		248		<0.1
4.1	8.4	490	7.4	262	44	36	5.00	1	241	<5	14	3	0.5	0.21	<0.001	0.21	<0.02	<0.005	<0.01	<0.01	1.8				0.04		<0.05	<0.02	0.001	<0.01	<1	170	0.02		<0.02	<0.02	0		241		258		<0.1
7.1	8.5	480	8.2	245	51	40	4.00	1	232	<5	21	3	0.4	<0.05	<0.001	0.21	<0.02	<0.005	<0.01	0.01	0.44				0.01		<0.05	<0.02	<0.001	<0.01	<1	28	0.05		0.03	<0.01	0		232		292		<0.1
8.2	8.2	430	6.6	256	48	38	5.00	1	241	<5	27	4	0.7	0.11	<0.001	0.25	<0.02	<0.005	<0.01	<0.01	0.38				0.02		<0.05	<0.02	<0.001	0.01	<1	22	<0.02		<0.02	<0.01	0		241		276		<0.2
9	8.2	525	9.3	302	49	36	4.00	1	243	<5	29	3	0.2	0.55	<0.001	0.22	<0.02	<0.005	<0.01	<0.01	2.77				0.05		<0.05	<0.02	<0.002	<0.01	<1	178	<0.02		0.03	<0.01	0		243		270		<0.2
.8	7.7	585	8	338	57	40	6.00	1	300	<5	33	7	0.2	0.45	<0.001	0.24	<0.02	<0.005	<0.01	<0.01	3.8				0.06		<0.05	<0.02	<0.001	0.04	<1	116	0.04		0.1	<0.01	0		300		307		<0.1
.3	8.2	550	9.3	306	47	38	4.00	1	250	<5	33	7	0.2	0.32	<0.001	0.24	<0.02	<0.005	<0.01	<0.01	2.83				0.06		<0.05	<0.02	<0.001	<0.01	<1	148	0.1		0.06	<0.01	0		250		273		0.2
.3	8.1	565	9.1	324	61	40	4.00	1	273	<5	31	3	0.2	2.01	<0.001	0.23	<0.02	<0.005	<0.01	<0.01	4.95				0.1		<0.05	<0.02	0.001	0.01	1	238	0.2		0.06	<0.01	0		273		317		0.1
.5	8.2	610	8.6	290	56	38	4.00	1	263	<5	29	<1	0.2	2.45	0.002	0.43	<0.02	<0.005	0.01	<0.01	30.8				0.46		<0.05	<0.02	0.001	0.03	1	2940	0.03		0.18	0.18	0		263		296		4
.5	8.38	566	6.78	366	59.2	44.1	6.75	1.03	368.2	<5.	34	5	0.06	<0.03	<0.01	0.221	0.02	<0.001	0.001	<0.01		<0.03	<0.2	<0.01		0.002	<0.005	<0.001	<0.02	<0.004	<2.		<0.1				<0.05	0.43	278		329	1000	
.8	8.41	493	7.35	274	51.4	37.7	6.63	1.03	243	<5	38	4	0.13	<0.03	<0.010	0.219	0.02	<0.001	<0.001	<0.01	0.66	<0.03	<0.2	<0.01	0.016	<0.002	<0.005	<0.001	<0.02	<0.004	<2		<0.1		0.08	<0.05		<0.05	243		284	12.9	
.0	8.36	536	6.71	298	48.4	38.9	6.09	0.99	250	<5	33	4	0.20	<0.03	<0.010	0.195	<0.02	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	<0.001	<0.02	<0.004	---		<0.1	0.03	<0.05	<0.05		<0.05	250				
.4	8.36	536	6.71	298	48.4	38.9	6.09	0.99	304.8	<5	33	4	0.2	<0.03	<0.01	0.195	0.02	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1										

(µs/m)	(°C)	pH	(µS/cm)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	NTU	Set Sol (mg/L)
45	25.2	8.25	1320	8.40																																									
117	18.4	8.1	1320	6.30																																									
144	11.2	8.05	1415	8.30	1050	114	142	33	5	430	<5	416	18	0.4	<0.05	<0.001	0.04	0.09	<0.005	<0.01	<0.01	0.27		<0.2	<0.02	0.03		<0.05	<0.02	<0.001	<0.01	<1	4	0.04		0.58	0.01	<0.1		430		867		<0.1
206	18.9	7.9	1260	7.0																																									
390	7.5	8	1510	11.3																																									
449	2.0	6.7	950	13.8	554	89	86	9	3	376	<5	150	8	0.2	0.17	<0.001	0.15	0.03	0.007	0.02	<0.01	1.8		<0.2	<0.02	0.06		<0.05	<0.02	<0.002	<0.01	<1	68	0.04		0.20	<0.02	<0.1		376		575		<0.1
3460	0.0	7.9	735	10.3																																									
3190	3.9	7.8	770	8.4																																									
3280	1.5	7.8	920	9.8	600	78	67	9	2	343	<5	181	7	0.2	0.28	<0.001	0.15	<0.02	<0.005	<0.01	<0.01	2.89		<0.2	<0.02	0.06		<0.05	<0.02	<0.001	0.01	<1	118	0.07		0.20	<0.01	<0.1		343		470		0.1
1830	21.9	8.20	813	7.21	578	72.4	82.1	10.4	2.33	299	<5	170	6	0.20	<0.03	<0.010	0.179	0.07	<0.001	<0.001	<0.01	0.77	<0.03	<0.2	<0.01	0.034	0.005	<0.005	<0.001	<0.02	0.005	<2		<0.1					<0.05	303		519	57.9	
161	12.2	7.9	1962	7.58	1293	146	160	37.9	3.78	609.61	<5.	521	14	0.21	<0.03	<0.01	0.073	0.09	<0.001	<0.001	0.01	<0.05	<0.03	<0.2	<0.01	<0.002	0.043	<0.005	<0.001	<0.02	<0.004	<2.		0.1	<0.02	<0.05	<0.05	<0.05	<0.05	500		1023	4.21	<0.1
893	8.4	8.24	1551	8.09	1085	124	136	27.4	5.46	560.84	<5.	453	14	0.15	<0.03	<0.01	0.12	0.08	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.011	<0.005	0.002		<0.004	<2.		<0.1					<0.05	460		870	25.1	<0.1
2770	10	8.89	846	8.32	530	77.2	70.2	9.31	2.65	416.97	18.33	154	7	0.2	<0.03	<0.01	0.145	0.04	<0.001	<0.001	<0.01	4.63	<0.03	<0.2	<0.01	0.071	0.007	<0.005	0.001		<0.004	<2.		<0.1		0.06	<0.05	<0.05		353		482	241	0.4
158	19.2	8.53	1544	7.22	815	104	150	35	4.27	520.6	<5.	485	19	0.32	<0.03	<0.01	0.043	0.1	<0.001	<0.001	<0.01	0.47	<0.03	<0.2	<0.01	0.026	0.002	<0.005	0.001	<0.02	<0.004	<2.	8	<0.1		<0.05	<0.05	<0.05	<0.05	427		877	6.47	<0.1
115	14.3	8.44	1579	7.93	1292	121.76	168.37	46.32	7.47	542.55	<5.	592	29	0.33	<0.03	<0.01	0.055	0.1	<0.001	<0.001	<0.01	0.52	<0.03	<0.2	<0.01	0.016	0.009	<0.005	<0.001	<0.02	<0.004	<2.	21	<0.1		<0.05	<0.05	<0.05		445		997	12.1	<0.1
300	0.1	8.76	738	11.2	442	78.38	59.23	7.04	1.7	402.34	<5.	95	4	0.16	<0.03	<0.01	0.199	0.02	<0.001	<0.001	<0.01	0.79	<0.03	<0.2	<0.01	0.025	0.012	<0.005	<0.001	<0.02	<0.004	<2.	27	<0.1	0.11				<0.05	330		440	27.4	<0.1
172	1.7	8.41	1592	10.99	1238	139	160	36.4	4.13	675.45	<5.	515	21	0.51	<0.03	<0.01	0.12	0.08	<0.001	<0.001	<0.01	0.56	<0.03	<0.2	<0.01	0.067	0.061	<0.005	0.002	<0.02	<0.004	<2.	6	<0.1		<0.05	<0.05	<0.05	<0.05	554		1006	8.51	<0.1
36	11.3	8.20	2490	8.4																																									
45	28.2	8.45	2440	6.3																																									
54	6.8	8.50	1950	9.4	1604	93	211	81	6	382	<5	700	27	0.5	<0.05	<0.001	0.020	0.17	<0.005	<0.01	<0.01	0.13		<0.2	<0.02	0.02		<0.05	<0.02	<0.001	<0.01	<1	<2	<0.02		<0.02	<0.01	<0.1		382		1098		<0.1
139	15.2	8.2	1910	8.8																				<0.2																					
---	2.1	8.3	1925	9.1	1474	113	194	58	7	400	<5	796	22	0.3	1.47	0.002	0.050	0.13	<0.005	<0.01	<0.01	10.1		<0.2	<0.02	0.18		<0.05	0.02	<0.002	0.01	<1	484	0.04		0.22	0.02	<0.1		400		1078		0.7
99	0.5	7.9	1030	11.7	674	86	92	24	3	332	<5	239	8	0.2	0.35	<0.001	0.130	0.03	<0.005	<0.01	<0.01	3.4		<0.2	<0.02	0.06		<0.05	<0.02	<0.001	<0.01	<1	88	0.02		0.22	<0.01	<0.1		332		592		<0.1
1975	0.0	9.1	1500	8.7	1046	112	130	41	4	364	<5	482	16	0.2	0.14	<0.001	0.130	0.08	<0.005	<0.01	<0.01	2.08		<0.2	<0.02	0.08		<0.05	<0.02	<0.001	<0.01	<1	82	0.05		0.13	<0.01	<0.1		364		813		<0.1
6283	0.0	8.3	1270	11.7	876	106	104	29	5	296	<5	428	10	0.3	3.81	0.001	0.150	0.07	<0.005	<0.01	0.01	16		<0.2	<0.02	0.33		<0.05	0.03	<0.001	0.01	<1	3272	0.07		0.12	<0.01	<0.1		296		691		0.5
3590	7.0	8.0	1215	9.5	624	75	73	15	2	318	<5	226	8	0.2	1.77	0.002	0.160	<0.02	<0.005	0.01	0.01	35.5		<0.2	<0.02	0.3		<0.05	<0.02	<0.001	0.02	<1	1168	0.17		0.17	<0.01	<0.1		318		487		2.5
934	15.8	8.4	1120	8.47	853	87.5	116	42	3.15	360	<5	353	12	0.22	<0.03	<0.010	0.155	0.10	<0.001	0.001	<0.01	16	<0.03	<0.2	<0.01	0.28	0.018	<0.005	0.001	<0.02	<0.004	<2		<0.1					0.88	360		696	>1,000	
934	15.8	8.35	1120	8.47	853	87.5	116	42	3.15	438.92	<5.	353	12	0.22	<0.03	<0.01	0.155	0.1	<0.001	0.001	<0.01	16	<0.03	<0.2	<0.01	0.28	0.018	<0.005	0.001	<0.02	<0.004	<2.		<0.1					0.88	360	<5.	696	1000	
32	6.1	8.22	1926	8.24	1625	112	212	94.2	5.24	439	<5	<1	22	0.18	<0.03	<0.010	0.037	0.22	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	0.049	<0.005	<0.001	<0.02	0.053	<2		0.2	<0.02	<0.05	<0.05		<0.05	439		1153	4.75	<0.1
32	6.1	8.22	1926	8.24	1625	112	212	94.2	5.24	535.24	<5.	<1.	22	0.18	<0.03	<0.01	0.037	0.22	<0.001	<0.001	<0.01	<0.05	<0.03	<0.200	<0.01	<0.002	0.049	<0.005	<0.001	<0.02	0.053	<2.		0.2	<0.02	<0.05	<0.05	<0.05	<0.05	439		1153	4.75	<0.1
430	5.9	8.09	1814	7.82	1513	127	183	58.6	7.04	505.97	<5.	821	16	0.17	<0.03	<0.01	0.054	0.18	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.048	<0.005	0.001		<0.004	<2.		<0.1					<0.05	415		1071	7.18	<0.1
51	8.5	8.69	1855	8.93	1156	113	186	80.8	5.77	508.41	<5.	763	24	0.44	<0.03	<0.01	0.034	0.2	<0.001	<0.001	<0.01	0.12	<0.03	<0.2	<0.01	0.024	0.016	<0.005	0.001	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	417		1048	2.31	<0.1
5.38	14.7	8	1959	7.99	1725	123.05	207.19	107.07	6.84	519.39	<5.	892	28	0.49	<0.03	<0.01	0.026	0.24	<0.001	<0.001	<0.01	0.07	<0.03	<0.2	<0.01	0.019	0.014	<0.005	<0.001	<0.02	<0.004	<2.	6	<0.1		<0.05	<0.05	<0.05		426		1160	3.26	<0.1
21.3	1.3	8.35	1847	9.65	1511	115	187	93.8	5.46	536.45	<5.	761	24	0.65	<0.03	<0.01	0.044	0.2	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.059	0.059	<0.005	<0.001	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	440		1057	1.37	<0.1
206	15.7	8.4	1210	8.20																																									
184	22.1	8.5	1110	6.20																																									
126	14.9	8.45	1450	8.40	1014	99	147	32	5	368	<5	438	17	0.4	<0.05	<0.001	0.03	0.08	<0.005	<0.01	<0.01	0.2		<0.2	<0.02	<0.01		<0.05	<0.02	<0.001	<0.01	<1	16	0.02		0.30	0.01	0		368		850		<0.1
233	18.5	8.1	1350	8.2																																									
350	7.5	8.3	1525	9.4																																									
54	0.2	7.9	860	11.0	518	63	69	9	3	300	<5	130	6	0.2	0.45	<0.001	0.16	<0.01	<0.005	<0.01	<0.01	5		<0.2	<0.02	0.08		<0.05	<0.02	<0.001	<0.01	<1	158	0.04		0.22	<0.01	0		300		440		<0.1
449	0.9	8.0	800	10.1																																									
3366	2.1	8.0	780	9.9																																									
3590	5.0	7.9	795	8.3	424	63	49	7	2	286	<5	111	5	0.2	3.05	0.004	0.30	<0.02	<0.005	0.01	0.01	56.8		<0.2	<0.02	0.71		<0.05	0.02	<0.001	0.03	<1	2836	0.10		0.12	<0.01	0		286		358		13.8
1854	12.1	8.26	874	9.2																																									
1850	12.1	8.26	874	9.22	644	84.1	92.5	12.4	2.47	410.88	<5.	210	7	0.19	<0.03	<0.01	0.17	0.05	<0.001	<0.001	<0.01	0.4	<0.03	<0.2	<0.01	0.033	<0.002	<0.005	0.001	<0.02	<0.004	2		<0.1									19.6	
119	9.8	8.12	1665	836	1281	110	167	35.7	0.86	477.93	<5.	<1.	16	0.21	<0.03	<0.01	0.01	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004	<2.		0.2	<0.02	<0.05	<0.05	<0.05	0.05	337	<5.	591	19.6	
320	9.6	8.33	1519	7.83	1144	125	147	30.1	5.22	507.19	<5.	538	14	0.07	<0.03	<0.01	0.096	0.08	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.008	<0.005	0.001		<0.004	<2.		<0.1					<0.05	416		917	4.06	<0.1
2690	9.5	8.94	878	7.44	554	79.3	74.1	9.94	2.63	348	<5	170	7	0.20	0.05	<0.010	0.143	0.04	<0.001	<0.001	<0.01	2.43	<0.03	<0.2	<0.01	0.049	0.010	<0.005	0.001	<0.02	0.008	<2		0.1	0.3	0.06	<0.05	<0.05		348		503	144	0.2
2692	9.5	8.94	878	7.44	554	79.3	74.1	9.94	2.63	424.29	<5.	170	7	0.2	0.05	<0.01	0.143	0.04	<0.001	<0.001	<0.01	2.43	<0.03	<0.2	<0.01	0.049	0.01	<0.005	0.001		0.008	<2.		0.1		0.06	<0.05	<0.05		348		503	144	0.2
166	12.4	8.64	1563	8.09	1255	100	156	33.4	4.42	491.34	<5.	554	18	0.3	<0.03	<0.01	0.059	0.1	<0.001	<0.001	<0.01	0.24	<0.03	<0.2	<0.01	0.011	0.002	<0.005	0.002	<0.02	0.006	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	403		892	2.16	<0.1
109	13.7	8.37	1465	8.11	1257	103.24	170.99	37.73	5.28	436.48	<5.	594	21	0.27	<0.03	<0.01	0.028	0.09	<0.001	<0.001	<0.01	0.2	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	13	<0.1		<0.05	<0.05	<0.05		358		962	6.73	<0.1
409	0	8.72	819	12.1	570	88	72.31	9.39	2.12	432.82	<5.	146	6	0.18	<0.03	<0.01	0.202	0.03	<0.001	<0.001	<0.01	0.46	<0.03	<0.2	<0.01	0.021	0.011	<0.005	<0.001	<0.02	<0.004	<2.	24	<0.1		0.1	<0.05	<0.05		355		518	13.3	<0.1
191	0.5	8.63	1503	10.8	1167	124	155	33.3	4.12	562.06	<5.	525	19	0.43	<0.03	<0.01	0.091	0.07	<0.001	<0.001	<0.01	0.23	<0.03	<0.2	<0.01	0.051	0.044	<0.005	0.002	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	461		948	7.07	<0.1
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36	10.3	8.5	490	8.65	286	37	38	7.00	1	228	<5	31	10	0.3	0.07	<0.001	0.22	<0.01	<0.005	<0.01	<0.01	0.19				0.01		<0.05	<0.02	0.001	<0.01	<1	20	<0.02		<0.02	<0.01	0		228		248		<0.1
22	14.1	8.4	490	7.4	262	44	36	5.00	1	241	<5	14	3	0.5	0.21	<0.001	0.21	<0.02	<0.005	<0.01	<0.01	1.8				0.04		<0.05	<0.02	0.001	<0.01	<1	170	0.02		<0.02	<0.02	0		241		258		<0.1
40	7.1	8.5	480	8.2	245	51	40	4.00	1	232	<5	21	3	0.4	<0.05	<0.001	0.21	<0.02	<0.005	<0.01	0.01	0.44				0.01		<0.05	<0.02	<0.001	<0.01	<1	28	0.05		0.03	<0.01	0		232		292		<0.1
36	18.2	8.2	430	6.6	256	48	38	5.00	1	241	<5	27	4	0.7	0.11	<0.001	0.25	<0.02	<0.005	<0.01	<0.01	0.38				0.02		<0.05	<0.02	<0.001	0.01	<1	22	<0.02		<0.02	<0.01	0		241		276		<0.2
40	9	8.2	525	9.3	302	49	36	4.00	1	243	<5	29	3	0.2	0.55	<0.001	0.22	<0.02	<0.005	<0.01	<0.01	2.77				0.05		<0.05	<0.02	<0.002	<0.01	<1	178	<0.02		0.03	<0.01	0		243		270		<0.2
13	0.8	7.7	585	8	338	57	40	6.00	1	300	<5	33	7	0.2	0.45	<0.001	0.24	<0.02	<0.005	<0.01	<0.01	3.8				0.06		<0.05	<0.02	<0.001	0.04	<1	116	0.04		0.1	<0.01	0		300		307		<0.1
40	0.3	8.2	550	9.3	306	47	38	4.00	1	250	<5	33	7	0.2	0.32	<0.001	0.24	<0.02	<0.005	<0.01	<0.01	2.83				0.06		<0.05	<0.02	<0.001	<0.01	<1	148	0.1		0.06	<0.01	0		250		273		0.2
49	-0.3	8.1	565	9.1	324	61	40	4.00	1	273	<5	31	3	0.2	2.01	<0.001	0.23	<0.02	<0.005	<0.01	<0.01	4.95				0.1		<0.05	<0.02	0.001	0.01	1	238	0.2		0.06	<0.01	0		273		317		0.1
49	1.5	8.2	610	8.6	290	56	38	4.00	1	263	<5	29	<1	0.2	2.45	0.002	0.43	<0.02	<0.005	0.01	<0.01	30.8				0.46		<0.05	<0.02	0.001	0.03	1	2940	0.03		0.18	0.18	0		263		296		4
290	17.5	8.38	566	6.78	366	59.2	44.1	6.75	1.03	368.2	<5.	34	5	0.06	<0.03	<0.01	0.221	0.02	<0.001	0.001	<0.01		<0.03	<0.2	<0.01		0.002	<0.005	<0.001	<0.02	<0.004	<2.		<0.1			<0.05	0.43		278		329	1000	
130	17.8	8.41	493	7.35	274	51.4	37.7	6.63	1.03	243	<5	38	4	0.13	<0.03	<0.010	0.219	0.02	<0.001	<0.001	<0.01	0.66	<0.03	<0.2	<0.01	0.016	<0.002	<0.005	<0.001	<0.02	<0.004	<2		<0.1		0.08	<0.05		<0.05	243		284	12.9	
69	14.0	8.36	536	6.71	298	48.4	38.9	6.09	0.99	250	<5	33	4	0.20	<0.03	<0.010	0.195	<0.02	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	<0.001	<0.02	<0.004	---		<0.1	0.03	<0.05	<0.05		<0.05	250		281	63	<0.1
69	14	8.36	536	6.71	298	48.4	38.9	6.09	0.99	304.8	<5.	33	4	0.2	<0.03	<0.01	0.195	0.02	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1	0.03	<0.05	<0.05	<0.05	<0.05	250		281	63	<0.1

58	20.2	8.63	568	8.71	336	44.7	39.4	11.7	1.22	274.52	<5.	89	7	0.22	<0.03	<0.01	0.161	0.03	<0.001	<0.001	<0.01	0.35	<0.03	<0.2	<0.01	0.011	<0.002	<0.005	0.001	<0.02	<0.004	<2.	26	<0.1		<0.05	<0.05	<0.05	<0.05	225		274	9.45	0.1
50.7	12.5	8.01	576	7.76	331	47.48	39.92	17.75	1.75	287.73	<5.	89	7	0.15	<0.03	<0.01	0.167	0.02	<0.001	<0.001	<0.01	13.76	<0.03	<0.2	<0.01	0.286	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	657	<0.1		0.06	<0.05	<0.05		239		293	608	0.9
32.1	10.1	8.84	553	10.8	337	64.07	39.43	8.45	0.91	335.28	<5.	46	5	0.19	<0.03	<0.01	0.205	0.64	<0.001	<0.001	<0.01	0.81	<0.03	<0.2	<0.01	0.024	0.007	<0.005	<0.001	<0.02	<0.004	<2.	49	<0.1	<0.05				0.06	275		322	21.1	<0.1
33.6	2.2	8.68	524	8.53	324	59.6	36.4	9.2	0.96	321.87	<5.	49	5	0.18	<0.03	<0.01	0.192	0.01	<0.001	<0.001	<0.01	1.39	<0.03	<0.2	<0.01	0.026	0.006	<0.005	<0.001	<0.02	<0.004	<2.	95	<0.1		<0.05	<0.05	<0.05	<0.05	264		299	54	<0.1
Dry	11.0	8.70	860	5.8	556	34	98	29.00	11	292	40	140	18	0.8	0.45	0.004	0.05	0.21	<0.005	<0.01	0.01	0.71		<0.2		0.02		<0.05	<0.02	<0.001	<0.01	<1	28	0.07		0.02	<0.01	0		332		487		<0.1
Dry	0.8	8.3	1840	8.2	1212	51	209	73.00	9	602	37	418	41	0.4	0.19	0.002	0.06	0.21	<0.005	<0.01	<0.01	0.3		<0.2		0.01		<0.05	<0.02	<0.001	<0.01	<1	12	0.02		<0.02	<0.01	0		639		984		<0.1
Dry	1.5	8.4	1600	6.9	992	45	182	63.00	5	590	<5	344	34	0.4	0.21	0.002	0.04	0.16	<0.005	<0.01	<0.01	0.34		<0.2		0.03		<0.05	<0.02	<0.001	<0.01	1	12	0.04		0.04	<0.01	0		590		859		<0.1
Dry																																												
58	13.8	8.91	1352	5.98	1028	58.9	161	31.30	12.5	436	47	361	22	0.27	<0.03	<0.010	0.089	0.17	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	0.002	<0.02	0.008	<2		<0.1	0.2	<0.05	<0.05	<0.05		483		810	3.13	<0.1
Dry																																												
Dry																																												
Dry																																												
Dry																																												
9	11.1	8.6	---	9.3	880	20	128	106.00	6	392	53	280	33	2.2	5.1	0.002	0.15	0.3	<0.005	<0.01	<0.01	23.8				0.31		<0.05	0.02	<0.001	0.03	<1	1140	0.03		0.03	0.01	0.1		445		575		12.5
18	2.1	8.4	1390	9.2	888	23	163	86	4	563	37	274	30	0.4	0.57	<0.001	0.06	0.24	<0.005	<0.01	<0.01	2.97				0.05		<0.05	<0.02	<0.002	<0.01	<1	110	0.02		0.04	<0.01	0		600		726		<0.2
763	-0.2	8.1	955	10.0	584	38	107	30	7	354	<5	165	15	0.3	2.84	0.002	0.16	0.09	<0.005	<0.01	<0.01	21.5				0.46		<0.05	<0.02	<0.001	0.02	1	1006	0.04		0.02	0.01	0.2		354		534		1.5
1.3	14.2	8.5	3820	7.7	1556	39	207	232.00	7	798	50	591	52	0.9	1.62	0.003	0.11	0.55	<0.005	<0.01	0.01	18.5				0.22		<0.05	<0.02	<0.001	0.04	1	784	<0.02		0.03	0.01	0		848		946		2.7
Dry																																												
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10.6	12	8.74	1715	6.63	1270	53.7	164	122	9.88	546.21	83.33	520	41	0.48	<0.03	<0.01	0.097	0.3	<0.001	<0.001	<0.01	0.36	<0.03	<0.2	<0.01	0.034	0.01	<0.005	0.001		<0.004	<2.		<0.1		<0.05	<0.05	<0.05		498		809	12.7	<0.1
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539	19.1	8.4	453	7.25	283	47.7	35.8	2.23	0.6	297.49	<5.	18	2	0.14	<0.03	<0.01	0.261	0.01	<0.001	<0.001	<0.01	25.5	<0.03	<0.2	<0.01	0.441	<0.002	<0.005	<0.001	<0.02	<0.004	<2.		<0.1					1.29	244	<5.	267	1000	
Dry																																												
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13.5	27.5	8.65	1680	5.9	984	39	160	69	7	433	49	403	24	0.8	0.42	0.002	0.05	0.17	<0.005	<0.01	<0.01	3.19		<0.2	<0.02	0.07		<0.05	<0.02	0.001	<0.01	<1	226	0.02		<0.02	<0.02	0		482		754		0.3
13.5	9.0	8.65	1480	8.4	1008	49	162	61	5	444	12	368	3	0.6	<0.05	<0.001	0.03	0.11	<0.005	<0.01	<0.01	0.06		<0.2	<0.02	0.02		<0.05	<0.02	<0.001	<0.01	<1	<2	<0.02		0.02	<0.01	0		456		787		<0.1
58	12.5	8.10	1070	8.5	666	42	105	49	4	290	<5	298	19	1	3.83	0.002	0.06	0.08	<0.005	<0.01	0.01	12		<0.2	<0.02	0.14		<0.05	<0.02	<0.001	0.03	<1	584	<0.02		0.02	<0.01	0		290		536		0.6
uddle	1.2	8.00	1305	9.2	886	54	129	58	4	402	16	350	21	0.4	1.55	<0.001	0.04	0.06	<0.005	<0.01	<0.01	9.1		<0.2	<0.02	0.17		<0.05	0.02	<0.002	0.02	<1	466	0.03		0.03	<0.01	0		418		664		0.3
36	0.0	8.00	665	6.9	446	46	59	23	6	204	<5	163	10	0.3	0.44	0.001	0.04	0.02	<0.005	<0.01	0.01	1.97		<0.2	<0.02	0.04		<0.05	0.02	<0.001	<0.01	1	92	0.03		0.06	<0.01	0.2		204		357		<0.1
4.5	9.1	8.20	1670	6.4	876	54	104	55	5	378	<5	344	21	0.4	1.3	0.002	0.06	0.06	<0.005	0.01	<0.01	10.1		<0.2	<0.02	0.14		<0.05	<0.02	0.001	0.01	<1	714	0.07		0.08	<0.01	0		378		561		1.6
4.5	9.1	8.2	1670	6.4																																								
410	18	8.46	721	7.23	469	63	60.6	20.2	1.84	404.78	8.3	144	6	0.19	<0.03	<0.01	0.18	0.04	<0.001	<0.001	<0.01	45.6	<0.03	<0.2	<0.01	0.825	<0.002	<0.005	<0.001	<0.02	<0.004	3		<0.1					2.38	338	<5.	407	1000	
Dry																																												
5.37	11.4	8.88	1543	8.67	1205	69.8	148	85.2	5.67	513.29	<5.	503	26	0.62	<0.03	<0.01	0.042	0.16	<0.001	<0.001	<0.01	0.21	<0.03	<0.2	<0.01	0.044	0.007	<0.005	0.001	<0.02	<0.004	<2.	32	<0.1		<0.05	<0.05	<0.05	<0.05	421		784	3.3	0.1
4.96	13.7	8.36	1394	7.89	1081	59.04	143.68	83.11	6.02	455.99	<5.	474	27	0.6	<0.03	<0.01	0.035	0.16	<0.001	<0.001	<0.01	0.37	<0.03	<0.2	<0.01	0.014	0.006	<0.005	<0.001	<0.02	<0.004	<2.	26	<0.1		<0.05	<0.05	<0.05		405		739	13.4	<0.1
Dry																																												
Dry																																												
734	17.7	8.41	495	8.03	309	54.2	36	4.67	1.02	345	8	45	4	0.17	<0.03	<0.010	0.182	0.02	<0.001	<0.001	<0.01	52.7	<0.03	<0.2	<0.01	0.882	<0.002	<0.005	<0.001	<0.02	<0.004	2		<0.1					2.94	353		284	>1000	
734	17.7	8.41	495	8.03	309	54.2	36	4.67	1.02	420.63	13.33	45	4	0.17	<0.03	<0.01	0.182	0.02	<0.001	<0.001	<0.01	52.7	<0.03	<0.2	<0.01	0.882	<0.002	<0.005	<0.001	<0.02	<0.004	2		<0.1					2.94	353	<5.	284	1000	
20.8	8.6	8.62	3120	7.77	3013	356	148	282	16.4	820	<5	1899	47	1.23	0.19	<0.010	0.061	0.19	<0.001	<0.001	<0.01	332	0.06	<0.2	<0.01	4.16	0.002	0.005	0.003	<0.02	0.01	<2		<0.1	2.0	1.85	<0.05	<0.05		820		1498	#####	82
Dry																																												
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64.7	1	8.73	376	9.29	250	47.5	36.8	1.76	0.87	290.17	<5	16	2	0.09	<0.03	<0.01	0.248	<0.01	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		<0.002	<0.005	<0.001		<0.004	<2.		<0.1					<0.05	238		270	13.1	<0.1
48.6	10.4	8.89	412	8.85	265	36.3	36.1	1.9	0.88	267.01	<5	17	3	0.14	<0.03	<0.01	0.217	0.01	<0.001	<0.001	<0.01	1.3	<0.03	<0.2	<0.01	0.022	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	64	<0.1		<0.05	<0.05	<0.05	0.07	221		239	42.5	0.1
6.2	0.1	8.87	470	11.8	273	54.32	35.81	1.85	0.9	295.05	18.3	19	2	0.13	<0.03	<0.01	0.246	<0.01	<0.001	<0.001	<0.01	3.29	<0.03	<0.2	<0.01	0.049	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	146	<0.1		<0.05	<0.05	<0.05		253		283	161	<0.1
12.8	1.5	8.83	412	7.82	254	43.7	32.6	1.69	0.64	271.88	20	17	2	0.12	<0.03	<0.01	0.208	<0.01	<0.001	<0.001	<0.01	16.9	<0.03	<0.2	<0.01	0.556	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	1775	<0.1		<0.05	<0.05	<0.05	1.63	234		243	890	2.5
4.5	13.8	8.4	---	8.1	390	59	45	25	4	264	<5	66	16	0.6	2.65	0.001	0.19	0.03	<0.005	<0.01	0.01	26.3				0.33		<0.05	0.02	0.004	0.03	<1	1084	0.07		0.45	0.01	0		264		332		5.6
1.8	28.9	8.85	520	7.9	270	31	37	24	3	159	33	56	14	0.6	0.19	<0.001	0.04	0.05	<0.005	<0.01	<0.01	0.21				<0.01		<0.05	<0.02	0.005	0.01	<1	8	<0.02		<0.02	<0.01	0		192		229		<0.1
4.5	14.9	8.65	525	7.7	316	41	40	13	3	218	<5	60	19	0.4	0.39	<0.001	0.05	0.03	<0.005	<0.01	0.01	0.84				0.01		<0.05	<0.02	0.003	0.01	<1	30	<0.02		0.03	<0.01	0		218		267		<0.1
18.0	10.1	8.2	450	10.2	266	34	33	22	2	171	8	60	13	0.9	2.35	<0.001	0.06	0.03	<0.005	<0.01	<0.01	2.71				0.03		<0.05	<0.02	0.002	0.02	2	114	<0.02		0.01	0.01	0		179		220		<0.2
13.5	3.0	8.0	540	9.1	10	<1	<1	<1	<1	2	<5	<2	<1	<0.1	<0.05	<0.001	0.01	<0.02	<0.005	<0.01	<0.01	<0.02				<0.01		<0.05	<0.02	<0.002	<0.01	<1	2	0.02		0.07	<0.01	0		2		<7		<0.2
9.0	0.1	7.6	735	10.4	408	48	45	30	3	270	<5	64	17	0.2	0.5	<0.001	0.08	0.03	<0.005	<0.01	0.01	2.81				0.05		<0.05	<0.02	0.003	0.01	<1	94	0.02		0.4	<0.01	0		270		305		<0.1
ozen	---	---	---	---																																								
13.5	0.6	8.1	325	9.8																																								
3.6	1.0	8.4	760	10.0	450	84	50	31	3	327	<5	86	17	0.2	0.19	<0.001	0.06	0.04	<0.005	<0.01	<0.01	0.82				0.01		<0.05	<0.02	0.003	0.1	<1	20	0.04		0.56	<0.01	0		327		415		<0.1
Dry																																												
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Table 4 Discharge and water-quality data for groundwaters and surface waters in the proposed Coal Hollow Mine permit and adjacent area.

	Date	Data Source	discharge (gpm)	T (°C)	pH	Cond. (µS/cm)	D.O. (mg/L)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	HCO3 (mg/L)	CO3 (mg/L)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	Al (mg/L)	As (mg/L)	Ba (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (t) (mg/L)	Fe (d) (mg/L)	Hg (µg/L)	Pb (mg/L)	Mn (t) (mg/L)	Md (d) (mg/L)	Mb (mg/L)	Ni (mg/L)	Se (mg/L)	Zn (mg/L)	Oil&G (mg/L)	TSS (mg/L)	NH3 (mg/L)	NO3+NO2 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	O-PO4 (mg/L)	T. Phos (mg/L)	Alkalinity (mg/L)	Acd. (mg/L)	Hard. (mg/L)	Turb. NTU	Set Sol (mg/L)
Streams																																															
Kanab Creek																																															
SW-1	1-Jul-87	Utah International	45	25.2	8.25	1320	8.40																																								
SW-1	3-Aug-87	Utah International	117	18.4	8.1	1320	6.30																																								
SW-1	4-Sep-87	Utah International	144	11.2	8.05	1415	8.30	1050	114	142	33	5	430	<5	416	18	0.4	<0.05	<0.001	0.04	0.09	<0.005	<0.01	<0.01	0.27		<0.2	<0.02	0.03		<0.05	<0.02	<0.001	<0.01	<1	4	0.04		0.58	0.01	<0.1		430		867		<0.1
SW-1	26-Oct-87	Utah International	206	18.9	7.9	1260	7.0																																								
SW-1	13-Nov-87	Utah International	390	7.5	8	1510	11.3																																								
SW-1	8-Dec-87	Utah International	449	2.0	6.7	950	13.8	554	89	86	9	3	376	<5	150	8	0.2	0.17	<0.001	0.15	0.03	0.007	0.02	<0.01	1.8		<0.2	<0.02	0.06		<0.05	<0.02	<0.002	<0.01	<1	68	0.04		0.20	<0.02	<0.1		376		575		<0.1
SW-1	15-Jan-88	Utah International	3460	0.0	7.9	735	10.3																																								
SW-1	20-Feb-88	Utah International	3190	3.9	7.8	770	8.4																											0.01													
SW-1	17-Mar-88	Utah International	3280	1.5	7.8	920	9.8	600	78	67	9	2	343	<5	181	7	0.2	0.28	<0.001	0.15	<0.02	<0.005	<0.01	<0.01	2.89		<0.2	<0.02	0.06		<0.05	<0.02	<0.001		<1	118	0.07		0.20	<0.01	<0.1		343		470		0.1
SW-1	27-May-05	Petersen	1830	21.9	8.20	813	7.21	578	72.4	82.1	10.4	2.33	299	<5	170	6	0.20	<0.03	<0.010	0.179	0.07	<0.001	<0.001	<0.01	0.77	<0.03	<0.2	<0.01	0.034	0.005	<0.005	<0.001	<0.02	0.005	<2		<0.1					<0.05	303		519	57.9	
SW-1	25-Sep-05	Petersen	161	12.2	7.9	1962	7.58	1293	146	160	37.9	3.78	609.61	<5.	521	14	0.21	<0.03	<0.01	0.073	0.09	<0.001	<0.001	0.01	<0.05	<0.03	<0.2	<0.01	<0.002	0.043	<0.005	<0.001	<0.02	<0.004	<2.		0.1	<0.02	<0.05	<0.05	<0.05	<0.05	500		1023	4.21	<0.1
SW-1	3-Nov-05	Petersen	893	8.4	8.24	1551	8.09	1085	124	136	27.4	5.46	560.84	<5.	453	14	0.15	<0.03	<0.01	0.12	0.08	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.011	<0.005	0.002		<0.004	<2.		<0.1					<0.05	460		870	25.1	<0.1
SW-1	31-Mar-06	Petersen	2770	10	8.89	846	8.32	530	77.2	70.2	9.31	2.65	416.97	18.33	154	7	0.2	<0.03	<0.01	0.145	0.04	<0.001	<0.001	<0.01	4.63	<0.03	<0.2	<0.01	0.071	0.007	<0.005	0.001		<0.004	<2.		<0.1		0.06	<0.05	<0.05		353		482	241	0.4
SW-1	30-May-06	Petersen	158	19.2	8.53	1544	7.22	815	104	150	35	4.27	520.6	<5.	485	19	0.32	<0.03	<0.01	0.043	0.1	<0.001	<0.001	<0.01	0.47	<0.03	<0.2	<0.01	0.026	0.002	<0.005	0.001	<0.02	<0.004	<2.	8	<0.1		<0.05	<0.05	<0.05	<0.05	427		877	6.47	<0.1
SW-1	7-Sep-06	Petersen	115	14.3	8.44	1579	7.93	1292	121.76	168.37	46.32	7.47	542.55	<5.	592	29	0.33	<0.03	<0.01	0.055	0.1	<0.001	<0.001	<0.01	0.52	<0.03	<0.2	<0.01	0.016	0.009	<0.005	<0.001	<0.02	<0.004	<2.	21	<0.1		<0.05	<0.05	<0.05		445		997	12.1	<0.1
SW-1	30-Dec-06	Petersen	300	0.1	8.76	738	11.2	442	78.38	59.23	7.04	1.7	402.34	<5.	95	4	0.16	<0.03	<0.01	0.199	0.02	<0.001	<0.001	<0.01	0.79	<0.03	<0.2	<0.01	0.025	0.012	<0.005	<0.001	<0.02	<0.004	<2.	27	<0.1	0.11				<0.05	330		440	27.4	<0.1
SW-1	29-Mar-07	Petersen	172	1.7	8.41	1592	10.99	1238	139	160	36.4	4.13	675.45	<5.	515	21	0.51	<0.03	<0.01	0.12	0.08	<0.001	<0.001	<0.01	0.56	<0.03	<0.2	<0.01	0.067	0.061	<0.005	0.002	<0.02	<0.004	<2.	6	<0.1		<0.05	<0.05	<0.05	<0.05	554		1006	8.51	<0.1
SW-2	7-Jul-87	Utah International	36	11.3	8.20	2490	8.4																																								
SW-2	10-Aug-87	Utah International	45	28.2	8.45	2440	6.3																																								
SW-2	14-Sep-87	Utah International	54	6.8	8.50	1950	9.4	1604	93	211	81	6	382	<5	700	27	0.5	<0.05	<0.001	0.020	0.17	<0.005	<0.01	<0.01	0.13		<0.2	<0.02	0.02		<0.05	<0.02	<0.001	<0.01	<1	<2	<0.02		<0.02	<0.01	<0.1		382		1098		<0.1
SW-2	29-Oct-87	Utah International	139	15.2	8.2	1910	8.8																				<0.2																				
SW-2	17-Nov-87	Utah International	---	2.1	8.3	1925	9.1	1474	113	194	58	7	400	<5	796	22	0.3	1.47	0.002	0.050	0.13	<0.005	<0.01	<0.01	10.1		<0.2	<0.02	0.18		<0.05	0.02	<0.002	0.01	<1	484	0.04		0.22	0.02	<0.1		400		1078		0.7
SW-2	16-Dec-87	Utah International	99	0.5	7.9	1030	11.7	674	86	92	24	3	332	<5	239	8	0.2	0.35	<0.001	0.130	0.03	<0.005	<0.01	<0.01	3.4		<0.2	<0.02	0.06		<0.05	<0.02	<0.001	<0.01	<1	88	0.02		0.22	<0.01	<0.1		332		592		<0.1
SW-2	13-Jan-88	Utah International	1975	0.0	9.1	1500	8.7	1046	112	130	41	4	364	<5	482	16	0.2	0.14	<0.001	0.130	0.08	<0.005	<0.01	<0.01	2.08		<0.2	<0.02	0.08		<0.05	<0.02	<0.001	<0.01	<1	82	0.05		0.13	<0.01	<0.1		364		813		<0.1
SW-2	11-Feb-88	Utah International	6283	0.0	8.3	1270	11.7	876	106	104	29	5	296	<5	428	10	0.3	3.81	0.001	0.150	0.07	<0.005	<0.01	0.01	16		<0.2	<0.02	0.33		<0.05	0.03	<0.001	0.01	<1	3272	0.07		0.12	<0.01	<0.1		296		691		0.5
SW-2	17-Mar-88	Utah International	3590	7.0	8.0	1215	9.5	624	75	73	15	2	318	<5	226	8	0.2	1.77	0.002	0.160	<0.02	<0.005	0.01	0.01	35.5		<0.2	<0.02	0.3		<0.05	<0.02	<0.001	0.02	<1	1168	0.17		0.17	<0.01	<0.1		318		487		2.5
SW-2	27-May-05	Petersen	934	15.8	8.4	1120	8.47	853	87.5	116	42	3.15	360	<5	353	12	0.22	<0.03	<0.010	0.155	0.10	<0.001	0.001	<0.01	16	<0.03	<0.2	<0.01	0.28	0.018	<0.005	0.001	<0.02	<0.004	<2		<0.1					0.88	360		696	>1,000	
SW-2	27-May-05	Petersen	934	15.8	8.35	1120	8.47	853	87.5	116	42	3.15	438.92	<5.	353	12	0.22	<0.03	<0.01	0.155	0.1	<0.001	0.001	<0.01	16	<0.03	<0.2	<0.01	0.28	0.018	<0.005	0.001	<0.02	<0.004	<2.		<0.1					0.88	360	<5.	696	1000	
SW-2	25-Sep-05	Petersen	32	6.1	8.22	1926	8.24	1625	112	212	94.2	5.24	439	<5	<1	22	0.18	<0.03	<0.010	0.037	0.22	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	0.049	<0.005	<0.001	<0.02	0.053	<2		0.2	<0.02	<0.05	<0.05		<0.05	439		1153	4.75	<0.1
SW-2	25-Sep-05	Petersen	32	6.1	8.22	1926	8.24	1625	112	212	94.2	5.24	535.24	<5.	<1.	22	0.18	<0.03	<0.01	0.037	0.22	<0.001	<0.001	<0.01	<0.05	<0.03	<0.200:	<0.01	<0.002	0.049	<0.005	<0.001	<0.02	0.053	<2.		0.2	<0.02	<0.05	<0.05	<0.05	<0.05	439		1153	4.75	<0.1
SW-2	3-Nov-05	Petersen	430	5.9	8.09	1814	7.82	1513	127	183	58.6	7.04	505.97	<5.	821	16	0.17	<0.03	<0.01	0.054	0.18	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.048	<0.005	0.001		<0.004	<2.		<0.1					<0.05	415		1071	7.18	<0.1
SW-2	30-May-06	Petersen	51	8.5	8.69	1855	8.93	1156	113	186	80.8	5.77	508.41	<5.	763	24	0.44	<0.03	<0.01	0.034	0.2	<0.001	<0.001	<0.01	0.12	<0.03	<0.2	<0.01	0.024	0.016	<0.005	0.001	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	417		1048	2.31	<0.1
SW-2	7-Sep-06	Petersen	5.38	14.7	8	1959	7.99	1725	123.05	207.19	107.07	6.84	519.39	<5.	892	28	0.49	<0.03	<0.01	0.026	0.24	<0.001	<0.001	<0.01	0.07	<0.03	<0.2	<0.01	0.019	0.014	<0.005	<0.001	<0.02	<0.004	<2.	6	<0.1		<0.05	<0.05	<0.05		426		1160	3.26	<0.1
SW-2	29-Mar-07	Petersen	21.3	1.3	8.35	1847	9.65	1511	115	187	93.8	5.46	536.45	<5.	761	24	0.65	<0.03	<0.01	0.044	0.2	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.059	0.059	<0.005	<0.001	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	440		1057	1.37	<0.1
SW-3	1-Jul-87	Utah International	206	15.7	8.4	1210	8.20																																								
SW-3	3-Aug-87	Utah International	184	22.1	8.5	1110	6.20																																								
SW-3	4-Sep-87	Utah International	126	14.9	8.45	1450	8.40	1014	99	147	32	5	368	<5	438	17	0.4	<0.05	<0.001	0.03	0.08	<0.005	<0.01	<0.01	0.2		<0.2	<0.02	<0.01		<0.05	<0.02	<0.001	<0.01	<1	16	0.02		0.30	0.01	0		368		850		<0.1
SW-3	26-Oct-87	Utah International	233	18.5	8.1	1350	8.2																																								
SW-3	13-Nov-87	Utah International	350	7.5	8.3	1525	9.4																																								
SW-3	16-Dec-87	Utah International	54	0.2	7.9	860	11.0	518	63	69	9	3	300	<5	130	6	0.2	0.45	<0.001	0.16	<0.01	<0.005	<0.01	<0.01	5		<0.2	<0.02	0.08		<0.05	<0.02	<0.001	<0.01	<1	158	0.04		0.22	<0.01	0		300		440		<0.1
SW-3	9-Jan-88	Utah International	449	0.9	8.0	800	10.1																																								
SW-3	20-Feb-88	Utah International	3366	2.1	8.0	780	9.9																																								
SW-3	17-Mar-88	Utah International	3590	5.0	7.9	795	8.3	424	63	49	7	2	286	<5	111	5	0.2	3.05	0.004	0.30	<0.02	<0.005	0.01	0.01	56.8		<0.2	<0.02	0.71		<0.05	0.02	<0.001	0.03	<1	2836	0.10		0.12	<0.01	0		286		358		13.8
SW-3	27-May-05	Petersen	1854	12.1	8.26	874	9.2																																							19.6	
SW-3	27-May-05	Petersen	1850	12.1	8.26	874	9.22	644	84.1	92.5	12.4	2.47	410.88	<5.	210	7	0.19	<0.03	<0.01	0.17	0.05	<0.001	<0.001	<0.01	0.4	<0.03	<0.2	<0.01	0.033	<0.002	<0.005	0.001	<0.02	<0.004	2		<0.1					0.05	337	<5.	591	19.6	
SW-3	25-Sep-05	Petersen	119	9.8	8.12	1665	836	1281	110	167	35.7	0.86	477.93	<5.	<1.	16	0.21	<0.03	<0.01	0.01	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004	<2.		0.2	<0.02	<0.05	<0.05	<0.05	<0.05	392		962	7.91	<0.1
SW-3	3-Nov-05	Petersen	320	9.6	8.33	1519	7.83	1144	125	147	30.1	5.22	507.19	<5.	538	14	0.07	<0.03	<0.01	0.096	0.08	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.008	<0.005	0.001		<0.004	<2.		<0.1					<0.05	416		917	4.06	<0.1
SW-3	31-Mar-06	Petersen	2690	9.5	8.94	878	7.44	554	79.3	74.1	9.94	2.63	348	<5	170	7	0.20	0.05	<0.010	0.143	0.04	<0.001	<0.001	<0.01	2.43	<0.03	<0.2	<0.01	0.049	0.010	<0.005	0.001	<0.02	0.008	<2		0.1	0.3	0.06	<0.05	<0.05		348		503	144	0.2
SW-3	31-Mar-06	Petersen	2692	9.5	8.94	878	7.44	554	79.3	74.1	9.94	2.63	424.29	<5.	170	7	0.2	0.05	<0.01	0.143	0.04	<0.001	<0.001	<0.01	2.43	<0.03	<0.2	<0.01	0.049	0.01	<0.005	0.001		0.008	<2.		0.1		0.06	<0.05	<0.05		348		503	144	0.2
SW-3	30-May-06	Petersen	166	12.4	8.64	1563	8.09	1255	100	156	33.4	4.42	491.34	<5.	554	18	0.3	<0.03	<0.01	0.059	0.1	<0.001	<0.001	<0.01	0.24	<0.03	<0.2	<0.01	0.011	0.002	<0.005	0.002	<0.02	0.006	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	403		892	2.16	<0.1
SW-3	7-Sep-06	Petersen	109	13.7	8.37	1465	8.11	1257	103.24	170.99	37.73	5.28	436.48	<5.	594	21	0.27	<0.03	<0.01	0.028	0.09	<0.001	<0.001	<0.01	0.2	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	13	<0.1		<0.05	<0.05	<0.05		358		962	6.73	<0.1
SW-3	21-Dec-06	Petersen	409	0	8.72	819	12.1	570	88	72.31	9.39	2.12	432.82	<5.	146	6	0.18	<0.03	<0.01	0.202	0.03	<0.001	<0.001	<0.01	0.46	<0.03	<0.2	<0.01	0.021	0.011	<0.005	<0.001	<0.02	<0.004	<2.	24	<0.1		0.1	<0.05	<0.05		355		518	13.3	<0.1
SW-3	29-Mar-07	Petersen	191	0.5	8.63	1503	10.8	1167	124	155	33.3	4.12	562.06	<5.	525	19	0.43	<0.03	<0.01	0.091	0.07	<0.001	<0.001	<0.01	0.23	<0.03	<0.2	<0.01	0.051	0.044	<0.005	0.002	<0.02	<0.004	<2.	<5.	<0.1		<0.05	<0.05	<0.05	<0.05	461		948	7.07	<0.1
Swapp Hollow																																															
SW-7	2-Jul-87	Utah International	Dry																																												
SW-7	4-Aug-87	Utah International	Dry																																												
SW-7	6-Sep-87	Utah International	Dry																																												
SW-7	27-Oct-87	Utah International	Dry																																												
SW-7	15-Nov-87	Utah International	Dry																																												
SW-7	4-Dec-87	Utah International	Dry																																												
SW-7	5-Jan-88	Utah International	Dry																																												
SW-7	16-Feb-88	Utah International	Dry																																												
SW-7	18-Mar-88	Utah International	Dry																																												
SW-7	4-Nov-05	Petersen	Dry																																												
SW-7	7-Sep-06	Petersen	Dry																																												
SW-7	21-Dec-06	Petersen	Dry																																												
SW-7	28-Mar-07	Petersen	Dry																																												
SW-8	6-Jul-87	Utah International	36	10.3	8.5	490	8.65	286	37	38	7.00	1	228	<5	31	10	0.3	0.07	<0.001	0.22	<0.01	<0.005	<0.01	<0.01	0.19				0.01		<0.05	<0.02	0.001	<0.01	<1	20	<0.02		<0.02	<0.01	0		228		248		<0.1
SW-8	6-Aug-87	Utah International	22	14.1	8.4	490	7.4	262	44	36	5.00	1	241	<5	14	3	0.5	0.21	<0.001	0.21	<0.02	<0.005	<0.01	<0.01	1.8				0.04		<0.05	<0.02	0.001	<0.01	<1	170	0.02		<0.02	<0.02	0		241		258		<0.1
SW-8	17-Sep-87	Utah International	40	7.1	8.5	480	8.2	245	51	40	4.00	1	232	<5	21	3	0.4	<0.05	<0.001	0.21	<0.02	<0.005	<0.01	0.01	0.44				0.01		<0.05	<0.02	<0.001	<0.01	<1	28	0.05		0.03	<0.01	0		232		292		<0.1
SW-8	28-Oct-87	Utah International	36	18.2	8.2	430	6.6	256	48	38	5.00	1	241	<5	27	4	0.7	0.11	<0.001	0.25	<0.02	<0.005	<0.01	<0.01	0.38				0.02		<0.05	<0.02	<0.001	0.01	<1	22	<0.02		<0.02	<0.01	0		241		276		<0.2
SW-8	17-Nov-87	Utah International	40	9	8.2	525	9.3	302	49	36	4.00	1	243	<5	29	3	0.2	0.55	<0.001	0.22	<0.02	<0.005	<0.01	<0.01	2.77				0.05		<0.05	<0.02	<0.002	<0.01	<1	178	<0.02		0.03	<0.01	0		243		270		<0.2
SW-8	15-Dec-87	Utah International	13	0.8	7.7	585	8	338	57	40	6.00	1	300	<5	33	7	0.2	0.45	<0.001	0.24	<0.02	<0.005	<0.01	<0.01	3.8				0.06		<0.05	<0.02	<0.001	0.04	<1	116	0.04		0.1	<0.01	0		300		307		<0.1
SW-8	13-Jan-88	Utah International	40	0.3	8.2	550	9.3	306	47	38	4.00	1	250	<5	33	7	0.2	0.32	<0.001	0.24	<0.02	<0.005	<0.01	<0.01	2.83				0.06		<0.05	<0.02	<0.001	<0.01	<1	148	0.1		0.06	<0.01	0		250		273		0.2
SW-8	17-Feb-88	Utah International	49	-0.3	8.1	565	9.1	324	61	40	4.00	1	273	<5	31	3	0.2	2.01	<0.001	0.23	<0.02	<0.005	<0.01	<0.01	4.95				0.1		<0.05	<0.02	0.001	0.01	1	238	0.2		0.06	<0.01	0		273		317		0.1
SW-8	21-Mar-88	Utah International	49	1.5	8.2	610	8.6	290	56	38	4.00	1	263	<5	29	<1	0.2	2.45	0.002	0.43	<0.02	<0.005	0.01	<0.01	30.8				0.46		<0.05	<0.02	0.001	0.03	1	2940	0.03		0.18	0.18	0		263		296		4
SW-8	18-Jun-05	Petersen	290	17.5	8.38	566	6.78	366	59.2	44.1	6.75	1.03	368.2	<5.	34	5	0.06	<0.03	<0.01	0.221	0.02	<0.001	0.001	<0.01		<0.03	<0.2	<0.01		0.002	<0.005	<0.001	<0.02	<0.004	<2.		<0.1				<0.05	0.43	278		329	1000	
SW-8	12-Aug-05	Petersen	130	17.8	8.41	493	7.35	274	51.4	37.7	6.63	1.03	243	<5	38	4	0.13	<0.03	<0.010	0.219	0.02	<0.001	<0.001	<0.01	0.66	<0.03	<0.2	<0.01	0.016	<0.002	<0.005	<0.001	<0.02	<0.004	<2		<0.1		0.08	<0.05		<0.05	243		284	12.9	
SW-8	24-Sep-05	Petersen	69	14.0	8.36	536	6.71	298	48.4	38.9	6.09	0.99	250	<5	33	4	0.20	<0.03	<0.010	0.195	<0.02	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	<0.001	<0.02	<0.004	---		<0.1	0.03	<0.05	<0.05		<0.05	250		281	63	<0.1
SW-8	24-Sep-05	Petersen	69	14	8.36	536	6.71	298	48.4	38.9	6.09	0.99	304.8	<5.	33	4	0.2	<0.03	<0.01	0.195	0.02	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1	0.03	<0.05	<0.05	<0.05	<0.05	250		281	63	<0.1

	Date	Data Source	discharge (gpm)	T (°C)	pH	Cond. (µS/cm)	D.O. (mg/L)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	HCO3 (mg/L)	CO3 (mg/L)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	Al (mg/L)	As (mg/L)	Ba (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (t) (mg/L)	Fe (d) (mg/L)	Hg (µg/L)	Pb (mg/L)	Mn (t) (mg/L)	Md (d) (mg/L)	Mb (mg/L)	Ni (mg/L)	Se (mg/L)	Zn (mg/L)	Oil&G (mg/L)	TSS (mg/L)	NH3 (mg/L)	NO3+NO2 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	O-PO4 (mg/L)	T. Phos (mg/L)	Alkalinity (mg/L)	Acd. (mg/L)	Hard. (mg/L)	Turb. NTU	Set Sol (mg/L)
SW-8	4-Nov-05	Petersen	71	6.2	8.63	555	7.99	321	59.8	39	7.95	1.04	265	<5	49	4	0.14	<0.03	<0.010	0.206	0.01	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.006	<0.005	<0.001	<0.02	<0.004	<2		<0.1	0.07				<0.05	265		310	16.4	<0.1
SW-8	30-May-06	Petersen	35	23.2	8.89	586	6.71	350	44.7	39.4	11.7	1.22	274.32	<5.	69	7	0.22	<0.03	<0.01	0.181	0.03	<0.001	<0.001	<0.01	0.35	<0.03	<0.2	<0.01	0.011	<0.002	<0.005	0.001	<0.02	<0.004	<2.	26	<0.1		<0.05	<0.05	<0.05	<0.05	225		274	9.45	0.1
SW-8	7-Sep-06	Petersen	50.7	12.5	8.01	576	7.76	331	47.48	39.92	17.75	1.75	287.73	<5.	89	7	0.15	<0.03	<0.01	0.167	0.02	<0.001	<0.001	<0.01	13.76	<0.03	<0.2	<0.01	0.286	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	657	<0.1		0.06	<0.05	<0.05		239		293	608	0.9
SW-8	20-Dec-06	Petersen	32.1	10.1	8.84	553	10.8	337	64.07	39.43	8.45	0.91	335.28	<5.	46	5	0.19	<0.03	<0.01	0.205	0.64	<0.001	<0.001	<0.01	0.81	<0.03	<0.2	<0.01	0.024	0.007	<0.005	<0.001	<0.02	<0.004	<2.	49	<0.1	<0.05				0.06	275		322	21.1	<0.1
SW-8	29-Mar-07	Petersen	33.6	2.2	8.68	524	8.53	324	59.6	36.4	9.2	0.96	321.87	<5.	49	5	0.18	<0.03	<0.01	0.192	0.01	<0.001	<0.001	<0.01	1.39	<0.03	<0.2	<0.01	0.026	0.006	<0.005	<0.001	<0.02	<0.004	<2.	95	<0.1		<0.05	<0.05	<0.05	<0.05	264		299	54	<0.1
Sink Valley																																															
SW-6	17-Sep-87	Utah International	Dry	11.0	8.70	860	5.8	556	34	98	29.00	11	292	40	140	18	0.8	0.45	0.004	0.05	0.21	<0.005	<0.01	0.01	0.71		<0.2		0.02		<0.05	<0.02	<0.001	<0.01	<1	28	0.07		0.02	<0.01	0		332		487		<0.1
SW-6	15-Dec-87	Utah International	Dry	0.8	8.3	1840	8.2	1212	51	209	73.00	9	602	37	418	41	0.4	0.19	0.002	0.06	0.21	<0.005	<0.01	<0.01	0.3		<0.2		0.01		<0.05	<0.02	<0.001	<0.01	<1	12	0.02		<0.02	<0.01	0		639		984		<0.1
SW-6	11-Mar-88	Utah International	Dry	1.5	8.4	1600	6.9	992	45	182	63.00	5	590	<5	344	34	0.4	0.21	0.002	0.04	0.16	<0.005	<0.01	<0.01	0.34		<0.2		0.03		<0.05	<0.02	<0.001	<0.01	1	12	0.04		0.04	<0.01	0		590		859		<0.1
SW-6	17-Jun-05	Petersen	Dry																																												
SW-6	30-Mar-06	Petersen	58	13.8	8.91	1352	5.98	1028	58.9	161	31.30	12.5	436	47	361	22	0.27	<0.03	<0.010	0.089	0.17	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	0.002	<0.02	0.008	<2		<0.1	0.2	<0.05	<0.05	<0.05		483		810	3.13	<0.1
SW-6	16-May-06	Petersen	Dry																																												
SW-6	29-May-06	Petersen	Dry																																												
SW-6	7-Sep-06	Petersen	Dry																																												
SW-6	30-Dec-06	Petersen	Dry																																												
SW-9	29-Oct-87	Utah International	9	11.1	8.6	---	9.3	880	20	128	106.00	6	392	53	280	33	2.2	5.1	0.002	0.15	0.3	<0.005	<0.01	<0.01	23.8				0.31		<0.05	0.02	<0.001	0.03	<1	1140	0.03		0.03	0.01	0.1		445		575		12.5
SW-9	17-Nov-87	Utah International	18	2.1	8.4	1390	9.2	888	23	163	86	4	563	37	274	30	0.4	0.57	<0.001	0.06	0.24	<0.005	<0.01	<0.01	2.97				0.05		<0.05	<0.02	<0.002	<0.01	<1	110	0.02		0.04	<0.01	0		600		726		<0.2
SW-9	16-Feb-88	Utah International	763	-0.2	8.1	955	10.0	584	38	107	30	7	354	<5	165	15	0.3	2.84	0.002	0.16	0.09	<0.005	<0.01	<0.01	21.5				0.46		<0.05	<0.02	<0.001	0.02	1	1006	0.04		0.02	0.01	0.2		354		534		1.5
SW-9	24-Mar-88	Utah International	1.3	14.2	8.5	3820	7.7	1556	39	207	232.00	7	798	50	591	52	0.9	1.62	0.003	0.11	0.55	<0.005	<0.01	0.01	18.5				0.22		<0.05	<0.02	<0.001	0.04	1	784	<0.02		0.03	0.01	0		848		946		2.7
SW-9	17-Jun-05	Petersen	Dry																																												
SW-9	24-Sep-05	Petersen	Dry																																												
SW-9	3-Nov-05	Petersen	Dry																																												
SW-9	30-Mar-06	Petersen	10.6	12	8.74	1715	6.63	1270	53.7	164	122	9.88	546.21	83.33	520	41	0.48	<0.03	<0.01	0.097	0.3	<0.001	<0.001	<0.01	0.36	<0.03	<0.2	<0.01	0.034	0.01	<0.005	0.001		<0.004	<2.		<0.1		<0.05	<0.05	<0.05		498		809	12.7	<0.1
SW-9	29-May-06	Petersen	Dry																																												
SW-9	18-Jun-06	Petersen	Dry																																												
SW-9	20-Dec-06	Petersen	Dry																																												
SW-9	29-Mar-07	Petersen	Dry																																												
Robinson Creek																																															
SW-4	2-Jul-87	Utah International	Dry																																												
SW-4	4-Aug-87	Utah International	Dry																																												
SW-4	6-Sep-87	Utah International	Dry																																												
SW-4	27-Oct-87	Utah International	Dry																																												
SW-4	15-Nov-87	Utah International	Dry																																												
SW-4	4-Dec-87	Utah International	Dry																																												
SW-4	5-Jan-88	Utah International	Dry																																												
SW-4	16-Feb-88	Utah International	Dry																																												
SW-4	18-Mar-88	Utah International	Dry																																												
SW-4	27-May-05	Petersen	539	19.1	8.4	453	7.25	283	47.7	35.8	2.23	0.6	297.49	<5.	18	2	0.14	<0.03	<0.01	0.261	0.01	<0.001	<0.001	<0.01	25.5	<0.03	<0.2	<0.01	0.441	<0.002	<0.005	<0.001	<0.02	<0.004	<2.		<0.1					1.29	244	<5.	267	1000	
SW-4	4-Nov-05	Petersen	Dry																																												
SW-4	16-May-06	Petersen	Dry																																												
SW-4	8-Sep-06	Petersen	Dry																																												
SW-4	21-Dec-06	Petersen	Dry																																												
SW-4	28-Mar-07	Petersen	Dry																																												
SW-5	10-Aug-87	Utah International	13.5	27.5	8.65	1680	5.9	984	39	160	69	7	433	49	403	24	0.8	0.42	0.002	0.05	0.17	<0.005	<0.01	<0.01	3.19		<0.2	<0.02	0.07		<0.05	<0.02	0.001	<0.01	<1	226	0.02		<0.02	<0.02	0		482		754		0.3
SW-5	14-Sep-87	Utah International	13.5	9.0	8.65	1480	8.4	1008	49	162	61	5	444	12	368	3	0.6	<0.05	<0.001	0.03	0.11	<0.005	<0.01	<0.01	0.06		<0.2	<0.02	0.02		<0.05	<0.02	<0.001	<0.01	<1	<2	<0.02		0.02	<0.01	0		456		787		<0.1
SW-5	29-Oct-87	Utah International	58	12.5	8.10	1070	8.5	666	42	105	49	4	290	<5	298	19	1	3.83	0.002	0.06	0.08	<0.005	<0.01	0.01	12		<0.2	<0.02	0.14		<0.05	<0.02	<0.001	0.03	<1	584	<0.02		0.02	<0.01	0		290		536		0.6
SW-5	18-Nov-87	Utah International	Puddle	1.2	8.00	1305	9.2	886	54	129	58	4	402	16	350	21	0.4	1.55	<0.001	0.04	0.06	<0.005	<0.01	<0.01	9.1		<0.2	<0.02	0.17		<0.05	0.02	<0.002	0.02	<1	466	0.03		0.03	<0.01	0		418		664		0.3
SW-5	11-Feb-88	Utah International	36	0.0	8.00	665	6.9	446	46	59	23	6	204	<5	163	10	0.3	0.44	0.001	0.04	0.02	<0.005	<0.01	0.01	1.97		<0.2	<0.02	0.04		<0.05	0.02	<0.001	<0.01	1	92	0.03		0.06	<0.01	0.2		204		357		<0.1
SW-5	17-Mar-88	Utah International	4.5	9.1	8.20	1670	6.4	876	54	104	55	5	378	<5	344	21	0.4	1.3	0.002	0.06	0.06	<0.005	0.01	<0.01	10.1		<0.2	<0.02	0.14		<0.05	<0.02	0.001	0.01	<1	714	0.07		0.08	<0.01	0		378		561		1.6
SW-5	17-Mar-88	Utah International	4.5	9.1	8.2	1670	6.4																																								
SW-5	27-May-05	Petersen	410	18	8.46	721	7.23	469	63	60.6	20.2	1.84	404.78	8.3	144	6	0.19	<0.03	<0.01	0.18	0.04	<0.001	<0.001	<0.01	45.6	<0.03	<0.2	<0.01	0.825	<0.002	<0.005	<0.001	<0.02	<0.004	3		<0.1					2.38	338	<5.	407	1000	
SW-5	25-Sep-05	Petersen	Dry																																												
SW-5	30-May-06	Petersen	5.37	11.4	8.88	1543	8.67	1205	69.8	148	85.2	5.67	513.29	<5.	503	26	0.62	<0.03	<0.01	0.042	0.16	<0.001	<0.001	<0.01	0.21	<0.03	<0.2	<0.01	0.044	0.007	<0.005	0.001	<0.02	<0.004	<2.	32	<0.1		<0.05	<0.05	<0.05	<0.05	421		784	3.3	0.1
SW-5	7-Sep-06	Petersen	4.96	13.7	8.36	1394	7.89	1081	59.04	143.68	83.11	6.02	455.99	<5.	474	27	0.6	<0.03	<0.01	0.035	0.16	<0.001	<0.001	<0.01	0.37	<0.03	<0.2	<0.01	0.014	0.006	<0.005	<0.001	<0.02	<0.004	<2.	26	<0.1		<0.05	<0.05	<0.05		405		739	13.4	<0.1
SW-5	30-Dec-06	Petersen	Dry																																												
SW-5	29-Mar-07	Petersen	Dry																																												
SW-101	27-May-05	Petersen	734	17.7	8.41	495	8.03	309	54.2	36	4.67	1.02	345	8	45	4	0.17	<0.03	<0.010	0.182	0.02	<0.001	<0.001	<0.01	52.7	<0.03	<0.2	<0.01	0.882	<0.002	<0.005	<0.001	<0.02	<0.004	2		<0.1					2.94	353		284	>1000	
SW-101	27-May-05	Petersen	734	17.7	8.41	495	8.03	309	54.2	36	4.67	1.02	420.63	13.33	45	4	0.17	<0.03	<0.01	0.182	0.02	<0.001	<0.001	<0.01	52.7	<0.03	<0.2	<0.01	0.882	<0.002	<0.005	<0.001	<0.02	<0.004	2		<0.1					2.94	353	<5.	284	1000	
SW-101	31-Mar-06	Petersen	20.8	8.6	8.62	3120	7.77	3013	356	148	282	16.4	820	<5	1899	47	1.23	0.19	<0.010	0.061	0.19	<0.001	<0.001	<0.01	332	0.06	<0.2	<0.01	4.16	0.002	0.005	0.003	<0.02	0.01	<2		<0.1	2.0	1.85	<0.05	<0.05		820		1498	#####	82
SW-101	21-May-06	Petersen	Dry																																												
SW-101	25-Sep-05	Petersen	Dry																																												
SW-101	3-Nov-05	Petersen	Dry																																												
SW-101	21-Dec-06	Petersen	Dry																																												
SW-101	30-Dec-06	Petersen	Dry																																												
Water Canyon																																															
RID-1 (irrigation)	4-Nov-05	Petersen	64.7	1	8.73	376	9.29	250	47.5	36.8	1.76	0.87	290.17	<5	16	2	0.09	<0.03	<0.01	0.248	<0.01	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		<0.002	<0.005	<0.001		<0.004	<2.		<0.1					<0.05	238		270	13.1	<0.1
RID-1 (irrigation)	29-May-06	Petersen	48.6	10.4	8.89	412	8.85	265	36.3	36.1	1.9	0.88	267.01	<5	17	3	0.14	<0.03	<0.01	0.217	0.01	<0.001	<0.001	<0.01	1.3	<0.03	<0.2	<0.01	0.022	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	64	<0.1		<0.05	<0.05	<0.05	0.07	221		239	42.5	0.1
RID-1 (irrigation)	21-Dec-06	Petersen	6.2	0.1	8.87	470	11.8	273	54.32	35.81	1.85	0.9	295.05	18.3	19	2	0.13	<0.03	<0.01	0.246	<0.01	<0.001	<0.001	<0.01	3.29	<0.03	<0.2	<0.01	0.049	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	146	<0.1		<0.05	<0.05	<0.05		253		283	161	<0.1
RID-1 (irrigation)	28-Mar-07	Petersen	12.8	1.5	8.83	412	7.82	254	43.7	32.6	1.69	0.64	271.88	20	17	2	0.12	<0.03	<0.01	0.208	<0.01	<0.001	<0.001	<0.01	16.9	<0.03	<0.2	<0.01	0.556	<0.002	<0.005	<0.001	<0.02	<0.004	<2.	1775	<0.1		<0.05	<0.05	<0.05	1.63	234		243	890	2.5
Other Drainage																																															
SW-10	9-Jul-87	Utah International	4.5	13.8	8.4	---	8.1	390	59	45	25	4	264	<5	66	16	0.6	2.65	0.001	0.19	0.03	<0.005	<0.01	0.01	26.3				0.33		<0.05	0.02	0.004	0.03	<1	1084	0.07		0.45	0.01	0		264		332		5.6
SW-10	10-Aug-87	Utah International	1.8	28.9	8.85	520	7.9	270	31	37	24	3	159	33	56	14	0.6	0.19	<0.001	0.04	0.05	<0.005	<0.01	<0.01	0.21				<0.01		<0.05	<0.02	0.005	0.01	<1	8	<0.02		<0.02	<0.01	0		192		229		<0.1
SW-10	14-Sep-87	Utah International	4.5	14.9	8.65	525	7.7	316	41	40	13	3	218	<5	60	19	0.4	0.39	<0.001	0.05	0.03	<0.005	<0.01	0.01	0.84				0.01		<0.05	<0.02	0.003	0.01	<1	30	<0.02		0.03	<0.01	0		218		267		<0.1
SW-10	29-Oct-87	Utah International	18.0	10.1	8.2	450	10.2	266	34	33	22	2	171	8	60	13	0.9	2.35	<0.001	0.06	0.03	<0.005	<0.01	<0.01	2.71				0.03		<0.05	<0.02	0.002	0.02	2	114	<0.02		0.01	0.01	0		179		220		<0.2
SW-10	17-Nov-87	Utah International	13.5	3.0	8.0	540	9.1	10	<1	<1	<1	<1	2	<5	<2	<1	<0.1	<0.05	<0.001	0.01	<0.02	<0.005	<0.01	<0.01	<0.02				<0.01		<0.05	<0.02	<0.002	<0.01	<1	2	0.02		0.07	<0.01	0		2		<7		<0.2
SW-10	16-Dec-87	Utah International	9.0	0.1	7.6	735	10.4	408	48	45	30	3	270	<5	64	17	0.2	0.5	<0.001	0.08	0.03	<0.005	<0.01	0.01	2.81				0.05		<0.05	<0.02	0.003	0.01	<1	94	0.02		0.4	<0.01	0		270		305		<0.1
SW-10	13-Jan-88	Utah International	frozen	---	---	---	---																																								
SW-10	11-Feb-88	Utah International	13.5	0.6	8.1	325	9.8																																								
SW-10	11-Mar-88	Utah International	3.6	1.0	8.4	760	10.0	450	84	50	31	3	327	<5	86	17	0.2	0.19	<0.001	0.06	0.04	<0.005	<0.01	<0.01	0.82				0.01		<0.05	<0.02	0.003	0.1	<1	20	0.04		0.56	<0.01	0		327		415		<0.1
SW-10	17-Jun-05	Petersen	Dry																																												
SW-10	24-Sep-05	Petersen	Dry																																												
SW-10	3-Nov-05	Petersen	Dry																																												

Site	Date	Data Source	discharge (gpm)	T (°C)	pH	Cond. (µS/cm)	D.O. (mg/L)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	HCO3 (mg/L)	CO3 (mg/L)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	Al (mg/L)	As (mg/L)	Ba (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (t) (mg/L)	Fe (d) (mg/L)	Hg (µg/L)	Pb (mg/L)	Mn (t) (mg/L)	Md (d) (mg/L)	Mb (mg/L)	Ni (mg/L)	Se (mg/L)	Zn (mg/L)	Oil&G (mg/L)	TSS (mg/L)	NH3 (mg/L)	NO3+NO2 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	O-PO4 (mg/L)	T. Phos (mg/L)	Alkalinity (mg/L)	Acd. (mg/L)	Hard. (mg/L)	Turb. NTU	Set Sol (mg/L)
SP-8	18-Feb-88	Utah International	15.4	7.8		675																																									
SP-8	18-Mar-88	Utah International	12.2	10.1	7.4	725		438	77	50	6	2	324	<5	82	5	0.2	<0.05	<0.001	0.05	<0.02	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		<0.01	<0.05	<0.02	0.001	0.02			0.02		0.22	<0.01	<0.01				398		
SP-8	27-May-05	Petersen	17.6	10.3	7.89	642		456	73.6	54.5	7.44	1.37	328	<5	77	4	0.17	<0.03	<0.010	0.052	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.005			<0.1					<0.05	328		408	1.52	
SP-8	24-Sep-05	Petersen	9.1	9.6	7.27	704		426	83.7	54.5	6.87	1.60	338	<5	71	3	0.18	<0.03	<0.010	0.300	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1	0.07	<0.05	<0.05		<0.05	338		433		
SP-8	27-May-05	Petersen	17.6	10.3	7.89	642		456	73.6	54.5	7.44	1.37	399.9	<5.	77	4	0.17	<0.03	<0.01	0.052	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.005			<0.1					<0.05	328	<5.	408	1.52	
SP-8	24-Sep-05	Petersen	9.1	9.6	7.27	704		426	83.7	54.5	6.87	1.6	412.09	<5.	71	3	0.18	<0.03	<0.01	0.3	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1	0.07	<0.05	<0.05	<0.05	<0.05	338		433		
SP-8	4-Nov-05	Petersen	12.8	9.6	7.48	706		413	80.1	47.7	6.47	1.43	406	<5.	65	2	<0.05	0.05	<0.01	0.047	0.02	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		<0.002	<0.005	<0.001		<0.004			<0.1					<0.05	333		396		
SP-8	31-Mar-06	Petersen	20.3	9.3	7.1	716		407	79.7	49.4	6.55	1.47	335	<5	74	4	0.20	<0.03	<0.010	0.048	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.005			<0.1	0.3	0.05	<0.05	<0.05		335		402		
SP-8	31-Mar-06	Petersen	20.3	9.3	7.1	716		407	79.7	49.4	6.55	1.47	408.44	<5.	74	4	0.2	<0.03	<0.01	0.048	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001		0.005			<0.1		0.05	<0.05	<0.05		335		402		
SP-8	29-May-06	Petersen	14.3	10.5	7.75	701																																									
SP-8	29-May-06	Petersen	14.3	10.5	7.75	701		432	83.8	52.4	6.99	1.67	410.88	<5.	69	4	0.2	<0.03	<0.01	0.051	0.03	<0.001	<0.001	<0.01	0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	0.001	<0.02	0.006		5	<0.1		<0.05	<0.05	<0.05	<0.05	337		425		
SP-8	8-Sep-06	Petersen	18.6	9.9	7.42	692																																									
SP-8	30-Dec-06	Petersen	19.3	8.1	7.79	668		417	85.06	50.96	6.98	1.34	413.31	<5.	72	3	0.16	<0.03	<0.01	0.051	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004		<5	<0.1	0.06				<0.05	339		422	161	
SP-8	29-Mar-07	Petersen	19.6	9.4	7.5	696		433	81.8	51.4	7.02	1.38	413.31	<5.	75	4	0.17	<0.03	<0.01	0.054	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004		<5.	<0.1		0.09	<0.05	<0.05	<0.05	339		416	54	
Sorensen Spring	12-Aug-05	Petersen	0.05	13.8	7.11	651		395	80.6	49.4	7.05	1.57	401.12	<5.	73	3	0.1	<0.03	<0.01	0.045	0.03	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1		0.09	<0.05		<0.05	329		405		
Sorensen Spring	4-Nov-05	Petersen	0.061	9.4	7.43	681		397	79.2	48.5	6.87	1.39	326	<5	73	3	0.11	<0.03	<0.010	0.039	0.02	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		<0.002	<0.005	<0.001	<0.02	<0.004			<0.1	0.12				<0.05	326		297		
Sorensen Spring	31-Mar-06	Petersen	0	8.7	7.68	698		381	79	49.1	7.19	1.53	329	<5	66	4	0.18	<0.03	<0.010	0.04	0.03	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.009			<0.01	0.3	0.07	<0.05	<0.05		329		399		
Sorensen Spring	29-May-06	Petersen	0	12.1	7.01	694		435	78.2	49.2	6.96	1.74	403.56	<5.	65	4	0.21	<0.03	<0.01	0.04	0.03	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.002	<0.002	<0.005	<0.001	<0.02	0.008		<5.	<0.1		0.08	<0.05	<0.05	<0.05	331		398		
Sorensen Spring	8-Sep-06	Petersen	0	10.8	7.67	663		389	80.56	49.99	6.87	1.47	412.09	<5.	65	4	0.18	<0.03	<0.01	0.046	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.017		<5.	<0.1		0.13	<0.05	<0.05		338		407		
Sorensen Spring	20-Dec-06	Petersen	0	8.2	7.52	655		423	81.03	50.11	6.89	1.41	401.12	<5.	66	3	0.17	<0.03	<0.01	0.04	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.004		<5.	<0.1	0.09				<0.05	329		409	21.1	
Sorensen Spring	29-Mar-07	Petersen	0	8.4	7.49	678																																									
SP-14	31-Mar-06	Petersen	5.77	8.6	7.40	708																																									
SP-14	28-Mar-07	Petersen	4.24	4.7	7.82	673																																									
SP-14	16-May-06	Petersen	6.30	12.7	7.83	734																																									
SP-16	25-Jan-06	Petersen	0.997	4.3	7.59	695		443	83.1	53.1	6.79	1.6	402.34	<5.	82	4	0.2	<0.03	<0.01	0.041	0.02	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.005	0.005	<0.005	<0.001		0.007			<0.1		<0.05	<0.05	<0.05		330		426		
SP-16	29-May-06	Petersen	0.86	10.5	7.68	712		460	79.8	52.2	6.42	1.79	397.46	<5.	76	4	0.21	<0.03	<0.01	0.043	0.03	<0.001	<0.001	<0.01	0.08	<0.03	<0.2	<0.01	0.004	<0.002	<0.005	<0.001	<0.02	0.005		<5.	<0.1		<0.05	<0.05	<0.05	0.1	326		414		
SP-16	30-Dec-06	Petersen	0.35	5	7.86	672		437	84.93	53.7	6.62	1.45	414.53	<5.	82	4	0.16	<0.03	<0.01	0.04	0.02	<0.001	<0.001	<0.01	0.08	<0.03	<0.2	<0.01	0.005	0.005	<0.005	<0.001	<0.02	<0.004		<5.	<0.1	0.07				<0.05	340		433	161	
SP-16	29-Mar-07	Petersen	0.88	8.2	7.66	719		446	79.9	54.7	6.77	1.36	421.85	<5.	87	4	0.16	<0.03	<0.01	0.037	0.02	<0.001	<0.001	<0.01	0.11	<0.03	<0.2	<0.01	0.006	0.003	<0.005	<0.001	<0.02	<0.004		5	<0.1		0.05	<0.05	<0.05	<0.05	346		425	54	
SP-20	31-Mar-06	Petersen	5.95	9.3	7.66	696		381	79	49.1	7.19	1.53	401.12	<5.	66	4	0.18	<0.03	<0.01	0.04	0.03	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001		0.009		<0.1			0.07	<0.05	<0.05		329		399		
SP-20	16-May-06	Petersen	6.76	9.5	7.39	704																																									
SP-20	15-Jan-07	Petersen	4.49																																												
SP-20	29-Mar-07	Petersen	9.87																																												
SP-27	18-Jun-05	Petersen	0.5	16.6	8.94	4,580		6550	60.5	88.0	1760	1.33	1627	179	1856	162	1.95	0.24	<0.010	0.053	4.60	<0.001	<0.001	0.02		0.94	<0.2	<0.01	<0.002		0.077	0.027	0.07	0.026			<0.1	2.50				1.71	1807		513		
SP-27	24-Sep-05	Petersen	damp																																												
SP-27	3-Nov-05	Petersen	seep	7.8	8.52	4,640																																									
SP-27	21-Dec-06	Petersen	Dry																																												
SP-27	29-Mar-07	Petersen	Dry																																												
Wells																																															
Y-102	18-Sep-87	Utah International		10.5	7.2	850		488	81	66	9	2	314	<5	138	6	0.4	<0.05	<0.001	0.03	<0.02	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		<0.01	<0.05	<0.02	<0.001	0.01			0.03		0.21	<0.01	<0.01				473		
Y-102	9-Dec-87	Utah International		9.8	7.0	840		498	84	67	8	2	316	<5	142	7	0.2	<0.05	<0.001	0.03	0.02	0.009	<0.01	<0.01		<0.02	<0.2	<0.02		<0.01	<0.05	<0.02	<0.002	<0.01			<0.02		0.22	<0.02	<0.01				485		
Y-102	18-Mar-88	Utah International		9.9	7.4	850		522	86	58	9	2	329	<5	146	8	0.2	<0.05	<0.001	0.04	<0.02	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		<0.01	<0.05	<0.02	<0.001	0.02			0.04		0.23	<0.01	<0.01				453		
Y-102	27-May-05	Petersen	0.64	9.5	7.25	662		492	82.2	56.8	10.2	1.6	401.12	<5.	98	4	0.18	<0.03	<0.01	0.039	0.03	<0.001	<0.001	0.04	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1					<0.05	329	<5.	439	1.5	
Y-102	24-Sep-05	Petersen	0.62	9.4	7.29	715		455	81.4	49.8	10.1	2.14	341	<5	89	3	0.18	<0.03	<0.010	0.413	0.03	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1	0.08	0.06	<0.05		<0.05	341		408		
Y-102	4-Nov-05	Petersen	0.78	9.5	7.45	739		440	81.8	49.8	8.71	1.51	401.12	<5.	91	4	0.06	<0.03	<0.01	0.035	0.02	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		<0.002	<0.005	<0.001		<0.004			<0.1					<0.05	329		409	16.4	
Y-102	26-Jan-06	Petersen						441	86.8	55.2	9.09	1.67	330	<5	91	5	0.21	<0.03	<0.010	0.043	0.02	<0.001	<0.001	<0.01	<0.05	<0.,03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	0.03	0.011			<0.1		0.07	<0.05	<0.05		330		444		
Y-102	26-Jan-06	Petersen	0.85	9.2	7.2	723		441	86.8	55.2	9.09	1.67	402.34	<5.	91	5	0.21	<0.03	<0.01	0.043	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001		0.011			<0.1		0.07	<0.05	<0.05		330		444		
Y-102	29-May-06	Petersen	0.85	9.5	7.61	726		453	80.1	50	6.5	1.49	395.03	<5.	84	5	0.21	<0.03	<0.01	0.049	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.004		<5.	<0.1		0.08	<0.05	<0.05	<0.05	324		406		
Y-102	21-Dec-06	Petersen	0.78	9.4	7.59	707		438	81.68	52.26	8.9	1.69	401.12	<5.	84	4	0.17	<0.03	<0.01	0.039	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.004		<5.	<0.1		0.08	<0.05	<0.05		329		419	161	
Y-102	28-Mar-07	Petersen	0.97	9.3	7.52	693		442	80	52.5	8.94	1.53	410.88	<5.	84	4	0.17	<0.03	<0.01	0.035	0.04	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.002	0.002	<0.005	<0.001	<0.02	<0.004		<5.	<0.1		0.1	<0.05	<0.05	<0.05	337		416	890	
Y-61	20-Sep-87	Utah International		10.1	7.3	775																																									
Y-61	13-Dec-87	Utah International		8.9	7.2	830																																									
Y-61	20-Mar-88	Utah International		11.0	6.8	790																																									
Y-61	31-Mar-05	Petersen						393	78.9	48.4	7.26	1.49	330	<5	63	4	0.20	<0.03	<0.010	0.043	0.03	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.003	0.003	<0.005	<0.001	<0.02	0.007			<0.1	0.3	0.06	<0.05	<0.05		330		396		
Y-61	12-Aug-05	Petersen	21.6	9.6	7.59	611		400	79.3	47.7	6.47	1.43	328	<5	69	3	0.10	<0.03	<0.010	0.046	0.03	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.005	<0.002	<0.005	<0.001	<0.02	<0.004			<0.1		0.09	<0.05		<0.05	328		394		
Y-61	4-Nov-05	Petersen	---		7.48	724		397	79.1	46.5	6.21	1.35	332	<5	68	3	0.11	<0.03	<0.010	0.046	0.02	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		<0.002	<0.005	<0.001	<0.02	<0.004			<0.1	0.08				<0.05	332		389		
Y-61	31-Mar-06	Petersen	21.6	9.6	7.65	695		393	78.9	48.4	7.26	1.49	402.34	<5.	63	4	0.2	<0.03	<0.01	0.043	0.03	<0.001	<0.001	<0.01	0.06	<0.03	<0.2	<0.01	0.003	0.003	<0.005	<0.001		0.007			<0.1		0.06	<0.05	<0.05		330		396		
Y-61	29-May-06	Petersen		9.2	7.69	677		433	77.8	48.6	6.57	1.49	396.24	<5.	60	4	0.2	<0.03	<0.01	0.04	0.02	<0.001	<0.001	<0.01	0.28	<0.03	<0.2	<0.01	0.007	0.005	<0.005	<0.001	<0.02	0.005		<5.	<0.1		0.07	<0.05	<0.05	<0.05	325		394		
Y-61	8-Sep-06	Petersen		9.8	7.16	662		385	80.37	49.21	6.36	1.34	404.78	<5.	62	4	0.17	<0.03	<0.01	0.043	0.02	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.002	0.002	<0.005	<0.001	<0.02	<0.004		9	<0.1		0.09	<0.05	<0.05		332		403		
Y-61	20-Dec-06	Petersen		9.2	7.68	652		422	80.62	49.26	6.35	1.42	407.22	<5.	63	3	0.16	<0.03	<0.01	0.046	0.02	<0.001	<0.001	<0.01	0.17	<0.03	<0.2	<0.01	0.011	0.002	<0.005	<0.001	<0.02	0.025		<5.	<0.1	0.09				<0.05	334		404	21.1	
Y-59	18-Sep-87	Utah International		10.7	7.2	800		468	83	59	10	2	320	<5	115	7	0.5	<0.05	<0.001	0.04	0.02	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		<0.01	<0.05	<0.02	<0.001	0.01			0.05		0.63	<0.01	0.01				449		
Y-59	15-Dec-87	Utah International		9.0	7.0	850		482	72	57	11	1	329	<5	123	8	0.2	<0.05	<0.001	0.04	0.04	<0.005	<0.01	0.01		<0.02	<0.2	0.02		<0.01	<0.05	0.02	0.002	<0.01			<0.02		0.58	<0.01	<0.01				414		
Y-59	21-Mar-88	Utah International		10.2	7.4	870		472	93	59	8	1	333	<5	107	6	0.2	<0.05	<0.001	0.05	0.02	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		<0.01	<0.05	<0.02	<0.001	<0.01			<0.02		0.33	<0.01	0.01				474		
Y-63	18-Sep-87	Utah International		10.2	8.05	740		400	41	65	33	3	362	<5	27	12	0.5	<0.05	<0.001	0.14	0.07	<0.005	0.01	<0.01		0.18	<0.2	<0.02		0.16	<0.05	<0.02	<0.001	<0.01			3.9		0.01	0.04	<0.01				369		
Y-63	9-Dec-87	Utah International		9.1	7.8	740		368	44	67	33	3	361	<5	25	12	0.2	<0.05	<0.001	0.22	0.13	<0.005	<0.01	<0.01		0.05	<0.2	<0.02		0.08	<0.05	<0.02	<0.002	<0.01			4.14		<0.02	<0.02	<0.01				385		
Y-63	31-Mar-88	Utah International		9.8	7.7	900		454	57	64	31	2	410	<5	51	14	0.3	<0.05	<0.001	0.27	0.07	<0.005	<0.01	<0.01		0.03	<0.2	<0.02		0.15	<0.05	<0.02	<0.001	<0.01			3.16		<0.02	<0.01	0.01				405		
Y-36	17-Sep-87	Utah International		10.2	7.2	1320		815	4	1	397	2	630	<5	<2	50	3.9	<0.05	<0.001	0.22	1.69	<0.005	<0.01	0.01		0.05	<0.2	<0.02		0.02	<0.05	<0.02	<0.001	0.02			0.54		0.02	<0.01	0.03				14		
Y-36	15-Dec-87	Utah International		10.2	7.9	1320		784	3	1	316	2	616	<5	10	54	3.9	0.08	<0.001	0.14	1.49	<0.005	<0.01	0.01		0.05	<0.2	<0.02		0.01	<0.05	<0.02	<0.001	0.01			0.49		<0.02	<0.01	<0.01				12		
Y-98 (A1)	16-Sep-87	Utah International		11.2	7.3	635		346	56	60	12	3	272	<5	70	6	0.9	<0.05	<0.001	0.08	0.06	0.005	<0.01	<0.01		<0.02	<0.2	<0.02		0.02	<0.05	<0.02	<0.001	0.03			0.03		0.13	<0.01	<0.01				386		
Y-98 (A1)	9-Dec-87	Utah International		8.9	7.3	955		548	62	86	27	3	355	<5	159	14	0.4	<0.05	<0.001	0.26	0.1	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		0.06	<0.05	<0.02	<0.002	0.01			<0.02		0.23	<0.2	<0.01				508		
Y-98 (A1)	18-Mar-88	Utah International		8.9	7.0	1000		600	79	73	13	3	337	<5	200	8	0.2	<0.05	<0.001	0.05	0.03	<0.005	<0.01	<0.01		0.03	<0.2	<0.02		0.02	<0.05	<0.02	<0.001	0.01			<0.02		0.19	<0.01	0.01				497		
Alluvial trenches																																															
SVT-01	21-Apr-06	Petersen		6.1	8.14	2030		1469	14	311	54.2	4.51	1040	<5	478	33	0.60	<0.03	<0.010	0.062	0.2	<0.001	<0.001	<0.01	1.22	<0.03	<0.2	<0.01	0.012	<0.002	<0.005	0.003	<0.02	<0.004			<0.1	<0.1	<0.05	<0.05	0.06		1040		1316		
SVT-03	21-Apr-06	Petersen		11.4	8.43	3700		3608	64.4	588	104	14.5	781	<5	2080	102	0.36	<0.03	<0.010	0.089	0.15	<0.001	<0.001	<0.01	6.88	<0.03	<0.2	<0.01	0.149	0.006	<0.005	0.001	<0.02	<0.004			<0.1	<0.1	<0.05	<0.05	<0.05		781		2582		
SVT-04	21-Apr-06	Petersen		7.2	8.12	2090		1561	54.6	224	122	3.46	490	<5	741	47	0.33	<0.03	<0.010	0.028	0.09	<0.001	<0.001	<0.01	3.37	<0.03	<0.2	<0.01	0.070	0.016	<0.005	<0.001	<0.02	0.024			<0.1	1.4	2.51	<0.05	<0.05		490		1059		
SVT-05	21-Apr-06	Petersen		7.3	7.89	1142		966	55.1	173	25.7	1.93	531	<5	966	20	0.41	<0.03	<0.010	0.047	0.08	<0.001	<0.001	<0.01	2.26	<0.03	<0.2	<0.01	0.037	0.003	<0.005	<0.001	<0.02	0.006			<0.1	0.1	<0.05	<0.05	<0.05		531		850		
SVT-06	21-Apr-06	Petersen		9.1	8.16	1288		903	62.4	147	30.3	1.53	440	<5	349	18	0.44	<0.03	<0.010	0.040	0.06	<0.001	<0.001	<0.01	1.29	<0.03	<0.2	<0.01	0.028	0.002	<0.005	<0.001	<0.02	0.009			<0.1	0.2	<0.05	<0.05	<0.05		440		761		

Site	Date	Data Source	discharge (gpm)	T (°C)	pH	Cond. (µS/cm)	D.O. (mg/L)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	HCO3 (mg/L)	CO3 (mg/L)	SO4 (mg/L)
SW-10	30-Mar-06	Petersen	Dry												
SW-10	29-May-06	Petersen	Dry												
SW-10	8-Sep-06	Petersen	Dry												
SW-10	20-Dec-06	Petersen	Dry												
SW-10	29-Mar-07	Petersen	Dry												
Lamb Canal	27-May-05	Petersen	1560	17.6	8.29	966	8.91								
Lamb Canal	25-Sep-05	Petersen	94.8	5.9	8.29	1602	8.73								
Lamb Canal	3-Nov-05	Petersen	Dry												
Lamb Canal	30-Mar-06	Petersen	157	9.2	8.68	1559	8.98								
Lamb Canal	8-Sep-06	Petersen	Dry												
Lamb Canal	29-Mar-07	Petersen	332	0.1	8.59	1989	9.33								
Springs															
SP-33	18-Jun-05	Petersen	13.2	9.1	7.87	1148		440	84.3	40.2	25.6	2.31	387.71	<5.	44
SP-33	24-Sep-05	Petersen	4.37	11.2	7.79	1386		859	47.2	161	47	4.87	615.7	<5.	5
SP-33	3-Nov-05	Petersen	4.36	10.6	7.86	1301		840	45.9	144	44	4.97	618.14	<5.	280
SP-33	30-Mar-06	Petersen						843	44.8	145	42.7	4.72	508	<5	237
SP-33	29-May-06	Petersen	8.98	9	7.96	1239		814	43.1	141	41.6	4.54	609.61	<5.	230
SP-33	8-Sep-06	Petersen	3.11	11.6	7.85	1208		804	45.4	141.73	43.31	4.85	624.24	<5.	233
SP-33	21-Dec-06	Petersen	4.36	8.8	7.98	1197		830	46.11	144.21	42.82	4.93	624.24	<5.	232
SP-33	30-Mar-07	Petersen	9.2	7.6	7.97	1185		808	44.4	144	43.2	4.58	638.87	<5.	230
SP-3	7-Jul-87	Utah International	1.8	14.2		805									
SP-3	7-Aug-87	Utah International	2.1	15.6		665									
SP-3	16-Sep-87	Utah International	1.7	12.5	7.55	700		360	71	43	18	2	290	<5	49
SP-3	31-Oct-87	Utah International	2.2	11.0		685									
SP-3	22-Nov-87	Utah International	2.1	5.0		630									
SP-3	16-Dec-87	Utah International	1.1	8.0	7.4	610		398	70	40	20	2	308	<5	39
SP-3	9-Jan-88	Utah International	1.2	4.0		690									
SP-3	15-Feb-88	Utah International	1.5	4.2		715									
SP-3	24-Mar-88	Utah International	1.8	11.5	6.6	840		418	81	41	25	2	329	<5	54
SP-3	18-Jun-05	Petersen						882	48.4	159	45.5	4.78	480	<5	276
SP-3	18-Jun-05	Petersen	5.94	9.8	7.43	658		882	48.4	159	45.5	4.78	585.22	<5.	276
SP-3	24-Sep-05	Petersen	7.23	9.5	7.58	777		391	83.4	41.4	25.7	2.24	324	<5	41
SP-3	24-Sep-05	Petersen	7.23	9.5	7.58	777		391	83.4	41.4	25.7	2.24	395.03	<5.	41
SP-3	3-Nov-05	Petersen	6.82	9.5	7.42	703		403	77.5	34.2	23.4	2.29	322	<5	43
SP-3	3-Nov-05	Petersen	6.82	9.5	7.42	703		403	77.5	34.2	23.4	2.29	392.59	<5.	43
SP-3	30-Mar-06	Petersen	7.37	9.9	7.48	703		394	77.1	35.8	23.1	2.21	395.03	<5.	40
SP-3	29-May-06	Petersen	7.73	9.5	7.57	747		402	77.1	35.9	23.4	2.23	382.83	<5.	41
SP-3	8-Sep-06	Petersen	7.52	9.4	7.57	662		402	81.69	37.62	25	2.19	406	<5.	42
SP-3	20-Dec-06	Petersen	7.28	9.1	7.59	667		426	80.87	37.09	24.32	2.23	388.93	<5.	44
SP-3	29-Mar-07	Petersen	7.65	9.3	7.49	697		407	78.2	36.9	24.6	2.11	399.9	<5.	47
SP-4	1-Jul-87	Utah International	0.74	15.4		1005									
SP-4	3-Aug-87	Utah International	0.57	15.0		975									
SP-4	4-Sep-87	Utah International	0.67	14.1		945		564	33	36	147	3	374	<5	123
SP-4	26-Oct-87	Utah International	0.63	13.9		900									
SP-4	13-Nov-87	Utah International	0.54	9.2		945									
SP-4	14-Dec-87	Utah International	0.86	5.1		990		566	52	38	142	3	390	<5	128
SP-4	9-Jan-88	Utah International	0.72	7.9		915									
SP-4	15-Feb-88	Utah International	0.71	6.8		920									
SP-4	11-Mar-88	Utah International	0.70	6.5		945		550	49	35	138	3	402	<5	103
SP-4	18-Jun-05	Petersen	0.96	11.1	7.48	961		692	53.3	42.1	148	3.1	480.37	<5.	158
SP-4	24-Sep-05	Petersen	0.72	12.5	7.47	990		506	47.9	30.5	135	3.64	400	<5	99
SP-4	24-Sep-05	Petersen	0.72	12.5	7.47	990		506	47.8	30.5	135	3.64	487.69	<5.	99
SP-4	24-Sep-05	Petersen	0.72	12.5	7.47	990									
SP-4	3-Nov-05	Petersen	0.76	10.6	7.61	984		576	46.2	31.0	124	2.79	395	<5	135
SP-4	3-Nov-05	Petersen	0.76	10.6	7.61	984		576	46.2	31	124	2.79	481.59	<5.	135
SP-4	30-Mar-06	Petersen	0.64	8.6	7.7	955		576	47.7	33	116	3.03	473.06	<5.	119
SP-4	29-May-06	Petersen	0.85	11.3	7.76	972		610	49.4	33.5	126	2.98	470.62	<5.	126
SP-4	7-Sep-06	Petersen	0.696	12.1	7.46	894		588	48.98	33	128.76	2.94	486.47	<5.	119
SP-4	21-Dec-06	Petersen	0.59	7.9	7.79	871		596	49.27	33.23	126.41	3.04	474.27	<5.	118
SP-4	30-Mar-07	Petersen	0.81	8	7.77	904		588	48.6	34.1	128	3.07	480.37	<5.	121
SP-6	3-Jul-87	Utah International	Seep	18.8		3485									
SP-6	5-Aug-87	Utah International	Seep	19.1		2900									
SP-6	17-Sep-87	Utah International	Seep	12.0		3140		2280	32	426	156		1268	<5	798
SP-6	28-Oct-87	Utah International	Seep	12.3		2520									
SP-6	17-Nov-87	Utah International	Seep	7.9		2830									
SP-6	9-Dec-87	Utah International	Seep	6.1		2385		1638	19	371	95		1069	<5	492
SP-6	15-Jan-88	Utah International	Seep	5.6		2350									
SP-6	15-Feb-88	Utah International	Frozen	---	---	---									
SP-6	11-Mar-88	Utah International	Seep	3.0		2265		1598	14	334	72		913	<5	572
SP-6	24-Sep-05	Petersen	Seep	16.0	7.41	1310		707	84.1	98.1	33	7.87	602	<5	112
SP-6	3-Nov-05	Petersen	Seep	10.5	7.76	1602		1083	84.5	133	81.3	18.8	612	<5	301
SP-6	3-Nov-05	Petersen		10.5	7.76	1602		1083	84.5	133	81.3	18.8	746.16	<5.	301
SP-6	29-May-06	Petersen	0	25.2	8.12	1475		944	63.4	162	55.6	5.58	948.55	<5.	139
SP-6	7-Sep-06	Petersen	<0.05	15.4	7.53	1038		666	71.06	89.43	38.5	10.14	587.66	<5.	126
SP-6	30-Dec-06	Petersen	<0.05	5.6	7.91	1175		935	81.17	152.19	46.92	4.08	657.16	<5.	300
SP-6	30-Mar-07	Petersen	0	2.2	8.46	2920		2365	13.3	505	113	4.52	1569.1	<5.	807
SP-8	3-Jul-87	Utah International	10.0	10.9		785									
SP-8	5-Aug-87	Utah International	8.6	10.7		795									
SP-8	18-Sep-87	Utah International	10.0	11.2	7.25	725		386	81	56	6	2	308	<5	76
SP-8	27-Oct-87	Utah International	10.7	10.8		750									
SP-8	15-Nov-87	Utah International	10.0	7.5		715									
SP-8	9-Dec-87	Utah International	10.0	10.0	6.8	765		420	88	60	6	2	329	<5	76
SP-8	9-Jan-88	Utah International	15.9	12.0		685									

Site	Date	Cl (mg/L)	F (mg/L)	Al (mg/L)	As (mg/L)	Ba (mg/L)	B (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (t) (mg/L)	Fe (d) (mg/L)	Hg (µg/L)	Pb (mg/L)	Mn (t) (mg/L)	Md (d) (mg/L)	Mb (mg/L)	Ni (mg/L)	Se (mg/L)	Zn (mg/L)
SP-33	18-Jun-05	17	0.13	<0.03	<0.01	0.075	0.05	<0.001	0.001	<0.01		<0.03	<0.2	<0.01		0.002	<0.005	<0.001	<0.02	<0.004
SP-33	24-Sep-05	12	0.44	<0.03	<0.01	0.131	0.23	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004
SP-33	3-Nov-05	15	0.28	0.09	<0.01	0.019	0.2	0.002	0.002	<0.01		0.03	<0.2	<0.01		<0.002	0.012	<0.001		<0.004
SP-33	30-Mar-06	18	0.42	<0.03	<0.010	0.018	0.19	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004
SP-33	29-May-06	17	0.44	<0.03	<0.01	0.016	0.18	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.004
SP-33	8-Sep-06	17	0.41	<0.03	<0.01	0.018	0.18	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004
SP-33	21-Dec-06	18	0.49	<0.03	<0.01	0.019	0.18	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	<0.004
SP-33	30-Mar-07	17	0.3	<0.03	<0.01	0.015	0.18	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	<0.002	<0.002	<0.005	<0.001	<0.02	0.006
SP-3	16-Sep-87	12	0.5	<0.05	<0.001	0.07	0.03	<0.005	<0.01	0.01		<0.02	<0.2	<0.02		0.03	<0.05	<0.02	<0.001	<0.01
SP-3	16-Dec-87	13	0.2	0.08	0.002	0.08	0.02	<0.005	<0.01	<0.01		0.15	<0.2	<0.02		0.04	<0.05	<0.02	0.003	0.01
SP-3	24-Mar-88	13	0.2	<0.05	<0.001	0.09	0.04	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		0.01	<0.05	<0.02	0.005	0.01
SP-3	18-Jun-05	20	0.26	<0.03	<0.010	0.017	0.18	<0.001	0.001	<0.01		<0.03	<0.2	<0.01		<0.002	<0.005	<0.001	<0.02	<0.004
SP-3	18-Jun-05	20	0.26	<0.03	<0.01	0.017	0.18	<0.001	0.001	<0.01		<0.03	<0.2	<0.01		<0.002	<0.005	<0.001	<0.02	<0.004
SP-3	24-Sep-05	15	0.23	<0.03	<0.010	1.08	0.05	<0.001	<0.001	<0.01	0.11	<0.03	<0.2	<0.01	0.003	<0.002	<0.005	<0.001	<0.02	<0.004
SP-3	24-Sep-05	15	0.23	<0.03	<0.01	1.08	0.05	<0.001	<0.001	<0.01	0.11	<0.03	<0.2	<0.01	0.003	<0.002	<0.005	<0.001	<0.02	<0.004
SP-3	3-Nov-05	17	0.17	0.07	<0.010	0.083	0.04	0.001	0.001	<0.01		<0.03	<0.2	<0.01		0.022	<0.005	<0.001	<0.02	<0.004
SP-3	3-Nov-05	17	0.17	0.07	<0.01	0.083	0.04	0.001	0.001	<0.01		<0.03	<0.2	<0.01		0.022	<0.005	<0.001		<0.004
SP-3	30-Mar-06	17	0.24	<0.03	<0.01	0.081	0.05	<0.001	<0.001	<0.01	0.15	<0.03	<0.2	<0.01	0.013	0.009	<0.005	<0.001		0.004
SP-3	29-May-06	18	0.25	<0.03	<0.01	0.077	0.05	<0.001	<0.001	<0.01	0.1	<0.03	<0.2	<0.01	0.011	0.006	<0.005	<0.001	<0.02	0.004
SP-3	8-Sep-06	18	0.23	<0.03	<0.01	0.079	0.04	<0.001	<0.001	<0.01	0.37	<0.03	<0.2	<0.01	0.02	0.017	<0.005	<0.001	0.03	<0.004
SP-3	20-Dec-06	19	0.21	<0.03	<0.01	0.081	0.05	<0.001	<0.001	<0.01	1.18	<0.03	<0.2	<0.01	0.044	0.016	<0.005	<0.001	<0.02	<0.004
SP-3	29-Mar-07	19	0.27	<0.03	<0.01	0.081	0.05	<0.001	<0.001	<0.01	0.34	<0.03	<0.2	<0.01	0.02	0.016	<0.005	<0.001	<0.02	<0.004
SP-4	4-Sep-87	11	0.6	<0.05	<0.001	0.02	0.15	<0.005	<0.01	0.01		<0.02	<0.2	<0.02		0.06	<0.05	<0.02	<0.001	<0.01
SP-4	14-Dec-87	14	0.5	0.10	0.001	0.02	0.15	<0.005	<0.01	<0.01		0.48	<0.2	<0.02		0.06	<0.05	<0.02	<0.001	0.01
SP-4	11-Mar-88	13	0.5	<0.01	<0.001	0.02	0.14	<0.005	<0.01	<0.01		0.4	<0.2	<0.02		0.07	<0.05	<0.02	<0.001	<0.01
SP-4	18-Jun-05	13	0.39	<0.03	<0.01	0.03	0.17	<0.001	0.001	<0.01		<0.03	<0.2	<0.01		0.06	<0.005	<0.001	<0.02	<0.004
SP-4	24-Sep-05	10	0.51	<0.03	<0.010	0.187	0.17	<0.001	<0.001	<0.01	0.17	<0.03	<0.2	<0.01	0.020	0.06	<0.005	<0.001	<0.02	<0.004
SP-4	24-Sep-05	10	0.51	<0.03	<0.01	0.187	0.17	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.06	<0.005	<0.001	<0.02	<0.004
SP-4	24-Sep-05										0.17				0.02					
SP-4	3-Nov-05	12	0.45	<0.03	<0.010	0.033	0.16	0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.06	<0.005	0.001	0.05	<0.004
SP-4	3-Nov-05	12	0.45	<0.03	<0.01	0.033	0.16	0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.06	<0.005	0.001		<0.004
SP-4	30-Mar-06	12	0.48	<0.03	<0.01	0.029	0.16	<0.001	<0.001	<0.01	0.46	<0.03	<0.2	<0.01	0.07	0.069	<0.005	<0.001		0.004
SP-4	29-May-06	13	0.51	<0.03	<0.01	0.03	0.17	<0.001	<0.001	<0.01	0.8	<0.03	<0.2	<0.01	0.069	0.068	<0.005	<0.001	<0.02	<0.004
SP-4	7-Sep-06	12	0.5	<0.03	<0.01	0.028	0.16	<0.001	<0.001	<0.01	0.16	<0.03	<0.2	<0.01	0.059	0.058	<0.005	<0.001	<0.02	<0.004
SP-4	21-Dec-06	12	0.45	<0.03	<0.01	0.029	0.16	<0.001	<0.001	<0.01	0.1	<0.03	<0.2	<0.01	0.057	0.057	<0.005	<0.001	<0.02	<0.004
SP-4	30-Mar-07	13	0.48	<0.03	<0.01	0.025	0.17	<0.001	<0.001	<0.01	<0.05	<0.03	<0.2	<0.01	0.057	0.057	<0.005	<0.001	<0.02	<0.004
SP-6	17-Sep-87	56	0.9	<0.05	<0.001	0.06	0.47	<0.005	<0.01	<0.01		0.08	<0.2	<0.02		0.05	<0.05	<0.02	<0.001	0.02
SP-6	9-Dec-87	44	0.4	<0.05	<0.001	0.04	0.31	<0.005	<0.01	<0.01		0.02	<0.2	<0.02		0.01	<0.05	<0.02	<0.002	<0.01
SP-6	11-Mar-88	46	0.4	<0.05	<0.001	0.03	0.20	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		0.01	<0.05	<0.02	<0.001	0.74
SP-6	24-Sep-05	6	0.38	<0.03	<0.010	0.069	0.10	<0.001	<0.001	<0.01	0.34	<0.03	<0.2	<0.01	0.011	<0.002	<0.005	0.001	0.03	<0.004
SP-6	3-Nov-05	44	0.22	<0.03	<0.010	0.087	0.14	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.064	<0.005	<0.001	<0.02	<0.004
SP-6	3-Nov-05	44	0.22	<0.03	<0.01	0.087	0.14	<0.001	<0.001	<0.01		<0.03	<0.2	<0.01		0.064	<0.005	<0.001		<0.004
SP-6	29-May-06	6	0.4	<0.03	<0.01	0.065	0.21	<0.001	<0.001	<0.01	0.26	0.04	<0.2	<0.01	0.021	<0.002	<0.005	0.001	<0.02	0.005
SP-6	7-Sep-06	23	0.27	<0.03	<0.01	0.029	0.1	<0.001	<0.001	<0.01	6.18	0.16	<0.2	<0.01	0.304	0.063	<0.005	<0.001	<0.02	<0.004
SP-6	30-Dec-06	19	0.43	<0.03	<0.01	0.023	0.09	<0.001	<0.001	<0.01	2.6	<0.03	<0.2	<0.01	0.052	0.051	<0.005	<0.001	<0.02	0.012
SP-6	30-Mar-07	52	0.98	<0.03	<0.01	0.054	0.25	<0.001	<0.001	<0.01	0.05	<0.03	<0.2	<0.01	0.011	0.011	0.009	0.001	<0.02	<0.004
SP-8	18-Sep-87	5	0.4	<0.05	<0.001	0.05	<0.02	<0.005	<0.01	<0.01		<0.02	<0.2	<0.02		<0.01	<0.05	<0.02	<0.001	0.11
SP-8	9-Dec-87	5	0.2	<0.05	<0.001	0.07	<0.02	0.007	<0.01	<0.01		<0.02	<0.2	<0.02		<0.01	<0.05	<0.02	<0.002	0.02

Site	Date	Oil&G (mg/L)	TSS (mg/L)	NH3 (mg/L)	NO3+NO2 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	O-PO4 (mg/L)	T. Phos (mg/L)	Alkalinity (mg/L)	Acd. (mg/L)	Hard. (mg/L)	Turb. NTU	Set Sol (mg/L)
Lamb Canal	27-May-05												16.0	
Lamb Canal	25-Sep-05												5.0	
Lamb Canal	30-Mar-06												1.8	
Lamb Canal	29-Mar-07												20.1	
SP-33	18-Jun-05			<0.1				<0.05	0.05	318		376	1000	
SP-33	24-Sep-05			<0.1	0.21	0.16	<0.05	<0.05	<0.05	505		781		
SP-33	3-Nov-05			<0.1					<0.05	507		708	16.4	
SP-33	30-Mar-06			<0.1	0.5	0.23	<0.05	0.07		508		709		
SP-33	29-May-06		<5.	<0.1		0.19	<0.05	0.08	<0.05	500		688		
SP-33	8-Sep-06		<5.	<0.1		0.23	<0.05	0.05		512		697		
SP-33	21-Dec-06		<5.	<0.1		0.19	<0.05	<0.05		512		709		
SP-33	30-Mar-07		<5.	<0.1	0.18				<0.05	524		704		
SP-3	16-Sep-87			<0.02		0.05	<0.01	<0.01				354		
SP-3	16-Dec-87			0.03		0.38	<0.01	<0.01				339		
SP-3	24-Mar-88			<0.02		0.45	<0.01	<0.01				371		
SP-3	18-Jun-05			<0.1	0.22				0.06	480		776		
SP-3	18-Jun-05			<0.1				<0.05	0.06	480		776	1000	
SP-3	24-Sep-05			<0.1	1.10	0.98	<0.05		<0.05	324		379		
SP-3	24-Sep-05			<0.1	1.1	0.98	<0.05	<0.05	<0.05	324		379		
SP-3	3-Nov-05			<0.1	1.00				<0.05	322		334		
SP-3	3-Nov-05			<0.1					<0.05	322		334	16.4	
SP-3	30-Mar-06			<0.1		1.04	<0.05	<0.05		324		340		
SP-3	29-May-06		5	<0.1		1.07	<0.05	<0.05	<0.05	314		340		
SP-3	8-Sep-06		20	<0.1		1.17	<0.05	<0.05		333		359		
SP-3	20-Dec-06		47	<0.1	1.09				0.1	319		355		
SP-3	29-Mar-07		21	<0.1		1.19	<0.05	<0.05	<0.05	328		347	8.51	
SP-4	4-Sep-87			0.56		<0.03	0.01	<0.01				230		
SP-4	14-Dec-87			0.57		0.02	<0.01	<0.01				286		
SP-4	11-Mar-88			0.59		0.03	<0.01	<0.01				266		
SP-4	18-Jun-05			<0.1				<0.05	<0.05	394		306	1000	
SP-4	24-Sep-05			0.2	<0.02	<0.05	<0.05		<0.05	400		245		
SP-4	24-Sep-05			0.2	<0.02	<0.05	<0.05	<0.05	<0.05	400		245		
SP-4	3-Nov-05			<0.1	0.04				<0.05	395		243		
SP-4	3-Nov-05			<0.1					<0.05	395		243	16.4	
SP-4	30-Mar-06			0.4		<0.05	0.31	<0.05		388		255		
SP-4	29-May-06		<5	<0.1		0.06	<0.05	<0.05	<0.05	386		261		
SP-4	7-Sep-06		<5.	<0.1		<0.05	<0.05	<0.05		399		258		
SP-4	21-Dec-06		<5.	<0.1		<0.05	<0.05	<0.05		389		260	13.3	
SP-4	30-Mar-07		<5.	<0.1	0.09				<0.05	394		262		
SP-6	17-Sep-87			0.06		0.02	<0.01	0.02				1827		
SP-6	9-Dec-87			0.05		<0.02	<0.02	0.02				1569		
SP-6	11-Mar-88			0.02		0.06	<0.01	0.02				1404		
SP-6	24-Sep-05			<0.1	0.03	<0.05	<0.05		<0.05	602		614		
SP-6	3-Nov-05			<0.1	0.03				<0.05	612		759		
SP-6	3-Nov-05			<0.1					<0.05	612		759	16.4	
SP-6	29-May-06		51	<0.1		<0.05	<0.05	<0.05	0.26	778		825		
SP-6	7-Sep-06		638	<0.1		<0.05	<0.05	<0.05		482		546		
SP-6	30-Dec-06		5	<0.1	<0.05				<0.05	539		829	161	
SP-6	30-Mar-07		<5.	<0.1	<0.05				<0.05	1287		2113		
SP-8	18-Sep-87			0.04		0.19	<0.01	<0.01				432		
SP-8	9-Dec-87			0.03		0.20	<0.02	<0.01				466		

Table 5 Monitoring well details.

Well	Date drilled	Screened formation	Collar elevation (feet)	Depth (feet)	Depth to bedrock (feet)	Screened interval From (feet)	Screened interval To (feet)
C0-18	Jan-07	*Lower Robinson alluvium*	6864.14	22	---	12	22
C0-54	Jan-07	Dakota Formation above coal	6862.59	54	40	47	54
C1-24	Jan-07	Lower Robinson alluvium	6949.19	26.5	24	16.5	26.5
C2-15	Jan-07	Sink Valley alluvium	6920.28	15	---	5	15
C2-28	Dec-06	Sink Valley alluvium	6919.81	28	---	17	27
C2-40	Dec-06	Sink Valley alluvium	6919.58	40	40	20	40
C3-15	Dec-06	Sink Valley alluvium	6890.41	15	---	5	15
C3-30	Dec-06	Sink Valley alluvium	6890.77	30	---	10	20
C3-40	Dec-06	Sink Valley alluvium	6890.73	40	38	20	40
C4-15	Dec-06	Sink Valley alluvium	6873.92	15	---	5	15
C4-30	Dec-06	Sink Valley alluvium	6873.91	30	---	10	30
C4-50	Dec-06	Sink Valley alluvium	6873.52	50	47	30	50
C5-130	Jan-07	Sink Valley alluvium	6938.92	130	123.5	90	130
C6-15	Jan-07	Lower Robinson alluvium	6897.63	15	11	5	15
C7-10	Jan-07	Sink Valley alluvium	6873.77	10	---	10	15
C7-20	Jan-07	Sink Valley alluvium	6872.89	20	19	15	20
C8-25	Jan-07	Sink Valley alluvium	6859.70	27	20	7	27
C9-15	Jan-07	Sink Valley alluvium	6846.77	15	---	5	15
C9-25	Jan-07	Sink Valley alluvium	6846.36	26	---	16	26
C9-40	Jan-07	Sink Valley alluvium	6846.94	42	39	22	42
SS-15	Jan-07	Lower Sink Valley alluvium	6831.57	15	---	5	15
SS-30	Jan-07	Lower Sink Valley alluvium	6830.47	29	---	19	29
SS-75	Jan-07	Lower Sink Valley alluvium	6832.06	75	75	54	74
UR-70	Jan-07	Upper Robinson alluvium	7005.14	70	62	50	70
LR-29	Jan-07	Dakota Formation (uppermost)	6803.10	29	20	19	29
LR-45	Jan-07	Lower Robinson alluvium	6798.41	42	41.5	21	41
LS-15	Jan-07	Lower Sink Valley alluvium	6810.28	15	---	4	14
LS-28	Jan-07	Lower Sink Valley alluvium	6810.23	28	---	17	27
LS-60	Jan-07	Lower Sink Valley alluvium	6810.35	60	---	39	59
LS-85	Jan-07	Lower Sink Valley alluvium	6810.53	87	---	64	84
Y-36	Dec-79	Smirl coal seam (Dakota Formation)	6956.97	230	155	194	214
Y-38	Nov-79	Smirl coal seam (Dakota Formation)	6860.85	105	50	71	86
Y-45	Aug-80	Smirl coal seam (Dakota Formation)	7043.55	352	40	314	330
Y-59	Dec-80	Sink Valley alluvium	6959.06	110	---	50	110
Y-61	Nov-80	Sink Valley alluvium	6962.10	150	145	112	142

Well	Date drilled	Screened formation	Collar elevation (feet)	Depth (feet)	Depth to bedrock (feet)	Screened interval From (feet)	To (feet)
Y-63	Nov-80	Lower Sink Valley alluvium	6789.34	51	34	Open hole	Open hole
Y-98 (A1)	Jul-86	Upper Robinson alluvium	7173.50	86	83.5	36.6	86
Y-99 (A2)	Jul-86	Upper Robinson alluvium	7055.54	22	20	5.1	13.2
Y-102 (A4	Jul-86	Sink Valley alluvium	6950.06	86	84.0	43.7	62.94

Table 6 Isotopic compositions of groundwaters and surface waters in the proposed Coal Hollow Mine permit and adjacent area.

		δ13C ‰	^{14}C pmC	Tritium TU	d18O ‰	d2H ‰	Mean residence time (radiocarbon years)
Streams							
Kanab Creek drainage							
SW-1	27-May-05				-12.55	-97	
SW-1	25-Sep-05				-11.96	-89	
SW-1	3-Nov-05				-12.52	-94	
SW-2	27-May-05				-12.17	-90	
SW-2	25-Sep-05				-10.95	-88	
SW-2	3-Nov-05				-11.63	-91	
SW-3	27-May-05				-12.54	-97	
SW-3	28-Sep-05				-12.16	-92	
SW-3	3-Nov-05				-12.10	-89	
Lower Robinson Creek drainage							
SW-101	27-May-05				-13.05	-96	
SW-4	27-May-05				-12.73	-95	
SW-5	27-May-05				-12.90	-97	
SW-8	18-Jun-05			8.07	-13.34	-98	Modern
SW-8	24-Sep-05				-12.89	-97	
SW-8	4-Nov-05				-12.68	-98	
Water Canyon drainage							
RID-1	4-Nov-05				-13.19	-99	
Springs and Wells							
Alluvial Groundwater systems (Area A)							
SP-8	27-May-05			3.38	-11.75	-94	
SP-8	24-Sep-05				-13.47	-96	
SP-8	4-Nov-05	-10.2	66.41	3.10	-13.22	-98	Modern
Camper	4-Nov-05				-13.16	-100	
Y-102	27-May-05			3.28	-12.18	-100	Modern
Y-102	24-Sep-05				-13.45	-101	
Y-102	4-Nov-05	-9.9	69.03	3.35	-13.90	-99	Modern
Sorensen Spring	12-Aug-05				-13.04	-99	
Sorensen Spring	4-Nov-05	-10.4	67.50	3.01	-13.32	-100	Modern
Y-61	12-Aug-05				-12.86	-100	
Y-61	4-Nov-05	-10.1	66.41	3.28	-13.34	-96	Modern
Alluvial Groundwater systems (Area B)							
SP-33	17-Jun-05				-12.36	-97	
SP-33	24-Sep-05				-12.70	-96	

		δ13C ‰	^{14}C pmC	Tritium TU	d18O ‰	d2H ‰	Mean residence time (radiocarbon years)
SP-33	3-Nov-05	-12.6	89.04	2.74	-7.72	-96	Modern
SP-6	24-Sep-05				-10.12	-85	
SP-6	3-Nov-05				-8.78	-73	
Dakota Formation							
SP-4	19-Jun-05				-13.58	-101	
SP-4	24-Sep-05				-13.47	-103	
SP-4	3-Nov-05	-10.5	46.64	-0.01	-13.44	-101	1,000
SP-27	18-Jun-05				-11.63	-95	
Upland pediment alluvium							
SP-3	18-Jun-05				-12.73	-99	
SP-3	24-Sep-05				-12.56	-96	
SP-3	3-Nov-05				-8.01	-99	

Table 7 Slug testing and pump testing results.

Well	Screened formation	Hydraulic conductivity (cm/sec)	Data source	Method
Sink Valley Alluvium				
Coarse upper-central coarse artesian system				
Y-61	Sink Valley alluvium (artesian system)	6.0×10^{-2}	Utah International	Pump test (Jacob; 1946)
Shallow clayey alluvium				
C2-15	Sink Valley alluvium	1.0×10^{-6}	Petersen	Slug test (Hvorslev; 1951)
C3-15	Sink Valley alluvium	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
C4-15	Sink Valley alluvium	6.0×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C7-20	Sink Valley alluvium	8.3×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C8-25	Sink Valley alluvium	3.8×10^{-7}	Petersen	Slug test (Hvorslev; 1951)
C9-15	Sink Valley alluvium	2.5×10^{-5}	Petersen	Slug test (Hvorslev; 1951)
SS-15	Lower Sink Valley alluvium	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
Middle and lower Sink Valley sandy, silty, clayey alluvium				
C2-28	Sink Valley alluvium	5.3×10^{-3}	Petersen	Slug test (Hvorslev; 1951)
C2-40	Sink Valley alluvium	1.5×10^{-3}	Petersen	Slug test (Hvorslev; 1951)
C3-30	Sink Valley alluvium	5.8×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C3-40	Sink Valley alluvium	4.7×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C4-30	Sink Valley alluvium	9.4×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C4-50	Sink Valley alluvium	1.5×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
C9-25	Sink Valley alluvium	1.1×10^{-3}	Petersen	Slug test (Hvorslev; 1951)
C9-40	Sink Valley alluvium	9.3×10^{-4}	Petersen	Slug test (Hvorslev; 1951)
SS-30	Lower Sink Valley alluvium	2.1×10^{-5}	Petersen	Slug test (Hvorslev; 1951)
Lower Sink Valley coal burned area				
SS-75	Lower Sink Valley alluvium	High ($>10^{-2}$)	Petersen	Slug test (Hvorslev; 1951)
Robinson Creek drainage alluvium				
Upper Robinson Creek drainage coarse alluvium				
Y-98 (A1)	Upper Robinson alluvium	3.2×10^{-2}	Utah International	Slug test (Bouwer and Rice; 1976)
Lower Robinson Creek drainage clayey alluvium				
C0-18	*Lower Robinson alluvium*	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
C1-24	Lower Robinson alluvium	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
Dakota Formation above coal				
C0-54	Dakota Formation above coal	Low ($<10^{-6}$)	Petersen	Slug test (Hvorslev; 1951)
Smirl Coal Seam				
Y-36	Smirl coal seam (Dakota Formation)	1.0×10^{-5}	Utah International	Slug test (Hvorslev; 1951)
Y-38	Smirl coal seam (Dakota Formation)	6.3×10^{-5}	Utah International	Slug test (Hvorslev; 1951)

Table 8 Estimated rates of groundwater inflows based on drilling and slug testing results.

	Saturated alluvial thickness (feet)	Hydraulic conductivity; Clayey alluvium (cm/sec)	Clayey alluvium thickness (feet)	Hydraulic conductivity; Silty alluvium (cm/sec)	Silty alluvium thickness (feet)	Hydraulic conductivity; Coal burn (cm/sec)	Coarse alluvium thickness (feet)	Hydraulic gradient	Discharge per 100 linear feet over saturated thickness (gpm)
Lower Robinson Creek									
C0 area	34	$< 1 \times 10^{-6}$	34	NA	0	NA	0	0.10	< 1
C1 area	6	$< 1 \times 10^{-6}$	6	NA	0	NA	0	0.10	< 1
Sink Valley									
C2 area	40	1.0×10^{-6}	10	5.3×10^{-3}	30	NA	0	0.10	24
C3 area	38	$< 1 \times 10^{-6}$	10	9.4×10^{-4}	28	NA	0	0.10	1.7
C4 area	47	6.0×10^{-4}	10	9.4×10^{-4}	30	NA	0	0.10	6.0
C6 area	0	NA	0	NA	0	NA	0	0.10	<1
C7 area	11	8.3×10^{-4}	11	NA	0	NA	0	0.10	1.3
C8 area	13	3.8×10^{-7}	13	NA	0	NA	0	0.10	<1
C9 area	31	2.5×10^{-5}	10	1.1×10^{-3}	21	NA	0	0.10	3.4
SS area	70	$< 1 \times 10^{-6}$	15	2.1×10^{-5}	40	$> 1 \times 10^{-1}$	15	0.10	> 220

Table 9 Hydrologic monitoring protocols and locations.

Discharge and water level measurements

Protocol	Applies to	Parameter	Frequency
A	Streams	Discharge	Quarterly
B	Springs	Discharge	Quarterly
C	Monitoring wells	Water elevation	Quarterly

Water quality

Protocol	Applies to	Parameters	Table	Frequency
1	Streams	Operational field and laboratory water quality measurements	7-6	Quarterly
2	Streams	Field water quality measurements only	7-6	Quarterly
3	Springs	Operational field and laboratory water quality measurements	7-7	Quarterly
4	Springs	Field water quality measurements only	7-7	Quarterly
5	Monitoring wells	operational field and laboratory water quality measurements	7-7	Quarterly
6	Monitoring wells	Field water quality measurements only	7-7	Quarterly

Table 10 Hydrologic monitoring locations.

Site	Protocols	Comments
Streams		
BLM-1	A, 2	Lower Robinson Creek adjacent to mined areas
RID-1	A, 2	Irrigation ditch in Robinson Creek
SW-2	A, 1	Kanab Creek below Robinson Creek
SW-3	A, 1	Kanab Creek above permit area
SW-4	A, 1	Lower Robinson Creek above permit area
SW-5	A, 1	Lower Robinson Creek above Kanab Creek
SW-6	A, 1	Sink Valley Wash at permit boundary
SW-8	A, 1	Swapp Hollow Creek above permit area
SW-9	A, 1	Sink Valley Wash below permit area
SW-101	A, 2	Lower Robinson Creek in permit area
Springs		
Sorensen Spring	B,4	Developed alluvial spring in Sink Valley at Sorensen ranch
SP-3	B, 4	Spring in upland pediment alluvium south of permit area
SP-4	B, 3	Developed spring in Sink Valley Wash 1 mile below permit area
SP-6	B, 3	Seep in Sink Valley below permit area
SP-8	B, 3	Developed alluvial spring in Sink Valley at Dames ranch
SP-14	B, 4	Alluvial spring in Sink Valley
SP-16	B, 4	Alluvial spring in Sink Valley
SP-19	B, 4	Alluvial spring in Sink Valley
SP-20	B, 4	Alluvial spring in Sink Valley
SP-22	B, 4	Alluvial spring in Sink Valley
SP-23	B, 4	Alluvial spring in Sink Valley
SP-33	B, 3	Developed spring in lower Sink Valley alluvium
Wells		
Y-36	C	Coal well in Sink Valley above permit area
Y-38	C	Coal well in Sink Valley in permit area
Y-45	C	Coal seam well in Swapp Hollow above permit area
Y-61	C, 5	Water well in Sink Valley artesian alluvial groundwater system above permit area
Y-63	C	Monitoring well in lower Sink Valley Alluvium below mining areas
Y-98	C	Alluvial well in Robinson Creek above permit area
Y-102	C	Alluvial well in upper Sink Valley in permit area
C0-18	C	Alluvial monitoring well in Lower Robinson Creek drainage
C0-54	C	Monitoring well in Lower Robinson Creek drainage near coal seam
C1-24	C	Alluvial monitoring well in Lower Robinson Creek drainage

Site	Protocols	Comments
C2-15	C	Monitoring well in Sink Valley alluvium
C2-28	C	Monitoring well in Sink Valley alluvium
C2-40	C	Monitoring well in Sink Valley alluvium
C3-15	C	Monitoring well in Sink Valley alluvium
C3-30	C	Monitoring well in Sink Valley alluvium
C3-40	C	Monitoring well in Sink Valley alluvium
C4-15	C	Monitoring well in Sink Valley alluvium
C4-30	C	Monitoring well in Sink Valley alluvium
C4-50	C	Monitoring well in Sink Valley alluvium
C5-130	C	Monitoring well in Sink Valley artesian alluvial groundwater system above permit area
C7-20	C	Monitoring well in Sink Valley alluvium
C9-15	C	Monitoring well in Sink Valley alluvium
C9-25	C	Monitoring well in Sink Valley alluvium
C9-40	C	Monitoring well in Sink Valley alluvium
LR-45	C, 5	Monitoring well in Lower Robinson Creek alluvium below mine area
LS-28	C	Monitoring well in Sink Valley Alluvium below mining areas
LS-60	C	Monitoring well in Sink Valley Alluvium below mining areas
LS-85	C, 5	Monitoring well in artesian Sink Valley Alluvium below mining areas
SS-15	C	Monitoring well in Sink Valley Alluvium below mining areas
SS-30	C, 5	Monitoring well in Sink Valley Alluvium below mining areas
SS-75	C	Monitoring well in burned coal area material
UR-70	C, 5	Monitoring well in Lower Robinson Creek alluvium above mine area

Table 11 Surface water operational water quality monitoring

FIELD MEASUREMENTS	REPORTED AS
pH	pH units
Specific Conductivity	µs/cm @ 25°C
Dissolved Oxygen	mg/L
Temperature	°C
LABORATORY MEASUREMENTS	
Total Dissolved Solids	mg/L
Total Suspended Solids	mg/L:
Bicarbonate	mg/L
Carbonate	mg/L
Calcium (dissolved)	mg/L
Chloride	mg/L
Iron (total)	mg/L
Iron (dissolved)	mg/L
Magnesium (dissolved)	mg/L
Manganese (total)	mg/L
Manganese (dissolved)	mg/L
Potassium (dissolved)	mg/L
Sodium (dissolved)	mg/L
Sulfate	mg/L
Oil and grease	mg/L
Cations	meq/l
Anions	meq/l
Cation/Anion Balance	%

Table 12 Groundwater operational water quality monitoring.

FIELD MEASUREMENTS	REPORTED AS
pH	pH units
Specific Conductivity	µs/cm @ 25°C
Temperature	°C
LABORATORY MEASUREMENTS	
Total Dissolved Solids	mg/L
Carbonate	mg/L
Bicarbonate	mg/L
Calcium (dissolved)	mg/L
Chloride	mg/L
Iron (total)	mg/L
Iron (dissolved)	mg/L
Magnesium (dissolved)	mg/L
Manganese (total)	mg/L
Manganese (dissolved)	mg/L
Potassium (dissolved)	mg/L
Sodium (dissolved)	mg/L
Sulfate	mg/L
Cations	meq/L
Anions	meq/L
Cation/Anion Balance	%

Table 13 Potentiometric levels in wells in the Coal Hollow Project area.

	Date	Elevation
Alluvial Wells		
Y47	6/22/1986	6857.0
	8/5/1986	6854.0
	9/8/1986	6853.0
	10/8/1986	6852.6
	10/28/1986	6852.9
	11/16/1986	6853.1
	12/9/1986	6853.4
	1/6/1987	6853.4
	2/11/1987	6852.8
Y50	6/22/1986	6862.5
	8/3/1986	6861.5
	9/7/1986	6861.2
	10/4/1986	6861.2
	11/1/1986	6861.2
	11/22/1986	6862.4
	12/15/1986	6861.1
	1/10/1987	6861.2
	1/31/1987	6861.0
Y57	6/21/1986	6985.2
	10/12/1986	6985
	12/16/1986	6984.3
Y-59	6/24/1986	7010.5
	8/5/1986	7005.9
	9/12/1986	6982.8
	10/13/1986	6982.8
	11/1/1986	6981.7
	11/23/1986	6982.8
	12/10/1986	6981.5
	1/5/1987	6984.3
	3/3/1987	6984.3
	1/16/2007	6977.5
Y-61	9/17/1986	6979.2
	12/16/1986	6978.6
Y62	6/21/1986	6825.5
	9/17/1986	6826.6
	12/16/1986	6828.0
Y102	8/14/1986	6965.6
	9/10/1986	6956.3
	10/5/1986	6958.6
	10/29/1986	6957.5
	11/22/1986	6957.5

	Date	Elevation
	12/16/1986	6957
	1/10/1987	6957.7
	2/3/1987	6956.3
	1/16/2007	6955.8
C5-130	1/17/2007	6986.9
	3/29/2007	7007.4
Y98	8/2/1986	7094.8
	9/3/1986	7093.5
	10/7/1986	7091.2
	10/30/1986	7091.1
	11/18/1987	7091.0
	12/11/1986	7091.1
	1/12/1987	7091.1
	2/1/1987	7091.4
	5/27/2005	7092.5
	9/25/2005	7102.0
	11/4/2005	7094.6
	1/25/2006	7090.8
	5/29/2006	7092.0
	12/21/2006	7088.7
	3/28/2007	7088.7
Y99	8/2/1986	dry (< 7040.5)
	9/3/1986	dry (< 7040.5)
	10/7/1986	dry (< 7040.5)
	10/30/1986	dry (< 7040.5)
	11/18/1987	dry (< 7040.5)
	12/11/1986	dry (< 7040.5)
	1/12/1987	dry (< 7040.5)
	2/1/1987	dry (< 7040.5)
	5/27/2005	dry (< 7040.5)
	9/25/2005	dry (< 7040.5)
	11/4/2005	dry (< 7040.5)
	5/30/2006	dry (< 7040.5)
	12/21/2006	dry (< 7040.5)
	3/28/2007	dry (< 7040.5)
Y63	7/21/1986	6781.9
	9/12/1986	6778.3
	10/12/1986	6774.2
	11/1/1986	6773.5
	11/21/1986	6773.1
	12/14/1986	6775.4
	1/20/1987	6776.1
	2/9/1987	6775.2
	6/18/2005	6780.8
	9/24/2005	6777.0
	11/3/2005	6776.3
	3/30/2006	6776.8
	5/16/2006	6778.2

	Date	Elevation
	9/7/2006	6775.6
	12/21/2006	6775.1
	3/30/2007	6775.8
Sorensen Spring box	11/4/2005	>6960.6
	3/31/2006	6960.4
	5/29/2006	6960.1
	9/8/2006	>6960.6
	12/20/2006	6960.0
	3/29/2007	6960.1
Coal Wells		
Y36	12/11/1979	6877.6
	6/12/1980	6876.9
	8/15/1980	6876.5
	9/4/1980	6876.3
	10/9/1980	6876.8
	11/13/1980	6876.9
	7/28/1986	6876.2
	8/27/1986	6876.2
	9/19/1986	6876.3
	10/27/1986	6876.4
	11/14/1986	6876.4
	12/10/1986	6876.7
	2/11/1987	6878.0
	8/12/2005	6878.1
	11/4/2005	6871.7
	3/31/2006	6872.6
	5/29/2006	6872.3
	9/7/2006	6871.7
	12/21/2006	6871.9
	3/29/2007	6873.4
Y38	11/17/1979	6812.7
	12/11/1979	6810.3
	6/12/1980	6811.3
	8/15/1980	6810.8
	9/4/1980	6810.7
	10/9/1980	6810.7
	11/13/1980	6810.7
	6/24/1986	6812.3
	10/14/1986	6811.4
	12/5/1986	6811.3
	6/17/2005	6808.0
	9/25/2005	6807.4
	11/3/2005	6807.5
	3/30/2006	6808.1
	5/30/2006	6807.9
	9/8/2006	6809.7
	3/30/2007	6809.4

	Date	Elevation
Y39	11/17/1979	6834.6
	12/11/1979	6827.5
	6/12/1980	6828.8
	8/15/1980	6828.8
	9/4/1980	6828.8
	10/9/1980	6828.7
	11/13/1980	6829.0
	6/25/1986	Dry
	8/3/1986	Dry
	9/12/1986	Dry
	10/15/1986	Dry
	11/5/1986	Dry
	11/23/1986	Dry
	12/16/1986	Dry
Y40	11/17/1979	6815.6
	12/11/1979	6810.1
	6/12/1980	6810.4
	8/15/1980	6810.2
	9/4/1980	6808.9
	10/9/1980	6810.6
	11/13/1980	6810.5
	6/21/1986	6811.0
	10/17/1986	6809.9
	12/16/1986	6809.9
Y41	11/17/1979	6796.2
	12/11/1979	6795.4
	6/12/1980	6798.9
	8/15/1980	6797.8
	9/14/1980	6797.4
	10/9/1980	6797.1
	11/13/1980	6796.8
	6/23/1986	6796.3
	10/14/1986	6795.2
	12/5/1986	6795.4
Y43	11/17/1979	6825.6
	12/11/1979	6815.5
	6/12/1980	6821.3
	8/15/1980	6825.1
	9/4/1980	6825.8
	10/9/1980	6825.8
	11/13/1980	6825.8
	6/21/1986	6859.0
	10/17/1986	6826.0
	12/15/1986	6825.2
Y45	10/9/1980	6804.4
	11/13/1980	6797.4
	12/13/1980	6798.4
	7/22/1986	6796.2

	Date	Elevation
	8/12/1986	6796.3
	9/22/1986	6796.1
	10/29/1986	6796.2
	11/17/1986	6795.9
	12/13/1986	6796.1
	1/24/1987	6796.4
	2/10/1987	6796.9
	11/4/2005	6794.2
	5/30/2006	6794.2
	9/7/2006	6793.7
	12/20/2006	6793.9
	3/29/2007	6793.9
Y48	10/9/1980	6837.4
	12/13/1980	6834.4
	6/22/1986	6838.1
	8/5/1986	6836.9
	9/8/1986	6836.8
	10/5/1986	6837.1
	10/28/1986	6837.3
	11/16/1986	6837.3
	12/9/1986	6837.5
	1/6/1987	6837.7
	2/10/1987	6837.9
Y49	10/9/1980	6832.1
	12/13/1980	6832.1
	6/24/1986	6832.6
	8/3/1986	6831.4
	9/7/1986	6831.1
	10/2/1986	6831.4
	10/24/1986	6831.2
	11/12/1986	6831.0
	12/6/1986	6830.3
	1/10/1987	6831.1
	1/31/1987	6831.0
Y53	10/9/1980	6860.6
	12/13/1980	6822.6
	6/27/1986	6822.6
	8/2/1986	6822.7
	9/10/1986	6822.7
	10/4/1986	6822.8
	11/3/1986	6824.1
	11/22/1986	6824.1
	12/14/1986	6822.9
	1/17/1987	6823.1
	2/13/1987	6824.0

Appendix A

Isotopic laboratory reporting sheets

GEOCHRON LABORATORIES

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711 Concord Avenue ✦ Cambridge, Massachusetts 02138-1002 ✦ USA
t (617) 876-3691 **f** (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32315**	Date Received:	01/20/2006
Your Reference:	Allen Childs, Coal Hollow Project	Date Reported:	02/08/2006
Submitted by:	Erik C. Petersen, P.G. Senior Hydrogeologist Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043		

Sample Name: **Solar Panel Spring 3 Nov 05**

AGE = **89.04 ± 1.04 % of the modern (1950) ^{14}C activity**

Description: Sample of barium carbonate

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-12.6 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32310**	Date Received:	01/20/2006
Your Reference:	Allen Childs, Coal Hollow Project	Date Reported:	02/08/2006
Submitted by:	Erik C. Petersen, P.G. Senior Hydrogeologist Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043		

Sample Name: **Y-61 4 Nov 05**

AGE = **66.41 ± 0.98 % of the modern (1950) ^{14}C activity**

Description: Sample of barium carbonate

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-10.1 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32311**	Date Received:	01/20/2006
Your Reference:	Allen Childs, Coal Hollow Project	Date Reported:	02/08/2006
Submitted by:	Erik C. Petersen, P.G. Senior Hydrogeologist Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043		

Sample Name: **Y-59 4 Nov 05**

AGE = **67.50 ± 0.97 % of the modern (1950) ^{14}C activity**

Description: Sample of barium carbonate

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-10.4 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32312**	Date Received:	01/20/2006
Your Reference:	Allen Childs, Coal Hollow Project	Date Reported:	02/08/2006
Submitted by:	Erik C. Petersen, P.G. Senior Hydrogeologist Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043		

Sample Name: **Y-102 4 Nov 05**

AGE = **69.03 ± 0.82 % of the modern (1950) ^{14}C activity**

Description: Sample of barium carbonate

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-9.9 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32313**	Date Received:	01/20/2006
Your Reference:	Allen Childs, Coal Hollow Project	Date Reported:	02/08/2006
Submitted by:	Erik C. Petersen, P.G. Senior Hydrogeologist Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043		

Sample Name: **SP-8 4 Nov 05**

AGE = **66.41 ± 0.99 % of the modern (1950) ^{14}C activity**

Description: Sample of barium carbonate

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-10.2 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

GEOCHRON LABORATORIES

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-32314**	Date Received:	01/20/2006
Your Reference:	Allen Childs, Coal Hollow Project	Date Reported:	02/08/2006
Submitted by:	Erik C. Petersen, P.G. Senior Hydrogeologist Petersen Hydrologic 2695 N. 600 E. Lehi, Utah 84043		

Sample Name: **SP-4 3 Nov 05**

AGE = **46.64 ± 0.84 % of the modern (1950) ^{14}C activity**

Description: Sample of barium carbonate

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-10.5 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

GENERAL COMMENTS ON TRITIUM RESULTS

Tritium Scale New Half-life

Tritium concentrations are expressed in TU, where 1 TU indicates a T/H abundance ratio of 10^{-18}. The values refer to the tritium scale recommended by U.S. National Institute of Science and Technology (NIST, formerly NBS), and International Atomic Energy Agency (IAEA). The TU-numbers are based on the NIST tritium water standard #4926E. Age corrections and conversions are made using the recommended half-life of **12.32 years**, i.e., a decay rate of λ = 5.626% year^{-1}. In this scale, 1 TU is equivalent to 7.151 dpm/kg H_2O, or 3.222 pCi/kg H_2O, or 0.1192 Bq/kg H_2O (Bq = disint/sec).

TU values are calculated for date of sample collection, REFDATE in the table, as provided by the submitter. If no such date is available, date of sample arrival at our laboratory is used.

The stated errors, eTU, are one standard deviation (1 sigma) including all conceivable contributions. In the table, QUANT is quantity of sample received, and ELYS is the amount of water taken for electrolytic enrichment. DIR means direct run (no enrichment).

Remark: From 1 Jan 1994 through 31 Dec 2001 we used the previously recommended value for the half-life, 12.43 years. The use of the new number, 12.32 years will in practice increase the reported TU-values by 0.9 %. This is insignificant since our reported values carry 1 sigma uncertainties of 3 % or more.

It is interesting to note that before 1994 we used the older, then recommended value of 12.26 years.

Very low tritium values

In some cases, negative TU values are listed. Such numbers can occur because the net tritium count rate is, in principle the difference between the count rate of the sample and that of a tritium-free sample (background count or blank sample). Given a set of "unknown" samples with no tritium, the distribution of net results should become symmetrical around 0 TU. The negative values are reported as such for the benefit of allowing the user unbiased statistical treatment of sets of the data. For other applications, 0 TU should be used.

Additional information

Refer to Services Rendered (Tritium), Section II.8, in the "Tritium Laboratory Price Schedule; Procedures and Standards; Advice on Sampling", and our Web-site www.rsmas.edu/groups/tritium.

Tritium efficiencies and background values are somewhat different in each of the nine counters and values are corrected for cosmic intensity, gas pressure and other parameters. For tritium, the efficiency is typically 1.00 cpm per 100 TU (direct counting). At 50x enrichment, the efficiency is equivalent to 1.00 cpm per 2.4 TU. The background is typically 0.3 cpm, known to about ± 0.02 cpm. Our reported results include not only the Poisson statistics, but also other experimental uncertainties such as enrichment error, etc.

End

Client: PETERSEN HYDROLOGIC-ALTON COAL
Recvd : 06/02/01
Job# : 2175
Final : 06/03/28 Alton Coal Hollow Investigation 2006

Purchase Order: Bill to: A. Childs
Contact: E. Petersen, 801/766-4000
2695 N. 600 E.
Lehi, UT 84043

Cust	LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
PETERSEN -	SW-8	2175.01	050618	1000	275	8.07	0.17
PETERSEN -	SP-8 MAY	2175.02	050527	1000	275	3.38	0.11
PETERSEN -	SP-8 NOV	2175.03	051104	1000	275	3.10	0.11
PETERSEN -	Y-102 MAY	2175.04	050527	1000	275	3.28	0.12
PETERSEN -	Y-102 NOV	2175.05	051104	1000	275	3.35	0.12
PETERSEN -	Y-61	2175.06	051104	1000	275	3.28	0.12
PETERSEN -	SP-4	2175.07	051103	1000	275	-0.01	0.09
PETERSEN -	Y-59	2175.08	051104	1000	275	3.01	0.10
PETERSEN -	SOLAR PANEL SPRING	2175.09	051103	1000	275	2.74	0.11

Appendix B

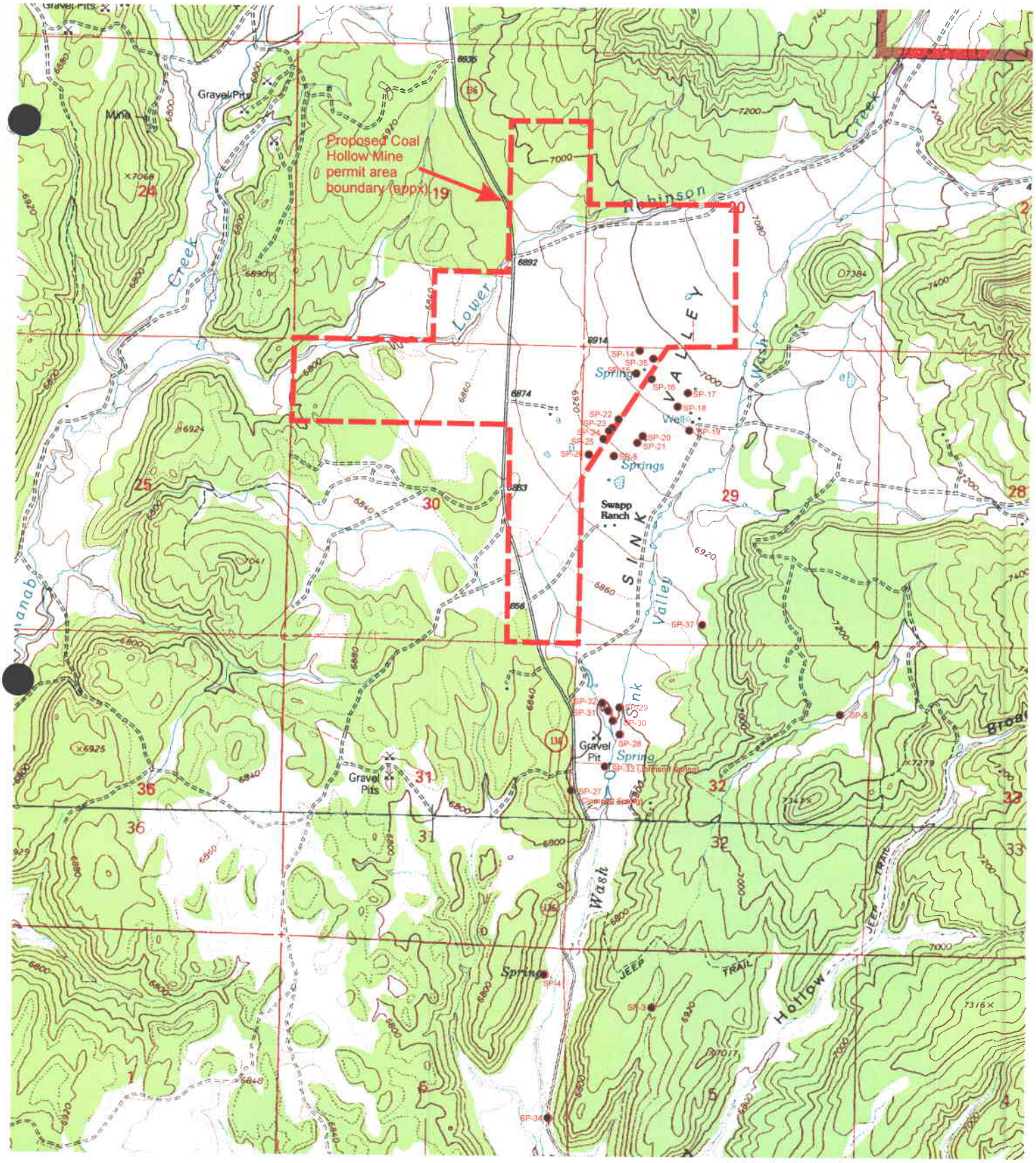
Spring and Seep Survey

Appendix B Spring and Seep survey data, Coal Hollow Project

Spring	Alternate name	Date	UTM location, Z12, NAD 27		Discharge (gpm)	T (°C)	pH	Sp. Cond. (µS/cm)
SP-33	Johnson Spring	17-Jun-05	371788	4137543	13.2	9.1	7.87	1148
SP-33	Johnson Spring	24-Sep-05			4.37	11.2	7.79	1386
SP-33	Johnson Spring	3-Nov-05			4.36	10.6	7.86	1031
SP-33	Johnson Spring	30-Mar-06			9.43	7.6	7.96	1254
SP-33	Johnson Spring	21-Apr-06				8	7.97	1293
SP-33	Johnson Spring	29-May-06			8.98	9	7.96	1239
SP-3		18-Jun-05	372028	4136009	5.94	9.8	7.43	658
SP-3		24-Sep-05			7.23	9.5	7.58	777
SP-3		3-Nov-05			6.82	9.5	7.42	703
SP-3		30-Mar-06			7.37	9.9	7.48	703
SP-3		29-May-06			7.73	9.5	7.57	747
SP-4		18-Jun-05	371531	4136427	0.96			
SP-4		24-Sep-05			0.72	12.5	7.47	990
SP-4		3-Nov-05			0.76	10.6	7.61	984
SP-4		30-Mar-06			0.64	8.6	7.7	955
SP-4		29-May-06			0.85	11.3	7.76	972
SP-5		18-Jun-05	373080	4137820	Dry			
SP-5		12-Aug-05			Damp			
SP-5		30-May-06			Dry			
SP-6		17-Jun-05	371717	4137977	Seep	19.2	8.5	804
SP-6		24-Sep-05			Seep	16.0	7.41	1310
SP-6		3-Nov-05			Seep	10.5	7.76	1602
SP-6		16-May-06			Seep	18.7	8.21	1918
SP-6		29-May-06			Seep	25.2	8.12	1475
SP-8		27-May-05			17.6	10.3	7.89	642
SP-8		18-Jun-05	371861	4139231		11.5	7.39	660
SP-8		24-Sep-05			9.1	9.6	7.27	704
SP-8		4-Nov-05			12.8	9.6	7.48	706
SP-8		31-Mar-06			20.3	9.3	7.5	716
SP-8		16-May-06			19.1	9.7	7.42	726
SP-8		29-May-06			14.0	10.5	7.75	701
SP-14		16-May-06	372023	4139790	6.3	12.7	7.83	734
		31-Mar-06			5.77	8.6	7.4	708
SP-15		10-Nov-05	371960	4139660	0.57	9.1	7.44	715
		16-May-06			0.9	11.1	7.71	733
SP-16	Teal Spring	4-Nov-05	372035	4139656	1.35	6.7	7.3	692
		25-Jan-06			1.00	4.3	7.59	695
		16-May-06			0.98	11.9	7.42	737
		29-May-06			0.86	10.5	7.68	712
SP-17		16-May-05	372236	4139559	Seep			
SP-18		16-May-05	372196	4139486	Seep	9.6	7.46	700
SP-19	Sorenson Pond	4-Nov-05	372256	4139384	Seep	8.7	8.07	779
		31-Mar-06			0.33	8.9	7.58	699
		16-May-06			0.24	9.3	7.53	730

Spring	Alternate name	Date	UTM location, Z12, NAD 27		Discharge (gpm)	T (°C)	pH	Sp. Cond. (µS/cm)
SP-20		31-Mar-06			5.95	9.3	7.66	696
		16-May-06	372014	4139325	6.76	9.5	7.39	704
SP-21		16-May-06	371980	4139289	0.98	9.6	7.43	709
		29-May-06			0.85	9.5	7.78	680
SP-22		10-Nov-05	371863	4139423	Seep	9.9	7.56	725
		16-May-06	371869	4139430	Seep	9.3	7.38	780
SP-23		10-Nov-05	371838	4139382	Seep	10	7.33	736
		16-May-06			0.84	9.2	7.38	735
SP-24		10-Nov-05	371822	4139356	Seep	8.6	7.45	1324
		16-May-06			Seep	12.5	7.42	1241
SP-25		10-Nov-05			Seep	9.4	7.47	911
		16-May-06	371798	4139322	0.21	12.2	7.49	1083
SP-26		10-Nov-05	371717	4139211	Seep	9.6	7.4	738
		16-May-06			1.5	9.6	7.44	742
SP-28	Seep #1	17-Jun-05	371896	4137718	Seep	23	7.99	2110
		12-Aug-05			Dry			
		3-Nov-05			Dry			
		16-May-06			Dry			
SP-29	Seep #2	17-Jun-05	371885	4137853	Seep	17.4	7.58	2570
		12-Aug-05			Dry			
		3-Nov-05			Dry			
		16-May-06			Seep	12.4	7.35	2740
SP-30	Seep #3	17-Jun-05	371852	4137787	Seep	20.9	7.98	2940
		12-Aug-05			Dry			
		3-Nov-05			Dry			
		16-May-05			Seep	15.8	8.45	3180
SP-31	Seep #4	17-Jun-05	371830	4137764	Seep	21.7	8.61	3080
		12-Aug-05			Dry			
		3-Nov-05			Dry			
		16-May-06			Seep	13.7	8.49	4150
SP-32	Seep #5	17-Jun-05	371810	4137864	Seep	22.2	9.1	2690
		12-Aug-05			Dry			
		3-Nov-05			Dry			
		16-May-06			0.2	17.8	8.34	2910
SP-34		16-May-06	371512	4135632	Seep	13	7.04	2470
SP-35		29-May-06	372051	4139747	0.21	9.5	7.62	706
SP-27	Clampett Spring	17-Jun-05	371645	4137416	0.5	16.6	8.94	4,580
SP-27		3-Nov-05			Seep	7.8	8.52	4,640
SP-36		1-Feb-07	371830	4139979	5 est.			

Spring	Alternate name	Date	UTM location, Z12, NAD 27		Discharge (gpm)	T (°C)	pH	Sp. Cond. (µS/cm)
SP-37		2-Jan-07	372316	4138266	<0.1	6.2	9.19	1035
		30-Mar-07			0.1	5.8	8.98	1191



Appendix B Spring and seep locations.

Appendix C

Large version of Figure 19, Surface-water drainages in the proposed Coal Hollow Mine permit and surrounding area.

APPENDIX 7-3

EXHIBIT 7-1

Stream Reaches

STREAM REACHES

REF #	WR #	OWNER	SOURCE
1	85-162	Garn L. Swapp	Kanab Creek
2	85-303	Sharon C. & Lorene C. Lamb	Kanab Creek
3	85-608	Lloyd, Ross, Gail & Vard Heaton	Lower Robinson Creek
4	85-463	BLM	Lower Robinson Creek
5	85-209	C. Burton Pugh	Lower Robinson Creek
6	85-210	C. Burton Pugh	Lower Robinson Creek
7	85-458	BLM	Lower Robinson Creek
8	85-211	C. Diane & Greg Braund & C. Burton Pugh	Lower Robinson Creek
9	85-459	BLM	Lower Robinson Creek
10	85-393	Sharon C. & Lorene C. Lamb	Lower Robinson Creek
11	85-213	C. Burton Pugh	Right Hand Wash
12	85-387	Darlynn & Arlene Sorensen	Right Hand Wash
13	85-388	Darlynn & Arlene Sorensen	Sink Valley Wash

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-162

SR 1

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-162 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Garn L. Swapp
ADDR: P.O. Box 354
Kanab UT 84741

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 08/01/1969 |PRIORITY: 00/00/1864 |PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/01/1969|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 4a

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Kanab Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in SW4NE4 Sec 24, T39S, R6W, SLBM,
to a point in NW4SE4 Sec 24, T39S, R6W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612239. Water Rights Appurtenant to the following use(s):
85-159,160,161,162,163

###STOCKWATER: Group Total: 400 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-162 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST NW NE SW SE	NORTH-EAST NW NE SW SE	SOUTH-WEST NW NE SW SE	SOUTH-EAST NW NE SW SE
Sec 24 T 39S R 6W SLBM	* : : : *	* : : X: *	* : : : *	* X: : : *

E N D O F D A T A

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-303

SR 2

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-303 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Sharon E. and Lorene C. Lamb
ADDR: Orderville UT 84758

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 09/03/1969|PRIORITY: 00/00/1864|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 09/03/1969|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 4a

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Kanab Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in SW4SE4 Sec 24, T39S, R6W, SLBM,
to a point in SW4SE4 Sec 24, T39S, R6W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612336. Water Rights Appurtenant to the following use(s):
85-303,304,393

###STOCKWATER: Group Total: 60 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-303 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST NW NE SW SE	NORTH-EAST NW NE SW SE	SOUTH-WEST NW NE SW SE	SOUTH-EAST NW NE SW SE
Sec 24 T 39S R 6W SLBM	* : : : *	* : : : *	* : : : *	* : : X: *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-608

SR 3

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-608 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Lloyd W. & Ross E. & Gail P. & Vard H. Heaton
ADDR: Alton UT 84710

NAME: Ross E. Heaton
ADDR: Alton UT

NAME: Gail P. Heaton
ADDR: Alton UT

NAME: Vard H. Heaton
ADDR: Alton UT

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 04/14/1970|PRIORITY: 00/00/1864|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 04/14/1970|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 5b

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Lower Robinson Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in NE4NE4 Sec 20, T39S, R5W, SLBM,
to a point in NE4NE4 Sec 20, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612401. Water Rights Appurtenant to the following use(s):
85-412,413,414,415,543,544,545,546,547,548,549,550,551,552,553,554,555,556,557,558,559,608,631,632,713,733

###STOCKWATER: Group Total: 1600 Stock Unit Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-608 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612515. Water Rights Appurtenant to the following use(s):
85-412,413,414,415,543,544,545,546,547,548,549,550,551,552,553,554,555,556,557,558,559,608,631,632,713,731,733

###STOCKWATER: Group Total: 1600 Stock Unit Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-608 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST NW NE SW SE	NORTH-EAST NW NE SW SE	SOUTH-WEST NW NE SW SE	SOUTH-EAST NW NE SW SE
Sec 20 T 39S R 5W SLBM	* : : : *	* : X: : *	* : : : *	* : : : *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-463

SR 4

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-463 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Kanab District USA Bureau of Land Management
ADDR: 320 North 1st East
Kanab UT 84741

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED:	|PRIORITY: 00/00/1864	|PUB BEGAN:	|PUB ENDED:	|NEWSPAPER:
ProtestEnd:	|PROTESTED: [No]	|HEARNG HLD:	|SE ACTION: [ ]	|ActionDate: |PROOF DUE:
EXTENSION:	|ELEC/PROOF: [ ]	|ELEC/PROOF:	|CERT/WUC:	|LAP, ETC: |PROV LETTER:
RENOVATE:	|RECON REQ:	|TYPE: [ ]		

PD Book No. 1 Map: 5b

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Lower Robinson Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in SW4NE4 Sec 20, T39S, R5W, SLBM,
to a point in SE4NW4 Sec 20, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612417. Water Rights Appurtenant to the following use(s):
85-458,462,463,464

###STOCKWATER: Group Total: 13 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-463 in this Group has NOT YET been evaluated
Cecil Pugh Allotment No. 39

PLACE OF USE for STOCKWATERING

	NORTH-WEST NW NE SW SE	NORTH-EAST NW NE SW SE	SOUTH-WEST NW NE SW SE	SOUTH-EAST NW NE SW SE
Sec 20 T 39S R 5W SLBM	* : : : X*	* : : X: *	* : : : *	* : : : *

E N D O F D A T A

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-209

SR 5

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-209 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: C. Burton Pugh
ADDR: 533 North 650 East
Lindon, Utah 84042

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 08/08/1969 | PRIORITY: 00/00/1864 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 08/08/1969 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5b

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Lower Robinson Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in SE4NE4 Sec 20, T39S, R5W, SLBM,
to a point in SE4NE4 Sec 20, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612093. Water Rights Appurtenant to the following use(s):
85-100,199,200,201,202,203,204,205,206,207,208,209,210,211,213,214,215

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-209 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612251. Water Rights Appurtenant to the following use(s):
85-94,95,96,97,98,183,184,185,186,187,188,208,209,210,211,212,213,221,222,227,228,229,256,282,284,614

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-209 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST NW NE SW SE	NORTH-EAST NW NE SW SE	SOUTH-WEST NW NE SW SE	SOUTH-EAST NW NE SW SE
Sec 20 T 39S R 5W SLBM	* : : : *	* : : : X*	* : : : *	* : : : *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-210

SR 6

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-210 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: C. Burton Pugh
ADDR: 533 North 650 East
Lindon, Utah 84042

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 08/08/1969|PRIORITY: 00/00/1864|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/08/1969|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 5b

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Lower Robinson Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in NE4SW4 Sec 20, T39S, R5W, SLBM,
to a point in SW4SE4 Sec 19, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612093. Water Rights Appurtenant to the following use(s):
85-100,199,200,201,202,203,204,205,206,207,208,209,210,211,213,214,215

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-210 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612251. Water Rights Appurtenant to the following use(s):
85-94,95,96,97,98,183,184,185,186,187,188,208,209,210,211,212,213,221,222,227,228,229,256,282,284,614

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-210 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST NW NE SW SE	NORTH-EAST NW NE SW SE	SOUTH-WEST NW NE SW SE	SOUTH-EAST NW NE SW SE
Sec 19 T 39S R 5W SLBM	* : : : *	* : : : *	* : : : *	* : : X: *
Sec 20 T 39S R 5W SLBM	* : : : *	* : : : *	* : X: : *	* : : : *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-458

SR 7

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-458 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Kanab District USA Bureau of Land Management
ADDR: 320 North 1st East
Kanab UT 84741

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED:	PRIORITY: 00/00/1864	PUB BEGAN:	PUB ENDED:	NEWSPAPER:	
ProtestEnd:	PROTESTED: [No	HEARNG HLD:	SE ACTION: [	ActionDate:	PROOF DUE:
EXTENSION:	ELEC/PROOF: [	ELEC/PROOF:	CERT/WUC:	LAP, ETC:	PROV LETTER:
RENOVATE:	RECON REQ:	TYPE: [ ]			

PD Book No. 1 Map: 4a

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Lower Robinson Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in SE4SW4 Sec 19, T39S, R5W, SLBM,
to a point in SW4SW4 Sec 19, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612417. Water Rights Appurtenant to the following use(s):
85-458,462,463,464

###STOCKWATER: Group Total: 13 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-458 in this Group has NOT YET been evaluated
Cecil Pugh Allotment No. 39

PLACE OF USE for STOCKWATERING

	NORTH-WEST	NORTH-EAST	SOUTH-WEST	SOUTH-EAST
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 19 T 39S R 5W SLBM	* : : : *	* : : : *	* : : X: X*	* : : : *

END OF DATA

STATE OF UTAH -- DIVISION OF WATER RIGHTS -- DATA PRINT OUT for 85-211

SR 8

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-211 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: C. Diane and Greg Braund
ADDR: 5720 Hedgehaven Court
Las Vegas, NV 89120
REMARKS: 1.008 acft, 36 elu's supp/w other rights (joint tenants)

NAME: C. Burton Pugh
ADDR: 533 North 650 East
Lindon, Utah 84042
REMARKS: 214 elu's supp/w other rights

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED: 08/08/1969	PRIORITY: 00/00/1864	PUB BEGAN:	PUB ENDED:	NEWSPAPER:	
ProtestEnd:	PROTESTED: [No]	HEARNG HLD:	SE ACTION: [ ]	ActionDate:	PROOF DUE:
EXTENSION:	ELEC/PROOF: [ ]	ELEC/PROOF:	CERT/WUC: 08/08/1969	LAP, ETC:	PROV LETTER:
RENOVATE:	RECON REQ:	TYPE: [ ]			

PD Book No. 1 Map: 4d

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Lower Robinson Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in NW4NW4 Sec 30, T39S, R5W, SLBM,
to a point in NW4NW4 Sec 30, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612093. Water Rights Appurtenant to the following use(s):
85-100,199,200,201,202,203,204,205,206,207,208,209,210,211,213,214,215

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-211 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612251. Water Rights Appurtenant to the following use(s):
85-94,95,96,97,98,183,184,185,186,187,188,208,209,210,211,212,213,221,222,227,228,229,256,282,284,614

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-211 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST	NORTH-EAST	SOUTH-WEST	SOUTH-EAST
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 30 T 39S R 5W SLBM	* X: : : *	* : : : *	* : : : *	* : : : *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-459

SR 9

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-459 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Kanab District USA Bureau of Land Management
ADDR: 320 North 1st East
Kanab UT 84741

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED:	PRIORITY: 00/00/1864	PUB BEGAN:	PUB ENDED:	NEWSPAPER:	
ProtestEnd:	PROTESTED: [No	HEARNG HLD:	SE ACTION: [	ActionDate:	PROOF DUE:
EXTENSION:	ELEC/PROOF: [	ELEC/PROOF:	CERT/WUC:	LAP, ETC:	PROV LETTER:
RENOVATE:	RECON REQ:	TYPE: [ ]			

PD Book No. 1 Map: 4d

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Lower Robinson Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in NE4NE4 Sec 25, T39S, R6W, SLBM,
to a point in NE4NE4 Sec 25, T39S, R6W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612418.

***STOCKWATER: 18 Stock Units Diversion Limit: PERIOD OF USE: 05/01 TO 10/31
Sharon Lamb Allotment No. 38.

PLACE OF USE for STOCKWATERING

	NORTH-WEST				NORTH-EAST				SOUTH-WEST				SOUTH-EAST			
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE
Sec 25 T 39S R 6W SLBM	*	:	:	: *	*	:	X:	: *	*	:	:	: *	*	:	:	: *

END OF DATA

STATE OF UTAH -- DIVISION OF WATER RIGHTS -- DATA PRINT OUT for 85-393

SR 10

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-393 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Sharon C. & Lorene C. Lamb
ADDR: Orderville UT 84741

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 02/17/1970 |PRIORITY: 00/00/1864 |PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 02/17/1970|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 4d

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Lower Robinson Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in NW4NE4 Sec 25, T39S, R6W, SLBM,
to a point in NE4NW4 Sec 25, T39S, R6W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612336. Water Rights Appurtenant to the following use(s):
85-303,304,393

###STOCKWATER: Group Total: 60 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-393 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST	NORTH-EAST	SOUTH-WEST	SOUTH-EAST
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 25 T 39S R 6W SLBM	* : X: : *	* X: : : *	* : : : *	* : : : *

E N D O F D A T A

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-213

SR 11

(WARNING: Water Rights makes NO claims as to the accuracy of this data) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-213 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: C. Burton Pugh
ADDR: 533 North 650 East
Lindon, Utah 84042

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 08/08/1969|PRIORITY: 00/00/1864|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/08/1969|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 5b

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Right Hand Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in SW4NW4 Sec 21, T39S, R5W, SLBM,
to a point in NW4SE4 Sec 21, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612093. Water Rights Appurtenant to the following use(s):
85-100,199,200,201,202,203,204,205,206,207,208,209,210,211,213,214,215

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-213 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612251. Water Rights Appurtenant to the following use(s):
85-94,95,96,97,98,183,184,185,186,187,188,208,209,210,211,212,213,221,222,227,228,229,256,282,284,614

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-213 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST NW NE SW SE	NORTH-EAST NW NE SW SE	SOUTH-WEST NW NE SW SE	SOUTH-EAST NW NE SW SE
Sec 21 T 39S R 5W SLBM	* : : X: *	* : : : *	* : : : *	* X: : : *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-387

(WARNING: Water Rights makes NO claims as to the accuracy of this data) RUN DATE: 05/24/2006

WATER RIGHT: 85-387 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970 | PRIORITY: 00/00/1864 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 01/29/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5b

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Right Hand Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in SW4SE4 Sec 20, T39S, R5W, SLBM,
to a point in NW4SW4 Sec 29, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-387 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST¼	NORTH-EAST¼	SOUTH-WEST¼	SOUTH-EAST¼
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 20 T 39S R 5W SLBM	* : : : *	* : : : *	* : : : *	* : : X: *
Sec 29 T 39S R 5W SLBM	* : : : *	* : : : *	* X: : : *	* : : : *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-388

SR 13

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-388 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970 | PRIORITY: 00/00/1864 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 01/29/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: SOURCE: Sink Valley Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point in NW4SW4 Sec 29, T39S, R5W, SLBM,
to a point at N500 ft. E580 ft. from W4 corner, Sec 32, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-388 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST	NORTH-EAST	SOUTH-WEST	SOUTH-EAST
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 29 T 39S R 5W SLBM	* : : : *	* : : : *	* X: : : *	* : : : *
Sec 32 T 39S R 5W SLBM	* : : X: *	* : : : *	* : : : *	* : : : *

E N D O F D A T A

APPENDIX 7-3

EXHIBIT 7-2

Surface Diversions

SURFACE DIVERSIONS

REF #	WR #	OWNER	SOURCE
1	85-366	Darlynn & Arlene Sorensen	Right Hand Wash
2	85-367	Darlynn & Arlene Sorensen	Right Hand Wash
3	85-368	Darlynn & Arlene Sorensen	Right Hand Wash
4	85-365	Darlynn & Arlene Sorensen	Swapp Canyon Creek
5	85-369	Darlynn & Arlene Sorensen	Sink Valley Wash
6	85-370	Darlynn & Arlene Sorensen	Sink Valley Wash
7	85-371	Darlynn & Arlene Sorensen	Sink Valley Wash
8	85-372	Darlynn & Arlene Sorensen	Sink Valley Wash
9	85-356	James, Julie & Lloyd Johnson	Sink Valley Wash

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-366

SD 1

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-366 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970 | PRIORITY: 00/00/1889 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 01/29/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 10.0 cfs SOURCE: Right Hand Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 1040 ft E 100 ft from N4 cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612373. Water Rights Appurtenant to the following use(s):
85-362,366

###IRRIGATION: Group Total: 101.1 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-366 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 29 T 39S R 5W SLBM		8.8000	10.0000	27.4000					14.3000	0.6000	29.8000						90.9000
Sec 32 T 39S R 5W SLBM	10.2000																10.2000

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-366 in this Group has NOT YET been evaluated

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-367

SD 2

(WARNING: Water Rights makes NO claims as to the accuracy of this data) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-367 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP**********

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.**********

LAND OWNED BY APPLICANT?

FILED: 01/29/1970	PRIORITY: 00/00/1889	PUB BEGAN:	PUB ENDED:	NEWSPAPER:
ProtestEnd:	PROTESTED: [No]	HEARNG HLD:	SE ACTION: [ ]	ActionDate:
EXTENSION:	ELEC/PROOF: [ ]	ELEC/PROOF:	CERT/WUC: 01/29/1970	LAP, ETC:
RENOVATE:	RECON REQ:	TYPE: [ ]		

PROOF DUE:
PROV LETTER:

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT**********

FLOW: 10.0 cfs SOURCE: Right Hand Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 200 ft E 1550 ft from W4 cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT**********

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-367 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612376. Water Rights Appurtenant to the following use(s):
85-363,367

###IRRIGATION: Group Total: 2.4 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-367 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM										2.4000							2.4000

SUPPLEMENTAL GROUP NO. 612377. Water Rights Appurtenant to the following use(s):
85-363,367,368

###IRRIGATION: Group Total: 1.1 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-367 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM									0.3000	0.8000							1.1000

This Right (85-367) has an evaluated sole-supply total for irrigation of 0.00 acres.

This Right (85-367) is a member of 3 supplemental water right groups with irrigated acreage totaling 0.00 acres.

**********E N D O F D A T A**********

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-368

SD 3

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-368 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970 | PRIORITY: 00/00/1889 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 01/29/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 10.0 cfs SOURCE: Right Hand Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 390 ft E 1360 ft from W4 cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-368 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612377. Water Rights Appurtenant to the following use(s):
85-363,367,368

###IRRIGATION: Group Total: 1.1 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-368 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM									0.3000	0.8000							1.1000

**********END OF DATA**********

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-365

SD 4

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-365 APPLICATION/CLAIM NO : CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970 | PRIORITY: 00/00/1889 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 01/29/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 10.0 cfs SOURCE: Swapp Canyon Creek

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 700 ft E 1375 ft from W4 cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-365 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612379. Water Rights Appurtenant to the following use(s):
85-364,365

###IRRIGATION: Group Total: 1.4 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-365 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM									0.2000	1.2000							1.4000

SUPPLEMENTAL GROUP NO. 612380. Water Rights Appurtenant to the following use(s):
85-364,365,369

###IRRIGATION: Group Total: 5.9 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-365 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM										0.8000	5.1000						5.9000

SUPPLEMENTAL GROUP NO. 612381. Water Rights Appurtenant to the following use(s):
85-364,365,369,370

###IRRIGATION: Group Total: 9.2 acres Diversion Limit: 0.0 acft PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-365 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM											0.9000	8.3000					9.2000

SUPPLEMENTAL GROUP NO. 612382. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371

###IRRIGATION: Group Total: 7.0 acres Diversion Limit: 0.0 acft PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-365 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM											2.3000	1.0000					3.3000
Sec 32 T 39S R 5W SLBM	3.7000																3.7000

SUPPLEMENTAL GROUP NO. 612383. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371,372

###IRRIGATION: Group Total: 13.9 acres Diversion Limit: 0.0 acft PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-365 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 32 T 39S R 5W SLBM	8.0000		5.9000														13.9000

This Right (85-365) has an evaluated sole-supply total for irrigation of 0.00 acres.

This Right (85-365) is a member of 6 supplemental water right groups with irrigated acreage totaling 0.00 acres.

**********E N D O F D A T A**********

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-369

SD 5

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-369 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED: 01/29/1970	PRIORITY: 00/00/1889	PUB BEGAN:	PUB ENDED:	NEWSPAPER:	
ProtestEnd:	PROTESTED: [No]	HEARNG HLD:	SE ACTION: [ ]	ActionDate:	PROOF DUE:
EXTENSION:	ELEC/PROOF: [ ]	ELEC/PROOF:	CERT/WUC: 01/29/1970	LAP, ETC:	PROV LETTER:
RENOVATE:	RECON REQ:	TYPE: [ ]			

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 10.0 cfs SOURCE: Sink Valley Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 1010 ft E 1290 ft from W4 cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-369 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612380. Water Rights Appurtenant to the following use(s):
85-364,365,369

###IRRIGATION: Group Total: 5.9 acres Diversion Limit: 0.0 acft PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-369 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 29 T 39S R 5W SLBM										0.8000	5.1000						5.9000

SUPPLEMENTAL GROUP NO. 612381. Water Rights Appurtenant to the following use(s):
85-364,365,369,370

###IRRIGATION: Group Total: 9.2 acres Diversion Limit: 0.0 acft PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-369 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 29 T 39S R 5W SLBM											0.9000	8.3000					9.2000

SUPPLEMENTAL GROUP NO. 612382. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371

###IRRIGATION: Group Total: 7.0 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-369 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 29 T 39S R 5W SLBM											2.3000	1.0000					3.3000
Sec 32 T 39S R 5W SLBM	3.7000																3.7000

SUPPLEMENTAL GROUP NO. 612383. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371,372

###IRRIGATION: Group Total: 13.9 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-369 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 32 T 39S R 5W SLBM	8.0000		5.9000														13.9000

SUPPLEMENTAL GROUP NO. 612384.
85-369

###IRRIGATION: 5.0 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 29 T 39S R 5W SLBM									1.2000		3.8000						5.0000

This Right (85-369) has an evaluated sole-supply total for irrigation of 0.00 acres.

This Right (85-369) is a member of 6 supplemental water right groups with irrigated acreage totaling 0.00 acres.

**********E N D O F D A T A**********

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-370

SD 6

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-370 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970 | PRIORITY: 00/00/1889 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 01/29/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 10.0 cfs SOURCE: Sink Valley Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) N 1050 ft E 1280 ft from SW cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-370 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612381. Water Rights Appurtenant to the following use(s):
85-364,365,369,370

###IRRIGATION: Group Total: 9.2 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-370 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM											0.9000	8.3000					9.2000

SUPPLEMENTAL GROUP NO. 612382. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371

###IRRIGATION: Group Total: 7.0 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-370 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM											2.3000	1.0000					3.3000
Sec 32 T 39S R 5W SLBM	3.7000																3.7000

SUPPLEMENTAL GROUP NO. 612383. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371,372

###IRRIGATION: Group Total: 13.9 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31

Sole Supply for Irrigation for 85-370 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 32 T 39S R 5W SLBM	8.0000		5.9000														13.9000

This Right (85-370) has an evaluated sole-supply total for irrigation of 0.00 acres.

This Right (85-370) is a member of 4 supplemental water right groups with irrigated acreage totaling 0.00 acres.

**********E N D O F D A T A**********

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-371

SD 7

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-371 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED: 01/29/1970	PRIORITY: 00/00/1889	PUB BEGAN:	PUB ENDED:	NEWSPAPER:
ProtestEnd:	PROTESTED: [No	HEARNG HLD:	SE ACTION: [	ActionDate:
EXTENSION:	ELEC/PROOF: [	ELEC/PROOF:	CERT/WUC: 01/29/1970	LAP, ETC:
RENOVATE:	RECON REQ:	TYPE: [		

PROOF DUE:
PROV LETTER:

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 10.0 cfs SOURCE: Sink Valley Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) N 490 ft E 1200 ft from SW cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-371 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612382. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371

###IRRIGATION: Group Total: 7.0 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-371 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 29 T 39S R 5W SLBM											2.3000	1.0000					3.3000
Sec 32 T 39S R 5W SLBM	3.7000																3.7000

SUPPLEMENTAL GROUP NO. 612383. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371,372

###IRRIGATION: Group Total: 13.9 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-371 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 32 T 39S R 5W SLBM	8.0000		5.9000														13.9000

This Right (85-371) has an evaluated sole-supply total for irrigation of 0.00 acres.

This Right (85-371) is a member of 3 supplemental water right groups with irrigated acreage totaling 0.00 acres.

**********E N D O F D A T A**********

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-372

SD 8

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-372 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970 | PRIORITY: 00/00/1889 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 01/29/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 10.0 cfs SOURCE: Sink Valley Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 290 ft E 860 ft from NW cor, Sec 32, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-372 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612383. Water Rights Appurtenant to the following use(s):
85-364,365,369,370,371,372

###IRRIGATION: Group Total: 13.9 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-372 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 32 T 39S R 5W SLBM	8.0000		5.9000														13.9000

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-356

SD 9

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006

WATER RIGHT: 85-356 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Julie Johnson
ADDR: PO Box 2063
Page AZ 86040

NAME: James Johnson
ADDR: PO Box 2063
Page AZ 86040

NAME: Lloyd Johnson
ADDR: PO Box 2063
Page AZ 86040

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 04/27/1970 | PRIORITY: 00/00/1889 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 04/27/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 0.25 cfs SOURCE: Sink Valley Wash

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) N 240 ft E 590 ft from W4 cor, Sec 32, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612367. Water Rights Appurtenant to the following use(s):
85-350,351,352,353,354,355,356,357,358,359

###STOCKWATER: Group Total: 125 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-356 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612370.
85-356

###IRRIGATION: 9.0 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 32 T 39S R 5W SLBM			1.0000						8.0000								9.0000

END OF DATA

APPENDIX 7-3

EXHIBIT 7-3

Springs

SPRINGS

REF #	WR #	OWNER	SOURCE
1	85-214	C. Burton Pugh	Tater Patch Spring
2	85-350	Richard L. & Alecia S. Dame	Swapp Ranch Spring Area #1
3	85-373	Darlynn & Arlene Sorensen	Sorensen Ranch Spring #1
4	85-374	Darlynn & Arlene Sorensen	Sorensen Ranch Spring #2
5	85-351	Richard L. & Alecia S. Dame	Swapp Ranch Spring Area #2
6	85-352	Richard L. & Alecia S. Dame	Swapp Ranch Spring Area #3
7	85-215	C. Burton Pugh	Spring House Spring
8	85-353	Richard L. & Alecia S. Dame	Swapp Ranch Spring Area #4
9	85-375	Darlynn & Arlene Sorensen	Sorensen Ranch Spring #3
10A	85-355	James, Julie & Lloyd Johnson	Pulsifer Spring
10B	85-1011	James, Julie & Lloyd Johnson	Pulsifer Spring

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-214

SPR 1

(WARNING. Water Rights makes NO claims as to the accuracy of this data) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-214 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: C. Burton Pugh
ADDR: 533 North 650 East
Lindon, Utah 84042

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 08/08/1969|PRIORITY: 03/04/1889|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/08/1969|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 0.033 cfs SOURCE: Tater Patch Spring

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 490 ft E 1040 ft from NW cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612092. Water Rights Appurtenant to the following use(s):
85-100,214

###IRRIGATION: Group Total: 0.6 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-214 in this Group has NOT YET been evaluated

###PLACE OF USE	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM	0.6000																0.6000

SUPPLEMENTAL GROUP NO. 612093. Water Rights Appurtenant to the following use(s):
85-100,199,200,201,202,203.204,205,206,207,208,209,210,211,213,214,215

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-214 in this Group has NOT YET been evaluated

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-350

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page

WATER RIGHT: 85-350 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Richard & Alecia S. Dame
ADDR: 1620 Georgia Ave.
Boulder City NV 89005-3643
INTEREST: 100% REMARKS: As Joint Tenants

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED: 04/27/1970	PRIORITY: 00/00/1889	PUB BEGAN:	PUB ENDED:	NEWSPAPER:
ProtestEnd:	PROTESTED: [No]	HEARNG HLD:	SE ACTION: [ ]	ActionDate:
EXTENSION:	ELEC/PROOF: [ ]	ELEC/PROOF:	CERT/WUC: 04/27/1970	LAP, ETC:
RENOVATE:	RECON REQ:	TYPE: [ ]		

PROOF DUE:
PROV LETTER:

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 1.0 cfs SOURCE: Swapp Ranch Spring Area No. 1

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 510 ft E 1090 ft from NW cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612366. Water Rights Appurtenant to the following use(s):
85-350,351,352,353

###IRRIGATION: Group Total: 93.0 acres Diversion Limit: 0.0 acft PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-350 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM	7.2000	0.2000	23.2000	0.3000					21.1000								52.0000
Sec 30 T 39S R 5W SLBM								1.0000						20.0000		20.0000	41.0000

SUPPLEMENTAL GROUP NO. 612367. Water Rights Appurtenant to the following use(s):
85-350,351,352,353,354,355,356,357,358,359

###STOCKWATER: Group Total: 125 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-350 in this Group has NOT YET been evaluated

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-373

SPR 3

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-373 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970 | PRIORITY: 00/00/1864 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 01/29/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 0.011 cfs SOURCE: Sorensen Ranch Spring No 1

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION:
(1)Stockwatering directly on spring located in NE4NW4 Sec 29, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365 366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-373 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612386.
85-373

###DOMESTIC: 1 Family Diversion Limit: PERIOD OF USE: 04/01 TO 12/31

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 29 T 39S R 5W SLBM		X															0.0000

PLACE OF USE for STOCKWATERING

	NORTH-WEST				NORTH-EAST				SOUTH-WEST				SOUTH-EAST			
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE
Sec 29 T 39S R 5W SLBM		X														

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-374

SPR 4

(WARNING: Water Rights makes NO claims as to the accuracy of this data) RUN DATE 05/24/2006 Page 1

WATER RIGHT: 85-374 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED: 01/29/1970	PRIORITY: 00/00/1864	PUB BEGAN:	PUB ENDED:	NEWSPAPER:	
ProtestEnd:	PROTESTED: [No]	HEARNG HLD:	SE ACTION: [ ]	ActionDate	PROOF DUE:
EXTENSION:	ELEC/PROOF: [ ]	ELEC/PROOF:	CERT/WUC: 01/29/1970	LAP. ETC:	PROV LETTER:
RENOVATE:	RECON REQ:	TYPE: [ ]			

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 0.011 cfs SOURCE: Sorensen Ranch Spring No. 2

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION:
(1)Stockwatering directly on spring located in SE4NW4 Sec 29, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386 387 388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-374 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST¼	NORTH-EAST¼	SOUTH-WEST¼	SOUTH-EAST¼
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 29 T 39S R 5W SLBM	* : : : X*	* : : : *	* : : : *	* : : : *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-351

SPR 5

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-351 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Richard L. & Alecia S Dame
ADDR: 1620 Georgia Ave.
Boulder City NV 89005-3643
INTEREST: 100% REMARKS: As Joint Tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 04/27/1970|PRIORITY: 00/00/1889|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 04/27/1970|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 0.25 cfs SOURCE: Swapp Ranch Spring Area No. 2

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 1635 ft E 1100 ft from NW cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

POINT OF DIVERSION:
(1)Stockwatering directly on spring located in SW4NW4 Sec 29, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612366. Water Rights Appurtenant to the following use(s):
85-350,351,352,353

###IRRIGATION: Group Total: 93.0 acres Diversion Limit: 0 0 acft PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-351 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM	7.2000	0.2000	23.2000	0.3000					21.1000								52.0000
Sec 30 T 39S R 5W SLBM								1.0000						20.0000		20.0000	41.0000

SUPPLEMENTAL GROUP NO. 612367. Water Rights Appurtenant to the following use(s):
85-350,351,352,353,354,355,356,357,358,359

###STOCKWATER: Group Total: 125 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-351 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST¼				NORTH-EAST¼				SOUTH-WEST¼				SOUTH-EAST¼			
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE
Sec 29 T 39S R 5W SLBM			X													

****
**********E N D O F D A T A**********
****

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-352

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-352 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Richard L. & Alecia S. Dame
ADDR: 1620 Georgia Ave.
Boulder City NV 89005-3643
INTEREST: 100% REMARKS: As Joint Tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 04/27/1970 | PRIORITY: 00/00/1889 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 04/27/1970 | LAP. ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 0.25 cfs SOURCE: Swapp Ranch spring Area No 3

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 1475 ft E 530 ft from NW cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612366. Water Rights Appurtenant to the following use(s):
85-350,351,352,353

###IRRIGATION: Group Total: 93.0 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-352 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM	7.2000	0.2000	23.2000	0.3000					21.1000								52.0000
Sec 30 T 39S R 5W SLBM								1.0000						20.0000		20.0000	41.0000

SUPPLEMENTAL GROUP NO. 612367. Water Rights Appurtenant to the following use(s):
85-350,351,352,353,354,355,356,357,358,359

###STOCKWATER: Group Total: 125 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-352 in this Group has NOT YET been evaluated

**********END OF DATA**********

STATE OF UTAH -- DIVISION OF WATER RIGHTS -- DATA PRINT OUT for 85-215

SPR 7

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-215 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: C. Burton Pugh
ADDR: 533 North 650 East
Lindon, Utah 84042

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 08/08/1969 |PRIORITY: 00/00/1864 |PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No] |HEARNG HLD: |SE ACTION: [ ] |ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF: [ ] |ELEC/PROOF: |CERT/WUC: 08/08/1969 |LAP, ETC: |PROV LETTER
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 0.007 cfs SOURCE: Spring House Spring

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION:
(1)Stockwatering directly on spring located in SW4NW4 Sec 29, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612093. Water Rights Appurtenant to the following use(s):
85-100,199,200,201,202 203,204,205,206,207,208,209,210,211,213,214,215

###STOCKWATER: Group Total: 250 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-215 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612269.
85-215

###DOMESTIC: 1 Family Diversion Limit: PERIOD OF USE: 01/01 TO 12/31

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM			X														0.0000

PLACE OF USE for STOCKWATERING

	NORTH-WEST				NORTH-EAST				SOUTH-WEST				SOUTH-EAST			
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE
Sec 29 T 39S R 5W SLBM			X													

END OF DATA

STATE OF UTAH -- DIVISION OF WATER RIGHTS -- DATA PRINT OUT for 85-353

SPR 8

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-353 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Richard L. & Alecia S. Dame
ADDR: 1620 Georgia Ave.
Boulder City NV 89005-3643
INTEREST: 100% REMARKS: As Joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 04/27/1970 | PRIORITY: 00/00/1889 | PUB BEGAN: | PUB ENDED: | NEWSPAPER:
ProtestEnd: | PROTESTED: [No] | HEARNG HLD: | SE ACTION: [ ] | ActionDate: | PROOF DUE:
EXTENSION: | ELEC/PROOF: [ ] | ELEC/PROOF: | CERT/WUC: 04/27/1970 | LAP, ETC: | PROV LETTER:
RENOVATE: | RECON REQ: | TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 1.0 cfs SOURCE: Swapp Ranch Spring Area No. 4

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) S 1930 ft E 570 ft from NW cor, Sec 29, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612366. Water Rights Appurtenant to the following use(s):
85-350,351,352,353

###IRRIGATION: Group Total: 93.0 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
Sole Supply for Irrigation for 85-353 in this Group has NOT YET been evaluated

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 29 T 39S R 5W SLBM	7.2000	0.2000	23.2000	0.3000					21.1000								52.0000
Sec 30 T 39S R 5W SLBM								1.0000						20.0000		20.0000	41.0000

SUPPLEMENTAL GROUP NO. 612367. Water Rights Appurtenant to the following use(s):
85-350,351,352,353,354,355,356,357,358,359

###STOCKWATER: Group Total: 125 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-353 in this Group has NOT YET been evaluated

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-375

SPR 9

(WARNING: Water Rights makes NO claims as to the accuracy of this data) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-375 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Darlynn and Arlene Sorensen
ADDR: P. O. Box 47
Orderville, UT 84758
INTEREST: 100% REMARKS: joint tenants

DATES, ETC.

LAND OWNED BY APPLICANT?
FILED: 01/29/1970|PRIORITY: 00/00/1864|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 01/29/1970|LAP, ETC: |PROV LETTER:
RENOVATE: |RECON REQ: |TYPE: [ ]

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 0.022 cfs SOURCE: Sorensen Ranch Spring No. 3

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION:
(1)Stockwatering directly on spring located in NW4NW4 Sec 32, T39S, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612374. Water Rights Appurtenant to the following use(s):
85-362,363,364,365,366,367,368,369,370,371,372,373,374,375,377,378,379,380,381,382,383,384,385,386,387,388,389

###STOCKWATER: Group Total: 300 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-375 in this Group has NOT YET been evaluated

PLACE OF USE for STOCKWATERING

	NORTH-WEST	NORTH-EAST	SOUTH-WEST	SOUTH-EAST
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 32 T 39S R 5W SLBM	* X: : : *	* : : : *	* : : : *	* : : : *

END OF DATA

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-355 SPR 10A

(WARNING: Water Rights makes NO claims as to the accuracy of this data) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-355 APPLICATION/CLAIM NO.: CERT. NO.:

OWNERSHIP

NAME: Julie Johnson
ADDR: PO Box 2063
Page AZ

NAME: James Johnson
ADDR: PO Box 2063
Page AZ 86040

NAME: Lloyd Johnson
ADDR: PO Box2063
Page AZ 86040

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED: 04/27/1970	PRIORITY: 00/00/1889	PUB BEGAN:	PUB ENDED:	NEWSPAPER:
ProtestEnd:	PROTESTED: [No]	HEARNG HLD:	SE ACTION: [ ]	ActionDate:	PROOF DUE:
EXTENSION:	ELEC/PROOF: [ ]	ELEC/PROOF:	CERT/WUC: 04/27/1970	LAP, ETC:	PROV LETTER:
RENOVATE:	RECON REQ:	TYPE: [ ]			

PD Book No. 1 Map: 5c

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

LOCATION OF WATER RIGHT

FLOW: 31.725 acre-feet SOURCE: Pulsifer Spring

COUNTY: Kane COMMON DESCRIPTION:

POINT OF DIVERSION -- SURFACE:
(1) N 460 ft E 450 ft from W4 cor, Sec 32, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612367. Water Rights Appurtenant to the following use(s):
85-350,351,352,353,354,355,356,357,358,359

###STOCKWATER: Group Total: 125 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 12/31
Sole Supply for Stockwatering for 85-355 in this Group has NOT YET been evaluated

SUPPLEMENTAL GROUP NO. 612369.
85-355

###IRRIGATION: 4.82 acres Diversion Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31

###STOCKWATER: 125 Stock Units Diversion Limit: PERIOD OF USE: 04/01 TO 10/31

###PLACE OF USE:

	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 32 T 39S R 5W SLBM			X						X								0.0000

PLACE OF USE for STOCKWATERING

```
                              NORTH-WEST¼       NORTH-EAST¼       SOUTH-WEST¼       SOUTH-EAST¼
                              NW NE SW SE       NW NE SW SE       NW NE SW SE       NW NE SW SE
Sec 32 T 39S R  5W SLBM      *  :  : X:  *     *  :  :  :  *     * X:  :  :  *     *  :  :  :  *
```

SEGREGATION HISTORY**********

This Right was Segregated from , with Appl#: , Approval Date: / / under which Proof is to be submitted.

This Right as originally filed:

FLOW IN CFS	QUANTITY IN ACRE-FEET	IRRIGATED ACREAGE	STOCK (ELUs)	DOMESTIC (FAM - PER)	MUNICIPAL	MINING	POWER	OTHER
	32.625	5.0000	125					

5 AF duty area/stockwater supplemental 350/359, based on 9 month period of use

The following Water Rights have been Segregated from 85-355:

(1) WRNUM: 85-1011 0.9 0.1800
APPL#:
NAME: Lloyd Swapp Johnson, et al
FILED: 01/03/1996 STATUS:
APPR:
segregated for change to be filed

	CFS	ACRE-FEET	IRRIGATED ACREAGE	STOCK (ELUs)	DOMESTIC (FAM - PER)	MUNICIPAL	MINING	POWER	OTHER
85-355 currently has: -		31.725	4.8200	125					

All IRRIGATION has been SEGREGATED OFF.
All STOCKWATERING has been SEGREGATED OFF.

**********END OF DATA**********

STATE OF UTAH – DIVISION OF WATER RIGHTS – DATA PRINT OUT for 85-1011

SPR 10B

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 05/24/2006 Page 1

WATER RIGHT: 85-1011 APPLICATION/CLAIM NO.: CERT. NO.:

CHANGES: a19658 Cert.

OWNERSHIP

NAME: Lloyd Johnson
ADDR: PO Box 2063
Page AZ 86040

NAME: James Johnson
ADDR: c/o Lloyd Johnson
PO Box 2063
Page AZ 86040

NAME: Julie Johnson
ADDR: c/o Lloyd Johnson
PO Box 2063
Page AZ 86050

DATES, ETC.

LAND OWNED BY APPLICANT?

FILED: 04/27/1970	PRIORITY: 00/00/1889	PUB BEGAN:	PUB ENDED:	NEWSPAPER:	
ProtestEnd:	PROTESTED: [No	HEARNG HLD:	SE ACTION: [	ActionDate:	PROOF DUE:
EXTENSION:	ELEC/PROOF: [	ELEC/PROOF:	CERT/WUC: 01/17/2001	LAP, ETC:	PROV LETTER:
RENOVATE:	RECON REQ:	TYPE: (			

PD Book No. Map:

Type of Right: Diligence Claim Source of Info: Certificate Status: Certificate

LOCATION OF WATER RIGHT

FLOW: 0.9 acre-feet SOURCE: Pulsifer Spring

COUNTY: Kane COMMON DESCRIPTION: South of Sink Valley

POINT OF DIVERSION -- SURFACE:
(1) N 462 ft E 440 ft from W4 cor, Sec 32, T 39S, R 5W, SLBM
Diverting Works: Source:

Stream Alt Required?: No

USES OF WATER RIGHT

SUPPLEMENTAL GROUP NO. 612106

###DOMESTIC: 2 Family Diversion Limit: 0.9 acft. PERIOD OF USE: 01/01 TO 12/31

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 32 T 39S R 5W SLBM				X						X							0.0000

SEGREGATION HISTORY

This Right was Segregated from 85-355 with Appl#: , Approval Date: / / under which Proof is to be submitted.

This Right as originally filed:

FLOW IN CFS	QUANTITY IN ACRE-FEET	WATER USES: IRRIGATED ACREAGE	STOCK (ELUs)	DOMESTIC (FAM - PER)	MUNICIPAL	MINING	POWER	OTHER

0.9 0.1800

**********E N D O F D A T A**********

APPENDIX 7-4

Water Engineering & Technology, Inc
Report

Geomorphical and Sedimentological
Characteristics of Sink Valley, Kane County
Utah

[redacted]

Shelf

GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL CHARACTERISTICS OF SINK VALLEY, KANE COUNTY, UTAH

Report Prepared for

NEVADA ELECTRIC INVESTMENT COMPANY

Water Engineering & Technology, Inc.

Consultants in
Applied Geomorphology,
Hydrology and
Water Resources
Engineering

GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL CHARACTERISTICS OF SINK VALLEY, KANE COUNTY, UTAH

Report Prepared for

NEVADA ELECTRIC INVESTMENT COMPANY

by

M.D. Harvey

and

K.J. Fischer

Water Engineering and Technology, Inc.
P.O. Box 1946
Fort Collins, Colorado 80522
Project No. 56-100-88

September 1988

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1. INTRODUCTION

Sink Valley is located in west-central Kane County, Utah, in the West Block of the proposed Alton Coal Project. The hydrologic behavior of the valley has been significantly modified by the capture of the upper part of the drainage basin (Dry Fork and Water Canyon) by Lower Robinson Creek. The surficial discharges passing through Sink Valley are now derived primarily from the unnamed tributary in Section 21 and from Swapp Hollow drainage basin. Within Sink Valley there is no continuous channel, but a continuous and deeply incised channel (Sink Valley Wash) exists downstream of the culvert on County Road 136 (Alton-Skutumpah).

The incision of Sink Valley Wash downstream of the road culvert post-dates the General Land Office Survey (Burrill, 1876). At the time of the survey, Sink Creek (his term for Sink Valley Wash) was 5 links (~ 3 feet) wide and 6 inches deep. In contrast, the present channel is about 69 feet wide and 23 feet deep. The diminutive size of the pre-incision channel in the comparatively narrow valley, about 2 miles downstream of the County Road 136 culvert, suggests that sheetflow, rather than confined channel flow, was the primary discharge mode. This observation tends to be supported by Gregory (1935), who described the area within Sink Valley as being swampy, and this is corroborated by the accounts of early settlers (Carroll, 1960).

1.1. Alluvial Valley Floor Definition

The regulatory definition of an alluvial valley floor is outlined in the Office of Surface Mining's (OSM, 1983), Alluvial Valley Floor Identification Guidelines, in which are laid down two sets of criteria (1) Geologic and (2) Water Availability. The geologic criteria are:

(a) a topographic valley with a continuous perennial, intermittent, or ephemeral stream channel running through it; and

(b) within that valley, those surface landforms that are either flood plains or terraces if these landforms are underlain by unconsolidated deposits (streamlaid); and

(c) within that valley, those side-slope areas that can reasonably be shown to be underlain by alluvium and which are adjacent to flood plain or terrace landform areas.

Specifically excluded from the OSM definition of alluvial valley floors are upland areas, which are defined as those geomorphic features located outside the flood plain and terrace complex, such as isolated higher terraces, alluvial fans, pediment surfaces, landslide deposits, and surfaces covered with residuum, mud flows or debris flows, as well as highland areas underlain by bedrock and covered by residual weathered material or debris deposited by sheetwash, rillwash, or windblown material.

On the basis of the geologic criteria it is apparent, therefore, that the requirement for an Alluvial Valley Floor determination is the presence of a continuous channel within a topographic valley, the floor

of which contains floodplain and terrace features that are underlain by unconsolidated streamlaid deposits that were deposited by the continuous channel. The flow regime of the channel may be perennial, intermittent or discontinuous. By the same criteria alluvial fans, areas underlain by bedrock and covered by residuum or colluvial deposits and surfaces covered by mud flows, debris flows or sheetwash deposits are not considered to meet the geologic criteria for alluvial valley floors.

Current regulations of the Utah Division of Oil, Gas and Mining (UDOGM) state that unconsolidated streamlaid deposits holding streams means, with respect to alluvial valley floors, all floodplains and terraces located in the lower portions of topographic valleys which contain perennial or other streams with channels that are greater than 3 feet in bankfull width and greater than 0.5 feet in bankfull depth.

1.2. Background

The results of previous investigations of Sink Valley reported in July 1987 (C.D.M., 1987) concluded that Sink Valley did not meet the regulatory definition of an alluvial valley floor for two reasons. First, there is no continuous stream channel through the valley. Second, the valley fill in Sink Valley is not streamlaid but rather was deposited by various processes including mudflows, debris flows, and sheetfloods that formed alluvial fans.

This information was presented to Utah Division of Oil, Gas and Mining (UDOGM) for their consideration. UDOGM concluded that further information was necessary before Sink Valley could be determined not to

be an AVF. UDOGM proposed that man's activities may have eliminated the continuous stream through Sink Valley. They suggested that further work be performed to identify whether there are continuous streamlaid deposits through the valley.

Second, they suggested that, while streamlaid deposits did not appear to be present on the surface, exploration drill holes have indicated the possible presence of streamlaid deposits at depth. They suggested that further information be submitted to determine whether the surface expression of possible streamlaid deposits has been obscured by recent development of alluvial fans or man's activities. Under this scenario careful subsurface investigations would identify the presence of streamlaid deposits at a shallow depth that have been overlain by more recent deposits.

Therefore, the objectives of this investigation of Sink Valley, that was conducted for the Nevada Electric Investment Company, under the supervision of Mr. Dean Williams of BHP-Utah International were: (1) to determine whether there were streamlaid deposits beneath the surface of the valley floor, and (2) to determine whether the alluvial fans, or man's activities had obscured a previously existing continuous channel that traversed the length of Sink Valley.

1.3. Methods of Investigation

This field investigation of Sink Valley was conducted between July 7, 1988 and July 17, 1988. Nine topographic cross sections (I to IX) were surveyed across the valley and two tributaries with an EDM-coupled

theodolite such that they were oriented perpendicular to the depositional axis of the valleys. The cross sections were tied to a common datum and fiducial point (10,000, 10,000): the section corner between Sections 19, 20, 29 and 30, T. 39S. R. 5W, where there is a monumented brass cap (EL. 6914 feet). The up-valley cross section (No. I) is located in Section 21, T. 39S., R. 5W and the down-valley cross section (No. IX) is located in Sections 5 and 6, T. 40S., R. 5W. The cross sections were surveyed in order to characterize the valley floor topography, and to provide ground surface elevations for the stratigraphic investigation (Drawings No. 1 to 9).

Stratigraphic data for the valley floor were obtained from bank exposures in the incised channels of Lower Robinson Creek and Sink Valley Wash, and from 28 backhoe pits. A total of 37 stratigraphic sections were measured and described in the pits and incised-channel banks. All of the pit and channel bank exposures were photographed.

In addition to the above, a debris flow lobe on the valley floor was roughly surveyed with a hip chain and Brunton compass. The axes of coarse clastic sediments on one of the debris flow levees were measured and recorded. A field reconnaissance of the Sunset Cliffs in Water Canyon was conducted to document the up-valley sediment source. These deposits and the source rocks were photographed. During the field investigation previously mapped discontinuous channel segments within Sink Valley (Harvey and Schumm, 1987) were field checked to determine their origin and continuity.

1.4. Geology

Sedimentary rocks associated with the Pausaugunt Plateau range in age from Jurassic to Recent (Fig. 1.1). In the Sink Valley area, sandstones and coal seams of the Cretaceous Dakota Formation are overlain by the slope forming Tropic Shale. The Tropic Shale consists of grey to brown argillaceous shale, which commonly erodes into badlands topography (Gregory, 1951). The Tropic Shale is approximately 750 feet thick in central Kane County (Doelling, 1972). Overlying the Tropic Shale, the Upper Cretaceous Straight Cliffs, Wahweap, and Kaiparowits Formations are composed of weakly cemented sandstones and minor arenaceous shales which reach a cumulative thickness of 1700 feet in the study area.

The Upper Cretaceous Kaiparowits Formation is unconformably overlain by the Eocene Wasatch (Claron) Formation, a sequence of basal conglomerate and pink and white limestone which is approximately 500 feet thick in the Sunset Cliffs above Sink Valley. The basal portion of the Wasatch Formation consists of a conglomeratic unit which ranges in thickness from 20 to 100 feet (Gregory, 1951). The unit contains rounded quartzite, chert, limestone, and volcanic clasts in a calcareous matrix. Clasts reach 3 feet in diameter on the rim of the Paunsaugunt Plateau (Gregory, 1951). The Wasatch Formation becomes sandy upsection (Doelling, 1972). Quaternary basalt flows are present south of Sink Valley, in the Bald Knoll and Buck Knoll areas.

Pre-Quaternary sediments of the Sink Valley area dip gently northeastward. Along strike, the lateral continuity of these units is

System	Series	Stratigraphic Unit			Thickness (Feet)	Description
Tertiary	Eocene	Claron Formation (Wasatch)			1000-1300	Pink, white, and varicolored limestone, cliff former eroding into picturesque slopes and forms, basal conglomerate of exotic quartzite and limestone cobbles and pebbles.
						Unconformity
Cretaceous	Campanian	Kaiparowits Formation			265-700	Dark gray to gray-green arkosic sandstone, friable with weak calcareous cementation.
						Unconformity
	Santonian	Wahweap Formation *Minor Coal*			500-1300	Alternating sandy shale and thin- to thick-bedded resistant sandstone, ledge and slope topography.
	? Coniacian ? Turonian	Straight Cliffs Formation *Minor Coal*			80-500	Yellow-gray to brown, thick-bedded to massive cliff-forming sandstone with subordinate intervening gray shale, shaley sandstone, *coal* and carbonaceous shale.
		Tropic Shale			700-1000	Drab gray shale with subordinate thin brown fine-grained sandstone, slope former.
	Cenomanian	Dakota Formation *Major Coal Seams*			150-450	Yellow-gray to brown fine- to medium-grained sandstone alternating with gray shale, sandy shale, carbonaceous shale and *coal*, ledge and slope former creating Gray Cliffs; best *coal* near bottom and top of unit.
						Angular Unconformity
Jurassic	Upper	Entrada Sandstone		Cannonville Member	0-300	White and reddish banded fine-grained sandstone and siltstone, friable and earthy weathering, massive.
				Gunsight Butte Member	0-300	Red-brown and light green siltstone; also red cross-bedded sandstone of the "slickrock" type.
		Carmel Formation		Wiggler Wash Member	0-60	Limestone, red siltstone, white and greenish gypsum.
				Winsor Member	180-250	White, pink, brown sandstone alternating with thin red siltstone and mudstone.
				Paria River Member	55-200	Interbedded light gray and red sandstone, limestone, siltstone, shale, and gypsum.
			Judd Hollow Tongue of Carmel	Thousand Pockets Tongue of Navajo Sandstone	0-60	Yellowish cross-bedded friable but resistant sandstone.
				Crystal Peak Member	120-190	Dark reddish brown and white to light gray fine-grained sandstone, medium-bedded with minor thin gypsiferous or calcareous shales and conglomerate.
				Kolob Limestone	122-350	Gray and tan dense limestone with some thin sandy red shale near the base and thin gypsum near top.
						Unconformity
	Lower	Navajo Sandstone			1000+	Light gray to tan, locally red fine-grained sandstone, massive, exhibiting large-scale aeolian cross-bedding, calcareous and cliff forming.

Figure 1.1. Generalized Section of Rock Formations in the Alton Coal Field (Doelling and Graham, 1972).

disrupted by two major northeasterly trending faults which bound the Paunsaugunt Plateau (Fig. 1.2). The Paunsaugunt fault marks the eastern boundary of the plateau and is located approximately 13 miles east of Sink Valley. The fault is generally normal and downthrown to the west. Offset along the Paunsaugunt fault ranges from 100 to 500 feet (Doelling and Graham, 1972).

The Sevier fault lies 3 miles west of Sink Valley, marking the boundary of both the Pausaugunt Plateau and the Alton coal field. The fault extends approximately 300 miles from south of the Grand Canyon to central Utah. The fault is normal and downthrown to the west. Total displacement on the Sevier fault ranges from 1000 to 2000 feet (Doelling and Graham, 1972).

The Bald Knoll fault runs parallel to the Sevier and Paunsaugunt faults, passing approximately 1 mile east of Sink Valley. The fault is normal and downthrown to the east. Total offset on the Bald Knoll fault may be as much as 500 feet (Doelling and Graham, 1972).

A topographic gradient which averages 600 ft/mile extends from the head of Sink Valley, up Water Canyon, to the top of the Paunsaugunt Plateau. The edge of the plateau consists of a steep 400 feet escarpment of Eocene Wasatch Formation known as the Sunset Cliffs. The cliffs have weathered into a large amphitheatre as a result of mass wasting of the Wasatch Formation. Massive debris flow and landslide deposits are present at the base of the cliffs. As a result, a large amount of debris which has eroded from the Sunset Cliffs has concentrated at the head of Water Canyon in a large debris flow-

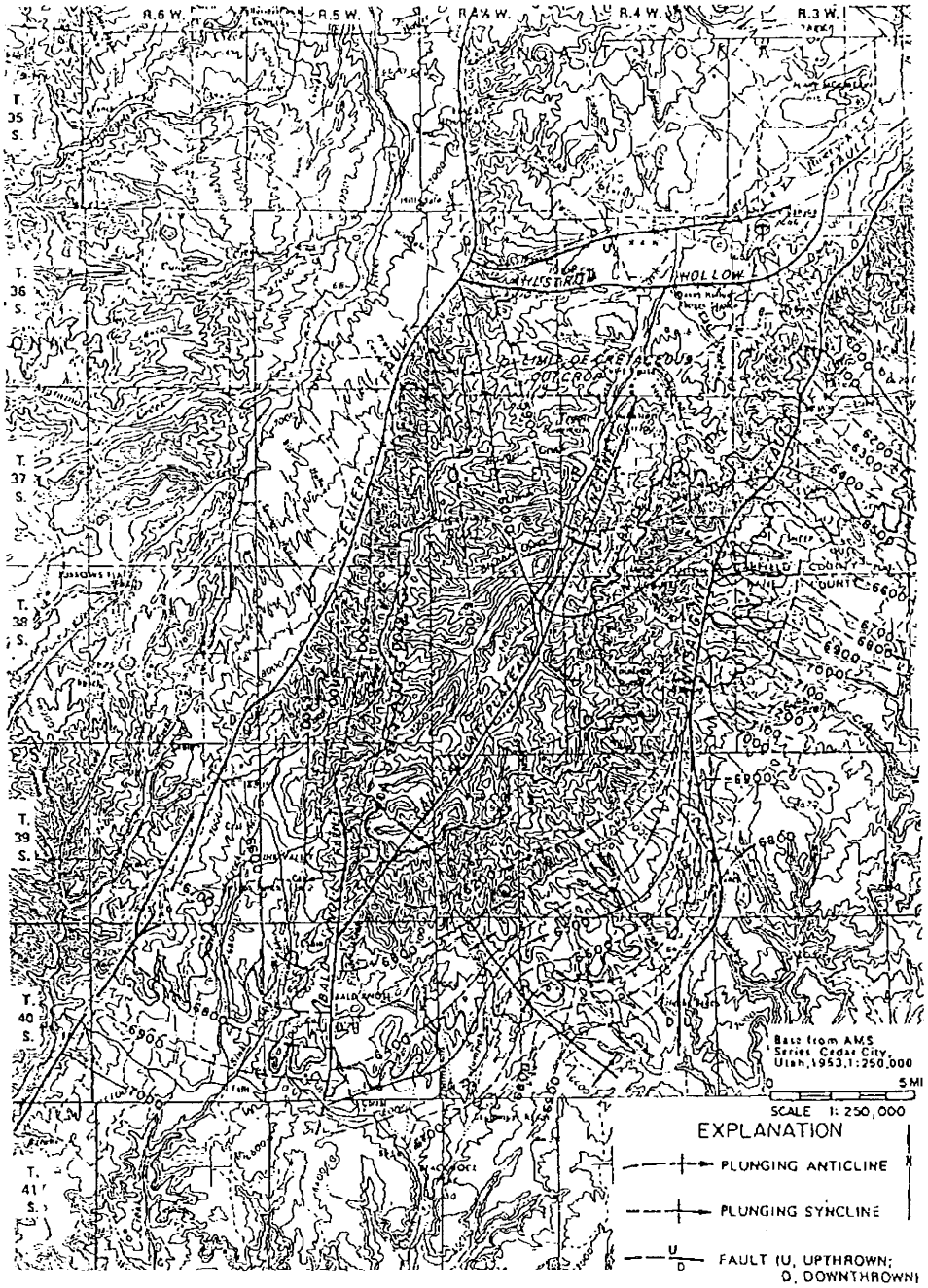

Figure 1.2. Generalized structure map, Alton coal field. (Doelling and Graham, 1972).

dominated fan. Subsequent events have remobilized and transported this material into Sink Valley, as evidenced by Sink Valley stratigraphic data presented in this report. Erosion as a result of mass wasting processes is characteristic of the Tropic Shale on the margins of Sink Valley.

Sink Valley lies on an erosional surface of Tropic Shale which, due to its lithologic character, has manifested itself into a relatively wide topographic depression in a region dominated physiographically by steep canyons in indurated sandstones. The margins of Sink Valley consist of laterally retreating Tropic Shale and a pediment. The pediment surface consists primarily of limestone, quartzite, and basalt clasts derived from the Wasatch Formation. Rounded clasts of quartzite and basalt on the pediments are derived from the basal conglomerate of the Wasatch Formation. The pediment gravels have provided a local source of coarse clastics during the most recent phase of Sink Valley deposition.

1.5. Alluvial Fan Literature Review

Previous studies of Sink Valley (Harvey and Schumm, 1987) indicated that the floor of Sink Valley was composed of alluvial fan sediments. Therefore, it is appropriate that a review of the alluvial fan literature be undertaken.

Numerous investigators have studied the sedimentology of alluvial fans. Although most research has been carried out on fans of arid regions, general controls on fan development may be extended to a range of climatic systems.

Reading (1978) described how alluvial fans develop in areas of high relief where an abundance of sediment exists. Deposition takes place when infrequent violent rainfall induces rapid erosion. Bull (1977) defines an alluvial fan as "a deposit whose surface forms a segment of a cone that radiates downslope from the point where the stream leaves the source area".

Climate plays a large role in alluvial fan development and sedimentation. Kochel and Johnson (1984) delineated four different fan types based on climate. Arid fans are characterized by periods of rapid deposition followed by long periods of inactivity. Humid-glacial fans consist of constantly shifting braided streams on an aggrading outwash plain. Humid-tropical fans reflect seasonal deposition by braided streams and debris flows, and humid-temperate fans are characterized by infrequent debris avalanching initiated by large rainstorms.

In general, alluvial fans form at the margins of steep basins due to a decreased confinement of streamflow (Bull, 1977). Deposition, is therefore, not due to a change in slope, but is the result of a rapid lateral expansion of sediment onto a fan surface (Reading, 1978). The reduction in lateral confinement which induces alluvial fan deposition is generally the result of base level lowering (Bull, 1977). An erosional base level reduction will generally produce a temporary thin fan, whereas tectonic base level lowering results in the development of a prolonged thick fan sequence (Bull, 1977).

High sediment supply is characteristic of alluvial fans. Therefore, the initiation of an alluvial fan may result from a climatic change

which increases rates of erosion. In addition, coarse unconsolidated materials on a fan surface will reduce downvalley surface discharges and promote deposition.

Three types of deposits are commonly found in small steep basins characteristic of alluvial fans: water floods, hyperconcentrated flows, and debris flows (Costa, 1988). Water floods behave as Newtonian fluids and, therefore, have no yield or shear strength. Waterflood deposits contain primary channels with width:depth ratios in excess of 12:1.

Sheetfloods are waterfloods on an alluvial fan surface. Sheetfloods are characterized by low viscosity flows which expand laterally at the downstream end of a confined channel onto a fan surface (Reading, 1978). They generally reflect upper flow regime conditions, and deteriorate into patterns of braided channels and bars which dissect the upper surface of the sediment sheet (Reading, 1978). Bull (1977) described sheetfloods as surges of sediment laden water which range in depth from 0.5 to 1.5 feet. The resultant deposit is a sheetlike unit of sand and gravel which may be traversed by shallow discontinuous channels which repeatedly divide and rejoin.

Hyperconcentrated flows are generally defined to begin at 40% sediment concentration by weight (Costa, 1988). Shear strength within hyperconcentrated flows is small but measurable (100-400 dynes/cm^2). The amount of fine material present in hyperconcentrated flows greatly affects fluid characteristics of the material, because shear stress is acquired very rapidly by clay rich deposits. Hyperconcentrated flows, also called noncohesive mudflows, mudfloods, and intermediate flows,

have a much higher sediment transport rate than waterfloods, because the increased sediment concentration increases fluid viscosity, thereby decreasing sediment fall velocities and enabling sediment to remain in suspension for longer periods of time (Costa, 1988).

The third primary mode of deposition on alluvial fans is that of debris flows, where solid particles and water move together as a single viscoplastic body (Costa, 1988). Debris flow cohesion is controlled by clay content. Debris flows occur when large quantities of water enter a basin over a short period of time; when steep slopes contain insufficient stabilizing vegetation, and when a proximal source contains both coarse detritus and a fine mud matrix.

Debris flow deposits are generally characterized by the following features (Reading, 1978): a) a steep lobate snout with large boulders concentrated at the front; b) lateral levees of coarse deposits; c) a tendency to flow in pulses or surges; d) a concentration of the largest particles towards the surface and edges of the flow, and 3) the formation of a rigid plug at the center of the flow. The presence of wood fragments is good evidence for debris flow deposition, as water rich floods would remove buoyant materials from the sediment. Debris flows lack stratification and sedimentary structures, and they are distinctly chaotic.

Kochel and Johnson (1984) described alluvial fans in humid-temperate regions, and identified debris flows based on the following evidence: a) very poor sorting and coarse textures, b) indistinct stratification, c) sharp basal contacts; d) an absence of current structures; 3) inverse graded bedding, and f) the preservation of ripups.

longitudinal profile found on many fans could be generated by both fluvial and mixed-mode (i.e., mudflow dominated) processes. Harvey (1984b) suggested that debris flow dominated fans are more likely to have numerous disconnected channel segments because of the greater irregularity of the fan surface. From the above discussion it is clear that fan sedimentology has important implications for understanding fan morphology, and this is especially true with respect to areas of local aggradation and degradation.

Experimental (Schumm et al., 1987) and field studies (Rust and Koster, 1984) of alluvial fans have shown that grain size generally diminishes in the down-fan direction such that the distal portion of the fan at any time is composed of the finest sediments (i.e., silts and clays). Schumm et al. (1987) suggested that a sharp break in the slope profile near the toe of the fan marks the point at which the silts and clays are deposited. Deposition of the fines forms a clay-rich basal layer over which the fan progrades through time. Progradation of the fan results in coarser sediments being deposited over the basal layer and therefore, at a given location on the fan the grain-size coarsens upwards. The net result of this type of sedimentation pattern would be confined or semi-confined flow within the fan. Because of the nature of depositional processes on alluvial fans, depositional units are more continuous longitudinally than they are laterally (Schumm et al., 1987) and, therefore, it is likely that subsurface flows will tend to follow the depositional axis of the fan. Galloway et al. (1979) showed that on alluvial fans groundwater recharge on the upper fan surface takes place

as a result of direct precipitation or infiltration of stream discharge. Groundwater discharge occurs in the lower fan region.

In contrast to laterally unconfined fans, the floors of valleys in the semi-arid regions of the western U.S. can be comprised of semi-confined valley alluvial fans that prograde down-valley (Patton, 1973; Patton and Schumm, 1975; Bergstrom and Schumm, 1981; Harvey, 1980; Schumm and Hadley, 1957; Laird and Harvey, 1986). In these valleys the flat-appearing alluvial-valley floors are irregular in the downstream direction. The processes that operate on the valley fans are very similar to those that have been described for the classical alluvial fans in semi-arid areas (Bull, 1964a, b; Denny, 1965; Hooke, 1967, 1968a; Lustig, 1965).

2. SINK VALLEY GEOMORPHOLOGY

The geomorphological characteristics of Sink Valley can be divided into three areas of concern: (1) the morphological characteristics of the valley itself, (2) the morphological characteristics of the valley floor, and (3) the spatial distribution and continuity of channels within Sink Valley.

2.1. Morphologic Characteristics of Sink Valley

The shape of Sink Valley is atypical of that of a valley formed in a uniform lithologic setting by fluvial processes. It is very evident that the resistance to erosion of the rock formations (Fig. 1.1) that comprise the margins of the valley has affected the shape of the valley. The rock formations bordering the valley margins are shown in Figure 2.1. From up-valley to down-valley the valley margins are composed of rock formations that get progressively older (Fig. 1.1). The upper reach of Sink Valley at the confluence of Dry Fork and Water Canyon (Fig. 2.1) is narrow and the valley margins at the elevation of the valley floor are composed of resistant sandstones of the Straight Cliffs Formation. Valley width is about 300 feet. Tropic shale forms the basin boundary for almost the remainder of Sink Valley in the down-valley direction. Valley width within the confines of the Tropic Shale, increases from 900 feet at cross section I (Fig. 3.1) to 3200 feet at cross section IV (Fig. 3.1) and then decreases to about 700 feet at cross section VIII (Fig. 3.1). The Dakota Fm. crops out down-valley from cross section VIII, and the valley width at cross section IX

(Fig. 3.1) is about 500 feet. The reduced valley width at this location is due to the resistance of Dakota Fm.

Field observation and aerial photograph analysis indicates that the shape of Sink Valley within the area whose margins are composed of Tropic Shale is strongly influenced by mass failure of the Tropic Shale. The distribution of mass failures in the Tropic Shale is shown in Figure 2.1. The mass failures are probably related to the distribution of faults (Fig. 1.2). The presence of mass failures on the perimeter of Sink Valley explains why the valley shape is atypical, but it also suggests that mass failure-derived deposits should make up a high proportion of the valley fill of Sink Valley.

The western margin of Sink Valley from where Lower Robinson Creek traverses the low relief outcrop of Tropic Shale to the area to the west of Swapp ranch (Fig. 2.1) is very subdued topographically. The Tropic Shale ridge and isolated remnants of Tropic Shale at the mouth of Swapp Hollow indicate that badland topography had formed on the Tropic Shale in Sink Valley and in the Lower Robinson Creek drainage basin. The eastern flank of the Tropic Shale ridge between Lower Robinson Creek and Swapp ranch has been buried by down-valley progradation of a valley fan. The western flank of this ridge, which is located in the Lower Robinson Creek drainage basin, forms a fairly steep and well defined escarpment. The southern extremity of the ridge is completely buried by sediments, and no Tropic Shale outcrop is visible at the ground surface. In fact at this location sheetfloods that are generated up-valley bifurcate into both lower Sink Valley and Lower Robinson Creek drainage basin. The

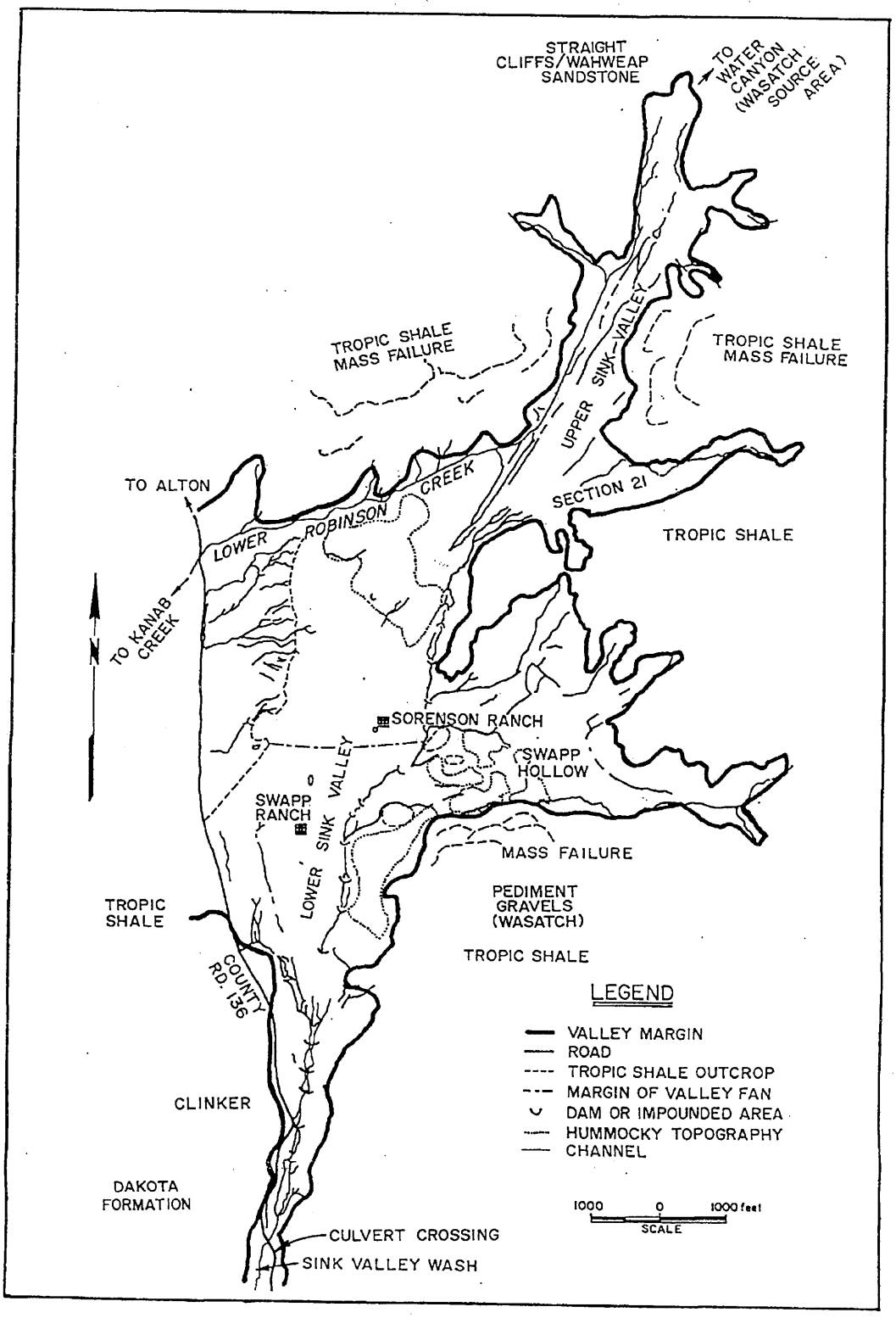

Figure 2.1. Map of significant features in Sink Valley.

western margin of Sink Valley has, therefore, been significantly modified by sedimentation in Sink Valley. The progradation of sediments onto the Tropic Shale outcrop has significantly affected the elevation of the water table within Sink Valley.

One further feature of the valley margin of Sink Valley has significant implications in terms of the valley fill sediments. A pediment surface is located on the south side of Swapp Hollow and it forms the eastern boundary of Sink Valley down-valley from the confluence with Swapp Hollow (Fig 2.1). The pediment was formed on Tropic Shale and it is capped by coarse-grained clasts that were originally derived from the Wasatch Formation. Mass failure of the Tropic Shale underlying the pediment and scarp retreat have introduced the coarse-grained Wasatch-derived clasts into Swapp Hollow and lower Sink Valley. Hillslope erosion processes and gullying of the valley walls are also introducing significant quantities of the coarse clasts to the floor of Sink Valley.

2.2. Valley Floor Morphology

The first indication that the floor of Sink Valley might be composed of a valley fan is seen on the Alton 7.5 min. Quadrangle (USGS, 1966). The 40-foot contour-interval map suggests that a fan-shaped body has prograded down valley from the confluence of Dry Fork and Water Canyon. Bull (1964) and Kochel and Johnson (1984) have demonstrated that there is a relationship between the size of the drainage basin and the surface area of the fan (Fig. 2.2). The fan area-drainage basin area

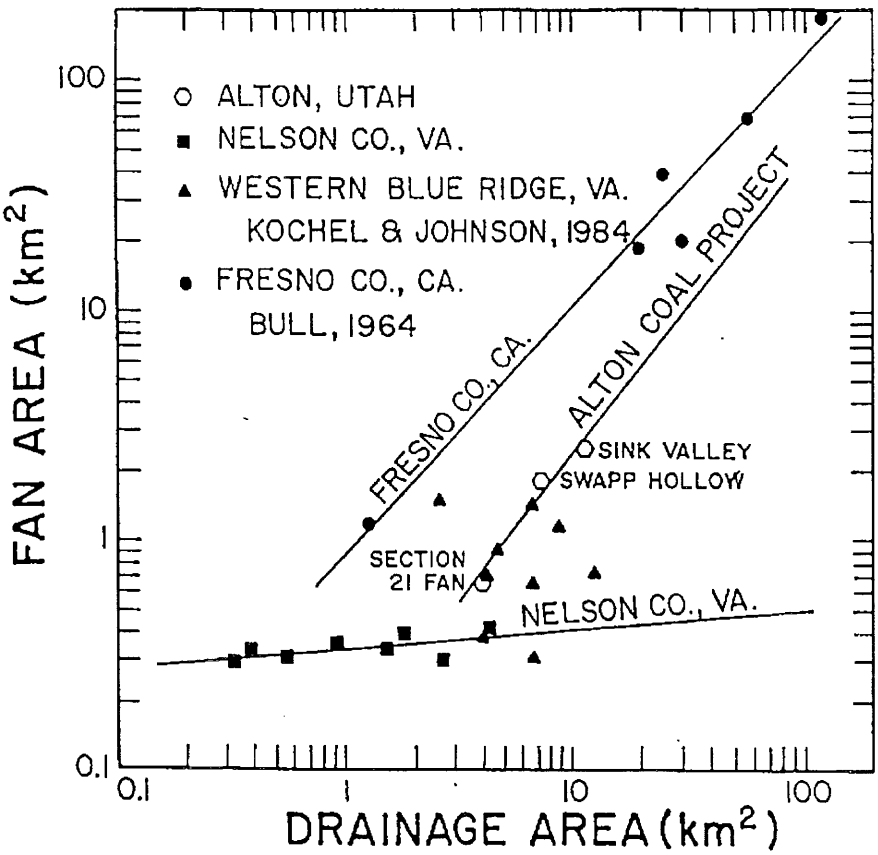

Figure 2.2. Plot of fan area versus drainage basin area for data sets from Fresno, CA, Nelson County, VA, and Sink Valley, Utah. (Figure modified from Kochel and Johnson, 1984).

relationships for three fans in the location of Sink Valley were determined from the USGS topographic map: (1) Sink Valley fan, (2) Section 21 fan, and (3) Swapp Hollow fan. These data were then plotted with the data from Bull (1964a) and Kochel and Johnson (1984) on Figure 2.2. The best-fit line for the Sink Valley data is sub-parallel to Bull's curve (Fresno, CA) and lies above the curve that fits the data for Nelson County, VA.

Two conclusions can be drawn from the data in Figure 2.2. First, there is a systematic relationship between fan and drainage basin areas in Sink Valley, which provides strong evidence that the floor of Sink Valley does contain a valley fan. The down-valley margin of the valley fan was determined from topographic and sedimentologic (Fig. 3.5) data (Fig. 2.1). It is evident that the valley fan is different morphologically from alluvial fans that were studied by previous investigators. The primary difference is one of shape. The conventional fan has a shape that is best described as a segment of a cone that radiates downslope from the point where the stream leaves the source area (Bull, 1977). The fan owes its existence to reduced confinement of the sediment and water discharges from the source area (Reading, 1978). However, the basic requirements for reduced confinement and a high supply of sediment are met in Sink Valley. Dry Fork and Water Canyon confluence in a reach of the valley whose width is narrow (~ 300 feet) and is controlled by outcrop of sandstones. Tropic Shale forms the valley margin down-valley from this location and the valley widens. The high sediment supply is derived primarily from the

Wasatch Formation in the Sunset Cliffs. The floor of Water Canyon is composed of numerous over-lapping debris flow deposits. Therefore, the confinement caused by the gradually widening valley has caused the fan to prograde down valley, but the fan area-drainage area relationship has been maintained. The rate of down-valley progradation of the fan must have been lower in the down-valley direction because the valley width increases significantly from about 300 feet at the head of the fan to about 3000 feet at the location of the fan toe at cross section V (Fig. 3.1).

The second conclusion that can be drawn from Figure 2.2 is that for a given drainage area the Sink Valley fans are larger than those in Nelson County, VA, but they are smaller than the ones in Fresno, CA. This may be due to differences in lithology of the source areas (Hadley and Schumm, 1961) but it may also be due to climatic differences. Mean annual precipitation at Alton, Utah is 16.56 ins. (CDM., 1987), which is intermediate between those in California and Virginia.

Longitudinal and cross-section profiles of Sink Valley were constructed from surveyed data to characterize the morphology of the valley floor. The longitudinal profile (Fig. 2.3) of the valley floor was constructed from the surveyed cross sections and the Alton Quadrangle. The profile extends from the base of the Sunset Cliffs in Water Canyon to cross section IX (Fig. 3.1). The irregular topography that is the result of the presence of over-lapping debris flow lobes in Water Canyon can be seen on the upper part of the profile. The profile of the valley floor shows clearly that the toe of the fan is located in

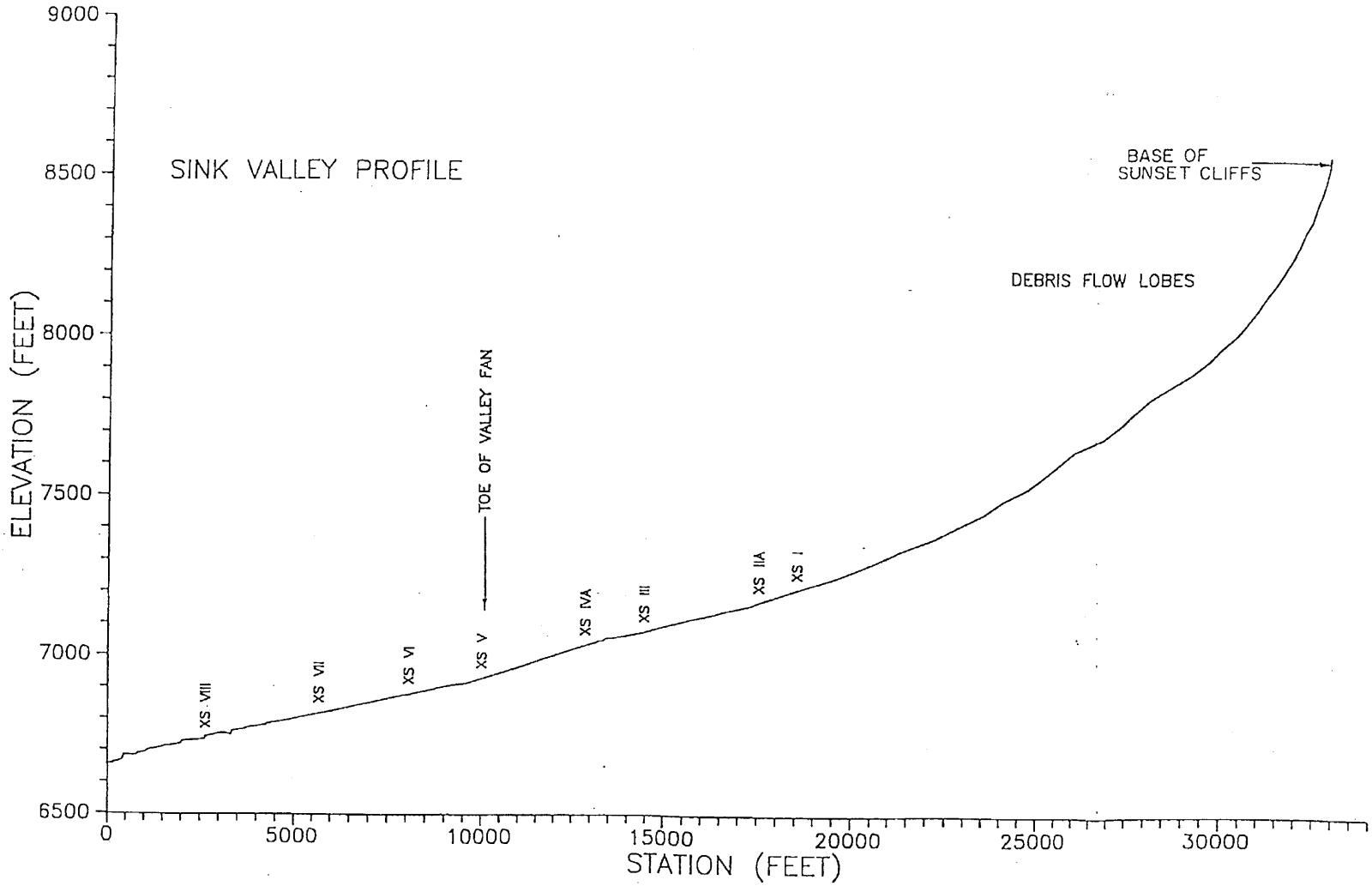

Figure 2.3. Longitudinal profile of Sink Valley showing the locations of surveyed cross sections.

the vicinity of cross section V, where there is a significant change in slope (Schumm et al., 1987). The crest of the fan is located between cross sections III and IVA.

The Sink Valley cross-section profiles (Fig. 2.4) further confirm the presence of a valley fan, and the effects on cross-section morphology of sediment contribution to the valley floor from valley margin hillslopes and tributary alluvial fans. The details of the cross-section morphology are more clearly seen on Drawings No. 1 to 9. Cross sections I and IIA show the irregularity of the valley floor in the upper fan region. Cross section III shows the cross-fan convexity very well, as does cross section IVA. Cross sections V and VI demonstrate that Swapp Hollow fan has prograded out onto the floor of Sink Valley. Valley wall contribution of sediment to the valley floor is clearly demonstrated in cross sections VII, VIII and IX.

2.3. Channels in Sink Valley

The locations of all the channels in Sink Valley are shown in Figure 2.1. With the exception of Lower Robinson Creek, Sink Valley Wash downstream of the culvert on County Road 136, and the incised former wagon road on the western margin of the lower reaches of the valley, the channels within Sink Valley are discontinuous. The majority of these channels have been either constructed, or modified, by local landowners. A number of the discontinuous channel segments are located on the eastern side of the valley between Section 21 tributary and the mouth of Swapp Hollow. These channel segments are located in areas that have

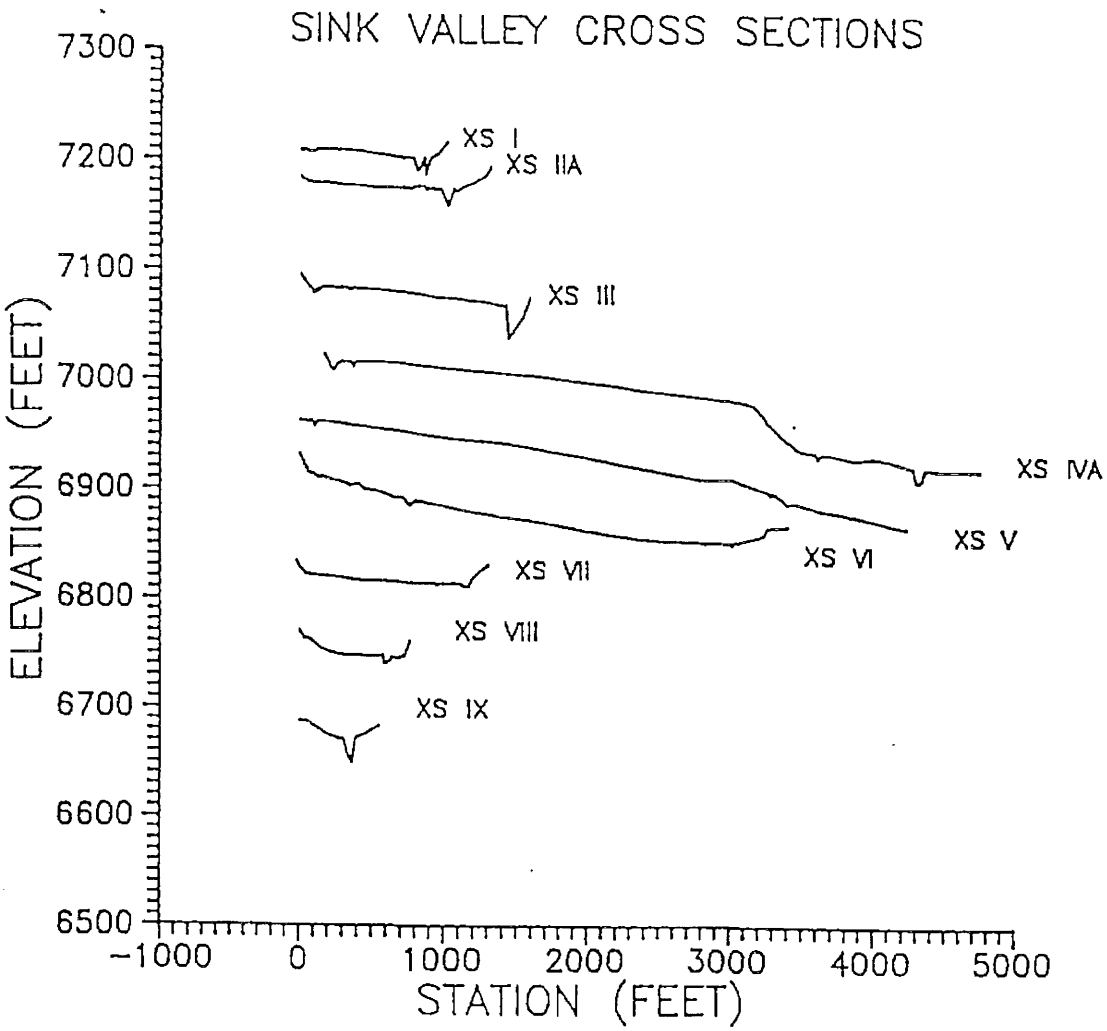

Figure 2.4. Cross-section profiles of Sink Valley.

been affected by localized sediment deposition on the medial part of the valley fan where aggradation and local oversteepening of the valley floor are to be expected (Harvey, 1987; Schumm et al., 1987). The presence of debris flow and mudflow deposits on the medial part of the fan can be expected to produce topographic irregularities on the valley floor which can lead to sheetflood concentration and, hence, the development of discontinuous gullies (Harvey 1984b). The absence of a continuous channel through Sink Valley is, therefore, further evidence that the valley floor is composed of a valley fan. The cross section profiles (Fig. 2.4: Drawings No. 1 to 9) show a strong cross-valley gradient to the west, and, therefore, if a channel was to be located through Sink Valley, it would be logical to find it towards the western part of the valley. Figure 2.1 shows that no such channel exists. Discontinuous channel segments are located on the valley floor south of the Swapp ranch where the valley narrows (Cross Section VI).

The incision of Kanab Creek (c. 1865) has significantly effected both Lower Robinson Creek and Sink Valley Wash by lowering their base levels which in turn has caused them to incise. The magnitude of the changes in these channels that was due to base level lowering can be seen by the changes that have taken place in Sink Valley Wash since 1876. Burrill (1876) states that Sink Creek, at a location that was down-valley from the culvert on County Road 136 (Fig. 2.1), was about 3 feet wide and 6 inches deep. In contrast the channel today is about 69 feet wide and 23 feet deep (see cross section IX, Fig. 2.4). There is little doubt that the culvert has prevented the bulk of the degradation

from migrating farther up-valley. However, the valley floor is being eroded by headcuts upstream of the culvert. Most of the headcut retreat appears to be related to sapping processes because of the high groundwater table. Undoubtedly when sheetfloods occur there is an element of surficial erosion of the gully headwalls.

The incision of Lower Robinson Creek has had a significant effect on both the sedimentology and morphology of Sink Valley, because Lower Robinson Creek has captured the headwaters of Sink Valley (Dry Fork and Water Canyon). Prior to capture the discharge from Sink Valley was delivered to Kanab Creek by Sink Valley Wash. Explicit evidence for the capture is provided by the sedimentological data.

There is no source of Wasatch-derived sediments in the pre-capture drainage basin of Lower Robinson Creek. Therefore, the Wasatch-derived sediments that were observed in the stratigraphic sections on the western end of cross section IVA (Figs. 2.4, 3.1) must have originated in Sink Valley. For these sediments to have been transported to Lower Robinson Creek drainage basin the divide between the two basins must have been overtopped. The intermittent presence of the Wasatch-derived sediments in the upper parts of the stratigraphic sections (measured sections #20, 14 , Fig. 3.1) indicates that this was not a continuous process, but rather it was related to discrete large magnitude events on the valley fan in Sink Valley. The fine-grained nature of the Wasatch-derived sediments indicates that they were fan margin sediments. Following incision of Lower Robinson Creek, and the burial of the eastern flank of the divide between the two basins by fan progradation,

floodflows that overtopped the divide would have been confined to the incised channel of Lower Robinson Creek. Flow confinement when coupled with the elevation difference between the top of the divide and the bed of the channel (approximately 60 feet; Fig. 2.4, cross section IVA) would have caused the channel to headcut through the divide, thereby initiating the capture of the Sink Valley headwaters.

The capture of the upper part of Sink Valley by Lower Robinson Creek has had significant effects on Sink Valley. First, following capture the discharge from the upper part of Sink Valley is now transported to Kanab Creek through Lower Robinson Creek which has reduced the discharge passing through Sink Valley. Second, the primary sediment source area for Sink Valley was Water Canyon. Capture has removed this source of sediments because the incised channel of Lower Robinson Creek at the confluence of Dry Fork and Water Canyon is now about 20 feet deep and 80 feet wide, and it is highly unlikely that there will be overbank discharge and sedimentation.

2.4. Summary of Geomorphological Characteristics of Sink Valley

The shape of Sink Valley and the valley widths are controlled by the resistance to erosion of the valley margin rock formations (Fig. 2.1). Where resistant formations (Straight Cliffs Fm., Dakota Fm.) crop out the valley is narrow (300 to 500 feet). Where the Tropic Shale crops out the valley is wide (700 to 3200 feet). Progradation of the valley fan has significantly modified the low relief western margin of Sink Valley. Mass failure of the Tropic Shale has contributed to the valley widening.

The presence of a valley fan within the floor of Sink Valley is confirmed by the valley floor topography. The longitudinal profile of the valley floor shows the presence of a fan-shaped body (Fig. 2.3), and the cross-sectional profiles show typical cross-fan shapes (Fig. 2.4). Confinement of the water and sediment discharges from upper Sink Valley has led to the down-valley progradation of a fan. The drainage area-fan area relationship developed by other investigators is supported by the Sink Valley data (Fig. 2.2).

No continuous channel that traverses the length of Sink Valley is present on the valley floor (Fig. 2.1). Discontinuous channel segments on the medial part of the fan are related to fan sedimentation. Base level lowering by the incision of Kanab Creek (c. 1865) has caused incision of both Sink Valley Wash and Lower Robinson Creek. Capture of the headwaters of Sink Valley by Lower Robinson Creek is attributable to both valley fan progradation in Sink Valley and incision of Lower Robinson Creek. The former eliminated the pre-existing drainage divide, and the latter caused sheetflood confinement into a single channel.

3. SINK VALLEY SEDIMENTOLOGY

In order to determine the sedimentologic characteristics of the valley fill deposits of Sink Valley, 9 cross sections (I to IX) were surveyed across the valley in orientations that are perpendicular to depositional strike (Fig. 3.1). Two cross sections (IIA, IVB) were surveyed across the mouths of tributary fans (Fig. 3.1). A total of 37 stratigraphic sections were measured and described along these cross sections; 5 on the banks of Lower Robinson Creek, 1 on the bank of Sink Valley Wash, and 31 in a total of 28 backhoe pits. The locations of the cross sections and measured stratigraphic sections are shown in Figure 3.1. Stratigraphic sections are compiled in Appendix I.

Measured stratigraphic sections are shown in relation to cross-sectional topography on the accompanying drawings, Nos. 1 to 9. All of the cross sections are oriented looking in a downvalley direction. Because the Cretaceous Tropic Formation weathers to dark brown silt and clay (10 YR 3/2 to 10 YR 4/4) whereas sediments derived from the Eocene Wasatch Formation are orange-red-brown in color (10 YR 5/4 to 10 YR 5/8) the two source areas were readily discernable in the valley fill stratigraphy. The Cretaceous sandstones are weakly cemented and hence do not resist chemical weathering as do the Wasatch sediments; as a result, the input of Cretaceous sandstone into Sink Valley generally consists of sands which are yellowish-grey in color (2.5Y 6/4).

The ability to delineate between Wasatch-derived, Tropic-derived, and Cretaceous sandstone-derived sediments is critical to the determination of sedimentation processes in Sink Valley. The Wasatch-

derived sediments in Sink Valley have been transported downvalley, whereas Tropic-derived sediments reflect a lateral component of deposition from the valley margins and tributary fans. The intermixing of the two types of sediment in a single depositional unit is indicative of surficial reworking of the valley fill. Cretaceous sandstone-derived sediments are primarily introduced to the valley floor of Sink Valley by the tributary fans and by hillslope processes.

3.1. Cross Section I (Drawing No. 1)

Cross section (XS) I is located in the upper portion of Sink Valley, where the valley is less than 1000 feet wide (Fig. 3.1). The two stratigraphic sections measured along Lower Robinson Creek are shown on the west side of the valley. Lower Robinson Creek consists of two channels along XS I. The bifurcation point of the channel is located approximately 100 feet upstream of the cross-section line. The thalweg of the east channel, at measured section (MS) #2, is located approximately 4 feet higher than the thalweg of the channel at MS #1. Where the main channel bifurcates upstream, the abandoned east channel contains a high concentration of boulders which consist of Wasatch-derived limestone, quartzite and conglomerate, which represent the leading edge of a debris flow. The boulders probably influenced the re-routing of the channel into the relatively erodible fine-grained deposits to the west. Subsequent incision of the west channel has perched the channel to the east.

Although several boulders present in the perched east channel are rounded, there is no evidence of reworking via conventional fluvial

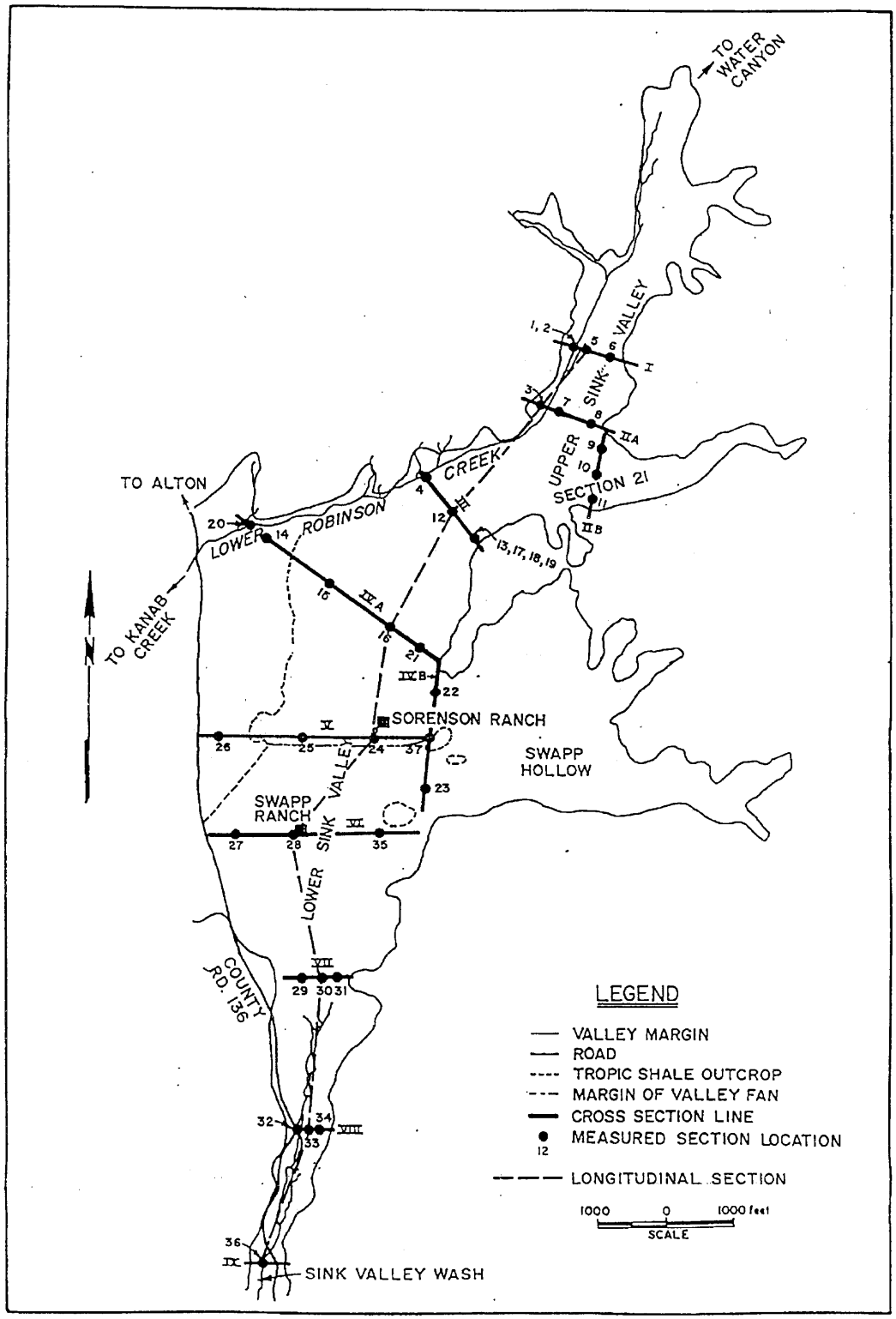

Figure 3.1. Locations of surveyed cross sections and measured stratigraphic sections in Sink Valley. Also shown is the longitudinal profile that was used to construct Figure 3.5.

transport. The rounded clasts are derived from the basal conglomerate of the Wasatch Formation, hence rounding occurred prior to this depositional cycle.

Measured section #1, on the west channel of Lower Robinson Creek, contains Wasatch-derived sand and minor gravel at its base which is overlain by a thick sequence of Tropic-derived silt and clay. Minor amounts of Wasatch-derived clasts are present within the Tropic sediments. The section is capped by Wasatch-derived silty sand. The thick sequence of Tropic-derived sediments is not present in MS #1, 78 feet to the east. The lateral thinning to the east of the unit as well as a high concentration of charcoal and dispersed pebbles suggests that the unit is a mudflow deposit from the western valley margin. Similar deposits exposed on the valley margins have been described by Harvey and Schumm (1987). The incorporation of Wasatch-derived pebbles reflects transport of the silt and clay over Wasatch-derived sediments. The valley margin is evident on the west side of XS I (Drawing No. 1); at station 9+00 the ground surface rises on Tropic Shale. The break in slope at station 9+50 probably represents a contact between intact Tropic shale to the west and mass wasted material to the east.

The lateral transport of sediment into Sink Valley from the valley walls is evident on the east end of XS I in MS #6. The base of the section is composed of both Tropic Shale and clasts of Cretaceous-age sandstone. The size of the sandstone boulder in MS #6 is striking (800 mm), because the poorly cemented nature of the sandstones generally favors chemical versus mechanical weathering (i.e., the sandstones break

down close to their source). Thus the association of Tropic-derived silt and clay with large clasts of Cretaceous age sandstone is indicative of rapid transport from a proximal source. The mass wasting of a sandstone block onto a Tropic Shale slope followed by transport of weathered shale by mudflow processes into the valley, provides a likely scenario for the observed deposit. Alternatively, the sequence represents two events; the deposition of a mudflow carrying sandstone boulders followed by a rockfall of Cretaceous age sandstone. The top of MS #6 contains thinly interbedded sands and clays of local derivation. These units represent lateral slopewash from the eastern bounding topographic high.

The mid-valley area of XS I consists primarily of Wasatch-derived sediments that reflect a transport direction oriented downvalley. MS #5 contains two Wasatch-derived coarse-grained horizons. The upper unit consists of a chaotic assemblage of matrix supported sand to boulder sized sediments which reach 170 mm in diameter. The unit pinches out to the west. Similar deposits are present in the lower portions of MS #1, #2, and #5. The matrix supported, chaotic nature of these units indicate downvalley deposition of Wasatch-derived sediments via debris flows. The absence of internal stratification, normally-graded bedding, and sorting indicates that deposition was not the result of fluvial processes.

The remainder of the sediments depicted on XS I consist of thinly bedded, structureless sands, horizontally laminated sands, and silt/clay drapes; these units are commonly separated by mud (silt/clay) drapes,

and the sand-mud couplets reflect deposition by shallow flow depth discrete events. The Wasatch-derived sands represent deposition during shallow sheetfloods on the fan surface, whereas the drapes document sediment deposition during recessional flows. Due to the narrowness of Sink Valley, a result of the presence of bounding Tropic Shale outcrops, distinct fan-margin facies were not present in the stratigraphic sections of XS I. The primary axis of deposition may be located generally at midvalley, where thick Wasatch-derived debris flow deposits are present (MS #5). This tends to be confirmed by the absence of Tropic-derived sediments in MS #5.

Cross section I (Fig. 3.1) effectively shows the complexity of Sink Valley sedimentation. Wasatch-derived sediments record downvalley transport directions, whereas deposits of Tropic Shale-derived sediments indicate mass wasting, and possibly sheetflow, from the valley margins. The sedimentary sequences described indicate deposition on an alluvial fan which, in the vicinity of XS I, is laterally confined by bounding topographic highs. Sedimentation at XS I has been dominated by down-valley transport of Wasatch-derived sediments by debris flow and sheetflood processes. The ubiquity of charcoal in the sediments indicates that fire has been a significant morphogenetic agent in this drainage basin. Fires followed by significant precipitation frequently result in the occurrence of debris and mud flows (Laird and Harvey, 1986).

3.2. Cross Section IIA (Drawing No. 2)

Cross section IIA (Fig. 3.1) is characterized by a predominance of Wasatch-derived sediments which range from thin clay/silt drapes to thick coarse gravels. The coarsest material observed in XS IIA is located on the west side of the valley in the left bank of Lower Robinson Creek. There, MS #3 contains 18 continuous feet of Wasatch-derived sediments. The section contains a basal gravel which consists of very poorly sorted gravel in a sandy silt matrix which displays faint inverse grading. The unit is overlain by interbedded gravels, sands, and silt drapes. Thirty-two individual events are distinguishable from the drapes in the section. The sand layers commonly contain trough crossbeds or coarse/fine couplets. These units are indicative of deposition by sheetflood; the sands containing coarse/fine couplets reflect shallow water flooding over the fan surface (Blair, 1986) and small-scale cross bedded sands are suggestive of deposition within an array of small braided channels on the fan surface during flood events. Silt drapes record the recession of discrete flow events. The distinctly bedded, cyclic nature of the sediments in MS #3, coupled with the presence of debris flow and sheetflood deposits reflect a typical vertical sequence of alluvial fan sediments.

The sediments of XS IIA fine eastward from Lower Robinson Creek, and at MS #8, only fine grained thinly bedded units are present. The eastward thinning and fining of individual units is coupled with an increase in Tropic-derived sediments. This relationship is due to the off-axis location of the section, where Tropic-derived sediments from

the valley slopes have been incorporated into the fan margin. A substantial portion of the units in MS #7 and MS #8 contain intermixed Wasatch- and Tropic-derived sediments, that reflect downfan reworking of the deposits on the fan margin.

The increase in Tropic-derived sediment on the east side of XS IIA is also due to the convergence of an alluvial fan from the east side of Sink Valley (Fig. 3.1), just downvalley from XS IIA in the vicinity of Section 21 (herewith referred to as the Section 21 fan). The Section 21 fan sediments are derived primarily from Tropic Shale and Cretaceous sandstones (see XS IIB), and deposition due to progradation of the fan has modified the depositional environment at XS IIA. The coalescence of the two fans has produced a topographically low area in the vicinity of MS #8 where slack-water sedimentation has produced the multiple-event deposits that are seen at the top of the section.

At MS #7, the upper 36 inches of the section document the presence of a mudflow deposit that was probably generated from the Tropic Shale outcrops on the margins of the valley. The mudflow travelled to at least the center of the valley.

The depositional axis of the Sink Valley fan in the vicinity of XS IIA is located on the west side of the valley, at the present location of Lower Robinson Creek. Displacement of the axis towards the west valley margin is due probably to the coalesence of the valley fan with the Section 21 fan. The convergence of the fans on the eastern side of the valley has produced a topographically low area on XS IIB that has resulted in considerable slack-water sedimentation. Mudflows generated

from the valley walls have the ability to travel a considerable distance into the valley (Costa, 1988).

3.3. Cross Section IIB (Drawing No. 3)

The absence of Wasatch-derived sediments is strikingly evident in XS IIB (Fig. 3.1), which traverses the distal margin of the Section 21 fan. As the drainage basin of the Section 21 fan does not include outcrop of Wasatch Formation, the deposits are relatively fine grained and are composed of Tropic Shale and Cretaceous age sandstone-derived sediment.

Small discontinuous channel segments are shown on XS IIA. They are located in the medial and distal parts of the fan, where discontinuous channels are to be expected (Harvey, 1984b; Schumm et al., 1987). The stratigraphic evidence in MS #9, 10, and 11, support the presence of the small scale discontinuous channels. One channel fill is present in MS #9, 3 are present in MS #10, and one is present in MS #11. The greater number of small-scale channel deposits in MS #10 tends to suggest that MS #10 is located along the depositional axis of Section 21 fan. Mudflow deposits are present in each of the measured sections, with higher frequency near the fan margins (MS #9, 11). Sheetflood deposits that consist of horizontally laminated and structureless sands that are separated by fine-grained silt/clay drapes are present in the three vertical sequences along XS IIB. The presence of ripup clasts and mudballs in all three sections argue for widespread reworking of surficial sediments that dry and crack between events.

3.4. Cross Section III (Drawing No. 3)

Cross section III (Fig. 3.1), located just downvalley from Section 21 fan, displays the effect of detrital input from Section 21 on Sink Valley sediments. The amount of Tropic-derived sediment increases markedly from XS IIA. In addition, coarse debris flow deposits are distinctly bimodal, with Wasatch-derived clasts included in a Tropic-derived silt/clay matrix (MS #12). The increased availability of silt and clay-sized sediments increases the viscosity of debris flows and thereby increases rates of sediment transport for a given event (Costa, 1988). The 4 measured sections on the east side of XS III represent 4 different localities in a single backhoe pit. In this pit, a paleotopographic surface that had formed on Tropic-derived mass wasted or sheetwash sediments is documented in the basal portions of MS #13 and MS #17. Sediments to the west of this surface are in tangential contact (i.e., lap onto) the Tropic-derived deposit. MS #17, MS #18, and MS #19 depict a convex paraconglomeratic unit which has eroded out a Tropic derived drape in MS #18. Sheetflood and minor channel features are common in the sand units in the four sections.

Measured sections #13, 17, 18 and 19 characterize the environment of deposition at this valley fan margin locality which is influenced by sediments that are derived from three sources; the valley wall, Section 21 fan and the valley fan. Sediments derived from the valley wall are characterized predominantly by fine-grained, Tropic-derived hillslope sheetwash and mudflow deposits. Mudflow and debris flow deposits that are derived from both the Wasatch source area and Section 21 fan make

up a significant portion of the sediments. Sheetflood deposits that include minor small-scale channel fills are generated by unconfined flood flows that are generated in the headwaters of both the valley fan and Section 21 fan drainage basins. Discontinuous channels are present on the eastern margin of XS III, and their presence is related to the relatively high rates of sedimentation at this locale, the result of sediment deposition from multiple source areas. The cross section demonstrates that the area around MS #13, 17, 18, 19, where the discontinuous channels are present, is a topographic high which indicates that the local valley slope is oversteepened and, it is, therefore, a logical location to find discontinuous gullies on a fan (Schumm, 1977; Schumm et al., 1987; Harvey, 1987).

The depositional axis of the valley fan at XS III is represented by MS #12. The stratigraphic column is dominated by debris flow and mudflow deposits that are separated by sheetflood deposits. The mudflow deposits can be subdivided on the basis of their sources. Where Wasatch-derived clasts are present, it is probable that the source area for the mudflow was Section 21 fan area, because the Wasatch-derived sediments were probably incorporated into the mudflow during the event. The source area for the Wasatch-derived clasts would have been the valley fan surface. In contrast, the mudflow deposits that do not contain appreciable quantities of Wasatch-derived clasts were probably generated on the eastern valley margin. Debris flow deposits contain sediments that were derived from both the Tropic Shale and the Wasatch Fm.

Both debris flows and mudflows produce irregular, hummocky terrain, and it is highly likely that this irregular terrain is responsible for producing some of the minor channel fills in the predominantly unconfined sheetflood deposits that cover the debris flow and mudflow deposits (Harvey, 1984b). Significant areas of hummocky terrain are located on the valley fan south of XS III. The spatial distribution of the coarser debris flow deposits is highlighted by the distribution of Gambol's oak (scrub oak) which has a preference for coarser grained deposits (Ed. Mogren, Forestry Department, Colorado State University, pers. comm).

During this field investigation one of the debris flow lobes that was located in the vicinity of XS III was mapped with a hip-chain and Brunton compass (Fig. 3.2). Raised ridges within the mapped lobe represent debris flow levees, and it was on the levees that very coarse grained cobble to boulder-size clasts were observed. Nineteen of the larger clasts were measured (Table 3.1), so that critical bottom velocity values (U.S.B.R., 1978) for initiation of motion under fluvial transport conditions could be calculated. For the range of clasts (b axis) in Table 3.1, the required bottom velocities ranged from 6.0 to 11.8 ft/sec. These velocities, which are conservative, are extreme for fluvial channels and therefore, it is unlikely that the clasts were deposited under fluvial conditions.

On the west side of XS III, the upper left bank of Lower Robinson Creek (MS #4) is characterized by thinly inter-bedded fine grained Wasatch- and Tropic-derived sediments which are indicative of a fan

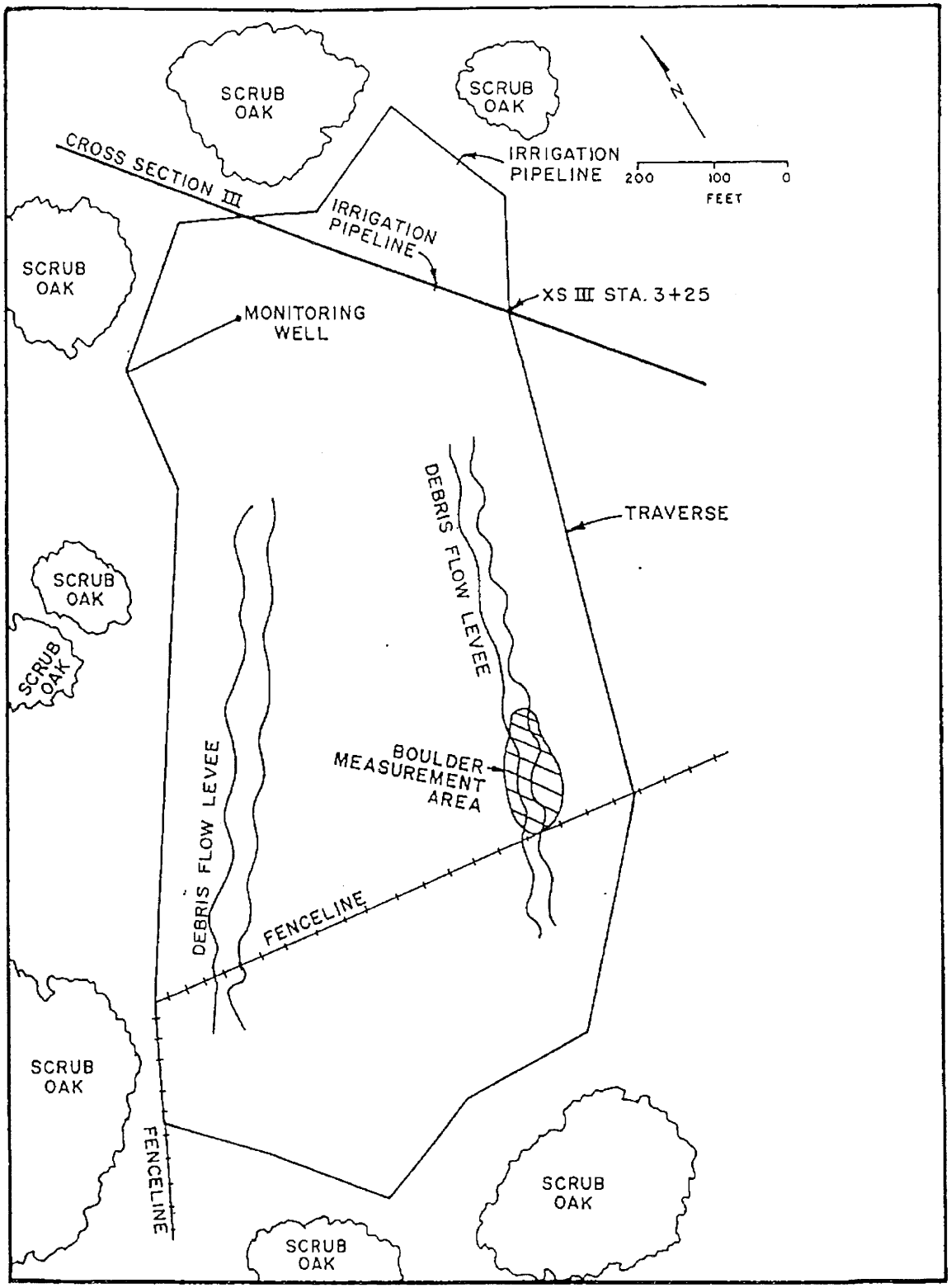

Figure 3.2. Map constructed from a Hip-Chain and Brunton compass survey of a debris flow lobe on the surface of Sink Valley.

Table 3.1. Boulder measurements on Sink Valley fan south of Cross Section III.

Sample No.	Clast Axes Dimensions (mm) A	B	C	Bottom[1] Velocity (ft/sec.)	Clast Lithology
1	320	160	90	6.7	sandstone
2	240	150	130	6.5	limestone
3	320	250	160	8.5	sandstone
4	230	190	150	7.3	sandstone
5	300	150	100	6.5	limestone
6	240	130	95	6.0	conglomerate
7	430	170	buried	7.0	sandstone
8	220	160	130	6.7	limestone
9	290	250	170	8.5	conglomerate
10	230	190	170	7.3	limestone
11	280	220	110	7.8	sandstone
12	290	170	130	7.0	conglomerate
13	330	190	130	7.3	limestone
14	400	260	200	8.6	sandstone
15	500	350	buried	9.8	sandstone
16	420	240	170	8.4	sandstone
17	330	210	180	7.6	limestone
18	480	310	260	9.4	conglomerate
19	700	500	240	11.8	sandstone

[1] Calculated from USBR (1978) using b axis diameter.

margin environment of deposition. A distinct cyclicity in the column reflects repeated relatively low energy deposition far off the axis of valley fan deposition (MS #12). The Wasatch-derived sediments of MS #4 are present only in the left bank of the channel; the right bank consists of only Tropic-derived sediments. Consequently, MS #4 is located at the extreme western margin of the Sink Valley Fan. This is supported by both topographic and sedimentologic evidence. Cross section III profile shows that the top of MS #4 represents the lowest elevation on the pre-incision cross section. This is consistent with a fan margin location because the cross profile of a fan in the medial location generally is convex (Bull, 1964b; Schumm et al., 1987). Sedimentologically, the evidence for a fan margin environment of deposition at MS #4 is fourfold. First, a comparison of grain size between MS #12 (depositional axis) and MS #4 shows that the sediments in MS #4 are much finer grained which can be expected in a fan margin environment (Rust and Koster, 1984). Second, a comparison of the grain sizes in MS #3 (XS II2A) and MS #4 also shows that the sediments in MS #4 are finer, which can be expected as one proceeds down-fan, (Blissenbach, 1954; Bull, 1964b; Rust and Koster, 1984). The third line of evidence for a fan margin environment of deposition at MS #4 is provided by the interbedding of Tropic Shale-derived and Wasatch-derived sediments. Sediments from both sources are fine grained and, therefore, it is unlikely that the Tropic-derived sediments originated from the eastern valley margin in the form of mudflows (c.f. MS #12).

The final piece of evidence that the sediments in MS #4 represent a valley margin environment of deposition is provided by the nature of the

contact between the Tropic-derived basal sediments and the overlying interbedded Tropic-derived and Wasatch-derived sediments that comprise the upper 6 feet of the section. Without doubt the Tropic Shale outcrop that forms the valley wall on the north side of Lower Robinson Creek is retreating today as a result of both mass wasting and sheet erosion processes, and there is no reason to believe that these processes were not active historically. Prior to the incision of Lower Robinson Creek, and progradation of the valley fan, channelized flow occurred from the Tropic Shale outcrop, across what is now Lower Robinson Creek, and southward into Sink Valley. Evidence for this is channel-shaped scour surfaces within the Tropic-derived basal sediments exposed in the banks of the left bank of Lower Robinson Creek (Fig. 3.3). The scour surfaces are oriented perpendicular to the present channel of lower Robinson Creek and prior to filling by the fan margin sediments it is likely that badland topography was present. The scoured channels have been filled by sediments derived from both the Tropic Shale and the Wasatch Formation. The interbedding of Tropic-derived and Wasatch-derived sediments in the upper part of MS #4 argues for discrete valley slope and valley fan events. On the slopes sheetwash was the transport mechanism whereas sheetfloods transported the sediments on the valley fan. Since there is no source of Wasatch Formation sediments on the north side of Lower Robinson Creek, the paleo-flow direction of the Wasatch-derived sediments must have been parallel or sub-parallel to the present course of Lower Robinson Creek, which makes the flow direction and, therefore, the direction of valley fan progradation sub-parallel to the depositional axis of the valley fan (MS #12).

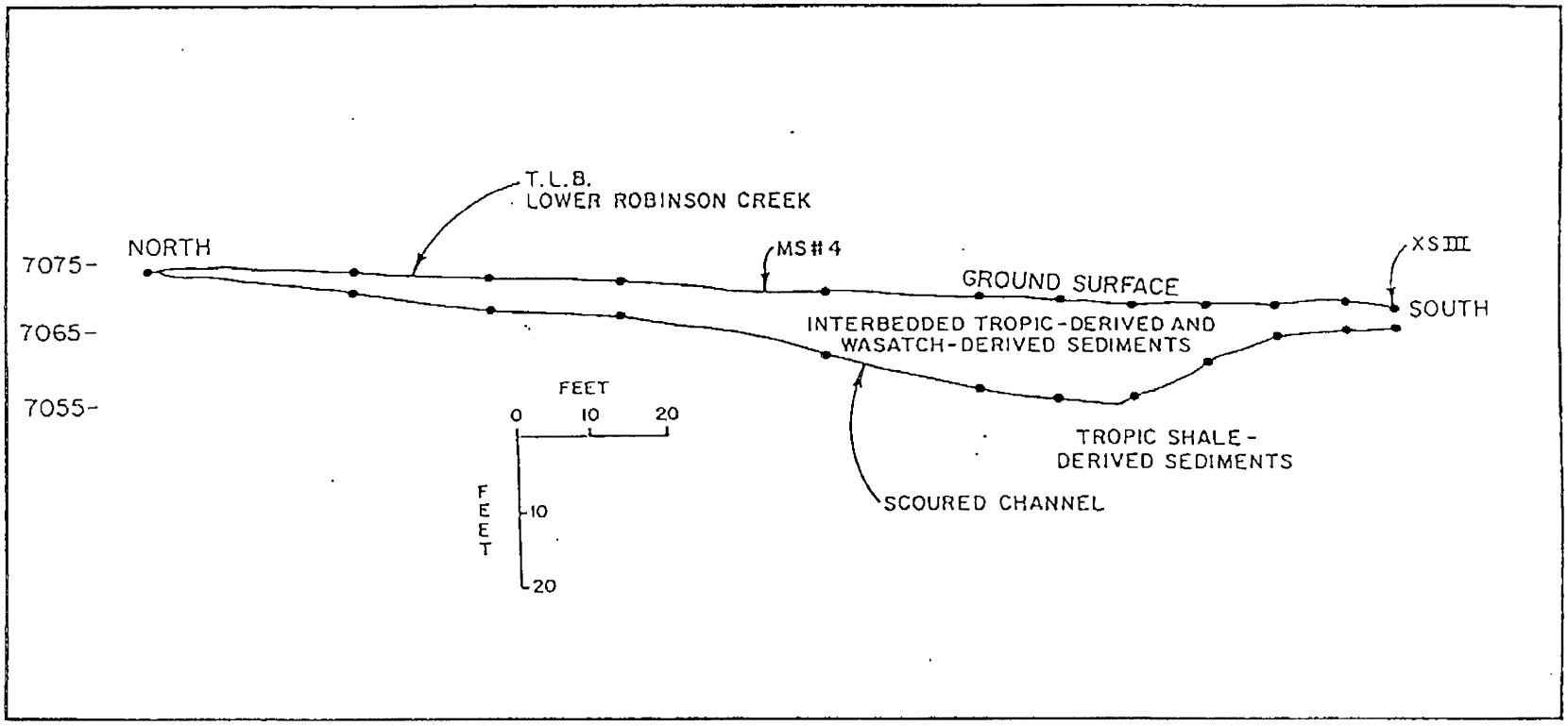

Figure 3.3. Cross section profile of a filled paleo-channel in the bank of Lower Robinson Creek in the vicinity of cross section III.

The measured sections along XS III provide very strong evidence to support the presence of a valley fan in Sink Valley. Sheetwash or mudflow deposits from the valley slopes contribute significantly to the valley fill on both the western (MS #4) and eastern (MS #13, 17, 18, 19) margins of the fan. The depositional axis of the valley fan contains significant mudflow and debris flow deposits which are characteristic of semi-arid fan sediments (Beaty, 1970). Sheetflood deposits and minor channel fills are deposited as a result of relatively shallow and unconfined flows. The absence of any laterally continuous channel deposits argues against the presence of a single major channel on the fan. Instead, it is highly likely that small discontinuous channels typical of the medial fan environment were present. The channels could originate as a result of local oversteepening of the valley floor due to high rates of local deposition (i.e., discontinuous gullies) or they could be the result of topographic irregularities caused by debris flow and mudflow deposits. The presence of a badland paleo-topography draining south into Sink Valley from the area to the north of the present location of the incised channel of Lower Robinson Creek is strong evidence that the valley fan prograded down valley and smoothed the topography. The presence on the fan surface of large cobble to boulder size clasts (Table 3.1) further argues for a non-fluvial transport mechanism.

3.5. Cross Section IVA (Drawing No. 4)

Cross Section IVA crosses the Tropic Shale ridge as shown in Figure 3.1. Due to the infilling of Sink Valley as a result of valley fan progradation, the ridge is characterized topographically by an escarpment which separates Sink Valley to the east and the lower Robinson Creek drainage to the west. The escarpment is approximately 50 feet high on XS IVA. The incision of Lower Robinson Creek through the north end of the ridge occurred just upvalley from XS IVA.

The two measured sections on the west side of XS IVA, MS #14 and MS #20, document the predominance of sheetwash transported, Tropic Shale-derived sediments in the Lower Robinson Creek drainage basin prior to capture of the upper drainage basin of Sink Valley. The presence of Wasatch-derived sediments records the overtopping by the Sink Valley fan of the Tropic ridge. Thus, two distinct sedimentologic phases are depicted within these sections. One is the initial overtopping of the Tropic ridge by the prograding valley fan, marked by the lowermost horizon of Wasatch-derived sand in MS #20. The second event recorded is the incision of Lower Robinson Creek and capture of a portion of the Sink Valley drainage basin. Following capture, the source of the Wasatch-derived sediments was removed from the valley fan as materials were transported down the new drainage. This event is stratigraphically located at the top of the section, because following capture by the incised channel of Lower Robinson Creek, it is highly unlikely that Wasatch-derived sediments could be deposited at the top of the section because of the depth of incision.

At the center of XS IVA, approximately 600 feet to the east of the Tropic ridge escarpment, the hydrologic complexity of Sink Valley becomes evident as the level of the water table is higher than the bottom of the backhoe pit. This emergence of groundwater is related to the impingement of the prograding valley fan sediments onto relatively impermeable Tropic Shale. In addition, the fine grained nature of the sediments overlying the water saturated horizon are indicative of both the down-fan fining of grain size and the fact that MS #15 is located off the major axis of fan deposition (MS #16) at the fan margin.

Measured Section #16 of XS IVA which is located towards the eastern side of the fan contains an excellent example of a debris flow deposit which was exposed in 3 dimensions in the backhoe pit. The coarse unit consists entirely of Wasatch-derived sediments which include boulders which reach 400 mm in diameter. The unit is matrix supported, very poorly sorted, and chaotic. The monolithologic nature of the unit suggests that it records a very large event which traversed a great deal of Sink Valley without being reworked and subsequently diluted by the inclusion of Tropic-derived silts and clays. The high frequency of debris flow and mudflow deposits in MS #16 indicates that the measured section represents the depositional axis of the valley fan. The vertical sequence is typical of a prograding fan in that it initially coarsens upwards and then fines upwards. The lowermost sediments probably represent fine grained fan toe deposits (Schumm et al., 1987). The debris flow and mudflow sediments represent progradation of a medial fan environment, and the upper sheetflood deposits represent deposition

on the back-slope of the fan crest. The mudflow deposits were probably generated from the Tropic Shale on the eastern valley margin. Minor channel fills within the section are located above and below debris flow deposits which tends to indicate that the debris flow deposits caused some channelization of the sheetfloods.

The east side of XS IVA consists of a section (MS #21) that contains laterally continuous, thinly bedded, fine grained deposits which are very similar to those of MS #8 on the east side of XS IIA. The two stratigraphic sections represent similar depositional sub-environments as they are both located up-valley of the point of coalescence between two alluvial fans. Both sections contain deposits indicative of low energy slackwater sedimentation. Consequently, each of the two alluvial fans which enter Sink Valley from the east (Section 21 and Swapp Hollow) must have produced sufficient sediment to prograde out onto the floor of Sink Valley, thereby creating a topographic depression which favored slackwater sedimentation.

The sedimentologic record preserved in the measured sections on XS IVA documents the down-valley progradation of the valley fan and it also highlights the role of the tributary fans. Progradation of the valley fan onto the Tropic Shale ridge, and the subsequent overtopping of the ridge are documented in MS #20 and MS #14. Both of these sections provide stratigraphic evidence that constrains the time of capture by Lower Robinson Creek of the upper drainage basin of Sink Valley, to within the period of time that Kanab Creek degraded (i.e., 1865). The fine grained and saturated sediments in MS #15 document the progradation

of the valley fan margin onto the Tropic Shale ridge and its effects on the elevation of the water table. MS #16 is located on the crest of the valley fan and it represents the axis of deposition which is characterized by a high frequency of debris flow and mudflow deposits. Progradation of Swapp Hollow fan onto the floor of Sink Valley created a topographically low area on the eastern margin of the valley fan that favored fine grained slackwater sedimentation (MS #21).

Cross section IVA (Fig. 3.1) shows an overall increase in the ratio of Tropic- to Wasatch-derived sediments relative to sections up-valley. Deposits are generally finer grained, although coarser horizons record large debris flow events. The combination of the down-valley transition towards the fan toe deposits with the onlapping of these fine sediments onto an impermeable bedrock ridge has induced the emergence of groundwater high in the stratigraphic section.

3.6. Cross Section IVB (Drawing No. 5)

Cross Section IVB (Fig. 3.1) traverses the mouth of Swapp Hollow fan from north (MS #22) to south (MS #23). Tropic-derived silts and clays constitute the majority of the sediments observed, however significant quantities of Wasatch-derived and Cretaceous sandstone-derived sediments are present as well. The Wasatch-derived sediments may have been emplaced from two sources. The finer grained sediments may represent sheetflood deposits formed as a result of large floods on the valley fan overtopping the toe of Swapp Hollow fan. The coarser grained sediments are derived from the pediment gravels that cap the Tropic Shale outcrop

to the east. Retreat of the Tropic Shale valley margins due to mass failure and gullying is delivering significant quantities of Wasatch-derived clasts to the valley floor.

An erosional remnant of Tropic Shale is present in the center of XS IVB. This outcrop is representative of the subsurface configuration of Sink Valley; the deposition of alluvial fan sediments has occurred on a surface of significant pre-existing relief. This shale is capped by pediment gravels which provide a local source of coarse rounded clasts, primarily limestone and quartzite of the Wasatch Formation.

In general the sediments exposed in the measured sections on XS IVB are fine grained and probably reflect the fine-grained nature of the proximal source rocks. Charcoal is abundantly distributed throughout the sections which indicates that fires have significantly affected fan sedimentation. The deposits in MS #22 reflect the predominance of local slope processes. The basal portion of MS #37 is composed of significant sheetflood deposits, but the upper portion contains significant mudflow deposits that include locally derived Wasatch clasts. MS #23 reflects mass failures of the Tropic Shale sediment on the south side of Swapp Hollow. The frequency of debris flow and mudflow deposits is higher in the upper portion of MS #37 and this probably correlates with the observed fairly recent mass failure deposits that are located up-fan from MS #23.

3.7. Cross Section V (Drawing No. 6)

Cross section V extends from the Lower Robinson Creek drainage basin in the west to the mouth of Swapp Hollow in the east (Fig. 3.1). The eastern end of the cross section is tied into MS #37 on XS IVB. This cross section provides further evidence for progradation of the valley fan and its effects on modifying pre-existing relief and drainage basin divides. Further, the effects of Swapp Hollow fan on the topography and sedimentologic characteristics of the valley floor are evident on this cross section. The sedimentologic evidence indicates that the toe of the valley fan is located in the vicinity of XS V, and this is supported by the valley slope and profile data (Fig. 2.3).

Measured section #26 documents the overtopping of the Tropic Shale ridge that formerly was the drainage divide between the Lower Robinson Creek drainage basin and Sink Valley drainage basin. The basal portion of MS #26 contains sediments that were primarily derived from the Lower Robinson Creek drainage basin prior to overtopping of the Tropic Shale divide. The coarser sandstone clasts were probably derived from local outcrops of the Dakota Formation. Wasatch-derived sediments document the down valley progradation of the valley fan. The upper portion of MS #26 is composed primarily of locally derived Tropic Shale sediments (sheetwash and mudflows), but the presence of Wasatch-derived sediments indicates that sheetfloods still transport valley fan sediments into this location. The sheetfloods that are generated up-valley split at a location between MS #26 and MS #27 because sedimentation has removed the divide between Sink Valley and Robinson Creek drainage basins. Part of

the flow and sediment travels down Sink Valley and the remainder enters the Lower Robinson Creek basin and is delivered to MS #26.

Measured section #25 is comprised mainly of finer-grained sediments that were deposited by sheetfloods in the distal portion of the valley fan (i.e., fan toe). The stratigraphic section shows an initial coarsening upwards trend followed by a fining upwards trend in the grain size. The sediments are dominantly Cretaceous sandstone-derived which suggests that Swapp Hollow was the source area. This tends to be supported by the cross section profile which dips fairly steeply to the west. The basal section of MS #25 is water saturated and this probably reflects the fact that sediments have prograded onto the Tropic Shale ridge at this location, a situation which is analogous to that at MS #15 (XS IVA).

Measured section #24 represents the depositional axis of the valley fan in a distal location. The sediments were transported down the valley fan and from Swapp Hollow fan. The basal portion of MS #24 contains mudflow deposits that appear to have originated from Swapp Hollow because they contain almost no Wasatch-derived sediments. Farther up section Cretaceous sandstone-derived sediments became more common and they consist of alternating horizontally laminated sand and drape units which are typical of discrete sheetflood events. The drapes tend to be composed of Wasatch-derived sediments. The interbedding of the sediments from the two source areas suggests that the mid section sediments represent events on both the valley fan and Swapp Hollow fan. The upper part of the section appears to be dominated by sheetflood and

mudflow sediments from Swapp Hollow, and this may be due to two causes. First, Swapp Hollow is proximally located with respect to the location of MS #24 and, therefore, it can be expected to exert considerable influence. Second, the relatively minor contribution of Wasatch-derived sediments may reflect the capture of the upper Sink Valley drainage basin by Lower Robinson Creek, thereby removing the source area.

The basal portion of MS #24 was water saturated. The reasons for the relatively high water table in MS #24 may be somewhat different from those responsible for the high water table in MS #25 and MS# 15. The high water table at the latter locations appear to be the result of fan margin sediments lapping onto impermeable Tropic Shale outcrop. The situation at MS #24 can probably be explained in terms of the fan dynamics and possibly by the geomorphic history of Sink Valley. The finest sediments on a prograding alluvial fan are located in the distal portion of the fan (Schumm et al., 1987). As the fan progrades coarser sediments are laid down over the silt-clay basal layer and, therefore, a perched water table can be formed. Groundwater tends to follow the depositional axis of the fan (Galloway et al., 1979) because depositional units are more continuous longitudinally than they are laterally (Schumm et al., 1987). Groundwater recharge takes place up-fan and discharge takes place in the lower fan region.

The high water table in MS #24 may also be related to the retreat of the valley margins. Isolated Tropic Shale remnants are located at the mouth of Swapp Hollow and there is little doubt that the Tropic Shale underlain pediment on the south side of Swapp Hollow is retreating

today. It is, therefore, conceivable that paleo-topography exists beneath the valley floor in the general location of MS # 24, and it is this relief that is causing the high water table. In this case the situations at MS #15, MS # 25 and MS #24 would be similar.

The eastern end of XS V is marked by MS #37 which has already been described (XS IVB). The basal part of the section is dominated by sheetflood deposits and the upper portion by mudflow deposits.

Cross section V (Fig. 3.1) is important as it documents the location of the toe of the valley fan and the progradation of the fan which resulted in elimination of the low-relief divide between Lower Robinson Creek drainage basin and Sink Valley drainage basin. The cross section profile, which dips to the west, indicates that significant cross-valley sediment transport has occurred from the Swapp Hollow drainage basin. All of the measured sections document the diminishing amount of Wasatch-derived sediments and the corresponding increase in the amount of Tropic-derived and Cretaceous sandstone-derived sediment. Further, the Wasatch-derived sediments are much finer than those encountered farther up-fan. The rather rapid dimunition of the size of the Wasatch-derived sediments and their reduced volumes in the stratigraphic sections argue very strongly for a non-channelized flow origin for the sediments along XS V. The coarse Wasatch-derived clasts in MS #37 were locally derived from pediment gravels that cap the Tropic Shale.

3.8. Cross Section VI (Drawing No. 7)

Cross section VI trends in an east-west direction across Swapp Ranch, and it is located where Sink Valley begins to narrow (Fig. 3.1). The western valley margin intersects outcrop of Tropic Shale, hence XS VI lies completely within the Sink Valley drainage basin. The narrowing of Sink Valley in the location of XS VI means that the valley slopes are contributing significant quantities of sediment to the valley floor and this is expressed in the stratigraphic sections.

Measured section #27 is located on the western margin of the cross section in the topographically lowest part of the cross section. Small discontinuous gullies are present on the valley floor and this probably reflects the confinement of the sheetfloods by the narrower valley. The sediments in MS #27 are fine grained and they reflect sheetwash deposition from the Tropic Shale outcrop to the west and sheetflood deposition from a down-valley direction. MS #27 is located south of the area where sheetfloods bifurcate into Lower Robinson Creek drainage basin and into Sink Valley. The interbedding of fine-grained Tropic-derived and predominantly Wasatch-derived sediments can probably be related to hillslope and valley events. Saturation of the basal part of MS #27 is probably due to the emergence of valley fan groundwater down valley from the toe of the fan and to the fact that sediments in MS #27 lap onto the Tropic Shale basin boundary.

Measured section #28 is located in the approximate center of the valley, and, therefore, it probably is representative of the depositional axis of the valley. Although it is located in the center

of the valley it is apparent that sediments derived from the eastern valley margin have significantly affected the sedimentological characteristics of the valley fill. The topographic cross section which dips to the west strongly confirms the observation. The basal part of the section is composed of horizontally laminated sands derived from Cretaceous sandstones in Swapp Hollow. The most noticeable depositional unit in MS #28 is the large, matrix supported debris flow deposit. The relatively coarse-grained Wasatch-derived sediments originated from the pediment gravels on the eastern valley margin. The generally coarser sediments in MS #28 probably can be attributed to the progradation of a lobe of Swapp Hollow fan onto the valley floor. This is supported by the cross section profile which shows a relatively steep (0.03) cross-valley gradient between MS #28 and MS #35. A relatively high water table was observed in MS #28, and it appeared to be perched on top of a mudflow deposit. Flow rates into the pit were very high.

Measured section #35 appears to be located on a former lobe of Swapp Hollow fan. Abandonment of this lobe may be related to the presence of the mass failure debris that is located up-fan on the southern margin of Swapp Hollow fan. The basal part of the section contains a mudflow deposit that is overlain by numerous sheetflood deposits that contain minor small-scale channel fills. Debris flow and mudflow deposits predominate in the upper part of the section. The coarse Wasatch-derived clasts must have been derived from the eroding hillslopes that form the eastern valley margin of this cross section. Field observation of the valley margin hillslopes showed that considerable quantities of

Wasatch-derived pediment gravels mantle the hillslope and they are also concentrated in hillslope gullies that are discharging to the valley floor.

Comparison of the size of the Wasatch-derived sediments across XS VI shows a marked fining in the westward direction. The coarsest sediments are located in MS #35 and the finest are found in MS #27. However, the ground surface elevation at MS #35 is 6903 feet, whereas that at MS #27 is 6851.9 feet, a difference of about 51 feet. It is highly unlikely that a channel, if one ever existed, would be located at the higher elevation on the valley cross profile. The cross-valley gradient would argue for a channel location in the lowest part of the valley where flows would be most confined. The fine grained nature of the Wasatch-derived sediments at MS #27 does not provide evidence of channelized flow, but rather it argues for unconfined sheetflows.

3.9. Cross Section VII (Drawing No. 8)

The valley width at XS VII (~ 1200 feet) is about half of that at XS VI, and the narrowing is an expression of the changing lithology at the basin margins (Fig. 3.1). The Dakota Fm, which is more erosion resistant than the Tropic Shale controls the width of the valley. Because of the topographic confinement, flow confinement occurs at this location and, therefore, the probability of having confined channel flow is high. However, only minor discontinuous channels are present on the valley floor. The larger channel on the western margin of the valley is at the location of the old Alton-Skutumpah wagon road which appears to

have incised relatively recently, probably as a result of flow concentration in the wagon wheel ruts.

Morphologically and stratigraphically XS VII is heavily influenced by valley margin contribution of sediments. On the eastern margin (MS #31), a detrital cone extends from the base of the hillslope for a distance of about 500 feet onto the valley floor. The basal sediments in MS #31 are sandy and they are water saturated. The absence of any sedimentary structures, other than horizontal laminations, in a relatively thick interval of well sorted sand indicates that these are sheetflood deposits. The remainder of MS #31 is comprised of hillslope derived sediments that encompass debris flow deposits, mudflow deposits and sheetwash deposits. The coarse Wasatch-derived sediments in the debris flow deposit are derived from the local pediment gravels.

MS #30 is located at the toe of the detrital cone. It reflects some valley margin sediment contribution, especially in the upper part of the section, which documents the progradation into the valley of the detrital cone. The lower part of the section appears to be composed of sheetflood deposits, as the sand units do not have structures other than horizontal laminations. The absence of cross-bedded structures in the relatively thick sand units argues for unchannelized flow conditions. The yellowish color of the sands in both MS #31 and MS #30 suggests that they were derived from the Cretaceous age sandstones that crop out in Swapp Hollow drainage basin rather than from an up-valley source such as the Wasatch Formation. The basal portion of MS #30 was water saturated.

Measured section #29 is located in the middle of the non-hillslope-modified part of the valley floor. The sediments in the base of the

section are similar to those in the basal portions of MS #31 and MS #30. The sands are water saturated. A mudflow deposit overlies the basal sand unit (Cretaceous Sandstone-derived). It could have been derived from either valley wall, but the presence of minor amounts of Wasatch-derived sediments in the mudflow deposit argues for an eastern source area. The remainder of the sediments in MS #29 are comprised primarily of fine grained Wasatch-derived silts and sands that are sheetflood deposits. The section appears to be capped by hillslope-sourced Tropic Shale-derived sheetwash deposits.

The stratigraphic data from XS VII indicate that the valley margins are significant source areas for the sediments. The relatively minor amounts of Wasatch-derived sediments and their fine grained nature in the stratigraphic sections further indicates that these sediments were not transported by channels that were continuously linked to their source area. The Wasatch-derived sediments were delivered to this lower valley location by periodic sheetflood events and their greater frequency in the upper parts of the stratigraphic sections provides evidence for valley fan progradation. The coarser Wasatch-derived clasts that are located in the eastern measured section (MS #31) were derived from a local source, the pediment. The yellow basal sands sections of the three measured sections indicate that Swapp Hollow drainage basin was probably the major source of sediments prior to valley fan progradation down Sink Valley, because the yellowish sands were derived from Cretaceous age sandstones. The absence of cross-bedding in the sands indicates strongly that the sands were transported by unconfined sheetfloods.

3.10. Cross Section VIII (Drawing No. 9)

The valley width at XS VIII (Fig. 3.1) is about 700 feet, but a detrital cone at the base of the hillslope on the eastern valley margin extends about 200 feet onto the valley floor. Sediments derived from the Dakota Formation on the western valley margin have been transported into the valley floor by slopewash processes. They include fragments of reddish colored clinker, the result of coal seam burns within the Dakota Formation.

Measured Section #34 is located at the toe of the detrial cone on the eastern side of the valley. MS #34 reflects considerable valley margin contribution of sediment in the form of both Tropic-derived and locally Wasatch-derived sediments. Coarse locally derived Wasatch clasts were observed on the surface of the detrital cone to the east of MS #34.

Measured section #33 is located in the middle of the valley. The basal part of the section contains numerous sheetflood deposits that contain clasts that were locally derived (i.e. Dakota SS and clinker chips) and those that may have been transported down valley (Wasatch), or from a local source such as the pediment (Wasatch). The base of the section was water saturated. The remainder of the section consists of interbedded sheetflood and locally derived sheetwash and mudflow deposits.

Measured section #32 is located to the east of a major incised channel on the western margin of the valley. The incised channel is in the former location of the Alton-Skutumpah wagon road, and it is

currently dammed. The basal portion of MS #32 contains a number of Wasatch-derived silt drapes which may reflect unusually large sheetfloods on the prograding valley fan. The remainder of the sediments in MS #32 are very fine grained and they contain abundant locally derived clinker and sandstone clasts. The coarser units were probably derived from the local hillslopes in the form of mudflows and debris flows. The base of the section was water saturated.

The small fraction of the total sediments that are exposed in the measured sections along XS VIII that were derived from Wasatch sources argues against channelized delivery of Wasatch-derived sediments to the lower valley region. Sediments in the valley fill appear to be strongly influenced by local sources.

3.11. Cross Section IX (Drawing No. 9)

The valley width at XS IX (Fig. 3.1) is about 500 feet. A small alluvial fan on the eastern valley margin has prograded out onto the valley floor for a distance of about 250 feet. Another small alluvial fan has prograded onto the valley floor from the western valley margin about 300 feet upstream of MS #36. Therefore, it is evident that sedimentation on the valley floor is very strongly influenced by valley margin sources. On the eastern valley margin coarse clastic sediments derived from the pediment gravels and outcrops of Dakota sandstone are being introduced to the valley floor. On the western valley margin the coarse clastics are derived from the Dakota sandstone.

Measured section #36 is located on the true right bank of the incised channel of Sink Valley Wash. The lowermost 14 feet of the

section is composed of shale-derived sediments, which include minor clinker chips. The frequency of occurrence of Wasatch-derived sediments increases up-section which suggests that the Wasatch-derived sediments were not available for deposition until late in the valley aggradation cycle which preceeded the incision of Sink Valley Wash, the result of base level lowering due to the incision of Kanab Creek. The upper part of MS #36 is dominated by interbedding of locally and down-valley-derived fine grained sediments.

There is no doubt that the bed of the currently incised channel of Sink Valley Wash contains significant quantities of coarse-grained clasts. It might be argued that they represent part of the valley fill. However, the field evidence indicates that the coarse clasts were locally derived and concentrated in the bed of the channel as a result of the processes of channel incision and incision-induced channel widening. The absence of coarse Wasatch-derived clasts in the measured sections up-valley (i.e., MS #32, MS #33, MS #27) indicates that the coarse clasts in the bed of the incised channel must have been locally derived. The majority of the coarser clasts were derived from the Dakota sandstone, but the quartzite, basalt and limestone clasts were derived from the pediment gravels on the eastern margin of the valley.

3.12. Summary of Sink Valley Sedimentology

The surveyed cross sections (9) and measured stratigraphic sections (37) in Sink Valley document a very complex valley fill. However, the very distinctive nature of the three principal sediment source

lithologies enable the sedimentology to be interpreted with a relatively high degree of confidence. Sedimentation in Sink Valley has significantly modified pre-existing relief in the basin and it has had a significant effect on flow distribution between Sink Valley drainage basin and the drainage basin of Lower Robinson Creek. A pre-existing drainage divide between Sink Valley and Lower Robinson Creek has been eliminated by stream capture and by burial of the divide. Sedimentation in the upper portion of Sink Valley has been the result of the down-valley progradation of a valley fan. This fan differs from more conventional alluvial fans in terms of its shape, but it has similar sedimentologic characteristics (Beaty, 1970; Costa, 1988).

The sedimentologic and morphologic characteristics of the valley fan have been in essence frozen by the capture of the Wasatch Formation source area by Lower Robinson Creek, which is deeply incised. Currently, sediments eroded from the Sunset Cliffs in Water Canyon are transported down-valley in this incised channel. An incised channel exists to the base of the Sunset Cliffs in Water Canyon, but the sediments eroded from the cliffs are being transported down Water Canyon principally as very coarse-grained debris flows. The debris flows, however, currently are unable to reach the valley fan in Sink Valley because of the presence of the incised channel. Channelized debris flow deposits were observed in the bed of the abandoned channel segment (east) of Lower Robinson Creek at XS I. It is reasonably certain that the capture by Lower Robinson Creek was related to the incision of Kanab Creek (c. 1865) and, therefore, it is likely that the morphologic and

sedimentologic characteristics of the valley fan represent events prior to the time of capture.

The dominant source rocks that contribute sediment to Sink Valley change along its length (Fig. 3.4). Cross section I (Fig. 3.1) sediments are predominantly Wasatch-derived and reasonably coarse grained. Sheetflood deposits with minor channel fills and debris flow deposits dominate the valley fill (MS #5). Valley margin influences are seen in MS #6 and MS #1 where sheetwash, mudflow and possibly gravity processes contribute sediment from the Tropic Shale and Cretaceous age sandstones. Cross Section II (Fig. 3.1) sediments are predominantly Wasatch-derived and consist of sheetflood and debris flow deposits (MS #3). Lateral contribution from the Tropic Shale is documented by a mudflow deposit in MS #7. The interbedded Wasatch-derived and Tropic-derived fine grained slackwater sediments at the top of MS #8 document the progradation of Section 21 fan onto the floor of Sink Valley and the displacement westward of the depositional axis of the valley fan (MS #3). Cross Section IIB (Fig. 3.1) across the mouth of Section 21 fan documents the delivery of both fine-grained (silt/clay) Tropic-derived sediments to the valley fan and yellowish-grey sands derived from the Cretaceous age sandstones.

Cross Section III (Fig. 3.1) documents the influence of Tropic-derived sediments on the character of the deposits along the depositional axis of the valley fan (MS #12). Mudflow and debris flow deposits dominate this cross section. Valley margin contribution of sediment to Sink Valley is evident in the eastern margin of the fan (MS

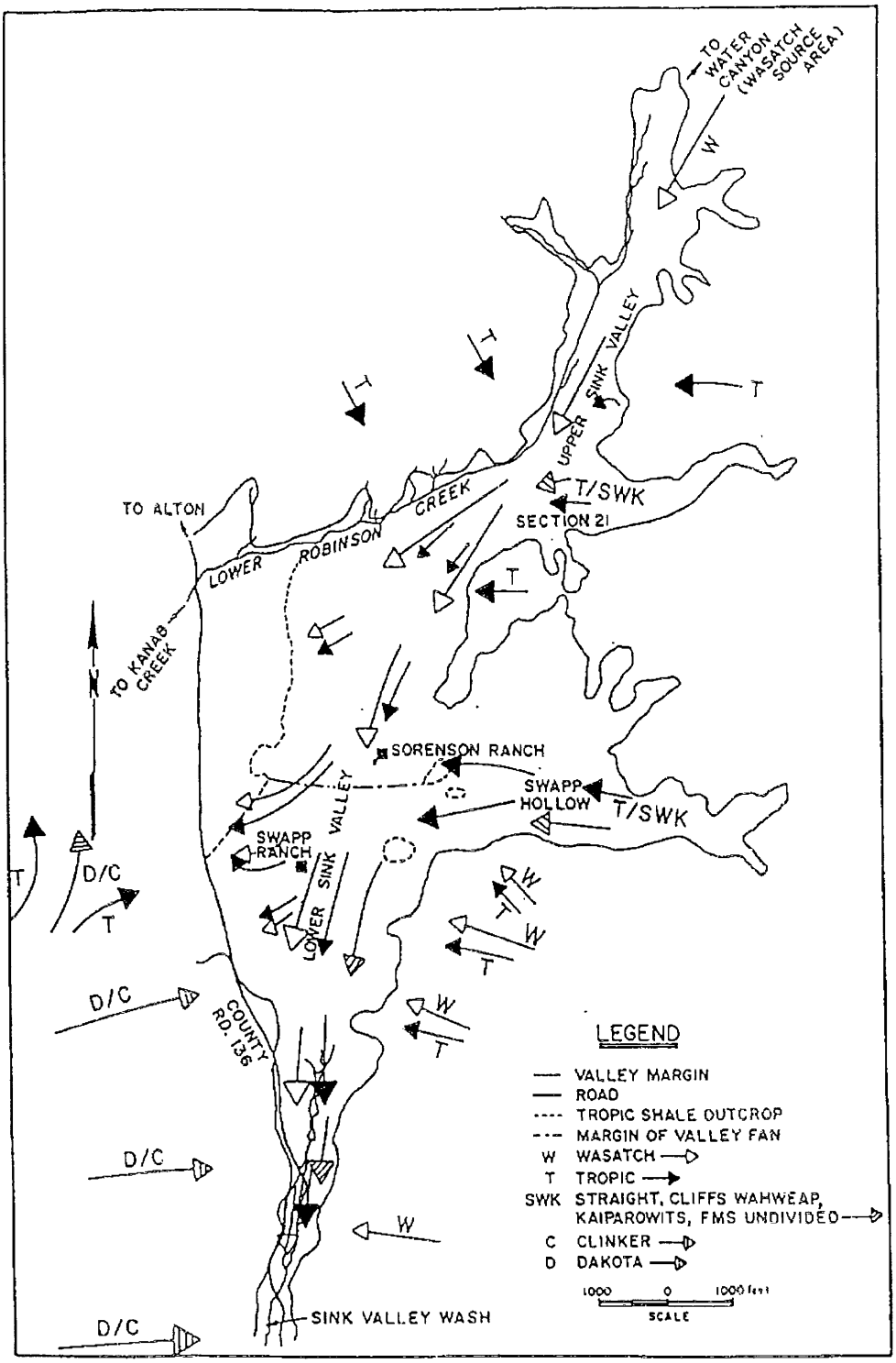

Figure 3.4. Source area lithologies for sediments in Sink Valley.

#13, 17, 18, 19). Localized deposition has created locally oversteepened topography and this has resulted in the formation of discontinuous gullies. Fan progradation towards the valley margin is documented in MS #4, where the Wasatch-derived sediments (sands and silts) have infilled a pre-existing badland topography (Fig. 3.3) that drained the area to the north of the presently incised channel of Lower Robinson Creek. The surveyed XS profile confirms that MS #4 is located on a fan margin.

Cross Section IVA extends from the drainage basin of Lower Robinson Creek on the west to the eastern margin of Sink Valley just up-valley from the junction with Swapp Hollow fan (Fig. 3.1). Progradation of the valley fan to the point where sheetfloods overtopped the Tropic Shale ridge which was the drainage divide between Lower Robinson Creek and Sink Valley is documented in MS #14 and MS #20. Since there is no outcrop of Wasatch Formation in the pre-capture drainage basin of lower Robinson Creek, then the Wasatch-derived sediments in MS #14 and MS #20 must have been derived from Sink Valley. The low frequency of the Wasatch-derived sediments in MS #14 and MS #20 and the fact that they are located in the upper portions of the stratigraphic sections indicates that the sediments were transported by extreme events on the valley fan. Deposition of the Wasatch-derived sediments must have pre-dated the incision of Lower Robinson Creek (c. 1865) and the capture of Upper Sink Valley because the Wasatch-derived sediments are interbedded with Tropic-derived sediments.

The on-lap of the valley fan onto the eastern side of the Tropic Shale ridge, and its effects on the water table are shown in MS #15,

which is composed of primarily fine grained fan-margin sediments. The depositional axis of the fan is located at MS #16 and it reflects the contribution of sediments from both the Wasatch Formation and the Tropic Shale. Progradation of Swapp Hollow fan into Sink Valley and its effects on slackwater sedimentation can be seen in MS #22 where fine-grained sediments from the Wasatch Formation and the Tropic Shale are interbedded. Cross Section IVA is located near the crest of the valley fan.

Cross Section IVB (Fig. 3.1) extends across the mouth of Swapp Hollow and it documents a number of important factors with respect to Sink Valley sedimentology. First, a considerable volume of Cretaceous age sandstone-derived sand-sized sediments are being introduced to Sink Valley (MS #37). Second, significant quantities of Tropic-derived sediment is also being introduced to Sink Valley. Finally, erosion of the pediment on the south side of Swapp Hollow is introducing coarse Wasatch-derived pediment gravels to Sink Valley.

Cross Section V extends from the Lower Robinson Creek drainage basin on the west to the mouth of Swapp Hollow on the east (Fig. 3.1). The cross section is located within Sink Valley at the approximate location of the down-valley terminus of the valley fan. The depositional axis of the valley fan is located at MS #24 and the sediments reflect different source lithologies; Wasatch Formation, Tropic Shale, and the Cretaceous age sandstones. The Wasatch-derived sediments have been diluted considerably in comparison to the sections that are located up-fan. MS #25 shows the effects on the water table of fan margin on-lap to the

impermeable Tropic Shale ridge. Sediment delivery from Swapp Hollow may have been responsible for displacing valley fan margin sedimentation towards the west, thereby eliminating the pre-existing drainage divide between Sink Valley and Lower Robinson Creek drainage basins. The coarse-grained basal sediments in MS #26 were derived from local Dakota Formation outcrops in the Lower Robinson Creek basin. Wasatch-derived sediments constitute a minor portion of MS #26. Elimination of the drainage divide as a result of sedimentation just south of XS V permits present day sheetfloods to bifurcate into both Sink Valley and Lower Robinson Creek. Groundwater discharge in the distal portion of the valley fan is confirmed in MS #24 and MS #25.

Cross Section VI lies completely within the margins of Sink Valley (Fig. 3.1). Pediment-derived Wasatch Formation clasts, Tropic-derived finer-grained sediments and Cretaceous age sandstone-derived sands were transported on a formerly active lobe of Swapp Hollow fan to the valley floor (MS #35, MS #28). This lobe formed a significant cross gradient across Sink Valley which must displace the sheetfloods to the west (MS #27). Very little Wasatch-derived sediment is present in MS #27, and the sediments in the section are dominated by sands derived from the Cretaceous age sandstones in Swapp Hollow and by local contributions of Tropic-derived sediments from the western valley margin. A shallow water table is present in both MS #28 and MS #27.

Cross Section VII (Fig. 3.1) demonstrates the importance to the valley fill of local sediment sources. A detrital cone has prograded from the eastern valley margin onto the valley floor. The coarse-

grained Wasatch-derived sediments in MS #31 and MS #30 originated from the pediment gravels. The basal portions of all the measured sections along XS VII are composed of yellowish-grey sands that were derived from Cretaceous age sandstones in Swapp Hollow. It is significant to note that Wasatch-derived finer grained sheetflood deposits are located in the upper part of MS #29. This tends to confirm that the delivery of Wasatch-derived sediments down-valley to this location was dependent on valley fan progradation rather than as the result of channelized flow.

The paucity of Wasatch-derived sediments other than silt/clay drapes in the measured sections (MS #32, 33, 34) along XS VIII (Fig. 3.1) indicates that it is highly unlikely that a continuous channel has been in existance through the length of Sink Valley during the time that the observed valley fill was deposited. The sediments in the measured sections are dominated by yellowish-grey sands that were derived from Swapp Hollow. Lateral contribution of sediments from the valley margins is documented by clasts of Dakota sandstone and clinker chips. Coarser-grained Wasatch-derived clasts and fine-grained Tropic-derived sediments are present in the detrital cone on the eastern valley margin (MS #34).

The absence of a continuous channel through Sink Valley in the time period represented by the valley fill is further confirmed by MS #36 on XS IX (Fig. 3.1). The coarse clasts in the bed of the incised channel of Sink Valley Wash have been derived from local sources. Dakota sandstone clasts were derived from both valley margins, and the Wasatch-derived clasts were transported by slope transport processes on the eastern valley margin.

The sedimentology of Sink Valley can be summarized in a longitudinal profile that follows the depositional axis (Fig 3.5). The measured sections that represent the depositional axis of the valley at each of the surveyed cross sections were arranged in a down-valley sequence (Fig. 3.1). The elevation of the top of each measured section was used to construct the longitudinal profile of the valley floor. The distances between the measured sections are to scale.

The valley fan extends from XS I (MS #5) to XS V (MS #24). The proximal (up-valley) part of the valley fan (MS #5, MS #3) is composed of predominantly Wasatch-derived, relatively coarse-grained sediments that were deposited by debris flows and sheetfloods. Minor channel fills are located within the horizontally laminated sheetflood deposits. The channels were probably small-scale and ephemeral, and they probably represent a braided pattern during sheetflood events (Reading, 1978; Bull, 1977; Blair, 1986). The coarse-fine couplets within the sheetflood deposits represent the down-fan passage of low relief sheets of sands and fine gravels (Bull, 1977; Blair, 1986).

The medial portion of the valley fan is represented by MS #12 (XS III) and MS #16 (XS IVA). The sediments were deposited by mudflows, debris flows and sheetfloods. However, there is a dilution of the Wasatch-derived sediments by Tropic-derived and Cretaceous sandstone-derived sediments. The Tropic-derived sediments probably originated from Section 21 tributary and the Tropic Shale eastern valley margin. Cross Section V marks the approximate location of the distal portion of the fan (MS #24). Both the volume and caliber of the Wasatch-derived

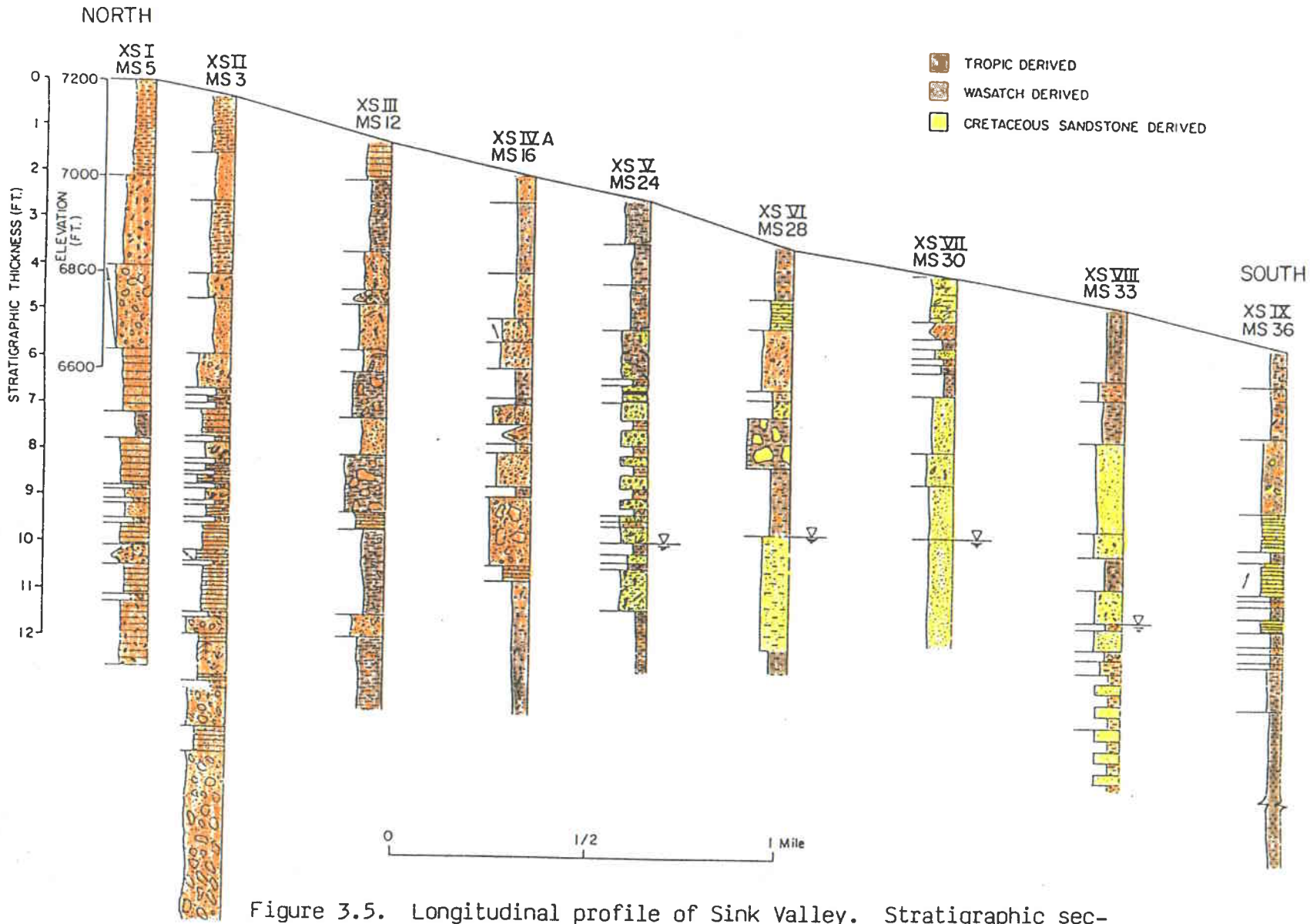

Figure 3.5. Longitudinal profile of Sink Valley. Stratigraphic sections represent the depositional axis of the valley.

sediments have declined significantly in MS #24 (XS V). The Wasatch-derived sediments are fine-grained and they represent drapes which document discrete down-valley flood events. The sediments in MS #24 also reflect a significant increase in the volume of sands that were derived from Cretaceous age sandstones in the Swapp Hollow drainage basin. The presence of groundwater at shallow depth in MS #24 also argues that this section represents the toe of the valley fan (Galloway et al., 1979).

Cross section VI is contained completely within Sink Valley, but the sediments in MS #28 are heavily influenced by Swapp Hollow fan, a lobe of which had prograded onto the floor of Sink Valley, thereby displacing the depositional axis to the west. The basal portion of MS #28 is dominated by Cretaceous sandstone-derived sands. Debris flow and mudflow deposits contain relatively coarse-grained Wasatch-derived sediments that originated from the pediment gravels on the south side of Swapp Hollow (Fig. 2.1).

Sink Valley narrows considerably at XS VII and the sediments in MS #30 are dominated by Cretaceous age sandstone-derived sands. The upper portion of MS #30 reflects progradation of a small detrital cone onto the valley floor. The sediments originated from the valley side slopes and they contain coarser clasts of both sandstone and the Wasatch-derived pediment gravels. The absence of fine-grained Wasatch-derived sediments (silt/clay drapes) in the basal parts of MS #30 and MS #28 may be the result of the relatively shallow depth of the pits. Very high rates of groundwater flow were encountered in the pits and wall caving

occurred rapidly and frequently. The Wasatch-derived fine-grained sediments (drapes) were prominent in the basal portion of MS #33 (XS VIII), which is a deeper section.

The bulk of the sediment in MS #33 were derived from the Cretaceous age sandstones in the Swapp Hollow drainage basin. The increasing dominance of these sands in MS #28, MS #30, and MS #33, and the concomittant reduction in the amount of Wasatch-derived sediments, may be related to the elimination of the Wasatch Formation source area due to its capture by Lower Robinson Creek. Conversely, the change in the character of the sediments may merely reflect the fact that the valley fan had not prograded far enough down-valley to deliver significant volumes of sediment to the lower valley. The presence of the multiple Wasatch-derived drapes in the basal portion of MS #33 indicates that sheetflood events that originated up-valley from XS VIII were more frequent in the earlier part of the valley fill cycle. It is also conceivable that the relative abundance of the sandstone-derived sediments is related to the dynamics of Swapp Hollow fan. Fan trenching (Schumm 1977; Schumm et al, 1987) may have delivered large quantities of fan sediments to the valley floor. The absence of sedimentary structures other than horizontal laminations in the sand units argues for unconfined flow conditions on the valley floor.

Minor amounts of fine-grained Wasatch-derived sediments are interbedded with Tropic-derived and Cretaceous age sandstone-derived sediments in MS #36 (XS IX). Coarser Wasatch-derived clasts interbedded with Tropic-derived sediments in the upper part of MS #36 were derived

from the pediment gravels on the eastern margin of the valley. Detrital cones and small scale fans at the base of both valley margins have significantly affected sedimentation in this narrow reach of the valley.

The morphological (Figs. 2.1, 2.3, 2.4) and sedimentological data (Fig. 3.5) strongly confirm that a valley fan exists in Sink Valley between XS I and XS V. Tributary fans (Section 21 and Swapp Hollow) have significantly affected the sedimentology and morphology of the valley floor (Fig. 3.3). Lateral inflow of sediments from the valley margins has introduced coarser grained sediments to the valley floor that interrupt the down-valley fining trends of the grain size (Fig. 3.4). The presence of a shallow groundwater table down-valley from XS V is consistent with the valley fan interpretation.

4. CONCLUSIONS

This investigation of Sink Valley was conducted to determine: (1) whether there were streamlaid deposits beneath the surface of the valley floor and (2) whether alluvial fans, or man's activities had obscurred a previously existing continuous channel that traversed the length of Sink Valley. Both of these factors are important with respect to determining whether Sink Valley meets the regulatory geologic criteria for an Alluvial Valley Floor (AVF). On the basis of these criteria, the requirement for an AVF determination is the presence of a continuous channel within a topographic valley, the floor of which contains floodplain and terrace features that are underlain by unconsolidated streamlaid deposits that were deposited by the continuous channel. Alluvial fans are specifically excluded from determination as AVF's

The results of this investigation have demonstrated that:

(1) there are no streamlaid deposits within the sediments that were observed in the backhoe pits and exposed banks of Lower Robinson Creek and Sink Valley Wash. The sediments were deposited by unconfined sheetfloods, debris flows and mudflows. Minor channel fill sediments were observed in the stratigraphic sections, but they are related to the presence of small ephemeral channels during sheetflood events and to topographic irregularities caused by the presence of mudflow and debris flow deposits.

(2) no continuous channel has traversed the length of Sink Valley within the time interval that is represented by the valley fill

that was observed in this investigation. The valley fan that prograded down-valley from the confluence of Dry Fork and Water Canyon is composed primarily of Wasatch-derived sediments. Capture of the upper part of the Sink Valley drainage basin by Lower Robinson Creek was due to base level lowering, the result of incision of Kanab Creek (c. 1865), and progradation of the valley fan that eliminated a pre-existing drainage divide between the basins. Capture of the source area for the Wasatch-derived sediments has in essence frozen the valley fan morphology into the pre-capture configuration, and therefore, the valley fan must pre-date the time of capture. Therefore, it cannot be argued that the valley fan is a recent feature that has obscurred the presence of a pre-existing continuous channel. Further, the absence of any sedimentary evidence for channelized flow in the investigated stratigraphic fill indicates that surface modifications of the valley floor by man's activities has not obscurred the presence of a continuous channel. This is further reinforced by the rapid down-valley fining of the size of the Wasatch-derived sediments, and by the relative paucity of Wasatch-derived sediments in the stratigraphic sections down-valley from the toe of the valley fan.

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APPENDIX I

SINK VALLEY STRATIGRAPHIC SECTIONS

LEGEND

- SILT/CLAY
- SAND
- GRAVEL
- CHARCOAL
- ROOT CASTS
- RIPUP CLASTS
- FINING UPWARD SEQUENCE
- COARSENING UPWARD SEQUENCE
- W — WASATCH DERIVED
- T — TROPIC DERIVED
- SW — SHEETWASH
- CH — CHANNEL FILL
- MF — MUDFLOW
- DF — DEBRIS FLOW
- HORIZONTAL STRATIFICATION
- RIPPLE CROSS STRATIFICATION
- TROUGH CROSS STRATIFICATION
- COARSE / FINE COUPLETS
- SILT/CLAY DRAPE
- PEDOGENIC STRUCTURE
- LENTICULAR BEDDING
- EROSIONAL CONTACT
- SWK — STRAIGHT CLIFFS/WAHWEAP DERIVED
- RF — ROCKFALL
- SF — SHEETFLOOD
- D — DRAPE
- WATER TABLE

MEASURED SECTION NO. 1
LOCALITY XS 1 WEST CHANNEL
SETTING TLB LOWER ROBINSON CREEK
STATION 8+56

DATE 7/11/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7202.4

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV: 64 4; SAND: VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS TOP OF SECTION
1	22			W	WASATCH DERIVED SILT TO MEDIUM SAND LATERALLY CONTINUOUS SHARP LOWER CONTACT
2	13			T	TROPIC DERIVED SILT/CLAY DENSE
3	6			W/T	WASATCH/TROPIC DERIVED SILT TO MEDIUM SAND INCREASE IN WASATCH DERIVED MATERIAL UPSECTION LATERALLY CONTINUOUS
4 5 6 7 8 9	67			W/T	PRIMARILY TROPIC DERIVED SILT AND CLAY WITH MINOR WASATCH DERIVED SAND-PEBBLE SIZE CLASTS HIGH CHARCOAL CONTENT
10 11 12	35			T	TROPIC DERIVED SILT AND CLAY WITH MINOR ANGULAR GRIT HIGH CHARCOAL CONTENT
					CONTINUED

MEASURED SECTION NO 1 (CONT.)
LOCALITY XS 1 WEST CHANNEL
SETTING TLB LOWER ROBINSON CREEK
STATION 8+56

DATE 7/11/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7202.4

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					CONTINUED SECTION
13	20			W/T	TROPIC DERIVED SILT AND CLAY WASATCH DERIVED FINE GRAVEL AND SAND MASSIVE
	3			W	GRAVEL TO COBBLES; LIMESTONE/QUARTZITE/BASALT CLAST B-AXIS = 55-100 MM MATRIX SUPPORTED CHAOTIC ⇒ DEB FLO
14	8			W/T	INTERBEDDED WASATCH DERIVED MEDIUM SAND AND TROPIC DERIVED SILT/CLAY DRAPES
	5			T	TROPIC DERIVED SILT TO FINE SAND
15	5			W	WASATCH DERIVED MEDIUM SAND
	4			W/T	TROPIC DERIVED SILT/CLAY DRAPE UNDERLAIN BY WASATCH DERIVED MEDIUM SAND
	1			W	SILT/CLAY DRAPE
16	6			W	WASATCH DERIVED MEDIUM SAND MASSIVE
					BASE OF SECTION

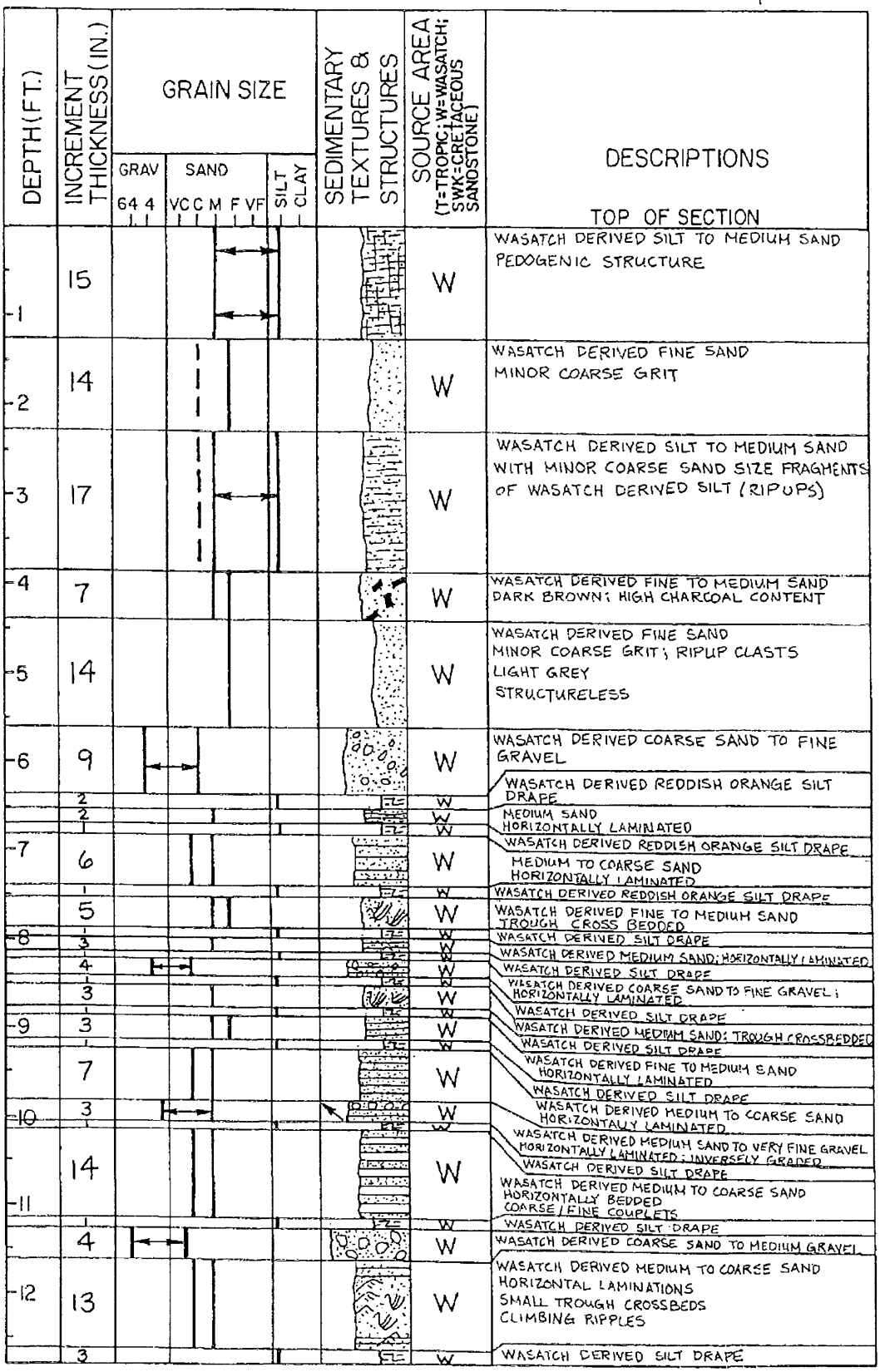
MEASURED SECTION NO. 2
LOCALITY XS 1 EAST CHANNEL
SETTING TLB LOWER ROBINSON CREEK
STATION 7+78

DATE 7/11/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7202.2

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV: 64 4; SAND: VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; S=WK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1	13			W	WASATCH DERIVED SILT TO FINE SAND
	10			W	WASATCH DERIVED FINE SAND
2	10			W	WASATCH DERIVED MEDIUM TO COARSE SAND
	1			W	WASATCH DERIVED REDDISH FINE GRAVEL
3 4	17			W	WASATCH DERIVED FINE TO MEDIUM SAND HIGH CHARCOAL CONTENT DENSE
	3			W	WASATCH DERIVED REDDISH FINE GRAVEL
5	5			W	WASATCH DERIVED FINE TO MEDIUM SAND MASSIVE
	7			W	GRAY VERY FINE TO MEDIUM SAND MINOR PINK WASATCH DERIVED COARSE SAND HORIZONTALLY LAMINATED
6	5			W	WASATCH DERIVED MEDIUM SAND UNDERLAIN BY 1/4" PINK SILT DRAPE
7	20			W	DARK BROWN FINE SAND MINOR COARSE SAND TO PEBBLE CLASTS MASSIVE HIGH CHARCOAL CONTENT FINE GRAINED DENSE BASE WITH WELL DEVELOPED ROOT CASTS
8	8			W	WASATCH DERIVED MEDIUM TO COARSE SAND MASSIVE
	5			W	WASATCH DERIVED GRAVEL MAXIMUM B-AXIS = 70MM QUARTZITE, LIMESTONE, BASALT CLASTS
9	12			W	MEDIUM SAND WELL SORTED
10 11 12					MODERN STREAM GRAVELS BASE OF SECTION

MEASURED SECTION NO 3
LOCALITY XS 2 A
SETTING TLB LOWER ROBINSON CREEK
STATION 9+79

DATE 7/12/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7174.8



DEPTH (FT.)	INCREMENT THICKNESS (IN.)	SOURCE AREA (T=TROPIC; W=WASATCH; S WK=CRETACEOUS SANDSTONE)	DESCRIPTIONS (TOP OF SECTION)
1	15	W	WASATCH DERIVED SILT TO MEDIUM SAND PEDOGENIC STRUCTURE
2	14	W	WASATCH DERIVED FINE SAND MINOR COARSE GRIT
3	17	W	WASATCH DERIVED SILT TO MEDIUM SAND WITH MINOR COARSE SAND SIZE FRAGMENTS OF WASATCH DERIVED SILT (RIPUPS)
4	7	W	WASATCH DERIVED FINE TO MEDIUM SAND DARK BROWN; HIGH CHARCOAL CONTENT
5	14	W	WASATCH DERIVED FINE SAND MINOR COARSE GRIT; RIPUP CLASTS LIGHT GREY STRUCTURELESS
6	9	W	WASATCH DERIVED COARSE SAND TO FINE GRAVEL
	2	W	WASATCH DERIVED REDDISH ORANGE SILT DRAPE
	2	W	MEDIUM SAND HORIZONTALLY LAMINATED
7	6	W	WASATCH DERIVED REDDISH ORANGE SILT DRAPE MEDIUM TO COARSE SAND HORIZONTALLY LAMINATED
		W	WASATCH DERIVED REDDISH ORANGE SILT DRAPE
	5	W	WASATCH DERIVED FINE TO MEDIUM SAND TROUGH CROSS BEDDED
8	3	W	WASATCH DERIVED SILT DRAPE
		W	WASATCH DERIVED MEDIUM SAND; HORIZONTALLY LAMINATED
	4	W	WASATCH DERIVED SILT DRAPE
		W	WASATCH DERIVED COARSE SAND TO FINE GRAVEL;
	3	W	HORIZONTALLY LAMINATED
		W	WASATCH DERIVED SILT DRAPE
9	3	W	WASATCH DERIVED MEDIUM SAND; TROUGH CROSSBEDDED
		W	WASATCH DERIVED SILT DRAPE
	7	W	WASATCH DERIVED FINE TO MEDIUM SAND HORIZONTALLY LAMINATED WASATCH DERIVED SILT DRAPE
10	3	W	WASATCH DERIVED MEDIUM TO COARSE SAND HORIZONTALLY LAMINATED
		W	WASATCH DERIVED MEDIUM SAND TO VERY FINE GRAVEL HORIZONTALLY LAMINATED; INVERSELY GRADED
11	14	W	WASATCH DERIVED SILT DRAPE WASATCH DERIVED MEDIUM TO COARSE SAND HORIZONTALLY BEDDED COARSE / FINE COUPLETS
		W	WASATCH DERIVED SILT DRAPE
	4	W	WASATCH DERIVED COARSE SAND TO MEDIUM GRAVEL
12	13	W	WASATCH DERIVED MEDIUM TO COARSE SAND HORIZONTAL LAMINATIONS SMALL TROUGH CROSSBEDS CLIMBING RIPPLES
	3	W	WASATCH DERIVED SILT DRAPE

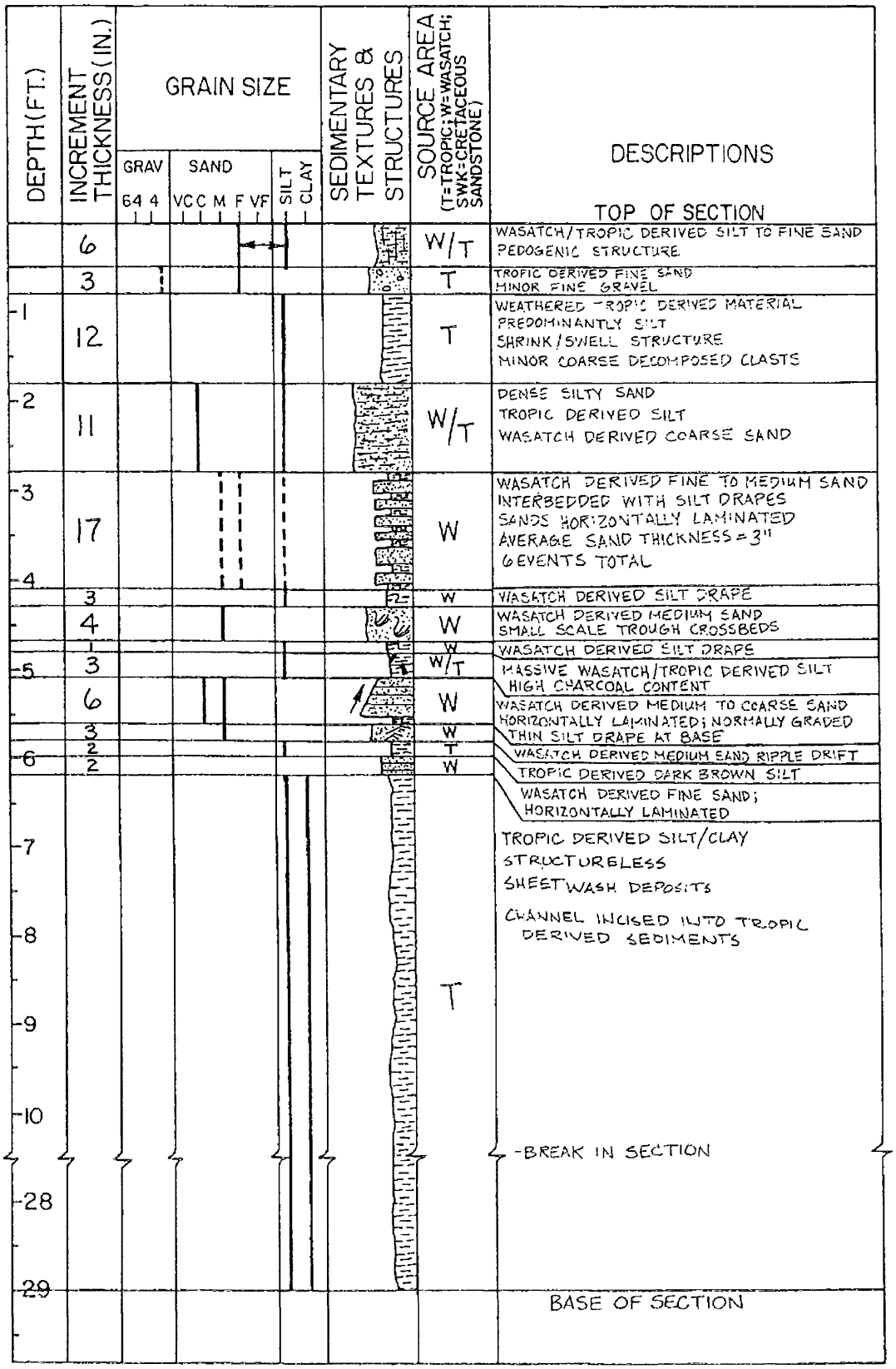
MEASURED SECTION NO 3(CONT.)
LOCALITY XS 2 A
SETTING TLB LOWER ROBINSON CREEK
STATION 9+79

DATE 7/12/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7174.8

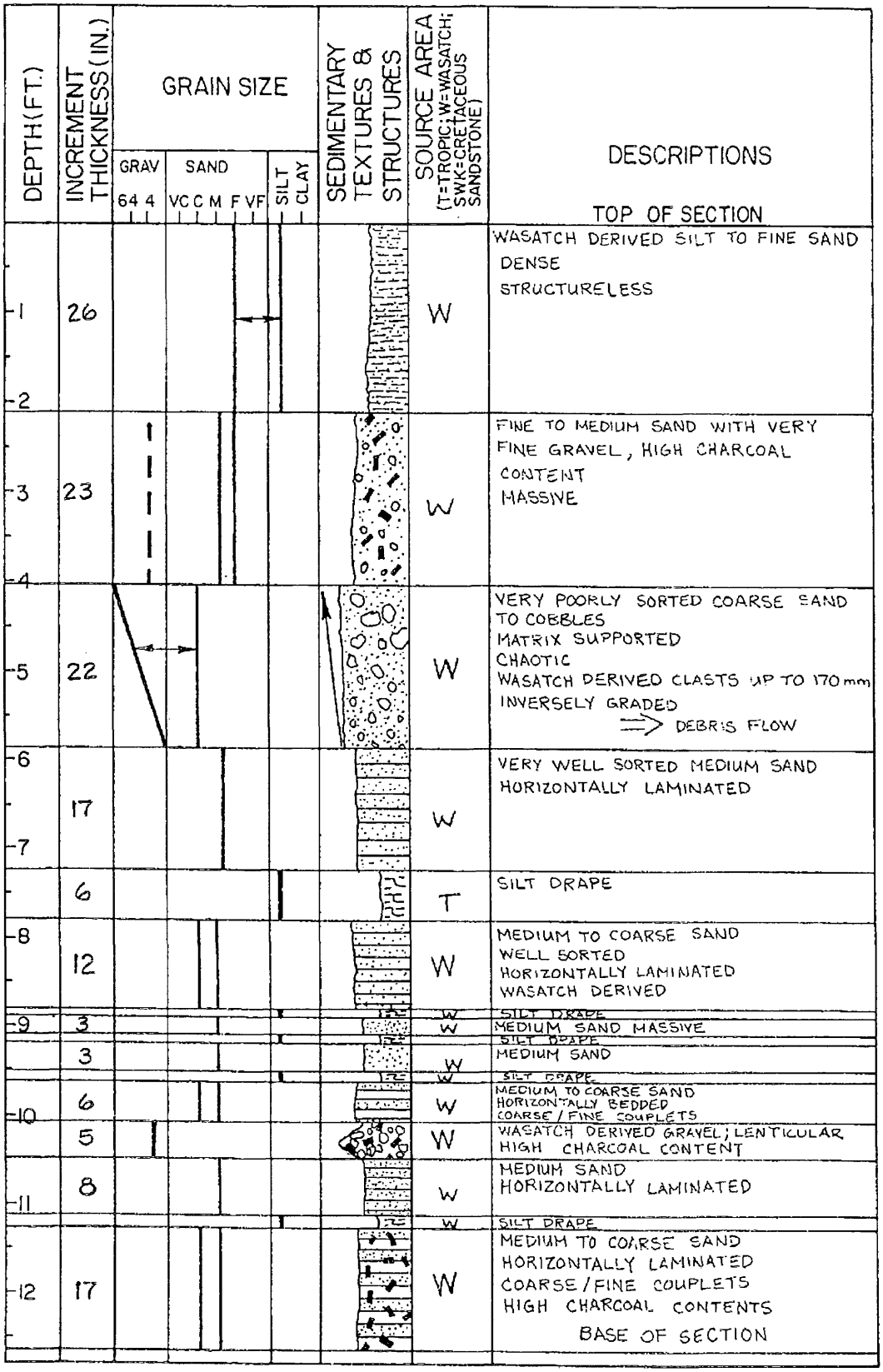
DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV: 64 4; SAND: VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					CONTINUED SECTION
13	10			W	WASATCH DERIVED VERY POORLY SORTED GRAVEL TO COBBLES MATRIX SUPPORTED SANDY MUD MATRIX MAXIMUM CLAST B-AXIS = 150 MM
14	6			W	WASATCH DERIVED MEDIUM TO COARSE SAND HORIZONTALLY LAMINATED
15 16 17	45			W	WASATCH DERIVED GRAVEL TO COBBLES VERY POORLY SORTED MINOR INVERSE GRADING
18					BASE OF SECTION

MEASURED SECTION NO 4
LOCALITY XS 3
SETTING TLB LOWER ROBINSON CREEK
STATION 15+22

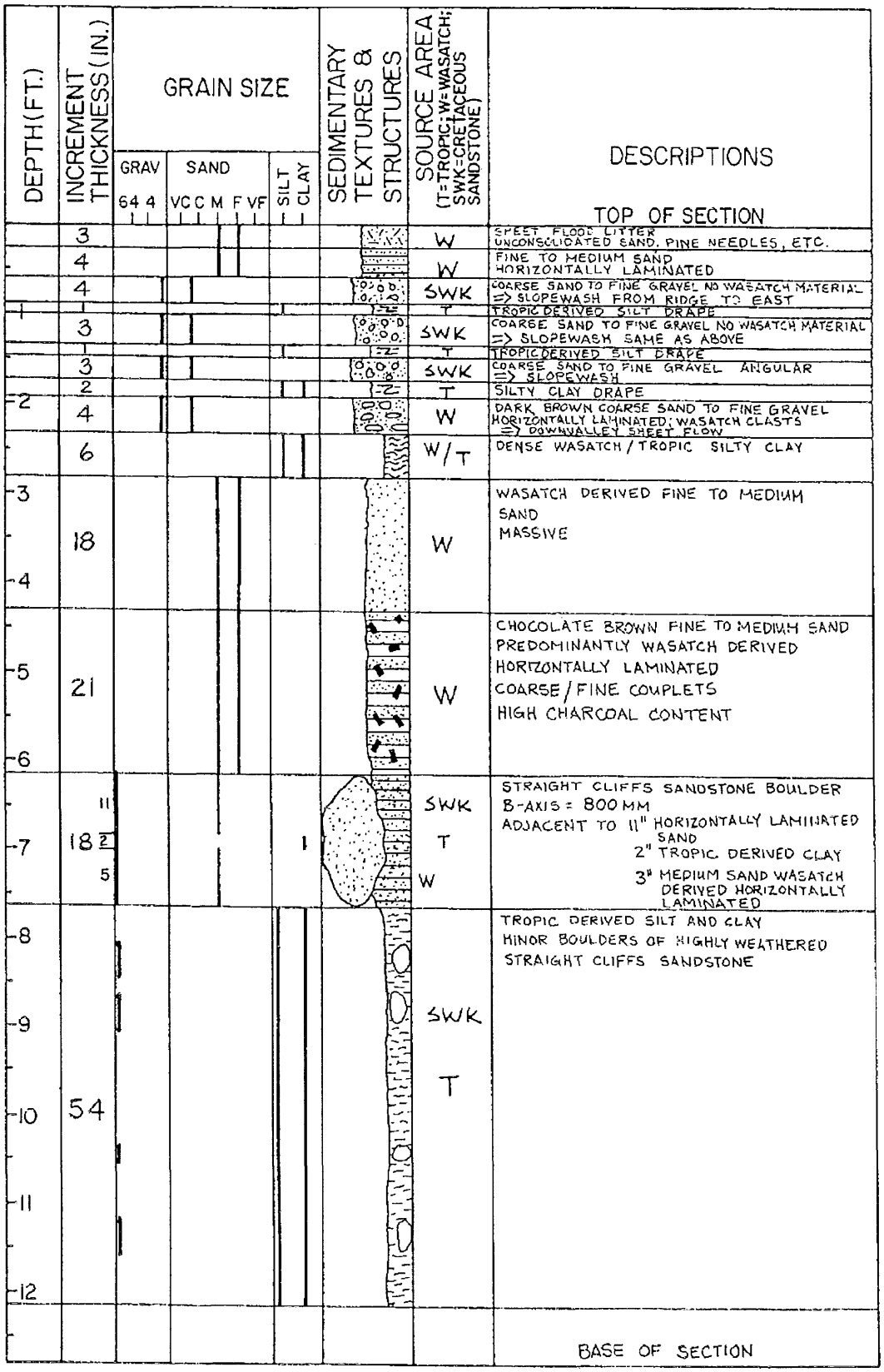
DATE 7/12/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7068.2



MEASURED SECTION NO. 5 DATE 7/12/88
LOCALITY XS 1 STRATIGRAPHIC UNIT VALLEY FILL
SETTING MIDVALLEY MEASURED BY MH/KF/JS/DW
STATION 5+14 ELEVATION 7204.9



MEASURED SECTION NO 6 DATE 7/12/88
LOCALITY XS 1 STRATIGRAPHIC UNIT VALLEY FILL
SETTING EAST SIDE VALLEY MEASURED BY MH/KF
STATION 0+00 ELEVATION 7208.9



MEASURED SECTION NO. 7
LOCALITY XS 2A
SETTING MID VALLEY
STATION 7+14

DATE 7/12/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7174.5

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV: 64 4; SAND: VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1–2	36			W/T	VERY POORLY SORTED SILT, SAND, & FINE GRAVEL DENSE CHAOTIC U-SHAPED SOME TROPIC DERIVED CLASTS HIGH CHARCOAL CONTENT ⇒ MUDFLOW
3–4	17			W	MEDIUM SAND TO MEDIUM GRAVEL MASSIVE CONTAINS RIPUPS OF WASATCH DERIVED SILT DRAPES
	2			W	WASATCH DERIVED SILT DRAPE
	2			W	WASATCH DERIVED MEDIUM-COARSE SAND; RIPPLES
5	6			W/T	DARK BROWN TROPIC DERIVED SILT WITH MINOR WASATCH COMPONENT, DENSE HIGH CHARCOAL CONTENT
	6			W	PINK WASATCH DERIVED FINE TO MEDIUM SAND LATERALLY CONTINUOUS; COARSE/FINE COUPLETS HIGH CHARCOAL CONTENT
6	11			W/T	WASATCH/TROPIC DERIVED SILT TO FINE SAND DENSE RIPUPS OF WASATCH SILT
7	9			W	MEDIUM TO COARSE SAND COARSE/FINE COUPLETS RIPUPS ⇒ SHEETFLOW
	3			W	WASATCH DERIVED COARSE SAND LATERALLY CONTINUOUS ⇒ SHEETFLOW COARSE/FINE COUPLETS; COARSENS TO GRAVEL EASTWARD
8	10			W	WASATCH DERIVED MEDIUM SAND SMALL SCALE TROUGH CROSSBEDS LATERALLY CONTINUOUS HIGH CHARCOAL CONTENT
	3			T	TROPIC DERIVED SILT DRAPE LATERALLY CONTINUOUS
9	4			W	WASATCH DERIVED FINE TO MEDIUM SAND; SMALL SCALE TROUGH CROSSBEDS; CHANNEL FILL 18" WIDE x 14" DEEP
	1			T	TROPIC DERIVED SILT DRAPE
	9			W	WASATCH DERIVED COARSE SAND SMALL SCALL THROUGH CROSSBEDS
10	3			W/T	WASATCH/TROPIC DERIVED SILT DRAPE
	3			W	WASATCH DERIVED FINE SAND
	4			W	WASATCH DERIVED SILT DRAPE
11	6			W	WASATCH DERIVED MEDIUM TO COARSE SAND HORIZONTALLY LAMINATED OVERLYING SILT DRAPE
12					BASE OF SECTION

MEASURED SECTION NO. 8 DATE 7/12/88
LOCALITY XS 2A STRATIGRAPHIC UNIT VALLEY FILL
SETTING EAST SIDE VALLEY MEASURED BY MH/KF/JS/DW
STATION 1+58 ELEVATION 7108.0

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1	16			T/W	COARSE SAND INTERBEDDED WITH SILT DRAPES. 11 DISTINGUISHABLE EVENTS ⇒ MULTIPLE SLACK WATER DEPOSITIONAL EVENTS ⇒ LOW TOPOGRAPHIC SPOT AT EASTERN SLOPE BREAK
2 3	22			T	BLACK-BROWN TROPIC DERIVED SILTY CLAY MINOR FINE SAND LATERALLY CONTINUOUS ⇒ SHEETWASH
4	18			W/T	WASATCH/TROPIC DERIVED SILT TO VERY FINE SAND DENSE NO STRUCTURE
5	6			W	WASATCH DERIVED MEDIUM SAND CONTAINS RIPUPS OF WASATCH DERIVED SILT
	3			W	WASATCH DERIVED SILT DRAPE; LATERALLY VERY CONTINUOUS
6	16			W	WASATCH DERIVED MEDIUM SAND INTERBEDDED WITH WASATCH DERIVED SILT DRAPES. 7 CYCLES DISTINGUISHABLE.
7	2			W	WASATCH DERIVED VERY COARSE SAND; LATERALLY CONTINUOUS COARSE/FINE COUPLETS
	4			T	TROPIC DERIVED SILT DRAPE
	3			W	WASATCH DERIVED FINE SAND; MASSIVE
	3			T	TROPIC DERIVED SILT DRAPE; LATERALLY CONTINUOUS
8	2			W	WASATCH DERIVED COARSE SAND; HORIZONTALLY LAMINATED; COARSE/FINE COUPLETS
	1			W	WASATCH DERIVED SILT DRAPE
	7			W/T	WASATCH DERIVED MEDIUM SAND RIPUP CLASTS OF TROPIC & WASATCH MATERIAL
	2			W/T	TROPIC/WASATCH DERIVED SILT DRAPE
9	4			T	TROPIC DERIVED MEDIUM SAND HORIZONTAL & TROUGH CROSS STRATIFICATION
	9			W/T	TROPIC DERIVED SILT DRAPE HIGH CHARCOAL CONTENT MINOR WASATCH COMPONENT
10	12			W/T	WASATCH DERIVED FINE TO MEDIUM SAND TROPIC RIPUPS
11 12					BASE OF SECTION

MEASURED SECTION NO _____ DATE _____

LOCALITY XS 2B

SETTING NORTH SIDE VALLEY

STATION 1+59

STRATIGRAPHIC UNIT SEC. 21 V. FILL

MEASURED BY MH/KF/JS/DW

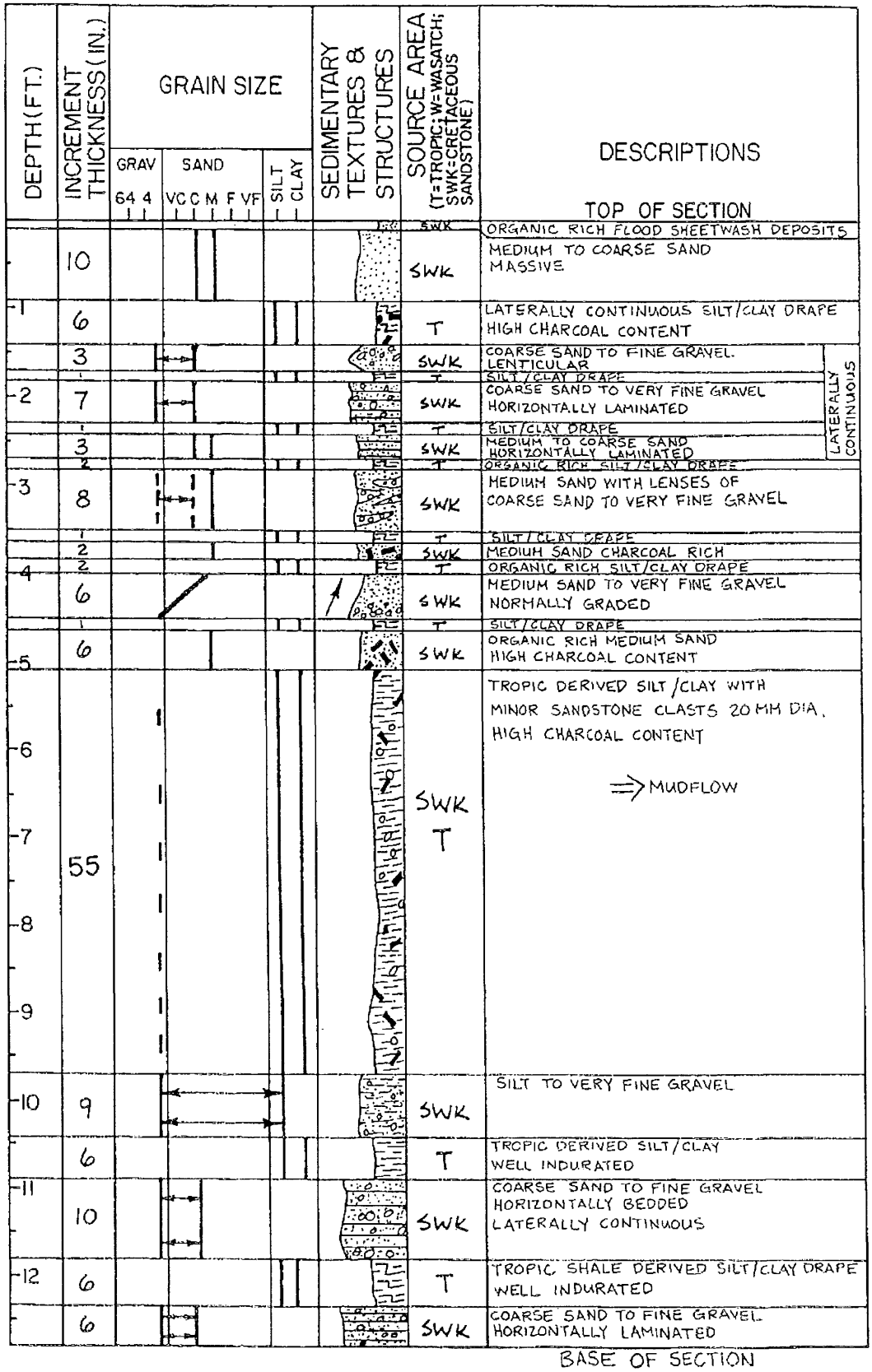
ELEVATION 7174.0

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV: 64 4; SAND: VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS (TOP OF SECTION)
	3			SWK	ORGANIC RICH SHEETFLOOD MATERIAL
	5			SWK	STRAIGHT CLIFFS DERIVED VERY WELL SORTED MEDIUM SAND; GREYISH
				T	SILT DRAPE
-1	10			SWK	MEDIUM SAND COARSE/FINE COUPLETS
	4			T	ORGANIC RICH SILT DRAPE
-2	3			SWK	MEDIUM SAND; HORIZONTALLY LAMINATED (COARSE/FINE COUPLETS
				T	SILT DRAPE
	3			SWK	MEDIUM SAND; HORIZONTALLY LAMINATED COARSE/FINE COUPLETS
				T	SILT DRAPE
-3	7			SWK	COARSE SAND TO FINE GRAVEL
				T	SILT DRAPE
-4	9			SWK	MEDIUM SAND HIGH ORGANIC CONTENT
				T	SILT/CLAY DRAPE
-5	9			SWK	COARSE SAND TO FINE GRAVEL RIPUPS, MUDBALLS
	4			SWK	FINE SAND HORIZONTALLY LAMINATED
				T	ORGANIC RICH SILT/CLAY DRAPE
	5			SWK	MEDIUM SAND MASSIVE
-6	2			T	SILT/CLAY DRAPE
	4			SWK	MEDIUM SAND MASSIVE
				T	SILT/CLAY DRAPE
-7	8			SWK	MEDIUM SAND COARSE/FINE COUPLETS
				T	SILT/CLAY DRAPE
	6			SWK	COARSE SAND ABUNDANT RIPUPS
				T	SILT/CLAY DRAPE
-8	5			SWK	MEDIUM SAND HORIZONTALLY LAMINATED COARSE/FINE COUPLETS
	2			T	SILT/CLAY DRAPE
	2			SWK	COARSE SAND HORIZONTALLY LAMINATED
	2			T	ORGANIC RICH SILT/CLAY DRAPE
	2			SWK	COARSE SAND
-9	7			T	TROPIC DERIVED CLAY/SILT DARK BROWN TO BLACK; FRIABLE
-10 -11	29			T	TROPIC DERIVED SILT/CLAY BLOCKY MASSIVE DENSE
-12	5			SWK	COARSE SAND TO FINE GRAVEL IN BLOCKY MASSIVE TROPIC DERIVED SILT AND CLAY

LATERALLY CONTINUOUS DIP 5° WESTWARD (DOWNFAN)

MEASURED SECTION NO. 10
LOCALITY XS 2B
SETTING MIDVALLEY
STATION 5+36

DATE 7/12/88
STRATIGRAPHIC UNIT SEC. 21 V. FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7168.2

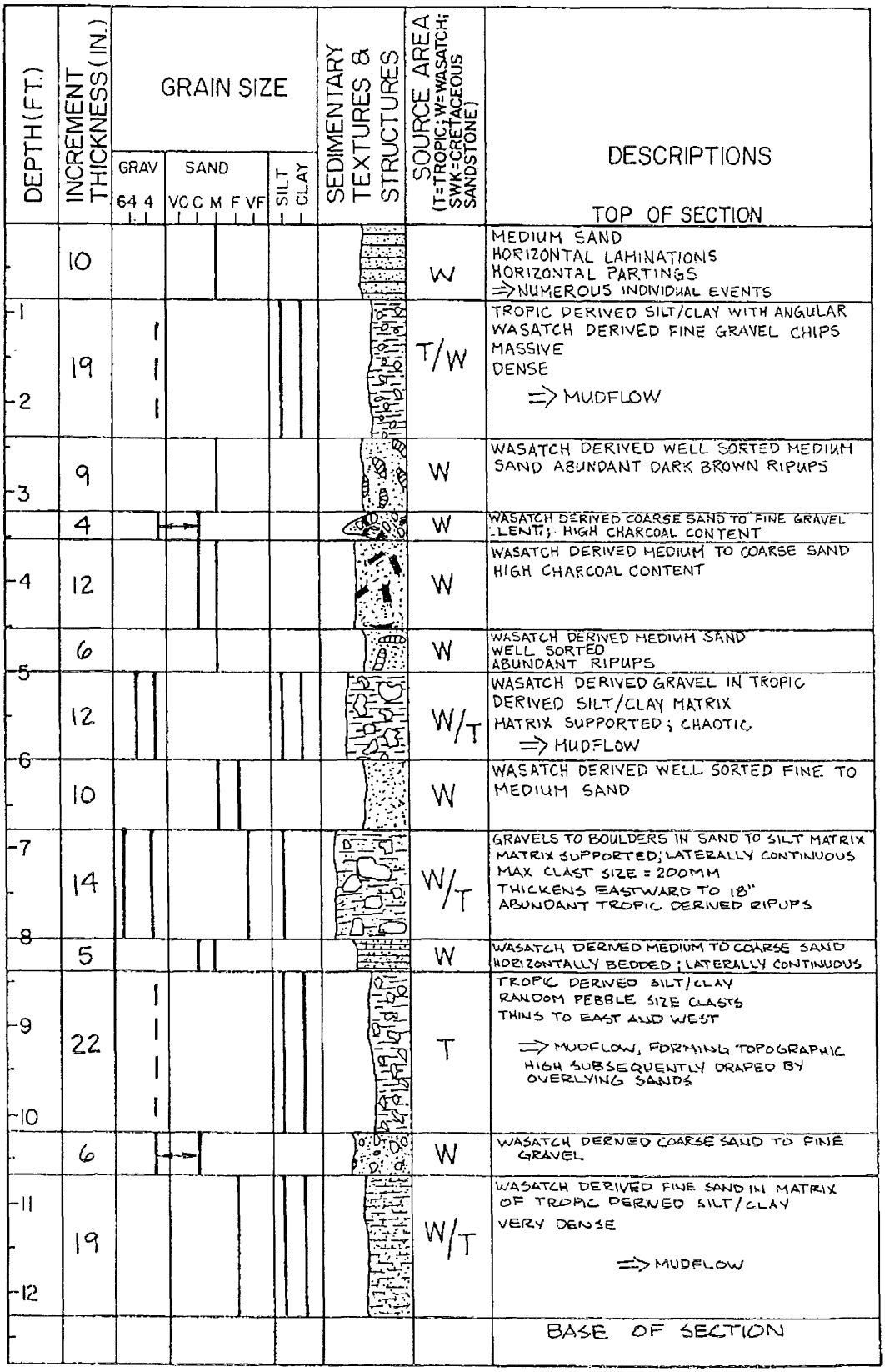


MEASURED SECTION NO. 11
LOCALITY XS 2B
SETTING SOUTH SIDE VALLEY
STATION 11+39

DATE 7/12/88
STRATIGRAPHIC UNIT SEC. 21 V. FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7159.5

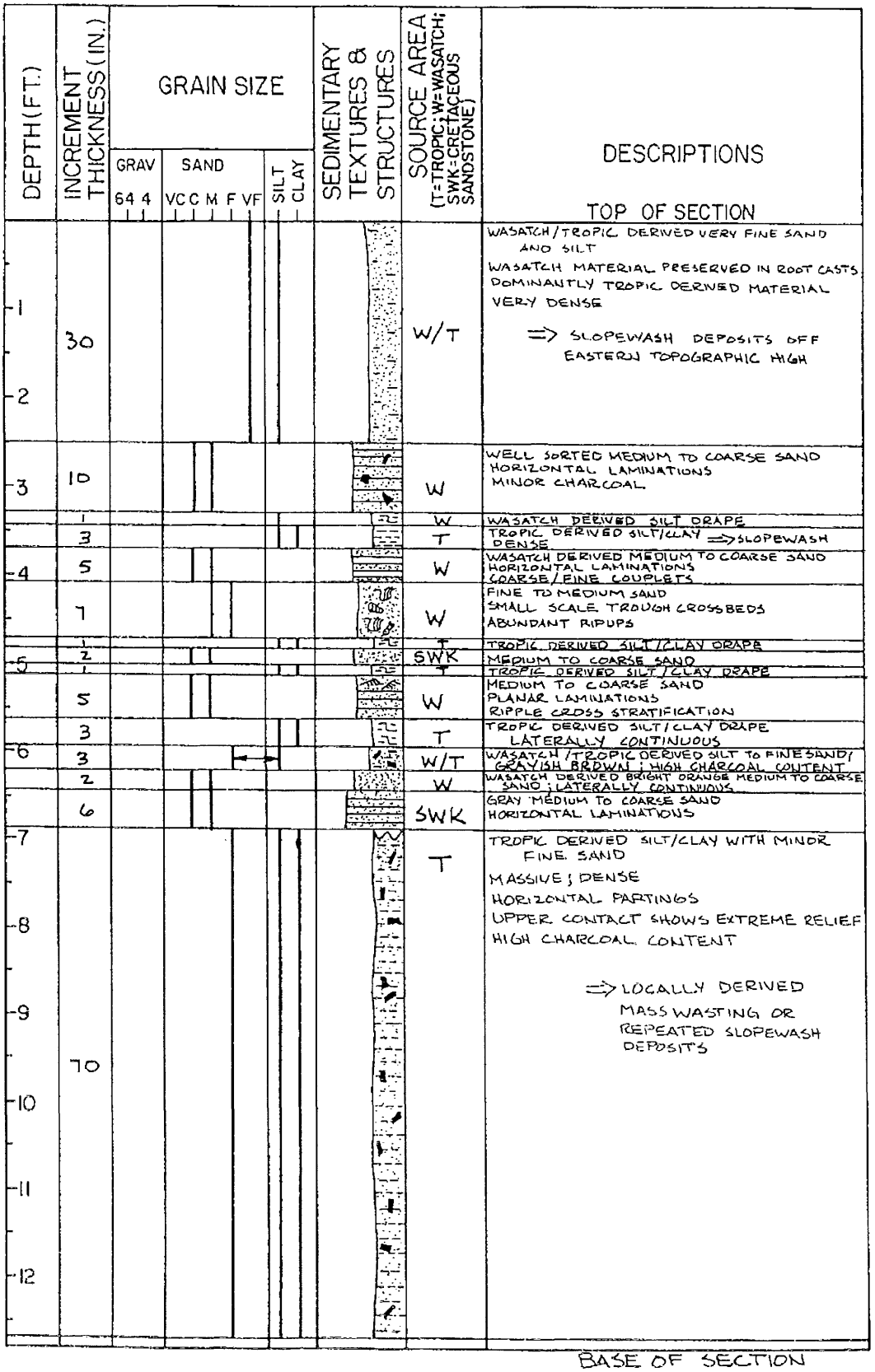
DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT; CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1	19			T	TROPIC DERIVED SILT AND CLAY DARK BROWN TO BLACK BLOCKY ; DENSE
	3			T/SWK	GRAVEL IN MUD MATRIX ; CHAOTIC MAX GRAVEL = 20MM ⇒ MUDFLOW
2 3	22			T	TROPIC DERIVED DENSE SILT AND CLAY ⇒ LOWER PORTION OF OVERLYING MUDFLOW?
4	14			SWK T	FINE GRAVEL IN SANDY MUD MATRIX ⇒ MUDFLOW
5	8			SWK	WELL SORTED MEDIUM SAND HIGH CHARCOAL CONTENT
	1			T	SILT/CLAY DRAPE
6	10			SWK	MEDIUM SAND HORIZONTAL LAMINATIONS MUD RIPUPS
	3			SWK	COARSE SAND TO FINE GRAVEL LENTICULAR
7	9			SWK	VERY POORLY SORTED FINE TO MEDIUM SANDS ABUNDANT CHARCOAL, RIPUPS, ORGANICS CHAOTIC
	2			T	SILT/CLAY DRAPE
8	5			SWK	MEDIUM TO COARSE SAND HORIZONTAL LAMINATIONS COARSE/FINE COUPLETS
	5			T	SILT/CLAY DRAPE
9	9			SWK	MEDIUM TO COARSE SAND HORIZONTALLY BEDDED LENTICULAR TOTAL UNIT 33" WIDE x 9" THICK
	6			T	TROPIC DERIVED SILT/CLAY DRAPE HIGH CHARCOAL CONTENT
	3			SWK	MEDIUM SAND
10	9			T	TROPIC DERIVED SILT/CLAY
11	5			SWK	MEDIUM SAND HORIZONTAL LAMINATIONS
12					BASE OF SECTION

MEASURED SECTION NO. 12 DATE 7/13/88
LOCALITY XS 3 STRATIGRAPHIC UNIT VALLEY FILL
SETTING MIDVALLEY MEASURED BY MH/KF/JS/DW
STATION 8+59 ELEVATION 7078.1



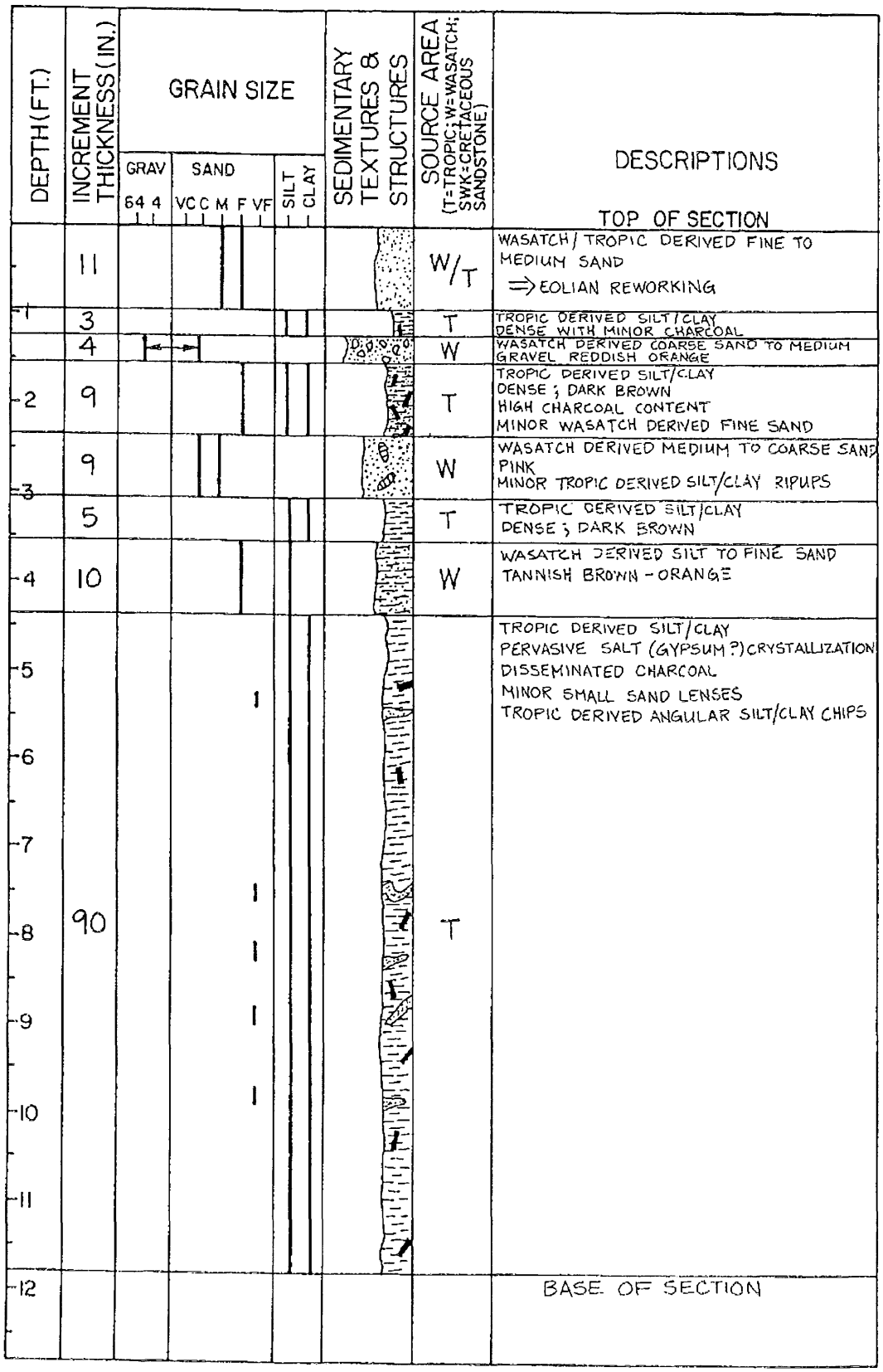
MEASURED SECTION NO 13
LOCALITY XS 3
SETTING EAST SIDE VALLEY
STATION 1+79

DATE 7/13/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 7084.0



MEASURED SECTION NO. 14
LOCALITY XS 4A
SETTING WEST SIDE VALLEY
STATION 39+88

DATE 7/13/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF
ELEVATION 6931.3

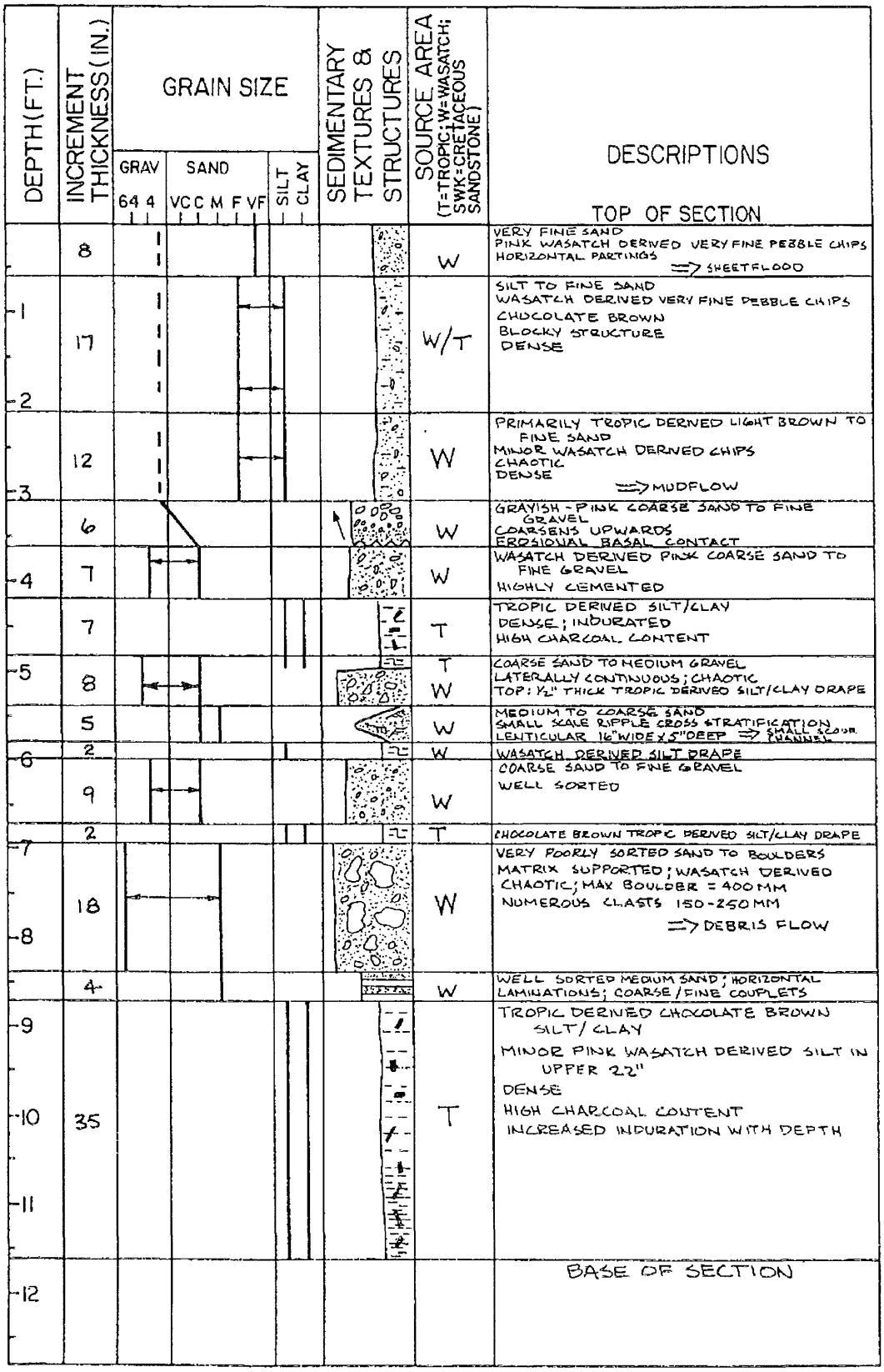


MEASURED SECTION NO 15
LOCALITY XS 4A
SETTING MIDVALLEY
STATION 26+00

DATE 7/13/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS/DW
ELEVATION 6988.2

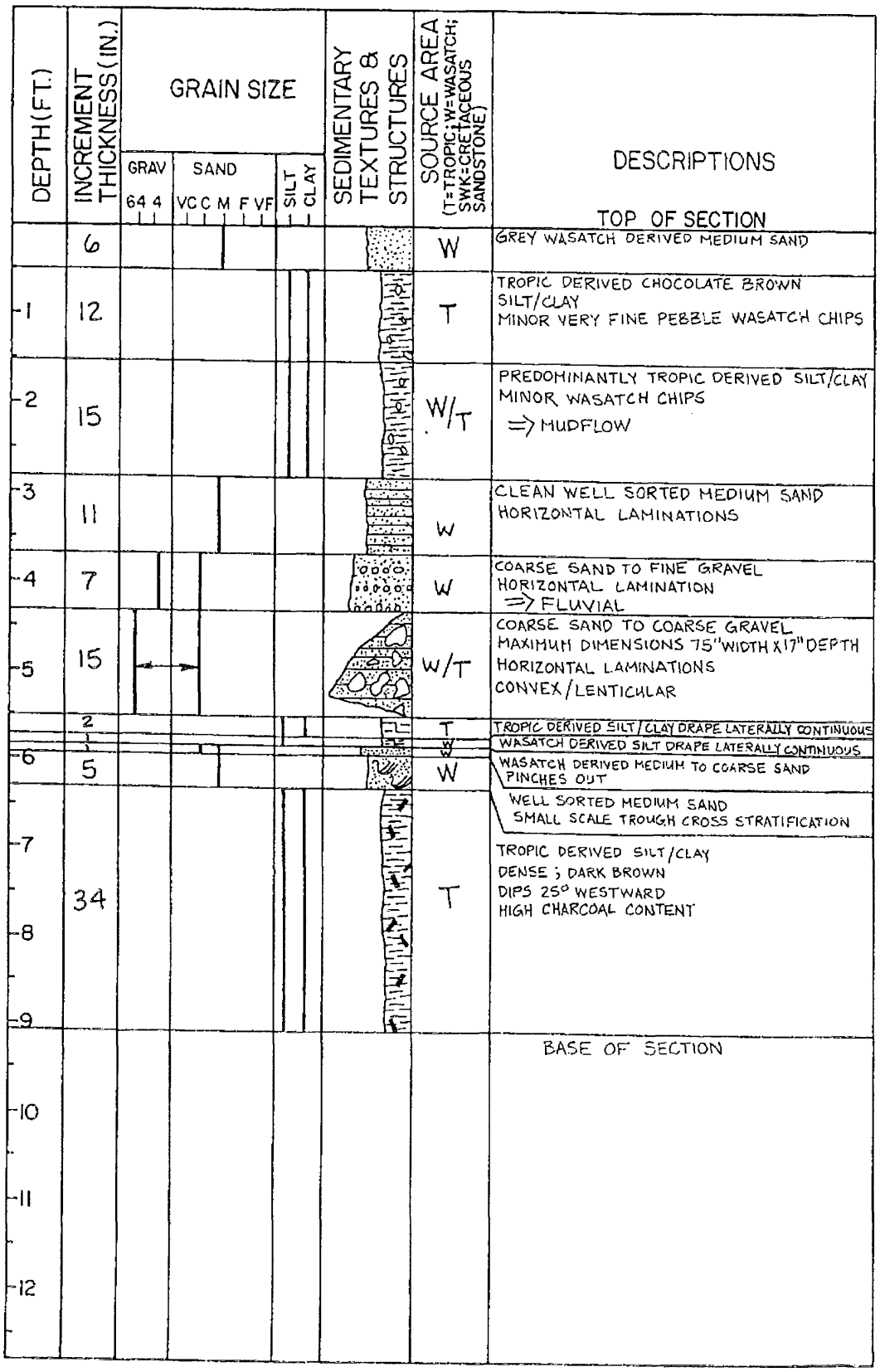
DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1	20			T/W	DARK GRAY SILT TO FINE SAND MINOR WASATCH DERIVED PINK FINE PEBBLE CHIPS ROOTING ZONE
2	15			W	WASATCH DERIVED FINE SAND TO SILT WELL SORTED WELL INDURATED
3–4	16			T/W	CLAY TO MEDIUM SAND WASATCH DERIVED FINE PEBBLE CHIPS VERY DENSE
	6			T/W	ORGANIC RICH HORIZON (ROOTS) PEAT TYPE DEPOSIT ⇒ MAXIMUM DEPTH OF OPTIMUM ROOTING; SEASONALLY HIGH POINT OF WATER TABLE
5–6	23			T	GLEY HORIZON WATER SATURATED SILT = ▽ =
7–9	37				BASE OF SECTION-WATER LEVEL STANDING WATER
10–12					BASE OF HOLE

MEASURED SECTION NO. 16 | DATE 7/13/88
LOCALITY XS 4A | STRATIGRAPHIC UNIT VALLEY FILL
SETTING MIDVALLEY | MEASURED BY MH/KF
STATION 11+82 | ELEVATION 7008.7



MEASURED SECTION NO. 17
LOCALITY XS 3
SETTING EAST SIDE; 9' WEST OF M.S. 13
STATION 1+79

DATE 7/13/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF
ELEVATION 7084.0

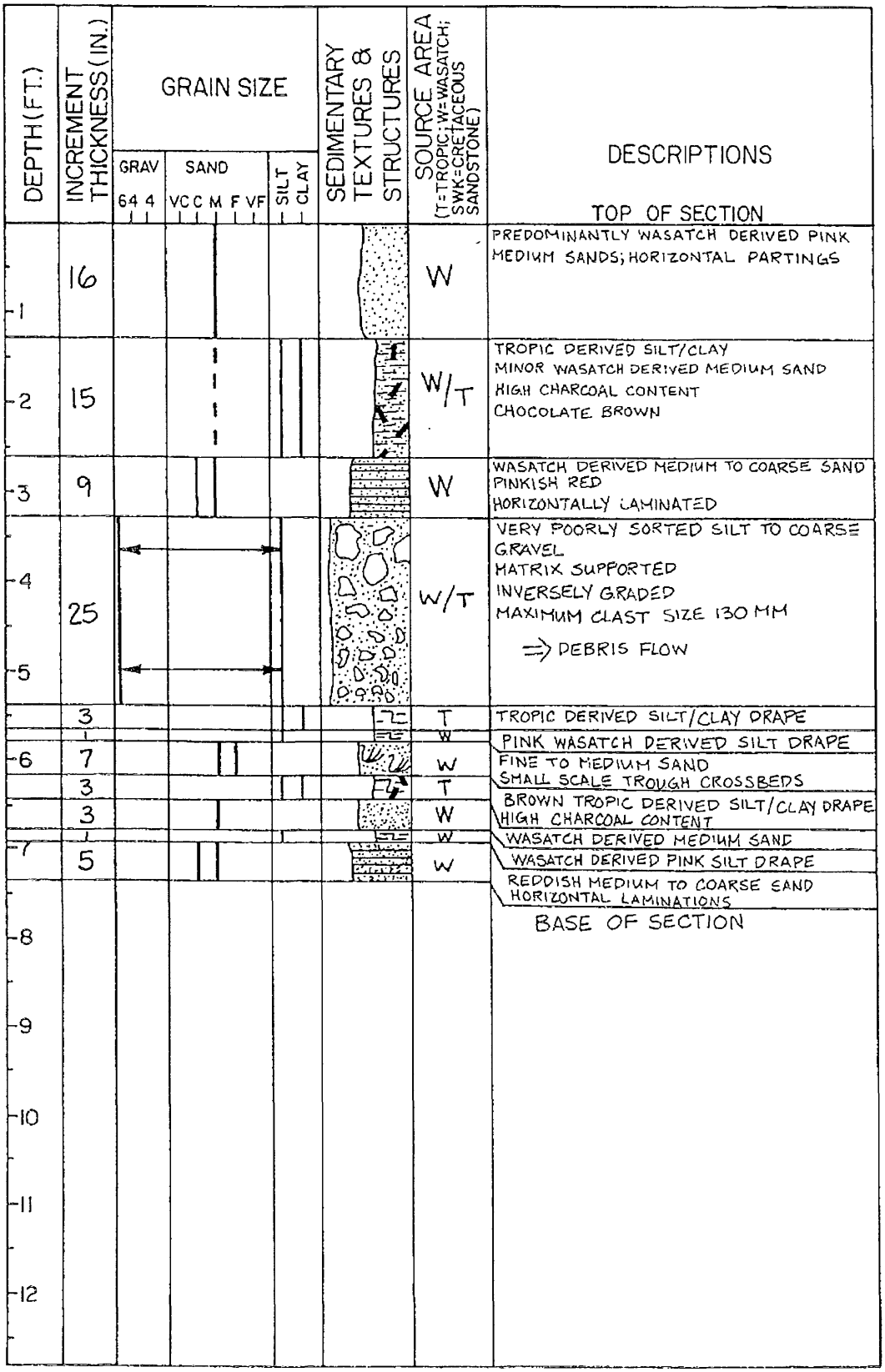


MEASURED SECTION NO 18 DATE 7/13/88
LOCALITY XS 3 STRATIGRAPHIC UNIT VALLEY FILL
SETTING EAST SIDE; 16' WEST OF M.S. 13 MEASURED BY MH/KF
STATION 1+79 ELEVATION 7048.0

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
	7			W/T	FINE TO MEDIUM SAND HORIZONTALLY LAMINATED MINOR WASATCH DERIVED VERY FINE PEBBLE CHIPS
1	15			T	TROPIC DERIVED SILT/CLAY CHOCOLATE BROWN MINOR ANGULAR WASATCH DERIVED VERY FINE PEBBLE CLASTS
2	10			W/T	MEDIUM SAND TROPIC DERIVED RIPUPS HIGH CHARCOAL CONTENT CHAOTIC
3	12			W/T	WELL SORTED MEDIUM SAND MINOR TROPIC/WASATCH SILT RIPUPS HORIZONTALLY LAMINATED
4 5	26			W/T	MATRIX SUPPORTED VERY POORLY SORTED SAND TO COBBLES CLASTS UP TO 100 MM CURVILINEAR BASAL CONTACT INVERSELY GRADED/CHAOTIC ⇒ DEBRIS FLOW INFILLING TOPOGRAPHIC LOW
				W	WASATCH DERIVED SILT DRAPE
6	6			W	MEDIUM TO COARSE SAND SMALL SCALE TROUGH CROSSBEDS
				W	WASATCH DERIVED PINK SILT DRAPE
7 8	25			W	SERIES OF ALTERNATING SILT DRAPES AND MEDIUM TO COARSE SANDS DRAPES 1" THICK SAND 2-3" THICK ALL WASATCH DERIVED
9 10 11 12					BASE OF SECTION

MEASURED SECTION NO 19
LOCALITY XS 3
SETTING EAST SIDE; 25' WEST OF M.S. 13
STATION 1+79

DATE 7/13/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF
ELEVATION 7084.0



MEASURED SECTION NO. 20
LOCALITY XS 4A
SETTING TLB LOWER ROBINSON CREEK
STATION 42+80

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/JS
ELEVATION 6921.4

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1	15			W/T	WASATCH/TROPIC DERIVED SILT TO FINE SAND MASSIVE; FRIABLE
2 3	31			T	TROPIC DERIVED SILT/CLAY DENSE; BLOCKY
4	1			W	WASATCH DERIVED SILT DRAPE DISCONTINUOUS
5 6	25			T	TROPIC DERIVED SILT/CLAY MASSIVE MINOR WASATCH DERIVED ROOT COATINGS
	3			W	WASATCH DERIVED FINE TO MEDIUM SAND MASSIVE; DISCONTINUOUS
7 8 9 10 11 12	71			T SWK	TROPIC DERIVED SILT/CLAY PERVASIVE SALT CRYSTALLIZATION 22" FROM TOP, MINOR STRAIGHT CLIFFS DERIVED PEBBLES, UP TO 20MM NO WASATCH MATERIAL
					BASE OF SECTION

MEASURED SECTION NO. 21
LOCALITY XS 4A
SETTING EAST SIDE VALLEY
STATION 4+42

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/JS
ELEVATION 7017.6

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
	8			T	TROPIC DERIVED SILT TO FINE SAND DESSICATED; FRIABLE; MASSIVE MINOR WASATCH INPUT
1	12			W W T	TROPIC DERIVED SILT/CLAY DISCONTINUOUS LENSES OF WASATCH DERIVED SILTS
2	15			T	TROPIC DERIVED SILT/CLAY DENSE
3	6			T	TROPIC DERIVED SILT TO FINE SAND HORIZONTAL LAMINATION
	3			T	TROPIC DERIVED SILT, HIGH CHARCOAL CONTENT
	1			W	WASATCH DERIVED SILT DRAPE
4	2			T	TROPIC DERIVED SILT, SOME CHARCOAL, WASATCH CHIPS
	1			W	WASATCH DERIVED SILT DRAPE
	3			W/T	WASATCH/TROPIC DERIVED SILT TO MEDIUM SAND
	2			W	WASATCH DERIVED SILT DRAPE
	3			W/T	ALTERNATING T/W/T/W SILT DRAPE
	2			W	WASATCH DERIVED SILT TO FINE SAND
5	2			W/T	W/T MED. SAND TROUGH CROSSBEDS C/F COUPLETS
	1			W	WASATCH DERIVED SILT DRAPE
	1			W	WASATCH DERIVED SAND TROUGH CROSSBEDS
	2			W	WASATCH DERIVED SILT TO FINE SAND
	2			W/T	W/T DERIVED SILT TO MED. SAND; TROUGH CROSSBEDS
	1			W	WASATCH DERIVED SILT DRAPE
6	5			W/T	WASATCH/TROPIC DERIVED SILT TO MEDIUM SAND POORLY SORTED, MINOR TROUGH CROSS STRATIFICATION
	2			W/T	ALTERNATING W/T DERIVED SILT/CLAY DRAPES
	3			SWK	SILT TO MEDIUM SAND LIGHT BROWN MINOR TROUGH CROSSBEDS
	1			W	WASATCH DERIVED SILT DRAPE
	2			W	WASATCH DERIVED SILT TO FINE SAND
7	2			W/T	ALTERNATING W/T DERIVED SILT/CLAY DRAPES
	3			W	WASATCH DERIVED SILT TO MEDIUM SAND HORIZONTAL LAMINATIONS
	4			W/T	ALTERNATING W/T DERIVED SILT/CLAY DRAPES
	3			SWK	COARSE SAND TO FINE GRAVEL; INVERSELY GRADED EROSIONAL BASE
	2			T	TROPIC DERIVED SILT
8	4			SWK	FINE TO MEDIUM SAND COARSE / FINE COUPLETS
	1			W	WASATCH DERIVED SILT DRAPE
	5			SWK/W	SILT TO COARSE SAND TROUGH CROSSBEDS HIGH CHARCOAL CONTENT
9	7			T	TROPIC DERIVED CLAY TO FINE SAND; CHARCOAL MINOR WASATCH CHIPS
	1			W	WASATCH DERIVED SILT TO MEDIUM SAND
10	13			W/T	INTERBEDDED MEDIUM SAND AND SILT/CLAY DRAPES SAND 2-4", DRAPES 1" LIGHT TO DARK BROWN PRIMARILY TROPIC DERIVED, WITH SOME WASATCH MATERIAL IN DRAPES
11	6			W/T	ALTERNATING WASATCH/TROPIC DERIVED SILT/CLAY MINOR VF SAND
	5			W/T	WASATCH/TROPIC DERIVED SILT/CLAY
	2			W	WASATCH DERIVED SILT TO COARSE SAND LENTICULAR; HORIZONTAL LAMINATIONS
	4			W/T/SWK	ALTERNATING W/T DERIVED SILT/CLAY PINK-BROWN-GRAY HIGH CHARCOAL CONTENT
12	2			SWK	LIGHT BROWN FINE TO MEDIUM SAND; MASSIVE
	6			T/SWK	SILT TO FINE SAND LIGHT BROWN; MASSIVE
					BASE OF SECTION

MEASURED SECTION NO 22
LOCALITY XS 4B
SETTING NORTH SWAPP HOLLOW
STATION 7+86

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/JS
ELEVATION 6988.7

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE: GRAV (64 4)	GRAIN SIZE: SAND (VC C M F VF)	GRAIN SIZE: SILT CLAY	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
							TOP OF SECTION
1	23					T/W	DENSE PRIMARILY TROPIC DERIVED SILT/CLAY WITH MINOR WASATCH DERIVED COARSE SAND POORLY SORTED; BROWN HIGH CHARCOAL CONTENT
2 3 4	32					T/W	DENSE TROPIC DERIVED SILT/CLAY WITH MINOR FLOATING FRAGMENTS OF WASATCH DERIVED COARSE SAND TO FINE GRAVEL
	4					W	WASATCH DERIVED CLAY TO MEDIUM SAND; DENSE; PINK LATERALLY CONTINUOUS; DIPS 4° SOUTHWARD
5 6 7 8	43					T/W	TROPIC DERIVED SILT/CLAY VERY DENSE; HIGH CHARCOAL CONTENT DISCRETE POCKETS OF WASATCH DERIVED SILT TO FINE SAND - BRIGHT ORANGE IN DARK BROWN MATRIX => CRACK INFILLING? PERVASIVE SALT CRYSTALLIZATION
9 10	25					T/W	TROPIC DERIVED SILT/CLAY SALT CRYSTALLIZATION MINOR WASATCH SILT TO FINE SAND
11 12							BASE OF SECTION

MEASURED SECTION NO 23
LOCALITY XS 4B
SETTING SOUTH SIDE SWAPP HOLLOW
STATION 23+67

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/JS
ELEVATION 6952.3

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1	15			W/T	TROPIC DERIVED SILT/CLAY MINOR WASATCH CLASTS UP TO 15MM CHAOTIC
2 3 4	42			W/T	TROPIC DERIVED SILT/CLAY FRIABLE; VERY DENSE RANDOM WASATCH CLASTS UP TO 35MM CHAOTIC => MUDFLOW
5	9			T/W/SWK	MED. SAND TO COARSE GRAVEL UP TO 130MM CHAOTIC; CONVEX; LENTICULAR FAINT INVERSE GRADING; HIGH CHARCOAL CONTENT; MINOR WASATCH DERIVED MATERIAL
	2			W	WASATCH DERIVED PINK SILT DRAPE
6	4			W/T	TROPIC DERIVED SILT/CLAY W/ MINOR WASATCH DERIVED CHIPS UP TO 10MM
	1			W	WASATCH DERIVED PINK SILT DRAPE
	2			T	TROPIC DERIVED SILT/CLAY; CHARCOAL; MASSIVE
	1			W	WASATCH DERIVED PINK SILT DRAPE
7	10			T	TROPIC DERIVED SILT/CLAY BROWN RIPUPS OF WASATCH DERIVED SILT DRAPES
	2			T	SILT TO FINE SAND; TROPIC/STRAIGHT CLIFFS; CHARCOAL
8	9			W/T	TROPIC DERIVED SILT/CLAY WITH RANDOMLY ORIENTED WASATCH DERIVED FINE GRAVEL
	2			W	WASATCH DERIVED SILT/CLAY; PINK
9 10	25			SWK	SILT TO FINE SAND; MOTTLED; BROWN TROPIC/STRAIGHT CLIFFS DERIVED
11	6			T/W/SWK	TROPIC DERIVED CLAY TO FINE SAND HIGH CHARCOAL CONTENT MINOR WASATCH COARSE SAND
	5			SWK/W	SILT TO FINE SAND; GREY TO LIGHT BROWN; CHARCOAL; COARSE SAND SIZE WASATCH DERIVED FRAGMENTS
12					BASE OF SECTION

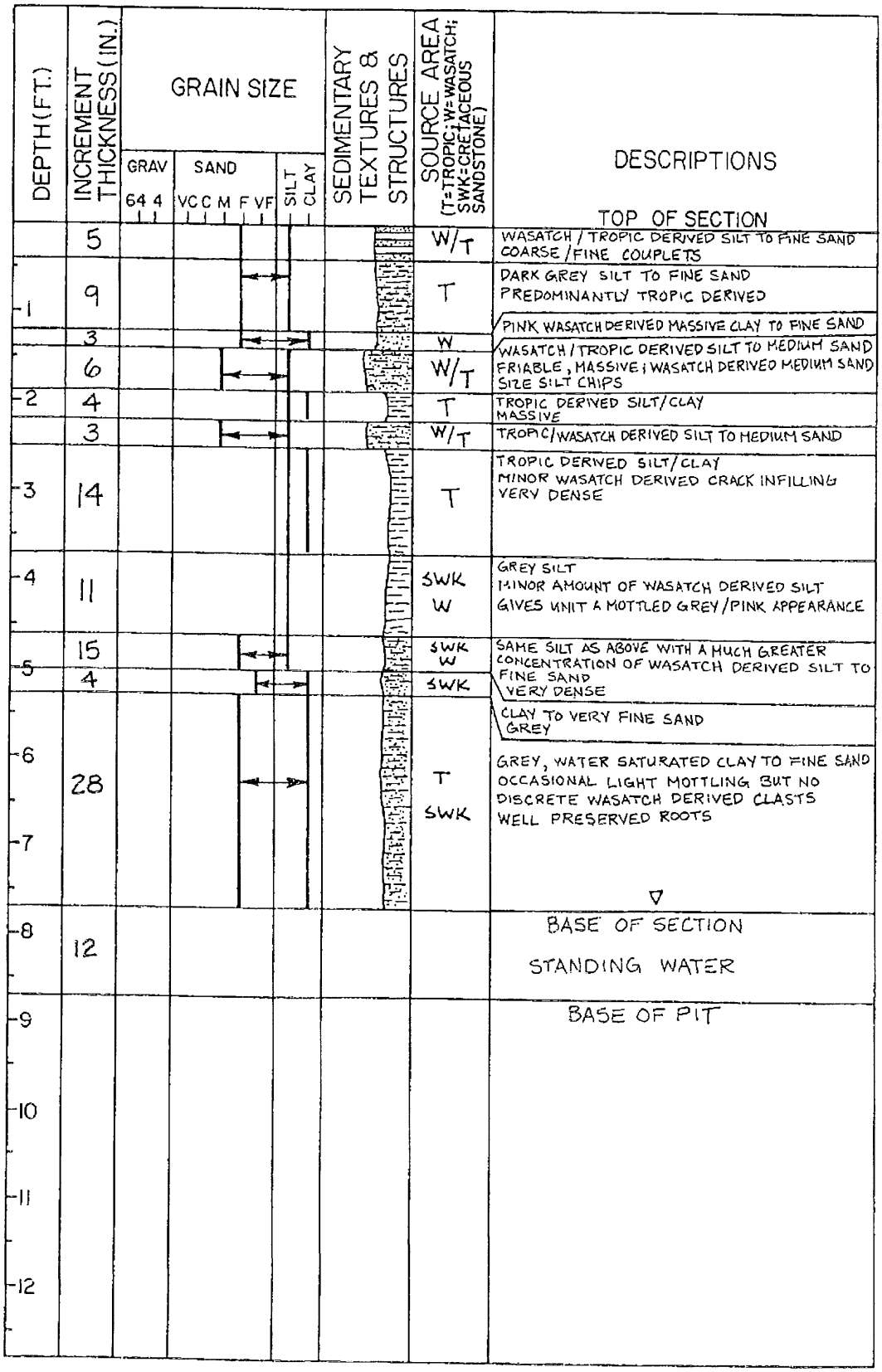
MEASURED SECTION NO 24
LOCALITY XS 5
SETTING WEST EDGE SORENSON'S GARDEN
STATION 10+14

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/JS
ELEVATION 6946.9

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
	12			T	TILLED SOIL DARK BROWN SILT TO MEDIUM SAND NO WASATCH DERIVED MATERIAL
1	10			T	ORGANIC RICH SILT/CLAY DENSE ; WET ⇒ A HORIZON ?
2	12			W/T	SILTY CLAY WITH MINOR COARSE WASATCH DERIVED SAND VERY DENSE ; WET
3	13			W/T/ SWK	BROWN SILT TO MEDIUM SAND HIGH CHARCOAL CONTENT CLASTS OF WASATCH DERIVED SILT 20 MM MASSIVE
4				W	WASATCH DERIVED SILT DRAPE ; LATERALLY CONTINUOUS
	5			SWK	SILT TO MEDIUM SAND ; DISTINCT ORGANIC RICH HORIZONS TO 1/2" THICK
5 6	28			SWK W	WELL SORTED SILT TO MEDIUM SAND WASATCH DERIVED CLASTS TO 25 MM SOFT ; NON-COHESIVE INTERBEDDED SILT DRAPES MEDIUM SAND ORGANIC RICH BLACK
7				SWK W	BRIGHT ORANGE LIMONITE MEDIUM SAND ⇒ SEASONAL WATER TABLE
	5			SWK	FINE TO MEDIUM SAND TROUGH CROSSBEDS STAINED TO BURNT ORANGE THICKENS NORTHERLY TO 12"
	2			T	GREY CLAY TO SILT WATER SATURATED
	2			SWK	LIGHT BROWN CLAY TO FINE SAND
				T	GREY-BROWN SILT TO FINE SAND
8	11			SWK	SILT TO MEDIUM SAND BROWN POORLY INDURATED HIGH CHARCOAL CONTENT
9 10	16			T/W	GREY TO BLACK MASSIVE CLAY DENSE CONTAINS SMALL WASATCH DERIVED SILT CHIPS PRESERVED ROOTS ⇒ REDUCING STANDING WATER LEVEL
11 12					BASE OF SECTION

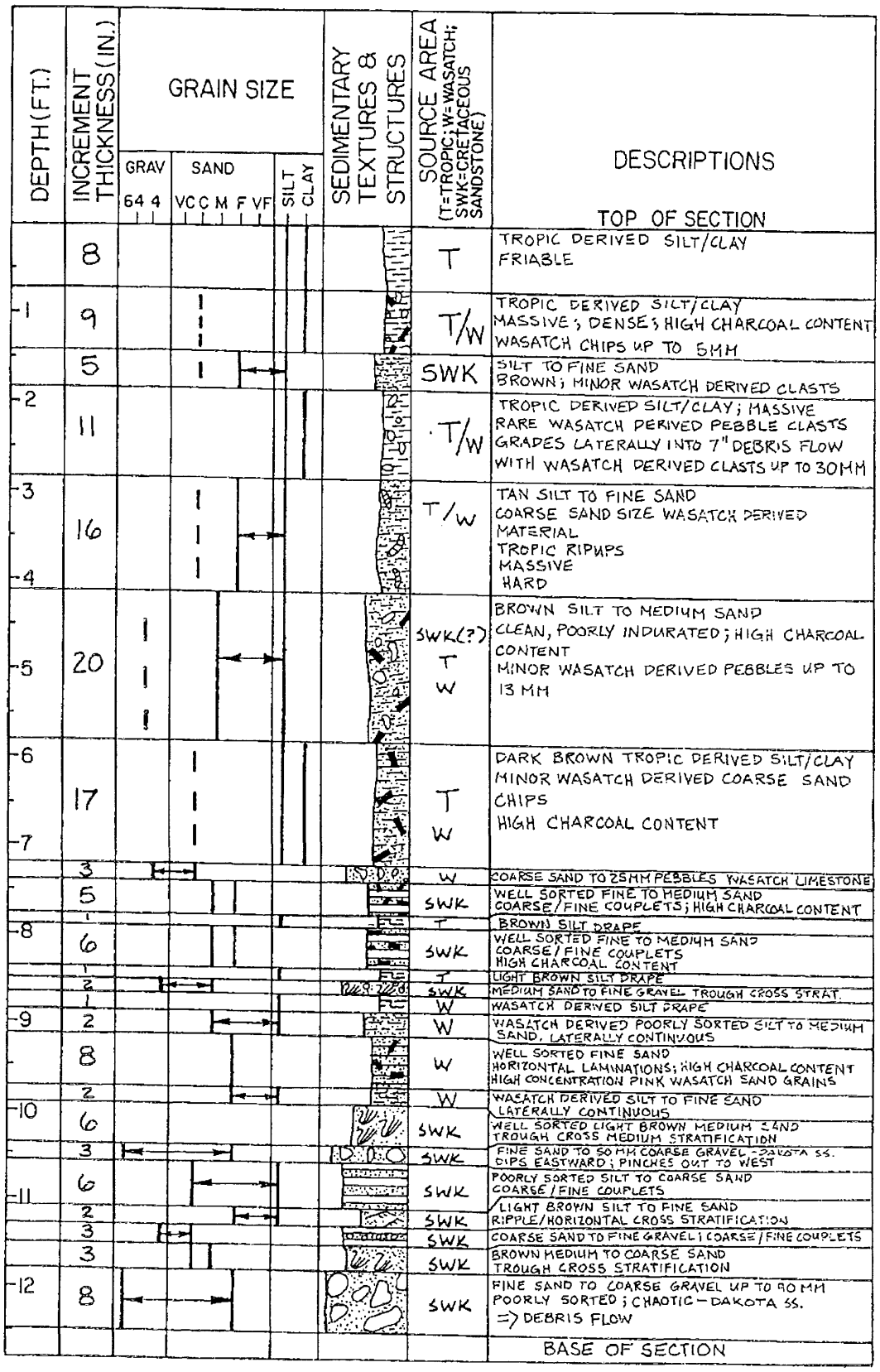
MEASURED SECTION NO. 25
LOCALITY XS 5
SETTING MIDVALLEY
STATION 24+29

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/JS
ELEVATION 6917.5



MEASURED SECTION NO 26
LOCALITY XS 5
SETTING WEST SIDE VALLEY
STATION 40+02

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/JS
ELEVATION 6871.1



DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
	8			T	TROPIC DERIVED SILT/CLAY FRIABLE
1	9			T/W	TROPIC DERIVED SILT/CLAY MASSIVE; DENSE; HIGH CHARCOAL CONTENT WASATCH CHIPS UP TO 5MM
	5			SWK	SILT TO FINE SAND BROWN; MINOR WASATCH DERIVED CLASTS
2	11			T/W	TROPIC DERIVED SILT/CLAY; MASSIVE RARE WASATCH DERIVED PEBBLE CLASTS GRADES LATERALLY INTO 7" DEBRIS FLOW WITH WASATCH DERIVED CLASTS UP TO 30MM
3 4	16			T/W	TAN SILT TO FINE SAND COARSE SAND SIZE WASATCH DERIVED MATERIAL TROPIC RIPUPS MASSIVE HARD
5	20			SWK(?) T W	BROWN SILT TO MEDIUM SAND CLEAN, POORLY INDURATED; HIGH CHARCOAL CONTENT MINOR WASATCH DERIVED PEBBLES UP TO 13 MM
6 7	17			T W	DARK BROWN TROPIC DERIVED SILT/CLAY MINOR WASATCH DERIVED COARSE SAND CHIPS HIGH CHARCOAL CONTENT
	3			W	COARSE SAND TO 25MM PEBBLES WASATCH LIMESTONE
	5			SWK	WELL SORTED FINE TO MEDIUM SAND COARSE/FINE COUPLETS; HIGH CHARCOAL CONTENT
	1			T	BROWN SILT DRAPE
8	6			SWK	WELL SORTED FINE TO MEDIUM SAND COARSE/FINE COUPLETS HIGH CHARCOAL CONTENT
	1			T	LIGHT BROWN SILT DRAPE
	2			SWK	MEDIUM SAND TO FINE GRAVEL TROUGH CROSS STRAT.
	1			W	WASATCH DERIVED SILT DRAPE
9	2			W	WASATCH DERIVED POORLY SORTED SILT TO MEDIUM SAND, LATERALLY CONTINUOUS
	8			W	WELL SORTED FINE SAND HORIZONTAL LAMINATIONS; HIGH CHARCOAL CONTENT HIGH CONCENTRATION PINK WASATCH SAND GRAINS
	2			W	WASATCH DERIVED SILT TO FINE SAND LATERALLY CONTINUOUS
10	6			SWK	WELL SORTED LIGHT BROWN MEDIUM SAND TROUGH CROSS MEDIUM STRATIFICATION
	3			SWK	FINE SAND TO 50 MM COARSE GRAVEL - DAKOTA SS. DIPS EASTWARD; PINCHES OUT TO WEST
11	6			SWK	POORLY SORTED SILT TO COARSE SAND COARSE/FINE COUPLETS
	2			SWK	LIGHT BROWN SILT TO FINE SAND RIPPLE/HORIZONTAL CROSS STRATIFICATION
	3			SWK	COARSE SAND TO FINE GRAVEL; COARSE/FINE COUPLETS
	3			SWK	BROWN MEDIUM TO COARSE SAND TROUGH CROSS STRATIFICATION
12	8			SWK	FINE SAND TO COARSE GRAVEL UP TO 90 MM POORLY SORTED; CHAOTIC – DAKOTA SS. => DEBRIS FLOW
					BASE OF SECTION

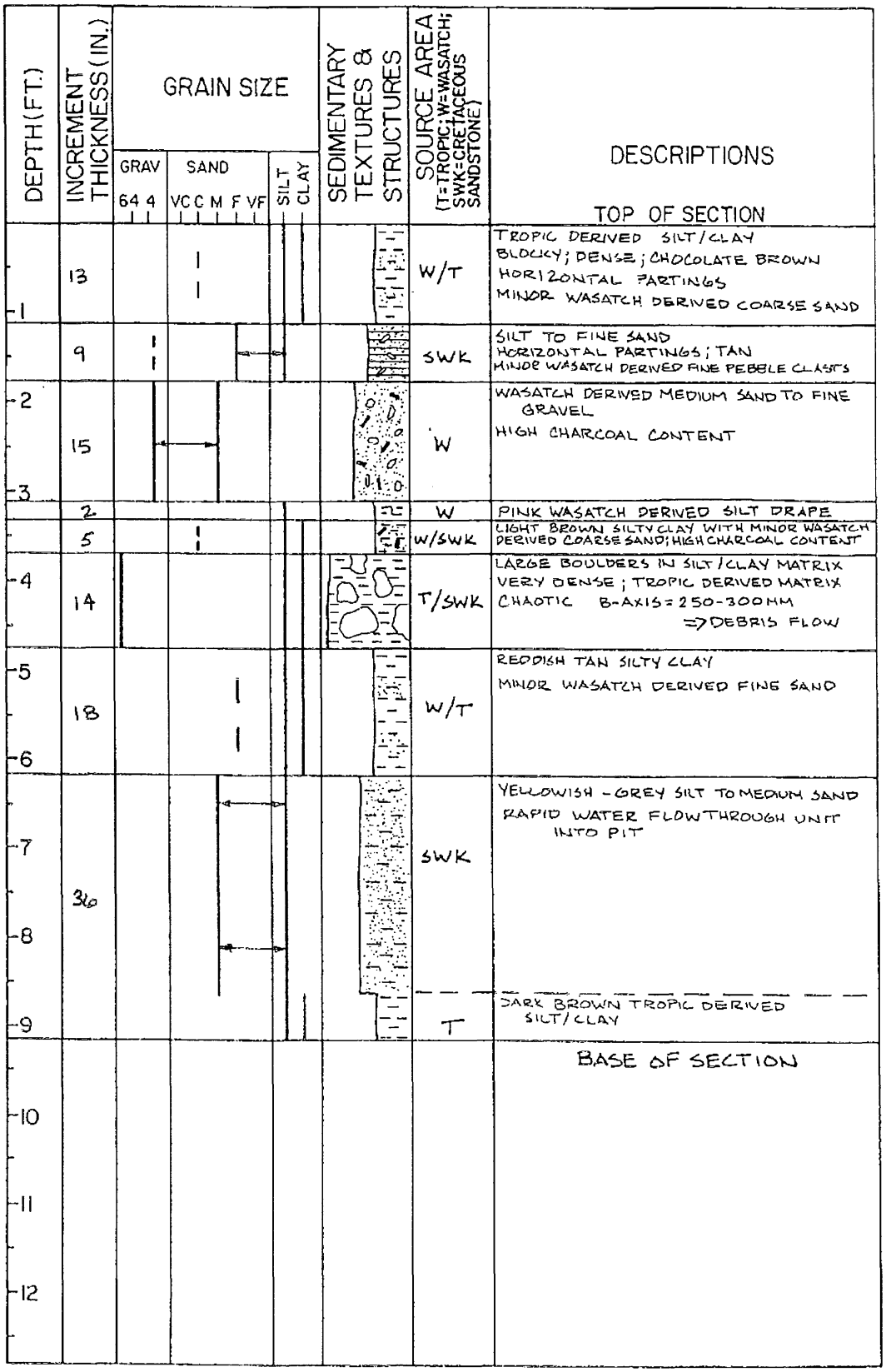
MEASURED SECTION NO. 27
LOCALITY XS 6
SETTING WEST SIDE VALLEY
STATION 29+92

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/JS
ELEVATION 6851.9

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV: 64 4; SAND: VC C M F VF; SILT; CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
	11			W	WASATCH DERIVED SILT TO FINE SAND HORIZONTAL PARTINGS ⇒ SHEETFLOW
1	2			T	TROPIC DERIVED SILT/CLAY; MASSIVE; HIGH CHARCOAL CONTENT
	7			W/T	WASATCH/TROPIC DERIVED SILT
2 3	20			T	TROPIC DERIVED SILT/CLAY HIGH CHARCOAL CONTENT MASSIVE
	5			SWK	SILT TO MED. SAND LIGHT BROWN HIGH CHARCOAL CONTENT
4 5	16			W/T	TROPIC DERIVED SILT/CLAY WITH WASATCH DERIVED FINE SAND
6 7	31			T	GREY CLAY WATER SATURATED ORANGE MOTTLING ▽
8 9					BASE OF SECTION STANDING WATER
10 11 12					BASE OF PIT

MEASURED SECTION NO 28
LOCALITY XS 6
SETTING SWAPP RANCH
STATION 18+91

DATE 7/15/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF
ELEVATION 6866.8



MEASURED SECTION NO. 29
LOCALITY XS 7
SETTING WEST SIDE VALLEY
STATION 8+99

DATE 7/15/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS
ELEVATION 6814.2

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE: GRAV (64 4)	SAND (VC C M F VF)	SILT	CLAY	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
								TOP OF SECTION
	8						T	DARK BROWN TROPIC DERIVED SILT/CLAY PEDOGENIC STRUCTURE
1	9						W	PREDOMINANTLY WASATCH DERIVED SILT TO FINE SAND MINOR SMALL PEBBLE SIZE WASATCH SILT FRAGMENTS
2	8						T	DARK BROWN TROPIC DERIVED SILT/CLAY HIGH CHARCOAL CONTENT
3	14						W/T	PINK-TAN WASATCH DERIVED SILT TO FINE SAND TROPIC SHALE RIPUPS
	1						W	PINK WASATCH DERIVED SILT DRAPE
4	10						SWK	VERY WELL SORTED MEDIUM SAND TANNISH, WITH MINOR PINK WASATCH DERIVED SILT FRAGMENTS
5	15						T/W	DARK BROWN TROPIC DERIVED SILT/CLAY VERY DENSE MINOR WASATCH DERIVED PINK SILT FRAGMENTS
6 7 8 9	42						SWK	YELLOWISH-GREY VERY WELL SORTED FINE TO MEDIUM SAND WATER SATURATED; CONSTANT SEEPAGE INTO PIT FROM UNIT
10 11 12								BASE OF SECTION

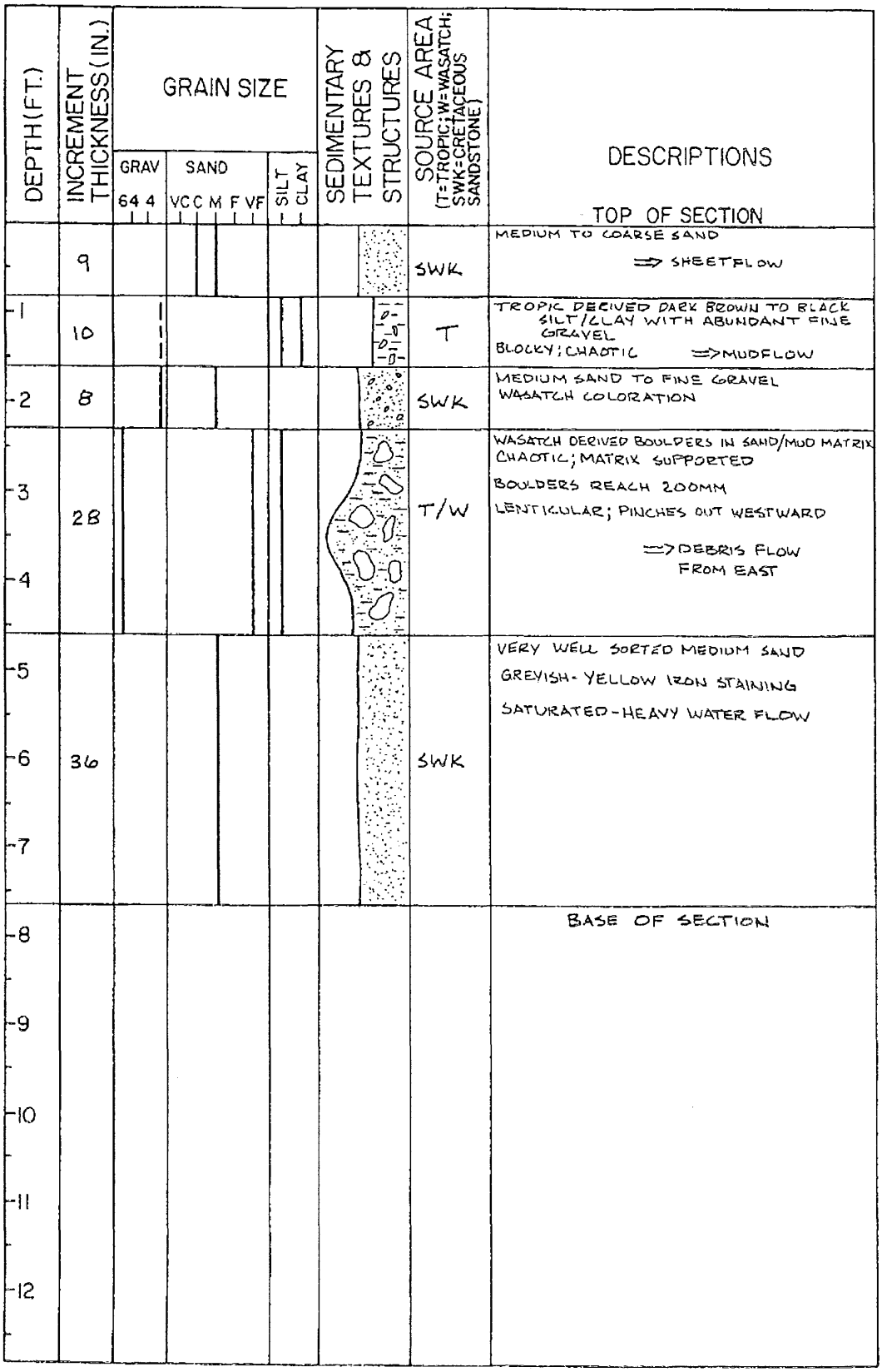
MEASURED SECTION NO 30
LOCALITY XS 7
SETTING MIDVALLEY
STATION 5+17

DATE 7/15/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/JS/KF
ELEVATION 6815.6

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
	12			SWK	FINE TO MEDIUM SAND WITH MINOR MEDIUM GRAVEL CLASTS HORIZONTAL PARTINGS
1	5			W	WASATCH DERIVED COARSE SAND TO FINE GRAVEL; EROSIONAL BASE; LENTICULAR
	2			T	TROPIC DERIVED SILT/CLAY DRAPE
	3			SWK	VERY WELL SORTED MEDIUM SAND
	1			W	WASATCH DERIVED SILT/CLAY DRAPE
2	2			T	LIGHT BROWN SILT TO FINE SAND; PREDOMINANTLY TROPIC DERIVED
	6			T	TROPIC DERIVED DARK BROWN TO BLACK SILTY CLAY
3	15			SWK	GREYISH YELLOW WELL SORTED MEDIUM SAND MINOR VERY FINE GRAVEL
4	8			SWK	MEDIUM TO COARSE SAND BROWN IRON STAINING TROPIC RIPUPS MASSIVE
5	15			SWK	FINE TO MEDIUM SAND GREYISH - YELLOW IRON STAINING DENSE
6 7	27			SWK	WELL SORTED MEDIUM SAND GREYISH - YELLOW WATER SATURATED
8					BASE OF SECTION
9					
10					
11					
12					

MEASURED SECTION NO. 31
LOCALITY XS 7
SETTING EAST SIDE VALLEY
STATION 1+72

DATE 7/15/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/JS/KF
ELEVATION 6820.3



MEASURED SECTION NO. 32 DATE 7/15/88
LOCALITY XS 8 STRATIGRAPHIC UNIT VALLEY FILL
SETTING WEST SIDE VALLEY MEASURED BY MH/KF/JS
STATION 5+50 ELEVATION 6747.7

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1	13			SWK	FINE TO MEDIUM SAND HORIZONTAL LAMINATION, PARTINGS GREY MINOR CLINKER CHIPS
2	15			T	TROPIC DERIVED SILT/CLAY DARK BROWN BLOCKY DENSE
3	9			SWK	LIGHT BROWN TO GREY SILT TO FINE SAND MINOR CLINKER CHIPS MASSIVE DENSE
4	11			SWK/W	SILT TO VERY FINE SAND VERY WELL SORTED MINOR WASATCH DERIVED SILT CHIPS
	1			T	TROPIC DERIVED CHOCOLATE BROWN SILT/CLAY DRAPE
5	13			SWK	VERY WELL SORTED FINE SAND MASSIVE MINOR CLINKER CHIPS
	7			SWK	MEDIUM SAND TO FINE GRAVEL GRAVEL IS REDDISH-ORANGE AND CONTAINS CLINKER MATERIAL
6	4			SWK	SILT TO FINE SAND GREYISH BROWN; MASSIVE; DENSE
	1			W	WASATCH DERIVED PINK SILT DRAPE
	3			SWK	WELL SORTED FINE SAND; HIGH CHARCOAL CONTENT
	1			W	WASATCH DERIVED SILT DRAPE
7	6			SWK	SILT TO VERY FINE SAND TAN; ABUNDANT CLINKER CHIPS
	1			W	WASATCH DERIVED SILT DRAPE
	5			T	BROWN SILT/CLAY ABUNDANT WASATCH DERIVED CHIPS; CHARCOAL
	2			W	TANNISH PINK SILT TO VERY FINE SAND CLINKER CHIPS
	1			W	PINK SILT DRAPE
8	8			T/W	ORANGE-BROWN SILT/CLAY ABUNDANT CLINKER CHIPS
	6			SWK	VERY FINE SAND WATER SATURATED ▽
9	13				BASE OF SECTION STANDING WATER
10					BASE OF PIT
11					
12					

MEASURED SECTION NO 33 DATE 7/15/88
LOCALITY XS 8 STRATIGRAPHIC UNIT VALLEY FILL
SETTING MIDVALLEY MEASURED BY MH/KF/JS
STATION 3+82 ELEVATION 6747.8

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
1	19			T	TROPIC DERIVED SILT/CLAY HEAVILY ROOTED THIN SAND STRINGERS TOP 12" PEDOGENIC
2	5			W/T	WASATCH DERIVED ORANGE FINE TO MEDIUM SAND WITH TROPIC DERIVED SILT/CLAY; DENSE; BLOCKY
	11			T	TROPIC DERIVED CLAY TO VERY FINE SAND DARK BROWN MINOR CLINKER CHIPS
3 4	23			SWK	TAN FINE TO MEDIUM SAND ABUNDANT ORGANICS, TROPIC CHIPS, CLINKER CHIPS IRON STAINING PRODUCES YELLOW MOTTLING
5	5			SWK	MEDIUM SAND TO VERY FINE GRAVEL GRAVEL CONSISTS OF SANDSTONE, CLINKER CHIPS ⇒ LOCAL SOURCE
6	9			T	CHOCOLATE BROWN TROPIC DERIVED SILT/CLAY DENSE HIGH CHARCOAL CONTENT
	8			SWK	WELL SORTED MEDIUM SAND MINOR AMOUNT OF FINE CLINKER, SANDSTONE CLASTS HIGH CHARCOAL CONTENT MASSIVE
	2			W	TANNISH-YELLOW SILT/CLAY DRAPE
7	5			SWK	WELL SORTED MEDIUM VERY WET; HIGH WATER FLOW
	3			W	PINKISH-ORANGE SILT DRAPE; HIGH CHARCOAL CONTENT
	3			W	BROWNISH-ORANGE SILT TO FINE SAND; DENSE ABUNDANT CLINKER OR WASATCH DERIVED CLASTS
8 9	15			W/SWK	ALTERNATING PINKISH ORANGE SILT AND GREY MEDIUM SAND. SAND - 2" SILT - 1". CONTINUES BELOW WATER LEVEL TO T.D. = ▽ =
10	16			W/SWK	STANDING WATER LEVEL
11 12					BASE OF SECTION

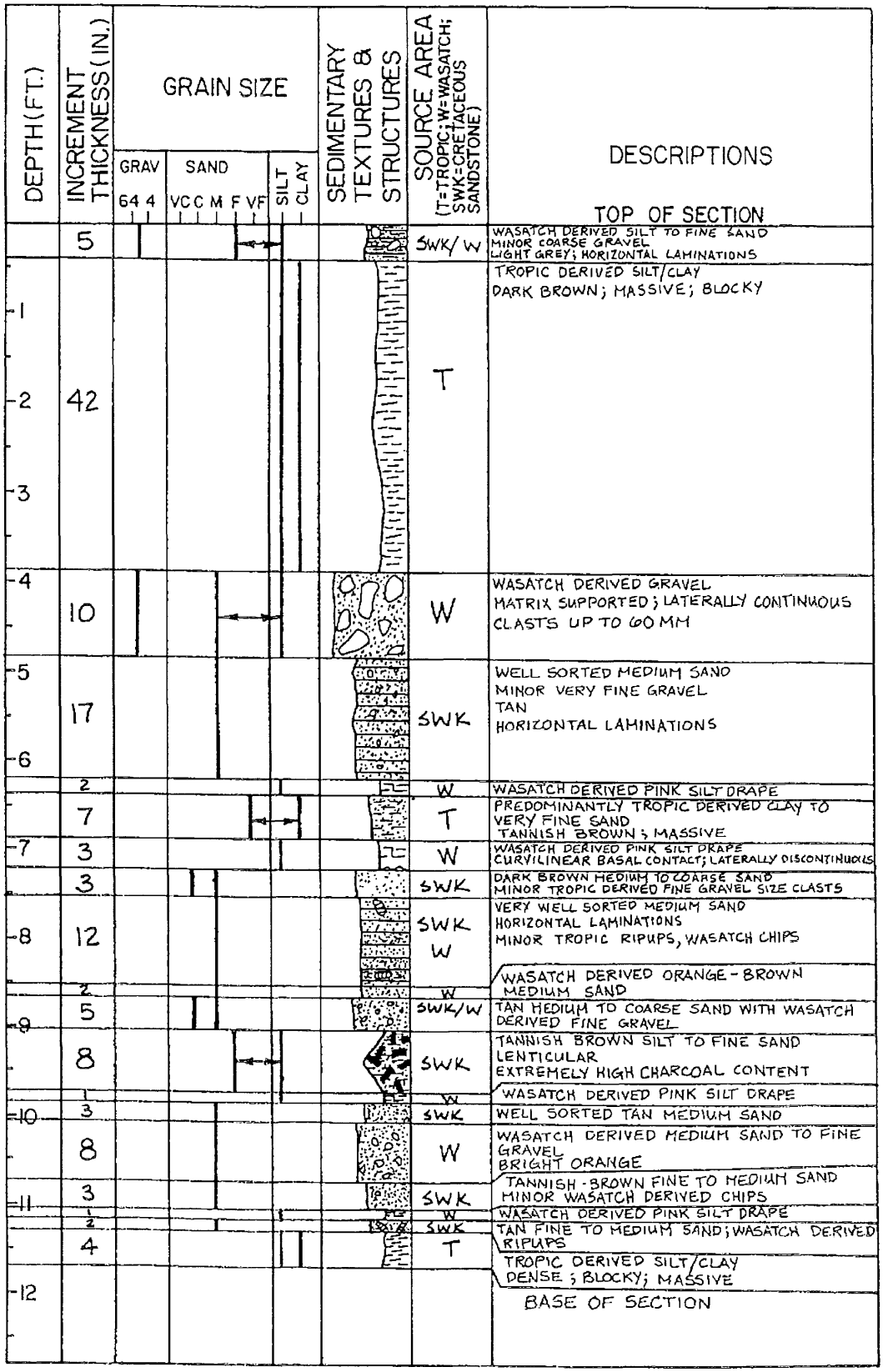
MEASURED SECTION NO 34
LOCALITY XS 8
SETTING EAST SIDE VALLEY
STATION 2+33

DATE 7/15/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS
ELEVATION 6750.0

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
	7			T	TROPIC DERIVED SILT/CLAY BLOCKY PEDOGENIC STRUCTURE MINOR PINK FINE CLASTS
1 2 3	32			W/T	DARK BROWN TROPIC DERIVED SILT/CLAY BLOCKY; DENSE; MASSIVE SOME WASATCH DERIVED FINE TO MEDIUM GRAVEL
4 5	23			SWK W/T	TAN MEDIUM SAND MINOR WASATCH DERIVED FINE GRAVEL LARGE TROPIC DERIVED RIPUPS MASSIVE; DENSE; WET
	6			SWK	WELL SORTED LENTICULAR MEDIUM SAND
6	7			W	WASATCH DERIVED MEDIUM TO COARSE SAND VERY WELL SORTED; PINK DIPS WESTWARD 4°
	1			W	SILT DRAPE
	4			SWK	WELL SORTED MEDIUM SAND MINOR WASATCH DERIVED RIPUPS
7 8	18			T W	TROPIC DERIVED SILT/CLAY HIGH CHARCOAL CONTENT DIP WESTWARD 4° LARGE RIPUP CLASTS OF WEATHERED WASATCH DERIVED MATERIAL
	2			W	PINK-GRAY WASATCH DERIVED SILT DRAPE; LATERALLY CONTINUOUS
	5			T	BROWN SILT/CLAY DENSE
	1			W	PINK WASATCH DERIVED SILT DRAPE
9	12			W SWK	WELL SORTED MEDIUM TO COARSE SAND HORIZONTAL LAMINATIONS; COARSE / FINE COUPLETS PEBBLES AT TOP; WASATCH DERIVED LIMESTONE, QUARTZITE BASAL SURFACE - HIGH WATER FLOW
10	4			W/T	WASATCH DERIVED SILT THINLY INTERBEDDED WITH TROPIC DERIVED SILT/CLAY
	6			T	TROPIC DERIVED SILT/CLAY - CONTINUES TO BASE OF SECTION
11	6			T	STANDING WATER LEVEL
12					BASE OF SECTION

MEASURED SECTION NO 35
LOCALITY XS 6
SETTING EAST SIDE VALLEY
STATION 3+84

DATE 7/15/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/KF/JS
ELEVATION 6903.0



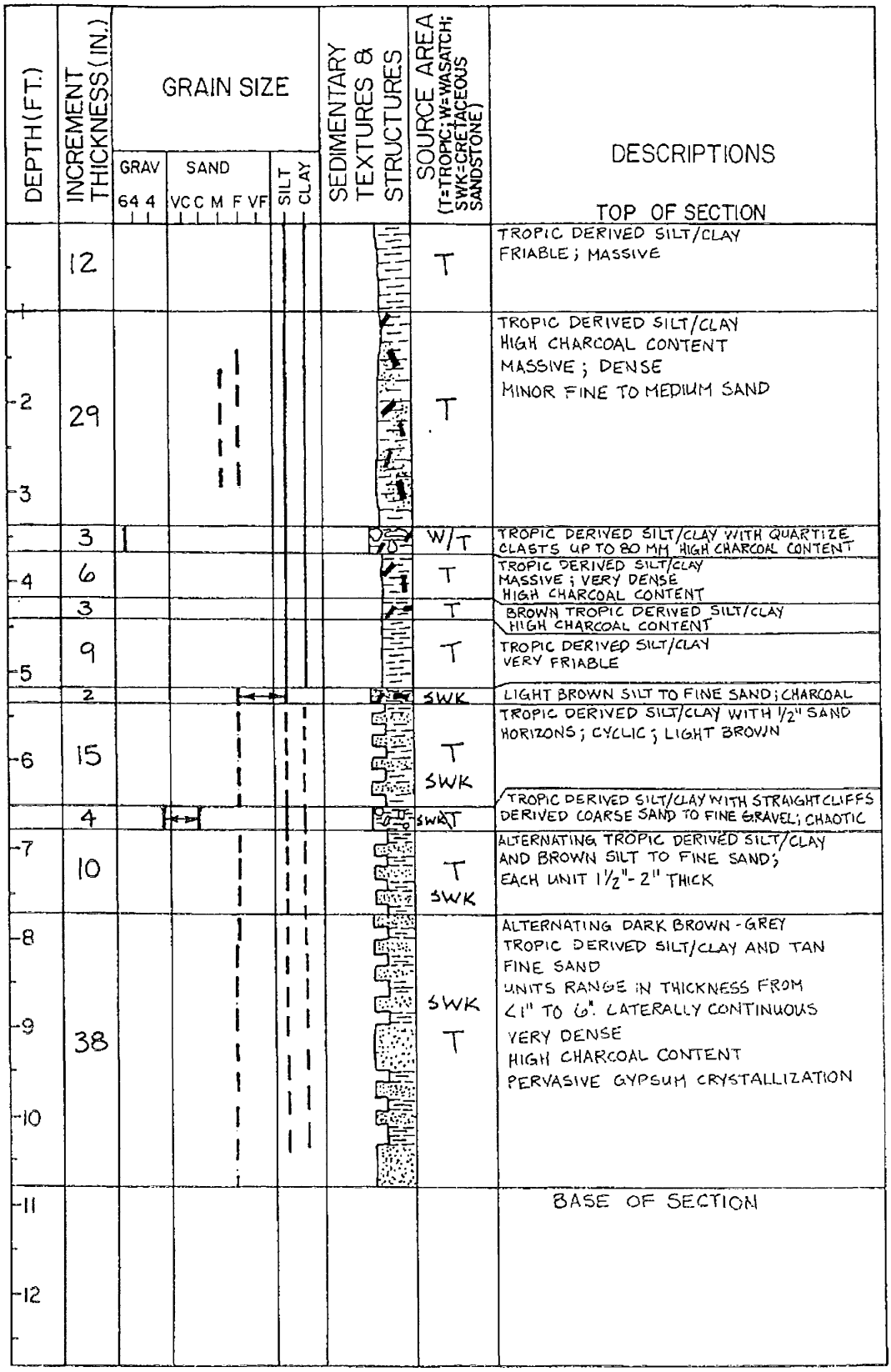
MEASURED SECTION NO 36
LOCALITY XS 9
SETTING TRB SINK VALLEY WASH
STATION 3+13

DATE 7/16/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY MH/JS/KF
ELEVATION 6670.4

DEPTH (FT.)	INCREMENT THICKNESS (IN.)	GRAIN SIZE (GRAV 64 4; SAND VC C M F VF; SILT CLAY)	SEDIMENTARY TEXTURES & STRUCTURES	SOURCE AREA (T=TROPIC; W=WASATCH; SWK=CRETACEOUS SANDSTONE)	DESCRIPTIONS
					TOP OF SECTION
	9			T	TROPIC DERIVED SILT TO FINE SAND WITH MINOR DISSEMINATED VERY FINE GRAVEL AND CLINKER CHIPS; ALL LOCALLY DERIVED CRUMB STRUCTURE ⇒ PEDOGENIC A HORIZON WITH SLOPE WASH
1	14			W/T	WASATCH/TROPIC DERIVED SILT TO FINE SAND MINOR TROPIC DERIVED RIPUPS BLOCKY MASSIVE DENSE
2 3	19			W/T	WASATCH/TROPIC DERIVED MEDIUM SAND MINOR ANGULAR SANDSTONE CLASTS UP TO 20MM DENSE; MASSIVE
4	10			SWK	FINE TO MEDIUM WELL SORTED SAND HORIZONTAL LAMINATIONS COARSE/FINE COUPLETS
	2			T	DARK BROWN TROPIC DERIVED SILT/CLAY DRAPE
5	8			SWK	TAN FINE TO MEDIUM SAND WELL SORTED; FINES UPWARDS HORIZONTAL LAMINATIONS; COARSE FINE COUPLETS
				T	TROPIC DERIVED DARK BROWN SILT/CLAY DRAPE
				W	WASATCH DERIVED PINK SILT DRAPE
	4			T	TROPIC DERIVED DARK BROWN SILT/CLAY DRAPE HORIZONTAL LAMINATIONS
6	4			SWK	FINE TO MEDIUM SAND; LATERALLY CONTINUOUS HORIZONTAL LAMINATIONS; COARSE/FINE COUPLETS
	3			T	TROPIC DERIVED DARK BROWN SILT/CLAY DRAPE
				W	WASATCH DERIVED ORANGE SILT DRAPE
	2			T	TROPIC DERIVED DARK BROWN SILT/CLAY DRAPE
				W	WASATCH DERIVED ORANGE SILT DRAPE
7	6			T	REDDISH BROWN CLAY TO FINE SAND PREDOMINANTLY TROPIC DERIVED MATERIAL ABUNDANT RIPUPS; CRACK PENETRATION OF WASATCH DERIVED MATERIAL
8 9	170			T	TROPIC DERIVED DARK BROWN SILT/CLAY MINOR DISSEMINATED CLINKER CHIPS BLOCKY LOWER SECTION COUPLED WITH A HIGH CONCENTRATION OF RECRYSTALLIZED SALTS
					BREAK IN SECTION
20 21				T	
					BASE OF SECTION
22					

MEASURED SECTION NO. 37
LOCALITY XS 4B; XS 5
SETTING CENTER SWAPP HOLLOW
STATION 14+59(4B); 0+00(5)

DATE 7/14/88
STRATIGRAPHIC UNIT VALLEY FILL
MEASURED BY KF/MH/JS
ELEVATION 6963.3



APPENDIX 7-6

Climate Data

Appendix 7-6 Climate data for the Coal Hollow Weather Station, 2006-2007

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
January 2006			
1/1/2006	N/A	39.4	16.9
1/2/2006	N/A	42.9	29.5
1/3/2006	N/A	40.0	26.5
1/4/2006	N/A	45.6	20.5
1/5/2006	N/A	52.6	23.4
1/6/2006	N/A	57.6	29.0
1/7/2006	N/A	49.5	23.9
1/8/2006	N/A	45.5	24.2
1/9/2006	N/A	40.3	13.5
1/10/2006	N/A	47.8	21.1
1/11/2006	N/A	48.8	28.1
1/12/2006	N/A	43.7	22.1
1/13/2006	N/A	49.6	20.9
1/14/2006	N/A	48.7	26.1
1/15/2006	N/A	37.5	17.6
1/16/2006	N/A	29.4	11.5
1/17/2006	N/A	48.3	9.9
1/18/2006	N/A	41.1	22.6
1/19/2006	N/A	33.5	19.8
1/20/2006	N/A	36.4	10.4
1/21/2006	N/A	41.1	14.1
1/22/2006	N/A	35.1	13.4
1/23/2006	N/A	43.7	14.9
1/24/2006	N/A	48.6	12.9
1/25/2006	N/A	42.9	23.1
1/26/2006	N/A	41.0	16.2
1/27/2006	N/A	29.7	14.8
1/28/2006	N/A	35.9	8.1
1/29/2006	N/A	46.3	19.8
1/30/2006	N/A	51.5	24.7
1/31/2006	N/A	43.7	27.7
Month	---	***57.6***	***8.1***
February 2006			
2/1/2006	N/A	52.8	24.3
2/2/2006	N/A	51.3	28.4
2/3/2006	N/A	48.3	25.3
2/4/2006	N/A	50.9	24.3
2/5/2006	N/A	39.3	19.4
2/6/2006	N/A	50.7	11.6
2/7/2006	N/A	56.3	21.7
2/8/2006	N/A	57.2	23.4
2/9/2006	N/A	57.8	20.2

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
2/10/2006	N/A	46.2	23.0
2/11/2006	N/A	49.1	20.4
2/12/2006	N/A	53.2	17.2
2/13/2006	N/A	52.2	17.7
2/14/2006	N/A	51.0	27.2
2/15/2006	N/A	45.1	17.9
2/16/2006	N/A	32.8	2.4
2/17/2006	N/A	40.6	19.1
2/18/2006	N/A	35.6	15.5
2/19/2006	N/A	30.0	12.3
2/20/2006	N/A	34.8	11.2
2/21/2006	N/A	38.9	1.0
2/22/2006	N/A	47.0	20.4
2/23/2006	N/A	51.9	15.5
2/24/2006	N/A	54.0	21.9
2/25/2006	N/A	54.9	24.3
2/26/2006	N/A	57.3	27.2
2/27/2006	N/A	56.8	30.0
2/28/2006	N/A	44.5	33.7
Month	---	***57.8***	***1.0***
March 2006			
3/1/2006	N/A	48.7	29.6
3/2/2006	N/A	51.2	25.2
3/3/2006	N/A	52.3	31.2
3/4/2006	N/A	46.3	28.5
3/5/2006	N/A	55.5	27.0
3/6/2006	N/A	50.6	30.0
3/7/2006	N/A	45.0	27.2
3/8/2006	N/A	37.4	19.4
3/9/2006	N/A	43.6	19.4
3/10/2006	N/A	31.1	12.9
3/11/2006	N/A	26.4	16.2
3/12/2006	N/A	25.1	14.1
3/13/2006	N/A	34.2	10.4
3/14/2006	N/A	39.4	9.6
3/15/2006	N/A	44.1	24.8
3/16/2006	N/A	44.2	21.6
3/17/2006	N/A	45.1	26.2
3/18/2006	N/A	38.6	19.0
3/19/2006	N/A	38.8	21.3
3/20/2006	N/A	36.6	6.9
3/21/2006	N/A	34.9	21.7
3/22/2006	N/A	43.9	21.6
3/23/2006	N/A	50.3	18.3
3/24/2006	N/A	55.1	29.8
3/25/2006	N/A	53.4	32.9
3/26/2006	N/A	52.3	26.4

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
3/27/2006	N/A	55.7	24.0
3/28/2006	N/A	43.3	36.5
3/29/2006	N/A	40.0	25.4
3/30/2006	N/A	46.8	19.1
3/31/2006	N/A	49.5	32.4
Month	***---***	***55.7***	***6.9***
April 2006			
4/1/2006	0.14	47.6	30.9
4/2/2006	0.00	54.4	28.7
4/3/2006	0.00	63.1	37.3
4/4/2006	0.00	59.1	43.9
4/5/2006	0.18	50.1	26.6
4/6/2006	0.10	48.5	26.0
4/7/2006	0.00	56.9	24.2
4/8/2006	0.00	61.7	35.4
4/9/2006	0.00	63.9	34.0
4/10/2006	0.00	55.7	35.7
4/11/2006	0.00	55.4	26.7
4/12/2006	0.00	65.0	31.2
4/13/2006	0.00	66.8	35.3
4/14/2006	0.28	60.1	34.6
4/15/2006	0.12	51.8	33.0
4/16/2006	0.01	60.8	31.5
4/17/2006	0.00	48.5	27.9
4/18/2006	0.00	49.8	21.9
4/19/2006	0.00	56.4	23.3
4/20/2006	0.00	65.4	21.5
4/21/2006	0.00	66.2	39.4
4/22/2006	0.00	67.6	39.7
4/23/2006	0.00	57.8	30.2
4/24/2006	0.00	56.2	27.4
4/25/2006	0.00	61.8	30.9
4/26/2006	0.00	66.6	34.2
4/27/2006	0.00	69.5	38.7
4/28/2006	0.00	67.8	45.6
4/29/2006	0.00	68.5	32.8
4/30/2006	0.00	71.0	40.2
Month	***0.83***	***71.0***	***21.5***
May 2006			
5/1/2006	0.06	68.3	38.3
5/2/2006	0.00	72.1	44.3
5/3/2006	0.00	70.3	38.8
5/4/2006	0.00	65.4	38.8
5/5/2006	0.04	58.9	39.7
5/6/2006	0.00	64.8	31.8
5/7/2006	0.00	71.7	39.8

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
5/8/2006	0.00	70.8	44.0
5/9/2006	0.00	67.0	32.8
5/10/2006	0.00	69.3	28.7
5/11/2006	0.00	71.8	34.5
5/12/2006	0.00	76.6	45.8
5/13/2006	0.00	78.6	53.3
5/14/2006	0.00	79.6	49.8
5/15/2006	0.00	76.2	42.5
5/16/2006	0.16	74.1	48.7
5/17/2006	0.00	81.8	48.8
5/18/2006	0.00	78.8	49.0
5/19/2006	0.00	77.6	52.8
5/20/2006	0.00	76.7	49.9
5/21/2006	0.00	76.3	48.9
5/22/2006	0.00	62.8	42.1
5/23/2006	0.00	69.2	35.4
5/24/2006	0.00	79.1	44.8
5/25/2006	0.00	80.0	47.1
5/26/2006	0.00	75.1	49.2
5/27/2006	0.00	66.0	43.8
5/28/2006	0.00	55.0	28.8
5/29/2006	0.00	64.7	28.3
5/30/2006	0.00	71.2	36.8
5/31/2006	0.00	77.4	40.7
Month	***0.26***	***81.8***	***28.3***
June 2006			
6/1/2006	0.00	81.9	37.2
6/2/2006	0.00	82.9	53.2
6/3/2006	0.00	82.0	52.7
6/4/2006	0.00	83.6	55.0
6/5/2006	0.00	85.5	57.4
6/6/2006	0.00	90.1	54.6
6/7/2006	0.00	76.5	53.9
6/8/2006	0.00	68.4	46.5
6/9/2006	0.00	76.3	45.0
6/10/2006	0.00	77.7	47.6
6/11/2006	0.00	79.4	48.9
6/12/2006	0.00	78.5	48.3
6/13/2006	0.00	78.5	44.5
6/14/2006	0.00	70.4	46.3
6/15/2006	0.01	63.8	45.7
6/16/2006	0.00	72.7	39.5
6/17/2006	0.00	81.9	37.1
6/18/2006	0.00	84.7	55.4
6/19/2006	0.00	83.9	53.5
6/20/2006	0.00	82.3	55.7
6/21/2006	0.00	82.1	54.8

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
6/22/2006	0.00	85.4	52.0
6/23/2006	0.00	91.8	45.8
6/24/2006	0.00	88.0	50.0
6/25/2006	0.00	90.0	55.5
6/26/2006	0.00	86.1	53.8
6/27/2006	0.00	79.9	57.0
6/28/2006	0.00	83.2	50.0
6/29/2006	0.00	81.8	52.2
6/30/2006	0.16	83.5	56.4
Month	***0.17***	***91.8***	***37.1***
July 2006			
7/1/2006	0.00	82.5	53.5
7/2/2006	0.16	83.3	54.7
7/3/2006	0.07	83.2	55.4
7/4/2006	0.00	75.9	55.9
7/5/2006	0.00	77.7	55.6
7/6/2006	0.72	75.2	54.1
7/7/2006	0.02	77.7	49.2
7/8/2006	0.00	77.5	55.5
7/9/2006	0.01	79.1	51.7
7/10/2006	0.03	77.6	49.5
7/11/2006	0.01	82.2	52.9
7/12/2006	0.00	83.1	55.0
7/13/2006	0.00	85.1	56.2
7/14/2006	0.00	88.4	58.9
7/15/2006	0.00	93.3	59.0
7/16/2006	0.03	92.1	64.2
7/17/2006	0.00	90.2	63.3
7/18/2006	0.00	86.5	63.7
7/19/2006	0.00	83.5	59.7
7/20/2006	0.00	83.6	57.1
7/21/2006	0.57	88.5	56.2
7/22/2006	0.02	85.6	60.3
7/23/2006	0.00	89.4	59.2
7/24/2006	0.07	90.5	59.4
7/25/2006	0.04	86.2	59.9
7/26/2006	0.00	86.2	61.7
7/27/2006	0.00	90.9	57.0
7/28/2006	0.10	86.6	57.3
7/29/2006	0.08	83.2	53.9
7/30/2006	0.27	78.8	58.3
7/31/2006	0.45	77.6	54.3
Month	***2.65***	***93.3***	***49.2***
August 2006			
8/1/2006	0.00	75.5	53.9
8/2/2006	0.00	75.8	53.2

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
8/3/2006	0.00	79.8	53.9
8/4/2006	0.17	71.4	55.8
8/5/2006	0.00	78.0	52.8
8/6/2006	0.00	82.4	53.3
8/7/2006	0.00	82.4	62.3
8/8/2006	0.00	83.2	55.1
8/9/2006	0.01	79.7	58.7
8/10/2006	0.00	84.1	57.8
8/11/2006	0.00	79.7	57.7
8/12/2006	0.00	79.6	53.6
8/13/2006	0.00	80.1	55.0
8/14/2006	0.00	82.3	56.4
8/15/2006	0.00	80.9	56.6
8/16/2006	0.00	77.8	52.2
8/17/2006	0.00	78.0	52.9
8/18/2006	0.00	79.5	53.6
8/19/2006	0.00	82.8	49.5
8/20/2006	0.00	83.7	52.9
8/21/2006	0.00	85.7	54.6
8/22/2006	0.00	86.0	56.5
8/23/2006	0.00	83.7	55.6
8/24/2006	0.00	84.1	56.6
8/25/2006	0.00	78.3	54.2
8/26/2006	0.00	77.2	50.1
8/27/2006	0.00	80.3	45.0
8/28/2006	0.00	82.3	44.5
8/29/2006	0.00	83.4	49.5
8/30/2006	0.00	81.7	54.5
8/31/2006	0.00	83.2	56.1
Month	***0.18***	***86.0***	***44.5***
September 2006			
9/1/2006	0.15	80.0	51.1
9/2/2006	0.00	80.2	49.2
9/3/2006	0.00	78.2	47.5
9/4/2006	0.00	81.0	51.2
9/5/2006	0.00	80.7	55.4
9/6/2006	0.06	74.6	50.1
9/7/2006	0.22	61.3	49.3
9/8/2006	0.50	68.8	43.9
9/9/2006	0.02	70.2	45.3
9/10/2006	0.05	71.1	45.0
9/11/2006	0.00	76.8	44.5
9/12/2006	0.00	80.1	51.7
9/13/2006	0.00	80.2	52.5
9/14/2006	0.40	65.4	50.7
9/15/2006	0.00	67.6	49.9
9/16/2006	0.00	59.3	37.7

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
9/17/2006	0.00	62.1	24.6
9/18/2006	0.00	67.6	23.2
9/19/2006	0.00	71.1	39.1
9/20/2006	0.00	57.5	38.4
9/21/2006	0.00	63.3	30.6
9/22/2006	0.00	52.3	36.6
9/23/2006	0.00	60.5	27.5
9/24/2006	0.00	63.6	29.4
9/25/2006	0.00	70.5	31.6
9/26/2006	0.00	75.6	43.3
9/27/2006	0.00	74.9	42.2
9/28/2006	0.00	78.4	40.4
9/29/2006	0.00	78.5	41.8
9/30/2006	0.00	77.1	40.8
Month	***1.40***	***81.0***	***23.2***
October 2006			
10/1/2006	0.00	74.2	49.5
10/2/2006	0.00	71.5	49.8
10/3/2006	0.10	69.7	44.4
10/4/2006	0.00	67.9	50.8
10/5/2006	0.27	63.5	45.6
10/6/2006	0.37	61.3	44.9
10/7/2006	0.00	60.5	32.5
10/8/2006	0.00	62.9	37.0
10/9/2006	0.02	55.0	36.6
10/10/2006	0.31	56.0	35.8
10/11/2006	0.00	62.2	33.2
10/12/2006	0.01	66.0	25.7
10/13/2006	0.00	66.9	35.7
10/14/2006	1.61	49.4	34.3
10/15/2006	0.00	58.7	31.6
10/16/2006	0.00	57.7	37.0
10/17/2006	0.42	46.2	32.0
10/18/2006	0.00	47.0	29.6
10/19/2006	0.00	58.8	25.1
10/20/2006	0.00	60.8	30.8
10/21/2006	0.00	54.6	26.9
10/22/2006	0.00	60.0	24.6
10/23/2006	0.00	62.5	31.9
10/24/2006	0.15	54.4	38.1
10/25/2006	0.09	48.3	29.9
10/26/2006	0.01	49.6	28.5
10/27/2006	0.00	62.6	27.4
10/28/2006	0.00	64.7	30.4
10/29/2006	0.00	60.7	34.3
10/30/2006	0.00	57.6	33.5
10/31/2006	0.00	56.3	32.8

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
Month	***3.36***	***74.2***	***24.6***
November 2006			
11/1/2006	0.00	57.0	27.2
11/2/2006	0.00	59.3	33.7
11/3/2006	0.00	59.4	32.0
11/4/2006	0.00	58.2	33.2
11/5/2006	0.00	59.3	25.7
11/6/2006	0.00	65.3	29.6
11/7/2006	0.00	70.5	35.9
11/8/2006	0.00	66.8	42.9
11/9/2006	0.00	58.2	30.7
11/10/2006	0.00	49.6	16.1
11/11/2006	0.00	44.5	26.4
11/12/2006	0.03	42.0	22.5
11/13/2006	0.00	50.3	25.4
11/14/2006	0.00	49.2	26.4
11/15/2006	0.00	51.5	19.0
11/16/2006	0.00	59.4	31.6
11/17/2006	0.00	63.0	32.7
11/18/2006	0.00	62.3	29.8
11/19/2006	0.00	58.7	25.8
11/20/2006	0.00	60.6	28.5
11/21/2006	0.00	60.9	29.9
11/22/2006	0.00	54.1	33.1
11/23/2006	0.00	53.8	32.0
11/24/2006	0.00	53.7	18.3
11/25/2006	0.00	47.3	28.5
11/26/2006	0.00	44.8	25.0
11/27/2006	0.01	35.5	23.8
11/28/2006	0.20	33.2	13.7
11/29/2006	0.01	16.4	6.8
11/30/2006	0.00	38.8	0.9
Month	***0.25***	***70.5***	***0.9***
December 2006			
12/1/2006	0.00	45.1	13.7
12/2/2006	0.00	28.5	10.4
12/3/2006	0.00	39.4	2.4
12/4/2006	0.00	50.3	16.8
12/5/2006	0.00	53.9	22.9
12/6/2006	0.00	54.0	19.3
12/7/2006	0.00	53.5	21.6
12/8/2006	0.00	49.6	21.7
12/9/2006	0.00	46.9	21.5
12/10/2006	0.12	36.5	18.4
12/11/2006	0.17	36.8	13.6
12/12/2006	0.00	44.4	11.6

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
12/13/2006	0.00	47.4	26.3
12/14/2006	0.00	50.3	28.6
12/15/2006	0.00	49.0	33.3
12/16/2006	0.00	40.3	26.6
12/17/2006	0.20	37.2	13.1
12/18/2006	0.01	33.1	4.4
12/19/2006	0.06	32.1	12.8
12/20/2006	0.00	34.7	11.4
12/21/2006	0.00	42.1	13.1
12/22/2006	0.23	34.3	21.8
12/23/2006	0.00	38.4	13.3
12/24/2006	0.00	40.0	16.4
12/25/2006	0.00	55.6	14.6
12/26/2006	0.00	50.9	31.4
12/27/2006	0.33	40.5	29.1
12/28/2006	0.03	31.1	22.7
12/29/2006	0.00	33.5	22.2
12/30/2006	0.00	46.1	16.4
12/31/2006	0.00	50.0	14.6
Month	***1.15***	***55.6***	***2.4***
January 2007			
1/1/2007	NA	38.4	17.1
1/2/2007	NA	49.1	16.4
1/3/2007	NA	50.4	22.7
1/4/2007	NA	43.0	24.3
1/5/2007	NA	34.3	10.9
1/6/2007	NA	38.1	-3.4
1/7/2007	NA	40.1	15.4
1/8/2007	NA	49.9	11.4
1/9/2007	NA	50.3	18.8
1/10/2007	NA	44.6	30.8
1/11/2007	NA	38.3	24.2
1/12/2007	NA	33.7	10.5
1/13/2007	NA	17.8	-6.4
1/14/2007	NA	22.5	-1.0
1/15/2007	NA	25.8	-7.3
1/16/2007	NA	32.4	-0.7
1/17/2007	NA	32.6	3.5
1/18/2007	NA	39.5	4.8
1/19/2007	NA	44.6	4.3
1/20/2007	NA	41.1	9.8
1/21/2007	NA	24.8	12.0
1/22/2007	NA	35.7	4.5
1/23/2007	NA	49.2	16.5
1/24/2007	NA	52.4	19.5
1/25/2007	NA	51.1	24.9
1/26/2007	NA	49.0	21.8

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
1/27/2007	NA	43.2	21.7
1/28/2007	NA	44.2	20.7
1/29/2007	NA	46.3	19.3
1/30/2007	NA	42.8	17.5
1/31/2007	NA	38.0	16.7
Month	***NA***	***52.4***	***-7.3***
February 2007			
2/1/2007	0	31.7	8.7
2/2/2007	0	36.5	4.4
2/3/2007	0	50.5	10.4
2/4/2007	0	54.9	26.7
2/5/2007	0	59.3	28.2
2/6/2007	0	57.2	31.1
2/7/2007	0	55.0	33.8
2/8/2007	0	52.5	30.6
2/9/2007	0	53.0	32.4
2/10/2007	0	53.9	36.6
2/11/2007	0.32	47.2	30.8
2/12/2007	0.02	47.2	25.6
2/13/2007	0.03	43.5	27.5
2/14/2007	0	35.4	23.9
2/15/2007	0	45.0	16.1
2/16/2007	0	51.9	24.0
2/17/2007	0	55.1	26.1
2/18/2007	0	52.6	25.2
2/19/2007	0.03	42.9	23.3
2/20/2007	0	43.7	10.5
2/21/2007	0	50.9	21.4
2/22/2007	0	55.1	26.2
2/23/2007	0.2	39.9	17.9
2/24/2007	0	35.8	12.9
2/25/2007	0	39.5	18.3
2/26/2007	0	45.0	25.4
2/27/2007	0.08	35.0	23.5
2/28/2007	0.23	29.7	8.3
Month	***0.91***	***59.3***	***4.4***
March 2007			
3/1/2007	0	34.0	6.3
3/2/2007	0	33.0	9.8
3/3/2007	0	40.5	6.8
3/4/2007	0	52.7	15.0
3/5/2007	0	58.2	28.2
3/6/2007	0	56.1	32.0
3/7/2007	0	57.7	31.1
3/8/2007	0	58.8	33.9
3/9/2007	0	60.2	30.7

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
3/10/2007	0	56.0	34.0
3/11/2007	0	64.7	23.3
3/12/2007	0	69.8	30.9
3/13/2007	0	72.1	32.6
3/14/2007	0	71.0	42.1
3/15/2007	0	67.2	34.4
3/16/2007	0	72.3	30.7
3/17/2007	0	72.7	38.3
3/18/2007	0	70.6	43.4
3/19/2007	0	67.3	35.8
3/20/2007	0	63.3	36.4
3/21/2007	0.34	49.7	33.8
3/22/2007	0	55.5	30.5
3/23/2007	0.1	48.7	34.9
3/24/2007	0	53.7	34.5
3/25/2007	0	61.4	33.5
3/26/2007	0	62.1	37.6
3/27/2007	0	51.6	20.9
3/28/2007	0.52	35.2	28.6
3/29/2007	0	38.7	27.0
3/30/2007	0	50.7	17.9
3/31/2007	0	63.8	23.7
Month	***0.96***	***72.7***	***6.3***
April 2007			
4/1/2007	0	63.8	37.0
4/2/2007	0	63.3	38.1
4/3/2007	0	66.6	40.4
4/4/2007	0	69.5	41.7
4/5/2007	0	67.3	40.7
4/6/2007	0	66.8	44.2
4/7/2007	0	65.1	43.7
4/8/2007	0.05	62.0	40.1
4/9/2007	0.01	61.4	29.3
4/10/2007	0	50.0	31.9
4/11/2007	0	48.9	29.5
4/12/2007	0	47.0	24.6
4/13/2007	0.12	50.4	29.6
4/14/2007	0	58.8	28.5
4/15/2007	0	51.7	32.5
4/16/2007	0	52.5	26.6
4/17/2007	0	61.2	29.5
4/18/2007	0	47.4	22.6
4/19/2007	0	51.4	16.1
4/20/2007	0	46.3	29.2
4/21/2007	0	51.6	27.0
4/22/2007	0.34	38.9	31.5
4/23/2007	0.52	42.7	28.4

	Measured Precipitation* (inches)	Maximum Temperature (°F)	Minimum Temperature (°F)
4/24/2007	0.03	53.5	31.5
4/25/2007	0	62.6	32.9
4/26/2007	0	63.0	38.3
4/27/2007	0	71.1	39.3
4/28/2007	0	73.7	40.2
4/29/2007	0	75.7	48.1
4/30/2007	0	73.2	49.2
Month	***1.07***	***75.7***	***16.1***
May 2007			
5/1/2007	0	67.5	47.7
5/2/2007	0	67.8	41.2
5/3/2007	0	53.4	41.5
5/4/2007	0	53.3	33.1
5/5/2007	0.02	43.7	27.8
5/6/2007	0	51.3	33.7
5/7/2007	0	63.1	28.4
5/8/2007	0	67.3	37.3
5/9/2007	0	72.2	44.1
5/10/2007	0	75.5	49.4
5/11/2007	0	77.3	50.6
5/12/2007	0	78.1	52.5
5/13/2007	0	74.8	51.8
5/14/2007	0	73.2	46.7
5/15/2007	0	75.0	38.9
5/16/2007	0	75.0	44.8
5/17/2007	0	72.2	48.8
5/18/2007	0	72.7	49.6
5/19/2007	0	75.1	50.6
5/20/2007	0	74.2	47.9
5/21/2007	0.02	68.6	44.2
5/22/2007	0.10	59.1	40.1
5/23/2007	0.03	56.2	34.5
5/24/2007	0	63.0	53.4
5/25/2007	0	72.4	42.2
5/26/2007	0	72.4	49.6
5/27/2007	0	75.0	49.5
5/28/2007	0	73.8	47.6
5/29/2007	0	73.1	46.1
5/30/2007	0	75.1	36.7
5/31/2007	0	77.1	48.5
Month	***0.17***	***78.1***	***27.8***

** Note: The coal hollow weather station precipitation gauge is not equiped with* a heating unit and consequently precipitation falling during freezing conditions may may not be recorded.

ALTON, UTAH (420086)

Period of Record Monthly Climate Summary

Period of Record : 1/ 1/1928 to 12/31/2005

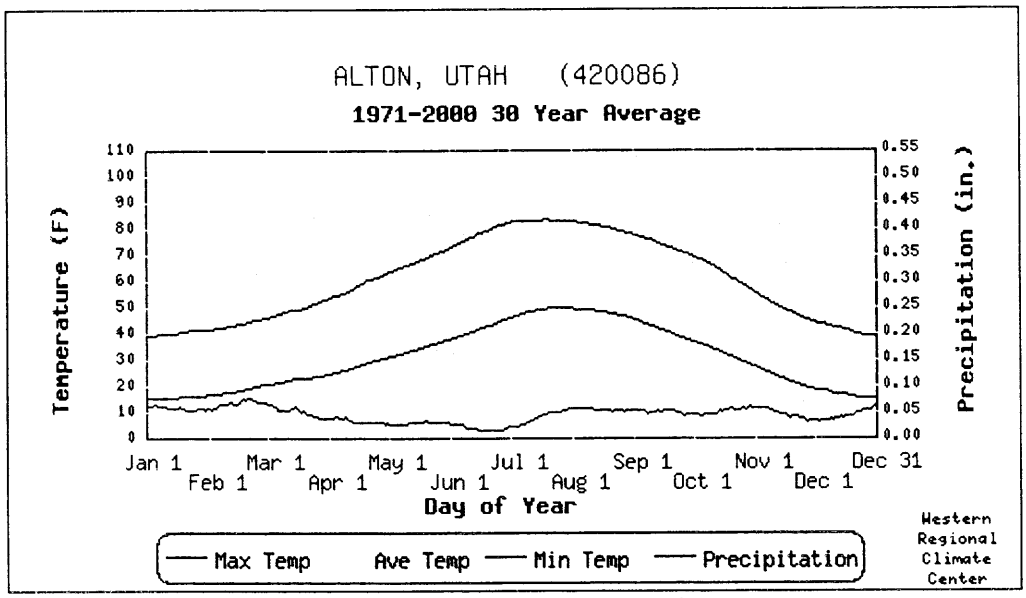
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	39.5	42.1	47.9	57.7	67.2	76.7	82.6	80.4	73.9	63.1	49.9	41.8	60.2
Average Min. Temperature (F)	15.1	17.5	21.8	28.0	34.8	42.0	49.8	48.9	41.8	33.0	23.0	16.8	31.0
Average Total Precipitation (in.)	1.79	1.80	1.54	1.05	0.85	0.57	1.40	1.76	1.49	1.40	1.23	1.52	16.38
Average Total SnowFall (in.)	21.2	19.5	14.3	4.5	0.6	0.2	0.0	0.0	0.0	1.3	6.6	15.4	83.4
Average Snow Depth (in.)	7	8	5	1	0	0	0	0	0	0	1	2	2

Percent of possible observations for period of record.
Max. Temp.: 99.1% Min. Temp.: 99.1% Precipitation: 99.6% Snowfall: 97.7% Snow Depth: 92.4%
Check Station Metadata or Metadata graphics for more detail about data completeness.

Western Regional Climate Center, wrcc@dri.edu

ALTON, UTAH

1971 - 2000 Temperature and Precipitation



Data is smoothed using a 29 day running average.

- Max. Temp. is the average of all daily maximum temperatures recorded for the day of the year between the years 1971 and 2000.
- Ave. Temp. is the average of all daily average temperatures recorded for the day of the year between the years 1971 and 2000.
- Min. Temp. is the average of all daily minimum temperatures recorded for the day of the year between the years 1971 and 2000.
- Precipitation is the average of all daily total precipitation recorded for the day of the year between the years 1971 and 2000.

ALTON, UTAH

30 Year Daily Temperature and Precipitation Summary

STATION 420086 AVERAGES FROM AVAILABLE YEARS IN PERIOD 1971 TO 2000 .

DOY	MON	DY	TMAX	#YRS	TMIN	#YRS	PRECIP	#YRS	SD MAX	SD MIN
1	1	1	39.4	30.	15.1	30.	0.062	29.	9.061	9.062
2	1	2	39.4	30.	15.0	30.	0.060	29.	9.095	9.099
3	1	3	39.4	30.	15.1	30.	0.062	30.	9.130	9.147
4	1	4	39.5	30.	15.3	30.	0.064	30.	9.160	9.183
5	1	5	39.6	30.	15.4	30.	0.064	29.	9.199	9.056
6	1	6	39.7	30.	15.5	30.	0.063	30.	9.279	8.977
7	1	7	39.8	30.	15.5	30.	0.062	30.	9.256	8.887
8	1	8	39.8	30.	15.6	30.	0.062	30.	9.240	8.763
9	1	9	39.9	30.	15.6	30.	0.061	30.	9.165	8.711
10	1	10	39.9	30.	15.7	30.	0.060	30.	9.105	8.672
11	1	11	40.0	30.	15.7	30.	0.059	30.	9.071	8.632
12	1	12	40.1	30.	15.7	30.	0.058	30.	9.037	8.667
13	1	13	40.1	30.	15.7	30.	0.057	30.	9.007	8.611
14	1	14	40.1	30.	15.7	30.	0.057	30.	8.992	8.555
15	1	15	40.2	30.	15.7	30.	0.059	30.	8.952	8.522
16	1	16	40.3	30.	15.7	30.	0.059	30.	8.948	8.563
17	1	17	40.4	30.	15.9	30.	0.060	30.	9.008	8.553
18	1	18	40.6	30.	16.0	30.	0.059	30.	8.991	8.497
19	1	19	40.8	30.	16.0	30.	0.057	30.	8.970	8.409
20	1	20	40.9	30.	16.0	30.	0.053	30.	8.941	8.372
21	1	21	41.1	30.	16.0	30.	0.054	30.	8.881	8.347
22	1	22	41.2	30.	16.2	30.	0.053	30.	8.871	8.318
23	1	23	41.2	30.	16.2	30.	0.052	30.	8.909	8.350
24	1	24	41.3	30.	16.2	30.	0.053	30.	8.875	8.410
25	1	25	41.3	30.	16.3	30.	0.054	30.	8.869	8.437
26	1	26	41.3	30.	16.4	30.	0.056	30.	8.834	8.532
27	1	27	41.4	29.	16.5	30.	0.058	30.	8.759	8.550
28	1	28	41.5	30.	16.5	30.	0.058	30.	8.683	8.593
29	1	29	41.5	29.	16.5	29.	0.056	30.	8.615	8.607
30	1	30	41.6	30.	16.5	30.	0.055	30.	8.645	8.654
31	1	31	41.7	30.	16.7	30.	0.058	30.	8.623	8.663
32	2	1	41.8	30.	16.6	30.	0.057	29.	8.650	8.756
33	2	2	41.9	30.	16.6	30.	0.055	30.	8.661	8.724
34	2	3	41.9	30.	16.7	30.	0.056	30.	8.646	8.725
35	2	4	42.0	30.	16.8	30.	0.057	30.	8.581	8.717
36	2	5	42.1	30.	16.9	30.	0.060	30.	8.597	8.721
37	2	6	42.3	30.	17.2	30.	0.064	30.	8.643	8.757
38	2	7	42.4	30.	17.3	30.	0.066	30.	8.696	8.751
39	2	8	42.5	30.	17.4	30.	0.067	30.	8.744	8.795
40	2	9	42.6	30.	17.4	30.	0.067	30.	8.784	8.795
41	2	10	42.7	30.	17.5	30.	0.067	30.	8.820	8.743
42	2	11	42.9	30.	17.6	30.	0.068	30.	8.880	8.751
43	2	12	43.1	30.	17.7	30.	0.068	30.	8.925	8.733
44	2	13	43.2	30.	17.8	30.	0.066	30.	8.967	8.813
45	2	14	43.4	30.	18.0	30.	0.067	30.	8.971	8.780
46	2	15	43.8	30.	18.2	30.	0.066	30.	8.914	8.797
47	2	16	43.9	30.	18.4	30.	0.068	30.	8.917	8.758
48	2	17	44.0	30.	18.7	30.	0.073	30.	8.883	8.744
49	2	18	44.1	30.	18.8	30.	0.076	30.	8.877	8.751
50	2	19	44.2	30.	19.0	30.	0.074	30.	8.929	8.721
51	2	20	44.4	30.	19.2	30.	0.075	30.	8.915	8.715

52	2	21	44.6	30.	19.4	30.	0.077	30.	8.883	8.602
53	2	22	44.8	30.	19.6	30.	0.077	30.	8.840	8.514
54	2	23	45.0	30.	19.7	30.	0.074	30.	8.820	8.418
55	2	24	45.3	30.	19.8	30.	0.072	30.	8.821	8.303
56	2	25	45.5	30.	20.0	30.	0.070	30.	8.834	8.233
57	2	26	45.7	30.	20.2	30.	0.071	30.	8.914	8.131
58	2	27	45.7	30.	20.4	30.	0.071	30.	8.995	8.107
59	2	28	45.9	30.	20.5	30.	0.070	30.	8.989	8.093
60	2	29	46.0	8.	20.6	8.	0.068	8.	9.013	8.040
61	3	1	46.2	29.	20.7	29.	0.066	29.	8.984	7.867
62	3	2	46.4	29.	20.8	29.	0.066	29.	8.960	7.810
63	3	3	46.6	29.	20.9	29.	0.064	29.	8.932	7.849
64	3	4	46.9	29.	21.1	29.	0.063	29.	8.943	7.774
65	3	5	47.2	29.	21.2	29.	0.060	29.	8.899	7.728
66	3	6	47.4	29.	21.3	29.	0.055	29.	8.862	7.673
67	3	7	47.7	29.	21.5	29.	0.054	29.	8.918	7.654
68	3	8	48.0	29.	21.6	29.	0.054	29.	8.972	7.539
69	3	9	48.3	29.	21.8	29.	0.054	29.	9.023	7.477
70	3	10	48.5	29.	22.0	29.	0.053	29.	8.996	7.447
71	3	11	48.7	29.	22.2	29.	0.053	29.	8.987	7.346
72	3	12	48.9	29.	22.4	29.	0.054	29.	8.939	7.291
73	3	13	49.0	29.	22.6	29.	0.057	29.	8.971	7.143
74	3	14	49.1	29.	22.7	29.	0.059	29.	9.013	7.099
75	3	15	49.0	29.	22.7	29.	0.061	29.	9.135	6.989
76	3	16	49.2	29.	22.7	29.	0.056	29.	9.108	7.005
77	3	17	49.5	29.	22.7	29.	0.052	29.	9.122	6.953
78	3	18	49.6	29.	22.8	29.	0.050	29.	9.133	6.869
79	3	19	49.8	29.	22.8	29.	0.052	29.	9.188	6.882
80	3	20	50.1	29.	22.9	29.	0.049	29.	9.258	6.780
81	3	21	50.3	29.	23.0	29.	0.046	29.	9.276	6.721
82	3	22	50.6	29.	23.2	29.	0.045	29.	9.368	6.687
83	3	23	50.9	29.	23.4	29.	0.045	29.	9.415	6.662
84	3	24	51.2	29.	23.5	29.	0.044	29.	9.523	6.717
85	3	25	51.5	29.	23.6	29.	0.043	29.	9.632	6.743
86	3	26	51.8	29.	23.6	29.	0.042	29.	9.660	6.736
87	3	27	52.2	29.	23.8	29.	0.040	28.	9.638	6.686
88	3	28	52.5	29.	24.0	29.	0.040	28.	9.682	6.634
89	3	29	52.8	29.	24.1	29.	0.038	29.	9.743	6.599
90	3	30	53.1	29.	24.3	29.	0.038	29.	9.767	6.652
91	3	31	53.4	29.	24.4	29.	0.039	29.	9.778	6.639
92	4	1	53.6	30.	24.7	30.	0.039	30.	9.794	6.556
93	4	2	54.0	30.	24.8	30.	0.040	30.	9.842	6.511
94	4	3	54.3	30.	25.0	30.	0.040	30.	9.927	6.474
95	4	4	54.5	30.	25.2	30.	0.041	30.	9.968	6.459
96	4	5	54.7	30.	25.4	30.	0.041	30.	9.963	6.429
97	4	6	54.9	30.	25.6	30.	0.040	30.	9.971	6.451
98	4	7	55.1	30.	25.8	30.	0.040	30.	9.989	6.443
99	4	8	55.4	30.	26.0	30.	0.040	30.	9.982	6.390
100	4	9	55.7	30.	26.2	30.	0.041	30.	9.966	6.342
101	4	10	56.0	30.	26.4	30.	0.040	30.	9.956	6.275
102	4	11	56.5	30.	26.6	30.	0.035	30.	9.869	6.252
103	4	12	56.8	30.	26.8	30.	0.033	30.	9.873	6.227
104	4	13	57.3	30.	27.0	30.	0.031	30.	9.800	6.238
105	4	14	57.8	30.	27.4	30.	0.031	30.	9.805	6.203
106	4	15	58.2	30.	27.7	30.	0.032	30.	9.784	6.195
107	4	16	58.7	30.	27.9	30.	0.031	30.	9.790	6.167
108	4	17	59.1	30.	28.2	30.	0.029	30.	9.742	6.038
109	4	18	59.6	30.	28.5	30.	0.029	30.	9.618	5.992
110	4	19	60.0	30.	28.8	30.	0.029	30.	9.492	5.959
111	4	20	60.4	30.	29.0	30.	0.029	30.	9.367	5.909

112	4	21	60.6	30.	29.2	30.	0.030	30.	9.301	5.878
113	4	22	60.8	30.	29.5	30.	0.031	30.	9.250	5.898
114	4	23	61.0	30.	29.7	30.	0.030	30.	9.196	5.851
115	4	24	61.2	30.	29.9	30.	0.029	30.	9.137	5.847
116	4	25	61.5	30.	30.1	30.	0.030	30.	9.055	5.845
117	4	26	61.8	30.	30.3	30.	0.030	30.	8.988	5.773
118	4	27	62.1	30.	30.4	30.	0.030	30.	8.941	5.773
119	4	28	62.5	30.	30.7	30.	0.029	30.	8.904	5.713
120	4	29	62.8	30.	30.9	30.	0.027	30.	8.876	5.688
121	4	30	63.2	30.	31.1	30.	0.029	30.	8.865	5.647
122	5	1	63.5	30.	31.4	30.	0.028	30.	8.766	5.632
123	5	2	63.7	30.	31.5	30.	0.028	30.	8.690	5.605
124	5	3	64.0	30.	31.7	30.	0.028	30.	8.607	5.594
125	5	4	64.4	30.	31.9	30.	0.027	30.	8.458	5.572
126	5	5	64.8	30.	32.1	30.	0.027	30.	8.329	5.548
127	5	6	65.0	30.	32.3	30.	0.027	30.	8.210	5.564
128	5	7	65.3	30.	32.5	30.	0.027	30.	8.211	5.619
129	5	8	65.6	30.	32.6	30.	0.027	30.	8.178	5.684
130	5	9	65.9	30.	32.8	30.	0.025	30.	8.142	5.689
131	5	10	66.2	30.	33.1	30.	0.028	30.	8.116	5.654
132	5	11	66.5	30.	33.3	30.	0.030	30.	8.044	5.604
133	5	12	66.8	30.	33.6	30.	0.030	30.	7.997	5.535
134	5	13	67.1	30.	33.8	30.	0.031	30.	7.953	5.468
135	5	14	67.3	30.	34.0	30.	0.032	30.	7.954	5.440
136	5	15	67.6	30.	34.2	30.	0.031	30.	7.970	5.393
137	5	16	67.9	30.	34.4	30.	0.030	30.	7.937	5.410
138	5	17	68.1	29.	34.6	29.	0.032	30.	7.983	5.438
139	5	18	68.3	30.	34.8	30.	0.032	30.	8.055	5.440
140	5	19	68.6	30.	35.0	30.	0.033	30.	8.055	5.469
141	5	20	68.9	30.	35.2	30.	0.033	30.	8.040	5.444
142	5	21	69.4	30.	35.4	30.	0.032	30.	7.964	5.370
143	5	22	69.8	30.	35.8	30.	0.032	30.	7.898	5.346
144	5	23	70.1	30.	36.0	30.	0.032	30.	7.848	5.344
145	5	24	70.4	30.	36.3	30.	0.032	30.	7.877	5.347
146	5	25	70.7	30.	36.5	30.	0.032	30.	7.912	5.397
147	5	26	71.0	30.	36.8	30.	0.031	30.	7.849	5.381
148	5	27	71.3	30.	37.0	30.	0.032	30.	7.763	5.368
149	5	28	71.6	30.	37.1	30.	0.032	30.	7.681	5.359
150	5	29	71.8	30.	37.4	29.	0.029	30.	7.549	5.361
151	5	30	72.1	30.	37.5	30.	0.029	30.	7.517	5.364
152	5	31	72.5	29.	37.8	29.	0.029	30.	7.499	5.418
153	6	1	72.9	30.	38.0	30.	0.027	30.	7.475	5.417
154	6	2	73.3	30.	38.3	30.	0.028	30.	7.464	5.444
155	6	3	73.6	30.	38.5	30.	0.027	30.	7.468	5.452
156	6	4	74.0	30.	38.8	30.	0.026	30.	7.460	5.442
157	6	5	74.4	30.	39.0	30.	0.025	30.	7.382	5.411
158	6	6	74.7	30.	39.3	30.	0.025	30.	7.279	5.419
159	6	7	75.1	30.	39.5	30.	0.026	30.	7.189	5.413
160	6	8	75.4	30.	39.7	30.	0.024	30.	7.098	5.403
161	6	9	75.8	30.	40.0	30.	0.021	30.	6.977	5.366
162	6	10	76.3	30.	40.3	30.	0.021	30.	6.868	5.334
163	6	11	76.6	30.	40.5	30.	0.020	30.	6.798	5.357
164	6	12	76.9	30.	40.8	30.	0.019	30.	6.719	5.387
165	6	13	77.3	30.	41.0	30.	0.018	30.	6.575	5.427
166	6	14	77.7	30.	41.4	30.	0.018	30.	6.463	5.429
167	6	15	78.1	30.	41.7	30.	0.016	30.	6.353	5.365
168	6	16	78.4	30.	42.0	30.	0.016	30.	6.236	5.388
169	6	17	78.8	30.	42.2	30.	0.015	30.	6.200	5.411
170	6	18	79.1	30.	42.5	30.	0.015	30.	6.121	5.415
171	6	19	79.3	29.	42.7	30.	0.015	30.	6.043	5.429

172	6	20	79.6	28.	42.9	30.	0.015	30.	5.992	5.415
173	6	21	80.0	29.	43.1	30.	0.015	30.	5.972	5.376
174	6	22	80.3	29.	43.4	30.	0.015	30.	5.893	5.331
175	6	23	80.7	29.	43.7	30.	0.015	30.	5.768	5.308
176	6	24	81.0	29.	44.1	30.	0.015	30.	5.737	5.299
177	6	25	81.2	29.	44.4	30.	0.016	30.	5.701	5.301
178	6	26	81.5	29.	44.7	30.	0.016	30.	5.619	5.239
179	6	27	81.7	29.	45.0	30.	0.017	30.	5.578	5.257
180	6	28	81.9	30.	45.2	30.	0.019	30.	5.519	5.237
181	6	29	82.1	30.	45.6	30.	0.020	30.	5.460	5.145
182	6	30	82.3	30.	45.9	29.	0.022	30.	5.388	5.124
183	7	1	82.5	30.	46.2	30.	0.022	30.	5.349	5.105
184	7	2	82.7	30.	46.5	30.	0.023	30.	5.308	5.055
185	7	3	82.8	30.	46.8	30.	0.023	30.	5.250	5.016
186	7	4	83.0	30.	47.1	30.	0.023	30.	5.255	4.965
187	7	5	83.1	29.	47.3	29.	0.024	29.	5.269	4.972
188	7	6	83.1	29.	47.5	29.	0.026	29.	5.310	4.979
189	7	7	83.2	29.	47.7	29.	0.027	29.	5.367	4.962
190	7	8	83.2	29.	47.9	29.	0.028	30.	5.421	4.981
191	7	9	83.2	29.	48.1	29.	0.029	30.	5.428	4.974
192	7	10	83.3	29.	48.3	29.	0.031	30.	5.413	4.910
193	7	11	83.4	29.	48.5	29.	0.034	30.	5.357	4.800
194	7	12	83.4	29.	48.6	29.	0.035	30.	5.336	4.747
195	7	13	83.4	29.	48.8	29.	0.038	30.	5.294	4.679
196	7	14	83.4	30.	48.9	29.	0.040	30.	5.320	4.660
197	7	15	83.4	30.	49.0	30.	0.042	30.	5.374	4.593
198	7	16	83.4	30.	49.2	30.	0.044	30.	5.407	4.490
199	7	17	83.4	30.	49.4	30.	0.045	30.	5.422	4.453
200	7	18	83.5	30.	49.5	30.	0.046	30.	5.408	4.393
201	7	19	83.5	30.	49.6	30.	0.048	30.	5.374	4.327
202	7	20	83.5	30.	49.7	30.	0.049	30.	5.334	4.275
203	7	21	83.4	30.	49.8	30.	0.049	30.	5.326	4.257
204	7	22	83.4	30.	49.7	29.	0.049	30.	5.297	4.237
205	7	23	83.4	30.	49.7	30.	0.049	30.	5.241	4.205
206	7	24	83.4	30.	49.8	30.	0.049	30.	5.204	4.182
207	7	25	83.4	30.	49.8	30.	0.050	30.	5.203	4.199
208	7	26	83.4	30.	49.8	30.	0.051	30.	5.170	4.156
209	7	27	83.4	30.	49.8	30.	0.053	30.	5.172	4.121
210	7	28	83.3	30.	49.8	30.	0.052	30.	5.191	4.122
211	7	29	83.2	30.	49.8	30.	0.054	30.	5.202	4.096
212	7	30	83.1	30.	49.7	30.	0.056	30.	5.222	4.050
213	7	31	83.0	30.	49.7	30.	0.056	30.	5.210	4.065
214	8	1	82.9	30.	49.7	30.	0.057	30.	5.234	4.078
215	8	2	82.8	30.	49.6	30.	0.058	30.	5.201	4.131
216	8	3	82.7	30.	49.5	30.	0.058	30.	5.166	4.108
217	8	4	82.6	30.	49.5	30.	0.059	30.	5.141	4.120
218	8	5	82.5	30.	49.4	30.	0.058	30.	5.117	4.118
219	8	6	82.4	30.	49.4	30.	0.057	30.	5.054	4.088
220	8	7	82.3	30.	49.3	30.	0.058	30.	5.037	4.089
221	8	8	82.2	30.	49.3	30.	0.059	30.	4.991	4.092
222	8	9	82.1	29.	49.2	29.	0.057	30.	5.004	4.144
223	8	10	81.9	29.	49.2	29.	0.058	30.	5.040	4.193
224	8	11	81.8	29.	49.1	29.	0.057	30.	5.080	4.242
225	8	12	81.6	29.	48.9	29.	0.055	30.	5.055	4.323
226	8	13	81.5	29.	48.8	29.	0.054	30.	4.999	4.393
227	8	14	81.4	29.	48.6	29.	0.053	30.	4.925	4.469
228	8	15	81.3	29.	48.5	29.	0.052	30.	4.901	4.462
229	8	16	81.1	29.	48.4	29.	0.053	30.	4.957	4.497
230	8	17	80.9	29.	48.3	29.	0.052	30.	5.002	4.534
231	8	18	80.8	29.	48.1	29.	0.052	30.	5.002	4.569

232	8	19	80.6	29.	48.0	29.	0.052	30.	4.983	4.626
233	8	20	80.5	29.	47.9	29.	0.052	30.	5.014	4.637
234	8	21	80.3	29.	47.8	29.	0.051	30.	5.018	4.650
235	8	22	80.1	29.	47.6	29.	0.053	30.	5.031	4.656
236	8	23	79.8	29.	47.5	29.	0.054	30.	5.109	4.664
237	8	24	79.6	29.	47.3	29.	0.054	30.	5.199	4.702
238	8	25	79.4	29.	47.2	29.	0.053	30.	5.205	4.751
239	8	26	79.2	29.	47.0	29.	0.052	30.	5.179	4.763
240	8	27	79.0	29.	46.9	29.	0.051	30.	5.215	4.764
241	8	28	78.7	29.	46.7	29.	0.053	30.	5.274	4.801
242	8	29	78.5	29.	46.4	29.	0.054	30.	5.339	4.839
243	8	30	78.3	29.	46.1	29.	0.053	30.	5.377	4.883
244	8	31	78.1	29.	45.8	29.	0.053	30.	5.405	4.922
245	9	1	77.9	29.	45.6	29.	0.054	30.	5.451	4.942
246	9	2	77.8	29.	45.4	29.	0.053	30.	5.470	4.911
247	9	3	77.6	29.	45.1	29.	0.052	30.	5.471	4.947
248	9	4	77.3	29.	44.9	29.	0.052	30.	5.534	4.992
249	9	5	77.1	29.	44.5	29.	0.053	30.	5.604	5.072
250	9	6	76.8	29.	44.2	29.	0.052	30.	5.698	5.106
251	9	7	76.5	29.	43.8	29.	0.050	30.	5.716	5.110
252	9	8	76.3	29.	43.5	29.	0.048	30.	5.679	5.078
253	9	9	76.0	29.	43.3	29.	0.049	30.	5.651	5.080
254	9	10	75.8	29.	43.0	29.	0.050	30.	5.721	5.058
255	9	11	75.5	29.	42.7	29.	0.050	30.	5.840	5.063
256	9	12	75.2	29.	42.5	29.	0.051	30.	5.920	5.065
257	9	13	74.8	29.	42.2	29.	0.052	30.	6.013	5.076
258	9	14	74.5	29.	41.9	30.	0.050	30.	6.068	5.097
259	9	15	74.2	30.	41.5	30.	0.050	30.	6.105	5.141
260	9	16	74.0	29.	41.2	30.	0.052	30.	6.198	5.154
261	9	17	73.7	29.	41.0	29.	0.052	30.	6.313	5.176
262	9	18	73.4	29.	40.7	29.	0.054	30.	6.393	5.207
263	9	19	73.0	29.	40.4	29.	0.055	30.	6.507	5.176
264	9	20	72.7	29.	40.1	29.	0.054	30.	6.606	5.169
265	9	21	72.5	29.	39.8	29.	0.052	30.	6.643	5.174
266	9	22	72.2	29.	39.4	29.	0.051	30.	6.700	5.216
267	9	23	71.9	30.	39.1	29.	0.050	30.	6.753	5.224
268	9	24	71.5	30.	38.8	30.	0.049	30.	6.822	5.310
269	9	25	71.3	30.	38.4	30.	0.047	30.	6.905	5.379
270	9	26	71.1	30.	38.2	30.	0.044	30.	6.954	5.361
271	9	27	70.8	30.	37.9	30.	0.045	30.	7.018	5.341
272	9	28	70.5	30.	37.7	30.	0.047	30.	7.110	5.349
273	9	29	70.2	30.	37.5	29.	0.047	30.	7.184	5.312
274	9	30	69.9	30.	37.3	30.	0.045	30.	7.251	5.308
275	10	1	69.5	30.	37.0	30.	0.045	30.	7.380	5.371
276	10	2	69.1	30.	36.7	30.	0.047	30.	7.549	5.416
277	10	3	68.8	30.	36.3	30.	0.046	30.	7.665	5.376
278	10	4	68.5	30.	36.1	30.	0.043	30.	7.764	5.346
279	10	5	68.2	30.	35.8	29.	0.044	30.	7.812	5.385
280	10	6	67.9	30.	35.6	30.	0.045	30.	7.936	5.436
281	10	7	67.5	30.	35.3	30.	0.048	29.	8.089	5.469
282	10	8	67.1	30.	35.0	30.	0.047	29.	8.191	5.484
283	10	9	66.7	30.	34.7	30.	0.047	29.	8.233	5.537
284	10	10	66.3	30.	34.4	30.	0.048	28.	8.260	5.585
285	10	11	65.8	30.	34.1	30.	0.048	29.	8.347	5.590
286	10	12	65.4	30.	33.8	30.	0.047	30.	8.421	5.633
287	10	13	64.9	30.	33.5	30.	0.049	30.	8.515	5.605
288	10	14	64.4	30.	33.2	30.	0.052	30.	8.631	5.598
289	10	15	63.9	30.	32.9	30.	0.051	30.	8.797	5.678
290	10	16	63.2	30.	32.6	30.	0.053	30.	8.945	5.754
291	10	17	62.7	30.	32.2	30.	0.052	30.	9.029	5.830

292	10	18	62.1	30.	31.8	30.	0.052	30.	9.048	5.940
293	10	19	61.6	30.	31.5	30.	0.057	30.	9.120	5.985
294	10	20	61.1	30.	31.2	30.	0.057	30.	9.230	6.037
295	10	21	60.8	30.	30.8	30.	0.055	30.	9.272	6.042
296	10	22	60.4	30.	30.6	30.	0.054	30.	9.323	6.049
297	10	23	60.0	30.	30.2	30.	0.054	30.	9.394	6.022
298	10	24	59.5	30.	29.9	30.	0.055	30.	9.408	6.005
299	10	25	59.0	30.	29.6	30.	0.057	30.	9.422	6.008
300	10	26	58.5	30.	29.3	30.	0.056	30.	9.450	6.062
301	10	27	58.1	30.	28.9	30.	0.055	30.	9.448	6.071
302	10	28	57.6	30.	28.6	30.	0.057	30.	9.555	6.089
303	10	29	57.2	30.	28.4	30.	0.060	30.	9.645	6.101
304	10	30	56.7	30.	28.0	30.	0.059	30.	9.671	6.172
305	10	31	56.2	29.	27.7	29.	0.058	30.	9.667	6.197
306	11	1	55.7	30.	27.4	30.	0.058	30.	9.672	6.263
307	11	2	55.2	30.	27.1	30.	0.057	30.	9.683	6.303
308	11	3	54.7	30.	26.8	30.	0.057	30.	9.752	6.355
309	11	4	54.2	30.	26.5	30.	0.059	30.	9.765	6.354
310	11	5	53.7	30.	26.1	30.	0.057	30.	9.810	6.431
311	11	6	53.2	30.	25.7	30.	0.056	30.	9.900	6.482
312	11	7	52.7	30.	25.3	30.	0.056	30.	9.951	6.483
313	11	8	52.3	30.	25.0	30.	0.054	30.	9.948	6.515
314	11	9	51.8	30.	24.7	30.	0.053	30.	9.921	6.585
315	11	10	51.4	30.	24.3	30.	0.051	30.	9.923	6.581
316	11	11	51.0	30.	24.0	30.	0.051	30.	9.907	6.647
317	11	12	50.6	30.	23.8	30.	0.049	30.	9.910	6.708
318	11	13	50.2	30.	23.4	30.	0.048	30.	9.812	6.722
319	11	14	49.8	30.	23.1	30.	0.047	30.	9.685	6.683
320	11	15	49.5	30.	22.8	30.	0.046	30.	9.662	6.663
321	11	16	49.1	30.	22.5	30.	0.047	29.	9.647	6.713
322	11	17	48.8	30.	22.2	30.	0.041	30.	9.590	6.736
323	11	18	48.5	30.	21.9	30.	0.040	30.	9.521	6.720
324	11	19	48.1	30.	21.6	30.	0.041	30.	9.535	6.680
325	11	20	47.7	30.	21.3	30.	0.041	30.	9.557	6.699
326	11	21	47.4	30.	21.1	30.	0.041	30.	9.556	6.761
327	11	22	47.0	30.	20.8	30.	0.041	30.	9.598	6.851
328	11	23	46.7	30.	20.6	30.	0.037	30.	9.668	6.932
329	11	24	46.3	30.	20.3	30.	0.039	29.	9.697	6.961
330	11	25	46.0	30.	20.0	30.	0.038	29.	9.724	7.043
331	11	26	45.7	30.	19.8	30.	0.036	29.	9.707	7.162
332	11	27	45.3	30.	19.6	30.	0.032	30.	9.682	7.258
333	11	28	45.0	30.	19.4	30.	0.034	30.	9.610	7.353
334	11	29	44.7	30.	19.3	30.	0.033	30.	9.614	7.361
335	11	30	44.5	30.	19.0	30.	0.033	30.	9.548	7.371
336	12	1	44.3	29.	18.8	29.	0.033	29.	9.487	7.432
337	12	2	44.2	29.	18.6	29.	0.033	29.	9.477	7.421
338	12	3	44.1	29.	18.5	29.	0.030	29.	9.489	7.449
339	12	4	44.0	29.	18.4	29.	0.033	29.	9.395	7.421
340	12	5	43.7	29.	18.4	29.	0.034	29.	9.338	7.407
341	12	6	43.5	29.	18.3	29.	0.034	29.	9.299	7.457
342	12	7	43.3	29.	18.1	29.	0.034	29.	9.316	7.545
343	12	8	43.0	29.	17.8	29.	0.035	29.	9.333	7.656
344	12	9	42.7	29.	17.6	29.	0.038	29.	9.335	7.819
345	12	10	42.4	29.	17.3	29.	0.036	29.	9.308	7.954
346	12	11	42.2	29.	17.1	29.	0.038	29.	9.285	8.017
347	12	12	42.2	29.	16.9	29.	0.038	29.	9.254	8.057
348	12	13	42.2	29.	16.9	29.	0.039	29.	9.253	8.105
349	12	14	42.0	29.	16.9	29.	0.041	29.	9.244	8.117
350	12	15	41.9	29.	16.8	29.	0.039	29.	9.265	8.142
351	12	16	41.7	29.	16.7	29.	0.041	29.	9.310	8.262

352	12	17	41.5	29.	16.6	29.	0.041	29.	9.369	8.394
353	12	18	41.2	29.	16.4	29.	0.041	29.	9.391	8.542
354	12	19	40.8	29.	16.2	29.	0.041	29.	9.378	8.713
355	12	20	40.5	29.	15.9	29.	0.043	29.	9.392	8.821
356	12	21	40.3	29.	15.8	29.	0.045	28.	9.374	8.926
357	12	22	40.1	29.	15.7	29.	0.049	29.	9.317	9.024
358	12	23	39.9	29.	15.6	29.	0.049	29.	9.284	9.112
359	12	24	39.8	29.	15.4	28.	0.051	29.	9.230	9.152
360	12	25	39.6	29.	15.2	29.	0.052	29.	9.168	9.160
361	12	26	39.5	29.	15.1	29.	0.052	29.	9.149	9.142
362	12	27	39.5	29.	15.1	29.	0.053	29.	9.164	9.105
363	12	28	39.5	29.	15.0	29.	0.054	29.	9.091	9.057
364	12	29	39.5	29.	15.1	29.	0.055	29.	9.108	9.111
365	12	30	39.4	29.	15.1	29.	0.057	29.	9.123	9.081
366	12	31	39.4	29.	15.1	29.	0.060	29.	9.114	9.088

Western Regional Climate Center, wrcc@dri.edu

ALTON, UTAH

NCDC 1971-2000 Monthly Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Monthly
Mean Max. Temperature (F)	40.0	42.9	48.6	58.1	68.0	78.6	84.0	81.7	74.9	64.2	50.2	42.1	61.1
Highest Mean Max. Temperature (F)	49.4	50.8	60.0	67.2	75.5	85.0	89.0	85.9	80.1	71.6	59.3	51.7	89.0
Year Highest Occurred	1986	1995	1972	1989	1984	1974	1972	1994	1979	1988	1995	1980	1972
Lowest Mean Max. Temperature (F)	30.8	36.2	41.2	48.1	60.7	72.1	79.5	78.1	69.7	56.9	41.3	32.6	30.8
Year Lowest Occurred	1979	1998	1973	1983	1977	1993	1993	1983	1986	1972	1994	1992	1979
Mean Temperature (F)	27.9	30.5	35.6	43.0	51.2	60.3	66.6	65.1	58.2	48.4	36.4	29.5	46.1
Highest Mean Temperature (F)	36.0	37.1	43.2	49.8	56.6	65.0	69.9	68.7	62.0	54.7	42.7	37.8	69.9
Year Highest Occurred	1986	1995	1972	1992	1984	1974	1996	1994	1979	1988	1995	1980	1996
Lowest Mean Temperature (F)	20.0	25.0	29.7	35.2	46.3	55.0	60.8	62.2	53.4	43.2	29.3	21.0	20.0
Year Lowest Occurred	1979	1993	1980	1975	1977	1993	1993	1976	1986	1984	1994	1990	1979
Mean Min. Temperature (F)	15.7	18.1	22.6	27.8	34.4	41.9	49.2	48.4	41.4	32.6	22.6	16.8	31.0
Highest Mean Min. Temperature (F)	22.5	23.5	28.2	33.2	38.4	45.2	53.3	51.9	46.3	37.7	26.3	23.9	53.3
Year Highest Occurred	1986	1991	1986	1992	1992	1994	1996	2000	1997	1988	1996	1980	1996
Lowest Mean Min. Temperature (F)	8.9	11.3	16.8	21.4	30.8	36.8	42.1	44.2	37.2	28.3	17.2	6.9	6.9
Year Lowest Occurred	1973	1979	1977	1975	1975	1998	1993	1976	1986	1982	1994	1990	1990
Mean Precipitation (in.)	1.76	1.90	1.75	0.95	0.97	0.51	1.34	1.62	1.53	1.59	1.40	1.19	16.51
Highest Precipitation (in.)	7.32	5.88	4.38	3.90	2.96	1.61	3.18	3.59	5.21	4.93	5.72	4.85	7.32
Year Highest Occurred	1993	1993	1978	1988	1992	1972	1999	1987	1997	2000	1978	1971	1993
Lowest Precipitation (in.)	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.03	0.00	0.11	0.00	0.00
Year Lowest													

Occurred	1976	1972	1997	1993	1972	1979	1993	1985	1989	1999	1980	1989	1976
Heating Degree Days (F)	1152.	966.	911.	661.	429.	174.	45.	60.	211.	516.	858.	1103.	7086.
Cooling Degree Days (F)	0.	0.	0.	0.	1.	31.	93.	60.	5.	0.	0.	0.	190.

Western Regional Climate Center, wrcc@dri.edu

ALTON, UTAH (420086)

1971-2000 Monthly Climate Summary

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	40.5	43.7	49.6	58.3	67.9	78.0	83.3	80.9	74.1	63.2	48.0	41.5	60.9
Average Min. Temperature (F)	15.9	18.4	22.6	27.8	34.5	41.8	48.8	48.2	41.4	32.4	22.1	16.7	31.0
Average Total Precipitation (in.)	1.81	1.97	1.59	1.01	0.93	0.59	1.25	1.69	1.51	1.60	1.37	1.32	16.62

Unofficial values based on averages/sums of smoothed daily data. Information is computed from available daily data during the 1971-2000 period. Smoothing, missing data and observation-time changes may cause these 1971-2000 values to differ from official NCDC values. This table is presented for use at locations that don't have official NCDC data. No adjustments are made for missing data or time of observation. Check NCDC normals table for official data.

Western Regional Climate Center, wrcc@dri.edu

CHAPTER 8

BONDING AND INSURANCE

R645-301-800

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R645-301-800

Bonding and Insurance

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Bonding and Insurance

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8-1	Preliminary Cost Estimates and Calculations

DRAWING No.	DESCRIPTION
None	

CHAPTER 8

R645-301-800. BONDING AND INSURANCE

820. REQUIREMENT TO FILE A BOND

820.100 The Operator Agrees to File a Bond.

After the permit application is approved, but before the permit is issued, the applicant will file with the Division, on a form prescribed and furnished by the Division, a bond or bonds conditioned upon performance of all requirements of the State Program, the permit and the reclamation bond.

820.110-111 Area to be Covered by the Performance Bond

The disturbed area at the Coal Hollow Project will be bonded. The disturbed areas are identified on Drawing 5-3. The area to be mined is also identified on Drawing 5-3.

820.112-114 Incremental Bonding

Not applicable at this time.

820.120 Acceptance of Bond

The applicant agrees not to commence operations until the Division approves a performance bond for the Coal Hollow Project.

820.130 Coverage of Bond

The applicant will provide a performance bond for the disturbed area within the permit.

820.200 Form of the Performance Bond

820.223 Surety Bond

Alton Coal Development, LLC is proposing to submit a surety bond consistent with the requirements of R645-301-860.100 and any additional requirements in the State Program.

830. DETERMINATION OF BOND AMOUNT

830.100 Determined by the Division

The amount of the bond required will be determined by the Division.

830.140 Detailed Estimated Costs

The bonding amount for final reclamation will depend upon the ***approved*** permit and reclamation plan (R645-301-830.120). As a preliminary estimate, costs for final reclamation are listed in Appendix 8-1. These cost calculations are for the disturbed area boundaries provided in the proposed plan in this application. For this preliminary evaluation, final reclamation has been estimated at $6,172,000 as shown in Appendix 8-1.

A revised bond estimate will be provided by the applicant to the Division following completion of the ***approved*** permit and reclamation plan.

840. GENERAL TERMS AND CONDITIONS OF THE BOND

General terms and conditions of the bond as stated at R645-301-840 through R645-301-840.520 will be met by Alton Coal Development, LLC

850. BOND REQUIREMENTS FOR UNDERGROUND COAL MINING

Not Applicable

860. FORM OF BOND

860.100 Surety Bond

The applicant will submit a surety bond as defined under R645-100-200 and meet all the requirements under R645-301-860.110 to .120.

870. REPLACEMENT OF BONDS

Equivalent bond coverage will be provided if Alton Coal Development, LLC replaces the surety bond.

880. REQUIREMENT TO RELEASE PERFORMANCE BONDS

Upon completion of reclamation operations, the applicant will apply for bond release and meet the requirements of R645-301-880.

890. TERMS AND CONDITIONS FOR LIABILITY INSURANCE

890.100 Certificate of Liability Insurance

A copy of the Certificate of Liability Insurance is provided in Appendix 1-3. Alton Coal Development, LLC will meet the requirements of R645-301-890 prior to commencing any mining operations.

APPENDIX 8-1

PRELIMINARY COST ESTIMATE
And CALCULATIONS
COAL HOLLOW MINE

Initial Estimate By: John T. Boyd Company
Updated (7-18-07) By: Alton Coal Development, LLC

BONDING

Introduction

The purpose of this section is to provide a preliminary reclamation cost estimate. The final bond estimate will depend upon the approved permit and reclamation plan (R645-301-820.120). Therefore, a final bond estimate will be provided by the applicant to the Division following completion of the approved plan.

The calculation of reclamation costs is intended to conform to "Handbook for Calculation of Reclamation Bond Amounts" published by the US Office of Surface Mining. That handbook provides a series of Worksheets used to perform the calculation. This calculation follows that same worksheet format and numbering system. Attached to this introduction are the following worksheets:

Worksheet 1 - Description of the Worst Case Reclamation Scenario
Worksheet 2 - Structure Demolition and Disposal Costs
Worksheet 3 - Material Handling Plan Summary
Worksheet 4 - Earthwork Quantity
Worksheet 5A - Equipment Productivity - Remove Ponds
Worksheet 5B - Equipment Productivity - D10R - Remove Ponds
Worksheet 5C - Equipment Productivity - Backfill Pit from Excess Spoil
Worksheet 5D - Equipment Productivity - Loader/Truck Backfill Pit from Excess Spoil
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Worksheet 5I - Equipment Productivity - Subsoil Replacement
Worksheet 5J - Equipment Productivity - Loader/Truck Subsoil Replacement
Worksheet 6A - Grading Requirements Haulroads, Facilities, Spoil, Topsoil
Worksheet 6B - Equipment Productivity - Grading & Ripping
Worksheet 7 - Summary Calculation of Earthmoving Costs
Worksheet 8 - Revegetation Costs
Worksheet 9 - Reclamation Bond Summary Sheet

Worksheet 1
Description of the Worst Case Reclamation Scenario

The "Worst Case" reclamation scenario occurs at the point during the permit term when the reclamation liabilities would be the highest. The determination of that point is based on the mining plans and material movement requirements, as well as the status of infrastructure and facilities. As with most truck/shovel mines, the major reclamation cost is pit backfilling and reclamation, and the "Worst Case" reclamation scenario occurs at the time when the largest pit void exists creating the largest backfilling requirements. At the Coal Hollow Mine, this will occur at the end of the mining process when the final pits (in the NE ¼ NE ¼ of Section 30) are fully open.

Structure Demolition:

The support facilities will be located at the north end of the permit area in the E ½ SE ¼ of Section 19. The facilities area covers approximately 29 acres. When returning the site to the post-mining land use, all structures not required for the post-mining land use will be removed. The facilities will generally be constructed of concrete and steel and will be demolished and the demolition debris hauled offsite to an approved disposal facility or properly disposed in the final pits. The coal stockpile pad will be excavated and the material buried in the final pit.

Earthmoving Activities:

Mining operations are conducted such that most of the spoil from the active pit is hauled to the previous mined-out pit which is backfilled and reclaimed. Thus, at any one time some portions of the planned mining area will have been mined and backfilled, some portions will have not been disturbed as yet, and some portion will be open and active. The worst-case reclamation scenario occurs when the active pit is at it's greatest extent. At Coal Hollow this occurs during the final phase of the mine plan when the final pits are fully open. The worst case scenario in this situation will be the Alternate scenario of final reclamation as provided in Chapter 5. This scenario assumes that Alton Coal Development, LLC is not successful with acquiring the adjacent federal coal reserves. In this situation, the variation from approximate original contour and part of the excess spoil structure will be rehandled to fill these final pits (refer to Drawings 5-19 and 5-37).

The main haulroad is located on the east side of the mining area and covers about 15 acres. The haulroad will be constructed with overburden material and surfaced with crushed rock. Since the slope along the haulroad from north to south is gradual, no significant cuts or fills are required. Road material will be removed and disposed of in the open pits or ramps using the truck and shovel fleet.

The "worst case" mining pit void will be about 75 feet deep (measured from the planned post-mining surface). The void volume was determined by superimposing the pit design including spoil slopes, sidewalls and pit advance wall slopes, over the planned post

mining contours using Carlson Software's SurvCADD software. (This phase can be viewed in Drawing 5-19).

Reclamation of the facilities area will require the removal of contaminated material where applicable. The material will be disposed of and buried in the open pit. All sediment ponds, diversion ditches, and berms will be removed during this same time frame.

Topsoil Replacement:

Suitable topsoil will be removed from the areas to be disturbed prior to that disturbance as specified in Chapter 2. Initially, the topsoil will be placed in stockpiles, however as mining progresses, the topsoil removed from ahead of the pit will be placed on mined over areas as part of normal reclamation. At the time of the "worst case" reclamation scenario, sufficient topsoil and subsoil will exist in stockpiles in the permit area to reclaim the pit area, roads facilities area and other disturbed zones. The stockpiled topsoil will be used to cover all areas where topsoil has been removed but not replaced. Subsoil will be separate layer below the topsoil placed over areas that have been mined. All topsoil will be graded in preparation for seeding.

Revegetation:

The worst-case reclamation situation is estimated to occur during the third year of mining. Seeding will occur during appropriate seasons, generally in the fall and spring. Depending on the timing of this final phase, seeding may be delayed to meet the appropriate seasonal weather conditions.

No prime farmland has been identified in the mining area.

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Worksheet 2
Structure Demolition and Disposal Costs

Structures to be demolished

Item	Construction Material	Volume (cuft)	Unit Cost Basis ($)	Demolition Cost ($)
Office (footers only)	Concrete	750	14.60	$ 10,950
Shop	Concrete	30,000	6.30	$ 189,000
Wash Bay	Concrete	7,000	6.30	$ 44,100
Fuel Storage	Concrete	3,000	6.30	$ 18,900
Oil Storage	Concrete	5,000	6.30	$ 31,500
Coal Hopper/Transfer	Concrete	48,000	6.30	$ 302,400
Coal Crusher (footers only)	Concrete	300	14.60	$ 4,380
Coal Conveyors and Tower	Concrete	5,000	14.60	$ 73,000
Reclaim Tunnel	Concrete	42,000	6.30	$ 264,600
Coal Loadout	Concrete	900	6.30	$ 5,670
Subtotal				$ 944,500
Item	Construction Material	Volume (cuft)	Unit Cost Basis ($)	Demolition Cost ($)
Shop	Steel	1,000,000	0.26	$ 260,000
Office	Steel	315,000	0.26	$ 81,900
Wash Bay	Steel	150,000	0.26	$ 39,000
Fuel Storage (3 tanks)	Steel	2,111	0.26	$ 549
Oil Storage (5 tanks)	Steel	628	0.26	$ 163
Coal Hopper	Steel	3,400	0.26	$ 884
Coal Crusher	Steel	16,000	0.26	$ 4,160
Reclaim Tunnel	Steel	14,240	0.26	$ 3,702
Coal Loadout	Steel	10,400	0.26	$ 2,704
Subtotal				$ 393,063
Item	Construction Material	Volume (feet)	Unit Cost Basis ($)	Demolition Cost ($)
Coal Conveyors and Tower	Steel	1,537	44.25	$ 68,012
Subtotal				$ 68,012
Total				$ 1,405,575

Reference: 2006 RSMeans Heavy Construction Cost Data

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Worksheet 3
Material Handling Plan Summary

Earthmoving Activity	Volume (LCY)	Origin	Destination	Haul Distance (Feet)	Grade* (%)	Equipment To Be Used
Haul subsoil	304,000	East Stockpile	South end of mining area	5,500	-0.05	Cat 777 trucks
Haul spoil	6,800,000	Spoil Stockpile	South end of mining area	4,092	1.5	Cat 777 trucks
Haul topsoil	130,000	Central Stockpile	South end of mining area	5,000	-0.7	Cat 777 trucks
Haul topsoil	373,000	Central Stockpile	Facilities, nonmined areas	2,200	3.4	Cat 777 trucks

* Includes grade resistance (% grade)

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Worksheet 4
Earthwork Quantity

Backfill Final Pits and Topsoil Haul Road

Active Pit volume = 6,800,000 cuyd
(Volumes derived from pit design and Carlson Software's SurvCADD)

Replace topsoil	=	80 acres X 1 foot	=	130,000	cuyd
Replace subsoil	=	80 acres x 2.35 feet	=	304,000	cuyd

Facilities Area Cleanup and Topsoil/Subsoil for disturbed/nonmined areas

Facilities area volume	=	29 acres X .25 ft	=	11,696	cuyd
Replace topsoil	=	231 acres X 1 foot	=	372,680	cuyd

Any contaminated material will be picked up and hauled to the pit for disposal before topsoil is replaced.

Sediment Ponds

Four sediment ponds = 30,000 cuyd

Worksheet 5A

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Earthmoving Activity:
Remove Ponds

Characterization of Dozer Used (type, size, etc.):

D10R, U-blade, ripper		
Power shift transmission	1.00	yes

Description of Dozer Use:

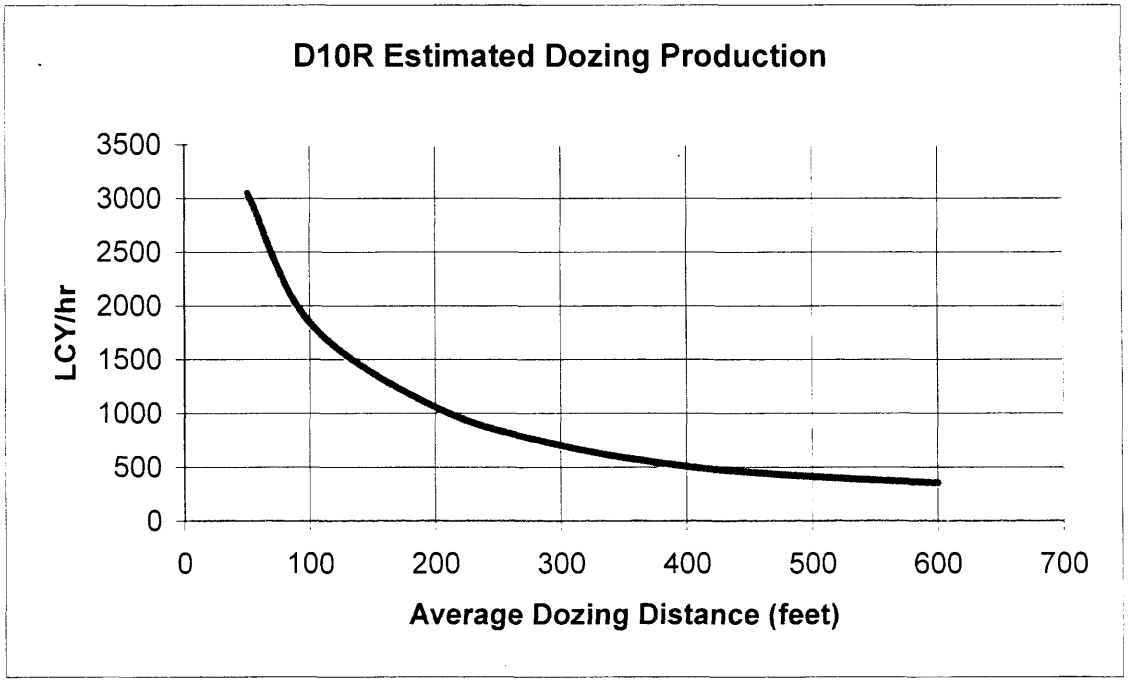
Average dozing distance (feet)	200
Hourly production (LCY/hr from chart)	1050
Grade (in percent)	-10
Grade Correction	1.20
Material Unit Weight (lb/LCY)	1,826
Density Correction	1.26

Production Adjustment Factors

Operator Factor		
Is operator excellent	1.00	no
Is operator average	0.75	yes
Is operator poor	0.60	no
Material Factor		
Loose stockpile	1.20	yes
Hard to cut, frozen with tilt cylinder	0.80	no
Hard to cut, frozen without tilt cylinder	0.70	no
Normal material	1.00	no
Hard to drift	0.80	no
Rock, ripped or blasted	0.75	no
Production Method/Blade Factor		
Slot dozing	1.20	no
Side by side dozing	1.20	no
Normal dozing	1.00	yes
Visibility		
Dust, rain, snow, fog, or darkness	0.80	no
Normal weather	1.00	yes
Job Efficiency		
50 min/hr	0.83	yes
40 min/hr	0.67	no
Elevation Factor		
<7,500 feet	1.00	yes

Quantity of Material to be Moved (LCY) 30,000

Worksheet 5B
Remove Ponds



Operating Adjustment Factor	=	0.75 Operator Factor	X	1.20 Material Factor	X	0.83 Job Efficiency Factor	X	1.20 Grade Factor	X	1.26 Weight Correction Factor			
	X	1.00 Production Method	X	1.00 Visibility Factor	X	1.00 Elevation Factor	=	1.13					
Net Hourly Production	=	1,050 Normal Hourly Production (see graph)	X	1.13 Operating Adjustment Factor	=	1190	LCY/hr						
Hours Required	=	30,000 Volume to be Moved (LCY)	/	1,190 Net Hourly Production (LCY/hr)	=	25	Hours						

Data Source: Caterpillar Performance Handbook, Edition 34

Worksheet 5C

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Earthmoving Activity:
Backfill Pit From Excess Spoil Area

Characterization of Loader Used (type, size, etc.):

992G Wheel Loader	15 cy
777D Rear Dump Trucks	79 cy

Loading and Haulage

Productivity Factors

Basic Loader Cycle (min)	0.55
Bulky Material (min)	0.03
Dumped Pile (min)	0.02
Common Loader/Truck Ownership (min)	-0.04
Work Hour Factor (50 min/hr)	0.83
Bucket Fill Factor	0.85
Truck Loaded Volume - 6 passes	79
Haulage Distance (feet)	4,092
Effective Grade (%)	1.5

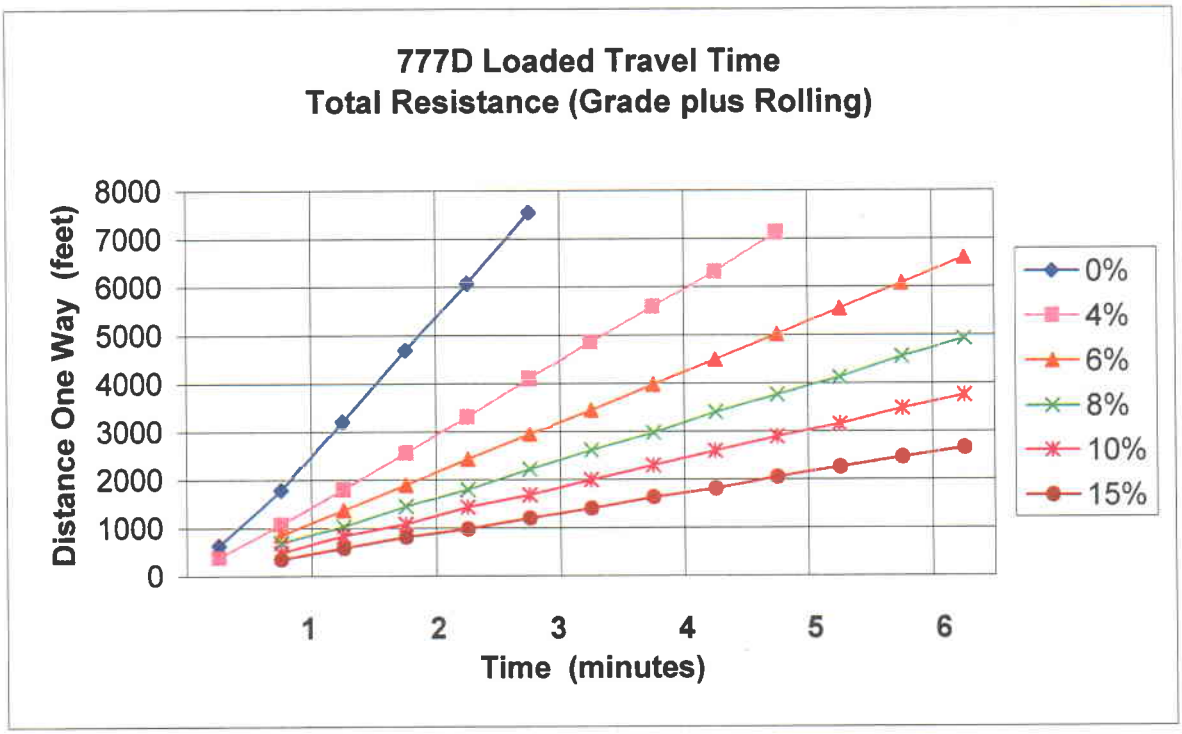
Production Times

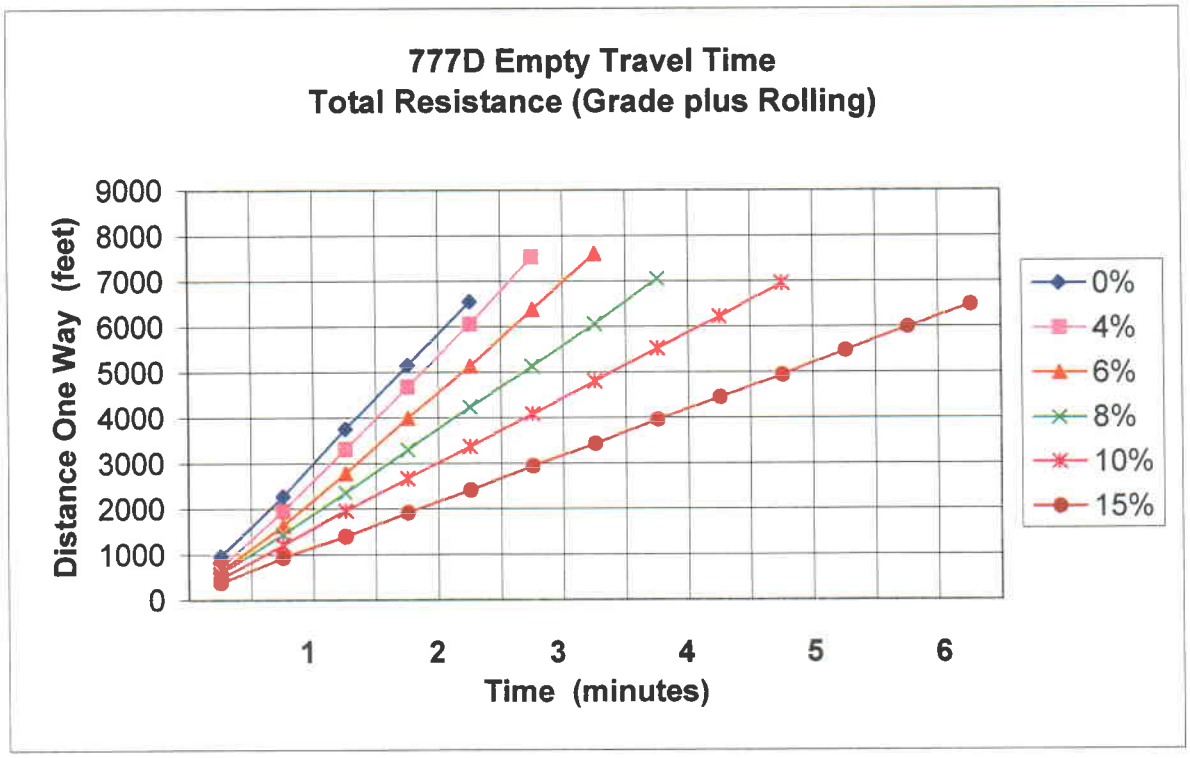
Haul Time (min)	2.3
Dump Time (min)	1.1
Return Time (min)	2

Truck / Loader Match (trucks per loader)	3
Quantity of Material to be Moved (LCY)	6,800,000

(Using Carlson Software's SurvCADD)

Worksheet 5D





Data Source: Caterpillar Performance Handbook, Edition 34

Worksheet 5D

Backfill Pit from Stockpile
Loader Summary

Loader Cycle Time	=	0.55 Basic Loader Cycle Time	+	0.03 Bulky Material	+	0.02 Dumped Pile	+	(0.04) Common Owner	=	0.56 minutes

Loader Volume per Cycle	=	15 Bucket Capacity	X	0.85 Bucket Fill Factor	=	12.75 cubic yards

Loader Cycle Time per Truck	=	0.56 Loader Cycle Time	X	6.0 Passes per Truck	=	3.36 minutes

Truck Summary

Truck Cycle Time	=	3.36 Load Time	+	2.30 Haul Time	+	1.10 Dump Time	+	2.00 Return Time	=	8.76 minutes

Production Rate	=	79 Truck Capacity (LCY)	X	3 Number of Trucks	/	8.76 Truck Cycle Time	=	27.05	LCY/min

Hourly Production	=	27.05 Production Rate	X	60 Minutes per Hour	X	0.83 Efficiency Factor	=	1,352	LCY/hour

Hours Required	=	6,800,000 Volume to be moved	/	1,352 Hourly Production	=	5,029 hours

Worksheet 5E

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Earthmoving Activity:
Topsoil Replacement From Central Stockpile to South End Pit and Haul Road

Characterization of Loader Used (type, size, etc.):

992G Wheel Loader	15 cy
777D Rear Dump Trucks	79 cy

Loading and Haulage

Productivity Factors

Basic Loader Cycle (min)	0.55
Bulky Material (min)	0.03
Dumped Pile (min)	0.02
Common Loader/Truck Ownership (min)	-0.04
Work Hour Factor (50 min/hr)	0.83
Bucket Fill Factor	0.85
Truck Loaded Volume - 5 passes	79
Haulage Distance (feet)	4,092
Effective Grade (%)	-0.7

Production Times

Haul Time (min)	2.4
Dump Time (min)	1.1
Return Time (min)	2.4

Truck / Loader Match (trucks per loader)	3
Quantity of Material to be Moved (LCY)	130,000

Worksheet 5F

Topsoil Replacement from Central Stockpile
Loader Summary

Loader Cycle Time	=	0.55 Basic Loader Cycle Time	+	0.03 Bulky Material	+	0.02 Dumped Pile	+	(0.04) Common Owner	=	0.56 minutes

Loader Volume per Cycle	=	15 Bucket Capacity	X	0.85 Bucket Fill Factor	=	12.75	cubic yards

Loader Cycle Time per Truck	=	0.56 Loader Cycle Time	X	6.0 Passes per Truck	=	3.36	minutes

Truck Summary

Truck Cycle Time	=	3.36 Load Time	+	2.40 Haul Time	+	1.10 Dump Time	+	2.40 Return Time	=	9.26 minutes

Production Rate	=	79 Truck Capacity (LCY)	X	3 Number of Trucks	/	9.26 Truck Cycle Time	=	25.59	LCY/min

Hourly Production	=	25.59 Production Rate	X	60 Minutes per Hour	X	0.83 Efficiency Factor	=	1,279	LCY/hour

Hours Required	=	130,000 Volume to be moved	/	1,279 Hourly Production	=	102	hours

Worksheet 5G

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Earthmoving Activity:
Topsoil Replacement from Central Stockpile to North Reclaim and Facilities

Characterization of Loader Used (type, size, etc.):

992G Wheel Loader	15 cy
777D Rear Dump Trucks	79 cy

Loading and Haulage

Productivity Factors

Basic Loader Cycle (min)	0.55
Bulky Material (min)	0.03
Dumped Pile (min)	0.02
Common Loader/Truck Ownership (min)	-0.04
Work Hour Factor (50 min/hr)	0.83
Bucket Fill Factor	0.85
Truck Loaded Volume - 5 passes	79
Haulage Distance (feet)	2,200
Effective Grade (%)	3.4

Production Times

Haul Time (min)	1.6
Dump Time (min)	1.1
Return Time (min)	1.1

Truck / Loader Match (trucks per loader)	3
Quantity of Material to be Moved (LCY)	373,000

Worksheet 5H

Topsoil Replacement from Central Stockpile to North Reclaim
Loader Summary

Loader Cycle Time	=	0.55 Basic Loader Cycle Time	+	0.03 Bulky Material	+	0.02 Dumped Pile	+	(0.04) Common Owner	=	0.56 minutes

Loader Volume per Cycle	=	15 Bucket Capacity	X	0.85 Bucket Fill Factor	=	12.75	cubic yards

Loader Cycle Time per Truck	=	0.56 Loader Cycle Time	X	6.0 Passes per Truck	=	3.36	minutes

Truck Summary

Truck Cycle Time	=	3.36 Load Time	+	1.60 Haul Time	+	1.10 Dump Time	+	1.10 Return Time	=	7.16 minutes

Production Rate	=	79 Truck Capacity (LCY)	X	3 Number of Trucks	/	7.16 Truck Cycle Time	=	33.10	LCY/min

Hourly Production	=	33.10 Production Rate	X	60 Minutes per Hour	X	0.83 Efficiency Factor	=	1,654	LCY/hour

Hours Required	=	373,000 Volume to be moved	/	1,654 Hourly Production	=	225	hours

Worksheet 5I

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Earthmoving Activity:
Subsoil Replacement From East Stockpile to South End Pit and Haul Road

Characterization of Loader Used (type, size, etc.):

992G Wheel Loader	15 cy
777D Rear Dump Trucks	79 cy

Loading and Haulage

Productivity Factors

Basic Loader Cycle (min)	0.55
Bulky Material (min)	0.03
Dumped Pile (min)	0.02
Common Loader/Truck Ownership (min)	-0.04
Work Hour Factor (50 min/hr)	0.83
Bucket Fill Factor	0.85
Truck Loaded Volume - 5 passes	79
Haulage Distance (feet)	5,500
Effective Grade (%)	-0.5

Production Times

Haul Time (min)	2.7
Dump Time (min)	1.1
Return Time (min)	2.6

Truck / Loader Match (trucks per loader)	3
Quantity of Material to be Moved (LCY)	304,000

Worksheet 5J

Subsoil Replacement From East Stockpile to South End Pit and Haul Road

Loader Summary

Loader Cycle Time	=	0.55 Basic Loader Cycle Time	+	0.03 Bulky Material	+	0.02 Dumped Pile	+	(0.04) Common Owner	=	0.56 minutes

Loader Volume per Cycle	=	15 Bucket Capacity	X	0.85 Bucket Fill Factor	=	12.75 cubic yards

Loader Cycle Time per Truck	=	0.56 Loader Cycle Time	X	6.0 Passes per Truck	=	3.36 minutes

Truck Summary

Truck Cycle Time	=	3.36 Load Time	+	2.70 Haul Time	+	1.10 Dump Time	+	2.60 Return Time	=	9.76 minutes

Production Rate	=	79 Truck Capacity (LCY)	X	3 Number of Trucks	/	9.76 Truck Cycle Time	=	24.28	LCY/min

Hourly Production	=	24.28 Production Rate	X	60 Minutes per Hour	X	0.83 Efficiency Factor	=	1,214	LCY/hour

Hours Required	=	304,000 Volume to be moved	/	1,214 Hourly Production	=	250 hours

Worksheet 6A

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Earthmoving Activity:
Grading of haulroads, facilities, final grading of spoil, and grading of topsoil

Characterization of Motorgrader Used (type, size, etc.):

16H Motorgrader with ripper	16	ft blade

Productivity Factors:

Average speed	3	mph
Effective blade width	13.9	ft
Work hour factor (50 min/hr)	0.83	

Work Activities:

Grade haulroads	14	acres
Grade spoil	62	acres
Grade topsoil	200	acres
Grade Subsoil	62	acres
Grade stockpile areas	55	acres
Facilities areas	29	acres
Sediment ponds	7	acres
Diversion ditches	6	acres
Total	435	acres

Worksheet 6B
Motorgrader Productivity Calculation - Final Preparation and Grading of Disturbed Areas

Grading

Hourly Production	=	3.0	X	13.9	X	5,280	/	43,560	X	0.83	=	4.21	acres/hr
		Average Speed		Effective Blade Width		Feet per Mile		Square feet per acre		Efficiency Factor			

Hours Required	=	435	/	4.21	=	103 hours
		Acres Graded		Hourly Production		

Ripping

Hourly Production	=	3.0	X	9.0	X	5,280	/	43,560	X	0.83	=	2.73	acres/hr
		Average Speed		Ripper Width		Feet per Mile		Square feet per acre		Efficiency Factor			

Hours Required	=	105	/	2.73	=	39 hours
		Acres Graded		Hourly Production		

Motorgrader is assumed to be onsite during total project.

Data Souce: Caterpillar Performance Handbook, Edition 34

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Worksheet 7
Summary Calculation of Earthmoving Costs

Equipment	Ownership & Operation Cost ($/hr)	Labor Cost ($/hr)	Total Hours Required	Total Cost
992G Wheel Loader	104.74	12.86	5,356	$ 629,866
777D Rear Dump Trucks	67.28	11.02	5,356	$ 1,258,124
16H Motorgrader	43.09	14.27	142	$ 8,145
Water Truck (7000 gal.)	42.48	11.02	5,356	$ 286,546
Subtotal				$ 2,182,681

Reference: US Department of Labor website, Labor Cost Data for Kane County, Utah
Reference: Western Mine Engineering, Inc., Mine and Mill Equipment Costs

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Worksheet 8
Revegetation Costs

Description of Area to be Revegetated:
Northeast corner and south end of mining area, haulroads, as well as area under spoil and topsoil stockpiles

Description of Revegetation Activities:
Seedbed preparation, seeding, fertilizing, mulching, tree planting and spraying

Cost calculation for Individual Revegetation Activities:

Initial Seeding

200.0	X	117	+	609	=	$ 145,200
Area to be seeded (acres)		Seedbed preparation ($/acre)		Seeding, fertilizing, & mulching ($/acre)		

Planting Trees and Shrubs

40.0	X	315	+	50	=	$ 14,600
Area to be planted (acres)		Planting ($/acre)		Herbicide Treatment ($/acre)		

Reseeding

233.0	X	0.25	X	45	+	609	=	$ 38,096
Area to be seeded & unreleased disturbed areas (acres)		Failure rate		Seedbed preparation ($/acre)		Seeding, fertilizing, & mulching ($/acre)		

Replanting Trees and Shrubs

40.0	X	0.50	X	315	+	50	=	$ 7,300
Area to be planted & unreleased disturbed areas (acres)		Failure rate		Planting ($/acre)		Herbicide Treatment ($/acre)		

Total revegetation cost for this area = $ 205,196

Project: Coal Hollow Mine
Date: May 1, 2006 (updated May 18, 2007)

Worksheet 9
Reclamation Bond Summary Sheet

1	Total Facility and Structure Removal Costs	$ 1,405,575
2	Total Earthmoving Costs	$ 2,182,681
3	Total Revegetation Costs	$ 205,196
4	Total Other Reclamation Activities Costs	$ -
5	Total Direct Costs (sum of 1 through 4)	$ 3,793,452
6	Inflated Total Direct Costs	$ 4,472,479
7	Mobilization/Demobilization 5% of line 6	$ 223,624
8	Contingencies 5% of line 6	$ 223,624
9	Engineering Redesign Fee 3% of line 6	$ 134,174
10	Contractor Profit/Overhead 20% of line 6	$ 894,496
11	Project Management Fee 5% of line 6	$ 223,624
12	Total Indirect Costs (sum of 7 through 11)	$ 1,699,542
13	Grand Total Bond Amount	$ 6,172,022

Inflation factor for prior 4.25 years = 17.90%

Source: U.S. Department of Labor, Producer Price Index, Bituminous coal & lignite surface mining
(Only available from December 2001 through March 2006)