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June 3, 2009

LeAnn Pyatt
Upper Big Sandy Management District
P.O. Box 241
Simla, Colorado 80835

Re: Phase 2 Water Balance Report
June 2009
Project Number 694.4

Dear Ms. Pyatt:

Enclosed please find one copy, on compact disc, of the final water balance report entitled *Upper Big Sandy Designated Ground Water Basin Phase 2 Water Balance Report*. The report contains the results of the water balance work performed using funding received from the Severance Tax Trust Fund and incorporates the analysis from the Phase 1 Water Balance project. Comments received on the draft report during the May 13, 2009 Board Meeting were incorporated into the enclosed final report.

Please do not hesitate to contact us by phone (303.526.2600) if you have any questions on the report.

Sincerely,

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Cristy R Radabaugh

Cristyn R. Radabaugh, P.E.
Project Engineer

William Berg, P.G.
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cc: Mr. Dave Taussig (1 hardcopy)
Mr. Gary Hlatki (1 hardcopy)
Mr. Joe Frasier (1 hardcopy)
File 694.4
Mr. Dave Stone (1 hardcopy)
Mr. Edward Stanko (1 hardcopy)
Mr. Andy Moore, CWCB (1 CD)
Mr. Morris Ververs (1 hardcopy)
Mr. Larry Mott (1 hardcopy)
Mr. Scott Krub, District attorney (1 CD)

UPPER BIG SANDY
DESIGNATED GROUND WATER BASIN

PHASE 2 WATER BALANCE REPORT
JUNE 2009

Big Sandy Creek near Simla, Colorado
Photo taken February 18, 2009

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PREPARED FOR:
Upper Big Sandy Ground Water
Management District
325 Pueblo Ave
Simla, Colorado 80835
Project No. 694.4
June 2009

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I. INTRODUCTION

Martin and Wood Water Consultants, Inc. (M&W) prepared this water balance report for the Upper Big Sandy Ground Water Management District (District). Figure 1, the Basin Location Map, presents the location of the District in eastern Colorado. The District was formed on October 22, 1976 with the purpose of managing the ground water resources within the Upper Big Sandy Ground Water Basin (Basin). The District makes recommendations to the State Engineer's Office on the approval or denial of new ground water well permits, and the District is responsible for planning for the current and future use of the alluvial ground water within the boundaries of the Basin.

1. Project Purpose

The purpose of this project is to assess the consumptive and non-consumptive water needs within the Upper Big Sandy Designated Ground Water Basin and compare those needs against the sustainable available alluvial water supply via a water balance assessment approach. This project assists the District by quantifying the use and supply of alluvial ground water within the Basin and creating a water balance of the Basin which will assist the District in developing long-term management policies for the ground water resources within the Basin, especially in regard to well pumping and maximum levels of pumping (safe yield) that can reliably be sustained within the Basin. The District has a goal of establishing and maintaining sustainable management of the ground water resources of the Basin.

In addition to the water balance, this project seeks to quantify the volume of alluvial ground water stored within the aquifer along with an estimate of the economically recoverable quantity of this water. The District may then have to decide how much of this storage volume they are willing to utilize in a given year or over a specified period (e.g., a maximum for a three-year period). The water in storage provides a buffer against years of low natural recharge, but the volume of water in storage is finite, may take considerable time to recover, and should be used cautiously.

2. Funding Source

This project is funded through a Severance Tax Trust Fund grant, administered by the Colorado Water Conservation Board (CWCB). The grant request process was started in October 2006, and the grant was submitted in January 2007. Funding became available in October 2008 after CWCB completed the purchase order. With the District Board's approval, M&W began work in October 2008 under the Severance Tax Trust Fund grant. The work completed under this grant is referred to as "Phase 2" of the water balance and builds on the work carried out for the first phase of work as described in the report dated March 2009.

3. Scope of Work

The broadly-defined Scope of Work for this project is to obtain and analyze data on the alluvial aquifer in the Basin and within the District boundary in order to develop a water balance which will assist the Upper Big Sandy Ground Water Management District in their decision-making and water management roles. This project is divided into two major categories: (1) Collection of Additional Data and (2) Technical Analysis for the Basin Water Balance. The work for this project will build on several previous studies conducted by the District. The project includes data development and analysis relating to the hydrology of the Basin, the Basin lateral extents, the hydrogeological characteristics, the nature and magnitude of the alluvial underflow, the volume of water in alluvial storage, the levels of well pumping, and the net water balance. All of the data collection and analysis is aimed at refining the Basin water balance such that the approximate sustainable yield of the Basin can be better determined, and so that there can be reliable and responsible long-term management of the water resources of the Basin so as to provide the maximum benefit to all the users within the Basin.

The below information provides a summary of the tasks in the scope of work associated with the grant application.

Collection of Additional Data

In order to accurately define the extent of the alluvial ground water aquifer and to develop an operational Basin water balance for the District, the following data collection is necessary.

- Conduct drilling and geologic investigations to obtain information on the subsurface. The goals include better defining of the alluvium at the downstream end of the Basin and to obtain subsurface data at several selected points to develop cross-sectional representations of the Basin, to determine saturation levels, and to examine the potential for multiple subsurface buried alluvial channels.

- Obtain field data to be utilized to develop defensible data needed for the water balance inputs. Data includes information obtained from pump testing existing wells utilized to obtain site-specific and basin wide average hydraulic parameters including the transmissivity, hydraulic conductivity, and specific yield of the alluvial aquifer.

Technical Analysis for Water Balance

Technical analyses will be performed to quantify the use and availability of alluvial water within the Basin and to create a water balance of the Basin to assist the District in developing long-term management policies for the ground water resources in the Basin, especially in regard to well pumping and the maximum levels of pumping (safe yield) that can reliably be sustained.

The following tasks were included.

- Analyze the current or recent alluvial water levels
- Analyze and provide new estimates of hydraulic conductivity, transmissivity, and specific yield based on field data and/or on the application of published appropriate ranges of values as correlated to the pump testing
- Develop a refined estimate of the irrigated acreage within the District
- Research the irrigation pumping records and the associated irrigated acreage

- Investigate the inclusion into the water balance of consumptive use associated with stock watering
- Evaluate the additional geologic data to better define the alluvial extent, storage volume, and underflow out of the District
- Quantify the amount of stored water within the alluvial aquifer and develop estimates of the volume of potentially recoverable ground water/usable storage
- Determine wet and dry year water budgets and vary the water balance accordingly
- Consider various ground water well withdrawals and compare with differing recharge estimates
- If funding allows, analyze the interaction between Denver Basin aquifers and the alluvial aquifer

The scope also defines that a draft and final report will be prepared which describes the results of the Phase 2 field work and the data, the water balance analysis, and M&W's technical conclusions. M&W will obtain comments on the draft report though attendance at one District Board Meeting where the project and the results will be presented to the Board. Additionally, data will be provided to the District and CWCB for their future use of the water balance as a management tool.

4. Past Studies

The District previously initiated the water balance process in 2001 when they contracted to ASCG Incorporated (ASCG) to carry out investigations into the Basin alluvial aquifer characteristics and water usage within the Basin. ASCG completed three phases of work over multiple years. ASCG Phase 1 comprised a geologic study of the alluvial aquifer; ASCG Phase 2 was a hydrologic study of the alluvial aquifer that resulted in an initial water balance; and the primary objective of ASCG Phase 3 was to provide recommendations for the District to manage the aquifer and to protect, preserve, and conserve the ground water resource in a sustainable manner. The results of all three phases were presented in the *Geo-Water Study for Upper Big Sandy Designated Ground Water Basin* (ASCG, undated).

In 2006, the District contracted M&W to review ASCG's work and to begin building on the Phases 1-3 work already conducted by ASCG. This led to the completion of M&W's *Upper Big Sandy Designated Ground Water Basin Phase 4 Basin Analysis Report* (2007). Phase 4 comprised a thorough evaluation of the ASCG work and allowed for the development of recommendations for further scopes of work while avoiding, to the greatest extent possible, any duplication of effort.

In May 2008, M&W began work on a new water balance for the District. M&W's water balance was divided into two phases since the work was conducted under two different grants. These phases are now referred to as the Phase 1 Water Balance and the Phase 2 Water Balance and are named separately from the work that ASCG conducted.

The Phase 1 Water Balance project was funded through a grant from the Arkansas Basin Roundtable Group who receives their funding from the Colorado Water Conservation Board. Phase 1 involved multiple analyses and quantification of the volumes of water that recharges the aquifer and that is removed from the aquifer annual. This initial water balance also addressed the volume of water in storage, the saturated alluvial extent, and the water balance-predicted changes to the water table. The study resulted in recognition of an apparent disconnect between the water balance-predicted changes and the observed water table changes based on the Colorado Division of Water Resources (DWR) monitoring well water level data. The difference between the predicted changes and the observed changes further indicated the need for the current, or Phase 2 Water Balance, study. While the average annual predicted water table changes based on the water balance are not likely to match specific years of observed changes (due to the large number of components which actually vary annually in comparison to the water balance data which are representative average values applied to any given year), the observed trends and predicted trends should agree. Therefore, this Phase 2 report further refines the work conducted in Phase 1 and provides the comprehensive water balance for the Basin. The final report for M&W's Phase 1 water balance work was completed in March 2009.

5. Report Layout

The water balance project conducted by M&W was funded through two grants received by the District, and this report comprises the summary report presenting the work carried out under both grants. This stand-alone comprehensive report provides information regarding all of the work that M&W has done toward the Upper Big Sandy water balance. As such, this report includes relevant information presented in the Final Phase 1 Water Balance Report and includes and reflects additional new information based on data obtained and analyses conducted for Phase 2. This Phase 2 report is meant to supersede the Final Phase 1 Water Balance Report (March 2009).

This report consists of nine sections, including this introduction which comprises Section I. Section II is a description of the Upper Big Sandy Designated Ground Water Basin, and Section III provides information on the field work conducted for this project. Section IV discusses the member survey conducted in Phase 1. Section V explains the components of the water balance, and Section VI presents a discussion of alluvial storage and water levels within the Basin. The water balance analysis is included in Section VII, and Section VIII includes our conclusions and recommendations. Section IX includes the references cited, and figures, tables and appendices follow the report text.

II. BASIN DESCRIPTION

1. Location and Geography

The Upper Big Sandy Designated Ground Water Basin comprises a land area of approximately 282,000 acres in portions of El Paso, Elbert, and Lincoln Counties in eastern Colorado. Figure 1, the Basin Location Map, graphically presents the location of the Basin within Colorado. The towns located within the Basin are Calhan, Matheson, Simla, Ramah, and Limon. The Basin begins at the headwaters of the Big Sandy Creek and extends into Lincoln County, just east of Limon. Note that the drainage basin of Big Sandy Creek extends beyond the District boundary; for purposes of this report the term "Basin" refers to that portion of the Big Sandy drainage area lying within the District boundaries. The ground surface elevations in the Basin range from approximately 7,000 feet above sea level at the western edge to approximately 5,250 feet above sea level on the eastern edge. The flow is generally toward the northeast until the River Bend area, where the channel of Big Sandy Creek begins to flow to the southeast. The Basin, located in an area of relatively minimal annual rainfall, generally exhibits sparse vegetation and there is rarely any active flow in the channel other than during or immediately after significant precipitation events.

It is important to note that, other than in areas immediately downstream of on-stream reservoirs, there is generally no continuous live streamflow in the channel of Big Sandy Creek within the Basin. While local intermittent flows are observed following heavier precipitation events, the creek bed is typically dry throughout the year. Thus, essentially the entire hydrologic system associated with the Upper Big Sandy Basin relates to subsurface alluvial flow with only occasional live flow events of relatively short duration and over relatively short reaches.

2. Geology

The geology in the Basin consists of sedimentary bedrock formations of Cretaceous to Tertiary age (125 million to 60 million years old), overlain by unconsolidated sedimentary deposits of Quaternary age (60 million years old to present). The District lies within a geologic structural basin known as the Denver Basin. The administrative ground water portion of the Denver Basin, as opposed to the entire structural basin, underlies a 6,700 square mile area extending into Weld County on the north; El Paso county on the south; Jefferson County on the west; and the eastern portions of Adams, Arapahoe, and Elbert Counties on the east (Ground Water Atlas of Colorado, Colorado Geological Survey, 2003). The administrative Denver Basin pertains to a major Colorado aquifer system, and underlies the Upper Big Sandy Basin from the head of the Basin in the west to the area near River Bend, near the eastern extent of the Basin (west of Limon). The administrative Denver Basin consists of four major sedimentary bedrock aquifers. The four bedrock aquifers, from oldest to youngest, are the Laramie-Fox Hills, Arapahoe, Denver, and Dawson aquifers. The Denver Basin aquifers are administratively defined and separated, and are in places somewhat inconsistent with the stratigraphic Denver Basin formations. Adding to this somewhat confusing mix is the fact that there have over time been multiple stratigraphic nomenclatures applied with respect to the structural Denver Basin bedrock formations. The United States Geological Survey (USGS) published the Geologic Map of the Limon 1° X 2° Quadrangle, Colorado and Kansas (Sharps, 1980) in 1980. The Sharps publication refers to the Denver Basin formations, from oldest to youngest, as the Pierre, Fox Hills, Laramie, and Denver formations; in the Basin area. The USGS published the Geologic Map of the Denver 1° X 2° Quadrangle, North-Central Colorado (Bryant et. al. 1981) in 1981. The Bryant et.al. publication refers to the Denver Basin formations, from oldest to youngest, as the Pierre, Fox Hills, Laramie, and Dawson formations, in the Basin area. Then, with the 1985 implementation of the Senate Bill 5 (SB5) legislation, the Dawson Formation was administratively subdivided, from oldest to youngest, into the Arapahoe, Denver, and Dawson aquifers. The Arapahoe and Dawson aquifers were in certain locations (northern portions of the overall Basin) further administratively subdivided into upper and lower units. This has resulted in some confusion regarding the structural Denver Basin formations and administrative Denver Basin aquifers, with the structural formations and administrative aquifers being referred to interchangeably. Recently, there has been a push within the geologic community to revise the structural nomenclature to one strongly resembling the pre-SB5 nomenclature. These nomenclature variations are illustrated below in the Denver Basin Nomenclatures table, with the Colorado Geologic Survey nomenclature representing the recent shift back to the pre-SB5 nomenclature. This presents a conundrum when considering stratigraphy and hydrogeologic units (aquifers). The current trend in stratigraphic nomenclature is towards the pre-SB5 nomenclature, whereas the Denver Basin bedrock aquifers are administered using the SB5 nomenclature. As such, this report will apply the pre-SB5 nomenclature for stratigraphic purposes while presenting SB5 nomenclature when describing hydrogeologic issues. Figure 2A, the Surficial Geology Map, presents a surface geology map for the Basin modified from USGS 1:250,000 Geologic Maps of The Denver and Limon 1° X 2° Quadrangle Series. The geologic map legend associated with the mapping presented in Figure 2A is presented in Figure 2B, the Surficial Geology Map Legend.

Denver Basin Nomenclatures

Administrative Denver Basin (1985)	United States Geological Survey (Sharps, 1980)	United States Geological Survey (Bryant, et. al., 1981)	Colorado Geologic Survey (recent)
Dawson Arkose (Tdw)	*Not in mapped area*	Dawson Arkose (Tdb)	Dawson Group (TKda$_{1-6}$)
		Upper Dawson (Td)	
Denver Formation (TKd)	Denver Formation (TKd)	Lower Dawson (TKdl)	
Arapahoe Formation (Ka)			Lower Part of Dawson Group (Kda)
Laramie Formation (Kl)	Laramie Formation (Kl)	Laramie Formation (Kl)	Laramie Formation (Kl)
Fox Hills Sandstone (Kf)	Fox Hills Sandstone (Kf)	Fox Hills Sandstone (Kf)	Fox Hills Sandstone (Kf)
Pierre Shale (Kp)	Pierre Shale (Kp)	Pierre Shale (Kp)	Pierre Shale (Kp)

Notes: Dashed line indicates uncertain transition from one formation to another.

The Laramie Formation and Fox Hills Sandstone are administratively considered a single aquifer

North of the study area the Administrative Denver Basin nomenclature separates both the Dawson and Arapahoe Formations into upper and lower units

The following bedrock and unconsolidated formation descriptions were modified from *The Geology and Ground-Water Resources of Parts of Lincoln, Elbert, and El Paso Counties, Colorado* (Thad G. McLaughlin, Colorado Water Conservation Board and the U. S. Geological Survey, 1946). The unconsolidated deposits consist of terrace deposits, alluvium, weathered bedrock and loess. The bedrock formations, from oldest to youngest, include the Pierre, Fox Hills, Laramie, Dawson, Castle Rock, and Ogallala formations. Note that this list reflects the pre-SB5 nomenclature.

Alluvial (Unconsolidated) Deposits

The terrace deposits consist of sand and gravel containing thin beds of silt and clay. The terrace deposits were created by deposition of material into valleys that were cut by streams during an erosional period. Like the terrace deposits, the mapped alluvium is composed of sand and gravel containing thin beds of silt and clay, but is confined to the bottoms of the alluvial valleys. Similar to the terrace deposits, the alluvium was deposited into valleys created during an erosional period subsequent to the erosional and depositional periods when the terrace deposits were formed. Weathered bedrock overlies, in close proximity, the parent bedrock, retains the original rock fabric, but in the case of the sandstones, is friable and unconsolidated. If the bedrock is a shale or claystone, it can weather out to either small brecciated fragments or it can disintegrate into clays. If the bedrock is a sandstone, the weathered bedrock at that location can look very similar to alluvial sands and may result in confusion when attempting to identify the alluvial–bedrock interface. Likewise, the bedrock sandstone can look very similar to the alluvial deposits, only the individual sand grains are consolidated or “cemented” – a term often heard during conversations with residents in the Basin. The loess, consisting of very fine-grained sand and silt, was derived from the terrace deposits and alluvium and, in the Basin, has been deposited primarily east of River Bend and south of Big Sandy Creek.

Bedrock Formations

The bedrock formations are described from oldest to youngest, with a physical description followed by a general description of the location where the formation is exposed within the Basin, indicating the transition from the older underlying formation to the younger overlying formation. The Pierre Formation consists of a gray to black shale and is exposed on the surface primarily to the east of River Bend and from there to the eastern edge of the Basin. The Pierre Formation is overlain by the Fox Hills Formation. The Fox Hills Formation is a massive buff to brown sandy shale in the lower part and poorly-consolidated white sandstone in the upper part. The Fox Hills Formation is exposed on the surface from approximately four miles east of Matheson to River Bend. The Laramie Formation consists of a dark coal-bearing shale containing beds of fine-grained sandstone. The Laramie Formation outcrops at a location approximately two miles east of Ramah and is present to its contact with the Fox Hills outcrop in the area east of Matheson. The Dawson Formation overlies the Laramie Formation and consists of coarse, conglomeratic sandstone in the upper part and an arkosic sand and shale containing beds of lignite coal in the middle and lower parts. The Dawson

Formation is present from the Laramie Formation outcrop to the western extent of the Basin. The Castle Rock Formation is a coarse-grained conglomerate that exists primarily along the higher elevation areas of the Palmer Divide. The Ogallala Formation is composed of sand, gravel, silt, and clay and is present in the higher elevations north of Limon. The latter two formations, the Castle Rock and Ogallala, are part of the structural Denver Basin, but are not a part of the administrative Denver Basin aquifers. The Castle Rock and Ogallala formations have no apparent hydrogeologic relationship or hydraulic connection to the alluvial aquifer, and are thus not discussed further in this report.

3. Hydrogeology

As noted above, this project focuses on the alluvial ground water resources in the Basin. There may be flows from the alluvial aquifer to the bedrock aquifers, and vice versa in certain parts of the Basin, although little hard data has yet been developed regarding these connections. Because of the current lack of data and the limited scope of work associated with this study, this report is not quantifying these fluxes. This section provides a general description of the hydrogeologic properties of the bedrock formations.

Although the unconsolidated deposits in the Basin reflect different erosional and depositional periods of time, the terrace deposits, alluvium, and loess are all unconsolidated hydraulically connected deposits and are considered as one with respect to the definition of the alluvial aquifer within the Basin. (Unconsolidated deposits are loose, generally young non-cemented geologic materials with greater porosity or void spaces, which may contain water, whereas consolidated deposits are generally far older and have been compacted and therefore have reduced porosities relative to unconsolidated deposits. Consolidated deposits are sometimes referred to as "cemented" to one degree or another. This cementing or induration can be caused by various phenomena including compaction and hydrochemically-derived mineral deposition.) Therefore, the boundary between alluvium and terrace deposits on the surficial geology map is not indicative of the true alluvial aquifer boundary. The saturated alluvial aquifer boundary, as interpreted by M&W, is based on the drilling work carried out for this project in 2008 and 2009, review of available literature, and personal communication with residents within the Basin. The saturated alluvial aquifer boundary is illustrated in Figure 3, the Interpolated Saturated Alluvial Extent, Cross Section Locations, and Test Hole Locations.

Alluvial Aquifer Properties

The alluvial aquifer properties are used in the water balance to calculate estimated ground water flow velocities and estimated volumes of water in storage. Ground water flow velocities are needed to calculate the annual volume of ground water that leaves the District as ground water underflow. Important aquifer parameters considered for ground water flow calculations include hydraulic conductivity, transmissivity, and specific yield. Hydraulic conductivity (K)reflects the ability of a porous medium to transmit water when submitted to a hydraulic gradient and is defined as the volume of water flowing through a 1 foot by 1 foot area of the aquifer, under a unit horizontal hydraulic gradient (1 foot per foot), in a given amount of time (typically a day). Transmissivity (T) is the volume of flow through a cross-sectional area of an aquifer that is 1 foot wide and as thick as the saturated aquifer matrix, under a unit horizontal hydraulic gradient (1 foot per foot), in a given amount of time (typically a day). Specific yield (Sy) is a measure of the quantity of water which a unit volume of aquifer, after being saturated, will yield by gravity drainage and under the negative pressure characteristics related to the depth from which pumping or drainage of water may be occurring.

Published literature values and data from the Town of Limon water supply wells have been evaluated and used in the estimates of underflow and storage presented in this report. Thad McLaughlin's 1946 Ground Water Resources report (McLaughlin Report) presented an average K of the Big Sandy Creek alluvium of 1,800 gallons per day per foot squared (gpd/ft^2). The McLaughlin Report alluvial data was based on three pumping tests performed in the Basin. Willard Owens Associates produced a report entitled *Ground Water Resources of the Big Sandy Creek Drainage Area, Southeastern Colorado* (Owens Report) for the DWR for the Designated Basin evaluation in 1971. The Owens Report alluvial data was based on nine pumping tests performed in the Big Sandy Creek drainage area, with three of the pump tests performed within the Basin. The Willard Owens report presented alluvial parameters of 20 percent for Sy, 1,600 gpd/ft^2 for average K, and 63,000 gallons per day per foot (gpd/ft) for average T. HRS Water Consultants, Inc. performed a study on the Vivian Mock property entitled *Ground Water Availability Vivian Mock Property Lincoln County, Colorado, December 2005* (HRS Report). Pump testing was performed in the alluvial aquifer as part of the HRS study on the Vivian Mock property. The HRS Report presents average K values of between 1,350 gpd/ft^2 and 1,500 gpd/ft^2. The HRS Report presents an average Sy of 20 percent. Alluvial Sy values found in hydrogeology textbooks typically range from 20 percent to 35 percent, depending on the alluvial matrix. However, the *Rules and Regulations for the Management and Control of Designated Ground Water* (State of Colorado Ground Water Commission, 2008) have mandated a default alluvial Sy value for the Upper Big Sandy Designated Basin of 20 percent.

A 24-hour pumping test was performed by the Town of Limon on April 16, 2009 at the well designated as Packard 4 or "P4". We performed analyses on the Town of Limon data and arrived at K values of between 1,017 gpd/ft^2 (136 ft/day) and 2,147 gpd/ft^2 (287 ft/day), for an average of 1,586 gpd/ft^2 (212 ft/day). Calculated transmissivities ranged from approximately 62,000 gpd/ft to 104,000 gpd/ft. The calculated Sy ranged from 19 to 20 percent.

We performed site specific hydraulic testing throughout the Basin and arrived at an average Sy value of 20 to 25 percent for the Big Sandy Creek mainstem area east of Matheson, 30 to 35 percent for the Big Sandy Creek mainstem area west of Matheson, and 23 percent for the Big Sandy Creek tributaries. These Sy values were estimated to be appropriate for the basin, as they are an average of the site specific Sy testing and the pump test performed by the Town of Limon as part of this investigation. These values are also well within the range of values reported from pump tests throughout the Basin and in the literature for unconsolidated alluvial aquifers similar in nature to the Big Sandy Creek alluvium.

An average K value of 1,586 gpd/ft^2 will be incorporated in calculations in this report. This average K value was estimated as appropriate, as it is an average result of the pump test performed by the Town of Limon as part of this investigation. The value of 1,586 gpd/ft^2 is also well within the range of values reported from other pump tests throughout the Basin and in the literature for unconsolidated alluvial aquifers similar in nature to the Big Sandy Creek alluvium.

Transmissivity values are site specific, as they are a function of the aquifer saturated thickness at a given site, which varies significantly from location to location throughout the Basin. The average transmissivity values are presented above, for comparison purposes to other alluvial systems.

4. Alluvial Water Table

The DWR publishes annual reports on the water levels within the Basin. Data for some wells have been collected annually since 1991. These water level data are used to measure and track changes in alluvial water levels across the Basin. The monitoring well locations are presented on Figure 4, the Monitoring Well Location Map, and the alluvial ground water elevations based on the most recent data collection in 2008 are presented on Figure 5, the Alluvial Ground Water Elevation Map. Hydrographs (plots of the ground water elevations through time) for the DWR monitoring wells are presented in Appendix A. The hydrographs are arranged by well in order from the upstream end of the Basin to the downstream end. Additional information on the changes in water levels over time is presented in Section VI of this report.

5. Permitted Wells/Administration

In the Upper Big Sandy Designated Basin, all wells must be permitted through the DWR. Wells within the alluvial aquifer are initially granted a conditional permit (given an “F” suffix). The well owner than has three years to file for a final permit by providing evidence of beneficial use and actual pumping rates and volumes (Section 37-90-108, C.R.S.). Once final, the well receives a new permit with an “FP” designation; these are typically assigned to the high capacity irrigation wells within the District. The Denver Basin aquifer wells within the District do not have the same permitting requirements and do not need the FP designation.

There are approximately 1,600 permitted wells (including permitted monitoring wells, small capacity wells, and large capacity wells) within the Basin, based on the DWR Master Well database (updated through June 2008). About 45 percent of the wells could be wells producing from the alluvial aquifer based on the reported information in the database (aquifer code and the depth of the well). There are 98 wells with an FP designation in the database, and an additional 24 wells with an F designation. Approximately 55 percent of all wells in the Basin are permitted for household or domestic use.

The well database contains multiple listings for wells and every attempt was made to eliminate duplicates from our data set. It is important to also keep in mind that the source of the data contained in the database is reports from drillers and sometimes well owners, and the data can contain errors and inaccurate information. It thus must be utilized with caution and with the realization that the data may not truly represent the actual conditions in the field. Further, there is generally no checking by the DWR to follow up on the data submitted except in rare circumstances.

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III. FIELD INVESTIGATIONS

The field investigations for this project included a drilling program for the collection of site-specific geologic and hydrogeologic data, slug testing of two piezometers east of Limon, a pump test on a Town of Limon municipal well, and visual observations of the general physiography of the Basin. The drilling program included test hole borings and collection of alluvial samples to provide data for the interpretation of the saturated alluvial width and alluvial specific yield, which were essential in storage volume and underflow calculations. The slug testing was performed in order to obtain site specific hydraulic conductivity values at the downstream terminus of the Basin, which are incorporated in the calculations of ground water outflow from the Basin. The Limon pump test was performed with the purpose of obtaining site specific K and Sy data relatively near the downstream end of the District. Selected photographs of field activities are included in Appendix B.

1. Location of Drilling Activities

The Phase 2 drilling program provided site-specific data for use in delineating the physical and hydraulic boundaries of the alluvial aquifer, as well as hydraulic data for the alluvium, from the head of the Basin to the River Bend area (west of Limon). Additionally, alluvial samples were collected throughout the Basin and slug testing was performed at the two locations where piezometers were installed during the August 2008 Phase 1 drilling program. Site specific information throughout the Basin was considered essential, as the field data provide information for use in determination of the alluvial extent, storage volume, and calculation of the volume of water leaving the Basin as alluvial underflow. The alluvial bedrock profile and ground water elevations are critical parameters used in the analysis and development of the refined water balance for the Basin.

The drilling program was designed to provide data along transects of the Big Sandy Creek mainstem and tributaries to the mainstem. The alluvial valley transects were distributed throughout the Basin. The test hole and cross section locations are presented in Figure 3. Seven cross sections (A-A’ through G-G’) were created from the results of the field investigations conducted by M&W in 2008 and 2009, and are presented in Figures 6 through 12, respectively.

The second phase of field investigations, performed during February 2009, included the collection of soil samples for laboratory analyses of hydraulic parameters. Additionally, slug testing was performed in April 2009 on the two piezometers (installed during the August 2008 field investigation) to obtain additional site-specific hydraulic parameters. A review of previous technical reports for the general area - including the ASCG Upper Big Sandy Report; the HRS Water Consultants, Inc. (HRS) study on the Vivian Mock property entitled *Ground Water Availability Vivian Mock Property Lincoln County, Colorado, December 2005*; and a literature search - was carried out to evaluate well and test hole data coverage in the Basin. A map presenting the various investigators' cross section locations within the Basin is presented on Figure 13, Composite Cross Section Locations. The M&W cross-section locations were selected to provide additional detailed geologic and hydrogeologic data in areas not previously assessed in this level of detail and to provide data to validate other consultant's cross sectional interpretations. Cross section C-C' incorporates data collected by HRS, from their investigation of the Vivian Mock property. The HRS data was included in section C-C', as results of three test holes (GP21, GP23, and GP24) advanced during the Phase 2 investigation were consistent with the HRS results.

M&W and members of the Upper Big Sandy District Board contacted land owners within the study area to obtain permission for access for the drilling. Approval was obtained from all land owners before accessing their property and before the drilling began. Utility locates were performed for each cross-section location to verify that no utilities or underground hazards were present near the drilling locations. Utility locates were initiated by placing a call to the Utility Notification Center of Colorado (UNCC). UNCC contacted individual providers for clearance, and "all clear" notifications were received from Level 3, Colorado Interstate Gas, Qwest, Longmont Electric, Broadwing Communication, Colorado Department of Transportation, LightCore, Aquila-Dist, Town of Limon, Mountain View Electric, and Underground Locators (electric and telephone).

2. Description of Drilling Equipment and Methods

The field work was conducted over three days in August 2008, and five days in February 2009 by M&W and its contractor Vironex Environment Field Services (Vironex). The field investigations were performed using a direct-push hydraulic probe, commonly referred to by the manufacture's name, Geoprobe®.

Soil samples were collected during the first phase of drilling by hydraulically advancing a 2-inch outside diameter (OD) hardened steel cylinder with a removable cutting shoe and drive head. Soil samples were collected using 1.75-inch diameter by 4-foot length clear acetate sleeves that were advanced within the hardened steel drive tube.

Soil samples were collected during the second phase of drilling by hydraulically advancing a 3-inch OD hardened steel cylinder with a removable cutting shoe and drive head. Soil samples were collected using 2.75-inch diameter by 4-foot length clear acetate sleeves that were advanced within the hardened steel drive tube.

During both field investigation phases, the native materials were geologically logged at initial locations in each alluvial valley transect, and the depth to water was determined by evaluating the relative wetness of the native materials, followed by direct water level sounding through the open borehole with a water level meter. If the borehole collapsed, preventing direct water level measurement through the open hole with the water level meter, a 1-inch OD perforated polyvinyl chloride (PVC) well string was advanced into the borehole to allow measurement of the water elevation, via water level meter, without matrix interference. Once the native materials were logged in each alluvial valley transect, the remaining test holes in the area were generally drilled without collecting soil samples (blind drilling). In these cases, lithology changes were based on changes to the Geoprobe® advancement rate. The changes in advancement rate were calibrated with the geologically logged samples from prior test holes. If there was uncertainty on the identification of material the Geoprobe® was penetrating, a discreet soil sample was collected to clarify the identification of the material. All test holes were advanced through the alluvium until the bedrock was encountered. Sixty-three test holes were advanced during the field investigation, twenty during the first phase and forty-three during the second phase, to depths ranging from 17.5 to 85 feet below ground surface. Geologically logged test hole logs and a table presenting the blind drilling results are presented in Appendix C – Test Hole Logs.

Upon completion of the drilling and sampling the test holes were backfilled with native materials and sand and/or bentonite as necessary, unless the location was chosen for piezometer installation (a piezometer is a monitoring well designed for measurement of water levels). Two of the test hole locations (GP2 and GP3, Figure 3) were so selected for installation of temporary piezometers during the Phase 1 field work. Piezometer installation consisted of setting into the borehole 1-inch PVC pipe with factory cut slots to allow water infiltration. After installation of the piezometer, the saturated material (generally sands with trace amounts of silt and clay) filled the space outside of the piezometer, and the remainder of the borehole annulus above the water table was backfilled with borehole cuttings. The tops of the piezometers were sealed with a plug, and a flush mounted steel protective cap was cemented over the PVC piezometer for protection and future access to the piezometers for additional water level data collection.

The piezometers were permitted through the DWR as monitoring wells (approved permits are included in Appendix D).

3. Aquifer Parameter Testing

During Phase 2, eight soil samples were collected for laboratory analyses of hydraulic parameters. Soil samples were collected with a Shelby tube, which is a 2-foot long, 3-inch OD pipe that is advanced hydraulically into an open hole, which was created by first advancing a 3-inch push rod with a solid tip. The Shelby tube was then advanced through the open hole and into the saturated alluvial material. The Shelby tube was then retrieved, with the alluvial material inside the tube due to adhesion from suction and friction. The Shelby tube is designed to minimize disturbance and collect an undisturbed sample. Before the Shelby tube sample was collected, soil samples were first collected in the previously described acetate sleeves to determine the appropriate sample collection interval from which to collect the alluvial materials. At locations where the saturated alluvium was particularly dense or interbedded with thin clay stringers above the primary clay that comprises the base of the alluvium, a hydraulic push of greater than 2-feet was necessary to reach a depth where clay was present. The clay would form a seal at the end of the Shelby tube; otherwise, the saturated coarse grained alluvium would simply flow back out the bottom of the tube upon retrieval. The ends of the Shelby tube were sealed by first placing foam packing material into any void space, then sealing the tube with plastic end caps and taping the caps with duct tape, followed by wrapping the tube in bubble wrap to prevent material settling. Once back at the M&W offices, the Shelby tubes were packed into bubble wrap lined plastic containers for shipping to the laboratory.

Shelby tube samples were collected at test hole locations GP2 and GP3 along cross section A-A', GP28 along cross section D-D', GP38 and GP41 along cross section E-E', GP49 along cross section F-F', GP52 between cross sections F-F' and G-G', and GP61 along cross section G-G'. Select Shelby tube samples were analyzed for both saturated hydraulic conductivity (K) and specific yield (Sy). The K values are utilized in the calculation of underflow out of the Basin, and Sy is utilized in storage calculations. The only location where K values are needed for the water balance calculations is at the downstream end of the Basin to estimate the volume of water leaving the Basin as underflow. Therefore, only GP2 and GP3 were tested for both K and Sy, with the remainder of the test holes being tested only for Sy.

The two piezometers were slug tested on April 15, 2009 to obtain site-specific hydraulic conductivity values at the downstream terminus of the Basin. These site-specific hydraulic conductivity values help provide a more accurate estimated calculation of underflow leaving the Basin.

Slug testing was performed by first collecting a static water level. A pressure transducer was then lowered to the bottom of the piezometer and the water level was allowed to stabilize. The pressure transducer records water levels on user-defined time intervals for data analyses at a later time. A liquid slug (contained in a 1-gallon plastic water container) was then quickly released into the piezometer immediately after starting transducer water level measurement recordings. The transducer data was monitored until the water level had recovered to at least 95 percent of the initial displacement, when water level recording was stopped.

A pump test was performed by Town of Limon personnel on the Town of Limon's Packard 4 (P4) municipal alluvial well on April 16, 2009. Pump tests provide data representative of a much larger area than slug tests because pump tests stress a larger area of the aquifer and over a much greater period of time.

The pump test data was obtained from dataloggers placed in both well P4 and the Upper Big Sandy Management District's monitoring well Big Sandy 2 (BS2). The observation well, BS2, is located 205.5 feet from P4. Both dataloggers were programmed to record on a logarithmic scale. A logarithmic scale was used to capture the water level changes that occur quickly at the beginning of the test and then increase the recording interval as the test progresses and water level changes decrease. BS2 was monitored so that data could be obtained to calculate Sy (Sy cannot be reliably calculated without water level drawdown data obtained from a nearby observation well). The datalogger in well P4 was first started, followed by starting the datalogger in well BS2, before returning to well P4 to start the pump. As a result, the recording interval had progressed to a point in well P4, such that a large portion of the early water level drawdown curve, when very frequent readings are being obtained, was not recorded. As noted above, observation well BS2 is located 205.5 feet from P4. Due to this distance, water level changes in BS2 occurred much slower, such that the data collection interval provided a detailed water level drawdown curve, and the loss of the early drawdown data in P4 was not an issue with respect to BS2. The water level drawdown curves and datalogger results for wells P4 and BS2 are presented in Appendix E. The pump test was terminated 24 hours after the start of the test, with a pumping rate of approximately 650 gallons per minute maintained throughout the first 2 hours of test. The pumping rate gradually increased to 678 gallons per minute over the remainder of the test.

4. Geologic Observations

Several general observations were noted during the field investigations. The southern flank of the alluvial valley, especially in the upper (western) extent of the Basin, appears to have a greater degree of mineralization than the northern flank. This is evidenced by the presence of iron, calcium, and manganese staining in the unsaturated alluvial sediments.

The observed bedrock composition varies throughout the valley. In the lower (eastern) end of the Basin, the bedrock is a consistent dark grey shale, which is the Pierre Shale. As one moves in an upstream (westerly) direction from the River Bend area, the bedrock can be either a grey shale or a yellowish-brown sandstone. This is characteristic of the Denver Basin aquifers, which are interbedded shales and sandstones. During conversations with residents in the Basin, there appeared to be a perception that the grey shale was bedrock and the hard sandstone was “cemented” alluvium. We believe the “cemented” materials are sandstone bedrock, whereas the unconsolidated materials truly represent the Upper Big Sandy alluvial deposits. Soil samples near Ramah indicated a transition from hard sandstone to weathered sandstone to alluvium. The transition sequence looked the same both visually and mineralogically, the difference was the degree of consolidation.

5. Wetlands Observations

During August 2008, M&W conducted a survey of the Basin to observe areas that may be considered wetlands. The survey was conducted by driving on public roads and observing areas in the Basin that could potentially be interpreted as wetlands. Observations were limited by access available through public roads and time constraints. Two general areas where wetlands are persistent were identified: the Ramah State Wildlife Area and several small areas along the Big Sandy Creek mainstem. In addition, there were numerous small wetland areas bordering small on-stream reservoirs and stock ponds. These small wetland areas may not be persistent, as they have the potential to dry up during drought periods. The Ramah State Wildlife Area and the areas near Limon appeared to be of such magnitude that the wetlands would persist through drought periods, but this ability has not been directly confirmed via observations. There are numerous areas within the Big Sandy Creek mainstem and tributaries where grasses, reeds, trees and other small brush were present. These areas are considered to be “phreatophyte areas” and not wetlands, as they are likely the result of roots penetrating the saturated alluvium with no persistent surface water. Pictures collected during the wetlands survey are presented in Appendix B.

Although the Arkansas darter fish was not viewed during the survey, it is reported that the species is found in the Big Sandy Creek drainage and may live within the Basin. The Arkansas darter prefers shallow, clear, sandy streams. Their distribution has reportedly not changed significantly based on comparisons of historic data, particularly since 1979. Darter populations live in large, deep pools during late summer low-water periods when streams can become intermittent. The Arkansas darter is listed as threatened in Colorado and is a candidate for protection under the federal Endangered Species Act (Colorado Division of Water Resources, 2008). In consideration of the wetlands areas, ponding, and reservoirs within the Basin, the potential for the existence of the darter appears likely.

6. Results

M&W used the results of the field investigations and incorporated information derived from other publications to interpolate the saturated alluvial extent of the Basin. The results of the M&W field investigations were compared to cross sections produced by HRS and ASCG to evaluate the other consultant's interpretations. M&W compared the data obtained from the field investigations to data presented by the other consultants at nearby locations to verify reported depth to bedrock and depth to water measurements. For the most part, other consultant's data compared favorably to the M&W data. Therefore, other consultant's data was considered with the M&W field data to produce the interpolated saturated alluvial extent and cross section figures. The locations of M&W test holes and cross sections are presented with the locations of the other consultant's cross sections in Figure 13. In some locations, M&W collected data on one side of a tributary or the mainstem valley, and projected the results to the opposite side of the valley to illustrate the structure and water level of the entire cross section through the tributary or valley. An example of this is illustrated in Figure 10 - Cross Section E-E', where data collected from test holes GP41 through GP43 was used to interpolate the structure and water level on the opposite side of the tributary. This report presents cross sections in areas where M&W field investigations were conducted. Other consultants cross sections are not presented, as, in ASCG's case, many of the cross sections were not considered complete or sufficient due to a lack of data points. HRS's cross sections were based on test hole data (ASCG's cross sections appear to be based on well log data from the DWR master well database), and was therefore considered to be more reliable. M&W advanced three test holes along the eastern extent of HRS's cross section

C-C' to fill in a data gap and verify the HRS data. As such, the HRS data is presented with M&W data in Figure 8 - Cross Section C-C'.

Geologic Results

The results of the drilling program indicate that saturated unconsolidated materials are present in both the Big Sandy Creek alluvial plain and the terrace deposits. The lateral extent of the saturated material appears to be limited by the topography of the bedrock. However, the field investigation yielded some inconsistent results. In one of the tributaries, a test hole, GP32, located immediately adjacent to the alluvial channel was dry, whereas a test hole located up the flank of the tributary valley from the dry hole had 20 feet of saturated alluvial material. This observation was noted in a tributary on the northern flank of the alluvial valley, along cross section D-D' (Figure 9). Possible reasons for this observation include, but are not limited to, significant lithologic differences between the two locations or the presence of a buried ancestral alluvial channel. The alluvial water table (and thus the saturated alluvium) generally extends laterally from the creek channel to where the alluvium and/or terrace deposits intersect the bedrock. The alluvial valley is formed by an inclined bedrock surface and, as such, unsaturated alluvium and terrace deposits are typically present further from the creek channel than the saturated alluvium and terrace deposits. Saturated weathered sandstone bedrock was found in some of the tributaries during the field investigation and is in hydraulic communication with the alluvium and terrace deposits. The saturated weathered sandstone was therefore included in the interpolated saturated alluvial extent. The interpolated saturated alluvial extent is presented in Figure 3.

The subsurface alluvial profile of the mainstem of Big Sandy Creek at the upstream (west) end of the Basin appears to be characterized by a single incised channel. The deepest part of the channel does not necessarily underlie the current surficial alluvial channel. This single incised channel is represented in cross section E-E'. As one moves in the downstream direction (east), the channel progressively appears to become braided, meaning there are deeper subsurface alluvial channels with subsurface bedrock highs separating the channels. This braided channelization is represented in cross sections A-A', B-B', and C-C'. The bedrock high illustrated in Cross Section C-C' is depicted due to the large difference in water levels noted between TH6 and TH7. This water level difference can be explained by the presence of an elongated bedrock ridge and a contributing ground water source from the C-C' side of the section. The presence of the bedrock ridge is also supported by the high bedrock elevation of TH6 relative to the bedrock elevations of TH20A and TH7 located on either side of TH6.

Springs that are present in the uplands to the south of Big Sandy Creek appear to originate from lenses, likely comprised of sand, in the Pierre Shale and do not appear to be part of the alluvial aquifer.

Specific Yield

Two sets of laboratory analyses were performed on the Shelby tube samples. The first was a two point analysis that provides maximum Sy values (the maximum value is obtained when very high negative pressure is applied to the sample). The second analysis provided intermediate Sy values at values in between the maximum negative pressures and no negative pressure. The two sets of Sy values were then combined to develop soil moisture retention curves, from which a Sy value at negative pressures similar to what would be found at an alluvial well location in the Big Sandy alluvium were interpolated. These interpolated Sy values are the basis for the values used in our calculations. The laboratory reports and a table summarizing the laboratory results are presented in Appendix F.

The Sy results of the laboratory analyses on the Shelby tubes range from 19.4 percent at GP2 to 42.9 percent at GP49. We believe the 42.9 percent value is an outlier and is not considered in the analyses. The laboratory analyses resulted with an average Sy of approximately 35 percent for the Big Sandy Creek mainstem and approximately 23 percent for the Big Sandy Creek tributaries. However, all three of the mainstem Sy values are located in the upstream end of the Basin, west of Matheson. The Town of Limon pump test results yielded averaged Sy values of approximately 20 percent, suggesting a decrease in Sy at the downstream end of the Basin. This difference in Sy values may be due to lithologic changes throughout the Basin; it is not uncommon for finer grained materials of the type more commonly observed at the upstream end of the basin where lower energy flows are expected to exhibit higher Sy values than more coarse and washed sediments. The laboratory Sy results (excluding the 42.9 percent outlier) are within the range of literature values and values from other studies. However, it is our professional opinion that that the laboratory Sy results are slightly elevated. Pump testing results for Sy tend to be lower and the laboratory analyses were performed on samples of relatively small volume that were likely disturbed during sample collection. As such, we are using average Sy values that incorporate the pump testing results and our professional judgment, average values that are slightly lower than the laboratory results average. These final values are 20 to 25 percent for the Big Sandy Creek mainstem area east of Matheson, 30 to 35 percent for the Big Sandy Creek mainstem area west of Matheson, and 23 percent for the Big Sandy Creek tributaries. It is these values that will be utilized for the aquifer storage calculations.

Hydraulic Conductivity

The hydraulic conductivity (K) results from the laboratory analyses on the Shelby tubes are 11.62 feet per day (ft/day) at GP2 and 31.18 ft/day at GP3. The K results of the slug testing range from 0.61 to 0.68 ft/day at GP2 and range from 0.86 to 1.00 ft/day at GP3. These results are well below what would be expected from tributary locations near the Big Sandy Creek mainstem. The Town of Limon pump test provided results that ranged from 136 to 287 ft/day, which are consistent with literature values and values from other studies. In our professional opinion, a K value range of 136 to 287 ft/day or 1,017 to 2,147 gpd/ft^2, is appropriate for underflow calculations in the water balance.

Some confusion over the relationship between K and ground water velocity was voiced by Board members during the Phase I project. K is not a velocity, although it appears to have the same units as velocity (ft/day; when referring to K this is actually cubic feet per square foot per day which reduces to the ft/day that misleadingly appears to be a velocity). K, when multiplied by the local hydraulic gradient (which is unitless) is equal to the flux, or the rate of flow across a given area. So, the only time when K is equal to a velocity is when the hydraulic gradient is equal to one. The hydraulic gradient east of Limon is estimated at 0.0035. The actual ground water velocity is complicated by other factors beyond the need or scope of this discussion, but suffice it to say that the average bulk ground water flow velocity throughout the basin is likely to be less than one foot per day.

IV. MEMBER SURVEY

In August 2008, the District mailed out to their members two surveys which were created as a part of Phase 1 of this water balance project and are provided in Appendix G. The surveys included a general questionnaire on irrigated areas, crops, stock watering, wells (alluvial and other), changes in water levels, past dry holes drilled on property, and a second questionnaire on streamflow observations.

Of approximately 50 surveys mailed out, 21 general questionnaires were returned to the District along with eight streamflow observation questionnaires. The data obtained from the questionnaires included the following items.

Quantitative Information

- Irrigated area and crops irrigated
- Stock counts and time herd is typically on property
- Number and size of stock ponds
- Alluvial wells on property and their use
- Presence of any Denver Basin aquifer wells

Qualitative Information

- Dry holes drilled on property
- Changes in well production
- Changes in observed water levels within wells
- Willingness to allow future measurement of water within wells
- Willingness to collect rainfall data
- Changes in plants located along the creek bed or banks
- Changes in stream channel size or location
- Times of year when creek typically has live flow
- Duration of live flow
- Dates of creek observations
- Seasonal variations of flow

The surveys indicated that there are at least 1,450 acres of irrigated land across the Basin. The two crops most commonly grown are alfalfa (approximately 60 percent) and pasture grass (approximately 40 percent). Some farms also grow sorghum, although only three farms reported this crop. The surveys indicated that most farms have less than 65 acres of irrigated land. About half the farms had stock ponds, and nearly all the farms (17 out of 20 that answered the question) had stock for some period during the year. According to the survey results, about 1,400 head of stock are kept on properties within the Basin for an average of 8 to 9 months of the year.

The surveys also indicated that if deep wells were present on the properties, the owners considered them to be Laramie-Fox Hills aquifer wells. Based on the geologic mapping of the Basin, this may or may not be the case, depending on the well location. Most surveys indicated either directly or indirectly through the information reported that there has been a decrease in the shallow water available. This was indicated through the following.

- Reported drops in ground water levels in wells
- Reductions in irrigated land due to reduced availability of water
- Reduced well yields
- Loss of vegetation along creek
- Pot holes in stream channel which used to hold water are now dry
- Observations that the creek dried up in the late 1970s or early 1980s
- Observations that the creek no longer flows continuously in the winter like it did prior to construction of Ramah Dam

Although multiple surveys indicated that plants along the creek were dying, two surveys indicated that there had been an increase in plants and weeds growing along the creek. Both of these surveys indicated this has occurred in areas where there used to be longer periods of live flow. This reported local increase in vegetation could be due to reduced scouring of the creek bed because of Ramah Dam’s control of the flows and/or less flow in the creek due to a lower alluvial water table. Both processes could allow for greater plant growth along the creek bed and associated margins

Information obtained from the surveys was used in the water balance to support the calculated irrigated area, verify the well database records, evaluate precipitation data, and indicate changes over time to the creek and surrounding area.

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V. COMPONENTS OF WATER BALANCE

The goal in creating the water balance for the Basin is to quantify the inflow (recharge) and outflow (discharge) components impacting the alluvial aquifer. This information can then be utilized by the District in managing the alluvial water resource and in making informed decisions on further well permitting, well pumping curtailments, and the use of defined amounts of available storage. The balance must incorporate all of the significant inflows and outflows to the alluvial aquifer system. Therefore, the following water balance components should be considered in the Basin water balance.

Inflow	Outflow
Precipitation/Natural Recharge	Municipal Pumping
Municipal Wastewater Return Flows	Residential Pumping
Irrigation Return Flows	Irrigation Pumping
Municipal/Residential Return Flows (not generated by a wastewater treatment plant)	Phreatophyte Consumptive Use Alluvial Underflow leaving the Basin Stock Watering
Seepage from Water Stored in Ponds	Evaporation from Water Stored in Ponds
Surficial Flows into the Basin	Runoff leaving the Basin as Live Streamflow
Discharge from Denver Basin Aquifers to the Alluvial Aquifer	Discharge from the Alluvial Aquifer to the Denver Basin aquifers

1. Inflows

Some inflows to the Basin recharge the alluvial aquifer and can at times create live flows in Big Sandy Creek. The water balance inflows include all the sources of water that add water to the alluvial aquifer system and which represent a positive accounting in the water balance.

Precipitation/Natural Recharge

The alluvial aquifer is primarily recharged through rainfall and snowmelt water within the Basin. Therefore, estimating precipitation and the associated natural recharge is essential to the water balance. A portion of the rainfall and snowmelt can, during heavier precipitation events and under certain favorable ground conditions, flow over the ground surface as runoff and can add directly to or induce the live flow of water in Big Sandy Creek and its tributaries. Another portion of the precipitation infiltrates into the ground and, assuming it is not captured by plant roots and evapotranspired or simply lost to the atmosphere via direct evaporation out of the shallow soil profile, it can become a part of the alluvial ground water.

Precipitation. Precipitation data is available for gages within and near the Basin, and annual precipitation estimates are available for the entire area of the Basin. Therefore, multiple data sources were used to determine average annual precipitation within the Basin.

Precipitation maps for the Basin were obtained from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) dataset through the Geospatial Data Gateway. PRISM is the U.S. Department of Agriculture's official climatological dataset and is generated using a geostatistical relationship between point precipitation data (measured data) and elevation data. The PRISM contours shown on Figure 14, the Basin Precipitation Map, represent the annual average precipitation for a 30-year period from 1971 through 2000.

The PRISM dataset was checked against the average measured precipitation in the Basin at the following gage stations: Ayer Ranch (period of record 1944-1970), Matheson (period of record 1996-2008), Limon 10SSW (period of record 1907-1971), Limon-Station 55018 (period of record 1971-1995), Limon-Station 55017 (period of record 1948-1971). For each of these stations the reported average annual precipitation was within the contour interval reported on the 1971-2000 PRISM map (14).

District Board members expressed concerns over using precipitation data from the 1971 through 2000 period as this period may overestimate the future amount of precipitation. Thirty-year time periods are commonly used in water resources to determine average precipitation values and specifically are used by the National Climatic Data Center (a part of National Oceanic and Atmospheric Association) in calculations of normal precipitation. As such, we are comfortable with the use of the PRISM precipitation data from the 1971 through 2000 period, but due to the Board's concerns, we reviewed additional precipitation data. These additional data included: annual PRISM precipitation data from 2001 through 2007, annual precipitation data from 1998 through 2008 received from Mr. Larry Mott (February 1, 2009) - a current District Board member, and the Community Collaborative Rain, Hail & Snow Network (CoCoRaHS) precipitation data. We also checked the CoAgMet database, but there were no data collection points within or bordering the Basin.

Annual PRISM precipitation data for the Basin was obtained from 2001 through 2007 and is presented in Table 1, Precipitation Data. These recent data indicate lower average annual precipitation than the 1971 through 2000 dataset. For this reason, the datasets were combined using a time-weighted average. This results in 16.37 inches per year as the weighted annual average precipitation over the 1971 to 2007 period.

The CoCoRaHS data for Limon 6.3 WNW (EL-12), Ramah 4.2 WNW (EL-49), and Calhan 3.1 N (EP-7) matched well with the recent (2001-2007) PRISM data. CoCoRaHS data were available from 2004 through 2008 at the Limon and Calhan sites and from 2007 to 2008 at the Ramah site (only data that contained a full year of record was used, as determined by the number of reports). A comparison of the Limon and Calhan CoCoRaHS data against the 2004 through 2007 PRISM data indicated the CoCoRaHS data were only 3.9 and 1.0 percent higher, respectively, than the PRISM data.

The Ramah CoCoRaHS data indicated more than 20 inches of precipitation in 2007 and less than 14 inches of precipitation in 2008. The other CoCoRaHS sites did not show such a large variance from 2007 to 2008, raising questions about the Ramah CoCoRaHS data and how to use it in the precipitation comparison. It is noted, however, that the average precipitation of these two years (17.43 inches) is within 2 percent of the average PRISM data for the region (17.80 inches for Zone 1, Table 1). At all three locations, the CoCoRaHS data indicated higher annual averages than the PRISM data. Using the PRISM data is therefore a more conservative estimate of the annual precipitation.

Mr. Larry Mott provided M&W with site specific precipitation data from 1998 through 2008. The data were collected on his property located east of Calhan and indicate an average annual precipitation of 15.95 inches based on the 1998 through 2007 data. The PRISM data from corresponding years are within 5 percent of Mr. Mott's annual average, and therefore the PRISM data are considered to be representative of precipitation in the area.

The PRISM data are also in reasonable agreement with data from across the Basin that M&W received from various parties during Phase 1, including Mr. Dave Stone (Limon Airport data) and Mr. Morris Ververs. Data for Simla were obtained from Morris Ververs and reported by Mr. Benny Kitten. The Simla data indicate an average precipitation about 10 percent lower than the Zone 2 PRISM data (Table 1). The Limon data indicate an average precipitation about 3 percent higher than the Zone 3 PRISM data. While the Limon data are higher than PRISM and the Simla data are lower, the PRISM dataset is still considered a good regional estimate of the precipitation in the Basin.

For this water balance, an average precipitation of 16.37 inches per year will be used based on 1971 through 2007 PRISM dataset. This longer PRISM dataset is in agreement with other precipitation data for the area and is more conservative than using the CoCoRaHS data.

As shown on Table 1, in Year 2001 there was more precipitation in the eastern side of the Basin than in the western side of the Basin. This is the only year from 2001 through 2007 in which this occurred. On average, the western side of the Basin receives at least two more inches of precipitation than the eastern side. Generally, the precipitation is lowest in the eastern regions of the Basin where an average of 15 inches per year of precipitation falls. Annual average precipitation amounts increase from east to west, with the western region of the Basin receiving an average of approximately 18 inches per year of precipitation (Table 1, Figure 14). This change in precipitation with elevation is a commonly observed orographic relationship in Colorado.

The average volume of precipitation per year in the Basin (study period 1971 through 2007) is approximately 384,700 acre-feet based on the area-weighted PRISM data as calculated in GIS (16.37 inches per year [Table 1] / 12 inches per foot * 282,000 acres).

The average precipitation by month in the Basin was calculated by averaging the precipitation by month from the Limon, Matheson, and Ayer Ranch weather stations. These stations represent good coverage across the region and are assumed to accurately represent the precipitation patterns in the Basin. To obtain the average volume of precipitation received in each month, the total average annual precipitation from PRISM data was multiplied by the average percent of annual precipitation received during each month and is presented in Table 2, Average Monthly Precipitation.

Natural Recharge. Natural recharge to the alluvial aquifer is difficult to quantify, as the recharge depends on many factors, including the soil conditions at the time of a precipitation event, the duration of the precipitation event, the depth to the water table, the local ground slope, the intensity of the precipitation event, the conditions of the Big Sandy Creek channel, and climate effects including temperature, wind speed, and solar radiation. For the water balance project, evaluating all of these factors was outside of the scope of the study. Additionally, since factors such as the rainfall intensity, storm duration, and soil conditions are not the same during each event, season, or year, a more generalized approach is warranted at this time.

Past studies considered natural recharge ranges within the Basin from 0.5 to 1 inch per year (ASCG, undated; McLaughlin, 1946), which is approximately 3 to 6 percent of the average annual total of 16.37 inches. McLaughlin (1946) reported that the valleys within the Basin receive above average recharge due to the shallow water table and to the relatively high porosity of the materials above the water table. The remaining areas receive below average recharge because of high runoff and relatively low permeability of the surficial materials. The McLaughlin estimate of aquifer recharge was based on an annual average precipitation ranging from about 13.5 inches to 17 inches, based on location. The annual average precipitation estimates developed for the M&W water balance are slightly higher, with an average of more than 16 inches per year and which would logically result in higher total recharge volume estimates.

In December 2008, the Colorado Geologic Survey published a report on the neighboring Upper Black Squirrel Creek Designated Basin. The Upper Black Squirrel project evaluated natural recharge based on two past studies within the designated basin – Erker and Romero (1967) and Colorado Springs Utilities (study conducted during the late 1980s and early 1990s). Erker and Romero (1967) estimated the recharge to the Upper Black Squirrel Basin at 4 percent of the annual precipitation within the basin. The Colorado Springs Utilities study found that ground water recharge varied between 3.42 and 7.69 percent of precipitation on irrigated and non-irrigated land, respectively. More information on the Colorado Springs Utilities study was not available at the time of the water balance. Our review of the Erker and Romero report resulted in the conclusion that the 4 percent recharge estimate applied to total precipitation within their project area.

For the Upper Big Sandy water balance, the average annual precipitation is 16.37 inches, or 1.36 feet. Applying the 4 percent recharge estimate results in 0.655 inches per year (0.0546 feet per year) of recharge. This equals 15,400 acre-feet of natural recharge per year (0.0546 feet * 282,000 acres) within the Basin, as presented in Table 3, Natural Recharge and Irrigation Calculations.

For the dry year and wet year recharge estimates, the percent of natural recharge was varied. The Colorado Springs Utilities study resulted in recharge between approximately 3.4 and 7.7 percent of precipitation, and these limits were used as guidelines for this water balance. Because the entire Basin is not expected to respond as irrigated land, 7.7 percent of precipitation for recharge is considered to be too high, and therefore a lower value of 6.5 percent is used in this water balance. To be conservative, 3.0 percent was used for the dry year recharge and 6.5 percent was used for the wet year recharge. This is a change from the Phase 1 water balance which applied the same percent of precipitation to recharge but varied the precipitation based on average, dry, and wet periods.

The natural recharge estimates used in the water balances are: 15,400 acre-feet for an average year, 11,500 for a dry year, and 25,000 for a wet year (Table 3).

For Phase 2 of the water balance, Martin and Wood evaluated precipitation and water level data in the Basin in order to try to develop a relationship between the two which might be helpful in predicting aquifer recharge. The analysis resulted in a conclusion that the data needed to predict the trends are not available, and the data that are available do not indicate a consistent qualitative trend (such as increasing water levels in wet years or increasing water levels in years with multiple high precipitation events) that can be applied. The analysis is described in more detail in Appendix H.

M&W received information for Mr. Mott regarding data he collected as a recharge study on his property east of Calhan. We were able to incorporate the precipitation data provided into our calculations and data checks, but we did not use his data for predicting the recharge to the alluvial aquifer. It is our professional opinion that Mr. Mott's well is not located within the saturated alluvial extent (including tributaries and terrace deposits) and is actually a bedrock well, and as such, we felt it inappropriate to use Mr. Mott's data as a representation of what is happening regarding recharge to the alluvial aquifer.

Return Flows

Wastewater Return Flows. The alluvial aquifer quantitatively benefits from the discharge of wastewater from wastewater treatment facilities (wastewater return flows) from towns within the Basin. The facilities, located in Calhan, Simla, and Limon, discharge their water to the Big Sandy Creek or its tributaries, which directly feed the aquifer.

Public data on file with the U.S. EPA (as reported by the wastewater treatment plants) shows the following approximate annual volumes of water discharged in 2006 and 2007.

Facility Location	Annual Volume of Wastewater Discharge (acre-feet)	Data Source
Calhan	70	U.S. EPA Envirofacts
Simla	47	U.S. EPA Envirofacts
Limon	480	U.S. EPA Envirofacts

Regardless of a city's water source, the alluvial aquifer water balance will experience a net gain when the wastewater effluent water is discharged to Big Sandy Creek or its tributaries (and thus into the alluvial aquifer). For this reason, 100 percent of the wastewater discharge is used as an inflow to the water balance. The total municipal wastewater inflow, based on the above table, is 597 acre-feet per year.

Irrigation Return Flows. Irrigation return flows are a source of recharge to the alluvial aquifer. Irrigation water that directly infiltrates into the alluvium or reaches the alluvium through streambed infiltration, recharges the alluvial aquifer. For the Arkansas River Basin, estimates of shallow aquifer recharge range from 15 percent to 40 percent of the irrigation water applied. To be conservative, this study utilizes an irrigation return to the alluvial aquifer of 15 percent, which is appropriate for sprinkler irrigation (80 percent efficiency, 5 percent evaporation and spray losses, 15 percent return flows from deep percolation).

Irrigated areas within the Basin were estimated using a combination of aerial photographs of the Basin obtained through the Geospatial Data Gateway provided by the U.S. Department of Agriculture Farm Service Agency Aerial Photography Field Office, Landsat images of the Basin, interviews with the Upper Big Sandy District Board members and other landowners in the Basin including Mr. George Fosha. (Landsat images are electronic images of the earth collected by satellites through a program jointly managed by NASA and the U.S. Geologic Survey.) An electronic survey to identify all potentially irrigated land was conducted for the water balance in GIS using the aerial photographs and Landsat images of the Basin. The purpose of this survey was to identify all land within the Basin that is potentially irrigated. Consequently, any land which appeared irrigated, or appeared to have historically been irrigated was included. During this survey, over 30,000 acres of potentially irrigated land were identified. However, it was clear that this was a large over-estimate of the area irrigated with alluvial well water due to the common practice of dry land farming (which would not use well water), the additional sources of irrigation water from bedrock wells, and the inclusion of several areas that were potentially irrigated in the past but are not currently irrigated.

To further refine the estimate of the total acreage irrigated with water pumped from the alluvial aquifer, the potentially irrigated acreage within the Basin was limited based on proximity to the alluvial boundary (contained by or within 0.5 miles of the interpolated alluvial extent) and then maps were presented to the Board and landowners with first-hand knowledge of the irrigated area within the Basin. During this interview process, the potentially irrigated fields in the Basin were verified to confirm that they were, or were not, irrigated with alluvial ground water. Only two fields comprising 126 acres that clearly appear irrigated according to the aerial photographs were not verified in the interview process. All other fields were verified as either irrigated or not irrigated. Additionally, the size or shape of several irrigated areas was modified in GIS to represent the actual irrigated area indicated by the interviewees. Through this process, it was determined that approximately 1,800 acres of land in the Basin are irrigated with water pumped from the alluvial aquifer. The irrigated areas within the Basin are presented in Figures 15 through 17, Western/Central/Eastern Irrigated Areas and Phreatophytes Maps.

During Phase 1, subirrigation was discussed as a potential category of irrigated land. Subirrigated land is land on which the crops or plants use water directly from the aquifer through their deep roots. The likelihood of subirrigation depends on the depth to the water table, the farmer's irrigation practices, and the crops or plants on the land. Fields that are subirrigated, instead of irrigated by water pumping from wells, were not specifically called-out in the irrigated area interview process but were included in the irrigated area files. While subirrigated fields are not specifically handled as their own class of irrigated area, this water balance considers the associated crop consumptive use of water by considering the withdrawal and return flows for all irrigated areas (consumptive use is the difference between total withdrawal and total return flow).

During Phase 1, information on irrigated areas was requested from the Lincoln County Assessor's Office and El Paso County. No information was obtained for Elbert County. Lincoln County indicated that there was no reported irrigated land in their county within the Basin, and El Paso County indicated that the data were not readily available. The information from Lincoln County does not agree with the irrigated area survey information obtained from the member questionnaires in which people reported that they irrigate land within Lincoln County or the information obtained from interviews. M&W believes the electronic survey combined with the first-hand knowledge of the Board members and landowners provides a more reasonable and accurate estimate of the irrigated land within the Basin. Therefore, 1,800 acres of irrigated land is used in the water balance.

As presented on Table 3, the area estimated to be irrigated with alluvial ground water is 1,800 acres. The *Rules and Regulations for the Management and Control of Designated Ground Water* (2 CCR 410-1, as re-amended April 30, 2008) specify the amount of ground water to be appropriated for irrigation of agriculture lands is 2.5 acre-feet per irrigated acre. This amount of water is close to meeting the average crop irrigation needs and will used for the water balance calculations. The crops reportedly most commonly grown in the Basin are alfalfa and pasture grass. The irrigation process leads to a 15 percent return flow to the alluvial system. Assuming that there is available water to meet the crop irrigation needs, the estimated 1,800 irrigated acres would require pumping of approximately 4,500 acre-feet of alluvial ground water (Table 3), and 680 acre-feet would be returned to the alluvial ground water system as irrigation return flows (Table 3).

Inflow and Surficial Flow from Upper Basin

While underground inflow and above-ground surficial flow from upper basins would normally be considered in a water balance, there is no inflow or surficial flow from upstream areas external to the Upper Big Sandy Basin. The Basin extends to the topographic divide at the west end of the Big Sandy Creek drainage area; thus this component to the alluvial aquifer is deemed to be zero and will not be considered further.

Other Inflows

Municipal/Domestic Return Flows (not generated from a wastewater treatment plant). Municipal water providers often claim a credit for the portion of the water which returns over time to alluvial aquifers due to lawn irrigation (referred to as lawn irrigation return flows or

LIRFs). Insofar as is known at this time, the towns and cities with the Basin have not quantified the timing or amounts of their LIRFs. Derivation of reliable estimates on the total acreage of irrigated lawns and their locations was not carried out, nor was quantification of this (assumed) very small component of return flows to the alluvial aquifer water balance.

Effluent discharges from individual septic disposal systems (ISDS) with the typical non-evaporative septic tank-leach field configuration recharge the shallow alluvial aquifer. Typical consumption for household use of the water is estimated as 10 percent for homes with ISDSs, with 90 percent of the water brought into the home for in-house domestic uses being returned to the alluvial aquifer. As reliable data on the domestic use of water in the Basin are not readily available, and given that 90 percent of the water returns to the aquifer via the ISDSs, this net impact to the water balance is likely very small relative to the other inflow components, such as natural recharge, and is not included in the water balance at this time.

Seepage from Ponds. The member survey indicated that ten of the 16 ponds reported in the member survey were made of metal or fiberglass. If these ponds are in good condition, they should not be leaking water. Earthen ponds (six of the 16 ponds reported) may be contributing to the alluvial aquifer through seepage of water from the pond. If the ponds are lined with a natural or man-made material, seepage is less likely. Sufficient detailed information on the stock ponds located through the Basin was not obtained from the member survey and thus no estimate of the amount of water potentially seeping from ponds into the alluvial aquifer has been made; as with the ISDS returns, this component is expected to be extremely small relative to the overall water balance. Support for not estimating alluvial recharge from pond seepage was found during the field investigation. A test hole (GP45) was advanced immediately adjacent to a tributary channel where standing water was observed. The test hole was dry, indicating that a relatively impermeable soil layer existed in the tributary channel, preventing seepage to the underlying alluvium. These same conditions are likely to exist at some of the pond locations as well.

Interaction with Denver Basin Aquifers. No work was specifically conducted to quantify the interaction between the Denver Basin aquifers and the alluvial aquifer for this phase of the water balance. Bedrock wells in the Basin typically have relatively low yields, with the possible exception of those completed in the Fox Hills Formation, indicating relatively low hydraulic conductivities and net sand thicknesses. Additional published data on the Denver basin aquifers support the conclusion that the aquifers are not well developed or productive along the eastern flanks. These factors will likely limit any appreciable exchanges of ground water into or from the alluvial aquifer. The Owens Report addresses ground water interaction between the alluvium and bedrock aquifers. The Owens Report states that minor amounts of alluvial ground water discharges to the bedrock aquifers and that ground water from the bedrock aquifers also discharges to the alluvium. In light of all the above information, we are assuming no net impact on the Upper Big sandy alluvial aquifer system from Denver Basin Formation ground water interactions.

2. Outflows

The outflow components of the water balance represent the water that is being lost to the system via natural or manmade removal of water. This includes irrigation pumping, natural evaporation and transpiration losses, alluvial underflow out of the Basin, surficial flows out of the Basin via the creek channel, and smaller-scale losses from stock and domestic well pumping, and evaporation from stock ponds.

Pumping and Withdrawals of Ground Water

The major uses of ground water within the Basin are municipal and domestic, irrigation, commercial, and stock watering. As mentioned in Section V.1, not all water withdrawn from the aquifer for various uses is consumed. For this water balance, returns are considered as inflows to the Basin and all pumping is considered as outflows from the Basin.

Irrigation Pumping. A well analysis was performed by M&W using data obtained from the DWR Master Well database. The analysis included review of tabulated information on all permitted wells within the Basin boundary that were included in the database through the

June 2008 database update. The analysis indicated that the District includes approximately 1,800 permitted (small and large capacity) wells, and of those, 155 permitted wells are permitted for irrigation use (based on the use codes in the database).

As described above in Section V.1 Irrigation Return Flows, aerial images of the Basin and interviews with the Board members and landowners indicate that 1,800 acres of land are irrigated within the Basin (Figures 15 through 17). The crops reportedly, per the member survey, most commonly grown in the Basin are alfalfa and grasses.

The *Rules and Regulations for the Management and Control of Designated Ground Water* (2 CCR 410-1, as re-amended April 30, 2008) specify the amount of ground water to be appropriated for irrigation of agriculture lands is 2.5 acre-feet per irrigated acre. Using this as the annual pumping is considered appropriate since 1) it is the maximum pumping allowed by the State, 2) it is conservative in that additional pumping should not be occurring, and 3) Board members and landowners indicated that deficit irrigation was occurring. Deficit irrigation occurs when crops are grown without the amount of water needed to satisfy the crop irrigation requirements and typically leads to lower yield crops. Deficit irrigation occurs throughout Colorado, particularly in the South Platte River and Arkansas River drainage basins, where farmers often do not have access to enough water to fully meet their crops needs.

The estimated 1,800 irrigated acres would require pumping of approximately 4,500 acre-feet of alluvial ground water. For this water balance, the estimated annual irrigation pumping is 4,500 acre-feet (Tables 3 and 4).

Municipal Pumping. Limon and Simla use the alluvial aquifer as a source of domestic water. Calhan and Ramah get their municipal water supplies from other sources, although Ramah has a small alluvial well that it used for fire fighting purposes only. Data on Ramah's limited use of the alluvial water well were not available but were reported to be considered as never or little. The annual estimates shown below are based on correspondence and records from the cities and towns and are for alluvial pumping only.

Limon = 910 acre-feet annually (based on annual average determine from January 2007 through September 2008 records)

Simla = 107 acre-feet annually (based on 80 acre-feet from January 15, 2008 through October 15, 2008, increased by one-third to account for remaining quarter)

Total average municipal pumping equals 1,017 acre-feet per year (Table 4).

Estimated Underflow Leaving the Basin

Underflow is the ground water moving under the ground surface within the alluvial aquifer. Underflow, q, is quantified by the equation below.

q = K*I*A, where

q = flow per unit of cross sectional area
K = hydraulic conductivity of the aquifer
I = the hydraulic gradient
A = the cross sectional area of flow

The alluvial aquifer discharges ground water to the east of the Basin boundary through underflow. Therefore, underflow at the downstream end of the Basin is an outflow in the water balance.

An average hydraulic conductivity of 1,586 gpd/ft^2 (212 ft/day) was estimated as appropriate for the downstream end of the aquifer. This average hydraulic conductivity value was based on M&W's analyses of the Town of Limon's pumping test results as presented in Section II.3 – Aquifer Parameter Testing. Additionally, the McLaughlin Report (1,800 gpd/ft^2 or 241 ft/day), the Willard Owens Report (1,600 gpd/ft^2 or 214 ft/day), and the HRS Report (1,350 to 1,500 gpd/ft^2 or 181 to 201 ft/day presented various values for hydraulic conductivity, as described in Section II.3 – Hydrogeology. The Town of Limon pumping test and the above cited references all reflected similar values for hydraulic conductivity; and, as all three report results cited were based on pump test results throughout the Basin, the Town of Limon average pumping test result of 1,586 gpd/ft^2 (212 feet per day) is utilized in this report, as it is recent and is located closer to the downstream end of the Basin.

M&W calculated the average gradient (or slope of the alluvial saturated water level) in the lower portion of the Basin utilizing the water table maps that were prepared based on the hydrograph data found in Appendix A. This analysis resulted in range of 0.0034 feet per foot to 0.0036 feet per foot, for an average gradient of 0.0035 feet per foot or 19 feet per mile.

Using the data obtained from the August 2008 drilling program, and which were utilized in the preparation of Figures 8 and 9, the cross-sectional area of saturated material on the eastern edge of the Basin is estimated to be approximately 368,000 square feet. Note that this figure will vary proportionally to the total saturated thickness of the aquifer at any given time. The figures presented herein represent the cross-sectional area based on conditions in late summer in the year 2008.

Combining these data, the estimated underflow leaving the Basin is 2,300 acre-feet per year.

q = K*I*A

= (1,586 gallons per day per square foot) * (0.0035 feet per foot) * (368,000 square feet)

= 273,000 cubic feet per day

= 2,300 acre-feet per year, approximate

Willard Owens Associates (1971) estimated the underflow near Limon as 2,350 acre-feet per year. The M&W estimate of 2,300 acre-feet per year is comparable to the Owens Report estimate. This water balance will use 2,300 acre-feet per year (as calculated above) for the estimated underflow leaving the Basin.

Phreatophyte Consumptive Use

Shallow ground water supplies water to phreatophytes (plants that rely on the ground water as their main source of water) commonly growing along Big Sandy Creek. Phreatophytes observed in the Basin include cottonwoods, thistle, willows, and small plants growing along the creek. The use of water by phreatophytes in areas with near-surface ground water tables is difficult to distinguish from water that directly evaporates from the ground out of pore storage or shallow ponded water. For the purposes of this study, the following will be considered as evapotranspiration: (1) water consumed by phreatophytes and (2) near-surface shallow water that is in the vicinity of mappable areas of phreatophytes and that may directly evaporate.

A review of digital images and aerial photos, supplemented by our field observations, indicates that the areas along Big Sandy Creek within the Basin generally exhibit considerable phreatophyte growth. The areas covered by phreatophytes were identified using aerial images from the U.S. Department of Agriculture Farm Service Agency (FSA) Aerial Photography Field Office. Phreatophyte areas were primarily identified from color FSA aerial images of the Basin flown between July 30, 2006 and August 11, 2006. Secondary verification was conducted with black and white aerial images of the Basin taken in 1993 and 1999.

Figures 15 through 17 present the phreatophyte areas and the FSA aerial images that were primarily used to identify the phreatophytes. Phreatophyte areas within the Basin primarily occur along the main channel of Big Sandy Creek. The phreatophyte areas on either side of the channel generally extend further from the channel in the eastern regions of the Basin. The area of phreatophyte growth within the Basin was estimated to be approximately 5,390 acres, of which 5,090 acres are along the main channel of Big Sandy Creek and approximately 300 acres are along the tributary channels.

Phreatophyte consumptive use depends on a number of factors including the types of plants involved, climate (temperature, sunlight, humidity, precipitation), depth to water, quality of ground water, and density of plant growth (Robinson, 1958). Ground water consumption by cottonwoods and willows, common phreatophytes along the Big Sandy Creek, is estimated to be between 2 and 4 acre-feet per acre (Bowie et al., 1968; Robinson et al. 1970). These numbers span a range due to the factors listed above and, most specifically, are directly affected by plant density. The density along the Big Sandy Creek varies greatly (Figures 15 through 17), and the depth to water also varies across the Basin. Based on the observed plant densities, the ranges in depth to water, and the literature data, M&W determined that the most appropriate estimate to use is 2 acre-feet per acre for phreatophyte consumptive use within the Basin. The phreatophyte areas (5,390 acres) are estimated to consume 10,780 acre-feet of water annually (Table 4).

Stock Watering

Stock watering, considered 100 percent consumptive, appears to be a minor component of the overall water uses within the Basin. The member survey indicated that there is stock watering occurring within the Basin, but the surveys only included a portion of stock watering within the Basin. The survey also indicated the water used for stock watering water comes from multiple sources including wells, springs, runoff/draws, and precipitation. Because these sources of water are likely to be from shallow wells or water tributary to Big Sandy Creek, and in order to be conservative, we are considering all stock watering to be from the alluvial aquifer. A commonly-used value for stock watering is 10 gallons per day per head of stock, and this water is considered to be fully consumed.

The U.S. Department of Agriculture did livestock counts by county within Colorado in early 2008. A May 19, 2008 news release from the U.S. Department of Agriculture was used to obtain the results of the survey. Additional information on stock within the Basin was obtained from Mr. Joe Frasier and Mr. Morris Vervors, both District Board members. Using the information they provided along with the U.S. Department of Agriculture estimates, it was estimated that there are approximately 15,150 stock equivalents in the Basin year-round (two head of stock in the Basin for half the year would be the equivalents of one stock in the Basin the entire year), as presented in Table 6, Stock Count and Stock Watering Calculations. The annual stock watering consumptive use is estimated to be 170 acre-feet per year (Table 6 and Table 4).

Other Outflows

Domestic Pumping. Ground water is pumped in small quantities from the shallow alluvial aquifer for domestic uses. Typical consumptive use of water for household use is estimated as 10 percent for homes with ISDSs, with 90 percent of the water brought into the home for in-house domestic uses being returned to the alluvial aquifer. As reliable data on the domestic use of water in the Basin where municipal supplies are not available is not readily available, and given that 90 percent of the water returns to the aquifer via the ISDSs, this net impact to the water balance is likely very small relative to the other outflow components, such as irrigation pumping, and is not included in the water balance at this time.

Evaporation from Ponds. Evaporation from ponds within the Basin is considered indirectly as a portion of the precipitation which does not recharge the aquifer. For this water balance, this specific component has not been quantified separately, but it is considered in the balance.

Live Streamflow Leaving the Basin. There is not continual flow in Big Sandy Creek as it leaves the Basin. The member survey indicated that flow typically only occurs after a storm event and rarely lasts more than a few weeks and often does not last that long. There is no gage on Big Sandy Creek to record streamflow out of the Basin when live flow does occur. As there are no specific data on the amount of water that flows with the creek or exits the Basin, this component of the water balance will not be considered in the analysis.

Interaction with Denver Basin Aquifers. As described in Section V.1., no work was specifically conducted to quantify the interaction between the Denver Basin aquifers and the alluvial aquifer for this phase of the water balance, but exchanges of ground water into or from the alluvial aquifer are assumed to be limited. As such, we are assuming no net impact on the system from Denver Basin Formation ground water interaction.

VI. ALLUVIAL AQUIFER STORAGE

In addition to the water balance, it is important to quantify the amount of ground water in storage within the alluvial aquifer. If the recharge and the discharge to the alluvial aquifer are not equal, the amount of ground water in storage will change. For example, if ground water is withdrawn from the aquifer at a rate that exceeds the rate of total recharge to the aquifer, the amount of ground water available in storage will decrease. The following parameters are important when determining the amount of ground water in storage: saturated thickness of aquifer, specific yield of the aquifer, and the extent/area of alluvium. Additionally, the amount of water that can actually be feasibly withdrawn from an aquifer by wells (recoverable storage) is also partially dependent on specific well hydraulics.

1. Volume of Water in Storage

The amount of ground water in storage is calculated by multiplying the surface area of the saturated alluvium by the averaged thickness of the saturated alluvium, and the specific yield of the alluvium. The surface area of the alluvial aquifer is inferred by evaluating data from test holes and ground water wells. Data from test holes and ground water wells were used to construct geologic cross sections across the alluvial valley. The cross sections provide a two dimensional interpretation of the alluvial aquifer across the alluvial valley and allow for development of the estimated lateral extent of the saturated alluvium. Finally, the lateral saturated alluvial extents from the various cross sections are interpolated from one cross section to the next to develop an interpolated saturated alluvial extent across the Basin. The cross sections also provide information for estimating the saturated thickness of the alluvium throughout the Basin.

As described earlier in this report, M&W designed the field investigations so that the lateral extent of the saturated alluvium would be fully delineated at each end of the cross sections. M&W then interpolated the saturated alluvial extent based on the relationships between the seven developed cross sections and the topography throughout the Basin. In contrast, prior work by ASCG in developing saturated alluvial extent appears to have been based on their interpretations of data from the DWR well database and on the USGS mapping of only the alluvium (as opposed to the combined alluvium and terrace deposits). As described in the Field Investigation results, M&W compared data obtained during the August 2008 and February 2009 field investigations to data presented in ASCG's and HRS's cross sections to evaluate the accuracy of the data presented in the respective consultants cross sections. Data from the other consultants cross sections that was deemed reasonable was then included with M&W's field investigation results to produce estimates of saturated alluvial extent and saturated thickness throughout the basin.

The areal extent of the saturated alluvium and the averaged alluvial saturated thickness multiplied by the specific yield produces the volume of water in storage. An estimated saturated thickness was developed for the upper and lower portions of the Basin, as well as the tributaries. The division between the upper and lower portions of the basin is defined in this report, as being located east of Matheson, where Big Sandy Creek turns north towards the River Bend area. The saturated thickness numbers were derived by estimating the average saturated thickness of each of the ASCG, HRS, and M&W cross sections, with preference weighted towards data developed by M&W during the field investigations. Where there is a bedrock ridge present between two channels, as is evident in several areas of the Basin, the estimated average saturated thickness from both channels was utilized. For example, if one channel was 20 percent of the entire saturated alluvial width, that channel's estimated average thickness was multiplied by 20 percent and added to the other channel's estimated average thickness multiplied by 80 percent, to arrive at a total average estimated cross section saturated thickness.

Cross Sections A-A' through G-G' were developed from data obtained during the field investigations and are presented in Figures 6 through 12. The data from these sources were interpreted to estimate the saturated alluvial extent presented in Figure 3. The cross sectional data were applied to both the mainstem of Big Sandy Creek and the tributaries of Big Sandy Creek.

The alluvium ranges in total thickness from 15 feet to 85 feet. The width of the alluvium ranges from approximately 1,000 feet to approximately 2.5 miles (13,200 feet). The thickness of the alluvium in the tributaries is considerably less than the mainstem valley, based on the results of the field investigations and professional knowledge of alluvial systems. The width of the tributaries is likewise also considerably less than the mainstem valley. The total saturated alluvial surface area is estimated to be approximately 58,000 acres in the Basin. The upper end of the Big Sandy Creek mainstem, the area west, or upstream, from where Big Sandy Creek changes from an eastward to a northward direction east of Matheson, is estimated to have a saturated alluvial extent of 19,000 acres. The average alluvial saturated thickness in the upper end of the Basin is estimated to be approximately 28 feet on average. The lower end of the Big Sandy Creek mainstem is estimated to have a saturated alluvial extent of approximately 22,000 acres. The average saturated alluvial thickness in the lower end of the Basin is estimated to be approximately 38 feet. The Big Sandy Creek tributaries are estimated to have a saturated alluvial extent of approximately 17,000 acres. The saturated thickness in the tributaries is estimated to be 15 feet on average. Applying the range of average saturated thicknesses to the estimated areas for the upper and lower portions of the Big Sandy Creek mainstem, in addition to the tributaries, results in approximately 1,623,000 acre-feet of saturated alluvial material in the Basin. Assuming a specific yield of 20 to 25 percent for the Big Sandy Creek mainstem area east of Matheson, the saturated alluvial volume for this area is estimated to be between 167,200 and 209,000 acre-feet. Assuming a specific yield of 30 to 35 percent for the Big Sandy Creek mainstem area west of Matheson, the volume of water in the saturated alluvium is estimated to be between 159,600 and 186,200 acre-feet. Assuming a specific yield of 23 percent for the Big Sandy Creek tributary areas, the volume of water in the saturated alluvium of the tributaries is estimated to be 58,650 acre-feet. This results in an estimated total saturated alluvial volume of between approximately 385,000 and 454,000 acre-feet.

Under unconfined conditions, such as an alluvial aquifer system, well yields will typically decline as the water table declines due to the decrease in hydraulic gradient in the vicinity of the well. While the exact magnitude of the impacts on pumping from loss of saturation is dependent upon a number of aquifer and well-related factors, it is a given that at some point, continued loss of water from storage and the accompanying lowering of the water table will result in the loss of a particular well's ability to pump. Further, well-to-well impacts will also be exacerbated by loss of storage and reduction in the aquifer transmissivity as the water table drops. These considerations are inherent in the concept of recoverable storage, or the amount of water that can reasonably be expected to be extractable from an aquifer without requiring numerous additional wells or incurring severe well interference impacts. In different settings involving confined aquifers, recoverable storage has often been assumed to be 50 percent. However, in an unconfined alluvial aquifer such as the Big Sandy Creek alluvium, it can be expected that the recoverable storage would be higher, possibly significantly, due to the higher hydraulic conductivities and specific yields. Once again there are a number of factors that would impact the actual figure, in particularly well densities, but absent construction of a numerical ground water flow model to accurately simulate the system under a variety of stresses and storage levels, it is difficult to estimate exactly what the appropriate numbers should be. This project uses a range of recoverable storage percentages from 50 to 70 percent.

Recoverable storage is also extremely important with respect to the management by the District of the alluvial resource. Unless there is the desire to utilize some of the water in storage as a drought mitigation supply (in other words, allow for "mining" of the stored water during droughts so as to maintain well pumping rates), there is no need to be concerned with the recoverable storage. As it is assumed that this information is of value to the District, however, and that they may wish to have the option of availing themselves of the utilization of the storage in the future, some assessment of this is required. For these purposes, it is assumed that removal of 50 percent of water in storage would not represent a responsible management of the aquifer as it would take many years to recover to the pre-drought conditions. An alternative would be to consider the range of fluctuation in the water table that would be acceptable. As an example, if the average saturated thickness is 30 feet, then a three foot drop in water table throughout the aquifer would represent a 10 percent loss of storage which would not be expected to seriously impair the ability of a well to pump nor to significantly increase well interference to levels where pumping would become a serious problem. Using this example as a guideline, the utilization of storage in the Basin may best be considered on a per foot basis. Thus, if the saturated area is approximately 58,000 acres, then each one foot drop in the water table that is acceptable to the District equates to between approximately 13,920 acre-feet and 16,240 acre-feet (58,000 acres multiplied by one foot of drop multiplied by an area weighted Sy range of 0.24 to 0.28) of water that could be pumped. Note that this is true only up to a point; the geometry of the Basin, especially at the flanks, dictates that there will be less volume per foot of saturation as the water table declines further because of the reduced area of saturation. Further, it has become evident though the course of these studies that the Basin exhibits differing characteristics and these differences have facilitated our division of the total area into the eastern mainstem, the western mainstem and the tributaries areas. These differences are expected to impact the manner in which well pumping or reduction in recharge impacts on the water table will be reflected.

The issue of recoverable storage will be addressed again below following the presentation of the water balance.

2. Water Level Analysis

The DWR collected water level data annually within the Basin from 1991 through 2008. The water level data collected for the monitoring wells is provided in graphical format (hydrographs) in Appendix A for each well. The wells are arranged in order from the upstream end of the Basin to the downstream end of the Basin (Figure 4 shows the location of each well). The water table with the Basin, as interpolated from the 2008 water level data, is presented in Figure 5.

Longer-Term Changes in Water Levels

To evaluate the long-term changes in water levels, the water levels at the beginning of the data collection period (1991) were compared to the water levels in 2008. The change in water level was typically less than 2 feet, and varied regionally. As indicated on Figure 18, all but one of the wells west of Simla shows an increase in water level over the 1991 to 2008 period. The wells east of Simla indicate some increases and some decreases, but all wells in the eastern third of the Basin show decreases in the water levels during this period. Additionally, the largest changes in water levels were recorded in the River Bend, as indicated by the red symbols on Figure 18. Generally, the green symbols indicate very small changes in water levels while the red/orange/yellow symbols indicate larger drops in the water levels, and the blue symbols indicate gains in the water levels. Only wells for which water level data in both 1991 and 2008 were available are included on Figure 18.

Trendlines for the change in water level at each well, using the data in Appendix A, were computed to further analyze the change in water levels between 1991 and 2008. Table 7 presents the change in the water level at each well predicted by the trendline for that well and the correlation coefficient (R^2) for the trendline at each well. In Table 7, the wells are sorted by the decreasing correlation coefficients between the observed versus the predicted water-level change. As shown in Table 7, the data in only a few wells show a reasonable trend toward increasing or decreasing water-levels (Big Sandy - 13/13(R), Big Sandy -30A, Big Sandy-19; R^2 values equal to or greater than 0.65). Because the trendlines are generally not good matches for the data, it is difficult to use the 1991 through 2008 data to predict what the water levels will do in the future. The variations in the water level data causing the poor correlations are likely because of the various time-variant stresses on the aquifer and the influences of the stressors and local levels of recharge to the water levels.

An additional comparison of the water levels collected in 2001 to those collected in 2008, indicates that the largest drops in water levels over this time period occurred in the River Bend and Limon areas (presented on Figure 19, Change in Alluvial Ground Water Levels 2001-2008). This figure also indicates that most water levels decreased during this period (only three wells west of Ramah had increasing water levels and one well east of Limon had an increasing water level). Notice that the areas of most change (signified by yellow to red colors in Figure 19) are generally east of Simla. The 2001 to 2008 water level changes in the downstream end of the Basin could be reflecting the impacts of municipal pumping by Limon and increased irrigation pumping in the River Bend area, although further investigations and observations will be required to determine if this represents a more permanent long-term phenomenon or a shorter-term anomaly. Another factor in the greater water level responses in the downstream portion of the Basin could be the lower specific yields that were determined for the lower Basin. Because of these lower specific yields, any unit change in a stressor on the system, whether pumping or precipitation recharge, for example, will result in a relatively larger unit change in water level as compared to application of similar stressors in portions of the Basin where the specific yields are observed to be higher.

Lowest and Highest Measured Water Levels

As presented in Appendix A, the hydrograph data for the DWR monitoring wells indicate that there is no consistent pattern with respect to the severe drought year of 2002. Some wells exhibited a drop and then a recovery, others exhibited the drop and no recovery, and others exhibit a rising water table. This may reflect changes in pumping practices in certain parts of the Basin during the drought period or may be related to other as yet unidentified factors.

The unpredictable response during a period of dry conditions is further presented on Figure 20, Date of Lowest Ground Level 1991-2008, which shows the date of the lowest water level measurement for each of the 21 wells that were measured from 1991 to 2008. There is no consistent year that stands out across the Basin, and in some instances, nearby wells, such as the wells located around Simla, each had their lowest water level in different years.

It is observed from Appendix A and Figure 21, Date of Highest Ground Water Level 1991-2008, that many of the wells across the Basin exhibited a high water level in 2000. Years 1998 and 1999 were both above-average precipitation years (based on Matheson precipitation records) and could be the cause for this ground water high. The large number of wells that experienced the highest water level between 1991 and 2008 in the year 2000 could indicate that the Basin generally responds similarly to increased precipitation.

Water Level Summary

The annual data indicate the water table is fluctuating across the Basin in different ways and with little consistency throughout the Basin. The greatest changes in the alluvial water table are observed in the eastern half of the Basin, particularly in the River Bend and Limon areas. Because the monitoring well east of Limon does not indicate the same water level changes as the wells in the Limon area, the drops in the water table near Limon are difficult to interpret. The difference in water level changes could partially be because the observed changes in water levels near Limon are due to localized drawdowns which do not extend eastward to the

Basin boundary. The increases in water levels on western half of the Basin (Figure 18) are a positive indicator of continued recharge to the aquifer.

VII. WATER BALANCE

The goal of creating the Upper Big Sandy water balance is to assess and quantify the inflow (recharge) and outflow (discharge) components associated with the alluvial aquifer in the Basin. As first discussed in Section V, the water balance includes multiple components, but not all components have been quantified for this phase of work, as was previously described in earlier sections of this report. The following components of the balance are quantified and considered in this project; the remainder of the water balance components in Section V of this report have either been disregarded or considered to be zero, as described previously.

Inflow	Outflow
Precipitation Recharge	Irrigation Pumping
Irrigation Return Flows	Phreatophyte Consumptive Use
Municipal Wastewater Return Flows	Municipal Pumping
	Stock Watering
	Underflow Leaving the Basin

1. Average Year Water Balance

Using the conservation of mass principle, shown below, the impact to the alluvial aquifer can be quantified.

Inflow – Outflow = Change in Storage

Using the actual figures developed from the water balance from Table 4: Inflow of 16,677 acre-feet minus an Outflow of 18,767 acre-feet = -2,090 acre-feet of Change in Storage in an average year (see Table 4).

As presented on Table 4, the Average Year Water Balance, the water balance indicates that the outflow would exceed the inflow by approximately 2,100 acre-feet in the average, or typical, year. This means that the outflows in excess of inflows would be removed from storage which would result in a corresponding reduction in the alluvial water table. If this excess removal of storage water resulted in an even drawdown across the entire saturated alluvium (estimated saturated alluvial extent is 58,000 acres), there would be less than a 2-inch decrease in the ground water level across the Basin (2,090 acre-feet divided by 58,000 acres, multiplied by 12 inches per foot, divided by an area-weighted Sy of 0.24 to 0.28) over the course of one full year as presented on Table 9, Water Balance-Predicted Water Level Changes.

2. Dry Year Water Balance

In a year of lower than average precipitation, the estimated deficit in the water balance is even greater than the average year deficit of approximately 2,100 acre-feet. As shown on Table 5, the Dry Year and Wet Year Water Balances, the dry year water balance indicates that the outflow would exceed the inflow by approximately 5,990 acre-feet annually. This means that the outflows in excess of inflows would be removed from storage which would result in a corresponding reduction in the alluvial water table. If this excess removal of storage water was evenly distributed across the entire saturated alluvium (estimated areal extent is 58,000 acres), there would be, over the course of a full year, about a 5-inch decrease in the ground water level across the Basin (5,990 acre-feet divided by 58,000 acres, multiplied by 12 inches per foot, divided by a Sy of 0.24 to 0.28) as presented on Table 9.

3. Wet Year Water Balance

In a wet year, the water balance indicates an increase of approximately 7,500 acre-feet in the amount of water in storage (Table 5). This number exceeds the dry year draft on the aquifer (approximately 6,000 acre-feet). The wet year water balance indicates that in a wet year, the inflows exceed the outflows, and recharge the alluvial water table. If this increase in storage water was evenly distributed across the entire saturated alluvium (estimated areal extent is 58,000 acres), there would be, over the course of a full year, about a 5.5 to 6.5-inch increase in the ground water level across the Basin (7,510 acre-feet divided by 58,000 acres, multiplied by 12 inches per foot, divided by a Sy of 0.24 to 0.28) as presented on Table 9.

4. Permitted Pumping Water Balance

An analysis of the DWR Well database indicated there are 98 FP permitted wells in the Basin. These wells are permitted to withdraw approximately 2,860 acre-feet of water for municipal uses and approximately 11,000 acre-feet for irrigation uses. The other uses of permitted FP wells includes stock (three wells - no maximum pumping listed for one well, other two wells also permitted for irrigation), commercial (three wells each permitted for 0.19 acre-feet per year), and domestic purposes (four wells – two wells are permitted for municipal and domestic use, two wells permitted for irrigation and domestic use). Table 8, Water Balance Based on Permitted Pumping, presents the water balance utilizing the maximum permitted amounts.

Because the municipal effluent could be captured and reused to extinction, the Permitting Pumping Water Balance in Table 8 considers the municipal wastewater returns to be zero. The irrigation pumping is considered to be used for sprinkler irrigation with a 60 percent irrigation efficiency and a 15 percent return flow to the aquifer.

As shown on Table 8, the permitted pumping water balance indicates that the outflow would exceed the inflow by approximately 10,060 acre-feet annually. This means that there would be a reduction in the alluvial water table if the maximum permitted pumping occurred and there were not municipal return flows. If the excess removal of storage water was evenly distributed across the entire saturated alluvium (estimated areal extent is 58,000 acres), there would be, over the course of a full year, about a 7.4 to 8.7-inch decrease in the ground water level across the Basin (10,060 acre-feet divided by 58,000 acres, multiplied by 12 inches per foot, divided by a Sy of 0.24 to 0.28) as presented on Table 9.

5. Discussion of Water Balances

The average year water balance indicates that outflow from the Basin exceeds inflows and therefore the volume of water in storage in the aquifer decreases. It is thus concluded from the water balance, developed in this phase of work, that the aquifer is currently over-appropriated. Depleting the water in storage at the rates estimated from this average year water balance reduces the water table approximately 2 inches per year, assuming the water table is evenly drawn-down across the entire Basin. The wet year water balance developed in this phase of work indicates that the aquifer would be recharged leading to an approximate 6-inch increase in the water table (Table 9). This means that the water balance work predicts that a wet year would offset a dry year and average year. The water balance data used in these analyses are based on our best estimates of the inflows and outflows from the Basin, but the actual inflows and outflows are expected to vary each year based on multiple factors including changes in irrigated area, precipitation, and water table elevation.

The water balance data from this phase of the study indicate that water levels within the Basin, under current conditions, are likely to generally decrease unless there is an extended period of wet years or multiple wet years. Continuing to use the aquifer at the current average rate, and with all other water balance components remaining constant, would allow approximately 92 to 150 years of additional usable life of the aquifer (based on the estimated recoverable volume of water in storage as being 50 to 70 percent of the total water in the alluvium). If the aquifer is used under the Permitted Pumping scenario, the volume of water in storage, considering an estimated recoverable volume as 50 to 70 percent, would allow approximately 19 to 32 years of additional usable life of the aquifer.

It is very important to note that the water level decline estimates derived from the water balances are assumed to be uniform across the entire basin. The work carried out for this study has indicated that there are hydrogeologic differences in the Basin, notably between the eastern and western portions. It must be kept in mind that water table changes in response to the average, dry, wet and permitted pumping scenarios may vary significantly in specific parts of the Basin from what has been predicted for the averaged Basin as a whole. This in turn could impact the predicted useful aquifer lifespans presented above for any areas where water table changes appear to be more sensitive to the water balance conditions.

6. Water Balance Sensitivity Analysis

To evaluate how the water balance responds to changes to the input parameters, a sensitivity analysis was performed. This allows identification of which parameters have the greatest influence over the water balance. The water balance sensitivity analysis is presented in Table 10.

The sensitivity analysis showed that the precipitation recharge percentage, the size of the land covered by phreatophytes, and the phreatophyte consumptive use factor have the greatest effect on the water balance. While all numbers in the water balance are estimates based on our analysis and the available data, we are comfortable with our precipitation recharge and phreatophyte values, those being the parameters having the greatest impact on the water balances.

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VIII. CONCLUSIONS AND RECOMMENDATIONS

Our water balance work for the District Board was started in 2006 when M&W reviewed the past water-balance related work within the Basin. Based on this 2006 work, the District pursued two grants to fund additional technical work. The water balance work completed by M&W was conducted in two phases funded through grants from the Arkansas Basin Roundtable Group and the Severance Tax Trust Fund. The water balance conclusions presented herein are comprehensive based on all of the water balance work conducted by M&W.

The water balance evaluated both the inflows and outflows to the aquifer through review of aerial photos, a member survey, discussions and informal interviews with Board members and landowners, field work, analysis of data obtained from the U.S. Department of Agriculture and U.S. Environmental Protection Agency, review of DWR water level data, review and analysis of USGS and Colorado Geological Survey data, evaluation of multiple sources of precipitation data, analysis of information presented in past studies of the Basin and a neighboring basin, additional technical publications, and our experience and professional judgment.

The Upper Big Sandy Basin has proven to be a very complex and highly variable system hydrogeologically, and it was repeatedly observed throughout the course of this study that as further data was developed, more questions were developed and inconsistencies were realized. It is clear that ultimately there will be uncertainties in any assessment of the Basin that attempts to incorporate a full and comprehensive picture of the hydraulics, hydrogeology and hydrology of the Basin. The studies and analyses summarized in this report, however, have greatly narrowed the focus, have significantly improved the estimates of many of the important water balance parameters and have identified the key components controlling the balance.

1. Conclusions

This project developed four water balances: average year, wet year, dry year, and permitted pumping. The average year, dry year, and permitted pumping water balances indicate there will be a net deficit to the aquifer under these scenarios, and the wet year water balance indicates the aquifer will recharge during the wet year scenario.

The major component of inflow to the alluvial aquifer is natural recharge from precipitation. This component accounts for more than 90 percent of the recharge to the aquifer. The major components of outflow from the aquifer during an average year are estimated to be phreatophyte consumptive use and current levels of irrigation pumping.

The average year water balance predicts a draft on the aquifer of approximately 2,100 acre-feet which leads to an anticipated drop in the water table of less than 2 inches. This trend agrees well with the water level data obtained from the DWR which indicates that water levels have decreased slightly on average over the period of record (1991 to 2008). Recognizing that, while the entire Basin as a whole has not consistently exhibited a declining water table, when considering all water level changes, the water levels in the Basin appear in general to be declining.

A reduced water table may ultimately result in both a loss of the ability to maintain pumping rates as in the past and in increased well-to-well interference impacts. (The survey results indicate this may already be happening in portions of the Basin.) It is noted, however, that the analyses carried out for this study have indicated that the lower, or eastern, Basin is experiencing greater water table lowering than the upper, or western, Basin, as a generalization. The water level changes observed in the western end of the Basin indicate that the water table has increased from 1991 to 2008. These data indicate that the water table changes are occurring differently across the Basin, and certain areas of the Basin may thus be more susceptible to the problems associated with declining water levels. This implies that the imbalance in the Basin may be somewhat localized and that the management of the pumping may be more critical in the lower Basin.

The average year water balance indicates that there will be a decline in the alluvial water level. It is anticipated that these declines will, over time, impact the natural wetlands within the Basin. Moderate declines in the water table will put a stress on the wetlands and will likely decrease their size. Significant declines in the water table will also put a greater stress on the wetlands and would have a larger impact. The result could be a large loss of these wetland areas within the Basin. Additionally, protection and maintenance of riparian buffer corridors and protection of springs, natural pools and groundwater levels would greatly enhance the Arkansas darters' habitat, abundance and distribution (Colorado Division of Wildlife, 2008).

The average year water balance is based on estimates of the current use of water within the Basin and estimates of inflows to the Basin. The estimates of pumping outflow for current use are lower than the full permitted amount of pumping (Table 4 and Table 8). The water balance based on permitted pumping leads to an annual draft of more than 10,000 acre-feet on the aquifer which results in a predicted water table decrease of approximately 7 to 9 inches. Pumping at the allowed levels (as per the permitted maximums) is predicted to significantly decrease the useable life of the aquifer.

The dry year water balances indicates a draft and net deficit on the aquifer nearly three times as great as the average year. The wet year balance indicates a net recharge to the aquifer which is nearly four three times greater than the net draft on the aquifer during the average year. This leads us to believe that if drought years are routinely offset by wet years, the average annual draft on the aquifer will remain nearly constant through time and the aquifer will continue in a net deficit mode approximated for an average year. It must be noted, however, that there is some evidence that ongoing climatic changes may increase the frequency of dry years and reduce the frequency of wet and average years.

The water balance data indicate that water levels within the Basin, under current conditions, are likely to generally decrease unless there is an extended period of wet years or at least multiple wet years. Continuing to use (pump) the aquifer at the current average rate, and with all other water balance components remaining constant, would allow approximately 92 to 150 years of additional usable life of the aquifer (based on the estimated recoverable volume of water in storage as being 50 to 70 percent of the total water in the alluvium). If the aquifer pumping is brought to the levels allowed for in the permitted pumping scenario, the volume of water in storage, considering an estimated recoverable volume as 50 to 70 percent, would allow approximately 19 to 32 years of additional usable life of the aquifer.

2. Recommendations and Limitations of the Study

Recommendations

Although phreatophye consumptive use represents a major estimated loss of water within the Basin, it is a very complex variable and it has not been studied in detail within the Basin. Further work to refine the estimates of this component of the water balance would allow better and more reliable estimates of the annual draft on the aquifer. Additionally, the water balances developed for this study quantify irrigation pumping based on assessment of the irrigated areas or the maximum allowable use of water, not on the actual use of the water, as no data is currently available on actual pumping throughout the Basin. Requiring metering of irrigation well pumping and regular reporting of the data would allow for actual assessment of the true pumping-related alluvial water withdrawals and would comprise a valuable administrative tool for the District Board. If such metering is implemented, it is recommended that the data be reviewed at regular intervals to assist in determining what levels of stress are being placed on the aquifer in any given year.

The water levels in the Basin and maintenance of these levels is of high importance to the longevity of the aquifer resources. It is recommended that the District implement an ongoing water level monitoring program and that the data collected be tabulated and reviewed on a regular basis.

Similarly, the precipitation occurring within the Basin has been observed to be often local, of varying durations, and of varying intensities. This has added to the uncertainty in the estimates of the aquifer precipitation recharge, recognized as the most important single factor in the inflows to the Basin. It is recommended that the District Board seek ways in which to develop additional precipitation and alluvial recharge data. A study on the change in alluvial water levels related to precipitation events could be used to further refine the recharge estimates. In addition, it is strongly recommended that the District consider monitoring regional climatic data trends to aid in determining whether longer term drying of the area is a potential and to aid in determining whether to administer the Basin pumping based on average year conditions or moving towards the dry year scenario.

One area of potential interest to the Board that has been addressed in this report but which is in need of more detailed study is the level of hydraulic interaction with the Denver Basin bedrock aquifers. To more fully assess what levels of water might be undergoing exchange between the alluvial aquifer and the bedrock aquifers, controlled pumping tests with nested monitor wells in both the alluvial aquifer and the bedrock aquifers will be required. It is recommended that the District give consideration to seeking funding to carry out such a study, noting however, that to the extent the exchange is occurring, it may be a bi-directional phenomena.

Limitations of the Study

To determine the anticipated changes in water levels presented in Table 9, the extent of the saturated alluvial material was estimated. The specific yield of the aquifer materials was calculated through field slug testing, pump testing, and laboratory analysis of soil samples as discussed in this report. While the actual extent of the aquifer is continually fluctuating, the estimates provided herein are our best judgment based on the data available to us. Quantifying what is occurring below the ground surface always involves uncertainty and we have attempted to reduce the uncertainty by obtaining additional data during the water balance process to help us better interpret the hydrogeology of the alluvial aquifer.

This level of uncertainly represents a limitation on a number of aspects of this study. As noted above, it has readily been observed that the Basin is a very dynamic, heterogeneous and complex system. Accordingly, while we have greatly refined the estimates for the various parameters of the water balances presented in the report over previous studies, there is still uncertainty in the figures that is unavoidable. The District should recognize that, in the event further study is carried out on any of the important water balance parameters, there will always be some level of uncertainty in the data.

Other limitations in this study that should be acknowledged relate to the level of funding available and the limitation such available funding placed on the scopes of work. Significant decisions had to be made as to how best to focus the work within the available budgets and timeframes. It goes without saying that additional funding to carry out some of the items listed in the recommendations, above, will result in expected further refinements to the developed water balances.

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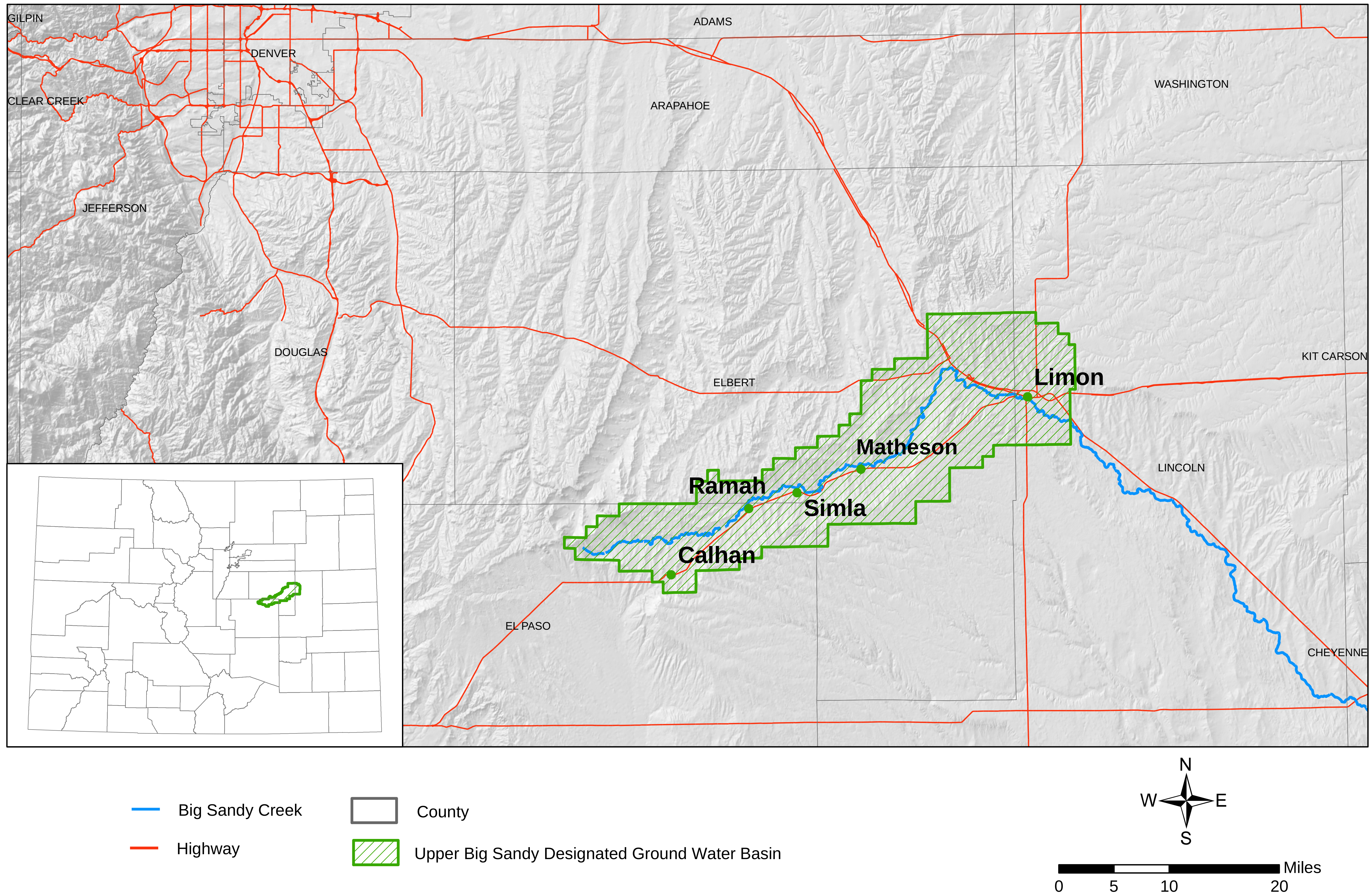
FIGURES



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Basin Location Map

Figure 1

Upper Big Sandy
Phase 2
Water Balance

Job No.: 694.4
Date: 12/18/08
Drawn: CRR
Checked: PLM

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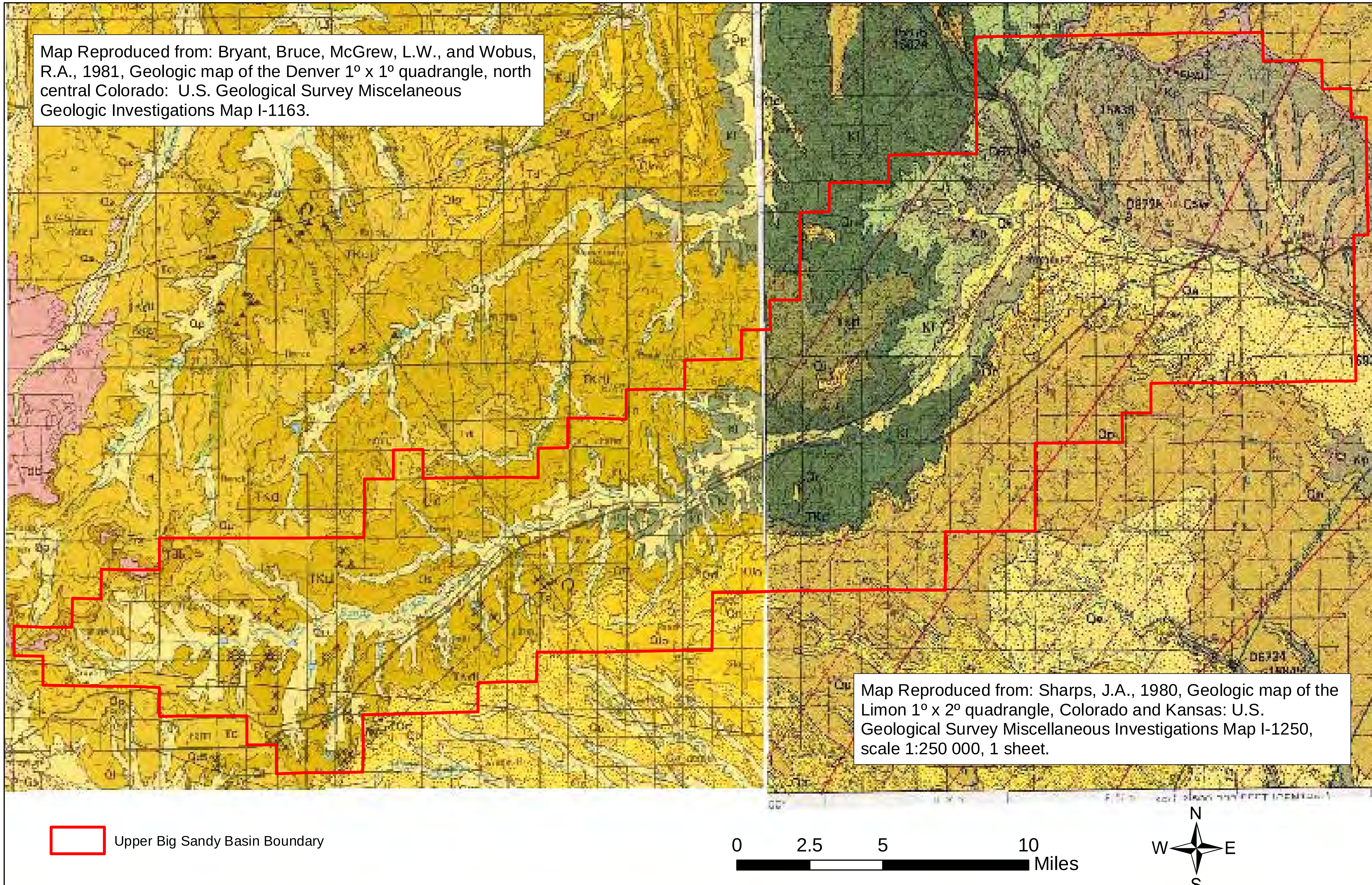

Surficial Geologic Map

Figure 2A

Upper Big Sandy
Phase 2
Water Balance

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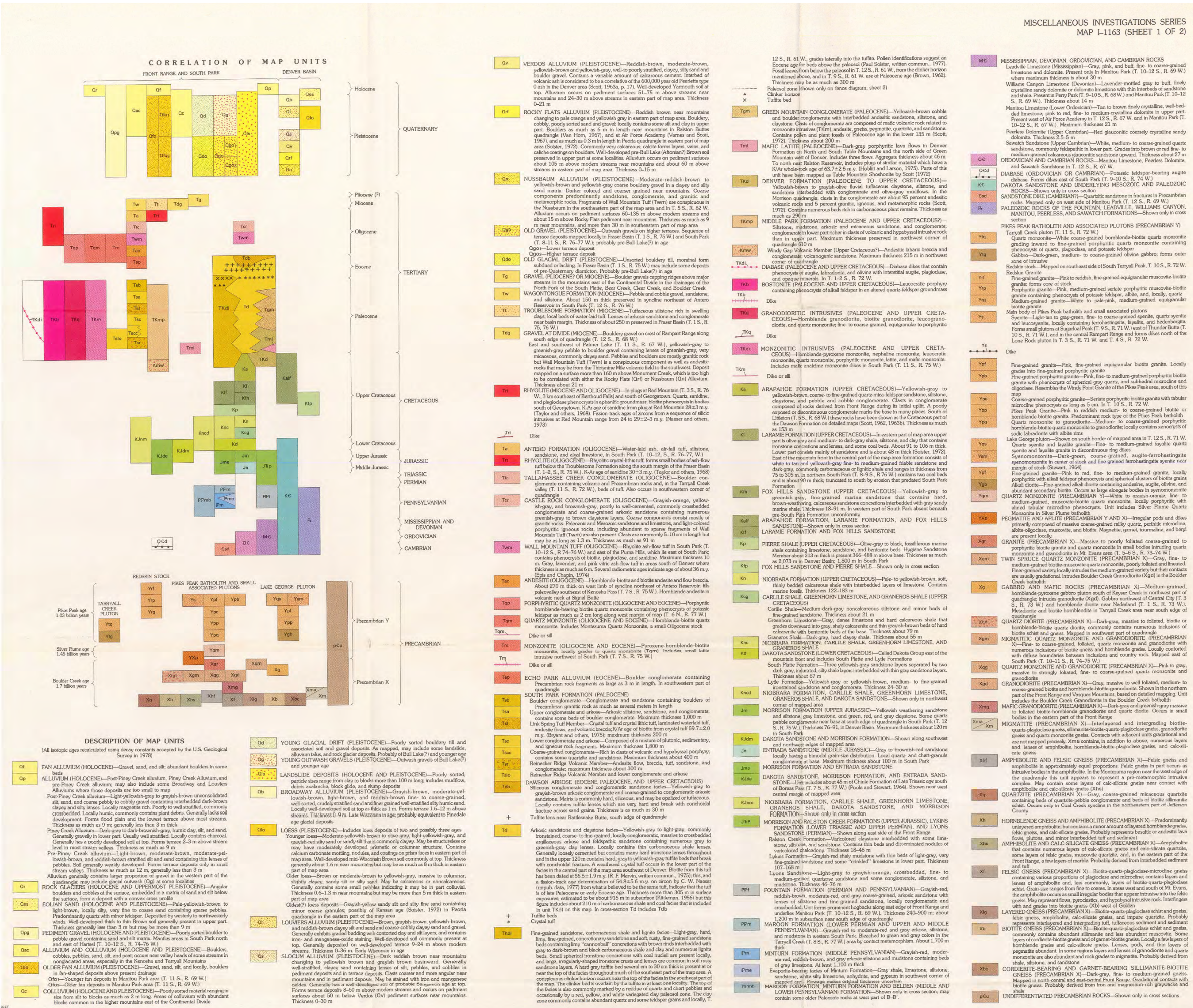
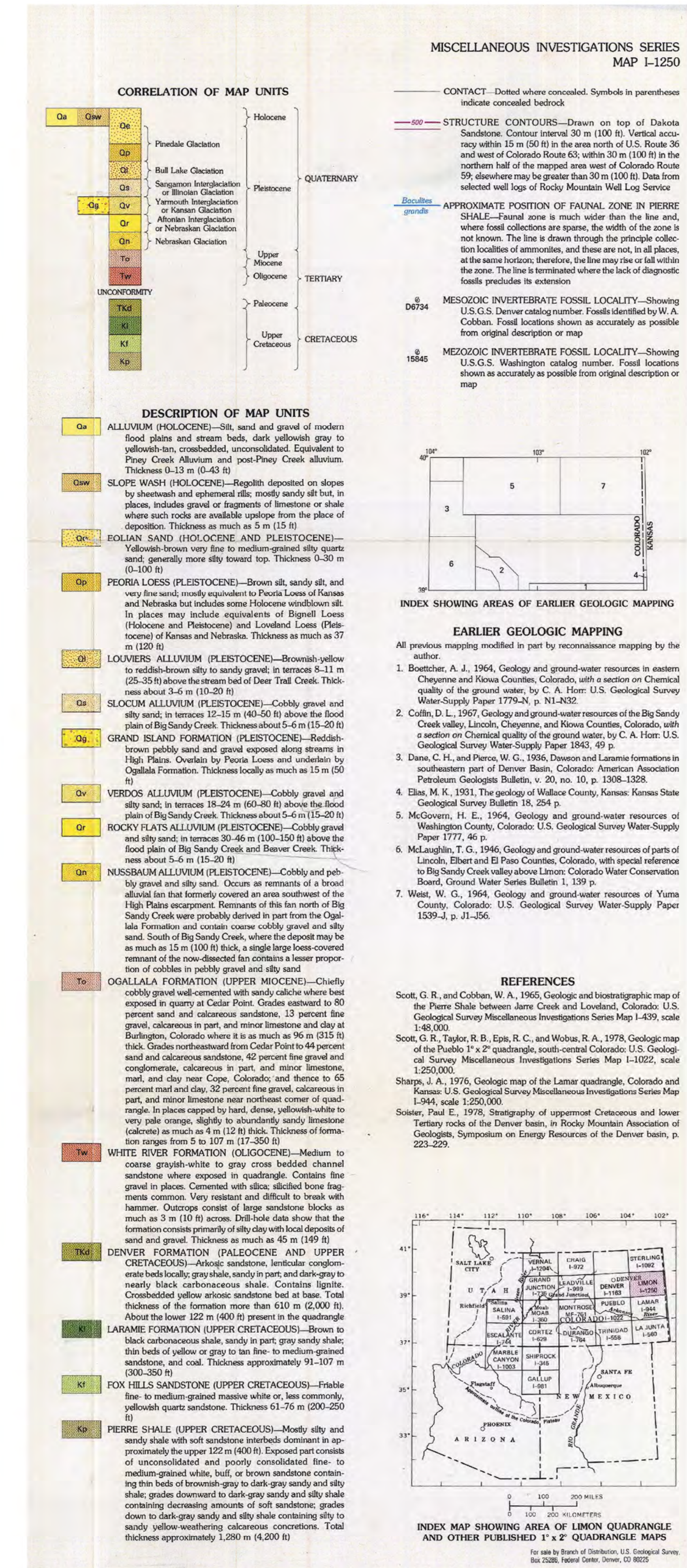
Job No.: 694.4
Date: 5/5/09
Drawn: JPB
Checked: WRB

S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\GeologicMap.mxd

Legend for: Bryant, Bruce, McGrew, L.W., and Wobus, R.A., 1981, Geologic map of the Denver 1º x 1º quadrangle, north central Colorado: U.S. Geological Survey Miscelaneous Geologic Investigations Map I-1163.



Legend for: Sharps, J.A., 1980, Geologic map of the Limon 1º x 2º quadrangle, Colorado and Kansas: U.S. Geological Survey Miscellaneous Investigations Map I-1250, scale 1:250 000, 1 sheet.



Job No.:	694.4
Date:	5-May-2009
Drawn:	JPB
Checked:	WRB

Upper Big Sandy
Phase 2 Water Balance

Surficial Geologic Map Legends
Figure 2B

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S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\GeologicMap\Geologic MapLegends.mxd

Legend

- Test Hole Locations
- Big Sandy Creek
- Cross Section Locations
- Interpolated Saturated Alluvial Extent
- Upper Big Sandy Basin Boundary

N
W E
S

0 2.5 5 10 Miles

Job No.:	694.4
Date:	4-8-2009
Drawn:	WRB
Checked:	PLM

Upper Big Sandy
Phase 2 Water Balance

Interpolated Saturated Alluvial Extent,
Cross Section Locations, and Test Hole Locations
Figure 3

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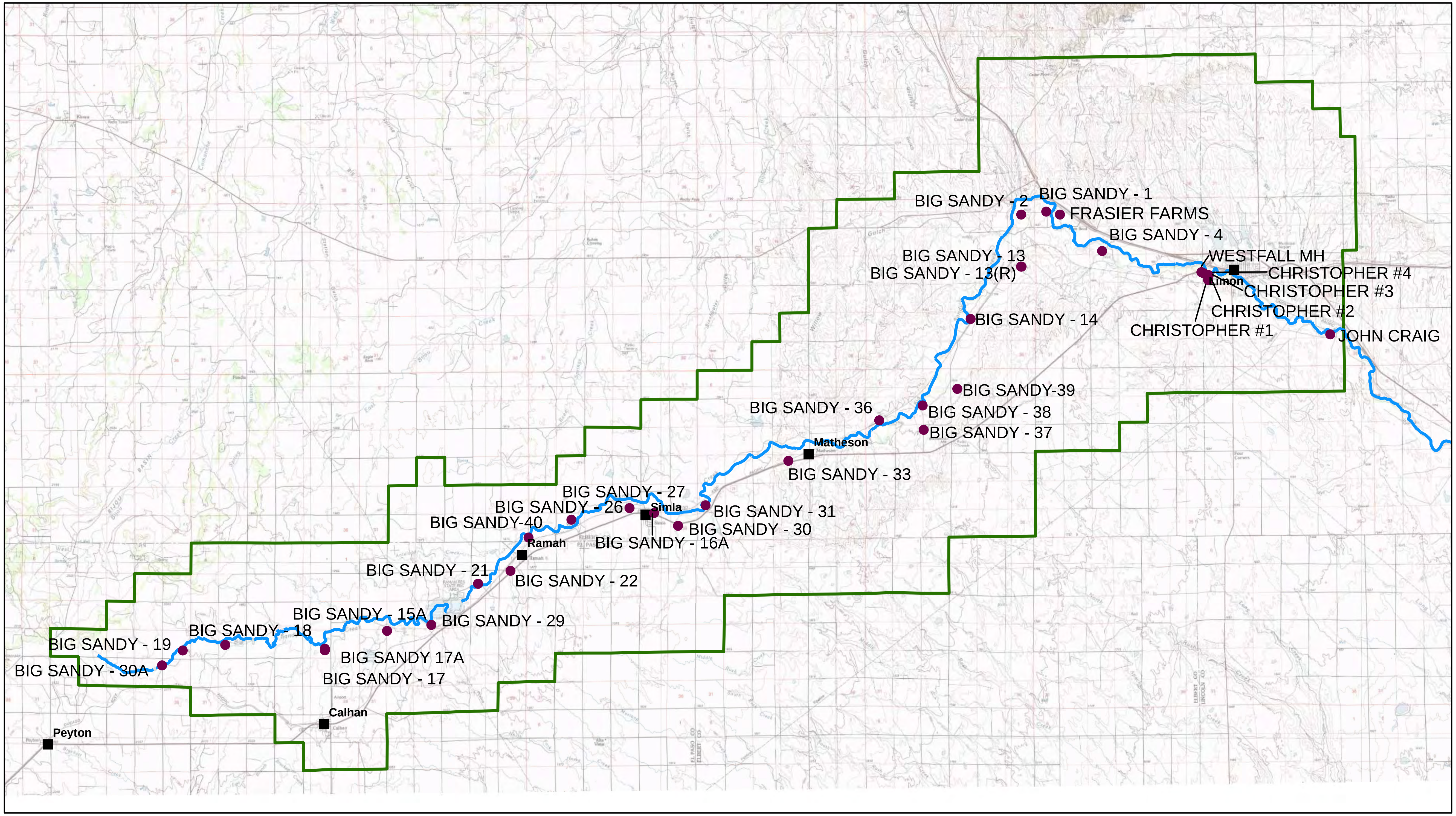
S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\Saturated Alluvial Extent and Cross Section Locations.mxd



Upper Big Sandy Basin Boundary

Monitoring Well with DWR Well Name

N W E S

0 2 4 8 Miles

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Fax: (303) 526-2624
mwi@martinandwood.com

MARTIN AND WOOD WATER CONSULTANTS, INC.

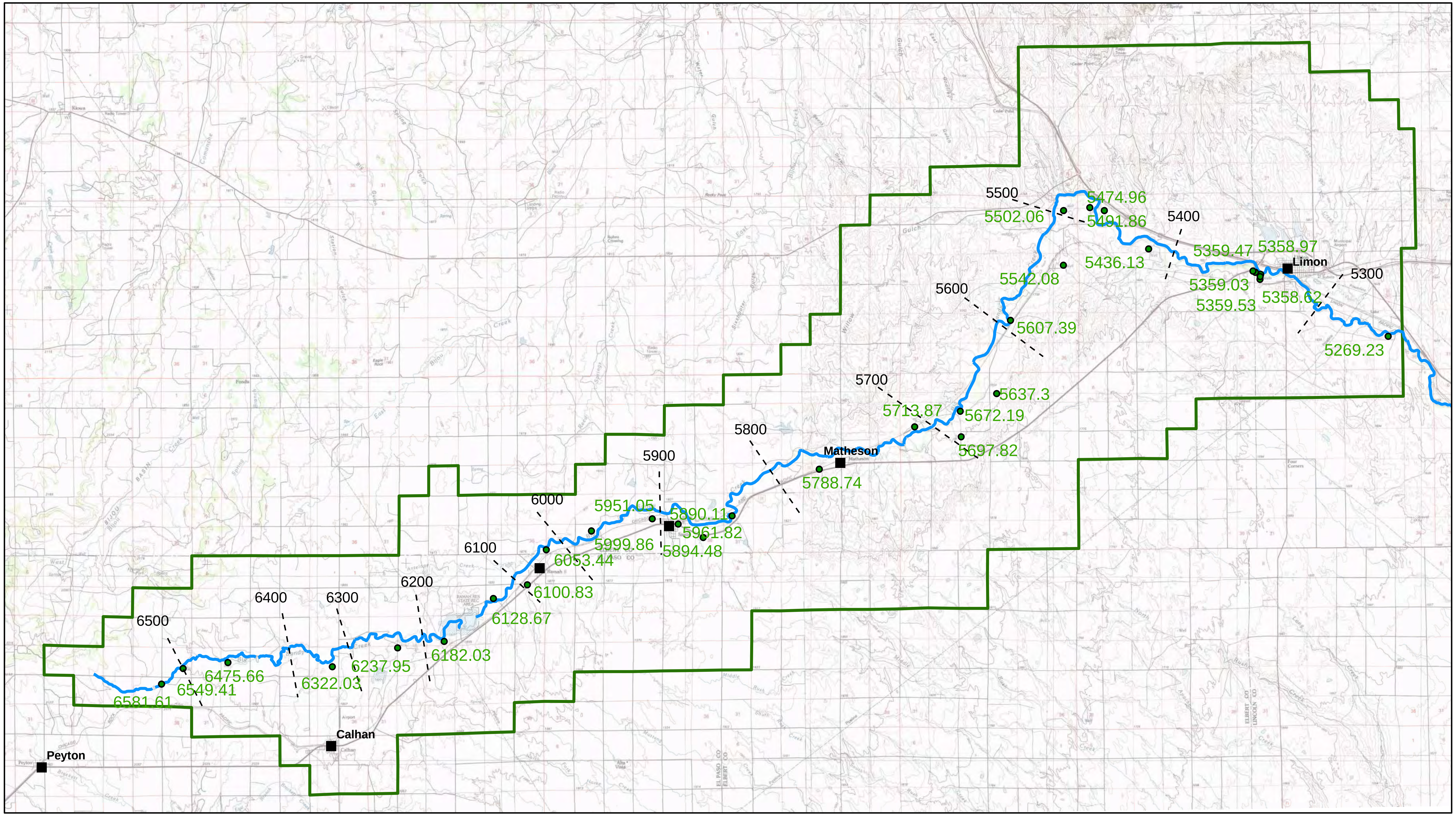
Montioring Well Location Map

Figure 4

Upper Big Sandy Phase 2 Water Balance

Job No.:	694.3
Date:	12/18/08
Drawn:	CRR
Checked:	PLM

S:\694 - Upper Big Sandy Mgmt Dist\694.41\GIS\Figure 4 - Monitoring Wells.mxd



Notes
1. Data based on most recent Division of Water Resources water level elevations: (March 6, 2007 for 2 wells and February 12-13, 2008 for 29 wells).
2. Dashed lines do not indicate that the saturated alluvium extends to that point.
3. The lines are dashed to indicate that the water levels are estimated.

● Monitoring Well with Ground Water Elevation (feet above mean sea level)

- - - - Approximate ground water elevation (feet above mean sea level)

Upper Big Sandy Basin Boundary

0 2 4 8 Miles

N W E S

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mwi@martinandwood.com

MARTIN AND WOOD WATER CONSULTANTS, INC.

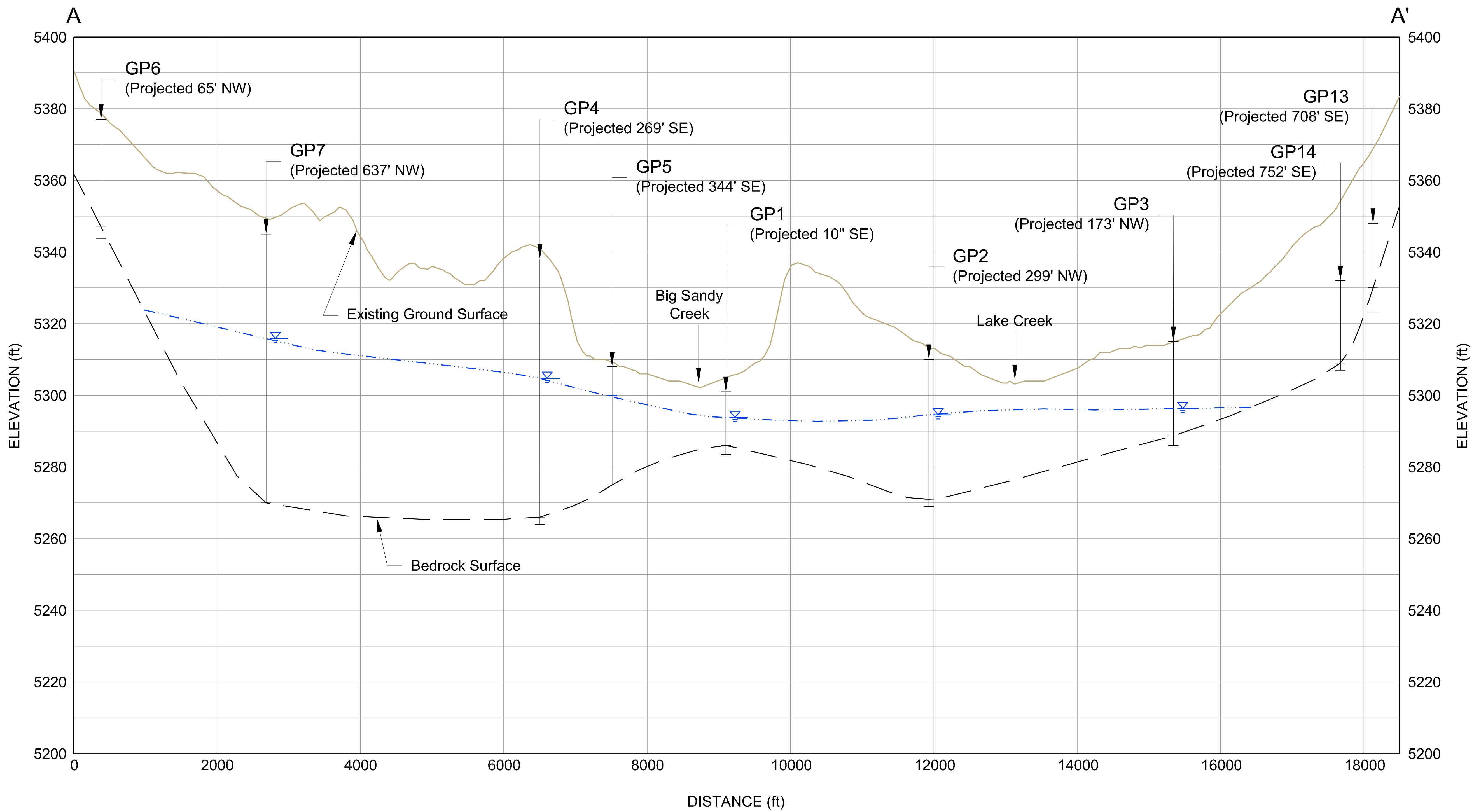
Alluvial Ground Water Elevation Map

Figure 5

Upper Big Sandy Phase 2 Water Balance

Job No.:	694.4
Date:	12/18/08
Drawn:	CRR
Checked:	PLM

S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Water Balance\GIS\Figure 5 - WaterLevels.mxd



CROSS SECTION A-A'

VERTICAL EXAGGERATION=50X

EXPLANATION

TEST HOLE

GP7

Water Level

Bedrock Surface

Total Depth

SCALE

1,500' 0 1,500' 3,000'

NOTE: PROJECTED TEST HOLES ARE NOTED AS DISTANCE AND DIRECTION PROJECTED TO SECTION LINE IN FEET

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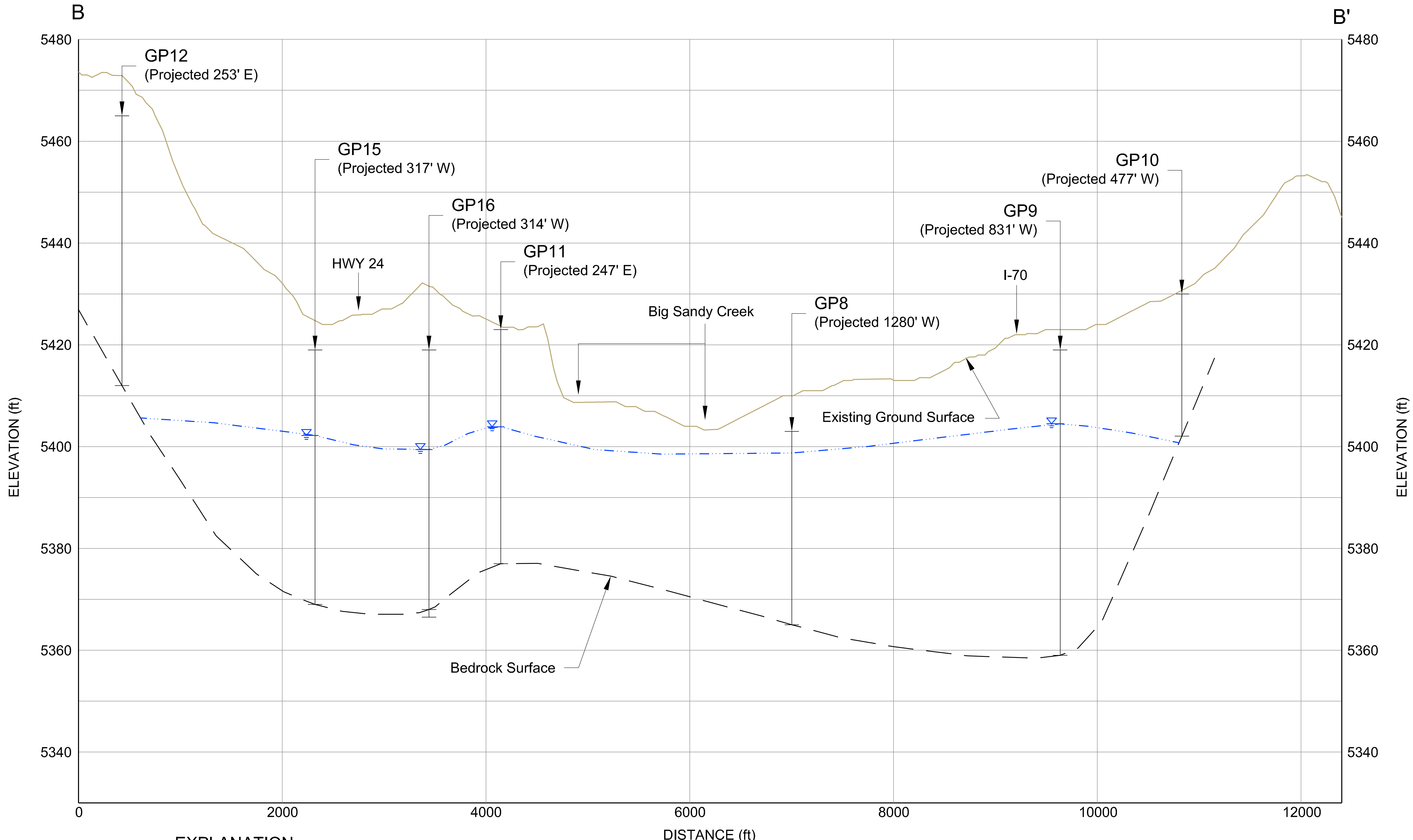
Cross Section A-A'

Figure 6

Upper Big Sandy Phase 2 Water Balance

Job No.: 694.3
Date: 27-Apr-2009
Drawn: TCH
Checked: WRB



EXPLANATION

TEST HOLE

GP8

Water Level

Bedrock Surface

Total Depth

CROSS SECTION B-B'

VERTICAL EXAGGERATION=50X

SCALE

1,000' 0 1,000' 2,000'

NOTE: PROJECTED TEST HOLES ARE NOTED AS DISTANCE AND DIRECTION PROJECTED TO SECTION LINE IN FEET

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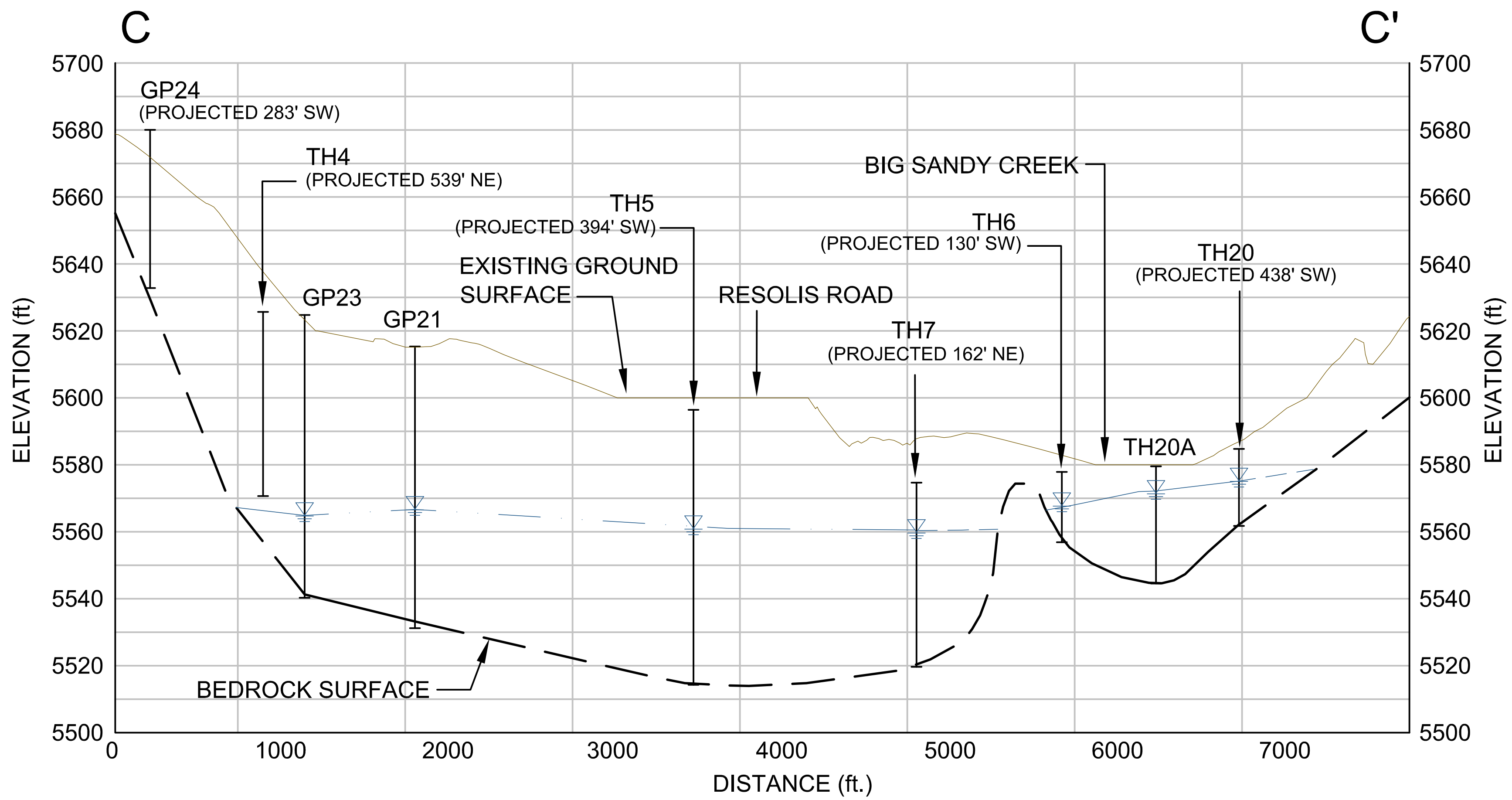
Cross Section B-B'

Figure 7

Upper Big Sandy
Phase 2
Water Balance

Job No.: 694.3
Date: 27-Apr-2009
Drawn: TCH
Checked: WRB



CROSS SECTION C-C'

VERTICAL EXAGGERATION = 50X

EXPLANATION

TEST HOLE

GP21

WATER LEVEL

BEDROCK SURFACE

TOTAL DEPTH

NOTE: GP LABELED TEST HOLES ARE FROM M&W FIELD INVESTIGATION AND TH LABELED TEST HOLES ARE FROM HRS FIELD INVESTIGATION.

PROJECTED TEST HOLES ARE NOTED AS DISTANCE AND DIRECTION PROJECTED TO SECTION LINE IN FEET.

0 1000 ft. 2000 ft.

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mwl@martinandwood.com

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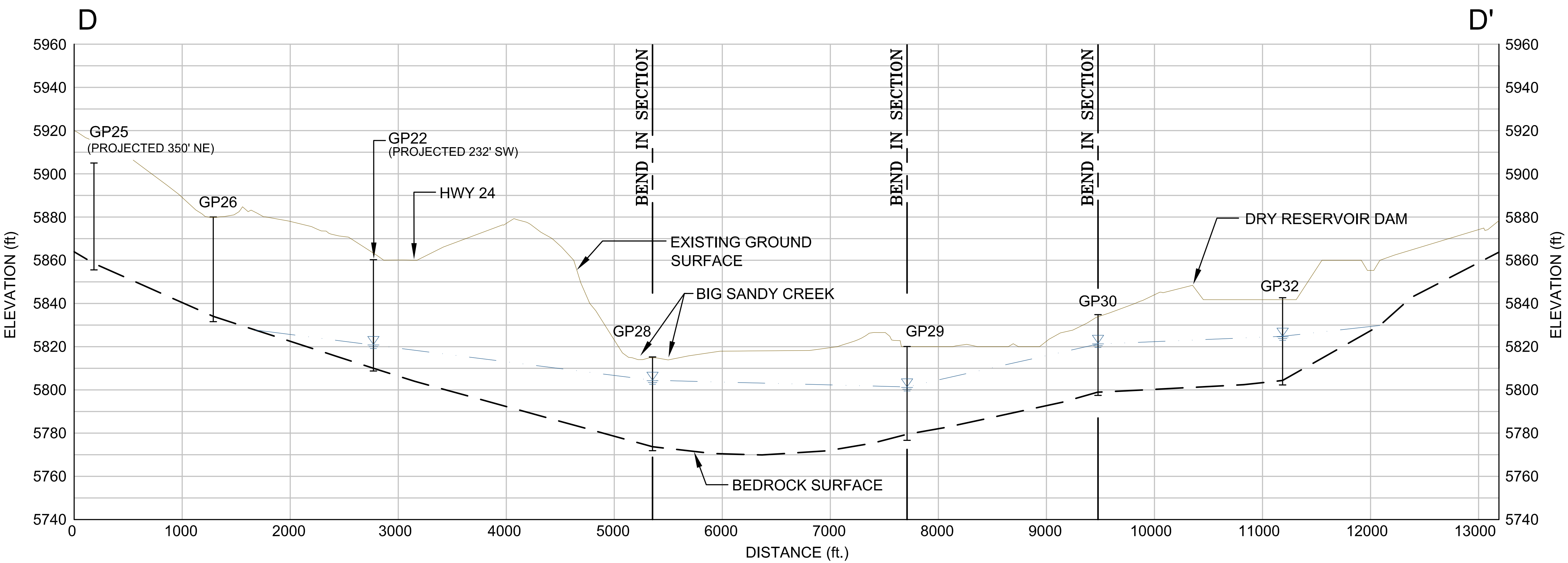
Cross Section C-C'

Figure 8

Upper Big Sandy
Phase 2
Water Balance

Job No.: 694.4
Date: 27-April-2009
Drawn: TMC
Checked: WRB



CROSS SECTION D-D'

VERTICAL EXAGGERATION = 50X

EXPLANATION

TEST HOLE

GP29

WATER LEVEL

BEDROCK SURFACE

TOTAL DEPTH

NOTE: PROJECTED TEST HOLES ARE NOTED AS DISTANCE AND DIRECTION PROJECTED TO SECTION LINE IN FEET.

0 1000 ft. 2000 ft.

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mwl@martinandwood.com

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Cross Section D-D'

Figure 9

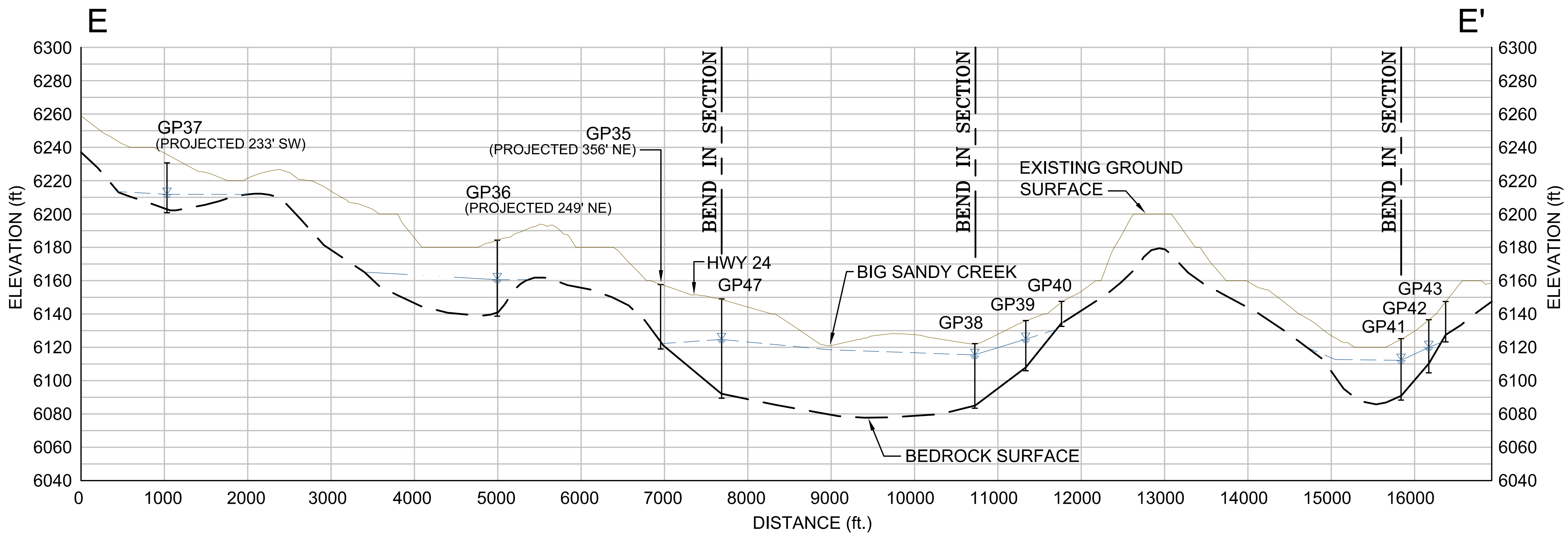
Upper Big Sandy
Phase 2
Water Balance

Job No.: 694.4

Date: 27–April–2009

Drawn: TMC

Checked: WRB



CROSS SECTION E-E'

VERTICAL EXAGGERATION = 50X

EXPLANATION

TEST HOLE

GP36

WATER LEVEL

BEDROCK SURFACE

TOTAL DEPTH

NOTE: PROJECTED TEST HOLES ARE NOTED AS DISTANCE AND DIRECTION PROJECTED TO SECTION LINE IN FEET.

0 1500 ft. 3000 ft.

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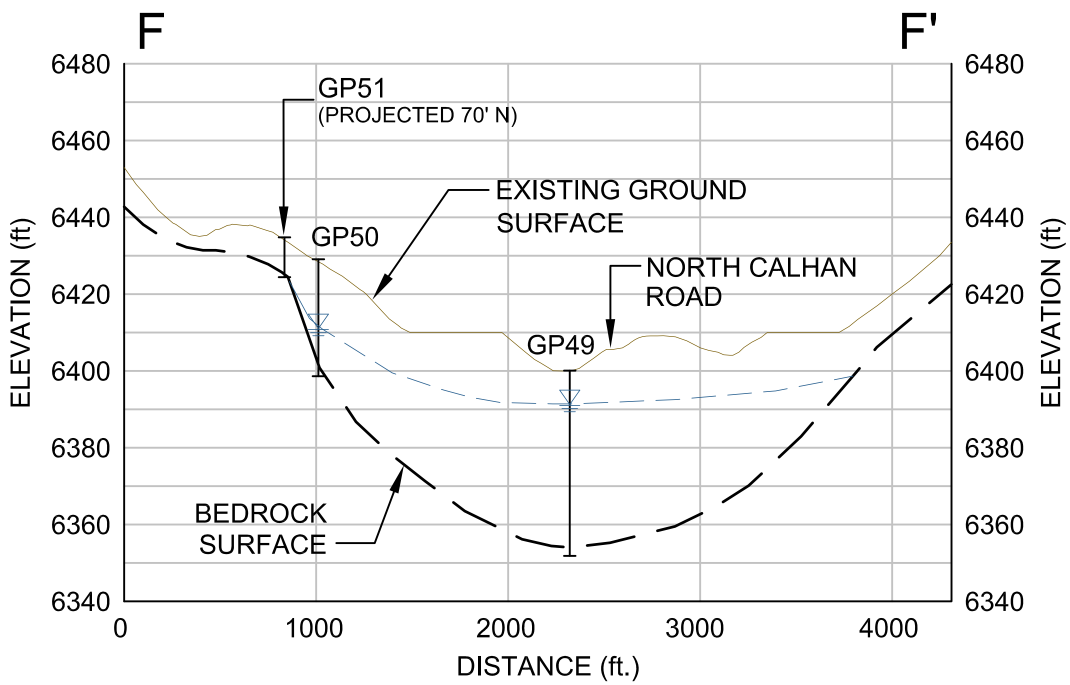
MARTIN AND WOOD WATER CONSULTANTS, INC.

Cross Section E-E'

Figure 10

Upper Big Sandy Phase 2 Water Balance

Job No.: 694.4
Date: 14-April-2009
Drawn: TMC
Checked: WRB



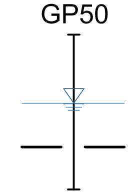
CROSS SECTION F-F'

VERTICAL EXAGGERATION = 50X

EXPLANATION

TEST HOLE

GP50



WATER LEVEL

BEDROCK SURFACE

TOTAL DEPTH

NOTE: PROJECTED TEST HOLES ARE NOTED AS DISTANCE AND DIRECTION PROJECTED TO SECTION LINE IN FEET.

0 1000 ft. 2000 ft.

Job No.: 694.4
Date: 27-April-2009
Drawn: TMC
Checked: WRB

Upper Big Sandy
Phase 2
Water Balance

Cross Section F-F'

Figure 11

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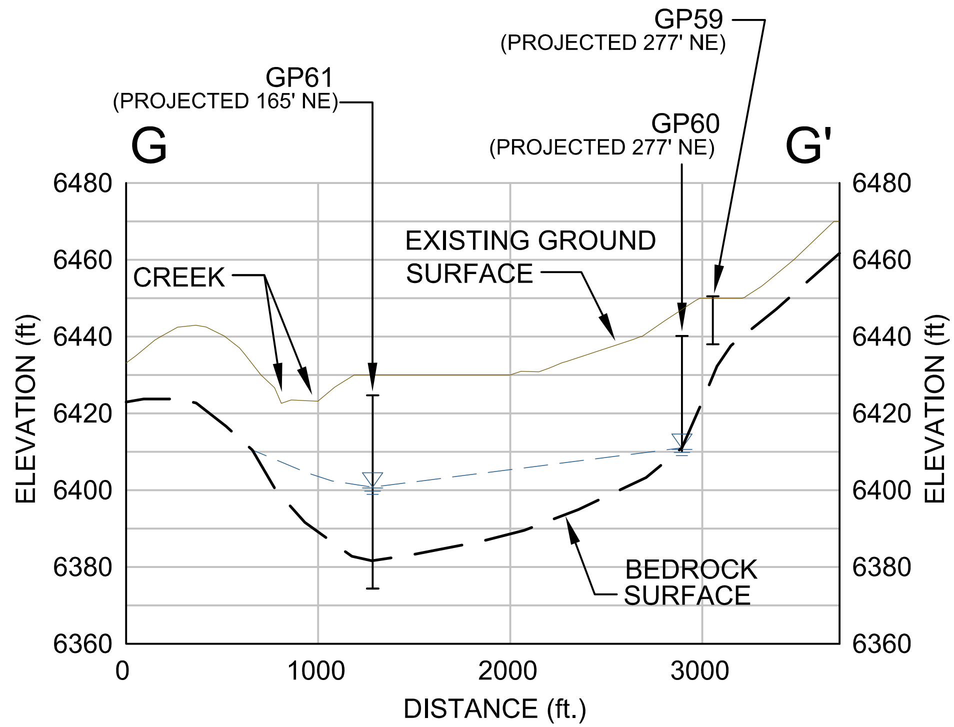
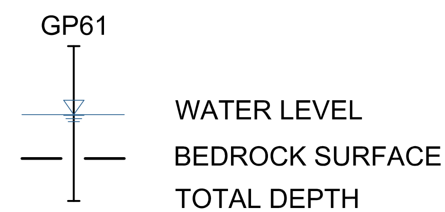


CROSS SECTION G-G'

VERTICAL EXAGGERATION = 50X

EXPLANATION

TEST HOLE



NOTE: PROJECTED TEST HOLES ARE NOTED AS DISTANCE AND DIRECTION PROJECTED TO SECTION LINE IN FEET.

0 1000 ft. 2000 ft.

Job No.: 694.4
Date: 27–April–2009
Drawn: TMC
Checked: WRB

Upper Big Sandy
Phase 2
Water Balance

Cross Section G-G'

Figure 12

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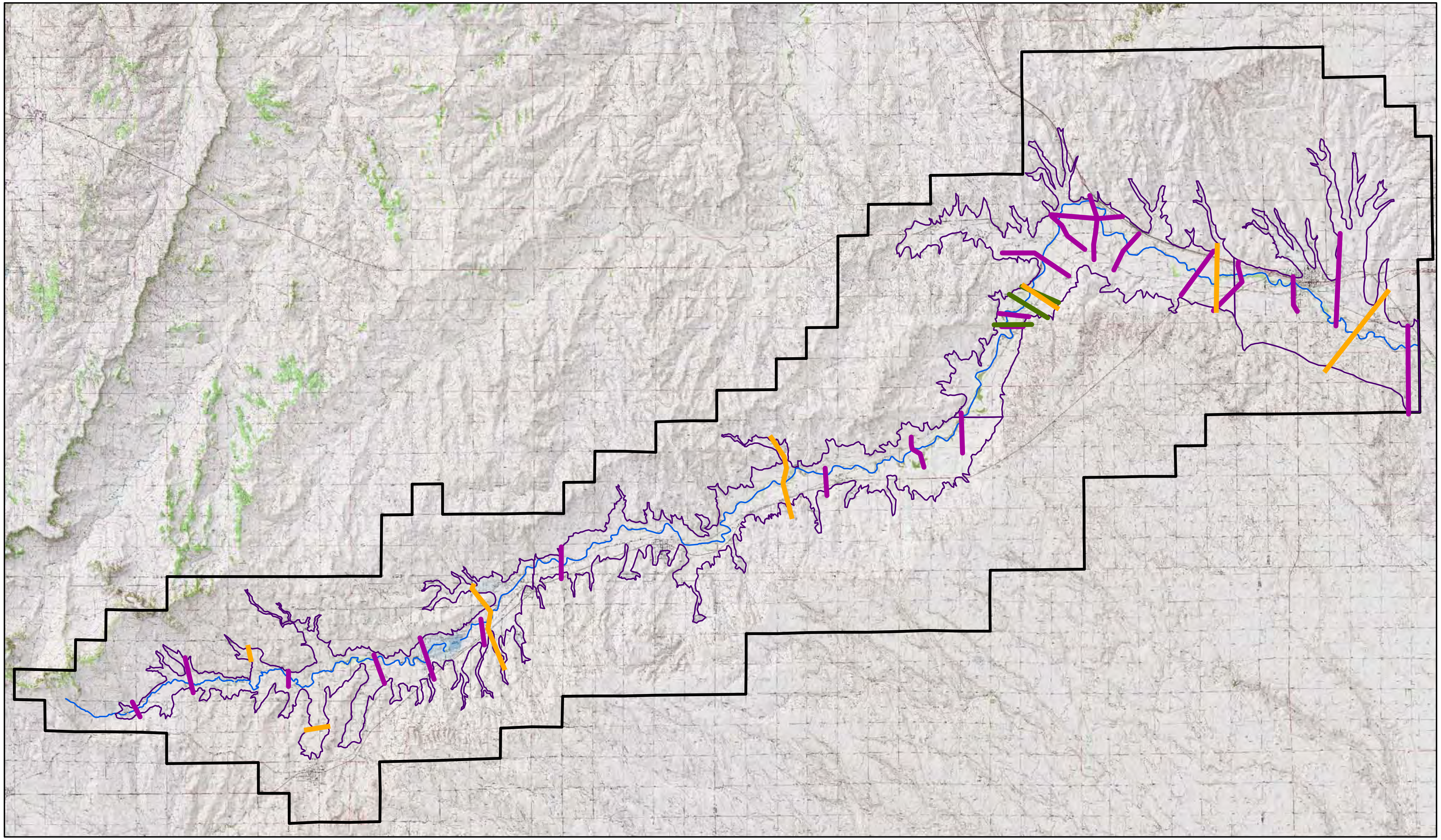

Legend

- Martin and Wood Sections
- HRS Sections
- ASCG Sections
- Big Sandy Creek and Tributary Interpolated Saturated Alluvaial Extent
- Upper Big Sandy Basin Boundary
- Big Sandy Creek

N
W E
S

0 4 8 16 Miles

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MARTIN AND WOOD WATER CONSULTANTS, INC.

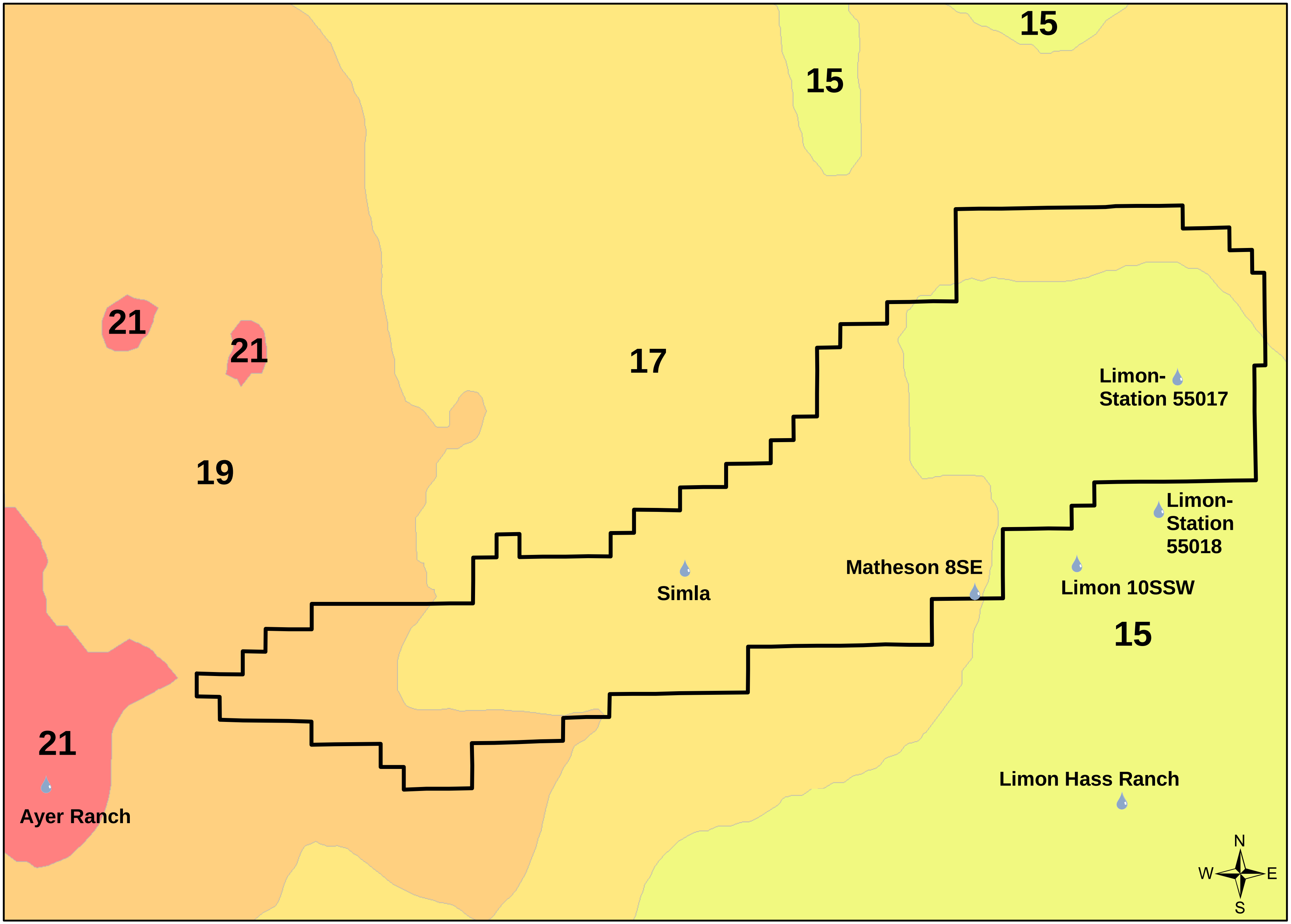
Composite Cross Section Locations

Figure 13

Upper Big Sandy Phase 2 Water Balance

Job No.:	694.4
Date:	4/8/2009
Drawn:	WRB
Checked:	PLM

S:\694 - Upper Big Sandy Mgmt Dist\694.3 - Water Balance\GIS\Composite Cross Section Locations.mxd



Precipitation Station

Upper Big Sandy Boundary

Numbers within each contour represent average annual precipitation in inches from 1971-2000 (PRISM data).

0 2 4 8 Miles

Job No.: 694.3

Date: 11/17/2008

Drawn: JPB

Checked: CRR

Upper Big Sandy
Phase 2
Water Balance

Basin Precipitation
Map
Figure 14

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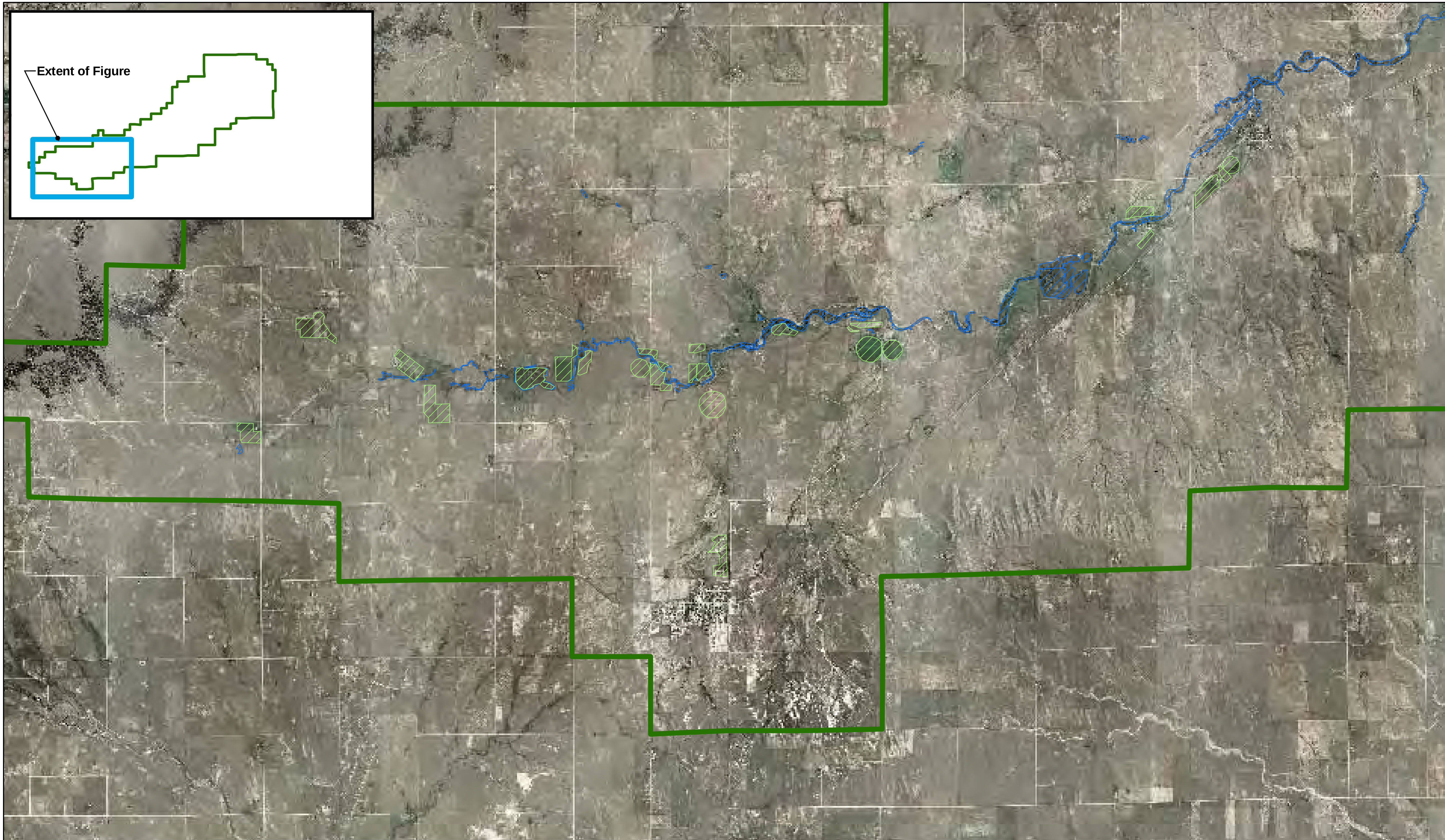
S:\694 - Upper Big Sandy Mgmt Dist\694.4\GIS\Figure14-Precipitation Map.mxd



Job No.:	694.3
Date:	4-10-2008
Drawn:	JPB
Checked:	CR

Upper Big Sandy
Phase 2 Water Balance

Legend

Irrigated Area

Phreatophyte Areas

Upper Big Sandy Basin Boundary

N W E S

0 0.5 1 2 Miles

Western Irrigated Areas and
Phreatophytes Map
Figure 15

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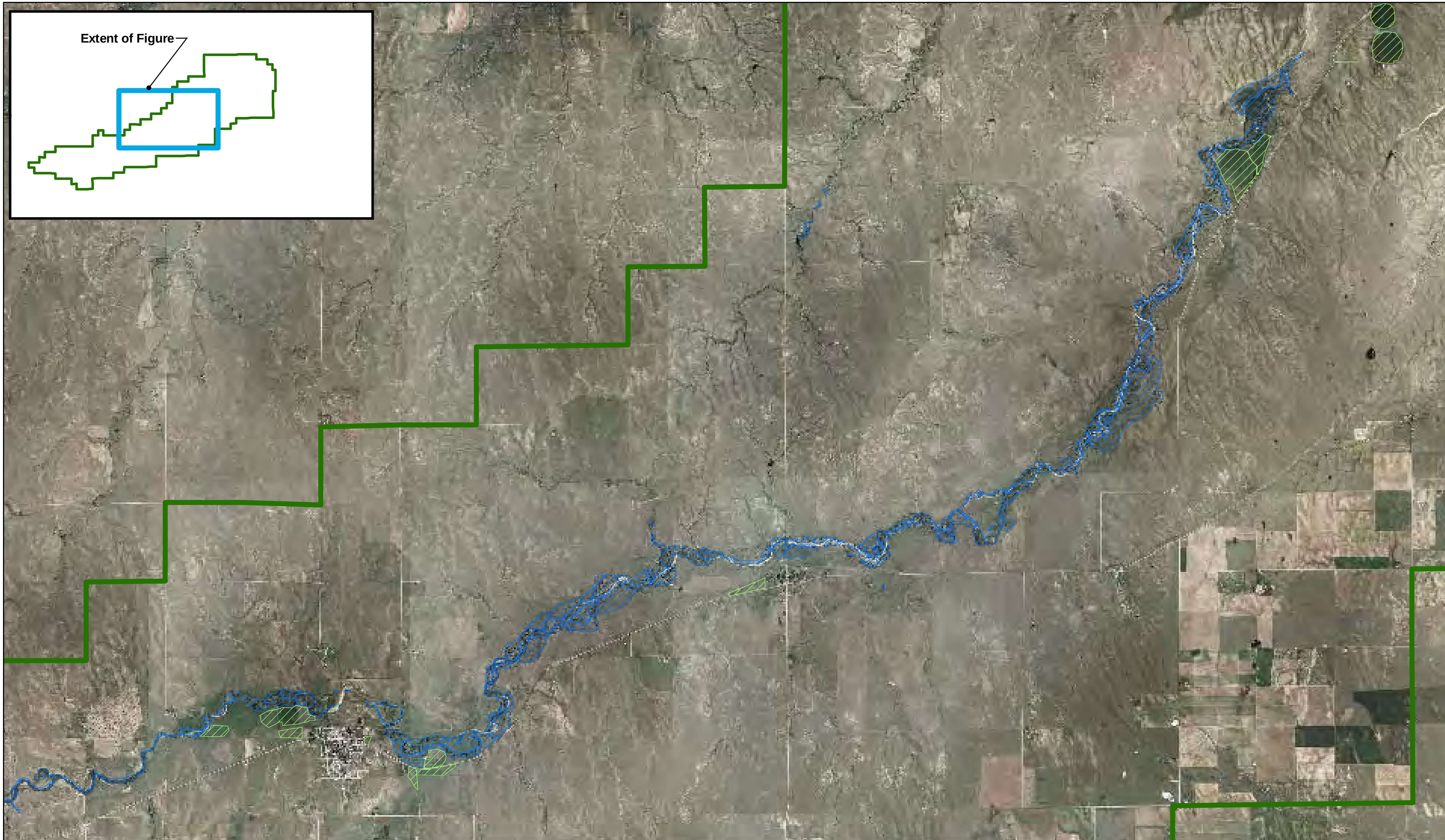
S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\Irrigated Area\Final Irrigated Area Maps\Plate3_IrrArea.mxd



Job No.:	694.3
Date:	4-10-2008
Drawn:	JPB
Checked:	CR

Upper Big Sandy
Phase 2 Water Balance

Legend

Irrigated Area

Phreatophyte Areas

Upper Big Sandy Basin Boundary

N
W E
S

0 0.5 1 2 Miles

Central Irrigated Areas and Phreatophytes Map
Figure 16

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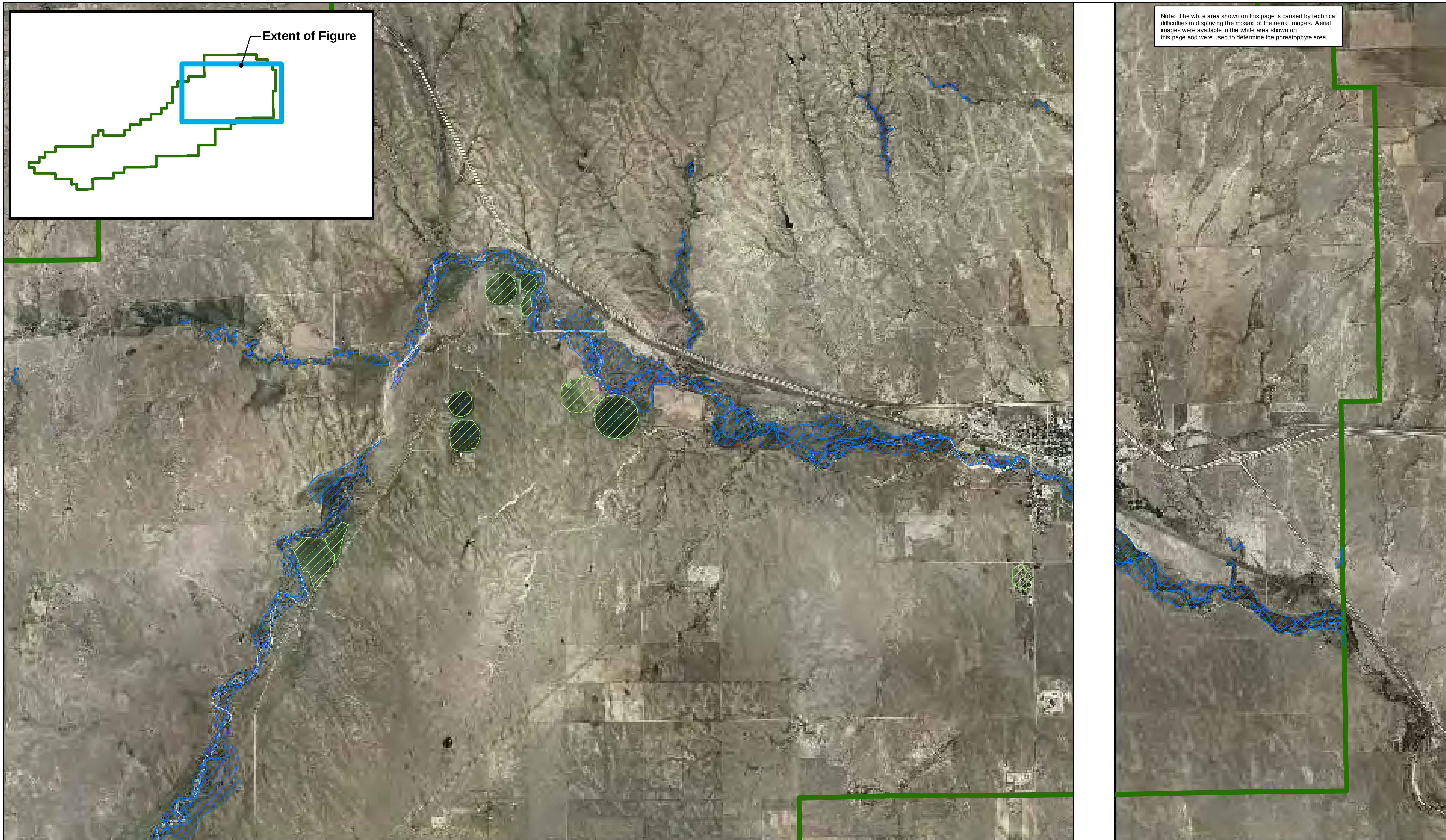
S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\Irrigated Area\Final Irrigated Area Maps\Plate2_IrrArea.mxd



Job No.:	694.3
Date:	4-10-2008
Drawn:	JPB
Checked:	CR

Upper Big Sandy
Phase 2 Water Balance

Legend
- Irrigated Area
- Phreatophyte Areas
- Upper Big Sandy Basin Boundary

N W E S

0 0.5 1 2 Miles

Eastern Irrigated Areas and Phreatophytes Map
Figure 17

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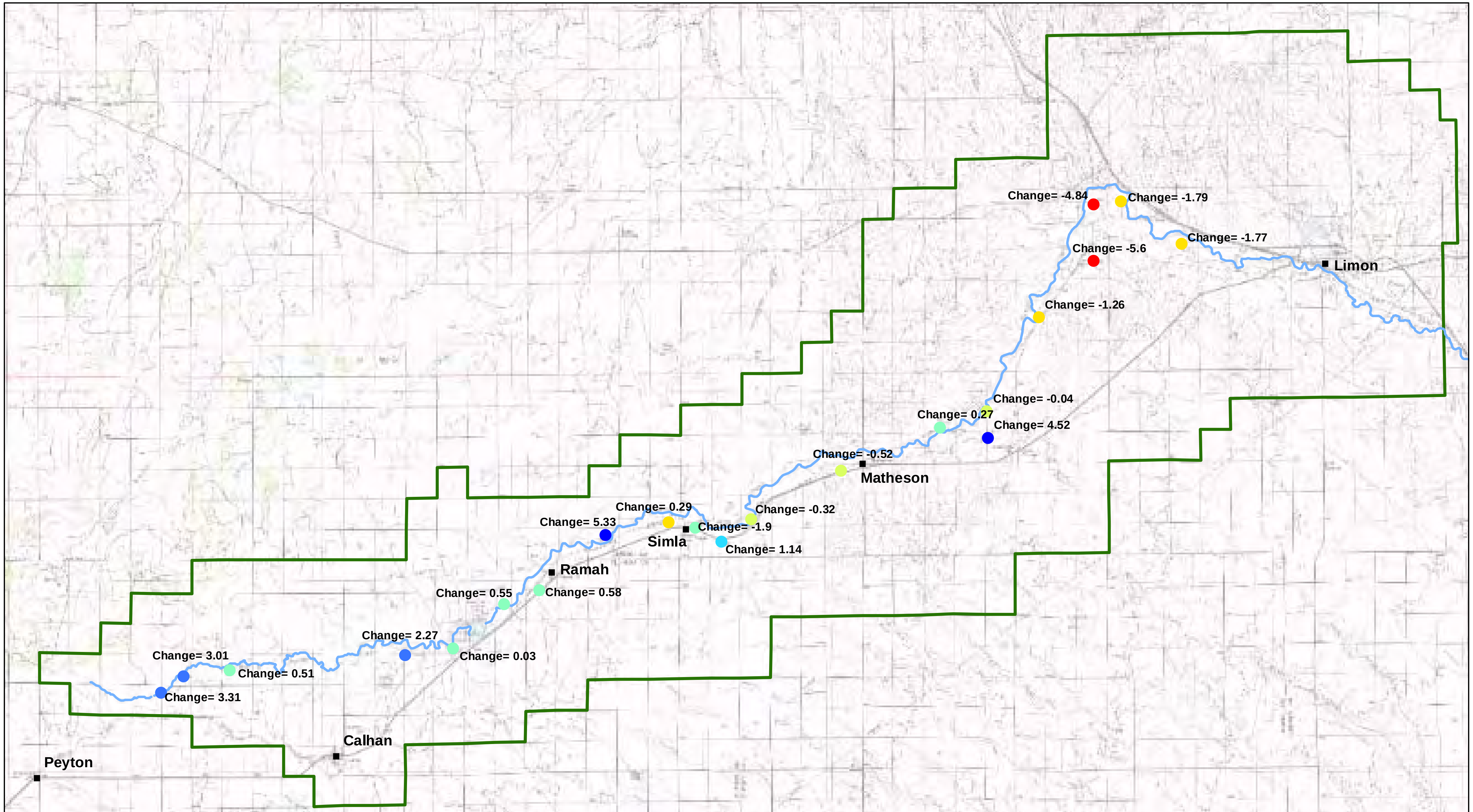
S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\Irrigated Area\Final Irrigated Area Maps\Plate1_IrrArea.mxd



Notes:
1. The change in water level for each well was determined using annual monitoring well water level data in 1991 and 2008 reported by the Division of Water Resources.
2. Each colored point represents a monitoring well location.
3. Data are displayed only when a water level measurement was collected during both 1991 and 2008.
4. The records for wells Big Sandy 13 and 13(R) were combined because Big Sandy 13(R) replaced Big Sandy 13 in March 1999.

Change in Water Level 1991 - 2008 (ft)

- < -4.00
- -3.99 - -2.00
- -1.99 - -1.00
- -0.99 - 0.00
- 0.01 - 1.00
- 1.01 - 2.00
- 2.01 - 4.00
- >4

Upper Big Sandy Basin Boundary

Big Sandy Creek

Cities

N W E S

Miles
0 1 2 4

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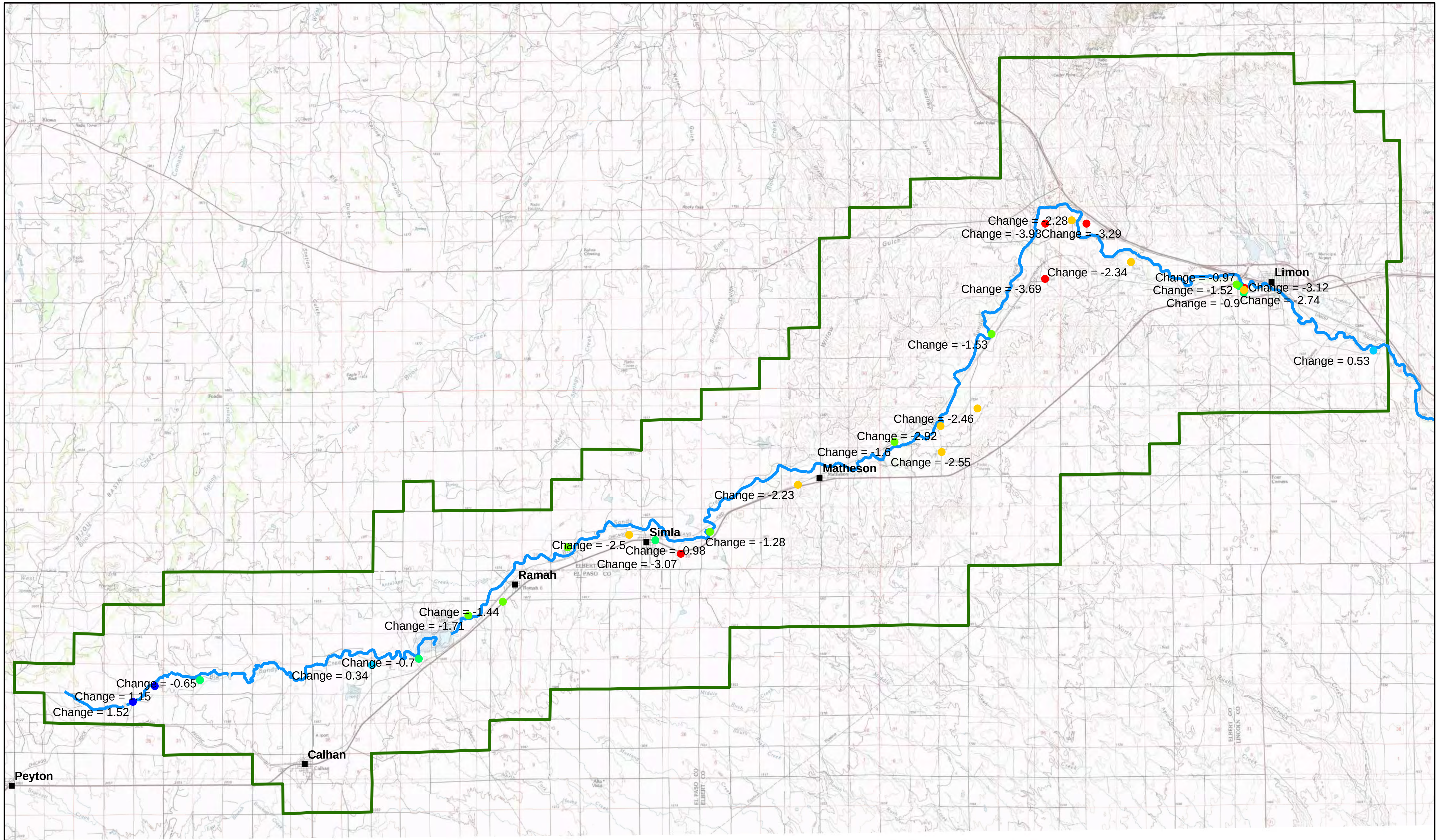
MARTIN AND WOOD WATER CONSULTANTS, INC.

Change in Alluvial Ground Water Levels 1991-2008
Figure 18

Upper Big Sandy Phase 2 Water Balance

Job No.: 694.4
Date: 4/1/2009
Drawn: JPB
Checked: CRR

S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\694.4 - Updated WL Change 1991-2008.mxd



Noes:

1. Change in water levels were determined using annual monitoring well water level data reported by the Division of Water Resources.
2. Data are displayed only when a water level measurement was collected during both years of the comparison.

Change in Water Level (feet)

+1.01 - +2.00	**-1.99 - -1.00**
+0.01 - +1.00	**-2.99 - -2.00**
-0.99 - 0.00	**-3.93 - -3.00**

Upper Big Sandy Basin Boundary

Big Sandy Creek

Cities

0 2 4 8 Miles

N S E W

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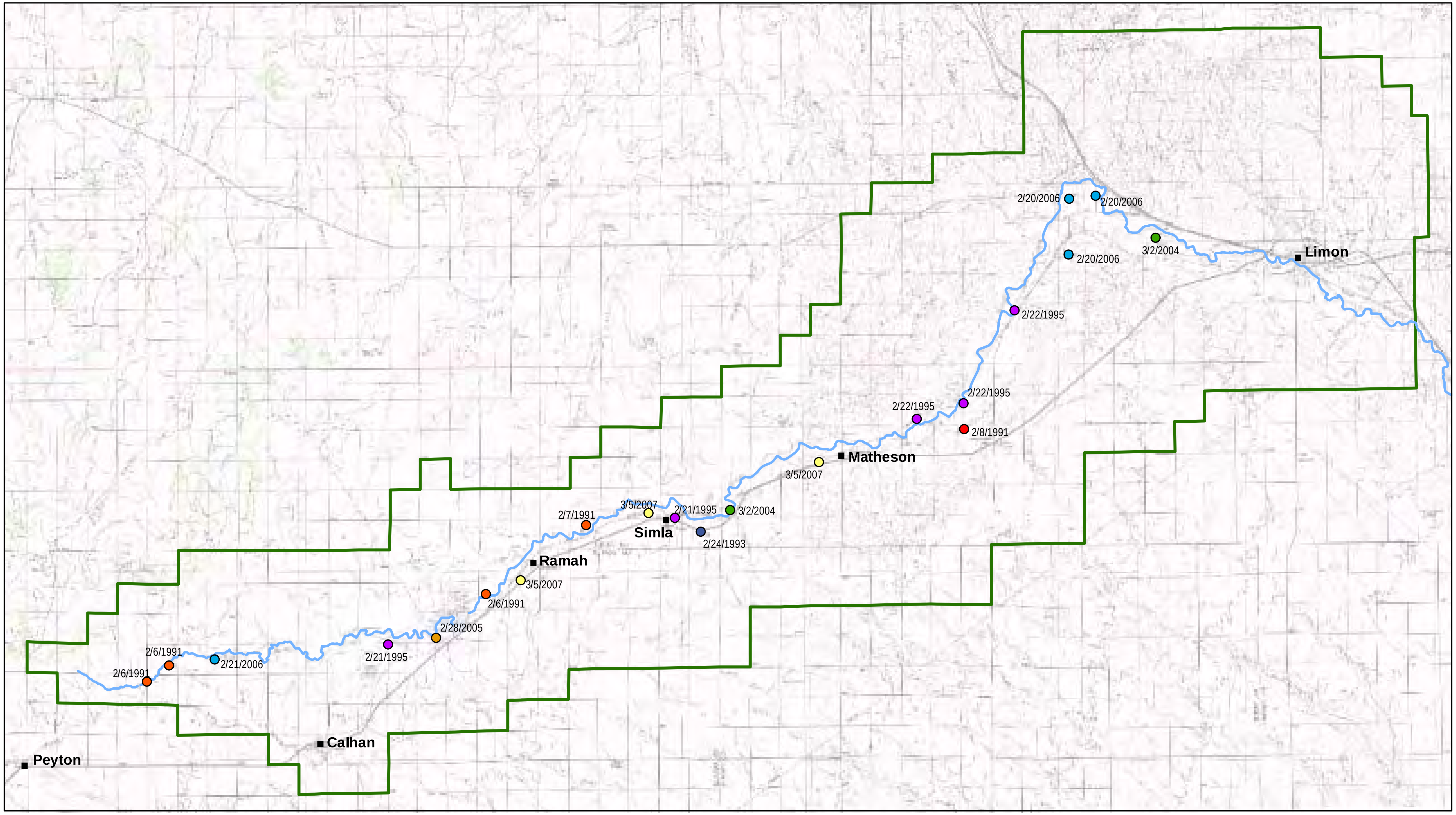
MARTIN AND WOOD WATER CONSULTANTS, INC.

Change in Alluvial Ground Water Levels 2001-2007
Figure 19

Upper Big Sandy Phase 2 Water Balance

Job No.: 694.4
Date: 4/29/09
Drawn: CRR
Checked: PLM

S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\WaterLevelChanges\694.4 - Change in WLs 2001-2007.mxd



Notes:
1. The date reported is the measurement date for the lowest water level recorded at each well that had annual data for the period 1991 through 2008.
2. The records for wells Big Sandy 13 and 13(R) were combined because Big Sandy 13(R) replaced Big Sandy 13 in March 1999.

Date of Lowest Water Level

- 2/6/1991
- 2/7/1991
- 2/8/1991
- 2/24/1993
- 2/21/1995
- 2/22/1995
- 3/2/2004
- 2/28/2005
- 2/20/2006
- 2/21/2006
- 3/5/2007

Upper Big Sandy Basin Boundary

Big Sandy Creek

Cities

N W E S

0 1 2 4 Miles

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Fax: (303) 526-2624
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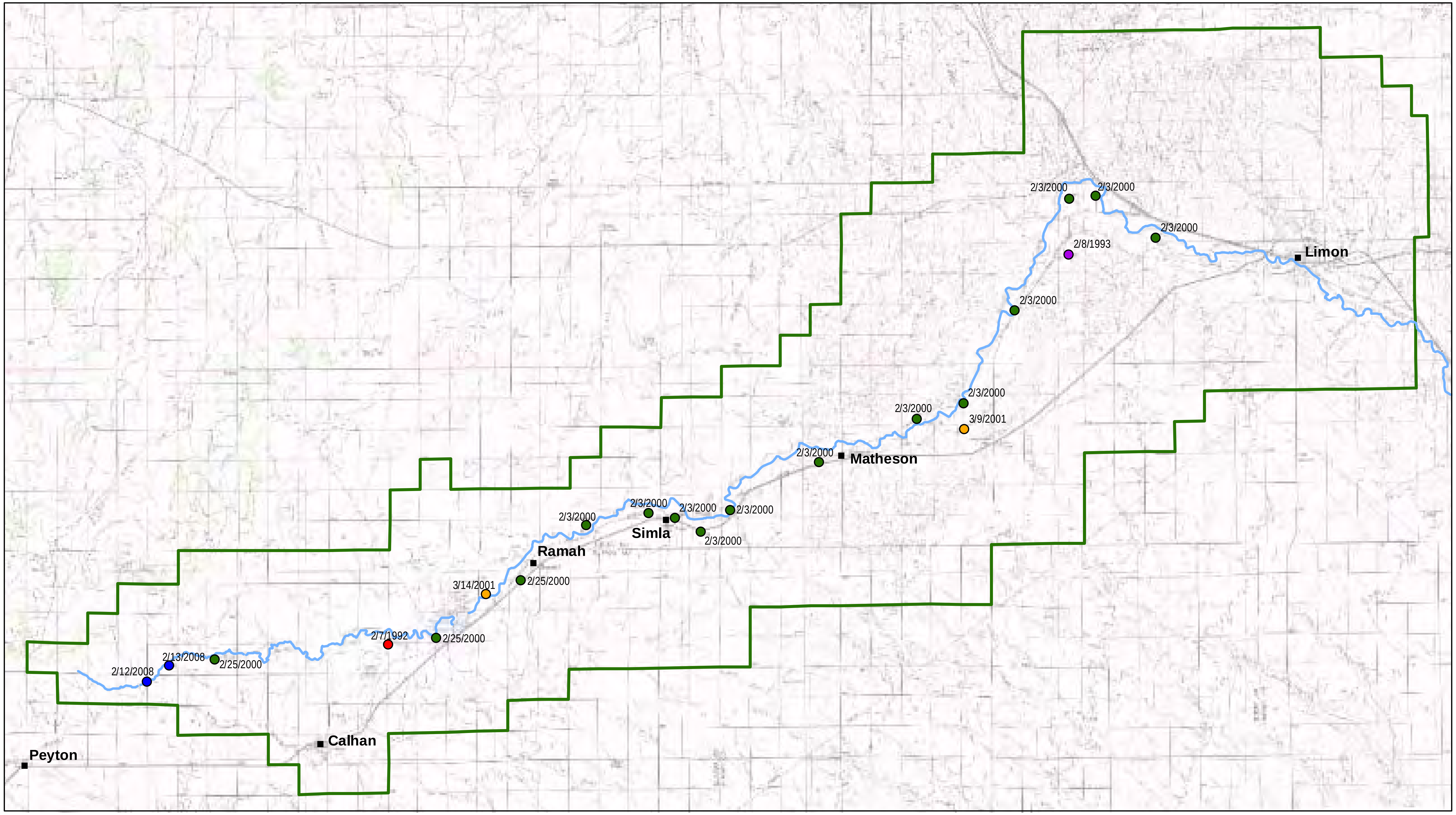
MARTIN AND WOOD WATER CONSULTANTS, INC.

Date of Lowest
Ground Water Level
1991 -2008
Figure 20

Upper Big Sandy
Phase 2
Water Balance

S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\WaterLevelChanges\694.4 - Min WL.mxd

Job No.:	694.4
Date:	4/1/2009
Drawn:	JPB
Checked:	CRR



Notes:
1. The date reported is the measurement date for the highest water level recorded at each well that had annual data for the period 1991 through 2008.
2. The records for wells Big Sandy 13 and 13(R) were ombined because Big Sandy 13(R) replaced Big Sandy 13 in March 1999.

Date of Highest Water Level

2/7/1992	3/14/2001
2/8/1993	3/9/2001
2/25/2000	2/12/2008
2/3/2000	2/13/2008

Upper Big Sandy Basin Boundary
Big Sandy Creek
Cities

N W E S

0 1 2 4 Miles

Upper Big Sandy
Phase 2
Water Balance

Date of Highest
Ground Water Level
1991 - 2008
Figure 21

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Job No.: 694.4
Date: 4/1/2009
Drawn: JPB
Checked: CRR

S:\694 - Upper Big Sandy Mgmt Dist\694.4 - Severance Tax\GIS\WaterLevelChanges\694.4 - MaxWL.mxd

TABLES

Table 1
Precipitation Data
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance Report

Year	Zone 1 (in/yr)	Zone 2 (in/yr)	Zone 3 (in/yr)	Area Weighted Average (in/yr)
1971-2000	18.23	16.62	15.72	16.71
2001	17.64	18.33	18.98	18.39
2002	9.44	9.92	9.27	9.57
2003	16.26	13.67	12.91	14.05
2004	16.92	14.68	13.64	14.87
2005	14.91	13.69	13.48	13.92
2006	19.41	17.35	16.29	17.49
2007	17.05	16.31	15.05	16.05
1971-2007 Average	17.80	16.29	15.44	16.37

Data presented in table based on ASCII gridded precipitation data downloaded from PRISM (www.prism.orgeonstate.edu) and processed in GIS.

Location of precipitation zones within the Basin.

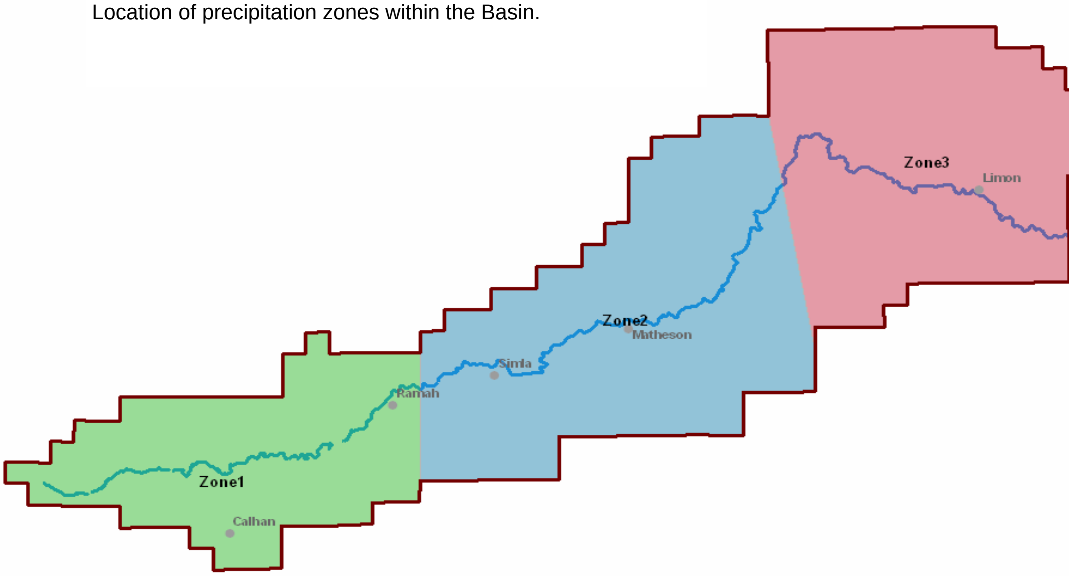


Table 2
Average Monthly Precipitation
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance Report

Month	**Average Precipitation within Basin** (1971-2007) (inches)	**Percent of Total Precipitation** (percent)
Jan	0.34	2.1
Feb	0.33	2.0
Mar	0.69	4.2
Apr	1.15	7.0
May	2.31	14.1
Jun	2.14	13.1
Jul	2.78	17.0
Aug	2.93	17.9
Sep	1.64	10.0
Oct	1.01	6.2
Nov	0.72	4.4
Dec	0.33	2.0
Total	16.37	100.0

Table 3
Natural Recharge and Irrigation Calculations
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance Report

ESTIMATED ANNUAL NATURAL RECHARGE	
Average Annual Precipitation (in)	16.37
Average Annual Recharge as Percent of Precipitation	4.0%
Average Precipitation Recharge (in)	0.65
Area of Basin (acres)	282,000
Average Recharge from Precipitation (acre-feet)	15,400
Dry Year Recharge (3.0% of average precipitation) (acre-feet)	11,500
Wet Year Recharge (6.5% of average precipitation) (acre-feet)	25,000

ESTIMATED ANNUAL AVERAGE IRRIGATION	
Total Irrigated Area overlying Alluvium (acres)	1,800
Irrigation Pumping (acre-feet per irrigated acres)	2.50
Estimated Total Irrigation Pumping from Alluvial Aquifer (acre-feet)	4,500
Irrigation Return Flow Percent of Pumping (%)	15%
Irrigation Return Flows (acre-feet)	680

Table 4
Average Year Water Balance
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance Report

AVERAGE YEAR WATER BALANCE	
Inflows	
Precipitation Recharge (acre-feet)	15,400
Irrigation Return Flows (from all irrigation) (acre-feet)	680
Municipal Wastewater Return Flow (acre-feet)	597
Total Inflow	**16,677**
Outflows	
Irrigation Pumping from Alluvial Aquifer (acre-feet)	4,500
Phreatophyte Consumptive Use (acre-feet)	10,780
Municipal Pumping from Alluvial Aquifer (acre-feet)	1,017
Underflow Leaving the Basin (acre-feet)	2,300
Stock Watering (acre-feet)	170
Total Outflow	**18,767**
Annual Change in Storage (Balance)	**-2,090**

All values based on estimates developed for the water balance analysis.

Table 5
Dry Year and Wet Year Water Balances
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance Report

DRY YEAR WATER BALANCE	
Inflows	
Precipitation Recharge (acre-feet)	11,500
Irrigation Return Flows (from all irrigation) (acre-feet)	680
Municipal Wastewater Return Flow (acre-feet)	597
Total Inflow	**12,777**
Outflows	
Irrigation Pumping from Alluvial Aquifer (acre-feet)	4,500
Phreatophyte Consumptive Use (acre-feet)	10,780
Municipal Pumping from Alluvial Aquifer (acre-feet)	1,017
Underflow (acre-feet)	2,300
Stock Watering (acre-feet)	170
Total Outflow	**18,767**
Annual Change in Storage (Balance)	**-5,990**

WET YEAR WATER BALANCE	
Inflows	
Precipitation Recharge (acre-feet)	25,000
Irrigation Return Flows (from all irrigation) (acre-feet)	680
Municipal Wastewater Return Flow (acre-feet)	597
Total Inflow	**26,277**
Outflows	
Irrigation Pumping from Alluvial Aquifer (acre-feet)	4,500
Phreatophyte Consumptive Use (acre-feet)	10,780
Municipal Pumping from Alluvial Aquifer (acre-feet)	1,017
Underflow (acre-feet)	2,300
Stock Watering (acre-feet)	170
Total Outflow	**18,767**
Annual Change in Storage (Balance)	**7,510**

All values based on estimates developed for the water balance analysis.

Table 6
Stock Count and Stock Watering Calculations
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance

County	(1) Total Cattle by County (number of head)	(2) Percent of County Inside Upper Big Sandy Basin --	(3) Stock Count Estimate (including cattle and horses) (number of head)
Elbert	42,000	14.4%	14,000
El Paso	26,000	5.5%	900
Lincoln	42,000	2.2%	500 PT
Total (year-round equivalents)	110,000	--	15,150
Estimated Stock Watering (ac-ft/yr)	**--**	**--**	**170**

Notes

PT = part-time, stock only spend a portion of the year within the Basin

Estimated stock watering calculated for one year. Based on 10 gallons/head/day, 365 days per year. All stock assumed to be in the Basin year-round unless specified as seasonal or part-time. Part-time calculations assume that 50 percent of the year the stock are in the Basin.

(1) Based on USDA and NASS May 19, 2008 News Release.

(2) Determined in GIS based on Deparment of Local Affairs county data and Division of Water Resources Upper Big Sandy Basin boundary.

(3) Estimate based on personal communication with Joe Frasier and Morris Vervors (April 10-11 and 13, 2008), and the USDA county stock counts.

Table 7

Estimated Saturated Alluvial Volume

Upper Big Sandy Designated Ground Water Basin

Phase 2 Water Balance

Location	**Interpolated Alluvial Area** (acres)	**Estimated Average Saturated Thickness** (feet)	**Esitmated Specific Yield** (%)	**Estimated Saturated Alluvial Volume** (acre-feet)
Upper Big Sandy Creek Mainstem	19,000	28	30 to 35	159,600 to 186,200
Lower Big Sandy Creek Mainstem	22,000	38	20 to 25	167,000 to 209,000
Tributaries	17,000	15	23	58,650
Total	**58,000**			**385,000 to 454,000**

Table 8
Trendline Data and Water Level Changes
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance

Well Name	Calculated Actual Water Level Change **1991-2008** (feet)	Trendline Predicted Water Level Change (feet)	Correlation Coefficient (R^2)
BIG SANDY - 13/13(R)	-5.60	-6.23	0.80
BIG SANDY - 30A	3.31	3.16	0.78
BIG SANDY - 19	3.01	2.16	0.65
BIG SANDY - 2	-4.84	-4.59	0.39
BIG SANDY - 37	4.52	3.68	0.33
BIG SANDY - 4	-1.77	-3.63	0.31
BIG SANDY - 1	-1.79	-1.87	0.26
BIG SANDY - 27	-1.90	-1.53	0.17
BIG SANDY - 21	0.55	0.59	0.12
BIG SANDY - 30	1.14	3.04	0.11
BIG SANDY - 38	-0.04	1.35	0.10
BIG SANDY - 14	-1.26	-0.74	0.04
BIG SANDY - 31	-0.32	-0.60	0.03
BIG SANDY - 26	5.33	1.01	0.03
BIG SANDY - 36	0.27	0.34	0.01
BIG SANDY - 22	0.58	-0.24	0.01
BIG SANDY - 33	-0.52	-0.27	0.01
BIG SANDY - 16A	0.29	0.18	0.00
BIG SANDY - 15A	2.27	0.28	0.00
BIG SANDY - 29	0.03	-0.07	0.00
BIG SANDY - 18	0.51	0.06	0.00
BIG SANDY-40		Not enough data	
BIG SANDY-17A		Not enough data	

Table 9
Water Balance Based on Permitted Pumping
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance Report

PERMITTED PUMPING WATER BALANCE	
Inflows	
Precipitation Recharge (acre-feet)	15,400
Irrigation Return Flows (from all irrigation) (acre-feet)	1,650
Municipal Wastewater Return Flow (acre-feet)	0
Total Inflow	**17,050**
Outflows	
Irrigation Pumping from Alluvial Aquifer (acre-feet)	11,000
Phreatophyte Consumptive Use (acre-feet)	10,780
Municipal Pumping from Alluvial Aquifer (acre-feet)	2,860
Underflow Leaving the Basin (acre-feet)	2,300
Stock Watering (acre-feet)	170
Total Outflow	**27,110**
Annual Change in Storage (Balance)	**-10,060**

All values based on estimates developed for the water balance analysis.

Table 10
Water Balance-Predicted Water Level Changes
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance Report

AVERAGE YEAR			
Estimated Average Year Annual Change in Storage	-2,090	-2,090	acre-feet
Estimated Volume of Water in Storage	385,000	454,000	acre-feet
Percent of Estimated Total Volume	-0.54%	-0.46%	unitless
Estimated Saturated Alluvial Extent	58,000	58,000	acres
Estimated Specific Yield	0.28	0.24	unitless
Predicted Annual Change in Ground Water Level	-0.13	-0.15	feet
Predicted Annual Change in Ground Water Level	**-1.5**	**-1.8**	**inches**

DRY YEAR			
Estimated Dry Year Change in Storage	-5,990	-5,990	acre-feet
Estimated Volume of Water in Storage	385,000	454,000	acre-feet
Percent of Estimated Total Volume	-1.56%	-1.32%	unitless
Estimated Saturated Alluvial Extent	58,000	58,000	acres
Estimated Specific Yield	0.28	0.24	unitless
Predicted Annual Change in Ground Water Level	-0.37	-0.43	feet
Predicted Annual Change in Ground Water Level	**-4.4**	**-5.2**	**inches**

WET YEAR			
Estimated Wet Year Change in Storage	7,510	7,510	acre-feet
Estimated Volume of Water in Storage	385,000	454,000	acre-feet
Percent of Estimated Total Volume	1.95%	1.65%	unitless
Estimated Saturated Alluvial Extent	58,000	58,000	acres
Estimated Specific Yield	0.28	0.24	unitless
Predicted Annual Change in Ground Water Level	0.46	0.54	feet
Predicted Annual Change in Ground Water Level	**5.5**	**6.5**	**inches**

PERMITTED PUMPING			
Estimated Change in Storage	-10,060	-10,060	acre-feet
Estimated Volume of Water in Storage	385,000	454,000	acre-feet
Percent of Estimated Total Volume	-2.61%	-2.22%	unitless
Estimated Saturated Alluvial Extent	58,000	58,000	acres
Estimated Specific Yield	0.28	0.24	unitless
Predicted Annual Change in Ground Water Level	-0.62	-0.72	feet
Predicted Annual Change in Ground Water Level	**-7.4**	**-8.7**	**inches**

Table 11
Water Balance Parameter Sensitivity Analysis
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance Report

Parameter	Phase 2 Water Balance Value	Alternate Sensitivity Value	Percent Change in Input Parameter (%)	Revised Water Balance Result (af)	Change in Water Balance (af)	Percent Change in Water Balance (%)	Ratio of Percent Water Balance Change to Percent Input Change
Precipitation Recharge (%)	4.0%	4.5%	-12.5	-190	1900	-91	7.27
Precipitation Recharge (%)	4.0%	3.5%	12.5	-3990	-1900	91	7.27
Irrigated Area (acres)	1,800	1,700	5.6	-1880	210	-10	-1.81
Irrigated Area (acres)	1,800	1,900	-5.6	-2310	-220	11	-1.89
Irrigation Application Rate (af/a)	2.5	2.25	10.0	-1710	380	-18	-1.82
Irrigation Application Rate (af/a)	2.5	2.0	20.0	-1330	760	-36	-1.82
Irrigation Return Flow (%)	0.15	0.2	-33.3	-2330	-240	11	-0.34
Irrigation Return Flow (%)	0.15	0.1	33.3	-1870	220	-11	-0.32
Phreatophyte Area (acres)	5390	5000	7.2	-1310	780	-37	-5.16
Phreatophyte Area (acres)	5390	5800	-7.6	-2910	-820	39	-5.16
Phreatophyte CU factor (af/acre)	2.0	1.8	10.0	-1012	1078	-52	-5.16
Phreatophyte CU factor (af/acre)	2.0	2.2	-10.0	-3168	-1078	52	-5.16
Hydraulic Conductivity (gpd/ft^2)	1586	1700	-7.2	-2290	-200	10	-1.33
Hydraulic Conductivity (gpd/ft^2)	1586	1475	7.0	-1890	200	-10	-1.37

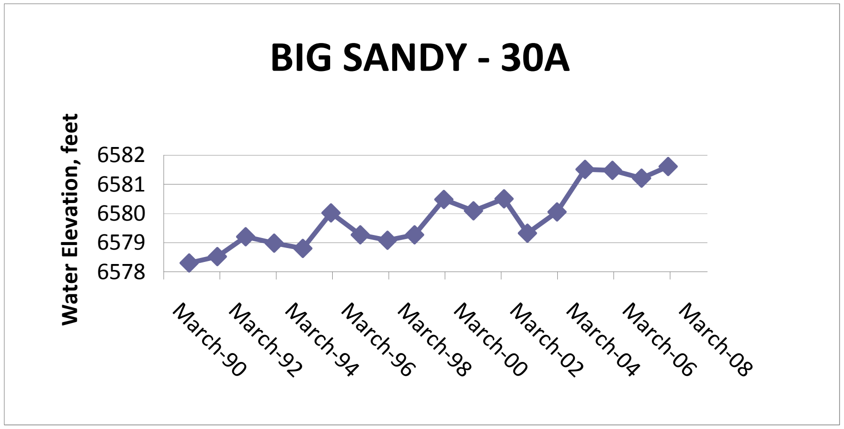
CU = Consumptive Use

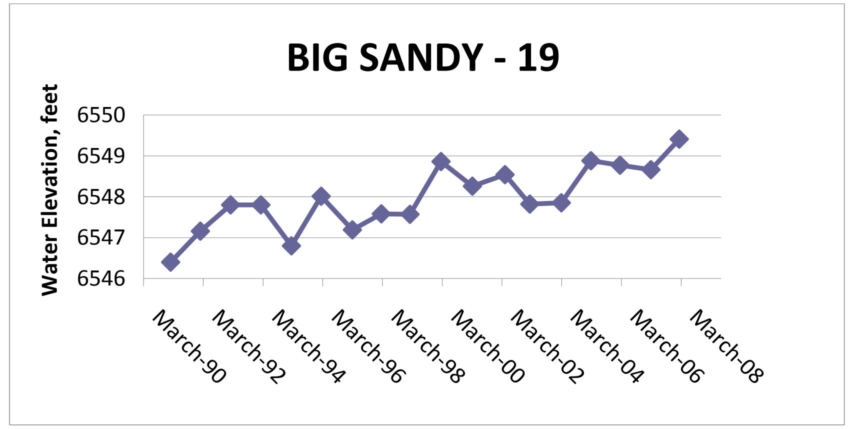
APPENDIX A

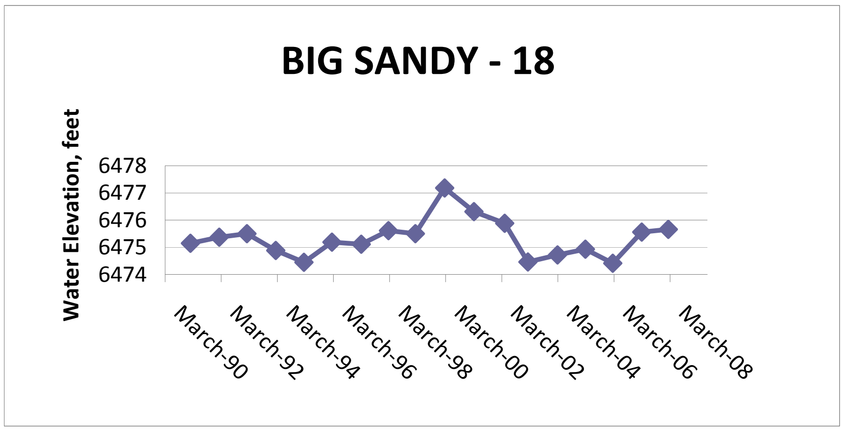
DIVISION OF WATER RESOURCES

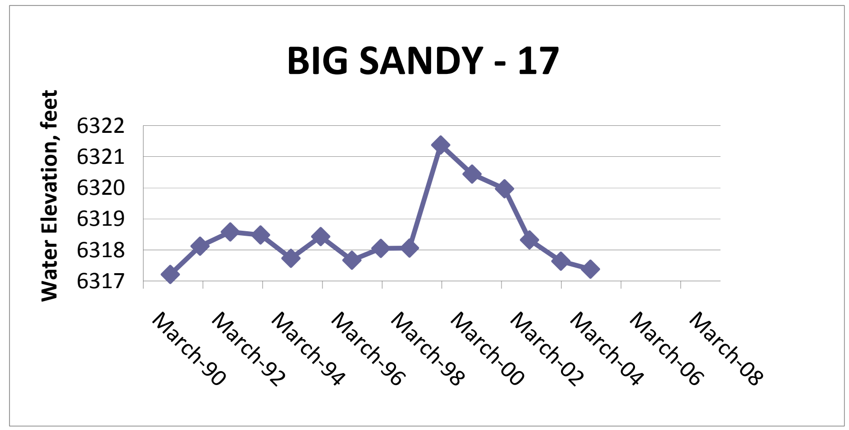
MONITORING WELL WATER LEVELS

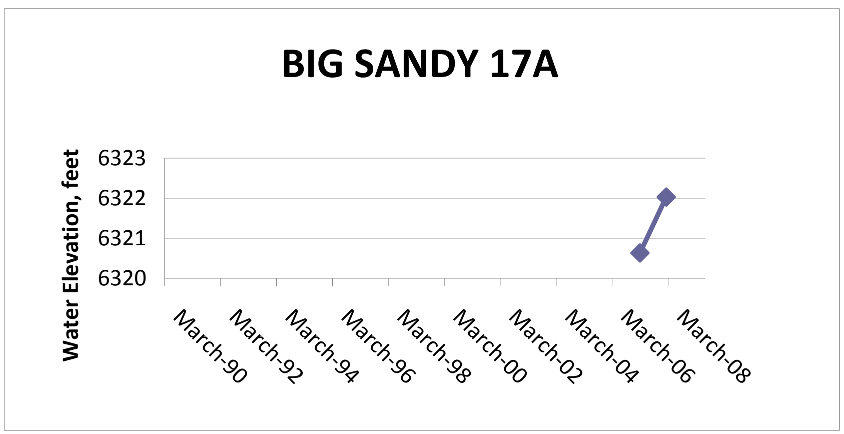
Appendix A
Division of Water Resources Monitoring Well Water Levels

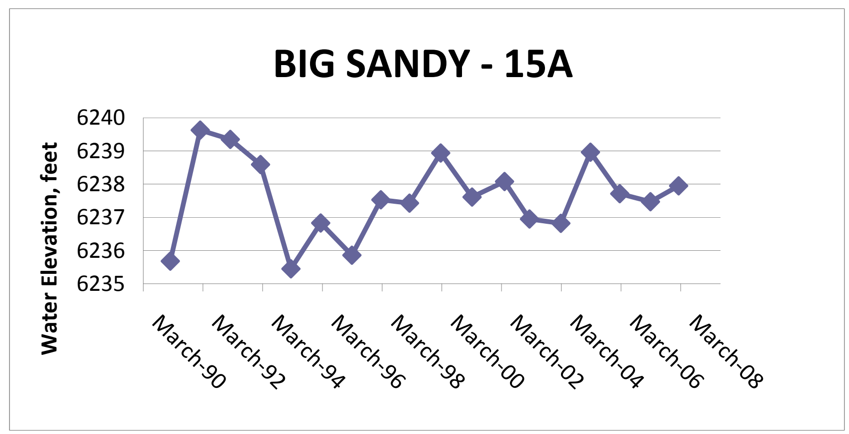




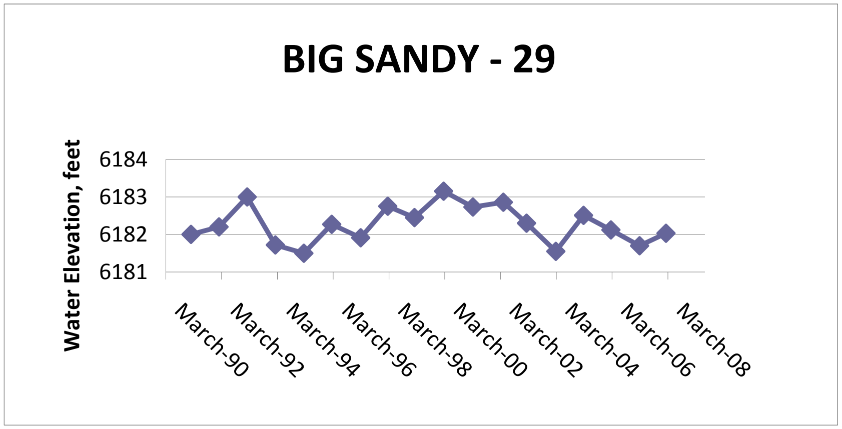


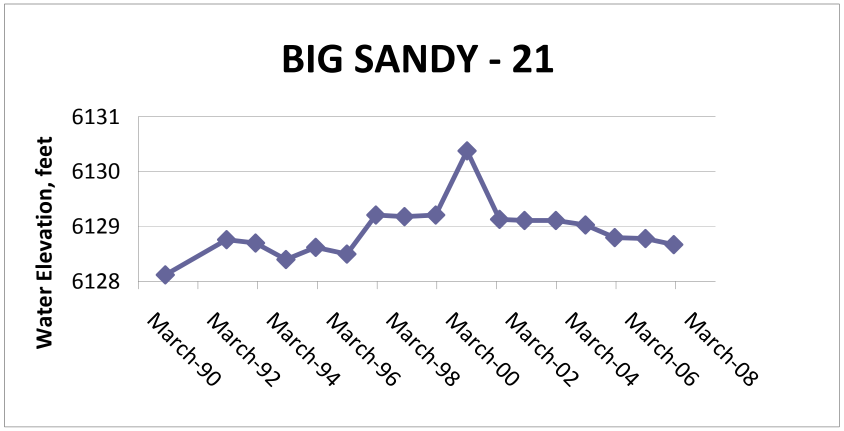


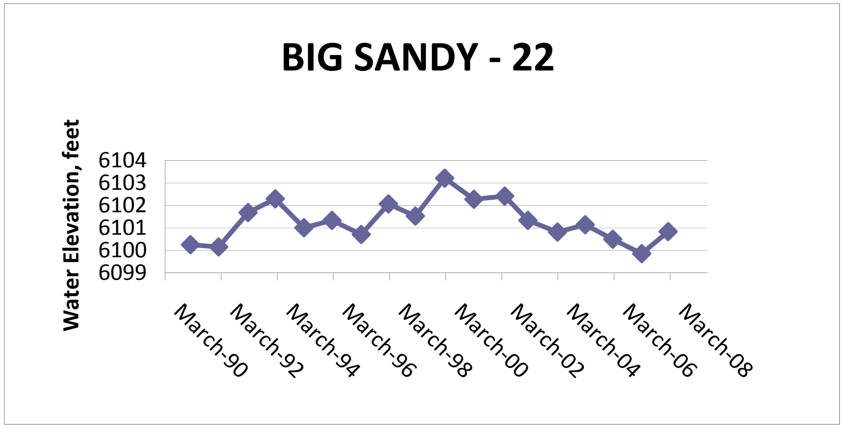


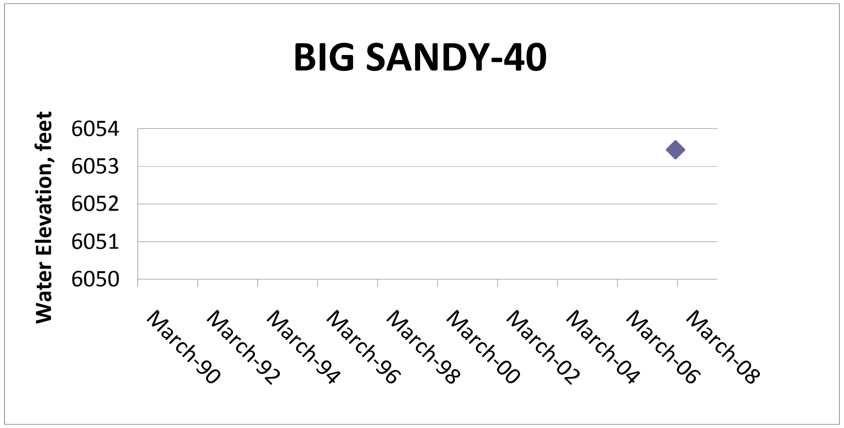


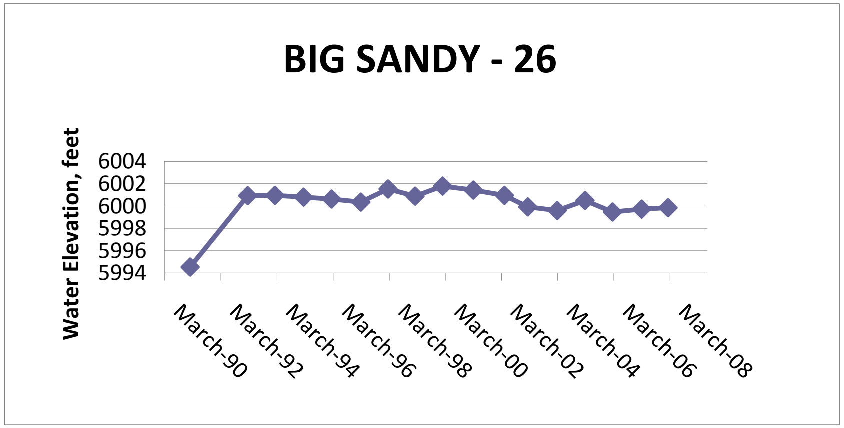
Appendix A
Division of Water Resources Monitoring Well Water Levels

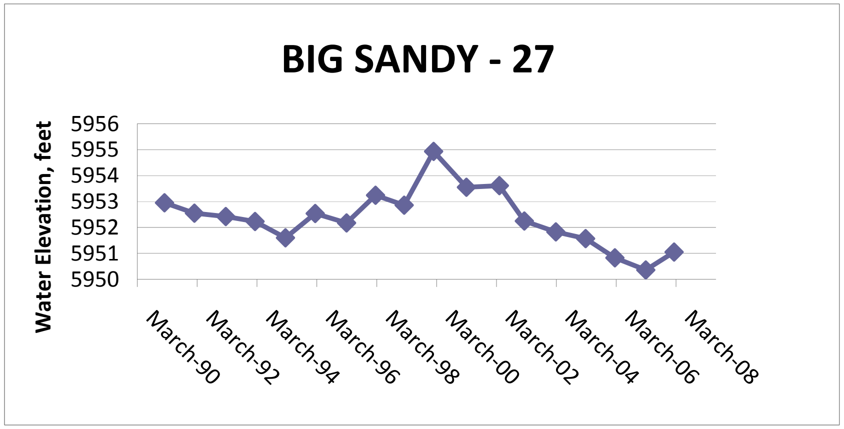




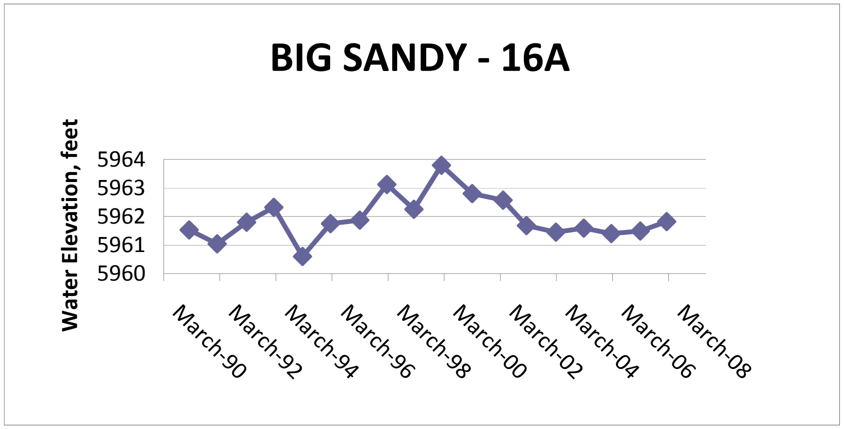


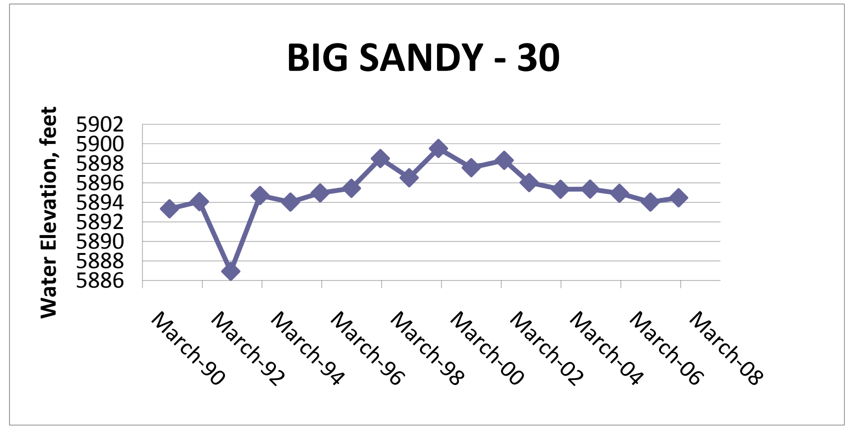


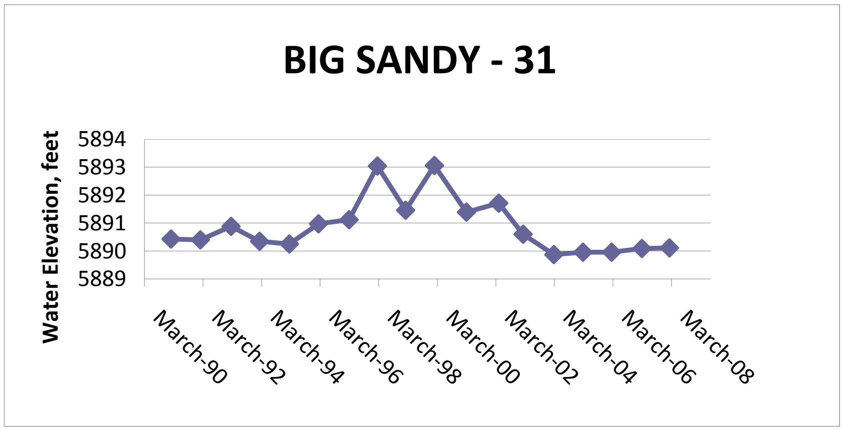


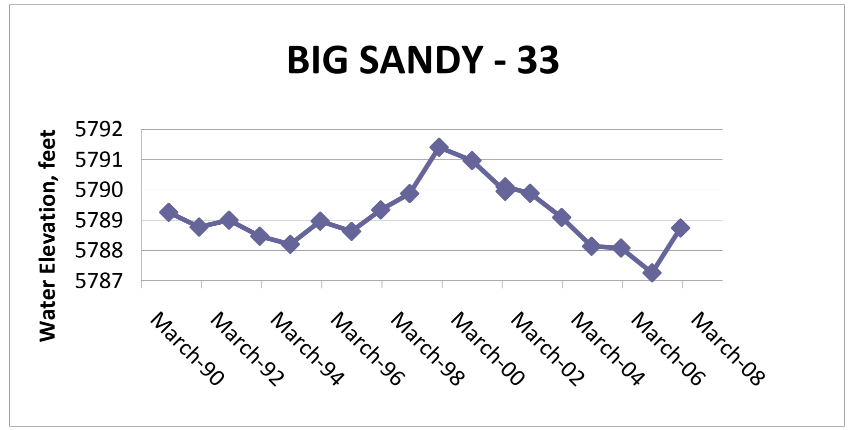


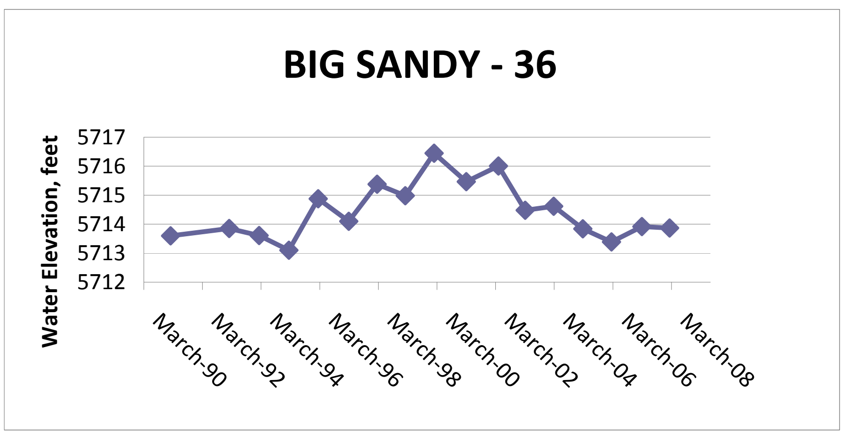
Appendix A
Division of Water Resources Monitoring Well Water Levels

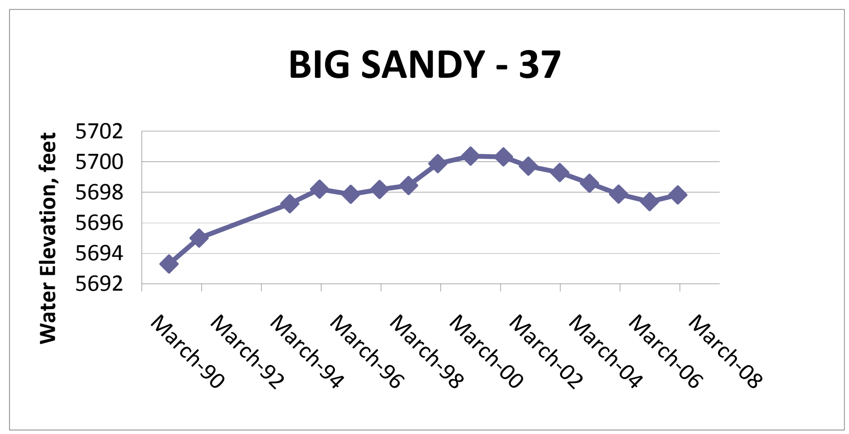












Appendix A
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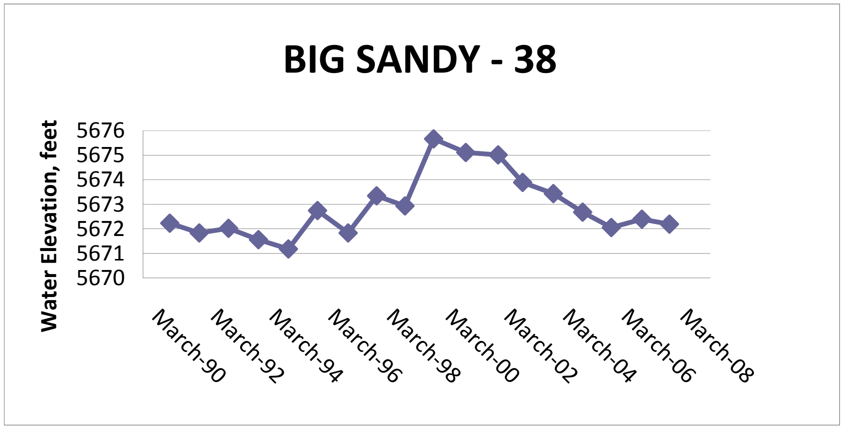
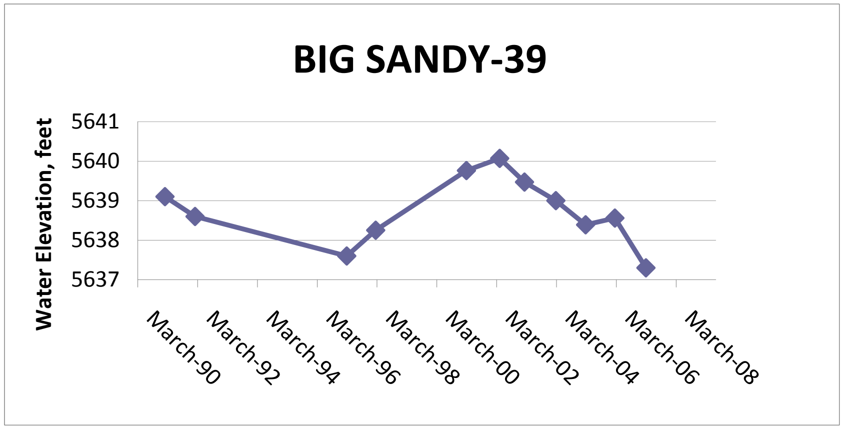
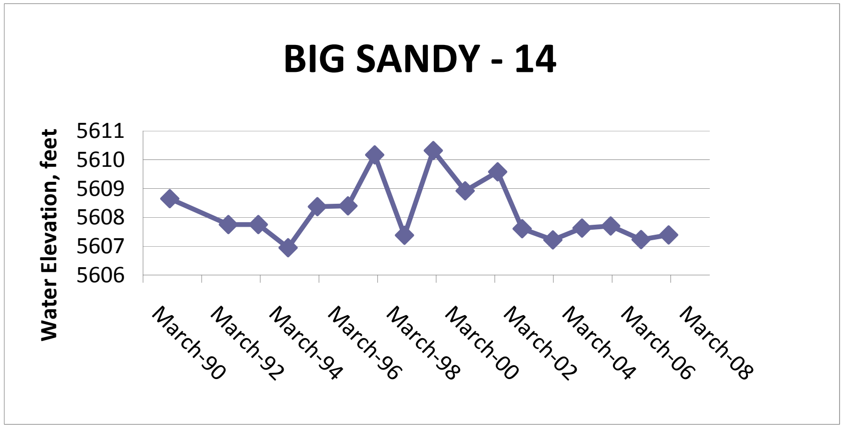
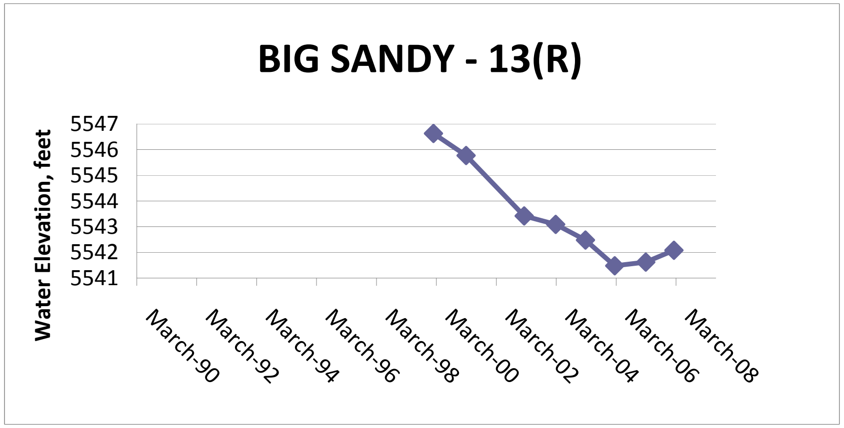
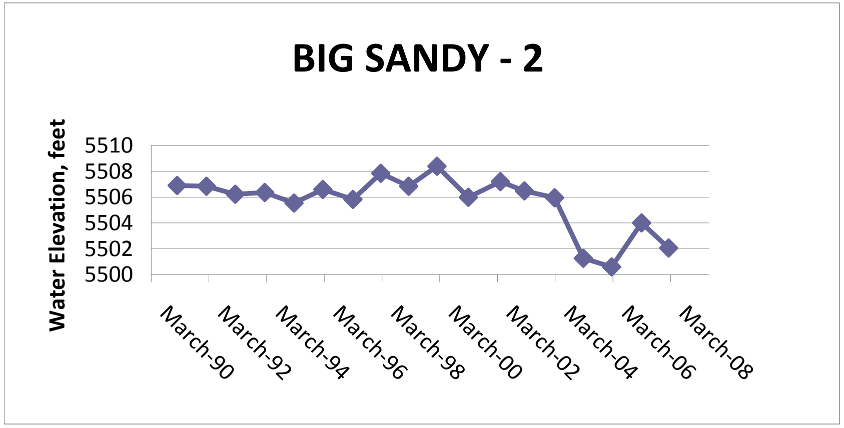
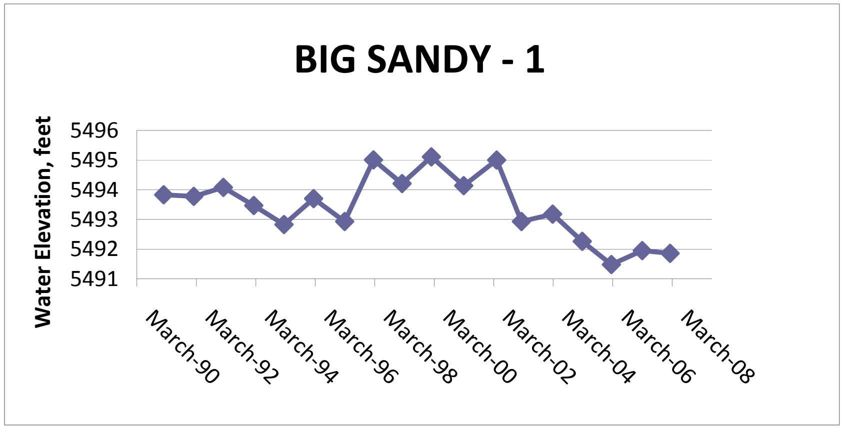




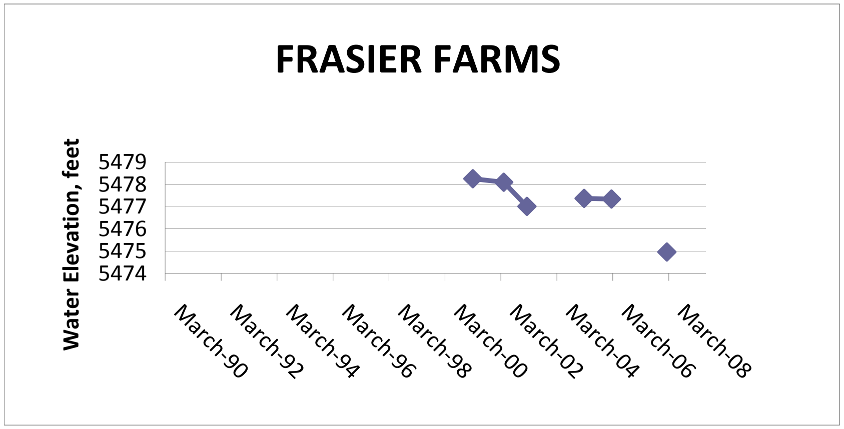


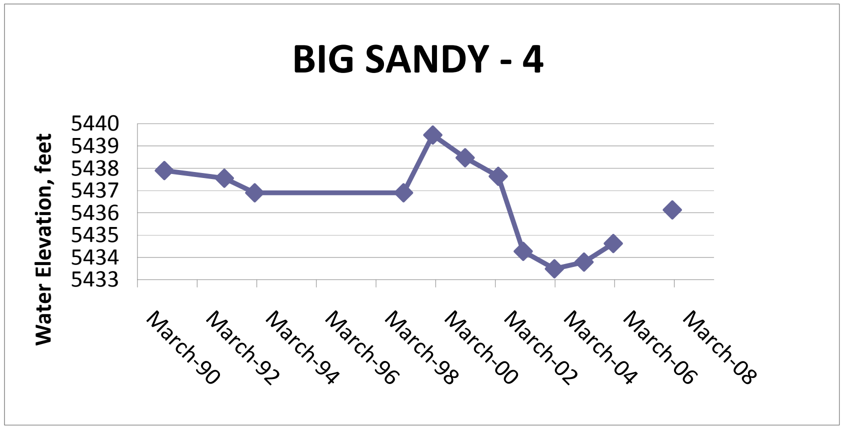


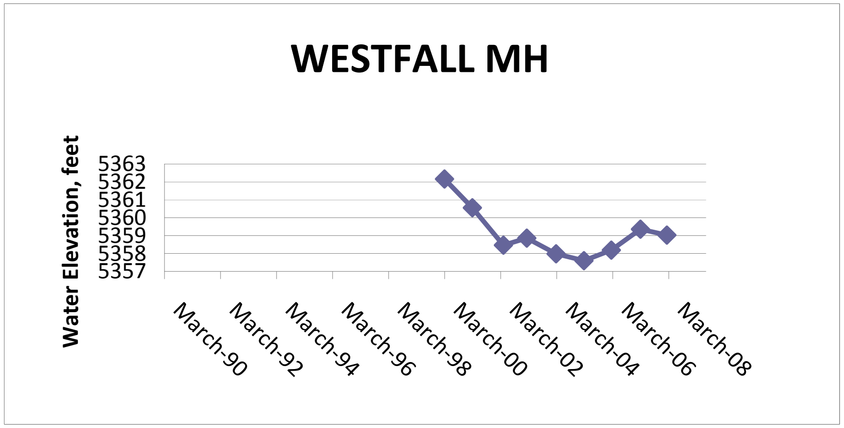


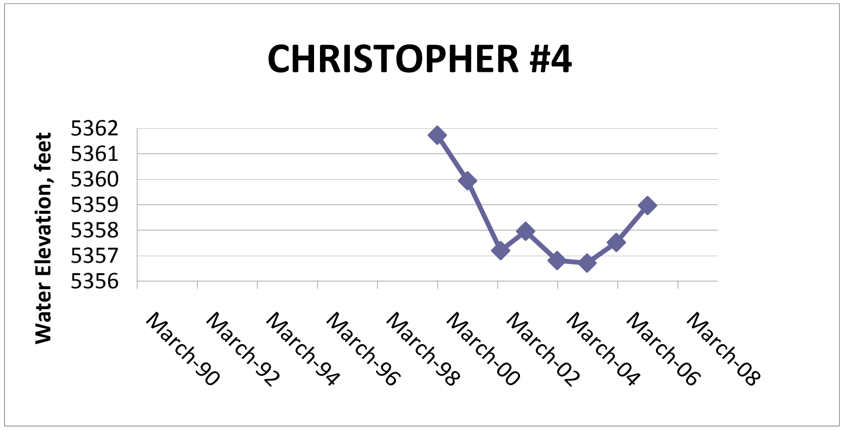


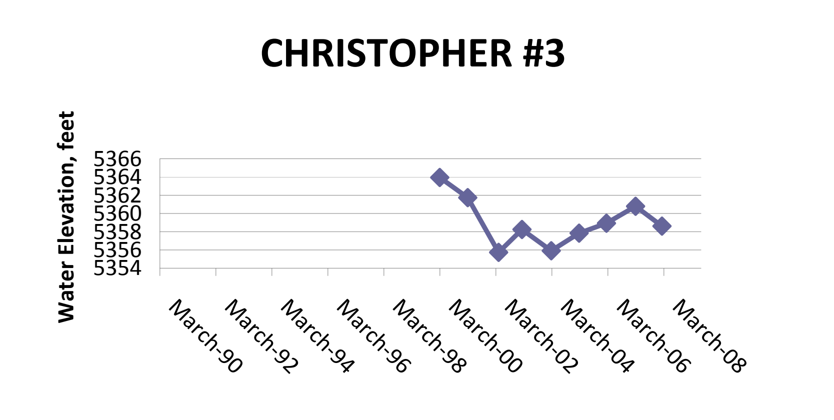
Appendix A
Division of Water Resources Monitoring Well Water Levels

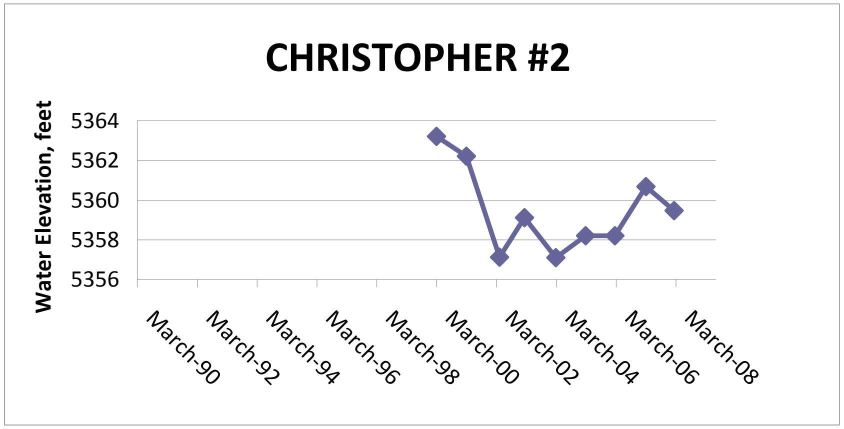


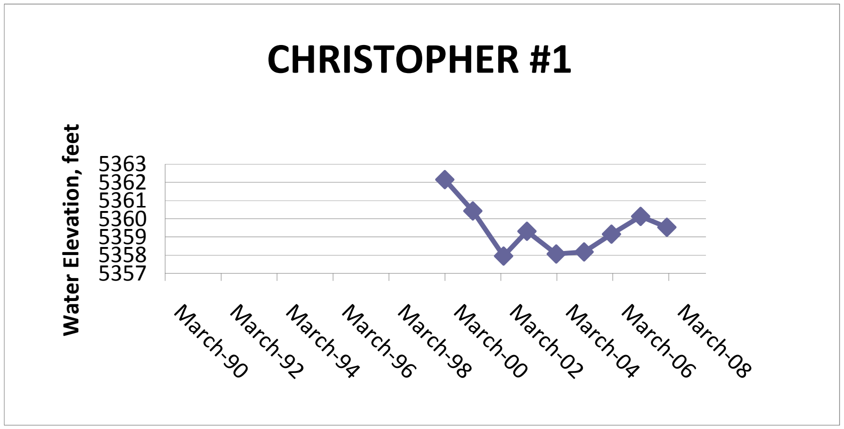








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Water Elevation, feet
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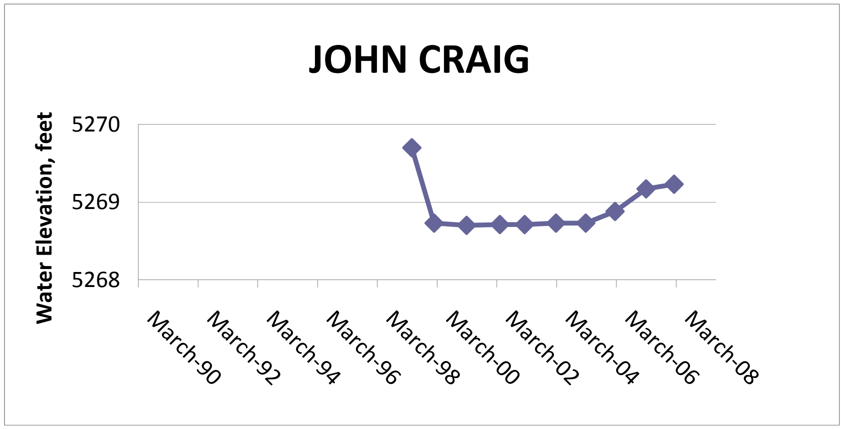
5362
5361
5360
5359
5358
5357
March-90
March-92
March-94
March-96
March-98
March-00
March-02
March-04
March-06
March-08


JOHN CRAIG
Water Elevation, feet
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5269
5268
March-90
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March-94
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March-08

APPENDIX B

FIELD WORK PHOTOGRAPHS

Appendix B
Field Work Photographs


Geoprobe rig with soil sample table


GP3 Location


Test hole soil samples


Piezometer with flush mount cover

Appendix B
Field Work Photographs

Looking across Big Sandy Creek Floodplain near Limon

Terrace south of Big Sandy Creek near Limon

Terrace near GP4

Terrace near GP15

Appendix B
Field Work Photographs

Uplands between Matheson and Limon

Uplands between Matheson and Limon

GP19 Location

Looking north from GP19 location

Appendix B
Field Work Photographs

Standing water after storm event in drainage channel

GP18 Location

Looking at spring from GP20 location

Spring near GP20

Appendix B
Field Work Photographs

Spring near GP20

Flow from spring near GP20

Pool of standing water off-channel after storm event near River Bend

View of Cottonwoods along Big Sandy Creek near River Bend

Appendix B
Field Work Photographs

View of Big Sandy Creek south of River Bend

Stock pond near Matheson

Stock pond discharge pipe and small phreatophytes near Matheson

Big Sandy Creek with Cottonwoods and small phreatophytes beyond grassland between Matheson and Simla

Appendix B
Field Work Photographs

Small pond along Big Sandy Creek near Simla

Looking towards Big Sandy Creek from last picture

Pond reeds

Big Sandy Creek east of Ramah

Appendix B
Field Work Photographs

Phreatophytes in Big Sandy Creek near Ramah

Phreatophytes in Big Sandy Creek near Ramah

Looking west at Ramah State Wildlife Area Dam

Looking west at Ramah State Wildlife Area wetlands

Appendix B
Field Work Photographs

Stock pond west of Ramah State Wildlife Area

Wetlands in Big Sandy Creek near Calhan

Wetlands in Big Sandy Creek near Calhan

View towards head of Basin near Calhan

Appendix B
Field Work Photographs

View of on-channel pond near Calhan

Wetlands above on-channel pond from previous picture

Wetlands above on-channel pond from previous two pictures

Ponded water in Big Sandy Creek at Fairplay Road

Ponded water in Big Sandy Creek at Fairplay Road

Headwaters of Big Sandy Creek near Rattlesnake Butte

Big Sandy Creek east of Simla near GP28

Big Sandy Creek with alluvial channel terrace near GP28

Appendix B
Field Work Photographs

Tributary channel east of Simla near GP29

Flood control dam on tributary east of Simla near GP33

Tributary channel in upper portion of tributary near GP34

Big Sandy Creek channel east of Simla near GP29

Appendix B
Field Work Photographs

Ponded water in upper portion of Antelope Creek near GP44

View to south across upper portion of Antelope Creek near GP46

Big Sandy Creek west of Ramah near GP38

Phreatophytes on Big Sandy Creek west of Ramah

Appendix B
Field Work Photographs

View west across Big Sandy Creek valley from Matheson Hill

Tributary north of Calhan from near GP49

View from bedrock exposure across tributary at GP51

Big Sandy Creek near GP52, north of Calhan

Appendix B
Field Work Photographs

View across Big Sandy Creek from near GP55

Tributary near GP61 location

Big Sandy Creek near GP62 location

Geoprobe Rig at GP28 location east of Simla

APPENDIX C

TEST HOLE LOGS

Appendix C
Drilling Summary

Upper Big Sandy Designated Ground Water Basin

Phase 2 Water Balance

				Water Level (feet below ground surface)							
Borehole ID	Elevation	Depth to Bedrock (feet)	Total Depth (feet)	8/5/2008	8/6/2008	8/13/2008	2/16/2009	2/17/2009	2/18/2009	2/19/2009	2/20/2009
GP1	5301	15	17.5	7.18	--	--	--	--	--	--	--
GP2	5310	39	41	16.3	15.42	--	15.11	--	--	--	--
GP3	5315	26	29	14.34	18.7	--	18.61	--	--	--	--
GP4	5338	72	74	33.25	--	--	--	--	--	--	--
GP5	5308	33	33	--	8	--	--	--	--	--	--
GP6	5377	30	33.2	--	Dry	--	--	--	--	--	--
GP7	5345	66	66	--	29.15	--	--	--	--	--	--
GP8	5403	38	38	--	4.25	--	--	--	--	--	--
GP9	5419	60	60	--	14.52	--	--	--	--	--	--
GP10	5430	28	28	--	Dry	--	--	--	--	--	--
GP11	5423	46	46	--	19.1	--	--	--	--	--	--
GP12	5465	53	53	--	Dry	--	--	--	--	--	--
GP13	5348	18	25	--	--	Dry	--	--	--	--	--
GP14	5332	23	25	--	--	Dry	--	--	--	--	--
GP15	5419	50	50	--	--	16.81	--	--	--	--	--
GP16	5419	51	52.5	--	--	19.56	--	--	--	--	--
GP17	5530	20	23	--	--	Dry	--	--	--	--	--
GP18	5499	33	40	--	--	Dry	--	--	--	--	--
GP19	5461	34	39	--	--	Dry	--	--	--	--	--
GP20	5615	22	25.4	--	--	Dry	--	--	--	--	--
GP21	5616	83	85	--	--	--	--	48.5	--	--	--
GP22	5860	49.5	50	--	--	--	38.7	--	--	--	--
GP23	5625	82	83	--	--	--	--	59.9	--	--	--
GP24	5680	43	45	--	--	--	--	Dry at 35	--	--	--
GP25	5905	46	48	--	--	--	--	Dry	--	--	--
GP26	5880	45	47	--	--	--	--	Dry	--	--	--
GP27	5839	23	25	--	--	--	--	Dry	--	--	--
GP28	5816	36	42	--	--	--	--	--	9.42	--	--
GP29	5820	40	42	--	--	--	--	--	17.3	--	--
GP30	5835	34	36	--	--	--	--	--	14.22	--	--
GP31	5854	36	38	--	--	--	--	--	Dry	--	--
GP32	5843	37	39	--	--	--	--	--	16.46	--	--
GP33	5872	34	36	--	--	--	--	--	Dry	--	--
GP34	5868	25	27	--	--	--	--	--	9.49	--	--
GP35	6158	35	37	--	--	--	--	--	Dry	--	--
GP36	6185	42	44	--	--	--	--	--	25.32	--	--
GP37	6231	26	28	--	--	--	--	--	--	16.99	--
GP38	6122	40	42	--	--	--	--	--	--	9.21	--
GP39	6137	30	32	--	--	--	--	--	--	8.63	--
GP40	6148	13	15	--	--	--	--	--	--	Dry	--
GP41	6126	33	35	--	--	--	--	--	--	11.13	--
GP42	6137	28	30	--	--	--	--	--	--	12.93	--
GP43	6148	20	22	--	--	--	--	--	--	Dry	--
GP44	6214	22	24	--	--	--	--	--	--	Dry	--
GP45	6200	26	28	--	--	--	--	--	--	Dry	--
GP46	6173	23	25	--	--	--	--	--	--	11.62	--
GP47	6149	56	58	--	--	--	--	--	--	21.46	--
GP48	6479	31	32	--	--	--	--	--	--	Dry	--
GP49	6400	45	47	--	--	--	--	--	--	9.09	--
GP50	6429	27	29	--	--	--	--	--	--	16.34	--
GP51	6435	7	9	--	--	--	--	--	--	--	Dry
GP52	6310	52	54	--	--	--	--	--	--	--	8.89
GP53	6329	40	42	--	--	--	--	--	--	--	27.19
GP54	6349	69	71	--	--	--	--	--	--	--	35.04
GP55	6340	39	41	--	--	--	--	--	--	--	24.7
GP56	6319	36	38	--	--	--	--	--	--	--	7.8
GP57	6371	33	35	--	--	--	--	--	--	--	23.6
GP58	6395	17	19	--	--	--	--	--	--	--	Dry
GP59	6451	10	12	--	--	--	--	--	--	--	Dry
GP60	6440	27	29	--	--	--	--	--	--	--	29
GP61	6425	48	50	--	--	--	--	--	--	--	24
GP62	6392	42	43	--	--	--	--	--	--	--	8.43
GP63	6478	45	47	--	--	--	--	--	--	--	34.41

MARTIN AND WOOD WATER CONSULTANTS, INC.

Well Sample Log

Page 1 of

Well Name: GP-1	Client: UBS	Job No.: 694.3

E 615720 N4344137 5312

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	(0-15.0) Dry, loose, f. to c. grain s.r. sand ALLUVIUM SP						
5	WL 9.75 - 2.57 = 7.18						
15.0	15.0 Pierre shale						
17.5	TD @ 17.5 Pierre Shale						

MARTIN AND WOOD WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name:	Client:	Job No.:
GP-2	UBS	694.3

E 616357 N 4344726 5325

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	(0 - 2⁴) Dry, firm, mod yel brn (10YR 5/4) silty CLAY w/ some f. to c. grain sand (CL)						
	(2⁴ - 6⁴) Moist, hard, dark yel brn (10YR 4/2) silty CLAY w/ little f. to c. grain sand (CL)						
	(6⁴ - 7⁰) Moist, soft, mod yel brn (10YR 5/4), f.g. silty sand (SP)						
	(7⁰ - 18³) Moist, firm mod yel brn (10YR 5/4) CLAY w/ some f.g. sand (CH)	Water	@ 16.3				
	(18³ - 32⁹) Wet, loose, mod yel brn (10YR 5/4) c.g. s.r. SAND (SP)						
	(32⁹ - 33⁸) Wet, firm, mod yel brn (10YR 5/4) CLAY w/ tr. v.f.g. sand (CH)						
	(33⁸ - 39⁰) SA 18³ - 32⁹						
	(39⁰ - 41⁰) Pierre Shale TD @ 41⁰						
	Screen piezo 15⁰ - 35⁰						

MARTIN AND WOOD WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name:	Client:	Job No.:
GP-3	UBS	694.3

E 617005 N 4345535 5366

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0 - 17²) Firm, dry, dark yel brn (10YR 4/2) silty CLAY, salt nodules. (CL)						
	(17² - 20²) Moist, soft, mod yel brn (10YR 5/4) CLAY (CH)						
	(20² - 22⁰) Wet, loose, mod yel brn (10YR 5/4) f.c.g. SAND (SP)	Water @		14.34			
	(22⁰ - 26³) Firm, moist, mod yel brn (10YR 5/4) to med bluish grey (5B 5/1) CLAY (CH)						
	(26³ - 29⁰) Pierre Shale TD @ 29⁰						

Well Sample Log

MARTIN AND WOOD WATER CONSULTANTS, INC.

Page ______ of ______

Well Name: GP-4	Client: UBS	Job No.: 694.3

E 615144 N 4343595 5367

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0 – 8⁵) Dry, Firm, dk yel brn (10YR 4/2) silty CLAY (CL)						
	(8⁵ – 43⁵) Dry, loose, mod yel brn (10YR 5/4) f to c.s. silty sand (SP)						
	Damp @ ~14⁰						
	(43⁵ – 72⁰) Wet, loose, med bl'ish grey (5B 5/1) f. to c.s. sr sand, tr silt, coal?	Water	@ 33.25				
	(72⁰ – 74⁰) Pierre Shale						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name:	Client:	Job No.:
GP-5	UBS	694.3

E 615323 N 4343837 5366

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	TD @ 33' Pierre Shale WL @ 10.58 - 2.58 = 8.0'						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name:	Client:	Job No.:
GP6	UBS	694.3

E 613999 N 4342123 5408

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0 – 30) Dry, loose, mod yel brn (10YR5/4), silty f. to c. sa. to s.r. SAND (SP)		Sample 15-20				
	(30 – 33) Pierre Shale Dry TD@ 33	Sample 30-33			stickup 1.8		

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name: GP 7	Client: VBS	Job No.: 694.3

E 614589 N 4342530 5366

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0-)						
	Water @ 29.15						
	Shale @ ~ 66'						

Well Sample Log

Page ______ of ______

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Name: GP 8	Client: UBS	Job No.: 694.3

E 608653 N 4347320 5481

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	Water @ 4.25						
	38^o Pierre shale						
	TD@ 38						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name: 6P9	Client: UBS	Job No.: 694.3

E 608495 N 4348115 5497

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	Water 16.4-1.88=14.52						
	60° Pierre Shale						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name: GP 10	Client: VBS	Job No.: 694.3

E 608088 N 4348473 5456

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	28' Pierre Shale						
	Dry Hole						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name: GP 11	Client: UBS	Job No.: 694.3

E 608212 N 4346435 5442

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	19' WL						
	46' Pierre Shale						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name: GP 12	Client: UBS	Job No.: 694.3

E 608237 N 4345303 5482

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	Dry Hole						
	53° Pierce Shale						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name:	Client:	Job No.:
GP 13	VBS	694.3

E 617368 N 4346359 5390

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0-18) Alluvial push						
	(18º - 23º) stiffer push Weathered Pierre Shale						
	(23º - 25º) Hard						
	TD @ 25º Dry Hole						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name: GP 14	Client: UBS	Job No.: 694.3

E 617262 N 4346259 5370

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0-23.0) Alluvial Push						
	(23.0-25.0) Pierre Shale						
	TD @ 25.0 Dry Hole						

Well Sample Log

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Page ____ of ____

Well Name:	Client:	Job No.:
GP-15	UBS	694.3

E 6083960 N 4345885 5443

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0-22') Alluvial Push						
	(22' - 50') Little stiffer, wet, Olive Gray (5Y4/1) CLAY w/ f. to c. sc. sand lenses weathered Pierre	Water @ 16.81					
	(50') Pierre Shale						
	TD@ 50'						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name:	Client:	Job No.:
GP 16	UBS	694.3

E 608386 N 4346225 5461

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0-28) Alluvial Push soft, dk yel brn (10YR 4/2) f to c sr. SAND, tr. silt (SP)						
	(28-29) little stiffer wet, firm, olive gray (5Y 4/1) silty f to c. sr SAND w/ CLAY lense (SP/CL)		Sample	27-30			
	(29-45) Easy Push (SP)	WL	19.56				
	(45-48) stiff						
	(48-51) Easy Push						
	(51-52.5) Pierre shale						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name: GP 17	Client: UBS	Job No.: 694.3

E 609214 N 4341389 5571

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0-20)						
	(20.0 23.0) Pierre shale						
	TD @ 23.0 Dry Hole						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name: GP18	Client: UBS	Job No.: 694.3

E 609381 N 4342761 5561

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0 - 35') Alluvial Push						
	(25' - 29') Stiffer, clay lense ...						
	(29' - 33') Softer						
	(33' - 38') Stiffer Weathered Pierre						
	(38' - 40') Hard Pierre Shale						
	TD 40' Dry Hole						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name:	Client:	Job No.:
GP19	UBS	694.3

E 611190 N 4341361 5537

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0-23) Alluvial push						
	(23-24) Hard push CLAY lense						
	(24-34) Soft push						
	(34^0 - 39^0) Hard Weathered Pierre						
	39^0 Pierre Shale						
	TD @ 39^0 Dry Hole						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name: GP 20	Client: UBS	Job No.: 694.3

E 607785 N 4341940 5656

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
	(0 – 16) easy push						
	(16-22) stiffer push	Dry					
	(22-25^{4}) hard push Pierre Shale w/ calcite? lenses						
	TD@ 25^{4} Dry Hole						

Well Sample Log

MARTIN AND WOOD WATER CONSULTANTS, INC.

Well Name:	Client:	Job No.:
GP.21	UBS	694.4

E 599592 N 4345658

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0							
	Dk brown CLAY w/ silt and c.s. Sand Dry TOPSOIL						
6^{3}							
	Dry, loose, f. to m. grain SAND, tr silt. (SP)						
8^{2}							
	Dry, firm, mod yel brn, CLAY, little silt. (ML)						
12^{6}							
	Dry, soft, mod yel brn, SILT (MH)						
12^{9}							
	Dry, firm, mod yel brn, CLAY, tr. silt (CH)						
13^{7}							
	SA 12^{6} - 12^{9}						
13^{8}							
	Dry, soft, mod yel brn f.s. SAND w/ silt (SM)						
16^{0}							
	Dry, firm, mod yel brn CLAY w/ stringers of silty f.s. Sand (CH)						
20^{3}							
	Dry, loose f.s. sand (SW)						
20^{7}							
	Dry, firm, mod yel brn. f.s. Sandy CLAY (CH/SC)						
23^{4}							
	Dry, soft, f to c.s. yelowish brn. silty SAND, few gravel stringers (SC)						
45 40^{0}							
	SAA, increasing c.s. SAND (SC)						
50/ 83^{0}							
	Starting to get harder						
85^{0}							
	EOH TD @ 85^{0}						

Well Sample Log

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Page ___ of ___

MARTIN AND WOOD WATER CONSULTANTS, INC.

Well Name: GP 22	Client: UBS	Job No.: 694.4

585697 4335263

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	Topsoil						
2	Dry, firm silty CLAY (CM)						
8.0	Dry, loose, silty, f to c.s. SAND (SM)						
14.0	Dry, soft, f. to c.s. sandy CLAY, some silt (CH/SC)						
25.0	SAA, calcite and MnOx and FeOx (CH/SC)						
38.8	Wet, firm mod yel brn CLAY (CH)						
39.0	Wet firm, f.s. sandy CLAY (CH/SC)						
39.3	Wet, firm, Gravel, w/ little clay, MnOx, FeOx calcite (GC)						
40.6	Wet, firm, Gravel and CLAY, MnOx, FeOx (GC)						
44.7	Wet, firm, grey, f.s. SAND, some silt, clay (SC)						
45.5	Wet, firm mod brn Gravel and CLAY, tr. silt (GC)						
49.5	Shale TD@ 50.0						
	WL=43.26 − 4.56 = 38.70						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ____ of ____

Well Name:	Client:	Job No.:
GP25	UBS	694.4

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	Dry, firm, dk brn SILT, little clay (MH)						
6.9	Dry, hard, med yel brn CLAY w/ little f.g. sand, little silt, (CL)						
11.7	Dry, firm, med brn, c. to m. g. SAND and CLAY (SC/CL)						
13.9	Moist, hard, med brn, CLAY w/ some c.g. sand (CH)						
14.5	SA 11.7-13.9						
		Silt w/ little v.f.g. sand 20.0					
	TD 48.0						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name: GP28	Client: UBS	Job No.: 694.4

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	Dry, loose, light brn poorly sorted f. to c.s. SAND, tr. silt (SP)						
8.2	Damp, firm, mod yel brn plastic CLAY (CH)						
9.0	Wet, soft, mod yel brn, v.f.s. sandy CLAY (CH)						
12.6	Wet, soft to firm, interbedded f. to c.s. SANDS and plastic CLAYS (SP/CH)						
16.0	wet, soft, mod brn f.s. SAND w/ little clay (SW)						
17.2	Wet, loose, med brn f. to c.s. SAND, tr. clay (SP)						
19.2	Wet, loose, med brn, f.s. SAND, tr. clay (SW)						
25.0	Sand is locking sample liner in barrel. Stop continuous sampling.						
36.6	Hard, Grey weathered SHALE						
42.0	TD @ 42.0						
	$37^{5} - 1^{7} = 35^{8}$						
	WL 9.97 − 0.55 = 9.42						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page ______ of ______

Well Name:	Client:	Job No.:
GP37	UBS	694.4

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
5⁰	Moist, firm, med brn, plastic CLAY (CH)						
8²	Moist, firm, salt and pepper clayey. f.s. SAND Look like weathered Dawson (SC)						

Well Sample Log

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Page ____ of ____

Well Name:	Client:	Job No.:
OP38	UBS	694.4

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	Topsoil						
3.0	Dry, loose light brown, f.g. silty SAND (SM)						
3.9	Dry, hard, dk brn, CLAY, tr. silt, tr. v.f. grain sand (CL)						
7.5	Dry, soft, m. to c.g. SAND, little silt (SP)						
9.6	SAA, wet (SP)						
12.3	Wet, hard, grey, plastic CLAY, little silt (CH/MH)						
13.0	Wet, loose, greyish brown, f. to c.g. SAND tr silt (SP)						
20.0	END Sampling @ 20.0						
	Sand locking sample barrel. End sampling						
40.0	Bedrock						
42.0	TD @ 42.0						

Well Sample Log

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Page ____ of ____

Well Name: GP41	Client: UBS	Job No.: 694.4

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	Dry, firm, dk brown, silty CLAY, calcite (CL/ML)						
9.5	Moist, firm, med brn, silty CLAY, tr. v.f.g. sand (CH/MH)						
11.9	Wet, soft, v.f.g. silty SAND med brn (SM)						
12.3	Wet, loose, m to c.g. SAND, med, brn, tr. silt (SW)						
18.3	Wet, firm, grey, silty CLAY (CH/MH)						

Well Sample Log

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Page ____ of ____

Well Name: GP49	Client: VBS	Job No.: 094.4

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	Topsoil Dk brn silty CLAY (CL/ML)						
4½	Dry, loose, med brn, f. to m.g. silty SAND (SM)						
7½	Wet, loose med brn, f. to c.g. SAND, tr clay (SP)						
12½	Wet, soft, med brn, f.g. SAND w/ some silt (SM)						

MARTIN AND WOOD
WATER CONSULTANTS, INC.

Well Sample Log

Page 1 of 1

Well Name:	Client:	Job No.:
GP 52	UBS	694.4

DEPTH (feet)	DESCRIPTION	LOGGER INITIALS	CLAYSTONE/ SHALE	SILTY CLAYSTONE	SILTSTONE	FINE SANDSTONE	MED to COARSE SANDSTONE
0	Dry, firm, dk grey Silty CLAY (CL/ML)						
4.5	SAA, highly oxidized w/ FeOx, MnOx, calcite (CL/ML)						
5.5	Moist, loose, red brn, f. to m. g. SAND tr silt (SW)						
7.6	Wet, loose, med brn, f. to c. g. SAND, tr. silt (SW)	WL=					
12.5	Wet, soft, grey, silty CLAY, w/ little v.f. g. sand (CL/ML/SW)						
13.0	Wet, loose, grey, f. to c. g. SAND, tr clay (SW)						
14.8	Wet, soft, dk grey, silty, sandy CLAY (CL/ML/SP)						
15.0	Stop sampling. Core barrel will lock						

APPENDIX D

PIEZOMETER PERMITS

(piezometers installed in 2008)

Copy

Form No. GWS-25

OFFICE OF THE STATE ENGINEER
COLORADO DIVISION OF WATER RESOURCES

818 Centennial Bldg., 1313 Sherman St., Denver, Colorado 80203
(303) 866-3581

LIC

WELL PERMIT NUMBER 278967 - -
DIV. 8 WD 67 DES. BASIN 7 MD 13

APPLICANT

UPPER BIG SANDY GWMD
35194 E HWY 24
RAMAH, CO 80832-

(719) 541-2669

APPROVED WELL LOCATION
LINCOLN COUNTY
SE 1/4 NE 1/4 Section 22
Township 9 S Range 56 W Sixth P.M.

DISTANCES FROM SECTION LINES
2225 Ft. from North Section Line
1090 Ft. from East Section Line

UTM COORDINATES (Meters,Zone:13,NAD83)
Easting: Northing:

PERMIT TO CONSTRUCT A WELL

CONDITIONS OF APPROVAL

1) This well shall be used in such a way as to cause no material injury to existing water rights. The issuance of this permit does not ensure that no injury will occur to another vested water right or preclude another owner of a vested water right from seeking relief in a civil court action.
2) The construction of this well shall be in compliance with the Water Well Construction Rules 2 CCR 402-2, unless approval of a variance has been granted by the State Board of Examiners of Water Well Construction and Pump Installation Contractors in accordance with Rule 18.
3) Approved pursuant to CRS 37-90-105(1)(d). Use of this well is limited to monitoring water levels and/or water quality sampling.
4) This well must be equipped with a locking cap or seal to prevent well contamination or possible hazards as an open well. The well must be kept capped and locked at all times except during sampling or measuring.
5) Sampling is limited to the alluvium of Big Sandy Creek or its tributaries. The depth of this well shall not exceed 30 feet or the depth at which sandstone or shale is first encountered, whichever comes first.
6) Records of any water level measurements and water quality analyses shall be maintained by the well owner and submitted to the Upper Big Sandy Ground Water Management District and the Division of Water Resources upon request.
7) Upon conclusion of the monitoring program the well owner shall plug this well in accordance with Rule 16 of the Water Well Construction Rules. A Well Abandonment Report must be completed and submitted to the Division of Water Resources within 60 days of plugging.
8) The owner shall mark the well in a conspicuous place with the well permit number and name of aquifer as appropriate, and shall take necessary means and precautions to preserve these markings.
9) This well shall be constructed within 300 feet of the location specified on this permit.
10) This well must have been constructed by or under the supervision of a licensed well driller or other authorized individual according to the Water Well Construction Rules.
11) A Well Construction and Test Report (Form GWS-31), including lithologic log must be submitted by the individual authorized to construct the well. For non-standard construction, the report must include an as-built drawing showing details such as depth, casing, perforated zones, and a description of the grouting type and interval.

NOTE: The owner has assigned this well identification no. GP3.

NOTICE: This permit has been approved for change to the 1/4, 1/4. You are hereby notified that you have the right to appeal the issuance of this permit, by filing a written request with this office within sixty (60) days of the date of issuance, pursuant to the State Administrative Procedures Act. (See Section 24-4-104 through 106, C.R.S.)

APPROVED
SMJ

Dick Wolfe
State Engineer

Sandy Johnson
By

Receipt No. 3634102B DATE ISSUED 10-15-2008 EXPIRATION DATE 10-15-2010 atten: William Berry

Copy

Form No. GWS-25

OFFICE OF THE STATE ENGINEER
COLORADO DIVISION OF WATER RESOURCES

818 Centennial Bldg., 1313 Sherman St., Denver, Colorado 80203
(303) 866-3581

LIC

WELL PERMIT NUMBER 278961 - -

DIV. 8 WD 67 DES. BASIN 7 MD 13

APPLICANT

UPPER BIG SANDY GWMD
35194 E HWY 24
RAMAH, CO 80832-

(719) 541-2669

APPROVED WELL LOCATION
LINCOLN COUNTY
SE 1/4 SW 1/4 Section 22
Township 9 S Range 56 W Sixth P.M.

DISTANCES FROM SECTION LINES
475 Ft. from South Section Line
1970 Ft. from West Section Line

UTM COORDINATES (Meters,Zone:13,NAD83)
Easting: Northing:

PERMIT TO CONSTRUCT A WELL

CONDITIONS OF APPROVAL

1) This well shall be used in such a way as to cause no material injury to existing water rights. The issuance of this permit does not ensure that no injury will occur to another vested water right or preclude another owner of a vested water right from seeking relief in a civil court action.
2) The construction of this well shall be in compliance with the Water Well Construction Rules 2 CCR 402-2, unless approval of a variance has been granted by the State Board of Examiners of Water Well Construction and Pump Installation Contractors in accordance with Rule 18.
3) Approved pursuant to CRS 37-90-105(1)(d). Use of this well is limited to monitoring water levels and/or water quality sampling.
4) This well must be equipped with a locking cap or seal to prevent well contamination or possible hazards as an open well. The well must be kept capped and locked at all times except during sampling or measuring.
5) Sampling is limited to the alluvium of Big Sandy Creek or its tributaries. The depth of this well shall not exceed 35 feet or the depth at which sandstone or shale is first encountered, whichever comes first.
6) Records of any water level measurements and water quality analyses shall be maintained by the well owner and submitted to the Upper Big Sandy Ground Water Management District and the Division of Water Resources upon request.
7) Upon conclusion of the monitoring program the well owner shall plug this well in accordance with Rule 16 of the Water Well Construction Rules. A Well Abandonment Report must be completed and submitted to the Division of Water Resources within 60 days of plugging.
8) The owner shall mark the well in a conspicuous place with the well permit number and name of aquifer as appropriate, and shall take necessary means and precautions to preserve these markings.
9) This well shall be constructed within 300 feet of the location specified on this permit.
10) This well must have been constructed by or under the supervision of a licensed well driller or other authorized individual according to the Water Well Construction Rules.
11) A Well Construction and Test Report (Form GWS-31), including lithologic log must be submitted by the individual authorized to construct the well. For non-standard construction, the report must include an as-built drawing showing details such as depth, casing, perforated zones, and a description of the grouting type and interval.

NOTE: The owner has assigned this well identification no. GP2.

APPROVED
SMJ

Dick Wolfe
State Engineer

Sandy Johnson
By

Receipt No. 3634102A DATE ISSUED 10-14-2008 EXPIRATION DATE 10-14-2010

APPENDIX E

PUMP TEST AND SLUG TEST DATA

Report Date:		4/21/2009 7:18
Report User Name:	ryarian	
Report Computer Name:	WTP	

Log File Properties			
File Name	Thursday April 16		2009 2009-04-16 18-07-38.wsl
Create Date		4/17/2009 15:26	

Device Properties		
Device	Level TROLL® 700	
Site	P4	
Device Name	Geotech Rental #1617	
Serial Number		102739
Firmware Version		2.04

Log Configuration

Log Name	Thursday April 16	2009
Created By	ryarian	
Computer Name	WTP	
Application	WinSitu.exe	
Application Version	5.6.4.6	
Create Date	4/16/2009 9:57	
Notes Size(bytes)	4096	
Type	True Logarithmic	
Overwrite when full	Disabled	
Scheduled Start Time	Manual Start	
Scheduled Stop Time	No Stop Time	
Max Interval	Days: 1 hrs: 06 mins: 00 secs: 00	

Level Reference Settings At Log Creation

Level Measurement Mode	Level Depth To Water
Specific Gravity	0.999
Level Reference Mode:	Set new reference
Level Reference Value:	294 (in)
Level Reference Head Pressure	0.0211718 (PSI)
Head Pressure	0.0222692 (PSI)
Temperature	11.5108 (C)
Depth of Probe	0.617028 (in)

Log Notes:

Date and Time	Note
4/16/2009 9:57	Device Reset
4/16/2009 9:58	Device Reset

4/16/2009 9:58	Device Reset
4/16/2009 9:58	Manual Start Command
4/16/2009 10:41	User Adjusted Time To (GMT): 4/16/2009 4:41:52 PM
4/16/2009 10:43	Suspend Command
4/16/2009 10:43	Resume Command
4/16/2009 18:07	User Note: "Downloading log - Used Batt: 22% Memory: 1% User: ryarian"
4/17/2009 15:25	User Adjusted Time To (GMT): 4/17/2009 9:25:39 PM
4/17/2009 15:26	Manual Stop Command

Log Data:
Record Count 194

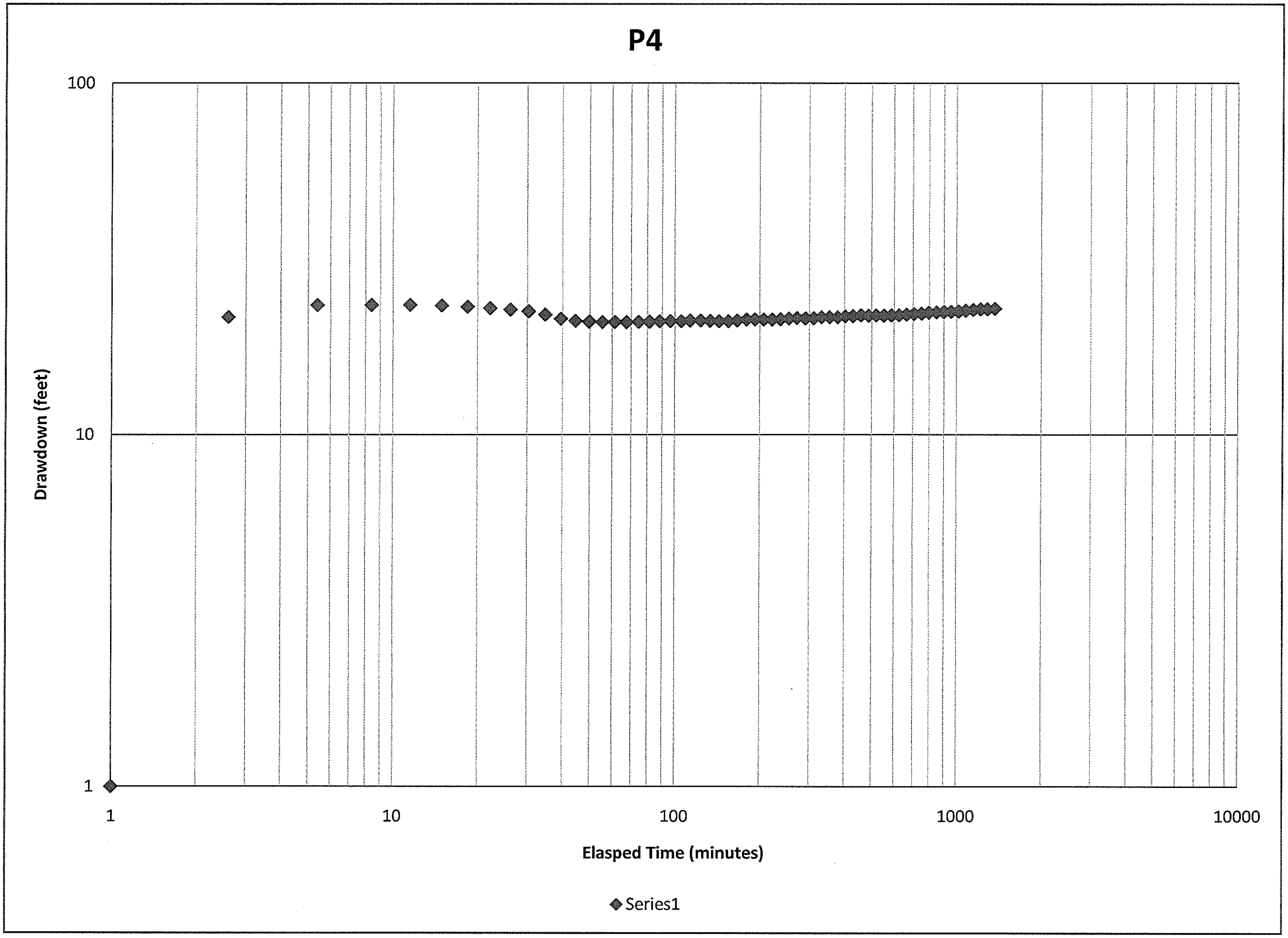
Date and Time	Elapsed Time Seconds	Sensor: Pres 69ft SN#: 102739 Level Depth To Water (in)
4/16/2009 9:58	0	-302.642
4/16/2009 9:58	0.251	-302.772
4/16/2009 9:58	0.501	-302.568
4/16/2009 9:58	0.751	-302.62
4/16/2009 9:58	1.02	-302.751
4/16/2009 9:58	1.251	-302.634
4/16/2009 9:58	1.501	-302.634
4/16/2009 9:58	1.751	-302.578
4/16/2009 9:58	2.083	-302.663
4/16/2009 9:58	2.285	-302.802
4/16/2009 9:58	2.674	-302.679
4/16/2009 9:58	3.071	-302.609
4/16/2009 9:58	3.28	-302.635
4/16/2009 9:58	3.482	-302.528
4/16/2009 9:58	3.684	-302.613
4/16/2009 9:58	3.887	-302.624
4/16/2009 9:58	4.09	-302.578
4/16/2009 9:58	4.292	-302.586
4/16/2009 9:58	4.501	-302.598
4/16/2009 9:58	4.751	-302.608
4/16/2009 9:58	5.001	-302.59
4/16/2009 9:58	5.251	-302.616
4/16/2009 9:58	5.501	-302.616
4/16/2009 9:58	5.751	-302.593
4/16/2009 9:58	6.001	-302.552
4/16/2009 9:58	6.36	-302.547
4/16/2009 9:58	6.72	-302.566
4/16/2009 9:58	7.186	-302.582
4/16/2009 9:58	7.576	-302.536
4/16/2009 9:58	7.98	-302.558
4/16/2009 9:58	8.46	-302.587

4/16/2009 9:58	9	-302.587
4/16/2009 9:58	9.48	-302.519
4/16/2009 9:58	10.08	-302.636
4/16/2009 9:58	10.68	-302.601
4/16/2009 9:58	11.405	-302.635
4/16/2009 9:58	11.94	-302.598
4/16/2009 9:58	12.66	-302.579
4/16/2009 9:58	13.44	-302.529
4/16/2009 9:58	14.22	-302.575
4/16/2009 9:58	15.06	-302.559
4/16/2009 9:58	15.99	-302.55
4/16/2009 9:58	16.92	-302.522
4/16/2009 9:58	17.88	-302.579
4/16/2009 9:58	18.96	-302.591
4/16/2009 9:58	20.1	-302.59
4/16/2009 9:58	21.483	-302.582
4/16/2009 9:58	22.56	-302.575
4/16/2009 9:59	23.88	-302.605
4/16/2009 9:59	25.32	-302.649
4/16/2009 9:59	26.821	-302.652
4/16/2009 9:59	28.38	-302.516
4/16/2009 9:59	30.061	-302.538
4/16/2009 9:59	31.86	-302.632
4/16/2009 9:59	33.72	-302.534
4/16/2009 9:59	35.761	-302.549
4/16/2009 9:59	37.86	-302.549
4/16/2009 9:59	40.08	-302.584
4/16/2009 9:59	42.481	-302.501
4/16/2009 9:59	45	-302.547
4/16/2009 9:59	47.64	-302.532
4/16/2009 9:59	50.46	-302.546
4/16/2009 9:59	53.46	-302.568
4/16/2009 9:59	56.64	-302.468
4/16/2009 9:59	60	-302.557
4/16/2009 9:59	63.6	-302.549
4/16/2009 9:59	67.2	-302.566
4/16/2009 9:59	71.4	-302.555
4/16/2009 9:59	75.6	-302.581
4/16/2009 9:59	79.8	-302.566
4/16/2009 10:00	84.6	-302.569
4/16/2009 10:00	90	-302.57
4/16/2009 10:00	94.8	-302.466
4/16/2009 10:00	100.8	-302.573
4/16/2009 10:00	106.8	-302.429
4/16/2009 10:00	112.8	-302.561
4/16/2009 10:00	119.4	-302.568
4/16/2009 10:00	126.6	-302.572

4/16/2009 10:00	134.4	-302.562
4/16/2009 10:00	142.2	-302.538
4/16/2009 10:01	150.6	-302.421
4/16/2009 10:01	159.6	-302.535
4/16/2009 10:01	169.2	-302.564
4/16/2009 10:01	178.8	-302.535
4/16/2009 10:01	189.6	-302.452
4/16/2009 10:01	201	-302.545
4/16/2009 10:02	213	-302.557
4/16/2009 10:02	225.6	-302.565
4/16/2009 10:02	238.8	-302.538
4/16/2009 10:02	253.2	-302.543
4/16/2009 10:03	268.2	-302.546
4/16/2009 10:03	283.8	-302.425
4/16/2009 10:03	300.6	-302.555
4/16/2009 10:03	318.6	-302.526
4/16/2009 10:04	337.2	-302.592
4/16/2009 10:04	357.6	-302.554
4/16/2009 10:04	378.6	-302.564
4/16/2009 10:05	400.8	-302.55
4/16/2009 10:05	424.8	-302.57
4/16/2009 10:06	450	-302.542
4/16/2009 10:06	476.4	-302.593
4/16/2009 10:07	504.6	-302.569
4/16/2009 10:07	534.6	-302.578
4/16/2009 10:08	566.4	-302.559
4/16/2009 10:08	600	-302.587
4/16/2009 10:09	636	-302.603
4/16/2009 10:09	672	-302.595
4/16/2009 10:10	714	-302.487
4/16/2009 10:11	756	-302.603
4/16/2009 10:11	798	-302.639
4/16/2009 10:12	846	-302.574
4/16/2009 10:13	900	-302.603
4/16/2009 10:14	948	-302.574
4/16/2009 10:15	1008	-302.646
4/16/2009 10:16	1068	-302.519
4/16/2009 10:17	1128	-302.673
4/16/2009 10:18	1194	-302.649
4/16/2009 10:19	1266	-302.525
4/16/2009 10:21	1344	-302.658
4/16/2009 10:22	1422	-302.635
4/16/2009 10:23	1506	-302.675
4/16/2009 10:25	1596	-302.646
4/16/2009 10:26	1692	-302.537
4/16/2009 10:28	1788	-302.624
4/16/2009 10:30	1896	-302.642

4/16/2009 10:32	2010	-302.643
4/16/2009 10:34	2130	-302.672
4/16/2009 10:36	2256	-302.712
4/16/2009 10:38	2388	-302.724
4/16/2009 10:40	2532	-296.26
4/16/2009 10:43	2675.818	-302.677
4/16/2009 10:45	2831.819	-43.229
4/16/2009 10:48	2999.819	-22.198
4/16/2009 10:51	3179.819	-21.966
4/16/2009 10:54	3365.819	-21.732
4/16/2009 10:58	3569.819	-22.978
4/16/2009 11:01	3779.819	-24.982
4/16/2009 11:05	4001.819	-27.768
4/16/2009 11:09	4241.819	-30.366
4/16/2009 11:13	4493.819	-33.224
4/16/2009 11:17	4757.819	-39.077
4/16/2009 11:22	5039.819	-46.156
4/16/2009 11:27	5339.819	-49.845
4/16/2009 11:32	5657.819	-50.897
4/16/2009 11:38	5993.819	-51.664
4/16/2009 11:44	6353.819	-51.518
4/16/2009 11:50	6713.819	-51.663
4/16/2009 11:57	7133.819	-51.374
4/16/2009 12:04	7553.819	-50.853
4/16/2009 12:11	7973.819	-50.441
4/16/2009 12:19	8453.819	-49.739
4/16/2009 12:28	8993.819	-49.903
4/16/2009 12:36	9473.819	-48.963
4/16/2009 12:46	10073.819	-48.793
4/16/2009 12:56	10673.819	-49.654
4/16/2009 13:06	11273.819	-50.021
4/16/2009 13:17	11933.819	-50.149
4/16/2009 13:29	12653.819	-48.882
4/16/2009 13:42	13433.819	-47.38
4/16/2009 13:55	14213.819	-47.176
4/16/2009 14:09	15053.819	-47.231
4/16/2009 14:24	15953.819	-47.51
4/16/2009 14:40	16913.819	-46.711
4/16/2009 14:56	17873.819	-45.694
4/16/2009 15:14	18953.819	-44.632
4/16/2009 15:33	20093.819	-45.349
4/16/2009 15:53	21293.819	-45.112
4/16/2009 16:14	22553.819	-43.481
4/16/2009 16:36	23873.819	-43.382
4/16/2009 17:00	25313.819	-43.556
4/16/2009 17:25	26813.819	-41.993
4/16/2009 17:51	28373.819	-41.385

4/16/2009 18:19	30053.819	-40.108
4/16/2009 18:49	31853.819	-40.731
4/16/2009 19:20	33713.819	-40.436
4/16/2009 19:54	35753.819	-40.842
4/16/2009 20:29	37853.819	-40.275
4/16/2009 21:06	40073.819	-40.085
4/16/2009 21:46	42473.819	-38.996
4/16/2009 22:28	44993.819	-37.716
4/16/2009 23:12	47633.819	-37.234
4/16/2009 23:59	50453.819	-35.516
4/17/2009 0:49	53453.819	-35.004
4/17/2009 1:42	56633.819	-34.398
4/17/2009 2:38	59993.819	-33.886
4/17/2009 3:38	63593.819	-33.272
4/17/2009 4:38	67193.819	-32.066
4/17/2009 5:48	71393.819	-30.633
4/17/2009 6:58	75593.819	-29.281
4/17/2009 8:08	79793.819	-29.287
4/17/2009 9:28	84593.819	-28.534
4/17/2009 10:58	89993.819	-291.094
4/17/2009 12:18	94793.819	-298.278
4/17/2009 13:58	100793.819	-301.601


P4
Drawdown (feet)
100
10
1
1
10
100
1000
10000
Elasped Time (minutes)
Series1

Report Date:		4/21/2009 7:18
Report User Name:	ryarian	
Report Computer Name:	WTP	

Log File Properties

File Name	Thursday April 16		2009 2009-04-16 18-22-08.wsl
Create Date		4/17/2009 15:39	

Device Properties

Device	Level TROLL® 700	
Site	BS 2	
Device Name		
Serial Number		125506
Firmware Version		2.07

Log Configuration

Log Name	Thursday April 16	2009
Created By	ryarian	
Computer Name	WTP	
Application	WinSitu.exe	
Application Version	5.6.4.6	
Create Date	4/16/2009 10:27	
Notes Size(bytes)	4096	
Type	True Logarithmic	
Overwrite when full	Disabled	
Scheduled Start Time	Manual Start	
Scheduled Stop Time	No Stop Time	
Max Interval	Days: 1 hrs: 06 mins: 00 secs: 00	

Level Reference Settings At Log Creation

Level Measurement Mode	Level Depth To Water
Specific Gravity	0.999
Level Reminder:	Enabled
Level Reference Mode:	Set new reference
Level Reference Value:	237 (in)
Level Reference Head Pressure	-0.00189209 (PSI)
Head Pressure	10.3802 (PSI)
Temperature	11.3578 (C)
Depth of Probe	287.612 (in)

Log Notes:

Date and Time	Note	
4/16/2009 10:27	User Note: "Level Reference adjusted to: 237	depth: 287.635(in)"
4/16/2009 10:27	User Note: "Pressure reference: 10.3818	offset: 0 (PSI)"
4/16/2009 10:27	User Note: "Temp at reference: 11.3554 (C)"	
4/16/2009 10:27	Manual Start Command	
4/16/2009 10:29	Suspend Command	
4/16/2009 10:40	Resume Command	
4/16/2009 18:22	User Note: "Downloading log - Used Batt: 11% Memory: 3% User: ryarian"	
4/17/2009 15:39	Manual Stop Command	

Log Data:

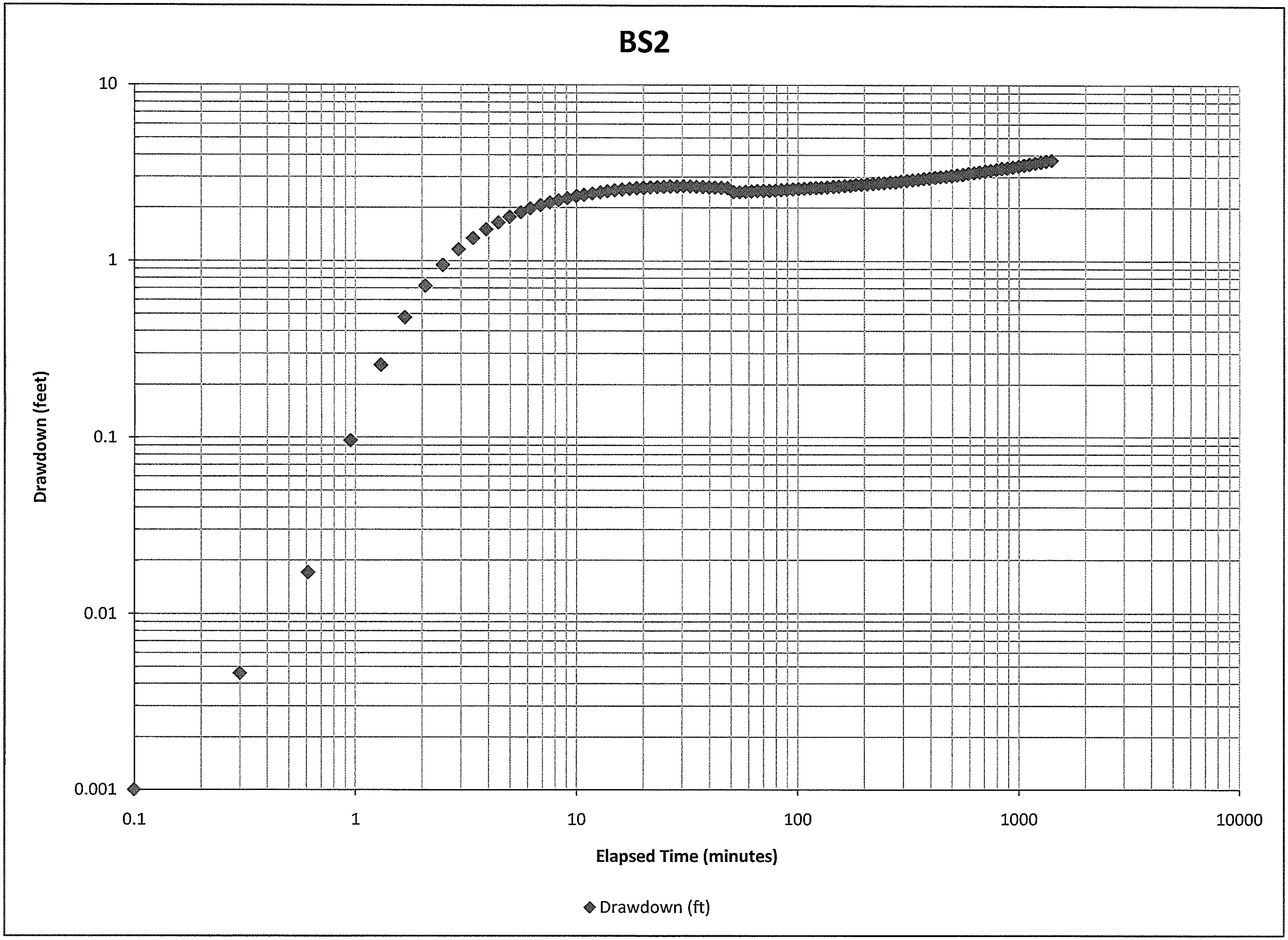
Record Count	194

Date and Time	Elapsed Time Seconds	Sensor: Pres 69ft SN#: 125506 Level Depth To Water (in)
4/16/2009 10:27	0	236.907
4/16/2009 10:27	0.251	236.941
4/16/2009 10:27	0.501	236.873
4/16/2009 10:27	0.751	236.902
4/16/2009 10:27	1.001	236.89
4/16/2009 10:27	1.251	236.924
4/16/2009 10:27	1.559	236.848
4/16/2009 10:27	1.78	236.828
4/16/2009 10:27	2.018	236.951
4/16/2009 10:27	2.251	236.862
4/16/2009 10:27	2.501	236.848
4/16/2009 10:27	2.751	236.882
4/16/2009 10:27	3.001	236.905
4/16/2009 10:27	3.251	236.922
4/16/2009 10:27	3.501	236.902
4/16/2009 10:27	3.753	236.879
4/16/2009 10:28	4.001	236.944
4/16/2009 10:28	4.251	236.918
4/16/2009 10:28	4.501	236.931
4/16/2009 10:28	4.751	236.898
4/16/2009 10:28	5.001	236.927
4/16/2009 10:28	5.251	236.902
4/16/2009 10:28	5.501	236.922
4/16/2009 10:28	5.751	236.914
4/16/2009 10:28	6.001	236.92
4/16/2009 10:28	6.361	236.956
4/16/2009 10:28	6.721	236.886
4/16/2009 10:28	7.141	236.905
4/16/2009 10:28	7.561	236.907
4/16/2009 10:28	7.98	236.824
4/16/2009 10:28	8.593	236.918
4/16/2009 10:28	9	236.936
4/16/2009 10:28	9.48	236.917
4/16/2009 10:28	10.081	236.876
4/16/2009 10:28	10.681	236.875
4/16/2009 10:28	11.281	236.97
4/16/2009 10:28	11.94	236.834
4/16/2009 10:28	12.687	236.892
4/16/2009 10:28	13.548	236.885
4/16/2009 10:28	14.22	236.937
4/16/2009 10:28	15.061	236.922
4/16/2009 10:28	15.961	236.902
4/16/2009 10:28	16.92	236.896
4/16/2009 10:28	17.892	236.898
4/16/2009 10:28	18.961	236.909
4/16/2009 10:28	20.101	236.89
4/16/2009 10:28	21.301	236.853
4/16/2009 10:28	22.64	236.922
4/16/2009 10:28	23.88	236.896
4/16/2009 10:28	25.321	236.883
4/16/2009 10:28	26.821	236.93
4/16/2009 10:28	28.38	236.874
4/16/2009 10:28	30.061	236.88
4/16/2009 10:28	31.86	236.916

4/16/2009 10:28	33.72	236.926
4/16/2009 10:28	35.76	236.893
4/16/2009 10:28	37.924	236.861
4/16/2009 10:28	40.08	236.922
4/16/2009 10:28	42.672	236.885
4/16/2009 10:28	45	236.919
4/16/2009 10:28	47.672	236.897
4/16/2009 10:28	50.463	236.808
4/16/2009 10:28	53.461	236.932
4/16/2009 10:28	56.64	236.906
4/16/2009 10:28	60	236.91
4/16/2009 10:28	63.6	236.831
4/16/2009 10:29	67.2	236.844
4/16/2009 10:29	71.4	236.919
4/16/2009 10:29	75.682	236.829
4/16/2009 10:29	79.8	236.887
4/16/2009 10:29	84.6	236.891
4/16/2009 10:29	90	236.887
4/16/2009 10:40	755.85	236.791
4/16/2009 10:40	761.851	236.829
4/16/2009 10:40	767.851	236.825
4/16/2009 10:40	773.851	236.854
4/16/2009 10:40	780.451	236.874
4/16/2009 10:41	787.651	236.884
4/16/2009 10:41	795.451	236.908
4/16/2009 10:41	803.251	236.829
4/16/2009 10:41	811.651	236.926
4/16/2009 10:41	820.651	236.908
4/16/2009 10:41	830.251	236.902
4/16/2009 10:41	839.851	236.9
4/16/2009 10:42	850.651	236.866
4/16/2009 10:42	862.051	236.845
4/16/2009 10:42	874.051	236.91
4/16/2009 10:42	886.651	236.888
4/16/2009 10:42	899.851	236.875
4/16/2009 10:43	914.251	236.814
4/16/2009 10:43	929.251	236.88
4/16/2009 10:43	944.851	236.895
4/16/2009 10:43	961.651	236.843
4/16/2009 10:44	979.651	236.955
4/16/2009 10:44	998.25	237.105
4/16/2009 10:44	1018.651	238.05
4/16/2009 10:45	1039.651	239.992
4/16/2009 10:45	1061.851	242.629
4/16/2009 10:46	1085.851	245.548
4/16/2009 10:46	1111.051	248.214
4/16/2009 10:46	1137.451	250.768
4/16/2009 10:47	1165.651	252.968
4/16/2009 10:47	1195.651	254.941
4/16/2009 10:48	1227.45	256.667
4/16/2009 10:48	1261.051	258.102
4/16/2009 10:49	1297.051	259.525
4/16/2009 10:50	1333.051	260.615
4/16/2009 10:50	1375.051	261.679
4/16/2009 10:51	1417.051	262.579
4/16/2009 10:52	1459.051	263.363
4/16/2009 10:53	1507.051	264.059
4/16/2009 10:53	1561.051	264.815

4/16/2009 10:54	1609.051	265.284
4/16/2009 10:55	1669.051	265.787
4/16/2009 10:56	1729.051	266.255
4/16/2009 10:57	1789.051	266.646
4/16/2009 10:58	1855.051	267.008
4/16/2009 11:00	1927.051	267.32
4/16/2009 11:01	2005.051	267.611
4/16/2009 11:02	2083.051	267.858
4/16/2009 11:04	2167.051	268.037
4/16/2009 11:05	2257.051	268.19
4/16/2009 11:07	2353.051	268.372
4/16/2009 11:08	2449.051	268.466
4/16/2009 11:10	2557.051	268.6
4/16/2009 11:12	2671.051	268.586
4/16/2009 11:14	2791.051	268.72
4/16/2009 11:16	2917.051	268.659
4/16/2009 11:18	3049.051	268.571
4/16/2009 11:21	3193.051	268.406
4/16/2009 11:23	3343.051	268.257
4/16/2009 11:26	3499.051	268.165
4/16/2009 11:29	3667.051	268.055
4/16/2009 11:32	3847.051	268.001
4/16/2009 11:35	4033.051	266.358
4/16/2009 11:38	4237.051	266.414
4/16/2009 11:42	4447.051	266.53
4/16/2009 11:45	4669.051	266.6
4/16/2009 11:49	4909.051	266.81
4/16/2009 11:53	5161.051	266.882
4/16/2009 11:58	5425.051	266.946
4/16/2009 12:03	5707.051	267
4/16/2009 12:08	6007.051	267.217
4/16/2009 12:13	6325.051	267.336
4/16/2009 12:18	6661.051	267.508
4/16/2009 12:24	7021.051	267.642
4/16/2009 12:30	7381.051	267.736
4/16/2009 12:37	7801.051	267.897
4/16/2009 12:44	8221.051	268.053
4/16/2009 12:51	8641.051	268.159
4/16/2009 12:59	9121.051	268.268
4/16/2009 13:08	9661.051	268.503
4/16/2009 13:16	10141.051	268.684
4/16/2009 13:26	10741.051	268.885
4/16/2009 13:36	11341.051	268.994
4/16/2009 13:46	11941.051	269.319
4/16/2009 13:57	12601.051	269.396
4/16/2009 14:09	13321.051	269.601
4/16/2009 14:22	14101.051	269.81
4/16/2009 14:35	14881.051	270.019
4/16/2009 14:49	15721.051	270.201
4/16/2009 15:04	16621.051	270.514
4/16/2009 15:20	17581.051	270.532
4/16/2009 15:36	18541.051	270.859
4/16/2009 15:54	19621.051	271.152
4/16/2009 16:13	20761.051	271.47
4/16/2009 16:33	21961.051	271.681
4/16/2009 16:54	23221.051	272.078
4/16/2009 17:16	24541.051	272.267
4/16/2009 17:40	25981.051	272.632

4/16/2009 18:05	27481.051	272.942
4/16/2009 18:31	29041.051	273.107
4/16/2009 18:59	30721.051	273.408
4/16/2009 19:29	32521.051	273.765
4/16/2009 20:00	34381.051	274.082
4/16/2009 20:34	36421.051	274.555
4/16/2009 21:09	38521.051	274.966
4/16/2009 21:46	40741.051	275.326
4/16/2009 22:26	43141.051	275.764
4/16/2009 23:08	45661.051	276.173
4/16/2009 23:52	48301.051	276.634
4/17/2009 0:39	51121.051	277.143
4/17/2009 1:29	54121.051	277.403
4/17/2009 2:22	57301.051	277.924
4/17/2009 3:18	60661.051	278.373
4/17/2009 4:18	64261.051	278.904
4/17/2009 5:18	67861.051	279.459
4/17/2009 6:28	72061.051	280.021
4/17/2009 7:38	76261.051	280.591
4/17/2009 8:48	80461.051	281.147
4/17/2009 10:08	85261.051	281.569
4/17/2009 11:38	90661.051	252.235
4/17/2009 12:58	95461.051	250.29
4/17/2009 14:38	101461.051	248.898


BS2
10
1
0.1
0.01
0.001
Drawdown (feet)
0.1
1
10
100
1000
10000
Elapsed Time (minutes)
Drawdown (ft)

Report Date:	4/15/2009 12:25
Report User Name:	WBerg
Report Computer Na	WBERG01

Log File Properties

File Name	Slug in 1 2009-04-15 12-24-38.wsl
Create Date	4/15/2009 12:25

Device Properties

Device	Level TROLL® 700
Site	GP2
Device Name	Geotech Rental # 1604
Serial Number	102501
Firmware Version	2.04

Log Configuration

Log Name	Slug in 1
Created By	WBerg
Computer Name	WBERG01
Application	WinSitu.exe
Application Version	5.6.4.6
Create Date	4/15/2009 12:08
Notes Size(bytes)	4096
Type	True Logarithmic
Overwrite when full	Disabled
Scheduled Start Time	Manual Start
Scheduled Stop Time	No Stop Time
Max Interval	Days: 0 hrs: 00 mins: 02 secs: 00

Level Reference Settings At Log Creation

Level Measurement Mode	Depth
Specific Gravity	0.999

Log Notes:

Date and Time	Note
4/15/2009 12:18	Manual Start Command
4/15/2009 12:24	User Note: "Downloading log - Used Batt: 23% Memory: 4% User: WBerg"
4/15/2009 12:25	Manual Stop Command

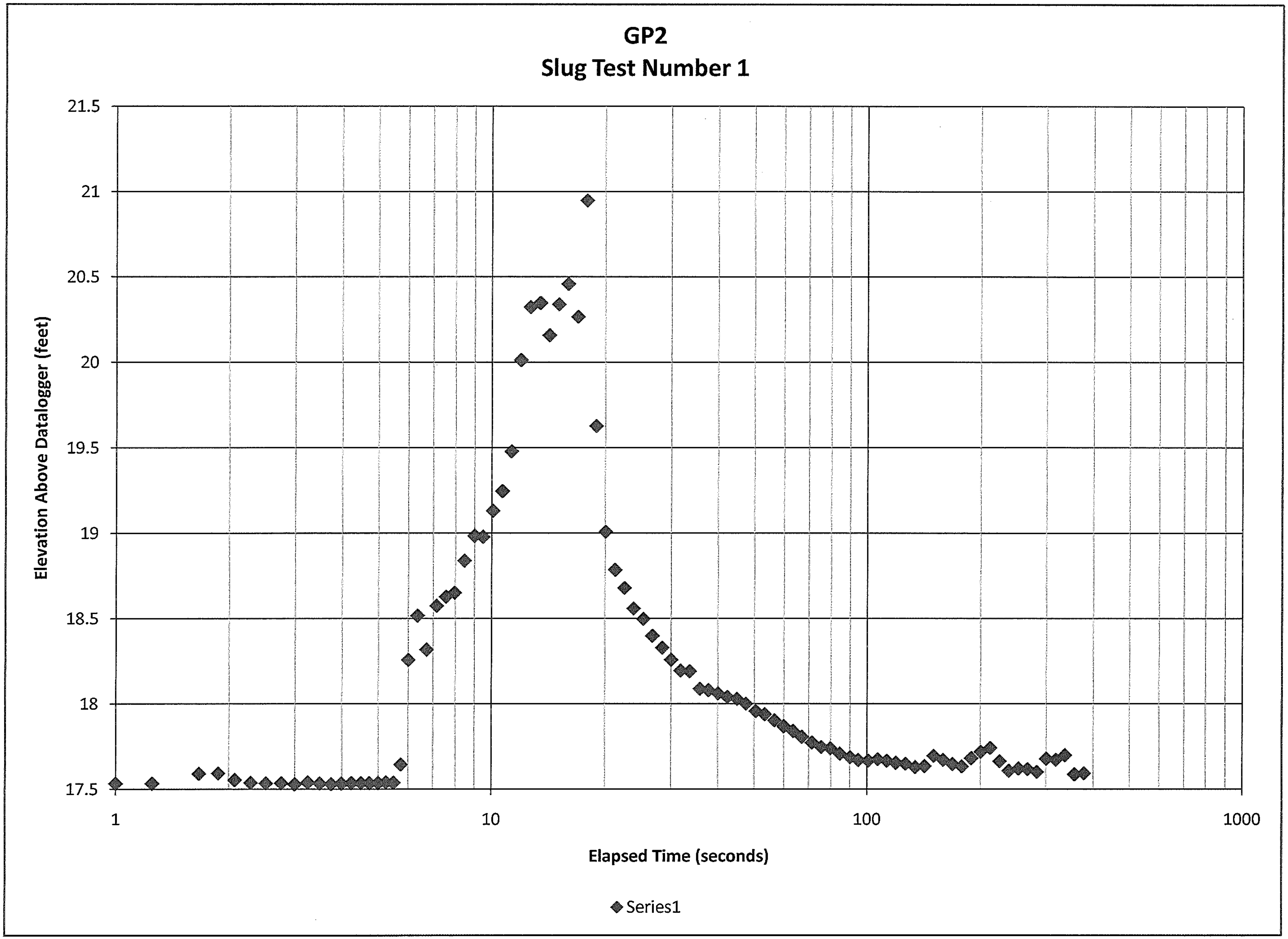
Log Data:

Record Count 97

Date and Time	Elapsed Time Seconds	Sensor: Pres 69ft SN#: 102501 Pressure (PSI)	Sensor: Pres 69ft SN#: 102501 Temperature (F)	Sensor: Pres 69ft SN#: 102501 Depth (ft)
4/15/2009 12:18	0	7.593	53.632	17.532
4/15/2009 12:18	0.251	7.595	53.669	17.537
4/15/2009 12:18	0.501	7.596	53.689	17.538
4/15/2009 12:18	0.751	7.595	53.709	17.536

4/15/2009 12:18	1.001	7.594	53.727	17.534
4/15/2009 12:19	1.251	7.594	53.738	17.533
4/15/2009 12:19	1.666	7.619	53.728	17.591
4/15/2009 12:19	1.873	7.619	53.75	17.593
4/15/2009 12:19	2.077	7.603	53.764	17.554
4/15/2009 12:19	2.29	7.596	53.784	17.538
4/15/2009 12:19	2.515	7.595	53.79	17.536
4/15/2009 12:19	2.761	7.595	53.79	17.536
4/15/2009 12:19	3.001	7.592	53.793	17.529
4/15/2009 12:19	3.251	7.595	53.798	17.538
4/15/2009 12:19	3.501	7.594	53.793	17.535
4/15/2009 12:19	3.751	7.592	53.801	17.531
4/15/2009 12:19	4.001	7.594	53.807	17.533
4/15/2009 12:19	4.251	7.595	53.806	17.536
4/15/2009 12:19	4.501	7.595	53.809	17.536
4/15/2009 12:19	4.751	7.595	53.802	17.536
4/15/2009 12:19	5.001	7.595	53.813	17.536
4/15/2009 12:19	5.251	7.597	53.813	17.54
4/15/2009 12:19	5.501	7.596	53.818	17.538
4/15/2009 12:19	5.751	7.642	53.818	17.646
4/15/2009 12:19	6.001	7.907	53.819	18.258
4/15/2009 12:19	6.36	8.02	53.801	18.518
4/15/2009 12:19	6.721	7.933	53.788	18.318
4/15/2009 12:19	7.141	8.045	53.782	18.575
4/15/2009 12:19	7.56	8.068	53.777	18.629
4/15/2009 12:19	7.981	8.078	53.768	18.652
4/15/2009 12:19	8.461	8.159	53.761	18.839
4/15/2009 12:19	9	8.222	53.744	18.984
4/15/2009 12:19	9.48	8.22	53.744	18.979
4/15/2009 12:19	10.08	8.286	53.732	19.132
4/15/2009 12:19	10.681	8.336	53.729	19.247
4/15/2009 12:19	11.28	8.436	53.727	19.479
4/15/2009 12:19	11.94	8.667	53.724	20.012
4/15/2009 12:19	12.66	8.801	53.719	20.322
4/15/2009 12:19	13.44	8.812	53.709	20.347
4/15/2009 12:19	14.22	8.731	53.699	20.159
4/15/2009 12:19	15.06	8.809	53.704	20.34
4/15/2009 12:19	15.96	8.861	53.692	20.46
4/15/2009 12:19	16.92	8.777	53.685	20.267
4/15/2009 12:19	17.88	9.073	53.688	20.948
4/15/2009 12:19	18.96	8.501	53.674	19.629
4/15/2009 12:19	20.1	8.233	53.673	19.01
4/15/2009 12:19	21.3	8.135	53.671	18.785
4/15/2009 12:19	22.56	8.09	53.668	18.68
4/15/2009 12:19	23.88	8.038	53.661	18.56
4/15/2009 12:19	25.32	8.011	53.656	18.498
4/15/2009 12:19	26.82	7.968	53.651	18.398
4/15/2009 12:19	28.456	7.938	53.71	18.329
4/15/2009 12:19	30.06	7.907	53.659	18.257
4/15/2009 12:19	31.86	7.88	53.662	18.194
4/15/2009 12:19	33.72	7.878	53.644	18.19
4/15/2009 12:19	35.862	7.833	53.692	18.087
4/15/2009 12:19	37.86	7.83	53.647	18.079
4/15/2009 12:19	40.08	7.822	53.636	18.061

4/15/2009 12:19	42.48	7.813	53.637	18.04
4/15/2009 12:19	45	7.808	53.624	18.028
4/15/2009 12:19	47.64	7.796	53.622	18.001
4/15/2009 12:19	50.46	7.777	53.612	17.957
4/15/2009 12:19	53.46	7.769	53.615	17.938
4/15/2009 12:19	56.64	7.754	53.621	17.903
4/15/2009 12:19	60	7.738	53.607	17.868
4/15/2009 12:20	63.6	7.727	53.598	17.841
4/15/2009 12:20	67.2	7.712	53.6	17.807
4/15/2009 12:20	71.4	7.698	53.608	17.774
4/15/2009 12:20	75.6	7.686	53.58	17.747
4/15/2009 12:20	79.8	7.683	53.58	17.739
4/15/2009 12:20	84.6	7.669	53.57	17.707
4/15/2009 12:20	90	7.66	53.557	17.687
4/15/2009 12:20	94.8	7.653	53.557	17.67
4/15/2009 12:20	100.858	7.652	53.598	17.667
4/15/2009 12:20	106.8	7.655	53.551	17.676
4/15/2009 12:20	112.8	7.652	53.535	17.667
4/15/2009 12:20	119.4	7.646	53.524	17.653
4/15/2009 12:21	126.6	7.644	53.535	17.65
4/15/2009 12:21	134.4	7.635	53.509	17.63
4/15/2009 12:21	142.2	7.638	53.506	17.635
4/15/2009 12:21	150.6	7.664	53.49	17.696
4/15/2009 12:21	159.6	7.653	53.48	17.672
4/15/2009 12:21	169.2	7.643	53.468	17.647
4/15/2009 12:21	178.8	7.637	53.456	17.634
4/15/2009 12:22	189.6	7.658	53.455	17.682
4/15/2009 12:22	201.095	7.675	53.467	17.72
4/15/2009 12:22	213	7.684	53.433	17.742
4/15/2009 12:22	225.6	7.65	53.415	17.664
4/15/2009 12:22	238.8	7.626	53.41	17.607
4/15/2009 12:23	253.2	7.631	53.404	17.62
4/15/2009 12:23	268.2	7.63	53.387	17.618
4/15/2009 12:23	283.8	7.623	53.373	17.602
4/15/2009 12:23	300.6	7.657	53.358	17.679
4/15/2009 12:24	318.6	7.654	53.353	17.673
4/15/2009 12:24	337.2	7.665	53.325	17.699
4/15/2009 12:24	357.6	7.617	53.326	17.587
4/15/2009 12:25	378.6	7.62	53.321	17.594


GP2
Slug Test Number 1
Elevation Above Datalogger (feet)
21.5
21
20.5
20
19.5
19
18.5
18
17.5
1
10
100
1000
Elapsed Time (seconds)
Series1

Report Date:	4/15/2009 12:36
Report User Name:	WBerg
Report Computer Name:	WBERG01

Log File Properties	
File Name	Slug in 2 2009-04-15 12-34-01.wsl
Create Date	4/15/2009 12:36

Device Properties	
Device	Level TROLL® 700
Site	GP2
Device Name	Geotech Rental # 1604
Serial Number	102501
Firmware Version	2.04

Log Configuration

Log Name	Slug in 2
Created By	WBerg
Computer Name	WBERG01
Application	WinSitu.exe
Application Version	5.6.4.6
Create Date	4/15/2009 12:27
Notes Size(bytes)	4096
Type	True Logarithmic
Overwrite when full	Disabled
Scheduled Start Time	Manual Start
Scheduled Stop Time	No Stop Time
Max Interval	Days: 0 hrs: 00 mins: 02 secs: 00

Level Reference Settings At Log Creation

Level Measurement Mode	Level Depth To Water
Specific Gravity	0.999
Level Reference Mode:	Set new reference
Level Reference Value:	17.5 (ft)
Level Reference Head Pressure	7.57982 (PSI)
Head Pressure	7.58108 (PSI)
Temperature	53.3066 (F)
Depth of Probe	17.5045 (ft)

Log Notes:

Date and Time	Note
4/15/2009 12:27	Manual Start Command
4/15/2009 12:33	User Note: "Downloading log - Used Batt: 23% Memory: 6% User: WBerg"
4/15/2009 12:35	User Note: "Downloading log - Used Batt: 23% Memory: 6% User: WBerg"
4/15/2009 12:36	Manual Stop Command

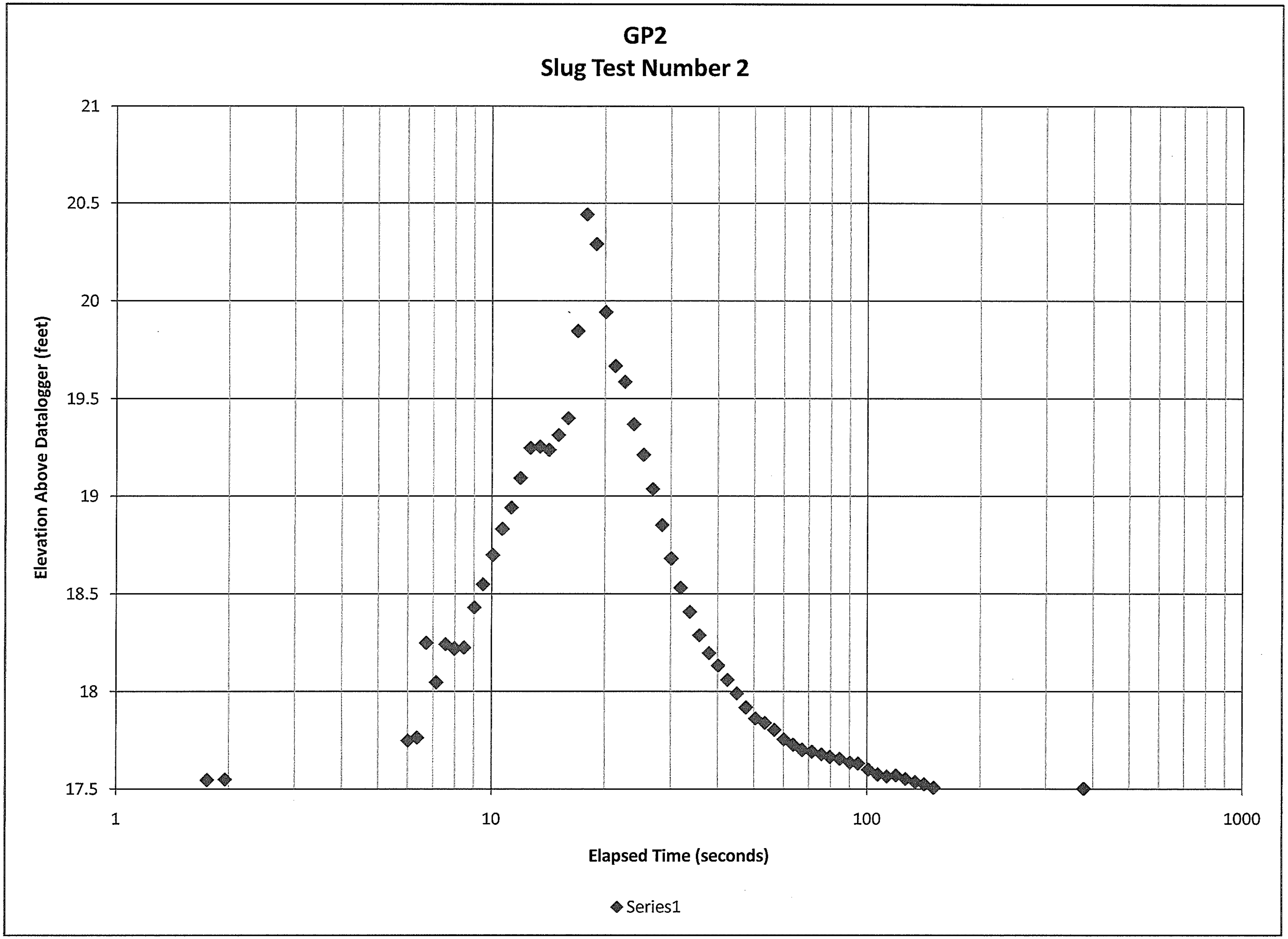
Log Data:

Record Count 102

Date and Time	Elapsed Time Seconds	Sensor: Pres 69ft SN#: 102501 Pressure (PSI)	Sensor: Pres 69ft SN#: 102501 Temperature (F)	Sensor: Pres 69ft SN#: 102501 Depth (ft)

4/15/2009 12:27	0	7.575	53.232	17.489
4/15/2009 12:27	0.25	7.575	53.268	17.488
4/15/2009 12:27	0.5	7.573	53.298	17.484
4/15/2009 12:27	0.75	7.576	53.313	17.491
4/15/2009 12:27	1	7.574	53.321	17.487
4/15/2009 12:27	1.25	7.575	53.34	17.49
4/15/2009 12:27	1.752	7.6	53.315	17.546
4/15/2009 12:27	1.955	7.601	53.343	17.55
4/15/2009 12:27	2.16	7.575	53.363	17.49
4/15/2009 12:27	2.363	7.573	53.38	17.485
4/15/2009 12:27	2.567	7.575	53.389	17.488
4/15/2009 12:27	2.779	7.575	53.401	17.488
4/15/2009 12:27	3	7.574	53.398	17.486
4/15/2009 12:27	3.25	7.573	53.399	17.485
4/15/2009 12:27	3.5	7.577	53.406	17.493
4/15/2009 12:27	3.75	7.571	53.404	17.481
4/15/2009 12:27	4	7.576	53.405	17.492
4/15/2009 12:27	4.25	7.574	53.41	17.487
4/15/2009 12:27	4.5	7.574	53.409	17.486
4/15/2009 12:27	4.75	7.572	53.418	17.483
4/15/2009 12:27	5	7.575	53.422	17.488
4/15/2009 12:27	5.25	7.573	53.415	17.484
4/15/2009 12:27	5.5	7.574	53.426	17.488
4/15/2009 12:27	5.75	7.576	53.419	17.491
4/15/2009 12:27	6	7.688	53.419	17.749
4/15/2009 12:27	6.36	7.695	53.405	17.765
4/15/2009 12:27	6.72	7.904	53.393	18.249
4/15/2009 12:27	7.14	7.817	53.38	18.047
4/15/2009 12:27	7.56	7.902	53.381	18.243
4/15/2009 12:27	7.98	7.891	53.373	18.219
4/15/2009 12:27	8.46	7.894	53.362	18.225
4/15/2009 12:27	9	7.983	53.358	18.431
4/15/2009 12:27	9.48	8.034	53.353	18.549
4/15/2009 12:27	10.08	8.099	53.346	18.699
4/15/2009 12:27	10.68	8.157	53.34	18.832
4/15/2009 12:27	11.28	8.204	53.337	18.941
4/15/2009 12:27	11.94	8.27	53.33	19.094
4/15/2009 12:27	12.66	8.336	53.33	19.247
4/15/2009 12:27	13.44	8.34	53.317	19.254
4/15/2009 12:27	14.22	8.332	53.321	19.238
4/15/2009 12:27	15.06	8.365	53.31	19.314
4/15/2009 12:27	15.96	8.403	53.311	19.401
4/15/2009 12:27	16.92	8.596	53.298	19.847
4/15/2009 12:27	17.88	8.855	53.302	20.444
4/15/2009 12:28	18.96	8.789	53.296	20.293
4/15/2009 12:28	20.1	8.638	53.302	19.944
4/15/2009 12:28	21.3	8.519	53.288	19.668
4/15/2009 12:28	22.56	8.484	53.288	19.587
4/15/2009 12:28	23.88	8.389	53.287	19.369
4/15/2009 12:28	25.32	8.321	53.279	19.212
4/15/2009 12:28	26.82	8.245	53.28	19.037
4/15/2009 12:28	28.38	8.166	53.275	18.852
4/15/2009 12:28	30.06	8.092	53.274	18.681
4/15/2009 12:28	31.86	8.026	53.287	18.531
4/15/2009 12:28	33.72	7.974	53.296	18.409
4/15/2009 12:28	35.76	7.921	53.279	18.288
4/15/2009 12:28	37.941	7.882	53.324	18.198

4/15/2009 12:28	40.08	7.854	53.273	18.133
4/15/2009 12:28	42.48	7.822	53.273	18.059
4/15/2009 12:28	45	7.792	53.272	17.991
4/15/2009 12:28	47.64	7.762	53.262	17.92
4/15/2009 12:28	50.46	7.737	53.261	17.863
4/15/2009 12:28	53.46	7.727	53.274	17.841
4/15/2009 12:28	56.64	7.712	53.255	17.804
4/15/2009 12:28	60	7.691	53.257	17.756
4/15/2009 12:28	63.6	7.678	53.269	17.728
4/15/2009 12:28	67.2	7.667	53.247	17.701
4/15/2009 12:28	71.4	7.663	53.245	17.692
4/15/2009 12:28	75.6	7.657	53.241	17.678
4/15/2009 12:29	79.8	7.652	53.246	17.666
4/15/2009 12:29	84.6	7.648	53.245	17.656
4/15/2009 12:29	90	7.639	53.239	17.636
4/15/2009 12:29	94.8	7.637	53.235	17.632
4/15/2009 12:29	100.8	7.623	53.232	17.601
4/15/2009 12:29	106.8	7.612	53.226	17.575
4/15/2009 12:29	112.8	7.608	53.22	17.565
4/15/2009 12:29	119.4	7.611	53.224	17.571
4/15/2009 12:29	126.6	7.603	53.219	17.554
4/15/2009 12:29	134.4	7.596	53.221	17.536
4/15/2009 12:30	142.2	7.591	53.203	17.526
4/15/2009 12:30	150.6	7.583	53.207	17.507
4/15/2009 12:30	159.6	7.578	53.208	17.495
4/15/2009 12:30	169.2	7.575	53.208	17.49
4/15/2009 12:30	178.8	7.57	53.203	17.477
4/15/2009 12:30	189.6	7.567	53.194	17.471
4/15/2009 12:31	201	7.56	53.184	17.455
4/15/2009 12:31	213.173	7.556	53.212	17.446
4/15/2009 12:31	225.6	7.552	53.175	17.437
4/15/2009 12:31	238.8	7.553	53.18	17.437
4/15/2009 12:31	253.2	7.547	53.196	17.425
4/15/2009 12:32	268.2	7.541	53.189	17.411
4/15/2009 12:32	283.8	7.536	53.175	17.398
4/15/2009 12:32	300.6	7.535	53.155	17.397
4/15/2009 12:32	318.6	7.542	53.167	17.412
4/15/2009 12:33	337.2	7.542	53.143	17.414
4/15/2009 12:33	357.6	7.56	53.138	17.454
4/15/2009 12:33	378.702	7.581	53.125	17.503
4/15/2009 12:34	400.8	7.544	53.133	17.416
4/15/2009 12:34	424.8	7.544	53.136	17.416
4/15/2009 12:35	450	7.537	53.126	17.401
4/15/2009 12:35	476.4	7.529	53.126	17.383
4/15/2009 12:36	504.709	7.525	53.166	17.373


GP2
Slug Test Number 2
21
20.5
20
19.5
19
18.5
18
17.5
Elevation Above Datalogger (feet)
1
10
100
1000
Elapsed Time (seconds)
Series1

Report Date:	4/15/2009 11:34	
Report User Name:	WBerg	
Report Computer Name:	WBERG01	

Log File Properties

File Name	Slug in 2009-04-15 11-33-19.wsl
Create Date	4/15/2009 11:34

Device Properties

Device	Level TROLL® 700
Site	GP3
Device Name	Geotech Rental # 1604
Serial Number	102501
Firmware Version	2.04

Log Configuration

Log Name	Slug in
Created By	WBerg
Computer Name	WBERG01
Application	WinSitu.exe
Application Version	5.6.4.6
Create Date	4/15/2009 11:17
Notes Size(bytes)	4096
Type	True Logarithmic
Overwrite when full	Disabled
Scheduled Start Time	Manual Start
Scheduled Stop Time	No Stop Time
Max Interval	Days: 0 hrs: 00 mins: 02 secs: 00

Level Reference Settings At Log Creation

Level Measurement Mode	Depth
Specific Gravity	0.999

Log Notes:

Date and Time	Note
4/15/2009 11:23	Manual Start Command
4/15/2009 11:33	User Note: "Downloading log - Used Batt: 23% Memory: 1% User: WBerg"
4/15/2009 11:33	Manual Stop Command

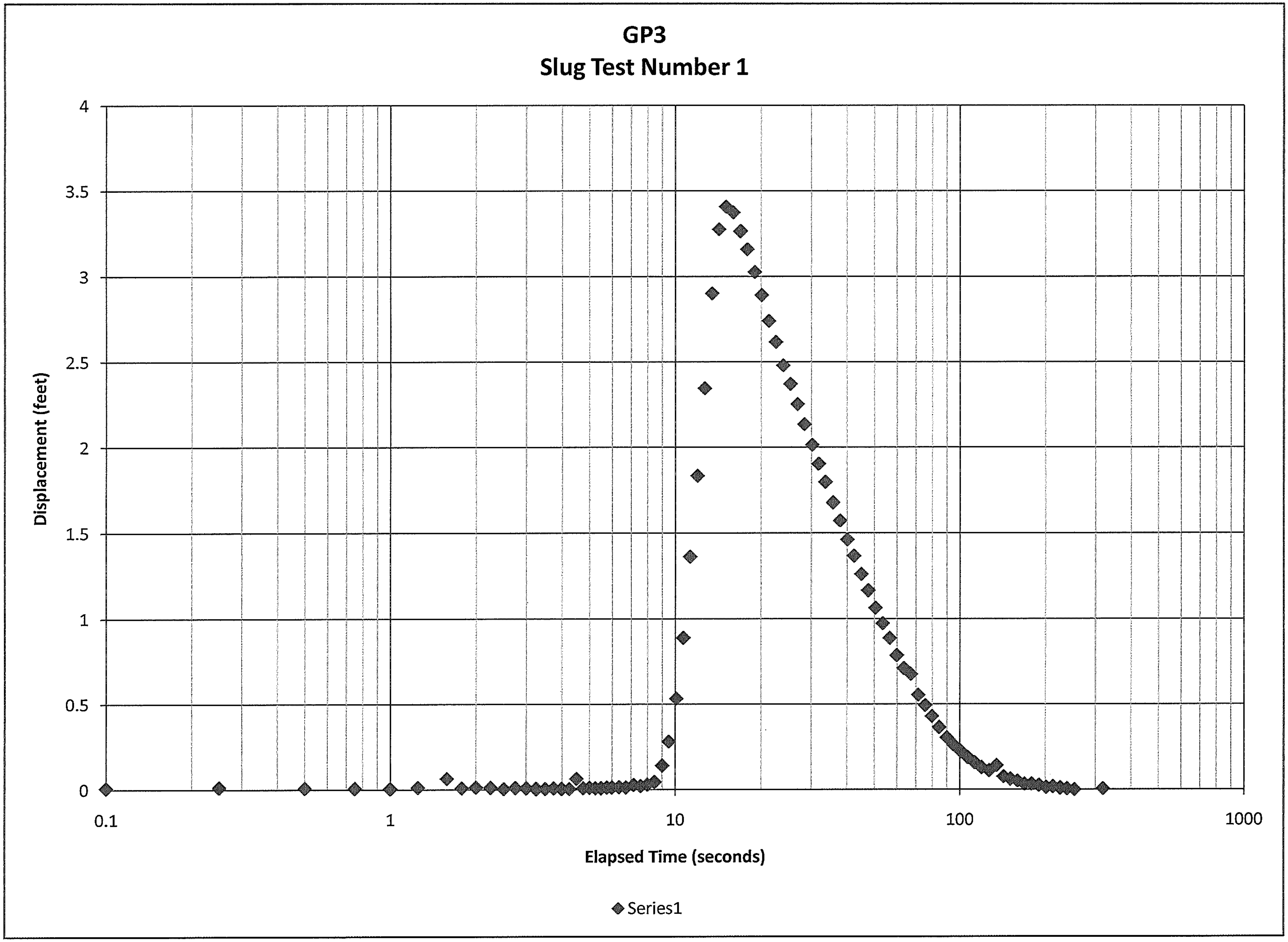
Log Data:

Record Count 105

Date and Time	Elapsed Time Seconds	Sensor: Pres 69ft SN#: 102501 Pressure (PSI)	Sensor: Pres 69ft SN#: 102501 Temperature (F)	Sensor: Pres 69ft SN#: 102501 Depth (ft)
4/15/2009 11:23	0	4.584	53.567	10.584
4/15/2009 11:23	0.25	4.581	53.603	10.578
4/15/2009 11:23	0.5	4.585	53.631	10.587
4/15/2009 11:23	0.75	4.583	53.647	10.582
4/15/2009 11:23	1	4.583	53.656	10.582
4/15/2009 11:23	1.25	4.583	53.674	10.583

4/15/2009 11:23	1.5	4.585	53.681	10.586
4/15/2009 11:23	1.75	4.588	53.692	10.593
4/15/2009 11:23	2	4.583	53.698	10.583
4/15/2009 11:23	2.25	4.583	53.703	10.582
4/15/2009 11:23	2.5	4.581	53.716	10.577
4/15/2009 11:23	2.75	4.582	53.712	10.58
4/15/2009 11:23	3	4.582	53.714	10.58
4/15/2009 11:23	3.25	4.582	53.718	10.58
4/15/2009 11:23	3.5	4.584	53.722	10.583
4/15/2009 11:23	3.75	4.582	53.724	10.579
4/15/2009 11:23	4	4.584	53.728	10.584
4/15/2009 11:23	4.25	4.583	53.728	10.582
4/15/2009 11:23	4.5	4.582	53.732	10.58
4/15/2009 11:23	4.75	4.58	53.738	10.575
4/15/2009 11:23	5	4.581	53.744	10.578
4/15/2009 11:23	5.25	4.582	53.743	10.58
4/15/2009 11:23	5.5	4.582	53.739	10.58
4/15/2009 11:23	5.75	4.581	53.742	10.578
4/15/2009 11:23	6	4.583	53.745	10.583
4/15/2009 11:23	6.36	4.583	53.725	10.582
4/15/2009 11:23	6.72	4.604	53.71	10.63
4/15/2009 11:23	7.14	4.582	53.703	10.579
4/15/2009 11:23	7.56	4.581	53.705	10.578
4/15/2009 11:23	7.98	4.581	53.691	10.578
4/15/2009 11:23	8.46	4.584	53.686	10.585
4/15/2009 11:23	9	4.582	53.671	10.58
4/15/2009 11:23	9.48	4.582	53.671	10.58
4/15/2009 11:23	10.08	4.581	53.661	10.577
4/15/2009 11:23	10.68	4.582	53.654	10.58
4/15/2009 11:23	11.28	4.585	53.652	10.586
4/15/2009 11:23	11.943	4.593	53.641	10.605
4/15/2009 11:23	12.66	4.587	53.631	10.592
4/15/2009 11:23	13.44	4.593	53.622	10.606
4/15/2009 11:23	14.22	4.792	53.624	11.065
4/15/2009 11:23	15.06	4.903	53.614	11.321
4/15/2009 11:23	15.96	5.286	53.606	12.206
4/15/2009 11:23	16.92	5.42	53.601	12.514
4/15/2009 11:23	17.88	5.626	53.591	12.99
4/15/2009 11:23	18.96	5.807	53.588	13.408
4/15/2009 11:23	20.1	5.926	53.584	13.682
4/15/2009 11:23	21.3	5.935	53.579	13.704
4/15/2009 11:23	22.56	5.864	53.568	13.539
4/15/2009 11:23	23.88	5.795	53.569	13.38
4/15/2009 11:23	25.32	5.718	53.554	13.203
4/15/2009 11:23	26.82	5.651	53.551	13.048
4/15/2009 11:23	28.38	5.588	53.548	12.901
4/15/2009 11:23	30.06	5.523	53.588	12.753
4/15/2009 11:23	31.86	5.461	53.544	12.609
4/15/2009 11:24	33.72	5.402	53.546	12.473
4/15/2009 11:24	35.76	5.343	53.529	12.336
4/15/2009 11:24	38.027	5.283	53.545	12.197
4/15/2009 11:24	40.08	5.231	53.516	12.078
4/15/2009 11:24	42.634	5.171	53.535	11.94
4/15/2009 11:24	45	5.122	53.508	11.826
4/15/2009 11:24	47.64	5.071	53.523	11.708
4/15/2009 11:24	50.46	5.048	53.485	11.656

4/15/2009 11:24	53.46	4.978	53.487	11.493
4/15/2009 11:24	56.64	4.935	53.466	11.394
4/15/2009 11:24	60	4.894	53.461	11.301
4/15/2009 11:24	63.601	4.858	53.46	11.217
4/15/2009 11:24	67.2	4.824	53.435	11.138
4/15/2009 11:24	71.4	4.792	53.427	11.064
4/15/2009 11:24	75.6	4.764	53.422	10.999
4/15/2009 11:24	79.8	4.739	53.41	10.942
4/15/2009 11:24	84.6	4.716	53.414	10.889
4/15/2009 11:24	90	4.694	53.389	10.839
4/15/2009 11:25	94.8	4.679	53.381	10.803
4/15/2009 11:25	100.8	4.662	53.357	10.765
4/15/2009 11:25	106.8	4.647	53.346	10.73
4/15/2009 11:25	112.911	4.635	53.354	10.703
4/15/2009 11:25	119.399	4.623	53.324	10.674
4/15/2009 11:25	126.6	4.615	53.302	10.655
4/15/2009 11:25	134.399	4.606	53.29	10.635
4/15/2009 11:25	142.199	4.603	53.268	10.629
4/15/2009 11:25	150.6	4.593	53.251	10.606
4/15/2009 11:26	159.6	4.589	53.238	10.596
4/15/2009 11:26	169.199	4.585	53.222	10.587
4/15/2009 11:26	178.8	4.582	53.211	10.58
4/15/2009 11:26	189.599	4.579	53.187	10.572
4/15/2009 11:26	201	4.576	53.166	10.565
4/15/2009 11:26	213	4.575	53.163	10.563
4/15/2009 11:27	225.599	4.572	53.121	10.556
4/15/2009 11:27	238.8	4.57	53.104	10.553
4/15/2009 11:27	253.199	4.566	53.091	10.544
4/15/2009 11:27	268.199	4.565	53.077	10.54
4/15/2009 11:28	283.799	4.564	53.051	10.537
4/15/2009 11:28	300.599	4.562	53.014	10.534
4/15/2009 11:28	318.599	4.559	53.002	10.528
4/15/2009 11:29	337.199	4.559	52.965	10.527
4/15/2009 11:29	357.599	4.557	52.979	10.522
4/15/2009 11:29	378.599	4.553	52.931	10.513
4/15/2009 11:30	400.799	4.553	52.9	10.512
4/15/2009 11:30	424.799	4.55	52.878	10.507
4/15/2009 11:30	450.002	4.548	52.856	10.5
4/15/2009 11:31	476.399	4.549	52.825	10.503
4/15/2009 11:31	504.599	4.543	52.807	10.491
4/15/2009 11:32	534.599	4.545	52.79	10.493
4/15/2009 11:32	566.399	4.548	52.758	10.502
4/15/2009 11:33	599.999	4.541	52.723	10.485


GP3
Slug Test Number 1
Displacement (feet)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
1
10
100
1000
Elapsed Time (seconds)
Series1

Report Date:		4/15/2009 11:47
Report User Name:	WBerg	
Report Computer Name:	WBERG01	

Log File Properties

File Name	Slug in 2 2009-04-15 11-46-22.wsl	
Create Date		4/15/2009 11:47

Device Properties

Device	Level TROLL® 700	
Site	GP3	
Device Name	Geotech Rental # 1604	
Serial Number		102501
Firmware Version		2.04

Log Configuration

Log Name	Slug in 2
Created By	WBerg
Computer Name	WBERG01
Application	WinSitu.exe
Application Version	5.6.4.6
Create Date	4/15/2009 11:38
Notes Size(bytes)	4096
Type	True Logarithmic
Overwrite when full	Disabled
Scheduled Start Time	Manual Start
Scheduled Stop Time	No Stop Time
Max Interval	Days: 0 hrs: 00 mins: 02 secs: 00

Level Reference Settings At Log Creation

Level Measurement Mode	Level Depth To Water
Specific Gravity	0.999
Level Reference Mode:	Set new reference
Level Reference Value:	10.425 (ft)
Level Reference Head Pressure	4.51603 (PSI)
Head Pressure	4.51702 (PSI)
Temperature	52.65 (F)
Depth of Probe	10.4297 (ft)

Log Notes:

Date and Time	Note
4/15/2009 11:38	Manual Start Command
4/15/2009 11:46	User Note: "Downloading log - Used Batt: 23% Memory: 3% User: WBerg"
4/15/2009 11:46	Manual Stop Command

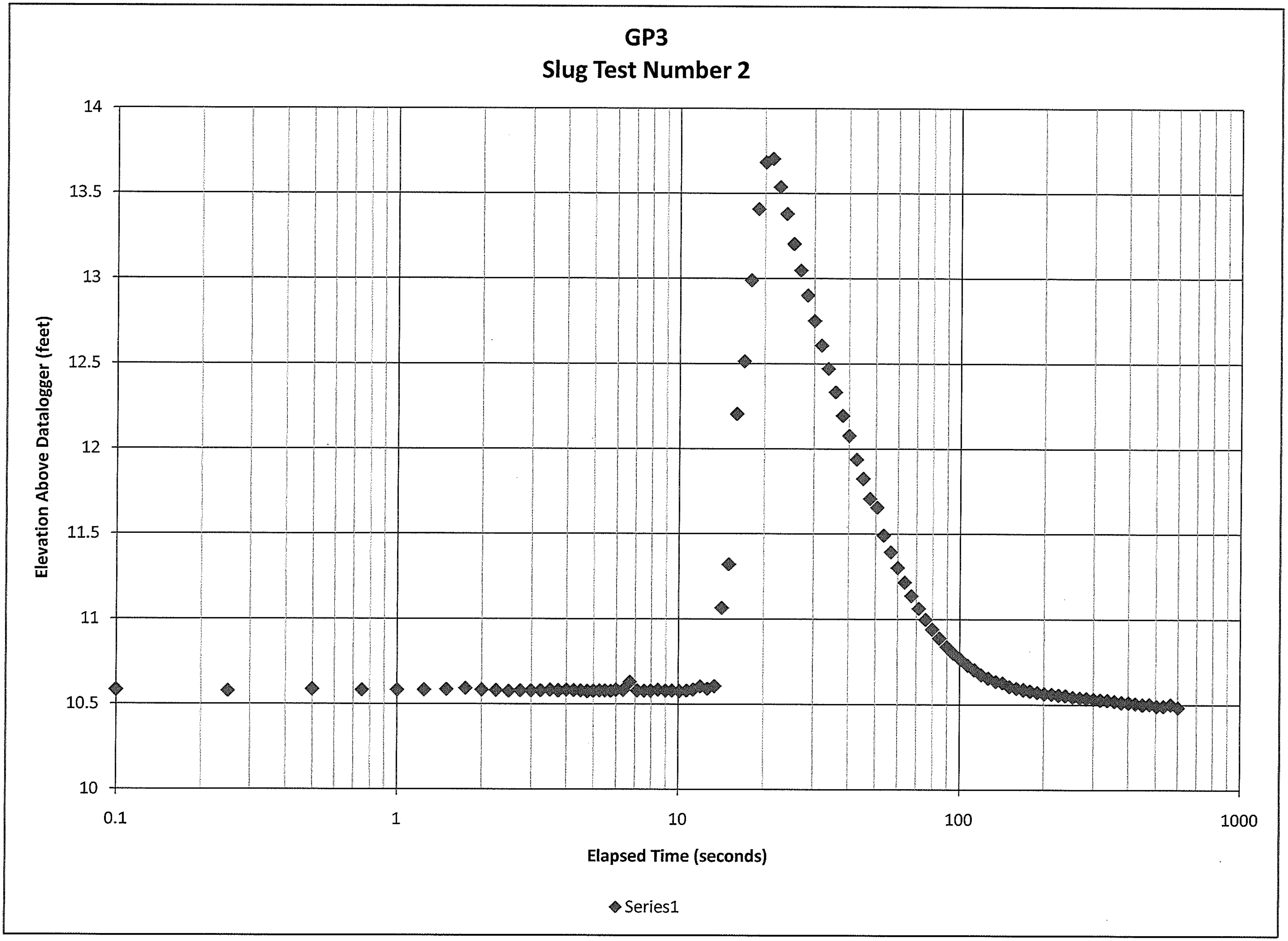
Log Data:

Record Count 101

Date and Time	Elapsed Time Seconds	Sensor: Pres 69ft SN#: 102501 Pressure (PSI)	Sensor: Pres 69ft SN#: 102501 Temperature (F)	Sensor: Pres 69ft SN#: 102501 Displacement (ft)
4/15/2009 11:38	0	4.52	52.577	0.01

4/15/2009 11:38	0.25	4.522	52.616	0.013
4/15/2009 11:38	0.5	4.52	52.642	0.01
4/15/2009 11:38	0.75	4.52	52.66	0.008
4/15/2009 11:38	1	4.519	52.675	0.006
4/15/2009 11:38	1.25	4.522	52.683	0.014
4/15/2009 11:38	1.578	4.544	52.679	0.065
4/15/2009 11:38	1.783	4.521	52.706	0.011
4/15/2009 11:38	2	4.523	52.72	0.015
4/15/2009 11:38	2.25	4.521	52.731	0.012
4/15/2009 11:38	2.5	4.519	52.727	0.006
4/15/2009 11:38	2.75	4.521	52.734	0.011
4/15/2009 11:38	3	4.521	52.733	0.01
4/15/2009 11:38	3.25	4.518	52.741	0.005
4/15/2009 11:38	3.5	4.519	52.746	0.006
4/15/2009 11:38	3.75	4.52	52.75	0.009
4/15/2009 11:38	4	4.518	52.752	0.006
4/15/2009 11:38	4.25	4.519	52.755	0.006
4/15/2009 11:38	4.5	4.544	52.754	0.064
4/15/2009 11:38	4.75	4.521	52.759	0.011
4/15/2009 11:38	5	4.521	52.765	0.011
4/15/2009 11:38	5.25	4.52	52.762	0.009
4/15/2009 11:38	5.5	4.52	52.764	0.009
4/15/2009 11:38	5.75	4.522	52.765	0.013
4/15/2009 11:38	6	4.522	52.771	0.014
4/15/2009 11:38	6.36	4.523	52.754	0.016
4/15/2009 11:38	6.72	4.522	52.748	0.013
4/15/2009 11:38	7.14	4.528	52.73	0.028
4/15/2009 11:38	7.56	4.526	52.725	0.022
4/15/2009 11:38	7.98	4.529	52.72	0.029
4/15/2009 11:38	8.46	4.536	52.715	0.045
4/15/2009 11:38	9	4.577	52.706	0.141
4/15/2009 11:38	9.48	4.638	52.707	0.282
4/15/2009 11:38	10.08	4.748	52.695	0.535
4/15/2009 11:38	10.68	4.902	52.694	0.891
4/15/2009 11:38	11.28	5.106	52.686	1.362
4/15/2009 11:38	11.94	5.31	52.681	1.834
4/15/2009 11:38	12.66	5.532	52.669	2.346
4/15/2009 11:38	13.44	5.773	52.669	2.902
4/15/2009 11:38	14.22	5.936	52.66	3.278
4/15/2009 11:38	15.06	5.992	52.662	3.408
4/15/2009 11:38	15.96	5.978	52.658	3.375
4/15/2009 11:38	16.92	5.93	52.655	3.265
4/15/2009 11:38	17.88	5.885	52.648	3.16
4/15/2009 11:38	18.96	5.827	52.651	3.027
4/15/2009 11:38	20.1	5.768	52.646	2.892
4/15/2009 11:38	21.3	5.703	52.638	2.741
4/15/2009 11:38	22.56	5.65	52.637	2.618
4/15/2009 11:38	23.88	5.591	52.663	2.481
4/15/2009 11:38	25.32	5.543	52.668	2.371
4/15/2009 11:38	26.82	5.492	52.641	2.252
4/15/2009 11:38	28.38	5.441	52.64	2.135
4/15/2009 11:38	30.216	5.388	52.67	2.014
4/15/2009 11:39	31.86	5.341	52.637	1.904
4/15/2009 11:39	33.72	5.295	52.632	1.799
4/15/2009 11:39	35.76	5.243	52.641	1.678
4/15/2009 11:39	37.86	5.197	52.631	1.573
4/15/2009 11:39	40.215	5.149	52.661	1.462

4/15/2009 11:39	42.48	5.108	52.622	1.367
4/15/2009 11:39	45	5.063	52.675	1.262
4/15/2009 11:39	47.64	5.021	52.618	1.166
4/15/2009 11:39	50.46	4.977	52.639	1.064
4/15/2009 11:39	53.46	4.938	52.615	0.974
4/15/2009 11:39	56.64	4.901	52.619	0.888
4/15/2009 11:39	60	4.858	52.659	0.788
4/15/2009 11:39	63.6	4.825	52.606	0.713
4/15/2009 11:39	67.2	4.81	52.61	0.678
4/15/2009 11:39	71.4	4.756	52.614	0.554
4/15/2009 11:39	75.6	4.73	52.619	0.494
4/15/2009 11:39	79.801	4.702	52.595	0.429
4/15/2009 11:39	84.6	4.674	52.596	0.364
4/15/2009 11:39	90	4.648	52.643	0.304
4/15/2009 11:40	94.8	4.63	52.596	0.264
4/15/2009 11:40	100.8	4.612	52.608	0.223
4/15/2009 11:40	106.8	4.597	52.592	0.188
4/15/2009 11:40	112.8	4.585	52.584	0.158
4/15/2009 11:40	119.4	4.571	52.585	0.128
4/15/2009 11:40	126.6	4.564	52.586	0.111
4/15/2009 11:40	134.409	4.577	52.572	0.142
4/15/2009 11:40	142.2	4.549	52.574	0.076
4/15/2009 11:41	150.6	4.543	52.587	0.062
4/15/2009 11:41	159.6	4.539	52.564	0.052
4/15/2009 11:41	169.2	4.531	52.564	0.034
4/15/2009 11:41	178.8	4.53	52.558	0.033
4/15/2009 11:41	189.6	4.527	52.552	0.025
4/15/2009 11:41	201	4.522	52.566	0.014
4/15/2009 11:42	213	4.523	52.547	0.017
4/15/2009 11:42	225.6	4.52	52.564	0.009
4/15/2009 11:42	238.8	4.518	52.542	0.005
4/15/2009 11:42	253.2	4.517	52.538	0.001
4/15/2009 11:42	268.2	4.515	52.536	-0.002
4/15/2009 11:43	283.8	4.514	52.53	-0.006
4/15/2009 11:43	300.6	4.512	52.546	-0.009
4/15/2009 11:43	318.6	4.519	52.531	0.006
4/15/2009 11:44	337.2	4.508	52.524	-0.018
4/15/2009 11:44	357.6	4.508	52.515	-0.02
4/15/2009 11:44	378.6	4.505	52.515	-0.025
4/15/2009 11:45	400.8	4.504	52.521	-0.028
4/15/2009 11:45	424.8	4.501	52.501	-0.034
4/15/2009 11:45	450.02	4.5	52.55	-0.037
4/15/2009 11:46	476.4	4.498	52.489	-0.041



GP3
Slug Test Number 2
Elevation Above Datalogger (feet)
14
13.5
13
12.5
12
11.5
11
10.5
10
0.1
1
10
100
1000
Elapsed Time (seconds)
Series1

APPENDIX F

LABORATORY DATA REPORTS

Appendix F
Laboratory Hydraulic Testing Summary
Upper Big Sandy Designated Ground Water Basin
Phase 2 Water Balance

Location	Pressure Head (-cm water)	Pressure Head (-bars)	Moisture Content (%, g/g)
GP2	0	0	8.5
	7139	7.1	3.1
	17439	17.3	2.0
	51806	51.4	1.5
	94433	93.7	1.3
		834.8	1.3
GP28	0	0	12.6
	5303	5.3	2.8
	18560	18.4	2.0
	56293	55.9	1.4
	100552	99.8	1.3
		834.8	1.2
GP41	0	0	16.3
	6731	6.7	3.2
	23149	23.0	2.4
	45789	45.5	2.1
	88825	88.2	1.8
		834.8	
GP49	0	0	11.2
	5056	5.0	2.0
	20396	20.2	1.3
	48135	47.8	1.1
	104020	103.3	1.0
		834.8	0.7

Conversion from -cm water to -bars = divide by 1007.37bars/cm water

Laboratory Report for
Martin and Wood Water Consultants
(694.4 Upper Big Sandy)

April 1, 2009

Daniel B. Stephens & Associates, Inc.

6020 Academy NE, Suite 100 • Albuquerque, New Mexico 87109

April 1, 2009

Mr. Bill Berg
Martin and Wood Water Consultants
602 Park Point Dr., Suite
Golden, CO 80401-7605
(303) 526-2600

Re: DBS&A Laboratory Report for Martin and Wood Water Consultants 694.4 Upper Big Sandy

Dear Mr. Berg:

Enclosed is the final report for the Martin and Wood Water Consultants 694.4 Upper Big Sandy samples. Please review this report and provide any comments as samples will be held for a maximum of 30 days. After 30 days samples will be returned or disposed of in an appropriate manner.

All testing results were evaluated subjectively for consistency and reasonableness, and the results appear to be reasonably representative of the material tested. However, DBS&A does not assume any responsibility for interpretations or analyses based on the data enclosed, nor can we guarantee that these data are fully representative of the undisturbed materials at the field site. We recommend that careful evaluation of these laboratory results be made for your particular application.

The testing utilized to generate the enclosed final report employs methods that are standard for the industry. The results do not constitute a professional opinion by DBS&A, nor can the results affect any professional or expert opinions rendered with respect thereto by DBS&A. You have acknowledged that all the testing undertaken by us, and the final report provided, constitutes mere test results using standardized methods, and cannot be used to disqualify DBS&A from rendering any professional or expert opinion, having waived any claim of conflict of interest by DBS&A.

We are pleased to provide this service to Martin and Wood Water Consultants and look forward to future laboratory testing on other projects. If you have any questions about the enclosed data, please do not hesitate to call.

Sincerely,

DANIEL B. STEPHENS & ASSOCIATES, INC.
LABORATORY / TESTING FACILITY

Joleen Hines
Laboratory Supervising Manager

Enclosure

Daniel B. Stephens & Associates, Inc.
Soil Testing & Research Laboratory
5840 Osuna Rd. NE 505-889-7752
Albuquerque, NM 87109 FAX 505-889-0258

Summaries

Summary of Tests Performed

Laboratory Sample Number	Initial Soil Properties[1]		Saturated Hydraulic Conductivity[2]			Moisture Characteristics[3]								Particle Size[4]			Specific Gravity[5]		Air Perm-eability	Specific Yield	Proctor Compaction
	VM	VD	CH	FH	FW	HC	PP	FP	DPP	RH	EP	WHC	K_{unsat}	DS	WS	H	F	C			
GP2	X		X																	X	
GP3	X		X																	X	
GP28	X																			X	
GP38	X																			X	
GP41	X																			X	
GP49	X																			X	
GP52	X																			X	
GP61	X																			X	

[1] VM = Volume Measurement Method, VD = Volume Displacement Method

[2] CH = Constant Head Rigid Wall, FH = Falling Head Rigid Wall, FW = Falling Head Rising Tail Flexible Wall

[3] HC = Hanging Column, PP = Pressure Plate, FP = Filter Paper, DPP = Dew Point Potentiometer, RH = Relative Humidity Box, EP = Effective Porosity, WHC = Water Holding Capacity, Kunsat = Calculated Unsaturated Hydraulic Conductivity

[4] DS = Dry Sieve, WS = Wet Sieve, H = Hydrometer

[5] F = Fine (<4.75mm), C = Coarse (>4.75mm)

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity

	Moisture Content						
	As Received		Remolded		Dry Bulk	Wet Bulk	Calculated
Sample Number	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)	Density (g/cm^3)	Density (g/cm^3)	Porosity (%)
GP2	8.5	16.6	—	—	1.95	2.12	26.4
GP3	12.5	23.9	—	—	1.90	2.14	28.2
GP28	12.6	19.8	—	—	1.58	1.78	40.5
GP38	26.9	39.2	—	—	1.45	1.85	45.1
GP41	16.3	29.2	—	—	1.79	2.09	32.3
GP49	11.2	15.2	—	—	1.35	1.51	48.9
GP52	23.7	37.5	—	—	1.58	1.95	40.4
GP61	14.6	25.5	—	—	1.75	2.01	33.9

NA = Not analyzed
— = This sample was not remolded

Summary of Specific Yield

	Sample Number		Total Porosity[1] (% cm³/cm³)	Moisture Content at -834.8 bars[2] (% cm³/cm³)	Specific Yield[3] (% cm³/cm³)
Limon	GP2	mainstem	26.4	1.3	25.1
Limon	GP3	tributary	28.2	2.3	25.8
Matheson	GP28	mainstem	40.5	1.2	39.3
Ramah	GP38	mainstem	45.1	4.0	41.1
Ramah	GP41	tributary	32.3	7.2	25.2
Calhan	GP49	tributary	48.9	0.7	48.2
Calhan	GP52	mainstem	40.4	1.7	38.7
Calhan	GP61	tributary	33.9	0.9	33.0

[1] Calculated total porosity assumed to be equal to saturated moisture content.
[2] Moisture content at -834.8 bars is used to define residual moisture content.
[3] Specific Yield defined as difference between saturated moisture content and residual moisture content.

Daniel B. Stephens & Associates, Inc.

Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Oversize Corrected K_{sat} (cm/sec)	Method of Analysis: Constant Head	Method of Analysis: Falling Head
GP2	4.1E-03	NA	X	
GP3	1.1E-02	NA	X	

$\frac{0\ 041\ \text{cm}}{\text{sec}} \times \frac{1\ \text{ft}}{30.48\ \text{cm}} \times \frac{86400\ \text{sec}}{\text{day}} = 11.62\ \text{ft/day}$ GP2

$\frac{.011\ \text{cm}}{\text{sec}} \times \frac{1\ \text{ft}}{30.48\ \text{cm}} \times \frac{86400\ \text{sec}}{\text{day}} = 31.18\ \text{ft/day}$ GP3

864 cm/d = 340.2"/d = 28.3'

Laboratory Data and Graphical Plots

Initial Properties and Specific Yield

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity

Sample Number	Moisture Content: As Received Gravimetric (%, g/g)	Moisture Content: As Received Volumetric (%, cm^3/cm^3)	Moisture Content: Remolded Gravimetric (%, g/g)	Moisture Content: Remolded Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
GP2	8.5	16.6	—	—	1.95	2.12	26.4
GP3	12.5	23.9	—	—	1.90	2.14	28.2
GP28	12.6	19.8	—	—	1.58	1.78	40.5
GP38	26.9	39.2	—	—	1.45	1.85	45.1
GP41	16.3	29.2	—	—	1.79	2.09	32.3
GP49	11.2	15.2	—	—	1.35	1.51	48.9
GP52	23.7	37.5	—	—	1.58	1.95	40.4
GP61	14.6	25.5	—	—	1.75	2.01	33.9

NA = Not analyzed
— = This sample was not remolded

Summary of Specific Yield

Sample Number	Total Porosity[1] (% cm^3/cm^3)	Moisture Content at -834.8 bars[2] (% cm^3/cm^3)	Specific Yield[3] (% cm^3/cm^3)
GP2	26.4	1.3	25.1
GP3	28.2	2.3	25.8
GP28	40.5	1.2	39.3
GP38	45.1	4.0	41.1
GP41	32.3	7.2	25.2
GP49	48.9	0.7	48.2
GP52	40.4	1.7	38.7
GP61	33.9	0.9	33.0

[1] Calculated total porosity assumed to be equal to saturated moisture content.
[2] Moisture content at -834.8 bars is used to define residual moisture content.
[3] Specific Yield defined as difference between saturated moisture content and residual moisture content.

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP2
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA

	As Received	Remolded
Test Date:	5-Mar-09	---
Field weight of sample* (g):	801.90	
Tare weight, ring (g):	188.21	
Tare weight, pan/plate (g):	0.00	
Tare weight, other (g):	0.00	
Dry weight of sample (g):	565.59	
Sample volume (cm^3):	290.04	
Assumed particle density (g/cm^3):	2.65	

Gravimetric Moisture Content (% g/g):	8.5	
Volumetric Moisture Content (% vol):	16.6	
Dry bulk density (g/cm^3):	1.95	
Wet bulk density (g/cm^3):	2.12	
Calculated Porosity (% vol):	26.4	
Percent Saturation:	62.8	

Laboratory analysis by:	K. Wright/ R. Marshall
Data entered by:	R. Marshall
Checked by:	J. Hines

Comments:

* Weight including tares

NA = Not analyzed

--- = This sample was not remolded

Moisture Retention (Specific Yield)

Job Name: Martin and Wood Water Consultants
Job Number: LB09.0055.00
Sample Number: GP2
Project Number and Name: 694.4 Upper Big Sandy
Depth: NA

Test Date: 9-Mar-09

Calculated Porosity (% cm^3/cm^3): 26.4
Bulk Density (g/cm^3): 1.95

Relative Humidity Chamber Data

*Sample Dry Weight** (g):	100.69
Tare Weight (g):	40.00
Relative Humidity Chamber Potential (-bars):	834.8
Sample weight at -834.8 bars (g):*	101.1
Moisture content (% g/g):	0.7
Moisture content (% cm^3/cm^3):	1.3

Saturated Moisture Content (θ_S) (Total Porosity) **(% cm^3/cm^3):**	**26.4**
Residual Mositure Content (θ_R) (-834.8 bars) **(% cm^3/cm^3):**	**1.3**
Specific Yield (θ_S - θ_R) **(% cm^3/cm^3):**	**25.1**

Comments:

* Weight including tares

Laboratory analysis by: D. O'Dowd
Data entered by: C. Krous
Checked by: J. Hines

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP3
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA

	As Received	Remolded
Test Date:	5-Mar-09	---
Field weight of sample* (g):	950.60	
Tare weight, ring (g):	233.63	
Tare weight, pan/plate (g):	0.00	
Tare weight, other (g):	0.00	
Dry weight of sample (g):	637.08	
Sample volume (cm^3):	334.68	
Assumed particle density (g/cm^3):	2.65	

Gravimetric Moisture Content (% g/g):	12.5	
Volumetric Moisture Content (% vol):	23.9	
Dry bulk density (g/cm^3):	1.90	
Wet bulk density (g/cm^3):	2.14	
Calculated Porosity (% vol):	28.2	
Percent Saturation:	84.7	

Laboratory analysis by: K. Wright/ R. Marshall
Data entered by: R. Marshall
Checked by: J. Hines

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded

Moisture Retention (Specific Yield)

Job Name: Martin and Wood Water Consultants
Job Number: LB09.0055.00
Sample Number: GP3
Project Number and Name: 694.4 Upper Big Sandy
Depth: NA

Test Date: 9-Mar-09

Calculated Porosity (% cm^3/cm^3): 28.2
Bulk Density (g/cm^3): 1.90

Relative Humidity Chamber Data

*Sample Dry Weight** (g):	85.90
Tare Weight (g):	41.72
Relative Humidity Chamber Potential (-bars):	834.8
Sample weight at -834.8 bars (g):*	86.4
Moisture content (% g/g):	1.2
Moisture content (% cm^3/cm^3):	2.3

Saturated Moisture Content **(θ_S)** ***(Total Porosity)*** **(% cm^3/cm^3):**	**28.2**
Residual Mositure Content (θ_R) (-834.8 bars) **(% cm^3/cm^3):**	**2.3**
Specific Yield (θ_S - θ_R) **(% cm^3/cm^3):**	**25.8**

Comments:

* Weight including tares

Laboratory analysis by: D. O'Dowd
Data entered by: C. Krous
Checked by: J. Hines

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP28
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA

	As Received	Remolded
Test Date:	30-Mar-09	---
Field weight of sample* (g):	987.20	
Tare weight, ring (g):	214.63	
Tare weight, pan/plate (g):	208.00	
Tare weight, other (g):	0.00	
Dry weight of sample (g):	501.47	
Sample volume (cm^3):	318.06	
Assumed particle density (g/cm^3):	2.65	

Gravimetric Moisture Content (% g/g):	12.6	
Volumetric Moisture Content (% vol):	19.8	
Dry bulk density (g/cm^3):	1.58	
Wet bulk density (g/cm^3):	1.78	
Calculated Porosity (% vol):	40.5	
Percent Saturation:	49.0	

Laboratory analysis by: D. O'Dowd/R. Marshall
Data entered by: R. Marshall
Checked by: J. Hines

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded

Moisture Retention (Specific Yield)

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP28
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA
Test Date:	9-Mar-09

Calculated Porosity (% cm^3/cm^3):	40.5
Bulk Density (g/cm^3):	1.58

Relative Humidity Chamber Data

*Sample Dry Weight** (g):	75.24
Tare Weight (g):	44.95
Relative Humidity Chamber Potential (-bars):	834.8
Sample weight at -834.8 bars (g):*	75.5
Moisture content (% g/g):	0.8
Moisture content (% cm^3/cm^3):	1.2

Saturated Moisture Content **(θ_S)** ***(Total Porosity)*** **(% cm^3/cm^3):**	**40.5**
Residual Mositure Content (θ_R) (-834.8 bars) **(% cm^3/cm^3):**	**1.2**
Specific Yield (θ_S - θ_R) **(% cm^3/cm^3):**	**39.3**

Comments:

* Weight including tares

Laboratory analysis by:	D. O'Dowd
Data entered by:	C. Krous
Checked by:	J. Hines

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP38
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA

	As Received	Remolded
Test Date:	30-Mar-09	---
Field weight of sample* (g):	1002.80	
Tare weight, ring (g):	210.46	
Tare weight, pan/plate (g):	212.65	
Tare weight, other (g):	0.00	
Dry weight of sample (g):	456.69	
Sample volume (cm^3):	314.15	
Assumed particle density (g/cm^3):	2.65	

Gravimetric Moisture Content (% g/g):	26.9	
Volumetric Moisture Content (% vol):	39.2	
Dry bulk density (g/cm^3):	1.45	
Wet bulk density (g/cm^3):	1.85	
Calculated Porosity (% vol):	45.1	
Percent Saturation:	86.7	

Laboratory analysis by: D. O'Dowd/R. Marshall
Data entered by: R. Marshall
Checked by: J. Hines

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded

Moisture Retention (Specific Yield)

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP38
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA
Test Date:	9-Mar-09

Calculated Porosity (% cm^3/cm^3):	45.1
Bulk Density (g/cm^3):	1.45

Relative Humidity Chamber Data

*Sample Dry Weight** (g):	75.96
Tare Weight (g):	36.51
Relative Humidity Chamber Potential (-bars):	834.8
Sample weight at -834.8 bars (g):*	77.1
Moisture content (% g/g):	2.8
Moisture content (% cm^3/cm^3):	4.0

Saturated Moisture Content **(θ_S)** ***(Total Porosity)*** **(% cm^3/cm^3):**	**45.1**
Residual Mositure Content **(θ_R)** ***(-834.8 bars)*** **(% cm^3/cm^3):**	**4.0**
Specific Yield **($\theta_S - \theta_R$)** **(% cm^3/cm^3):**	**41.1**

Comments:

* Weight including tares

Laboratory analysis by:	D. O'Dowd
Data entered by:	C. Krous
Checked by:	J. Hines

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP41
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA

	As Received	Remolded
Test Date:	30-Mar-09	---
Field weight of sample* (g):	1075.80	
Tare weight, ring (g):	213.06	
Tare weight, pan/plate (g):	209.67	
Tare weight, other (g):	0.00	
Dry weight of sample (g):	561.67	
Sample volume (cm^3):	313.20	
Assumed particle density (g/cm^3):	2.65	
Gravimetric Moisture Content (% g/g):	16.3	
Volumetric Moisture Content (% vol):	29.2	
Dry bulk density (g/cm^3):	1.79	
Wet bulk density (g/cm^3):	2.09	
Calculated Porosity (% vol):	32.3	
Percent Saturation:	90.3	

Laboratory analysis by:	D. O'Dowd/R. Marshall
Data entered by:	R. Marshall
Checked by:	J. Hines

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded

Moisture Retention (Specific Yield)

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP41
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA
Test Date:	9-Mar-09

Calculated Porosity (% cm^3/cm^3):	32.3
Bulk Density (g/cm^3):	1.79

Relative Humidity Chamber Data

*Sample Dry Weight** (g):	63.03
Tare Weight (g):	40.74
Relative Humidity Chamber Potential (-bars):	834.8
Sample weight at -834.8 bars (g):*	63.9
Moisture content (% g/g):	4.0
Moisture content (% cm^3/cm^3):	7.2

Saturated Moisture Content **(θ_S) *(Total Porosity)* (% cm^3/cm^3):**	**32.3**
Residual Mositure Content **(θ_R) *(-834.8 bars)* (% cm^3/cm^3):**	**7.2**
Specific Yield **(θ_S - θ_R) (% cm^3/cm^3):**	**25.2**

Comments:

* Weight including tares

Laboratory analysis by:	D. O'Dowd
Data entered by:	C. Krous
Checked by:	J. Hines

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP49
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA

	As Received	Remolded
Test Date:	30-Mar-09	---
Field weight of sample* (g):	986.80	
Tare weight, ring (g):	241.15	
Tare weight, pan/plate (g):	211.99	
Tare weight, other (g):	0.00	
Dry weight of sample (g):	479.86	
Sample volume (cm^3):	354.24	
Assumed particle density (g/cm^3):	2.65	

Gravimetric Moisture Content (% g/g):	11.2	
Volumetric Moisture Content (% vol):	15.2	
Dry bulk density (g/cm^3):	1.35	
Wet bulk density (g/cm^3):	1.51	
Calculated Porosity (% vol):	48.9	
Percent Saturation:	31.1	

Laboratory analysis by:	D. O'Dowd/R. Marshall
Data entered by:	R. Marshall
Checked by:	J. Hines

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded

Daniel B. Stephens & Associates, Inc.

Moisture Retention (Specific Yield)

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP49
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA
Test Date:	9-Mar-09

Calculated Porosity (% cm^3/cm^3):	48.9
Bulk Density (g/cm^3):	1.35

Relative Humidity Chamber Data

*Sample Dry Weight** (g):	84.66
Tare Weight (g):	38.34
Relative Humidity Chamber Potential (-bars):	834.8
Sample weight at -834.8 bars (g):*	84.9
Moisture content (% g/g):	0.5
Moisture content (% cm^3/cm^3):	0.7

***Saturated Moisture Content (θ_S) (Total Porosity)* (% cm^3/cm^3):**	**48.9**
***Residual Mositure Content (θ_R) (-834.8 bars)* (% cm^3/cm^3):**	**0.7**
***Specific Yield (θ_S - θ_R)* (% cm^3/cm^3):**	**48.2**

Comments:

* Weight including tares

Laboratory analysis by:	D. O'Dowd
Data entered by:	C. Krous
Checked by:	J. Hines

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP52
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA

	As Received	Remolded
Test Date:	30-Mar-09	---
Field weight of sample* (g):	889.10	
Tare weight, ring (g):	174.08	
Tare weight, pan/plate (g):	208.59	
Tare weight, other (g):	0.00	
Dry weight of sample (g):	409.31	
Sample volume (cm^3):	259.05	
Assumed particle density (g/cm^3):	2.65	

Gravimetric Moisture Content (% g/g):	23.7	
Volumetric Moisture Content (% vol):	37.5	
Dry bulk density (g/cm^3):	1.58	
Wet bulk density (g/cm^3):	1.95	
Calculated Porosity (% vol):	40.4	
Percent Saturation:	92.9	

Laboratory analysis by:	D. O'Dowd/R. Marshall
Data entered by:	R. Marshall
Checked by:	J. Hines

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded

Daniel B. Stephens & Associates, Inc.

Moisture Retention (Specific Yield)

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP52
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA
Test Date:	9-Mar-09

Calculated Porosity (% cm^3/cm^3):	40.4
Bulk Density (g/cm^3):	1.58

Relative Humidity Chamber Data

*Sample Dry Weight** (g):	96.46
Tare Weight (g):	42.10
Relative Humidity Chamber Potential (-bars):	834.8
Sample weight at -834.8 bars (g):*	97.0
Moisture content (% g/g):	1.1
Moisture content (% cm^3/cm^3):	1.7

***Saturated Moisture Content (θ_S) (Total Porosity)* (% cm^3/cm^3):**	**40.4**
***Residual Mositure Content (θ_R) (-834.8 bars)* (% cm^3/cm^3):**	**1.7**
***Specific Yield (θ_S - θ_R)* (% cm^3/cm^3):**	**38.7**

Comments:

* Weight including tares

Laboratory analysis by:	D. O'Dowd
Data entered by:	C. Krous
Checked by:	J. Hines

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP61
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA

	As Received	Remolded
Test Date:	30-Mar-09	---
Field weight of sample* (g):	984.90	
Tare weight, ring (g):	194.16	
Tare weight, pan/plate (g):	213.58	
Tare weight, other (g):	0.00	
Dry weight of sample (g):	503.76	
Sample volume (cm^3):	287.39	
Assumed particle density (g/cm^3):	2.65	
Gravimetric Moisture Content (% g/g):	14.6	
Volumetric Moisture Content (% vol):	25.5	
Dry bulk density (g/cm^3):	1.75	
Wet bulk density (g/cm^3):	2.01	
Calculated Porosity (% vol):	33.9	
Percent Saturation:	75.4	

Laboratory analysis by:	D. O'Dowd/R. Marshall
Data entered by:	R. Marshall
Checked by:	J. Hines

Comments:

* Weight including tares
NA = Not analyzed
--- = This sample was not remolded

Daniel B. Stephens & Associates, Inc.

Moisture Retention (Specific Yield)

Job Name:	Martin and Wood Water Consultants
Job Number:	LB09.0055.00
Sample Number:	GP61
Project Number and Name:	694.4 Upper Big Sandy
Depth:	NA
Test Date:	9-Mar-09

Calculated Porosity (% cm^3/cm^3):	33.9
Bulk Density (g/cm^3):	1.75

Relative Humidity Chamber Data

*Sample Dry Weight** (g):	88.03
Tare Weight (g):	41.90
Relative Humidity Chamber Potential (-bars):	834.8
Sample weight at -834.8 bars (g):*	88.3
Moisture content (% g/g):	0.5
Moisture content (% cm^3/cm^3):	0.9

***Saturated Moisture Content (θ_S) (Total Porosity)* (% cm^3/cm^3):**	**33.9**
***Residual Mositure Content (θ_R) (-834.8 bars)* (% cm^3/cm^3):**	**0.9**
***Specific Yield ($\theta_S - \theta_R$)* (% cm^3/cm^3):**	**33.0**

Comments:

* Weight including tares

Laboratory analysis by:	D. O'Dowd
Data entered by:	C. Krous
Checked by:	J. Hines

Saturated Hydraulic Conductivity

Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Oversize Corrected K_{sat} (cm/sec)	Method of Analysis: Constant Head	Method of Analysis: Falling Head
GP2	4.1E-03	NA	X	
GP3	1.1E-02	NA	X	

Saturated Hydraulic Conductivity
Constant Head Method

Job name:	Martin and Wood Water Consultants	*Type of water used:*	TAP
Job number:	LB09.0055.00	*Collection vessel tare* (g):	9.17
Sample number:	GP2	*Sample length* (cm):	7.10
Project Number and Name:	694.4 Upper Big Sandy	*Sample diameter* (cm):	7.21
Depth:	NA	*Sample x-sectional area* (cm^2):	40.84

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
09-Mar-09	13:13:38	20.0	0.6	19.9	10.8	762	4.1E-03	4.1E-03
09-Mar-09	13:26:20							
Test # 2:								
09-Mar-09	15:38:20	22.0	0.5	17.2	8.0	663	4.2E-03	4.0E-03
09-Mar-09	15:49:23							
Test # 3:								
10-Mar-09	10:09:07	20.5	0.9	18.8	9.6	448	4.1E-03	4.1E-03
10-Mar-09	10:16:35							

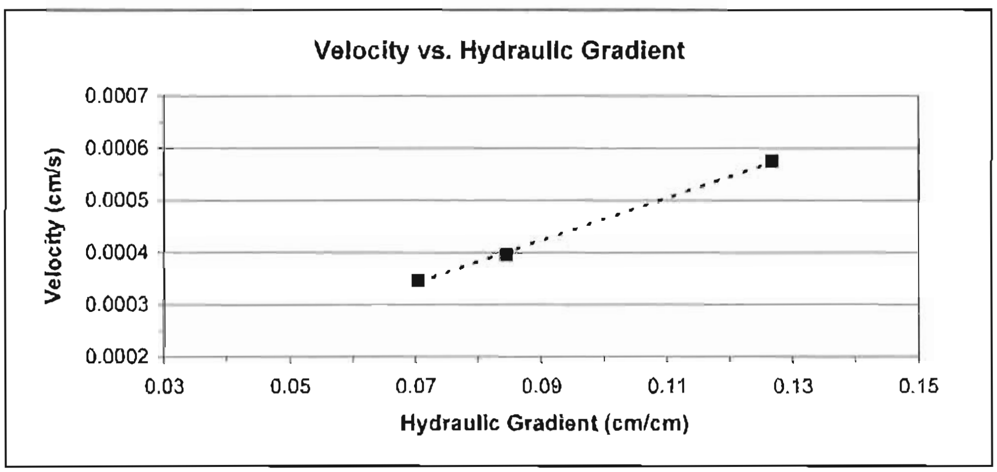
***Average Ksat* (cm/sec): 4.1E-03**

***Oversize Corrected Ksat* (cm/sec): NA**

Comments:

-- = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NA = Not analyzed



Laboratory analysis by: R. Marshall/K. Wright

Data entered by: K. Wright

Checked by: J. Hines

Daniel B. Stephens & Associates, Inc.

Saturated Hydraulic Conductivity
Constant Head Method

Job name:	Martin and Wood Water Consultants	*Type of water used:*	TAP
Job number:	LB09.0055.00	*Collection vessel tare* (g):	9.17
Sample number:	GP3	*Sample length* (cm):	8.30
Project Number and Name:	694.4 Upper Big Sandy	*Sample diameter* (cm):	7.16
Depth:	NA	*Sample x-sectional area* (cm^2):	40.31

Date	Time	Temp (°C)	Head (cm)	Q + Tare (g)	Q (cm^3)	Elapsed time (sec)	Ksat (cm/sec)	Ksat @ 20°C (cm/sec)
Test # 1:								
09-Mar-09	11:08:07	19.5	0.5	45.6	36.5	1313	1.1E-02	1.2E-02
09-Mar-09	11:30:00							
Test # 2:								
09-Mar-09	12:39:25	20.0	0.7	27.6	18.4	534	1.0E-02	1.0E-02
09-Mar-09	12:48:19							
Test # 3:								
09-Mar-09	13:13:52	20.0	0.7	34.1	24.9	785	1.0E-02	1.0E-02
09-Mar-09	13:26:57							

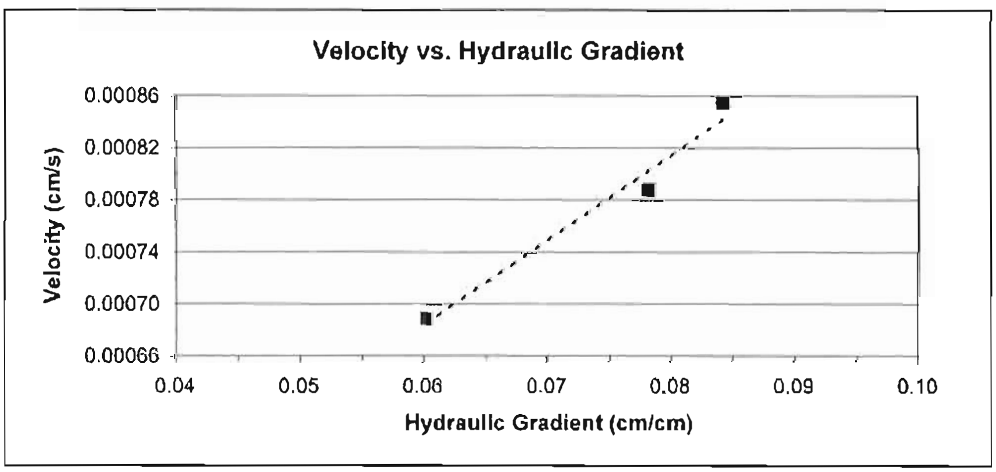
***Average Ksat* (cm/sec): 1.1E-02**

***Oversize Corrected Ksat* (cm/sec): NA**

Comments:

— = Oversize correction is unnecessary since coarse fraction < 5% of composite mass

NA = Not analyzed



Laboratory analysis by: R. Marshall/K. Wright

Data entered by: K. Wright

Checked by: J. Hines

Laboratory Tests and Methods

Tests and Methods

Dry Bulk Density:	ASTM D6836
Moisture Content:	ASTM D2216; ASTM D6836
Calculated Porosity:	ASTM D6836
Saturated Hydraulic Conductivity:	
Constant Head: (Rigid Wall)	ASTM D 2434 (modified apparatus)
Relative Humidity (Box) Method:	Karathanasis & Hajek. 1982. Quantitative Evaluation of Water Adsorption on Soil Clays.SSA Journal 46:1321-1325; Campbell, G. and G. Gee. 1986. Water Potential: Miscellaneous Methods.Chp. 25, pp. 631-632, in A. Klute (ed.), Methods of Soil Analysis, American Society of Agronomy, Madison, WI

Laboratory Report for
Martin and Wood Water Consultants

(694.4 Upper Big Sandy)

April 14, 2009

Daniel B. Stephens & Associates, Inc.

6020 Academy NE, Suite 100 • Albuquerque, New Mexico 87109

April 14, 2009

Mr. Bill Berg
Martin and Wood Water Consultants
602 Park Point Dr., Suite
Golden, CO 80401-7605
(303) 526-2600

Re: DBS&A Laboratory Report for Martin and Wood Water Consultants 694.4 Upper Big Sandy

Dear Mr. Berg:

Enclosed is the final report for the Martin and Wood Water Consultants 694.4 Upper Big Sandy samples. Please review this report and provide any comments as samples will be held for a maximum of 30 days. After 30 days samples will be returned or disposed of in an appropriate manner.

All testing results were evaluated subjectively for consistency and reasonableness, and the results appear to be reasonably representative of the material tested. However, DBS&A does not assume any responsibility for interpretations or analyses based on the data enclosed, nor can we guarantee that these data are fully representative of the undisturbed materials at the field site. We recommend that careful evaluation of these laboratory results be made for your particular application.

The testing utilized to generate the enclosed final report employs methods that are standard for the industry. The results do not constitute a professional opinion by DBS&A, nor can the results affect any professional or expert opinions rendered with respect thereto by DBS&A. You have acknowledged that all the testing undertaken by us, and the final report provided, constitutes mere test results using standardized methods, and cannot be used to disqualify DBS&A from rendering any professional or expert opinion, having waived any claim of conflict of interest by DBS&A.

We are pleased to provide this service to Martin and Wood Water Consultants and look forward to future laboratory testing on other projects. If you have any questions about the enclosed data, please do not hesitate to call.

Sincerely,

DANIEL B. STEPHENS & ASSOCIATES, INC.
LABORATORY / TESTING FACILITY

Joleen Hines
Laboratory Supervising Manager

Enclosure

Summary of Moisture Retention Data
Dew Point Potentiometer

Sample Number	Pressure Head (-cm water)	Moisture Content (%, g/g)
GP2	7139	3.1
	17439	2.0
	51806	1.5
	94433	1.3
GP28	5303	2.8
	18560	2.0
	56293	1.4
	100552	1.3
GP41	6731	3.2
	23149	2.4
	45789	2.1
	88825	1.8
GP49	8056	2.0
	20396	1.3
	48135	1.1
	104020	1.0

Laboratory Data

WP-4 Analysis

Summary of Moisture Retention Data

Dew Point Potentiometer

Sample Number	Pressure Head (-cm water)	Moisture Content (%, g/g)
GP2	7139	3.1
	17439	2.0
	51806	1.5
	94433	1.3
GP28	5303	2.8
	18560	2.0
	56293	1.4
	100552	1.3
GP41	6731	3.2
	23149	2.4
	45789	2.1
	88825	1.8
GP49	8056	2.0
	20396	1.3
	48135	1.1
	104020	1.0

Moisture Retention Data
Dew Point Potentiometer

Sample Number: GP2

Dry weight of dew point potentiometer sample* (g): 162.48
Tare weight, jar (g): 117.48

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content† (% g/g)
Dew point potentiometer:	10-Apr-09	11:25	163.86	7138.6	3.06
	9-Apr-09	15:43	163.38	17438.6	2.01
	9-Apr-09	12:10	163.14	51805.8	1.46
	9-Apr-09	9:35	163.04	94433.5	1.25

Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: D. O'Dowd
Data entered by: C. Krous
Checked by: J. Hines

Moisture Retention Data
Dew Point Potentiometer

Sample Number: GP28

Dry weight of dew point potentiometer sample* (g): 177.24
Tare weight, jar (g): 116.29

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content† (% g/g)
Dew point potentiometer:	10-Apr-09	12:25	178.94	5303.0	2.78
	10-Apr-09	9:30	178.44	18560.4	1.96
	9-Apr-09	13:45	178.11	56293.0	1.42
	9-Apr-09	11:40	178.01	100552.3	1.26

Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: D. O'Dowd
Data entered by: C. Krous
Checked by: J. Hines

Moisture Retention Data
Dew Point Potentiometer

Sample Number: GP41

Dry weight of dew point potentiometer sample* (g): 155.42
Tare weight, jar (g): 113.22

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content† (% g/g)
Dew point potentiometer:	10-Apr-09	10:45	156.79	6730.7	3.23
	9-Apr-09	14:57	156.41	23149.5	2.36
	9-Apr-09	12:55	156.30	45789.0	2.09
	9-Apr-09	11:00	156.20	88824.6	1.84

Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: D. O'Dowd
Data entered by: C. Krous
Checked by: J. Hines

Moisture Retention Data
Dew Point Potentiometer

Sample Number: GP49

Dry weight of dew point potentiometer sample* (g): 176.06
Tare weight, jar (g): 116.39

	Date	Time	Weight* (g)	Water Potential (-cm water)	Moisture Content† (% g/g)
Dew point potentiometer:	10-Apr-09	11:30	177.28	8056.4	2.04
	9-Apr-09	14:40	176.85	20396.0	1.32
	9-Apr-09	12:30	176.73	48134.6	1.12
	9-Apr-09	10:10	176.63	104019.6	0.95

Comments:

* Weight including tares
† Assumed density of water is 1.0 g/cm^3

Laboratory analysis by: D. O'Dowd
Data entered by: C. Krous
Checked by: J. Hines

Laboratory Tests and Methods

Tests and Methods

Water Potential (Dewpoint Potentiometer) Method:	ASTM D6836; Rawlins, S.L. and G.S. Campbell, 1986. Water Potential: Thermocouple Psychrometry. Chp. 24, pp. 597-619, in A. Klute (ed.), Methods of Soil Analysis, Part 1. American Society of Agronomy, Madison, WI.

Summary of Moisture Retention Data
Dew Point Potentiometer

Sample Number	Pressure Head (-cm water)	Moisture Content (%, g/g)
GP2	7139	3.1
	17439	2.0
	51806	1.5
	94433	1.3
GP28	5303	2.8
	18560	2.0
	56293	1.4
	100552	1.3
GP41	6731	3.2
	23149	2.4
	45789	2.1
	88825	1.8
GP49	8056	2.0
	20396	1.3
	48135	1.1
	104020	1.0

Summary of Tests Performed

Laboratory Sample Number	Initial Soil Properties[1]		Saturated Hydraulic Conductivity[2]			Moisture Characteristics[3]								Particle Size[4]			Specific Gravity[5]		Air Perm-eability	Specific Yield	Proctor Compaction
	VM	VD	CH	FH	FW	HC	PP	FP	DPP	RH	EP	WHC	K_{unsat}	DS	WS	H	F	C			
GP2									X												
GP28									X												
GP41									X												
GP49									X												

[1] VM = Volume Measurement Method, VD = Volume Displacement Method
[2] CH = Constant Head Rigid Wall, FH = Falling Head Rigid Wall, FW = Falling Head Rising Tail Flexible Wall
[3] HC = Hanging Column, PP = Pressure Plate, FP = Filter Paper, DPP = Dew Point Potentiometer, RH = Relative Humidity Box, EP = Effective Porosity, WHC = Water Holding Capacity, Kunsat = Calculated Unsaturated Hydraulic Conductivity
[4] DS = Dry Sieve, WS = Wet Sieve, H = Hydrometer
[5] F = Fine (<4.75mm), C = Coarse (>4.75mm)

Summaries

APPENDIX G

SAMPLE QUESTIONNAIRES

C'nty

Upper Big Sandy
GROUND WATER MANAGEMENT DISTRICT

August 14, 2008

Dear Upper Big Sandy Members:

The Upper Big Sandy Ground Water Management District is currently gathering data to assist in developing a water balance for the basin. The water balance will help us to better understand the alluvial ground water resources within the basin and plan for the future.

The attached survey is being conducted as a part of the project. The first two pages are requested to be filled out by all members. The second two pages are specifically related to streamflow observations. The first page requests historical streamflow observations. The second page includes information that would be helpful to gather and report for future observations. If you have not made any streamflow observations and are unlikely to do so in the future, please disregard the last two pages.

Please complete and return the forms by September 12 to:

Ms. Angela Wingard
Upper Big Sandy GWMD
35194 E. Hwy. 24
Ramah, CO. 80832

Your help with this important project is greatly appreciated.

Sincerely,

Angela Wingard, Office Manager
UPPER BIG SANDY GWMD

UPPER BIG SANDY
MEMBER QUESTIONNAIRE

Please fill out this survey by **September 12, 2008** and mail it to
Ms. Angela Wingard, Upper Big Sandy, 35194 East Hwy 24, Ramah, CO 80832

1. Approximate size of irrigated area (include fallow lands which will be farmed in the next two years).
Size (acres) ____________________
Location/Address of Farm ____________________
____

2. List the crops typically grown and the associated percent of your total irrigated land.
Crop____________ Percent of irrigated land ________
Crop____________ Percent of irrigated land ________
Crop____________ Percent of irrigated land ________

3. Any plans to increase/decrease area irrigated in the next few years? Yes No
If yes, describe the change including the area affected and crops involved. ____________
____
____

4. Do you have any ponds on your property? (circle one) Yes No
If yes, approximate size _____ acres
Time of year when pond used/full from __________ to __________
How long will the pond remain full after being filled? __________ days
How is pond filled? __________ (well water, field runoff, precipitation)

5. How many stock are on your property? ________ head of stock
Circle one: year-round seasonal If seasonal, number of months on property__________

6. Approximate size and description of stock water tank/pond
Shape ____________ Size ____________ (such as 10 ft by 20 ft or 15 ft diameter)
Material: ____________ (such as metal, pond dug in ground, etc.)

Shape ____________ Size ____________ (such as 10 ft by 20 ft or 15 ft diameter)
Material: ____________ (such as metal, pond dug in ground, etc.)

7. Number of wells used for irrigation ________ for stock watering ________

Please provide additional well information, if possible.	Well 1	Well 2	Well 3	Well 4
Permit Number				
Approximate Age of Well (years)				
Depth of Well (feet below ground surface)				
Approximate Water Level at Start of Irrig Season				
Approximate Water Level at End of Irrig Season				
Approximate Water Level in Winter				
Well Production or Pumping Rate (gallons per minute)				
Average hours pumped per day/week/mo/yr (circle time period)				
Use of Well (irrigation, stock, both)				

* Please list depths and water levels as feet below ground surface. Attach additional sheets if necessary.

UPPER BIG SANDY
MEMBER QUESTIONNAIRE
(continued)

8. Would you be willing to provide monthly data on water levels within your wells? Yes No
If not, would you allow access to your wells for someone else to collect water level data? Yes No

9. Were any dry holes previously drilled on your property? Yes No
If yes, would you be willing to provide the general locations of these holes? ____________

10. Has production from your well or wells changed in the last 10 years? Yes No
If yes, please explain how (higher or lower flowrates?) and if you've had any improvements that explain the change (such as installation of a new pump). ____________________

11. Over the past 10 years, have you observed any drawdown in your wells? Yes No
If yes, list any reasons that you think could have lead to the drawdown.

12. Have any of your wells been removed from production in the last 10 years? Yes No
If yes, describe the well, location, and reason. ____________________

13. Do you own any wells that produce from the Denver Basin aquifers (Dawson, Denver, Arapahoe, or Laramie-Fox Hills)? Yes No
If yes, which aquifers? ____________________
approximate production rates (gpm) ____________________
depth to water information ____________________
Would you allow someone to measure depth to water? ____________________

14. Have you observed any increase/decrease in the amount of naturally growing plants along the creek bed or banks over the past 10 years? Yes No If yes, please describe. ____

15. Have you observed any significant change in the size or location of the stream channel in that last 10 years? Yes No If yes, please describe. ____________________

16. Provide historical or additional information including but not limited to well measurements, meter records, or precipitation records. Attach data, notes, or additional sheets if necessary.

17. Person Who Completed Survey ____________________
Address ____________________
Phone Number ____________________
Can we contact you by phone with additional follow-up questions if necessary? Yes No

Mail completed survey to Ms. Angela Wingard, Upper Big Sandy, 35194 East Hwy 24, Ramah, CO 80832.

BIG SANDY CREEK
Historical Streamflow Observations

Name ______________________________

Location ______________________________

1. When does the creek usually have live flow (seasonally, year-round, only after a storm, etc.)?

____

2. How long does live flow last following a storm?

____

3. What is the widest and deepest you have ever seen the creek and when was that?

____

____

4.

____

____

5. How long have you observed creek in this location (e.g., from when purchased land until 1990 to 2008)?

From __________ To __________

Comments: ______________________________

6. Please provide your description of the seasonal variations of flow and creek condition.

____

____

____

7. Would you be willing to monitor a rain gauge if one were provided to you? (circle one) Yes No

(please note if you already have a rain gauge)

BIG SANDY CREEK
Streamflow Observations After/During a Storm

Name ____

Location of Observations ________________________________

Date ______________________ Time ______________

1. Is it currently raining outside? (circle one) Yes No

2. When was last rain? Date ______________

   Approx. duration ____________ minutes

   Total rainfall from storm ________ inches

3. Live flow in Big Sandy Creek? (circle one) Yes No

4. Approximately how far up and downstream does the live flow persist?

   ____

   (e.g., upstream about 100 feet and downstream out of sight, at least 400 feet)

5. Estimated depth of water in creek

   average ________ inches

   deepest ________ inches

6. Estimate of width of flow ________ feet

7. Estimate of how long creek had live flow

   ____________ hours/days/weeks

8. Comments/Additional Observations ______________________

   ____

   ____

APPENDIX H

PRECIPITATION RECHARGE

ANALYSIS MEMO

Martin and Wood Water Consultants, Inc.
602 Park Point Drive, Suite 275 . Golden, CO 80401
Phone: (303) 526-2600 . Fax: (303) 526-2624
www.martinandwood.com

Memorandum

To: File 694.4

From: Robin Kelley, E.I.
Cristy Radabaugh, P.E.

Date: April 10, 2009

Subject: Upper Big Sandy Precipitation/Recharge Study

There are many factors influencing the ground water levels in the Upper Big Sandy Basin. Recharge in the Basin comes primarily from precipitation. Therefore, developing a relationship between precipitation patterns and recharge could be very useful in quantifying recharge to the shallow alluvial aquifer.

An analysis of precipitation and water level data in the area was done in order to try to develop a relationship between the two which might be helpful in predicting aquifer recharge. For precipitation, the data collection would ideally be hourly and at least daily so that storm events could be evaluated. For water levels, the data collection would also be ideally hourly for some wells and at least daily for most wells so that the effect of the storm, if any, and the associated lag-time could be evaluated. There are multiple precipitation gages within and in close proximity to the Upper Big Sandy Designated Basin, several of which have over 20 years of data. Most of these National Climatic Data Center (NCDC) gages record only daily data. However, there is sparser hourly data available for some of the gages as well.

The U.S. Geological Survey (USGS) has collected data at several wells within the Upper Big Sandy Basin for decades. For most of the wells, only two or three data points have been recorded. However, there is a small collection of wells with longer periods of study. Plots of well levels for wells with more than three data points are attached. In two of these five plots, water levels have actually risen over their respective periods of record. At two of the remaining three gages, the water level drops are less than half a foot over the entire available period of record, which is far less than the upward and downward fluctuations sometimes experienced over a single year.

Unfortunately, without detailed water level data and the corresponding influence of pumping at a location, it is difficult to do an accurate assessment of whether more intense or more frequent storms are more apt to cause more significant recharge to the groundwater aquifer in the Upper Big Sandy Basin. However, looking at overall annual change of water level in the Basin, compared to a plot of rainfall throughout the year may visually give some idea as to whether the intensity and duration of storms and change in water level are directly correlated.

The water level and precipitation gage chosen for analysis were those both closest to the centroid of the Basin and each other, with overlapping periods of record. Data from the most appropriate precipitation gage No. 05 5018 was therefore compared to data from the water level observation well No. 391717103475001. Visually, some years seem to respond to years with intense storms with a water level rise, and other years with a water level decline. There is nothing conclusive in these plots to indicate that there is a direct correlation between water level and general storm characteristics. There is also nothing conclusive in the data to indicate that larger volumes of rainfall alone necessarily lead to gains in ground water level. Breaking down the data numerically for a closer investigation of possible relationships did not reveal identifiable connections between ground water level changes and the intensity or frequency of precipitation in the region. The following table presents annual precipitation and water level patterns for qualitative trend comparison. Values in Column 2 represent the percentage of daily precipitation values which exceed the average quantity of precipitation per storm per day. In Column 3, the frequency of precipitation was designated average, above average or below average, based upon the number of days in which precipitation was reported at the gage. In Column 4, the precipitation volume for each year is assigned a label of average, dry year or wet year based upon the calendar year's precipitation, relative to the average annual precipitation for the period of record at the gage. Column 5 describes the water level trend for each calendar year. It is difficult to truly identify the influence of precipitation duration and intensity without daily water level data and without taking into consideration the localized pumping, temperatures and other factors that may have a role in ground water hydrology.

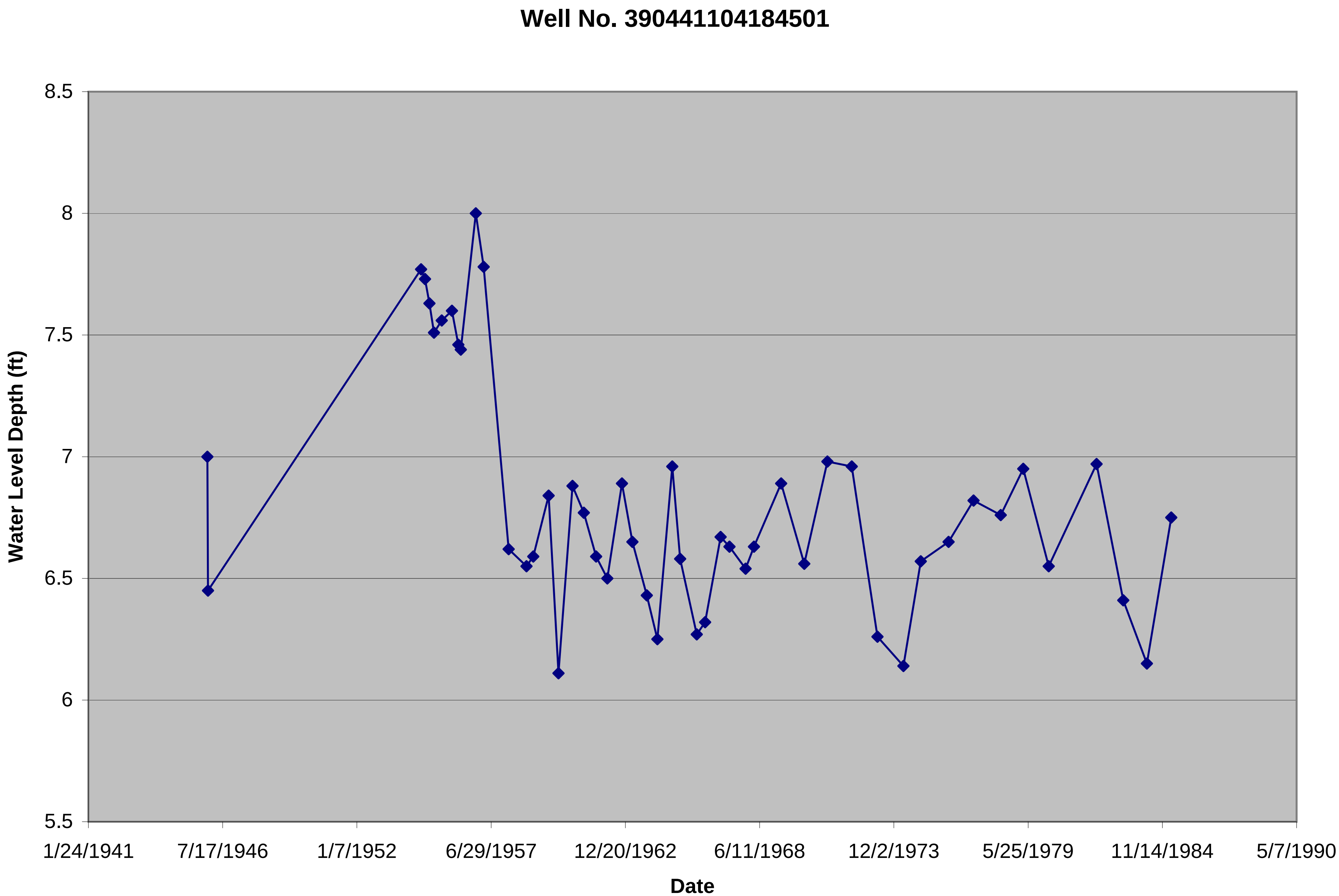
Table 1: Qualitative Recharge-Precipitation Assessment

Year	% Daily Precipitation Designated Intense	Precipitation Frequency	Precipitation Volume	Water Level Change
(1)	(2)	(3)	(4)	(5)
1972	26.6%	Above Ave	Average	Fall
1973	25.6%	Above Ave	Average	Rise
1974	21.9%	Below Ave	Dry Year	Rise
1975	Insufficient Data	Insufficient Data	Insufficient Data	Rise
1976	19.7%	Below Ave	Dry Year	Rise
1977	36.8%	Below Ave	Average	Fall
1978	13.9%	Average	Dry Year	Rise
1979	32.6%	Above Ave	Wet Year	Fall
1980	28.6%	Below Ave	Average	Rise
1981	28.4%	Average	Average	Rise
1982	28.1%	Above Ave	Average	Fall
1983	29.3%	Average	Average	Fall
1984	30.6%	Average	Wet Year	Rise
1985	25.8%	Above Ave	Average	Fall

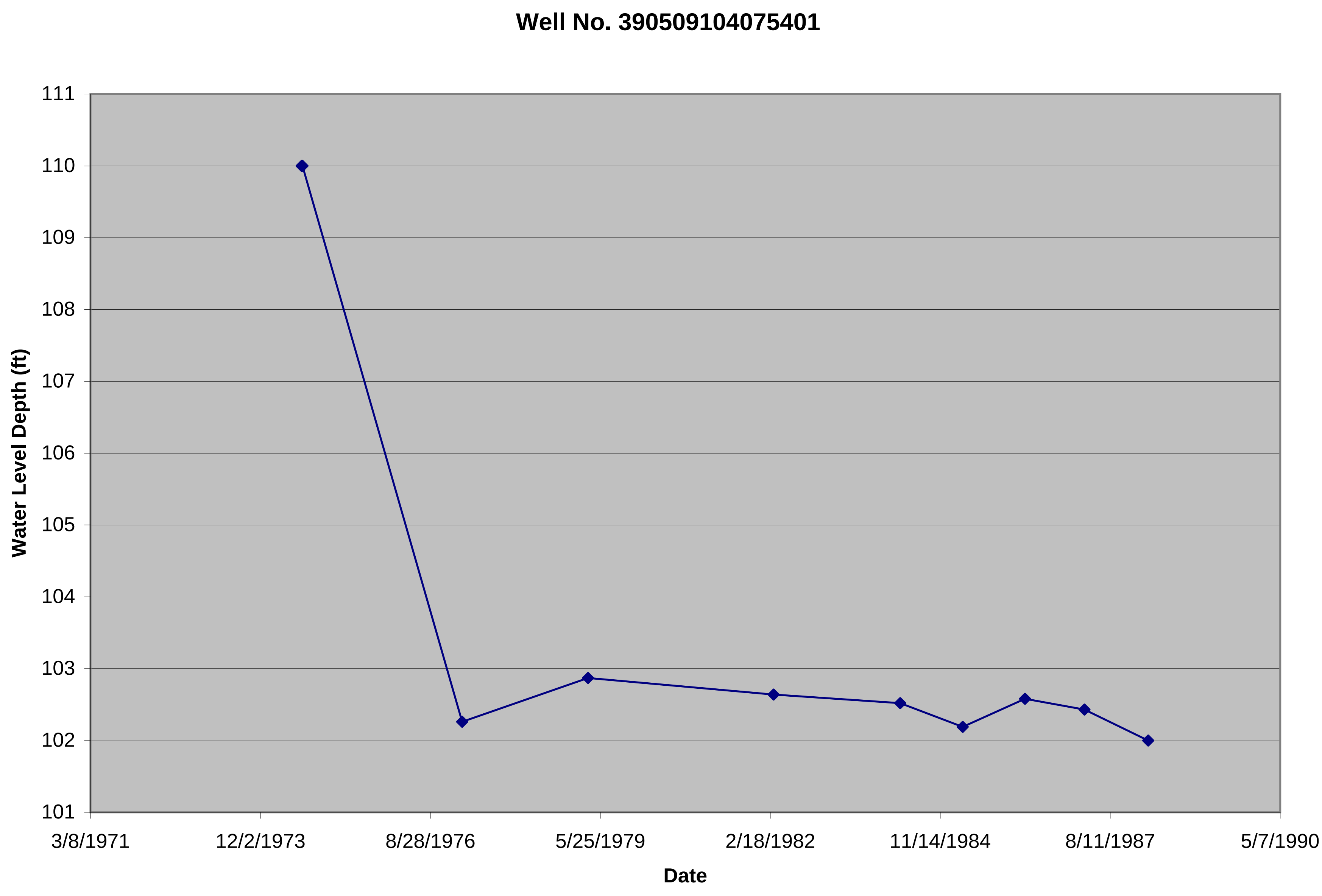
A report done by TZA (1989) in the Upper Big Sandy Basin relied on multiple observation wells to track the overall change in groundwater level in the mid 1980s in order to evaluate recharge.

These wells located throughout the Basin showed varying degrees of change in the water level, some of them rising, some of them dropping, and many of them changing very little over the short period of observation. TZA also used two of the long term wells maintained by USGS, previously mentioned in this report, demonstrating no distinguishable trend in overall drop or rise in the ground water level over larger periods of record.

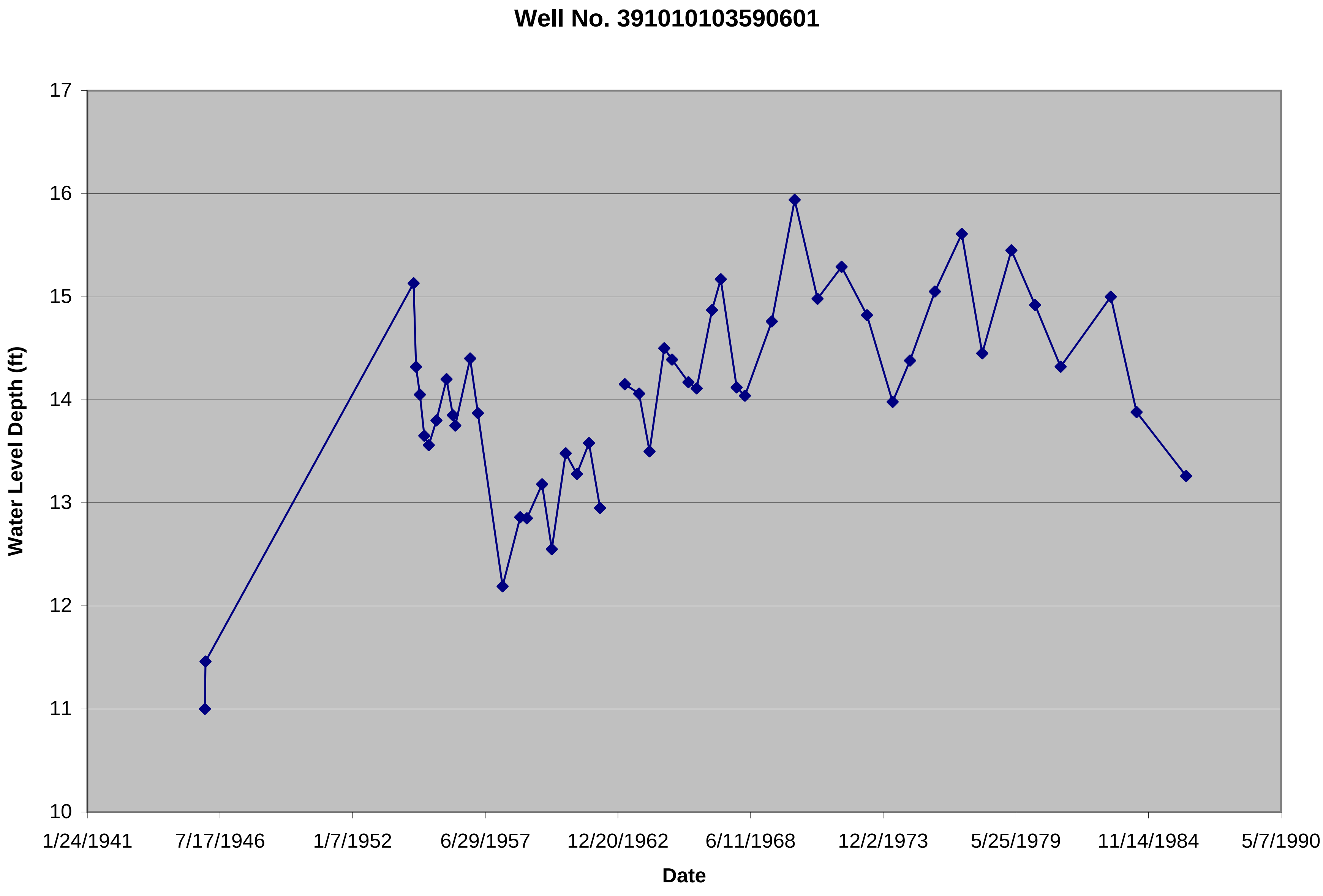
The available data did not indicate a qualitative predictable trend relative to wet and dry precipitation years and the associated changes in water levels. The available data also did not indicate identifiable connections between ground water level changes and the intensity or frequency of precipitation events in the region. Based on our research, the available data do not indicate the connection between changes in precipitation and changes in water levels within the Basin.

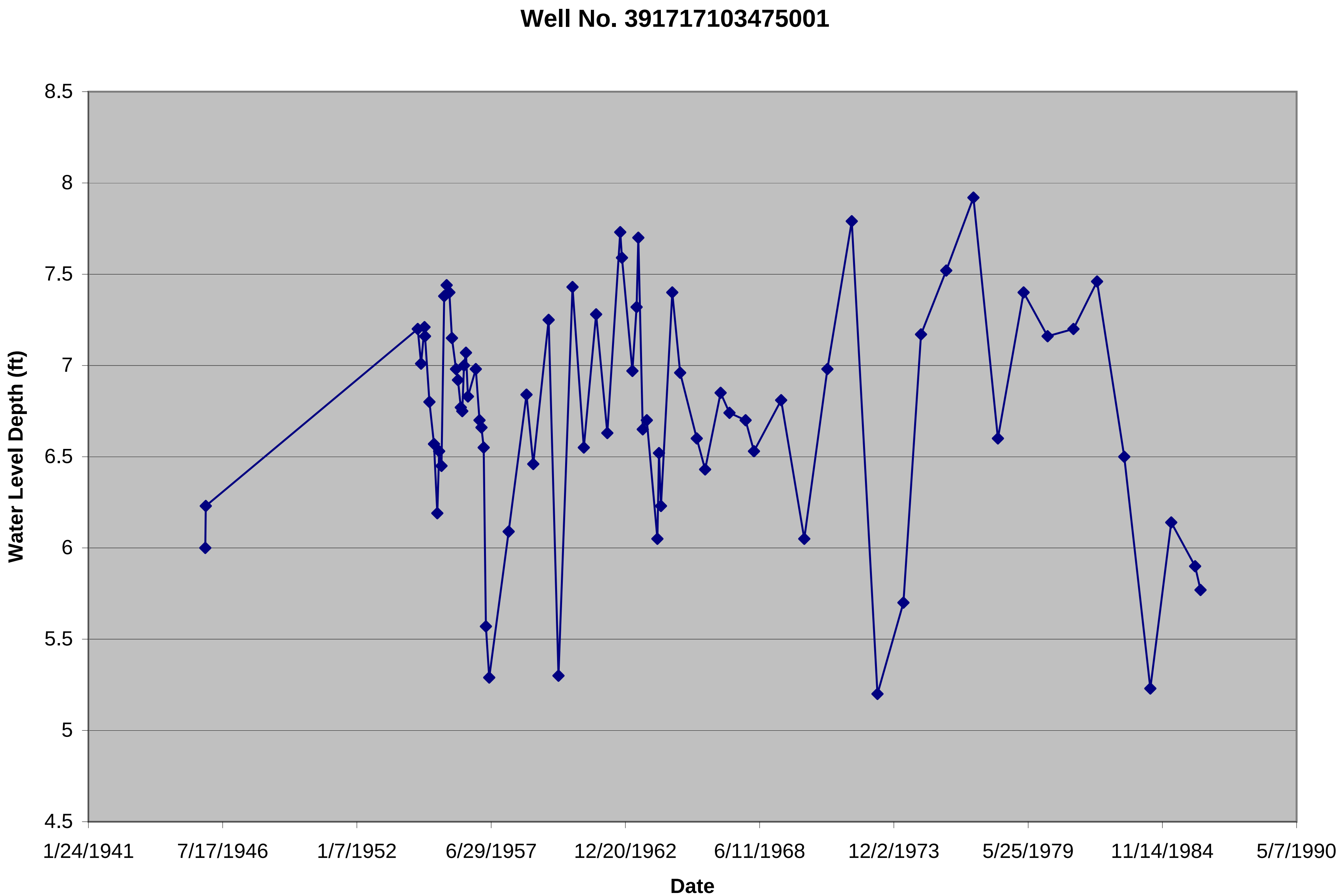


Well No. 390441104184501
Water Level Depth (ft)
8.5
8
7.5
7
6.5
6
5.5
1/24/1941
7/17/1946
1/7/1952
6/29/1957
12/20/1962
6/11/1968
12/2/1973
5/25/1979
11/14/1984
5/7/1990
Date

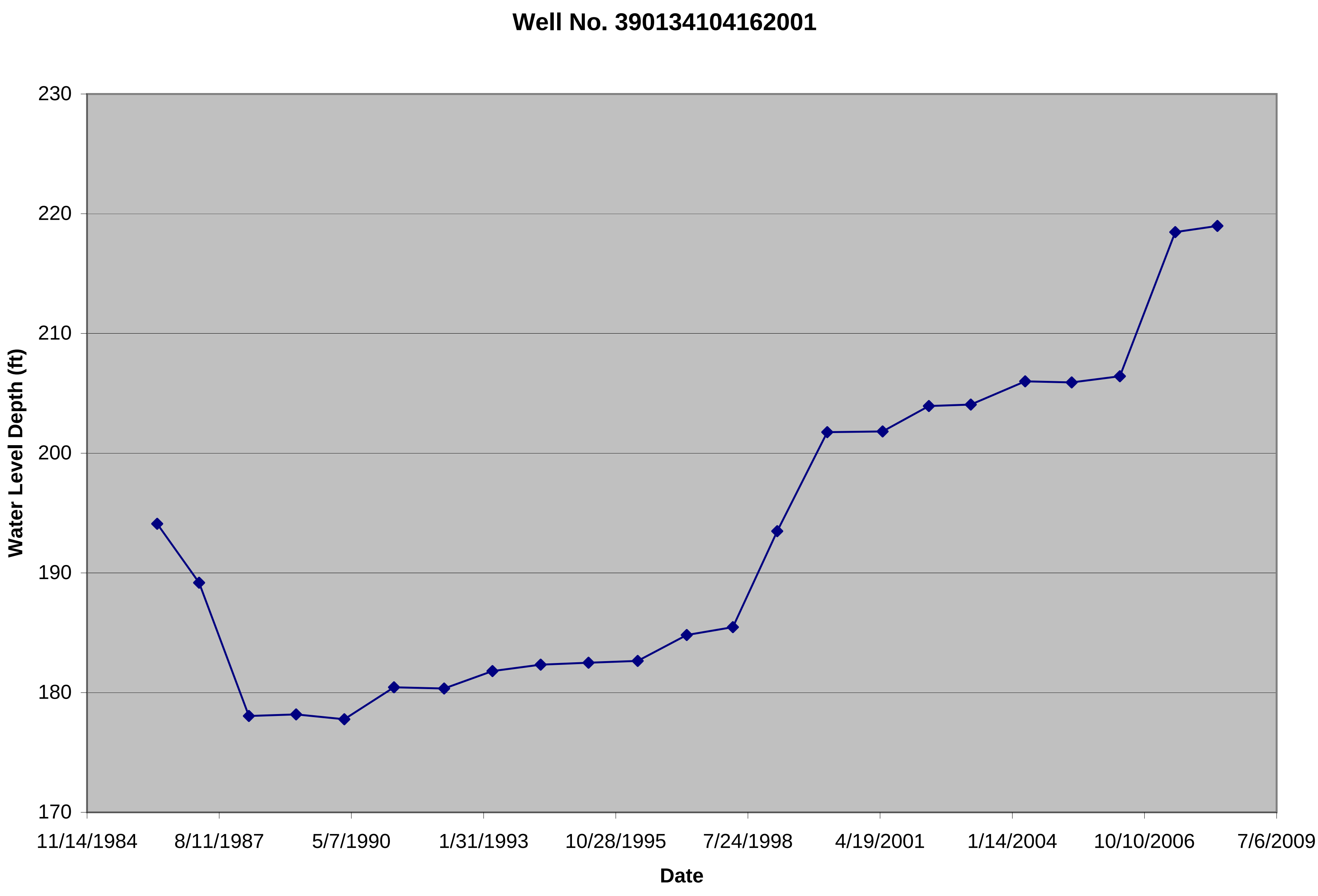


Well No. 390509104075401
Water Level Depth (ft)
111
110
109
108
107
106
105
104
103
102
101
3/8/1971
12/2/1973
8/28/1976
5/25/1979
2/18/1982
11/14/1984
8/11/1987
5/7/1990
Date


Well No. 391010103590601
Water Level Depth (ft)
17
16
15
14
13
12
11
10
1/24/1941
7/17/1946
1/7/1952
6/29/1957
12/20/1962
6/11/1968
12/2/1973
5/25/1979
11/14/1984
5/7/1990
Date



Well No. 391717103475001
Water Level Depth (ft)
8.5
8
7.5
7
6.5
6
5.5
5
4.5
1/24/1941
7/17/1946
1/7/1952
6/29/1957
12/20/1962
6/11/1968
12/2/1973
5/25/1979
11/14/1984
5/7/1990
Date


Well No. 390134104162001
Water Level Depth (ft)
230
220
210
200
190
180
170
11/14/1984
8/11/1987
5/7/1990
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
Date