HYDROLOGIC and NITRATE ANALYSIS of the BUD KING RANCH FRENCHTOWN, MONTANA

Prepared For:

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INTRODUCTION

Bud King proposes to intermingle 36 lots with a golf course on approximately 18 acres just west of Frenchtown, Montana. The proposed subdivision, which has been divided into three phases, is located in the center of the west half, Section 34, T15N, R21W (Figure 1). A small westerly corner of Phase I is located in Section 33. The purpose of this report is to address the potential effects of 36 on-site septic systems on deep and shallow groundwater.

METHODS

Previous groundwater information was gathered relative to water quality and aquifer characteristics. A field investigation was undertaken to gather additional site specific information.

Literature Review. Geology and Ground-Water Resources of the Missoula Basin, Montana (McMurtrey et al., 1965) and Basic Water Data Report No. 1 (Brietkrietz, 1964) was reviewed relative to aquifer test data, seasonal groundwater level fluctuations, direction of flow and hydraulic gradient in the Frenchtown area. Generalized hydraulic conductivity values in the Frenchtown area were also obtained from a map prepared by Shannon (1990). The Chemical Section of Missoula Valley Water Study, Well and Surface Water Analysis (Juday and Keller, 1978) was examined for chemical water quality data of area wells.

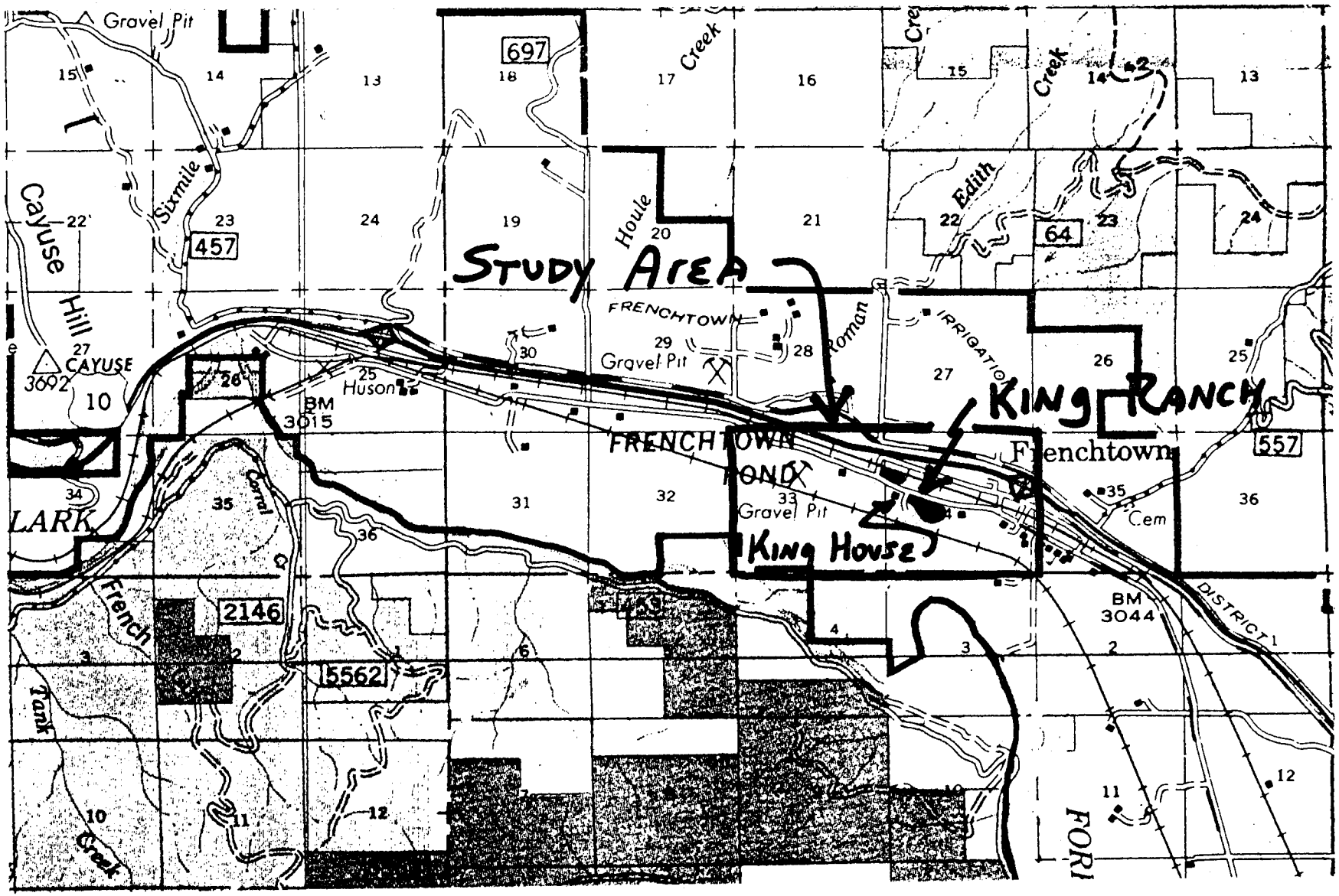
Drillers logs for Section 33 (Supplement A) and 34 (Supplement B) were obtained from the D,N.R.C. Water Rights Office in Missoula and the Bureau of Mines and Geology in Butte and summarized (Appendix A and B).

Aquifer Tests. Separate aquifer tests were conducted on the two Bud King wells. The 5 inch, 172 foot deep domestic well (no well log) was pumped for 131 minutes at 27.7 gpm using a centrifugal pump. The 6 inch, 22 foot deep shop well (no well log) was pumped for 102 minutes at 24.3 gpm. A pressure transducer was installed in each well prior to pumping to measure drawdown and recovery in both the pumped well and adjacent non-pumped well and connected to a datalogger system that recorded water levels at 30 second intervals. Data from the datalogger was then downloaded into a computer for analysis. Pre-pumping static water levels were measured with an electric well sounder. Pumping rates were measured throughout each test with a 20 gallon container and a stopwatch.

The distance between the domestic and shop well was measured using a 500 foot engineer's tape. The mean sea level (MSL) elevation of each well was determined by Mike Schwarts, P.E., PCI, Missoula. MSL static water levels were then compared.

Data Analysis. ISOAQX (v 2.85), a graphics oriented aquifer characterization and prediction program, developed by HydraLogic, Missoula, Montana, was used to analyze drawdown and recovery data,

Figure 1. General viciity map showing the location of the proposed subdivision on the Bud King Ranch west of Frenchtown, Montana.



to graph results relative to observed drawdown and to estimate the effects of increased withdrawal rates on the King domestic well.

Groundwater Mapping. Direction of flow and hydraulic gradient were determined using shallow groundwater wells located in the central part of Section 34 (Brietkrietz, 1964). Water levels measured on or about September 20, 1961, and MSL elevations were provided by Brietkrietz (1964). Individual wells were precisely located on a Missoula County Plat map (Figure 2). Groundwater elevations for wells belonging to Erickson, Hamel, Lauzier, McDonald, and the Northern Pacific Railroad (22 foot deep well - no drillers log) were used. Based on the assumption that water levels in all shallow wells in the center of Section 34 fluctuate in a like manor, water levels in the Hamel, Lauzier and Northern Pacific wells were adjusted to September 20, 1961, using the continuous water level record for the Northern Pacific well (Brietkrietz, 1964). A groundwater map was then developed using a programmable calculator. Lines of equal elevation were hand drawn.

Nitrate-N Samples. Water samples were collected from the Bud King shallow and deep wells and the Richards 176 foot deep well (Thompson log #20, Supplement A) at 10,545 El Toro Lane on 12/18/91. Water samples were analyzed for nitrate by Dr. Richard Juday, Department of Chemistry, University of Montana, Missoula. Additional nitrate data for three additional wells was obtained from the Missoula City County Health Department records.

Nitrate Sensitivity Model. A spreadsheet was developed to estimate the effects of 8, 12 and 16 septic systems (Phases I, II and III) on groundwater down-gradient from the three phases based the methodology described by Bauman and Schafer (1984). Background nitrates in the shallow aquifer were assumed to be the average of the King deep and shallow wells and the Richards deep well. All data used in the model was the best available. The hydraulic conductivity value used was the lowest figure obtained by analyzing the King shallow well data with different analytical models.

Nitrate sensitivity analysis was not performed for the deeper artesian aquifer because the pressure head in the deep aquifer was found to be greater than the shallow aquifer. This would preclude vertical migration of surface water into the deep aquifer.

RESULTS

Hydrogeology. There are two separate and distinct aquifers in the Frenchtown area. Although McMurtrey et al. (1965) did not identify two separate aquifers, they conducted aquifer analysis on data from both the deep and shallow wells in Section 34, test pumped a shallow well in Section 34, and presented drillers log data for two obviously different aquifers (Brietkrietz, 1964).

Table 1. List of wells in Sections 25 and 26, T15N, R22W, near Huson, Montana. (from Montana Bureau of Mines and Geology, Butte, Montana.)

~~LIST WELLS LOCAT SHORT NAME TO STATIC WATER LEVEL YIELD YEAR WATER USE AQUIFER WITH TWN RNG = "15N 22W" WITH SEC = 25 26 36 34~~

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LOCATION	SITE NAME	TOTAL DEPTH FEET	STATIC WATER LEVEL (FT)	YIELD GPM	YEAR	WATER USE	AQUIFER	LITH LOG
15N 22W 25 A	ROSE RAYMOND J.	40.0	16.00	800.0	1955	UNKNOWN		2
15N 22W 25 ACB	ROSE RAYMOND J.	115.0	17.00	75.0	1972	DOMESTIC		1
15N 22W 25 B	CYR KENNETH C.		30.00		1933	DOMESTIC		2
15N 22W 25 B	MURRAY H O	181.0	2.00	50.0	1987	DOMESTIC		1
15N 22W 25 BC	BEELER BEN	180.0	2.00	50.0	1985	DOMESTIC	110ALVM	1
15N 22W 25 BD	RICE MCCOY	47.0	5.00	35.0	1964	DOMESTIC	110ALVM	1
15N 22W 25 BD	RICE MCCOY	44.0	5.00	35.0	1964	DOMESTIC	110ALVM	1
15N 22W 25 BD	BEELER BEN & B	178.0	+.	43.0	1973	DOMESTIC STOCKWATER	120SDMS	1
15N 22W 25 BD	GARNETT JAMES	178.0	4.00	100.0	1973	DOMESTIC	120SDMS	1
15N 22W 25 BD	BRUCE DOUG	202.0	5.00	50.0	1979	DOMESTIC	120SDMS	1
15N 22W 25 C	BEELER BEN	184.0	4.00	60.0	1987	DOMESTIC		1
15N 22W 25 CA	VINTON TED	185.0	+11.5	30.0	1979	DOMESTIC	110ALVM	1
15N 22W 25 DA	SCHEFFER RALPH P.		17.00		1890	DOMESTIC STOCKWATER		2
15N 22W 25 DB	LEHMAN JOHN	188.0	0.00	100.0	1971	DOMESTIC	120SDMS	1
15N 22W 25 DB	LEHMAN JOHN	132.0	0.00	100.0	1970	DOMESTIC	120SDMS	1
15N 22W 25 DD	ROSE RAY	184.0	0.00	60.0	1969	DOMESTIC	120SDMS	1
15N 22W 26 AA	BROWN AL	199.0	0.00	100.0	1985	DOMESTIC	110ALVM	1
15N 22W 26 AA	SHERRY TOM	178.0	+.	75.0	1980	UNKNOWN	120SDMS	1
15N 22W 26 AAD	UNRUH KEN	183.0	+5.0	75.0	1983	UNKNOWN	110ALVM	1
15N 22W 26 AB	BIGGERS GENE	200.0		0.0	1977	DOMESTIC	120SDMS	1
15N 22W 26 ABBC	BONOURENT J.A.	111.0	1.00	20.0	1965	DOMESTIC	120SDMS	1
15N 22W 26 ABD	JONES M.E.	122.0		300.0	1960	IRRIGATION	120SDMS	1
15N 22W 26 AD	TIENSVOLD BERNIE	179.0	+.	100.0	1985	DOMESTIC	110ALVM	1
15N 22W 26 AD	CLARK ROGER	180.0	+.	30.0	1979	DOMESTIC	120SDMS	1
15N 22W 26 AD	WILLIAMS DENNIS	178.0	9.00	100.0	1973	DOMESTIC	120SDMS	1
15N 22W 26 BBA	MEARE ALLEN	80.0	6.00	16.0	1966	DOMESTIC	120SDMS	1
15N 22W 26 BD	JOHNSON DALE	124.0	+.	35.0	1970	DOMESTIC		1
15N 22W 26 DAA	STENERSON CHARLES	184.0		40.0	1976	DOMESTIC		1
15N 22W 26 DAA	STENERSON CHARLES	184.0			1976	DOMESTIC	120SDMS	1

29 records listed.

The strongest evidence supporting a two aquifer system is the MSL elevation of the water surface in the Bud King deep and shallow wells. On December 23, 1991, the MSL elevation of the water surface in the King shallow well was 3Ø83.68 feet. The MSL elevation was 3Ø89.43 feet in the King deep domestic well. Therefore, at the Bud King residence, the potentiometric surface in the deep well was 5.75 feet **above** the surface water elevation in the shallow well.

In addition to this, numerous drillers logs indicate the presence of "quicksand" (Supplements A and B). A positive (upward) vertical flow component causes this "quick" condition. Drillers logs that noted "quicksand" were:

Supplement A - Sec.33	
# 2	Joseph Boyer

Supplement B - Sec. 34	
# 6	Frenchtown Fire Department
#16	Harvey McDonald
#2Ø	Northern Pacific Railway
#21	Joe Pineur
#25	Herbert Seibert

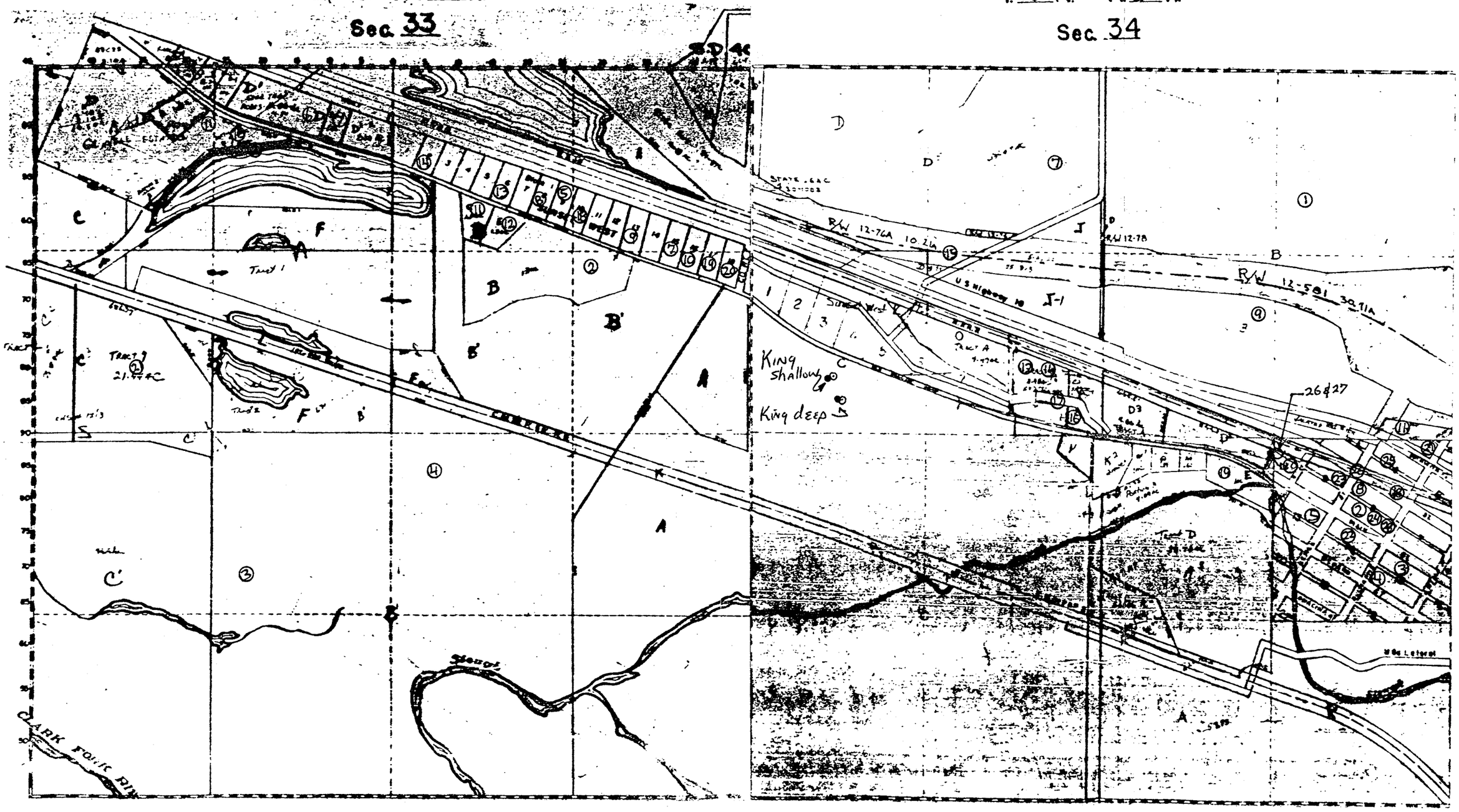
Evidence of different MSL elevations between the deep and shallow aquifer is also apparent both east and west of Frenchtown. To the east in Sec. 13, T14N, R21W, the water level in the 4Ø foot deep Cardon shallow well (B14-21-cd, Brietkrietz, 1964) is **above** that of the 153 foot deep Williams well (B14-21-dc2, Brietkrietz, 1964). This relationship becomes apparent when MSL water levels of these adjacent deep and shallow well pairs are plotted. MSL elevations of measured water levels in the Williams and Cardon wells (Brietkrietz, 1964) were plotted versus time for the available period of record (Appendix C). It can be noted that water level fluctuations in the two wells are synchronized and that a 6 to 7.5 foot MSL head separation is maintained (Appendix D).

Several miles to the west in the Huson area the same situation occurs only the potentiometric surface in the deep aquifer appears to be greater than that of the shallow aquifer. In the vicinity of Huson, Montana, the potentiometric surface in some wells is above land surface (Table 1) while the top of the shallow water table remains 1Ø to 2Ø feet below land surface.

Based on the static water level and the MSL elevations of individual wells given by Brietkrietz (1964), the direction of groundwater flow in the shallow aquifer just east of the King Ranch was estimated to be approximately 19Ø° true or S1Ø°W (Appendix E). The hydraulic gradient was Ø.ØØ94 through the area mapped (Appendix E) and is assumed to be the same in the vicinity of the Bud King Ranch. Direction of flow and hydraulic gradient are not expected to vary much seasonally.

The direction of groundwater flow in the deep confined aquifer is not known. But, in the vicinity of the King Ranch, it is assumed parallel the Clark Fork River or be slightly towards the river. It

Figure 2. Copy of Missoula County Plat Maps of Sections 33 and 34, T15N, R21W used to locate known wells in the vicinity of Bud King Ranch.



is further assumed that the hydraulic gradient in the deep aquifer is less than that of the water table aquifer.

Aquifer Test. Aquifer test results of the Bud King well indicate that the Transmissivity (T) of the shallow aquifer is between 13,635 ft^2/day (Appendix F and G) and 30,777 ft^2/day (Appendix H) depending on the analytical model used. When the King test data was analyzed it was assumed that the saturated thickness (M) of the shallow aquifer was 10 feet (actual thickness will vary by site). Since T = K * M, hydraulic conductivity (K) is believed to range between 1,363 ft/day and 3,078 feet/day (Table 2).

Because the King wells were pumped using a centrifugal pump and a small diameter lift hose, pumping rate oscillated slightly causing the pumping level to rise and fall. Due to the cyclic nature of the data (Appendix F and I), the Gravity Drainage Water-Table Model could not be used to evaluate drawdown in the shallow aquifer and the Hantush-Jacob Model could not be effectively used to determine leakance values in the deep aquifer.

McMurtrey et al. (1965) reported Transmissibility values (old term for Transmissivity) for both a deep and shallow wells in Section 34 approximately 3/4 mile due east of the King Ranch. Transmissivity (T) of the shallow, 22 foot deep Northern Pacific well, based on an actual test, was 11,364 ft^2/day (K = 1,136 ft/day assuming M = 10 feet). This K value is very close to the 1,363 ft/day value obtained from the King shallow well test.

The Hydraulic Conductivity Map of Missoula Valley (Shannon, 1990) (Appendix N), indicates a range of K values for the S/2, Sec. 34 as being between 500 and 2000 gpd/ft^2 (66.8 to 267.4 ft/day) or 7,436 to 29,747 meters/year. Shannon's 2,000 gpd/ft^2 value is 4.25 times smaller than the value reported by McMurtrey et al. (1965) and 5 times smaller than the value obtained from the test of that Bud King shallow well. Regardless of whose numbers one chooses to believe, the hydraulic conductivity in the portion of the shallow aquifer west of Frenchtown near the Clark Fork River is very high.

Nitrate-N in Groundwater. The nitrate-N concentration of the Bud King shallow well was 0.57 mg/l (Appendix J). The other two nitrate samples were taken from nearby deep wells. Average nitrate-N concentration for the three wells sampled was 0.70 mg/l (Appendix J). This suggests that nitrate values are lower in the shallow aquifer than in the deeper confined aquifer.

Nitrate concentrations in three other deep wells in the area were looked at but were not used to calculate background nitrates because two of the wells (Frenchtown High School and Frenchtown Grade School)(Appendix K) were somewhat removed from the project area. The well(s) serving the Grinnell Estates (No.15 and No.16, Appendix A, Supplement A), although closer to the King Ranch, are also deep.

Table 2. Hydraulic constants determined by aquifer tests on wells in T15N, R21W, Sec. 34.

Well	Depth	Analytical Model	Transmissivity	K(ft/day)	Test Date	Tested by
Bud King	22'	Theis W-T	13,635 ft^2/day	1,363	12/23/91	H. Newman
"	22'	Semi-Log Drwn.	20,898 ft^2/day	2,089	12/23/91	H. Newman
"	22'	Semi-Log Rec.	30,777 ft^2/day	3,078	12/23/91	H. Newman
Bud King	172'	Theissian	17,934 ft^2/day	-	12/23/91	H. Newman
"	172'	Semi-Log Rec.	7,094 ft^2/day	-	12/23/91	H. Newman

Aquifer test data for wells in T15N, R21W, Sec. 34, from McMurtrey, et al (1965).

Well	Depth	Analytical Model	Transmissivity	K(ft/day)	Test Date	Tested by
15-21-34da1	22'	Theis (1935)	85,000 gpd/ft		1965 (?)	McMurtrey et al
N.P. Railroad			11,364 ft^2/day	1,136		
	22'	Jacob (1947)	93,000 gpd/ft	1,243	?	Driller
15-21-34da2	165'	Jacob (1947)	25,000 gpd/ft	-	1965 (?)	Driller
Seibert, H.			3,342 ft^2/day	-		

NOTE: Theis (1935) Model - It is assumed that the Theis non-equilibrium method was used to analyze drawdown data.

Jacob (1947) Model - Transmissivity was calculated from Specific Capacity based on pumping rate and drawdown reported by drillers.

The last nitrate-N value for Grinnell Estates was Ø.5Ø mg/l on 4/5/9Ø (Appendix L) and was half the concentration reported at the Frenchtown Schools. The Grinnell data was also disregarded.

Nitrate Sensitivity Analysis. Nitrate sensitivity analysis asserts that the addition of 8, 12 and 16 home sites (36 units total) on the King Ranch will cause nitrate levels to increase Ø.Ø6 mg/l below Phase I, Ø.Ø9 mg/l below Phase II and Ø.11 mg/l below Phase III (Appendix M). Resultant nitrate-N concentrations down-gradient from the individual phases will be Ø.76 mg/l, Ø.79 mg/l and Ø.81 mg/l in Phases I, II and III based on a background concentration of Ø.7Ø mg/l.

If lower values of K are used in the Nitrate Sensitivity Model, nitrate impacts to shallow groundwater will be proportionally greater. K values of 2,ØØØ gpd/ft^2, 1,ØØØ gpd/ft^2 and 5ØØ gpd/ft^2, as reported by Shannon (199Ø), would result in nitrate-N concentrations of 1.Ø2 mg/l, 1.33 mg/l and 1.93 mg/l (Appendix M, bottom of spreadsheet) down-gradient from Phase I. Because these K values have been shown to be too small, they were not deemed appropriate for this assessment.

Water Availability. It is proposed to use the King domestic well to provide water for the golf course club house. Analysis revealed Specific Capacity of this well to be 33.8 gpm/foot of drawdown. T was 17,934 ft^2/day (Appendix I). Therefore, this well is capable of being pumped in excess of 1ØØ gpm and will easily meet the estimated demand of 45 gpm for both club house and King residence. If pumped at 45 gpm drawdown will be about 2.5 feet.

CONCLUSIONS

The following conclusions can be made based on the analysis of groundwater quality and quantity relative to the proposed development of the Bud King Ranch.

1. The only shallow well tested for nitrates (King shop) had the lowest nitrate-N concentration of the three wells sampled. Average nitrate-N concentrations in both the deep and shallow aquifer was Ø.7Ø mg/l.

2. There appear to be two distinguishable aquifers in this area, a shallow water table system and a deeper confined, or more likely leaky confined, aquifer.

3. Transmissivity of King shop well was similar to the value reported by McMurtrey et al. (1965) for the 22 foot deep Northern Pacific well. Therefore, a K value of 1,363 ft/day was considered appropriate to use in the Nitrate Sensitivity Model. Although the depth of the shallow aquifer varies, there is a large volume of water moving through this system.

4. The King Ranch Subdivision, as proposed by PCI, will have a minimal impact on the shallow groundwater in the area. Resultant nitrate-N concentrations in the shallow aquifer, down-gradient from the individual phases, are estimated to be 0.76 mg/l, 0.79 mg/l and 0.81 mg/l below Phases I, II and III respectively.

5. The direction of flow, in the vicinity of the King ranch, is southerly. Therefore, it appears that no domestic well will be affected by this proposed development.

6. Due to the differences in pressure head between the deep and shallow aquifers, and because it appears that this relationship doesn't change for at least five miles to the west, there is little doubt that nitrate contributions to the shallow aquifer will enter and adversely impact the deeper aquifer.

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Appendix A. Drillers log record for wells in Section 33, T15N, R21W, Frenchtown, Montana.

No.	Name or Owner	Date Completed	Well Depth	Static Water Level	Pump Rate (gpm)	Spec. Cap. gpm/ft	Aqu. Type	Well Location
1	Block, Warren	07/20/87	178.75	8	100+	0.59	C	Good
2	Boyer, Joseph	10/10/49	176	6	80?	6.7	C	Excellent
3	Boyer Land	04/15/91	22.5	10	25	50	W	Fair
4	Boyer Land	04/17/91	22	10.5	25	50	W	Fair
5	Klaudt, Gorden	05/20/76	171	10.3	50	75	C	Excellent
6	Korman, Donald	02/15/77	165	2	20	4.35	C	Good
7	Leach, Don	03/30/77	175	12	80	10	C	Excellent
8	McNeal, Thomas	05/05/80	170	20	50	4.2	C	Excellent
9	Nordberg, John	10/06/74	174	10	30	3.75	C	Excellent
10	Nordwick, Kalvin	11/16/89	170	5	50	7.1	C	Excellent
11	Parker, James	07/17/62	27	14	60	15	W	Fair
12	Parker, James	05/29/80	174	10.5	100	5.13	C	Good
13	Parker, Jon V.	03/21/76	171	11	100+	11.1	C	Excellent
14	Parker, Less	05/01/74	178	10.5	30	20	C	Excellent
15	Putnam, Bette	09/17/79	182.5	9.5	150	21.4	C	Excellent
16	Putnam, Bette	09/20/79	184	10	175	25	C	Excellent
17	Simpson, Gene	08/07/79	180	9	20	1.82	C	Excellent
18	Ternes, Lee	03/29/78	30	12	15	1.15	W	Excellent
19	Thompsen, Dewey	06/24/77	167.5	6	99	1.06	C	Excellent
20	Thompson, Robt.	07/27/74	176	10	30	15	C	Excellent
21	Woodworth, J.	11/14/85	166	5	50	3.33	C	Good

Aquifer Type: C = confined, W = water table

Well Location:
Excellent - Well located with certainty according to Plat Map and COS.
Good - Well located on County Plat Map. Lot too big for exact location.
Fair - Well location only generally known relative to County Plat Map.

Note: Drillers logs of above mentioned wells are contained in Supplement A.

Appendix B. Drillers log record for wells in Section 34, T15N, R21W, Frenchtown, Montana.

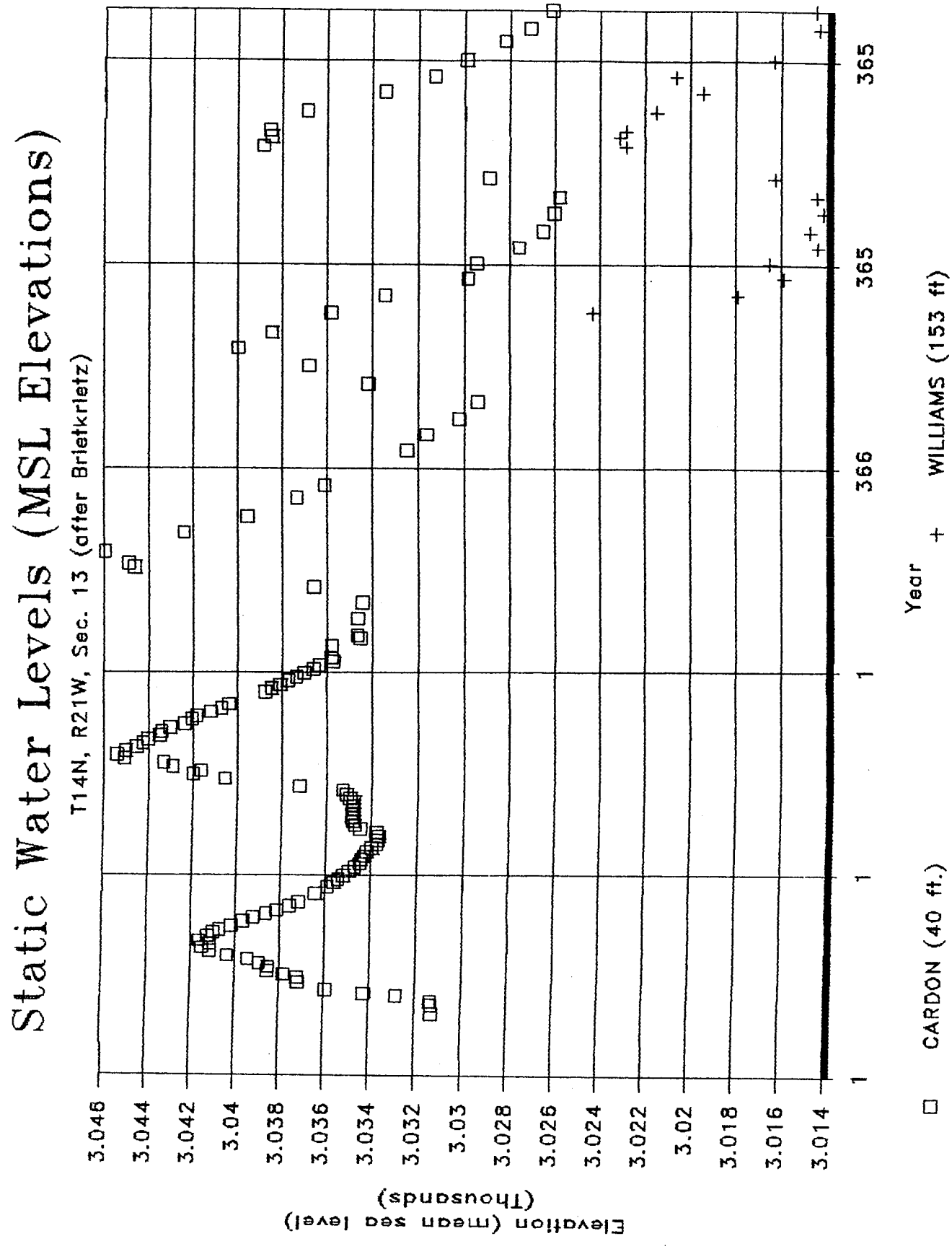
No.	Name or Owner	Date Completed	Well Depth	Static Water Level	Pump Rate (gpm)	Spec. Cap. gpm/ft	Aqu. Type	Well Location
1	Alexander, M.	10/24/88	161	10?	30	?	C	Fair
2	Chappus, Joseph	12/15/73	160	6.5	80	-	C	Excellent
3	Corcoran, Robert	1943	17	14	20	-	W	Excellent
4	DeBack, Camiel	1941	22	14	20	-	W	Excellent
5	Fink Cyr., James	11/01/60	34	25?	11	-	W	Excellent
6	Frenchtown Fire	11/29/74	176.3	8	300	3.26	C	Excellent
7	Frenchtown H.S.	06/13/80	177	11	200	2.25	C	Good
8	Hamel, Edmond	1915	24	-	-	-	W	Fair
9	Hamel, Edmond	06/21/74	161	7	47	1.24	C	Fair
10	Hamel, Flore	1890	25	15	40	-	W	Excellent
11	Lindback, Robert	1935	14	10	10	-	W	Fair
12	McDonald, Harry	10/11/73	31.5	12	35	2.69	W	Excellent
13	McDonald, Harry	1949	188	-	-	-	C	Fair
14	McDonald, Anna	06/29/88	168	12	80	6.67?	C	Excellent
15	McDonald, Harvey	04/29/78	161	10.5	40	0.45	C	Excellent
16	McDonald, Harvey	1948	192	16	200	-	C	Good
17	McDonald, Jess	1917	27	17	400	-	W	Fair
18	Moore, Amos	04/08/66	177	12	80	80?	C	Poor
19	Nikoleyczik, O.	02/13/91	170	30	75	3	C	Good
20	Northern Pacific	11/22/55	160	10	12	0.86	C	Good
21	Pineur	06/18/66	165	6.3	30	2.2	C	Good
22	Raymond, Bertha	01/10/74	160	8	60	60	C	Excellent
23	Running, Clinton	03/17/66	35	22	45	11.25	W	Excellent
24	Running, Clinton	08/22/59	30	-	40	-	W	Excellent
25	Seibert, Herbert	1954	165	11	15	7.5	C	Fair
26	Smith, Marvin	06/13/74	160	8	60	0.65	C	Fair
27	Smith, Marvin	04/12/82	146	4	50	4.55	C	Fair
28	Smith, Otto	02/26/54	158	10	20	2	C	Poor

Aquifer Type: C = confined, W = water table

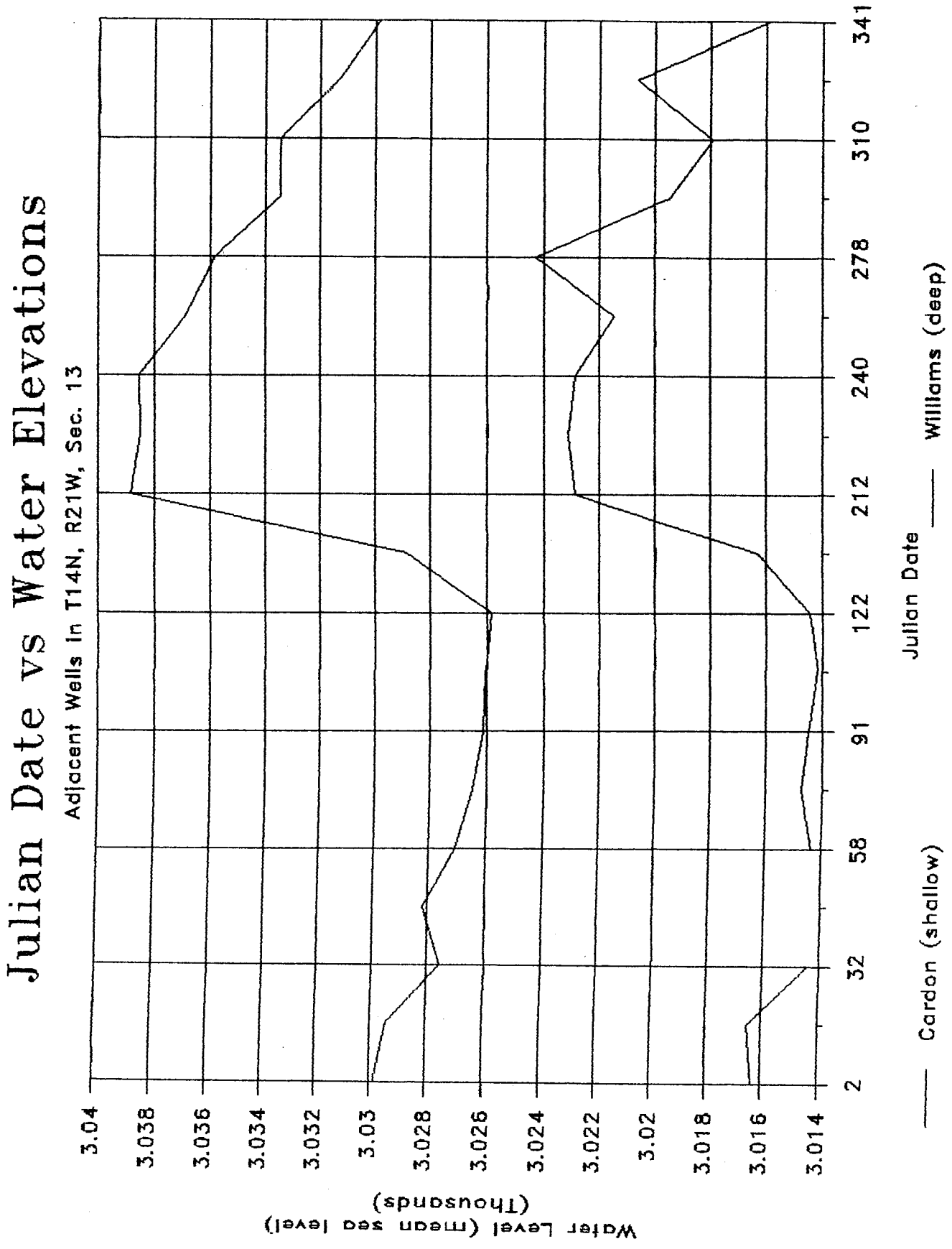
Well Location:
Excellent - Well located with certainty according to Plat Map and COS.
Good - Well located on County Plat Map. Lot too big for exact location.
Fair - Well location only generally known relative to County Plat Map.

Note: Drillers logs for above mentioned wells are contained in Supplement B.

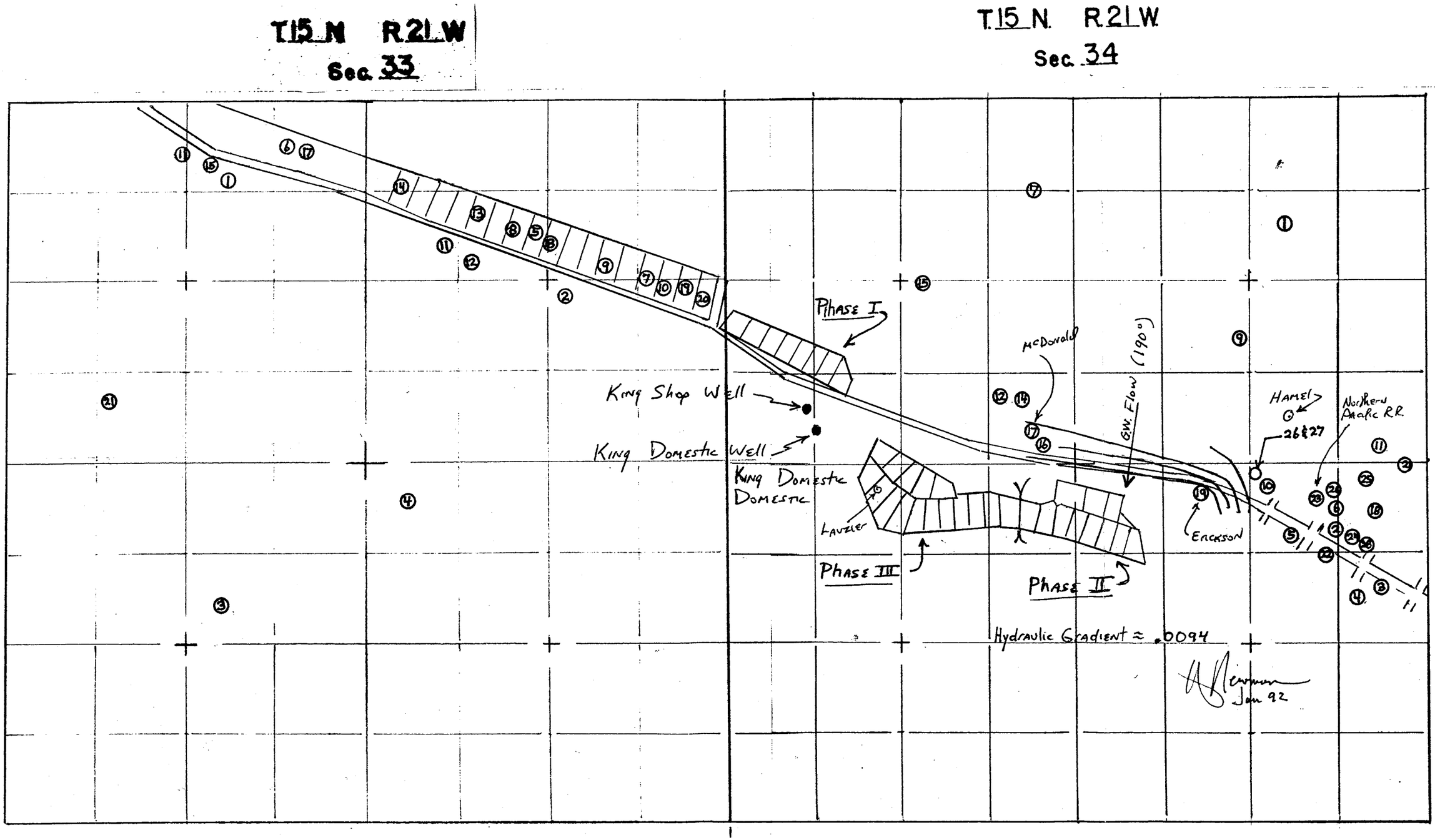
Appendix C


Static Water Levels (MSL Elevations)
T14N, R21W, Sec. 13 (after Brietkrietz)
Elevation (mean sea level)
(Thousands)
3.046
3.044
3.042
3.04
3.038
3.036
3.034
3.032
3.03
3.028
3.026
3.024
3.022
3.02
3.018
3.016
3.014
1
1
366
1
365
365
Year
CARDON (40 ft.)
WILLIAMS (153 ft)

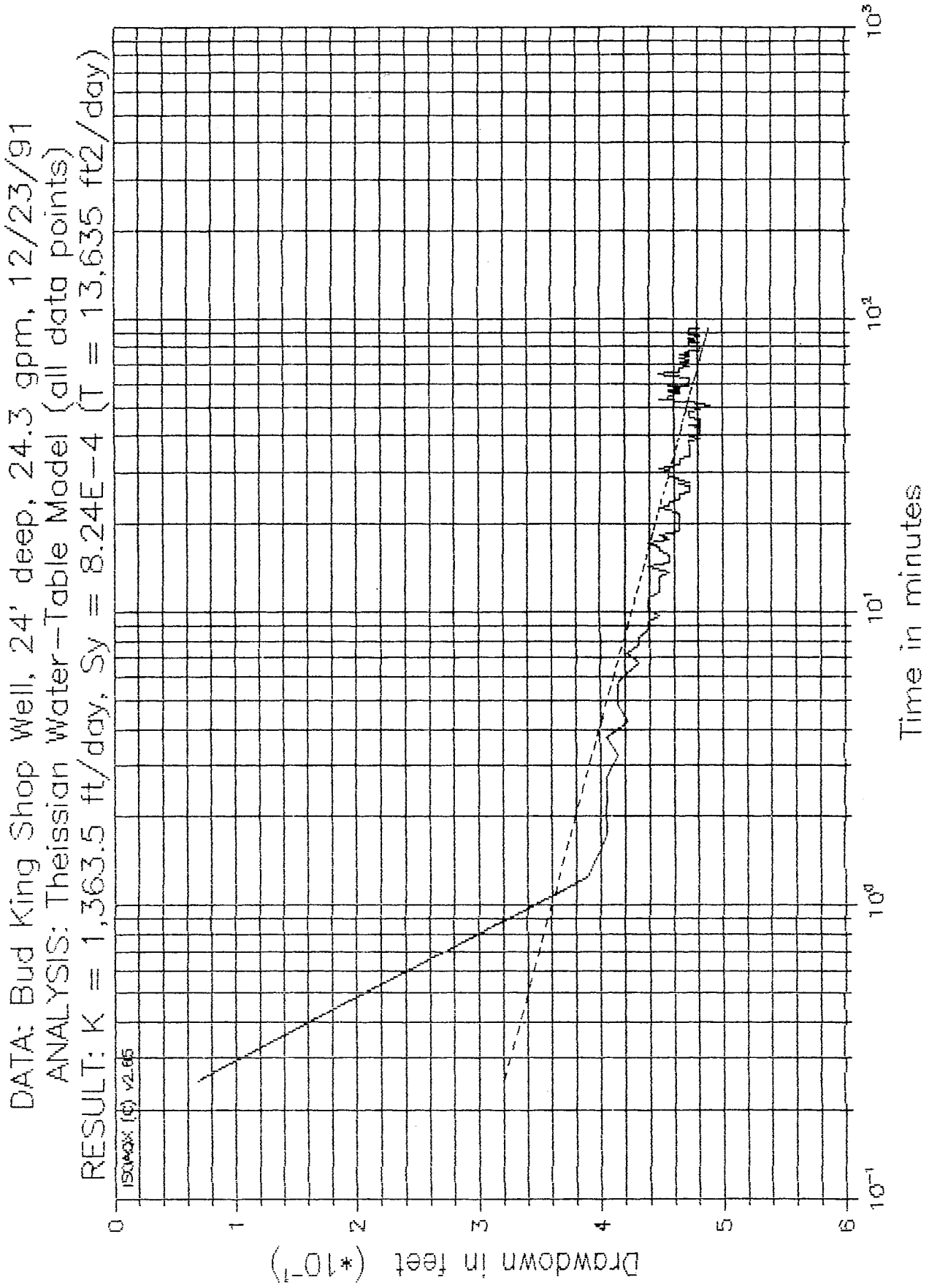
Appendix D


Julian Date vs Water Elevations
Adjacent Wells in T14N, R21W, Sec. 13
Water Level (mean sea level)
(Thousands)
3.04
3.038
3.036
3.034
3.032
3.03
3.028
3.026
3.024
3.022
3.02
3.018
3.016
3.014
2
32
58
91
122
212
240
278
310
341
Julian Date
Cardon (shallow)
Williams (deep)

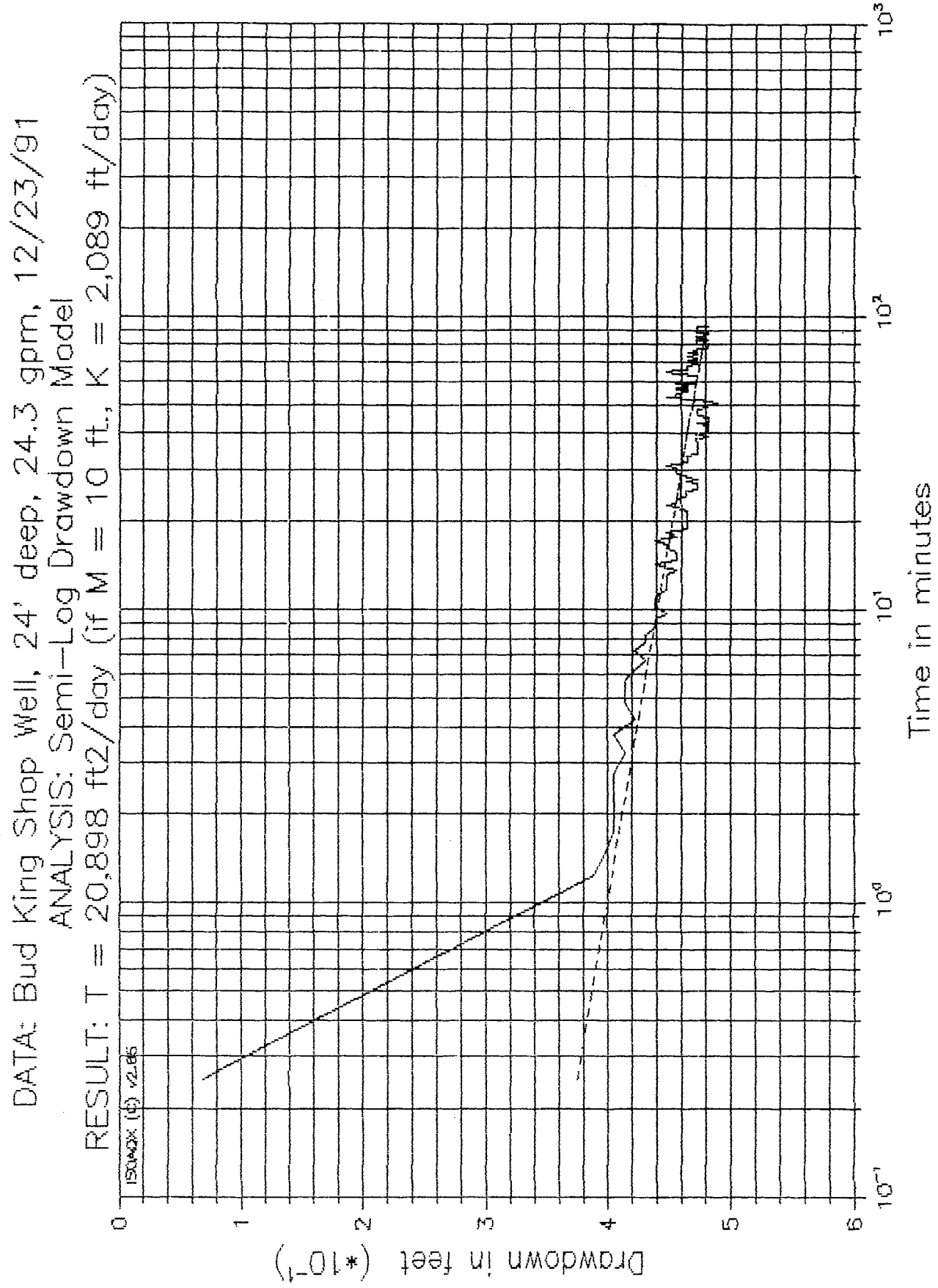
Appendix E. Overlay of Sections 33 and 34, T15N, R21W showing the location of all known wells in the vicinity of the Bud King Ranch including the wells used to determine direction of groundwater flow and hydraulic gradient.



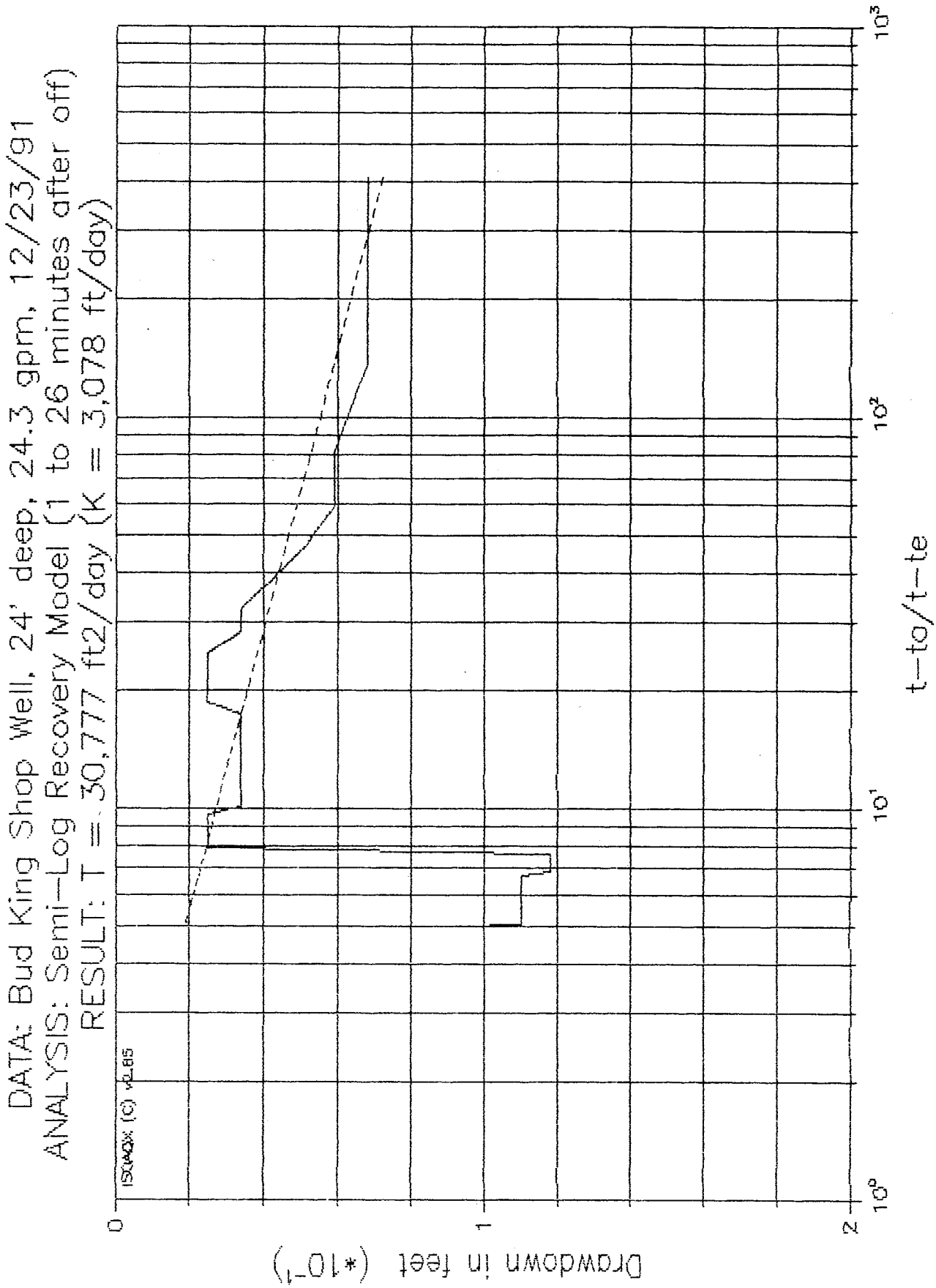
Appendix F


DATA: Bud King Shop Well, 24' deep, 24.3 gpm, 12/23/91
ANALYSIS: Theissian Water-Table Model (all data points)
RESULT: K = 1,363.5 ft/day, Sy = 8.24E-4 (T = 13,635 ft2/day)
AQTESOLV (tm) v2.65
Drawdown in feet (*10^-1)
Time in minutes
0
1
2
3
4
5
6
10^-1
10^0
10^1
10^2
10^3

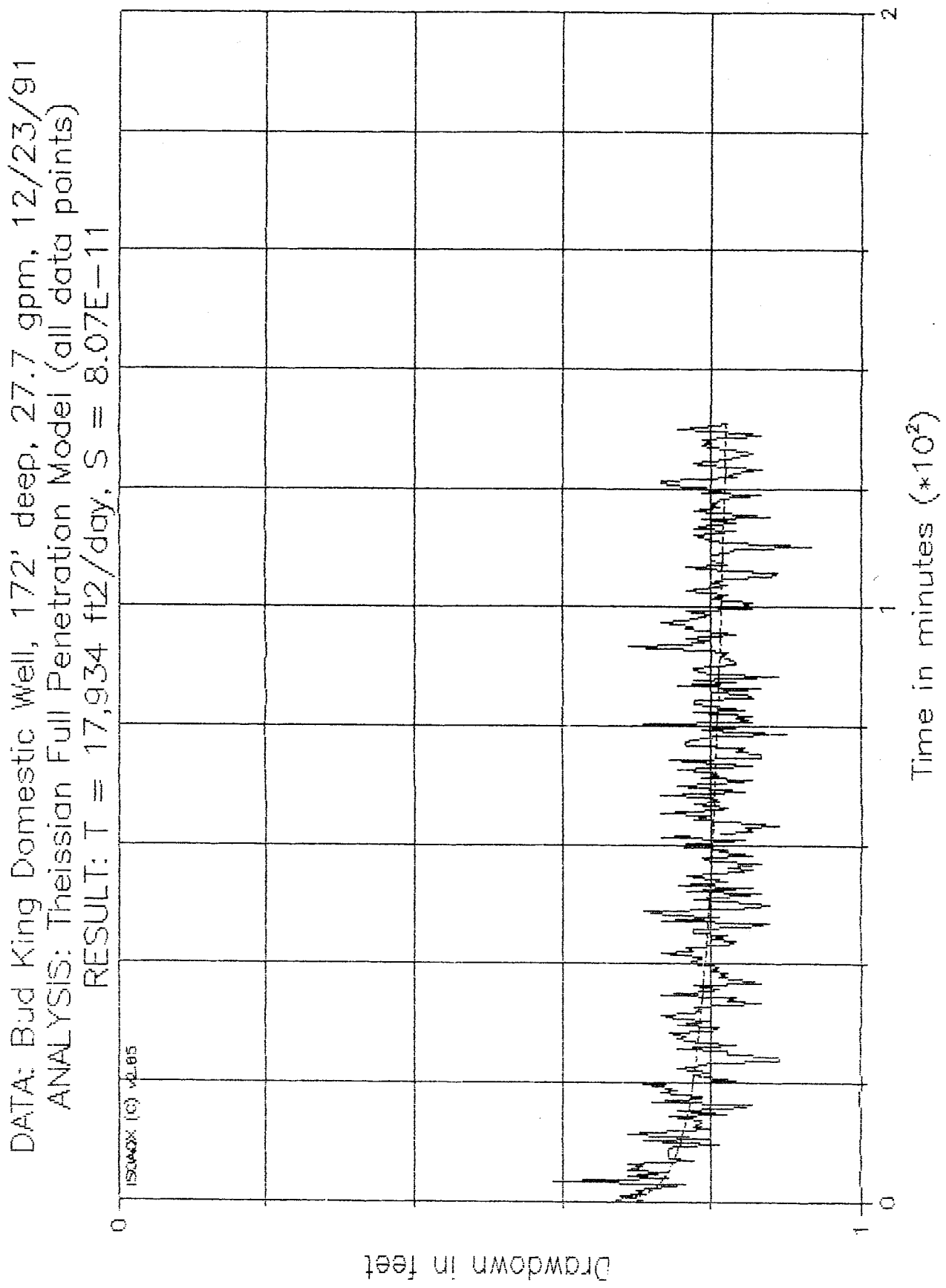
Appendix G


DATA: Bud King Shop Well, 24' deep, 24.3 gpm, 12/23/91
ANALYSIS: Semi-Log Drawdown Model
RESULT: T = 20,898 ft2/day (if M = 10 ft., K = 2,089 ft/day)
Drawdown in feet (*10⁻¹)
Time in minutes
0
1
2
3
4
5
6
10⁻¹
10⁰
10¹
10²
10³

Appendix H


DATA: Bud King Shop Well, 24' deep, 24.3 gpm, 12/23/91
ANALYSIS: Semi-Log Recovery Model (1 to 26 minutes after off)
RESULT: T = 30,777 ft2/day (K = 3,078 ft/day)
AQTESOLV (C) v2.65
0
1
2
Drawdown in feet (*10^-1)
10^0
10^1
10^2
10^3
t-to/t-te

Appendix I


DATA: Bud King Domestic Well, 172' deep, 27.7 gpm, 12/23/91
ANALYSIS: Theissian Full Penetration Model (all data points)
RESULT: T = 17,934 ft2/day, S = 8.07E-11
Drawdown in feet
Time in minutes (*10²)
0
1
2
0
1
AQTESOLV (C) v2.65

Appendix J

WELL WATER ANALYSIS

Name Bud King (H. Newman) Date 12/19/91

Location Frenchtown, Domestic well

Nitrate-nitrogen(ppm) 0.62

Conductivity (m-mhos) _____

Signed R E Juday
R.E. Juday

WELL WATER ANALYSIS

Name Bud King (H. Newman) Date 12/19/91

Location Frenchtown shallow, shop well

Nitrate-nitrogen(ppm) 0.57

Conductivity (m-mhos) _____

Signed R. E. Juday
R.E. Juday

WELL WATER ANALYSIS

Name Richards (H. Newman) Date 12/18/91

Location 10545 El Toro Ln

Nitrate-nitrogen(ppm) 0.91

Conductivity (m-mhos) _____

Signed R E Juday
R.E. Juday

Appendix K

OCT 31, 1991 MONTANA DEPT. OF HEALTH - NON-COMMUNITY WATER SUPPLIES
LISTING OF ALL NITRATE SAMPLES ON FILE
(NO3 + NO2 IN MILLIGRAMS PER LITER AS N)

CITY & WATER SUPPLY NAME	TYPE	ID	S	DATE	NO3-N
MISSOULA COUNTY					
FLORENCE					
LOLO TAVERN	N	0000804	G	02/11/91	.3
				02/11/91	.3
				09/01/81	1.0
				/ /	.3
FRENCHTOWN					
FRENCHTOWN GRADE SCHOOL	P	0002536	G	03/05/87	1.1
				07/20/81	.6
FRENCHTOWN HIGH SCHOOL	P	0000856	G	07/03/91	.9
				05/12/87	.7
				08/31/81	.2
FRENCHTOWN SHOPPING CENTER	N	0007392	G	11/28/88	.7
GREENOUGH					
CLEARWATER SUPPLY STONEY'S	N	0000816	S	05/13/80	.1
				/ /	.3
KOZY KORNER BAR	N	0000866	G	01/08/85	.6
				04/21/80	.4
ROUNDUP BAR	N	0000858	G	02/06/90	.2
				01/03/85	.1
				09/25/84	.1
				04/15/80	.2
WILD WEST TRADING POST	N	0000853	G	02/05/91	.1
				02/05/91	.1
				02/06/90	.1
				01/03/85	4.6
				04/01/80	1.0
HUSON					
NINE MILE HOUSE & TRLR CT	N	0000492	G	02/26/87	.0
				07/24/81	.1
NINEMILE RANGER STATION	N	0062578	G	09/14/93	.2
				09/01/80	.5
SIX MILE TAVERN	N	0000800	G	03/05/87	.6
				07/24/81	.4
LOLO					
HAYLOFT SALOON	N	0000808	G	02/11/91	.3
				02/11/91	.3
				04/01/86	.2
				08/13/80	1.1
LOLO HOT SPRINGS CAFE MOTEL	N	0000805	G	09/06/88	.1
				03/02/82	.1
LUMBER JACK SALOON	N	0000803	G	01/07/87	.0
				03/02/82	.1
PINEY WOODS CAFE & MOTEL	N	0000832	G	02/10/87	.2
				09/11/81	.2
TRIPPS STORE AND CAFE	N	0000815	G	11/30/88	.3
				09/01/81	.3
MILLTOWN					
HAPPY BUNGALO	N	0002150	G	05/12/87	.5
MISSOULA					
AERIAL FIRE DEPOT COMPLEX	N	0062369	G	09/02/80	1.2
AL CAN BAR	N	0000812	G	03/03/87	.9

Appendix L. Copy of Montana State Department of Health computer printout showing the chemistry of water from well(s) serving Grinnell Estates, Fremchtown, Montana.

, 1991 MONTANA STATE DEPARTMENT OF HEALTH - CHEMICAL ANALYSES OF COMMUNITY WATER SUPPLIES PAGE 192
(ALL VALUES IN MG/L EXCEPT PH AND CORROSION INDICES ARE IN STANDARD UNITS, AND ORGANICS ARE IN UG/L)

SAMPLING SITE	DATE / LAB NO.	PH / TDS / NO3-N	CA / MG / HARD	CO3 / HCO3 / ALK	CL / F / SO4	NA / K / BA	FE / SE / CD	PB / MN / HG	AS / AG / CR	ENDRIN / METHOX. / TOXAPH.	LINDANE / SILVEX / 2,4-D	LANG. / RYZN. / AGGR.
OULA COUNTY												
TOWN	GLESSNER TRAILER COURT						0000405 G					
GLESSNERS TRAILER COURT	01/17/89	7.7	39			7	# 1.01	< .005	.004			-0.3
			14	177	.1		.002	< .005	< .001			8.3
	89W0109	1.4	156	145	9	.3	.001	< .0002	< .005			11.9
GLESSNER TR CT FRENCHTOWN MT 59834	11/04/85	7.8	73			6	< .01	< .005	.004			0.0
			12	165	.1		< .002	< .005	< .01			7.7
	85W2454	.9	234	135	9	.3	.001	< .0002	< .005			12.2
GLESSNERS TRAILER CT	01/18/83	8.1	34			5		< .005	.005			-0.0
				132	.1		< .002		< .01			6.2
	83W0083	.7		108		.2	.001	< .0002	< .005			12.1
153 04901	09/04/81											
	81W1809	.5										
GLESSNER TR CT WC GLESSNER	01/09/79	8.2	32	1		5	< .01	< .005	.005			0.0
		210	11	154	.1	1	< .002	< .005	< .005			3.1
	79W0096	.2	127	129	3 <	.1	< .001	< .0002	< .005			12.2
HTOWN	GRINELL ESTATES						0003261 G					
GRINNELL ESTATES	04/05/90	8.2	40			11	.04	< .005	.006			0.2
			13	183	.1		< .001	< .005	< .001			7.7
	90W0785	.5	158	150	15	.3	< .001	< .0002	< .005			12.4
HTOWN	SORREL SPRINGS HOA						0000518 G					
SORREL SPRINGS FRENCHTOWN	03/25/86	8.0	36			8	< .01	< .005	.004			-0.0
			9	163	.1		< .002	< .005	< .01			9.1
	86W0593	1.1	133	134	5	.2	< .001	< .0002	< .005			12.1
SORREL SPRINGS	03/16/82	8.0	37			8		< .005	.005			-0.0
				182	.1		< .002		< .01			8.0
	82W0439	.0		149		.2	.001	< .0002	< .005			12.1
SORRELL SPRINGS DRAWER 3	08/29/79	8.2	40			8	.01	.006	.004			0.2
		248	10	183	.1	1	< .002	< .005	< .005			7.7
	79W2150 <	.0	146	150	3	.3	< .001	< .0002	< .005			12.4

Appendix M

EFFECTS OF VARYING HYDRAULIC CONDUCTIVITY AND MIXING DEPTH ON PREDICTED NITRATE-N CONCENTRATIONS IN GROUNDWATER IN THE W/2, SEC. 34, T13N, R20W IN THE VICINITY OF PROPOSED KING RANCH SUBDIVISION, FRENCHTOWN, MONTANA.

Nitrate concentrations are based on the following assumptions:

Average Annual Effective Ppt. = 3.31 inches = 0.084 meters (Frenchtown receives 18" of ppt. anually.)
Width across PHASE I perpendicular to direction of groundwater flow: 900 feet 274.3 meters
Width across PHASE II perpendicular to direction of groundwater flow: 950 feet 289.6 meters
Width across PHASE III perpendicular to direction of groundwater flow: 1080 feet 329.2 meters
Slope of water table within Section 34 (dh/dl) 0.0094 (McMurtrey, et al, 1965, modified by Newman, 1992)
Background Nitrate-N concentration = 0.70 (Average concentration of Bud King shallow and deep wells and the Richards, 176 foot deep well (Sec.33, #20) sampled on 12/19/91)
Nitrate-N concentration in soil = 0.1 mg/l
Nitrate-N concentration in septic effluent = 62 mg/l (Bauman & Schafer, 1984)
Maximum occupancy within proposed subdivision. 36 lots total in proposed Bud King Ranch development.
Area within proposed Phase I = 3.73 acres = 15,097 square meters
Area within proposed Phase II = 6.43 acres = 26,022 square meters
Area within proposed Phase III = 8.04 acres = 32,535 square meters
Septic effluent generated on-site = 155,125 l/house/y (Bauman & Schafer, 1984, and Missoula Census, 1991)
Hydraulic conductivity based on: Aquifer test of Bud King shallow well by H. Newman on 12/23/91.
Hydraulic gradient based on: Measured gradient (after Brietkrietz (1964), modified by Newman, 1992).
Aquifer thickness assumed to be 10 feet for purpose of analysis.

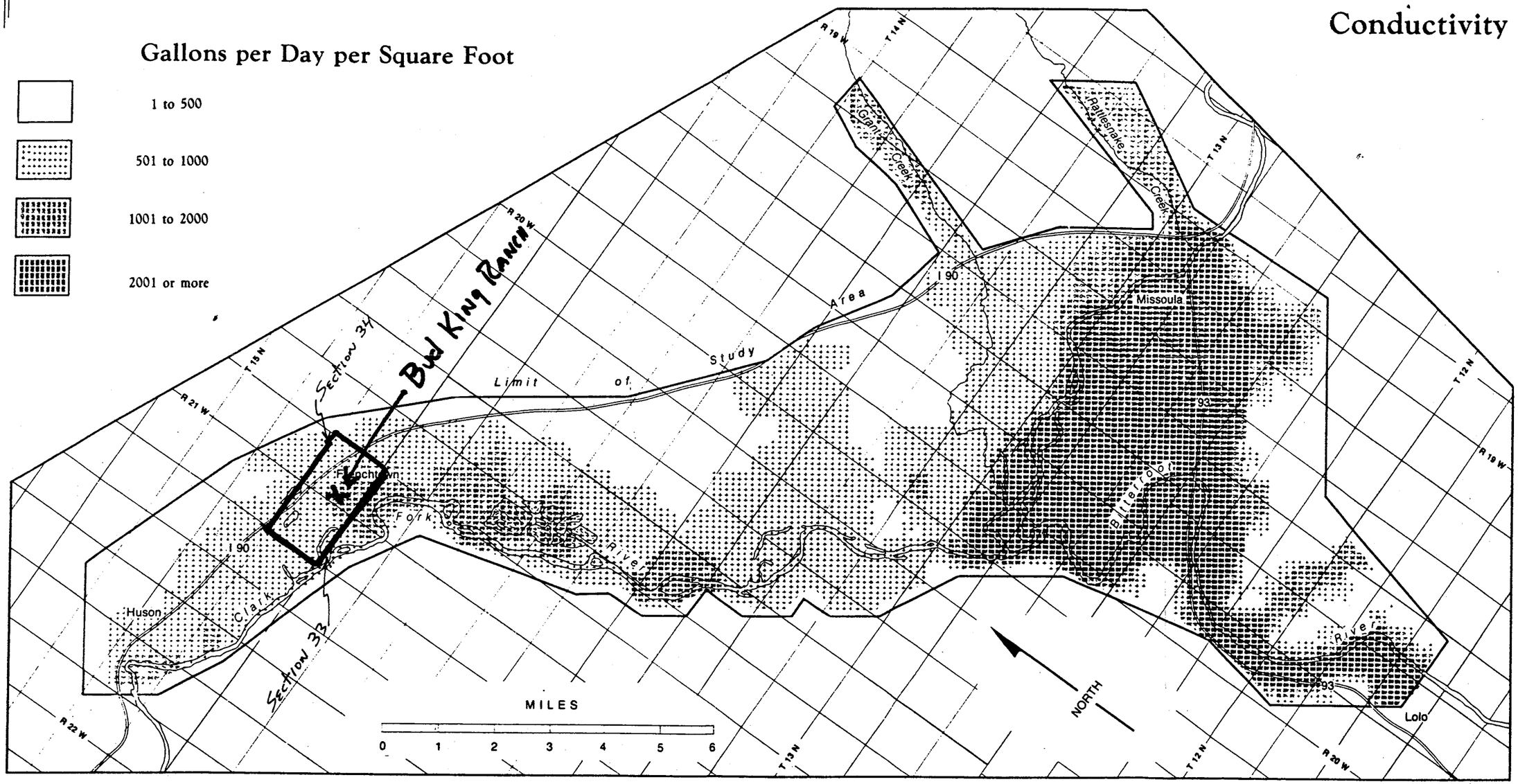
Wg = Groundwater entering upgradient boundary Ng = Nitrate N in groundwater (mg/l)
Wr = Natural recharge (varies) Nr = Nitrate-N in recharge (mg/l)
We = Septic system effluent generated on-site Ne = Nitrate-N in effluent (mg/l)

Hydraulic Cond. (gpd/ft2)	Hydraulic Cond. (m/yr)	Mixing Depth (meters)	Wg (m3/yr)	Wr (m3/yr)	We (m3/yr)	Wt (m3/yr)	Ng (g/yr)	Nr (g/yr)	Ne (g/yr)	Nt (g/yr)	Resulting Nitrate-N Nt/Wt (mg/l)
					Phase I - 8 Units						
10,199	151,697	3.05	1,193,057	1,268	1,241	1,195,566	835,140	127	76,942	912,208	0.76
					Phase II - 12 Units						
10,199	151,697	3.05	1,193,057	2,186	1,862	1,263,385	755,603	219	115,413	871,234	0.79
					Phase III - 16 Units						
10,199	151,697	3.05	1,193,057	2,733	2,482	1,436,883	859,001	273	153,884	1,013,158	0.81
					Phase I - 8 Units						
2,000	29,747	3.05	233,956	1,268	1,241	236,465	163,769	127	76,942	240,838	1.02
1,000	14,874	3.05	116,978	1,268	1,241	119,487	81,884	127	76,942	158,953	1.33
500	7,437	3.05	58,489	1,268	1,241	60,998	40,942	127	76,942	118,011	1.93

Howard Newman
01/15/92

Missoula Valley Aquifer Pollution Potential

Hydraulic Conductivity



Compiled by Jon Shannon 1988

Figure 7

Cartography by Steven R. Holloway