An Update on the Hydrogeology of Magdalena, Socorro County, New Mexico

Open-file Report 556

August 2013

New Mexico Tech
New Mexico Bureau of Geology
and Mineral Resources

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AQUIFER MAPPING PROGRAM

New Mexico Bureau of Geology and Mineral Resources

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INTRODUCTION

On June 5, 2013, the Village of Magdalena notified the New Mexico Environment Department (NMED) that their primary pumping well was not functioning properly. At that time, the NMED contacted the New Mexico Bureau of Geology and Mineral Resources (the Bureau) for geologic and hydrologic information and technical support in the region. In reaction to the Magdalena village well problems, broad community concern developed regarding the present water conditions. To help address this concern, the Bureau and its Aquifer Mapping Program (with the NMED), commenced a small-scale hydrogeologic assessment supported entirely from New Mexico state funding. Bureau staff was onsite on several occasions in June 2013 to measure water levels and provide historic hydrogeologic information regarding the Village of Magdalena wells.

DATA COLLECTION

The Bureau and NMED staff conducted a water-testing event on June 18 to 19, 2013 (Table 1). During this event, water-testing included water level measurements in wells by the Bureau and field-testing for water quality by the NMED. Teams went to domestic wells upon owner request. Additional site visits were conducted by the Bureau in June and July 2013. The Bureau measured water levels in 37 wells total (Table 2), with additional sites measured in subsequent weeks. Water levels were measured with steel water level measuring tapes. Well locations were obtained from Garmin handheld GPS devices. Well records from drillers on file with the NM Office of the State Engineer (OSE) were obtained where possible.

During the water-testing event on June 18 and 19, approximately 24 water samples were collected for preliminary "Water Fair" testing by the NMED field team. A subset of 16 samples was also submitted to the Bureau Chemistry Laboratory for full cation, anion, and trace metals analyses. All water levels and water quality testing were done at no cost to the well owners or community.

Table 1–Inventory of wells used in this study. Site elevation is in feet above sea level (ft asl) as estimated from a 10-meter digital elevation model.

Site ID	Site Elevation (ft asl)	UTM Easting NAD83	UTM Northing NAD83	Water Level available	Water Sample collected
MG-001	6918.27	294240	3773750		x
MG-002	7018.33	293746	3773043	x	x
MG-003	7168.18	295503	3773306	x	x
MG-004	7047.14	294454	3773049	x	x
MG-005	7165.06	295542	3773587	x	x
MG-006	7319.59	294357	3771292	x	x
MG-007	7112.13	293310	3772261	x	
MG-008	7200.46	293715	3771765	x	
MG-009	7197.93	293687	3771800	x	
MG-010	6595.52	294087	3777164	x	x
MG-011	7510.35	294920	3770223	x	
MG-012	7488.73	295098	3770551	x	x
MG-013	7185.28	295273	3772038	x	
MG-014	7481.96	294781	3770325	x	
MG-015	7097.35	293201	3772735	x	
MG-016	7260.82	295886	3773400	x	x
MG-017	7098.89	293541	3772523	x	x
MG-018	6318.48	294166	3781447	x	x
MG-019	6638.47	290622	3777660	x	x
MG-020	6597.90	291133	3776248	x	
MG-021	6727.35	288392	3774145	x	x
MG-022	6641.16	290420	3775673	x	x
MG-023	7338.03	294283	3771025	x	x
MG-024	7388.05	294465	3770788	x	x
MG-025	6614.61	289917	3776257	x	x
MG-026	6357.33	296734	3780209		x
MG-027	6283.41	297649	3779995	x	x
MG-028	6426.50	294668	3780974	x	x
MG-029	6409.29	296181	3778953	x	
MG-030	6633.78	290575	3775752	x	
MG-031	6690.13	288873	3774921	x	x
MG-032	6415.47	297872	3779303		
MG-033	6342.74	298001	3779570	x	
MG-034	6362.05	296746	3780306	x	x
MG-035	6697.10	294960	3776610	x	x
MG-036	6751.69	294932	3776346	x	x
MG-037	6409.15	296308	3778926	x	
MG-038	6408.17	296263	3778936	x	
MG-039	6536.86	290982	3776833	x	
MG-040	7424.88	294816	3770724	x	
MG-041	6541.27	291108	3776817	x	
MG-042	6654.08	293446	3776345		

Table 2–Water level data from drilling records and 2013 Bureau measurements.

Site ID	Well depth (ft)	Date of water level meas.	Depth to water (bMP)	Measurement Point (MP) height (ft)	NMOSE well record	Drill date	Driller's static water level	Screen top (ft bgs)	Screen bottom (ft bgs)
MG-001	150			-2.08	X				
MG-002	120	18-Jun-13	84.84	1.01	RG-71116	7/30/99	75.00	80	120
MG-003	650	18-Jun-13	143.68	1.56	RG-78488	7/31/02	112.00	510	650
MG-004	320	18-Jun-13	144.16	0.50	RG-70713	1/10/99	265.00	280	320
MG-005	730			0.26	RG-77110	1/23/02	115.00	690	730
MG-006	200	18-Jun-13	31.92	1.03	RG-53834	9/30/91	24.00	180	200
MG-007	165	18-Jun-13	120.38	1.08	X				
MG-008	190	18-Jun-13	152.09	1.38	RG-89989	12/18/07	118.00	150	190
MG-009	200	18-Jun-13	153.17	0.30	RG-60643	11/1/94	134.00	160	200
MG-010	400	19-Jun-13	181.40	1.15	RG-65536		172.00		
MG-011	150	19-Jun-13	101.77	1.78	RG-73383	4/10/00	100.00		
MG-012		19-Jun-13	33.96	0.25	X				
MG-013	200	19-Jun-13	48.53	0.37	RG-37124	10/23/81	28.00	40	200
MG-014	160	19-Jun-13	65.37	0.40	RG-56202	12/1/92	80.00	100	160
MG-015	210	19-Jun-13	110.45	3.78	RG-80960	3/9/05	106.00	150	210
MG-016	400	19-Jun-13	113.18	1.42	X				
MG-017	240			0.00	RG-77549	6/19/02	95.00	97	237
MG-018	355	18-Jun-13	146.93	0.70	RG-77510	4/12/02	109.00	155	355
MG-019	201	16-Jul-13	171.31	1.60	RG-33186	9/12/79	172.00	160	200
MG-020	196	18-Jun-13	92.50	1.20	RG-81782	2/9/04	96.00	96	196
MG-021	295	18-Jun-13	134.00	-3.50	RG-82820	10/18/04	116.00	235	295
MG-022	160	18-Jun-13	114.70	2.00	RG-76655	11/8/01	110.00	120	160
MG-023	182	18-Jun-13	150.51	0.60	RG-36094	10/15/81	122.00	142	182
MG-024	100			-4.10	RG-35038	10/31/80	52.00	70	100
MG-025	325	19-Jun-13	193.21	0.70	RG-71718	11/1/99	250.00	225	325
MG-026	350				X				
MG-027	530	25-Jun-13	427.86	0.00	RG-74352	11/12/01	325.00	490	530
MG-028	275	19-Jun-13	134.48	2.80	RG-81752	1/13/04	106.00	215	275
MG-029	200	19-Jun-13	134.88	1.20	RG-51978	7/17/90	111.00	160	200
MG-030	420	16-Jul-13	122.86	2.00	RG-80064	4/18/03	150.00	380	420
MG-031	325	19-Jun-13	110.76	1.70	RG-84914POD2	7/16/10	190.00	225	325
MG-032	12	19-Jun-13	dry/collapsed		RG-50907	6/15/89			
MG-033	760	19-Jun-13	192.40	1.00	RG-50907CLW	1/2/06	199.00	218	738
MG-034	335	25-Jun-13	285.86	1.00	RG-92816	6/23/11	300.00		
MG-035	440	25-Jun-13	83.25	0.00	RG-82741	5/24/04	100.00	380	420
MG-036	420	25-Jun-13	144.72	2.00	RG-82740	5/20/04	76.00	400	440
MG-037	156	06-Jun-13	143.00	1.30	X				
MG-038	150	06-Jun-13	142.20	2.00	X				
MG-039	185	06-Jun-13	27.60	1.90	X				
MG-040	160	16-Jul-13	74.51	0.25	RG-56419	12/3/92	65.00	120	160
MG-041	135	16-Jul-13	67.09	1.60	RG-84734	4/30/05	60.00	75	135
MG-042		06-Jun-13	142.00	2.00	X				

NMOSE = New Mexico Office of the State Engineer; BMP = Below Measuring Point; ft bgs = feet below ground surface.

PREVIOUS WORK

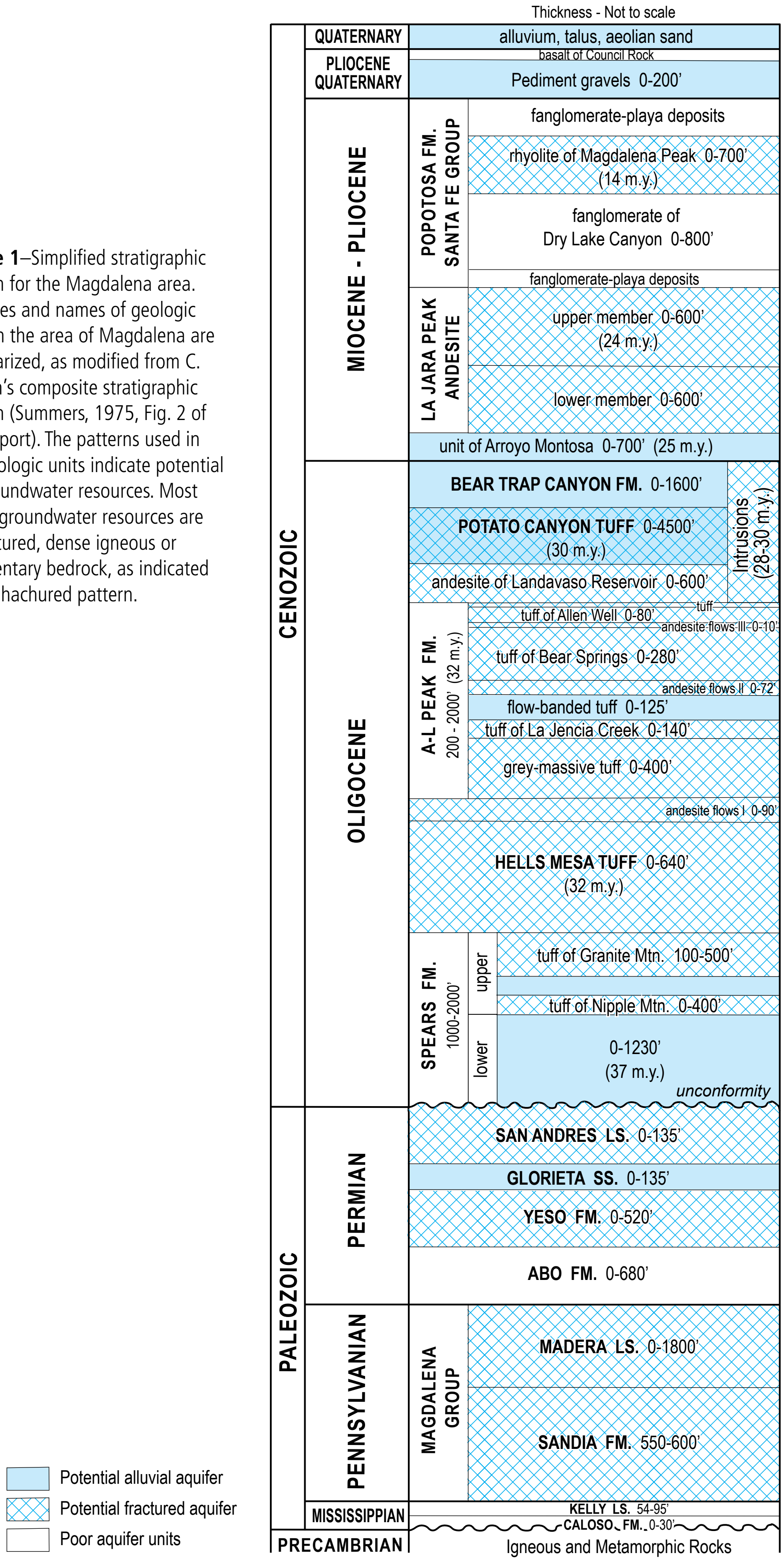
Little hydrologic and geologic work has been done recently in the Magdalena area. Numerous publications related to economic geology, sedimentary geology, and volcanism of the surrounding mountains are available (Siemers, 1973; Bowring, 1980; Krewedl, 1974; and Loughlin and Koschmann, 1942). Magdalena area hydrogeology was studied by Summers (1975) and by Bishop (1972) (included in Appendix 1). Groundwater recharge to the area is discussed in Summers et al. (1972) and in Anderholm (1987). A detailed geologic map is available in Summers (1975), which provides the most detailed geology available for this area; however, there are no cross sections. The Socorro County geologic map compiled by Osburn (1984) also provides some useful information.

GEOLOGY

The geology of the region is complex, with geologic units ranging from Precambrian granite and metamorphic-sedimentary units, to Paleozoic sedimentary rocks, with Oligocene to Pliocene igneous rocks, covered in places with deposits of Cenozoic alluvial units (Fig. 1). The sedimentary rocks observed in this study include Pennsylvanian and Permian age units of the Madera, Abo, Yeso, and San Andres Formations. Many of the tuffs and volcanic flows from the Oligocene, Miocene and Pliocene eruptions are dense and form fairly low porosity, low permeability units that are highly fractured. Additional sedimentary units (composed of re-worked volcanic rocks) exist locally between volcanic deposits, deposited during volcanically inactive periods. The region in and around Magdalena has been further complicated by extensive faulting and fracturing, with additional intrusions of igneous dikes and sills in many locations.

Important structural features are the La Jencia fault on the east side of Magdalena and the northeast trending Magdalena Fault (Fig. 2). Numerous northwest trending faults related to rifting in the Rio Grande region have been identified by previous mapping (Summers, 1975), and likely play a role in groundwater flow. Unfortunately, detailed subsurface geologic data is limited, making interpretations of the subsurface features and their relationship to groundwater especially challenging.

Figure 1–Simplified stratigraphic column for the Magdalena area. The ages and names of geologic units in the area of Magdalena are summarized, as modified from C. Chapin's composite stratigraphic column (Summers, 1975, Fig. 2 of that report). The patterns used in the geologic units indicate potential for groundwater resources. Most of the groundwater resources are in fractured, dense igneous or sedimentary bedrock, as indicated by the hachured pattern.



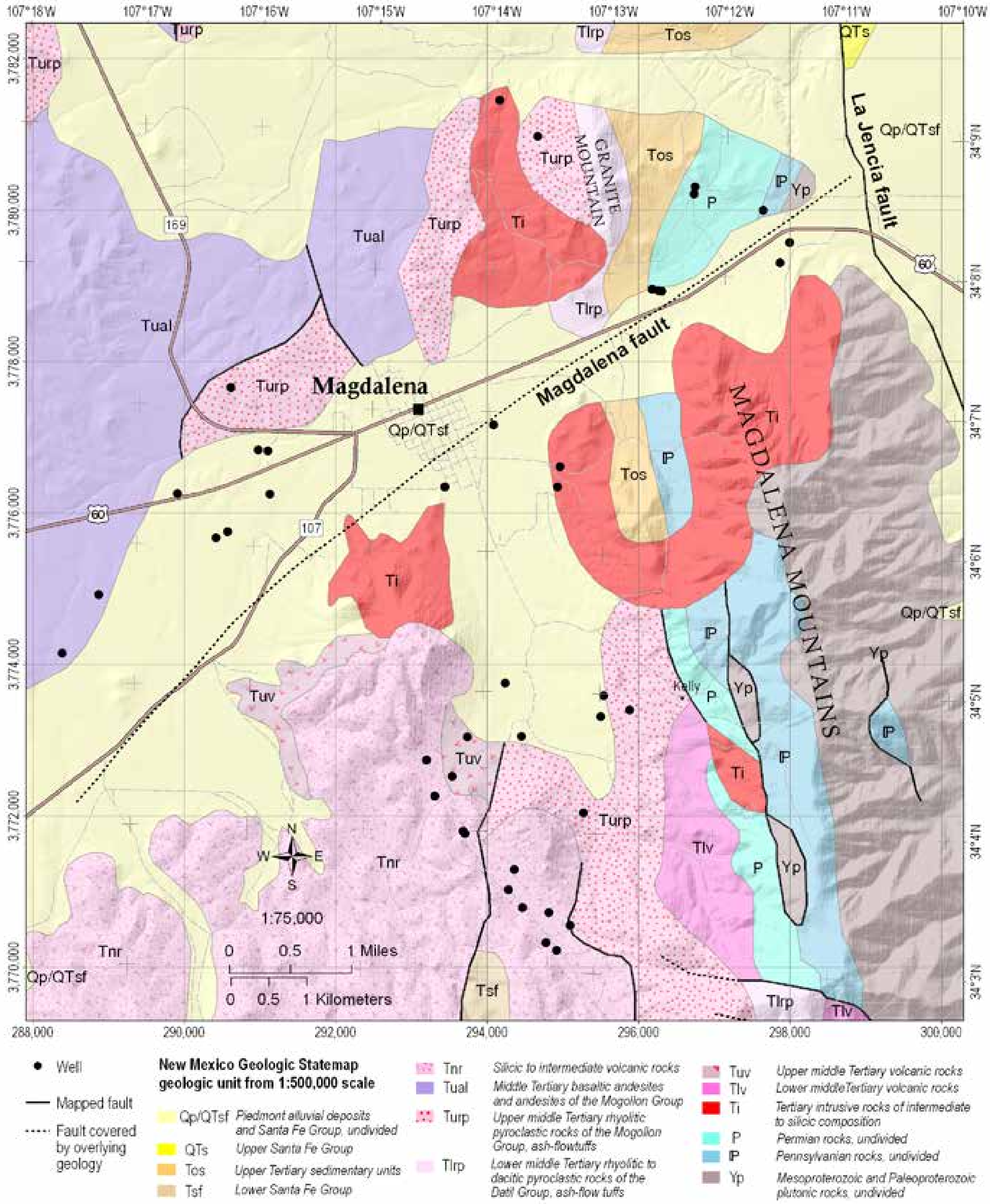


Figure 2–Generalized geologic map. The major geologic structures are the Magdalena and the La Jencia faults. These faults are likely fault "zones" and are not limited to the linear feature on this map. Additional faults and fractures (not shown) trend in northwest-southeast and northeast-southwest directions. This is a very simplified geologic map from the 1:500,000-scale Geologic Map of New Mexico (2003). Black points identify wells used for this study. Many of the northwest trending faults indicated on Summers (1975) map are not shown in this map. See Appendix 1 included with this report for the Summers (1975) and included geologic map.

HYDROGEOLOGY

The Village of Magdalena and surrounding community are located at elevations approximately 6300 to 7800 feet above sea level. The average annual precipitation for the area is approximately 12 inches per year, most of which falls in summer monsoons during July, August and September.

In this region of New Mexico, groundwater is typically found within 1) fractured/faulted bedrock aquifers and 2) alluvial aquifers. The fractured bedrock aquifers hold water within the cracks (fractures) of the rock. Fractured aquifers generally have little stored water within the rock itself, as it has little pore space (low porosity), but these aquifers can transmit water quickly through fractures. In the Magdalena area, these aquifers are typically in crystalline bedrock such as granite or metamorphic rocks, dense volcanic material (i.e. densely welded tuff, andesite flows), or carbonates (i.e. limestone) (Fig. 1).

Alluvial aquifers, on the other hand, have more groundwater stored within the pore spaces between sand, gravel and clay deposits. Alluvial aquifers tend have more water storage capacity, but transmit water slower than fractured aquifers. In the Magdalena area, alluvial aquifers are shallow, found at the land surface and intermittently at depth between volcanic deposits. These deeper alluvial deposits are often well cemented, and may have low permeability and porosity.

A review of well records available publicly from the OSE shows that the water producing zones in most local wells are within Cenozoic igneous rocks and alluvial deposits (sand and gravel). The records indicate that a small number of wells produce from fractured Paleozoic sedimentary units (limestone and sandstone). The highest production wells in the area are found along the northeast-southwest trending Magdalena fault zone. Wells along this fault zone (such as the Village of Magdalena's Trujillo well and the Magdalena School well) may produce upwards of 200 gallons per minute (gpm). Previous work by Summers (1975) identifies that wells in close proximity to fractures and especially faults are likely the highest producing wells.

WATER LEVELS IN THE REGION

Wells which were approximately located using OSE well records indicate that the general trend that water is shallower in the mountains (30-40 feet below land surface) and gets deeper to the east near the La Jencia fault (>300 feet deep). Using the water levels obtained during this study in the summer of 2013, a water table elevation map was created (Fig. 3, Table 2). Our water level measurements suggest that groundwater generally flows from the mountains into the valley traversed by Highway 60. Groundwater then flows from west to east, through the Village of Magdalena. East of the La Jencia Basin fault, depth to water increases (Fig. 3).

Changes in water levels

Using the water level elevation contours from June 2013 (blue lines, Fig. 4), we compared current water levels with a water table elevation map created by Summers (1975) (pink lines, Fig. 4). In most areas, the water table is roughly the same as it was in 1975; however, in the region east of the Village of Magdalena, there is marked water level declines (100 to 200 feet).

Further analysis of water level declines was performed by comparing static water levels at the time of drilling, with current 2013 water levels (Fig. 5, Table 2). This was only possible where wells could be matched with a OSE well record to provide a historic static water level from time of drilling. On Figure 5, the pink symbols indicate water level declines ranging from 1.8 to 102.9 feet below their driller's static water level. Approximately 70% of the measured wells (22 of 31 wells) had water level declines of more than one foot since they were drilled.

In general, the comparison of the driller's historic static water levels with recent water levels indicate that there have been water level declines in the Magdalena area. Water declines are most notable on the east side of the region, where water levels declined by 40 to 100 feet since they were drilled. Some areas (shown by blue symbols, Fig. 5) indicate water levels rose since drilling. However, there are fewer wells with increases to water levels in the region (9 of 31 wells).

Using a comparison with the static water level upon drilling must be examined carefully though, as these declines occur over various time scales (shown in years, Fig. 5). In addition, the method of static water level measurement by the driller is not provided in the OSE well records.

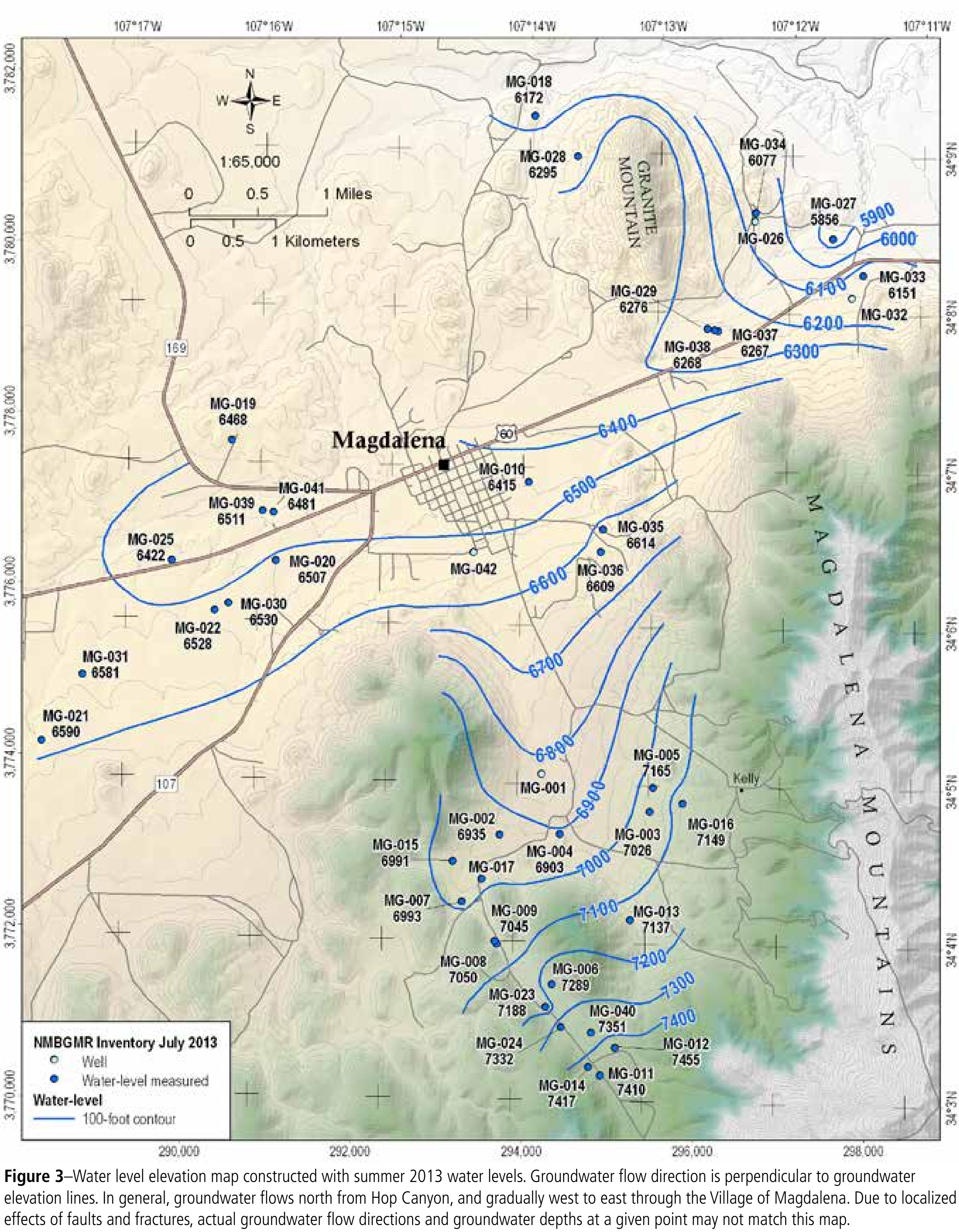


Figure 3–Water level elevation map constructed with summer 2013 water levels. Groundwater flow direction is perpendicular to groundwater elevation lines. In general, groundwater flows north from Hop Canyon, and gradually west to east through the Village of Magdalena. Due to localized effects of faults and fractures, actual groundwater flow directions and groundwater depths at a given point may not match this map.

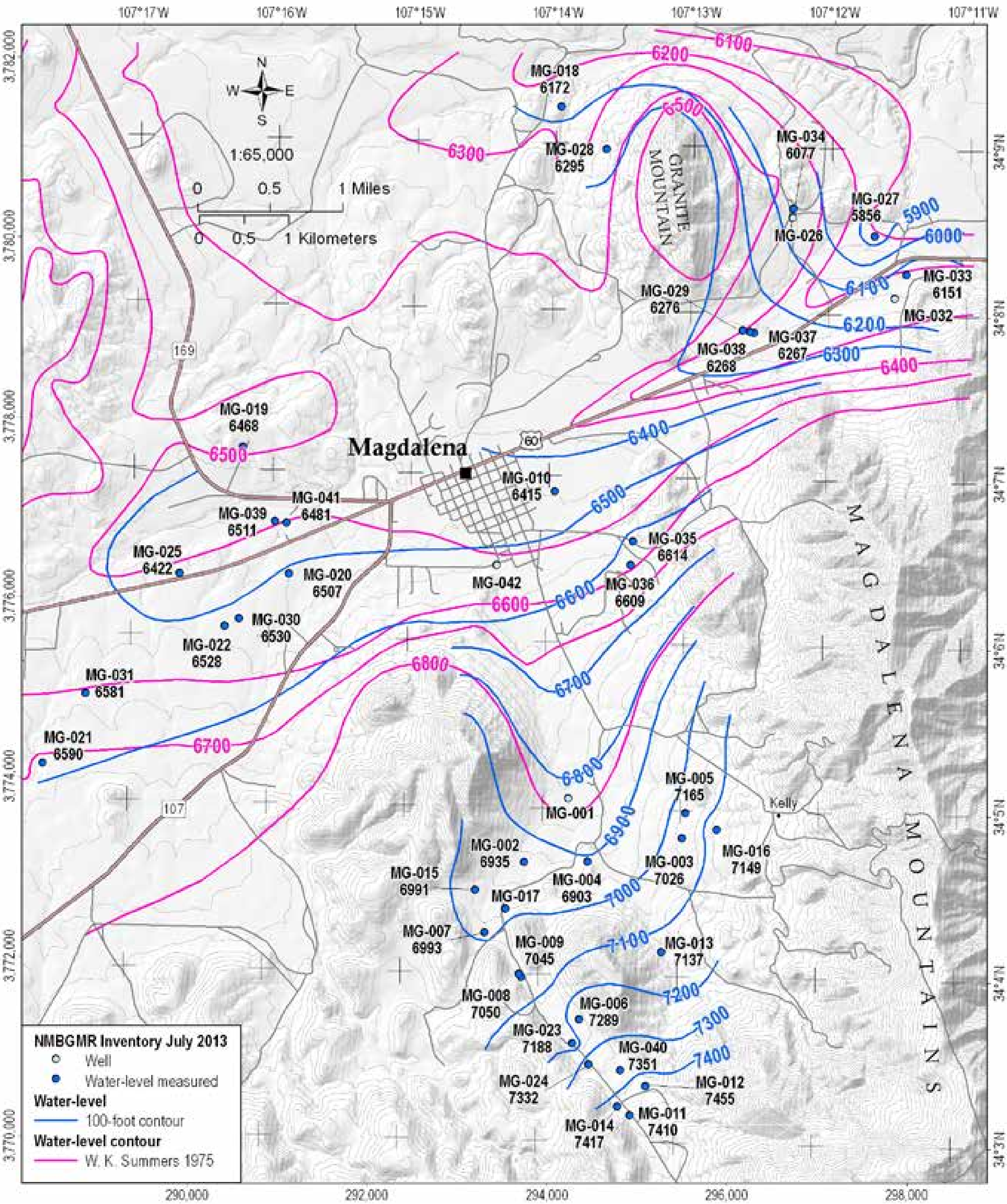


Figure 4–Comparison of recent and historic water table elevations. The pink groundwater elevation contours, from Summers (1975), are compared with the current water levels (2013) in blue. In general, present day groundwater flow mimics the trends observed in the 1970's. However, there is significant decline in the water levels in the area on the east side of the map, along Highway 60, where 1975 vs. 2013 contours differ as much as 200 feet.

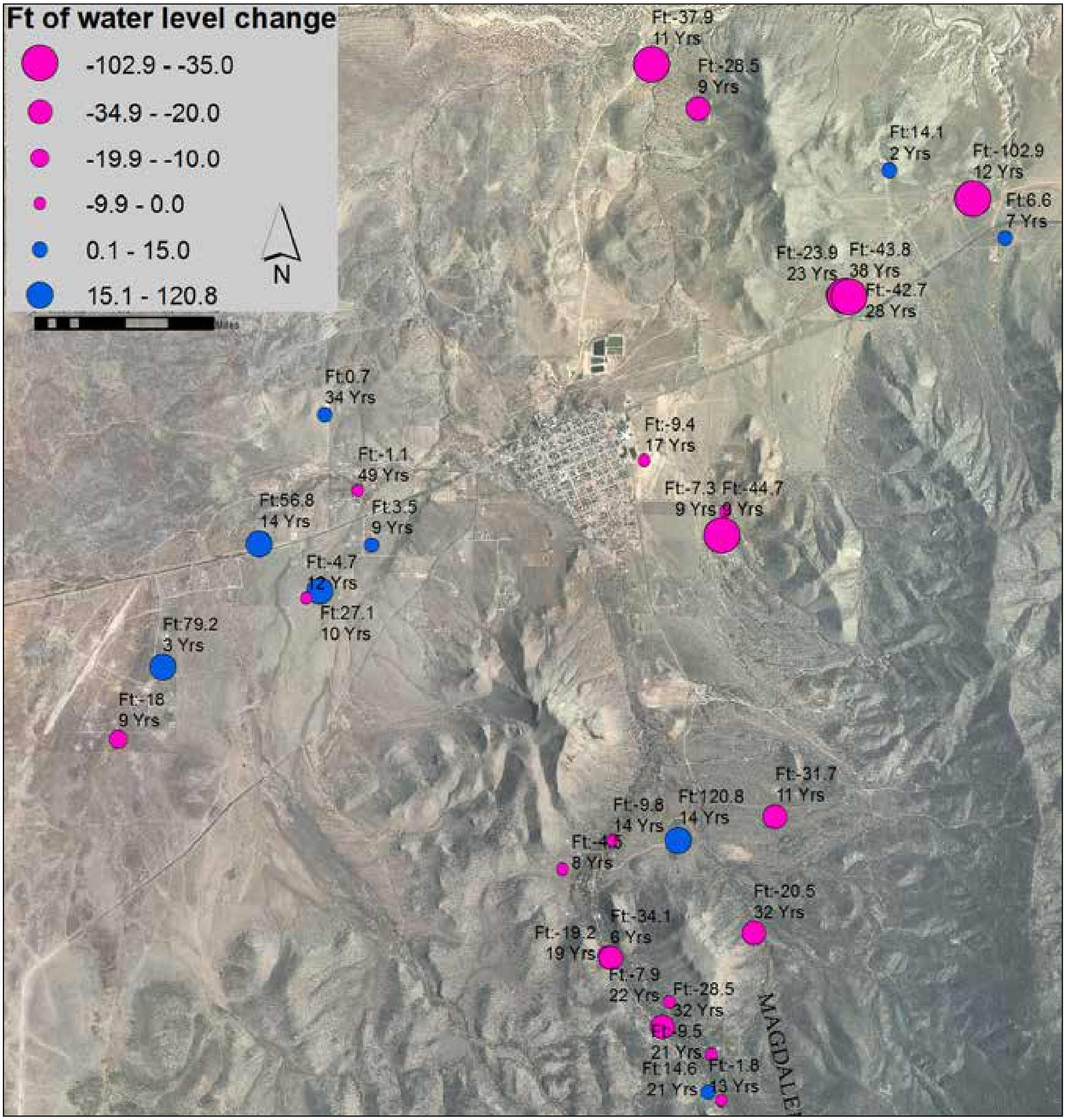


Figure 5–Comparison of driller's static water levels with summer 2013 water levels within the same well. The difference in depth to water (ft) was calculated by subtracting the 2013 water level from the original static water level noted on the OSE driller's record. The pink points indicate wells where water levels have dropped, as noted by "Ft," which is a negative number (feet of water level change). Blue points indicate wells where water levels have risen since the well was drilled. The number of years is the difference between the drilled date and the recent date of measurement. The symbol size is proportional to the amount of change in the water level (i.e. larger declines have larger symbols).

WATER QUALITY

As groundwater interacts with and dissolves rocks in the subsurface, the ion content and trace metal chemistry of the water can change. One simple way to examine this is with a measurement of the water's specific conductivity. The specific conductivity describes the ion content of the water as a measure of its ability to conduct electricity at a specific temperature (25°C). The groundwater sampled in this region ranges from 223 to 1557 microsiemens/centimeter (µS/cm), with an average of 462 µS/cm. In Figure 6, a map of field-measured specific conductivity shows distributed ranges mostly less than 600 µS/cm; however, there are two sites with rather high values of 1540 and 1557 µS/cm. Water with higher levels of specific conductivity may indicate 1) that it has dissolved more ions from the rock it flowed through, 2) groundwater had a longer flow path from where it recharged, and/or 3) possible natural or anthropogenic contaminants to groundwater.

A total of sixteen samples were analyzed for complete major ion and trace metal chemistry (Table 3). In most areas of this study, the water quality (in terms of major ion and trace metal chemistry) is very good. The drinking water standards set for public water supplies are good guidelines for examining water quality (http://www.nmenv.state.nm.us/NMED_regs/gwb/20_6_2_NMAC.pdf), but they are not enforceable for domestic wells. The most common issue in the groundwater in this region is high sodium. According to the drinking water standards, sodium levels over 20 mg/L are a health concern. Of the sixteen analyzed samples, nine of them had sodium above this recommended level. The other issues with groundwater in this region were two wells with high sulfate, hardness, and high total dissolved solids (TDS). These are the two wells mentioned previously with high specific conductivity.

Plotting concentrations of ions on a Piper diagram (Fig. 7) shows the percentages of 1) cations (calcium (Ca), sodium + potassium (Na+K) and magnesium (Mg)) and 2) anions (bicarbonate + carbonate (HCO_3 + CO_3), chloride (Cl) and sulfate (SO_4)). The dominant anion in the sampled water in this area is HCO_3, while a few samples have higher SO_4. Calcium is the dominant cation. However, some samples have nearly equal percentages of Ca to Na+K. In samples with higher levels of sodium, there has likely been more groundwater interaction with clay minerals providing opportunities for cation exchange. In this region, igneous rocks that have weathered to clay or localized sedimentary deposits of clay provide sources for this cation exchange to occur.

Precipitation that recharges the groundwater system with minimal soil interaction typically has a chemical signature dominated by Ca and HCO_3. The majority of the samples in the Magdalena area are dominated by Ca and HCO_3, indicating that this groundwater is fresh (very similar to precipitation) and has had little rock-interaction time to pick up additional ions along its flow path. Where groundwater flows quickly through the subsurface, such as though fractures in crystalline bedrock, this "fresh" water chemistry is common.

The Piper diagram shown in Figure 7 also shows symbols to represent the geology

Table 3a–Water sampling results – Field parameters, lab calculations, and major ions. Units, where not labeled, are in mg/L (except pH). All NMED analyses were done using field kits.

Site ID	Sample date	Chemistry analysis agency	Temp (deg C)	Field specific conduct-ivity (uS/cm)	Field pH	Lab specific conduct-ivity (uS/cm)	Lab pHL	Total dissolved solids	Hard-ness	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	Br	F	Fe	Mn	NO_3
MG-001	18-Jun-13	NMBGMR	16	330		366	7.4	217	144	46.6	6.77	14.1	3.01	183	<5	11.2	4.74	0.1	0.24	0.057	0.027	1.63
MG-002	18-Jun-13	NMBGMR	17.4	331		348	7.4	241	130	41.9	6.14	16.7	5.2	183	<5	9.11	5.02	0.1	0.16	<0.02	0.004	1.11
MG-003	18-Jun-13	NMBGMR	20	560		544	7.4	334	234	78	9.4	19.1	1.29	255	<5	54	12.2	0.2	0.22	<0.02	0.002	8
MG-004	18-Jun-13	NMBGMR	21.7	1557		1510	7.5	1180	584	215	11.5	129	1.64	162	<5	650	52.6	0.72	1.02	0.105	0.026	0.63
MG-005	18-Jun-13	NMBGMR	24	510		513	7.7	330	139	50.6	3.21	51.2	0.962	160	<5	108	11.1	0.11	0.43	<0.02	0.001	4.54
MG-006	18-Jun-13	NMED	15.1	314															0.3	0.06		4.87
MG-007	18-Jun-13	NMED	21.4	309															0.1	0.13		5.76
MG-009	18-Jun-13	NMED	19.1	289															0.2	0		5.32
MG-011	19-Jun-13	NMED	21.5	270															0.5	<0.01		8.42
MG-012	19-Jun-13	NMED	15.2	321															1.6	0.08		6.65
MG-013	19-Jun-13	NMED	18.5	560															1.2			9.3
MG-014	19-Jun-13	NMED	20.9	258															0.5	0.06		8.86
MG-015	19-Jun-13	NMED	22.1	315															0.5			10.19
MG-016	19-Jun-13	NMBGMR	24	391		383	7.7	236	123	39.9	5.62	31.9	0.804	163	<5	31.4	14.5	0.15	0.39	<0.02	0.001	8.3
MG-017	19-Jun-13	NMED	22.6	265															0.3	0.03		3.54
MG-018	18-Jun-13	NMBGMR		627		612	7.4	386	267	66.1	24.8	35.4	2.24	291	<5	70.8	12.2	0.18	0.77	0.067	0.003	3.38
MG-019	18-Jun-13	NMED		420															1	0.74		10.63
MG-020	18-Jun-13	NMED		325															0.8	0.01		6.65
MG-021	18-Jun-13	NMBGMR	18.51	500	7.76	316	7.8	229	95.8	28.8	5.8	27.4	4.57	157	<5	16.8	9.57	0.15	0.57	<0.02	0.001	2.42
MG-022	18-Jun-13	NMED	21.3	297	8.14														0	0.01		4.87
MG-023	18-Jun-13	NMBGMR	14.6	223	7.87	232	7.4	158	104	33.7	4.89	8.81	1.63	123	<5	11	3.6	0.072	0.17	<0.02	0.001	0.52
MG-024	19-Jun-13	NMBGMR	13.7	250	7.3	262	7.2	181	109	35.8	4.84	13.3	2.71	135	<5	12.8	4.82	0.087	0.2	0.036	0.003	1.58
MG-025	19-Jun-13	NMBGMR	19.26	359	8.35	384	8	230	93.2	23.7	8.28	40.3	1.72	169	<5	29	11.9	0.16	0.37	<0.02	<0.001	1.82
MG-026	19-Jun-13	NMED	20	440	8.13														0.5			10.63
MG-027	19-Jun-13	NMBGMR	23.9	469	7.78	471	7.6	302	214	69	10	18.1	1.96	210	<5	47.6	14	0.18	0.42	<0.02	<0.001	7.06
MG-028	19-Jun-13	NMBGMR	18.12	1540	7.3	1580	7.2	1280	929	236	82.4	38.1	3.73	257	<5	727	31.5	0.53	0.5	<0.1	0.034	<0.1
MG-031	19-Jun-13	NMBGMR	24.4	433	7.88	437	7.7	276	133	31.7	13.1	43.2	1.95	198	<5	41	13.9	0.19	0.51	<0.02	0.005	3.07
MG-034	25-Jun-13	NMBGMR				473	7.6	294	216	45.5	24.9	16.6	1.87	204	<5	50.7	15.2	0.16	0.31	<0.02	0.002	8.5
MG-036	25-Jun-13	NMBGMR				637	7.7	396	237	61.3	20.4	40.4	2.12	174	<5	113	46.8	0.49	0.73	<0.02	0.001	0.57

Table 3b–Water sampling results – trace metals, units are in mg/L. Analysis by the New Mexico Bureau of Geology Chemistry Laboratory.

Site ID	Ag	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Li	Mo	Ni	Pb	PO_4	Sb	Se	Si	SiO_2	Sn	Sr	Th	Ti	Tl	U	V	Zn
MG-001	<0.0005	0.0083	0.0009	0.026	0.116	<0.0005	<0.0005	<0.0005	0.0014	0.0022	0.009	0.001	0.0125	<0.0005	<0.5	<0.0005	0.001	17.1	36.6	<0.0005	0.332	<0.0005	0.003	<0.0005	0.001	0.003	0.0072
MG-002	<0.0005	0.006	0.0015	0.026	0.036	<0.0005	<0.0005	<0.0005	0.0019	0.0013	0.008	<0.001	0.0012	<0.0005	<0.5	<0.0005	0.001	29.7	63.5	<0.0005	0.297	<0.0005	0.004	<0.0005	0.0012	0.0064	0.0524
MG-003	<0.0005	0.0062	<0.0005	0.025	0.139	<0.0005	<0.0005	0.0009	0.0016	0.0075	0.012	0.001	0.0021	0.0007	<0.5	<0.0005	0.002	10.9	23.3	<0.0005	1.07	<0.0005	0.002	<0.0005	0.0016	0.0026	0.0242
MG-004	<0.0025	0.006	<0.0025	0.126	0.009	<0.0025	<0.0025	<0.0025	<0.0025	0.0077	0.032	<0.005	0.0072	<0.0025	<0.5	<0.0025	0.005	13.5	28.9	<0.0025	4.03	<0.0025	<0.005	<0.0025	<0.0025	<0.0025	0.0213
MG-005	<0.0005	0.0075	0.0008	0.06	0.031	<0.0005	<0.0005	<0.0005	0.0011	0.0106	0.131	0.002	0.0012	0.0006	<0.5	0.0007	0.001	8.79	18.8	<0.0005	1.49	<0.0005	0.001	<0.0005	0.0098	0.0015	0.0236
MG-016	<0.0005	0.0067	<0.0005	0.031	0.046	<0.0005	<0.0005	<0.0005	0.0011	0.009	0.032	0.001	0.001	<0.0005	<0.5	<0.0005	0.001	9.68	20.7	<0.0005	0.898	<0.0005	0.002	<0.0005	0.0011	0.0023	0.0152
MG-018	<0.0005	0.0336	0.0007	0.084	0.042	<0.0005	<0.0005	0.0005	0.0008	0.0101	0.024	0.007	0.0023	0.0022	<0.5	0.0008	0.002	10.8	23.2	<0.0005	1.22	<0.0005	0.002	<0.0005	0.0059	0.0016	0.0262
MG-021	<0.0005	0.0092	0.0051	0.068	0.054	<0.0005	<0.0005	<0.0005	0.0015	0.0012	0.011	0.002	0.0008	<0.0005	<0.5	<0.0005	0.002	25.1	53.7	<0.0005	2.82	<0.0005	0.003	<0.0005	0.0013	0.0178	0.0061
MG-023	<0.0005	0.0051	0.0007	0.015	0.065	<0.0005	<0.0005	<0.0005	0.0007	0.0034	0.006	<0.001	0.0008	<0.0005	<0.5	<0.0005	0.001	14.9	31.9	<0.0005	0.178	<0.0005	0.002	<0.0005	0.0005	0.0017	0.0296
MG-024	<0.0005	0.0081	0.0012	0.021	0.017	<0.0005	<0.0005	0.0011	0.0007	0.0054	0.01	<0.001	0.0031	0.0005	<0.5	<0.0005	0.001	17.5	37.5	<0.0005	0.157	<0.0005	0.003	<0.0005	0.0006	0.0042	0.032
MG-025	<0.0005	0.0065	0.006	0.105	0.074	<0.0005	<0.0005	<0.0005	0.0026	0.001	0.015	0.002	0.0006	<0.0005	<0.5	<0.0005	0.002	12.9	27.6	<0.0005	0.641	<0.0005	0.002	<0.0005	0.0019	0.0192	0.0019
MG-027	<0.0005	0.0067	0.0011	0.036	0.151	<0.0005	<0.0005	<0.0005	0.0014	0.0023	0.009	0.002	0.0015	0.0005	<0.5	<0.0005	0.003	13.5	28.8	<0.0005	0.387	<0.0005	0.002	<0.0005	0.0048	0.0037	0.0209
MG-028	<0.0025	0.0052	<0.0025	0.093	0.015	<0.0025	<0.0025	<0.0025	<0.0025	0.0026	0.022	<0.005	0.0059	<0.0025	<0.5	<0.0025	<0.005	14.6	31.2	<0.0025	2.56	<0.0025	<0.005	<0.0025	0.0065	<0.0025	0.0126
MG-031	<0.0005	0.0062	0.0039	0.161	0.073	<0.0005	<0.0005	<0.0005	0.0014	0.0062	0.013	0.002	0.0009	<0.0005	<0.5	<0.0005	0.002	12.7	27.2	<0.0005	1.15	<0.0005	0.002	<0.0005	0.0029	0.0177	0.0138
MG-034	<0.0005	0.0048	0.0011	0.043	0.071	<0.0005	<0.0005	<0.0005	0.0012	0.0013	0.009	0.003	0.01	<0.0005	<0.5	<0.0005	0.003	12.8	27.4	<0.0005	0.426	<0.0005	0.002	<0.0005	0.0028	0.0026	0.0535
MG-036	<0.0005	0.0052	0.0016	0.098	0.043	<0.0005	<0.0005	<0.0005	0.0007	0.0023	0.018	0.007	0.0013	0.0005	<0.5	0.0005	0.003	10.5	22.5	<0.0005	1.36	<0.0005	0.002	<0.0005	0.0053	0.0007	0.0071

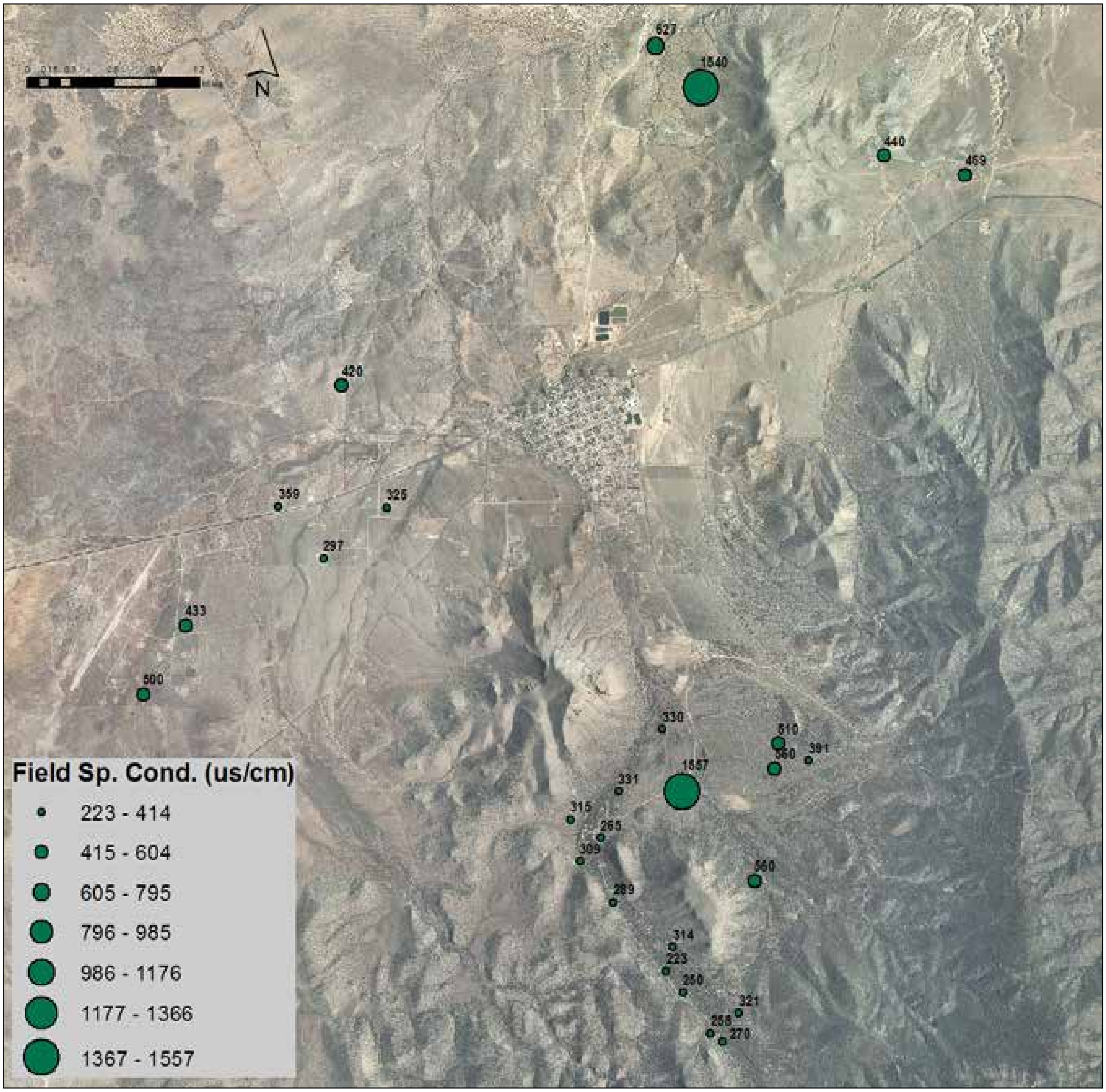


Figure 6–Field measurements of specific conductivity in the Magdalena area. High specific conductivity measurements are due to Paleozoic carbonate rocks that these wells access for groundwater. Units are microsiemens/centimeter (µS/cm).

that the sampled wells access, as interpreted from the OSE well records. Most wells are completed in igneous rock, which in this area are quite variable. Using only the drillers' descriptions of the geology, it is extremely difficult to interpret subtle but important differences in the igneous rock materials. However, the driller's records are still useful as with the two wells previously noted with high specific conductance, hardness, and TDS, which also plot with high sulfate on the Piper diagram (Fig. 7). Review of the OSE well driller's records for these two wells indicate that they are likely accessing water from Paleozoic carbonate rocks.

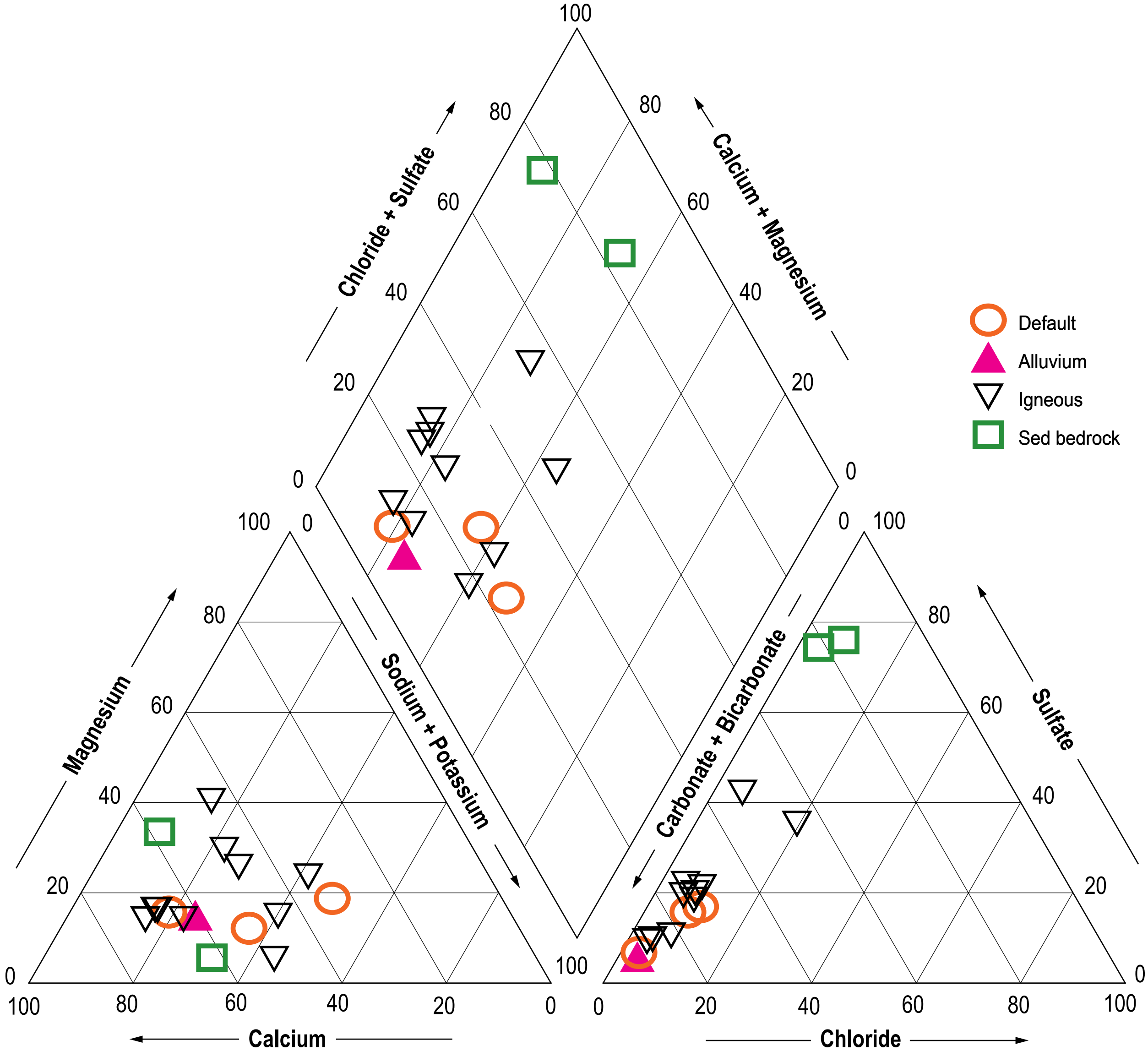


Figure 7–Piper diagram showing percentages of major cations and anions. The Piper diagram also indicates the geology of the sampled wells interpreted from the OSE well records. For simplicity, these were grouped into general categories of igneous, sedimentary, and alluvium. Any wells which were sampled, but did not have a drillers record available were labeled "default."

HYDROGEOLOGIC SUMMARY

Precipitation is the primary source of recharge in the Magdalena region. Extended periods without precipitation can result in reduced groundwater production from wells with potentially rapid water level declines due to the fractured nature of the aquifer. Water level declines can occur for numerous reasons, including - but not limited to – short or long-term drought, increased usage and demand on the aquifer, and reduction in recharge by snowmelt or summer rains. By comparing original driller's static water levels and current water levels in this study, we find trends of water level declines from a few feet to more than 100 feet in the Magdalena area. Based on present and historic data, water level declines are greatest on the east side of the study area, along Highway 60.

As discussed by Summers (1975), wells located along 1) faults and 2) fractures can provide some of the highest production rates. Wells in fractured igneous rocks and/or fractured sedimentary rocks will have higher production than wells in these same units with no fractures or faults. However, fractured aquifers generally have very low available storage of groundwater. Therefore, in times of drought and a lowered water table, the availability of groundwater within fractures may be greatly reduced, causing reduction in pumping rates.

Wells completed in alluvium maybe sufficient for smaller production needs, such as domestic usage (less than ~20 gpm). Because the alluvium is fairly thin (less than ~200 feet), there is not a large thickness of these deposits to draw from as in other areas in New Mexico, such as the Rio Grande valley.

Water quality is better in fractured igneous rocks and alluvium than in the fractured Paleozoic sedimentary units, which have higher sulfate concentrations and higher specific conductance. Wells completed in thick shale or clay deposits will likely have poor water quality as well.

CONSIDERATIONS FOR THE FUTURE

- Water levels should be measured on a frequent basis. During times of drought conditions, if feasible, the static water level in a well should be measured at least monthly. Water levels that drop to the level of the pump can potentially cause pump damage.

- Observation of water levels can indicate when water conservation techniques are most needed. Often this will be during the early summer months, as temperatures rise. This is especially true in years with little snowmelt.

- Over-pumping, such as using multiple wells in close proximity or heavy pumping on any one well, can cause rapid water level declines and stress the aquifer system.

- Well owners/operators could consider purchasing water level monitoring equipment and installing observation tubes to do water level measurements, or hire trained experts (i.e. consultants or well drillers) to do this. Some Soil and Water Conservation districts have acquired equipment that can be borrowed by well owners to measure water level changes.

- Water quality in fractured aquifers could quickly decline with dropping water levels. Special care should be taken to place wells appropriate distances from groundwater contaminants (i.e. septic disposal sites).

- Water quality testing can also help indicate declines in water levels; however, repeated measurements are needed. Simple specific conductivity measurements can be done onsite, if possible, on a monthly basis. These measurements can provide additional indication of declines in available groundwater with increasing levels of specific conductivity. Pursuing funding to repeat detailed chemistry sampling at sites measured in this study may also prove useful in future years.

- Develop funding for additional regional hydrologic and geologic research. Further work could be greatly supplemented by adding more wells to the study. Repeating measurements of water levels can help to better understand the aquifer behavior as it responds to further stress and/or recharge. Detailed geologic mapping with more comprehensive studies of groundwater resources can be used to develop a subsurface hydrogeologic model. Using geophysical techniques such as gravity surveys, electrical resistivity, and ground penetrating radar may help identify locations of faults, fractures, and possible groundwater resources.

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Appendix 1: See website
http://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=556

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