Review of the Hydrogeology of the Spanish Valley Area, and Effects on Water Levels from Proposed Groundwater Withdrawals at Bureau of Land Management Water Rights Sites

Administrative Report
March 2012

U.S. Department of the Interior
U.S. Geological Survey
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By Melissa D. Masbruch

Prepared in cooperation with the Bureau of Land Management

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Review of the Hydrogeology of the Spanish Valley Area, and Effects on Water Levels From Proposed Groundwater Withdrawals at Bureau of Land Management Water Rights Sites

By Melissa D. Masbruch

Abstract

The San Juan Spanish Valley Special Service District (SJSV-SSD) has filed a water-right change application with the State of Utah with a proposal to develop 23 water wells on state lands in and around Spanish Valley, south of Moab, Utah, with a combined planned groundwater use of 5,000 acre-ft per year. The Bureau of Land Management (BLM) has identified four BLM water rights that may be impacted by this proposed groundwater development; one domestic well located at the Interagency Fire Center, and three springs in southern Spanish Valley and in Kane Springs Creek Wash that are the primary water sources in two grazing allotments. This report presents a hydrogeologic analysis of the Spanish Valley area to assess the potential range of effects to BLM water rights in southern Spanish Valley from proposed groundwater withdrawals in the area. This report includes a summary and synthesis of previous investigations conducted within the Spanish Valley area and vicinity from the
early 1970s to the late 2000s. This information is then incorporated into Theis analyses to quantify drawdown from the proposed groundwater withdrawals at the four BLM water rights locations.

In the Spanish Valley area there are two principal aquifers that currently supply the majority of irrigation and public supply water. First is the Glen Canyon aquifer, which consists of consolidated rocks of the Glen Canyon Group, namely the Jurassic Navajo Sandstone and Kayenta Formation, and the Triassic Wingate Sandstone, and is the principal source of public drinking water. Second is the valley-fill aquifer, which consists of unconsolidated Quaternary deposits. The valley-fill aquifer is currently the principal source of irrigation water in the Spanish Valley area.

The Glen Canyon aquifer consists of the Glen Canyon Group, namely the Jurassic Navajo Sandstone and Kayenta Formation, and the Triassic Wingate Sandstone, and is classified as having moderate permeability which is further enhanced where fractures exist. Recharge to the Glen Canyon aquifer primarily occurs as infiltration from precipitation or as infiltration of surface water where perennial streams traverse the Navajo Sandstone. Discharge from the aquifer occurs to numerous seeps and springs, to reaches of Mill Creek and the North Fork of Mill Creek, to wells, and as inflow to the valley-fill aquifer in Moab and Spanish Valleys. Groundwater movement within the Glen Canyon aquifer is to the west and northwest towards the Colorado River.

The valley-fill aquifer consists of unconsolidated Quaternary-age deposits consisting of stream, alluvial fan, mass-movement (including glacial till), and eolian sand deposits and is classified as having low to high permeability. Recharge to the valley-fill aquifer occurs as inflow from the (underlying) Glen Canyon aquifer along the northeast side of the valley, as infiltration from precipitation that falls directly on the valley-fill deposits, and seepage from Ken’s Lake and Pack Creek. Discharge from the valley-fill aquifer occurs to springs and wells, as seepage to reaches of Mill and Pack Creeks, as evapotranspiration in the Matheson Wetland area, and as seepage to the Colorado River. Groundwater
movement within the valley-fill aquifer is generally to the northwest from southern Spanish Valley towards the Colorado River.

To investigate the effects of the proposed groundwater withdrawals, Theis analyses were performed to estimate potential drawdown at each of the four BLM water rights sites, namely the Interagency Fire Center Well, and three springs located in southern Spanish Valley or in Kane Springs Creek Wash. The Glen Canyon aquifer is the likely target aquifer for the proposed wells. The Theis analyses, therefore, were performed using the range of reported transmissivities and storativities for the Glen Canyon aquifer, under both the minimum and maximum water supply demand scenarios identified for the proposed wells; effects were calculated at times of 5, 10, 20, 50, and 100 years.

Results of the Theis analyses for the Interagency Fire Center Well show drawdowns that range from a few to tens of feet. Near the Interagency Fire Center Well, it is likely that the transmissivity of the aquifer is similar to that of the fractured Glen Canyon aquifer. Assuming a high T of 5,500 ft²/day, representative of fractured conditions, drawdown at the Interagency Fire Center Well would likely be 2.3 and 8.7 ft for the minimum groundwater withdrawal scenario, and between 5.2 and 19.1 ft for the maximum groundwater withdrawal scenario for configuration 1 (all withdrawals occurring at most distal proposed wells). Results of the Theis analyses for configuration 1 (distal wells) assuming a moderate T of 1,500 ft²/day show drawdowns at the Interagency Fire Center Well between 2.6 and 23.3 ft for the minimum groundwater withdrawal scenario, and between 5.9 and 51.4 ft for the maximum groundwater withdrawal scenario. Results of the Theis analyses for configuration 2 (all wells pumping simultaneously, maximum withdrawal) show drawdowns at the Interagency Fire Center Well between 7.1 and 21.2 ft assuming T=5,500 ft²/day, and between 10.9 and 59.1 ft assuming a more moderate T of 1,500 ft²/day. Estimated drawdowns at the Interagency Fire Center Well due to the proposed groundwater withdrawals indicate that the water level in the Interagency Fire Center Well could potentially drop below the level of the pump in the Interagency Fire Center Well, or even below the
bottom of the well. It is possible, therefore, that additional drawdown induced by the proposed
groundwater withdrawals could have adverse effects on the ability to obtain groundwater from the
Interagency Fire Center Well.

Results of the Theis analysis for the three springs show similar results, with drawdowns that
could range from a few tens to hundreds of feet. It is unknown, however, if these springs are connected
to the larger regional groundwater flow system, or if they represent perched conditions. Minimum
estimated drawdowns at the three springs range between 6.7 and 11.3 ft under the minimum
groundwater withdrawal scenarios, and between 15.9 and 26.9 ft under the maximum pumping scenario.
If the springs are connected to the regional groundwater flow system and drawdowns of this magnitude
occur, it is likely that flow at these springs would decrease or cease altogether.

Introduction

The San Juan Spanish Valley Special Service District (SJSV-SSD) has filed a water-right change
application with the State of Utah (Utah Division of Water Rights change application number a37400)
with a proposal to develop 23 water wells on state lands in and around Moab-Spanish Valley, south of
Moab, with a combined planned groundwater use of 5,000 acre-ft per year (fig. 1). The newly proposed
wells in the Spanish Valley area would provide municipal water for future developments on state lands.
The Bureau of Land Management (BLM) has identified four BLM water rights that may be impacted by
this proposed groundwater development; one domestic well located at the Interagency Fire Center (Utah
Division of Water Rights water right number 05-3067), and three springs (Utah Division of Water
Rights water right numbers 05-2163, 05-1902, and 05-1901) in southern Spanish Valley and in Kane
Springs Creek Wash that are the primary water sources in two grazing allotments (fig. 1).
**Purpose and Scope**

This report presents a hydrogeologic analysis of the Spanish Valley area to assess the potential range of effects to BLM water rights in southern Spanish Valley from proposed groundwater withdrawals in the area. This report includes a summary and synthesis of previous investigations conducted within the Spanish Valley area and vicinity from the early 1970s to the late 2000s. This information is then incorporated into Theis analyses to quantify drawdown from the proposed groundwater withdrawals on the four BLM water rights of concern. **Limitations in time and funding preclude the collection of additional data, or the development of a groundwater flow model of the area.** This assessment, however, provides a general understanding of the susceptibility of BLM water rights to proposed groundwater withdrawals in the Spanish Valley area, and helps identify additional data required to improve the results of any future analyses.

**Previous Investigations**

There have been several hydrogeologic studies conducted in the Spanish Valley area and vicinity. Sumsion (1971) studied the geology and water resources of the Spanish Valley area, including Moab and Spanish Valleys. Eychaner (1977) developed a digital model of the same area using data from Sumsion (1971) to investigate the effects of a proposed area of artificial recharge in the vicinity of what is now Ken’s Lake, and increased well withdrawals for irrigation. Rush and others (1982) assessed the regional hydrology of the Green River-Moab area just north of the Colorado River, which did not include Moab or-Spanish Valley. Weir and others (1983) studied the geology and water resources of the Moab-Monticello area, which included portions of Moab and Spanish Valleys, as well as other areas to the south of the Colorado River. Blanchard (1990) provided a reconnaissance of groundwater conditions in the bedrock aquifers of Grand County and parts of San Juan County, with emphasis on bedrock aquifers in the Mill Creek-Spanish Valley area. Steiger and Susong (1997) present a map of recharge...
areas and groundwater quality data for the Spanish Valley area. Kovacs (2000) and Downs and Kovacs (2000) developed a numerical groundwater flow model to investigate the effects of increased well withdrawals in an unincorporated area of Moab and Spanish Valleys at the request of the Grand Water and Sewer Service Agency (GWSSA). Gardner (2004) investigated the hydrogeology and groundwater conditions within the Scott M. Matheson Wetland Preserve located between Moab and the Colorado River using a suite of environmental tracers to characterize the basin-fill aquifer at the low (downgradient) end of Moab Valley. Lowe and others (2007) summarized the geology, groundwater conditions, and groundwater quality within Moab and Spanish Valleys in order to determine the potential impacts of projected increased numbers of septic-tank systems on water quality in the valley-fill aquifer, including modifying the numerical groundwater flow model developed by Downs and Kovacs (2000).

While most of these studies encompass the area where the BLM Interagency Fire Center Well and Mud Spring are located, none of them extend far enough south to encompass the area around Kane Springs and the other two BLM springs. The Kane Springs area, however, is only a few miles south of the extent of the previous studies; it is likely, therefore, that the controls on groundwater occurrence and flow in the Kane Springs area are similar to areas to the north.

**General Description of the Spanish Valley Area**

The Spanish Valley area, located in southeastern Utah, covers about 180 square miles (fig 1). In previous studies, the Spanish Valley area has been defined as including Moab Valley, Spanish Valley, and the mesa areas and La Sal Mountains to the northeast and east, stopping at the topographic divide in southern Spanish Valley. For this study, the Spanish Valley area is extended southward to include the area around Kane Springs and the mesas to the north and west of Kane Springs Creek Wash (fig. 1). Within the Spanish Valley area, the Spanish and Moab valleys (encompass about 23 square miles (Steiger and Susong, 1997). Spanish and Moab valleys (hereafter referred to as Moab-Spanish Valley)
are located within a northwest-trending, elongate trough formed by the collapse of the Moab salt-cored anticline (Lowe and others, 2007); they are not topographically or geologically separable (Sumison, 1971).

Altitudes within the study area range from 3,950 ft at the Colorado River near Moab to 12,645 ft at Mount Mellenthin in the La Sal Mountains. Because of the large range in altitude, the Spanish Valley area encompasses a wide variety of climatic conditions. Mean annual precipitation in the Spanish Valley area ranges from less than 6 inches near Moab, to more than 30 inches in the La Sal Mountains (Blanchard, 1990; Steiger and Susong, 1997). The mean annual temperature near Moab (altitude 4,000 ft) is 13 °C (56 °F) (Sumison, 1971; Blanchard, 1990), whereas the mean annual temperature in the La Sal Mountains at an altitude of 9,560 ft is 4 °C (39 °F) (data from SNOTEL station number 572 downloaded from http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=572&state=ut accessed on September 22, 2011).

Principal streams within the study area are Mill, North Fork Mill, Pack, and Kane Springs Creeks (fig. 1). Mill, North Fork Mill, and Pack Creeks flows from southeast to northwest from the La Sal Mountains to the Colorado River; they join near Moab, and Mill Creek then enters the Colorado River (Sumison, 1971). Kane Springs Creek flows from east to west between the southern La Sal Mountains and Hatch Wash (outside of study area). Kane Springs Creek is intermittent upstream of Kane Springs, and perennial below Kane Springs.

Groundwater within the study area is heavily used for domestic supply, stock watering, and irrigation. Groundwater use data from the Utah Division of Water Rights website report 2010 groundwater use estimates of 1,825-2,336 acre-ft/yr for Moab City Water, and 788-1,301 acre-ft/yr for the Grand County Conservancy District (http://www.waterrights.utah.gov/cgi-bin/wuseview.exe accessed on October 12, 2011). These two agencies are the main public water suppliers in the Spanish Valley area. There is little data on the number and withdrawals of privately owned wells in the Spanish Valley area.
Valley area. The Utah Division of Water Rights indicates that there are 724 current water rights for wells that are used for domestic supply, stock watering, and irrigation that have been “approved” or “perfected”; 680 of these are located within Moab-Spanish Valley (dataset WRPOD downloaded from http://www.waterrights.utah.gov/gisinfo/wrcover.asp accessed on December 9, 2011). Assuming that groundwater withdrawals from these water rights are about 1 acre-ft/yr, then estimated withdrawals from these privately owned wells are approximately 724 acre-ft/yr from the entire Spanish Valley area, and 680 acre-ft/yr for Moab-Spanish Valley.

Geology

The Spanish Valley area is located in the Salt Anticline section of the Paradox Basin (Lowe and others, 2007; Loughlin Water Associates, LLC, 2010) and is also part of the Colorado Plateau physiographic province (Blanchard, 1990). The Pennsylvanian Paradox Formation underlies the Paradox Basin, and consists of thick salt layers that were deposited under marine conditions (Hintze, 1988). As these salt layers were buried beneath younger sedimentary deposits, the increase in overlying pressure caused the salt to flow and deform into a series of northwest-trending salt cored anticlines alternating with northwest-trending synclines (Blanchard, 1990).

During the Tertiary, subsequent uplift and erosion of the Colorado Plateau allowed surface water and groundwater to come into contact with, and dissolve, the salt layers from the core of the anticlines (Doelling and others, 2002; Lowe and others, 2007). The overlying rock strata collapsed as the dissolved salt was removed by groundwater. Moab-Spanish Valley represents one of these collapsed salt anticlines. The collapse occurred along high-angle normal faults located along the margins of the valley; one such example is the Moab fault, which has a maximum offset of about 1,000 ft, and an average offset of about 650 ft (Lowe and others, 2007). Also during the Tertiary, the La Sals were formed as
intrusive igneous rocks were injected through and into the surrounding older deposits, causing uplift and doming of the strata along the flanks of the mountains (Sumsion, 1971; Blanchard, 1990).

**Hydrogeology**

**Principal Aquifers and Aquifer Properties**

In the Spanish Valley area there are two principal aquifers that currently supply the majority of irrigation and public supply water. First is the Glen Canyon aquifer, which consists of consolidated rocks of the Glen Canyon Group, namely the Jurassic Navajo Sandstone and Kayenta Formation, and the Triassic Wingate Sandstone (Blanchard, 1990; Lowe and others, 2007), and is the principal source of public drinking water (Blanchard, 1990; Steiger and Susong, 1997; Lowe and others, 2007). Second is the valley-fill aquifer, which consists of unconsolidated Quaternary deposits (Sumsion, 1971; Lowe and others, 2007). The valley-fill aquifer is currently the principal source of irrigation water in the Spanish Valley area (Blanchard, 1990; Steiger and Susong, 1997; Lowe and others, 2007), although at one time it was the principal source of all groundwater used in Moab-Spanish Valley (Sumsion, 1971). The water in the valley-fill aquifer is of slightly poorer quality than water in the Glen Canyon aquifer, with higher total dissolved concentrations (Steiger and Susong, 1997; Lowe and others, 2007).

Groundwater has also been developed in a group of Mesozoic-age sandstone aquifers including (from youngest to oldest): (1) the Dakota aquifer which consists of the consolidated rocks of the Cretaceous Dakota Sandstone and the Burro Canyon Formation (Blanchard, 1990; Lowe and others, 2007); (2) the Morrison aquifer, which consists of consolidated rocks of the Jurassic Salt Wash Member of the Morrison Formation (Lowe and others, 2007); and (3) the Entrada aquifer, which consists of consolidated rocks of the Jurassic Moab Member of the Curtis Formation and the Jurassic Slick Rock Member of the Entrada Formation (Blanchard, 1990; Lowe and others, 2007).
Glen Canyon Aquifer

The Glen Canyon Group consists of the Lower Jurassic-age Navajo Sandstone and Kayenta Formation, and the Upper Triassic-Age Wingate Sandstone (Blanchard, 1990; Lowe and others, 2007). The three units together form one aquifer designated as the Glen Canyon aquifer. The Navajo Sandstone is a well-rounded, well-sorted, fine- to medium-grained eolian sandstone, and has a thickness of 0-550 ft in the Spanish Valley area (Sumsion, 1971; Lowe and others, 2007). The Kayenta Formation is a very fine- to coarse-grained, locally conglomeratic, fluvial sandstone, siltstone and shale, and has a thickness of 140-300 ft (Sumsion, 1971; Lowe and others, 2007). The Wingate Formation is a well-sorted, very fine- to medium-grained calcareous, massively bedded, well-cemented, eolian sandstone, and has a thickness of 150-450 ft (Sumsion, 1971; Lowe and others, 2007).

The Glen Canyon Group crops out along the northeastern and southwestern walls of Moab-Spanish Valley, and exists at depth below the unconsolidated deposits along the northeast margin of the valley floor (Doelling and others, 2002; Doelling, 2004). It also exists at depth beneath the area around Kane Springs. In many areas of the Colorado Plateau, the Kayenta Formation acts as a barrier to groundwater flow; in the Spanish Valley area, however, the unit is mainly composed of sandstone and provides hydraulic connection between the Navajo Sandstone and Wingate Formation (Blanchard, 1990; Steiger and Susong, 1997). All three units are highly faulted and fractured, especially near the valley margins and along the flanks of the La Sal Mountains.

All three units in the Glen Canyon aquifer are classified as being moderately transmissive, and which is further enhanced where fractures exist. Transmissivities for the Navajo Sandstone were estimated to range from 400-700 ft²/d by Jobin (1962) and from 100-5,000 ft²/d by Freethey and Cordy (1991); Sumsion (1971) estimated transmissivities between 1,200 and 1,500 ft²/d in areas where the Navajo Sandstone is relatively unfractured, and up to 6,000 ft²/d in areas where the Navajo Sandstone is highly fractured from wells near Moab. These transmissivities for the Navajo Sandstone are similar to
reported transmissivities from aquifer tests in other areas of the Navajo Sandstone (Heilweil and others, 2000). Transmissivities for the Kayenta Formation and the Wingate Sandstone were estimated by Jobin (1962) as 20-55 ft²/d and 55-150 ft²/d, respectively. Near Moab-Spanish Valley, the Glen Canyon aquifer is connected to overlying formations and considered to be unconfined. Freethey and Cordy (1991) provide estimates of specific yield for the unconfined regions of the Navajo Sandstone that range from 0.05 to 0.1. Confined sections of the aquifer exist in the area surrounding Kane Springs; Freethey and Cordy (1991) estimated storage coefficients for confined portions of the aquifer to be 0.0003-0.008, with a geometric mean of 0.0008.

Recharge to the Glen Canyon aquifer primarily occurs as infiltration from precipitation, mainly in the form of snow, in the upland areas to the northeast and east of Spanish Valley (Blanchard, 1990; Steiger and Susong, 1997). Recharge to the aquifer is enhanced in areas where the formations are covered by shallow deposits of eolian sand or sandy soil, where the formations are highly fractured, or where younger sedimentary deposits, such as the Entrada Sandstone, overlie the Navajo Sandstone (Blanchard, 1990; Steiger and Susong, 1997). Recharge can also occur from the infiltration of surface water where perennial streams, such as Mill Creek, traverse the Navajo Sandstone (Steiger and Susong, 1997). Discharge from the aquifer occurs to numerous seeps and springs, to some reaches of Mill Creek and the North Fork of Mill Creek, to wells, and as inflow into the valley-fill aquifer.

Groundwater movement within the Glen Canyon aquifer to the northeast and east of Moab-Spanish Valley is generally toward the west and northwest from the La Sal Mountains towards the Colorado River, and is a source of recharge to the valley-fill aquifer. Rocks of the Glen Canyon Group that are exposed on the southwest side of Moab-Spanish valley receive much less recharge (Steiger and Susong, 1997) and are underlain by less permeable rocks which inhibit groundwater movement toward the valley (Eychaner, 1977).
Valley-Fill Aquifer

The valley-fill aquifer consists of unconsolidated Quaternary-age deposits consisting of stream, alluvial fan, mass-movement (including glacial till), and eolian sand deposits (Steiger and Susong, 1997; Lowe and others, 2007). These deposits comprise interbedded and lenticular deposits of sand, silt, and clay, and exist within the basin of Moab-Spanish Valley (Loughlin Water Associates, LLC, 2010). The average saturated thickness of the alluvial aquifer in Moab-Spanish Valley is 70 ft, but in some places within the valley the saturated thickness can be more than 300 ft (Sumsion, 1971; Lowe and others, 2007).

The valley-fill aquifer is classified as being low to highly transmissive (Lowe and others, 2007). Sumsion (1971) estimated transmissivities from 18 wells in the valley from 1,600-13,900 ft²/d, with an average of 6,000 ft²/d; based on aquifer data from pumping tests in basin fill in other areas of Utah, Sumsion (1971) believed that a more realistic average value for the transmissivity of the valley fill in Moab-Spanish Valley was about 10,000 ft²/d. Lowe and others (2007) estimated transmissivities from 32 wells (including those estimated by Sumsion, 1971) from 197-72,750 ft²/d, with an average of 6,956 ft²/d. Due to a lack of extensive layers of low-permeability materials within the valley-fill deposits, the valley-fill aquifer is considered to be unconfined throughout most of Moab-Spanish Valley (Sumsion, 1971) and is likely in hydraulic connection with the underlying Glen Canyon aquifer. Sumsion (1971) estimated the long-term specific yield of the saturated gravelly sand in Moab-Spanish Valley to be about 0.25.

The majority of recharge to the valley-fill aquifer occurs as inflow from the Glen Canyon aquifer along the northeast side of the valley. Lesser amounts of recharge to the valley-fill aquifer occur as infiltration from precipitation that falls directly on the valley-fill deposits and seepage from Ken’s Lake and Pack Creek. Discharge from the valley-fill aquifer occurs to springs and wells, as seepage to reaches of Mill and Pack Creeks, as evapotranspiration in the Matheson Wetland area, and as seepage to the
Colorado River. Groundwater movement within the valley-fill aquifer is generally to the northwest from southern Spanish Valley towards the Colorado River (Sumsion, 1971; Eychaner, 1977; Lowe and others, 2007).

**Mesozoic-Age Sandstone Aquifers**

The Dakota, Morrison, and Entrada aquifers are important sources of groundwater to seeps and springs throughout the Spanish Valley area. In the Spanish Valley area, these units occur locally along the flanks of the La Sal Mountains, along the topographic divide along the southern boundary of Spanish Valley, and in the Kane Springs area (Doelling, 2004). These sandstone aquifers are often separated from one another by intervening confining units such as the Jurassic Brushy Basin Member of the Morrison Formation (between the Dakota aquifer and the Morrison aquifer), the Jurassic Tidwell Member of the Morrison Formation and the Summerville Formation (between the Morrison aquifer and the Entrada aquifer), and the Jurassic Dewey Bridge Member of the Carmel Formation (between the Entrada aquifer and the Glen Canyon aquifer). Discharge to the seeps and springs often occurs near the bases of these aquifers just above the intervening confining units.

**Dakota Aquifer**

The Dakota aquifer consists of the Cretaceous Dakota Sandstone and Burro Canyon Formation. The Dakota Sandstone consists of sandstone and conglomerate, interbedded with siltstone, and has a thickness of 0-120 ft in the Spanish Valley area (Sumsion, 1971; Lowe and others, 2007). The Burro Canyon Formation consists of sandstone and conglomerate interbedded with mudstone, and has a thickness of 0-250 ft in the Spanish Valley area (Sumsion, 1971; Lowe and others, 2007).

The Dakota aquifer is classified as being low to moderately transmissive, except where faulted or fractured where transmissivity is enhanced (Lowe and others, 2007). Jobin (1962) estimated transmissivities ranging between 55-150 ft²/d, and Freethey and Cordy (1991) estimated transmissivities
ranging between 10-50 ft\(^2\)/d. Freethey and Cordy (1991) also estimated a storage coefficient of 0.001 for the aquifer. Recharge to the Dakota aquifer is likely from infiltration from precipitation that falls locally on areas where the aquifer crops out. Discharge from the aquifer occurs to seeps, springs, and flowing wells which typically discharge at less than 1 gal/min (Blanchard, 1990). Discharge may also occur to the underlying Morrison aquifer in areas where the Brushy Basin Member of the Morrison Formation does not exist between the Dakota aquifer and the Morrison aquifer. Because the Dakota aquifer is not contiguous throughout the Spanish Valley area, groundwater movement within the Dakota aquifer is likely towards localized discharge areas.

**Morrison Aquifer**

The Morrison aquifer consists of the Jurassic Salt Wash Member of the Morrison Formation. It is a well-sorted, fine- to medium-grained, fluvial cross-bedded sandstone, with less common conglomeratic sandstone interbedded with mudstone, and has a thickness of 0-300 ft in the Spanish Valley area (Sumsion, 1971; Lowe and others, 2007).

The Morrison aquifer is classified as having low transmissivity. Jobin (1962) estimated transmissivies ranging between 20-55 ft\(^2\)/d, and Freethey and Cordy (1991) estimated transmissivities of less than 50 ft\(^2\)/d. Freethey and Cordy (1991) also estimated storage coefficients ranging between 0.00003-0.0004 for the aquifer. Similar to the Dakota aquifer, recharge is likely from infiltration from precipitation that falls locally on areas where the aquifer crops out, or in areas where the Brushy Basin Member of the Morrison Formation does not exist between the overlying Dakota aquifer and the Morrison aquifer. Discharge from the aquifer occurs to seeps, springs, and flowing wells which typically discharge at less than 1 gal/min and are slightly saline (Blanchard, 1990; Lowe and others, 2007). Additionally, the Morrison Formation contains large quantities of uranium, and the groundwater can contain high concentrations of radionuclides (Blanchard, 1990). Discharge may also occur to the underlying Entrada aquifer in areas where the Tidwell Member of the Morrison Formation and the
Summerville Formation do not exist between the Morrison aquifer and the Entrada aquifer. Because the Morrison aquifer is not contiguous throughout the Spanish Valley area, groundwater movement within the Morrison aquifer is likely towards localized discharge areas.

**Entrada Aquifer**

The Entrada aquifer consists of the Jurassic Moab Member of the Curtis Formation and the Slick Rock Member of the Entrada Formation. The Moab Member of the Curtis Formation is a well-sorted, medium- to fine-grained, cross-bedded, eolian sandstone, and has a thickness of 0-140 ft in the Spanish Valley area (Sumsion, 1971; Lowe and others, 2007). The Slick Rock Member of the Entrada Formation is a well-sorted, very fine- to medium-grained, cross-bedded sandstone of eolian or possibly shallow marine origin, and has a thickness of 140-500 ft in the Spanish Valley area (Sumsion, 1971; Lowe and others, 2007).

Both units of the Entrada aquifer are classified as being moderately transmissive. Jobin (1962) estimated transmissivities ranging between 55-150 ft²/d, and Freethy and Cordy (1991) estimated transmissivities ranging between 50-100 ft²/d for the aquifer. Freethy and Cordy (1991) also estimated storage coefficients ranging between 0.0003-0.008. Similar to the Dakota and Morrison aquifers, recharge is likely from infiltration from precipitation that falls locally on areas where the aquifer crops out, in areas where the Tidwell Member of the Morrison Formation and the Summerville Formation do not exist between the overlying Morrison aquifer and the Entrada aquifer, or where the aquifer is mantled by unconsolidated deposits (Blanchard, 1990). Discharge from the aquifer occurs to wells, and to seeps and springs where the vertical hydraulic conductivity is decreased by contacts between cross-bed sets or by the finer-grained Dewey Bridge Member of the Carmel Formation that underlies the aquifer (Blanchard, 1990). Discharge may also occur to the underlying Glen Canyon aquifer in areas where the Dewey Bridge Member of the Carmel Formation does not exist between the Entrada aquifer and the Glen Canyon aquifer, such as in the area to the east and northeast of Moab-Spanish Valley.
Because the Entrada aquifer is not contiguous throughout the Spanish Valley area, groundwater movement within the Entrada aquifer is likely towards localized discharge areas.

**Groundwater Budget**

Previous studies provide estimates of the groundwater budget for the Moab-Spanish Valley (table 1), including both the valley-fill and the Glen Canyon aquifers. Most of these studies based their estimates on those first proposed by Sumsion (1971). Later studies refined these estimates, and after the construction of Ken’s Lake in the 1980s, seepage from the lake was also included in the estimates of recharge.

**Recharge**

The majority of groundwater recharge to Moab-Spanish Valley originates as infiltration of precipitation in the La Sal Mountains and adjacent upland areas, which then flows into the valley through the Glen Canyon aquifer. Additional groundwater recharge may come from infiltration of direct precipitation over the valley-fill deposits (Eychaner, 1977; Steiger and Susong, 1997; Downs and Kovacs, 2000; Lowe and others, 2007), by seepage from Ken’s Lake (Steiger and Susong, 1997; Downs and Kovacs, 2000; Lowe and others, 2007), and by infiltration of water from Pack Creek (Sumsion, 1971; Eychaner, 1977; Steiger and Susong, 1997). Previously reported estimates of total groundwater recharge to the Moab-Spanish Valley basin range between 14,000 and 17,000 acre-ft/yr (table 1).

**Groundwater Inflow and Direct Infiltration of Precipitation**

Previously reported estimates of groundwater recharge from inflow through the Glen Canyon aquifer to the Moab-Spanish Valley range between 13,000 and 14,000 acre-ft/yr (Sumsion, 1971; Eychaner, 1977; Downs and Kovacs, 2000; Lowe and others, 2007). Sumsion (1971) assumed that groundwater recharge to the valley as inflow through the Glen Canyon aquifer equaled the sum of
discharge to the Colorado River, evapotranspiration within the Matheson Wetland, discharge to springs, and well withdrawals, which Sumson (1971) estimated as 14,000 acre-ft/yr. Subsequent studies by Eychaner (1977), Downs and Kovacs (2000), and Lowe and others (2007) adjusted this number to 13,000 acre-ft/yr based on the difference between Sumson’s inflow estimate and estimated infiltration of direct precipitation over the valley-fill deposits, which ranged between 560 and 730 acre-ft/yr (table 1).

Because Sumson (1971) assumed that recharge to the Moab-Spanish Valley was balanced by discharge, any error in discharge estimates could result in errors of the recharge estimate from inflow to the valley. An important example of this is the estimated discharge to the Colorado River. Sumson (1971) estimated groundwater discharge to the Colorado River using an adaptation of Darcy’s law assuming a thickness of saturated fill of about 140 ft; discharge to the Colorado River was then calculated to be about 8,000 acre-ft/yr. In a more recent study of the Matheson Wetland (Gardner, 2004) a new estimate of the groundwater discharge to the Colorado River was made based on data from piezometers that were installed within the wetland. Gardner (2004) showed that the thickness of (freshwater) saturated fill was much less than previously assumed by Sumson (1971) due to the existence of a dense brine layer at a depth of only 2-3 m (6.6-9.8 ft) below the water table within the wetland adjacent to the Colorado River. Using the same Darcy’s law adaptation and a conservative estimate of thickness of saturated fill of only 10 m (33 ft), Gardner (2004) calculated groundwater discharge to the Colorado River to be between about 110 and 1,500 acre-ft/yr. Gardner (2004) concluded that unless there was a considerable amount of groundwater discharging from the Glen Canyon aquifer at unknown locations within the valley not previously accounted for, the total inflow and, therefore, recharge as subsurface inflow from the Glen Canyon aquifer to the valley was significantly overestimated by Sumson (1971). Additionally, any subsequent groundwater budgets using Sumson’s recharge estimates may also be in error.
Seepage From Ken’s Lake

Ken’s Lake, located in the southeast portion of Moab-Spanish Valley, was constructed during the late 1970s and early 1980s and completed in 1981 (fig 1). Water in the lake is diverted from Mill Creek through the Sheley Tunnel. The lake was originally constructed as a proposed area of artificial groundwater recharge to offset an equal increase in net irrigation well withdrawals lower in the valley (Eychaner, 1977); currently, water from the lake is piped to a pressurized irrigation system from March through October.

Estimates of seepage from the lake were given in a personal communication from Dale Pierson of the Grand Water and Sewer Service Agency (GWSSA) in 2000 to Downs and Kovacs in the amount of 3,300 acre-ft/yr (Kovacs, 2000); there was no discussion in the Kovacs (2000) report, however, as to how this estimate was calculated. Lowe and others (2007) estimated seepage of 3,200 acre-ft/yr in their numerical model which attempted to match the water budget estimates reported in Downs and Kovacs (2000).

Estimates of seepage from the lake for the period 2000-2010 are given in the GWSSA’s 2010 annual report (accessed October 12, 2011 at http://grandwater.org/ReportsandLinks.aspx). Seepage estimates from the report vary between 187 acre-ft/yr (in 2009) and 2,677 acre-ft/yr (in 2007), and average 1,283 acre-ft/yr. These estimates are lower than those reported by Downs and Kovacs (2000) and Lowe and others (2007). Seepage estimates in GWSSA’s 2010 report were calculated using a water budget balance approach in which:

\[
\text{seepage} = \text{lakeprev} + \text{div} - \text{irr} - \text{evap} - \text{lakecurr}
\]

where seepage is the seepage from the lake for the current year, lakeprev is the amount of water in the lake at the end of the previous year, div is the amount of water diverted to the lake in the current year, irr is the amount of lake water delivered to the irrigation system in the current year, evap is the amount
of water evaporated from the lake in the current year, and \textit{lakecurr} is the amount of water in the lake at the end of the current year.

GWSSA (2010) assumes a yearly evaporation estimate of 200 acre-ft/yr which is likely low for this area; this estimate equates to a yearly evaporation rate of about 4 ft/yr. Evapotranspiration studies in the Lake Powell area (U.S. Bureau of Reclamation Report, 1986), where climatic conditions are similar to those within Moab-Spanish Valley, estimated evaporation rates of about 5.7 ft/yr. Additionally, evapotranspiration studies in the central Great Basin and Death Valley areas give estimates of open water evaporation rates of 5.1 ft/yr (Welch and others, 2007) and 8.4-8.8 ft/yr (Laczniak and others, 2001) for the two areas, respectively. Climatic conditions controlling evaporation within Moab-Spanish Valley likely fall between climatic conditions within these two other areas. The evaporation rate for Ken’s Lake, therefore, is likely higher than 4 ft/yr. If evaporation from the lake is higher, this would effectively decrease the amount of seepage from the lake (possibly between 45 and 80 percent), thereby reducing the amount of estimated recharge from the lake to the valley-fill aquifer than has previously been reported.

\textbf{Infiltration of Water From Pack Creek}

Pack Creek drains an area of about 64 square miles in the southern portion of the Spanish Valley area (Sumsion, 1971). Shortly after its origin near Barber and Pack Creek Springs, the entire amount of water within the channel is diverted for irrigation. The channel of Pack Creek, therefore, is dry between the diversion site and the springs near Moab City Park, except during infrequent and brief periods of heavy runoff (Sumsion, 1971). The springs near Moab City Park provide a perennial source of water for the stream, and below this point to its confluence with Mill Creek, Pack Creek is a gaining stream (Sumsion, 1971).

Infiltration of water diverted from Pack Creek is a source of recharge to the valley-fill aquifer where it is applied for irrigation (Sumsion, 1971; Steiger and Susong, 1997). Only one previous study,
Eychaner (1977), gives an estimate of groundwater recharge from Pack Creek of 330 acre-ft/yr. Discharge in the creek was measured just above the diversion from 1954-1959 with a mean annual discharge of 1,840 acre-ft/yr. This discharge was measured during a prolonged period of below average precipitation (Burden and others, 2011, fig. 40), and likely represents a minimum discharge amount within the creek. Assuming that this value represents the average minimum discharge within the channel, that the entire amount of water within the channel is diverted for irrigation, and about 50 percent of this water infiltrates into the valley-fill aquifer (Sumsion, 1971; Eychaner, 1977), average minimum groundwater recharge from the infiltration of water applied as irrigation from Pack Creek could be as high as about 900 acre-ft/yr, and under more normal precipitation conditions could be even greater.

Discharge

Groundwater discharge in Moab-Spanish Valley occurs as seepage to gaining reaches of Mill (including the North Fork) and Pack Creeks, as evapotranspiration within the Matheson Wetland, to springs and well withdrawals, and as seepage to the Colorado River (Sumsion, 1971; Eychaner, 1977; Downs and Kovacs, 2000; Lowe and others, 2007). Previously reported estimates of total groundwater discharge from Moab-Spanish Valley range between 14,000 and 17,000 acre-ft/yr (table 1).

Seepage to Streams (Mill and Pack Creeks)

Pack Creek, as mentioned above, is a gaining stream from the springs near Moab City Park to its confluence with Mill Creek. Mill Creek, including the North Fork of Mill Creek, drain an area of about 80 square miles in the northern portion of the Spanish Valley area (Sumsion, 1971), and in general is a gaining stream throughout its entire length (Sumsion, 1971). A portion of the water in Mill Creek is diverted to Ken’s Lake through the Sheley Tunnel. The North Fork of Mill Creek joins the main channel
of Mill Creek just to the east of Moab-Spanish Valley; Pack Creek joins with Mill Creek near the city of Moab, and then discharges into the Colorado River on the northwest side of the valley (fig. 1).

Groundwater discharge estimates to Mill and Pack Creeks range between 1,100 and 1,300 acre-ft/yr (Eychaner, 1977; Downs and Kovacs, 2000; Lowe and others, 2007). All of the estimates, however, are from numerical modeling results where the streams were modeled as drains. There is increased uncertainty, therefore, in these estimates due to uncertainty in the streambed conductances and geometries used in these models.

Blanchard (1990) looked at gains and losses of stream flow along the entire reaches of Mill Creek and North Fork of Mill Creek during October 1985 to determine areas and approximate quantities of groundwater recharge and discharge along the streams. Blanchard (1990) estimated approximately 2,050-3,800 acre-ft/yr of groundwater discharge to the two streams. This estimate includes groundwater discharge to the streams from the Glen Canyon aquifer outside of Moab-Spanish Valley. It should also be noted that these measurements were made following a substantially long wet period that began in 1980, so these estimates may be higher than long-term averages. Additional seepage studies along Pack and Mill Creeks within the Moab-Spanish Valley basin would be needed to provide more precise estimates and locations of groundwater discharge to these streams.

**Evapotranspiration (Matheson Wetland)**

Estimates of groundwater discharge by evapotranspiration range between 2,200 and 3,700 acre-ft/yr (Sumison, 1971; Eychaner, 1977; Gardner, 2004). Groundwater evapotranspiration mainly occurs within the Matheson Wetland in the northwest portion of Moab-Spanish Valley adjacent to the Colorado River.
Withdrawals from wells/springs

Groundwater discharge to well withdrawals and springs is estimated to range from 2,000-3,300 acre-ft/yr (Sumsion, 1971; Eychaner, 1977) for periods in the late 1960s and mid-1970s, and are 6,400 acre-ft/yr (Downs and Kovacs, 2000; Lowe and others, 2007) for the period after the late 1990s. These estimates are net estimates, whereby 50 percent of the well withdrawals for irrigation are assumed to return to the groundwater system (Sumsion, 1971); therefore, only 50 percent of the total well withdrawals for irrigation are reported in these estimates.

Well withdrawals have likely increased since 2000 (Loughlin Water Associates, LLC, 2010); however, no current well withdrawal inventory exists for Moab-Spanish Valley. Water use data from the Utah Division of Water Rights website report 2010 water use estimates of 1,825-2,336 acre-ft/yr for Moab City Water, and 788-1,301 acre-ft/yr for the Grand County Conservancy District ([http://www.waterrights.utah.gov/cgi-bin/wuseview.exe](http://www.waterrights.utah.gov/cgi-bin/wuseview.exe) accessed on October 12, 2011). These two agencies are the primary public water suppliers in the Spanish Valley area.

There is little data on the number and withdrawals of privately owned wells in the Spanish Valley area. The Utah Division of Water Rights website provides GIS datasets that can be queried to determine the number of water rights for wells that are used for domestic supply, stock watering, and irrigation that have been “approved” or “perfected”. The total number of water rights that fit these criteria in the Spanish Valley area is 724; 680 of these are located within Moab-Spanish Valley (dataset WRPOD downloaded from [http://www.waterrights.utah.gov/gisinfo/wrcover.asp](http://www.waterrights.utah.gov/gisinfo/wrcover.asp) accessed on December 9, 2011). Assuming that groundwater withdrawals from these water rights are about 1 acre-ft/yr, then estimated withdrawals from these privately owned wells would be approximately 724 acre-ft/yr from the entire Spanish Valley area, and 680 acre-ft/yr for Moab-Spanish Valley.
Seepage to the Colorado River

The Colorado River is the terminal groundwater discharge point for water within the Moab-Spanish Valley basin. Estimates of groundwater discharge to the Colorado River range between 110 and 9,500 acre-ft/yr (Sumption, 1971; Eychaner, 1977; Downs and Kovacs, 2000; Gardner, 2004; Lowe and others, 2007). The estimates of 9,500 acre ft/yr from Downs and Kovacs (2000) and 9,200 acre-ft/yr from Lowe and others (2007) may include evapotranspiration from the Matheson Wetland, but it is unclear in these reports. The large difference in estimates between Sumption (1971) and Gardner (2004) are due to differences in the estimated saturated thicknesses used in the Darcy calculations of the seepage estimates as discussed above (see “Infiltration of Precipitation” section).

Water Levels

The locations of selected wells with long-term (23 years or greater) water level records in the Spanish Valley area are shown in figure 2. Hydrographs showing water levels in these wells are shown in figure 3. Wells 1 and 5 are completed in the valley-fill aquifer, wells 3, 4, and 6 are completed in the Glen Canyon aquifer, and it is unknown in which aquifers wells 2, 7, 8, and 9 are completed.

Generally, water levels show a decline from the late 1960s to the late 1970s (fig. 3), corresponding to a period of below average precipitation in the area (Burden and others, 2011, fig. 40). Water levels in the 1980s show a large increase, which corresponds to an increase in precipitation to near average or above average conditions in the mid- to late 1980s (Burden and others, 2011, fig. 40). Water levels generally remained constant in the 1990s, followed by a decline of about 2 to 18 ft from the early to mid-2000s corresponding to a slight decrease in precipitation (Burden and others, 2011, fig. 40). Since the mid-2000s, water levels have remained relatively constant, except at well 2 which shows continuing water level declines through the late 2000s and early 2010s suggesting that it may be impacted by nearby well withdrawals.
Effects on Water Levels From Proposed Groundwater Withdrawals

The proposed SJSV-SSD groundwater withdrawals will service State of Utah School and Institutional Trust Lands Administration (SITLA) property in the Spanish Valley area. These lands have been broken up into 27 planned development areas (PDAs) by SITLA, and groundwater needs for each of the PDAs have been estimated under conceptual minimum and maximum potential development scenarios (Loughlin Water Associates, LLC, 2010). The current proposed wells in the Spanish Valley area would service PDAs 7 (1 proposed well), 8 (3 proposed wells), and 9 (3 proposed wells) located to the northwest of the Interagency Fire Center Well; PDAs 12 (4 proposed wells) and 13 (4 proposed wells) located to the southwest of the Interagency Fire Center Well; PDAs 21 (1 proposed well, 1 pre-existing well), 22 (1 proposed well), 23 (1 proposed well), and 25 (1 proposed well) on the northwest side of Bridger Jack Mesa; and PDA 27 (3 proposed wells) on the southeast side of Bridger Jack Mesa (fig. 1). The BLM has identified at four water rights that may be impacted by this proposed groundwater development: the Interagency Fire Center Well, Mud Spring, and two unnamed springs in Kane Springs Creek Wash (fig. 1).

Theis analyses were conducted to estimate potential drawdown at each of the four BLM water rights sites. Theis (1935) developed an analytical equation that can be used to calculate a theoretical drawdown at an observation well for any time and at various distances from any number of wells pumping at various rates. The Theis equation is:

\[ s = \frac{Q}{4\pi T} W(u) \]

\[ u = \frac{r^2 S}{4Tt} \]

where \( s \) is the drawdown, \( u \) is a dimensionless time parameter, \( Q \) is the discharge (pumping) rate, \( T \) is the aquifer transmissivity, \( S \) is the storativity of the aquifer, \( r \) is the distance between the pumping well
and the observation well, $t$ is the time since the pumping began, and $W(u)$ in the “Well function”. Due to the principle of superposition, the total drawdown from two or more wells pumping simultaneously is equal to the sum of the drawdown of each of the wells acting separately, thereby making it easy to calculate drawdown effects from multiple pumping wells. The TheisGUI Version 1.0 Theis Equation for Well Drawdown computer program, developed by S. Bartholoma of the U.S. Geological Survey, was used to calculate the Theis drawdown.

The assumptions under which the Theis equation applies are: (1) the aquifer is confined, homogeneous, isotropic, and of infinite areal extent; (2) the pumping well fully penetrates the aquifer, has zero radius, is 100 percent efficient, and has a constant pumping rate; (3) groundwater flow is horizontal; and (4) all changes in the potentiometric surface (water levels) are the result of the pumping well alone. In the Spanish Valley area, the Glen Canyon aquifer occurs under both unconfined and confined conditions. In general, the Theis equation can be applied to unconfined conditions if the drawdowns calculated are less than 10 percent of the thickness of the aquifer (http://www.astm.org/Standards/D4105.htm). Despite this limitation, the Theis analyses are used to provide a reasonable first approximation of potential drawdown in the Spanish Valley area.

The Theis analyses were run using three transmissivities: (1) 100 ft$^2$/d, the lowest $T$ reported for the Glen Canyon aquifer (Jobin, 1962; Freethy and Cordy, 1991); (2) 1,500 ft$^2$/d, the highest reported $T$ for unfractured portions of the Glen Canyon aquifer (Sumsion, 1971); and (3) 5,500 ft$^2$/d, the middle of the reported range of $T$ for fractured portions of the Glen Canyon aquifer (Sumsion, 1971; Freethy and Cordy, 1971). Results using the lowest $T$ (100 ft$^2$/d) produced drawdowns that were more than 10 percent of the aquifer thickness, and sometimes produced drawdowns that were larger than the total thickness of the aquifer. This is a significant violation of the assumptions for using the Theis equation and, therefore, drawdown results using the lowest $T$ were subsequently excluded from the analyses.
Additionally, the Theis analyses were run using the limits of the range of reported storativities for the Glen Canyon aquifer. The storativities used in the Theis analyses for unconfined aquifer conditions (e.g. near the Interagency Fire Center Well) were 0.05 and 0.1, while the storativities used for confined conditions (e.g. near the springs) were 0.0003 and 0.008 (Freethey and Cordy, 1991).

For each of the four BLM sites, Theis analyses were run using total times of 5, 10, 20, 50, and 100 years. The Theis analyses results show that lower transmissivities and (or) lower storativities will produce larger drawdowns; additionally, drawdowns also increase with larger pumping rates and longer times.

**Estimated Effects on Water Levels at the Interagency Fire Center Well**

The Interagency Fire Center Well is located just to the west of Ken’s Lake along the eastern margin of Spanish Valley (fig. 1). The water right associated with this well, Utah Division of Water Rights water right number 05-3067, indicates that this water right had a priority date of 7/14/2005 and the status of the water right has been approved. Authorized uses for this water right include domestic and irrigation use for the BLM fire facility. The authorized flow rate for this water right is 6.73 acre-ft/yr. The well is drilled to a total depth of 365 ft, and the well is screened between depths of 245 and 365 ft (State of Utah Division of Water Rights Well Driller’s Report for water right 05-3067). At this site, the Navajo Sandstone exists at a depth of approximately 225 ft, and is overlain by valley-fill sediments. Because the Glen Canyon aquifer is unconfined at the site, the well was screened across both the valley-fill aquifer and the Glen Canyon aquifer. Depth to water in the well, however, was measured at 305 ft, which is below the top of the Glen Canyon aquifer; therefore, the valley-fill aquifer is unsaturated. Additional information from the Well Driller’s report indicates that the Navajo Sandstone is fractured at this site.

SITLA PDAs 7, 8, 9, 12, and 13 are the closest in proximity to the Interagency Fire Center Well (fig. 1). Wells in these PDAs will likely be finished in either the Navajo Sandstone or the Wingate
Sandstone of the Glen Canyon aquifer (Loughlin Water Associates, LLC, 2010). Blanchard (1990) reported that these two members of the aquifer were hydraulically connected, because the intervening Kayenta Formation in the Spanish Valley area is mostly sandstone, providing a hydraulic connection between the Navajo Sandstone and the Wingate Sandstone. The combined estimated water supply demand for PDAs 7, 8, and 9 under both the minimum and maximum scenarios is 158 acre-ft/yr. The combined total estimated water supply demand for PDAs 12 and 13 under the minimum and maximum scenarios is 893 acre-ft/yr and 2,139 acre-ft/yr (Loughlin Water Associates, LLC, 2010). The term water supply demand is used in Loughlin Water Associates, LLC, (2010) and, assuming that all water to meet this demand will be coming from groundwater, is equivalent to proposed groundwater withdrawals within these PDAs.

The Theis analyses for the Interagency Fire Center Well were run under two different configurations of pumping. In the first configuration, it was assumed that all pumping for each PDA or groups of PDAs occurred at the most distal wells to the Interagency Fire Center Well. Theis analyses were performed under both the minimum and maximum water supply demands for PDAs 7, 8, and 9, and for PDAs 12 and 13. It was assumed that all the withdrawals were occurring at the most distal wells from the Interagency Fire Center well in PDAs 7, 8, and 9 (proposed well 7A, at a distance of 10,200 ft), and in PDAs 12 and 13 (proposed well 12D, at a distance of 7,700 ft), and drawdown was calculated at the Fire Center Well. This produces a minimum estimate of drawdown, as drawdown is inversely proportional to distance from the pumping well; that is, the closer the pumping well, the larger the drawdown. In the second configuration, the maximum pumping for each PDA was allocated equally among the proposed wells for that PDA, with all of the proposed wells pumping simultaneously. This produces a maximum estimate of drawdown at the Interagency Fire Center Well.

Table 2 summarizes the input parameters and results of the Theis analyses performed for the Interagency Fire Center Well. Near the Interagency Fire Center Well, it is likely that the transmissivity
of the aquifer is similar to that of the fractured Glen Canyon aquifer (T=5,500 ft\(^2\)/day), as indicated by the Well Driller’s report. Based on the Theis analyses results for configuration 1 (distal wells) using this fractured T, drawdown at the Interagency Fire Center Well would likely be between 2.3 and 8.7 ft for the minimum groundwater withdrawal scenario, and between 5.2 and 19.1 ft for the maximum groundwater withdrawal scenario (tables 2a and 2b). Results of the Theis analyses for configuration 1 (distal wells) assuming a moderate T of 1,500 ft\(^2\)/day show drawdowns at the Interagency Fire Center Well between 2.6 and 23.3 ft for the minimum groundwater withdrawal scenario, and between 5.9 and 51.4 ft for the maximum groundwater withdrawal scenario (tables 2a and 2b). Results of the Theis analyses for configuration 2 (all wells pumping simultaneously, maximum withdrawal) show drawdowns at the Interagency Fire Center Well between 7.1 and 21.2 ft assuming T=5,500 ft\(^2\)/day, and between 10.9 and 59.1 ft assuming a more moderate T of 1,500 ft\(^2\)/day (tables 2c and 2d).

Estimated drawdowns at the Interagency Fire Center Well due to the proposed groundwater withdrawals indicate that the water level in the Interagency Fire Center Well could potentially drop below the level of the pump in the Interagency Fire Center Well, or even below the bottom of the well. It is possible, therefore, that additional drawdown induced by the proposed groundwater withdrawals could have adverse effects on the ability to obtain groundwater from the Interagency Fire Center Well.

**Estimated Effects on Water Levels at the Springs**

The three springs that the BLM is concerned about are Mud Spring, an unnamed spring in Kane Creek Wash (designated Unnamed Spring), and a second unnamed spring in Kane Creek Wash near Kane Springs (designated Unnamed Spring near Kane Springs) (fig. 1). These springs are located to the south of PDAs 12 and 13, and to the south and (or) east of PDAs 21, 22, 23, 25, and 27 (fig. 1).

It is unknown whether these springs represent perched conditions, or if they are connected to the larger regional groundwater system. Two of the springs (Mud Spring and Unnamed Spring) discharge from the Dakota and the Morrison aquifers, respectively, which often represent perched aquifers in the
Spanish Valley area. It is also undetermined whether Unnamed Spring near Kane Springs emerges from the base of the Entrada aquifer, which can also represent perched conditions, or at the top of the Glen Canyon aquifer. In addition to the possibility of these springs representing perched conditions, they are located adjacent to faults; without further study, it is unknown if these faults act as barriers to groundwater flow, or if they may enhance drawdown at the springs due to the proposed groundwater withdrawals. For the purpose of this analysis, and to assess the possibility of the effects of the proposed groundwater withdrawals, the springs were assumed to be in connection with the regional groundwater system.

There is no data on the aquifer that the proposed wells in the Bridger Jack Mesa area will be targeting. Because most of the existing wells on the mesa are completed within the Navajo Sandstone it was assumed for the purposes of this analysis that the proposed wells in this area will be targeting the Glen Canyon aquifer. Well Driller’s reports from existing wells in the Bridger Jack Mesa area show that the Glen Canyon aquifer is likely confined in this area by the overlying, low permeability Carmel Formation. Little is known of the fractured nature of the Glen Canyon aquifer near Bridger Jack Mesa, and, therefore, it is difficult to determine which transmissivity used in the Theis analyses is closest to actual aquifer conditions in this area.

**Mud Spring**

Mud Spring is located near the topographic divide in southern Spanish Valley (fig. 1). The water right associated with this spring, Utah Division of Water Rights water right number 05-2163, indicates that this water right had a priority date of 4/21/1986 and the status of the water right has been approved. Authorized use for this water right is for stock watering for the Blue Hill grazing allotment. The authorized flow rate for this water right is 0.002 ft$^3$/s (~1.4 acre-ft/yr). Mud Spring occurs at a break in slope and appears to emerge from the contact between the Dakota Sandstone and a small outcrop of Mancos Shale. The spring has been developed to enhance capture of discharge and consists of a buried
underground collection chamber which is piped to a trough at the surface. Discharge from the pipe at this spring is less than 1 gal/min.

Mud Spring lies between SITLA PDAs 12 and 13, and PDAs 21, 22, 23, 25, and 27 near Bridger Jack Mesa (fig. 1). The total estimated water supply demand under the minimum and maximum scenarios is: 893 acre-ft/yr and 2,139 acre-ft/yr for PDAs 12 and 13; 1,662 acre-ft/yr and 3,965 acre-ft/yr for PDAs 21, 22, 23, and 25; and is 219 acre-ft/yr and 500 acre-ft/yr for PDA 27 (Loughlin Water Associates, LLC, 2010).

To determine the potential drawdown effects from the proposed groundwater withdrawals on Mud Spring, Theis analyses were performed under both the minimum and maximum water supply demands for PDAs 12 and 13; PDAs 21, 22, 23 and 25; and PDA 27. It was assumed that all the withdrawals were occurring at the most distal wells from Mud Spring in PDAs 12 and 13 (proposed well 12A, at a distance of 14,300 ft), PDAs 21, 22, 23, and 25 (proposed well 25A, at a distance of 22,500 ft), and PDA 27 (proposed well 27C, at a distance of 23,500 ft).

Table 3 summarizes the input parameters and results of the Theis analyses performed for Mud Spring. Based on the Theis analyses results, water levels near Mud Spring could drop from 6.7 to 223.1 ft (table 3). The minimum amount of drawdown that may occur at Mud Spring was calculated using the following parameters: t=5 years, T=5,500 ft²/day, S=0.008 for unconfined portions of the aquifer and S=0.1 for confined portions of the aquifer, and Q=the minimum groundwater withdrawal scenarios for each of the PDAs). If this amount of drawdown were to occur flow at Mud Spring would likely decrease or may cease altogether. Under the maximum groundwater withdrawal scenarios for each PDA, the minimum amount of drawdown that may occur at Mud Spring is 15.9 ft; if this amount of drawdown were to occur flow at Mud Spring would likely cease.
Unnamed Spring

Unnamed Spring is located in Kane Springs Creek Wash, upstream of Kane Springs, and south of Spanish Valley (fig. 1). The water right associated with this spring, Utah Division of Water Rights water right number 05-1902, indicates that this water right had a priority date of 1903 and the status of the water right is unknown. Authorized uses for this water right is for stock watering and wildlife use. Authorized flow rate for this water right is 0.0036 ft$^3$/s (~2.6 acre-ft/yr). The spring emerges as a seep between the contact of the canyon wall (Morrison Formation) and the alluvium in the wash. Discharge from this spring is too small to be measurable.

Unnamed Spring lies near PDAs 21, 22, 23, 25, and 27 near Bridger Jack Mesa (fig. 1). For PDAs 21, 22, 23, and 25, the total estimated water supply demand for these PDAs under the minimum and maximum scenarios is 1,662 acre-ft/yr and 3,965 acre-ft/yr, respectively; for PDA 27, the total estimated water supply demand under the minimum and maximum scenarios is 219 acre-ft/yr and 500 acre-ft/yr, respectively (Loughlin Water Associates, LLC, 2010).

To determine the potential drawdown effects from the proposed groundwater withdrawals on Unnamed Spring, Theis analyses were run under both the minimum and maximum water supply demands for PDAs 21, 22, 23, 25, and 27. It was assumed that all the withdrawals were occurring at the most distal wells from Unnamed Spring in PDAs 21, 22, 23, and 25 (proposed well 25A, at a distance of 12,500 ft), and PDA 27 (proposed well 27C, at a distance of 12,200 ft). Because the Glen Canyon aquifer is confined near Bridger Jack Mesa, a storativities of 0.0003 and 0.008 (limits of range reported in Freethey and Cordy, 1991).

Table 4 summarizes the input parameters and results of the Theis analyses performed for Unnamed Spring. Based on the Theis analyses results, water levels near Unnamed Spring could drop from 9.5 to 222.5 ft (table 4). The minimum amount of drawdown that may occur at Unnamed Spring was calculated using the following parameters: t=5 years, T=5,500 ft$^2$/day, S=0.008, and Q=the
minimum groundwater withdrawal scenarios for each PDA. If this amount of drawdown were to occur flow at Unnamed Spring would likely decrease or may cease altogether. Under the maximum groundwater withdrawal scenarios for each PDA, the minimum amount of drawdown that may occur at Unnamed Spring is 22.6 ft; if this amount of drawdown were to occur flow at Unnamed Spring would likely cease.

**Unnamed Spring Near Kane Springs**

Unnamed Spring near Kane Springs is located in Kane Springs Creek wash, just to the east of Bridger Jack Mesa, and south of Spanish Valley (fig. 1). The water right associated with this spring, Utah Division of Water Rights water right number 05-1901, indicates that this water right had a priority date of 1903 and the status of the water right is unknown. Authorized uses for this water right is for stock watering and wildlife use. Authorized flow rate for this water right is 0.0066 ft³/s (~4.8 acre-ft/yr). The spring emerges directly in the bed of Kane Springs Creek wash, and appears to support perennial flow in the creek downstream, along with additional springs which enter the creek along the banks downstream. Discharge from this spring is estimated at less than 1 gal/min.

Unnamed Spring near Kane Springs lies near PDAs 21, 22, 23, 25, and 27 (fig. 1). For PDAs 21, 22, 23, and 25, the total estimated water supply demand for these PDAs under the minimum and maximum scenarios is 1,662 acre-ft/yr and 3,965 acre-ft/yr, respectively; for PDA 27, the total estimated water supply demand under the minimum and maximum scenarios is 219 acre-ft/yr and 500 acre-ft/yr, respectively (Loughlin Water Associates, LLC, 2010).

To determine the potential drawdown effects from the proposed groundwater withdrawals on Unnamed Spring near Kane Springs, Theis analyses were run under both the minimum and maximum water supply demands for PDAs 21, 22, 23, 25, and 27. It was assumed that all the withdrawals were occurring at the most distal wells from Unnamed Spring near Kane Springs in PDAs 21, 22, 23, and 25 (proposed well 21A, at a distance of 10,400 ft), and PDA 27 (proposed well 27C, at a distance of 4,100
This produces a minimum estimate of drawdown, as drawdown is inversely proportional to distance from the pumping well; that is, the closer the pumping well, the larger the drawdown. Because the Glen Canyon aquifer is confined near Bridger Jack Mesa, a storativities of 0.0003 and 0.008 (limits of range reported in Freethey and Cordy, 1991).

Table 5 summarizes the input parameters and results of the Theis analyses performed for Unnamed Spring near Kane Springs. Based on the Theis analyses results, water levels near Unnamed Spring near Kane Springs could drop from 11.3 to 238.6 ft (table 5). The minimum amount of drawdown that may occur at Unnamed Spring near Kane Springs was calculated using the following parameters: \( t=5 \text{ years}, T=5,500 \text{ ft}^2/\text{day}, S=0.008, \) and \( Q=\)the minimum groundwater withdrawal scenarios for each PDA. If this amount of drawdown were to occur flow at Unnamed Spring near Kane Springs would likely decrease or may cease altogether. Under the maximum groundwater withdrawal scenarios for each PDA, the minimum amount of drawdown that may occur at Unnamed Spring near Kane Springs is 26.9 ft; if this amount of drawdown were to occur, flow would likely cease at Unnamed Spring near Kane Springs and many of the other springs emerging along the banks of Kane Springs Creek in this area.

**Summary**

The San Juan Spanish Valley Special Service District has filed a water-right change application with the State of Utah with a proposal to develop 23 water wells on state lands in and around Spanish Valley with a combined planned groundwater use of 5,000 acre-ft per year. The BLM has identified four water rights that may be impacted by this proposed groundwater development. This report presents a limited hydrogeologic analysis of the Spanish Valley area to assess the probable range of effects to BLM water rights in southern Spanish Valley from the proposed groundwater withdrawals in the area. The hydrogeologic assessment presented in this report is a summary and synthesis of previous
investigations conducted within the Spanish Valley area and vicinity from the early 1970s to the late 2000s.

To investigate the effects of the proposed groundwater withdrawals, Theis analyses were conducted to estimate potential drawdown at each of the four BLM water rights sites, namely the Interagency Fire Center Well near Ken’s Lake, and three springs located in southern Spanish Valley or in the vicinity of Kane Springs Creek Wash to the south and southwest of Spanish Valley. The Glen Canyon aquifer is the likely target aquifer for the proposed wells. The Theis analyses, therefore, were run using the range of reported transmissivities and storativities for the Glen Canyon aquifer, under both the minimum and maximum water supply demand scenarios identified for each group of PDAs; effects were calculated at times of 5, 10, 20, 50, and 100 years.

Results of the Theis analyses for the Interagency Fire Center Well show drawdowns that range from a few to tens of feet. Near the Interagency Fire Center Well, it is likely that the transmissivity of the aquifer is similar to that of the fractured Glen Canyon aquifer. Assuming a high T of 5,500 ft²/day, representative of fractured conditions, drawdown at the Interagency Fire Center Well would likely be 2.3 and 8.7 ft for the minimum groundwater withdrawal scenario, and between 5.2 and 19.1 ft for the maximum groundwater withdrawal scenario for configuration 1 (all withdrawals occurring at most distal proposed wells). Results of the Theis analyses for configuration 1 (distal wells) assuming a moderate T of 1,500 ft²/day show drawdowns at the Interagency Fire Center Well between 2.6 and 23.3 ft for the minimum groundwater withdrawal scenario, and between 5.9 and 51.4 ft for the maximum groundwater withdrawal scenario. Results of the Theis analyses for configuration 2 (all wells pumping simultaneously, maximum withdrawal) show drawdowns at the Interagency Fire Center Well between 7.1 and 21.2 ft assuming T=5,500 ft²/day, and between 10.9 and 59.1 ft assuming a more moderate T of 1,500 ft²/day. Estimated drawdowns at the Interagency Fire Center Well due to the proposed
groundwater withdrawals indicate that the water level in the Interagency Fire Center Well could potentially drop below the level of the pump in the Interagency Fire Center Well, or even below the bottom of the well. It is possible, therefore, that additional drawdown induced by the proposed groundwater withdrawals could have adverse effects on the ability to obtain groundwater from the Interagency Fire Center Well.

Results of the Theis analysis for the three springs show similar results, with drawdowns that could range from a few tens to hundreds of feet. It is unknown, however, if these springs are connected to the larger regional groundwater flow system, or if they represent perched conditions. Minimum estimated drawdowns at the three springs range between 6.7 and 11.3 ft under the minimum groundwater withdrawal scenarios, and between 15.9 and 26.9 ft under the maximum pumping scenario. If the springs are connected to the regional groundwater flow system and drawdowns of this magnitude occur, it is likely that flow at these springs would decrease or cease altogether.

**Suggestions for Future Work**

To better understand and quantify the effects that the proposed groundwater withdrawals will have on the BLM water rights, several lines of future work need attention. First, a comprehensive, up-to-date water budget for the Spanish Valley area needs to be investigated, including: (1) a more rigorous calculation of recharge to the Glen Canyon aquifer in the upland areas to the east of Moab-Spanish Valley, and (2) a more complete inventory of discharge, including well withdrawals, which have likely increased greatly in the last decade. Second, environmental tracers could provide a better understanding of the connection of the BLM springs to the larger regional groundwater flow system, and whether or not these springs represent perched conditions. Third, aquifer tests near the springs and well would provide much better data on transmissivities and storativities in these areas of the aquifer, and indicate if these sites would be susceptible to increased groundwater withdrawals; additionally aquifer tests across
the faults in these areas would also provide indications if the faults act as barriers to groundwater flow. Finally, incorporation of this newer information into a three-dimensional numerical groundwater flow model of the Spanish Valley area would greatly enhance the quantification of the potential impacts that the proposed groundwater withdrawals will have on the BLM water rights sites, as well as other water rights within the Spanish Valley area.

References Cited

Blanchard, P.J., 1990, Ground-water conditions in the Grand County area, Utah, with emphasis on the Mill Creek-Spanish Valley area: State of Utah Department of Natural Resources Technical Publication No. 100, 69 p, 2 pl.


Freethey, G.W., and Cordy, G.E., 1991, Geohydrology of Mesozoic rocks in the Upper Colorado River Basin in Arizona, Colorado, New Mexico, Utah, and Wyoming, excluding the San Juan Basin:


Figure 1. Location of study area, Bureau of Land Management (BLM) water rights sites, and San Juan Spanish Valley Special Service District (SJSV-SSD) proposed well sites categorized by planned development area (PDA) number.
Figure 2. Location of wells in study area with long-term water level records. Corresponding hydrographs are shown in figure 3.
Figure 3. Hydrographs from wells with long-term water level records within the Spanish Valley area. Numbers to the right of the hydrographs correspond to the well numbers on figure 2.
Figure 3. Hydrographs from wells with long-term water level records within the Spanish Valley area. Numbers to the right of the hydrographs correspond to the well numbers on figure 2.