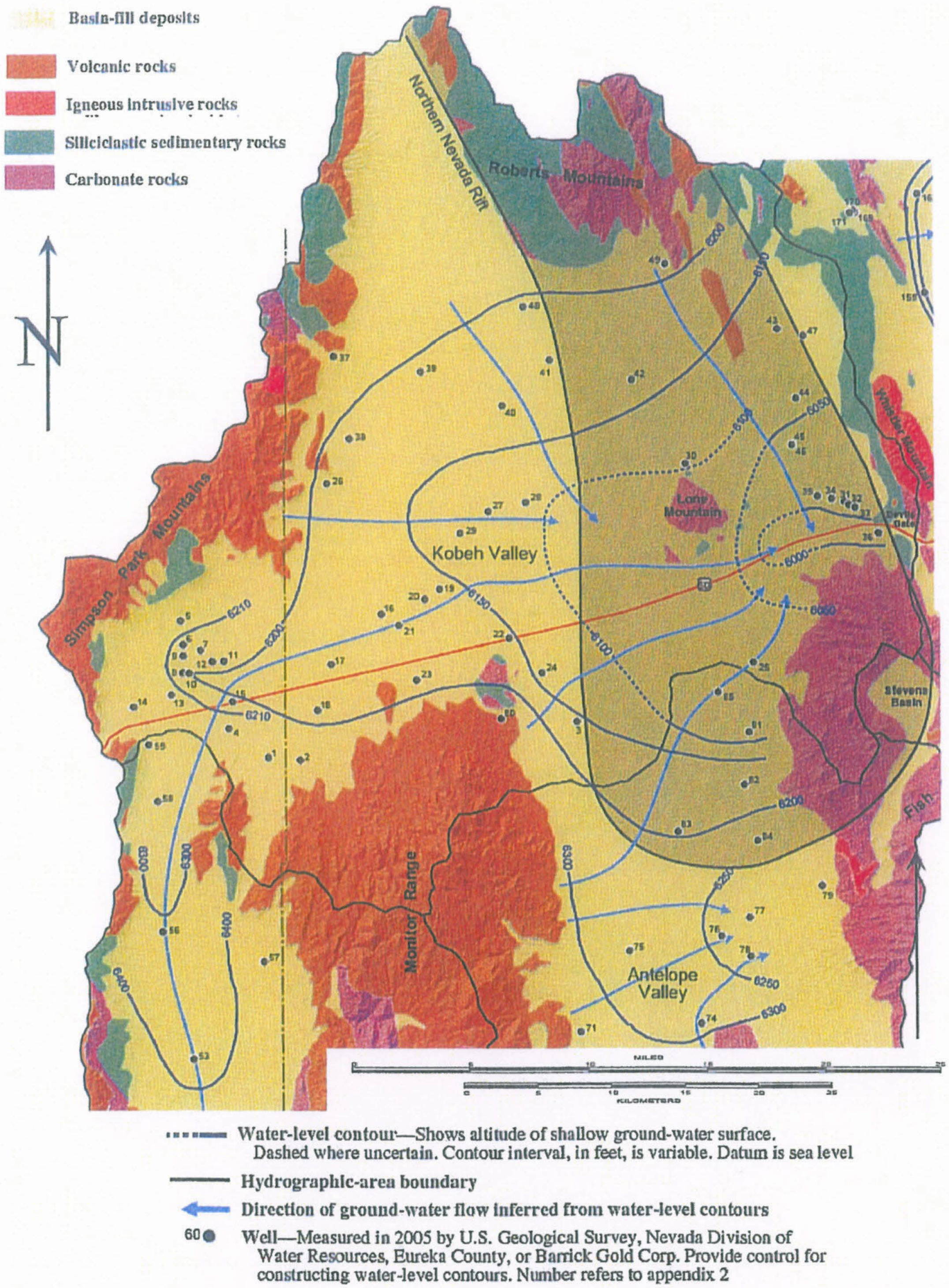


Figure 44. General potentiometric map of Kobeh Valley. Shaded area is the approximate location of the Northern Nevada Rift. Source: Cropped and modified from Tumbusch and Plume (2006).

as conduits for mineralized fluids, thus potentially reducing fracture permeability, and/or may contain healed tectonic breccia from precipitated calcite or silica. The older two sets of faults are known pathways for later Tertiary hydrothermal fluid flow (Yigit et al, 2003). The hydraulic characteristics of the north striking faults such as the Western Roberts Mountains Range-Front Fault and the two prominent faults framing Roberts Creek may enhance fracture permeability in carbonates, but reduce permeability in basin-fill sediments by forming seals along fault planes from interbedded clays in alluvium, and juxtaposition of permeable beds with impermeable beds. North striking faults east of 206T have been identified from drilling results at 203 and 204, and offset Miocene basalt and Oligocene(?) siltstones and fanglomerates by more than 500 feet. The fault system also juxtaposes permeable carbonates near 206T with lower-permeability sedimentary and volcanic rocks tested at 203 and 204. This situation imposes limitation on the carbonate rocks in the well field by reducing the aerial extent of these potential aquifer units. On **Figure 42,** major normal faults with significant offset have been marked as red lines, and are inferred hydrologic boundaries based on the fact that these faults significantly offset differing geologic units (**Figure 43**), and, based on potentiometric contours, may affect groundwater flow (see **Figure 44**).

Between the three major horst blocks mentioned above graben complexes have developed and accumulated volcanic, lacustrine, and fluvial materials during at least the last ~20 million years (Roberts, 1978) as a result of extensional tectonics. As the basins developed, climates fluctuated between arid and semi-arid to temperate, and to cool, continental glaciated environments. During wet climate cycles, lakes formed in the developing Kobeh Valley basin, and lacustrine clays and siltstones have been identified at altitudes of 6,500 feet in the northern Kobeh Valley area. Where located in the present day basin of Kobeh Valley, these older lacustrine deposits were progressively down dropped by episodic faulting related to basin and range extension. The youngest documented lake to form extensively in Kobeh Valley was pluvial Lake Jonathan, which occupied nearly all of Kobeh Valley to an approximate highstand of 6,300 feet above sea level (Reheis et al, 2003). Sometime after 675,000 years ago, the Devils Gate Gap was breached, and although Diamond Valley contained Lake Diamond in the late Quaternary, no major pluvial lake has occupied Kobeh Valley since the middle Pleistocene (Reheis et al, 2003).

Table 14: Well locations, elevations and periodic manual water level measurements, Kobeh Valley Well Field area

Well I.D.	NORTHING (FT)	EASTING (FT)	Ground Elevation (ft amsl)	Date	SWL (ft below MP)	Height of Measuring Point (ft)	SWL (ft. below ground surface)	Water Surface Elevation (ft)	Water Surface Elevation (ft)
LRCMW	14419587.96	1839141.97	6768.99	11/8/2008	89.63	2.15	87.48	6681.51	Average
LRCMW			6768.99	3/20/2009	92.72	2.15	90.57	6678.42	6679.84
LRCMW			6768.99	5/25/2009	91.56	2.15	89.41	6679.58	
MRCMW	14451270.79	1836899.09	6771.6	11/8/2008	80.48	2	78.48	6693.12	Average
MRCMW			6771.6	3/20/2009	79.92	2	77.92	6693.68	6693.86
MRCMW			6771.6	5/23/2009	78.82	2	76.82	6694.78	
KFWMW	14435735.75	1813975.75	6631.96	11/8/2008	174.85	2.92	171.93	6460.03	Average
KFWMW			6631.96	3/20/2009	173.16	2.92	170.24	6461.72	6461.26
KFWMW			6631.96	5/23/2009	172.86	2.92	169.94	6462.02	
KFEMW	14445210.12	1853429.42	6709.58	3/20/2009	48.35	2.28	46.07	6663.51	Average
KFEMW			6709.58	5/25/2009	48.43	2.28	46.15	6663.43	6663.47
RWX 203MD	14439891.26	1851658.16	6,568.16	2/7/2008	84.96	1.85	83.11	6485.05	Average
RWX 203MD			6,568.16	11/8/2008	80.82	1.85	78.97	6489.19	6488.55
RWX 203MD			6,568.16	3/20/2009	80.09	1.85	78.24	6489.92	
RWX 203MD			6,568.16	5/25/2009	79.98	1.85	78.13	6490.03	
RWX 203MS	14439891.26	1851658.16	6568.16	2/7/2008	80.23	1.85	78.38	6489.78	Average
RWX 203MS			6568.16	11/8/2008	78.22	1.85	76.37	6491.79	6491.64
RWX 203MS			6568.16	3/20/2009	77.55	1.85	75.7	6492.46	
RWX 203MS			6568.16	5/25/2009	77.48	1.85	75.63	6492.53	
RWX 203T	14439886.92	1851744.7	6568.88	11/8/2008	78.55	1.5	77.05	6491.83	Average
RWX 203T			6568.88	3/20/2009	77.75	1.5	76.25	6492.63	6492.42
RWX 203T			6568.88	5/25/2009	77.58	1.5	76.08	6492.8	
RWX 204P	14437530.95	1850177.51	6510.56	2/7/2009	55.24	2.04	53.2	6457.36	Average
RWX 204P			6510.56	11/8/2008	56.06	2.04	54.02	6456.54	6456.56
RWX 204P			6510.56	3/20/2009	56.35	2 .04	54.31	6456.25	

"blocked" indicates a temporary obstruction was in the well, thus no water level information was obtained, NR= not reported, SWL = Static Water Level

Well I.D.	NORTHING (FT)	EASTING (FT)	Ground Elevation (ft amsl)	Date	SWL (ft below MP)	Height of Measuring Point (ft)	SWL (ft. below ground surface)	Water Surface Elevation (ft)	Water Surface Elevation (ft)
RWX 204P			6510.56	5/27/2009	56.52	2.04	54.48	6456.08	
RWX 205MD	14429688.61	1846291.61	6379.21	11/8/2008	36.28	0.77	35.51	6343.7	Average
RWX 205MD			6379.21	2/7/2008	30.16	2.04	28.12	6351.09	6345.34
RWX 205MD			6379.21	3/20/2009	36.57	0.77	35.8	6343.41	
RWX 205MD			6379.21	5/23/2009	36.82	0.77	36.05	6343.16	
RWX 205MS	14429688.61	1846291.61	6379.21	2/7/2008	30.04	0.77	29.27	6349.94	Average
RWX 205MS			6379.21	11/8/2008	36.43	0.77	35.66	6343.55	6344.88
RWX 205MS			6379.21	3/20/2009	36.77	0.77	36	6343.21	
RWX 205MS			6379.21	5/23/2005	37.16	0.77	36.39	6342.82	
RWX 206T	14434589.89	1843679.79	6,444.49	2/7/2008	94.51	0.97	93.54	6350.95	Average
RWX 206T			6,444.49	11/9/2008	100.58	0.97	99.61	6344.88	6346.09
RWX 206T			6,444.49	3/20/2009	100.99	0.97	100.02	6344.47	
RWX 206T			6,444.49	5/26/2009	101.42	0.97	100.45	6344.04	
RWX 206MD	14434570.44	1843750.19	6443.55	2/7/2008	95.06	0.42	94.64	6348.91	Average
RWX 206MD			6443.55	11/9/2008	blocked	0.42	blocked	unknown	6344.48
RWX 206MD			6443.55	3/20/2009	101.64	0.42	101.22	6342.33	
RWX 206MD			6443.55	5/26/2009	101.78	0.42	101.36	6342.19	
RWX 206MS	14434570.44	1843750.19	6443.55	2/7/2008	95.00	0.42	94.58	6348.97	Average
RWX 206MS			6443.55	11/9/2008	101.60	0.42	101.18	6342.37	6344.06
RWX 206MS			6443.55	3/20/2009	101.32	0.42	100.9	6342.65	
RWX 206MS			6443.55	5/26/2009	101.72	0.42	101.3	6342.25	
RWX 209MD	14432946.14	1830080.27	6510.21	11/9/2008	145.05	1.58	143.47	6366.74	Average
RWX 209MD			6510.21	3/20/2009	149.35	1.58	147.77	6362.44	6382.69
RWX 209MD			6510.21	5/25/2009	150.24	1.58	148.66	6361.55	
RWX 209MS	14432946.14	1830080.27	6510.21	11/9/2008	71.77	1.58	70.19	6440.02	Average
RWX 209MS			6510.21	3/20/2009	71.42	1.58	69.84	6440.37	6440.25
RWX 209MS			6510.21	5/25/2009	71.42	1.58	69.84	6440.37	
RWX 213M	14444466.77	1840499.63	6639.74	11/8/2008	294.46	2.3	292.16	6347.58	Average

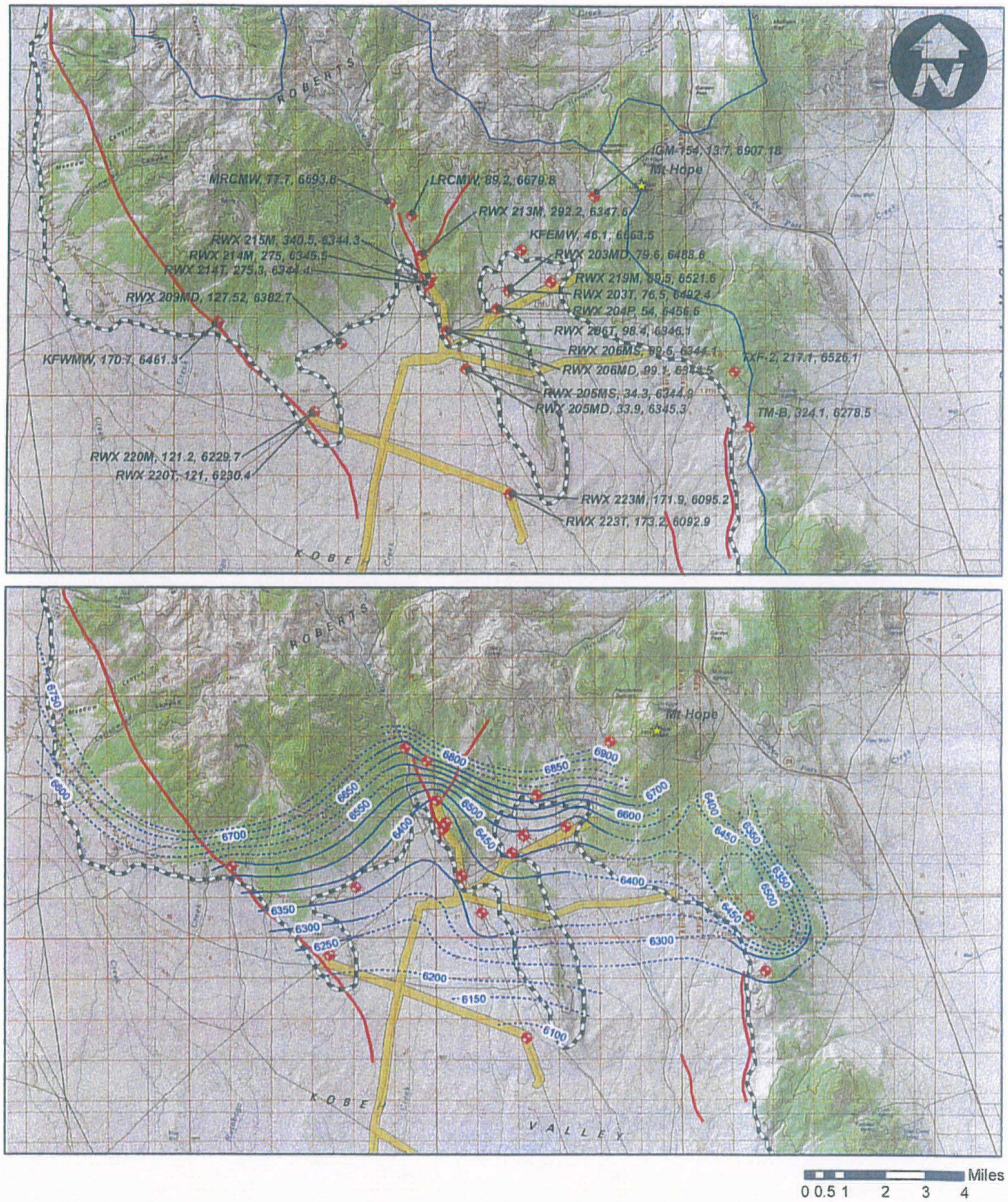
Well I.D.	NORTHING (FT)	EASTING (FT)	Ground Elevation (ft amsl)	Date	SWL (ft below MP)	Height of Measuring Point (ft)	SWL (ft. below ground surface)	Water Surface Elevation (ft)	Water Surface Elevation (ft)
RWX 213M			6639.74	3/20/2009	294.80	2.3	292.5	6347.24	6347.57
RWX 213M			6639.74	5/25/2009	294.15	2.3	291.85	6347.89	
RWX 214T	14440772.06	1841371.79	6619.64	11/8/2008	276.58	1.63	274.95	6344.69	Average
RWX 214T			6619.64	3/20/2009	276.88	1.63	275.25	6344.39	6344.35
RWX 214T			6619.64	5/25/2009	277.30	1.63	275.67	6343.97	
RWX 214M	14440714.11	1841368.69	6620.53	11/8/2008	275.32	0.64	274.68	6345.85	Average
RWX 214M			6620.53	3/20/2009	275.60	0.64	274.96	6345.57	6345.54
RWX 214M			6620.53	5/25/2009	275.98	0.64	275.34	6345.19	
RWX 215M	14441553.63	1841698.0	6684.77	11/8/2008	342.83	2.7	340.13	6344.64	Average
RWX 215M			6684.77	3/20/2009	343.14	2.7	340.44	6344.33	6344.30
RWX 215M			6684.77	5/25/2009	343.53	2.7	340.83	6343.94	
RWX 219M	14441010.89	1857186.35	6611.18	11/8/2008	93.26	1.58	91.68	6519.5	Average
RWX 219M			6611.18	3/20/2009	90.72	1.58	89.14	6522.04	6521.67
RWX 219M			6611.18	5/6/2009	90.10	1.58	88.52	6522.66	
RWX 219M			6611.18	5/25/2009	90.29	1.58	88.71	6522.47	
RWX 220T	14424058.11	1826689.18	6,351.38	11/9/2008	122.37	1.78	120.59	6230.79	Average
RWX 220T			6,351.38	3/20/2009	122.83	1.75	121.08	6230.3	6230.38
RWX 220T			6,351.38	5/25/2009	123.09	1.75	121.34	6230.04	
RWX 220M	14424094.94	1826674.29	6350.84	11/9/2008	122.39	1.24	121.15	6229.69	Average
RWX 220M			6350.84	3/20/2009	122.33	1.22	121.11	6229.73	6229.65
RWX 220M			6350.84	5/25/2009	122.54	1.22	121.32	6229.52	
RWX 222T	14416286.37	1844000.77	6271.07	11/9/2008	80.76	1.9	78.86	6192.21	Average
RWX 222T			6271.07	3/20/2009	81.65	1.9	79.75	6191.32	6191.56
RWX 222T			6271.07	5/23/2009	81.81	1.9	79.91	6191.16	
RWX 222M	14416304.8	1843978.42	6270.55	11/9/2008	81.33	1.74	79.59	6190.96	Average
RWX 222M			6270.55	3/20/2009	81.68	1.74	79.94	6190.61	6190.68
RWX 222M			6270.55	5/23/2009	81.82	1.74	80.08	6190.47	
RWX 223T	14413341.07	1852070.56	6266.09	11/9/2008	176.42	1.4	175.02	6091.07	Average

Well I.D.	NORTHING (FT)	EASTING (FT)	Ground Elevation (ft amsl)	Date	SWL (ft below MP)	Height of Measuring Point (ft)	SWL (ft. below ground surface)	Water Surface Elevation (ft)	Water Surface Elevation (ft)
RWX 223T			6266.09	3/20/2009	173.67	1.4	172.27	6093.82	6092.91
RWX 223T			6266.09	5/23/2009	173.65	1.4	172.25	6093.84	
RWX 223M	14413328.14	1852081.65	6267.19	11/9/2008	175.42	1.86	173.56	6093.63	Average
RWX 223M			6267.19	3/20/2009	173.08	1.86	171.22	6095.97	6095.23
RWX 223M			6267.19	5/23/2009	172.96	1.86	171.1	6096.09	
RWX 228T	14431124.4	1889442.56	6414.3	11/9/2008	205.44	1.73	203.71	6210.59	Average
RWX 228T			6414.3	3/20/2009	208.58	1.73	206.85	6207.45	6208.22
RWX 228T			6414.3	5/26/2009	209.42	1.73	207.69	6206.61	
RWX 228M	14431109.74	1839190.05	6410.27	11/9/2008	204.96	1.35	203.61	6206.66	Average
RWX 228M			6410.27	3/20/2009	209.43	1.35	208.8	6201.47	6203.34
RWX 228M			6410.27	5/26/2009	209.72	1.35	208.37	6201.9	
RWX 229T	14430607.86	1843061.43	6401.59	11/9/2008	204.53	1.67	202.86	6198.73	Average
RWX 229T			6401.59	3/20/2009	205.07	1.67	203.04	6198.55	6198.39
RWX 229T			6401.59	5/26/2009	205.38	1.67	203.71	6197.88	
RWX 229M	14430638.3	1843077.08	6403.72	11/9/2008	202.72	1.53	201.19	6202.59	Average
RWX 229M			6403.72	3/20/2009	202.51	1.53	200.98	6202.74	6202.64
RWX 229M			6403.72	5/26/2009	202.61	1.53	201.08	6202.64	
Wells with a single manual water level measurement									
IGM-154	14,452,685.01	1,862,269.57	6920.88	3/19/2009	16.1	2.4	13.7	6907.18	
RWX-235P	14,422,187.27	1,883,272.77	6,603.57	3/19/2009	326.4	NR	NR	6277.17	
KV01	14395700.62	1866807.41	6,083.09	7/14/2006	NR	NR	35.7	6047.39	
KV05	14388753.92	1861852.94	6,043.74	7/12/2006	NR	NR	4.8	6038.94	-
KV11	14401916.05	1863832.616	6128.62	6/11/2006	NR	NR	90.3	6038.32	
9211R	14379392.1	1882512.8	6008.55	8/6/2006	NR	NR	2.3	6006.25	
TM-1	14419940.94	1874242.13	6269.9	2/7/2008	NR	NR	209.43	6060.47	
TM1B	14420623.4	1873090.6	6,275.17	5/25/2009	NR	NR	208.1	6067.07	
EW1	14434028.9	1793139.8	6361.20	10/25/2006	NR	NR	134.95	6226.25	
EW2	14433520.3	1792112.9	6364.60	10/25/2006	NR	NR	135.95	6228.65	

Well I.D.	NORTHING (FT)	EASTING (FT)	Ground Elevation (ft amsl)	Date	SWL (ft below MP)	Height of Measuring Point (ft)	SWL (ft. below ground surface)	Water Surface Elevation (ft)	Water Surface Elevation (ft)
TXF-2	1881186.89	14429378.01	6743.18	5/5/2009	219.19	2.07	217.12	6526.06	
TM-B	1883279.65	14422152.46	6602.61	3/19/2009	326.48	2.41	324.07	6278.54	
Wells from the USGS NWIS database near the Kobeh Valley Well Field area used in figure 46 [NR - Not Reported]									
139 N20 E51 13AC 1	14384351	1873234	6014	2005	NR	NR	5	6009	
139 N20 E51 05CBCC	14392864	1848770	6139	2005	NR	NR	11	6128	
139 N20 E49 24ACAB	14381760	1810128	6113	2005	NR	NR	6	6107	
139 N20 E52 18ABDB	14381987	1879910	6006	2005	NR	NR	4	6002	
139 N22 E50 31CCAC	14426765	1809657	6408	2005	NR	NR	234	6174	
139 N20 E52 21DBDA	14374745	1890708	6004	2005	NR	NR	7	5997	
139 N21 E50 17BACC	14414965	1814945	6222	2005	NR	NR	59	6163	
139 N21 E50 23AABD	14409953	1834233	6191	2005	NR	NR	40	6151	
139 N21 E49 16CCBB	14411717	1785990	6234	2005	NR	NR	41	6193	
139 N22 E51 30BABB	14436616	1841916	6470	2005	NR	NR	149	6321	
139 N21 E49 25BBDA	14403974	1804828	6185	2005	NR	NR	13	6172	

Figure 45: Potentiometric water level map for consolidated rocks near the Kobeh Valley well field area.

Figure 46: Potentiometric water level map for the basin-fill aquifer in the Kobeh Valley Well Field area.



Explanation

GMI Well Completed in Consolidated Rocks (Name, Depth to Water, Water Level Elevation in Feet)

Lines of Equal Water Level Elevation, in Feet Above Sea Level

Type

- Higher Certainty
- Lower Certainty
- Approximate Limit of Basin-Fill Aquifer
- Quaternary Faults
- Well Field Corridor

Figure 45 - Potentiometric water level contour map for consolidated rocks in the study area

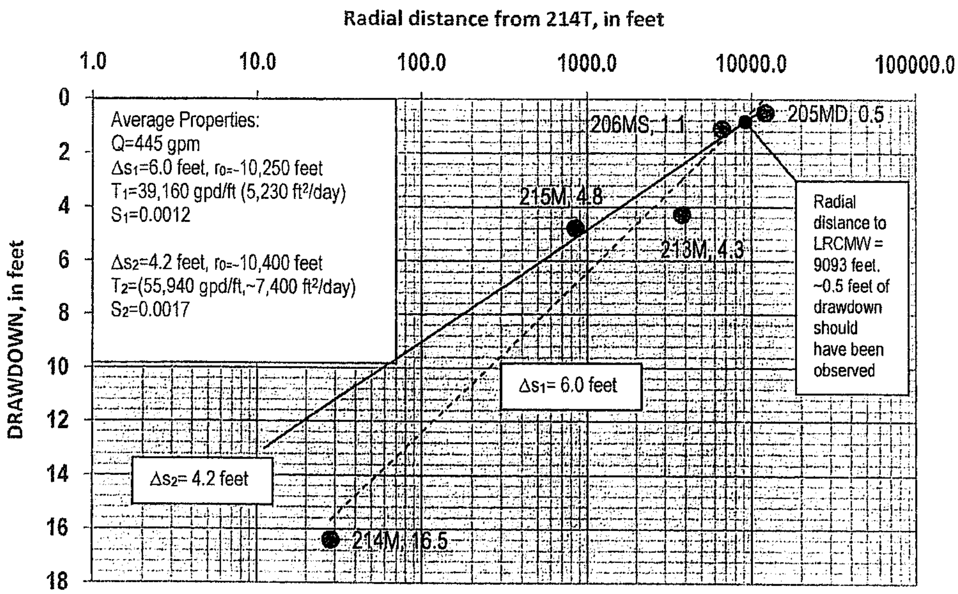


Figure 22: Semi-log distance-drawdown plot using all observation wells with drawdown response, 214T test. Point labels indicate well name and amount of drawdown after 10.98 days of pumping. Utilizing only 215M, 206MS, and 205MS results in a Δs of 4.2, which equates to a transmissivity of 7,400 ft²/day.

A Cooper-Jacob (1964) distance drawdown analysis of data from the observation wells (**Figure 22**) indicates an overall average transmissivity value of about 5,230 ft^2/day, and a storage coefficient of 0.001. The evaluation may be skewed toward a slightly smaller transmissivity value because it utilizes a best-fit straight line affected by 213M, which experienced a greater degree of drawdown due to its proximity to a boundary condition. Well 214M may have been too close (28 feet) to the pumping well in this fractured rock aquifer, and may also have experienced greater-than-expected drawdown, perhaps through non-Darcian flow in fractures that connect both well locations. If wells 214M and 213M are omitted from the analysis for the above mentioned reasons, the transmissivity is approximately 7,400 ft^2/day, and the storage coefficient is approximately 0.0017. Utilizing a Theis curve analysis on wells 215M, 206MS, and 205MS, a simultaneous match was obtained that indicates that the best-fit to drawdown observed from those observation wells is obtained with a transmissivity value of 7,020 ft^2/day with a storage coefficient of 0.002 (Appendix E). Therefore, it is understood that the best estimate for the average transmissivity of the carbonate rocks near 214T are around 6,000-7,000 ft^2/day, with a storage coefficient of 0.001 to 0.002.

A second feature of the distance-drawdown analysis is the fact that the Lower Roberts Creek Monitor Well (LRCMW) should have experienced approximately 0.5 feet of drawdown during the test, according to **Figure 22**. Prior to pumping 214T, background data were collected on LRCMW (**Figures 23 and 24**). A relationship between water level response and barometric pressure fluctuations was established, and barometric efficiency was estimated to be 76%. In addition, the background data indicated that a pre-testing downward trend was present (synthetic hydrograph in **Figure 24**). This trend continued during and after the pumping test of 214T. The slight oscillations in the synthetic hydrograph shown in **Figure 24** are most likely earth tides, the slight diurnal changes in the lithosphere in response to gravity loading by the moon and other celestial bodies.

Data from the pumping and recovery phase were adjusted to account for barometric effects, and the linear pre-test downward trend (**Figure 23**). The barometrically compensated hydrograph (Barometric Compensation Hydrograph, **Figure 25**) does not show a recovery response at the end of the test, and when the pre-testing trend is removed with a linear function consistent with the pre-test water level data trend (linear trend on the synthetic hydrograph in **Figure 24**), the water level is relatively constant, suggesting no influence from the 214T pumping test (Detrended and Baro Filtered Hydrograph, **Figure 25**). Because the LRCMW did not show any response to drawdown or recovery, 213M showed a greater-than-expected amount of drawdown, and a large disparity exists in water level elevations at the LRCMW and carbonate wells to the south, the interpretation of a significant fault-related barrier to groundwater flow between LRCMW and 213M is warranted.

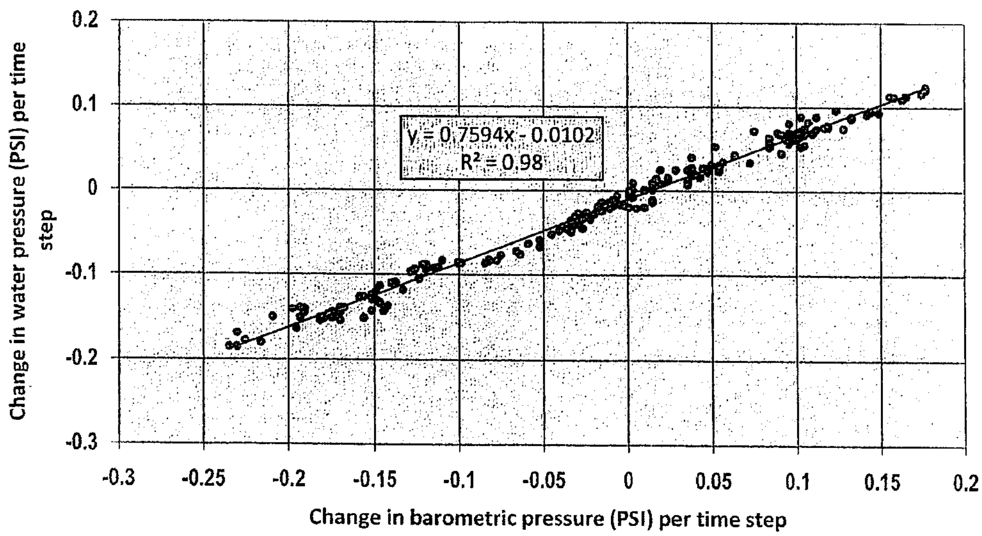


Figure 23: Regression of change in barometric pressure and change in water pressure on transducer, with estimated barometric efficiency (~76%), Lower Roberts Creek Monitor Well

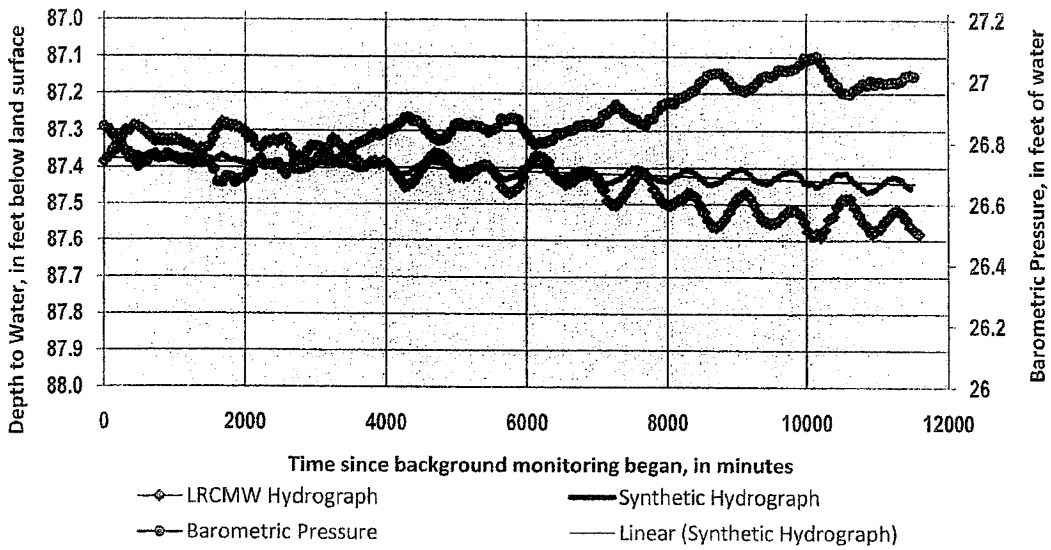


Figure 24: Plot of barometric pressure and water levels with pre-testing background trend noted in the synthetic hydrograph for the Lower Roberts Creek Monitor Well.

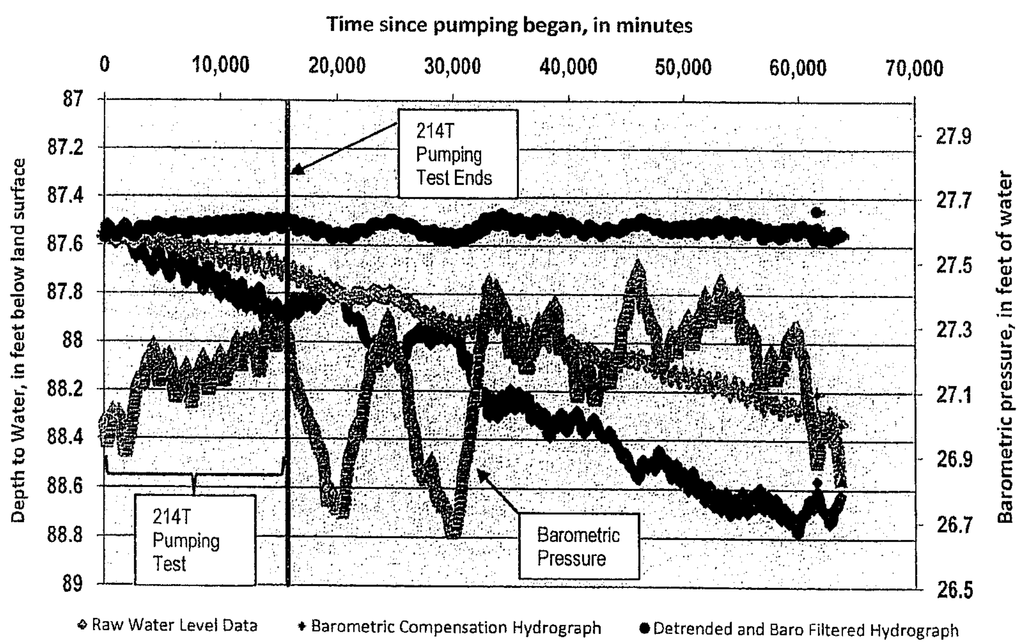


Figure 25: Plot of depth-to-water and barometric pressure for Lower Roberts Creek Monitoring Well during and after the pumping of well 214T. Effects of barometric pressure on water levels have been filtered out of the "Barometric Compensation Hydrograph", and a linear pre-test trend has been removed in the "Detrended and Baro Filtered Hydrograph".

6.7 Test Well 220T

Although drilled predominantly through black shale of the Vinini, well 220T derived nearly all of its water from a fault zone at 960 fbls, where shattered Vinini and Devonian carbonates were encountered. A step drawdown test was performed at 220T, and water levels were monitored in both the pumping and observation well 220M. The pumping rates were varied from 308 gpm to 405 gpm, with maximum drawdown, approximately 93 feet, occurring during the last step of the test. Pumping rates and the resulting drawdown for both 220T and 220M during the step test are shown in **Table 6**, and drawdown and recovery is shown in **Figure 26.**

Table 6: Summary of drawdown, pumping rates, and durations, test well 220T.

Test Well	Pumping Rate (gpm)	Duration (minutes)	Drawdown (feet)	Specific Capacity	Specific Discharge
220T	308	120	54	5.7	0.18
220T	353	33	63	5.6	0.18
220T	380	87	72	5.3	0.19
220T	450	120	93	4.8	0.21

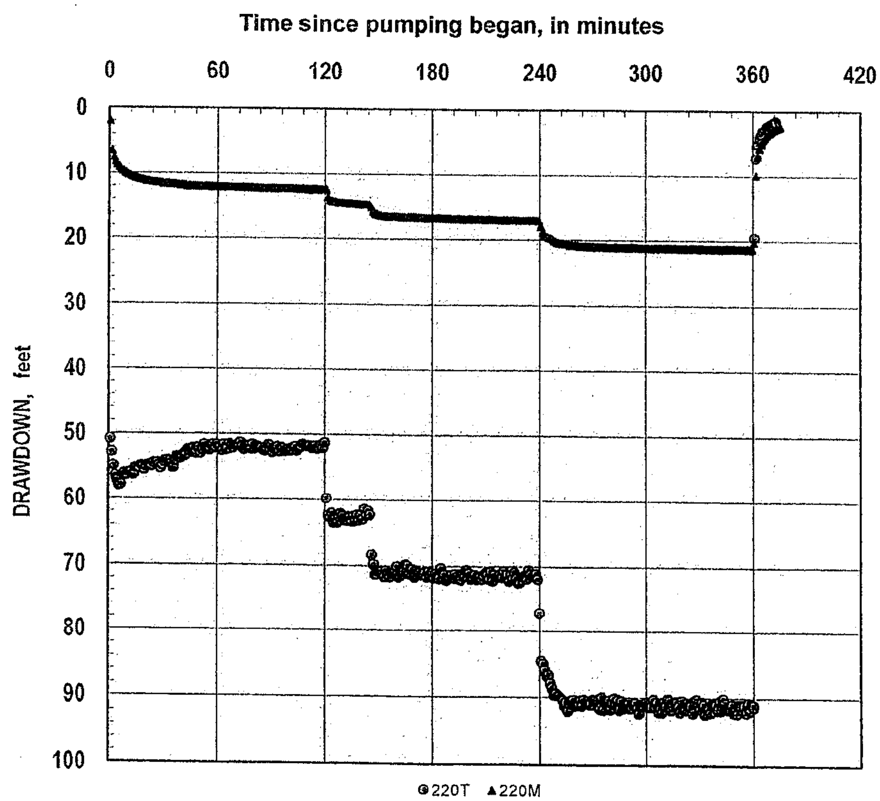


Figure 26: Step drawdown and recovery data from 220T and 220M, Kobeh Valley Well Field area

The constant-rate aquifer test at 220T was conducted for 7 days at an average pumping rate of 475 gpm. Prior to the constant rate test, the static water level in 220T was 164 fbls. Total drawdown in the pumping well was 101 feet with 26 feet of drawdown recorded at 220M located approximately 50 feet away (**Figures 27 and 28**). Analysis of the drawdown data for the 220T step and constant rate indicated transmissivity on the order of 3,600 to 3,700 ft²/day, and a storage coefficient of 0.0001.

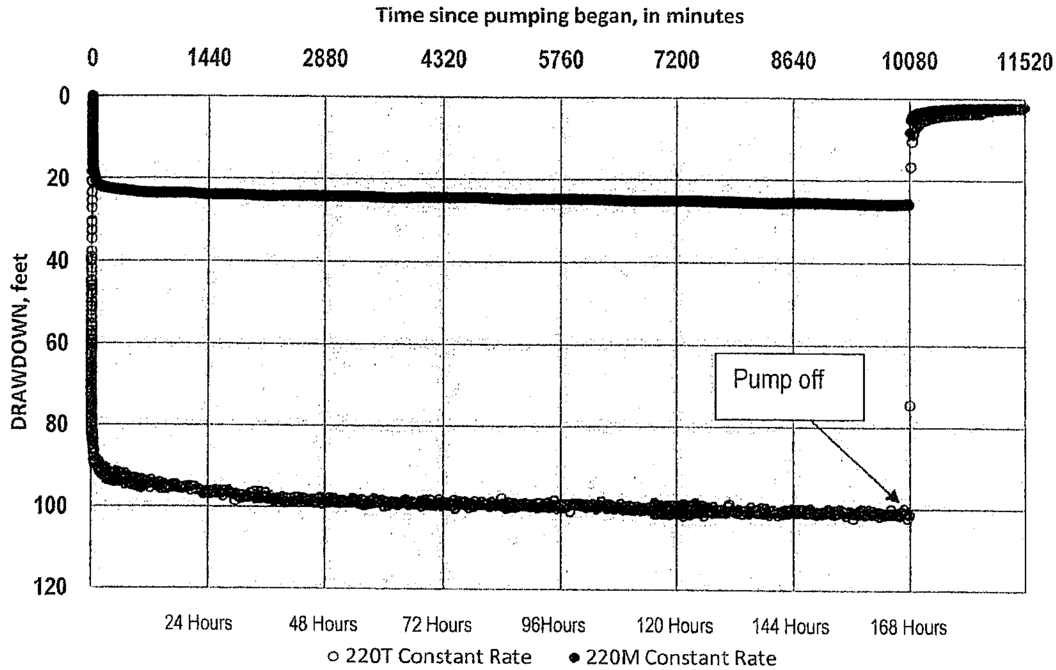


Figure 27: Drawdown data from 220T and 220M, Kobeh Valley Well Field Area. Well 220T was pumping at an average rate of 600 gpm

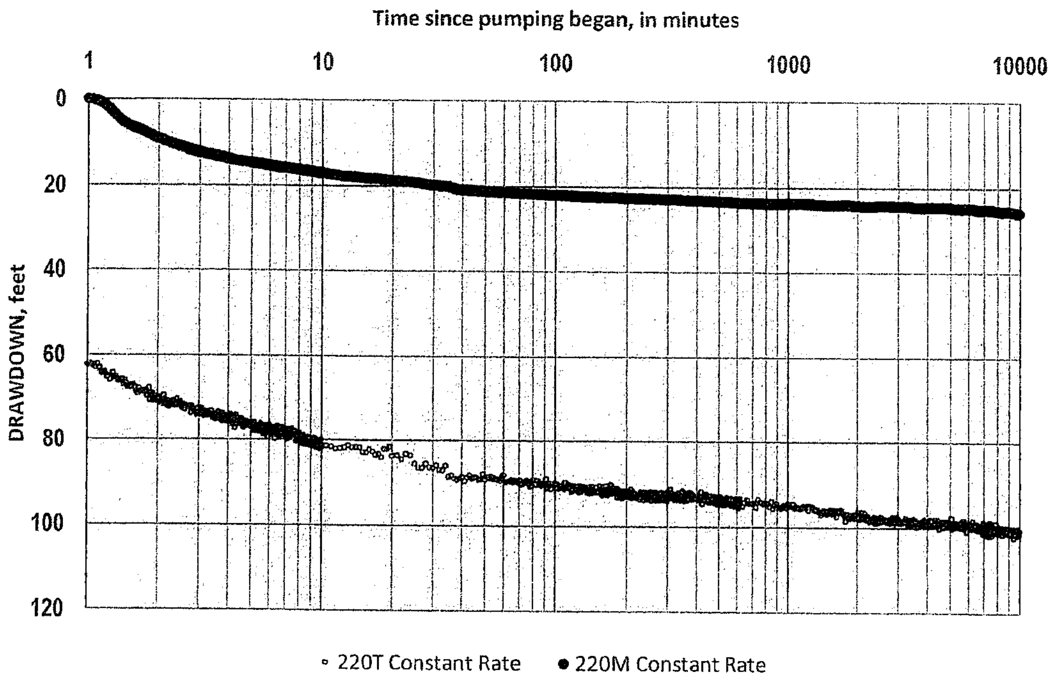


Figure 28: Semi-log plot of drawdown data from 220T and 220M. 220T was pumping at an average rate of 475 gpm.

6.8 Test Well 222T

A step drawdown test was performed on 222T prior to constant rate testing. Pumping rates and resultant drawdown are shown in **Table 7**, and ranged from an average 396 gpm to 626 gpm; total drawdown was less than 33 feet. Drawdown and recovery data from 222T and 222M are provided as **Figure 29**. From the step-testing data generated at the monitor well 222M, transmissivity was estimated at 12,920 ft^2/day (~96,640 gpd/ft) and a storage coefficient of 0.0009 was derived (**Appendix E**).

Table 7: Summary of drawdown, pumping rates, and durations, test well 222T.

Test Well	Pumping Rate (gpm)	Duration (minutes)	Drawdown (feet)	Specific Capacity	Specific Discharge
222T	396	120	20.08	19.7	0.05
222T	514	120	26.3	19.5	0.05
222T	626	121	32.83	19.1	0.05

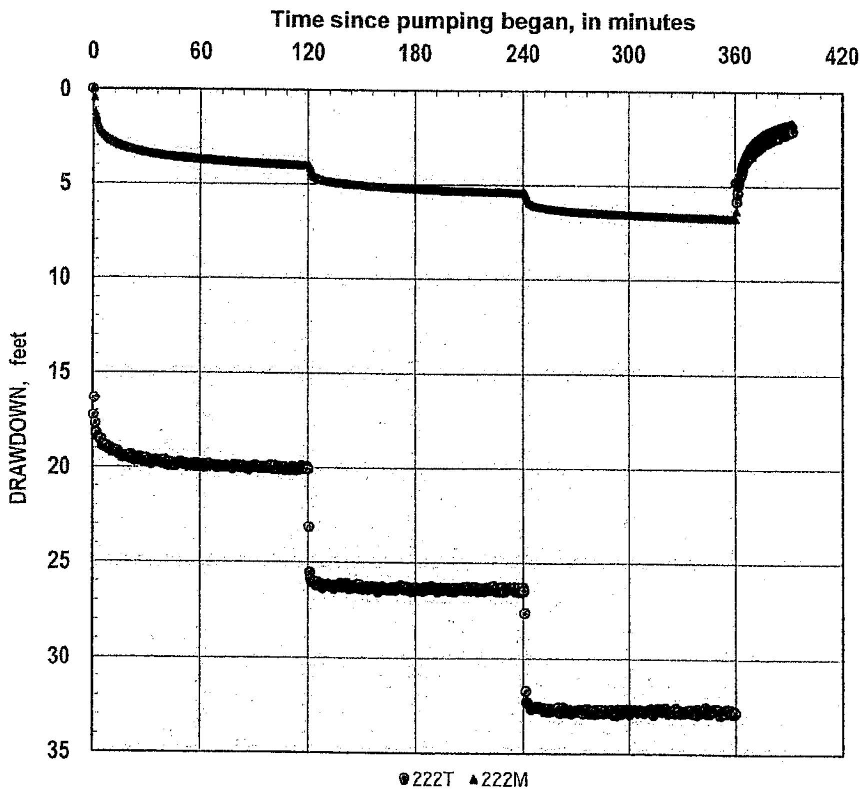


Figure 29: Step drawdown and recovery data from 222T and 222M, Kobeh Valley Well Field area

Well 222T was also tested at an average pumping rate of 600 gpm for approximately 7 days and incurred a maximum drawdown of about 33 feet (**Figures 30** and **31**). Observation well 222M, 223M, 228M, and 229M were monitored during the aquifer test. Observable drawdown was only noted in 222T, and 222M. Drawdown at 222M, located approximately 50 feet away was 8.2 feet. Transmissivity was estimated using the Thies (1935) method at the 222M, and resulted in a value of 12,890 ft^2/day (~96,400 gpd/ft) with a storage coefficient of 0.0011, values similar to that derived from the step-drawdown testing.

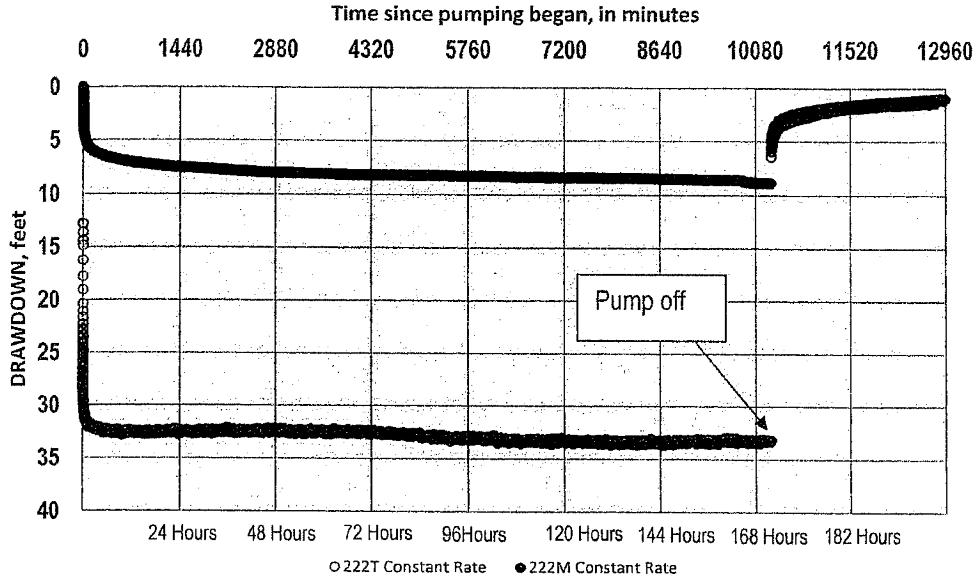


Figure 30: Drawdown and recovery data from 222T and 222M, Kobeh Valley Well Field Area. Well 222T was pumping at an average rate of 600 gpm

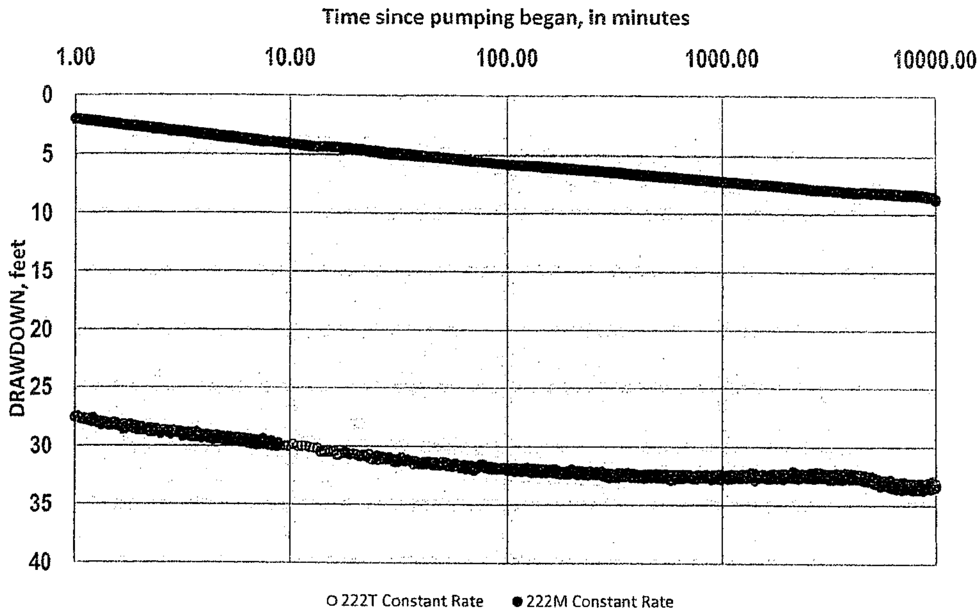


Figure 31: Drawdown data from 222T and 222M, Kobeh Valley Well Field Area. Well 222T was pumping at an average rate of 600 gpm

6.9 TEST WELL 223T

Testing at 223T, completed in mudstone and quartzite of the Vinini Formation, began at approximately 200 gpm and caused the well to immediately drawdown roughly 170 feet. The discharge was throttled back to 120 gpm, where the pumping water level and rate of decline stabilized slightly (**Figure 32**). Because of the excessive drawdown, field personnel terminated the pumping test after roughly two hours of total pumping time. Based on this limited pumping information, transmissivity was estimated to be between 90 and 59 ft^2/day using the Cooper-Jacob (1964) and Thies (1935) methods, respectively. Because of the short duration of the test, the computed transmissivity may not be completely indicative of aquifer conditions at this location. No determination of storage coefficient could be made from the test data. Hydraulic analysis for well 223T appears in **Appendix E.**

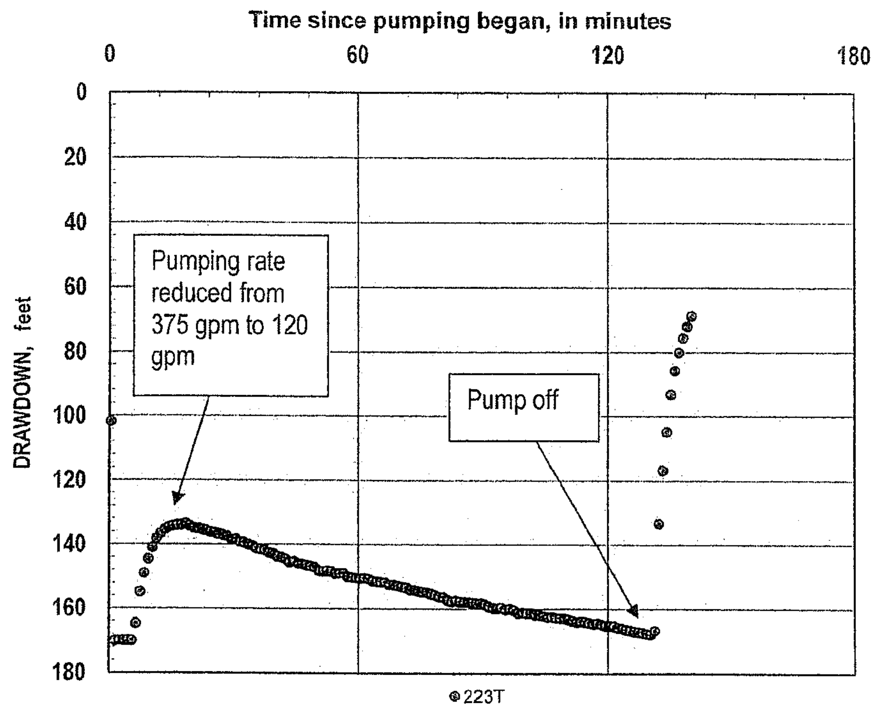


Figure 32: Plot of drawdown data from a short-duration pumping test at 223T.

6.10 TEST WELL 228T

Well 228T taps saturated alluvium and older basin-fill and was subjected to a step-drawdown test at rates ranging from 355 gpm to 488 gpm. The maximum drawdown observed during step testing was approximately 86 feet in 228T, at the highest pumping rate. Drawdown from the three pumping rates used in step testing is presented below as **Table 8**, and shown in **Figure 33**. Using the Theis (1935) method applied to variable rate tests, and using the drawdown data from 228M (located 50 feet from the pumping well), hydraulic properties were estimated for the basin-fill aquifer. Transmissivity at this location is approximately 2,400 -2,770 ft^2/day, and the storage coefficient is estimated to be approximately 0.003-0.005. Hydraulic analyses are presented in **Appendix E**.

Table 8: Summary of drawdown, pumping rates, and durations, test well 228T.

Test Well	Pumping Rate (gpm)	Duration (minutes)	Drawdown (feet)	Specific Capacity	Specific Discharge
228T	355	121	63.05	5.6	0.18
228T	448	121	79.35	5.6	0.18
228T	488	119	86.15	5.7	0.18

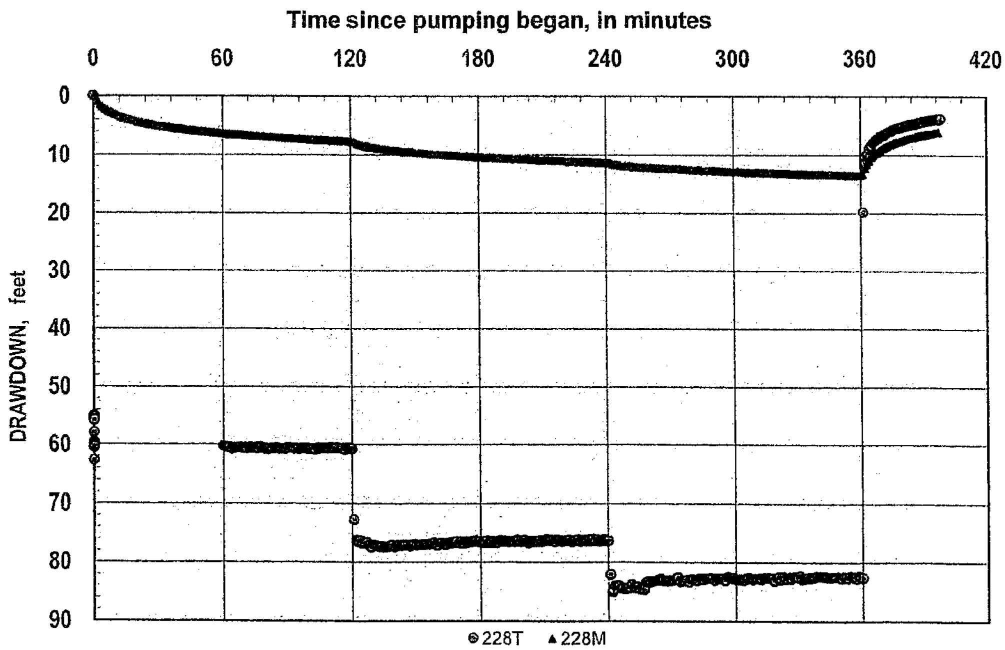


Figure 33: Step drawdown and recovery data from 222T and 222M, Kobeh Valley Well Field area

A constant rate test was performed at well 228T at an average rate of 451 gpm for 7 days (**Figures 34** and 35). Wells 228T and 228M, located 50 feet from the pumping well were monitored. Drawdown at the end of testing was approximately 75 feet for 228T, and about 18 feet at 228M.

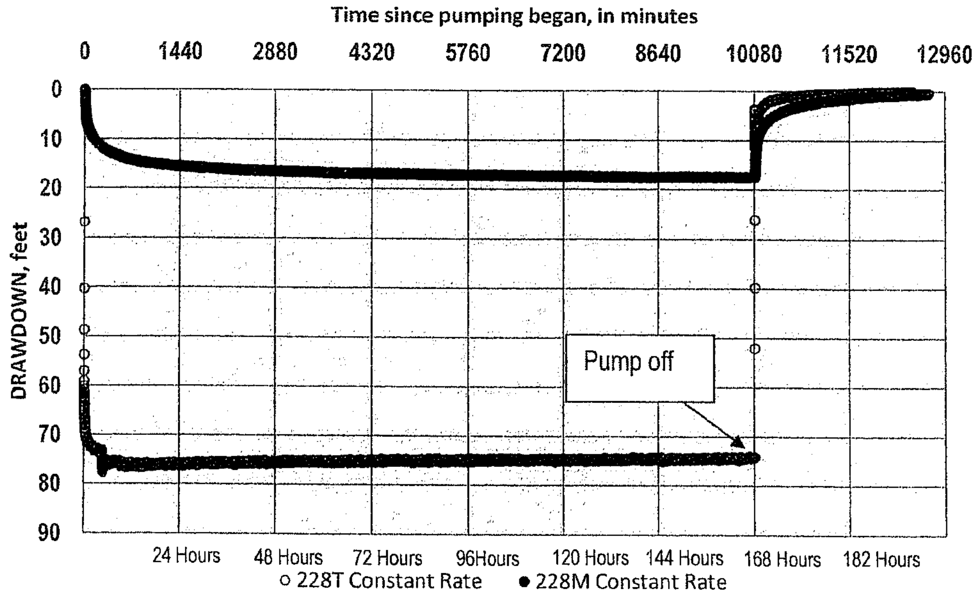


Figure 34: Drawdown data from 228T and 228M, Kobeh Valley Well Field Area. Well 228T was pumping at an average rate of 451 gpm

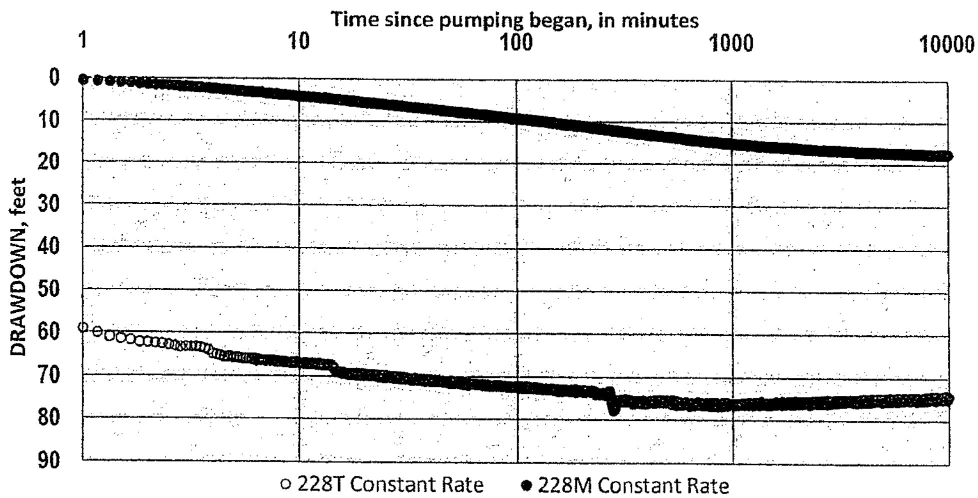


Figure 35: Semi-log plot of drawdown data from 228T and 228M, Kobeh Valley Well Field area. Well 228T was pumping at an average rate of 451 gpm

6.11 TEST WELL 229T

Because of the similarity between the cuttings, airlifting, and geophysical logs at 228T and 229T, no step-drawdown testing was performed at 229T. Instead, a 5-day constant discharge test was attempted at 490 gpm. The test ran without incident until at approximately 3-days when the pump tripped off (**Figures 36** and 37). The pump was serviced and restarted after a short recovery period of about 33 minutes. The test was run for another two days and recovery was monitored for two additional days after the cessation of pumping. Drawdown was recorded at two observation wells, 229M, located 35 feet from 229T and 228M, located 3,600 feet from 229T. Maximum drawdown at 229M was approximately 22 feet, 1.5 feet at 228M, and 77 feet in the pumping well. Estimated transmissivity based on the recovery data is approximately 3,000 ft^2/day using the Theis (1935) recovery method, and 2,500 to 3,000 ft^2/day using all drawdown and recovery data. The estimated storage coefficient of the aquifer, derived from the 229M and 228M data, is between 0.001 to 0.0001.

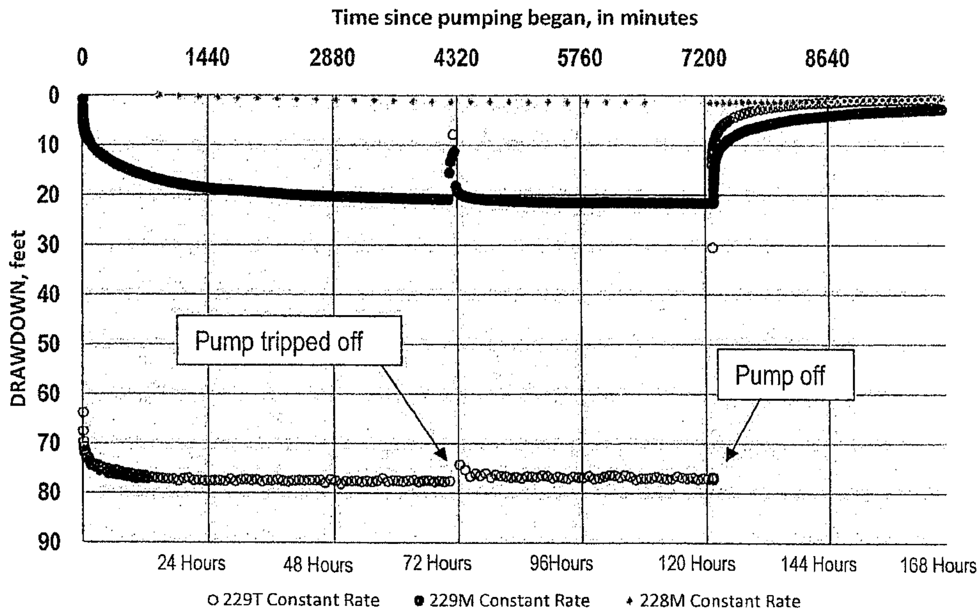


Figure 36: Plot of drawdown and recovery data from 229T and 229M, Kobeh Valley Well Field area. Well 229T was pumping at an average rate of 451 gpm

001825

JA1991

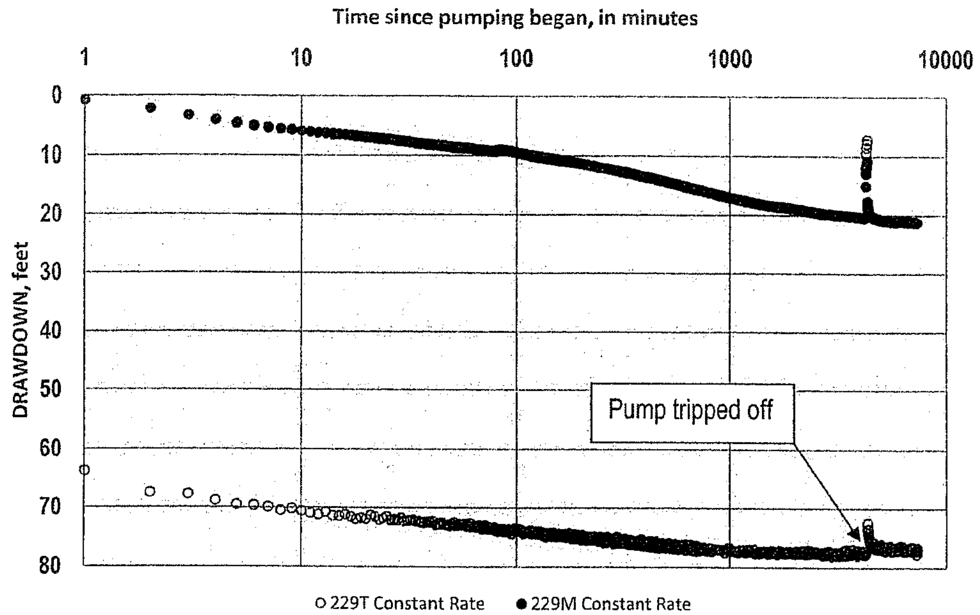


Figure 37: Semi-log plot of drawdown data from 228T and 228M, Kobeh Valley Well Field area. Well 228T was pumping at an average rate of 451 gpm

6.12 Test Well TM-B

TM-B was tested with a 60 hp pump placed at 672 fbls. Prior to well development, the static water level was 315.8 fbls. The following day, the water level had not fully recovered, and was at 353.5 fbls prior to attempting a step-test. In addition to monitoring the pumping well, nearby piezometer 235P, positioned approximately 65 feet away, was also monitored. The initial pumping rate for the step test was 100 gpm, and within a few minutes, the pumping water level had dropped to approximately 650 fbls. Because of the degree of drawdown, the pumping rate was reduced to 60 gpm after an elapsed time of 30 minutes. The 60 gpm rate was maintained for approximately 30 minutes, during which time the depth to water rose, leveled off, and then began to decline at a rate of about 0.1 feet per minute (**Figure 38**). Because of the poor well and aquifer performance, no further testing was completed on this well. Transmissivity was estimated from the recovery data from well TM-B using the Theis (1935) recovery method, and is approximately 69 ft^2/day. Utilizing data from observation well 235P, transmissivity was calculated to be approximately 109 ft^2/day, with a storage coefficient of 0.0027 using the Cooper-Jacob (1964) method.

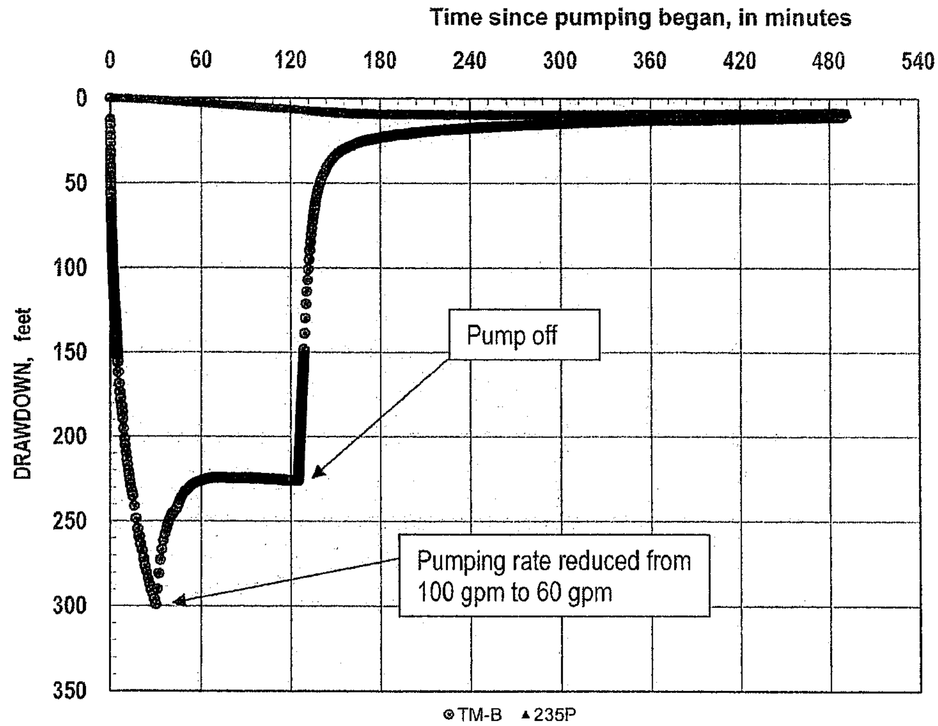


Figure 38: Step drawdown and recovery data from TM-B and monitor well 235P, east of Kobeh Valley Well Field area

6.13 Test Well TXF-2

A step test was performed on TXF-2 at rates of 150, 225, and 300 gpm, with specific capacity varying between 1.2 and 1.8 gpm/ft. Drawdown and recovery data for TXF-2 for each cycle of the step test are shown in **Table 9** and in **Figure 39**.

Table 9: Summary of drawdown, pumping rates, and durations, test well TXF-2.

Test Well	Pumping Rate (gpm)	Duration (minutes)	Drawdown (feet)	Specific Capacity	Specific Discharge
TXF-2	150	120	82.4	1.8	0.5
TXF-2	225	120	149.5	1.5	0.7
TXF-2	300	120	244	1.2	0.8

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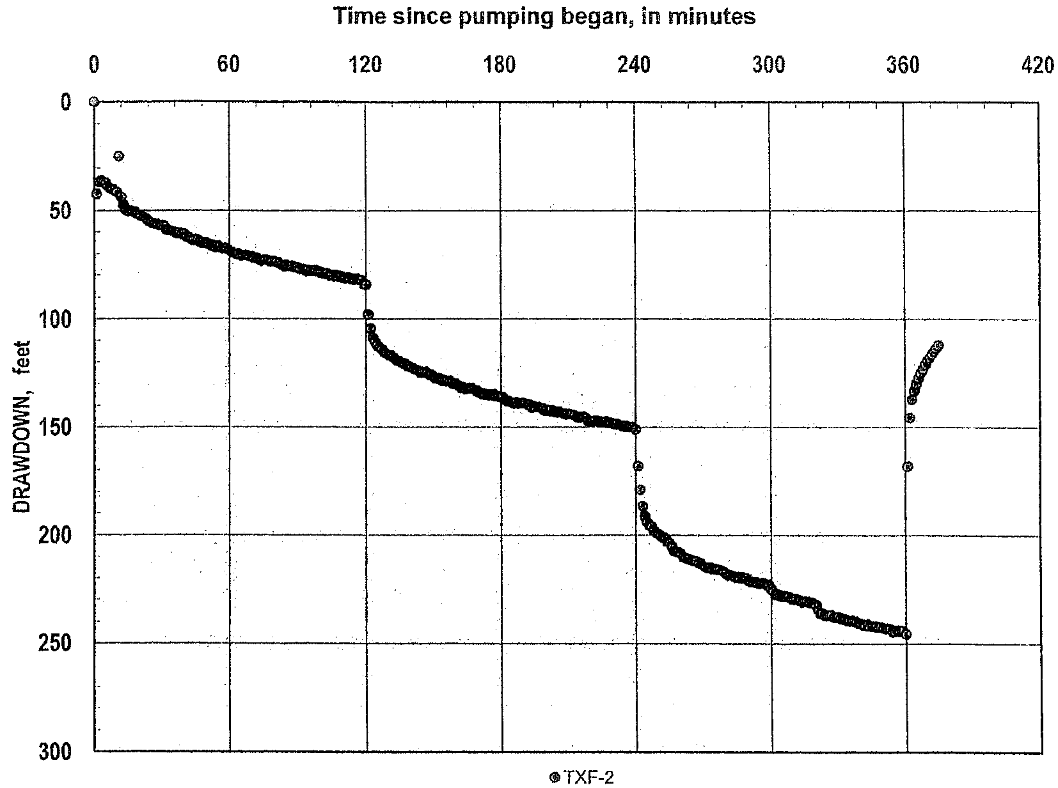


Figure 39: Step drawdown and recovery data from TXF-2, east of Kobeh Valley Well Field area

A constant rate test was performed on TXF-2 at an average pumping rate of 150 gpm. A small change in discharge rate occurred about a day into testing where the flow rate was adjusted from an average of 145 gpm to approximately 154 gpm (see **Figure 40** and **41**). After approximately 2 days, the generator providing power to the pump began to periodically fail and/or have large voltage swings. In addition, the backflow valve that assists in regulating flow began to freeze at night, causing problems with flow regulation. Because of the erratic performance of the generator, and the uncertainty in the actual pumping rate, the data generated from the transducer after 2 days of pumping is of questionable value. Before the generator failure, the average calculated pumping rate was 147 gpm, and the greatest amount of drawdown was approximately 218 feet. Utilizing a Cooper-Jacob (1964) approximation yielded a transmissivity value of approximately 50-60 ft^2/day. No determination of storage coefficient could be made from the well test.

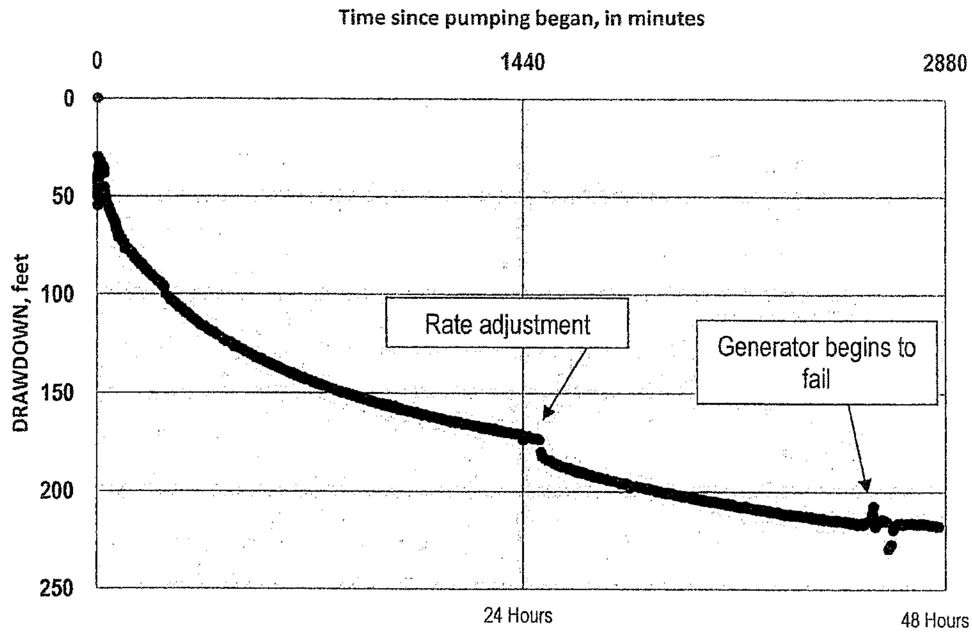


Figure 40: Drawdown recorded from pumping TXF-2 pumping at an average of 147 gpm, east of Kobeh Valley Well Field area. Data generated after 2880 minutes is not presented.

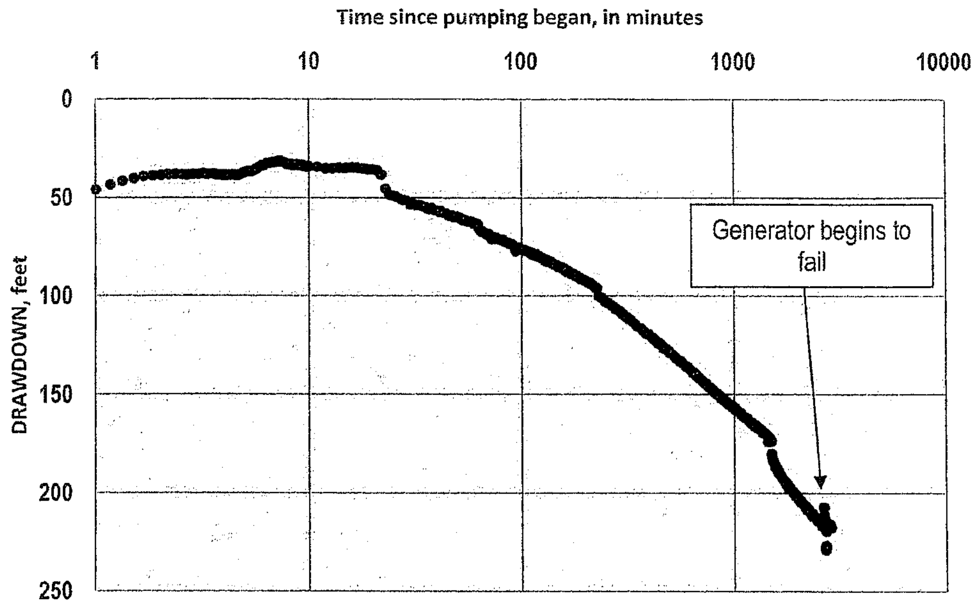


Figure 41: Semi-log plot of drawdown recorded from pumping TXF-2 pumping at an average of 147 gpm, east of Kobeh Valley Well Field area. During the test, the flow rate was varied slightly on several occasions. Data generated after 2880 minutes is not presented.

6.14 SUMMARY OF CONSTANT RATE AQUIFER TESTING

EMLLC has conducted a total of thirteen (13) constant rate tests in Kobeh Valley. The tests ranged in duration from 2 hours to 32 days. Most wells completed in basin-fill materials were tested for at least 5 days, while wells completed in carbonate rocks were generally tested a minimum of 7 days. A summary of well testing is provided below as **Table 10**.

Table 10: Summary of constant rate well and aquifer testing, Kobeh Valley Well Field area.

Pumped Well	Dates of Constant Rate Testing	Duration	Step-Test Performed ?	Well Diameter (inches/feet)	Pumping Rate (gpm)	Pumping Well Maximum Drawdown (feet)	Static Water Level (fbls)	Pumping Water Level (fbls)	Specific Capacity (gpm/ft)
206T	4/10/2008 - 5/12/2008	32 days	yes	8/0.67	1,350-1,450	30	103	133	48.3
214T	9/18/2008 - 9/29/2008	11 days	no	8/0.67	445	95	240	335	4.7
228T	10/16/2008 - 10/23/2008	5 days	yes	8/0.67	451	76	276	352	5.9
229T	9/20/2008 - 9/25/2008	5 days	no	8/0.67	490	77	202	279	6.4
220T	9/30/2008 - 10/7/2008	7 days	yes	8/0.67	475	101	164	265	4.7
222T	10/5/2008 - 10/12/2008	7 days	yes	8/0.67	600	33	77	110	18.2
223T	10/14/2008	2.5 hours	no	8/0.67	120	168	175	343	0.7
TM-B	12/3/2008	8.2 hours	yes	8/0.67	100-60	300	354	654	0.3
TM-1	3/9/2006	8 hours	yes	12/1.0	8	40	208	248	0.2
TXF-2	12/13/2008 - 12/15/2008	1 day	yes	8/0.67	147	218	247	420	0.7
EW-1	10/25/2006	1 day	yes	12/1.0	490	82	135	217	6.0
9211R	8/8/2006	1.1 days	no	16/1.33	600	19.4	2.48	22	30.9
KV11	6/26/2006	2 hours	yes	14/1.17	412	58	90	148	7.1

6.15 SUMMARY OF DERIVED HYDRAULIC PROPERTIES

Hydraulic properties derived from the aquifer testing were estimated from either the step-drawdown testing or from the constant rate tests (or both), and are summarized in **Table 11**. Hydraulic conductivity is provided in **Table 11** and was derived by dividing the estimated transmissivity by the gravel packed interval of the well (aquifer thickness), where that interval was below the pumping and static water table.

Table 11: Summary of aquifer properties estimated from well and aquifer testing, Kobeh Valley Well Field area.

Pumped Well	Analysis or Application Method	Transmissivity, ft²/day	Storage Coefficient (unitless)	Observation Wells Used in Analysis?	Aquifer Matrix	Notes	Aquifer Thickness (ft)	Hydraulic Conductivity (ft/day)
206T	Cooper-Jacob (1964) Distance- drawdown, early time data (100-1,000 minutes)	170,000	–	yes	Fractured Carbonate Rocks	Significant boundaries, high transmissivity zone is likely not extensive, T value not representative of most of the aquifer	670	254
206T	Cooper-Jacob (1964) Distance- drawdown, early time data (1,000-10,000 minutes)	26,500	–	yes	Fractured Carbonate Rocks	Transmissivity value probably not representative of most of the aquifer	670	10
206T	Cooper-Jacob (1964), late time data (10,000-20,000 minutes)- 205MD observation well	6,300	–	yes	Fractured Carbonate Rocks	Long-term behavior (30+ days) of carbonate aquifer from 32-day test	670	9
214T	Cooper-Jacob (1946), Distance- drawdown using all observation wells	5,230	0.0012	yes	Fractured Carbonate Rocks	Negative boundary noted near 213M	410	13
	Cooper-Jacob (1946), Distance- drawdown using 215M, 205MD, 206MS	7,400	0.0017	yes			410	18
	Theis (1935), 215M, 206MS, 205MD, Drawdown and recovery	7,020	0.002	yes			410	17
	Theis (1935), Drawdown and Recovery at 215M	6,620	0.002	yes			410	16
	Theis (1935), Recovery at 214M and 215M	5,140	–	yes			410	13

Table 11: Summary of aquifer properties estimated from well and aquifer testing, Kobeh Valley Well Field area.

Pumped Well	Analysis or Application Method	Transmissivity, ft^2/day	Storage Coefficient (unitless)	Observation Wells Used in Analysis?	Aquifer Matrix	Notes	Aquifer Thickness (ft)	Hydraulic Conductivity (ft/day)
	Theis (1935), Recovery at 213M	3,460	-	yes		Not considered representative because of boundary condition	410	8
228T	Theis (1935), Variable Rate	2,770	0.003	yes	Alluvium	some leakage indicated after 1000 minutes	550	5
	Hantush-Jacob (1955)	2,600	0.003	yes		1/B= 0.0007	550	5
	Hantush-Jacob (1935), All Drawdown and Recovery data at 228M	2,400	0.005	yes		1/B= 0.001	550	5
229T	Theis (1935), Recovery Method from 229M	2,990	-	yes	Alluvium (Vinini or Webb Formation at Depth)	-	550	5
	Theis (1935), All Drawdown and Recovery data at 229M	3,300	0.001	yes		Fair match to type curve	550	7
	Neuman (1974), All Drawdown and Recovery data at 229M	2,500	0.009	yes		Fair match to type curve, Sy=0.11	550	4.5
220T	Cooper-Jacob (1946), Drawdown at 220M	3,700	0.0001	yes	Fractured Carbonate Rocks	-	390	9
222T	Theis (1967), Variable Rate and Recovery, 220M data	12,920	0.0009	yes	Alluvium	Derived from step-test analysis	690	19
	Theis (1935), Recovery at 220M	12,900	0.0011	yes		-	690	19
223T	Cooper-Jacob (1946), Drawdown	73	-	no	Vinini Fm.	Test terminated early b/c of poor performance	650	0.11
	Theis (1935), Recovery	52	-	no	Vinini Fm.		650	0.09

Table 11: Summary of aquifer properties estimated from well and aquifer testing, Kobeh Valley Well Field area.

Pumped Well	Analysis or Application Method	Transmissivity, ft²/day	Storage Coefficient (unitless)	Observation Wells Used in Analysis?	Aquifer Matrix	Notes	Aquifer Thickness (ft)	Hydraulic Conductivity (ft/day)
TXF-2	Cooper-Jacob (1946), Drawdown	57	–	no	Vinini Fm.	–	360	0.16
	Theis (1935), Recovery	25	–	no			360	0.07
TM-B	Cooper-Jacob (1946), Drawdown	69	–	no	Vinini Fm.	Test terminated early b/c of poor performance	375	0.18
	Theis (1935), drawdown at 235P	109	0.0027	yes	Vinini Fm.		375	0.29
KV-11	Cooper-Jacob (1946), Drawdown	11,400	–	no	Alluvium	–	620	18
	Theis (1935), Recovery	14,700	–	no	Alluvium		620	24
9211R	Neuman (1974)	30,200	0.003	no	Alluvium	–	530	57
EW-1	Cooper-Jacob (1946), Drawdown	3,200	–	no	Alluvium	–	324	10
EW-1	Theis (1935), Recovery	2,670	–		Alluvium	–	324	8
EW-1	Neuman (1974)	1,840	0.0003	yes	Alluvium	–	324	6

6.16 Falling-Head Permeability Tests

Several falling head permeability tests were conducted on wells and piezometers in the Kobeh Valley Well Field area. Prior to testing, each well was instrumented with a recording transducer. Water was then introduced into the well casing from a water truck. The data from the transducers were downloaded and analyzed using AQTESOLV (HydroSolve, 2008).

Uncertainty exists with the results of the falling head tests, and aquifer parameters generated from these test should be used with caution. The introduction of water down the well casing can violate many assumptions that form the basis for the analytical procedures used to determine hydraulic conductivity. Poor well development or construction, biofilms adjacent to well perforations, prolonged/non-instantaneous introduction of water down the casing, and large pre-test depths-to-water all may potentially contribute to poor data and analysis of falling head tests.

The results of the falling head analyses are summarized in **Table 12**, and the individual analyses are presented in Appendix E. The monitoring wells completed in the basalt and valley-fill sediments at RWX-203 and RWX-204 exhibited hydraulic conductivity values of approximately 0.1 ft/day to 0.7 ft/day. These low values indicate that the lacustrine sediments and basalt are not potential targets for groundwater development. Similarly, the monitoring wells in the Vinini Formation at RWX-209 exhibited hydraulic conductivity values on the order of 0.2 ft/day.

Table 12: Hydraulic conductivity estimates from falling head permeability tests, Kobeh Valley Well Field area

Well Name	Type of Analysis	K (ft/day)	Lithology Tested
RWX-209MS	KGS Model[1]	0.2	Lacustrine sediments
RWX-209MD	KGS Model[1]	0.2	Vinini Fm.
RWX-203MS	KGS Model[1]	0.1	Lacustrine sediments
RWX-203T	KGS Model[1]	0.5	Lacustrine Sediments/Basalt
RWX-204P	Cooper et al[2]	0.7	Basalt

1: Hyder et al., 1994, 2: Bower, 1989, K: hydraulic conductivity

6.17 GROUNDWATER CHEMISTRY

Water quality samples were collected from test wells during drilling, and also during step and constant rate testing, and are presented as **Table 13**. Where samples were collected during drilling, they are shown with the approximate depth at which the drill bit was located when the sample was collected. Water chemistry samples taken at the end of a constant rate pumping test are delineated by "PRO 2" to indicate a complete Nevada Profile II quality analysis was obtained. Full water quality analyses and quality assurance reports are available in **Appendix F**.

Water quality sampling was conducted primarily to assess the feasibility of using this water for metallurgical and mine process purposes, however the results are presented here to document background conditions.

Table 13: Summary of common ions from groundwater samples obtained during drilling and aquifer testing, Kobeh Valley Well Field area

Well Name	CONCENTRATION IN mg/L								
	CATIONS				ANIONS				
	Na	K	Ca	Mg	Cl	HCO3	CO3	SO4	TDS
IGMI-154	31	2	98	53	19	400	0	190	793
TM-1	119	5	51.6	21.6	15	234	0	161	586
TM-B 340'	42	20	110	69	18	760	<1	210	540
TM-B 980'	110	11	91	54	8.5	410	19	97	460
206T	17	1.5	52	21	10	320	0	35	457
RWX203	100	18	68	12	8.5	110	0	330	647
KCT #1	37	6.5	68	24	34	126	0	260	496
KV11	27	3.4	49	15	19	200	0	69	382
EW-1	19	3.5	42	6.9	17	160	0	34	282
KFE	120	3.2	26	11	14	210	0	230	614
KFW	99	1.9	200	76	88	220	0	800	1485
LRCMW 245'	42	2	77	26	29	290	4.8	140	470
LRCMW 478'	32	1.4	63	24	20	280	<1	110	310
MRCMW 300'	28	4.5	200	27	23	310	<1	410	840
MRCMW	29	4.3	220	28	26	320	<1	450	830
213M 580'	32	2.1	56	24	25	300	<1	61	350
213M 505'	36	2	51	21	24	640	<1	72	350
213M 1000'	28	1.7	55	22	23	270	2.4	70	360
214T 700'	19	2.2	54	19	13	880	<1	38	310
214T 605'	26	2.1	53	20	13	960	<1	33	330
214T PRO 2	20	2.1	62	24	9.8	290	<1	32	280
215M 465'	29	1.9	49	22	19	1000	<1	51	370

Well Name	CONCENTRATION IN mg/L								
	CATIONS				ANIONS				
	Na	K	Ca	Mg	Cl	HCO3	CO3	SO4	TDS
215M 1000'	24	1.9	52	22	16	280	<1	46	330
219 870'	69	5.4	40	32	20	190	<1	220	450
220 645'	70	1.9	51	26	15	210	<1	190	440
220 998'	9	1.5	67	23	6.2	350	<1	29	260
220T 998'	9.4	1.2	55	23	5.8	290	<1	28	260
220T PRO 2	9.5	2.3	82	33	6	280	<1	26	300
220T RSI	9.9	1.2	56	22	5.6	270	<1	25	260
222 160'	19	1.8	56	17	8.9	240	9.6	23	260
222 755'	27	2.6	28	13	6.8	210	<1	24	260
222T PRO 2	13	1.7	50	16	5.9	220	<1	18	240
223 340'	62	5.6	22	9.5	11	270	<1	49	410
223 1000'	69	4.2	22	7.3	16	300	4.8	53	460
223T 385'	88	5.5	25	7.8	7.5	710	<1	42	390
228 750'	18	2.9	30	11	7.5	150	9.6	23	190
228 PRO 2	30	1.6	36	14	7.9	1000	<1	36	140
228T 320'	22	14	100	18	14	21	<1	220	610
228T 320'	26	2	49	17	9.3	900	<1	30	250
228T 900'	18	3.5	51	19	7.6	190	2.4	23	220
228T PRO 2	13	2.4	41	16	6.1	210	<1	20	240
229 380'	18	1.7	42	20	13	130	<1	30	280
229 840'	31	2.6	36	15	13	210	2.4	30	290
229T 840'	31	2.6	36	15	13	210	2.4	30	290
229T 900'	21	2	45	18	9.2	270	<1	40	260
229T PRO 2	14	1.6	49	20	8.8	270	<1	25	260
235P 450	58	2.6	19	29	16	300	2.4	58	340
235P PRO II	67	2.2	26	28	10	280	2.4	120	390
TXF-2	16	3.7	150	54	24	240	<1	480	830

7.0 Geology and Hydrogeology of the Kobeh Valley Well Field

An overview of the regional geology was provided in **Section 3**. The purpose of this section is to detail the geologic setting of the well field and southern Roberts Mountains, and to assimilate the results of the pumping tests, geophysical surveys, information from and geologic mapping to assist with an understanding of the hydrogeologic conditions.

7.1 Geology, Structure, and Hydrogeologic Conditions

A large portion of the well field and the mountain block to the north are underlain by two contrasting sedimentary assemblages separated by a major thrust fault, the Roberts Mountain Thrust. These two tectono-stratigraphic units are the lower-plate Paleozoic carbonate units (and underlying siliciclastics of the lower eastern assemblage), and upper-plate siliciclastic rocks of the Roberts Mountain Allochthon (RMA). The RMA includes off-shore and near shore facies such as the Silurian Elder Sandstone, the Cambrian-Ordovician Vinini Formation, unnamed Devonian limestones, and the Mississippian Webb Formation (Finney, 1993). Upper plate rocks of the RMA often display the results of a high degree of tectonic strain and are commonly stacked in imbricate, duplex faults, folds, and structural nappes (Finney, 1993). Although highly disturbed, these formations have proven to be poor water-producing units (See results of testing 223T, TM-B, and **Table 11**). The exposed carbonate package consists mostly of upper and middle Devonian limestones and dolomites with subordinate units of mudstone. In general, the upper Devonian strata of the lower plate are considered the most porous and permeable of the Devonian units, with the middle to lower Devonian carbonates being largely dolomitized below a regional unconformity (Murphy et al. 1978).

The subsurface structure of the well field is inferred and interpreted from drilling results and mapped geology from the adjacent Roberts Mountains and the Atlas Gold Bar Mine, as well as geophysics. Lower plate Devonian carbonate rocks form the highest altitude areas in the Roberts Mountains, in particular a prominent north-south trending ridgeline that includes Roberts Creek Mountain. The area to the west of Roberts Creek (in the mountain range) is generally at lower elevations produced by progressive westward down-stepping across major north-northeast and north-northwest-trending normal faults (Finney, 1993). Accelerated weathering of the relatively weak rocks of the RMA that overlie the lower-plate carbonates has resulted in suppressed topography in the western portion of the Roberts Mountains and exposed the upper plate carbonates in windows, often in compartmentalized structural blocks. In some of these blocks, the Devils Gate Limestone, the youngest and highest carbonate formation in the lower plate, is exposed at the surface with only a thin cover of upper-plate rocks preserved. These fault-bounded blocks stand in contrast to, and at higher elevation than, other blocks where the lower plate rocks are at much greater depth and overlain by several thousand feet of upper-plate siliciclastic rocks.

Subsurface geology of northern Kobeh Valley is dominated by three major north-northwest trending horst and graben complexes. The western-most horst was targeted by Atlas (**Figure 42**) in the 1980s and 1990s for gold mineralization. The shallow nature of the carbonates at this location can be observed today from the open pit at the Gold Bar Mine site, and is referred to as the Gold Bar Horst in mining and economic geology literature (Yigit, 2003). South and southeast of Rutabega Creek, Paleozoic carbonate rocks outcrop along a weathered north-south oriented ridge that plunges southward under alluvial fans. This ridge forms the central horst block in northern Kobeh Valley. Exposures of carbonate rocks in this location are locally silicified, faulted, and display some jasperoid alteration. Well 220T was drilled along the southwest exposure of the carbonates and targeted fractured rock associated with the West Roberts Mountain Range-Front Fault, a major Quaternary northwest-southeast trending range front feature (USGS, 2008). Although the fault was not encountered, the well was important for defining the subsurface geology. The exposures of carbonate rocks at this location, initially indicated that additional carbonates may be present at depth, however, below 65 fbls, lithology encountered by the borehole was almost exclusively black mudstone of the Vinini Formation. The carbonates at the surface are probably a klippen of carbonates incorporated into the thrust package, or a tectonic slide block from low angle-extensional faulting described in other areas of the Roberts Mountains by Winterer (1968). An interpreted low-angle fault was encountered at 960 fbls where grey limestone consistent with Eastern Assemblage carbonates was encountered. The fault structure may be associated with the Roberts Mountain Thrust.

The eastern portion of the well field contains the third prominent horst block of lower plate carbonates that dip at intermediate angles (~30-50 degrees) to the east. The horst block is structurally overlain by the RMA to the east, which is in turn is overlain unconformably by Tertiary sediments and basalt. Wells 205MS/MD, 206T, 213T, 214T, 215T were designed to target major fault or fracture systems in the carbonate rocks in this area, and were placed in a northwest-southeast fashion based on geophysical surveys and/or lineament analyses. Test well 223T, located far to the south of the carbonate outcrops targeted alluvium, but penetrated rocks of the RMA at depth (which certainly overlie lower plate carbonates, but at an unknown depth), demonstrating the southern extension of the eastern horst block. Normal faulting patterns in the bedrock associated with the Kobeh Valley Well Field area are interpreted from the closest exposed and most well described outcrops from the scientific literature; those outcrops just north of the well field at the Gold Canyon mine. The faulting pattern described is probably only applicable to the southern and western portions of the Roberts Mountains, as other areas are not as well described in the literature (Yigit et al, 2003). Three sets of normal faults are recognized in the area, from oldest to youngest: east-northeast striking, northwest-to-west striking, and north-striking (Yigit et al., 2003). The east-northeast striking faults do not generally cut Tertiary volcanic rocks or Quaternary alluvium, while the younger two normal fault orientations displace Quaternary gravels and alluvium.

The hydrogeologic significance of the normal fault sets is not precisely known, however because the east-northeast faults predate many Tertiary volcanics, they may have acted

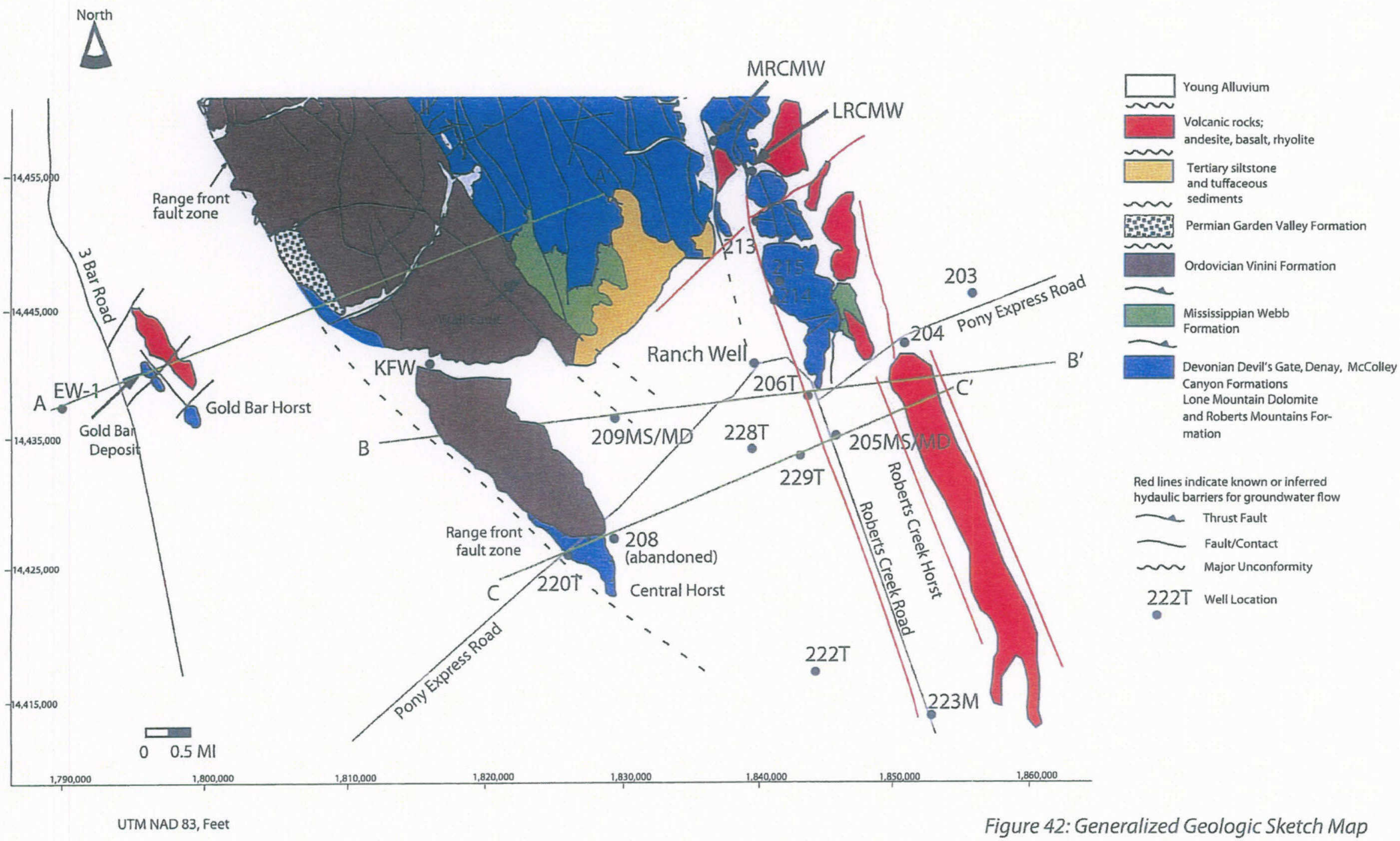


Figure 42: Generalized Geologic Sketch Map of the Central Kobeh Valley Well Field

Figure 43: Simplified geologic cross-sections through portions of the Kobeh Valley Well Field area

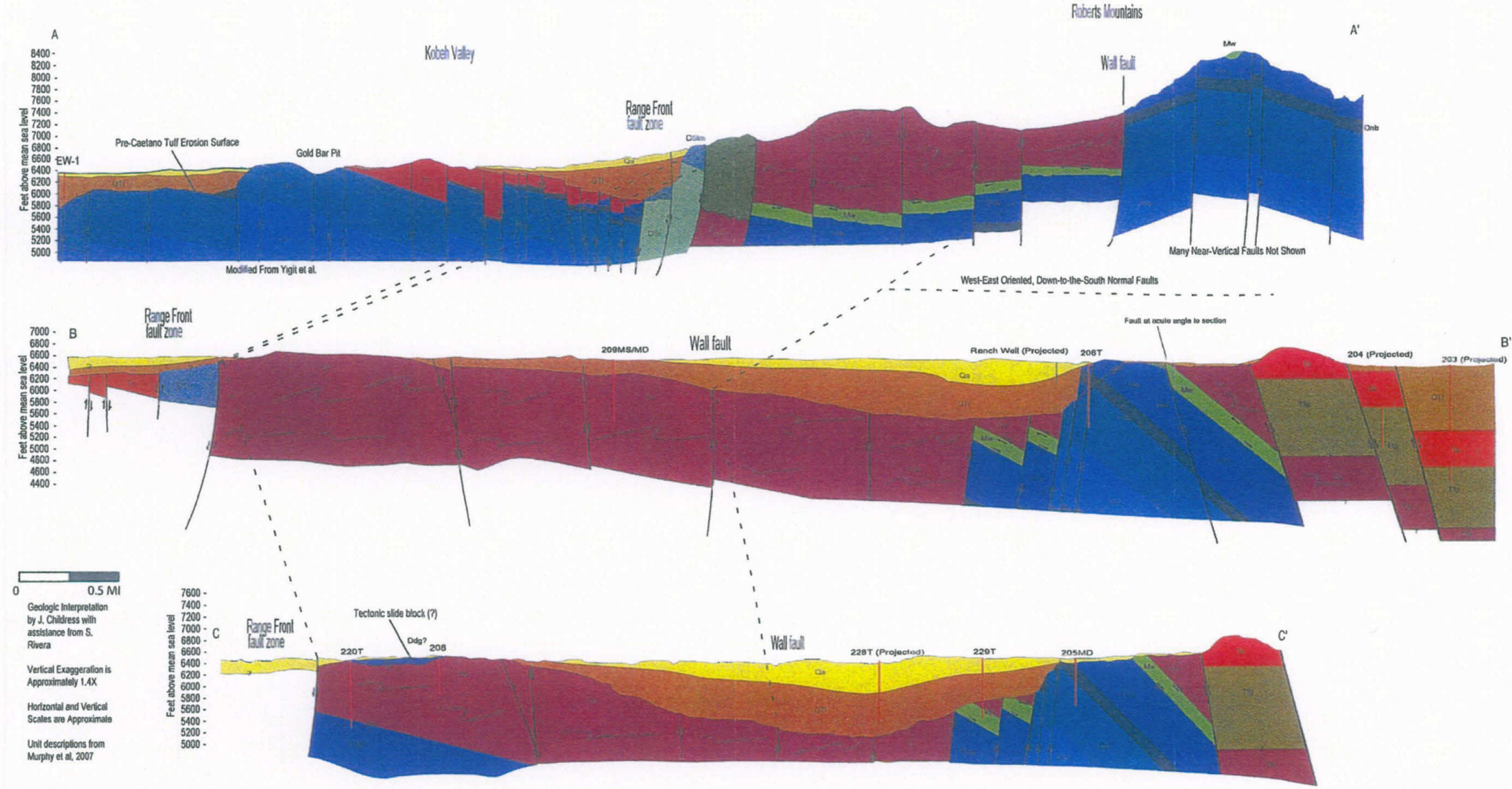


Figure 43: Simplified Geologic Cross-Sections, Kobeh Valley Central Well Field

Legend to Geologic Units

Qa Younger alluvium (Quaternary) Mostly sands and gravels.

QTl Older alluvium and lake sediments (Quaternary and Tertiary). Contains some indurated gravels and tuffaceous sediments.

Basalt (Miocene) Massive lava flows and dikes

Unnamed fanglomerate and siltstone, (Oligocene?), Massive unit of partially indurated fanglomerales, siltstones, and tuffaceous sediments

Caetano Tuff (Eocene) Rhyolite airfall and ashflow tuffs, tan to grey. Eruptive center located in Cortez Hills area.

Garden Valley Formation (Permian) Basal part of this formation consists of a limestone unit that contains medium-bedded, gray packstones. Limestones are interbedded with sandstone and shales Above limestone unit, formation consists of red-brown siliceous pebble and cobble conglomerate, coarse grits, sandstone, and some bedded chert. Where unfaulted, basal contact of Garden Valley Formation overlies the Ordovician Vinini Formation with an angular discordance of about 20°.

Upper Plate of the Roberts Mountain Thrust.

Vinini Formation, undifferentiated (Ordovician) Thin-bedded pastel chert, black organic shale that weathers light gray; locally contains limestone and basalt/greenstone stringers. Some Devonian to Cambrian cherts and limestones are structurally interleaved via imbricate thrusts.

Mw Webb Formation (Mississippian) Thin-bedded, fine-grained siliceous mudstone and shale. Interbedded ribbon chert beds and chert-quartz grits.

Lower Plate of the Roberts Mountain Thrust.

Devils Gate Limestone (Devonian) Massive- to medium-bedded gray limestone–mostly algal and stromatoporoid wackestone and boundstone and Amphipora packstone..

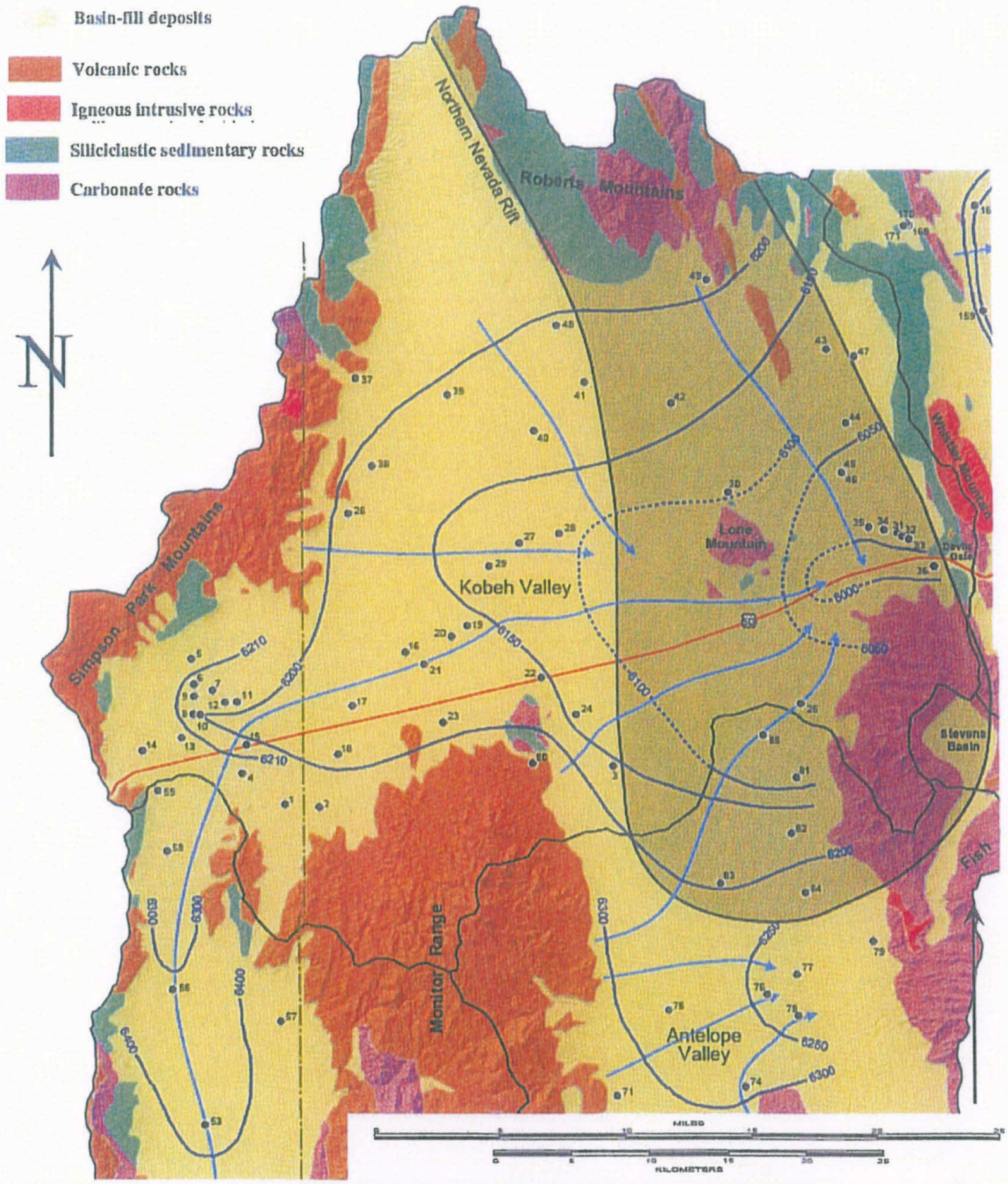
Ddu Denay Limestone, upper part (Devonian) Lower part thin-bedded laminated siliceous dark lime mudstone. Upper part medium-bedded gray lime mudstone, wackestone, and packstone. Stippled where silicified.

Denay Limestone, lower part (Devonian) Thin- to medium-bedded light- to dark-gray lime mudstone and intercalated light-gray calcarenities. Calcarenities mostly bioclastic and are graded.

McColley Canyon Formation (Devonian) Lower part is well-bedded, fine-grained silty dolomitic limestone that is cherty in places and moderately fossiliferous. Higher in the formation are alternating thinto medium-bedded, gray fine-grained limestone, and pale-orange argillaceous limestone. Contains abundant fossils. The upper part is thick-bedded, gray fine-grained crinoidal limestone, with a fauna of horn corals, dacryoconarids, and pelmatozoans.

Lone Mountain Dolomite (Devonian and Silurian)Dense light-colored dolomite. Includes fenestralgrainstones, peloidal and bioclastic grainstones, and some finegrainedlaminated dolomites. The bioclastic dolomite interfingers with limestone units of the Roberts Mountains Formation.

DSr Roberts Mountains Formation (Devonian and Silurian) The lowest part of the formation contains thin-bedded dolomite and dark chert overlain by laminated limestone with chert nodules. Thin to medium beds of graded bioclastic limestones are interstratified with the platy splitting, tan-weathering laminated limestone higher in the formation. Thick beds of bioclastic limestone grade laterally and vertically into bioclastic dolomite of the Lone Mountain Dolomite.



Water-level contour—Shows altitude of shallow ground-water surface. Dashed where uncertain. Contour interval, in feet, is variable. Datum is sea level

Hydrographic-area boundary

Direction of ground-water flow inferred from water-level contours

60● Well—Measured in 2005 by U.S. Geological Survey, Nevada Division of Water Resources, Eureka County, or Barrick Gold Corp. Provide control for constructing water-level contours. Number refers to appendix 2

Figure 44. General potentiometric map of Kobeh Valley. Shaded area is the approximate location of the Northern Nevada Rift. Source: Cropped and modified from Tumbusch and Plume (2006).

7.2 Groundwater Occurrence and Flow

Groundwater occurs at depth throughout Kobeh Valley, ranging in depth from at or near the land surface in the lowland areas to 200 ft or greater in the upland areas. A generalized potentiometric map of the basin-fill aquifer in Kobeh Valley is shown in **Figure 44** taken from Tumbusch and Plume (2006). In the valley floor area, the elevation of the water table ranges from about 6,400 ft near the mountain fronts to about 6,000 ft in the Devils Gate area.

Since Tumbusch and Plume's 2005 potentiometric map, many additional wells have been installed in Kobeh Valley by EMLLC. Depths to water have been periodically measured in the well field area in a variety of seasons to capture natural variation or trends. A list of miscellaneous field measurements of depths-to-water is presented in **Table 14**. Where several water levels are available, an average is provided. Water levels from wells and piezometers were compiled to establish potentiometric conditions for both the Kobeh Central Well Field areas. Water level data were separated in two groups to distinguish potentiometric conditions in both the saturated basin-fill and the consolidated rocks that form the "bedrock". Equipotential groundwater elevation contours for the bedrock are shown in **Figure 45**, and indicate a radial flow away from high altitude recharge areas in the Roberts Mountains, Mount Hope area, and northern Whistler Range, and are generally a function of land surface altitude. One notable exception is the apparent bend in contours east of the carbonate test wells 205T, 206T, 213T, 214T, and 215T, and the steepened potentiometric surface north of 213T. Water levels in the carbonate horst tapped by these wells are remarkably flat, possibly indicating a high degree of fracture connectivity and/or compartmentalization. The potentiometric water level elevation map for the basin-fill aquifer within the Kobeh Valley Well Field area(**Figure 46**) is similar to that of Tumbush and Plume (2006).

Table 2: Hydrostratigraphic Units in the study area.

	Rock Type	HSU	Map Symbol	General Conceptual Characteristics
Valley-Fill Deposits	Younger Alluvium	VF1		Valley-fill deposits - Thickness ranges from 0 ft along mountain fronts to more than 6,700 ft in central Kobeh Valley. Younger alluvium comprises unconsolidated sand and gravel deposits ranging in thickness from 150 to 200 ft and is considered to have moderate to high production potential. Younger and Older alluvium may be consolidated and cemented, with low to moderate production potential.
	Older Alluvium			
	Volcaniclastic Sediments	VF2		Volcaniclastic sediments include re-worked ash-flow tuffs interbedded with the lacustrine sediments; the thickness of tuff units ranges from 10 ft to about 370 ft. Although usually not exposed at land surface in many locations, these rocks have been penetrated in the structural basins. Hydraulic properties of these units are not known but the production potential is likely low to moderate, and the units may likely be aquitards.
	Lacustrine Sediments	VF3		Lacustrine sediments include claystone, sandstone, freshwater limestone, and conglomerate with thicknesses of individual lithologies ranging from a few tens of feet to more than 260 ft, and with limited water production potential. Conglomerates are generally considered aquitard units except where intensely fractured. Minerals exploration holes in the vicinity of Lone Mountain have penetrated lost-circulation zones in the lower valley-fill units that may be productive horizons.
	Conglomerate			
Volcanic/Intrusive	Basalt	VOL1		Extrusive Igneous/Volcanic Rocks: Numerous mafic dike swarms intrude the Paleozoic rocks and older volcanic rocks in the northern Nevada rift portions of the Roberts Mountains. Associated with these intrusive dikes are numerous basalt and andesite/dacite flows along the flanks of the rift may have moderate production potential at the base of flows or where intensely fractured. The rhyolite, andesite, and tuff units total as much as 1,000 ft. In general, the production potential of these units depends on the degree of welding, post-depositional deformation, and the degrees of mineralization and fracture filling. Because of the limited extent of these units in the Kobeh Valley watershed, they are not considered a primary target for development but may augment yields from wells drilled into underlying Paleozoic rocks.
	Rhyolite, Tuffs			
	Intrusive Igneous Rocks	VOL2		Intrusive Igneous Rocks: Intrusive igneous rocks occur at Mount Hope (quartz porphyry) and Whistler Mountains (alaskite), and are generally not prolific aquifer units.
Paleozoic Rocks	Garden Valley Formation	AQT1		Siliciclastic Rocks: The Garden Valley Fm is limited in to the west slopes of the Sulfur Springs Mountains and a small portion of the western Roberts Mountians where the upper 1,000 ft thick silica cemented conglomerate member likely forms an effective flow barrier between portions of Pine and Kobeh Valley and Diamond Valley. The Vinini and Webb Fms outcrop in the Roberts and Sulfur Spring Mountains, and at Whistler Mountain, and may be as much as 2,000 feet thick. The lower Vinini comprises fine grained limestone, quartzite, and calcareous sandstone, the upper Vinini includes chert and shale. Likely only moderate production potential for development.
	Vinini and Webb Formations			
	Devils Gate Limestone	CA1		Carbonate Rocks: The Devils Gate LS is a thick-bedded limestone that can be more than 2,000 ft thick, outcropping in the Roberts Mountains, Devils Gate area, and the Mahogany Hills. Where fractured and dissolved, and not intruded, the Devils Gate LS may be very productive.
	Denay Limestone	CA2		Carbonate Units: These Paleozoic carbonates outcrop in the Roberts Mountains, the Sulfur Spring Range, and Lone Mountain areas, and in general have more dolomite and mudstone content than the overlying Devils Gate Limestone. Where sufficiently faulted, karsted, or fractured, the units may provide large quantities of water to wells.
	McColley Canyon Formation			
	Nevada Formation			
	Lone Mountain Dolomite	CA3		Dolomitic Units: The Roberts Mountains Fm and the Lone Mountain Dolomite are about 1,900-2,200 ft thick. Although they may be a productive aquifer where fractured and dissolved, they are not widespread at shallow depths in the Kobeh Valley watershed portion of the Roberts Mountains..
	Roberts Mountains Formation			
	Lower Eastern Assemblage	CA4		Siliciclastics and some Carbonate Rocks: The Lower Eastern Assemblage includes the Eureka Quartzite, Pogonip Group, and Hamburg Dolomite and, in Kobeh Valley is only exposed at Lone Mountain. These units are deeply buried in most of Kobeh Valley. Where sufficiently fractured, they may be water bearing.

HSU: Hydrostratigraphic Unit, Map Symbol refers to cross sections in Appendix A

3.4.2 *AQUIFERS*

The primary aquifers are the younger and older alluvium and two carbonate units, the Devils Gate Limestone and the Roberts Mountains Formation. Specific sequences within the Nevada formation may transmit moderate volumes of groundwater and the Lone Mountain Dolomite, where fractured, may transmit appreciable quantities of flow.

In Kobeh Valley, the younger and older alluvium forms a thin veneer over lacustrine sediments deposited in the ancestral Lake Jonathan. Above the valley floor, these units are generally unsaturated. Near the former margins of the lake, older alluvium deposits of fluvial origin are interbedded with lake deposits. This interbedding is likely a result of variations in lake level, source rocks, and specific environments of deposition since the Eocene.

3.5 GEOLOGIC STRUCTURES

Geologic structures can have a pronounced impact on groundwater flow and well yields (Maurer et al, 2004, Dettinger et al, 1995, and Fetter, 1980). Three types of faults in the study area that can be of hydrologic significance are thrust faults, normal faults, and young faults (with generally normal displacement). The thrust faults are generally oriented north-south and reflect the eastward thrusting of western assemblage siliciclastic rocks over younger Paleozoic rocks. In some cases, thrust fault contacts may have fine-grained gouge, and are often associated with mineralization that reduces the permeability of the fault zone resulting in the compartmentalization of the Paleozoic rocks vertically.

Later tectonic activity was manifested by extensive normal faulting that resulted in numerous northwest to southeast and conjugate east-northeast to west-southwest trending high-angle faults. In the central Roberts Mountains, some of these structures likely provided conduits for the upward movement of, and ultimate precipitation from, metal rich fluids (Riedell, 1981, Tingley and Bonham, 1986). The mineralization of many of these faults and the juxtaposition of rocks with contrasting hydraulic properties creates barrier conditions to groundwater flow, and can further deform the Paleozoic sedimentary rocks into horizontal compartments.

The third category of faults, and perhaps the most significant with respect to groundwater flow, is the young faults mapped by Dohrenwend et al (1996). Young faults bound the Roberts Mountains on the west, Lone Mountain on the north, south, and southwest, in portions of the south-central Roberts Mountains, and in an area in eastern Kobeh Valley. Young faults are of particular significance where they cross carbonate rocks because of the secondary dissolution of fault zones and associated fractures by chemical interaction with groundwater. In areas of northwest Clark County, high yield water supply wells have been completed (greater than 2,500 gallon per minute) in areas with similar geologic characteristics. However, it should be noted, that because of the complex geologic conditions, well yields and performance can be highly variable over distances as small as 100 feet, and each of the high volume wells are located near other wells with much lower yields and greater drawdown of the head in response to pumping.

4.0 Drilling and Well Construction

This section details the drilling and construction of water exploration wells and wells drilled to collect information used to understand the hydrology and/or site exploration wells, in and near the Kobeh Valley Well Field area. Some wells were drilled as part of previous exploration efforts, or as supply wells to projects unrelated to the Mount Hope Project. These wells include EW-1 and EW-2. Other wells, such as 9211R, KV01, KV05, and KV11 were drilled in eastern Kobeh Valley during a previous exploration effort. Information about these wells is included in this report to provide a more complete picture of the subsurface conditions in Kobeh Valley. Well locations are shown in **Figure 10,** and are provided in **Table 3**. On **Figure 10**, a well corridor connecting wells has been established to minimize surface disturbances, while connecting well locations for use in future water distribution. Additional information regarding well construction is available in **Appendix B**.

Water exploration sites drilled and tested as part of this effort were selected based on access, environmental constraints, and hydrogeologic conditions. Within these constraints a large area of Kobeh Valley could be investigated. Sites explored consisted exclusively of public land administered by the BLM. Target areas for exploration and specific locations for boreholes and wells were selected on the basis of past studies of the region, consultations with EMLLC staff knowledgeable about the hydrogeologic conditions of the region, and screening studies. The screening studies included the evaluation of imagery of the area, mapping of lineaments on imagery and topographic maps at different scales, the conceptual definition of hydrostratigraphic units, and preparation of maps of key geologic and hydrologic features. A phased approach was used to allow site locations to be refined on the basis of the results obtained from each borehole or well.

4.1 Atlas Wells: EW-1 and EW-2

Two water supply wells were drilled by Atlas Precious Metals in 1986 for the Gold Bar Project. Both wells penetrated sands and gravels of the valley-fill sediments. EW-1 was constructed as a 12-inch production well with perforations extending from 160 to 540 fbls (feet below land surface) and a total depth of 560 fbls. The reported static water level in June, 2007 was 131.6 fbls. EW-2 was constructed nearby and is also a 12-inch well with perforations extending from 169 to 549 fbls and a total constructed depth of 561 ft. A more complete report on these wells, including the results of hydraulic testing appears in Montgomery (2008).

4.2 IGMI-154

Well 154 is located west of Mount Hope and northeast of the well field area and was drilled for water level information, and not in an area identified as having large water supply potential. The well was collared in the Vinini Formation and is detailed in a report by SRK (2007). The well is constructed as a 2-inch piezometer with perforations set at 35 to 75 fbls. The static water level at 154 is approximately 16 fbls.

4.3 KV01

KV01 was completed as a 4.5-inch test well to a depth of 206 feet. Casing perforations extend from 46 to 186 fbls. The borehole encountered sand and gravel to approximately 200 fbls where increasingly fine-grained materials described as sandy, gravelly clay were penetrated to a total

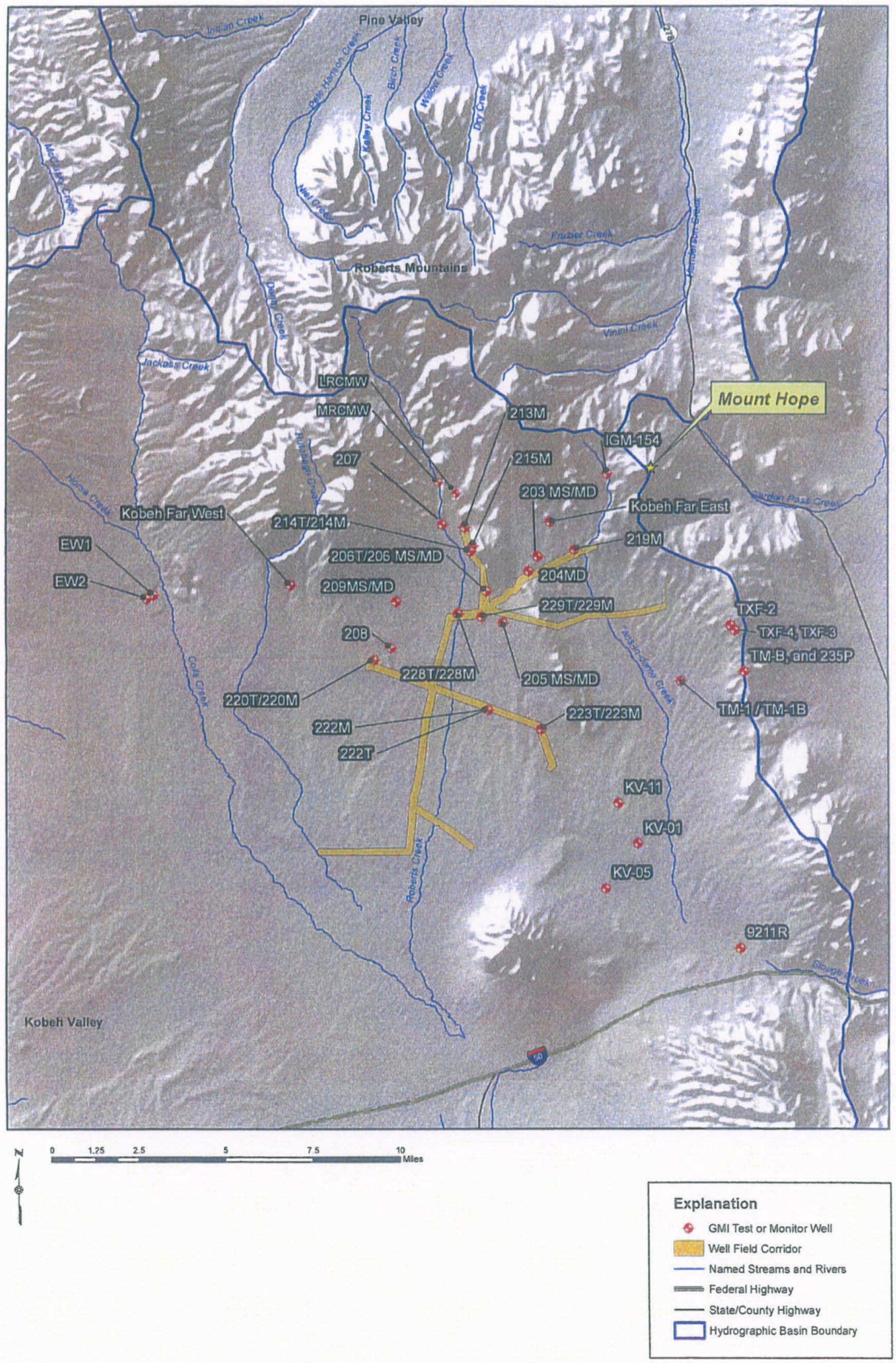


Figure 10: Test and monitoring well locations, Kobeh Valley

Figure 10: Test and Monitoring Well Locations, Kobeh Valley.

borehole depth of 1,200 fbls. Approximately 1000 feet of the borehole was backfilled because of poor production potential, and the well was completed utilizing only the upper 200 feet of valley-fill sediments. At the conclusion of drilling and construction activities, the static water level was approximately 36 fbls on June 21, 2007. A complete report on this well, including geophysical logs and hydraulic testing appears in Montgomery (2008).

4.4 KV05

The borehole associated with well KV05 was drilled to a total depth of 900 fbls and penetrated mainly sand and gravel to a depth of approximately 130 fbls, followed by gravelly sandy clay to 210 fbls. Between 210 fbls and 280 fbls, a volcanic tuff, or water-lain ash was encountered. Below the volcanic/volcaniclastic rocks, clay was encountered to total depth of 900 fbls. The well was completed with 4.5-inch casing to 165 fbls with perforations extending from 50 to 150 fbls. The static water level of the well is approximately 4.8 fbls. A complete report on this well, including geophysical logs and hydraulic testing appears in Montgomery (2008).

4.5 KV11

KV11 was drilled to a depth 800 fbls and encountered sand and gravel to a depth of 200 fbls, sandy clay with gravel to 400 fbls, followed by sandy clay to 800 fbls. An 8-inch steel casing was used for well construction, with perforations present from 78 fbls to 793 fbls. The static water level after well construction activities was 90.4 fbls. A complete report on this well, including geophysical logs and hydraulic testing appears in Montgomery (2008).

4.6 9211R

Eureka Moly installed a replacement well for well 9211(Nevada Department of Water Resources well log number) on the Hay Ranch west of the Devils Gate near Highway 50. The well was constructed with 8-inch casing to 551 fbls, with machine slotted perforations extending from 38 fbls to 551 fbls. The borehole encountered course sands and gravels from land surface to total depth. At the conclusion of well drilling and construction activities, the static water level was approximately 2.3 fbls. A complete report on this well, including geophysical logs and hydraulic testing appears in Montgomery (2008).

4.7 TM-1 AND TM-1B

TM-1 was drilled to a total depth of 1,300 fbls and encountered sand and gravel to approximately 340 feet with finer-grain material present below that depth. The borehole was backfilled to 298 fbls, and a 5-inch monitoring well was constructed with factory-perforations present between 198 and 278 fbls. The static water level after well completion was approximately 208 fbls. A complete report on this well, including geophysical logs and hydraulic testing appears in Montgomery (2008). In 2008, the well casing of TM-1 failed, and the well was replaced with TM-1B, a well completed to 300 fbls with 4-inch diameter PVC. Perforated intervals of the TM-1B casing are present from 198 to 278 fbls.

4.8 RWX-203 AND RWX-204

The locations for these two wells were predicated on the basis of the inferred depth to the pre-Cenozoic surface shown on **Figure 4**. It was anticipated that a shelf of carbonate rocks was overlain by about 500 feet or less of alluvium and valley-fill deposits. The results of the drilling found this not to be the case. At RWX-203 an upper valley-fill unit comprising 1,025 ft of lacustrine sediments and older alluvium was penetrated. This unit is underlain by a 516 ft thick basalt layer which, in turn, is underlain by at least 120 ft of semi-lithified conglomerate with an expansive clay matrix. The basalt layer was cored and although fractures were found at a number of depth horizons, no indication of significant groundwater production was observed during air lifting of water from the borehole.

Similar conditions were found at RWX-204 with the major exception that the basalt layer at this location is overlain by only 55 ft of valley-fill deposits. The basalt is 550 ft thick and is underlain by at least 640 ft of silty sandstone and conglomerate. The 445 ft offset between the top of the basalt layer between these two wells is evidence of a normal fault that post-dates the basalt flow. Following the installation of nested piezometers at RWX-203 and a single piezometer at RWX-204, a test well was constructed at RWX-203T. A brief test indicated only negligible water production. 204 was constructed as an 8-inch steel well with perforations from 560 to 610 fbls; the static water level was approximately 56 fbls. 203 was completed as a dual string PVC piezometer set with 203MS perforated against valley-fill sediments from 220 to 270 fbls, and 203MD was perforated against basalt from 1125 to 1175 fbls. The static water level in 203 MS was 76.4 fbls, and at 203 MD, the static water level is 79 fbls.

4.9 205MS/MD

Paleozoic carbonate rocks were penetrated at a depth of only 80 fbls surface at this location and extend to at least 790 fbls, the total depth of the borehole. The overlying valley-fill deposits are older alluvium interbedded with lacustrine deposits. Dual-string nested 2-inch PVC piezometers were installed in the borehole. Piezometer 205MS has factory cut perforations from 400 to 450 fbls with a static water level of 31.8 fbls while 205MD has perforations from 590 to 640 fbls and a static water level of 32.1 fbls.

4.10 206T, 206MS/MD

Drilling at RWX-206 penetrated a thin veneer of interbedded fluvial and lacustrine sediments underlain by a limestone to a depth of 400 ft and then a dolomitic marble to the total depth of 800 ft. A number of fracture zones were penetrated in both the limestone and dolomitic marble. Dual-string nested PVC piezometers were constructed in the borehole with one piezometer set in the limestone and one set in the underlying dolomitic unit. An 8-inch steel test well was then constructed to a depth of 800 fbls with perforations from 262 to 351 fbls, 412 to 612 fbls, and 704 to 763 fbls; the static water level is 99.6 fbls. Piezometer 206MS has perforations from 120 to 180 fbls and a static water level of 101.2 fbls, while 206MD has casing perforations from 550 to 600 fbls with a static water level of 99 fbls.

4.11 207T

An exploratory borehole was started at RWX-207 but never tested or completed. A 3 ft cavern in carbonate rocks was penetrated at a depth of 246 to 249 ft and the borehole produced significant quantities of groundwater during drilling. The site was abandoned however, because of the discovery of archaeological resources near the drill pad. No piezometers or wells were completed at this site, and no reliable depth-to-water information is available. The borehole was properly abandoned per Nevada Well Regulations.

4.12 208T

An exploratory borehole was advanced to a total depth of 730 ft at RWX-208. The borehole penetrated mudstones and black shale, and only negligible quantities of water were produced during drilling. No piezometers or wells were completed at this site, and no data were collected from the site. The borehole was properly abandoned per Nevada Well Regulations.

4.13 209T, 209MS/MD

Drilling at this site penetrated 30 ft of unsaturated younger alluvium underlain to a depth of 185 ft by lacustrine deposits and older alluvium. From 185 ft to the total depth of 800 ft, various units of the Vinini formation were penetrated comprising siltstone, chert, mudstone, and silty dolomite with greenstone from 342 to 458 ft below land surface. A few interbeds of dark limestone occur in the interval from 735 to 800 ft. Significant quantities of water were not produced during drilling. Dual-string nested piezometers were completed in the borehole and a test well was completed nearby to a total depth of 660 ft. Development of this well was very difficult and it was determined that the water production at this location in the Vinini Formation was not adequate enough to allow development, indicating no potential for water supply development at this site. The test well was constructed with 8-inch steel casing with perforations from 125 to 175 fbls and 400 to 650 fbls. Dual string piezometers were installed to monitor deep and shallow zones. 209MS is perforated against basin-fill materials from 110 to 160 fbls, and 209MD is perforated against Vinini sediments from 400 to 450 fbls. The static water level in 209T was 77.7 fbls, while 209MS records a static water level of 70.2 fbls, and 209MD displays a static water level of 106.9 fbls. The disparity in water levels between 209MS and 209MD indicates a downward hydraulic gradient from the basin-fill to the Vinini Formation in this location at the time of measurement.

4.14 213M

A monitoring well was completed at 213M to total depth of 978 ft. The borehole penetrated about 55 ft of weathered dolomite underlain by a 5 ft thick clay layer. The clay was underlain by 960 ft of dolomite with calcite filled fractures. The first sustainable water was at a depth of 425 ft where airlifting produced 20 gpm. The water production increased to 70 gpm or more from 765 ft to 940 ft and increased to 100 gpm from 940 to 980 ft. Following completion of the test well, a six hour airlift test was conducted during which the well produced an average of 81 gpm. Based upon these results, a test well was not drilled at this location. Static water level in the 213M piezometer was 292.2 fbls.

4.15 214T

A monitoring and test well were completed at 214T. The monitoring well was completed to a depth of 1000 fbls and penetrated 150 ft of weathered limestone underlain by 850 ft of comparatively un-weathered limestone. When the borehole reached total depth, a six hour airlift test resulted in an average production rate of 116 gpm. The test well was drilled to a total depth of 1040 ft and constructed with 8-inch steel casing with a perforated interval from 660 ft to 1220 ft. The monitor well was constructed of 2-inch PVC casing with perforations extending from 658 to 1018 fbls. Following completion of the test well, a six hour airlift test was conducted during which the well produced an average of 96 gpm. Static water levels for 214T and 214M are 275.0 and 274.7 fbls, respectively.

4.16 215M

A monitoring well was completed at 215M to a total depth of 1,000 ft. The borehole penetrated weathered limestone to a depth of 90 fbls underlain by unweathered limestone to a depth of 940 fbls and a dolomite from 940 to 1,000 fbls. During drilling, airlift of the well produced 90 gpm or more below a depth of 960 ft. Because of the proximity of this well location to 214T, no test well was drilled. A monitor well was constructed in the 215M borehole using 2-inch PVC with perforated intervals from 390 to 410 fbls, and 470 to 990 fbls. The static water level in the piezometer was 340.1 fbls after well completion.

4.17 219M

A monitoring well was completed at 219M to a total depth of 998 ft with screen set from 358 to 978 ft. The borehole penetrated 405 ft of clayey and gravelly sands underlain by argillic mudstone to a depth of 960 ft and limestone to the total borehole depth of 1,000 ft. When the borehole reached the total depth, a six hour airlift test resulted in an average production rate of only 28 gpm. Subsequent evaluation of this well location found that the site cleared was not at the intersection of mapped structures, as originally planned. Because of the limited water production during drilling, no test well was completed at this location.

4.18 220T

A monitoring and test well were completed at the 220T location. The boreholes penetrated weathered limestone followed by black mudstone at 60-65 fbls; limestone was encountered at approximately 960 fbls below an interpreted low-angle fault to total depth. Water production during drilling ranged from 23 to 79 gpm above a depth of 900 ft and then increased to 115 to 177 gpm from 900 to 1,000 fbls. After the borehole for the monitoring well reached the total depth of 1,000 ft, a six hour airlift test resulted in an average production rate of 165 gpm. The test well was completed to a depth of 1,040 ft with screens from 660 to 1,020 ft. Following completion of the test well, a six hour airlift test was conducted during which the well produced an average of 96 gpm. The monitor well 220M was constructed with 2-inch PVC casing with perforations from 620 to 980 fbls. Depth to water in 220T was 120.6 fbls, and 121.2 fbls at 220M at the end of drilling and well construction activities.

4.19 222T

A monitoring and test well were completed at 222T and penetrated coarse sand and gravels interbedded with fine silt and clay layers. When the borehole reached total depth of 1,000 ft, a six hour airlift test resulted in an average production rate of 165 gpm. Following completion of the test well, a six hour airlift test was conducted during which the well produced an average of 96 gpm. The test well was constructed with 8-inch steel casing with screens between 240 and 380 fbls and 420 to 860 fbls. The monitor well was constructed of PVC with perforations between 258 and 298 fbls, and 780 to 980 fbls. Depth to water in 222T was 78.9 fbls, and 79.6 fbls at 223M at the end of drilling and well construction.

4.20 223T

A monitoring and test well were completed at 223T. The borehole penetrated alluvial sand, gravel and clay to a depth of 325 ft which is underlain by mudstone with thin limestone layers with calcite filled fractures to the total depth of 1,000 ft. Water produced by airlifting during drilling ranged from 30 to 65 gpm from 185 ft to 865 ft and then increased to 95 to 107 gpm from 865 ft to 1,000 ft. The test well was constructed with 8-inch steel casing with perforations between 380 and 520 fbls and 560 to 980 fbls. The monitor well was constructed of PVC with perforations between 600 and 990 fbls. Depth to water in 223T was 175.0 fbls, and 173.6 fbls at 223M.

4.21 228T

A monitoring and test well were completed at 228T. The monitoring well borehole penetrated mixtures of sand and gravel with occasional clay layers from land surface to the total depth of 1,000 ft. During drilling, water production in the well ranged from only 24 gpm at 315 to 320 ft (the first sustainable flow) to 100 to 150 gpm from 620 ft to 1000 ft. The test well was constructed with 8-inch steel casing with screens between 400 and 600 fbls and 640 to 880 fbls. The monitor well was constructed of PVC with perforations between 400 and 500 fbls and 890 to 990 fbls. Depth to water in 228T was 203.7 fbls, and 203.6 fbls at 228M.

4.22 229T

A monitoring and test well were completed at 229T. The monitoring well borehole penetrated mixtures of sand and gravel with occasional clay layers from land surface to 970 ft with a mudstone present from 970 to total depth of 1,000 ft. During drilling, the monitor well borehole produced an average of 90 gpm from 605 to 1,000 ft with a maximum rate of 132 gpm. The test well, drilled to a total depth of 900 ft, produced 100 gpm or more from 600 ft to 900 ft with a maximum flow rate of 117 gpm. The test well was constructed with 8-inch steel casing with screens between 400 and 600 fbls and 640 to 880 fbls. The monitor well was constructed of PVC with perforations between 400 and 500 fbls and 890 to 990 fbls. Depth to water in 229T was 202.9 fbls, and 201.2 fbls at 229M post construction.

4.23 235P

235P was drilled as a monitoring well near test well TM-B, and was completed to 460 fbls with 4-inch PVC casing. The borehole encountered Vinini Formation mudstones 27 fbls to total depth, with the overlying material consisting of colluvium. At total depth, the maximum air-lifting yield was in excess of 100 gpm. After completion of the well, the static water level was approximately 220 fbls.

4.24 Middle Roberts Creek Monitoring Well (MRCMW)

The MRCMW borehole penetrated clayey gravel to 65 fbls followed by dacite to 105 fbls and more clayey gravel to 120 fbls. Below 120 fbls, bluish grey mudstone was penetrated to 190 fbls, where dolomite and limestone were present to total depth of 300 fbls. Maximum airlifting yield was approximately 50 gpm from total depth. A 2-inch PVC piezometer was constructed in the borehole, with factory-cut perforations extending between 258 to 278 fbls. The static water level at the completion of all drilling and well construction activities was 88 fbls.

4.25 Lower Roberts Creek Monitoring Well (LRCMW)

The borehole of the LRCMW site penetrated 30 feet of decomposed limestone with clay that graded to more competent limestone between 30 and 220 fbls. From 220 fbls to total borehole depth of 405 fbls, fractured dolomite was present. A highly brecciated zone was noted from 285 to 290 fbls. Maximum airlifting yield was approximately 86 gpm. At the conclusion of drilling and construction activities, the static water level was approximately 89 fbls.

4.26 RWX-KFE

An exploratory borehole was drilled to a total depth of 1,000 ft at KFE (Kobeh Far East). This site was selected to investigate the subsurface east of the main well field. The only unit penetrated in the borehole was mudstone of the Vinini Formation. Water production during drilling was 14 gpm or less. A 2-inch PVC piezometer was constructed in the borehole with factory cut perforations present from 225 to 265 fbls. The static water at the KFE site was approximately 60 fbls after well completion.

4.27 RWX-KFW

An exploratory borehole was located at site Kobeh Far West (RWX-KFW) on or near the younger fault that bounds the southwest side of the Roberts Mountains block. The borehole advanced to a total depth of 640 ft when caving resulted in the termination of drilling. The borehole penetrated unsaturated alluvium and basin-fill to a depth of 140 ft underlain by a 35 ft thick sandstone unit and a 5 ft thick orange clay. Vinini Formation is present from 180 to 640 fbls. Negligible quantities of groundwater were produced above 430 fbls, but production increased to 30 gpm at 460 ft and to a maximum of 57 gpm at 580 ft. A 2-inch PVC piezometer was constructed in the borehole with factory cut perforations extending from 427 to 467 fbls; the static water level at the site was reported to be 192.25 fbls immediately after construction and 171.92 fbls in November of 2008.

4.28 TM-B

A test well was completed at TM-B to a total depth of 1,000 ft. The borehole penetrated 20 ft of alluvium underlain by mudstone from 20 to total depth. Water produced by airlifting was slight ranging from less than 5 gpm to a maximum of 27 gpm. A test well was constructed with 8-inch steel casing to 1000 fbls.; louvered casing was positioned between 520 and 660 fbls and 760 and 980 fbls. After well completion, the depth-to-water was approximately 325 ft.

4.29 TXF-2

Well TXF-2 was drilled in the Whistler Range, east of the Kobeh Valley Well Field area as a possible source of construction water for making concrete. The well penetrated quartzite and dark grey mudstones of the Vinini from land surface to total depth of 1000 fbls. Water-bearing fractures were noted at 310-550 fbls, 610 – 760 fbls, and 820 to 980 fbls. TXF-2 was completed as an 8-inch steel well with louvered casing between 300 and 520 fbls, and factory cut mill slot casing between 620-980 fbls. Immediately after completion, the depth-to-water was approximately 220 ft.

4.30 TXF-3

Borehole TXF-3 was advanced to 880 fbls through mudstone and minor quartzite and produced approximately 70 gpm at total depth. Severe borehole stability issues were encountered below 700 fbls, and the drilling method was altered from air-rotary to mud-rotary, though difficulties persisted. Ultimately, the borehole was deemed too unstable to construct a monitoring well. The borehole was properly abandoned per Nevada Well Regulations, and no water level data were obtained.

4.31 TXF-4

Borehole TXF-4 was drilled to a total depth of 1000 fbls through mudstone and some minor quartzite. Fracture zones were noted at 320-325 fbls, and 449-455 fbls. At total depth of 1000 fbls, the borehole was only producing 30-40 gpm. The borehole was properly abandoned per Nevada Well Regulations, and no water level data were obtained.

Table 3: Well completion summary for exploration wells in the Kobeh Valley well field area

WELL NAME	TOTAL DEPTH (ft bls)	UTM COORDINATES NAD 83 NORTHING (ft)	UTM COORDINATES NAD 83 EASTING (ft)	GROUND ELEV.(ft amsl)	DEPTH TO WATER (ft)	SCREENED INTERVAL ft FROM	SCREENED INTERVAL ft TO	SAND PACK INTERVAL (ft) FROM	SAND PACK INTERVAL (ft) TO	FORMATION / LITHOLOGY AT SAND PACK INTERVALS	CASING TYPE	CASING T.D. (ft)	O.D. (in)
KV01	1200	14395700.62	1866807.41	6,083.09	35.7	46	186	40	206	ALLUVIUM	PVC	206	4.5
KV05	900	14388753.92	1861852.94	6,043.74	4.8	45	145	22	165	ALLUVIUM	PVC	165	4.5
KV11	800	14401916.05	1863832.6	6128.62	90.3	73	793	73	800	ALLUVIUM	STEEL	793	8.8
9211R	647	14379392.1	1882512.8	6008.55	2.3	38	551	40	570	ALLUVIUM	STEEL	551	8.5
TM1B	1310	14420623.4	1873090.6	6,275.17	208.1	198	278	188	298	ALLUVIUM	PVC	298	5
EW1	560	14434028.9	1793139.8	6361.20	131.6	160	540	50	560	ALLUVIUM	STEEL	560	12
EW2	561	14433520.3	1792112.9	6364.60	131.3	169	549	50	560	ALLUVIUM	STEEL	561	12
203T	1080	14439886.92	1851744.70	6,568.88	77.1	255	1070	0	1080	LACUSTRINE SEDIMENTS AND OLDER ALLUVIUM; BASALT BELOW 1025 FT.	STEEL	1080	8
RWX-203MS	280	14439891.26	1851658.16	6,568.16	76.4	220	270	215	280	BASIN-FILL - LACUSTRINE SEDIMENTS AND OLDER ALLUVIUM	PVC	280	2
RWX-203MD	1200				79	1125	1175	1120	1200	BASALT	PVC	1200	2
RWX-204		14437530.95	1850177.51	6,510.56	55.5	560	610	555	635	BASALT	PVC	620	2

WELL NAME	TOTAL DEPTH (ft bls)	UTM COORDINATES NAD 83 NORTHING (ft)	EASTING (ft)	GROUND ELEV.(ft amsl)	DEPTH TO WATER (ft)	SCREENED INTERVAL ft FROM	TO	SAND PACK INTERVAL (ft) FROM	TO	FORMATION / LITHOLOGY AT SAND PACK INTERVALS	CASING TYPE	T.D. (ft)	O.D. (in)
RWX-205MS	460	14429688.61	1846291.61	6,379.21	31.8	400	450	396	460	DOLOMITE & ALTERED LIMESTONE	PVC	460	2
RWX-205MD	650	14429688.61	1846291.61	6,379.21	32.1	590	640	585	650	LIMESTONE	PVC	650	2
206T	800	14434589.89	1843679.79	6,444.49	99.6	262	351	0	800	LIMESTONE	STEEL	800	8
						412	612						
						704	763						
RWX-206MS	190	14434570.44	1843750.19	6,443.55	101.2	120	180	113	190	LIMESTONE	PVC	190	2
RWX-206MD	650	14434570.44	1843750.19	6,443.55	99	550	600	545	650	LIMESTONE	PVC	610	2
RWX-207	800	14444796.55	1837049.47	6,629.50	n/a	Borehole was plugged and abandoned.							
209T	660	14433014.20	1830153.04	6,508.40	77.7	125	175	0	660	LACUSTRINE SEDIMENTS AND OLDER ALLUVIUM	STEEL	660	8
						400	650			GREENSTONE, SILTSTONE, MUDSTONE, & CHERT			
RWX-209MS	170	14432946.14	1830080.27	6,510.21	70.2	110	160	105	170	LACUSTRINE SEDIMENTS AND OLDER ALLUVIUM	PVC	170	2
RWX-209MD	460	14432946.14	1830080.27	6,510.21	106.9	400	450	395	460	GREENSTONE	PVC	460	2
RWX-213M	1000	14444466.77	1840499.63	6,639.74	292.2	558	618	556	623	DOLOMITE	PVC	998	2
						758	958	745	1000				

WELL NAME	TOTAL DEPTH (ft bls)	UTM COORDINATES NAD 83 NORTHING (ft)	EASTING (ft)	GROUND ELEV.(ft amsl)	DEPTH TO WATER (ft)	SCREENED INTERVAL ft FROM	TO	SAND PACK INTERVAL (ft) FROM	TO	FORMATION / LITHOLOGY AT SAND PACK INTERVALS	CASING TYPE	T.D. (ft)	O.D. (in)
RWX-214T	1020	14440772.06	1841371.79	6,619.64	275	660	1000	610	1020	LIMESTONE & DOLOMITE	STEEL	1020	8
RWX-214M	1040	14440744.11	1841368.69	6,620.53	274.7	658	1018	655	1040	ALTERED MUDSTONE & DOLOMITE	PVC	1038	2
RWX-215M	1000	14441553.63	1841693.60	6,684.77	340.1	390	410	388	412	LIMESTONE	PVC	1000	2
						470	990	468	1000				
RWX-219M	1000	14441016.89	1857186.35	6,611.18	91.7	358	978	355	980	ALTERED MUDSTONE & LIMESTONE	PVC	990	2
RWX-220M	1000	14424094.94	1826674.29	6,350.84	121.2	620	980	618	1000	ALTERED DOLOMITE & LIMESTONE	PVC	1000	2
RWX-220T	1000	14424058.11	1826689.18	6,351.38	120.6	660	740	610	1000	ALTERED DOLOMITE & LIMESTONE	STEEL	1000	8
						780	980						
RWX-222M	750	14416304.80	1843978.42	6,270.55	79.6	258	298	255	300	LACUSTRINE SEDIMENTS & OLDER ALLUVIUM	PVC	750	2
						418	748	415	750				
RWX-222T	880	14416286.37	1844000.77	6,271.07	78.9	240	380	190	880	LACUSTRINE SEDIMENTS & OLDER ALLUVIUM	STEEL	880	8
						420	860						
RWX-223M	1000	14413328.14	1852081.65	6,267.19	173.6	600	990	598	1000	ALLUVIUM AND MUDSTONE	PVC	1000	2

WELL NAME	TOTAL DEPTH (ft bls)	UTM COORDINATES NAD 83 NORTHING (ft)	UTM COORDINATES NAD 83 EASTING (ft)	GROUND ELEV.(ft amsl)	DEPTH TO WATER (ft)	SCREENED INTERVAL ft FROM	SCREENED INTERVAL ft TO	SAND PACK INTERVAL (ft) FROM	SAND PACK INTERVAL (ft) TO	FORMATION / LITHOLOGY AT SAND PACK INTERVALS	CASING TYPE	CASING T.D. (ft)	O.D. (in)
RWX-223T	1000	14413341.97	1852070.56	6266.09	175	380 560	520 980	330	1000	ALLUVIUM AND MUDSTONE	STEEL	1000	8
RWX-228M	1000	14431109.74	1839490.05	6,410.27	203.6	400 890	500 990	396 886	502 992	LACUSTRINE SEDIMENTS & ALLUVIUM	PVC	990	2
RWX-228T	900	14431124.40	1839442.56	6,414.30	203.7	400 640	600 880	350	900	LACUSTRINE SEDIMENTS & ALLUVIUM	STEEL	900	8
RWX-229M	1000	14430638.30	1843077.08	6,403.72	201.2	400 890	500 990	396 886	502 992	LACUSTRINE SEDIMENTS & OLDER ALLUVIUM	PVC	990	2
RWX-229T	900	14430607.86	1843061.43	6,401.59	202.9	400 640	600 880	350	900	BASIN-FILL - LACUSTRINE SEDIMENTS & OLDER ALLUVIUM	STEEL	900	8
RWX-235P	460	14,422,187.27	1,883,272.77	6,603.57	220	418	438	415	440	MUDSTONE	PVC	460	4
KVFW	640	14435735.75	1813975.75	6,631.96	416	427	467	424.5	467	SILTSTONE	PVC	477	2
KVFE	1000	14445210.12	1853429.42	6,709.58	60	225	265	221	265	MUDSTONE	PVC	285	2
LRCMW	378	14449587.96	1839141.97	6,768.99	87.5	258	358	256	378	DOLOMITE	PVC	378	2
MRCMW	298	14451270.79	1836399.09	6,771.60	80.5	258	278	256	300	LIMESTONE	PVC	300	2
TM-B	1000	14422152.46	1883279.65	6,602.61	325	520 760	660 980	470	1000	MUDSTONE	STEEL	1000	8
TXF-2	1000	14,429,378.01	1881186.89	6,743.18	37.5	520 760	660 980	255	1000	MUDSTONE	STEEL	1000	8
TXF-3	880	14428805.28	1881618.80	6742.84	n/a	Borehole was plugged and abandoned.							
TXF-4	1000	14428032.55	1882162.58	6721.75	n/a	Borehole was plugged and abandoned.							

5.0 SURFACE AND BOREHOLE GEOPHYSICS PROGRAM

5.1 SURFACE GEOPHYSICAL SURVEYING

During the exploratory drilling and testing in the Kobeh Central area, marked contrasts in the aquifer types and their hydraulic properties were noted. To assist in the siting of additional exploratory boreholes and test wells in the carbonate aquifer in this area, EMLLC commissioned a detailed geophysical survey by Quantec USA, Inc. The survey comprised a high density magnetic survey, and a detailed controlled source audio-frequency magnetotellurics (CSAMT) survey was also conducted. The locations of the surveyed areas are shown in **Appendix C** and include two areas, the north and south Roberts Ranch areas. The equipment used, procedures employed, and the results of the survey are presented in Quantec (2008) and provided in digital format, also in **Appendix C**.

5.1.1 NORTH ROBERTS CREEK RANCH AREA

A map of the total magnetic field with the interpreted geologic structures is shown in **Appendix C** as **C-1**. Areas underlain by shallow carbonate rocks are shown as warm colors (yellow through magenta) while areas with thicker accumulations are shown in cooler colors (green through deep blue). A number of north-northwest trending magnetic curvilinear elements are interpreted as normal faults that have down dropped the carbonate rocks progressively deeper to the west. A number of northeast trending linear elements are inferred to represent cross cutting structures.

Maps of the 100 m and 250 m deep CSAMT results are shown in **C-2** and **C-3**, respectively. Resistivity lows and curvilinear elements are also shown on the maps. Of note are a north-south trending series of lows through the northeast part and east-central parts of the North Roberts Ranch, area and a northeast trending series of two lows and a distinct low resistivity "embayment" in the east-central part of the area. Cross sections of the CSAMT results are shown in **C-4** and **C-5**. The CSAMT results show the shallow carbonates and the bounding faults to the west and a number of discrete resistivity lows (shown as blue linears on the cross sections). These lows are interpreted as likely fracture zones associated with faulting that exhibit lower resistivity because of higher porosity.

A map that combines the linear and curvilinear elements from both CSAMT depths *and* the interpretation of the total magnetic field is shown on **C-6**. This map also includes the locations of two of the exploratory boreholes in Kobeh Central (Sites RWX-214 and RWX-215). The sites were selected at or near the intersection of inferred geologic structures that correspond with resistivity lows.

5.1.2 South Roberts Ranch Area

A series of maps and cross sections for the South Roberts Ranch Area are shown on Figures **C-7** through **C-10**. The total magnetic field map and inferred structures (**C-6**) suggests that the existing test well at RWX-206T and piezometer at RWX-205 are completed in a compartment (horst block) of carbonate rocks. The CSAMT resistivity maps for depths of 100 m and 250 m are shown **C-8** and **C-9**. The results indicate much less structural deformation and no distinct resistivity lows in the area underlain by carbonates (shown as yellow on the eastern side of these maps).

5.2 Geophysical Logging and Tests

Borehole geophysical logs were run in most boreholes after total depth had been achieved. The suite of logs includes gamma, fluid resistivity, temperature, deviation, caliper, and electric logs. Because of borehole instability and swelling of clays immediately after drilling, it was not possible to obtain geophysical logs in all boreholes. In these instances, logs were run in the cased wells and piezometers after completion. The suite of logs run in the test wells included video, gamma, fluid resistivity, temperature, and differential temperature logs. Pump spinner surveys were also done in most test wells. A reduced suite of fluid resistivity, temperature, and differential temperature were run in the piezometers. The logs are in **Appendix D**.

6.0 Well and Aquifer Testing

A well and aquifer testing program for the Kobeh Valley Well Field area was undertaken to provide information on the hydraulic properties of the basin-fill and carbonate aquifers present in the area. These tests, in conjunction with tests previously completed by EMLLC, provide information on the transmissivity and storage properties of the aquifers present, and can provide insight into the locations of barriers to groundwater flow. For all tests conducted by EMLLC, pumping and observation wells were equipped with data-recording pressure transducers and manual measurements were taken at most wells to augment automatic measurement methods. In all tests, discharge was routed at least 1000 feet away from the pumping well, and away from nearby observation wells. All test wells installed by EMLLC have a piezometer about 50-70 feet away that additionally recorded water level changes during the pumping tests.

Complementing the drilling and well construction program, were step-discharge and constant rate pumping tests at thirteen (13) well site locations in Kobeh Valley. The rock types tested include basin-fill materials, carbonate rocks, and siliciclastic rocks.

Hydraulic analyses of the aquifer tests utilized standard graphical methods such as Cooper-Jacob (1946), and other published type-curve matching solutions, primarily using the software package AQTESOLV (HydroSolve, 2008). AQTESOLV is a software package that simplifies the process of matching field data to type-curves of theoretical transmissivity and storage coefficients, under a variety of aquifer conditions. Hydraulic analyses are presented for review in **Appendix E**.

The following section is a narrative of the well and aquifer testing completed at each location. Plots of drawdown data are presented for each well, and where there is measurable drawdown in observation wells, those data are also presented graphically. Estimates of hydraulic properties based on the drawdown data are provided for most wells. Where hydraulic properties are provided in the text, they are presented in the units that were provided from the original source, if citing other published or unpublished work. The results of the pumping tests and the hydraulic analyses are summarized at the end of the section.

6.1 Test Well KV11

A step drawdown test was performed on well KV11 prior to a relatively short constant rate discharge test. Pumping rates for the step drawdown test varied between 418 and 480 gpm and produced a maximum of 92 feet of drawdown. The constant rate test was performed at 412 gpm for approximately two hours and produced a maximum drawdown of 58 feet. Based on the drawdown data, a transmissivity of 85,000 gpd/ft (~11,400 ft^2/day) was estimated, and based on the recovery data, a transmissivity of 110,000 gpd/ft (~14,700 ft^2/day)was derived. More detail on the pumping test and subsequent hydraulic analysis of well KV11 is available in Montgomery (2008).

6.2 Test Well 9211R

Well 9211R was tested at an average pumping rate of 600 gpm for approximately 1.1 days. The maximum drawdown in the pumping well was 19.4 feet, which occurred approximately 6 hours after pumping began. The test was terminated because drawdown in the well was decreasing, indicating possible recirculation of discharge water. Montgomery evaluated the first 500 minutes of the test and using the Neuman (1974) type-curve analysis. The results of their curve matching produced a transmissivity value of 226,000 gpd/ft (~30,200 ft^2/day), a storativity of 0.003, and a specific yield of 0.005 while using a ratio of horizontal to vertical anisotropy of 10:1. The report cautioned that the results may not accurately reflect aquifer conditions at the location due to the recirculation of water during the test. More detail on the pumping test and hydraulic analysis of well 9211R is available in Montgomery (2008).

6.3 Test Well TM1

Well TM1 was subjected to a several short term pumping tests, which indicated very low well yield, between 2 and 8.6 gpm (Montgomery, 2008). At the highest pumping rate of an average of 8.6 gpm, the pumping well experienced 40 feet of drawdown after 480 minutes. It is suspected that well construction and lack of complete well development may have caused the poor well performance. Well TM-1 collapsed during the summer or fall of 2007, and was replaced by TM-1B, which has not been tested. Drawdown data from the well was not analyzed to determine hydraulic properties (Montgomery, 2008).

6.4 Atlas Production Wells EW-1 and EW-2

One of the Atlas wells (EW-1) was tested at 600 gpm with 52 feet of drawdown after 24 hours of pumping. The second well (EW-2) was tested at 490 gpm with 225 feet of drawdown after 49 hours of testing. A subsequent 24 hour test of EW-1 by Montgomery (2008) at 490 gpm resulted in drawdown of 82 feet. Based on the pumping well data, a transmissivity of 24,000 gpd/ft (~3,200 ft^2/day)was estimated, while the recovery data resulted in a transmissivity estimate of 20,000 gpd/ft (~2,700 ft^2/day). The data generated from the observation well resulted in a transmissivity estimate of 13,500 gpd/ft and a storage coefficient of 0.0003. More detail regarding the aquifer tests at EW-1 and EW-2 appears in Montgomery (2008).

6.5 Test Well 206T

Two constant discharge tests were performed at 206T to evaluate well and aquifer conditions in the carbonate rocks present in the central portion of the Kobeh Valley Well Field. An initial 48-hour constant discharge test was conducted at 206T at a rate of 450 gpm, the highest rate that could be achieved with the available pump. The results indicated that 206T is capable of producing appreciable quantities of groundwater. Only 2.7 ft of drawdown were present in the pumping well equating to a specific capacity of approximately 166 gpm/ft.

Because of the limited pumping rate, the aquifer test was not considered to be of sufficient discharge or duration to adequately stress the aquifer. To address this concern, EMLLC conducted a 32-day constant discharge test at a target pumping rate of 1,400 gpm using a specially designed pump capable of delivering nearly 1,500 gpm from an 8-inch well. During the test, the pumping rate was stable, and ranged from 1,342 to 1,358 gpm and averaged 1,350 gpm for the first 22 days of the test. The pump was shut down for 2 hours and 31 minutes for routine maintenance and then turned back on at a rate of 1,450 gpm. The maximum drawdown in the test well was approximately 30 ft at the end of the 32-day test (**Figure 11**). Following the shutdown of the pump, the water level in the pumping well recovered about 20.5 feet in the first minute of recovery. A check valve in the pump insured that this recovery was real and not water falling down the column pipe. This rapid initial recovery likely reflects the low efficiency of the well. The water level in the pumping well then continued to recover very slowly for about three days (about 2 ft of additional recovery). During recovery of water levels, cattle disrupted the monitoring equipment, and automated measurements were ruined. A month after pumping ceased, the residual drawdown was equal to approximately 4.5 feet.

A semi-log plot of drawdown during the long-term test and recovery for the first 17 days following the cessation of pumping are shown on **Figure 12**. During the 32-day aquifer test at 206T, water levels were monitored at wells 206T, 206MS, 206MD, 205MD, 205MS, 204MD, and 209MS/MD, 204 and 209MD. At the time of this testing, no other wells drilled in the carbonate rocks were present. No drawdown was recorded in piezometers 204 or 209MD (See **Appendix E** for monitoring data).

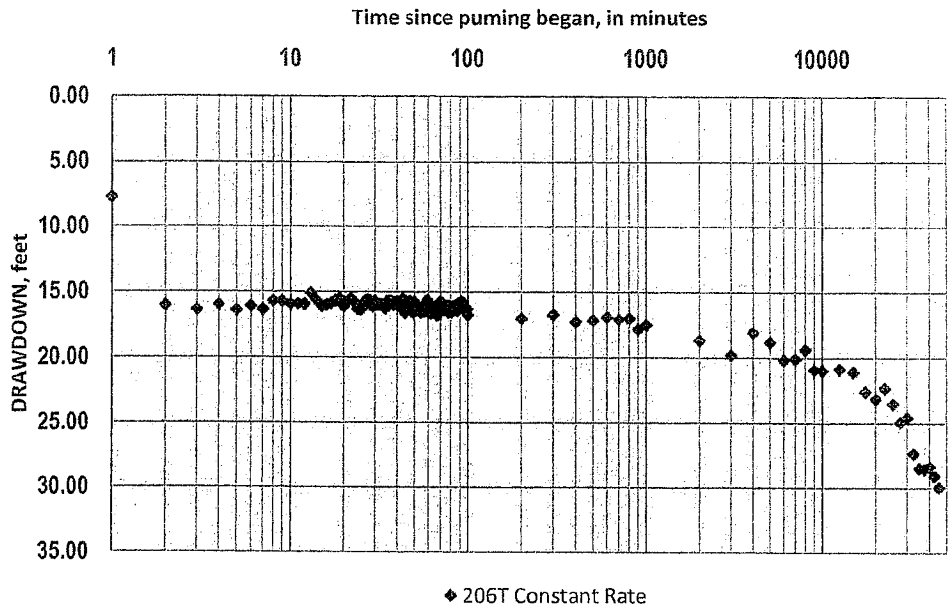


Figure 11: Semi-log plot of pumping well 206T

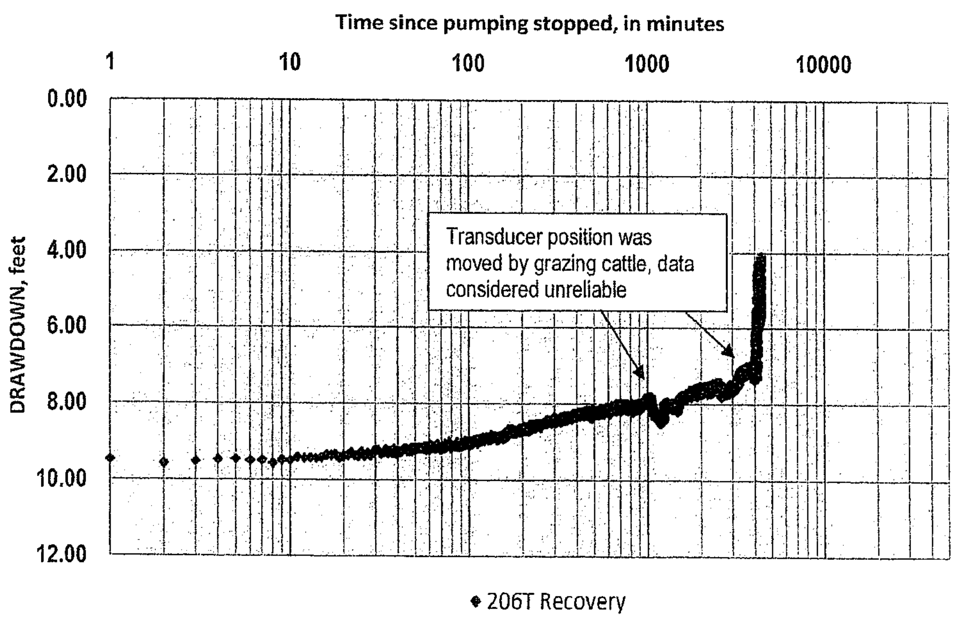


Figure 12: Semi-log plot of recovery of water levels from well 206T

Data collected from the 206T test contains a high degree of "painting" or erratic data, likely caused by barometric pressure fluctuations. Because some pre-testing pumping was conducted to test generators and pump equipment prior to the 32-day test, determining barometric efficiency for the wells was not possible. In order to effectively evaluate the datasets in lieu of barometric compensation, dynamic smoothing techniques were utilized using both Microsoft Access and SigmaPlot software. Data were summarized by mean hourly drawdown in Access, and variations, outliers, and data scatter were removed by applying a negative exponential smoothing technique that applies localized polynomial weights and regression. Localized regression smoothes over a finite interval and maintains the overall data trend. Analysis of residuals, the difference between transducer reading and smoothed data, revealed that smoothing was extremely effective at removing scatter while preserving actual trends of the data. Although the smoothing exercise was successful for most of the data, early-time measurements that displayed rapidly decreasing water levels (common during early-times of aquifer tests) were over-corrected by the smoothing algorithms used to match the overall trend of the data set. For this reason, transducer data collected on minute intervals were preserved exactly as provided from transducer readings and used instead of smoothed data for times up to 200 minutes (see **Figures 13** through **16**).

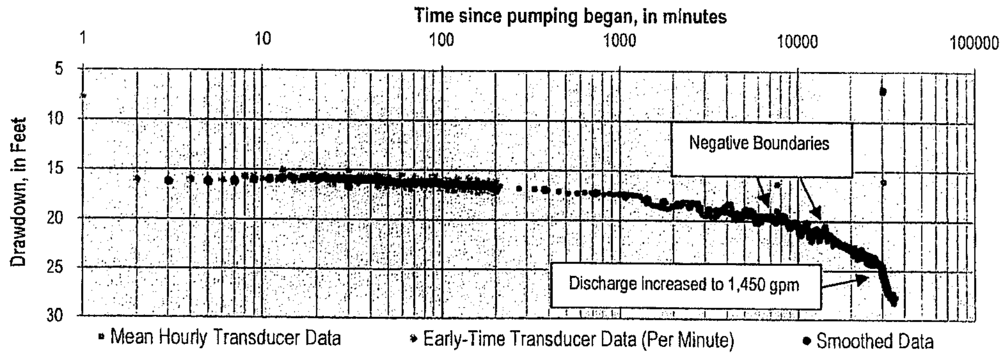


Figure 13: Transducer and smoothed drawdown data from pumping well 206T

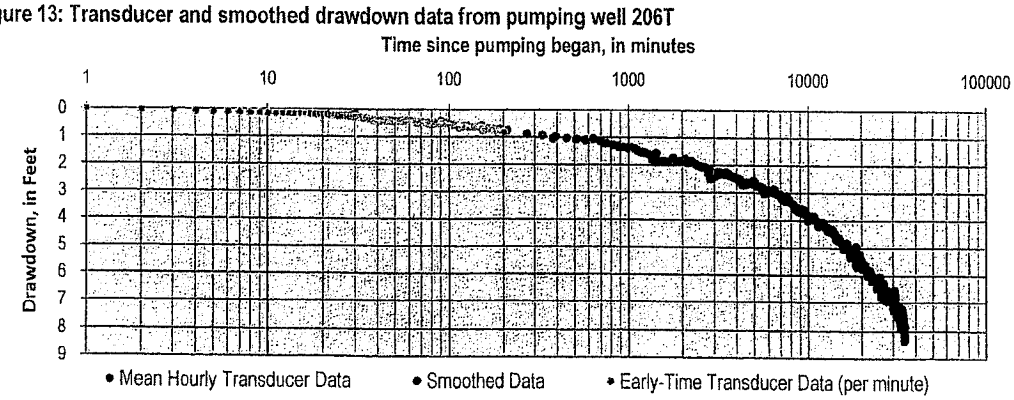


Figure 14: Transducer and smoothed drawdown data from piezometer 206MS

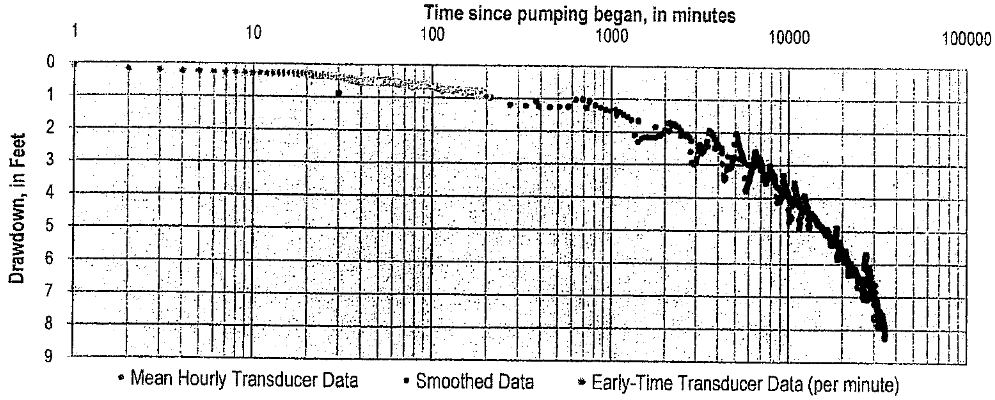


Figure 15: Transducer and smoothed drawdown data from piezometer 206MD

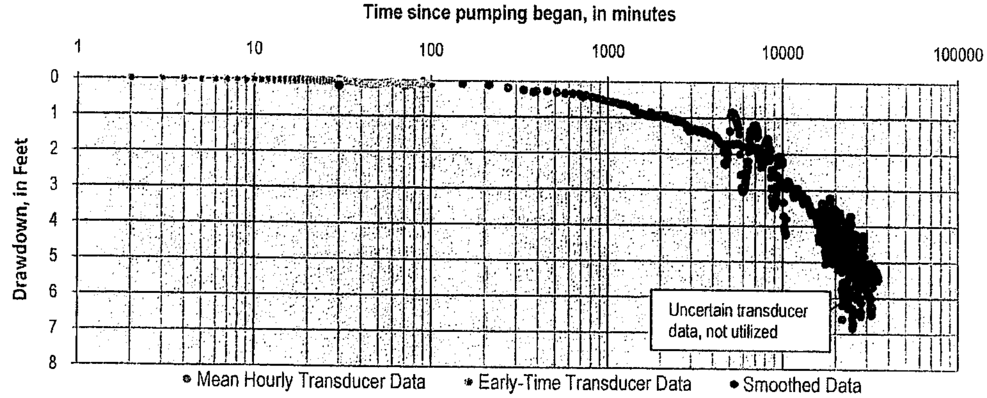


Figure 16: Transducer and smoothed data from piezometer 205MD.

Traditional analysis of multi-well aquifer tests usually involves use of distance-drawdown plots to derive transmissivity and storage coefficient values. The results of which usually provide excellent aquifer parameters over the aerial extent of the aquifer (Batu,1998). Data presented in **Figure 17** and **Table 4** indicate large transmissivity values, as calculated using the Cooper-Jacob (1964) distance-drawdown method. Paired drawdown values from 206MD and 205 MD indicate, for a given pumping rate, both transmissivity and storage coefficients decrease as a function of time. The fact that computed storage coefficients are reduced to implausibly low values and computed transmissivity values drop over time, are an indication that boundary conditions and/or flow conditions not consistent with idealized Theis-type (Theis, 1935) assumptions are present. It is likely that boundary conditions are imposing additional drawdown that cause the straight line extrapolation of r_0 to be too high, producing impossibly small S-values (Driscoll, 1987, Pg. 248).

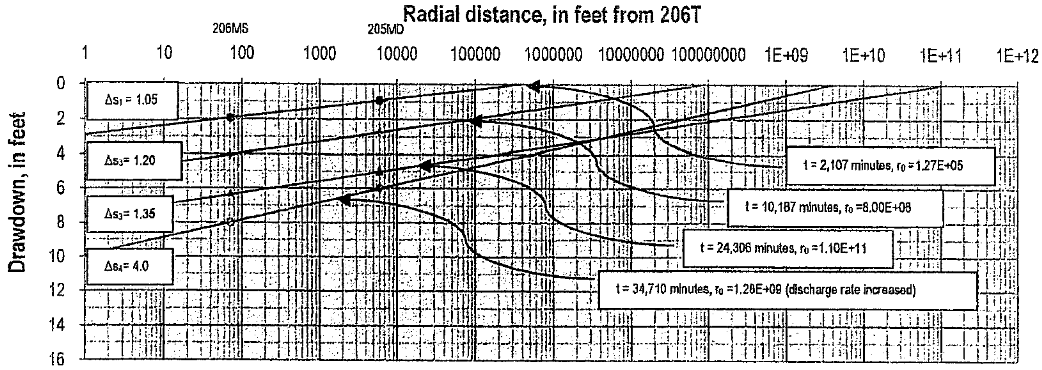


Figure 17: Distance-drawdown evaluation for 206MD and 205MD

Table 4: Data to accompany distance-drawdown evaluation in Figure 17. Computation of transmissivity (T) and storage coefficient (S) utilizes the distance-drawdown form of the Cooper-Jacob equation (1964).

Time (minutes)	Time (days)	Average Discharge (gpm)	Δs (feet)	T (ft²/day)	r_0 (feet)	S[1] (unitless)
2107	1.46	1,350	1.05	90,740	1.27E+05	1.85E-05
10087	7.00	1,350	1.10	86,620	8.00E+06	2.13E-08
24306	16.88	1,350	1.35	70,580	1.10E+11	2.21E-16
34710	24.10	1,450	4.00	25,290	1.28E+09	8.35E-13

1 Computed storage values (S) are not considered valid because of boundary conditions.

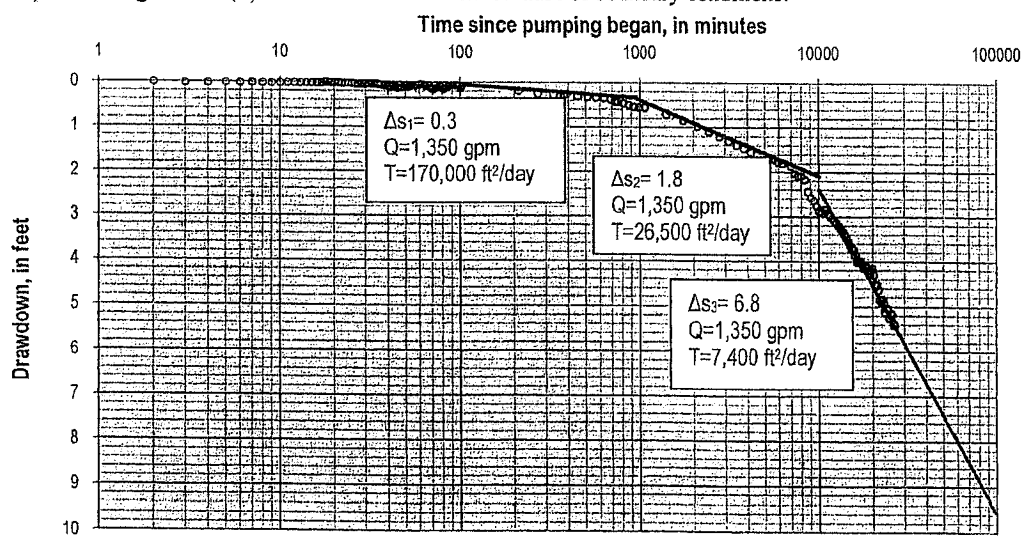


Figure 18: Example of declining computed transmissivity from barrier affect(s) as shown by semi-log plot of drawdown from piezometer 205MD. The analysis does not consider data after pumping rate was increased to 1450 gpm from 1,350 gpm.

Although the data from the first portion of the test initially indicated large transmissivity values, late-time data indicate that the system behaves in a manner similar to an aquifer with a transmissivity value on the order of 7,000 ft^2/day (**Figure 18**). It is likely that in the vicinity of 206T, enhanced permeability from karst and/or faulting may be responsible for low amount of drawdown for the early and middle portions of the test. Dewatering of these features and/or barrier boundaries are possible explanations for the decline in aquifer performance over time. Because of the limited number of observation wells locations of barriers could not be confirmed, though the local geology and geophysics indicate a number of faults surrounding the 206T area. Specifically, the following points indicate likely boundary conditions around 206T:

- Geologic maps containing the well field area show that the carbonate rocks tapped by 206T run in a north-south fashion and dip to the east (Childress and Ferdock, 2008).
- A basin-bounding fault mapped by Dohrenwend et al. (1996) as a Quaternary fault, and corroborated by geophysical data from CSAMT surveys frames the western edge of the carbonate block (see **Appendix C**), and essentially compartmentalizes the carbonates.
- The USGS (Dohrenwend, 1996) show an east-west oriented normal fault that bisects the carbonate horst block north of 206T, between the LRCMW and 213M. Differences in water level elevations on each side of the fault indicate that the fault is a likely barrier to groundwater flow (see next section on 214T testing and barrier effects near 213M).
- A basalt ridge is present at land surface southeast of the carbonate horst block and is fault-bound to the east of the carbonate block, as determined from geologic logs from 204 and 203 (see **Section 8**, and **Figures 41** and **42**).
- No drawdown was observed at 204 (east of the margin of the horst block) or 209 (west of the margin of the horst block)

In summary, the aquifer test at 206T indicates that the carbonate rock immediately adjacent to 206T is extremely permeable. This high transmissivity zone is probably limited in extent as the performance of well 206T and surrounding carbonate aquifer declines substantially over time. Long-term term behavior of the aquifer at this location is consistent with an aquifer with a transmissivity of 6,000-7,000 ft^2/day. Because of the limited number of observation wells, and the boundary conditions, estimation of the Storage Coefficient from the 206T test is uncertain. Subsequent testing of the carbonate-rock aquifer at this location during the 214T test indicates an S-value of approximately 0.001 to 0.002 (see Section 6.6).

6.6 Test Well 214T

A constant rate test was performed at well 214T for 11 days at an average pumping rate of 445 gpm. The pre-testing static water level was 240 fbls, and after the pumping rate was stabilized, 214T maintained a relatively constant pumping water level of 336 fbls equaling approximately 96 feet of drawdown (**Figure 19**). Testing of 214T induced measurable drawdown at 213M, 214M and 215M, 206MS and 205MS (**Figure 20-21** and **Table 5**). The drawdown trend for well 213M, located to the north of 214T steepened over time indicating the presence of a boundary condition. The boundary was not as conspicuous in the data from 214M or 215M, suggesting that the boundary was closer to 213M, to the north.

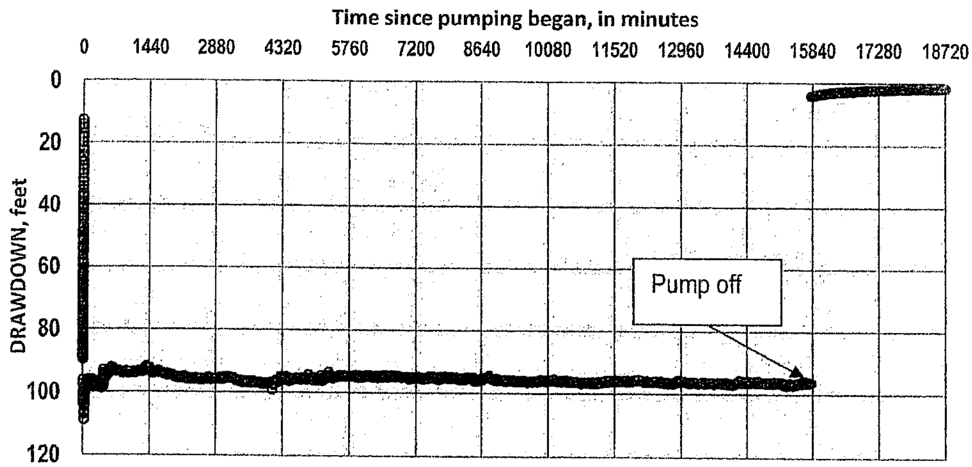


Figure 19: Drawdown and recovery for well 214T pumping at 445 gpm for 11 days

Table 5: Monitored wells, distance from 214T, and measured drawdown after 11 days of pumping 214T at 445 gpm.

Well Name	Northing (ft)	Easting (ft)	Distance from 214T (ft)	Maximum Drawdown (ft)
214T	14440772.1	1841371.8	0.9	96
214M	14440744.1	1841368.7	28.1	16.5
215M	14441553.6	1841693.6	845.2	4.8
213M	14444466.8	1840499.6	3796.2	4.3
206 MS	14434570.4	1843750.2	6642.1	1.1
LRCMW	14449588.0	1839142.0	9093.5	0
205 MS	14429688.6	1846291.6	12126.3	0.5

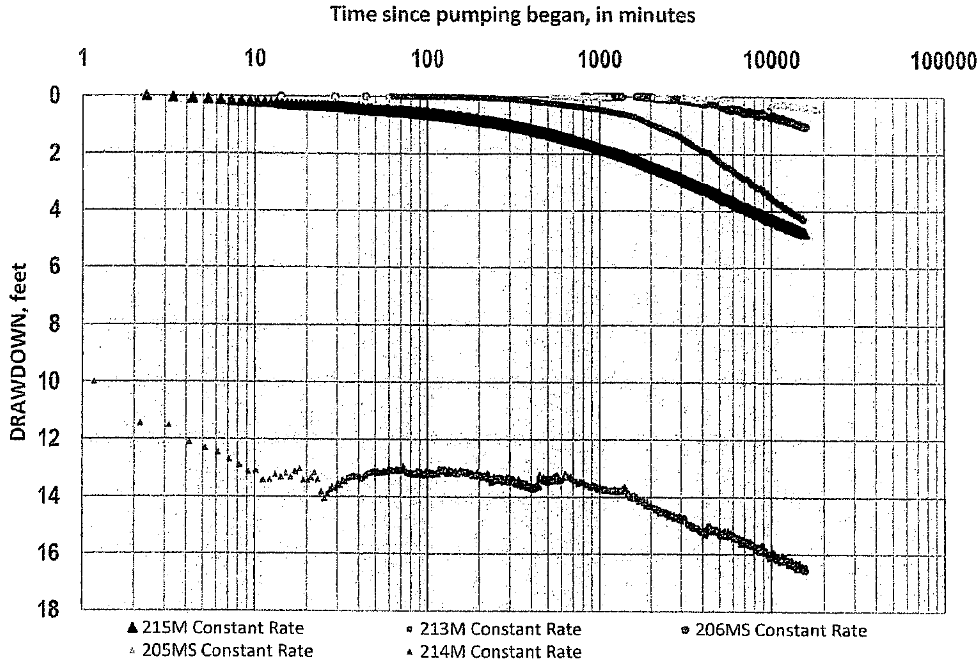


Figure 20: Semi-log plot of drawdown from observation wells, 214T test.

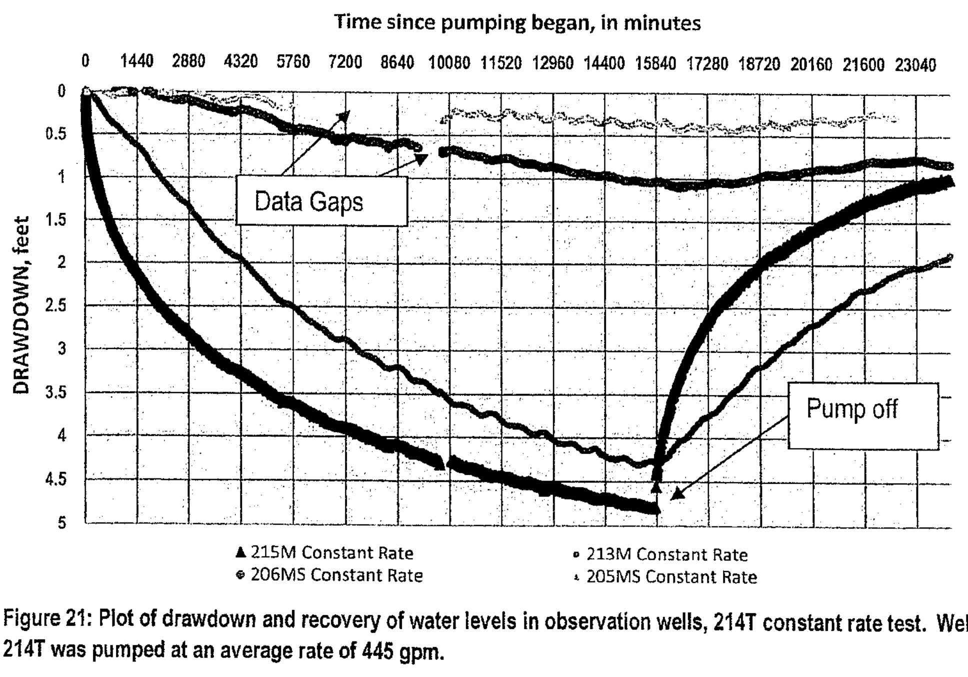


Figure 21: Plot of drawdown and recovery of water levels in observation wells, 214T constant rate test. Well 214T was pumped at an average rate of 445 gpm.