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ABSTRACT

Groundwater geochemical and isotopic data have been collected to estimate the age, residence time, sources, and mixing of groundwater at various depths within the Mesilla Basin aquifer system. The objective of the study was to use the aqueous isotopic and geochemical data to characterize the deep groundwater system in the Mesilla Basin. Within the last year (2016 and 2017), several groundwater wells were sampled, and the water samples characterized using a number of isotopic and chemical analyses. This report provides a description of sampling and analysis methods, and presents the data that have been collected. The age dating results indicate that the Mesilla Basin aquifer system contains groundwater of both relatively young and older ages. The concentrations of the radioisotopes of carbon (^{14}C) and tritium results indicate a large range of modeled ages in the groundwater, it suggests that half of the samples have >50% modern water. Noble gas isotope age dating indicated that groundwater at well LC-2A (310 feet depth) was ~8 years old and groundwater at well LC-2F (650 feet depth) was ~50-90 years old. There were also significant variabilities within the groundwater geochemistry. Many of the analytical results had standard deviation values that were equal or larger than the mean values. These results suggest significant spatial variability (i.e., heterogeneity) in the aqueous geochemistry of the groundwater within the Mesilla Basin, which has implications for various flow, transport, and geochemical processes. Quantifying these processes and evaluating the groundwater residence time is critical for sustainable management of our groundwater as a water supply resource.

Keywords: Mesilla, groundwater, geochemistry, isotopes, water quality

TABLE OF CONTENTS

List of Tables and Figures

INTRODUCTION

New Mexico is in a long-term drought that threatens the sustainability of the agricultural industry as well as drinking water supply. In 2012, Governor Martinez declared a state of emergency (NM Exec. Order No. 2012-006), but drought conditions are expected to continue (IPCC 2014). The region is experiencing drastically reduced surface water supplies, declining ground water quality and quantity, and cumulative effects of more than a decade of drought conditions (Alley, 2013). In response, the Mesilla/Conejos-Médanos aquifer system (Mesilla Basin) is being depleted at a faster rate than it is being replenished (USGS, 2017), due to the confluence of climate/drought impacts and pumping for irrigated agriculture and public domestic water supply (Ackerman and Stanton, 2011). Additionally, litigation between Texas and NM in the US Supreme Court may limit the options for water management in the Lower Rio Grande basin which includes the Mesilla Basin (Texas v. New Mexico and Colorado, 2017). Surface water is continuing to decrease due to climate change despite being over allocated (Reclamation, 2016), and groundwater is potentially being used without replenishment to buffer declines in surface water. At the same time, vast development plans are being implemented in the Santa Teresa/San Geronimo area along the US/Mexican border. Stakeholders require accurate groundwater characterization for sustainable groundwater production.

Based on the resource challenges presented above, it is important to improve our understanding of the Mesilla Basin groundwater aquifer. Presently, we are lacking quantitative estimates of groundwater recharge and its spatial variability across the Basin. We do not know how much flow, mixing, and salinity transfer occurs between the shallow and deeper aquifers. Because of this lack of understanding we do not know how sustainable our water resources are, because we have not characterized the storage, flow dynamics, and resiliency of the groundwater system, especially for the deeper aquifers.

The project described herein aims to develop and improve groundwater flow information for residence times, recharge, salinity transfer, and flow path mixing of the Mesilla Basin using geochemical tracers, including the use of radioisotopes of dissolved noble gases. Groundwater geochemical and isotopic data have been collected to characterize the age (and residence time) and sources (and mixing) of groundwater at various depths within the Mesilla Aquifer system. This has included the development and use of radioisotopes of noble gases for the first time in this region of the world, which can fill a critical time-gap in methods commonly used for groundwater age dating.

The objectives of the study have been to collect the aqueous isotopic and geochemical data needed to characterize the deep groundwater system in the Mesilla Basin, which supports the determination of the contribution of deep groundwater to flow and salinity in the shallow groundwater of the Mesilla Basin. Geochemical and isotopic tracers were used to pursue these objectives, as well as to evaluate the potential for cross-basin recharge from the adjacent basins. Within the last year (2016-2017), several groundwater wells were sampled, and the samples were characterized using a number of isotopic and chemical analyses. The purpose of the following report is to provide a description of sampling and analysis methods, and to present the data that have been collected.

BACKGROUND

New Mexico Groundwater

Increased water use, drought, and climate change all threaten the sustainability of our limited surface water and groundwater supplies in New Mexico. Over the last century, temperatures in the Rio Grande basin have increased significantly. Due to rising temperatures reductions in snowpack and stream flow of the Rio Grande are projected (Seager et al., 2007; Gutzler and Robbins 2010; Pederson et al., 2011; Reclamation, 2011; Reclamation, 2016). This decrease in surface water supply, will potentially shift use from surface water to groundwater development. However, the groundwater system is recharged, in part, by surface water (e.g., Witcher et al., 2004). Increased groundwater withdrawal as well as decreased recharge from surface water poses a serious threat to the sustainability of the Mesilla Basin's water supply. While the use of groundwater supports short-term resiliency during drought, it comes at the potential cost of long-term sustainability (Ackerman and Stanton, 2011). There is an urgent need to evaluate the impact of groundwater pumping on the storage and sustainability of the aquifer system.

In addition to decreasing flows, salination of surface water and groundwater in the Rio Grande has intensified as population growth in desert areas has increased and more water is used to support agriculture and municipalities (Phillips et al., 2003; Oren et al., 2004; Hogan et al., 2007; Szynkiewicz et al., 2011). Salt sources include agricultural irrigation, municipal sources, natural upwelling of salt-rich groundwater, and evaporation (Phillips et al., 2003; Witcher et al., 2004; Hibbs and Merino, 2006; Hogan et al., 2007; Eastoe et al., 2008; Moore et al., 2008). It has long been reported that salinity increases as the Rio Grande flows downstream (Moyer et al., 2013). A growing body of evidence suggests that a large source of that salinity at the distal end of the Mesilla Basin is the saline discharge from deep groundwater flow, but the magnitude and distribution of discharge from those deep saline flow paths has not been determined.

The amount of cross-basin groundwater flow between the Mesilla Basin and the adjacent Jornada Basin and Hueco Bolson has also not been delineated (Alley, 2013; Hawley and Kennedy, 2004). Finally, it is unclear what fraction of present-day groundwater recharge is contributing to sustainable fresh groundwater yields and what fraction is the “paleo-recharge” contribution (Hawley and Kennedy, 2004). There is an urgent need to evaluate salinization, residence time, recharge, and flow paths within the Mesilla Basin aquifer system.

Groundwater Age Dating Using Isotopes

The use of geochemical and isotopic tracers is well developed for determining recharge sources, residence times, and surface-water/groundwater interactions. In the Mesilla Basin and the adjacent basins Jornada del Muerto (Jornada) and Hueco-Bolson (together forming the Mesilla Basin study area), stable isotopes of water (^{2}H and ^{18}O) have been used to identify recharge sources (e.g., Druhan et al., 2007; Eastoe et al., 2008); ion concentrations and isotopes of chloride, boron, strontium and sulfur, along with the chloride to bromide ratio, have been used to identify sources of salinity (e.g., Witcher et al., 2004; Druhan et al., 2007; Hogan et al., 2007; Moore et al., 2008; Szynkiewicz et al., 2011); and carbon-14 (^{14}C) has been used to estimate the age of groundwater (Anderholm and Heywood, 2003). Although they have not been used within New Mexico, noble gas radioisotopes can provide complementary chronometric and geochemical source and mixing information to groundwater investigations (Yokochi et al., 2013). Because of their geophysical and geochemical properties, noble gases are ideal groundwater tracers. The low abundance and solubility of the radioisotopes of krypton and argon, have required impractical sampling volumes in the past. With the advent of low-level analysis techniques such as Atom Trap Trace Analysis (ATTA) (Chen et al., 1999) and Low-Level Counting (LLC) (Oeschger and Wahlen, 1975), the noble gas isotopes krypton-81 (^{81}Kr), krypton-85 (^{85}Kr), and argon-39 (^{39}Ar) have become practical age-dating techniques for groundwater. The isotope argon-39 (^{39}Ar) is particularly valuable, as it is the only isotope the only isotope that will effectively bridge the groundwater age gap in the very important intermediate range of 50 to 1,000 years, as can be seen in Figure 1.

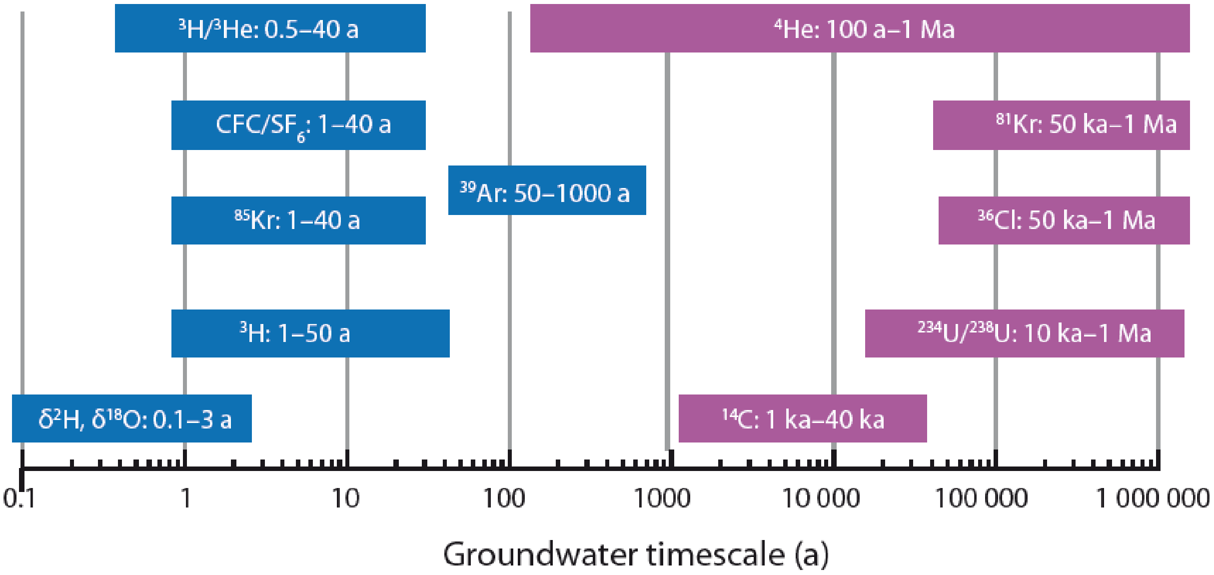

Figure 1. Isotope and chemical tracer groundwater age dating ranges (adapted from IAEA, 2013)

METHODOLOGY

Hydrogeology and Well Selection

The Mesilla Basin aquifer system primarily consists of Quaternary basin-fill alluvial deposits and the Quaternary and Tertiary Santa Fe Group. The quaternary alluvium consists of 50 to 125 feet of unconsolidated Rio Grande deposits that overlie the Santa Fe Group (Wilson et al., 1981; Hawley, 1984). Hawley and Kennedy (2004) subdivide the Santa Fe Group in the study area into lower, middle, and upper lithographic units, which consist of up to 2500 feet of alluvial and fluvial sediments overlying the igneous bedrock (Hawley and Kennedy, 2004). Despite some distinguishable variations in deposition patterns and grain size, the basin fill sediments are conceptualized as one aquifer system without significant lower-permeability zones that could cause hydraulic divisions between portions of the unconsolidated sediments. The samples collected for geochemical and isotopic analyses were obtained from this unconsolidated aquifer system to support characterization of the potential spatial variability within the Mesilla Basin aquifer system.

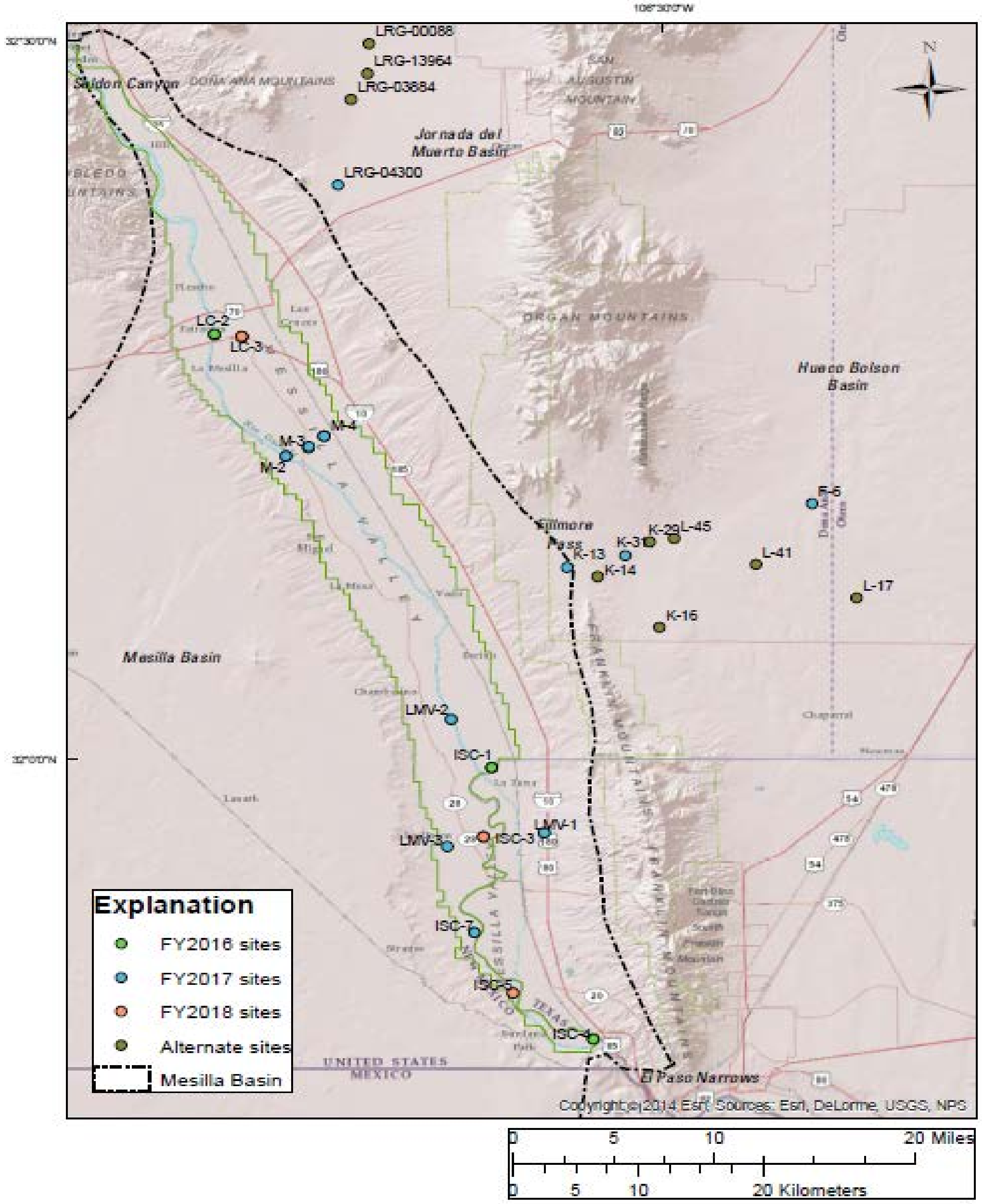

Figure 2. Study Site Map Showing Locations of Groundwater Wells Considered for Sampling

Discrete water-quality groundwater samples were collected from 19 existing wells (USGS and other deep monitoring wells) located throughout the Mesilla Basin between 2016 and 2017 (Figure 2). In total, 21 samples were collected for analyses reported herein. The two replicate samples were collected at the same time and location as another sample. The replicate samples were analyzed along with the other samples, and the results are reported here for comparison and evaluation of Quality Assurance and Quality Control of the isotopic and chemical analysis results. Tables 1.1, 1.2, and 1.3 provide a description of the location, ID, well construction information, sampling conditions, and sampling date information. The wells were used to obtain representative samples from different depths, zones, and formations of the Mesilla Basin aquifer with locations throughout the Mesilla Valley. Several of the wells were selected, because they were installed as nested wells (with negligible lateral distance between wells and significant vertical variation between screen elevations) for vertical profiling at a few locations away from the basin margins and along the Rio Grande River, which is where the unconsolidated sediments have the largest thicknesses. One sample (i.e., Jornada Range South Well), was collected to evaluate the potential variation in water quality between the Jornada del Muerto Basin aquifer (to the north) and the Mesilla Basin aquifer, and to attempt to assess potential mixing or discharge between these aquifer systems.

USGS Site Identification Number	Site Name	Alternate ID 1	Alternate ID 2	Sample Date & time	Time datum	Time Datum Reliability code	Medium Code	Agency Collecting Sample, Code	Site visit purpose, code	Sampler type, code	Sample purpose, code	Sampling Condition, code	Sampling Method, code
315940106372301	MBOWN-152 - 27S.03E.03.2	27S.03E.03.211A	ISC-1A	9/18/2016 17:30	MDT	K	WG	USGS-WRD	2001	4040	10	8	4040
315940106372302	MBOWN-153 - 27S.03E.03.2	27S.03E.03.211B	ISC-1B	9/19/2016 17:00	MDT	K	WG	USGS-WRD	2001	4040	10	8	4040
315940106372303	MBOWN-154 - 27S.03E.03.2	27S.03E.03.211C	ISC-1C	9/19/2016 18:00	MDT	K	WG	USGS-WRD	2001	4075	10	8	4040
315940106372304	MBOWN-155 - 27S.03E.03.2	27S.03E.03.211D	ISC-1D	9/21/2016 17:30	MDT	K	WG	USGS-WRD	2001	4075	10	8	4040
314817106325801	MBOWN-209 - 29S.04E.08.2	29S.04E.08.224A	ISC-4A	9/20/2016 16:00	MDT	K	WG	USGS-WRD	2001		10	8	4040
314817106325802	MBOWN-210 - 29S.04E.08.2	29S.04E.08.224B	ISC-4B	9/20/2016 13:00	MDT	K	WG	USGS-WRD	2001	4040	10	8	4040
315245106380601	MBOWN-189 - 28S.03E.16.221A	28S.03E.16.221A	ISC-7A	2/27/2017 16:00	MST	K	WG	USGS-WRD	2001		10		4040
315245106380602	MBOWN-190 - 28S.03E.16.221B	28S.03E.16.221B	ISC-7B	2/27/2017 13:30	MST	K	WG	USGS-WRD	2001		10		4040
321745106492101	MBOWN-29 - 23S.01E.22.24	23S.01E.22.241A	LC-2A	9/13/2016 15:30	MDT	K	WG	USGS-WRD	2001	4075	10	8	4040
321745106492102	MBOWN-30 - 23S.01E.22.24	23S.01E.22.241B	LC-2B	9/15/2016 16:00	MDT	K	WG	USGS-WRD	2001	4040	10	8	4040
321745106492103	MBOWN-31 - 23S.01E.22.24	23S.01E.22.241C	LC-2C	9/12/2016 16:30	MDT	K	WG	USGS-WRD	2001	4040	10	8	4040
321745106492106	MBOWN-32 - 23S.01E.22.24	23S.01E.22.241F	LC-2F	9/18/2016 11:30	MDT	K	WG	USGS-WRD	2001	4075	10	8	4040
320141106390601	MBOWN-133 - 26S.03E.20.4	26S.03E.20.423A	LMV-2A	2/25/2017 15:00	MST	K	WG	USGS-WRD	2001		10		4040
320141106390602	MBOWN-134 - 26S.03E.20.4	26S.03E.20.423B	LMV-2B	3/1/2017 14:00	MST	K	WG	USGS-WRD	2001		10		4040
321241106461601	MBOWN-84 - 24S.02E.19.22	24S.02E.19.223A	M-2A	2/24/2017 17:00	MST	K	WG	USGS-WRD	2001		10		4040
321241106461602	MBOWN-85 - 24S.02E.19.22	24S.02E.19.223B	M-2B	2/24/2017 14:00	MST	K	WG	USGS-WRD	2001		10		4040
321241106461603	MBOWN-86 - 24S.02E.19.22	24S.02E.19.223C	M-2C	2/23/2017 14:00	MST	K	WG	USGS-WRD	2001		10		4040
321043106235001	24S.05E.36.131 HBNM-4, F-6	24S.05E.36.131	F-6	5/31/2017 17:00	MDT	K	WG	USGS-WRD	2001		10		4040
323201106444901	20S.02E.28.33 Jornada Range South Well	20S.02E.28.33	Range South Well	2/28/2017 14:00	MST	K	WG	USGS-WRD	2001		10		8010

Table 1.1. Well Information for Mesilla Basin Sampling Sites

Alternate ID 2	Longitude	Latitude	Elevation (ft NAVD 88)	Well Depth (ft)	Hole Depth (ft)	Sampling Depth (ft)	Screen Length (ft)	Depth to water level below LSD (m)	Depth to water level below LSD (ft)
ISC-1A	-106.623056	31.994444	3791	90	100	57		2.46	8.06
ISC-1B	-106.623056	31.994444	3791	310	1380	250		8.49	27.85
ISC-1C	-106.623056	31.994444	3791	810	1380	285		18.2	59.59
ISC-1D	-106.623056	31.994444	3791	1310	1380	230		19.5	64.01
ISC-4A	-106.549989	31.804829	3734	75	78	50		1.6	5.26
ISC-4B	-106.549989	31.804829	3734	165.5	180	120		1.91	6.27
ISC-7A	-106.635547	31.879271	3761	198	500		20 (167-187)		
ISC-7B	-106.635547	31.879271	3761	426.8	500		20 (396-416)		
LC-2A	-106.823061	32.295927	3889.86	310	768	182		10	32.89
LC-2B	-106.823061	32.295927	3889.86	110	314	95		4.87	15.98
LC-2C	-106.823061	32.295927	3889.86	40	119	32		2.42	7.94
LC-2F	-106.823061	32.296205	3889.83	650	40	197		11.3	37.01
LMV-2A	-106.652216	32.028156	3798	700	915		10 (680-690)		
LMV-2B	-106.652216	32.028156	3798	1880	2300		10 (1860-1870)		
M-2A	-106.771669	32.211485	3860.97	319	2300		5 (309-314)		
M-2B	-106.771669	32.211485	3860.97	120	321		5 (110-115)		
M-2C	-106.771669	32.211485	3860.97	50	122		5 (40-45)		
F-6	-106.392278	32.178583	3980	464					
Jornada Range South Well	-106.746944	32.533611	4312	500	52				

Table 1.2. Well Information for Mesilla Basin Sampling Sites (Continued)

Alternate ID 2	Temperature, water, deg C	Temperature, air, deg C	Barometric Pressure, mmHg	pH, water, unfltrd field, std units	pH, water , unfltrd, lab, std units	Alkalinity, wat flt fxd end lab, mg/L asCaCO3	Alkalinity, wat flt inf tit field, mg/L as CaCO3	Dissolved solids dried @ 180degC wat flt mg/L	Dissolved solids, sum of constituents, mg/L	Dissolved solids, water, tons/acre-ft	Turbidity white light, det ang 90 +/ -30 corrected NTRU
ISC-1A	20.5	33	664	7.5	8	452	448	1980	2040	2.69	
ISC-1B	23.5	33	665	7.4	7.9	290	283	1090	1160	1.48	
ISC-1C	23.8	32.5	665	8.4	8.3	65.3	61	287	282	0.39	
ISC-1D	24.5	32	664	8.5	8.5	73.4	70	294	291	0.4	
ISC-4A	21.5	33	662	7.3	7.6	430	432	16900	16300	22.9	
ISC-4B	21.5	32	662	7.3	7.4	200	194	31100	29700	42.3	
ISC-7A	24.6		662	7.3	8	919	865	1490	1500	2.03	0.6
ISC-7B	30		664	7.1	8	819	816	3530	3390	4.8	0.6
LC-2A	20.2	22	664	7.5	8	174	173	636	634	0.87	
LC-2B	22.8	30	662	7.6	8	167	164	586	577	0.8	
LC-2C	25	32	662	7.6	7.9	163	161	493	498	0.67	
LC-2F	22.5	28	663	7.7	8.2	133	132	295	288	0.4	
LMV-2A	20.3		664	8	8.2	228	227	528	541	0.72	2.1
LMV-2B	20.2			8.7	8.7	142	138	969	949	1.32	5.5
M-2A	17.4		662	7.9	8.1	154	152	409	405	0.56	3.2
M-2B	19		662	7.5	7.9	184	191	722	715	0.98	0.4
M-2C	21.2		656	7.8	8	169	165	569	569	0.77	0.4
F-6	26.5		658	6.9			27.9				5
Jornada Range South Well	25.1		649	8	7.7	24.2	19.7	3380	3120	4.6	0.4
Average	22.63684211	30.75	661.666667	7.684210526	8.0222222	269.8176	248.4	3625.444	3497.722	4.926667	2.0222222
STD DEV	2.87881747	3.28062494	3.7859389	0.462559422	0.2935521	245.1819	231.0304	7640.977	7302.864	10.38427	1.9520802

Table 1.3. Sample Conditions at Mesilla Basin Wells

Well Purging and General Groundwater Sampling

The pump and sampling equipment was cleaned and decontaminated prior to sampling. Any signs of anthropogenic, hydrologic, or meteorological damage were noted. Static water height within the well was measured prior to pumping. At least three well volumes of water were purged from the well casing to remove resident water and allow groundwater inflow prior to sample collection. Field water-quality parameters, including water temperature, pH, specific conductance, and dissolved oxygen were monitored during well purging and water-quality samples were collected after these field parameters stabilized (U.S. Geological Survey, variously dated). Water-quality samples were collected using an existing pump if present or by a portable submersible pump appropriately sized to the well dimensions and powered by a generator or compressed air or nitrogen. At the land surface, the waterline from the submersible pump was sampled for geochemical and isotopic analyses.

Dissolved Noble Gas Isotope Sampling and Analysis

The two samples collected for the noble gas radioisotopes analysis (referred to herein as ultra-trace samples) were collected by passing the groundwater through a membrane contactor for gas extraction. Separate samples for ^{39}Ar were collected, but ^{85}Kr and ^{81}Kr were analyzed concurrently from the same gas sample. More than 1,500 g of water was degassed using the system shown in the schematic Figure 3. Water was pumped through a 25µm filter and a 5µm filter, and then drawn through a membrane contactor by a vacuum pump and finally pumped into a 10 liter sample cylinder using another vacuum pump as a compressor before being sent to the laboratory at the University of Bern, Switzerland. The samples were then analyzed using the Atom Trap Trace Analysis (ATTA) method (Chen et al., 1999). ATTA is an atom counting method that is accomplished using lasers and a magneto optical trap (MOT) that can selectively capture and count atoms. Argon-39 was also be analyzed by low level counting (LLC).

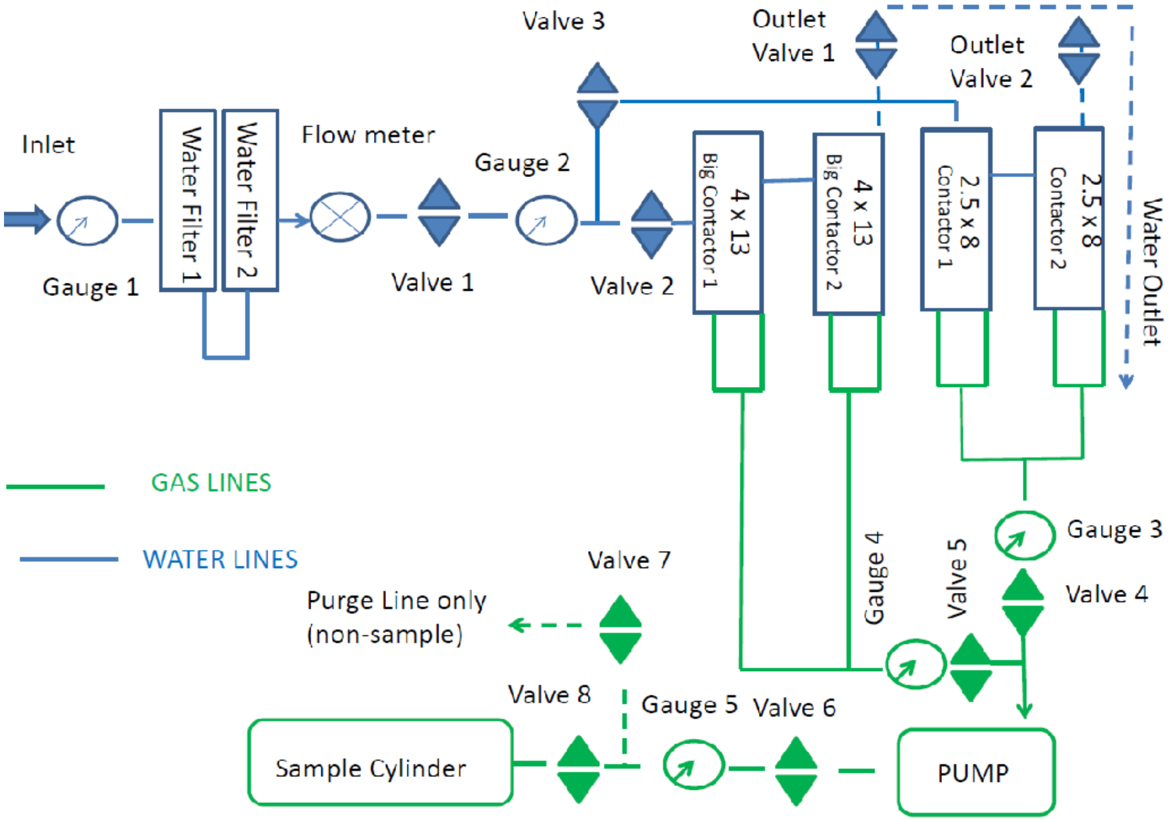

Figure 3. Dissolved Gas Isolation and Sampling Apparatus Schematic

Sample Collection for USGS Laboratory Analyses

Samples collected for common ions and trace elements were analyzed at the USGS National Water Quality Laboratory in Denver, CO. The stable isotopes of water (^{2}H and ^{18}O) were analyzed at the Reston Stable Isotope Laboratory in Reston, VA and the carbon isotopes of dissolved inorganic carbon (^{13}C and ^{14}C) were analyzed at Woods Hole National Oceanographic Institute, MA. Water samples to be used for noble gas concentrations and helium isotope analyses were collected and shipped in 50-ml copper tubing to the USGS Noble Gas Laboratory in Denver, CO. Field blanks and sample duplicates were collected for common ions and trace elements, for ~10% of the total number of samples. A multi-tracer approach is being used to minimize uncertainty of the results by providing, to the extent possible, overlapping time signatures leading to confirmation among the various isotopes. This is particularly important in the determination of groundwater residence times where there has been historically been gaps and/or significant variations in age estimates.

RESULTS AND DISCUSSION

Data and Results from USGS Laboratory Analyses

Groundwater samples were successfully collected from 19 different wells throughout the Mesilla Basin over a wide range of depths below land surface (i.e., 40-1870 feet). The two replicate samples were collected at the LC-2F well and LMV2B. The laboratory analysis results for the isotopes of water and carbon are presented in Table 2. the groundwater samples for the stable isotopes of water, deuterium (δD) and oxygen-18 ($\delta^{18}O$). The stable-isotope ratios are reported in per mil (‰) relative to Vienna Standard Mean Ocean Water (VSMOW) (Révész and Coplen, 2008a; Révész and Coplen, 2008b). Less than half of the wells used for this study were analyzed for their concentration of ^{2}H and ^{18}O. From the wells that were sampled it was determined that the relative hydrogen ratio ranged from -88.3‰ (ISC-7A) to -67.9‰ (M-2C). The average relative hydrogen ratio of the sites sampled was -78.9‰ with a standard deviation of 8.88‰. The relative oxygen ratio had a smaller range with the smallest value being -11.96‰ (ISC-7A), and the greatest value being -7.98‰ (M-2C). The average relative oxygen ratio of Mesilla Basin well samples was -10.20‰ and had a standard deviation of 1.48‰ (Table 2).

Dissolved inorganic carbon (DIC) samples for carbon-13 (13C) and carbon-14 (14C) to carbon-12 (12C) analysis were collected in two 1,000-mL safety-coated glass bottles and sealed with polycone caps. The ^{13}C to ^{12}C ratio of sampled wells had an average ^{13}C to ^{12}C ratio of -7.92 with a standard deviation of 2.80. A range of -3.1 and -11.9 for the ^{13}C to ^{12}C ratio has been shown for non-thermal waters in the Mesilla Basin (Witcher et al., 2004). With the exception of ISC-1A (-13.6) and ISC-4A (-13.7) all of the sampled wells fell within this range. The percent modern ^{14}C of well water samples from the Mesilla Basin ranged from 0.0927 pmc (ISC-1A) to 112.5 pmc (ISC-7A). Percent modern carbon (pmc) is defined as the ratio of 14C to 12C of the sample divided by the standard

14C to 12C ratio of the National Bureau of Standards oxalic acid in 1950 and multiplied by 100 (Plummer and Glynn, 2013)., There are three possibilities as to why Mesilla Basin Water samples had a low percent modern carbon: (1) very little water in the sample was recharged after 1950, (2) biogeochemical processes accelerated 14C decay, or (3) a combination of the two. The average percent modern ^{14}C in the samples was 54.61 pmc with a standard deviation of 45.03 pmc.

Alternate ID 2	delta H-2/H-1 water, unfltrd per mil	delta O-18 / O-16, water, unfltrd per mil	C-13 / C-12, water, unfltrd per mil	C-14, water, fltrd, non-normalized, percent modern
ISC-1A			-13.55	102.056289
ISC-1B			-5.65	11.0197912
ISC-1C			-8.7	8.2039642
ISC-1D			-7.9	8.41236985
ISC-4A			-13.74	89.8459981
ISC-4B			-11.58	68.3299385
ISC-7A	-88.3	-11.96	-3.88	0.89052338
ISC-7B	-72	-9.44	-6.35	0.09273271
LC-2A			-7.79	96.727749
LC-2B			-7.81	96.7649431
LC-2C			-7.89	96.7082525
LC-2F			-7.3	74.7539714
LMV-2A	-86.8	-11.32	-6.45	15.3081187
LMV-2B	-88.3	-11.83	-4.73	0.1757334
M-2A	-87.4	-11.28	-9.61	88.0410064
M-2B	-71.1	-8.47	-8.67	112.503668
M-2C	-67.9	-7.98	-7.6	111.616113
F-6				
Jornada Range South Well	-69.4	-9.3	-3.31	1.50318267
Average	-78.9	-10.198	-7.917	54.6085747
STD DEV	8.8817	1.47835	2.7992	45.0325674

Table 2. Hydrogen, Oxygen, and Carbon Isotope Concentrations from Mesilla Basin Well Samples

Tritium and the uranium (U)-Series (^{238}U, ^{234}U, ^{235}U, and total uranium content) were collected for the Mesilla Basin sample wells (Table 3). The results show a range in tritium concentration from -0.15 pCi/L (LMV-2A) to 18.4 pCi/L (M-2B). The average tritium concentration was 4.71 pCi/L with a standard deviation of 6.31 pCi/L. Tritium concentrations greater than 1.61 pCi/L were recharged after the 1950's or are mixtures containing pre-and post-1950's water (Plummer et al., 2004). 7 of the 18 wells samples appear to be comprised of post-1950's groundwater or mixtures between pre-and post-1950's groundwater, and the other 11 of the groundwater samples were less than 1.61 pCi/L (underlined in Table 3) indicating groundwater at those depths/locations was recharged before the 1950s. These results are also supported by the previously discussed ^{14}C analysis results.

The U-Series showed that samples had a higher average concentration of U-234 (5.34 pCi/L) then either U-238 (3.39 pCi/L) or U-235 (0.187 pCi/L). The median total uranium content of the samples was 0.585 ug/L.

Alternate ID 2	Tritium water, unfltrd pCi/L	U-238, water, fltrd, pCi/L	U-234, water, fltrd, pCi/L	U-235, water, fltrd, pCi/L	Uranium natural water, fltrd, ug/L	C-14, water, fltrd, non-normalized, percent modern
ISC-1A	11	0.41	0.72	0.016	1.12	102.05629
ISC-1B	0.1	0.65	1.94	0.053	2.08	11.019791
ISC-1C	-0.03	0.08	0.08	0.013	0.1	8.2039642
ISC-1D	0.08				0.11	8.4123699
ISC-4A	2.39	1.46	2.4	0.12	4.65	89.845998
ISC-4B	0.24	38	60	2.1	112	68.329938
ISC-7A	0.02	6.2	9.5	0.31		0.8905234
ISC-7B	0.1	9.1	11.9	0.43		0.0927327
LC-2A	13.1	0.4	0.47	0.008	0.82	96.727749
LC-2B	11.9	0.12	0.12	0.026	0.35	96.764943
LC-2C	13.5	0.033	0.22	0.011	0.25	96.708253
LC-2F	0.15	0.028	0.12	0.007	0.06	74.753971
LMV-2A	-0.15	0.08	0.32	0.007		15.308119
LMV-2B	0.16	0.003	0.019	0.013		0.1757334
M-2A	1.37	0.73	2.1	0.05		88.041006
M-2B	18.4	0.24	0.57	0.006		112.50367
M-2C	12.4	0.1	0.22	0.017		111.61611
F-6						
Jornada Range South Well	0.09	0.034	0.049	0		1.5031827
Average	4.71222222	3.392235	5.338118	0.187471	12.154	54.608575
Median	0.2	0.24	0.47	0.016	0.585	71.541955
STD DEV	6.31071536	8.987375	14.06429	0.492002	33.30899	45.032567

Table 3. Tritium, U-Series Isotopes, Carbon Isotopes, and Total Uranium Concentrations from Mesilla Basin Well Samples

Table 4 presents dissolved gas composition of the groundwater samples including noble gas results. Water samples from the Mesilla Basin study wells show N_2 being the most prominent dissolved gas (average concentration of 1.338 E-02 ccSTP/g) followed by Argon (2.986E-04 ccSTP/g), Helium (1.469 E-06 ccSTP/g), Neon (1.903 E-07 ccSTP/g), Krypton (6.583 E-08 ccSTP/g), Xeon (8.842 E-09 ccSTP/g), and Methane (below detection limits or BDL) (Table 4.1 and 4.2).

USGS Site ID	Date Sampled	Date Run	Kr ccSTP/g(H2O)	Xe ccSTP/g(H2O)	N2 ccSTP/g(H2O)
ISC-1A	9/18/16 17:30	12/15/2016	6.797E-08	8.962E-09	1.897E-02
ISC-1B	9/19/16 17:00	12/12/2016	6.792E-08	9.327E-09	1.202E-02
ISC-1C	9/19/16 18:00	12/12/2016	7.022E-08	9.621E-09	1.153E-02
ISC-1D	9/21/16 17:30	12/13/2016	6.918E-08	9.675E-09	1.181E-02
ISC-4A	9/20/16 16:00	12/12/2016	6.192E-08	8.271E-09	CO2inf
ISC-4B	9/20/16 13:00	12/13/2016	5.663E-08	7.380E-09	1.087E-02
LC-2A	9/13/16 15:30	12/15/2016	6.357E-08	8.483E-09	1.271E-02
LC-2B	9/15/16 16:00	12/14/2016	6.789E-08	8.749E-09	1.349E-02
LC-2C	9/13/16 15:30	12/14/2016	6.633E-08	8.624E-09	1.380E-02
LC-2F	9/18/16 11:31	12/14/2016	7.129E-08	9.829E-09	1.252E-02
LC-2F	9/18/16 11:30	12/15/2016	7.034E-08	9.688E-09	1.090E-02
M-2C	2/23/2017	3/10/2017	6.038E-08	7.680E-09	1.271E-02
LMV-2A	2/25/2017	3/10/2017	6.913E-08	9.480E-09	1.114E-02
M-2A	2/24/2017	3/13/2017	6.866E-08	9.485E-09	1.156E-02
M-2B	2/24/2017	3/13/2017	7.138E-08	9.639E-09	1.574E-02
LMV-2B	3/1/2017	3/13/2017	6.961E-08	9.431E-09	1.220E-02
ISC-7B	2/27/2017	3/14/2017	3.796E-08	5.159E-09	CO2inf
F-6					
Jornada Range South Well	2/28/2017	3/14/2017	7.236E-08	8.949E-09	2.016E-02
Jornada Range South Well DUP	2/28/2017	3/15/2017	6.604E-08	8.919E-09	1.539E-02
ISC-7A	2/27/2017	3/15/2017	6.783E-08	9.494E-09	CO2inf
Average			6.583E-08	8.842E-09	1.338E-02
STD DEV			7.46993E-09	1.07344E-09	0.002640477
Lab QA/QC	4/8/16 0:00	12/13/2016	5.604E-08	7.583E-09	9.750E-03
Lab QA/QC	1/9/2017	3/9/2017	5.647E-08	7.546E-09	9.361E-03

Table 4.1. Dissolved and Noble Gas Concentrations from Mesilla Basin Well Samples

USGS Site ID	Date Sampled	Date Run	4He ccSTP/g(H2O)	Ne ccSTP/g(H2O)	Ar ccSTP/g(H2O)	CH4 ccSTP/g(H2O)	H2S water, unltrd (mg/L)
ISC-1A	9/18/16 17:30	12/15/2016	6.767E-08	2.015E-07	3.105E-04	BDL	1
ISC-1B	9/19/16 17:00	12/12/2016	7.629E-07	1.677E-07	2.961E-04	BDL	1
ISC-1C	9/19/16 18:00	12/12/2016	1.294E-07	1.701E-07	3.029E-04	BDL	
ISC-1D	9/21/16 17:30	12/13/2016	1.048E-07	1.704E-07	3.005E-04	BDL	0
ISC-4A	9/20/16 16:00	12/12/2016	1.079E-06	1.714E-07	2.796E-04	BDL	
ISC-4B	9/20/16 13:00	12/13/2016	9.519E-07	1.578E-07	2.524E-04	BDL	0
LC-2A	9/13/16 15:30	12/15/2016	4.642E-08	1.868E-07	2.890E-04	BDL	0
LC-2B	9/15/16 16:00	12/14/2016	5.893E-08	2.309E-07	3.224E-04	BDL	0
LC-2C	9/13/16 15:30	12/14/2016	6.906E-08	2.600E-07	3.179E-04	BDL	0
LC-2F	9/18/16 11:31	12/14/2016	4.144E-08	1.664E-07	3.049E-04	BDL	1
LC-2F	9/18/16 11:30	12/15/2016	4.168E-08	1.673E-07	2.972E-04	BDL	
M-2C	2/23/2017	3/10/2017	5.854E-08	2.307E-07	2.953E-04	BDL	
LMV-2A	2/25/2017	3/10/2017	8.862E-08	1.686E-07	3.059E-04	BDL	
M-2A	2/24/2017	3/13/2017	4.340E-08	1.759E-07	3.076E-04	BDL	
M-2B	2/24/2017	3/13/2017	5.095E-08	2.068E-07	3.294E-04	BDL	
LMV-2B	3/1/2017	3/13/2017	3.189E-06	1.778E-07	3.094E-04	BDL	
ISC-7B	2/27/2017	3/14/2017	1.900E-05	1.088E-07	1.803E-04	BDL	
F-6							
Jornada Range South Well	2/28/2017	3/14/2017	1.724E-07	3.031E-07	3.582E-04	BDL	
Jornada Range South Well DUP	2/28/2017	3/15/2017	1.240E-07	2.026E-07	3.077E-04	BDL	
ISC-7A	2/27/2017	3/15/2017	3.300E-06	1.814E-07	3.039E-04	BDL	
Average			1.469E-06	1.903E-07	2.986E-04		3.750E-01
STD DEV			4.1327E-06	4.05E-08	3.3611E-05		0.48412
Lab QA/QC	4/8/16 0:00	12/13/2016	3.753E-08	1.526E-07	2.510E-04	BDL	
Lab QA/QC	1/9/2017	3/9/2017	3.711E-08	1.458E-07	2.534E-04	BDL	

Table 4.2. Dissolved and Noble Gas Concentrations from Mesilla Basin Well Samples (Continued)

Ratios of noble gas isotopes have been presented in Table 5. The ratio of ^{3}He to ^{2}He (shown in Table 5 as R/Ra) shows an average of 1.251 and a standard deviation of 0.81. A larger ratio of R/Ra, but smaller concentration of tritium in wells ISC-7B and ISC-7A may be the result of contamination or natural sources of tritiogenic ^{3}He. Further analysis is needed to derive useful information for the rest of the noble gas ratios listed in Table 5. It should be noted that the ratio of ^{20}Ne to ^{22}Ne, ^{40}Ar to ^{36}Ar, ^{86}Kr to ^{84}Kr, and ^{30}Xe to ^{132}Xe have little variation between each well. This occurrence will be examined in detail in the future.

USGS Site ID	Date Sampled	Date Run	R/Ra	20Ne/22Ne	40Ar/36Ar	86Kr/84Kr	130Xe/132Xe
ISC-1A	9/18/16 17:30	12/15/2016	1.284	9.876	303.3	0.306	0.145
ISC-1B	9/19/16 17:00	12/12/2016	1.759	9.795	296.2	0.304	0.146
ISC-1C	9/19/16 18:00	12/12/2016	1.375	9.840	295.8	0.305	0.146
ISC-1D	9/21/16 17:30	12/13/2016	1.264	9.799	296.5	0.305	0.146
ISC-4A	9/20/16 16:00	12/12/2016	0.365	9.819	296.7	0.305	0.146
ISC-4B	9/20/16 13:00	12/13/2016	0.246	9.776	295.5	0.306	0.145
LC-2A	9/13/16 15:30	12/15/2016	1.093	9.842	296.7	0.306	0.147
LC-2B	9/15/16 16:00	12/14/2016	1.026	9.790	296.2	0.306	0.148
LC-2C	9/13/16 15:30	12/14/2016	0.988	9.805	296.1	0.304	0.146
LC-2F	9/18/16 11:31	12/14/2016	1.210	9.793	296.0	0.305	0.147
LC-2F	9/18/16 11:30	12/15/2016	1.206	9.795	296.0	0.307	0.149
M-2C	2/23/2017	3/10/2017	0.999	9.813	295.6	0.305	0.150
LMV-2A	2/25/2017	3/10/2017	1.242	9.851	295.9	0.305	0.149
M-2A	2/24/2017	3/13/2017	1.070	9.827	295.8	0.306	0.147
M-2B	2/24/2017	3/13/2017	2.929	9.822	296.2	0.305	0.149
LMV-2B	3/1/2017	3/13/2017	0.263	9.845	296.6	0.306	0.150
ISC-7B	2/27/2017	3/14/2017	2.917	9.913	319.9	0.305	0.151
F-6							
Jornada Range South Well	2/28/2017	3/14/2017	0.451	9.811	296.9	0.305	0.150
Jornada Range South Well DUP	2/28/2017	3/15/2017	0.395	9.818	295.8	0.306	0.148
ISC-7A	2/27/2017	3/15/2017	2.945	9.816	297.8	0.306	0.147
Average			1.251	9.822	297.774	0.305	0.148
STD DEV			0.81	0.03150076	5.34018904	0.00063877	0.001793147
Lab QA/QC	4/8/16 0:00	12/13/2016	1.005	9.864	296.0	0.305	0.147
Lab QA/QC	1/9/2017	3/9/2017	0.989	9.835	296.7	0.305	0.150

Table 5. Noble Gas Isotope Ratios from Mesilla Basin Well Samples

Cation concentrations measured within groundwater samples have been presented in Table 6.1 and 6.2. The minor or trace ions are reported in micrograms per liter (ug/L) and the major ions are reported in milligrams per liter (mg/L). Average concentrations of beryllium, cadmium, chromium, cobalt, copper, nickel, silver, zinc, aluminum, lead, and antimony all averaged less than twenty micrograms per liter. Slightly higher average concentrations of beryllium (53.863 ug/L), iron (268.272 ug/L), manganese (441.072 ug/L), lithium (473.78 ug/L), and strontium (4954.03 ug/L) were observed. Large average concentrations of magnesium (76.956 mg/L), calcium (164.684 mg/L), sodium (956.417 mg/L), and potassium (9.823 mg/L) were measured in the water samples (Table 6.1), and these were the dominant cations in the groundwater. However, the most dominant cation did vary between sodium and calcium, which suggested some variability in the geochemical conditions and history of the groundwater. In fact, the standard deviation was comparable to or larger than the mean for many of the analyses, which suggests significant spatial variability in the aqueous geochemistry within the aquifer system.

Alternate ID 2	Hydro-gen ion, water, unfltrd calcd, mg/L	Calcium water, fltrd, mg/L	Magnes-ium, water, fltrd, mg/L	Sodium, water, fltrd, mg/L	Sodium adsorp-tion ratio	Sodium frac-tion of cations percent	Specif. conduc-tance, wat unf lab, uS/cm @ 25 degC	Specif-ic conduc-tance, wat unf uS/cm @ 25 degC	Hard-ness, water, mg/L as CaCO3	Noncarb hard-ness, wat flt field, mg/L as CaCO3	Noncarb hard-ness, wat flt lab, mg/L as CaCO3	Barium, water, fltrd, ug/L	Beryll-ium, water, fltrd, ug/L	Boron, water, fltrd, ug/L	Cadmium water, fltrd, ug/L	Chrom-ium, water, fltrd, ug/L	Cobalt water, fltrd, ug/L
ISC-1A	0.00003	113	46.5	536	10.7	70	3170	3080	477	30	25	34	0.02	514	0.06	1	0.11
ISC-1B	0.00004	78.7	26.1	292	7.3	67	1950	1980	307	23	16	27.9	0.03	297	0.09	1.5	0.36
ISC-1C	M	13.4	0.573	76.8	5.58	81	442	441	36			15.8	0.01	80	0.03	0.5	0.03
ISC-1D	M	10.1	0.231	88.2	7.51	87	466	470	26.2			3.83	0.01	86	0.03	0.5	0.04
ISC-4A	0.00005	593	288	4590	38.7	79	22800	22100	2690	2250	2260	15.3	0.15	3070	0.45	7.5	0.45
ISC-4B	0.00005	987	805	8480	48.5	76	43700	42600	5810	5610		12.5	0.2	2810	0.6	10	0.68
ISC-7A	0.00005	27	42.6	487	13.6	81	2250	2290	243								
ISC-7B	0.00009	58.8	23.5	1190	33.2	91	5350	5550	244								
LC-2A	0.00003	86.1	13.1	110	2.91	46	1020	1020	270	97	96	130	0.03	213	0.09	1.5	0.09
LC-2B	0.00003	69.6	11.8	109	3.18	51	940	920	224	60	57	111	0.03	200	0.09	1.5	0.38
LC-2C	0.00003	62.1	11.9	86.9	2.65	47	802	801	205	44	42	98.6	0.03	138	0.09	1.5	0.09
LC-2F	0.00002	42.1	6.71	45.8	1.73	42	469	469	133	1	0	89.7	0.01	75	0.3	0.5	0.03
LMV-2A	0.00001	26.5	6.71	150	6.74	77	818	815	93.7								
LMV-2B	M	7.72	0.912	332	30.1	96	1630	1640	23								
M-2A	0.00001	58.2	9.67	66.4	2.12	43	663	662	185	33	31						
M-2B	0.00003	121	18.3	89.4	2	34	1110	1110	378	188	194						
M-2C	0.00002	64	10.4	114	3.48	54	903	906	203	37	34						
F-6	0.00014							2750									
Jornada Range South Well	0.00001	546	63.2	372	4.02	33	3600	3590	1620	1600	1600						
Average	0.00004	164.6844	76.95589	956.4167	12.44556	64.16667	5115.722	4904.947	731.55	831.0833	395.9091	53.863	0.052	748.3	0.183	2.6	0.226
STD DEV	3.24E-05	258.1945	187.7727	2093.415	14.18372	19.87531	10614.37	10065.5	1391.17	1603.652	738.443	45.34962	0.063056	1104.432	0.188523	3.152777	0.214439

Table 6.1. Cation Concentrations from Mesilla Basin Well Samples

Alternate ID 2	Copper, water, fltrd, ug/L	Iron, water, fltrd, ug/L	Lead, water, fltrd, ug/L	Manganese, water, fltrd, ug/L	Nickel, water, fltrd, ug/L	Silver, water, fltrd, ug/L	Strontium, water, fltrd, ug/L	Zinc, water, fltrd, ug/L	Antimony, water, fltrd, ug/L	Aluminum, water, fltrd, ug/L	Lithium water, fltrd, ug/L	Potassium, water, fltrd, mg/L	Silica, water, fltrd, mg/L as SiO2
ISC-1A	0.4	437	0.04	370	0.83	2	2920	4.2	0.07	6	419	23.7	41.7
ISC-1B	0.6	68.6	0.06	31.8	0.6	3	2150	6	0.09	9	275	9.38	43.5
ISC-1C	0.2	8.5	0.02	7.51	0.2	1	174	2	0.04	3	33.2	2.84	34.3
ISC-1D	0.2	6.5	0.02	4.38	0.2	1	80.3	2	0.03	7.4	42.4	2.12	26
ISC-4A	3	2090	0.3	1760	3	15	16600	30	0.45	45	1340	24.5	41.2
ISC-4B	5.4	487	0.4	3030	5.8	20	24600	40	0.6	60	2280	37	16
ISC-7A		101		36.5								8.25	70.6
ISC-7B		224		26.6								6.98	63.5
LC-2A	0.6	12.2	0.13	520	0.63	3	1030	6	0.09	9	88.4	4.98	26.6
LC-2B	0.6	7.2	0.06	463	1.3	3	803	6	0.09	9	91	5.27	25.6
LC-2C	0.6	412	0.06	383	0.6	3	771	6	0.09	9	97.7	7.6	22.7
LC-2F	0.2	50.1	0.02	102	0.2	1	412	2	0.03	3	71.1	2.9	24.3
LMV-2A		406		101								3.83	45.2
LMV-2B		334		119								3	18.8
M-2A		5		18.5								3.98	25
M-2B		11.2		385								5.12	25.4
M-2C		141		459								5.07	27.6
F-6													
Jornada Range South Well		27.6		122								20.3	12.7
Average	1.18	268.272222	0.111	441.07	1.336	5.2	4954.03	10.42	0.158	16.04	473.78	9.82333333	32.81667
STD DEV	1.6111	473.49854	0.125415	743.76	1.685433	6.306	8068.156	12.601	0.188032	18.668	709.5144	9.52647597	15.14241

Table 6.2. Cation Concentrations from Mesilla Basin Well Samples (Continued)

This type of major ion variability may be attributed to a variety of processes including mineral dissolution/precipitation, mixing, oxidation/reduction reactions, and variability of these along groundwater flow pathways. Higher concentrations of calcium can be the result of dissolution of calcium carbonate or gypsum minerals. It should be noted that precipitation of carbonate minerals would decrease calcium concentrations (Witcher et al., 2004). The use of the USGS program PHREEQC to calculate saturation indices could determine whether or not precipitation of carbonate minerals is occurring within the Mesilla Basin. Dissolution of salt minerals including halite adds sodium and chloride to solution, which may also be contributing to the high concentration of sodium found throughout the Mesilla Basin (Witcher et al., 2004). Sodium, potassium, calcium, magnesium, and silica are also contributed by weathering of silicate minerals within the Mesilla Basin (Witcher et al., 2004). High silica, sodium, chloride, potassium, lithium, boron, and fluoride concentrations may also be indicators of geothermal water sources (Witcher et al., 2004).

Table 7 contains the results of the anion measurements and the dissolved oxygen and carbon dioxide. The average dissolved oxygen concentration from sampled wells was 0.176 mg/L, which is approximately two orders of magnitude below the typical aqueous solubility for oxygen. This suggests that, although the groundwater is not significantly reducing, it is also not significantly aerobic, and there is not significant exchange of atmospheric gas to the groundwater system. This is likely due to the significant depth of the groundwater system. Among the cations analyzed, low average concentrations of fluoride, carbonate, potassium, and bromide were also observed. High average concentrations of bicarbonate (315.494 mg/L), chloride (1,221.111 mg/L), and sulfate (874.083 mg/L) were detected (Table 7). The variability in the concentrations and dominance of the major anions between bicarbonate, chloride, and sulfate also suggested some variability in the geochemical signature and history of the groundwater. In fact, the standard deviation was comparable to or larger than the mean for many of the analyses, which suggests significant variability in the aqueous geochemistry within the aquifer system.

Alternate ID 2	Dissolved oxygen, mg/L	Dissolved oxygen, percent of saturation	Carbon dioxide water, unfltrd mg/L	Carbonate, wat flt infl pt titr., field, mg/L	Bicarbonate, wat flt infl pt titr., field, mg/L	Chloride, water, fltrd, mg/L	Sulfate water, fltrd, mg/L	Fluoride, water, fltrd, mg/L	Bromide water, fltrd, mg/L
ISC-1A	0.1	1	30	3	540	393	614	0.46	0.456
ISC-1B	0.1	2	21	1	344	339	202	0.58	0.255
ISC-1C	0.1	0	0.4	0	73	44	72.6	0.82	0.064
ISC-1D	0.1	0	0.4	1	83	43.9	77	0.73	0.062
ISC-4A	Below Detection	0	45	2	523	5390	5090	0.25	3.78
ISC-4B	0.1	1	21	0	236	14100	5100	0.5	8.81
ISC-7A	0.2	3	91	2.1	1050	74.1	274	0.7	0.249
ISC-7B	0.2	3	140	1.8	992	703	854	0.65	0.64
LC-2A	0.4	5	9.6	0	210	109	178	0.41	0.211
LC-2B	0.2	3	8.9	0	199	97.8	157	0.51	0.145
LC-2C	0.2	3	7.9	0	195	68.1	140	0.71	0.127
LC-2F	0.3	4	4.7	0	160	38.4	46.9	0.45	0.058
LMV-2A	0.4	5	4.1	1.2	274	47.3	124	0.43	0.067
LMV-2B	0.1		0.5	4.4	160	240	259	4.85	0.274
M-2A	0.1	0	4.2	0.6	184	57	93	0.33	0.09
M-2B	0.2	2	13	0.5	231	117	223	0.32	0.195
M-2C	0.1	2	4.9	0.5	201	88.2	159	0.61	0.147
F-6	0.2	2	7.8	0.1	34				
Jornada Range South Well	0.1	2	0.4	0.1	23.9	30.2	2070	0.61	0.412
Average	0.17777778	2.111111	21.83158	0.963158	300.6789	1221.111	874.0833	0.773333	0.891222
STD DEV	0.0974996	1.559519	34.92636	1.185531	280.7454	3349.196	1562.197	1.000311	2.091811

Table 7. Anion Concentrations from Mesilla Basin Well Samples

Table 8 presents the analysis results for a few additional trace ions. Approximately half of the groundwater samples were analyzed for these trace ions. From the trace samples that were analyzed the results showed molybdenum (9.58 ug/L) had the greatest concentration followed by vanadium (0.83 ug/L), selenium (0.26 ug/L), and thallium (0.104 ug/L) (Table 8). Low concentrations were typically observed for these elements. However, the variability was similar or greater than the mean, as was observed for the other cations and anion results.

Alternate ID 2	Thall- ium, water, fltrd, ug/L	Molyb- denum water, fltrd, ug/L	Vana- dium, water, fltrd, ug/L	Selen- ium, water, fltrd, ug/L
ISC-1A	0.04	17	0.2	0.1
ISC-1B	0.06	17.9	0.3	0.15
ISC-1C	0.02	4.9	0.1	0.05
ISC-1D	0.02	5.7	0.1	0.05
ISC-4A	0.3	22.9	1.5	0.75
ISC-4B	0.4	2.78	5.1	1
ISC-7A				
ISC-7B				
LC-2A	0.06	7.35	0.3	0.15
LC-2B	0.06	7.24	0.3	0.15
LC-2C	0.06	6.84	0.3	0.15
LC-2F	0.02	3.19	0.1	0.05
LMV-2A				
LMV-2B				
M-2A				
M-2B				
M-2C				
F-6				
Jornada Range South Well				
Average	0.104	9.58	0.83	0.26
STD DEV	0.12611106	6.661	1.476516	0.315278

Table 8. Trace Ion Concentrations from Mesilla Basin Well Samples

Data and Results from Dissolved Noble Gas Isotope Analyses

Two of the groundwater samples were additionally analyzed for isotopes of dissolved noble gases for age dating. The samples collected at LC-2A and LC-2F well locations were sent to at University of Bern, Switzerland, for the analyses. The results of the analysis of the total gas composition suggested that well LC-2A and well LC-2F had similar compositions of dissolved gas, which was mainly composed of nitrogen (Table 9).

	Ar	CH4	N2	Co2	O2	Total
LC-2A	1.67	0.08	96.32	0.55	0.68	100
LC-2F	2.08	0.29	97.04	0.20	0.38	100

Table 9. Total Dissolved Gas Composition (as %) from Mesilla Basin Well Samples

Despite the similarity in total gas compositions, the samples did have variability in the dissolved noble gas isotopic signatures (Table 10). The ^{85}Kr and ^{39}Ar compositions of the dissolved gas samples were also analyzed using the ATTA method as well as LLC at University of Bern. For LC-2A, the concentration of 52.2 dpm/ccKr indicates a young water with a piston flow age of approximately 8 years (Table 10). Both piston flow and exponential age calculations are presented in Table 10, which illustrates the potential variability in age estimates based on the two common conceptual models for the groundwater flow pathways. The concentration of 103 ^{39}Ar and piston flow age of -11 for LC-2A also indicates a "very young" water. However, the sample from LC-2F had a 0.5 concentration of ^{85}Kr, which indicates the groundwater at that location is an older water (than LC-2A) with a piston flow age of 53 years. The piston flow age of 91 years derived from the concentration 79 for ^{39}Ar in the LC-2F sample also indicates older groundwater (Table 10 and Figure 4). High tritium concentrations for LC-2A (13.1 pCi/L) suggests it is younger than the 1950s, and the lower tritium concentrations found for LC-2F (0.15 pCi/L) suggest the groundwater at that location is older than the 1950s. These tritium results support the piston flow age data determined by the dissolved noble gas isotopic signatures.

					Piston flow age (years)				Exponential age (years)	
Sample	85Kr (dpm/cckr)	err (dpm/cckr)	39Ar (dpm/cckr)	err (dpm/cckr)	85Kr	err	39Ar	err	85Kr	39Ar
LC-2A	52.2	2.2	103	8	8	0.3	-11	30	12	-11
LC-2F	0.5	0.2	79	15	53	21.2	91	74	598	103

Table 10. Piston Flow Age and Exponential Age of Krypton and Argon Isotope Composition Results

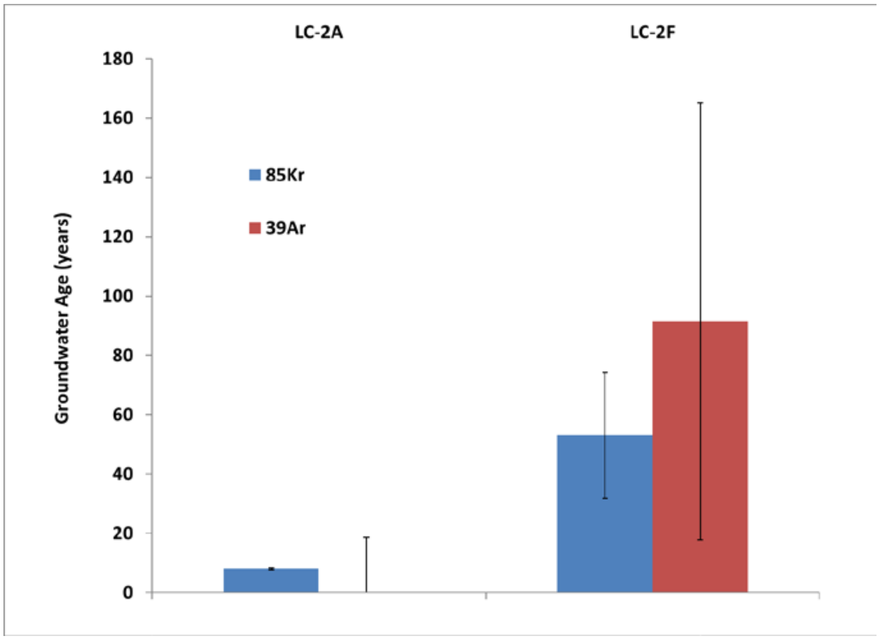

Figure 4. Comparison of Piston Flow Ages Between Wells LC-2A and LC-2F for ^{85}Kr and ^{39}Ar

The variability in the age of these groundwaters is likely dependent on the residence time and subsurface flow pathways. Assuming a primary flow path within the Basin is vertical flow (i.e., piston flow age) due to recharge from infiltration at the land surface, we might expect deeper groundwater to have an older age. For the groundwater samples obtained from wells LC-2A and LC-2F, that is the case. Despite having essentially the same land surface elevation, LC-2A has a total well depth (i.e., where the well screen is and where groundwater enters the well) of 310 feet (below land surface), and LC-2F has a total depth of 650 feet, which is a difference of 340 feet in elevation. The piston flow age difference for ^{85}Kr was 45 years, and the similar age difference for ^{39}Ar was ~100 years. The ratio of these two difference estimates suggests groundwater flow in the aquifer in this area ranges between 7.5 feet/year and 3.4 feet/year.

RECOMMENDATION FOR ADDITIONAL WORK

A significant number of groundwater samples have been collected and a wide array of isotopic and geochemical analyses have been completed on these samples within the last year for this project. Additional data analysis, modeling, and sampling will be needed to characterize the hydrology and geochemistry of the deep groundwater system of the Mesilla Basin. Using the recently collected data, there are a number of calculations and analyses which are still needed to develop our understanding of residence times, salinity transfer, recharge, and flow paths within the aquifer. For developing residence times additional water samples for ^{81}Kr, ^{85}Kr, and ^{39}Ar analyses are needed. Additional noble gas isotopic analysis samples could be collected at wells M-2B, LMV-2A, and ISC-4A to represent various geographic well clusters throughout the basin. These wells also display an array of tritium concentrations (Table 3), which is often an indicator of groundwater age. Having additional ^{81}Kr, ^{85}Kr, and ^{39}Ar ATTA data for these wells would allow for a better understanding of recharge sources and groundwater residence times. In addition, groundwater age dating calculations should be completed using the recently collected ^{14} C and the U-Series results (reported herein) with comparisons to previously collected data, which could be used to identify flow paths and rock-water interactions within the Mesilla Basin aquifer.

Salinity processes within the Mesilla basin can be expanded upon by analyzing the ratios of Cl/Br, ^{2}H/^{1}H, and ^{18}O/^{16}O. Indicators of saline or geothermal water in the Mesilla Basin are distinguished by Cl/Br ratios greater than 600 (Witcher et al., 2004), and large stable isotope ratios of groundwater (^{2}H/^{1}H, and ^{18}O/^{16}O) in lower hydro-stratigraphic units (with the exception of water from the Rio Grande, which has greater ratios). In addition, the stable isotope ratios of groundwater in combination with dissolved gas concentrations as an estimate of recharge temperatures can be useful in determining the presence of paleowater and environmental conditions during recharge (Witcher et al., 2004).

SUMMARY

This project aims to develop and improve groundwater flow information for residence times, recharge, salinity transfer, and flow path mixing of the Mesilla Basin using geochemical tracers, including the isotopes of dissolved noble gases. Geochemical and isotopic data have been collected to characterize the age (and residence time) and sources (and mixing) of groundwater at various depths within the Mesilla Aquifer system. This has included the development and use isotopes of noble gases for the first time in this region of the world, which fills a critical time gap in methods commonly used for groundwater age dating. The objective of the study has been to collect isotopic and geochemical data needed to characterize the deep groundwater system in the Mesilla Basin, which could support the determinations of the contributions of deep groundwater to flow and salinity in the shallow groundwater of the Mesilla Basin.

Twenty groundwater samples have been collected within the last year including two duplicate samples from eighteen groundwater wells within the Mesilla Basin. A comprehensive suite of geochemical and isotopic analyses has been completed on each of these samples including general aqueous chemistry of bulk elements including cations, anions, and trace inorganics. The isotopes of water, carbon, uranium, and noble gases. Tritium and dissolved gas composition analyses were also completed. The results of the duplicate samples were comparable, and age dating methods produced highly comparable results.

The age dating results indicate that the Mesilla Basin aquifer system contains groundwater of both relatively young and older ages. The results indicate a large range and standard deviation of percent modern (younger than 1950s) groundwater, and suggest 10/18 of the samples have >50% modern water. The tritium results also suggested that 9/18 (50%) of the samples are younger and older than the ~1950s. These results were also supported by the noble gas isotope age dating, which indicated that groundwater at LC-2A (310 feet depth) was ~8 years old and groundwater at LC-2F (650 feet depth) was ~50-90 years old. The multi-isotope approach for age-dating groundwater used herein has been shown to be highly effective within the Mesilla Basin. Additional samples will be collected for analysis of ^{81}Kr, ^{85}85, and ^{39}Ar in the summer and early fall of 2017. These data and analyses will be used to advance our understanding of residence times, recharge, salinity transfer, and flow path mixing within the Mesilla Basin.

One consistent observation based on the geochemical composition analysis of the groundwater samples collected herein was that variability was significant. Despite the conceptualization that the basin-fill sediments act hydraulically and geochemically as a relatively uniform (i.e., homogeneous) system unconsolidated sediments, there are significant spatial variabilities within the groundwater geochemistry. Many of the analysis results had standard deviation values that were equal or larger than the mean values. These results suggest significant spatial variability (i.e., heterogeneity) in the aqueous geochemistry of the groundwater within the Mesilla Basin, which has implications for various flow, transport, and geochemical processes. Quantifying these processes and evaluating the groundwater residence time and age support evaluation of recharge, upwelling flow sources, flow dynamics, and resiliency of the groundwater system, which is critical for sustainable management of our groundwater as a water supply resource.

Data Disclaimer

Data in the New Mexico Water Quality Database should be used for general informational purposes only. The uncertainties in data collection procedures, analysis quality and specific sample sources make it unsuitable as a basis for any significant business or policy decisions. Information should be independently verified prior to use in any administrative or legal application.

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