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May 23, 1975

Robert Borton
State Engineer's Office
Battan Memorial Bld.
State Capital
Santa Fe, New Mexico 87501

Dear Bob:

Here is a copy for the state engineers files of my report to Ralph E. Vail, Consulting Engineer, on the ground water resource of the Village of Magdalena.

I would appreciate your comment.

Yours Truly

Kelly

W.K. Summers
Geologist

cc. R.E. Vail

W.K.Summers

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Ground Water Resources of the Village of Magdalena Socorro County, New Mexico

A hydrogeologic report on the results of test drilling during February 1975

Prepared for

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W.K. Summers
Ground-water Geologist

April 1975

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INTRODUCTION

Purpose and scope

This report serves three purposes:

(1) it summarizes ground-water conditions in the Magdalena area,
(2) it describes the results of the drilling program of February 1975, and
(3) it discusses the availability of ground water to supply the needs of the Village of Magdalena.

This report draws upon the following information sources:
(1) Published reports.
(2) Open-file reports of the state engineer and the New Mexico Bureau of Mines and Mineral Resources.
(3) Data generated specifically for the purpose of defining Magdalena's water resources.

For the most part only the data obtained during the test drilling program are presented in detail. No attempt has been made to totally and inclusively document all the information presented here, other than to choose sources I believe to be reliable.

Location

The Village of Magdalena is in secs. 22 and 27, T. 2 S., R. 4 W., Socorro County, New Mexico. As Figure 1 shows, it is in the drainage basin of La Jinca Creek, a tributary of the Rio Salado.

Acknowledgements

Three people merit special thanks:

(1) Charles E. Chapin, Geologist, New Mexico Bureau of Mines and Mineral Resources, who compiled the geologic map, provided information about the geology of the Magdalena area used in this report, and prepared the sample logs.

(2) Richard Montoya who helped me find and run down the history of existing wells.

(3) The state engineer who made available the notes of and a report by Philip H. Bishop (Geohydrology of the Magdalena area, Socorro County, New Mexico, August, 1972).

REGIONAL HISTORY

Plate 1 is the geologic map of the Magdalena prepared by Chapin in 1974. It is based upon Chapin's own work in the area, the work of graduate students that wrote theses and dissertations under Chapin, and Chapin's interpretation of a 1942 map of the Magdalena mining district (Loughlin and Koschman).

Stratigraphy

Figure 2 is the composite stratigraphic column prepared by Chapin (1974) for the Magdalena area, Socorro County.

The rocks of the Magdalena area may be divided into four convenient catagories.

(1) massive granite and meta-sedimentary rocks of Precambrian age;
(2) sedimentary rocks, dominantly limestone and sandstone of Paleozoic (Mississippian to Permian) age;
(3) igneous (both volcanic and intrusive) rocks and terrestrial sedimentary rocks of Late Mesozoic and Cenozoic age (dominantly of Oligocene to Quaternary age); and
(4) Recent unconsolidated deposits.

Structure

Figure 3 is Chapin's (1974) structural framework of the Magdalena area. This map and plate 1 show that in the immediate area of Magdalena faults and igneous stocks are the controlling geologic structures. A shear zone extends through the east side of the area in which it is feasible to develop the ground-water resources.

Water-bearing and water-yielding properties of the rocks

For most rocks in the Magdalena area the porosity and hydraulic conductivity derive from fractures. This is especially true even of the sedimentary rocks of Paleozoic age and seems to apply to the fanglomerates, sandstones, conglomerates, mudflow breccias, and other sedimentary rocks interbedded with the volcanics. Even the pediment gravels seem to be indurated enough to stand without sloughing in wells.

Only in the alluvial sand and gravel does the porosity and hydraulic conductivity derive from interstitial and intergranular pores.

In general then the porosity and hydraulic conductivity of the rocks is governed by the factors that control the number and distribution of fractures:

(1) For beds of equal strength the thick beds will have fewer fractures than the thin beds.
(2) For beds of equal thickness the brittle rock will contain more fractures than the ductile rock.
(3) Within a given bed the number of fractures per unit volume is largest near a fault.

Applying these criteria to the rocks of figure 2 and plate 1 as elucidated above I conclude:

(1) Precambrian rocks . . . These rocks are massive and brittle; therefore, I expect them to have relatively low porosity and hydraulic conductivity. However, the hydraulic conductivity may be relatively large near faults and in the shear zones.
(2) Paleozoic rocks . . . These rocks are comparatively brittle and thin bedded. Therefore I expect them to have moderate porosity and relatively large hydraulic conductivity -- especially near faults where the hydraulic conductivity could be as much as ten times the average. As the analysis of the pumping test for the new well reported below shows, the hydraulic conductivity of the rocks is on the order of 1500 gpd/ft^2. But because this well is near a fault zone, this value is probably well above average for the rocks.
(3) Cenozoic rocks . . . These rocks range from thin-bedded to ultra-massive in stocks. However the more ductile rocks tend to be thin bedded. So I expect the average rocks to have relatively low to moderate hydraulic conductivity. Local intergranular porosity may persist in the sedimentary rocks thereby causing the porosity and hydraulic conductivity to be above average. The sedimentary rocks are thin-bedded. So that with intergranular pores also contributing to the effective porosity, the porosity and hydraulic conductivity of these rocks will tend to be somewhat larger than for the average for volcanic rocks. A possible exception is the La Jara Peak Andesite, which consists of relatively autobrecciated, thin flows of andesite interbedded with fanglomerate and playa deposits. The La Jara Peak Andesite, especially near faults, could have a hydraulic conductivity well above the average for Cenozoic rocks.

Porosity and hydraulic conductivity of the rocks that make up the stocks should be very low because these rocks are ultra-massive.

The wells within the village limits used to top alluvium and A-L Peak Formation. Near the pumping wells the alluvium has been dewatered. Bishop (1972) analyzing 1962 pumping test data for two wells determined that the transmissivity of the A-L Peak is about 1200 gpd/ft (163 ft^2/day), which indicates a hydraulic conductivity of about 10 gpd/ft^2. This value is probably above the average, because the pumped wells were both near faults.

(4) Alluvium . . . Porosity and hydraulic conductivity of the alluvial sand and gravel tend to be very large. Unfortunately the areal distribution and their relatively thin-saturated thickness near Magdalena eliminates them as a significant water-bearing unit.

REGIONAL HYDROLOGY

Precipitation and recharge

The Atmospheric Physics Research Group at the New Mexico Institute of Mining and Technology have kept records of precipitation in the Magdalena area for several years. The bulk of their data are for summer precipitation (Wilkening, personal comm., 1974) but enough annual records are maintained to provide a basis for estimating the annual average by altitude range.

Recharge rates can be estimated using the relationship

$$R = .5 \times p\ (P-4)/100$$

where R = annual average recharge (inches)

p = annual average precipitation

The following tabulation gives the average annual precipitation and estimated recharge by altitude range.

Altitude range (ft.) From	To	Estimated Annual Precipitation (inches)	Estimated Annual Recharge (inches)
4501	5000	7.7	.14
5001	5500	9.0	.23
5501	6000	10.3	.31
6001	6500	11.5	.43
6501	7000	12.8	.55
7001	7500	14.0	.76
7501	8500	15.3	.86
8501	9500	17.8	1.22
9501	10,000	20.3	1.62
10001	10,630	21.8	1.95

The average altitude of the Magdalena
feet; so the average recharge is larger than .55 inches, but since most of the area is below 7500 the average recharge is probably less than .86 inches. So if we use .55 as the recharge rate or recharge area we shall be conservative.

Ground-water flow systems

Plate 2 is a map of the water-table. Regions where the water table is concave downward are recharge areas; regions where the water table is concave upward are discharge areas. (Plate 3) Some discharge occurs to springs in local flow systems; some discharge occurs via evapotranspiration over the discharge areas; but the bulk of the discharge is via underflow to the Rio Grande. Pumpage of water by Magdalena has altered the shape of the water table there. Detailed mapping of the water table might show that even though the wells are in a discharge area that the pumpage has created a local area where induced recharge may occur. This condition should be relieved to prevent ground-water pollution.

Recharge occurs over about 90 percent of the La Jencia Creek basin. Assuming a discharge rate of 0.55 inches per year and an area above Magdalena of 72 square miles (approx. two townships) the annual recharge in the area is

$$R_a = \frac{.55}{12} \times .9 \times 72 \times (5280)^2$$

$$= 8.28 \times 10^8 \text{ ft}^3$$

This is an average rate for a very large area of only 2.6 ft^3/sec or 4500 gpm.

TEST DRILLING

Basis for locations

Mid-summer 1974 I chose four sites as locations for test holes. These sites were

Proposed site no	Location
1	NW$\frac{1}{4}$, NE$\frac{1}{4}$, sec. 10, T. 2 S., R. 4 W.
2	SE$\frac{1}{4}$, NW$\frac{1}{4}$, sec. 24, T. 2 S., R. 4 W.
3	SW$\frac{1}{4}$, NW$\frac{1}{4}$, sec. 36, T. 2 S., R. 5 W.
4	NE$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 19, T. 2 S., R. 4 W.

Proposed site 1, the location of test hole #1, was a few hundred feet north of La Jencia Creek. We had hoped to find an extraordinary saturated thickness of alluvium, pediment gravels, and fanglomerates at a point where the recharge area contribution to underflow at the point would be a maximum.

Proposed site 2, not drilled, was at the approximate intersection of faults at the then maximum distance from town and near the maximum lower altitude limit for economic pumping to Magdalena. This site was not drilled because of the difficulties attendant with obtaining easements.

Proposed site 3, not drilled, was in the Muligan Gultch Graben where bolson deposits (alluvium, fanglomerate, playa deposits, etc.) attain a thickness of more than 1000 feet. We had hoped that this great thickness of sedimentary rocks would proved to be productive. Moveover, the cost of transporting water relatively large distances from town was offset in part by the higher altitude of the site relative to Magdalena. However a test hole 1000 ft deep drilled by the Bunker Hill Mining Company in sec. 5, T. 3 S., R. 5 W. was reported to produce only 10-20 gpm. So this site was not tested.

Proposed site 4, the location of test hole #2, was designed to test the La Jara Peak Andesite, a thin-bedded volcanic sequence which is similar in many respects to the very productive basalts of Idaho, Oregon, and Washington. The site was also considerably higher than the village of Magdalena and would have afforded relatively low cost to pump the water to town.

Test holes and water well

During February 1975 the Kenneth D. Huey Company (Capitan, New Mexico) drilled three test holes with an Ingersoll Rand compressed air rotary drilling rig using a down-hole hammer and completed the third hole as a water well.

Test hole no. 1 -- Test hole no. 1 (2 S.4 W.3. 430) was spudded on Feb. 5, 1975 and drilled to its total depth of 308 feet on Feb. 7, 1975. The location was somewhat north of the proposed site. The drillers' log and the graphic drilling time log are in the appendix.

Chapin's log of samples follows:

Depth (feet)			
From	To	Lithology	Formation
0	100	Alluvium	--
100	230	Andesite, dark gray with small red hematized ferromagnesium minerals	La Jara Peak Andesite
230	250	sandstones, green to tan, fine grained, volcanoclastic	La Jara Peak Andesite
250	300	andesite, dark gray with abundant amygdules	La Jara Peak Andesite
300	308	andesite, dark gray	La Jara Peak Andesite

A piece of 8-inch casing 6-feet long was set in the hole. An effort to develop this test hole with compressed air on Feb. 8 was non-productive. Using compressed air this hole produced 2 or 3 gpm.

Observed water levels from the top of the casing which was about 1 foot above the ground were:

Date Feb. 1975	hour	depth to-water (feet)
8	0945	176.3
9	1115	169.91
10	1010	144.05
11	1505	139.82
13	1305	137.88
16	1050	136.20

Clearly, the alluvial material was not saturated.

I believe that explosive stimulation would increase the yield of this well at least one order of magnitude.

Test hole no. 2. -- Test hole no. 2 (2S.4W.19.410) was spudded February 10, 1975 at proposed site no. 4 and drilled to its total depth of 368 feet on February 13. The drillers' log and the graphic drilling time log are in the appendix.

Chapin's log of samples follows:

Depth (feet)

From	To	Lithology	Formation
0	10	Allůvium	All below are La Jara Peak Formation
10	44	Andesite, dark gray, with small red hematized ferro-magnesium minerals	
44	50	red oxidized flow top	
50	160	andesite, dark gray	
160	190	andesite, somewhat bleached and altered with greenish fracture fillings and slick-ensides (probably fault zone)	
190	264	andesite, dark gray	
264	280	sandstone, red, fine-grained, volcaniclastic	
280	340	andesite, dark gray	
340	347	sandstone, red, fine-grained, volcaniclastic	
347	366	andesite, dark gray	

In an effort to learn the possible yield of the well on February 13 from 1117 to 1222 we poured 600 gallons (9.2 gpm) of water into the hole. Efforts to learn the water level rise were not fruitful. However, the water-level change must have been fairly small since a 300 foot tape did not reach the water level.

On February 16, 1975 (1115 AM) the water level was 309 feet.

I believe that a well at this site could be fairly productive (50 gpm) because (1) the driller reported a 4-inch fracture at 330 feet and (2) the well accepted 10 gpm with ease. However; the prepumping level of 309 feet would make the cost of producing water in volume at this site prohibitive.

Test hole no. 3 -- Test hole no. 3 (2S.4W.13.430) was spudded February 14, 1975, and drilled to its total depth 183 feet February February 20.

The location of the test hole was changed from the proposed location because easement had not been easily obtained for the proposed site. The decision to locate the test hole about one half mile east was based largely on two factors. First, Hydro Nuclear Corporation drilling a mile or so south of U. S. Highway 60 had discovered considerable water in their test holes that penetrated the sedimentary rocks of Paleozoic age. I therefore concluded that a test hole in these rocks (where future mining would probably not be a factor) would be appropriate. Second an easement to drill the test hole could be easily obtained. A third factor that weighed heavily upon the decision to drill this site was that existing wells provided adequate information on the rocks we were likely to tap at sites nearer town where the village owned the land or could obtain the necessary easements.

The following are Chapin's log and comments about the samples he examined:

Depth (feet)

From	To	Lithology
0	133	Alluvium
133	158	No returns
158	167	limestone, light green, gray and yellow highly bleached and altered with traces of pyrite, manganese oxides, and abundant epidote and chorite
167	183	as above but with abundant rusty gossan

comments: Formation from 133-183 unknown because of severe alteration. This hole appears to have hit an altered and somewhat mineralized fault zone. The limestone may be the Madera Limestone of Pennsylvanian age or the San Andres Limestone of Permian age. It is probably Madera.

During the drilling of this test hole progress was rapid in the unsaturated alluvium (0 - 100 feet). By 133 feet, the base of the alluvium is about 127 feet, the hole was caving so much that the driller decided to set casing, so he reamed the hole and began setting 8" casing. Setting casing was a slow process because caving continued. The hole had to be drilled out below the casing repeatedly. Eventually 127' of 8-inch casing was set below the land surface. The hole was then drilled to a depth of 158 with no returns. Initially the alluvium was not totally sealed off by the casing and gravel was produced to a depth of 158 feet where a seal seemed to become effective. From 158 to 183 unconsolidated sand and gravel from the alluvium did not enter the hole.

From 158 to 177 the walls of the hole to slough and in the interval from 174 to 183 sloughing became so severe that the driller said he could not drill deeper without casing the hole or changing rigs or both. The well was producing an ample supply of water, so we decided to conduct a pumping test. After test pumping the well was 156 feet deep. Actually the well was pumped three times:

(1) it was pumped during and following drilling using air. This period of discharge ended about 1200, February 20th.
(2) the well was surged with a test pump from 0800 to 1200 February 25th.
(3) The well was pumped 25 hours at a constant rate from 1730 Feb. 25th to 1830 Feb. 26th. Recovery was obtained by chalked-tape measurement until 1752 Feb. 27th and by water-level recorder from Feb. 27th to March 22, 1975.

The pumping rate during the steady rate test averaged 381.7 gpm and probably did not vary more than ± 5 gpm. The discharge was observed using a totalizing meter correct to ± 2½ percent. The initial reading was 4.7478 acre-feet; the final reading 6.5051 acre feet.

Temperatures and specific conductance of the discharging water were measured frequently using a Yellow Springs Instruments meter. The variation in rates obtained for temperature were probably due to measuring technique. The temperature appears to have increased slightly toward the end of the pumping period. The average was about 17.5 C (63.5 F).

The specific conductance varied from 470 to 530 micromhos at 25 C. Again probably owing to technique inconsistances. The specific conductance may also have increased slightly toward the end of the test. The average specific conductance was probably 500 micromhos. (A laboratory value for specific conductance of 524 micromhos at 25 C was obtained from a sample collected 60 minutes before the pump was turned off.

The appendices contain the water-level measurement made in this well and the chemical analyses of water samples.

After correction for a modest regional water level rise, the pumping-test data reflect the influence of three different factors:

(1) The early drawdown show a "skin effect" or energy loss at the well face.
(2) The drawdown rate from 30 to 600 minutes suggest that the well has tapped an extremely permeable lithologic unit (on the order of 1,000,000 gpd/ft) and probably is the fault zone.
(3) The measurements from 600 to 1500 minutes suggest a much less permeable rock with an average transmissivity of about 40,000 gpd/ft. However, since this must be some sort of geometric mean that includes the highly permeable unit (2 above), the transmissivity of the rock remote from the fault zone is probably less, possibly much less.

The recovery measurements are consistant with this interpretation.

The final water level in this well was 98.98 feet below the measuring point which was about 0.5 feet above the land surface.

DISCUSSION

The ground-water resources of the Magdalena area depend largely upon the capacity of wells to tap fractures and the average number, aperatures, and distribution of fractures in a region. Locally large yields can be obtained for times as long as a year or more when wells tap rocks containing an extraordinarily large number of fractures. However the yield of a well inevitably falls back to the average for the region. As a consequence the apparently high yield of the new well should <u>not sustain</u>.

The question then becomes: What yield can we expect this well to sustain? We can estimate this yield by making some conservative assumptions:

(1) We assume that Bishop's value for transmissivity of 1200 gpd/ft is the average value of regional transmissivity.
(2) We assume the water table (plate 2) reflects the hydraulic gradient, therefore the average gradient across the 6350 contour would be about 100/1000 or .01 ft/ft.
(3) If we assume that all the water crossing the 6750 contour west of the well can be diverted to the well then the length of this line west of the well, 12,000 feet, gives us the third quantity we used to determine the minimum daily flow to the well or that could be expected at the well.

Thus using the relationship

$$Q = T\,I\,L$$

where Q is the daily discharge
T is the transmissivity (12,000 gpd/ft)
I is the hydraulic gradient (.01), and
L is the length of the surface 12,000 feet across which ground-water flow occurs

we get

$$Q = 1200 \times .01 \times 12{,}000 = 144{,}000 \text{ gpd.}$$

This is equivalent to a sustained steady pumping rate of 100 gpm in perpetuity. If we consider recharge from the overlying saturated gravels, and a higher value of transmissivity for the rocks of Paleozoic age, and an allowance for water that could be derived from transient storage this estimate of 100 gpm seems reasonably conservative.

I, therefore, recommend that the yield of this well be held to 100 gpm (52 million gallons per year) for the first several years of operation.

I further recommend that my estimates should be reappraised after the well has been in service 500 days. To make this appraisal, the water level should be measured and the flow meter should be read on the following schedule.

Time since pumping began (Days)	Time between observations (Days)
0 - 10	1 (once a day)
10 - 100	3 - 4 (twice a week)
100 - 500	7 (weekly)

The water level should be measured

(1) while the well is pumping
(2) from a fixed reference point, and
(3) with an accuracy of ± 0.1 foot.

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Table 1. -- Depth-to-water measurements
Magdalena Well (2S.4W.13.430)

Date 1975	Hour	Depth-to-water (feet)	Remarks
Feb. 20	1344	99.29	
	1350	99.28	
	1523	99.28	
	1718	99.25	
Feb. 21	1030	99.18	
Feb. 23	1350	99.12	
Feb. 24	1448	99.10	
	1909	99.18	
Feb. 25	0709	99.18	
	0744	99.18	
	0800	--	Begin development pumping
	0803	99.67	
	0833	99.92	
	0843	95.31	
	0900	99.95	
	0915	100.21	
	0917	--	Increased pumping rate
	0932	100.84	
	1001	101.54	
	1034	101.64	
	1103	100.98	
	1106	100.99	
	1125	101.03	
	1150	101.13	
	1159	101.14	
	1200	--	Pump off
	1201	99.83	
	1202.50	99.82	
	1204	99.80	
	1205.25	99.79	
	1206.50	99.78	
	1208	99.79	
	1210.25	99.76	
	1212.50	99.77	
	1214.75	99.74	
	1219	99.73	
	1237	99.74	
	1240.50	99.70	
	1247	99.66	
	1250.50	99.67	
	1259	99.66	
	1306	99.66	

Table 1. -- Depth-to-water measurements
Magdalena Well (2S.4W.13.430) (cont)

Date 1975	Hour	Depth-to-water (feet)	Remarks
Feb. 25	1313	99.65	
	1322	99.62	
	1329	99.60	
	1343	99.65	
	1345	99.61	
	1350	99.58	
	1357	99.58	
	1416	99.55	
	1431	99.57	
	1434	99.55	
	1446	99.55	
	1500	99.54	
	1516	99.53	
	1530	99.52	
	1546	99.50	
	1601	99.51	
	1604	99.50	
	1615	99.49	
	1630	99.48	
	1646	99.48	
	1700	99.47	
	1717	99.47	
	1727	99.47	
	1730	--	Pump on
	1730.50	100.60	
	1732.50	100.65	
	1734	100.68	
	1736	100.70	
	1737.50	100.73	
	1739	100.74	
	1740	100.75	
	1741	100.74	
	1743	100.76	
	1744	100.80	
	1746	100.78	
	1748	100.82	
	1750	100.80	
	1752	100.83	
	1754	100.83	
	1756.50	100.83	
	1800	100.83	
	1803	100.84	
	1805.50	100.87	
	1809	100.89	

Table 1. -- Depth-to-water measurements
Magdalena Well (2S.4W.13.430) (cont)

Date 1975	Hour	Depth-to-water (feet)	Remarks
Feb. 25	1811.50	100.90	
	1814.50	100.91	
	1824	100.94	
	1830	100.95	
	1833	100.95	
	1836	101.02	
	1838	100.99	
	1841	101.00	
	1847	101.02	
	1855	101.03+	
	1900	100.98	
	1902	101.04	
	1910	101.02	
	1920	101.09	
	1937	101.14	
	1950	101.11	
	2000	101.11	
	2011	101.11	
	2020	101.13	
	2030	101.23	
	2040	101.22	
	2050	101.24	
	2100	101.24	
	2130	101.24	
	2200	101.23	
	2231	101.24	
	2300	101.24	
	2330	101.24	
	2400	101.24	
Feb. 26	0030	101.24	
	0130	101.24	
	0200	101.24	
	0230	101.24	
	0300	101.26	
	0430	101.75	
	0500	101.75	
	0530	101.75	
	0600	101.78	
	0630	101.80	
	0700	101.80	
	0733	101.98	
	0800	101.97	
	0835	102.01	
	0900	102.04	

Table 1. -- Depth-to-water measurements
Magdalena Well (2S.4W.13.430) (cont)

Date 1975	Hour	Depth-to-water (feet)	Remarks
Feb. 26	0948	102.09	
	1000	102.05	
	1033	102.10	
	1103	102.13	
	1130	102.14	
	1203	102.18	
	1230	102.18	
	1305	102.24	
	1330	102.29	
	1400	102.29	
	1434	102.29	
	1500	102.32	
	1502	102.32	
	1533	102.33	
	1550	102.37	
	1602	102.38	
	1618	102.35	
	1627	102.47	
	1628	102.37	
	1637	102.37	
	1652	102.81	
	1654	102.38	
	1712	102.39	
	1724	102.41	
	1744	102.41	
	1807	102.44	
	1815	102.45	
	1820	102.45	
	1823	102.46	
	1826	102.48	
	1830	--	Pump off
	1830.50	101.99	
	1832	102.22	
	1833.50	101.73	
	1835	101.18	
	1837	101.17	
	1838.50	101.17	
	1840	101.15	
	1842	101.13	
	1844	101.14	
	1846	101.29	
	1848	101.12	
	1851	101.05	
	1853	101.09	

Table 1. -- Depth-to-water measurements
Magdalena Well (2S.4W.13.430) (cont)

Date 1975	Hour	Depth-to-water (feet)	Remarks
Feb. 26	1855	101.08	
	1858	101.06	
	1900	101.06	
	1903	101.06+	
	1906	101.03	
	1908	101.02	
	1910	101.02	
	1914	101.02+	
	1917	101.18	
	1918	101.00	
	1924	100.98	
	1927	100.98	
	1931	100.98	
	1935	100.95	
	1938	101.12	
	1941	101.09	
	1943	100.92	
	1948	100.93	
	2003	100.89	
	2020	100.82	
	2025	100.85	
	2040	100.79	
	2045	100.85	
	2100	100.87	
	2120	100.73	
	2123	100.79	
	2125	100.78	
	2140	100.70	
	2145	100.78	
	2200	100.71	
	2203	100.70	
	2220	100.65	
	2226	100.64	
	2240	100.63	
	2243	100.63	
	2307	100.59	
	2320	100.57	
	2344	100.55	
	2400	100.53	
Feb. 27	0030	100.50	
	0100	100.48	
	0130	100.46	
	0200	100.46	
	0230	100.42	

Table 1. -- Depth-to-water measurements
Magdalena Well (2S.4W.13.430) (cont)

Date 1975	Hour	Depth-to-water (feet)	Remarks
Feb. 27	0300	100.41	
	0330	100.37	
	0400	100.34	
	0430	100.32	
	0500	100.31	
	0530	100.26	
	0600	100.21	
	0630	100.23	
	0922	100.15	
	1000	100.13	
	1030	100.13	
	1100	100.10	
	1222	100.09	
	1321	100.05	
	1429	99.98	
	1431	100.02	
	1800	99.98	
	1900	99.97	
	2000	99.96	
	2100	99.95	
	2200	99.94	
	2300	99.93	
	2400	99.92	
Feb. 28	0001	99.92	
	0002	99.91	
	0003	99.90	
	0004	99.89	
	0005	99.88	
	0006	99.86	
	0007	99.85	
	0008	99.84	
	0009	99.83	
	0010	99.82	
	0011	99.81	
	0012	99.80	
	0013	99.79	
Mar. 1	0000	99.76	
	0012	99.70	
Mar. 2	0000	99.66	
	0012	99.63	
Mar. 3	0000	99.55	
	0012	99.50	
Mar. 4	0000	99.46	
	0012	99.44	

Table 1. -- Depth-to-water measurements
Magdalena Well (2S.4W.13.430) (cont)

Date 1975	Hour	Depth-to-water (feet)	Remarks
Mar. 5	0000	99.39	
	0012	99.38	
Mar. 6	0000	99.36	
	0012	99.35	
Mar. 7	0000	99.34	

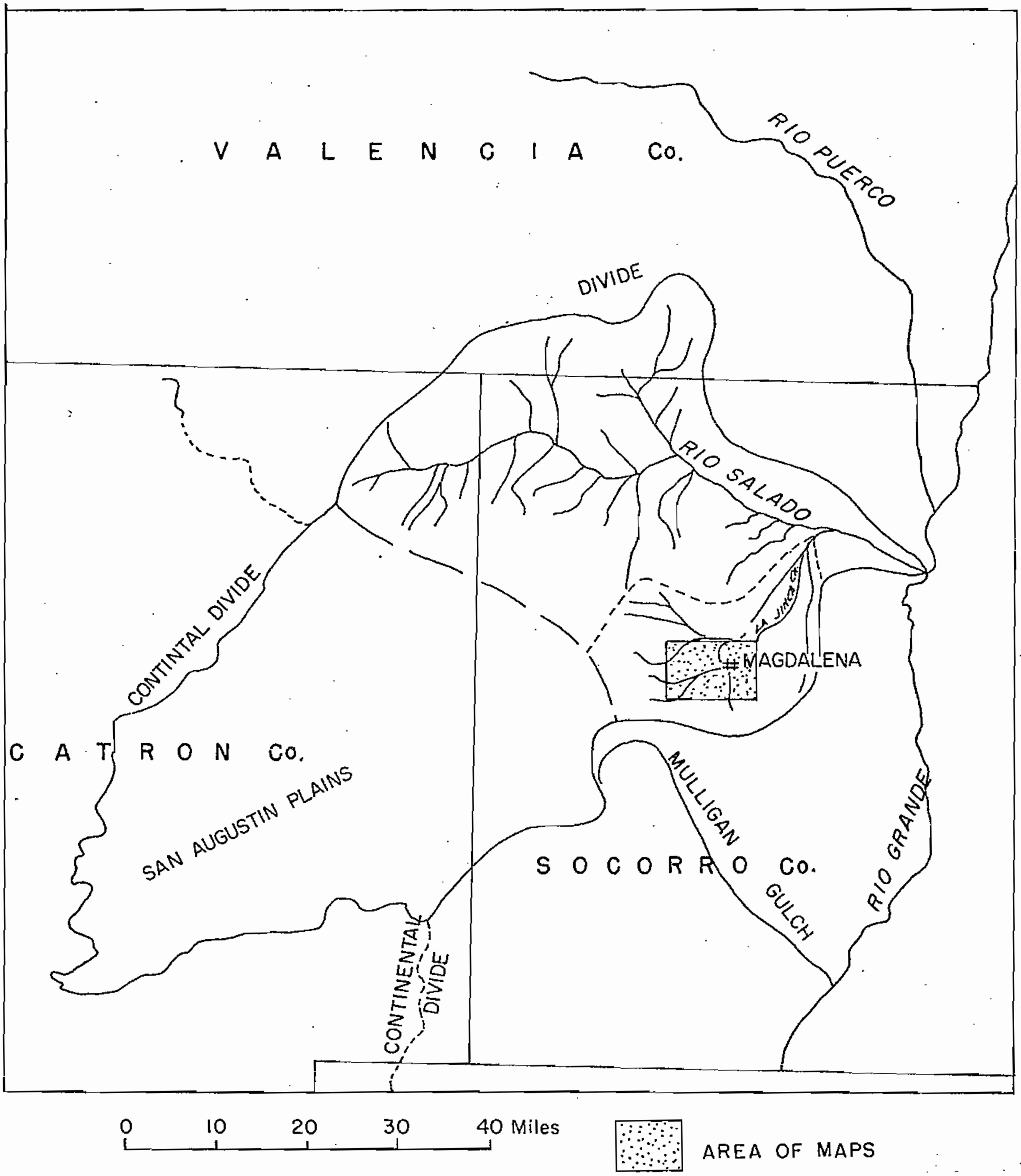
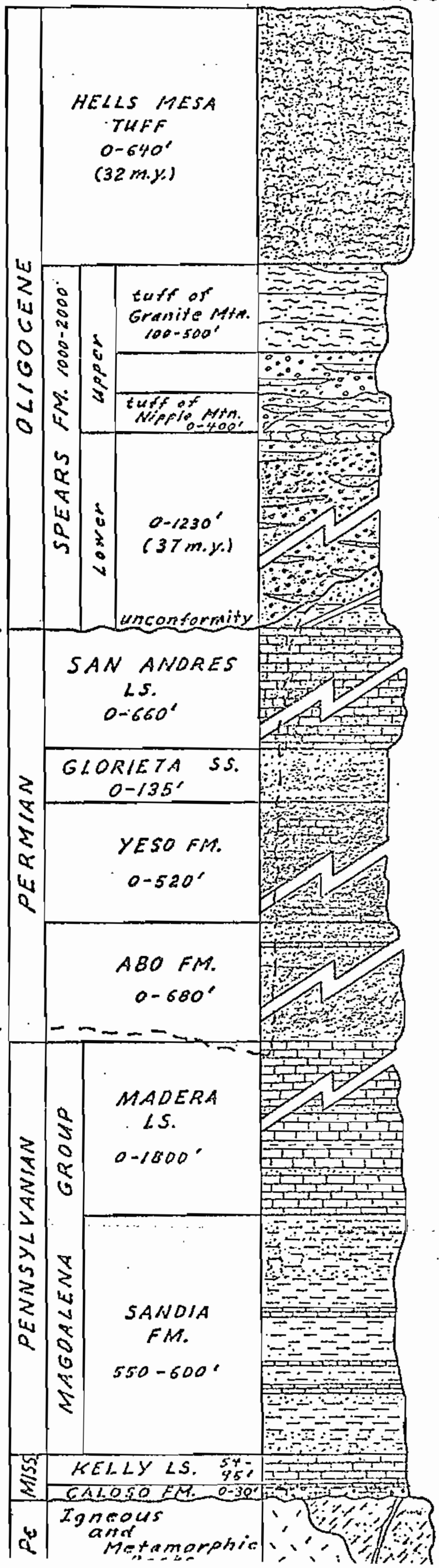


FIGURE I. -- RELATION OF MAGDALENA AREA TO REGIONAL DRAINAGE.

W. K. Summers, Geology - Fluid Dynamics
Socorro, New Mexico

COMPOSITE STRATIGRAPHIC COLUMN of the MAGDALENA AREA

FIGURE 2.



ASH-FLOW TUFFS: qtz. latite (chem. rhyolite), multiple-flow, simple cooling unit of densely welded, crystal-rich, qtz.-rich, massive tuffs; pk. to rd.-brn. when fresh, gry. when propyliticaliy altered; forms cliffs and talus-covered slopes; weathers to blky. bldrs. rather than to grus; abrupt change from latite to qtz. latite 10-25 ft. above base; basal tuffs strongly resemble underlying tuffs in Spears Fm.; formation boundary placed at abrupt increase in qtz. when cgl. is absent; mapped as rhyolite porphyry sill by Loughlin and Koschmann.

ASH-FLOW TUFFS: latite (chem. qtz. latite), multiple-flow, simple cooling unit of densely welded, crystal-rich, lithic-rich, massive tuffs; rd.-brn. when fresh, dk. grn. gry. when propylitically altered; mapped as upper latite tuff by Loughlin and Koschmann; overlain by distinctive hem.-stnd. cgl. N. of Magdalena; grades into mud-flow breccias at base.

VOLCANICLASTIC and VOLCANIC ROCKS: latitic to andesitic conglomerates, sandstones, mud-flow breccias, and lava flows.

ASH-FLOW TUFFS: latite, multiple-flow, compound cooling unit of moderately to densely welded, crystal-poor, pumiceous tuff; pk. when fresh, buff to wht. when altered; distinctive "turkey track" andesite at base; interbedded andesite flow near Tres Montosas; mapped as white felsite tuff by Loughlin and Koschmann.

CONGLOMERATES and SANDSTONES: volcaniclastic apron of early latitic phase of Datil-Mogollon field; fluvial deposits of latitic to andesitic debris; crs. sandstones to pbl. and bldr. conglomerates; purp.-brn. when fresh, grn.-gry. when propylitically altered.

BACA FM (Eocene) } Present in Baca basin north of Magdalena area;
MESOZOIC ROCKS } position of basin margin uncertain due to burial by Tertiary volcanic rocks.

LIMESTONES: blk., fetid, v.-thk.-bdd., homogeneous, sparsely fossil., dolomicrites; weathers to rough, hackly sruface; mapped as Madera Limestone by Loughlin and Koschmann.

SANDSTONES: lt. to med.-gry., v. thk. bdd., med.-gnd. v. well srt. calc., qtz. arenites and minor limestones; mapped as upper quartzite member of Sandia by Loughlin and Koschmann.

LIMESTONES, SANDSTONES, and SHALES: faulted, incomplete, poorly exposed section near Magdalena; dk.-gry., unfossil., dol. micrites only exposed lithology; mapped as upper limestone member of Sandia Fm. by Loughlin and Koschmann.

SANDSTONES, SILTSTONES, and SHALES: rd.-brn., fn.-gnd., thn.-bdd., qtz. arenites and siltstones; abun. thn. lam. and ripple xlam.; bleached to lt.-rd.-brn. and grn.-gry. near Magdalena and Tres Montosas plutons; mapped as Sandia shales by Loughlin and Koschmann (1942).

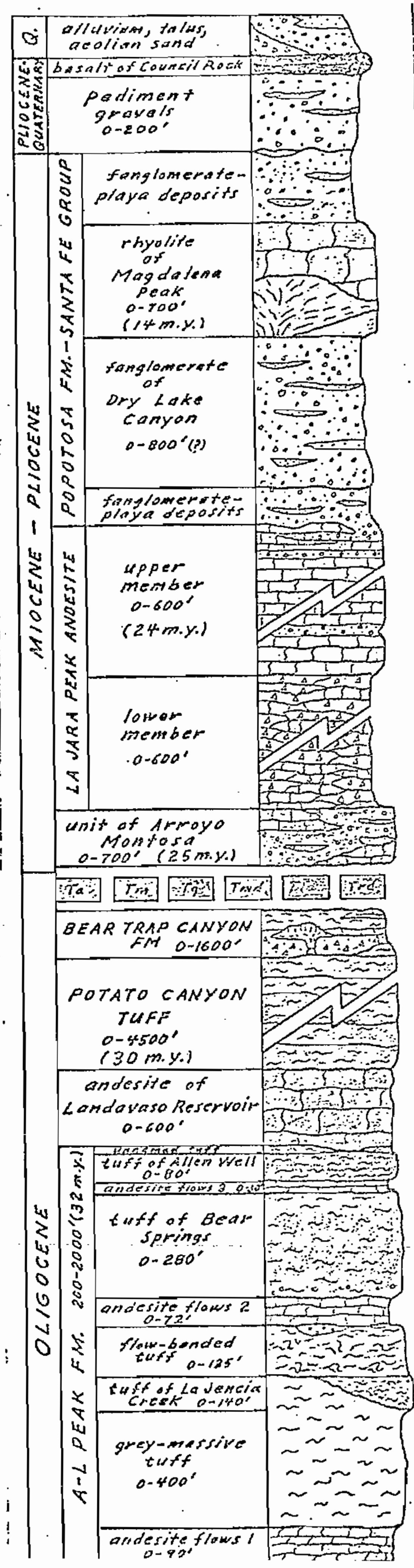
LIMESTONES: Thick, homogeneous sequence of lime muds (micrites) with a few thn. bds. of grn.-gry. to gry., med. to crs.-gnd. quartzite; upper 200-300 ft. consists of rd., grn., and gry. micrites grading upward into arkosic strata of Abo Fm.; nodular micrites common throughout; micrites generally gry. to blk. with strata becoming darker and more fossilferous towards base.

SHALES, QUARTZITES, and LIMESTONES: gry. to blk., sdy., carb., shales and siltstones with thn. bds. of gry., med.-gnd., crinoidal limestones and grn.-gry. to brn., med.-crs.-gnd. quartzites. Loughlin and Koschmann (1942) divided the Sandia into six members but lenticular bedding and rapid facies changes make this subdivision of limited value.

LIMESTONES: lt. gry., med.-crs. gnd., thk.-bdd., crinoidal sparrites; thn. bd. of dol. micrite near middle (Silver Pipe).

LIMESTONES and CONGLOMERATES: gry., pbly., sdy., mas., qtz. micrites and basal ark. cgls.

ARGILLITES, QUARTZITES, and GRANITES: thick sequence of metasedimentary rocks intruded by granites, gabbros, felsites, and diabase dikes.



ALLUVIUM, TALUS, and AEOLIAN SAND: sand extensive N. of Hwy. 60 and N. of La Jencia Creek.

BASALT FLOWS and DIKES: thin flows of dk. gry., dense to vesicular basalt; dikes near Council Rock apparent source; widely scattered remnants west of Magdalena.

PEDIMENT GRAVELS: coarse, heterogeneous gravels and thin sands grading laterally into alluvial fans; caliche deposits and aeolian sand at top; dissected as deep as 200 ft. by arroyos.

FANGLOMERATE-PLAYA DEPOSITS: similar to below but with increasing amounts of detritus from units lower in section; overlain with angular unconf. by buff, poorly indur., deposits of upper Santa Fe Group containing abun. detritus from Paleoz. & Precambrian rocks and by pediment gravels.

RHYOLITE FLOWS and DOMES: pk., dense slightly porphyritic flow-banded rhyolite; vitrophyric and perlitic zones present locally; thin interbedded tuffs; Magdalena Peak dome main eruptive center.

FANGLOMERATES: buff to gry., well-indurated andesitic cgls., thin ss., and mud-flow deposits derived from erosion of La Jara Peak Andesite; other detritus absent to sparse; forms clastic wedge along west side of Bear Mtns.; locally interbedded with uppermost La Jara Peak Andesite; unique facies of Popotosa Fm.

FANGLOMERATE-PLAYA DEPOSITS: rd.-brn. to gry., well-indurated, volc. cgls., thin ss., and mud-flow deposits derived from erosion of volcanic pile during block faulting; A-L Peak, Potato Canyon, and La Jara Peak detritus especially abun.; fangls. grade laterally into rd., poorly indur., siltstones and mudstones of playas.

ANDESITE FLOWS: gry., locally rd., dense, basaltic andesite characterized by abun. small, rd. hematized pyroxene and/or olivine phenocrysts and lack of plagioclase phenocrysts; lower member mostly thin autobrecciated flows that weather to slopes and rounded hills; upper member consists of cliff-forming vesicular flows with fresh pyroxene phenocrysts; amygdules of silica and/or calcite abun. in lower member; upper member interbedded with Popotosa Fm.

DACITE FLOWS and FANGLOMERATES: dk. gry. to rd. flows with unusual phenocryst assemblage of plag. (up to 4 cm), qtz. (up to 1 cm), and sanidine; interbedded cgls. are highly indurated and rd.-brn. like Popotosa but lack La Jara Peak detritus.

STOCKS, PLUGS, and DIKES: major period of intrusive activity at 28-30 m.y.; andesitic, monzonitic and granitic stocks; mafic, latite, and rhyolite dike swarms.

TUFFS, DOMES, FLOWS, and VOLCANICLASTIC ROCKS: Complex sequence of rhyolite pyroclastic rocks, domes, flows, breccias, and sedimentary rocks filling moat of Mt. Withington cauldron (Deal and Rhodes, in press).

ASH-FLOW TUFFS: rhyolite, multiple-flow sequence of slightly to densely welded, moderately crystal-rich to crystal-poor, rd.-brn. to pk. or lt. gry. tuffs; crystal content intermediate between that of crystal-rich and crystal-poor tuffs; perthitic "moonstone" potash feldspar.

ANDESITE: thin flows of rd. to gry. porphyritic andesite with phenocrysts of plagioclase, pyroxene, and biotite; flows highly variable but generally platy with abun. hematite stained bands.

ASH-FLOW TUFFS and ANDESITE FLOWS: Composite sheet of rhyolite crystal-poor tuffs with interbedded quartz latite (chem. rhyolite) crystal-rich tuffs and andesite flows. Relatively homogeneous 2000-foot-thick "puddle" of crystal-poor tuffs in Mt. Withington cauldron (Deal and Rhodes, in press) grades laterally into complex unit shown at left. Crystal poor, rhyolite tuffs are gry., pk., and rd.-brn., moderately to densely welded, platy tuffs that weather to grus of small platy fragments. The flow-banded member is very platy and shows abundant laminar flow structures, such as lineated pumice, flow folds etc. All crystal-poor tuffs are characterized by 6-8% small, euhedral sanidine phenocrysts and 1-2% small, rounded qtz. grains. Crystal-rich, qtz.-rich, qtz. latite tuffs strongly resemble the Hells Mesa tuffs except that they contain more glassy matrix and more biotite. Andesite flows 2 and 3 are thn., dk. gry. to rd.-brn., fn.-gnd. flows similar to the La Jara Peak Andesite in lack of feldspar phenocrysts and abundance of small red, hematized pyroxene and/or olivine phenocrysts. Andesite flows 1 are thn., bl.-gry., porphyritic, vesicular flows with abun. plagioclase phenocrysts. Distribution of the tuff of La Jencia Creek was controlled by NE-trending paleo-valleys. Small channels containing tuffaceous sedimentary rocks are common above flow-banded member.

Prepared by C. Chapin, NMBM&MR

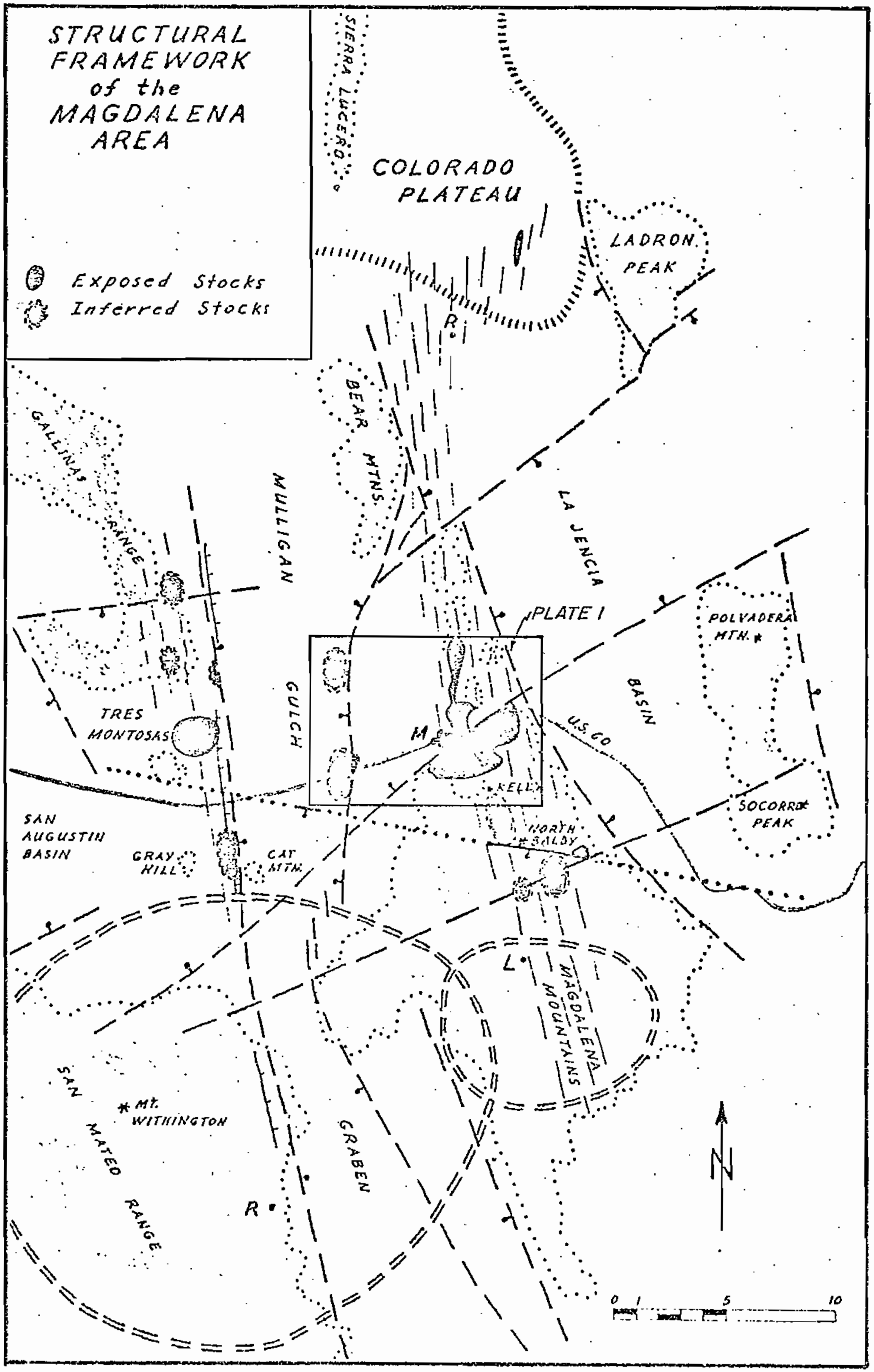


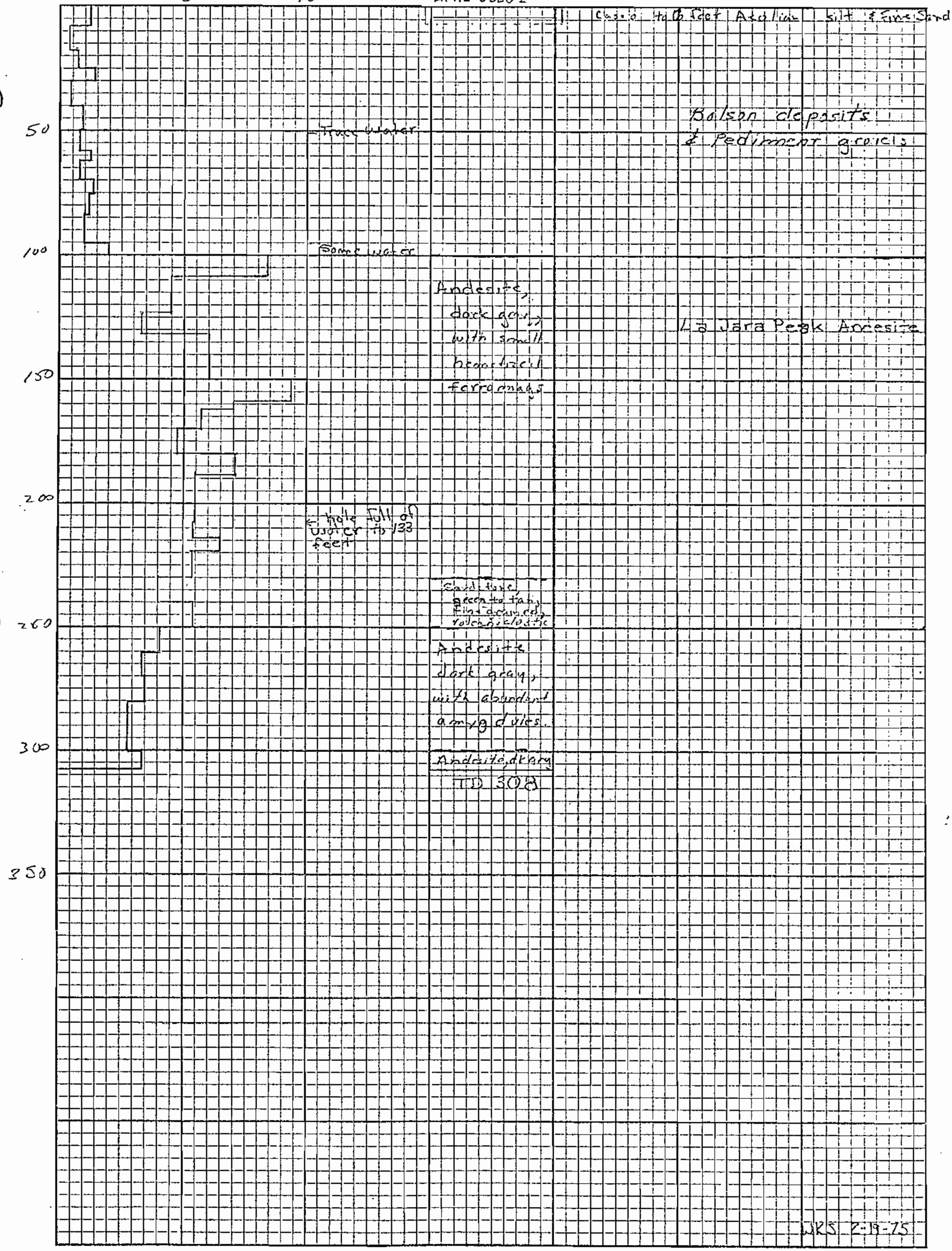
FIGURE 3.

Prepared by C. Chapin, NMBM&MR

APPENDICES

MAGDALENA #1 2S 4W. 3 430

Alt.= 6320±



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VILLAGE OF MAGDALENA
WELL SITE #1

NW¼, NE¼, Sec. 10, Twp. 2 S. Rge. 4 W Approx. 2½ mi. South off County Rd.

February 5, 1975- Move Rig on location, Rig up

Log off Well:

From	To	Formation
0	4	Blow Sand
4	91	Gravel Fill
91	100	Gravel & Clay
100	308	Black to Purple Basalt

February 5, 1975

Time	Description
10:30	Start Drilling
2:15	Come out of hole, put on new hammer & Bit
3:30	Run to bottom, start drilling
5:40	Stop Drilling- Pull 75' off Bottom
6:00	Shut down, Total depth 123 ft.

February 6, 1975

9:15	Start drilling at 123'
12:45	Haul Water
2:00	Start Drilling
7:00	Shut down- Total Depth 208 Ft.

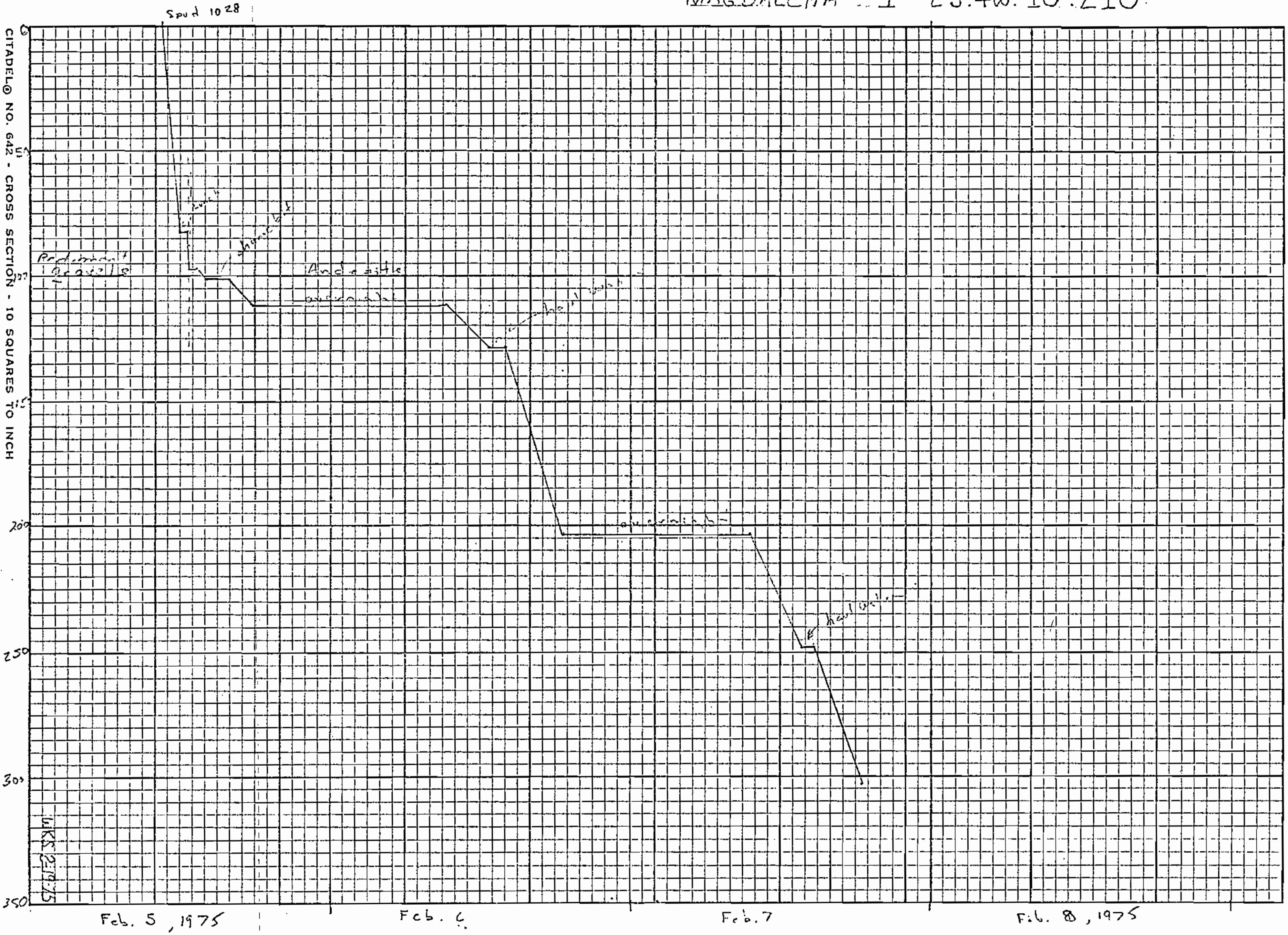
February 7, 1975

9:30	Start drilling
9:50	Repair injection pump
10:00	Drill
1:20	Haul Water
2:35	Drill
6:35	Pull 100' of Pipe , Set on Wrench
6:45	Shut down- Total Depth 308 Ft.

February 8, 1975

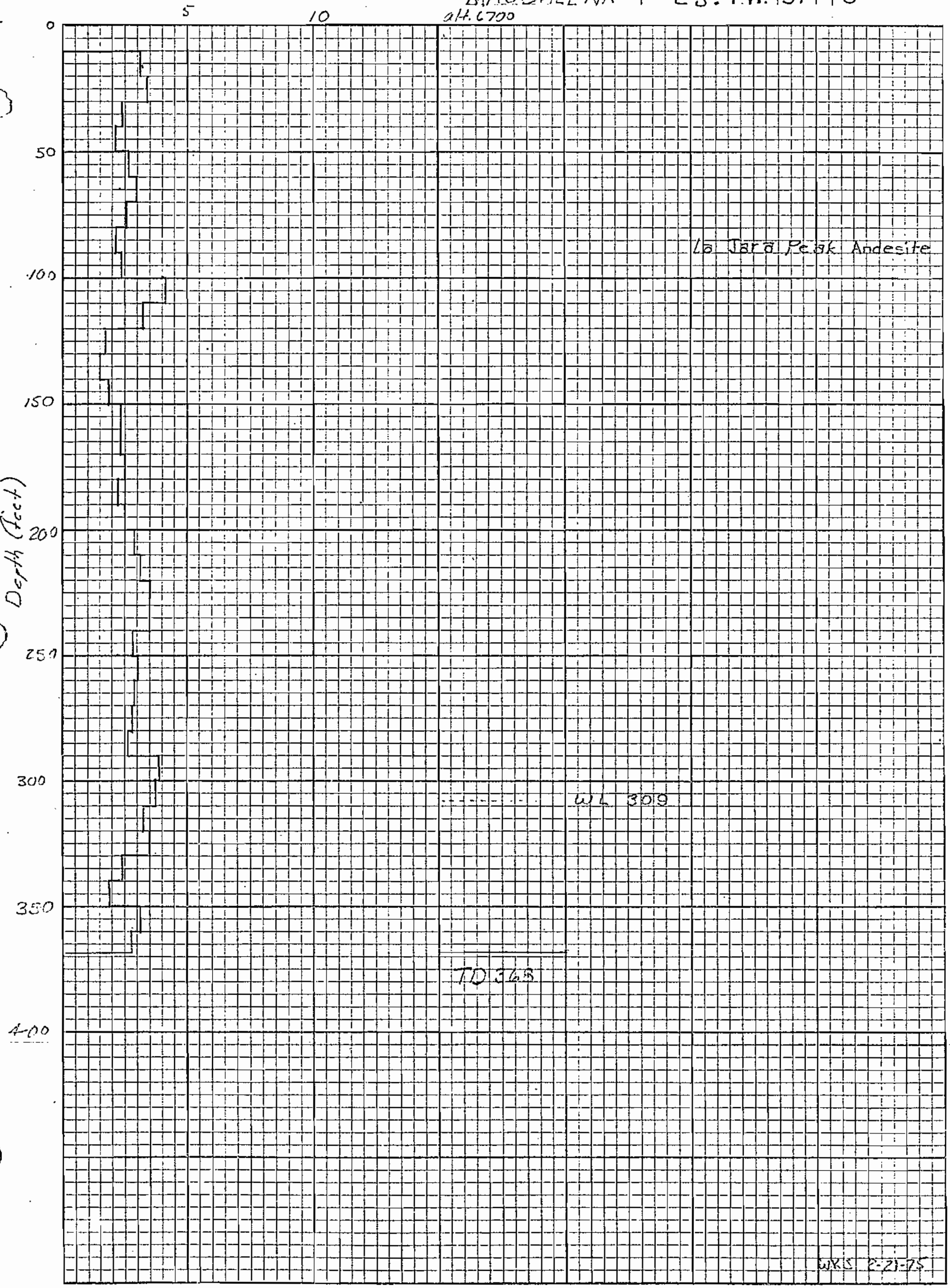
8:00	Rig ready for development
9:50	Go to Bottom& Surge Well
10:50	Jet & try to Develope well
12:30	Come out of hole & install 6' of 8" Casing
1:30	Shut Down

MAGDALENA #1 2S.4W.10.210



CITADEL® NO. 642 - CROSS SECTION - 10 SQUARES TO INCH

MAGDALENA #4 2S.4W.19.410



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Village of Magdalena
Well Site # 4 Hole #2

NE¼, SE¼, Section 19, T2S, R4W- 2½ mi. west ofMagdalena

February 10, 1975- Move Rig on location, Rig up.

Log of well:

From	To	Formation
0	8	Limestone
8	118	Basalt
118	158	Basalt with Stringers of Red Clay
158	366	Basalt 4" Crack at 330 ft.

February 10, 1975

	Time	Description
	7:00-AM- 10:53 AM	Move Rig to Well Location, haul water & Rig up.
	10:53 AM- 11:20 Am	Drill
	11:20 AM- 1140 AM	Work on injection Pump
	11:40 AM- 11:49 AM	Drill
	11:49 AM- 11:58 AM	Work on injection pump
	11:58 AM- 12:30 PM	Drill
	12:30 PM- 1:00 PM	Lunch
	1:00 PM- 7:00 Pm	Drill & Come off Bottom 50 Ft. Total Depth 158 Ft.
February 11, 1975	7:00 AM- 8:32 AM	Daily Maintenance
	8:32 Am- 12:04 Pm	Drill
	12:04 PM- 1:22 PM	Lunch & Haul Water
	1:22 PM- 2:37 PM	Drill
	2:37 PM- 3:10 PM	Come out of hole (Left hammer & Bit in) TD- 258 Ft.
February 12, 1975	8:00 AM- 9:30 AM	Daily Maintenance- Tighten Swivel
	9:30 AM- 12:30 PM	Prepare fishing tool
	12:30 PM- 1:00 PM	Lunch
	1:00 PM- 4:10 PM	Fish out hammer & Bit- Repair return to Bottom
	4:10 PM- 8:00 PM	Drill- Pull off bottom- 50 Ft. TD- 308 Ft.
February 13, 1975	7:00 AM- 7:36 Am	Daily Maintenance
	7:36 AM- 10:03 AM	Drill
	10:03 AM- 10:55 AM	Haul Water
	10:55 AM- 11:17 AM	Drill
	11:17 AM- 12:22 PM	Put water in hole (600 gal.)
	12:22 PM- 12:40 PM	Lunch
	12:40 PM- 3:15 PM	Haul water & Try to Develope well
	3:15 PM- 5:00 PM	Come out of Hole and Rig Down

County Saro Range ____ Township ____ Section ____ Collection Date ____

Collected by Summers Special Handling ____ Remarks ____

Sample Identification New Magdalena Well Lab Number ____ Appearance ____

pH 7.92 Date 4-8-75 Analyst L.B.

Total Dissolved Solids (not filtered)
Residue at 180° + dish ____
dish ____
Solids ____
Date 4-9-74 Analyst SMB ppm 436

Conductivity 550 μmho/cm Date 4-8-7 Analyst L.B.

Carbonate Sample size 50, ml acid 0	Date 4-8-75, Analyst L.B., ppm CO_3 0	epm 0	
Bicarbonate Sample size 50, Ml acid 8.1	Date 4-8-75, Analyst L.B., ppm HCO_3 198	3.25	
Chloride Sample size 25, Ml $HgCl_2$ .85	Date 3-17-75, Analyst SMB, ppm Cl^- 17	0.48	
Sulfate Sample size ____, crucible + ppt ____, ppt ____	Date 4-14-75, Analyst SMB, ppm $SO_4^=$ 76	1.58	
Nitrate Sample size ____, Abs. ____	Date ____, Analyst ____, ppm NO_3^- ____	____	
Phosphate Aliquot ____, Abs. ____	Date ____, Analyst ____, ppm $PO_4^{≡}$ ____	____	
Fluoride Aliquot ____, Mv ____	Date ____, Analyst ____, ppm F^- ____	____	
Total epm anions		5.31	
Silica Aliquot ____, Abs. ____	Date ____, Analyst ____		

Nitrite NO_2 ppm ____

Sodium dilution 1/10, Abs. ____	Date 4-7-75, Analyst S.M., ppm Na^+ 20	epm .87
Potassium Dilution ____, Abs. ____	Date 4-8-75, Analyst SMB, ppm K^+ 2.94	.08
Magnesium Dilution ____, Abs. ____	Date 3/20/75, Analyst L.B., ppm Mg 8.8	.72
Calcium Dilution ____, Abs. ____	Date 3-17-75, Analyst SMB, ppm Ca^{++} 72.7	3.63
Aluminum Aliquot ____, Abs. ____	Date ____, Analyst ____, ppm Al^{+++} ____	____
Iron Aliquot ____, Abs. ____	Date ____, Analyst ____, ppm Fe ____	____
Boron Aliquot ____, Abs. ____	Date ____, Analyst ____, ppm B ____	____
Manganese Aliquot ____, Abs. ____	Date ____, Analyst ____, ppm Mn ____	____

Total epm Cations 5.30
Cation-Anion Balance .01
% Error .19

Bromine ppm ____
Iodide ppm ____

Copper Concentration ____	Analyst ____, Date ____, ppm Cu ____
Cobalt Concentration ____	Analyst ____, Date ____, ppm Co ____
Chromium Concentration ____	Analyst ____, Date ____, ppm Cr ____
Cadmium Concentration ____	Analyst ____, Date ____, ppm Cd ____
Lead Concentration ____	Analyst ____, Date ____, ppm Cd ____
Molybdenum Concentration ____	Analyst ____, Date ____, ppm Mo ____
Nickel Concentration ____	Analyst ____, Date ____, ppm Ni ____
Zinc Concentration ____	Analyst ____, Date ____, ppm Zn ____
Mercury Concentration ____	Analyst ____, Date ____, ppm ____
Arsenic Concentration ____	Analyst ____, Date ____, ppm ____

Lithium ppm ____
Selenium ppm ____

Kelley [illegible]

State of New Mexico
Environmental Improvement Agency
Albuquerque, New Mexico 87106
LAB 007
Issued 1/73 5m

CHEMICAL AND PHYSICAL ANALYSIS FOR WATER SAMPLES

Check individual items for analysis or appropriate square below:

- ☐ Routine Chemical Analysis
- ☐ Partial Chemical Analysis
- ☒ Complete Chemical Analysis
- ☐ Routine Heavy Metals

Date Received: 3/13/75 Lab. No.: 16677

Collection Date: Feb 25 '75
CITY OR LOCATION: Magdalena County: Socorro Elev.:

Collected by: Cris Torres
Owner: Village of Magdalena
Report to: F M Garcia
Address: P O Box 2348
S F NM 87503

Source: ☒ Well ☐ Spring ☐ Stream ☐ Other Depth: 156
☒ Untreated ☐ Treated
☐ Drain ☐ Lake ☐ Pool

River Basin: ☒ Rio Grande ☐ Canadian ☐ Pecos ☐ San Juan ☐ Gila ☐ Little Colorado ☐ Other

WATER SUPPLIES: ☒ MUNICIPAL ☐ MDWCA ☐ PRIVATE ☐ INDUSTRIAL ☐ COMMERCIAL ☐ RECREATIONAL

64201
7.9

Other Information: 2S. 4W. 13.430
Collection Point: Main well
Lat.: 107° 12.5 Long.: 34° [illegible]

Cations	mg/l	me/l	Anions	mg/l	me/l	Parameter	mg/l	Parameter	mg/l	Parameter	mg/l	Parameter	mg/l
✓ 00930 Sodium (as Na)	134	5.85	✓ 00940 Chloride (as Cl)	26.0	0.73	✓ 00900 Total Hardness (as $CaCO_3$)	224	00365 Chlorine demand mg/l		01030 chromium		01145 selenium	
✓ 00935 Potassium (as K)	1.95	0.05	✓ 00950 Fluoride (as F)	0.42	0.02	✓ 00430 Alkalinity (as $CaCO_3$)	177	✓ 00080 color	neg	01040 copper		01090 zinc	
✓ 00915 Calcium (as Ca)	76.2	3.81	✓ 71850 Nitrate (as NO_3)	10.62	0.17	✓ 00515 Total Dissolved Residue	340	✓ 00070 turbidity	0.8	00720 cyanide		09501 radium 226	pc/l
✓ 00925 Magnesium (as Mg)	8.1	0.66	✓ 00440 Bicarbonate (as HCO_3)	216.2	3.54	32005 Carbon chloroform extract		✓ 00095 Conductance Micromhos 25°C	524	01049 lead		13501 strontium 90	
✓ 01045 Iron - Total (as Fe)	<0.25		✓ 00445 Carbonate (as CO_3)	—	—	00010 Field water temperature		01000 Arsenic		07180 mercury		03501 gross beta	
✓ 01056 Manganese (as Mn)	<0.05		✓ 00945 Sulfate (as SO_4)	60.6	1.26	✓ 38260 Surfactants (as LAS)	<0.05	01005 barium		01062 molybdenum			
			00650 Phosphate (as PO_4)			✓ 00400 pH	7.80	01022 boron		01067 nickel			
Total		5.37	Total		5.72	✓ 01330 odor	neg	01025 cadmium		01075 silver			

Remarks: SUP-4-75

RECEIVED
MAR 28 1975
WATER SUPPLY
REGULATION SECTION

Date: 3-26-75
Analyst: [illegible]
Reviewed by: [illegible]
Date Reported: 3/27/75

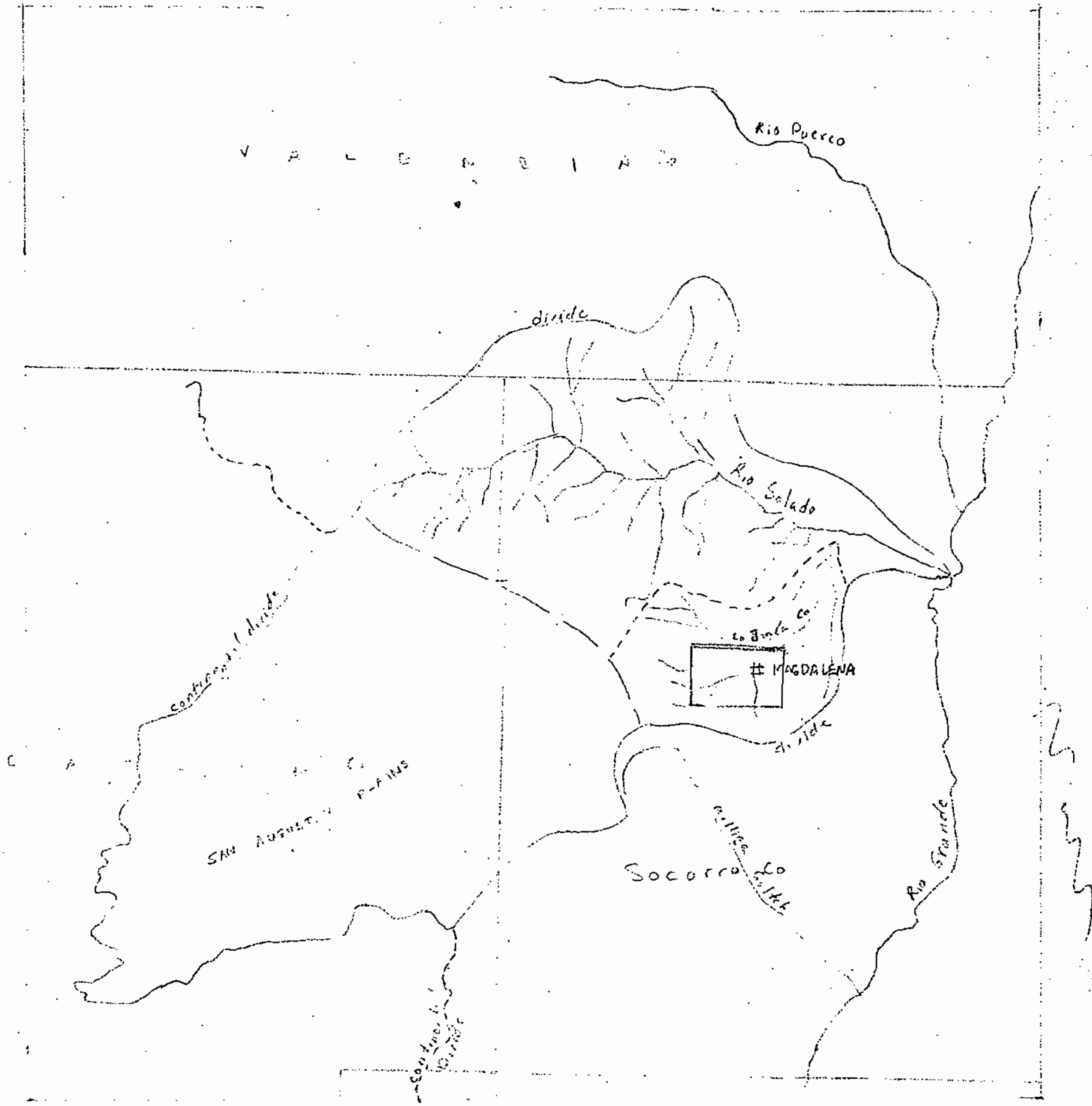
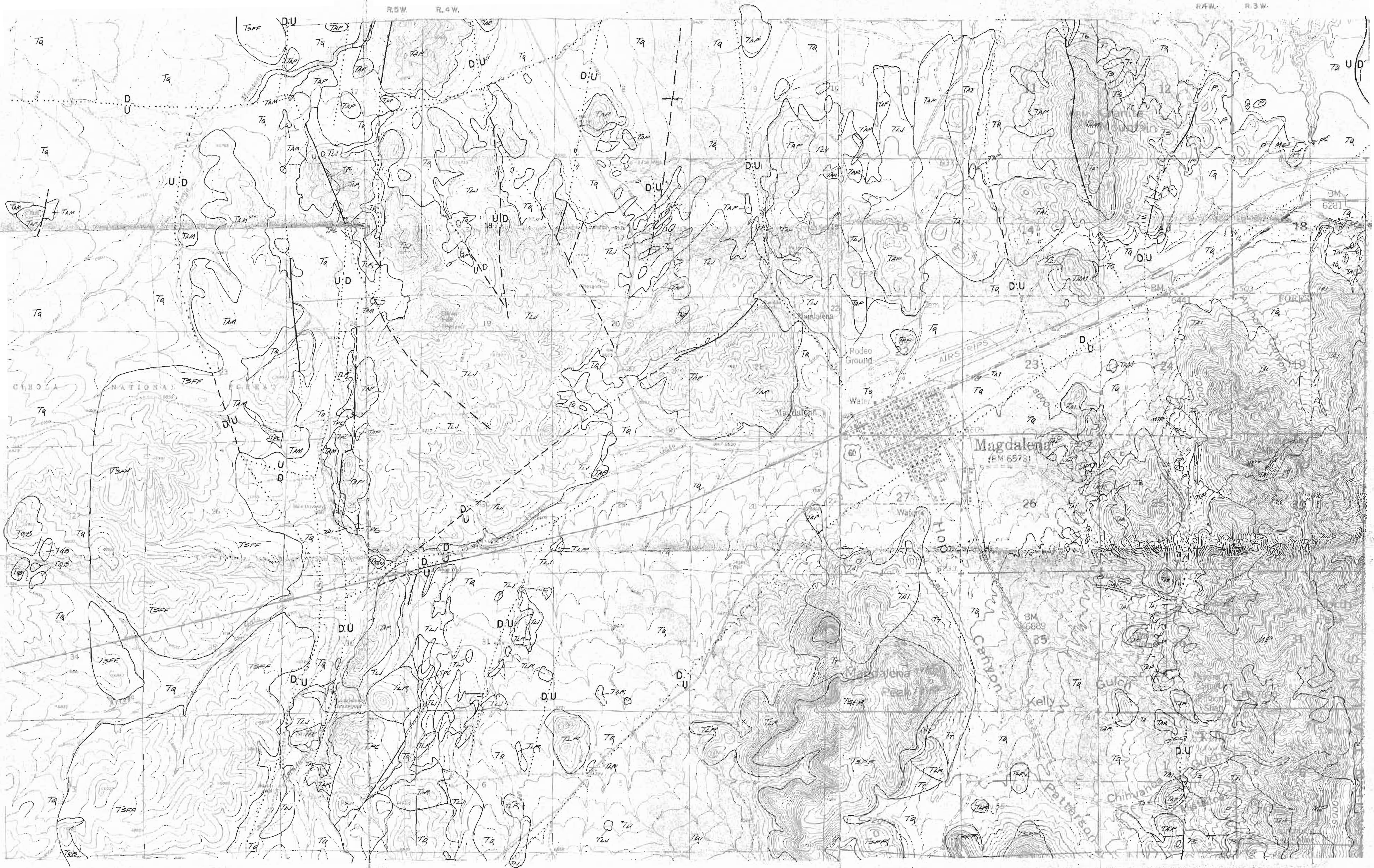
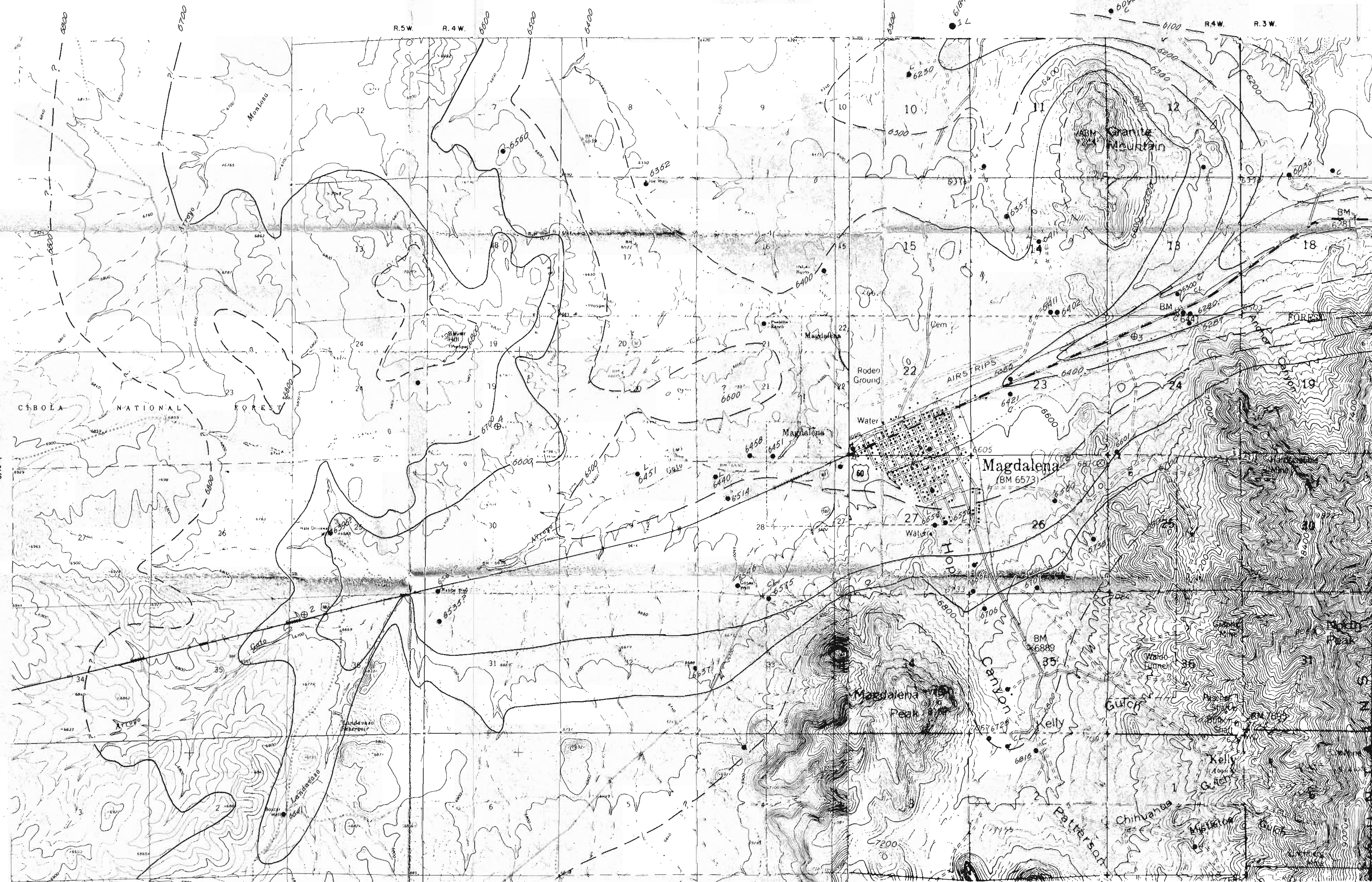


Figure 1. - Relation of Magdalena area to regional drainage.



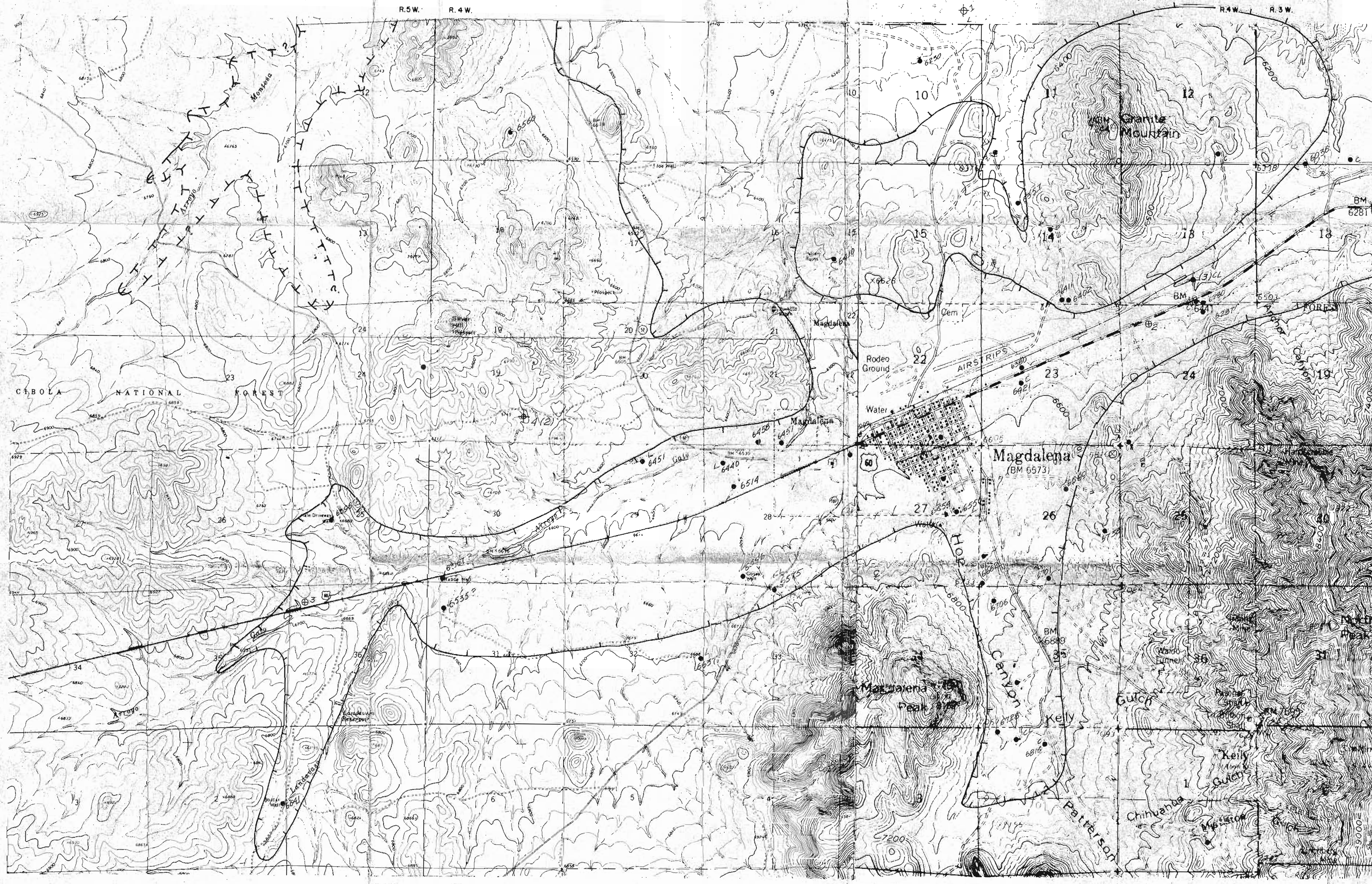
Base map compiled from the following USGS quadrangles: Arroyo Landavaso, Magdalena, and Silver Hill, New Mexico

PLATE I. -- GEOLOGIC MAP - MAGDALENA AREA, NEW MEXICO



Base map compiled from the following USGS quadrangles:
Arroyo Landavaso, Magdalena, and Silver Hill, New Mexico

PLATE 2. -- WATER TABLE MAP - MAGDALENA, NEW MEXICO



Base map compiled from the following USGS quadrangles:
Arroyo Landavaso, Magdalena, and Silver Hill, New Mexico

PLATE 3. -- MAP SHOWING RECHARGE AND DISCHARGE AREAS, MAGDALENA AREA, NEW MEXICO