

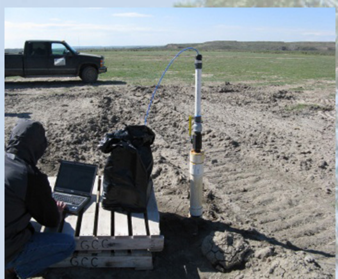


POWERTECH (USA) INC.

Dewey-Burdock Project
Application for NRC Uranium Recovery License Fall River and Custer Counties, South Dakota Technical Report

Appendices Volume III Appendix 2.7-J – 2.8-H

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LIST OF APPENDICES - VOLUME III

Powertech (USA) Inc.

APPENDIX 2.7-J

TVA GROUNDWATER QUALITY DATA

Table C-1. Historic Water-Quality Data From Well #2

Analyte	6/15/1979	10/6/1980	1/16/1981	4/6/1981	7/6/1981	10/19/1981	4/12/1982	7/26/1982	4/11/1983	4/17/1984
Alkalinity (mg/L)	200	229	218	220	218	210	220	242	220	218
Arsenic (mg/L)	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	0.021	<0.005	<0.005	<0.005
Bicarbonate as HCO3 (mg/L)	171	229	218	220	218	210	220	242	220	218
Boron (mg/L)	<1									
Calcium (mg/L)	50	60	86	91	64	63	46	49	51	50
Carbonate (mg/L)	36									
Cation/Anion Balance (%)	-67.8								0.8	2.86
Chlorine (mg/L)	16	5.5	9	10	10	9	10	8	11	10
Conductivity (umhos)	1450	1525	1530	1475	1520	1505	1590	1560	1570	1750
hardness (mg/L)	203	233	234	226	220	240	184	190	192	192
Iron (mg/L)	0.34	0.45	0.95	0.32	0.48	6.4	0.5	0.8	1.3	1.19
Lead (mg/L)	<0.05	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005
Magnesium (mg/L)	19	20	16	20	22	20	16	15	15	16
Manganese (mg/L)	0.14	0.1	0.28	0.1	0.1	0.25	0.15	0.1	0.09	0.09
Nitrogen (mg/L)	1.5	<0.1	0.21	0.13	<0.1	0.49	0.15	<0.1	1.39	0.94
pH	8.2	7.74	7.57	7.67	7.89	7.16	7.69	7.78	7.69	7.63
Phosphate (mg/L)	<0.01	<0.03	<0.03	<0.03	0.03	0.08	0.069	0.06	0.04	<0.03
Potassium (mg/L)	16	15	16.6	16	13	16	15	14	14	14
Radium 226 (pCi/L)					1.04		1.26	0.09		0.5
Selenium (mg/L)	<0.01								297	
Silicon (mg/L)	7.3	4.44	<1	9.4	6.42	8.6	<2	9.2	8.7	9.73
Sodium (mg/L)	288	269	251	264	280	244	306	300	297	318
Sulfate (mg/L)	604	415	536	556	556	626	580	582	574	590
Total Dissolved Solids (mg/L)	1113	1030	1004	1039	1052	1008	1038	1062	1010	1074
Total Suspended Solids (mg/L)	1.6	1	1	<1	<1	22	<1	<1	3	5
Uranium (ug/L)					0.007		1.6	0.4		
Vanadium (mg/L)	<0.05									
Zinc (mg/L)	0.01	0.005	<0.01	<0.01	<0.01	<0.01	<0.03	<0.01	<0.03	<0.005

Table C-2. Historic Water-Quality Data From Well #7

Analyte	6/15/1979	8/10/1979	9/12/1979
Alkalinity (mg/L)	191		171
Arsenic (mg/L)	<0.01		<0.01
Bicarbonate as HCO3 (mg/L)	159		37
Boron (mg/L)	<1		<1
Calcium (mg/L)	33		38
Carbonate (mg/L)	36		84
Cation/Anion Balance (%)	-73.2		-64.9
Chlorine (mg/L)	18		6
Conductivity (umhos)	1350		1325
hardness (mg/L)	153		182
Iron (mg/L)	0.48		0.5
Lead (mg/L)	<0.05		<0.05
Magnesium (mg/L)	17		21
Manganese (mg/L)	0.04		0.03
Nitrogen (mg/L)	2.3		0.39
pH	8.3		8.7
Phosphate (mg/L)	<0.01		<0.01
Potassium (mg/L)	15		14
Radium 226 (pCi/L)		1	
Selenium (mg/L)	<0.01		<0.01
Silicon (mg/L)	6.6		6.4
Sodium (mg/L)	307		277
Sulfate (mg/L)	600		600
Total Dissolved Solids (mg/L)	1104		1058
Total Suspended Solids (mg/L)	1.2		3.2
Uranium (ug/L)			
Vanadium (mg/L)	<0.05		<0.05
Zinc (mg/L)	0.08		0.08

Table C-3. Historic Water-Quality Data From Well #8

Analyte	6/15/1979	8/14/1979	9/12/1979	10/6/1980	1/6/1981	4/8/1981	7/6/1981	10/19/1981	4/12/1982	7/26/1982	4/11/1983	4/17/1984
Alkalinity (mg/L)	170	0	180	181	166	182	176	184	170	194	178	177
Arsenic (mg/L)	<0.01	0	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Bicarbonate as HCO3 (mg/L)	207	0	195	181	166	182	148	184	170	194	178	177
Boron (mg/L)	<1	0	<1	0	0	0	0	0	0	0	0	0
Calcium (mg/L)	52	0	58	52	74	79	55	55	59	60	54	60
Carbonate (mg/L)	0	0	12	0	0	0	28	0	0	0	0	0
Cation/Anion Balance (%)	-66.7	0	-64.1	0	0	0	0	0	0	0	0.03	3.71
Chlorine (mg/L)	16	0	16	9	9	12	12	13	11	8.5	12	12
Conductivity (umhos)	1285	0	1300	1450	1430	1375	1400	1380	1425	1390	1390	1410
hardness (mg/L)	233	0	243	229	264	216	218	220	248	232	260	266
Iron (mg/L)	0.71	0	0.13	0.25	0.46	0.26	0.15	0.3	0.25	0.17	0.26	0.25
Lead (mg/L)	<0.05	0	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium (mg/L)	25	0	24	25	22	22	25	23	26	22	24	26
Manganese (mg/L)	0.11	0	0.08	0.08	0.23	0.09	0.07	0.13	0.14	0.08	0.09	0.1
Nitrogen (mg/L)	2.9	0	0.29	0.1	0.15	1.62	0.1	1.23	0.24	<0.1	0.81	0.17
pH	8.5	0	8.3	7.8	7.74	7.85	8.08	7.59	7.62	7.67	7.74	7.64
Phosphate (mg/L)	<0.01	0	<0.01	<0.03	<0.03	<0.03	0.03	0.03	<0.03	<0.03	0.03	<0.03
Potassium (mg/L)	18	0	19	16	18.9	18	14	18	19	17	18	17
Radium 226 (pCi/L)	0	1.9	0	0	0	0	1.27	0	1.37	1.44	0	1.6
Selenium (mg/L)	<0.01	0	<0.01	0	0	0	0	0	0	0	218	0
Silicon (mg/L)	6.6	0	4.9	3.6	<1	8.1	10.7	7.5	<2	5.8	6.7	7.23
Sodium (mg/L)	277	0	265	226	215	232	245	210	218	253	218	242
Sulfate (mg/L)	640	0	616	400	504	536	488	520	520	514	520	530
Total Dissolved Solids (mg/L)	1130	0	1106	918	942	972	974	904	904	964	860	942
Total Suspended Solids (mg/L)	4.8	0	0.4	1	2	4	1	1	2	<1	<1	5
Uranium (ug/L)	0	0	0	0	0	0	0.007	0	0.8	2.2	0	1
Vanadium (mg/L)	<0.05	0	<0.05	0	0	0	0	0	0	0	0	0
Zinc (mg/L)	0.01	0	0.01	0.005	<0.01	<0.01	<0.01	0.01	<0.03	<0.01	<0.03	<0.005

Table C-4. Historic Water-Quality Data From Well #13

Analyte	6/15/1979	8/16/1979	9/12/1979	10/7/1980	1/13/1981	4/6/1981	7/6/1981	10/19/1981	4/12/1982	7/26/1982	4/11/1983	4/17/1984
Alkalinity (mg/L)	160		170	180	176	166	167	183	169	196	168	172
Arsenic (mg/L)	<0.01		<0.01	<0.005	0.009	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005
Bicarbonate as HCO3 (mg/L)	171		207	180	176	166	167	183	169	196	168	172
Boron (mg/L)	<1		<1									
Calcium (mg/L)	66		74	66	102	103	67	70	68	65	67	69
Carbonate (mg/L)	12											
Cation/Anion Balance (%)	-58.6		-54.7								4.84	3.57
Chlorine (mg/L)	16		14	9	9	12	11	9	11	8	11	11
Conductivity (umhos)	1200		1100	1290	1400	1275	1300	1280	1300	1310	1280	1275
hardness (mg/L)	284		304	298	248	262	264	268	268	274	266	276
Iron (mg/L)	1.61		1.38	4.3	8.1	1.18	0.6	2.3	1.6	1.65	1.8	1.62
Lead (mg/L)	<0.05		<0.05	<0.005	0.027	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	<0.005
Magnesium (mg/L)	29		29	34	23	25	28	26	27	24	26	25
Manganese (mg/L)	0.13		0.09	0.14	0.45	0.08	0.09	0.13	0.15	0.1	0.09	0.1
Nitrogen (mg/L)	0.78		0.24	<0.1	0.69	<0.1	<0.1	0.52	0.11	<0.1	0.94	0.28
pH	8.1		8.1	7.69	7.79	7.94	7.86	7.5	7.48	7.55	7.75	7.63
Phosphate (mg/L)	<0.01		<0.01	<0.03	0.06	0.09	0.03	0.03	<0.03	0.03	0.03	<0.03
Potassium (mg/L)	15		14	14	16.2	15	11	16	15	15	15	15
Radium 226 (pCi/L)		2.1					2.01		2.98	2.37		1
Selenium (mg/L)	<0.01		<0.01								199	
Silicon (mg/L)	6.4		6.6	2.4	7.8	6.6	10.7	7.5	<2	7.1	7.4	7.85
Sodium (mg/L)	216		169	164	185	191	195	162	184	207	199	205
Sulfate (mg/L)	568		480	404	464	480	468	500	472	492	456	480
Total Dissolved Solids (mg/L)	1006		882	950	936	854	912	862	836	842	792	876
Total Suspended Solids (mg/L)	0.4		1.6	11	71	4	3	2	2	1	1	6
Uranium (ug/L)							0.004		0.6	2.5		1
Vanadium (mg/L)	<0.05		<0.05									
Zinc (mg/L)	<0.01		<0.01	0.03	0.3	<0.01	<0.01	<0.01	0.13	<0.01	<0.03	<0.005

Table C-5. Historic Water-Quality Data From Well #16

Analyte	7/22/1981	10/19/1981	4/12/1982
Alkalinity (mg/L)	157	156	144
Arsenic (mg/L)	0.005	<0.005	<0.005
Bicarbonate as HCO3 (mg/L)	157	156	144
Boron (mg/L)			
Calcium (mg/L)	130	130	128
Carbonate (mg/L)			
Cation/Anion Balance (%)			
Chlorine (mg/L)	7	7	6
Conductivity (umhos)	1150	1160	1175
hardness (mg/L)	540	520	528
Iron (mg/L)	0.25	0.12	0.05
Lead (mg/L)	<0.005	0.015	<0.005
Magnesium (mg/L)	55	51	54
Manganese (mg/L)	0.15	0.17	0.17
Nitrogen (mg/L)	<0.1	0.28	0.22
pH	7.32	7.31	7.39
Phosphate (mg/L)	<0.03	0.03	<0.03
Potassium (mg/L)	28	24	21
Radium 226 (pCi/L)	4.9		5.38
Selenium (mg/L)			
Silicon (mg/L)	14.27	7.5	<2
Sodium (mg/L)	55	45	50
Sulfate (mg/L)	510	494	488
Total Dissolved Solids (mg/L)	894	796	848
Total Suspended Solids (mg/L)	1	1	<1
Uranium (ug/L)	0.007		1.7
Vanadium (mg/L)			
Zinc (mg/L)	<0.01	0.05	0.07

Table C-6. Historic Water-Quality Data From Well #18

Analyte	8/6/1979	8/15/1979	9/12/1979	10/9/1980	1/8/1981	4/8/1981	7/1/1981	10/1/1981	4/13/1982	7/27/1982	4/11/1983	4/17/1984
Alkalinity (mg/L)	200		238	202	180	192	195	184	190	214	184	182
Arsenic (mg/L)	<0.01		<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	0.018	<0.005	<0.005	<0.005
Bicarbonate as HCO3 (mg/L)	195		168	202	180	162	195	184	190	214	184	182
Boron (mg/L)	<1		<1									
Calcium (mg/L)	37		39	35	44	53	38	38	19	40	38	37
Carbonate (mg/L)	24		60			30						
Cation/Anion Balance (%)	-75.4		-75.9								2.69	2.47
Chlorine (mg/L)	14		20	13	13	12	11	12	12	8	12	13
Conductivity (umhos)	1325		1300	1420	1370	1375	1410	1350	1400	1390	1420	1410
hardness (mg/L)	142		139	136	136	138	140	140	124	141	140	135
Iron (mg/L)	7.42		1.25	1.4	2.1	1.34	1.9	1.4	1.3	2.6	2.6	1.45
Lead (mg/L)	<0.05		<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium (mg/L)	12		10	15.5	12	13	14	13	7	12	14	13
Manganese (mg/L)	0.15		0.05	0.08	0.16	0.07	0.07	0.06	0.12	0.08	0.08	0.08
Nitrogen (mg/L)	0.87		0.28	0.34	0.35	0.39	0.25	1.4	0.36	<0.1	1.04	0.42
pH	8.4		8.3	7.88	7.98	8.02	7.82	7.77	7.81	7.69	7.89	7.75
Phosphate (mg/L)	<0.01		<0.01	<0.03	<0.03	<0.03	0.03	0.03	0.033	0.03	0.04	<0.03
Potassium (mg/L)	10		11	9	9.4	10	9	12	10	9	10	9
Radium 226 (pCi/L)		0.96					1.87		4.44	1.26		2.2
Radium 226 (pCi/L)										0.57		
Selenium (mg/L)	<0.01		<0.01								279	
Silicon (mg/L)	6.4		5.6	3	<1	7.4	2.14	6.4	<2	7.9	7.4	7.85
Sodium (mg/L)	281		325	287	263	266	280	252	137	287	279	280
Sulfate (mg/L)	525		570	538	504	468	520	510	520	530	506	506
Total Dissolved Solids (mg/L)	999		1118	926	948	974	898	876	906	922	908	520
Total Suspended Solids (mg/L)	3.6		0.4	1	3	4	4	2	2	2	1	5
Uranium (ug/L)		8					0.008		7.6	6.7		8
Vanadium (mg/L)	<0.05		<0.05									
Zinc (mg/L)	0.01		<0.01	<0.005	<0.01	<0.01	0.03	<0.01	<0.03	<0.01	<0.03	<0.005

Table C-7. Historic Water-Quality Data From Well #42

Analyte	8/6/1979	8/15/1979	9/12/1979	10/9/1980	1/8/1981	4/8/1981	7/22/1981	10/21/1981	4/13/1982	7/27/1982	4/11/1983
Alkalinity (mg/L)	180		180	198	188	189	192	179	186	204	188
Arsenic (mg/L)	<0.01		<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	0.025	<0.005	<0.005
Bicarbonate as HCO3 (mg/L)	171		195	198	188	165	192	179	186	204	188
Boron (mg/L)	<1		<1								
Calcium (mg/L)	47		49	39	48	54	38	39	36	42	37
Carbonate (mg/L)	24		12			24					
Cation/Anion Balance (%)	-75.1		-75.8								0.33
Chlorine (mg/L)	14		14	12	9	11	12	11	12	10.5	12
Conductivity (umhos)	1250		1200	1400	1360	1380	1400	1365	1400	1375	1400
hardness (mg/L)	138		147	142	140	142	144	140	148	146	164
Iron (mg/L)	0.61		0.63	0.25	1.5	0.42	0.55	0.4	0.5	0.84	0.38
Lead (mg/L)	<0.05		<0.05	0.026	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005
Magnesium (mg/L)	5		6	16	13	13	14	13	13	13	11
Manganese (mg/L)	0.12		0.07	0.08	0.2	0.1	0.08	0.07	0.12	0.09	0.09
Nitrogen (mg/L)	0.52		0.05	0.38	0.28	0.17	<0.1	0.4	0.13	<0.1	0.84
pH	8.3		8.4	7.86	7.96	8	7.79	7.67	7.86	7.68	7.92
Phosphate (mg/L)	<0.01		<0.01	<0.03	<0.03	<0.03	<0.03	0.03	<0.03	0.03	<0.03
Potassium (mg/L)	10		10	10	9.4	10	9	12	10	10	10
Radium 226 (pCi/L)		51					37.4		82.62	80.33	
Selenium (mg/L)	<0.01		<0.01								276
Silicon (mg/L)	6.4		5.8	3	1.7	6.6	4.81	7.5	<2	7.9	8
Sodium (mg/L)	274		286	282	260	266	280	252	264	283	276
Sulfate (mg/L)	525		560	576	504	498	520	520	520	514	516
Total Dissolved Solids (mg/L)	984		1033	920	964	964	910	906	903	916	888
Total Suspended Solids (mg/L)	4.8		5.2		2	8	2	1	<1	<1	<1
Uranium (ug/L)		7					0.02		13.6	12	
Vanadium (mg/L)	<0.05		<0.05								
Zinc (mg/L)	0.01		<0.01	0.01	<0.01	<0.01	0.01	0.01	<0.03	<0.01	<0.03

Table C-8. Historic Water-Quality Data From Well #4002

Analyte	9/12/1979	4/12/1982	7/26/1982	7/27/1982	4/11/1983	4/17/1984
Alkalinity (mg/L)	150	144	202		146	146
Arsenic (mg/L)	<0.01	<0.005	<0.005		<0.005	<0.005
Bicarbonate as HCO3 (mg/L)	134	144	202		146	146
Boron (mg/L)	<1					
Calcium (mg/L)	45	46	23		45	46
Carbonate (mg/L)	24					
Cation/Anion Balance (%)	-62.2				0.99	0.12
Chlorine (mg/L)	8	5	3		6	7
Conductivity (umhos)	1100	1195	1160		1160	1190
hardness (mg/L)	187	90	168		168	184
Iron (mg/L)	2.3	2.6	1.38		8.3	3.35
Lead (mg/L)	<0.05	<0.005	<0.005		<0.005	0.005
Magnesium (mg/L)	18	16	10		13	15
Manganese (mg/L)	0.06	0.14	0.1		0.09	0.1
Nitrogen (mg/L)	0.46	0.17	<0.1		0.67	0.91
pH	8.5	7.52	7.51		7.6	7.61
Phosphate (mg/L)	<0.01	0.033	<0.03		0.03	<0.03
Potassium (mg/L)	13	10	9		9	9
Radium 226 (pCi/L)		43.36	32.13	32.13		
Selenium (mg/L)	<0.01				212	
Silicon (mg/L)	5.1	<2	3.4		8	7.23
Sodium (mg/L)	191	198	226		212	197
Sulfate (mg/L)	440	448	427		450	440
Total Dissolved Solids (mg/L)	805	766	770		740	784
Total Suspended Solids (mg/L)	1.6	6	2		5	9
Uranium (ug/L)		2.1	5	5		
Vanadium (mg/L)	<0.05					
Zinc (mg/L)	0.01	<0.03	<0.01		<0.03	<0.005

Table C-9. Historic Water-Quality Data From Well #7002

Analyte	6/15/1979	9/12/1979	10/6/1980	1/6/1981	4/6/1981	7/6/1981	10/19/1981	4/12/1982	7/26/1982	4/11/1983	4/17/1984
Alkalinity (mg/L)	210	224	269	264	264	263	280	264	300	268	267
Arsenic (mg/L)	<0.01	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.011	<0.005	<0.005
Bicarbonate as HCO3 (mg/L)	256	273	269	264	264	263	280	264	300	268	267
Boron (mg/L)	<1	<1									
Calcium (mg/L)	194	233	235	337	375	238	230	243	238	242	243
Carbonate (mg/L)											
Cation/Anion Balance (%)	-37.9	-39.3								0.55	3.52
Chlorine (mg/L)	16	16	6	9	10	9	8	9	6	9	10
Conductivity (umhos)	1925	2000	2500	2400	2400	2400	2400	2400	2400	2400	2500
hardness (mg/L)	1002	948	990	904	968	956	928	944	970	1020	928
Iron (mg/L)	3.56	2.48	2.5	3.38	2.55	2.1	2.7	2.5	2.47	5.8	2.16
Lead (mg/L)	<0.05	<0.05	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium (mg/L)	126	89	95	72	96	100	93	98	90	90	109
Manganese (mg/L)	0.46	0.32	0.38	0.82	0.37	0.3	0.38	0.51	0.37	0.39	0.33
Nitrogen (mg/L)	1.6	0.29	<0.1	0.16	0.52	<0.1	1.01	0.15	<0.1	0.44	0.37
pH	7.8	8	7.27	7.33	7.59	7.63	7.14	7.21	7.26	7.3	7.26
Phosphate (mg/L)	<0.01	<0.01	0.03	<0.03	<0.03	0.03	0.03	0.045	<0.03	0.04	<0.03
Potassium (mg/L)	25	25	32	33	35	24	33	29	30	32	27
Radium 226 (pCi/L)								8.69	9.37		
Selenium (mg/L)	<0.01	<0.01								200	
Silicon (mg/L)	7.3	7.3	4.17	<1	7.4	8.83	8.6	<2	8.6	8.7	8.45
Sodium (mg/L)	181	191	172	181	193	201	180	210	195	200	192
Sulfate (mg/L)	1150	1105	800	973	1097	1107	987	973	1090	1107	1077
Total Dissolved Solids (mg/L)	1818	1793	1940	1822	1942	1970	1690	1780	1886	1820	1810
Total Suspended Solids (mg/L)	4	7.2	8	4	6	4	6	5	2	6	10
Uranium (ug/L)								0.2	2		10
Vanadium (mg/L)	<0.05	<0.05									
Zinc (mg/L)	<0.01	<0.01	0.005	<0.01	<0.01	<0.01	<0.01	<0.03	<0.01	<0.03	<0.005

Powertech (USA) Inc.

APPENDIX 2.7-K

TVA Pump Tests
(Boggs, 1983 and Boggs & Jenkins, 1980)

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Keith Andersen

WR28-1-520-109

ANALYSIS OF AQUIFER TESTS CONDUCTED AT THE PROPOSED BURDOCK URANIUM MINE SITE BURDOCK, SOUTH DAKOTA

TENNESSEE VALLEY AUTHORITY
OFFICE OF NATURAL RESOURCES
DIVISION OF WATER RESOURCES
WATER SYSTEMS DEVELOPMENT BRANCH
NORRIS, TENNESSEE

Tennessee Valley Authority
Office of Natural Resources
Division of Water Resources
Water Systems Development Branch

ANALYSIS OF AQUIFER TESTS CONDUCTED AT THE PROPOSED BURDOCK URANIUM MINE SITE BURDOCK, SOUTH DAKOTA

Report No. WR28-1-520-109

Prepared by

J. M. Boggs
and
A. M. Jenkins

Norris, Tennessee
May 1980

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ABSTRACT

Separate aquifer tests were conducted in two aquifers which may be affected by TVA's proposed uranium mining operation near Burdock, South Dakota. In April 1979, a constant-discharge test was conducted in the Chilson member of the Lakota formation which comprises the principal ore body and an aquifer of regional importance. The hydraulic properties of both the Lakota (Chilson) aquifer and the overlying Fuson shale aquitard were determined. A second test was conducted in July 1979 in the Fall River aquifer which overlies the Fuson. The hydraulic characteristics of the Fall River aquifer and a second estimate of the Fuson aquitard properties were obtained from the test. The test results indicate that the two aquifers are hydrologically connected via (1) general leakage through the Fuson shale, and (2) direct pathways, probably in the form of numerous old (pre-TVA) unplugged exploration boreholes.

The hydraulic properties of the Fall River, Fuson and Lakota units obtained from the aquifer test analyses were incorporated into a computer model of the site geohydrologic system. These parameters were refined in a calibration process until the model could reproduce the drawdown responses observed during the Lakota aquifer test. Results indicate the transmissivity and storativity of the Lakota (Chilson) aquifer are approximately 1400 gallons per day per foot (gpd/ft) and 1.0×10^{-4}, respectively. The Fall River aquifer has an estimated transmissivity of 400 gpd/ft and a storativity of about 1.4×10^{-5}. The hydraulic conductivity of the Fuson aquitard is estimated at approximately 10^{-3} foot per day. The specific storativity of the Fuson was not measured but is assumed to be about 10^{-6} feet $^{-1}$.

INTRODUCTION

This report describes the aquifer testing program conducted at the proposed uranium mine site in Burdock, South Dakota. The purpose of the program was to determine the hydrogeologic conditions in the mining area in order to predict mine dewatering requirements and impacts.

The Fall River formation and the Chilson member of the Lakota formation comprise the principal aquifers in the vicinity of the proposed mine. These aquifers are separated by the Fuson shale member of the Lakota formation which acts as an aquitard. The uranium deposits to be mined lie within the Chilson unit.

Two unsuccessful aquifer tests were conducted at the site prior to those described in this report. The first test was conducted at the Burdock test well in February 1977. Pumping took place from both the Fall River and Lakota aquifers during the 14-day test. The test results were invalidated by questionable well discharge measurements and by mechanical difficulties with a deep-well current meter used to measure the quantity of water pumped from each aquifer. A second test lasting three days was performed in November 1977. Pumping was restricted to the Lakota aquifer during the test in order to determine the potential for leakage through the Fuson shale from the overlying Fall River aquifer. The results of the test were inconclusive because (1) five observation wells used in the test were subsequently found to be improperly constructed and (2) pressure gauges used to monitor pumping response at several wells malfunctioned during the test.

The problems associated with the two earlier tests were corrected for the tests described in this report. The defective observation wells were pressure sealed with cement grout and replaced with properly constructed wells. More reliable instrumentation for monitoring potentiometric heads in observation wells was used in subsequent tests.

HYDROGEOLOGY

Regional Setting

The proposed mine site is located in the northwestern corner of Fall River County, South Dakota, less than one mile southeast of the community of Burdock. Geologically, the site is situated on the southwest flank of the Black Hills Uplift (see Appendix, Figure 1). The stratigraphy of the region consists of a sequence of rocks ranging in age from Precambrian to Recent which crop out peripherally to the Black Hills. The Precambrian rocks crop out near the center of the Black Hills, and progressively younger rocks crop out to the southwest. Surficial rocks in the site area range in age from lower Cretaceous to Recent. A generalized stratigraphic column for the site is shown in Table 1.

The major structural features of the region are the southwesterly-trending Dewey and Long Mountain structural zones. Faults, fractures and breccia pipes in these zones are believed to affect the ground-water water regime.

Aquifers

The principal aquifers in the region are the alluvial deposits associated with the Cheyenne River and its major tributaries, the Fall River formation, the Lakota formation, the Sundance formation, and the Pahasapa (or Madison) formation. Except for the alluvium, these aquifers crop out peripherally to the Black Hills where they receive recharge from precipitation. Ground-water movement is in the direction of dip, radially from the central Black Hills. In most instances, ground water in these aquifers is under artesian conditions away from the

TABLE I : GENERALIZED STRATIGRAPHIC COLUMN FOR SITE REGION
(FROM KEENE, 1973)

PERIOD	FORMATION NAME	SYMBOL	COLUMN	LITHOLOGIC DESCRIPTION	THKNS. IN FEET	HYDROLOGIC CHARACTERISTICS
Quaternary	Alluvium	Qal		Gravel, sand, and silt floodplain deposits. Alluvial terraces and windblown material.	1-30	Good to excellent aquifer along floodplains; terraces generally non-productive except for scattered springs.
Cretaceous	Pierre Fm.	Kp		Dark gray shale, weathering brown or buff and containing many fossiliferous concretions. Scattered concretions which form "teepee buttes" Black fissile shale, cone-in-cone concretions.	1000+	Relatively no value as an aquifer; locally large diameter wells in stream valleys may yield small amounts of highly mineralized water during wet seasons.
	Niobrara Fm.	Kn		Gray calcareous shale, weathering yellow and impure chalk with Ostrea Congesta.	100-225	No known wells.
	Turner sand Carlile Fm. Wall Creek sand	Kcr		Light gray shale with large concretions. Gray shale with thin sandstone layers. Bed of impure limestone. Thin sandstone.	520-540	Relatively impermeable; possible small yields from Turner and Wall Creek sands.
	Greenhorn Lms.	Kg		Thin bedded hard limestone, weathering creamy white, contains Inoceramus Labiatus.	50	Too thin and dense to be an aquifer.
	Belle Fourche Fm. Mowry Shale Graneros Group Newcastle sand Skull Creek Shale	Kgs		Light gray shale, bentonite, large concretions. Light gray siliceous shale. Thin brown-to-yellow sandstone. Black shale	870	Newcastle sand may yield water, permeability is variable.
	Fall River Fm.	Kfr		Interbedded red-brown massive sandstone and Carbonaceous shales.	30-165	Largest producer in the area. Yields up to 60 gpm of highly mineralized water (flow). Water quality generally poor, sometimes yields hydrogen sulfide.
	Fuson Shale Minnewasta Lms. Lakota Fm.	Klk		Gray-to-purple shale, thin shales. Light gray massive limestone. Coarse, hard, cross-bedded sandstone, buff-to-gray, coal beds locally near base.	0-180 0-25 130-230	Relatively good aquifer from the lower Chilson member, up to 30 gpm artesian flow
	Morrison Fm.	Km		Green-to-maroon shale, thin sandstone.	0-125	No known wells, possible aquifer
Jurassic	Unkpapa Fm.	Ju		Fine grained, massive, vari-colored sandstone.	0-240	No known wells, possible aquifer
	Sundance Fm.	Jsd		Alternating beds of red sandstone and red-to-green marine shales.	250-450	Produces small amounts of water from the sands suitable for domestic use.
Triassic ?	Spearfish Fm.	TRs		Red silty shale, limestone, and anhydrite near the top. Redbeds. Gypsum locally near the base.	400	Poor producer, small yields of sulfate water
Permian	Minnekahta Lms.	Cmk		Pale brown, to gray dense, crystalline limestone.	50	Locally secondary fracture porosity
	Opeche Fm.	Co		Red thinly bedded sandstones and shales, purple shale near top.	100	No known wells
? Pennsylvanian	Minnelusa Fm.	Cml		Converse sand, red-to-yellow cross bedded sand. Red marker, thin red shale near middle. Leo sands, series of thin limestones. Dolomite at bottom with basal laterite zone.	755-1040	Permeability variable; tremendous flows of warm mineralized water recorded near the perifery of the Black Hills. Excellent potential.
Mississippian	Pahasapa Fm.	Cps		Massive, light colored dolomite and limestone, cavernous in upper 100 feet	165-465	Most promising aquifer in the area. The 2 wells in this aquifer produce large amounts of water suitable for domestic use
Precambrian	Metamorphic and igneous rocks	P€		Granite, schists, quartzite, and slates.	---	No potential.

outcrop area, and water flows from numerous wells in the area at ground surface.

The Fall River and Lakota formations which form the Inyan Kara Group are the principal aquifers in the region. The alluvium is used locally as a source of domestic and stock water. The Sundance formation is used near its outcrop area in central and northwestern Fall River County. The Pahasapa (Madison) formation is locally accessible only by very deep wells and is the source for five wells in the city of Edgemont.

The Fall River and Lakota aquifers are of primary concern because of the potential impact of mine dewatering on the numerous wells developed in these aquifers in the vicinity of the mine. At the proposed mine site, the Fall River consists of approximately 120 feet of interbedded fine-grained sandstone, siltstone and carbonaceous shale. The Fall River aquifer is overlain by approximately 250 feet of the Mowry and Skull Creek shales unit, which act as confining beds. Twenty-six domestic and stock-watering wells are known to be developed in the Fall River formation within a four-mile radius of the mine site. Many of these are flowing at the surface.

The Fall River formation is underlain by Fuson shale member of the Lakota formation. Thickness of the Fuson is on the order of 60 feet in the site vicinity. The Fuson acts as a leaky aquitard between the Fall River and Lakota aquifers. A physical examination of undisturbed core samples of Fuson indicates that the shale itself has a very low permeability. However, aquifer tests suggest a direct connection through the Fuson which may be the result of some as-yet-unidentified structural features or old unplugged exploration holes.

The Chilson member of the Lakota formation is the second most widely used aquifer in western Fall River County, as the source for some 23 wells within a four-mile radius of the mine site. It is also the uranium-bearing unit to be mined. The Chilson consists of about 120 feet of consolidated to semi-consolidated, fine-grained sandstone and siltstone. It is underlain by the Morrison formation consisting of interbedded shale and fine-grained sandstone. Regionally, the Morrison is not considered an aquifer. Under conditions of groundwater withdrawal from the Chilson, the Morrison is expected to act as an aquitard.

Recharge to the Fall River and Lakota aquifers is believed to occur at their outcrop areas. Bowles (1968) has theorized that recharge to these aquifers may also be derived from the upward movement of ground water along solution collapses and breccia pipes from the deeper Minnelusa and Pahasapa aquifers. The solution collapse and breccia pipe features lie within the Dewey and Long Mountain structural belts.

AQUIFER TEST DESIGN

The objective of the aquifer testing program was to obtain sufficient quantitative information about local hydrogeologic conditions to enable prediction of mine dewatering requirements and impacts to both the Fall River and Lakota aquifers. Since the two aquifers involved are separated by the Fuson aquitard, two distinct pumping tests were required to obtain the necessary information about each formation: one test in which the Lakota aquifer was pumped, and another in which pumping was limited to the Fall River aquifer. During both tests ground-water levels were monitored in observation wells developed in each of the three formations. Data obtained from these tests were then analyzed to obtain estimates of the hydraulic properties of the aquifers and aquitard.

The Burdock test well was constructed approximately 600 feet north of the proposed mine shaft. Total depth of the well is 559 feet. The well is screened in both the Fall River and Lakota aquifers as shown in Figure 2.

Fifteen observation wells were constructed within an approximate one-mile radius of the pumping well as indicated in Figure 3. Seven of these wells are developed in the Fall River formation, five in the Lakota, and three in the Fuson. In addition, there is a single well developed in the Sundance formation located approximately one mile from the test well. This well was not constructed specifically for the aquifer tests, but was monitored periodically during the Lakota aquifer test. Construction details for these wells are given in Table 2.

TABLE 2. Observation Well Construction Details

Well No.	Total Depth (feet)	Casing Diameter (inches)	Depth Interval of Open Borehole or Well Screen (feet)	Distance From Pumped Well (feet)
B-10LAK	550	4	510-550	195
B-10FU	395	4	377-395	255
B-10FR	350	4	300-350	177
B-1LAK	570	4	525-570	405
B-1FU	440	4	420-440	350
B-1FR	376	4	334-376	373
B-11LAK	550	4	504-550	618
B-11FR	360	4	315-360	620
B-9LAK	545	1	503-545	1540
B-9FR	293	1	251-293	1540
B-7LAK	441	1	399-441	2507
B-7FR	252	1	210-252	2540
Sundance Well	880	7 7/8	666-780	4763

Inasmuch as water levels in each hydrogeologic unit will respond differently during pumping tests, it is important that each observation well reflect the potentiometric head in the intended uncased borehole interval. Several observation wells used in previous tests were suspected of leaking along the grout seal placed in the annular space between well casing and borehole wall. As a result, special precautions were taken to ensure proper construction of the observation wells used in the present tests. A geophysical device known as a cemeton logging probe was used to check the continuity of the cement grout seal in each well after construction. All were found to be properly sealed.

The so-called ratio-method of multiple-aquifer test analysis (Neuman and Witherspoon, 1973) requires that the response of water levels in both the pumped and unpumped aquifers and in the interven-ing aquitard be monitored during the test. Water level responses in these units must be measured in wells located at approximately the same radial distance from the pumped well. To obtain the necessary data, two groups of observation wells were constructed, each group having one well developed in the Fall River, one in the Fuson, and one in the Lakota (Chilson member). The B-10 group was located approximately 200 feet northeast of the pumping well, while the B-1 group was located approximately 375 feet to the southwest. These well groups were located close to the pumped well to ensure response in the aquitard and in the unpumped aquifer, if such responses were to occur at all. The remaining well groups (B-7, B-9 and B-11 series) contain only Fall River and Lakota wells.

Under natural conditions, the test well and all monitor wells except for those of the B-7 group flow at ground surface if not capped. The two previous tests conducted at the site indicated that observation wells in the pumped aquifer located close to the pumping well would become non-flowing at some point during the test. Thus, pressure sensing devices would be required during the early part of the test and depth measuring techniques during later periods. To ensure adequate data records, each flowing well was equipped with two pressure measuring devices. Malfunctions of several pressure gauges on previous tests pointed out the need for a back-up pressure measuring device.

Three types of pressure sensors were used: mercury manometers, electronic pressure transducers, and mechanical pressure gauges. The B-1 and B-10 observation well groups were equipped with mercury manometers and pressure transducers. As the closest wells to the pumping center, the data from these wells are most important in the multiple aquifer analysis and warrant the best instrumentation. Pressure transducers from all wells were wired to a central terminal and could be monitored frequently during the tests. Each well in groups B-9 and B-11 was equipped with a mercury manometer and a mechanical pressure gauge. Electric probes were used to measure water levels in the non-flowing wells of the B-7 group. These devices were also used to measure water levels in other wells which became non-flowing during pumping tests. Potentiometric head in the pumped well was measured with a mercury manometer, an air line and an electric probe.

LAKOTA AQUIFER TEST

Several months prior to the Lakota test, a pneumatic packer was set within the Fuson section of the test well to prevent communication between the Fall River and Lakota aquifers through the well. A submersible pump was set below packer to restrict pumping to the Lakota aquifer. Well-head valves on the test well and other artesian observation wells were closed to prevent flow in order to bring the ground-water system into equilibrium before testing.

Hydrographs for the test well and observation wells prior to test are shown in Figures 4 and 5. These hydrographs typify the basic relationship between the potentiometric heads in the Fall River, Fuson and Lakota, i.e., heads are highest in the Lakota, lowest in the Fall River, and at an intermediate position within the Fuson. The irregular readings recorded during January and February 1979 were due to depressurization of the aquifers during the installation of instrumentation and new wells. The pre-test ground-water level configuration in the Lakota aquifer on April 18 is shown in Figure 6.

Test Procedures and Results

A constant-discharge aquifer test was initiated at 1300 hours on April 18, 1979. Discharge from the well was pumped via pipeline to a stock-watering pond located approximately 0.75 miles from the test well. Pumpage was measured with an in-line flow meter and with an orifice plate and manometer device at the end of the discharge line. The pumping rate varied little during the test ranging from 201 to 205 gpm and averaging 203 gpm. The pumping phase of the test lasted for

73 hours (3.04 days) and was followed by a 30 day period of recovery measurements.

Figure 7 shows a semilogarithmic graph of drawdown (s) versus time (t) for the pumping well (Lakota aquifer). Erratic readings during the first 200 minutes of the test are the result of problems with the airline equipment, and are not due to discharge variations. These difficulties were subsequently corrected, but in general airline measurements are believed to be accurate only to within about ±2 feet.

Semilog graphs for the observation well groups are shown in Figures 8 through 12. Note that a slight initial increase in hydrostatic pressure is indicated in the Fall River and Fuson wells of the B-10 and B-1 well groups. This anomalous trend is more pronounced in the Fuson wells than in the Fall River wells and persists for approximately 90 minutes in B-10FU. The response is believed to be due to an increase in pore pressure resulting from deformation of the matrix of these formations.[1] In any case, the anomalous trend was recorded by both the pressure transducers and mercury manometers, and is not the result of measurement error.

The Jacob straight-line method (see Walton, 1970, pp. 130-133) was applied to the semilog graphs for the Lakota wells to obtain the values of transmissivity (T) and storativity (S) presented in Table 3. In the case of the closer observation wells, two straight-line

[1]During the early stages of pumping, water removed from the Lakota in the immediate vicinity of the well causes compaction of the aquifer. This, in turn, may cause the overlying strata to flex slightly in the area where the underlying support of the Lakota has been reduced. The resulting deformation in the overlying formations causes compressive forces which temporarily increase pore pressures in these materials. Subsequently, the effect of pumping-induced depressurization is transmitted through the overlying materials, gradually lowering the hydrostatic pressure.

TABLE 3. Lakota Aquifer Properties

Well No.	r (ft)	Jacob Method T_e (gpd/ft)	Jacob Method S_e --	Jacob Method T_ℓ (gpd/ft)	Jacob Method S_ℓ --	Theis Method T_e (gpd/ft)	Theis Method S_e --	Theis Method T_ℓ (gpd/ft)	Theis Method S_ℓ --	Recovery Method T_e (gpd/ft)	Recovery Method T_ℓ (gpd/ft)
PW-LAK	0.67	1980	--	1260	--	--	--	--	--	--	--
B-10LAK	195	2680	$7.6x10^{-5}$	1370	$3.5x10^{-4}$	2530	$8.4x10^{-5}$	1660	$1.6x10^{-4}$	2060	1300
B-1LAK	405	2140	$4.4x10^{-5}$	1340	$1.2x10^{-4}$	2120	$4.8x10^{-5}$	1550	$8.4x10^{-5}$	1970	1240
B-11LAK	620	--	--	--	--	2530	$1.1x10^{-4}$	1530	$1.5x10^{-4}$	--	1250
B-9LAK	1540	--	--	--	--	--	--	1370	$1.3x10^{-4}$	--	1290
B-7LAK	2507	--	--	--	--	--	--	1760	$6.5x10^{-5}$	--	1500
Average:		2270	$6.0x10^{-5}$	1320	$2.4x10^{-4}$	2390	$8.1x10^{-5}$	1570	$1.2x10^{-4}$	2015	1270

NOTE: Subscript "e" denotes an aquifer parameter determined using early drawdown (or recovery) data. Similarly, subscript "ℓ" denotes a parameter computed from late data.

solutions were possible: one using the early data and another using the late data. Note that data for wells B-7L, B-9L and B-11L cannot be analyzed by the Jacob method because data do not satisfy the criterion that $r^2S/4Tt \leq 0.01$ (consistent units), where r is the distance between the pumped well and the observation well.

Logarithmic graphs of drawdown data for all observation wells are given in Figures 13 through 17. Theis curve-matching techniques (Walton, 1970, pp. 209-211) were applied to the Lakota curves to obtain T and S estimates for the Lakota aquifer. As with the Jacob analyses, two curve-match solutions were possible: one using the early, steeply-rising portions of the s-t curves, and another using the later data. Both solutions are given in Table 3.

A semilogarithmic graph of distance versus drawdown (Figure 18) was constructed by plotting the final drawdown in each Lakota well versus its radial distance from the pumped well. The Jacob straight-line techniques were applied to these data to obtain T and S values for the Lakota of 1780 gpd/ft and 7.7×10^{-5}, respectively. However, this type of analysis is applicable only to nonleaky aquifer systems. Since leakage obviously occurred during the test, the results are considered unreliable.

Contour maps of the final drawdown in the Lakota and Fall River aquifers at the end of the test are shown in Figures 19 and 20, respectively. The drawdown cone in both aquifers is slightly elongated in a northwesterly direction. This is probably an indication of anisotropic transmissivity, with the transmissivity in the direction parallel to the axis of elongation being somewhat greater than that in the direction normal to the axis of elongation. The principal direction of transmissivity parallels the strike of a regional fracture-joint set, suggesting a possible explanation for the observed drawdown configuration.

Following the pumping phase of the test, water level recovery measurements were made at all observation wells for a period of 30 days. Attempts were also made to monitor recovery in the pumped well using an airline. However, data collected were highly erratic suggesting a malfunction of the airline equipment. Semilogarithmic graphs of residual drawdown versus t/t' (ratio of time since pumping started to time since pumping stopped) for the observation wells are shown in Figures 21 through 25. Lakota graphs were analyzed using Jacob straight-line techniques to obtain the estimates of transmissivity presented in Table 3. Again, two straight-line fits are possible for the closer Lakota wells. Both are given in Table 3.

Interpretation of Test Results

The drawdown trends recorded in the observation wells indicate some important qualitative information about hydrogeologic conditions at the proposed mine site, in addition to providing a basis for determining hydraulic properties of materials. The relative response of the Fall River, Fuson and Lakota formations as reflected in the B-10 and B-1 groups (Figures 13 and 14), is not typical of the response that would be expected in an ideal leaky multiple aquifer system. Ideally, the s-t curve for the intervening aquitard lies between the curves for the pumped and unpumped aquifers. That is, in a logarithmic plot of s-t data the aquitard (Fuson) curve would lie below the curve for the pumped aquifer (Lakota), and above the curve for the unpumped aquifer (Fall River). However, "ideal" trends are not evident in the observed data until after 300 minutes of pumping in the case of the B-10 group, and not until after 2000 minutes in the case of the B-1 group. The fact that a greater pumping response is observed in Fall River formation than in the Fuson during the early part of the test indicates that direct (though restricted) avenues through the Fuson must exist. This condition was suspected before the test, and is believed to be the result of numerous old, unplugged uranium exploration boreholes in the test site vicinity. The shift to a more ideal relationship among the s-t curves exhibited during the latter part of test possibly indicates that general leakage through the Fuson itself has caught up with leakage through the open boreholes.

The leakage condition which is apparent in the response of the Fuson and Fall River wells is not evident in the Lakota well data. Under ideal conditions, the rate of drawdown in the Lakota observation wells would be expected to gradually decrease and perhaps even level off completely for some period of time. However, the opposite effect is noted in Lakota s-t plots, particularly the semilog graphs for B-10 LAK and B-1 LAK (Figures 8 and 9). The rate of drawdown increases in the latter stages of pumping which might indicate decreasing transmissivity of the Lakota aquifer in the site vicinity. The decrease in transmissivity may be due to aquifer thinning or possibly a facies change to less permeable materials. In any case, it is suspected that the leakage effects in the Lakota drawdown data are masked by the conflicting effect of a decreasing transmissivity in the site vicinity.

In general, the agreement between the Theis and Jacob analyses of s-t data is good. T values computed using early drawdown data average 2390 gpd/ft using the Theis method, and about 2270 gpd/ft using the Jacob method. Early data storativities are also in good agreement averaging $6.0x10^{-5}$ for the Jacob method and $8.1x10^{-5}$ for the Theis method. The T values computed from the late data (T_{ℓ}) are significantly lower than those determined from the early data, whereas late storativities are larger. The Jacob method yields T_{ℓ} values which average 1320 gpd/ft and storatitivies averaging $2.4x10^{-4}$. The Theis method produced an average T_{ℓ} of 1570 gpd/ft and an average S_{ℓ} of $1.2x10^{-4}$. The late Theis T values are somewhat higher than the Jacob T's because the Theis method gives some consideration to the earlier data which the Jacob method does not. Transmissivities estimated by the recovery data average 1270 gpd/ft, and are in close agreement with the late Jacob results, although slightly lower.

Ordinarily, in selecting representative T and S for the pumped aquifer in a leaky multiple aquifer system, more emphasis would be placed on the early data collected in the pumped aquifer at the pumped well and closest observation wells. These data are considered least affected by leakage. However, because of the apparent decrease in transmissivity of the Lakota aquifer during the latter stages of the test, it is believed that Lakota parameters computed from the late data are more representative of aquifer properties under a long-term pumping situation such as mine dewatering. On this basis the average transmissivity of the Lakota is estimated to be 1400 gpd/ft and the average storativity $1.8x10^{-4}$.

FALL RIVER AQUIFER TEST

Following completion of recovery measurements associated with the Lakota aquifer test, pumping equipment in the Burdock well was rearranged for the Fall River test. A submersible pump was set within the Fall River section of the well and the pneumatic packer reset below the pump in the Fuson section of the well in order to restrict pumping to the Fall River. A preliminary test of the pump and other equipment lasting less than one hour was conducted on May 29. Unexpectedly, the Fall River aquifer was capable of yielding only about 10 gpm on a sustained basis. Since other Fall River wells in the region yield up to 40 gpm, it was assumed that either the well screen was encrusted or the well was not fully developed, or both. An unsuccessful effort was made to develop the well by pumping. A television camera was subsequently lowered into the well to examine the well screen. Little or no encrustation was observed on the screen. Ultrasonics were used in the well to remove any existing encrustation but the yield of the well was not improved. The low productivity of the well is, therefore, attributed to locally poor water-bearing characteristics of the Fall River formation.

Test Procedures and Results

A constant discharge test commenced at 1100 hours on July 24. Water levels in all geologic units were stable prior to the test, as there was no pumping activity in the site vicinity since the completion of well development on July 3. Discharge was measured with an in-line flowmeter, and checked with a 55-gallon container and stopwatch.

During the test the pumping rate varied from 7.6 to 10.4 gpm, and averaged 8.5 gpm. Ground-water levels were monitored in all observation wells shown in Figure 3. The constant discharge test was terminated at 1200 hours on July 26 after 49 hours of pumping. Subsequently, ground-water level recovery measurements were made for a period of six days.

Semilog graphs of drawdown data recorded at the pumped well and observation well groups B-1, B-10 and B-11 are shown in Figures 26 through 29, respectively. No graphs are presented for B-11LAK or the B-7 and B-9 groups as there was no measureable drawdown in these wells. Except for B-11FR, these graphs exhibit a typical straight-line drawdown trend during the first part of the test, followed by a gradual decrease in slope towards the end of the test. This slope change is the result of leakage from adjacent formations, and/or an increase in aquifer transmissivity at some distance from the pumped well. The Jacob method was applied to the semilog graphs to obtain the transmissivity and storativity values shown in Table 4. The T_e and S_e values were obtained using early drawdown data recorded during approximately the first 500 minutes of the test. T_l and S_l values were computed from data recorded after about 1000 minutes. The only reliable estimates are considered to be those computed for B-1FR and B-10FR. Drawdown data for the pumped well is affected by wellbore storage which is significant in this test because of the relatively low pumping rate. The pumped well drawdown data may also be affected by low well efficiency. The semilog plot for B-11FR cannot be analyzed by the Jacob method because the criterion that $r^2S/4Tt \leqq 0.01$ is not satisfied for any of the data.

TABLE 4. Fall River Aquifer Properties

Well No.	r (ft)	Jacob Method T_e (gpd/ft)	Jacob Method S_e --	Jacob Method T_ℓ (gpd/ft)	Jacob Method S_ℓ --	Theis Method T_e (gpd/ft)	Theis Method S_e --	Recovery Method T_e (gpd/ft)	Recovery Method T_ℓ (gpd/ft)
PW-FR	0.67	16.(?)	--	--	--	--	--	11(?)	--
B-10FR	177	140.	1.8×10^{-5}	410.	--	150.	1.7×10^{-5}	80.	340.
B-1FR	373	150.	0.8×10^{-5}	420.	--	150.	1.1×10^{-5}	90.	350.
B-11FR	618	--	--	--	--	--	--	--	--
Average:		145	1.3×10^{-5}	415.	--	150.	1.4×10^{-5}	85.	345.

Logarithmic graphs of drawdown data for the pumped well and observations well groups B-10, B-1 and B-11 are presented in Figures 30 through 33, respectively. Theis curve-matching techniques were applied to the Fall River curves to obtain the aquifer properties given in Table 4.

Semilog recovery curves for the pumped well and well groups B-10, B-1 and B-11 are shown in Figures 34 through 37, respectively. Again, properties computed from the pumped well recovery data are invalidated by well-bore storage effects. Separate estimates of transmissivity obtained from early and late phases of the recovery data are given in Table 4.

Interpretation of Fall River Aquifer Test Results

There is good agreement between the early Jacob and Theis results for B-1FR and B-10FR. These analyses indicate an average T_e of about 150 gpd/ft and an average S_e of approximately $1.4x10^{-5}$. Application of the Jacob method to the late drawdown data yields an average T_l of 415 gpd/ft. No meaningful storativity values could be computed from the late data. The T_e values computed by the recovery method are considerably lower than those computed by the other two methods and are believed to be unrealistic. The T_l values derived from the recovery analyses compare reasonably well with the Jacob late drawdown results.

The computed transmissivity and storativity values are representative of the aquifer only within the relatively small area influenced by the pumping test. The yield of the test well is substantially less than that of several other wells in the region. The difference in well yields suggests that the Fall River aquifer is less permeable in the mine site vicinity than in certain surrounding areas. The aquifer parameters computed from the early drawdown and recovery data are believed to be representative of the aquifer in the immediate vicinity of the test wells. Parameters obtained from analysis of the late data are probably more representative of regional aquifer characteristics.

FUSON AQUITARD PROPERTIES

The hydraulic properties of the Fuson aquitard were estimated using an analytical technique known as the "ratio method" developed by Neuman and Witherspoon (1973). The method requires (1) a knowledge of the transmissivity and storativity of the pumped aquifer; (2) draw-down data for the pumped and unpumped aquifers and the aquitard measured in wells located at approximately the same radial distance from the pumped well; and (3) the vertical distance between the aquifer-aquitard boundary and the perforated section of each aquitard well (Z). The method yields a value of aquitard hydraulic diffusivity, α', equal to K'_V/S'_S, where K'_V is the vertical hydraulic conductivity of the aquitard and S'_S is the specific storativity of the aquitard. To determine K'_V or S'_S from α', either K'_V or S'_S must first be known. In the following analyses a value of $S'_S = 10^{-6}$ ft^{-1} is assumed for the Fuson aquitard. Experience indicates that specific storativities of geologic materials do not vary over as wide a range as do hydraulic conductivities. For this reason, and considering the difficulty and expense of obtaining an accurate measure of S'_S over the site vicinity, it appears justifiable to assume a value of S'_S typical of similar geologic materials.

The first step in the analysis is to compute a value of s'/s at a given radial distance from the pumped well, r, and at a given time, t. Next a value of t_D (dimensionless time for the aquifer equal to tT/r^2S) is determined. The values of s'/s and t_D are used to compute a value for t'_D (dimensionless time for the aquitard equal to $K't/S'_SZ^2$) using a family of type curves given in Figure 3 of Neuman and Witherspoon (1973). The vertical hydraulic conductivity of the aquitard K'_V is then obtained from the following equation:

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$$K'_v = t'_D Z^2 S'_s/t \qquad (1)$$

Since separate pumping tests were conducted in the Lakota and Fall River aquifers, it is possible to calculate two independent values of K'_v for each well group. Fuson aquitard properties computed by the ratio method along with certain pertinent parameters used in the calculations are presented in Table 5.

Note that since the Fall River, Fuson and Lakota observation wells in each well group do not lie at exactly the same radial distance from the pumped well, an average radial distance r_{avg} is used in the calculations. The r_{avg} values shown in Table 5 were obtained by averaging the radial distance for the pumped aquifer observation well and the radial distance for the aquitard observation well. Also note that the column labeled "Time Interval" represents the time interval during which K'_v values were computed. Generally, three or four values of K'_v were computed at specific times within this interval. These values were then averaged to obtain the K'_v values shown in Table 5.

The vertical hydraulic conductivity of the Fuson ranges from about 10^{-4} ft/d at the B-1 well group to about 10^{-3} ft/d at the B-10 well group. The agreement between the conductivities computed at each well group site for both tests is good. The reason for the order of magnitude difference between the conductivities at the different well sites is unknown, but may be related to errors caused by differences in the radial distances of observation wells--these differences being somewhat greater for the wells of the B-10 group.

TABLE 5. Fuson Aquitard Properties

Test	Well Group	$r_{avg.}$ (ft)	Z (ft)	Time Interval (min.)	K'_v (gpd/ft^2)	K'_v (ft/d)
Lakota	B-10	225	28	100-393	2.0×10^{-2}	2.7×10^{-3}
	B-1	378	11	100-393	1.0×10^{-3}	1.3×10^{-4}
Fall R.	B-10	216	25	100-300	4.8×10^{-3}	6.6×10^{-4}
	B-1	362	40	1200-2350	1.3×10^{-3}	1.8×10^{-4}

The magnitudes of computed conductivities are slightly higher than expected on the basis of the physical characteristics of the Fuson, although they are still within reason. The presence of open boreholes may have caused a more rapid drawdown response in the Fuson monitor wells than would have occurred otherwise. As a result, the calculated K'_v values are probably larger than the actual conductivity of the Fuson shale. The calculated K'_v values are, however, probably smaller than the effective K'_v of the aquitard in the areas where it is breached by open boreholes.

COMPUTER MODEL SIMULATIONS

The hydraulic properties estimated for the Fall River, Fuson and Lakota formations were incorporated into a computer model of the site geohydrologic system. Simulations of the Lakota aquifer test were performed to see if the model could reproduce the drawdown responses observed during the test. An acceptable match between the measured and computed responses would indicate the validity of the estimated formation properties, and thus enhance the credibility of the model for predicting mine dewatering requirements and impacts.

A finite element numerical model developed by Narasimhan et al. (1978) was used for the aquifer test simulations. The aquifer/ well-field system was modeled in three dimensions using axial symmetry. The hydraulic properties of the Fall River, Fuson and Lakota formations obtained from the aquifer test analyses were used as initial input data (see Table 6). Uniform properties were assumed for each hydrogeologic unit. The shale units which lie above the Fall River formation and those which lie below the Lakota were assumed to be impermeable in the model. All simulation comparisons were made for the Lakota aquifer test. The Lakota test stressed a larger portion of the multiple aquifer system than did the Fall River test, and more closely approximates the flow regime expected during mine dewatering.

A comparison of the measured and computed results for the initial simulation run are shown in Figure 38. In general, the agreement between the computed and observed drawdown graphs for the Lakota aquifer are good. However, there are large discrepancies in the Fall River and Fuson responses.

TABLE 6. Parameters Used In Computer Simulations

	Initial Parameters					Final Parameters				
Formation	T (gpd/ft)	S (--)	K_v (ft/d)	K_v/K_h (--)	Ss (ft^{-1})	T (gpd/ft)	S --	K_v (ft/d)	K_v/K_h --	Ss (ft^{-1})
Fall River	150.	1.4×10^{-5}	5.6×10^{-2}	1/3	1.2×10^{-7}	400	1.4×10^{-5}	4.6×10^{-2}	1/10	1.2×10^{-7}
Fuson	0.13	6.0×10^{-5}	1.7×10^{-4}	1/3	1.0×10^{-6}	0.45	6.0×10^{-5}	1.0×10^{-3}	1/1	1.0×10^{-6}
Lakota (Chilson)	1400.	1.8×10^{-4}	5.0×10^{-1}	1/3	1.5×10^{-6}	1400.	1.0×10^{-4}	1.5×10^{-1}	1/10	8.3×10^{-7}

Several attempts were made to improve the match between the computed and observed drawdown responses by trial-and-error adjustment or calibration of model parameters. The most reliable parameters, such as the computed Lakota and Fall aquifer coefficients, were only slightly altered in the calibration process, whereas the least reliable parameters, including the ratio of vertical to horizontal permeability and the Fuson properties, were allowed to vary over a wider (though reasonable) range. The hydraulic properties within each hydrogeologic unit were assumed to be uniform throughout the calibration process.

The set of hydraulic parameters yielding the best agreement between measured and observed drawdown data is given in Table 6. The final parameter set differs only slightly from the original. The largest changes were made in the K_v/K_h terms which were unknown to begin with; and in the Fuson hydraulic conductivity which was increased by a factor of five. Both the early and late Fall River T values computed from the aquifer test analyses (150 and 415 gpd/ft, respectively) were tested during model calibration. The drawdown response of the model was found to be relatively insensitive to the value of T used. A transmissivity of 400 gpd/ft is included in the final parameter set as it is believed to be more characteristic of the aquifer regionally.

The match between the measured and computed drawdown responses, shown in Figure 39, is considered acceptable in light of the fact that uniform aquifer-aquitard properties were used in the model. The apparent discrepancies are believed to be due to the heterogeneity and anisotropy of the actual system. The departures which occur during the early phase of the simulation appear large, but are not significant.

The ability of the model to predict the long-term response of system is more important. Thus, more significance is attached to the agreement between the simulated and observed results for the latter part of the test which, in most cases, is quite good. The final set of aquifer-aquitard properties are considered to represent a valid basis for future predictive modeling.

SUMMARY AND CONCLUSIONS

The aquifer test results indicate that the Fuson member of the Lakota formation is a leaky aquitard separating the Fall River and Lakota aquifers. The hydraulic communication between the two aquifers observed during the tests is believed to be the result of (1) general leakage through the primary pore space and naturally occurring joints and fractures of the Fuson shale, and (2) direct connection of aquifers via numerous old unplugged exploratory boreholes. Whereas, the former leakage mechanism is a regional characteristic of the Fuson, leakage caused by borehole short-circuiting is probably limited to the relatively small area of intensive uranium exploration in the Burdock vicinity.

The Lakota (Chilson) aquifer has an estimated transmissivity of approximately 1400 gpd/ft and a storativity of about 1.0×10^{-4}. These properties are representative of the Lakota in the area affected by the pumping test, and are consistent with what is known or suspected about the aquifer regionally. The transmissivity and storativity of the Fall River aquifer are estimated at approximately 400 gpd/ft and 1.4×10^{-5}, respectively. Test results indicate that the transmissivity of the Fall River may be considerably less than 400 gpd/ft in the immediate vicinity of the test site. However, the selected transmissivity value is more consistent with regional aquifer characteristics.

The hydraulic conductivity of the Fuson aquitard is estimated at approximately 10^{-3} ft/d. The specific storativity of the Fuson was not measured but is assumed to be about 10^{-6} ft^{-1}. If open boreholes are present at the test site as suspected, the computed hydraulic conductivity is probably higher than the true conductivity of the shale, yet lower than the effective conductivity of the aquitard where short-circuited by open boreholes. For this reason, the selected aquitard conductivity of 10^{-3} ft/d should provide a conservative estimate of mine dewatering impacts. Outside of the relatively small area where the aquitard is breached by boreholes, leakage between the two aquifers will be governed by the true conductivity of the shale which is probably on the order of 10^{-4} ft/d or less.

The hydraulic properties of the Fall River, Fuson and Lakota (Chilson) formations computed from aquifer test data were incorporated into a computer model of the site geohydrologic system. These parameters were refined through repeated simulations of the Lakota aquifer test until the model could reproduce the drawdown responses observed during the test. The agreement between the observed and computed responses indicates the validity of the aquifer-aquitard properties, and should enhance the credibility of future predictive models using these parameters.

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APPENDIX

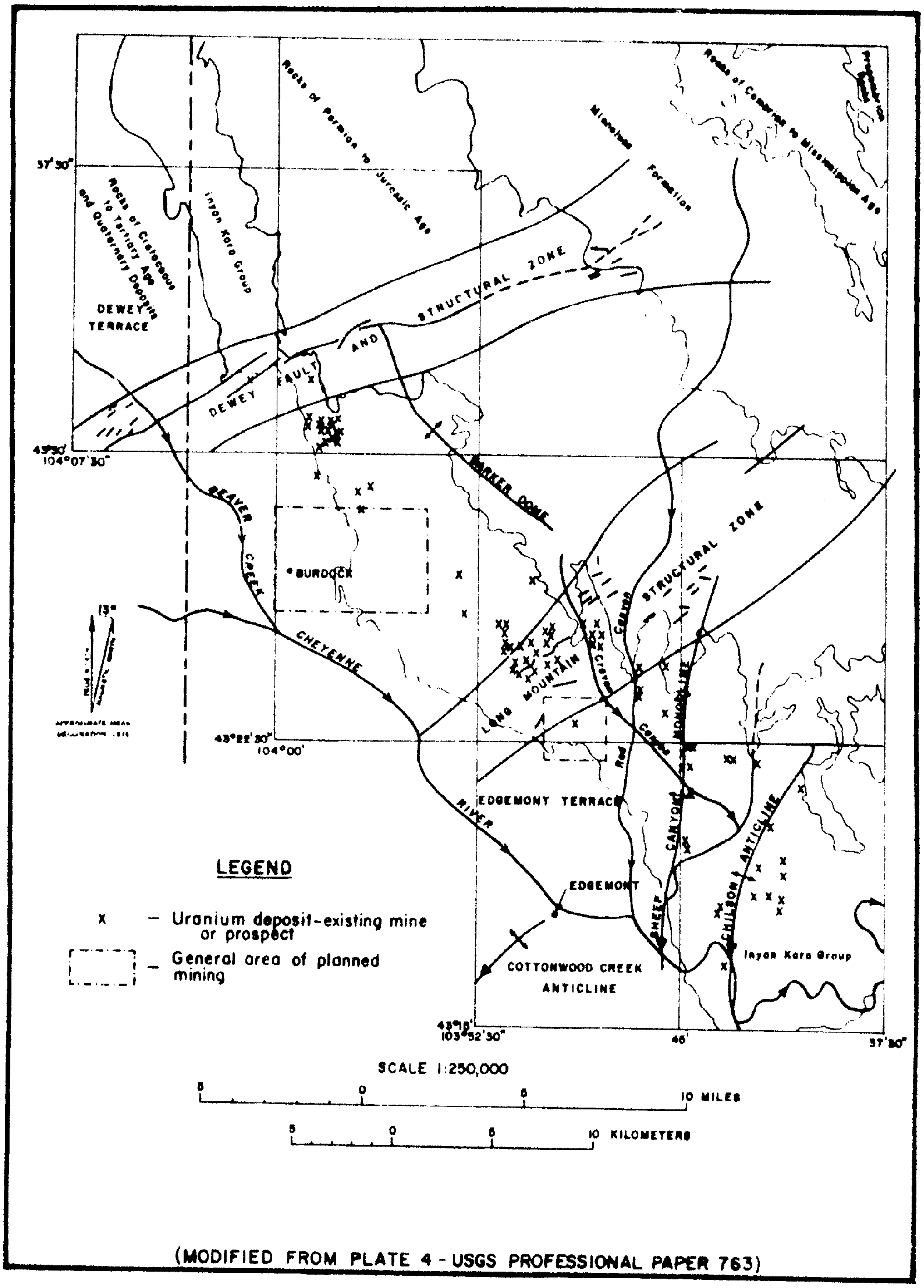

Figure 1 : Generalized Geologic Map of Site Region

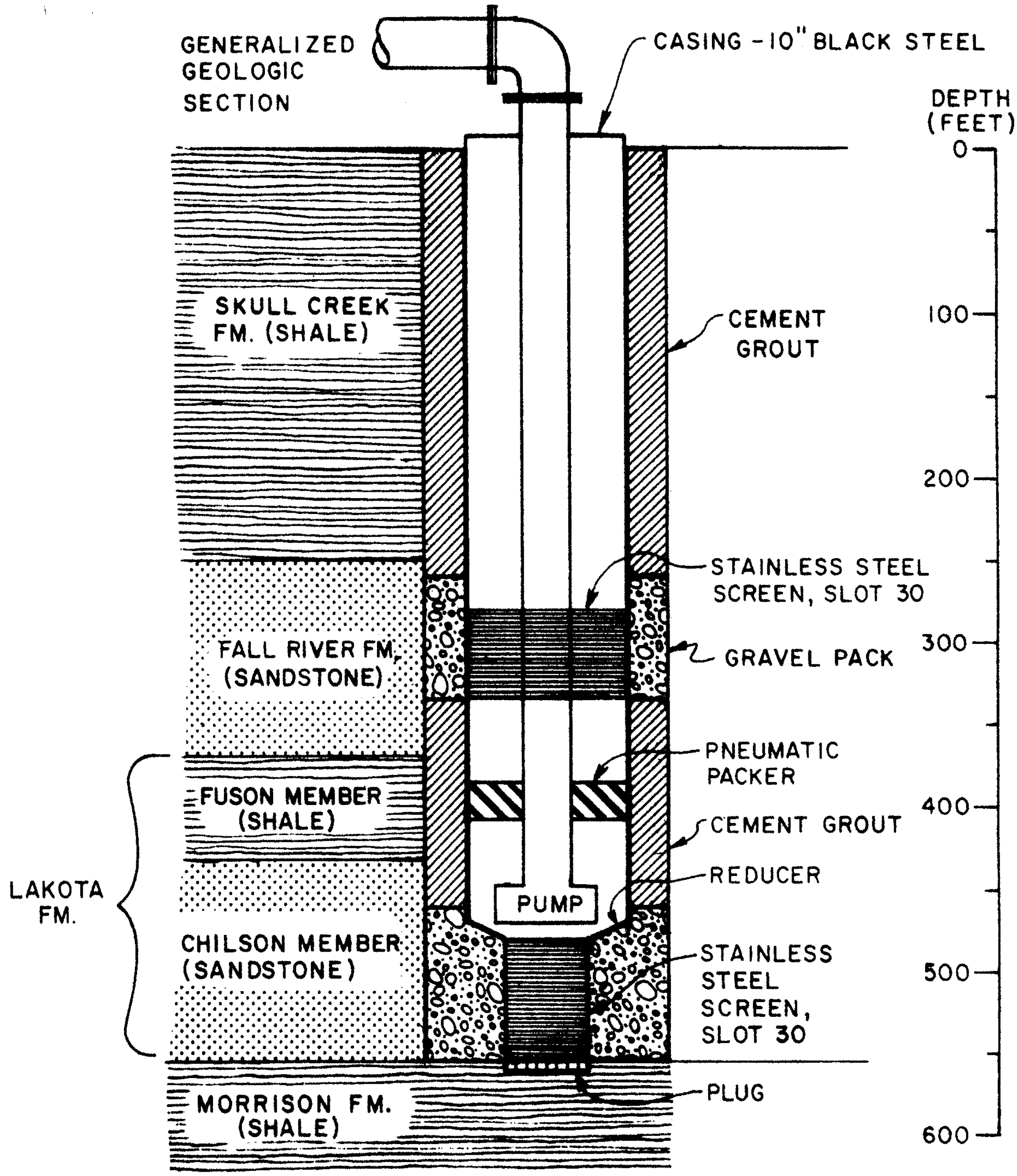

Figure 2 : Burdock Well Profile

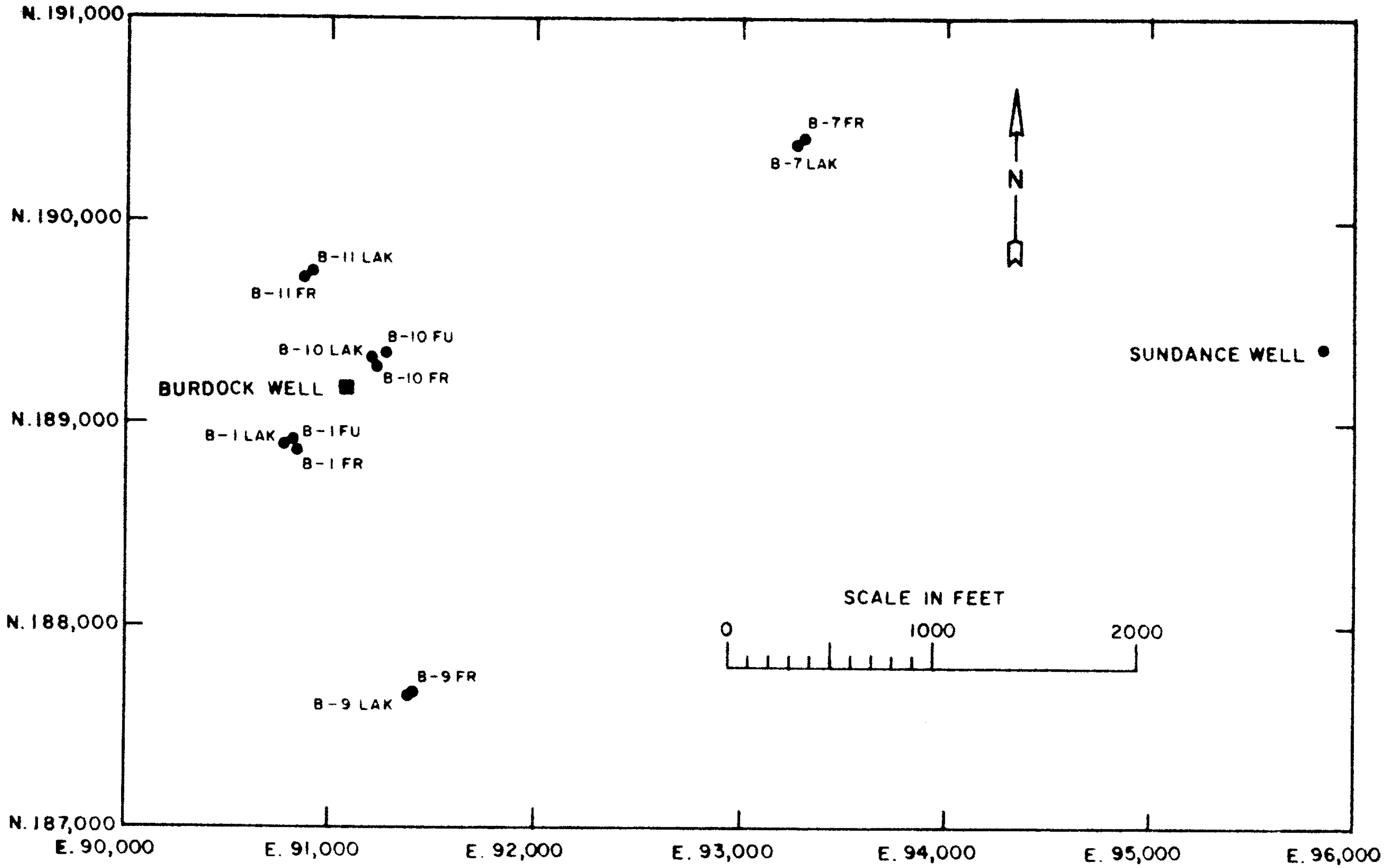

Figure 3: Well Location Map

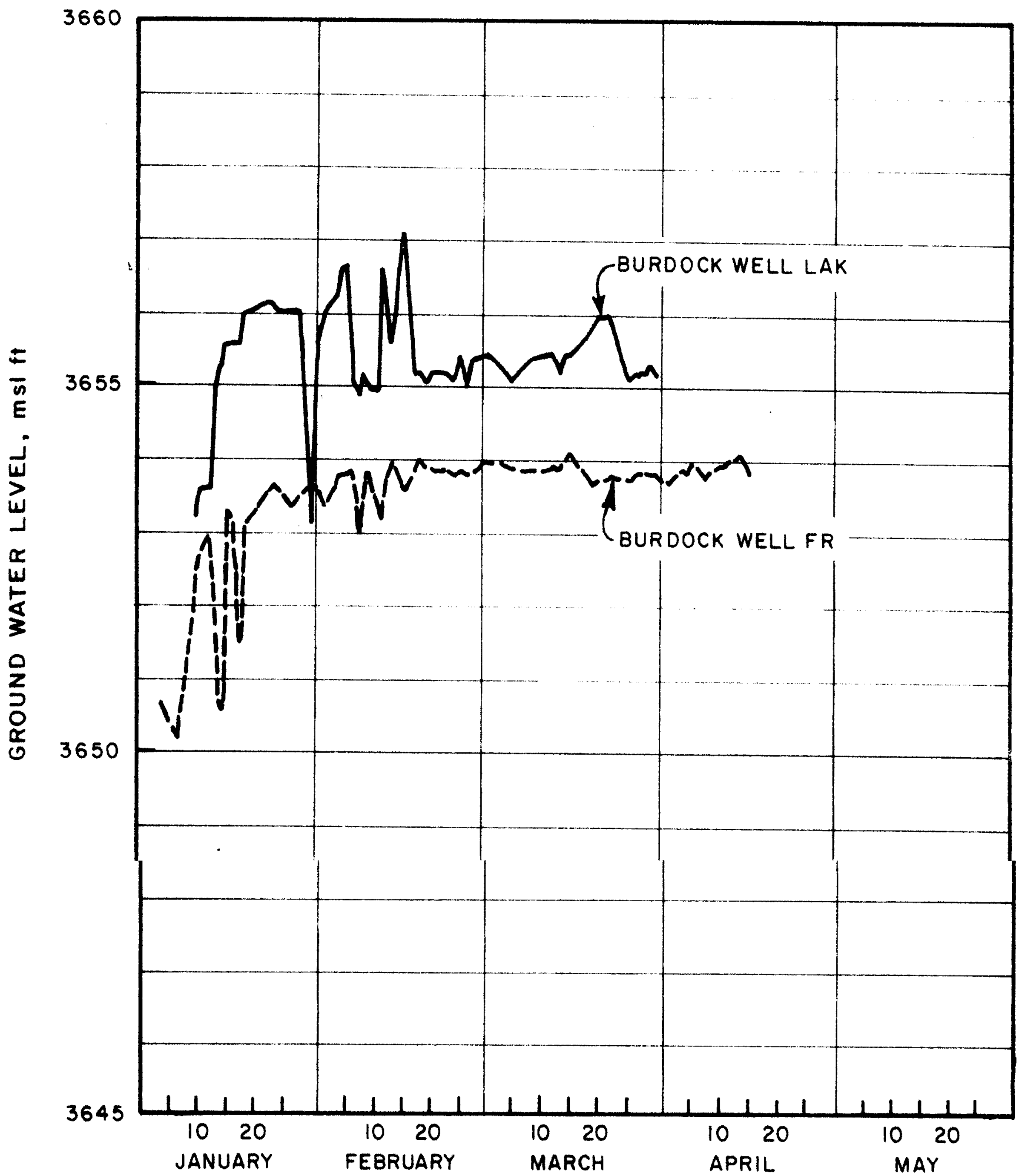

Figure 4 : Hydrographs for Burdock Test Well, January 1 through April 17, 1979

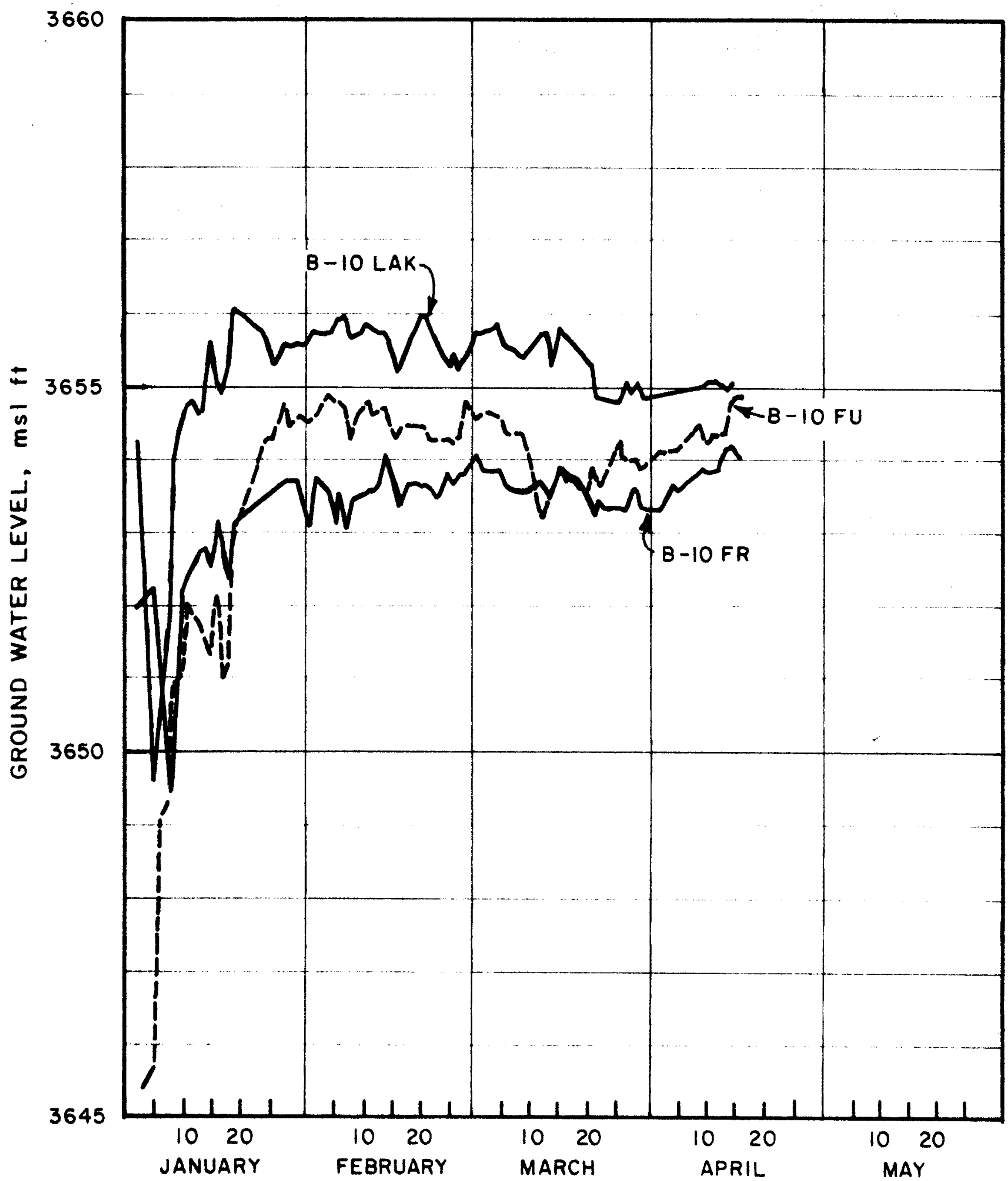

Figure 5 : Hydrographs for B-10 Observation Well Group, January 1 through April 17, 1979

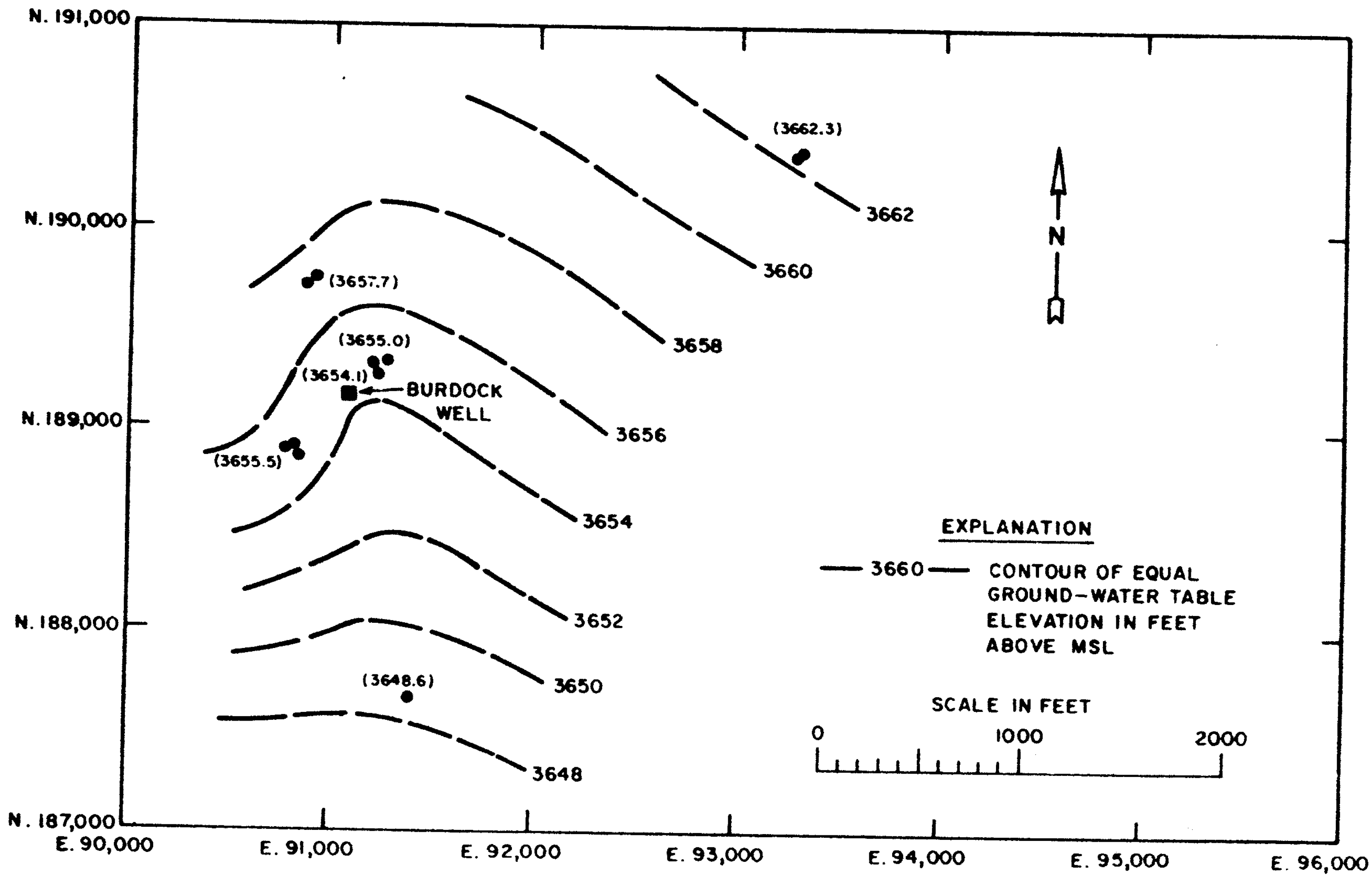

Figure 6 : Pre-Test Ground-Water Level Contour Map for Lakota Aquifer

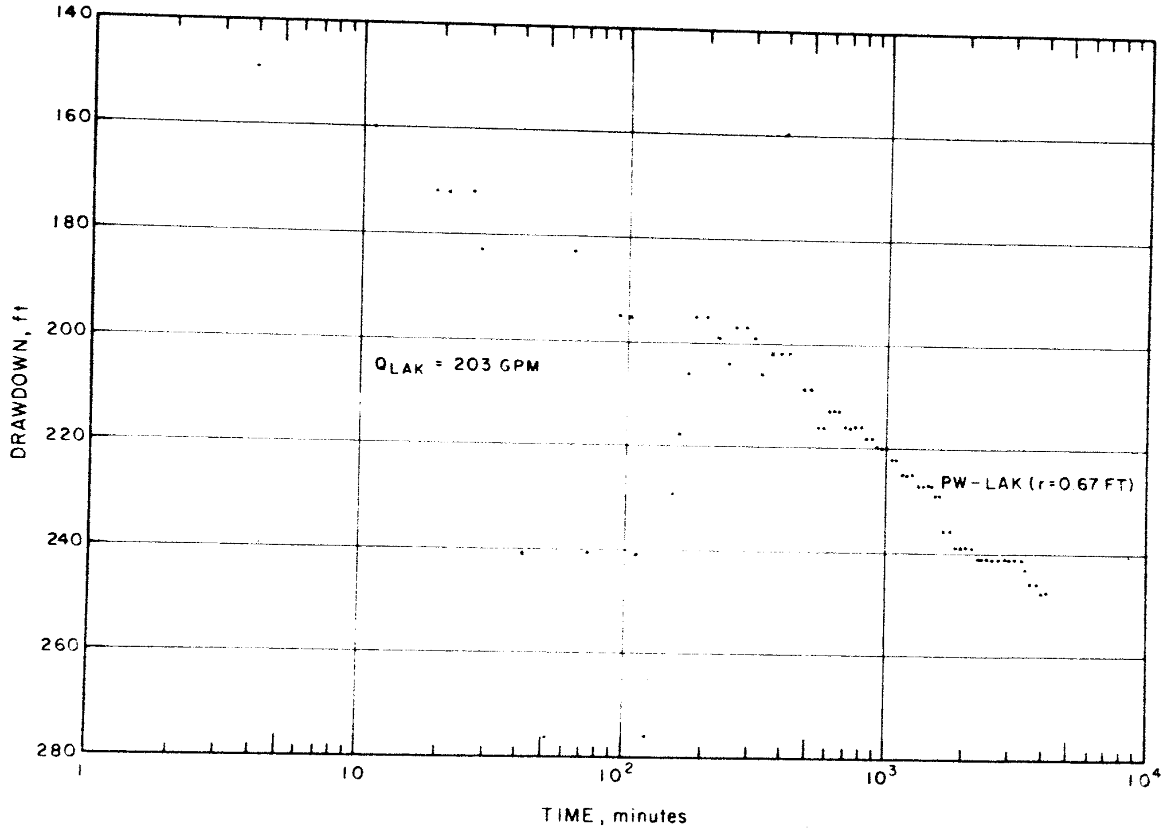

Figure 7: Semilogarithmic Graph of Drawdown for Pumped Well, Lakota Aquifer Test

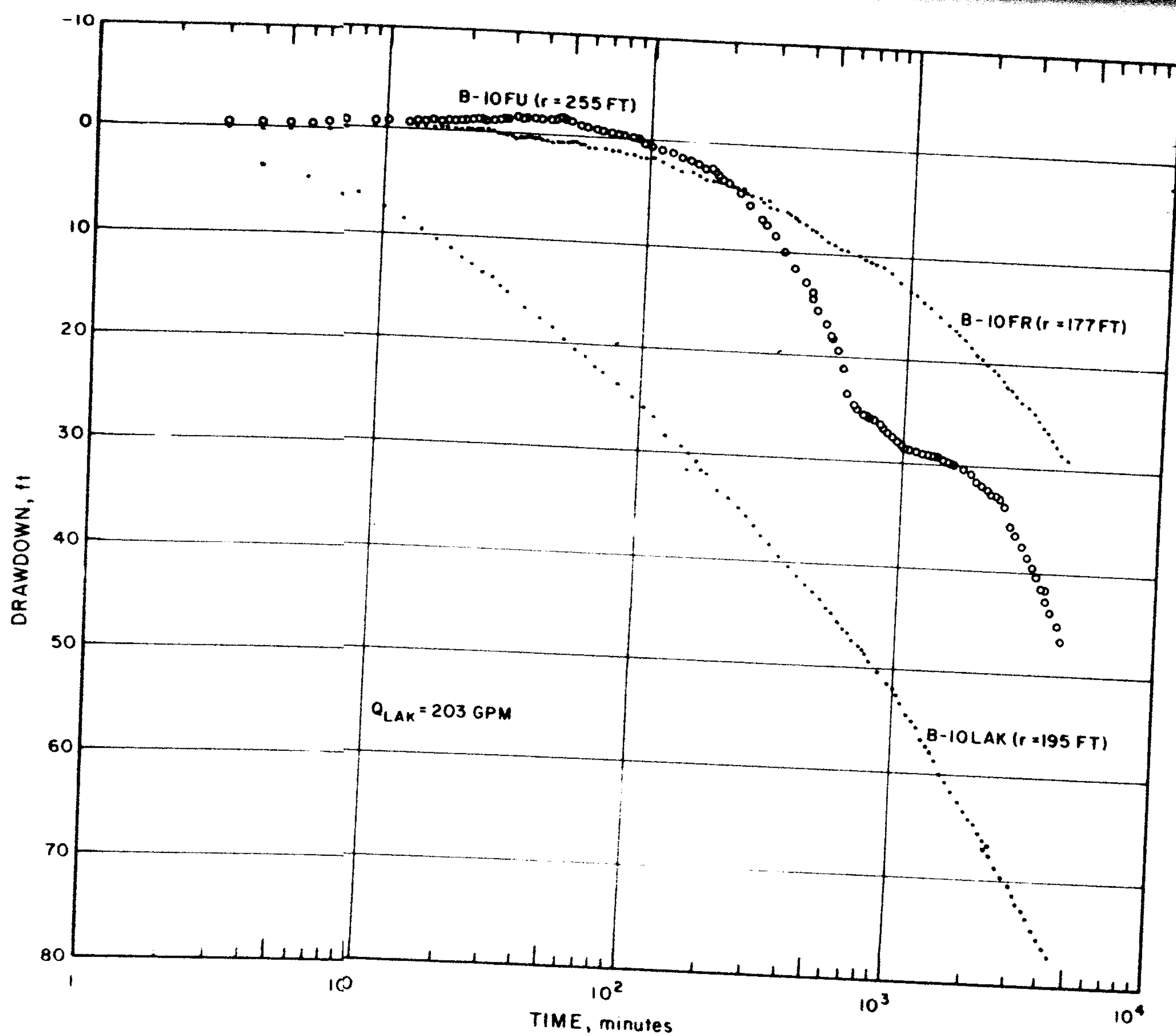

Figure 8 : Semilogarithmic Graphs of Drawdown for B-10 Observation Well Group, Lakota Aquifer Test

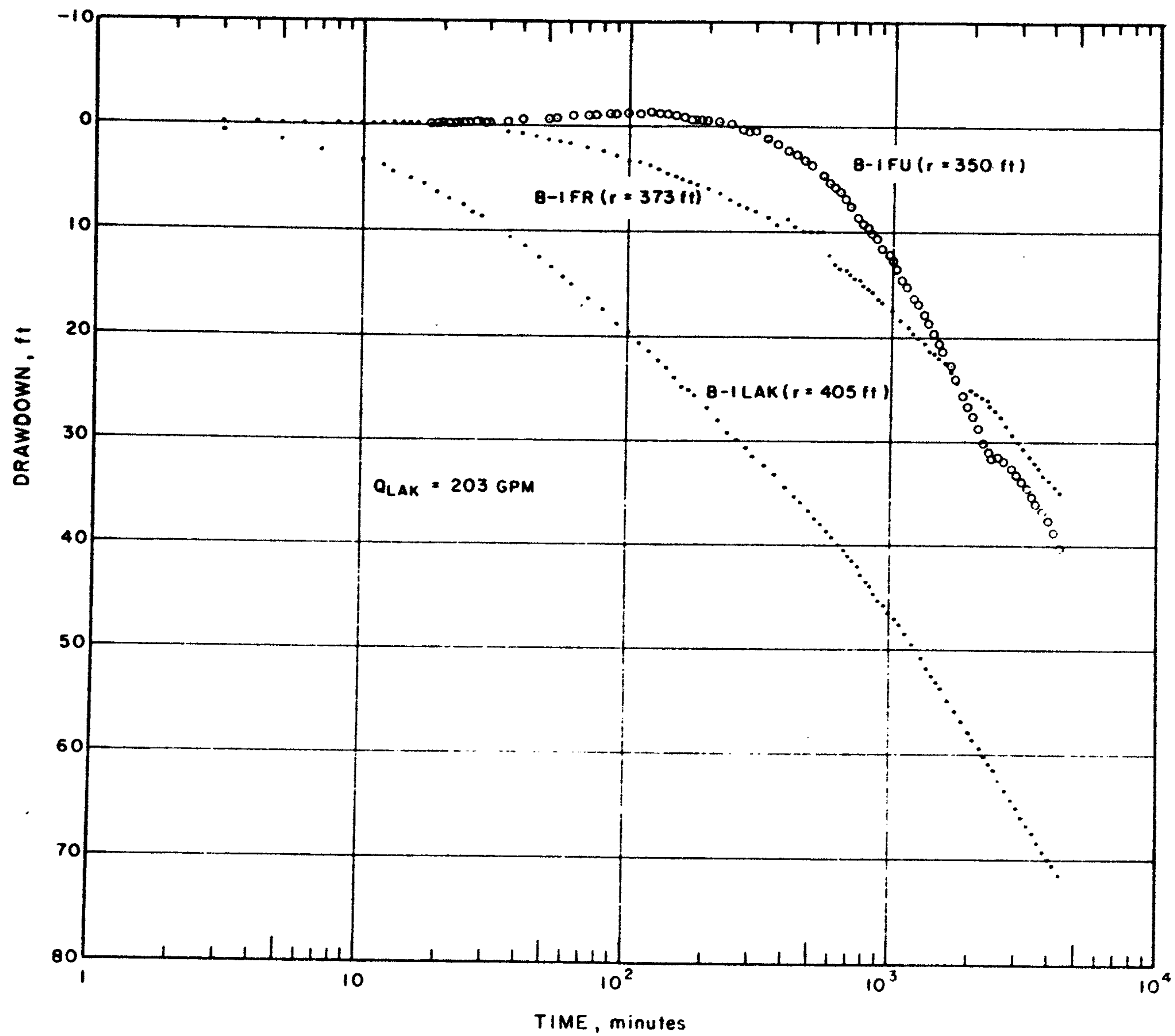

Figure 9: Semilogarithmic Graphs of Drawdown for B-1 Observation Well Group, Lakota Aquifer Test

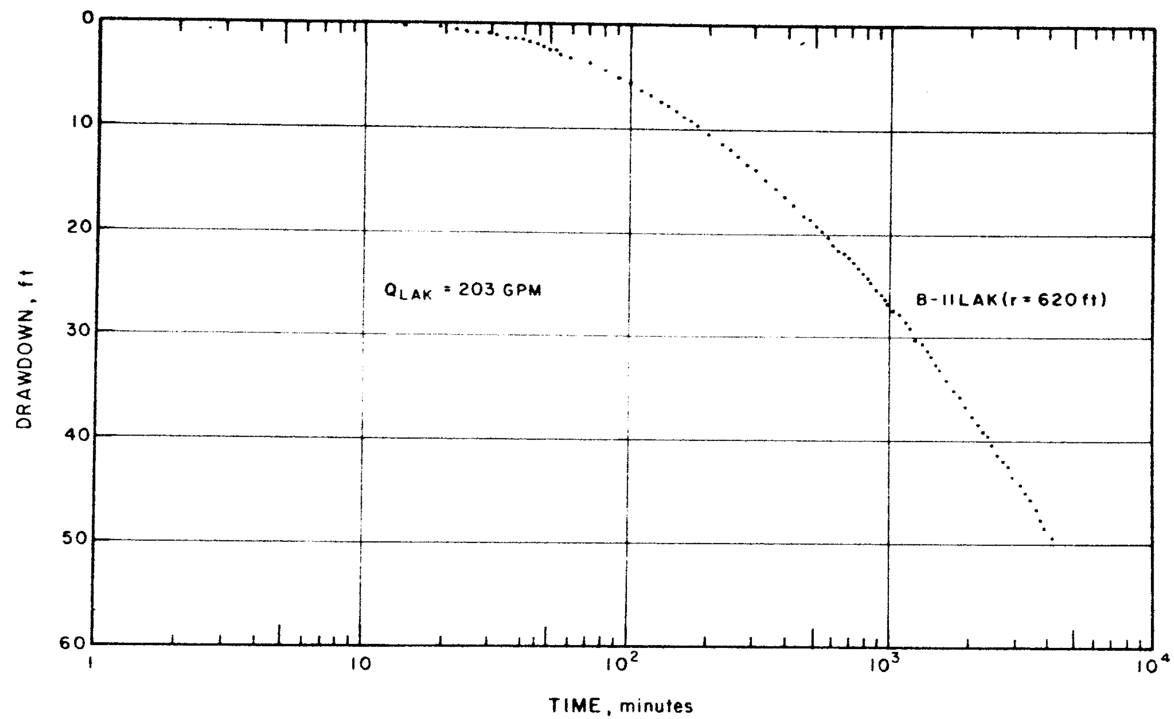

Figure 10: Semilogarithmic Graph of Drawdown for B-11 Observation Well Group, Lakota Aquifer Test

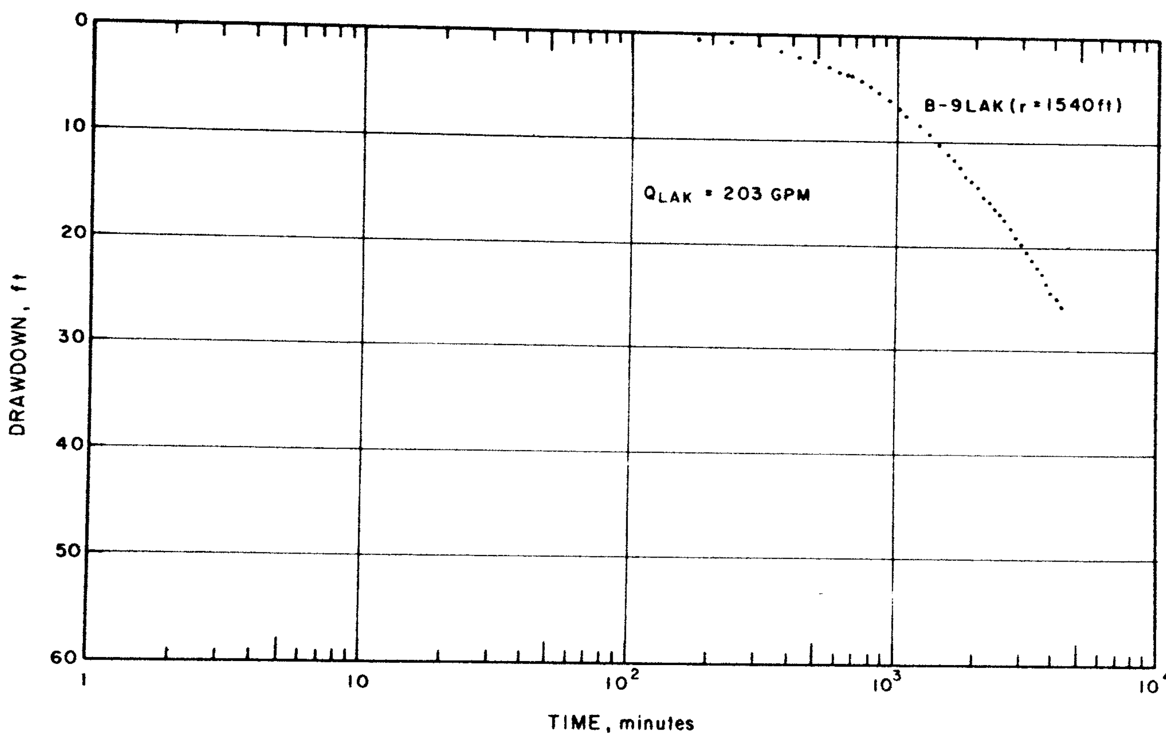

Figure 11: Semilogarithmic Graph of Drawdown for B-9 Observation Well Group, Lakota Aquifer Test

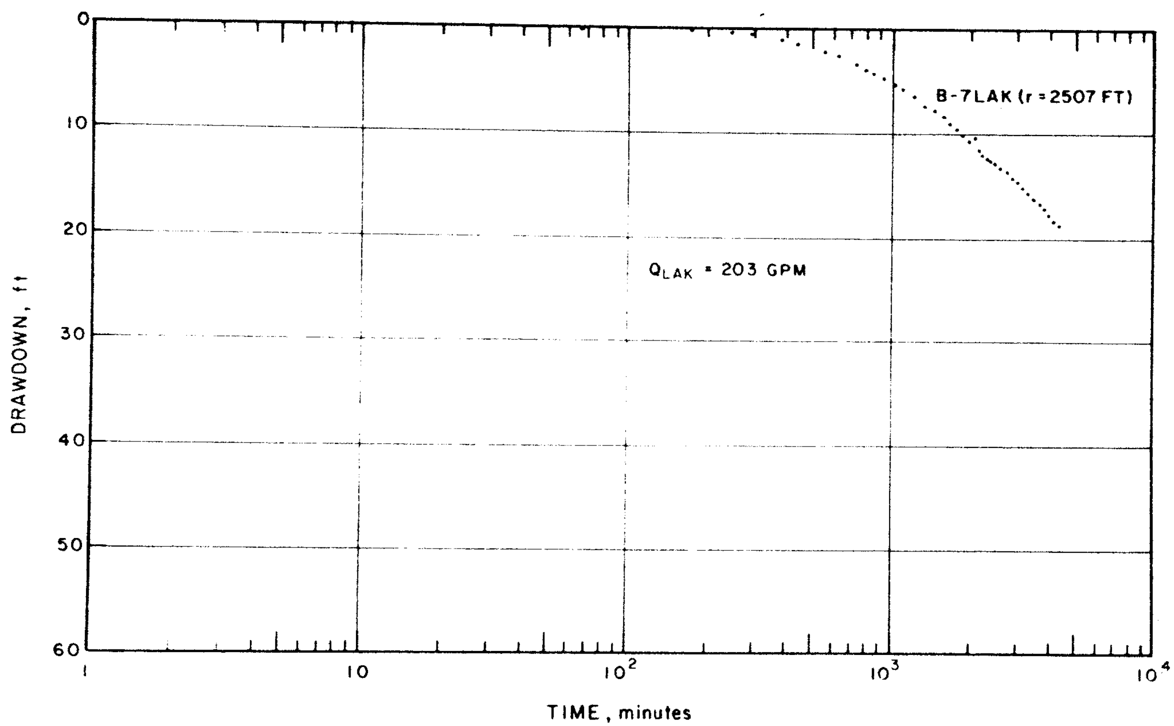

Figure 12: Semilogarithmic Graph of Drawdown for B-7 Observation Well Group, Lakota Aquifer Test

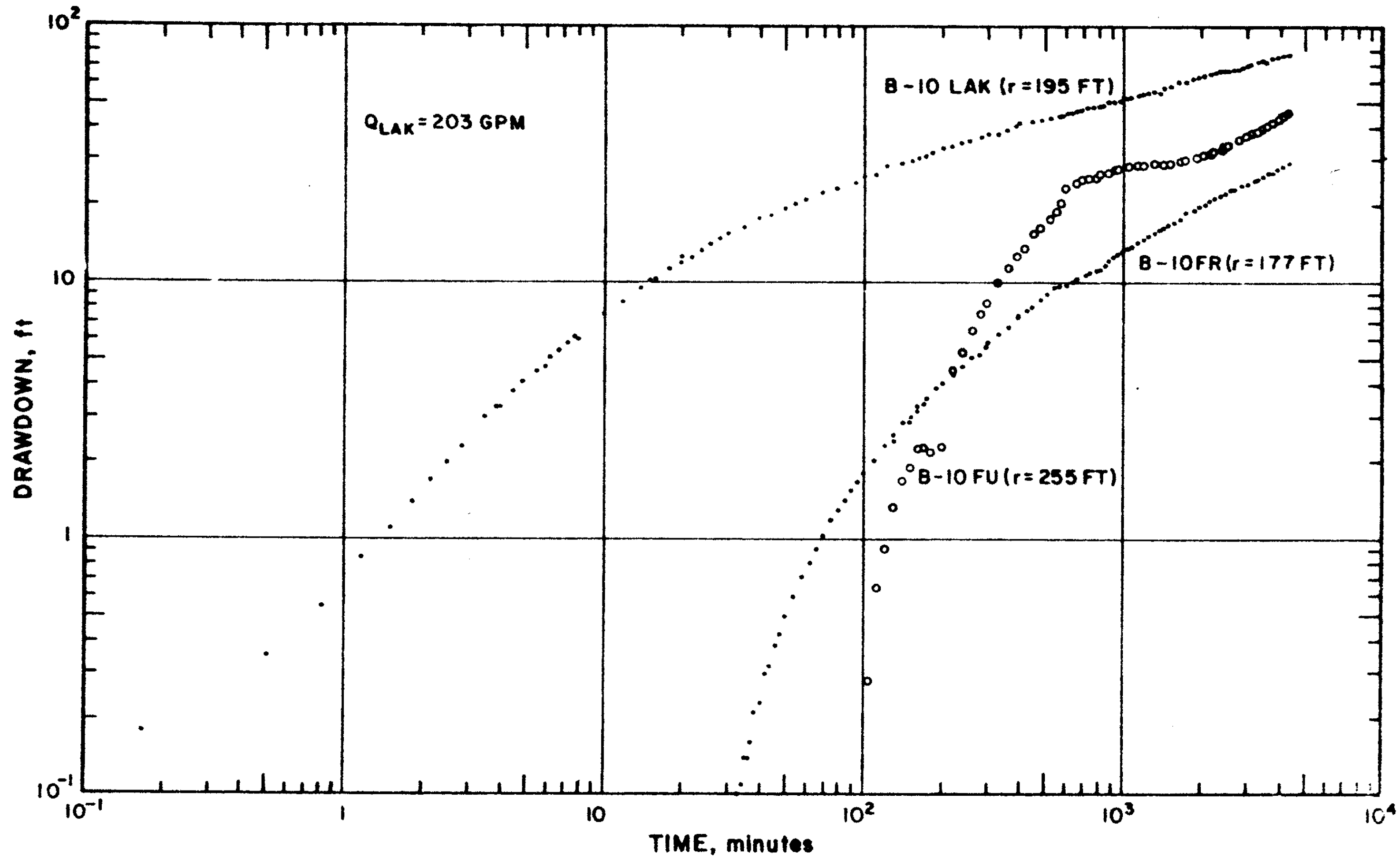

Figure 13 : Logarithmic Graphs of Drawdown for B-10 Observation Well Group, Lakota Aquifer Test

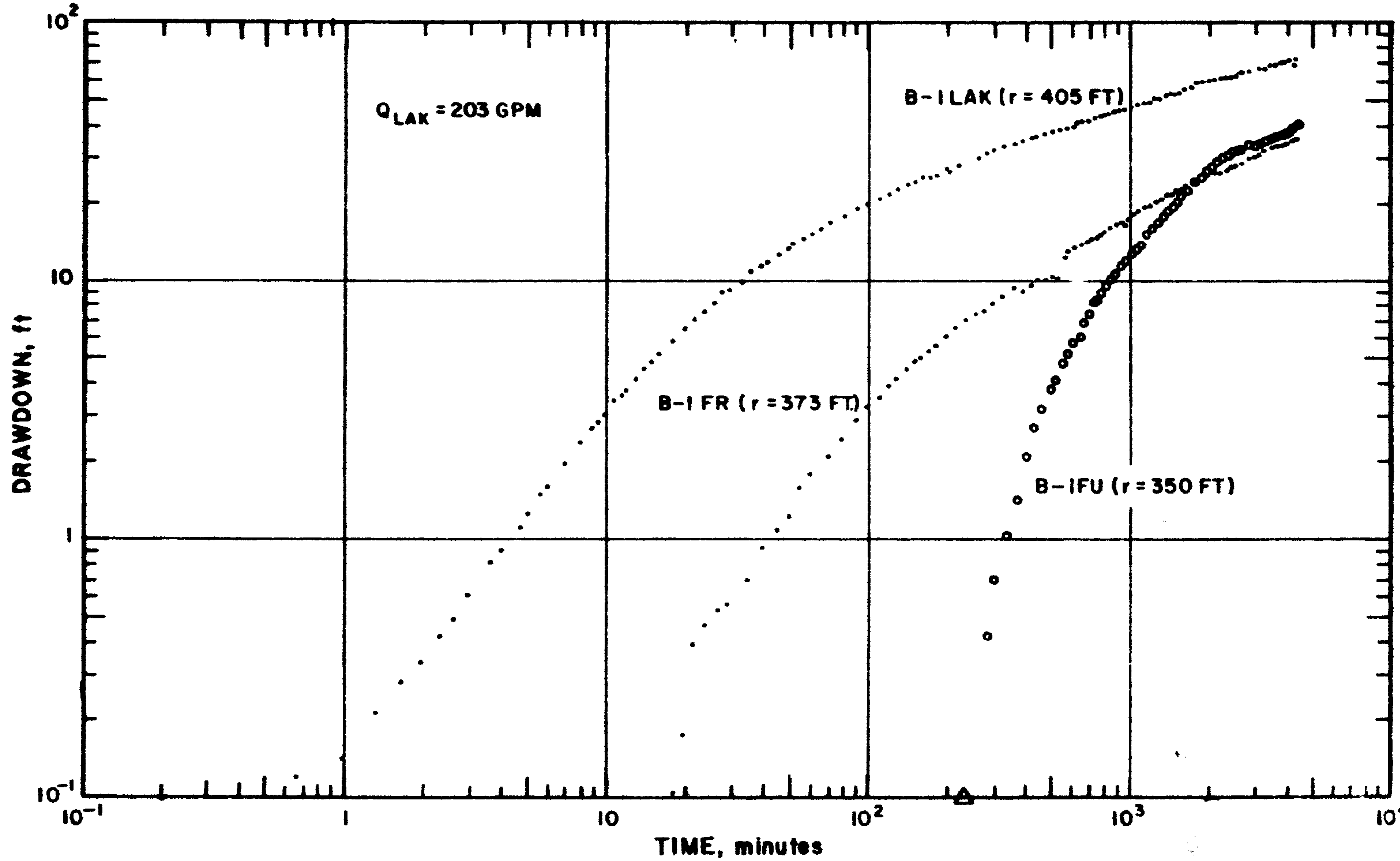

Figure 14 : Logarithmic Graphs of Drawdown for B-1 Observation Well Group, Lakota Aquifer Test

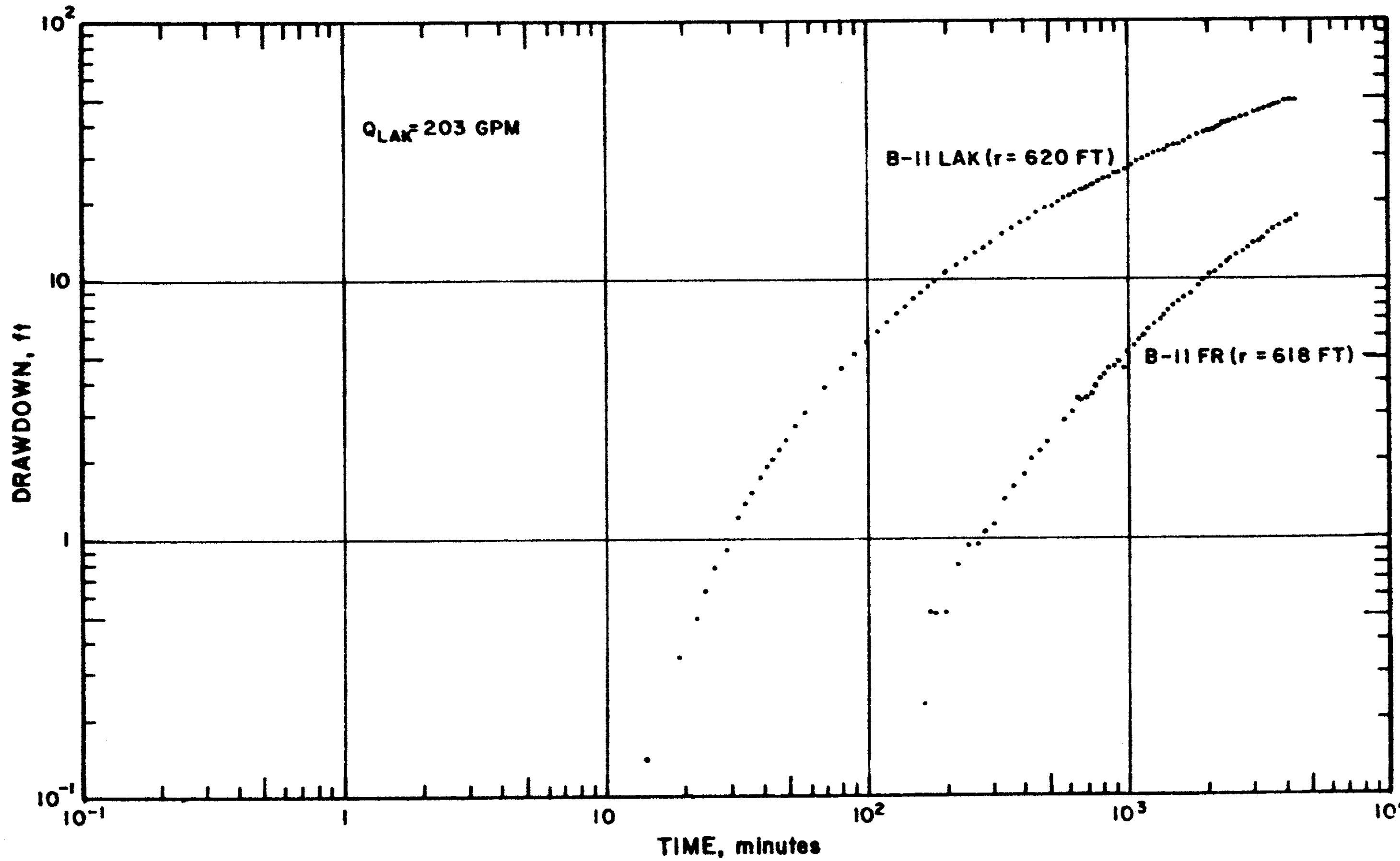

Figure 15: Logarithmic Graphs of Drawdown for B-11 Observation Well Group, Lakota Aquifer Test

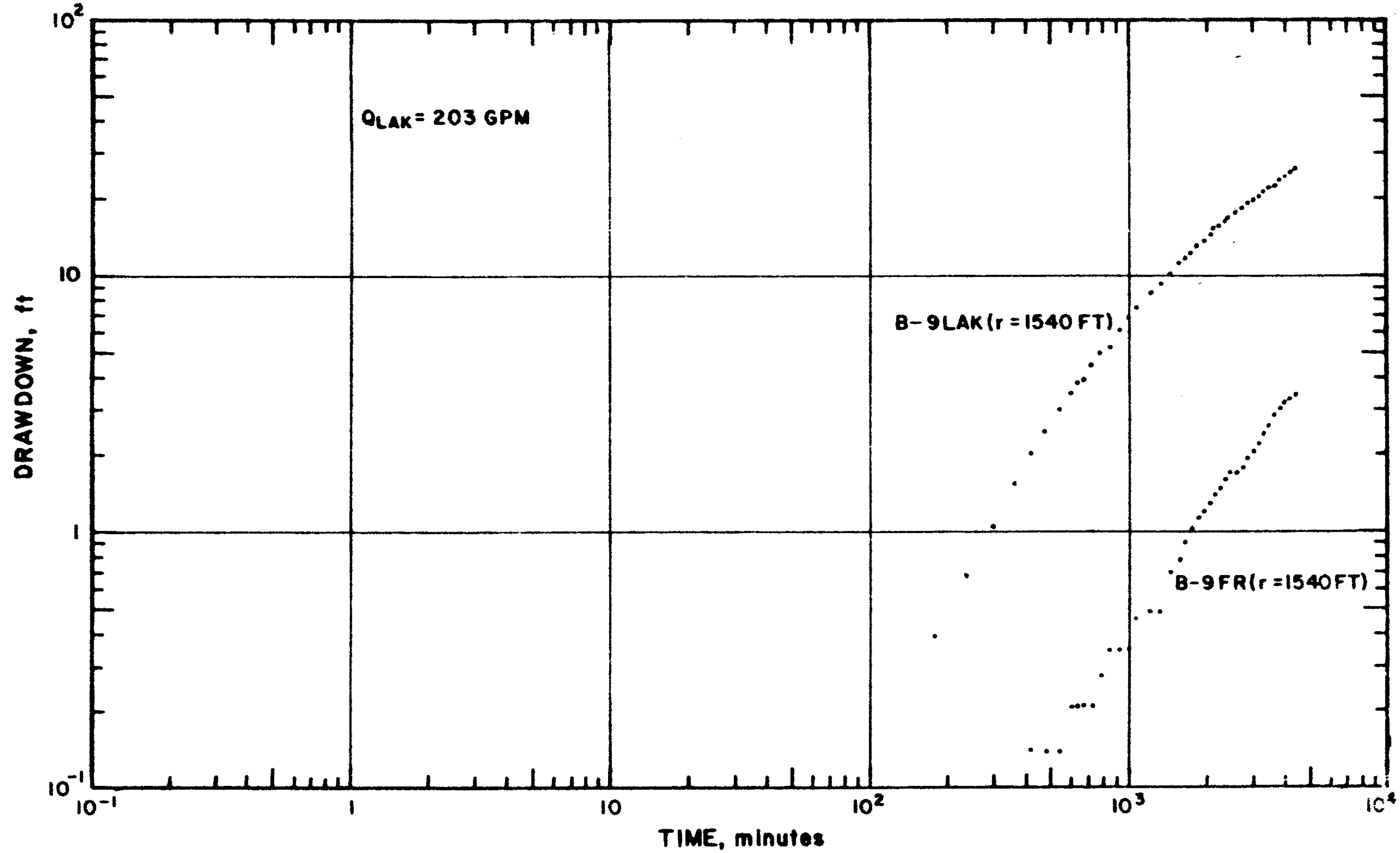

Figure 16 : Logarithmic Graphs of Drawdown for B-9 Observation Well Group, Lakota Aquifer Test

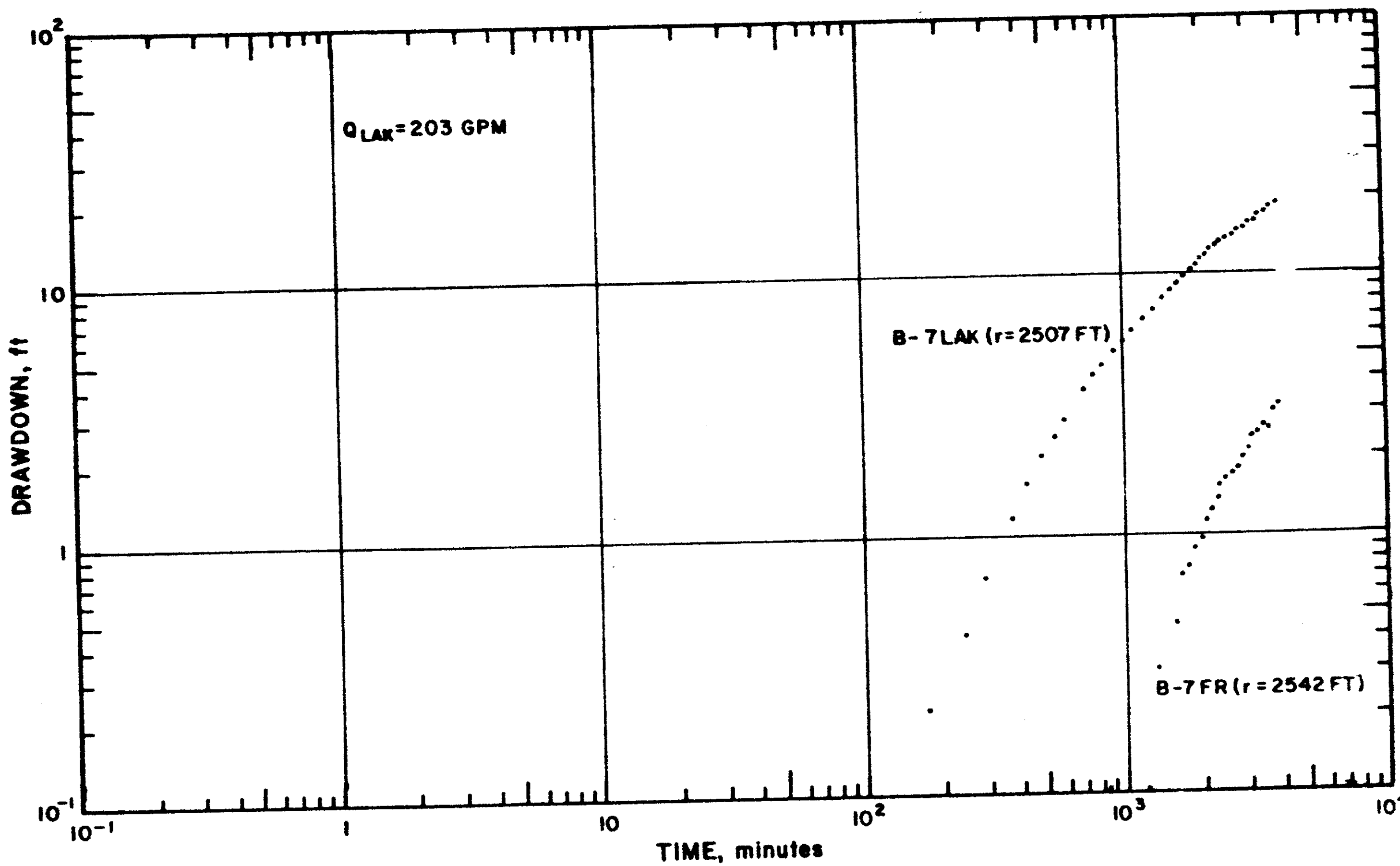

Figure 17 : Logarithmic Graphs of Drawdown for B-7 Observation Well Group, Lakota Aquifer Test

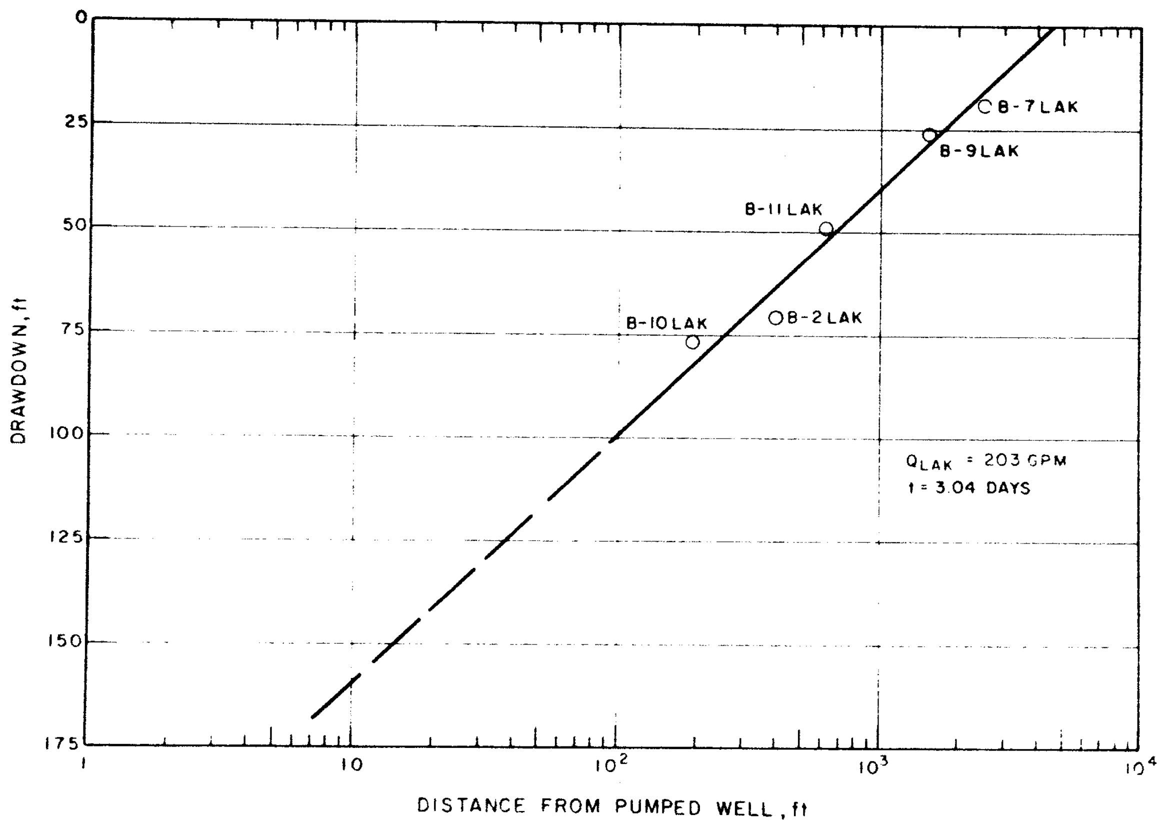

Figure 18 : Semilogarithmic Graph of Distance vs. Drawdown at End of Pumping Test, Lakota Aquifer Test

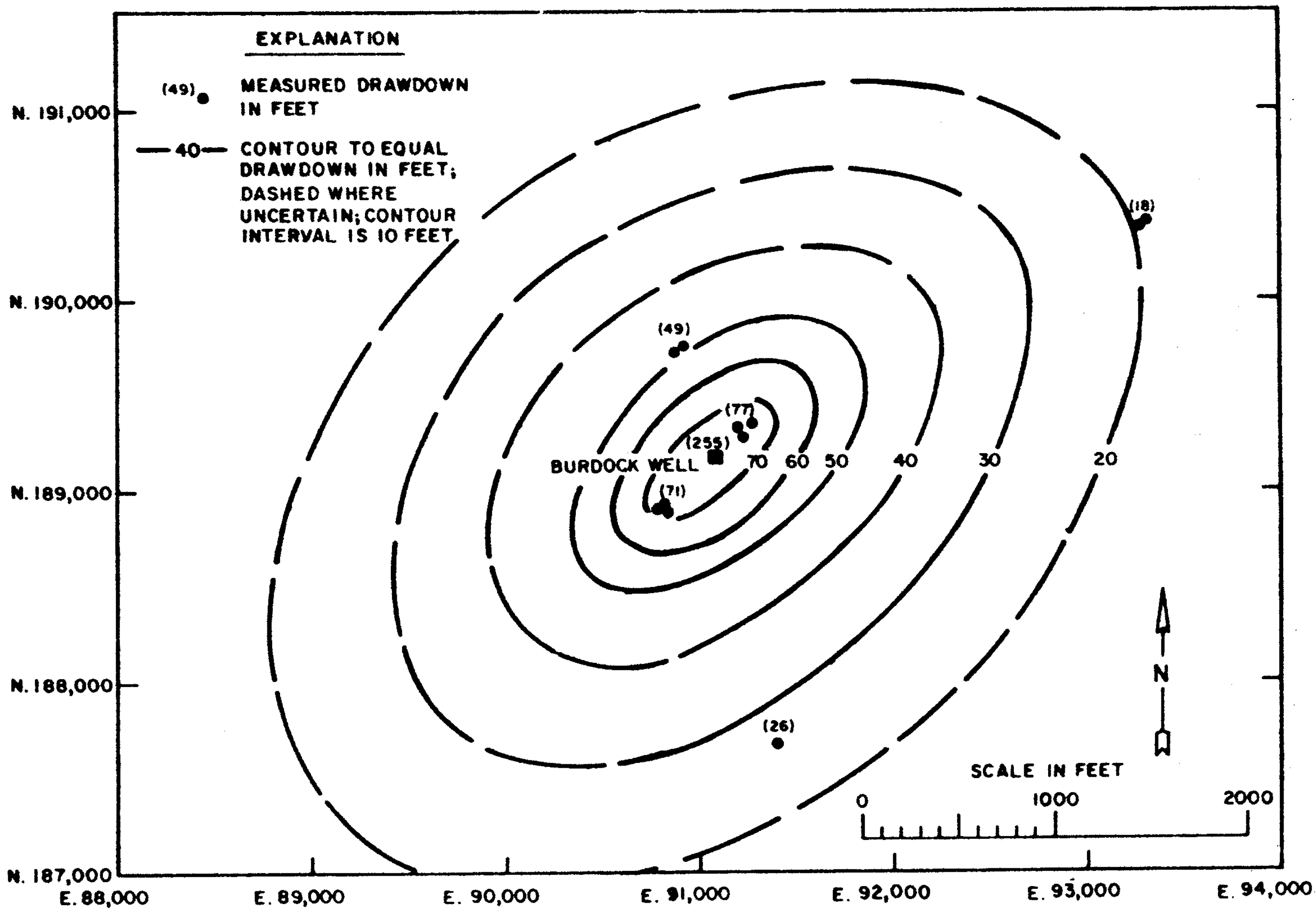

Figure 19 : Drawdown in Lakota Aquifer at End of Lakota Test

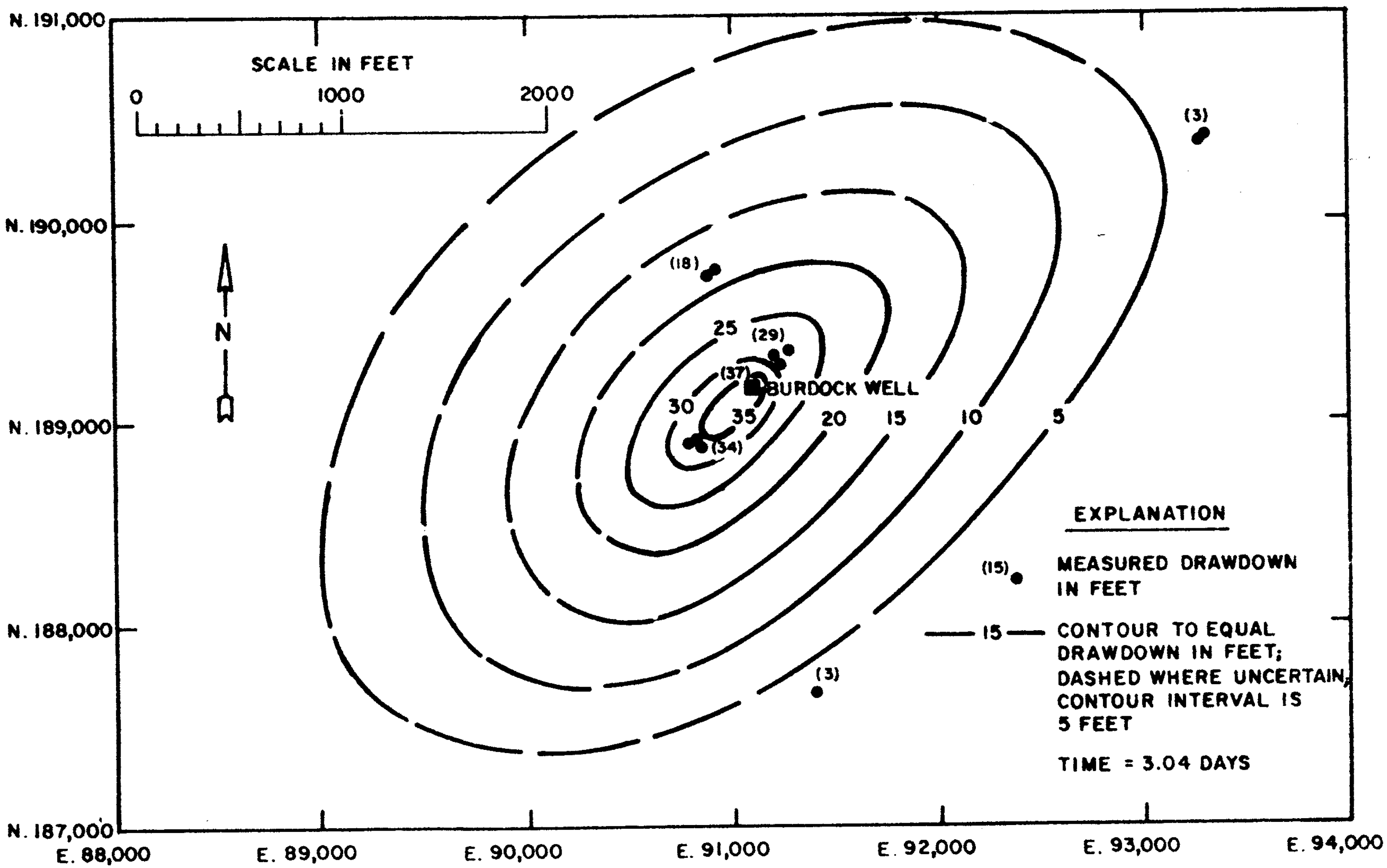

Figure 20 : Drawdown in Fall River Aquifer at End of Lakota Test

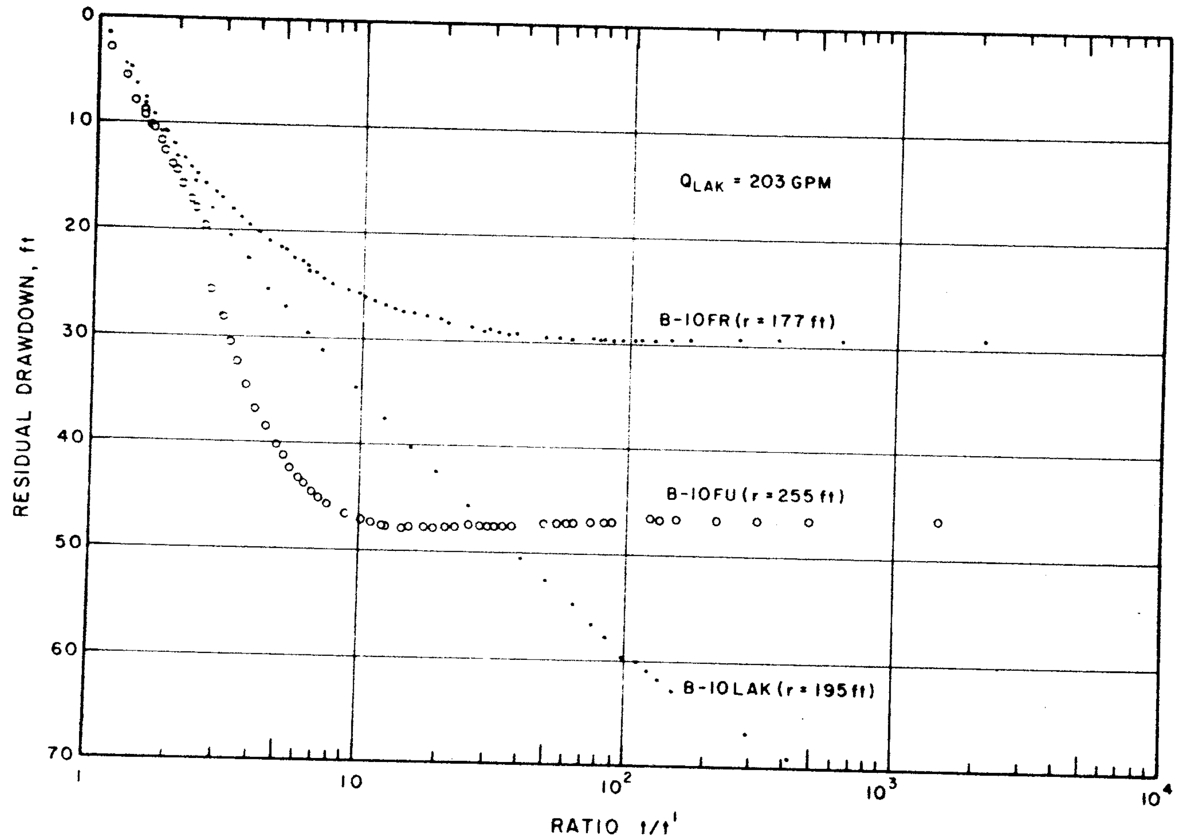

Figure 21: Recovery Graphs for B-10 Observation Well Group, Lakota Aquifer Test

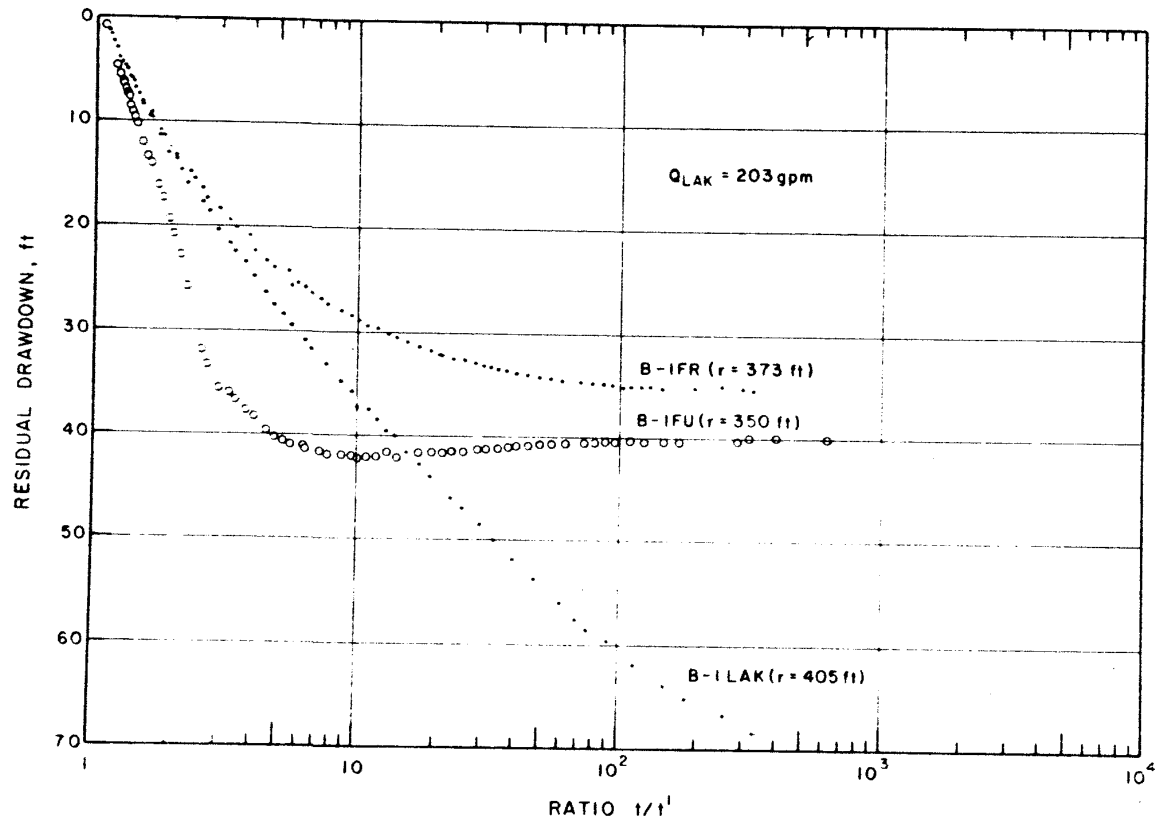

Figure 22 Recovery Graphs for B-1 Observation Well Group, Lakota Aquifer Test

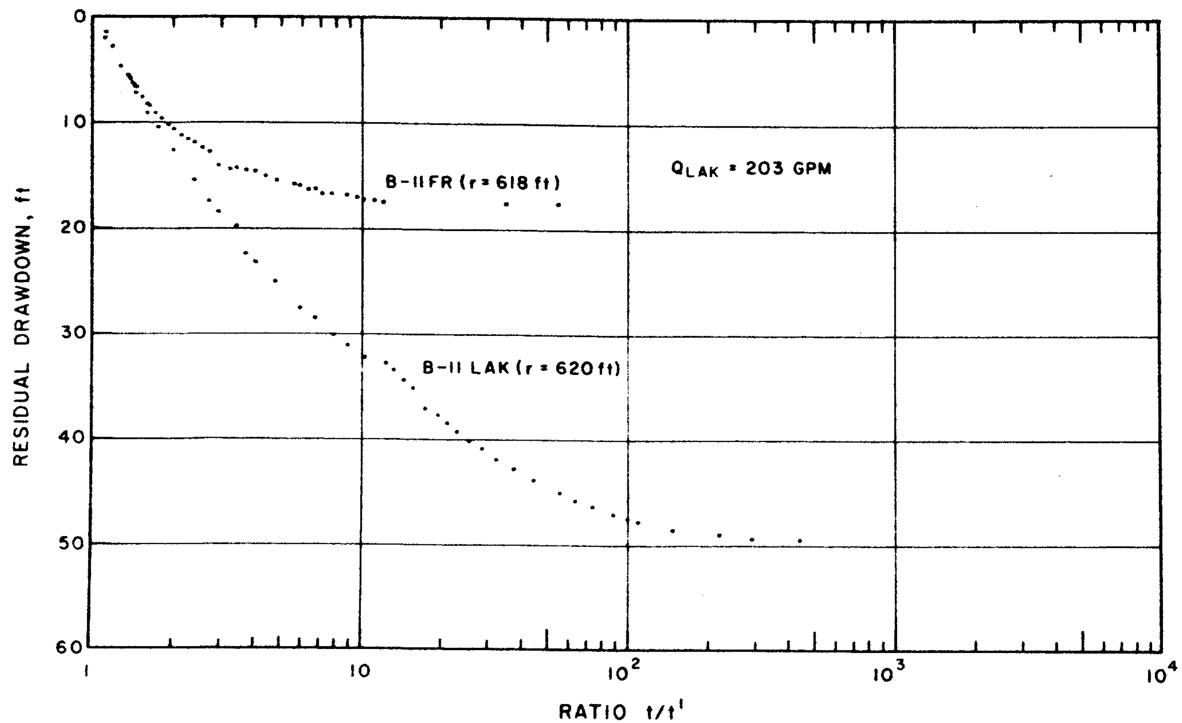

Figure 23: Recovery Graphs for B-11 Observation Well Group, Lakota Aquifer Test

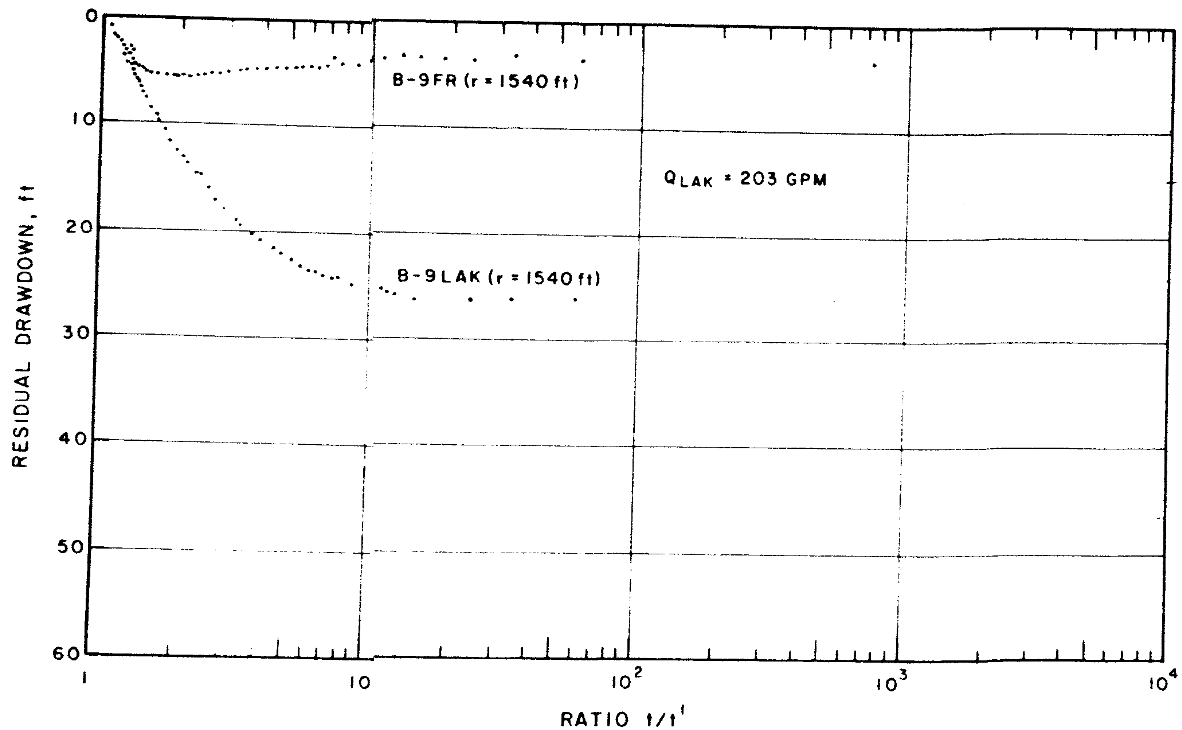

Figure 24 Recovery Graphs for B-9 Observation Well Group, Lakota Aquifer Test

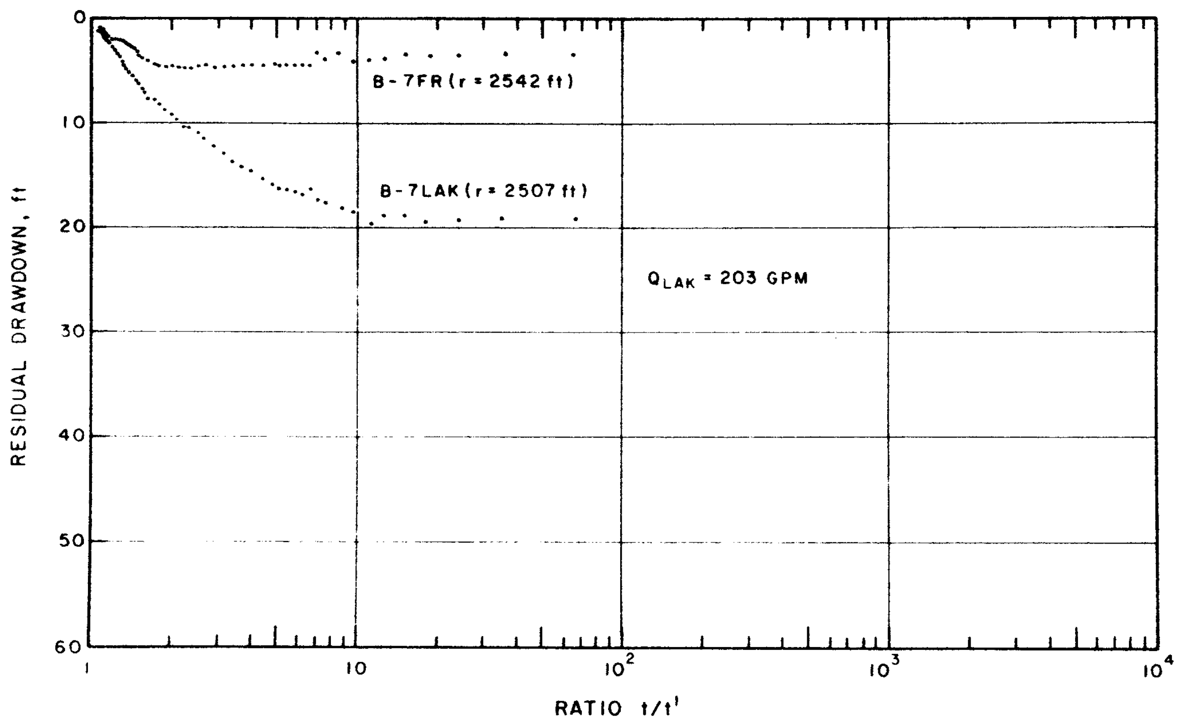

Figure 25: Recovery Graphs for B-7 Observation Well Group, Lakota Aquifer Test

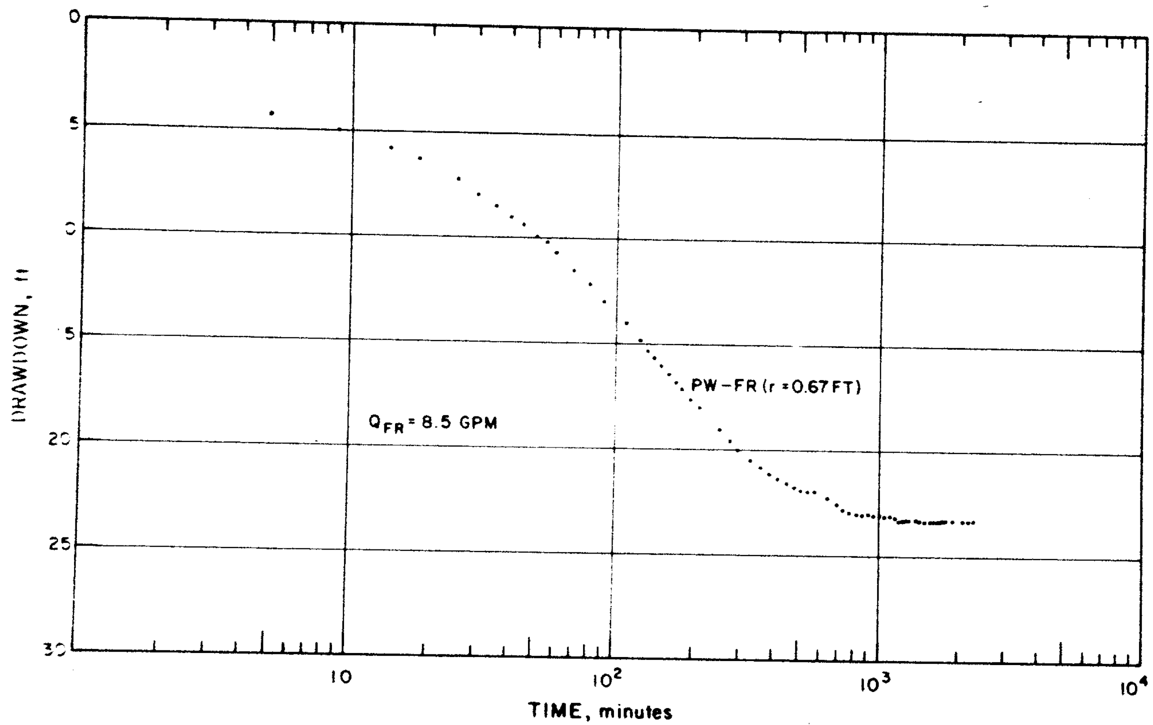

Figure 26: Semilogarithmic Graph of Drawdown for the Pumped Well, Fall River Aquifer Test

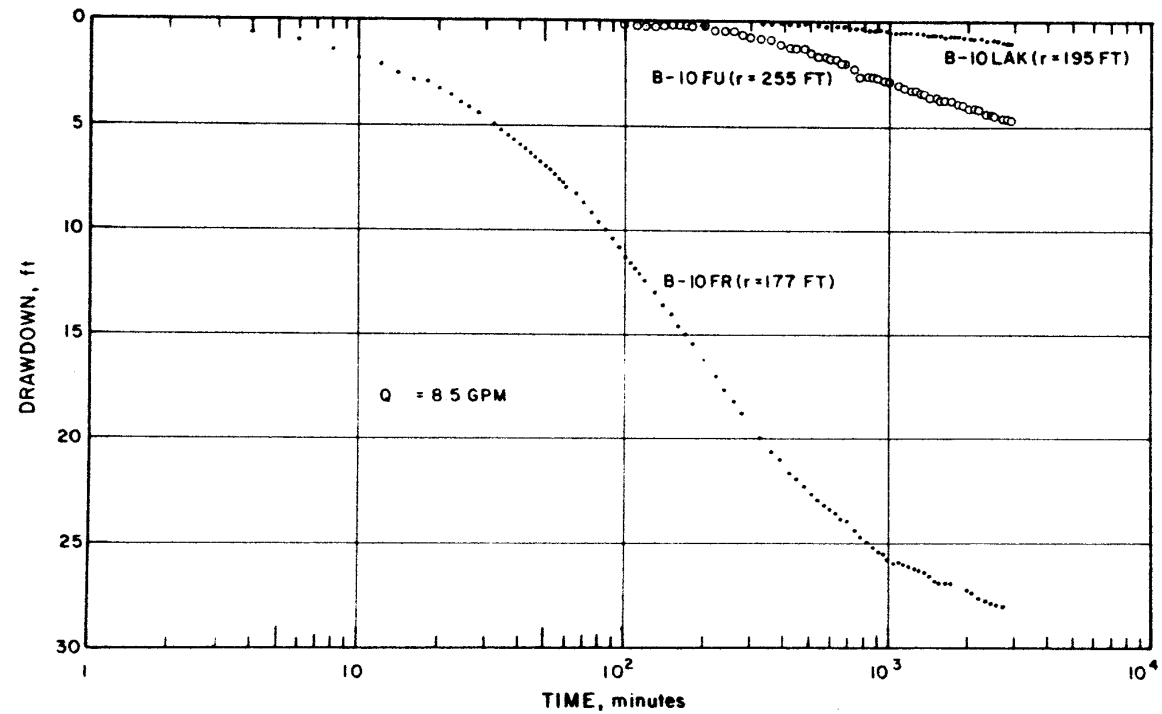

Figure 27: Semilogarithmic Graphs of Drawdown for B-10 Observation Well Group, Fall River Aquifer Test

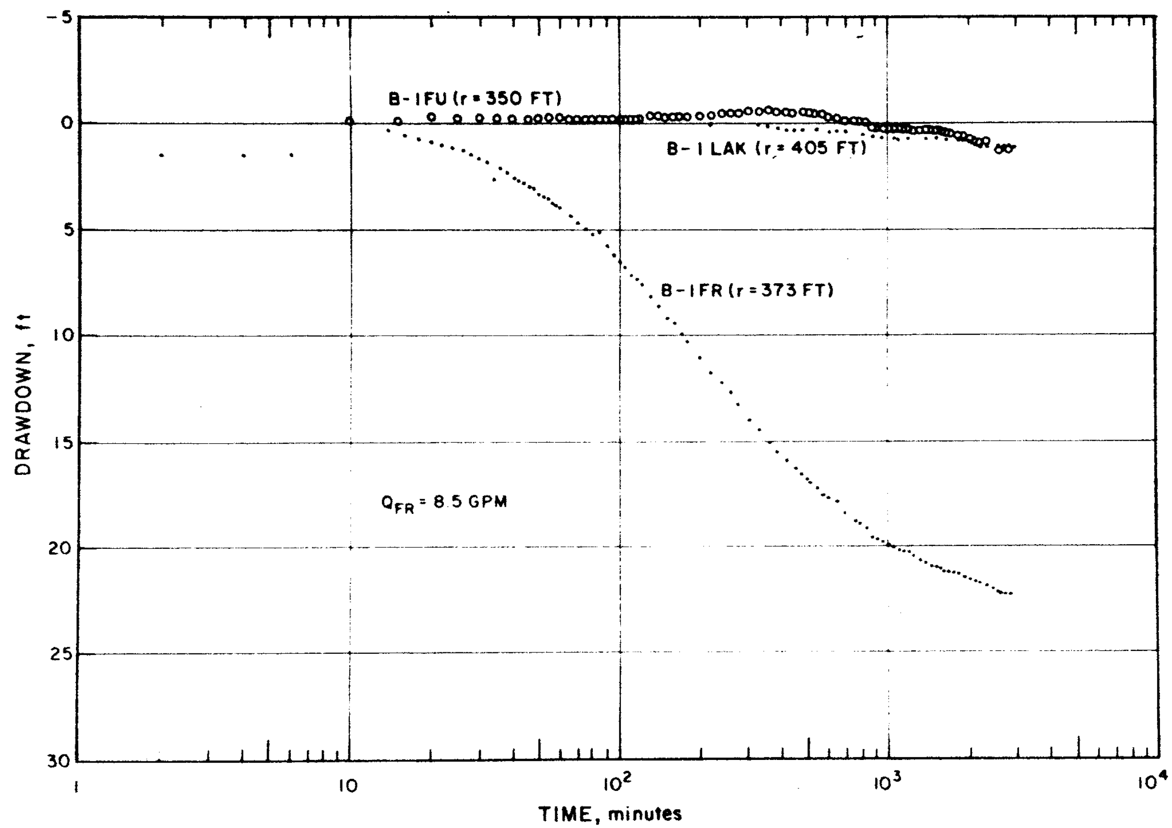

Figure 28 : Semilogarithmic Graphs of Drawdown for B-1 Observation Well Group, Fall River Aquifer Test

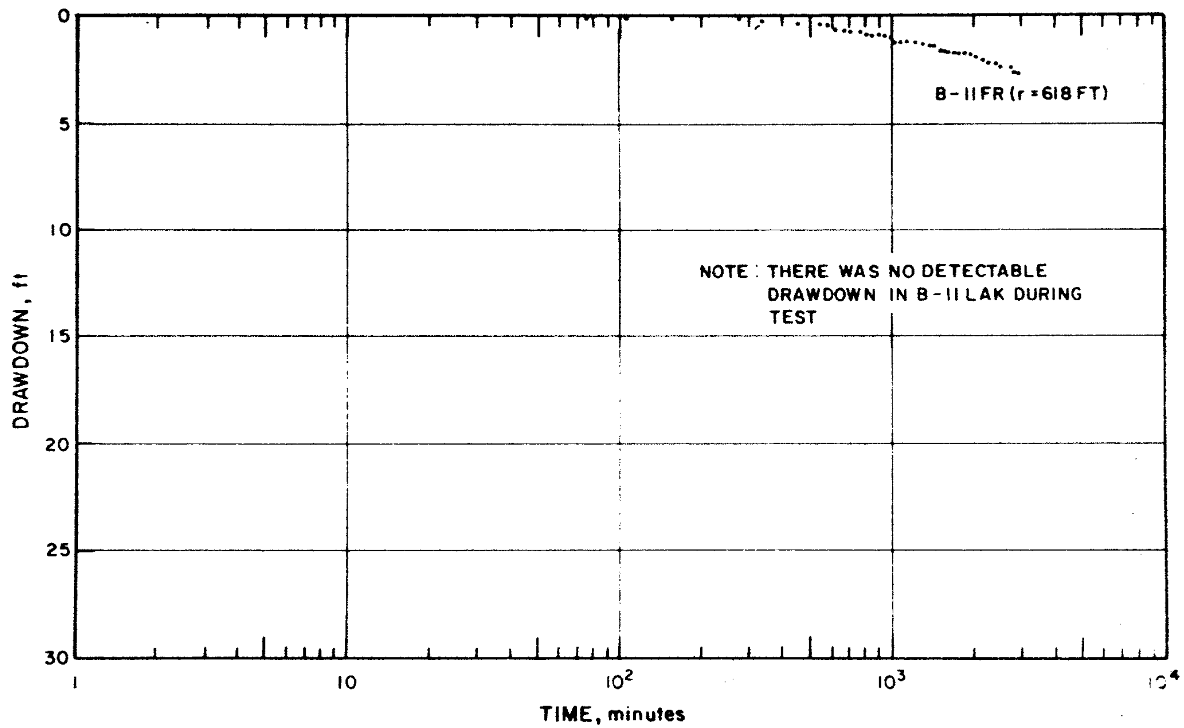

Figure 29: Semilogarithmic Graph of Drawdown for B-11 Observation Well Group, Fall River Aquifer Test

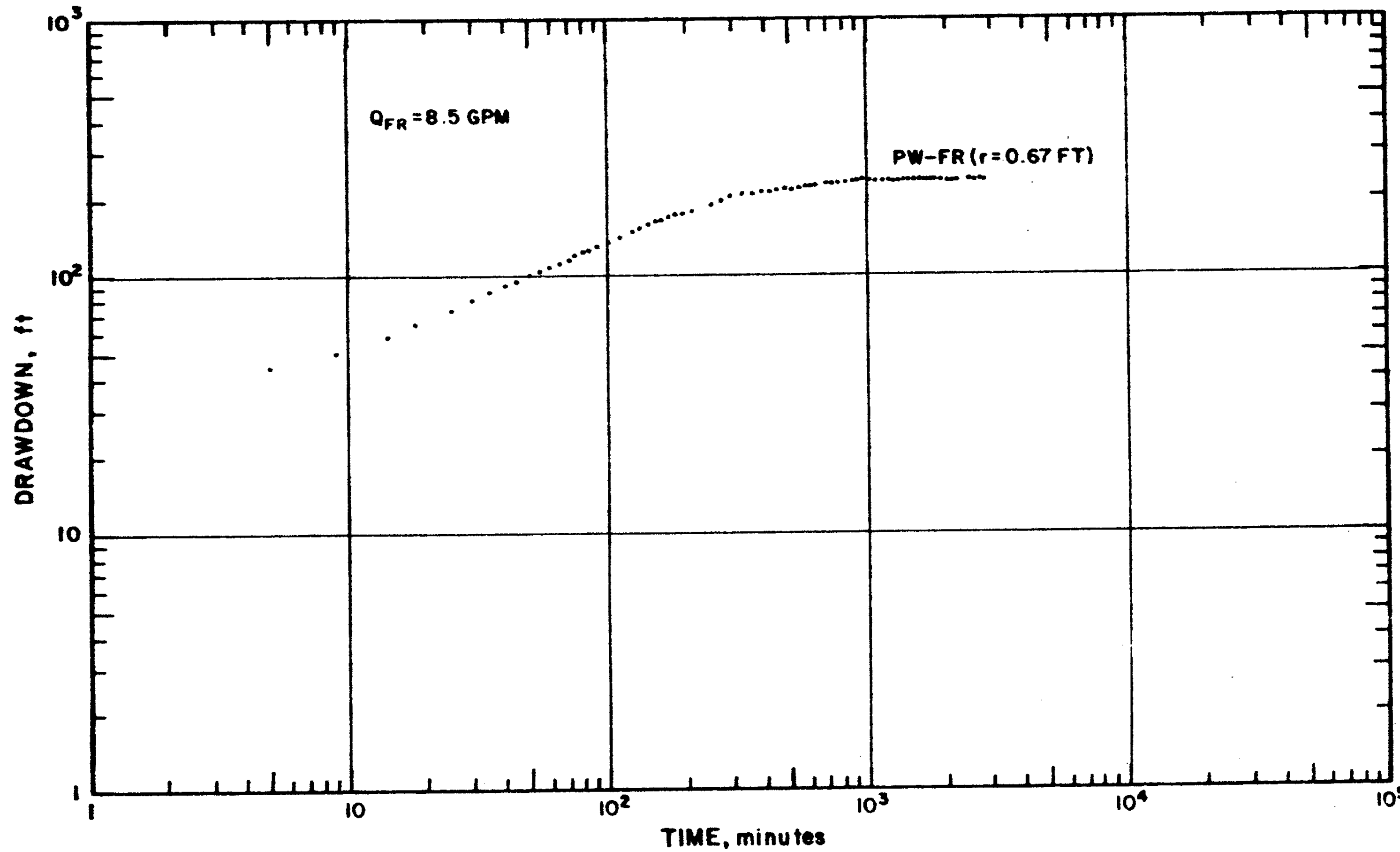

Figure 30: Logarithmic Graph of Drawdown for Pumped Well, Fall River Aquifer Test

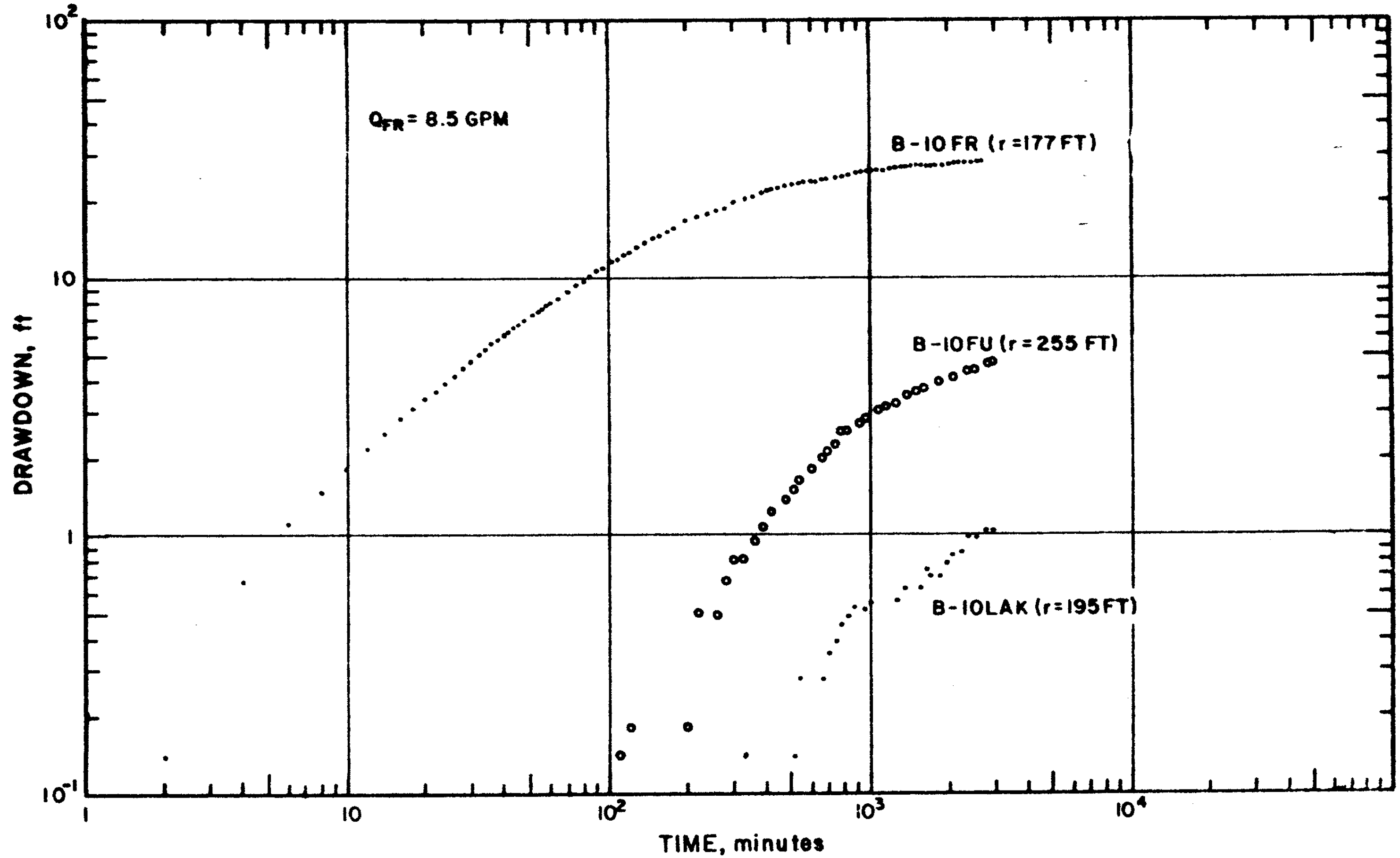

Figure 31: Logarithmic Graphs of Drawdown for B-10 Observation Well Group, Fall River Aquifer Test

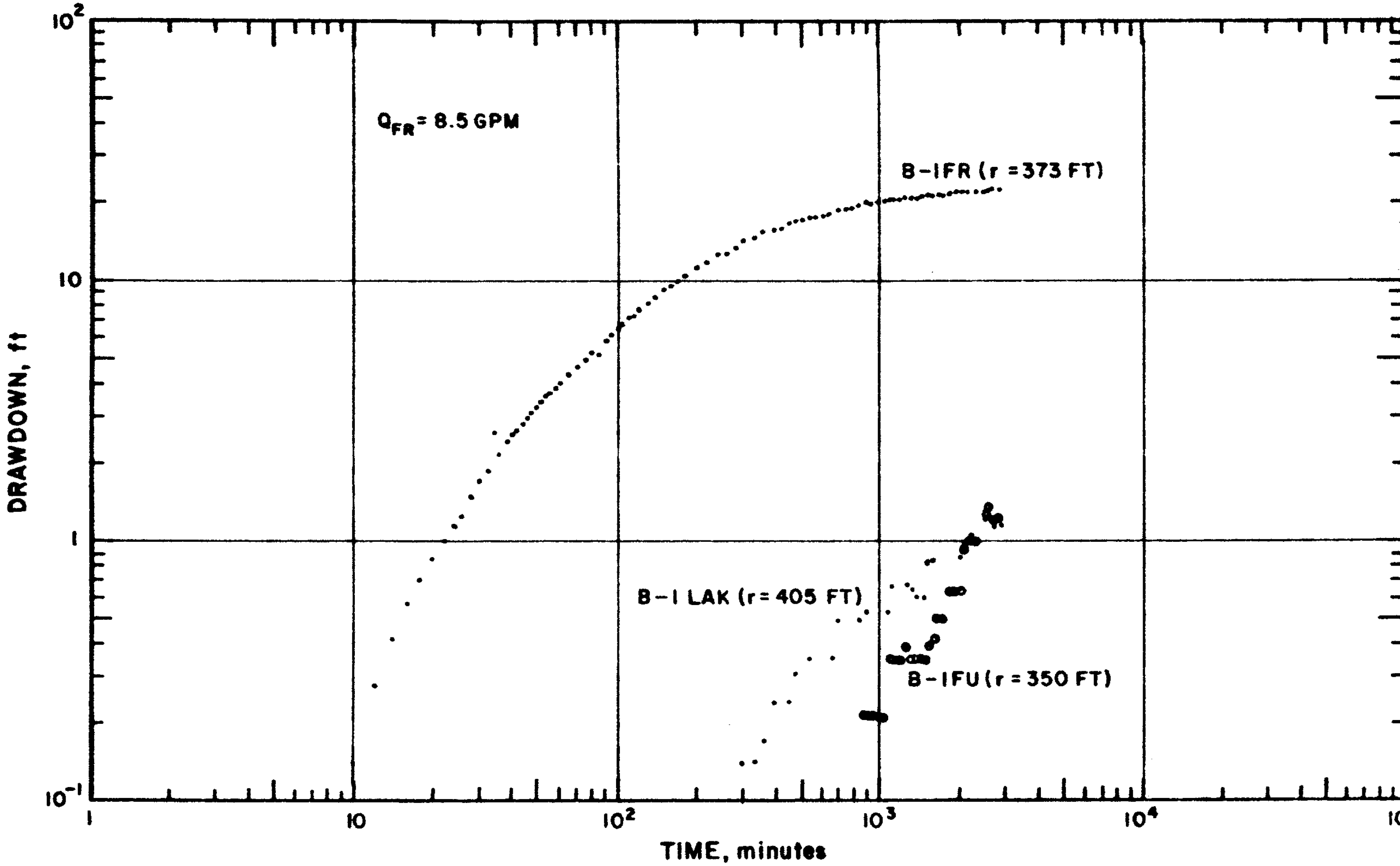

Figure 32: Logarithmic Graphs of Drawdown for B-1 Observation Well Group, Fall River Aquifer Test

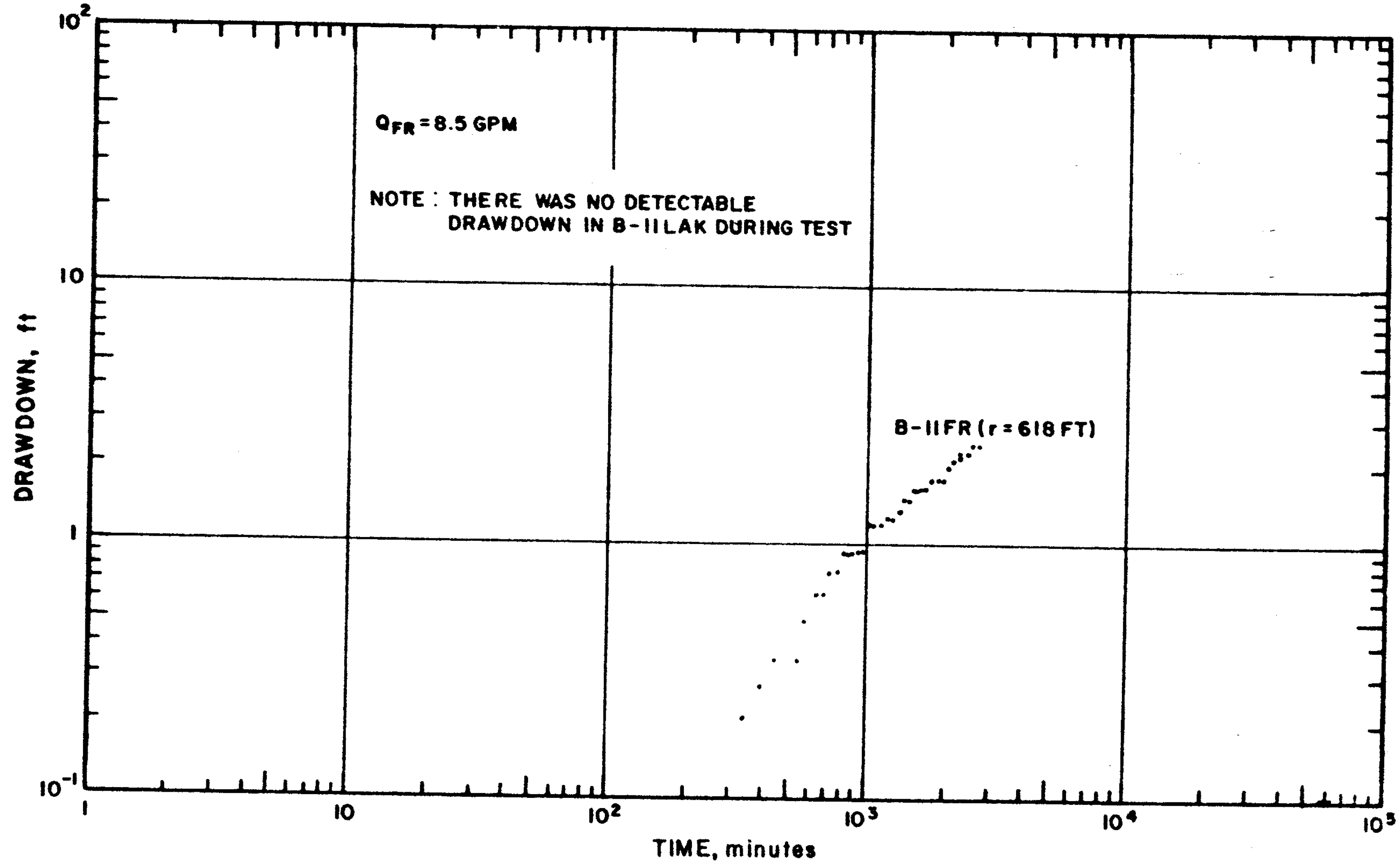

Figure 33: Logarithmic Graphs of Drawdown for B-11 Observation Well Group, Fall River Aquifer Test

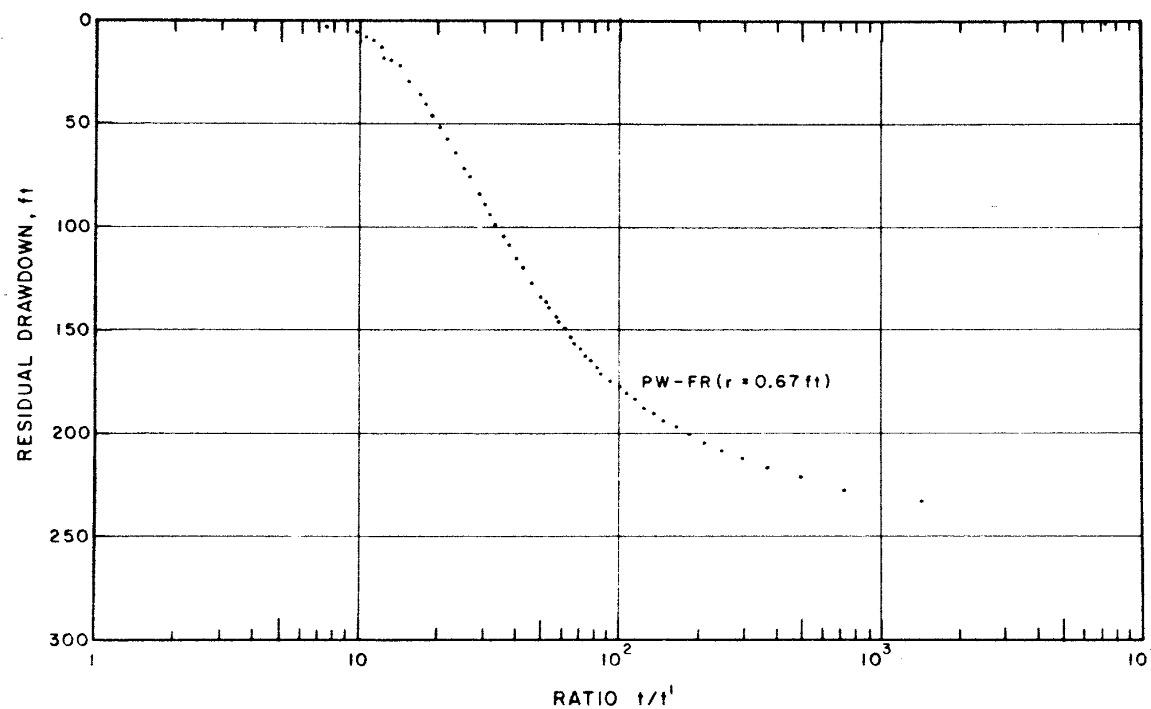

Figure 34: Recovery Graph for Pumped Well, Fall River Aquifer Test

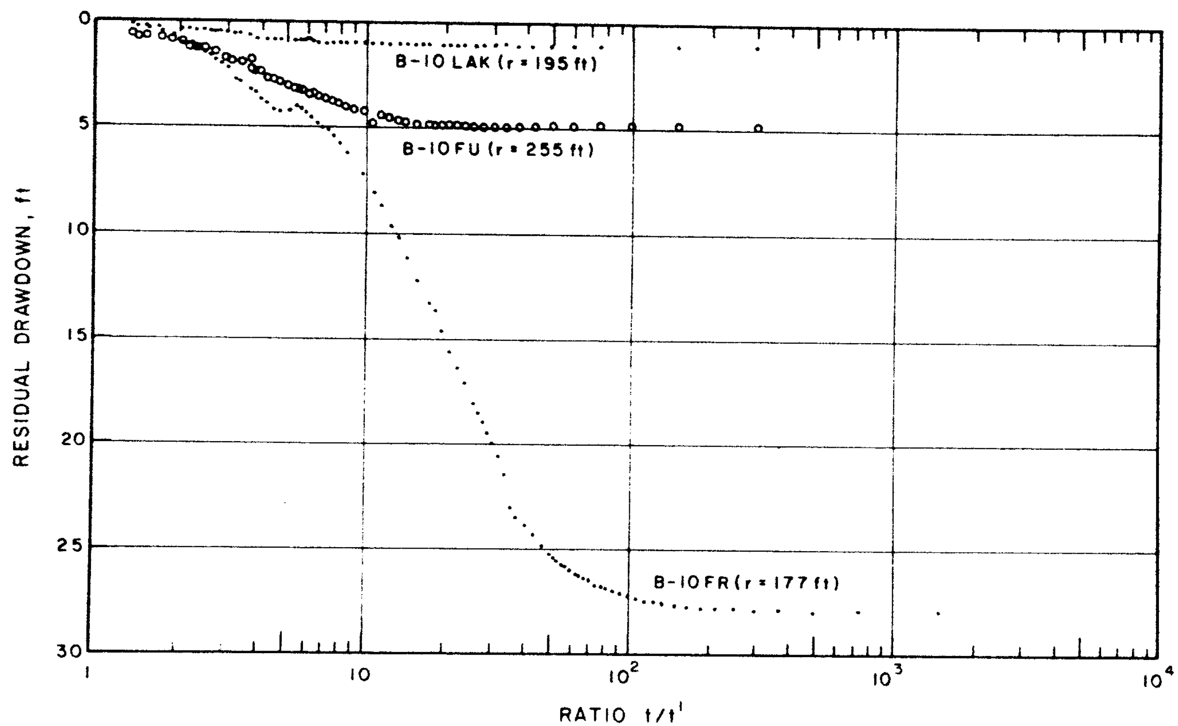

Figure 35: Recovery Graphs for B-10 Observation Well Group, Fall River Aquifer Test

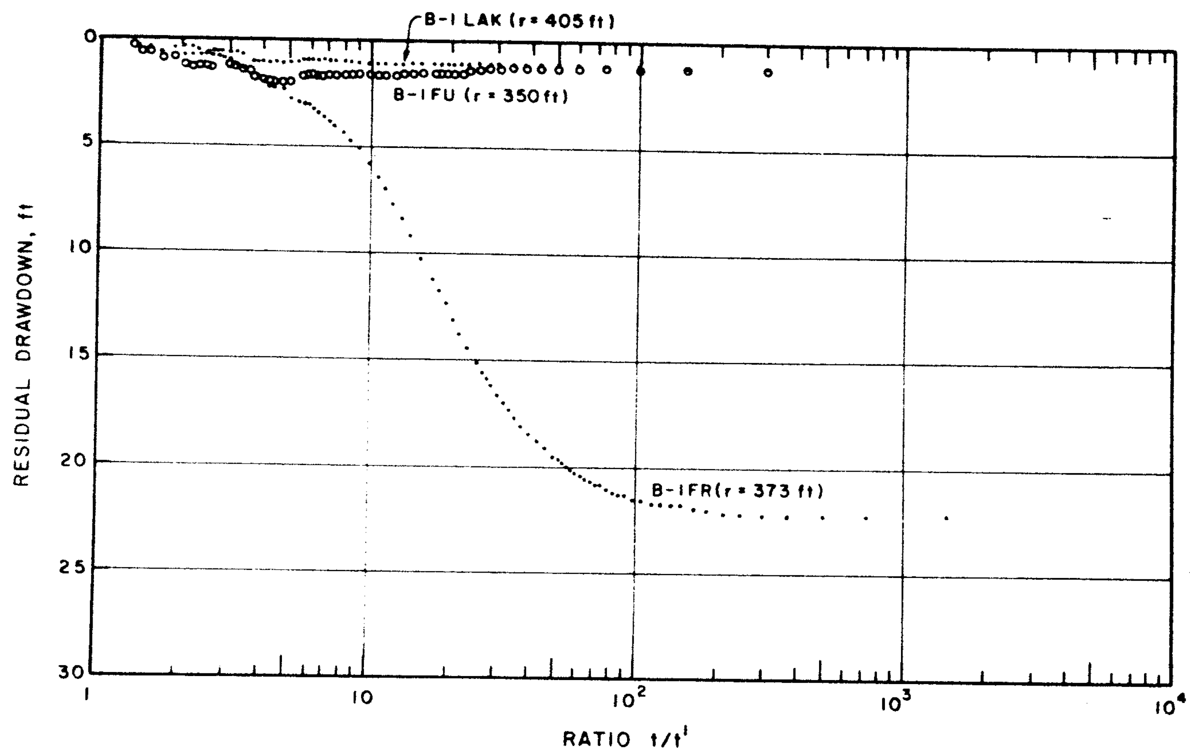

Figure 36: Recovery Graphs for B-1 Observation Well Group, Fall River Aquifer Test

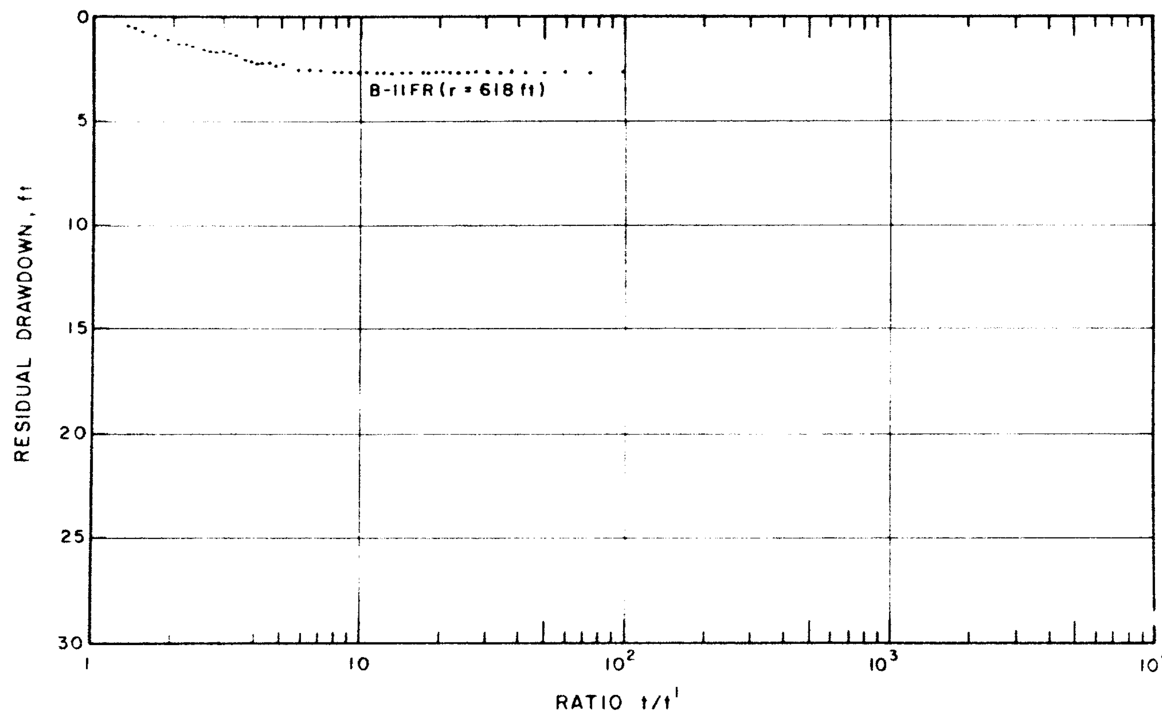

Figure 37 Recovery Graph for B-11 Observation Well Group, Fall River Aquifer Test

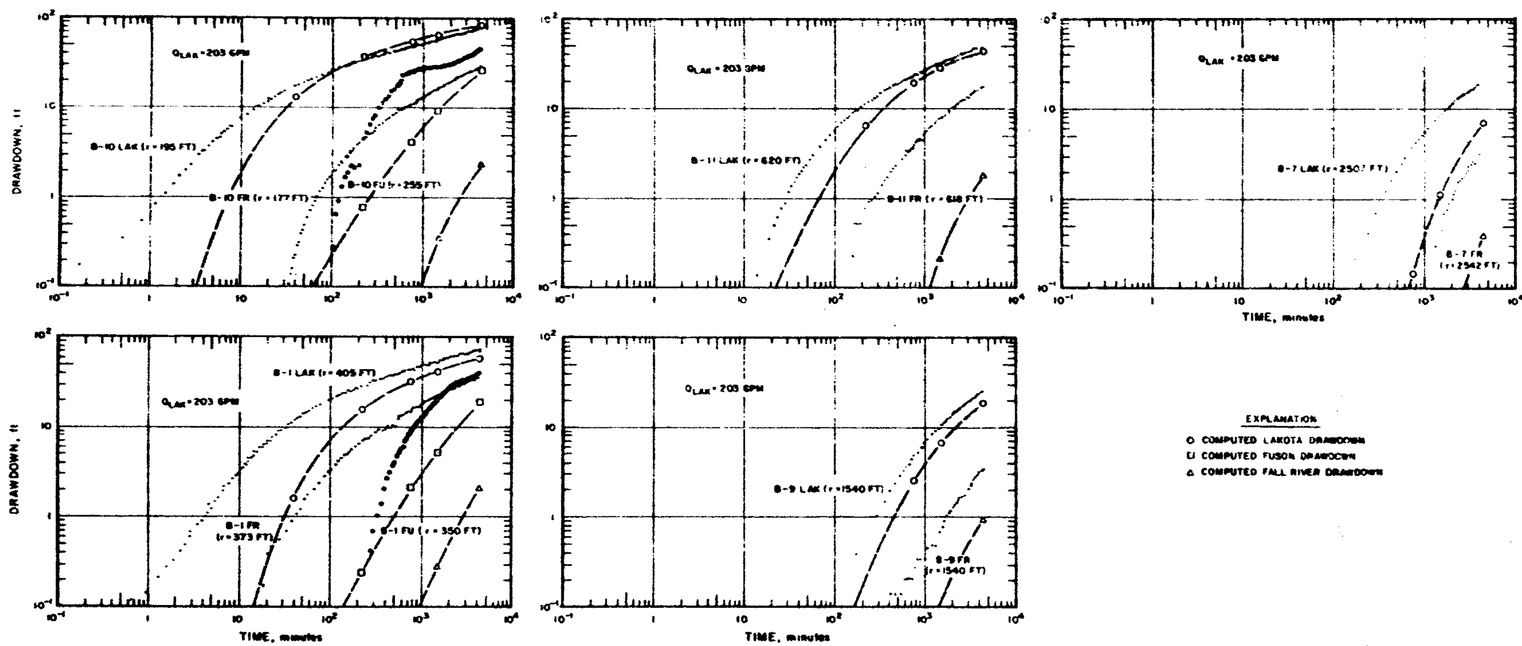

Figure 38 : Results of Initial Lakota Aquifer Test Simulation

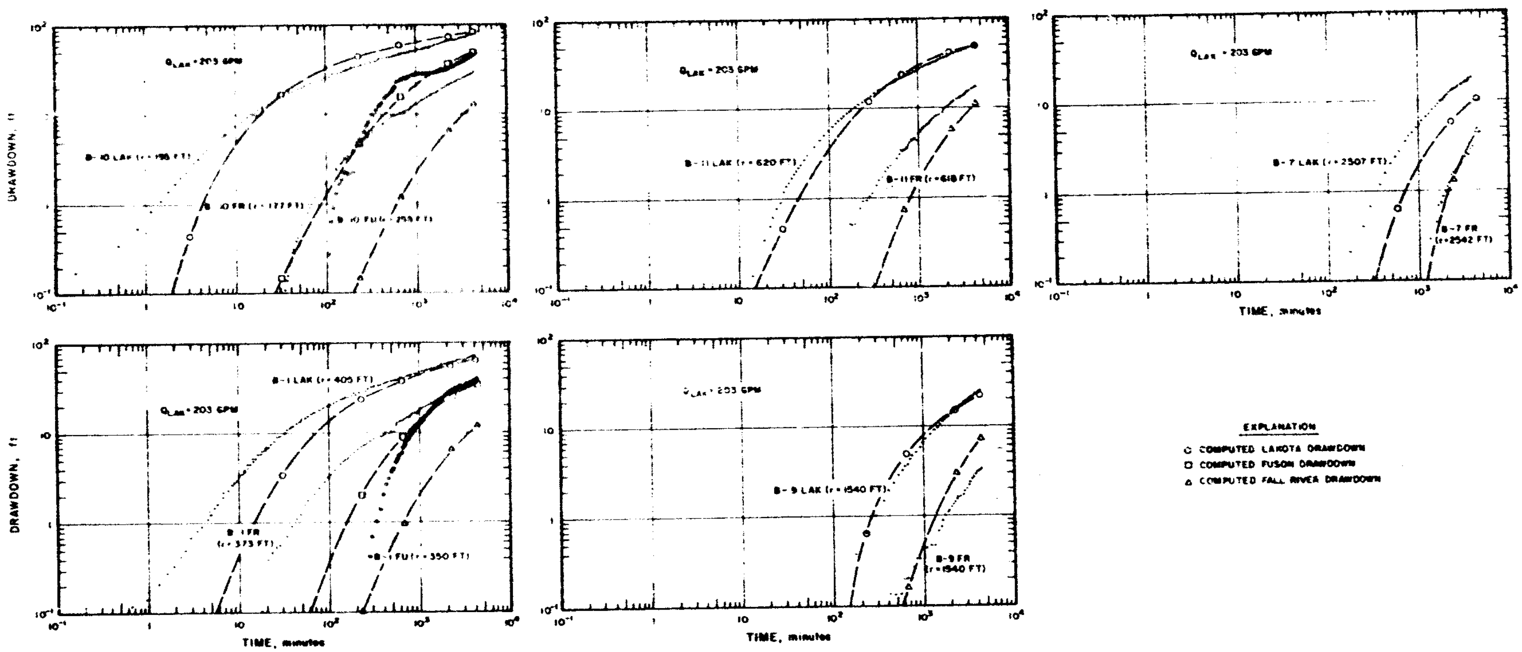

Figure 39 : Results of Final Lakota Aquifer Test Simulation

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HYDROGEOLOGIC INVESTIGATIONS AT PROPOSED URANIUM MINE NEAR DEWEY, SOUTH DAKOTA

TENNESSEE VALLEY AUTHORITY
OFFICE OF NATURAL RESOURCES
DIVISION OF AIR AND WATER RESOURCES
WATER SYSTEMS DEVELOPMENT BRANCH
NORRIS, TENNESSEE

Tennessee Valley Authority
Office of Natural Resources
Division of Air and Water Resources
Water Systems Development Branch

HYDROGEOLOGIC INVESTIGATIONS AT PROPOSED URANIUM MINE NEAR DEWEY, SOUTH DAKOTA

Report No. WR28-2-520-128

Prepared by
J. Mark Boggs

Norris, Tennessee
October 1983

ABSTRACT

The Lakota and Fall River Formations represent aquifers of major importance in the Southern Black Hills Region as well as host rock for uranium ore. An 11-day constant discharge test involving 13 observation wells and numerous private wells was conducted in the Lakota aquifer at TVA's proposed uranium mine near Dewey, South Dakota. The pumping phase of the test was followed by several months of water-level recovery measurements. Results indicate that the test site is located in an area where the Lakota is exceptionally permeable having a transmissivity of 4,400 gpd/ft and a storativity of about $1x10^{-4}$. Outside of this locality the Lakota transmissivity decreases substantially due to aquifer thinning and a change to finer-grained sedimentary facies. The drawdown response in the Fall River aquifer was substantially less than that observed during a similar test conducted at TVA's proposed Burdock mine, indicating that the Fuson shale unit lying between the two aquifers is a more effective aquitard in the Dewey area. It is further concluded that the nearby Dewey fault acts as a barrier to horizontal ground-water movement in the Lakota and Fall River aquifers.

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INTRODUCTION

The following report describes a hydrogeologic test conducted February 1982 at TVA's proposed uranium mine shaft site near Dewey, South Dakota (Figure 1). The Dewey test is one of a series of tests TVA has conducted in aquifer units of the Inyan Kara Group in the southwestern Black Hills area. The purpose of these tests is to obtain sufficient quantitative information about local hydrogeologic conditions to enable prediction of mine depressurization requirements and impacts to local ground-water users.

HYDROGEOLOGIC ENVIRONMENT

The principal aquifers in the region are the alluvial deposits associated with the Cheyenne River and its major tributaries, the Fall River formation, the Lakota formation, the Sundance formation, and the Pahasapa (or Madison) formation. Except for the alluvium, these aquifers crop out peripherally to the Black Hills where they receive recharge from precipitation. Ground-water movement is in the direction of dip, radially from the central Black Hills. In most instances, ground water in these aquifers is under artesian conditions away from the outcrop area, and water flows at ground surface from numerous wells in the area.

The Fall River and Lakota formations which form the Inyan Kara Group are the most widely used aquifers in the region. The alluvium is used locally as a source of domestic and stock water. The Sundance formation is used near its outcrop area in central and northwestern Fall River County. The Pahasapa (Madison) formation is locally accessible only by very deep wells and is the source for five wells in the city of Edgemont.

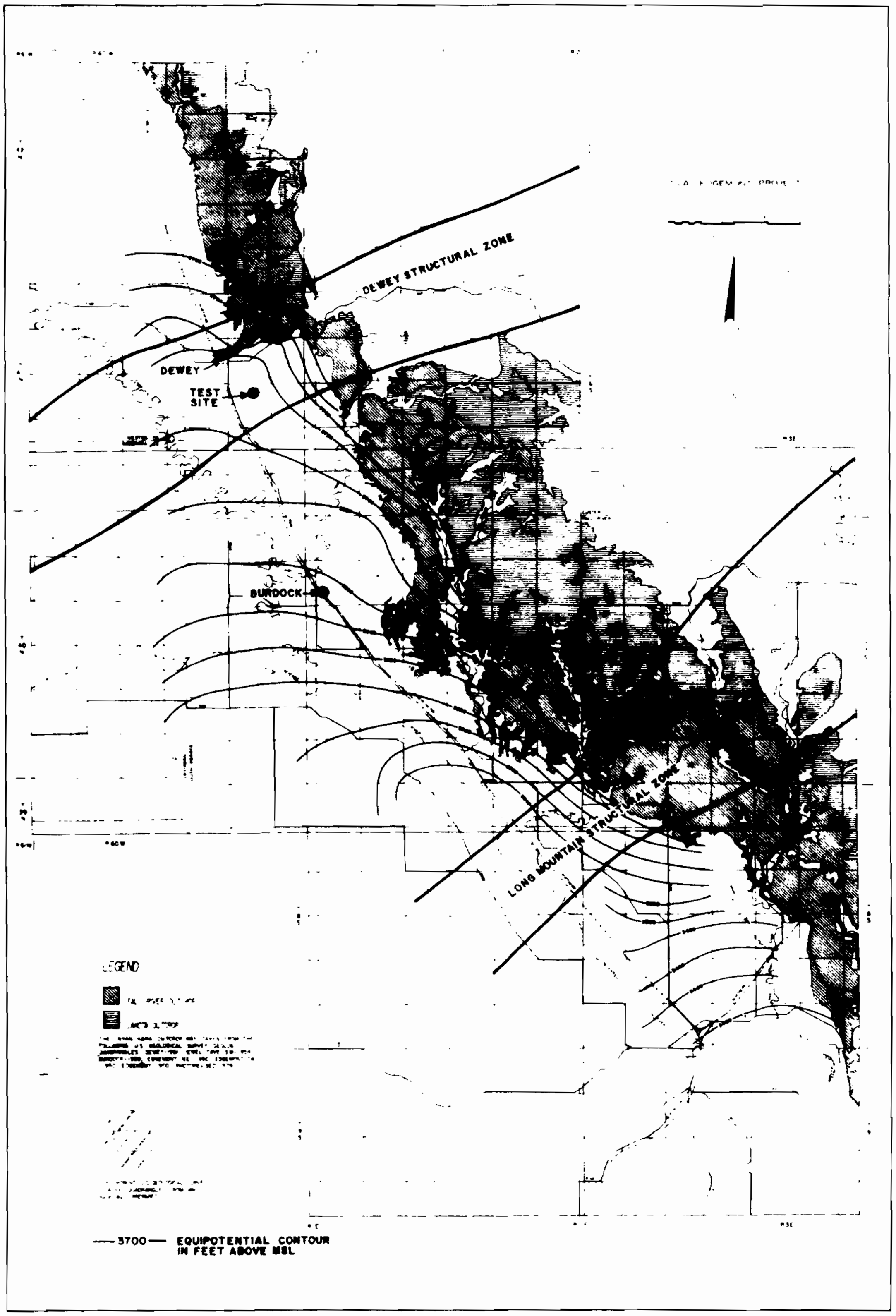

Figure 1: Site Location and Potentiometric Surface Map

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The Fall River and Lakota aquifers are of primary concern because of the potential impact of mine dewatering on the numerous wells developed in these aquifers in the vicinity of the mine. At the proposed mine site, the Fall River consists of approximately 180 feet of interbedded fine-grained sandstone, siltstone and carbonaceous shale. The Fall River aquifer is overlain by approximately 400 feet of the Mowry and Skull Creek shales unit, which act as confining beds. Five domestic and stock-watering wells are known to be developed in the Fall River formation within a four-mile radius of the mine site.

The Fall River formation is underlain by Fuson member of the Lakota formation consisting primarily of siltstone and shale with occasional fine-grained sandstone lenses. Thickness of the Fuson is on the order of 100 feet in the site vicinity. The Fuson acts as a leaky aquitard between the Fall River and Lakota aquifers.

The Chilson member of the Lakota formation is the source for some 30 wells within a four-mile radius of the mine site. It also represents the primary uranium-bearing unit targeted for mining. The Chilson (also referred to as the "Lakota aquifer" in this report) consists of about 120 feet of consolidated to semi-consolidated, fine-to-coarse grained sandstone with interbedded siltstone and shale. It is underlain by the Morrison formation consisting of interbedded shale and fine-grained sandstone. Regionally, the Morrison is not considered an aquifer. Under conditions of ground-water withdrawal from the Chilson, the Morrison is expected to act as an aquitard.

Recharge to the Fall River and Lakota aquifers is believed to occur at their outcrop areas. Gott, et al. (1974), suggest on the basis of geochemical data that recharge to these aquifers may also be derived from the upward movement of ground water along solution collapses and breccia pipes from the deeper Minnelusa and Pahasapa aquifers. The solution collapse and breccia pipe features lie within the Dewey and Long Mountain structural zones (Figure 1).

Inasmuch as the proposed mine site lies only about one mile south of the Dewey fault trace, one of the primary objectives of the test was to determine the hydrologic significance of the fault and its affect on the propagation of drawdown in the vicinity of the mine during depressurization. Vertical displacement on the major fault generally increases toward the southwest, and is on the order of 200 feet at the point where the fault trace crosses the South Dakota-Wyoming border. Thus, it appears that the Fall River and Lakota aquifers are completely offset by the fault in the site vicinity.

LAKOTA AQUIFER TEST

Design

The shaft site for the Dewey mining area had not been selected at the time the aquifer testing designs were made. The test site was, therefore, located in the general vicinity of the proposed mine site within close proximity to the Dewey fault. The test well was completed to a depth of 804 feet and was screened within the Chilson member of the Lakota Formation. A network of eleven observation wells were constructed along two perpendicular lines intersecting at the pumped well for the purpose investigating hydrologic boundary conditions. One line of wells was oriented normal to the Dewey fault trace, and the other was approximately normal to the aquifer outcrop belt to the east (see Figure 2). Seven of these wells were developed in the Chilson member, three in the Fall River formation,

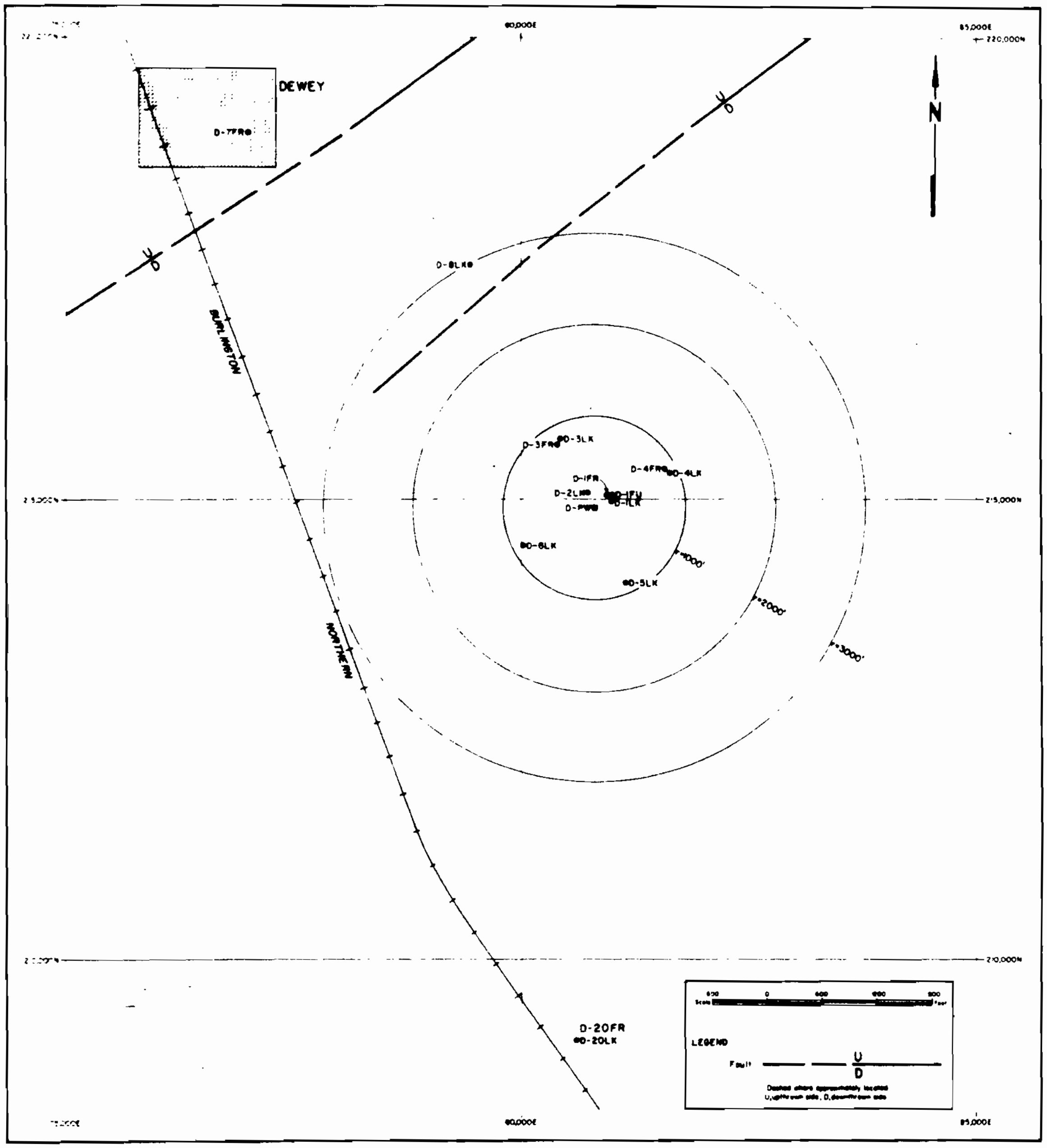

Figure 2: Well Location Map

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and one in the Fuson. Preexisting observation wells BPZ-20LAK and BPZ-20FR (hereafter referred to as D-20LK and D-20FR, respectively) located about one mile south of the test well were also monitored during the test. Construction details for these wells are given in Table 1. In addition, periodic measurements of water level (or well flowrate) were made during the test at all private wells within the test site vicinity.

Based upon preliminary drilling results in the Dewey test site area and experience from the Burdock aquifer tests, it was expected that the Fall River and Lakota aquifers in the Dewey area would respond essentially as a single aquifer system. As a result less emphasis was placed on measurement of the Fuson aquitard properties.

Procedures

A constant-discharge aquifer test was initiated at 1000 hours on February 16, 1982. Discharge from the well was pumped into an arroyo which ultimately drained into a stock pond located about one mile west of the test site. There was no possibility of recirculation of well discharge water during the test due to the 400+ feet thickness of shale between ground surface and the top of the Fall River aquifer. The well pumping rate was monitored with an in-line flow meter and with an orifice plate and manometer device at the end of the discharge line. The pumping rate varied little during the test ranging from 493 to 503 gpm and averaging 495 gpm. The pumping phase of the test lasted 11 days and was followed by approximately 10 months of recovery measurements. Water level measurements in all wells were made with electric probes. Flow rates associated with offsite private wells were checked with a bucket and stop watch.

TABLE 1. Well Construction Data

Well No.	Depth (feet)	Casing Diameter (inches)	Depth Interval of Open Borehole or Well Screen (feet)	Distance From Pumped Well (feet)
D-PW	804	10	695-725, 755-800	--
D-1LK	800	4	712-800	189
D-1FU	620	4	609-620	229
D-1FR	580	4	504-580	186
D-2LK	800	4	692-800	191
D-3LK	800	4	715-800	851
D-3FR	590	4	505-590	810
D-4LK	780	4	714-780	905
D-4FR	580	4	503-580	879
D-5LK	835	4	735-835	872
D-6LK	810	4	715-810	890
D-7FR	120	4	119-120	5610
D-8LK	750	4	650-750	2785
D-20LK	860	4	798-860	5700
D-20FR	672	1	671-672	5700

Analysis

Semilogarithmic graphs of drawdown (s) versus time (t) for the pumped well and observation wells are given in Appendix A. The drawdown trends in wells D-PW, D-1LK and D-2LK are essentially the same, i.e., there is a period of roughly linear drawdown during the first 1000 minutes of the test, followed by a gradual increase in the rate of drawdown during the remainder of the test. The remaining Lakota wells exhibit s-t curves which have a continuous increase in slope throughout the test without stabilizing to a linear drawdown trend. A slight increase in hydrostatic water level was observed during the early period of the test in the Fall River and Fuson wells. This seemingly paradoxical behavior, known as the Noordbergum effect, is due to a transfer of stress from the pumped aquifer to the adjacent aquitards and aquifers (Gambolati, 1974). Drawdowns observed in the Fall River and Fuson wells were much less than those recorded during a similar test conducted near Burdock (Boggs and Jenkins, 1980). The Jacob straight-line method (Walton, 1970) was applied to the semilog graphs for the Lakota wells to obtain the values of transmissivity (T) and storativity (S) presented in Table 2. In the case of the closer observation wells, two straight-line data fits were possible: one using the early data and another using the late data. Only the late data for the more distant observation wells were analyzed by this method.

Logarithmic s-t graphs for all test wells are given in Appendix B. Theis curve-matching techniques (Walton, 1970) were applied to the Lakota aquifer curves to obtain the T and S estimates presented in Table 2. Due to the somewhat unusual shape of the s-t response curves, the only curve-match solutions possible were those using the early data.

TABLE 2. Computed Lakota Aquifer Properties

Well	r (ft)	Jacob Method — Drawdown T_e	Jacob Method — Drawdown S_e	Jacob Method — Drawdown T_1	Jacob Method — Recovery T_e	Jacob Method — Recovery T_1	Theis Method T_e	Theis Method S_e
D-PW	0.67	4400	--	890	4890	680	--	--
D-1LK	189	5280	3.E-05	890	4890	650	5210	3.E-05
D-2LK	191	4400	3.E-04	910	4710	650	4090	2.E-04
D-3LK	851	--	--	920	--	670	6900	7.E-05
D-4LK	905	--	--	900	--	680	4090	8.E-05
D-5LK	872	--	--	900	--	670	4410	7.E-05
D-6LK	890	--	--	900	--	650	6030	8.E-05
D-8LK	2785	--	--	940	--	680	3180	5.E-05
D-20LK	5700	--	--	--	--	680	1400	3.E-05

Note: Transmissivity (T_e, T_1) in units of gpd/ft.

A semilog plot of the final drawdown in each Lakota well versus its radial distance from the pumped well is shown in Figure 3. The Jacob straight-line method was applied to this plot to obtain T and S values of 4400 gpd/ft and 10^{-6}, respectively, for the Lakota aquifer. The storativity value computed by this method is considered highly unreliable since it is two orders of magnitude lower than expected.

Water level recovery data for all wells are presented in Appendix C. Data are plotted as semilog graphs of residual drawdown versus t/t' (ratio of time since pumping started to time since pumping stopped). The Lakota graphs were analyzed using the Jacob method. Again, two straight-line fits are possible for the closer Lakota wells. Both are given in Table 2.

Fuson aquitard properties were estimated from the D-l well group data using the ratio method (Neuman and Witherspoon, 1973). The vertical hydraulic conductivity of the aquitard (K'_v) is computed to be approximately $2x10^{-4}$ ft/d based on the average of several computed K'_v during the interval between 1800 and 5000 minutes. For purposes of the analysis, the specific storativity (S'_s) of the aquitard was assumed to be approximately equal to that computed for the Lakota aquifer (about $7x10^{-7}$ ft^{-1}).

Interpretation

The T estimates obtained from all methods using the early drawdown and recovery data are in reasonably good agreement. Values range from 3180 to 6900 gpd/ft and average approximately 4800 gpd/ft. The T of 4400 gpd/ft derived from the distance drawdown analysis is also consistent with the early T estimates. These values are believed to represent the transmissivity of the Lakota aquifer within the immediate vicinity of the test

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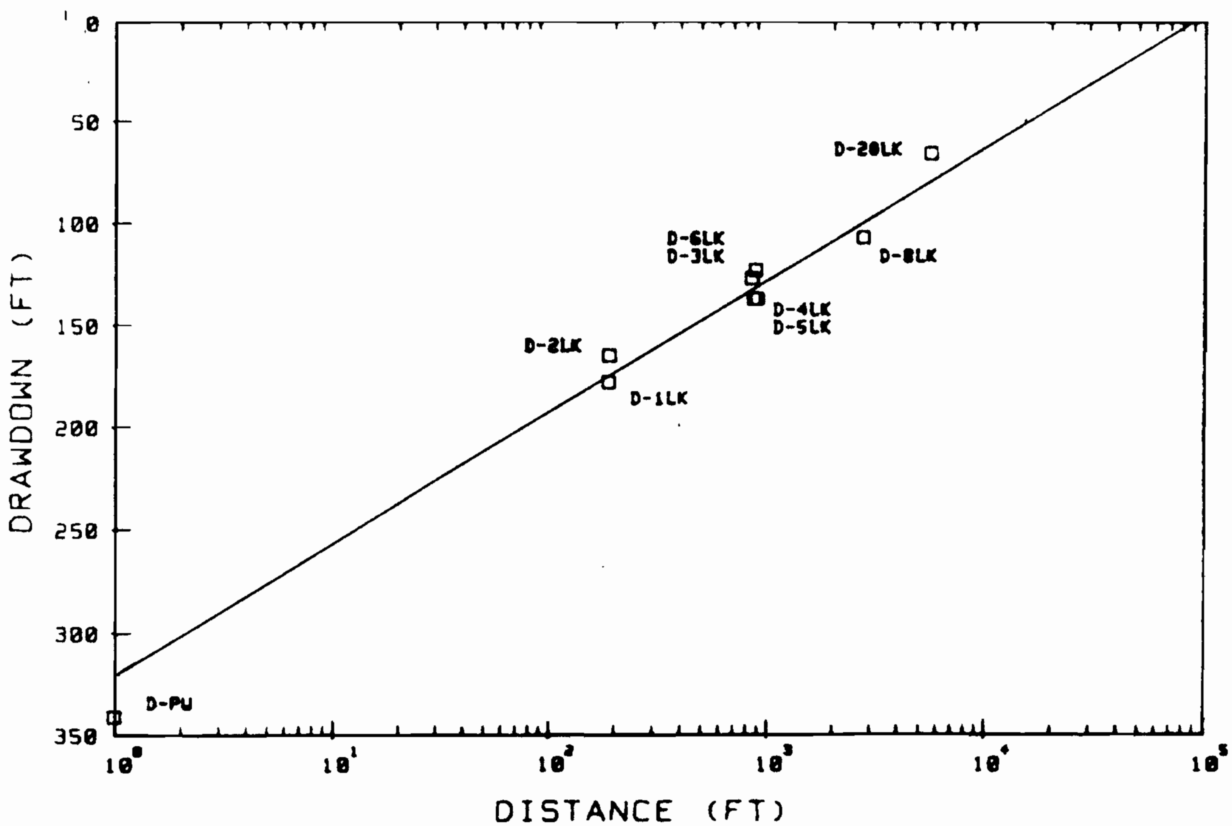

FIGURE 3. DISTANCE-DRAWDOWN GRAPH

site, and are consistent with the physical characteristics of the aquifer materials within this area. The T values computed from the late drawdown data, although consistent from well to well, are not reliable since the rate of drawdown during the later stage of the test never stabilized to the linear or ideal Theis-curve trend. The late recovery data provide the best estimates of the regional or long-term transmissivity of the Lakota aquifer in the Dewey region because of the long duration of this phase of the test.

In general, drawdown response in the pumped well and closer observation wells is characterized by a period of approximately linear drawdown during the first 1000 minutes of the test, followed by a steadily increasing rate of drawdown until the end of the test. The recovery data reflects the same sort of trend. The late response may be interpreted as either the effect of barrier boundary conditions or a decrease in transmissivity with distance from the test site or both.

Most of the available hydrogeologic information indicates that the Dewey fault acts as a barrier to horizontal ground-water movement in the Inyan Kara aquifers. Vertical displacement along the Dewey fault is on the order of 200 feet in the test site vicinity causing the complete separation of the Lakota aquifer on either side of the fault. Despite the geochemical evidence of Gott, et al. (1974), that the fault may act as conduit for upward circulation of ground water from deeper aquifers to the Inyan Kara Group, a recharge condition is not reflected in the potentiometric surface configuration in the fault zone (Figure 1) or in the test results. A reduction in the rate of drawdown would be expected in the s-t graphs for observation wells closest to the fault if significant recharge occurred in the fault zone. Instead the opposite response is observed in the test data. The s-t curve for well D-8LK (the closest observation well to the fault) exhibits the steepest slope during the late stage of the test, supporting the idea that the fault is a hydrogeologic barrier. Upward recharge may occur in the fault zone but at relatively low rates. Consequently, the fault does not behave as a recharge boundary.

Computer Simulations

A computer ground-water model of the Dewey region was developed to aid in interpreting the test results and refining aquifer parameters. A three-dimensional ground-water flow code developed by Trescott (1975) was used for the simulations. The Inyan Kara is conceptualized as a three-layer aquifer system consisting of the Lakota (Chilson) aquifer, the Fuson aquitard and the Fall River aquifer, with model layers having uniform thicknesses of 120, 100, and 180 feet, respectively. Impervious boundaries are set above the Fall River layer and below the Lakota layer to represent the relatively impermeable shales which bound the Inyan Kara Group. The model area and finite-difference grid are shown in Figure 4. The outcrop area of the Inyan Kara represents the eastern limit of the modeled region. The remaining three sides of the model are set at sufficient distances from the test pumping well to eliminate the possibility of artificial boundary effects in model simulations. The Dewey fault zone was treated as a barrier boundary.

Simulations were made using two basic conceptual models of the Inyan Kara aquifer system to determine which model best represented observed responses during the Dewey test. For case I, uniform T and S values of 4,400 gpd/ft and $1x10^{-4}$, respectively were assigned to the Lakota aquifer. A uniform T was used for this case despite evidence of a much lower transmissivity outside of the immediate test site in order to determine

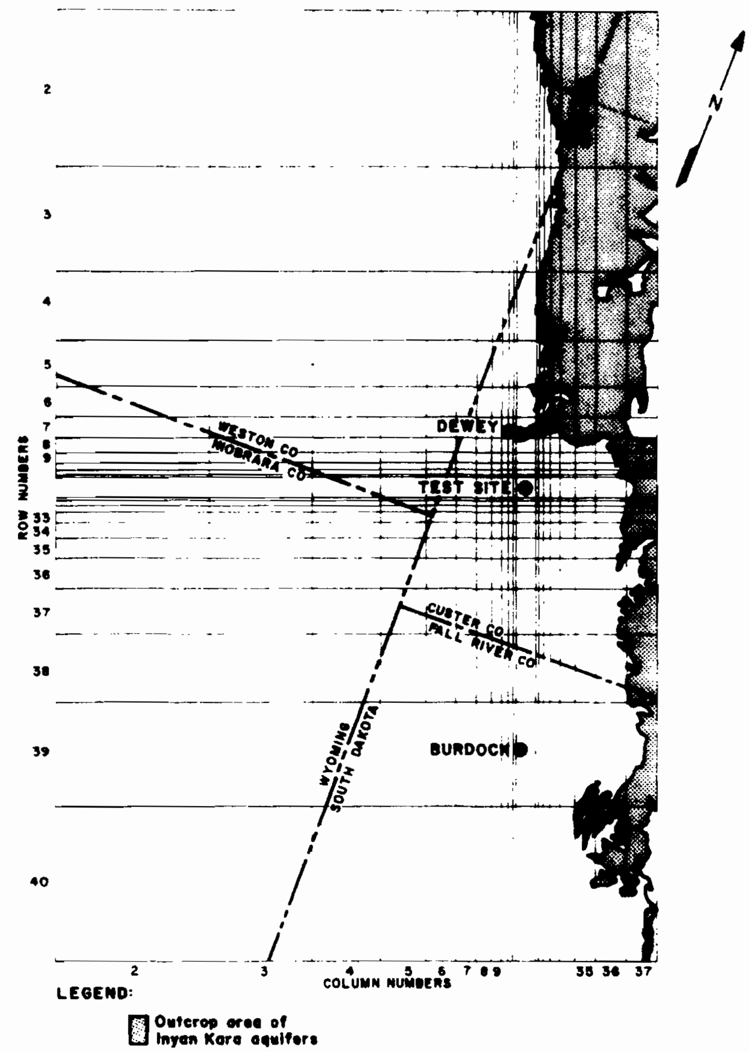

Figure 4: Ground-Water Model Grid

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whether the fault alone could account for late drawdown trends. The Fuson aquitard was assigned a uniform K'_v of 10^{-4} ft/d. The Fall River aquifer was represented by uniform T and S values of 400 gpd/ft and 10^{-4} respectively, based on the results of the Burdock tests (Boggs and Jenkins, 1980). A simulation was then made of the 11-day Dewey aquifer test using the average pumping rate of 495 gpm in an attempt to reproduce the test results. A comparison of computed and observed s-t graphs for the Lakota observation wells is shown in Figure 5. Clearly, the barrier boundary condition created by the fault does not fully account for the observed increase in drawdown rate during the latter part of the test.

In Case II, the model was modified to account for the suspected spatial variability of transmissivity in the Lakota aquifer. Geologic evidence indicates that the test site is located in an area where the Lakota is composed of an exceptionally thick course-grained sandstone. Outside of this locality the aquifer becomes thinner and its composition changes to finer-grained sedimentary facies. These changes are particularly evident in the area east of the site. The test results indicate a local T in the immediate site area of about 4,400 gpd/ft and a regional average of about 670 gpd/ft. These T estimates were used along with areal variations in the sandstone-shale composition of the Lakota aquifer in the site vicinity to arrive at the T distribution shown in Figure 6. Exploration borehole geophysical logs were used to estimate the relative amounts of sandstone and shale in the Lakota across the site area. The horizontal hydraulic conductivity of the sandstone is estimated at approximately 5.7×10^{-5} ft/sec based upon the near-field T estimate of 4,400 gpd/ft, an aquifer thickness of 120 feet, and the assumption that the aquifer in the immediate vicinity of the test well and closest observation wells is essentially all sandstone. The

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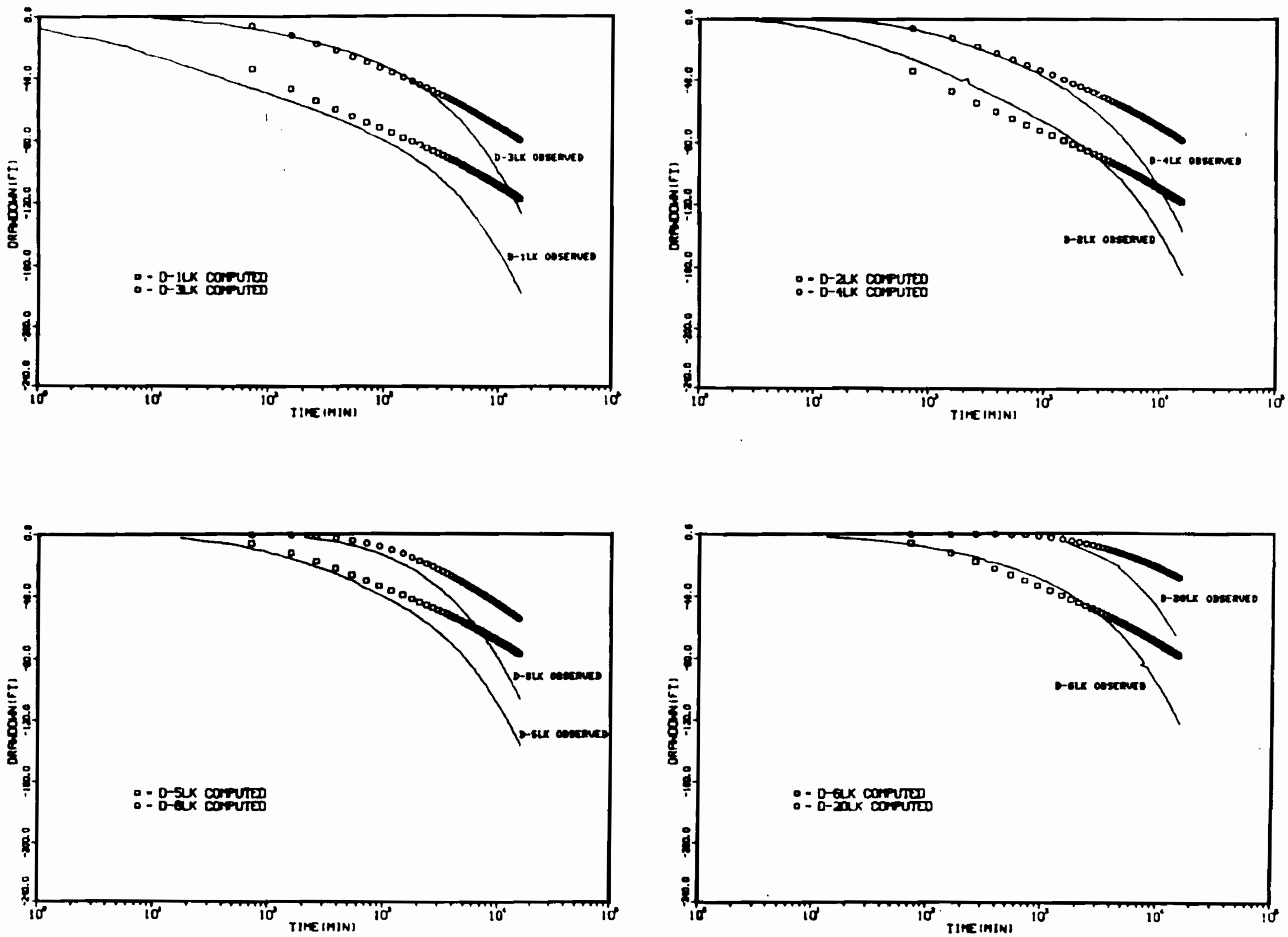


Figure 5. Comparison of Observed and Computed Drawdown, Case I

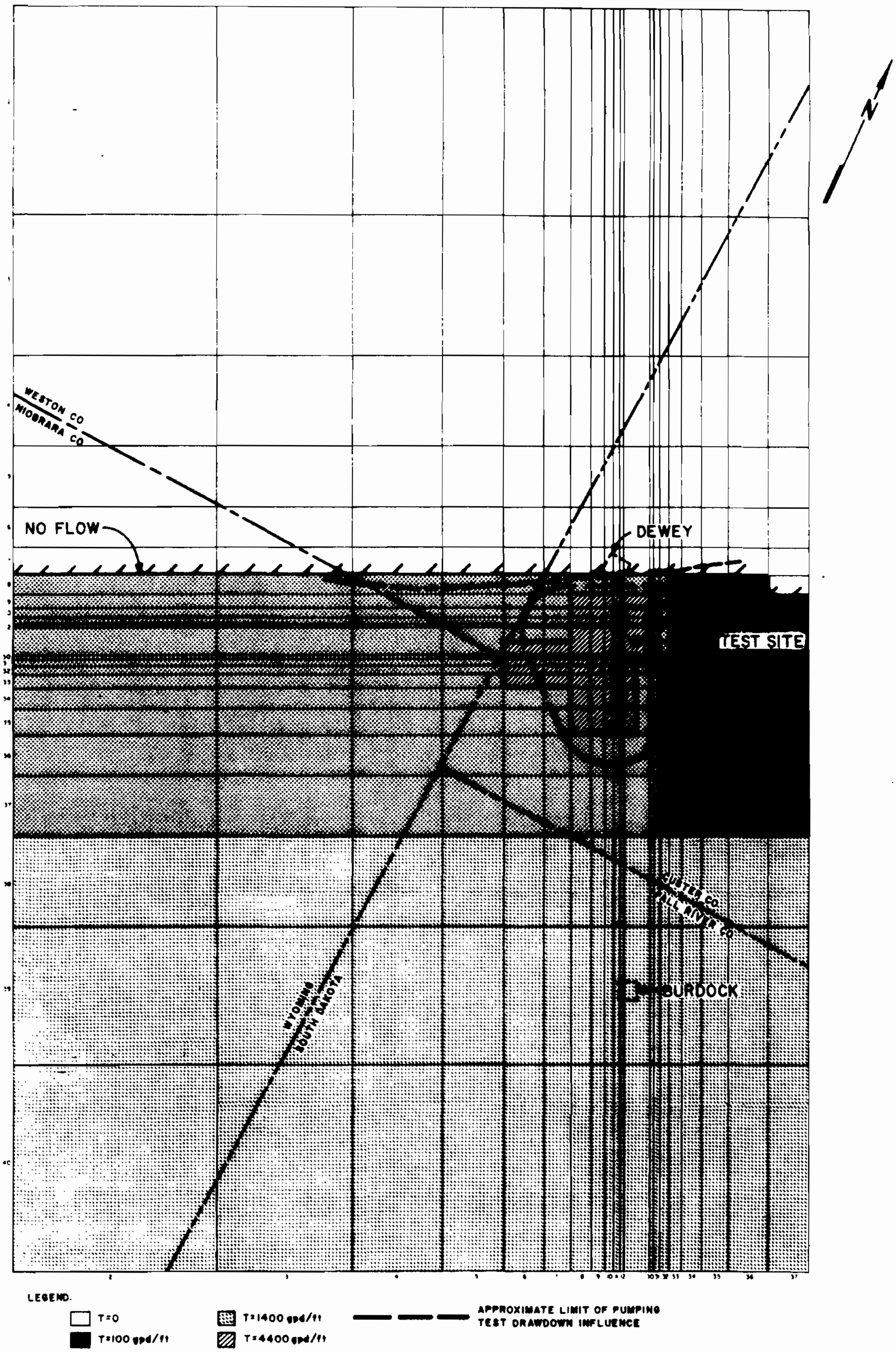


Figure 6: Transmissivity Distribution, Case II

WR28-2-520-128.6

horizontal conductivity of the shale is estimated to be about 10^{-8} ft/sec assuming (1) the measured vertical conductivity of the Fuson shale is also representative of shale in the Lakota aquifer and (2) the ratio of horizontal to vertical conductivity is about 10:1. Given the estimated horizontal conductivities for the sandstone and shale, a representative average conductivity was computed for areas having similar aquifer sandstone-shale ratios. The representative average conductivity was computed from the geometric mean of the conductivity samples as suggested by Bouwer (1969). The transmissivity of 1,400 gpd/ft assigned to the southern portion of the model is based on results of the Burdock aquifer test. Note that although an attempt was made to assign realistic transmissivity values to the entire model region, model simulation results are mainly affected by the transmissivity distribution within the observed limits of influence of the 11-day aquifer test as indicated in Figure 6. Outside of this region the model is relatively insensitive to the assigned T values.

The Case II simulation results are shown in Figure 7. The agreement between the computed and observed drawdown trends in the Lakota wells is quite good overall. At least part of the discrepancy between observed and computed responses in these units is due to the fact that computed hydraulic heads are average values over the thickness of the aquifer or aquitard layer.

The observed drawdown trends could, perhaps, be reproduced using some alternative T distribution without the barrier boundary condition assumed for the Dewey fault. However, if the fault did not represent a barrier, substantial pressure changes should have been observed during the test in the private Lakota wells located north of the fault. These wells are located at approximately the same radial distance as observation well

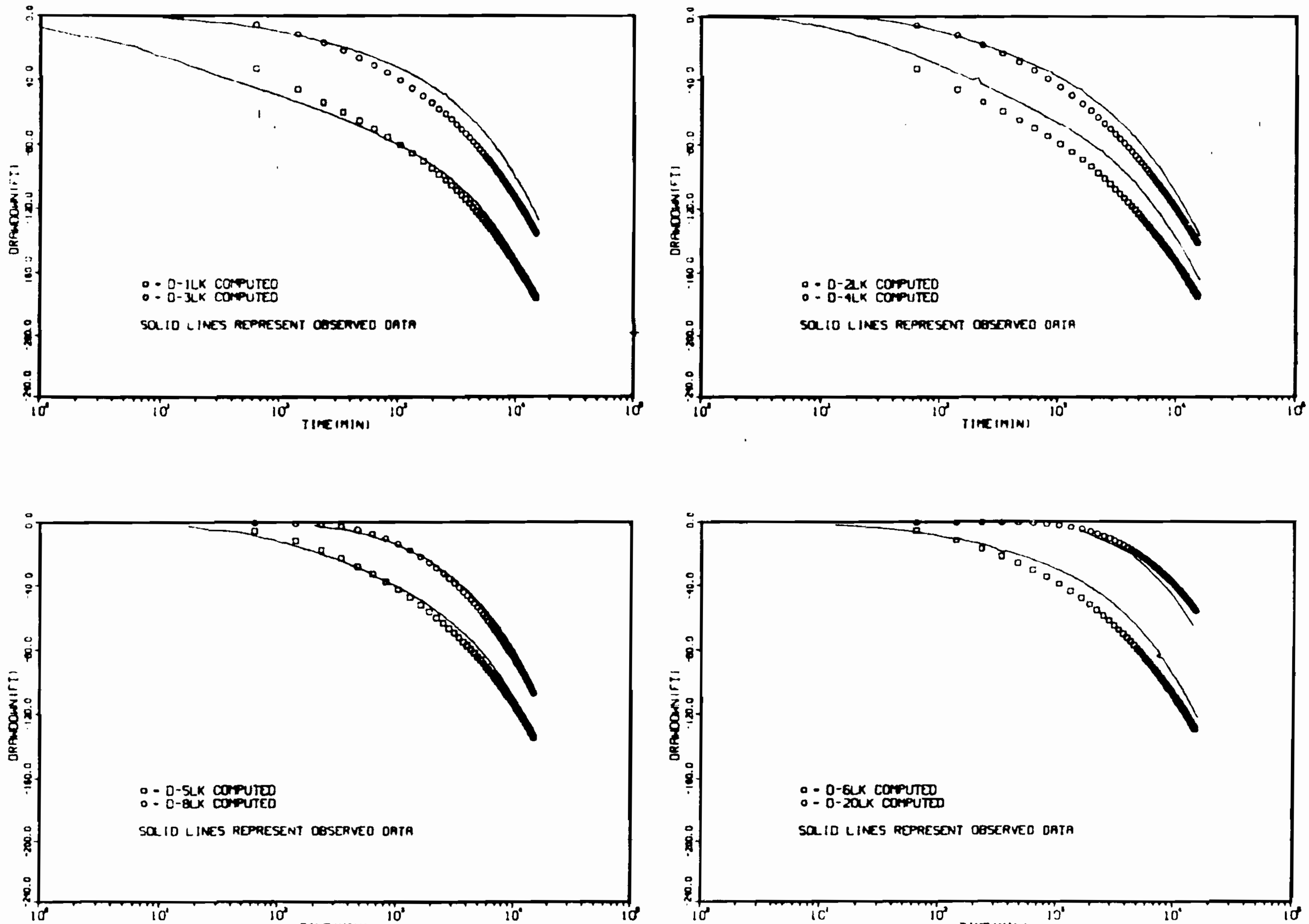


Figure 7. Comparison of Observed and Computed Drawdown, Case II

D-20LK which exhibited 66 feet of drawdown at the end of the test. As no drawdown occurred in these wells, it is concluded that the Dewey fault represents a hydrogeologic barrier.

The Case II simulation results support the concept of the Lakota as a patchy aquifer of relatively low-transmissivity overall but having within it localized zones of substantially higher transmissivity. The proposed mine site lies within one of these high transmissivity localities. Although the T distribution used in the Case II model is based upon reasonable assumptions, it is considered only an approximation of actual conditions in the test site area. Nevertheless, this approximation is adequate for assessing long-term mine depressurization impacts. The significance of the Case II model result is that it provides an interpretation of the test results which is consistent with what is known or suspected about the hydrogeologic conditions in the site region.

CONCLUSIONS

Hydrogeologic investigations in the Dewey area indicate that the proposed mine site lies within an area where the Lakota Formation is composed of relatively thick permeable sandstone. The transmissivity of the Lakota aquifer in this locality is estimated to be approximately 4,400 gpd/ft. Storativity of the aquifer is about 10^{-4}. Outside of this area the Lakota transmissivity decreases substantially. The variation in transmissivity over the region is consistent with geologic evidence of thinning of the Lakota sandstone away from the test site and a change to finer-grained sand and shale facies. The significance of this condition is that long-term mine depressurization rates and drawdown response in the Dewey vicinity will be governed by the lower transmissivity material. As a result, dewatering rates will be lower and the areal extent of drawdown impacts smaller than if the higher transmissivity prevailed.

There is evidence that hydraulic communication between the Fall River and Lakota aquifers occurred during the Dewey test. However, the degree of interconnection between these units is substantially less than that observed at the Burdock test site. The vertical hydraulic conductivity of the intervening Fuson aquitard estimated from the Dewey test data is approximately 10^{-4} ft/d. This value is about an order of magnitude lower than the estimate obtained at Burdock. The difference is somewhat surprising in that the Fuson aquitard is thinner in the Dewey area than at Burdock. A possible explanation may be that the direct avenues of hydraulic communication (e.g., numerous open pre-TVA exploration boreholes) believed to exist at Burdock, are not present in the Dewey area.

Evaluation of the drawdown responses recorded in test wells and private wells during the aquifer test and review of existing subsurface geologic data indicates that the Dewey fault zone acts as a hydrogeologic barrier to horizontal ground-water movement between the Inyan Kara aquifers located on opposite sides of the fault zone. Some upward vertical recharge to the Inyan Kara may occur in the fault zone as suggested by Gott, et al. (1968). However, rate of recharge from this source must be relatively small, otherwise recharge effects would be apparent in the aquifer test results and in the configuration of the steady-state potentiometric surface. It is expected that the fault will significantly reduce mining drawdown impacts on ground-water supplies located north of the fault zone.

3. The model should be calibrated by adjustment of hydraulic parameters to reproduce the existing steady-state potentiometric surface shown in Figure 1. The hydraulic properties for the Inyan Kara units measured at the Dewey and Burdock test sites should be held constant in the calibration process, while parameter adjustments are made in other areas to obtain a reasonable match between the computed and observed potentiometric levels. An estimate of net ground-water recharge can be obtained from the calibrated model by assigning observed potentiometric head values to the model nodes which lie within the aquifer recharge (outcrop) area. The aquifer recharge fluxes may be incorporated directly into the model to more accurately represent drawdown conditions in the outcrop areas during mine depressurization simulations.

4. Significant pumping stresses on the Inyan Kara aquifers other than the TVA mining operations should be identified and incorporated into the model.

REFERENCES

Boggs, J. M., and A. M. Jenkins, 1980, "Analysis of Aquifer Tests Conducted at the Proposed Burdock Uranium Mine Site, Burdock, South Dakota," TVA Report No. WR28-1-520-109.

Bouwer, H., 1969, "Planning and Interpreting Soil Permeability Measurements," ASCE Journal of Irrigation and Drainage Division, V. 95, No. IR3, pp. 391-402.

Gambolati, G., 1974, "Second-Order Theory of Flow in Three-Dimensional Deforming Media," Water Resources Research, V. 10, No. 6, pp. 1217-1228.

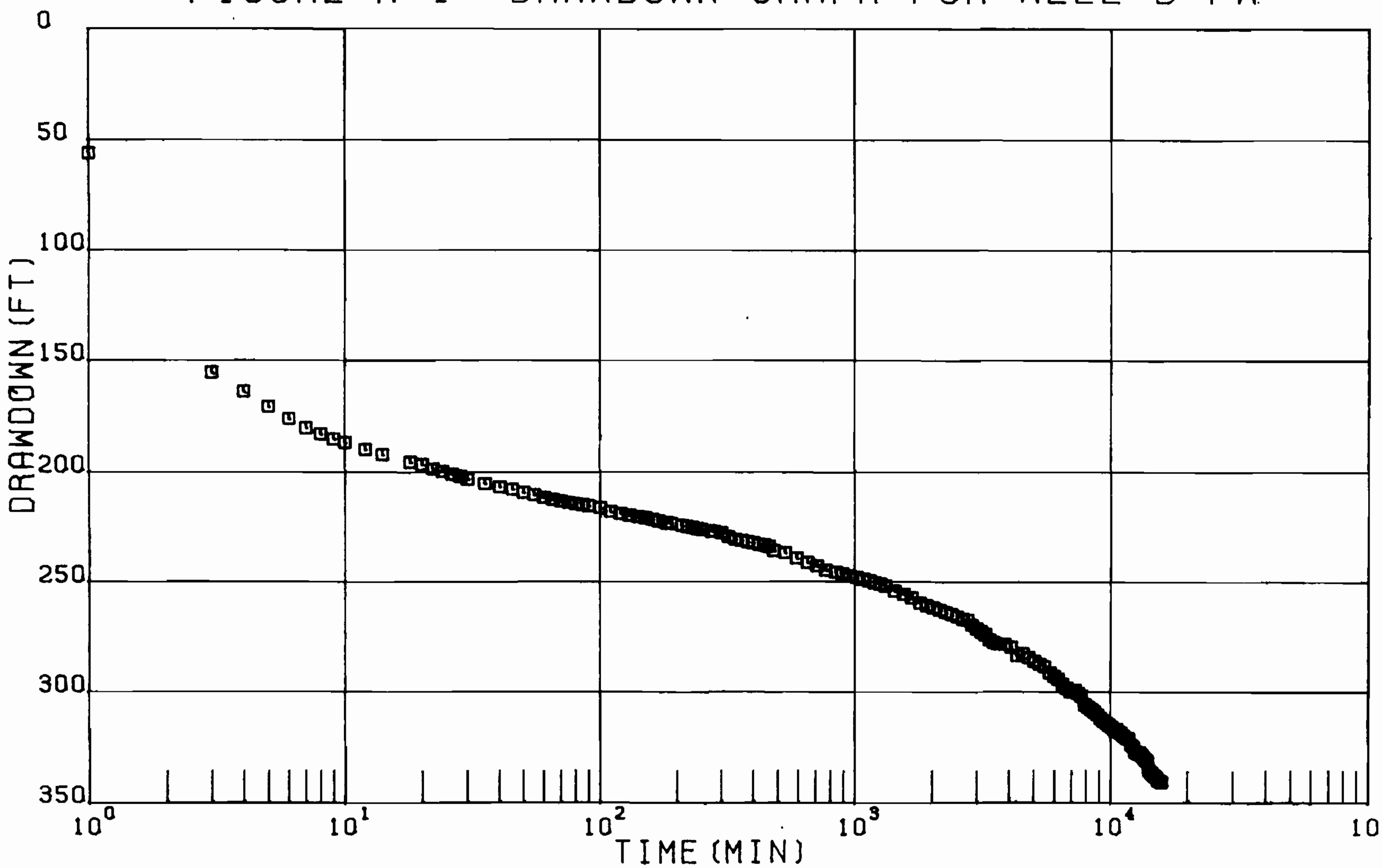
Gott, G. B., D. E. Wolcott, and C. G. Bowles, 1974, "Stratigraphy of the Inyan Kara Group and Localization of Uranium Deposits, Southern Black Hills, South Dakota and Wyoming," USGS Prof. Paper 763.

Trescott, P. C., 1975, "Documentation of Finite-Difference Model for Simulation of Three-Dimensional Ground-Water Flow," USGS Open File Report 75-438.

Walton, W. C., 1970, Groundwater Resource Evaluation, McGraw-Hill, New York.

WR28-2-520-128.A-1

FIGURE A-1: DRAWDOWN GRAPH FOR WELL D-PW



WR28-2-520-128.A-2

FIGURE A-2: DRAWDOWN GRAPH FOR D-1 WELL GROUP

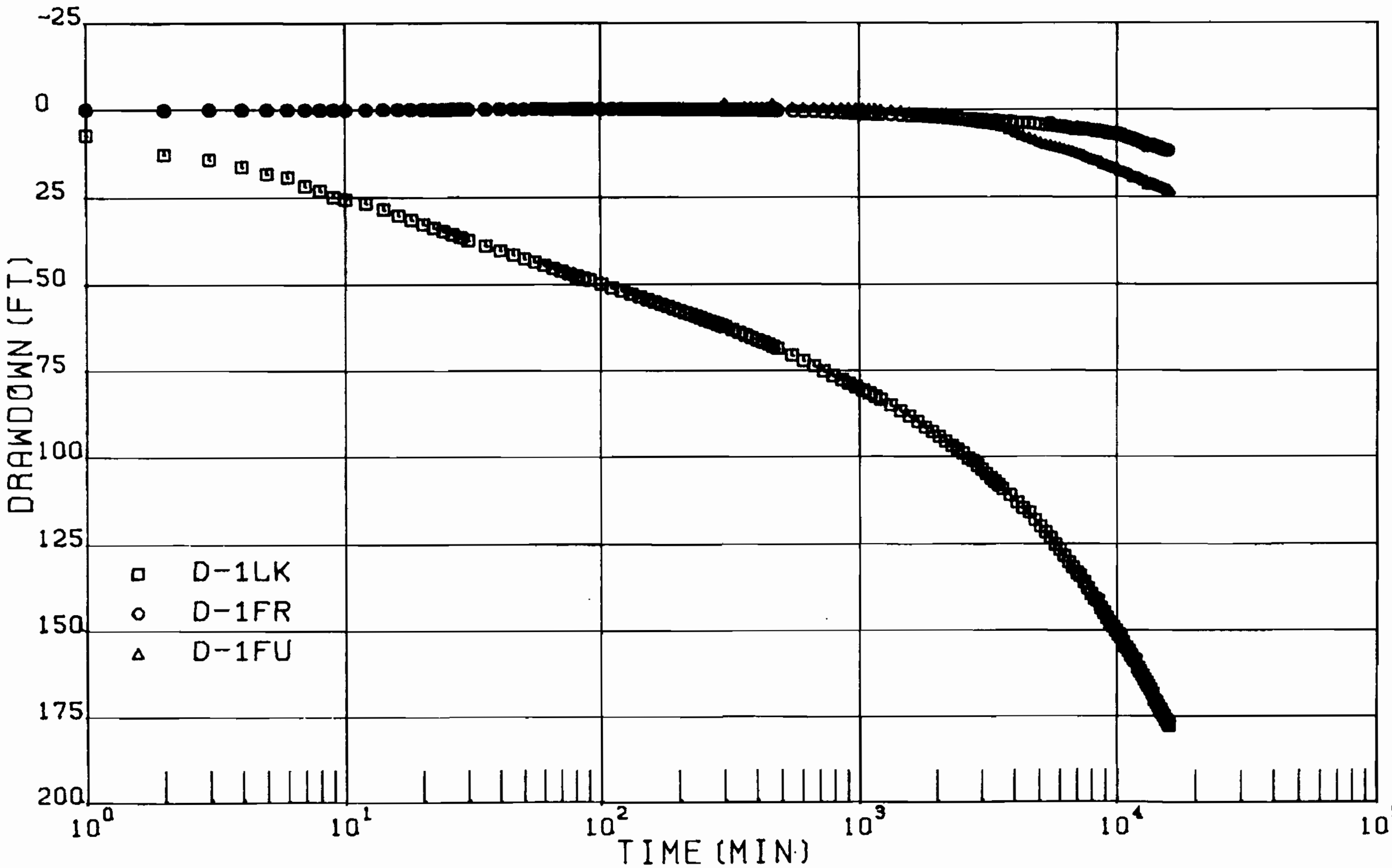
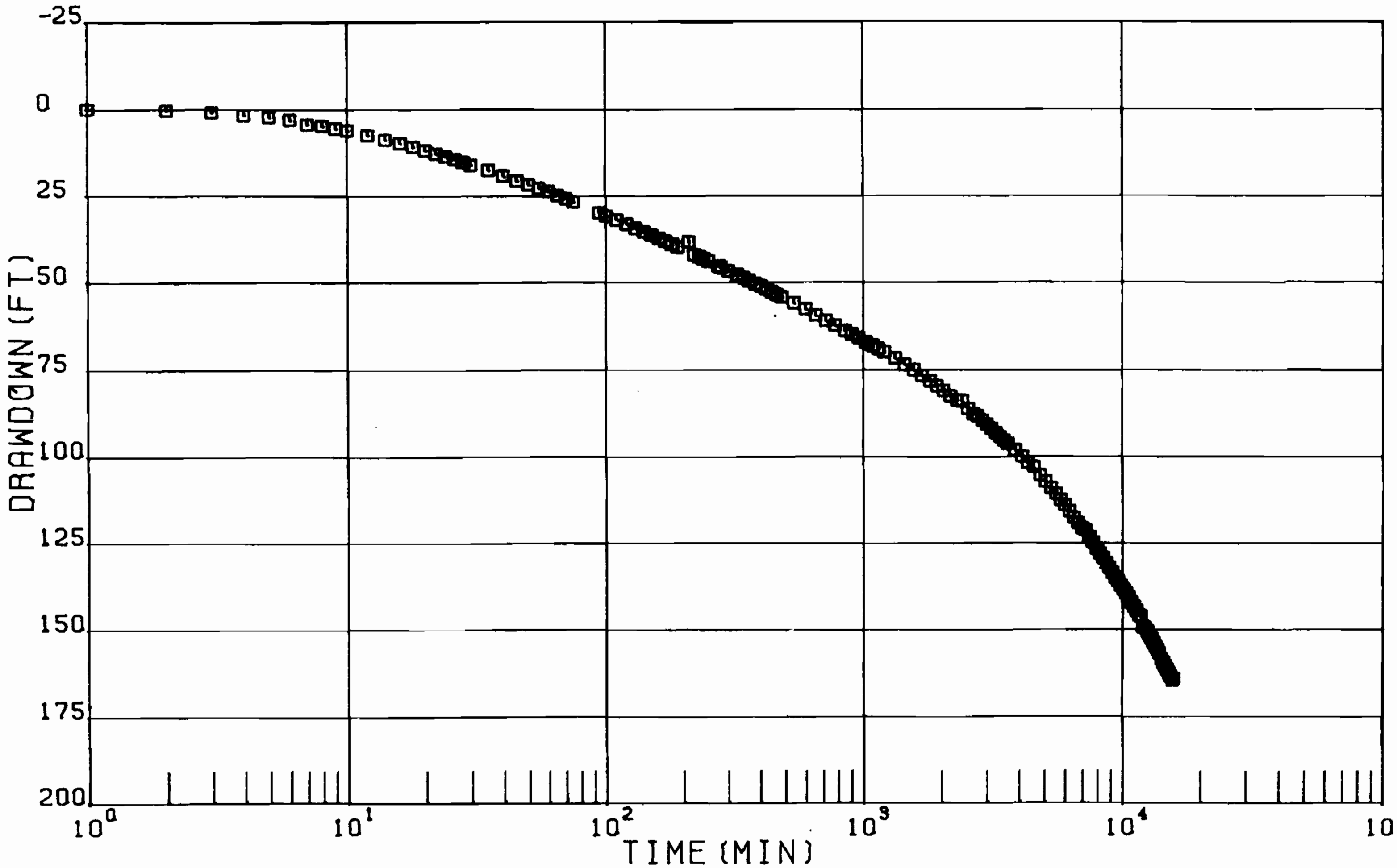
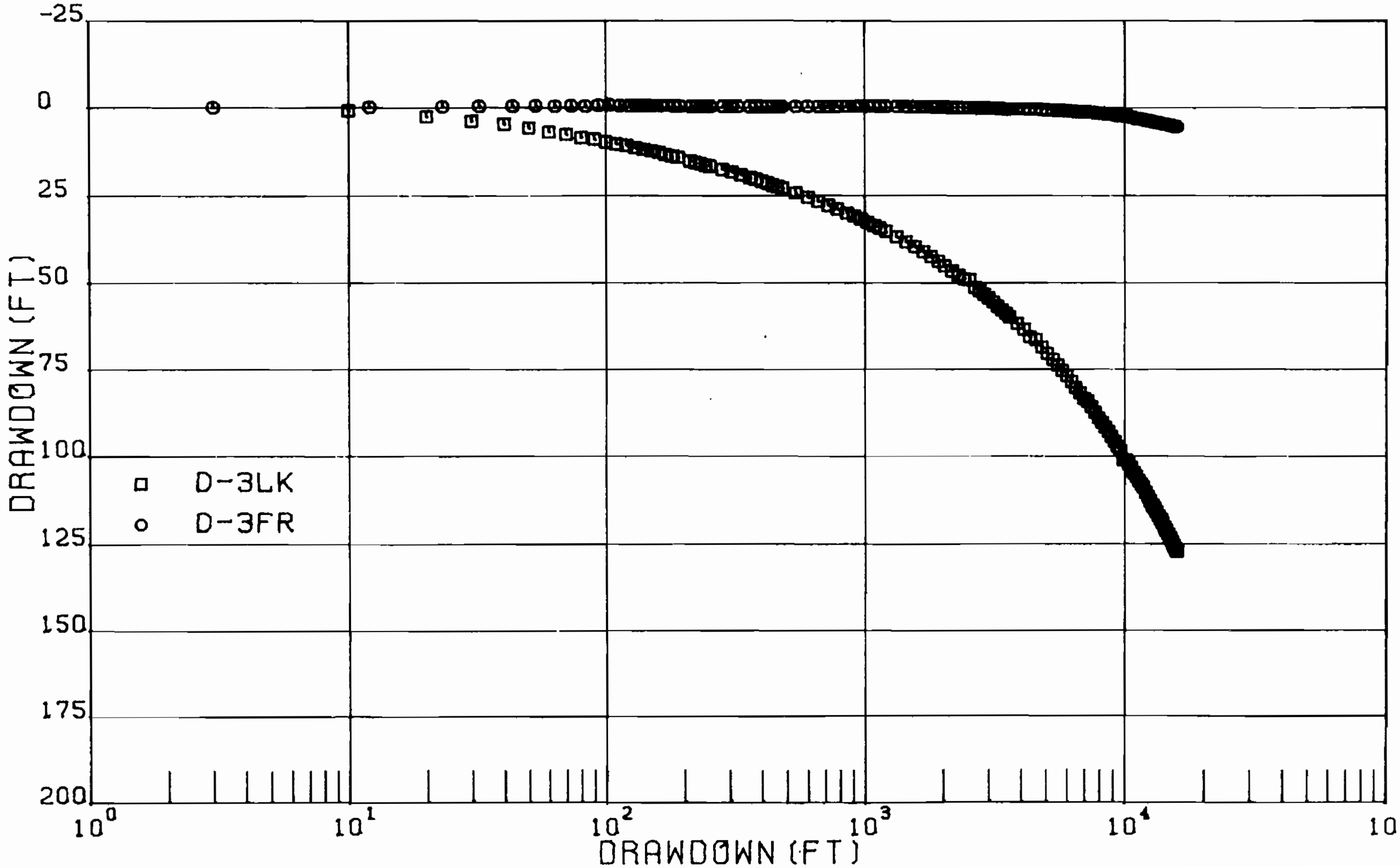


FIGURE A-3: DRAWDOWN GRAPH FOR WELL D-2LK



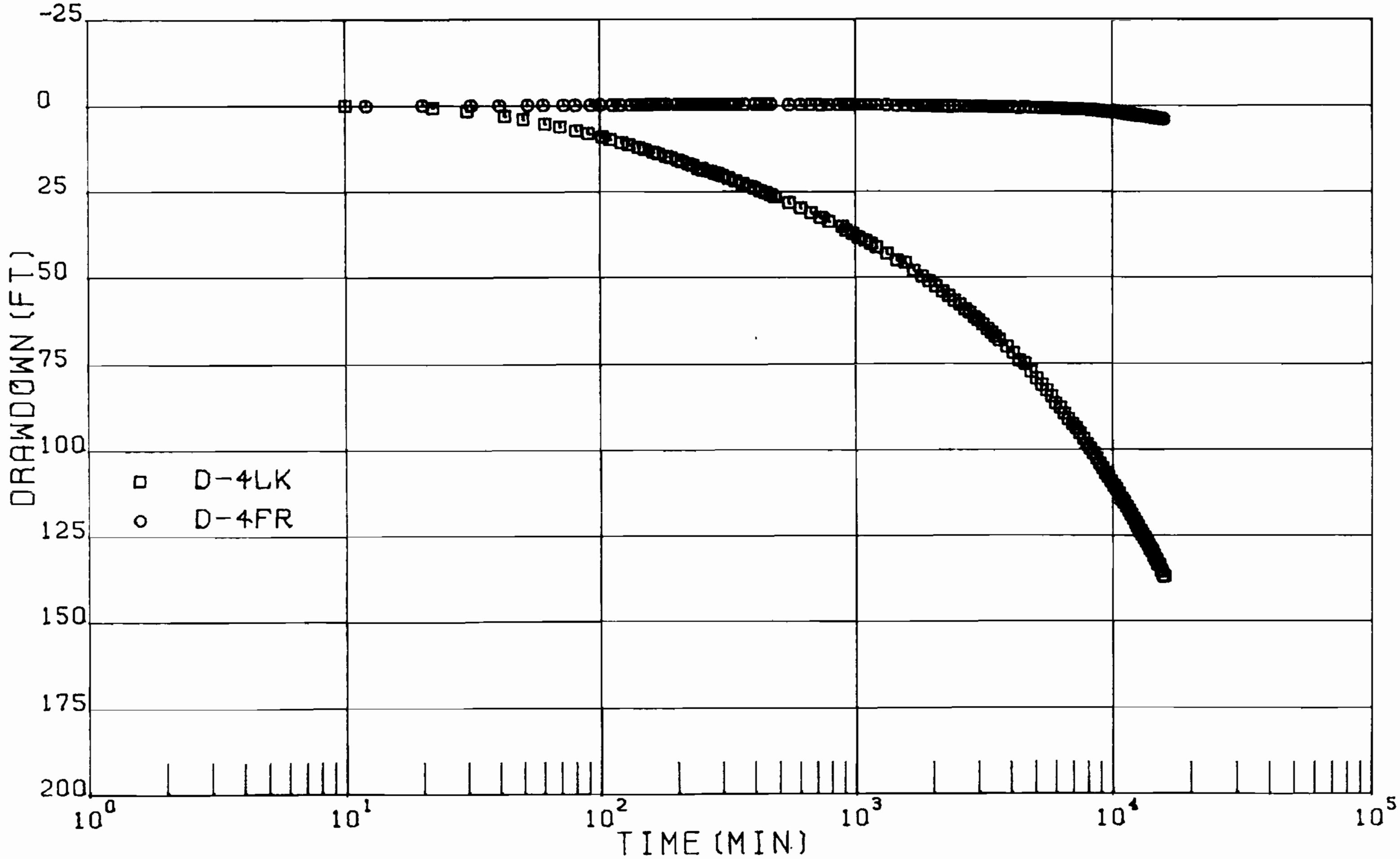
WR28-2-520-128.A-4

FIGURE A-4: DRAWDOWN GRAPH FOR D-3 WELL GROUP



WR28-2-520-128.A-5

FIGURE A-5: DRAWDOWN GRAPH FOR D-4 WELL GROUP



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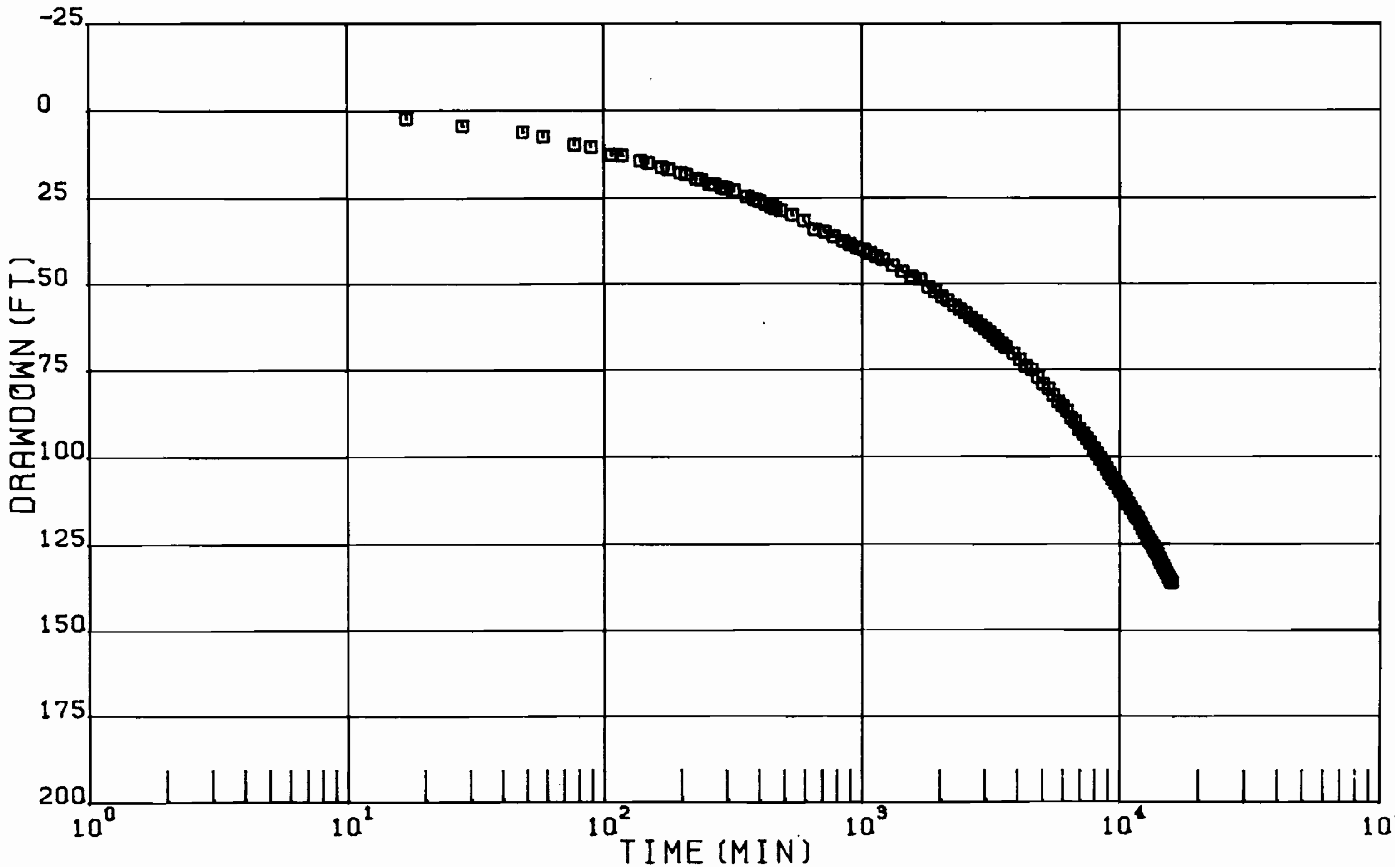
WR28-2-520-128.A-6

FIGURE A-6: DRAWDOWN GRAPH FOR WELL D-5LK



WR28-2-520-128.A-7

FIGURE A-7: DRAWDOWN GRAPH FOR WELL D-6LK

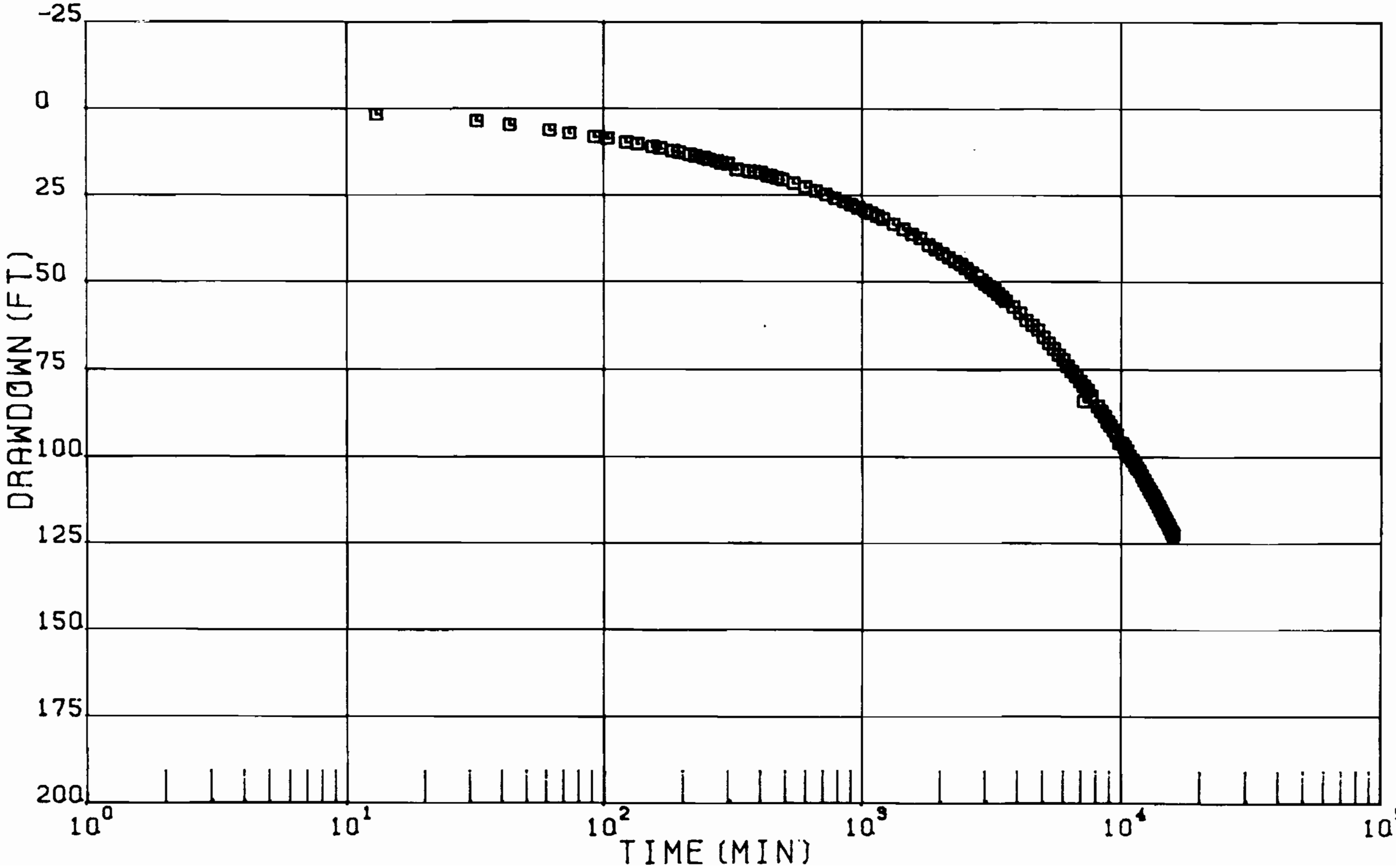
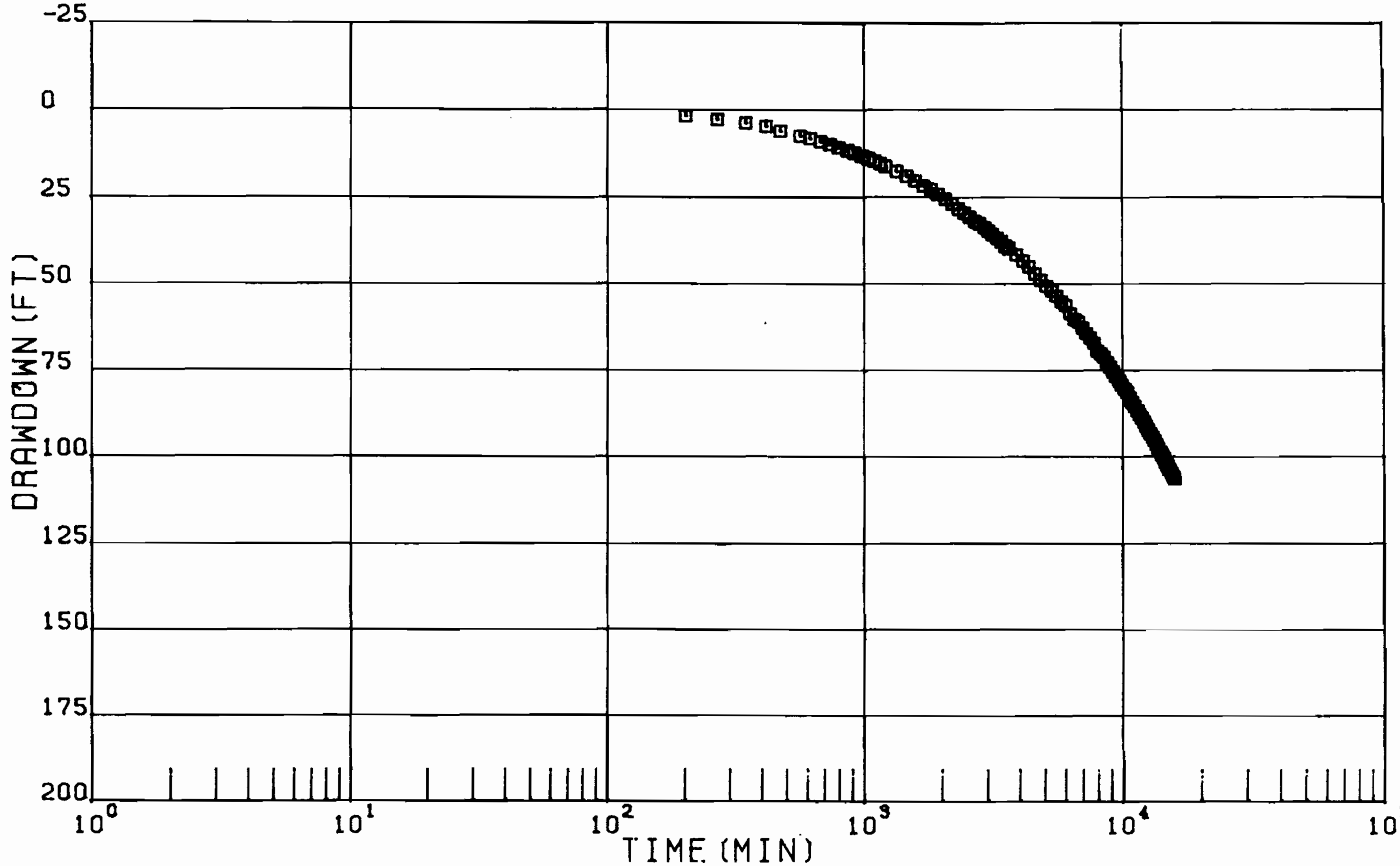
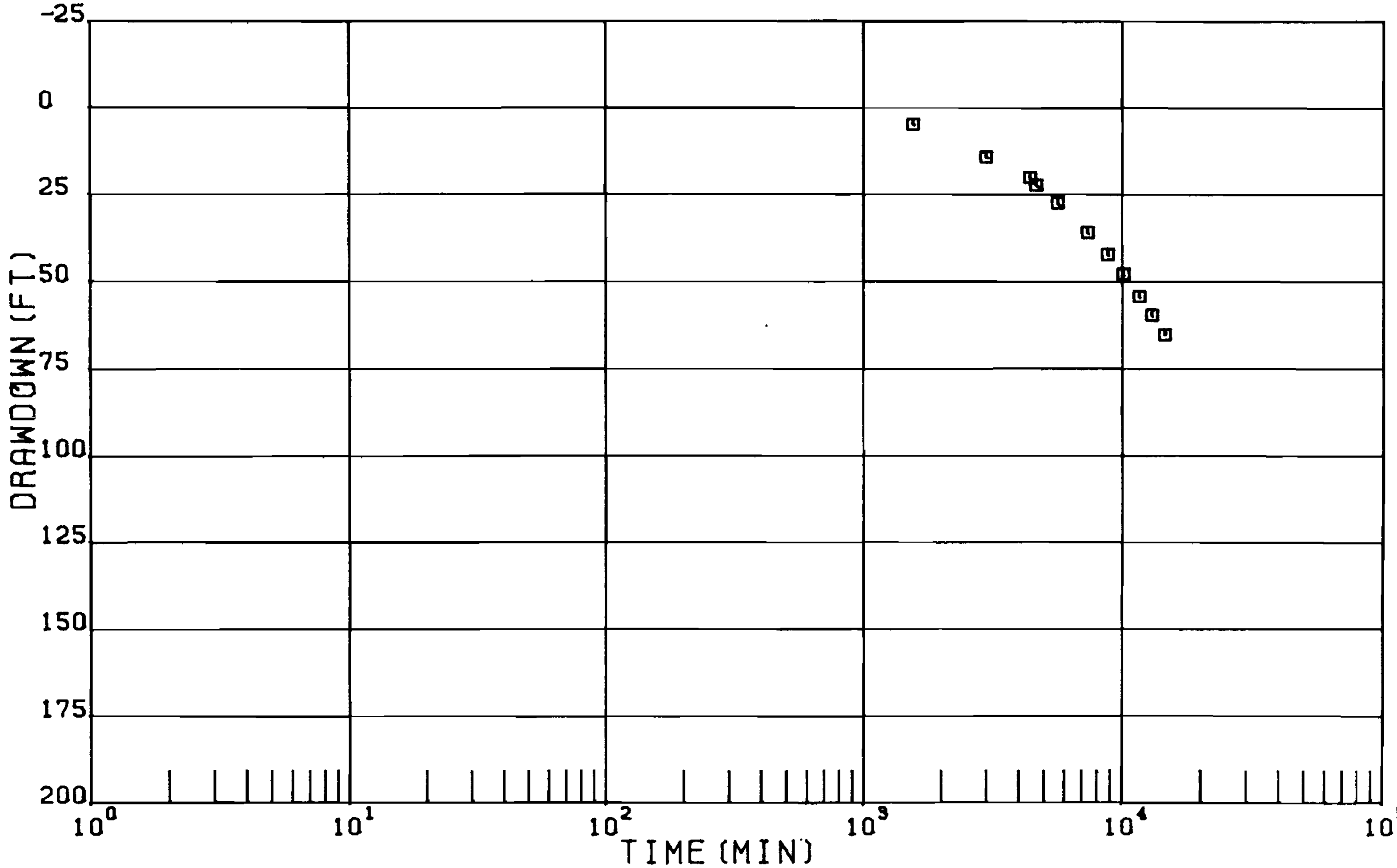


FIGURE A-8: DRAWDOWN GRAPH FOR WELL D-8LK



WR28-2-520-128.A-9

FIGURE A-9: DRAWDOWN GRAPH FOR WELL D-20LK



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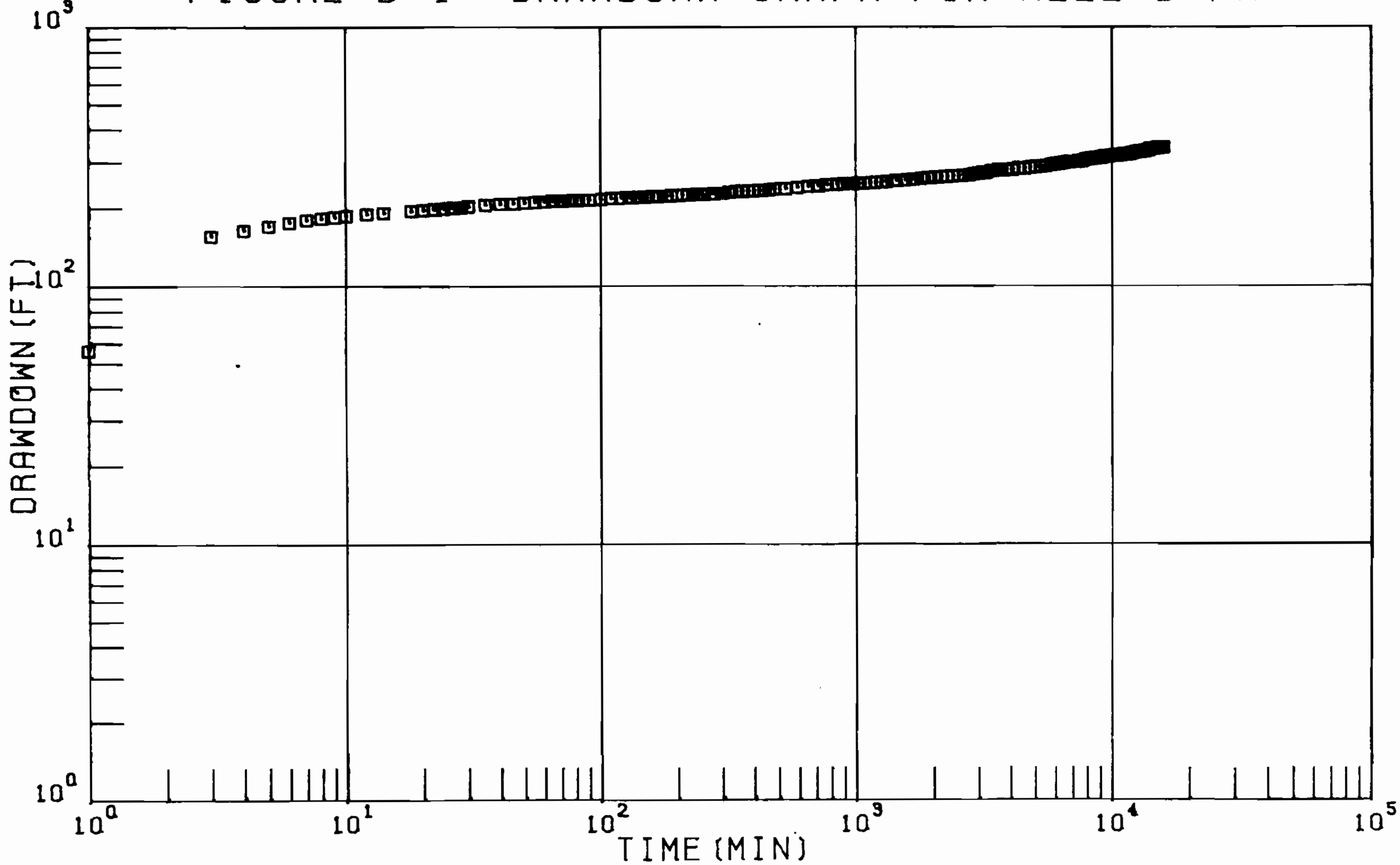
APPENDIX B

LOGARITHMIC TIME-DRAWDOWN GRAPHS

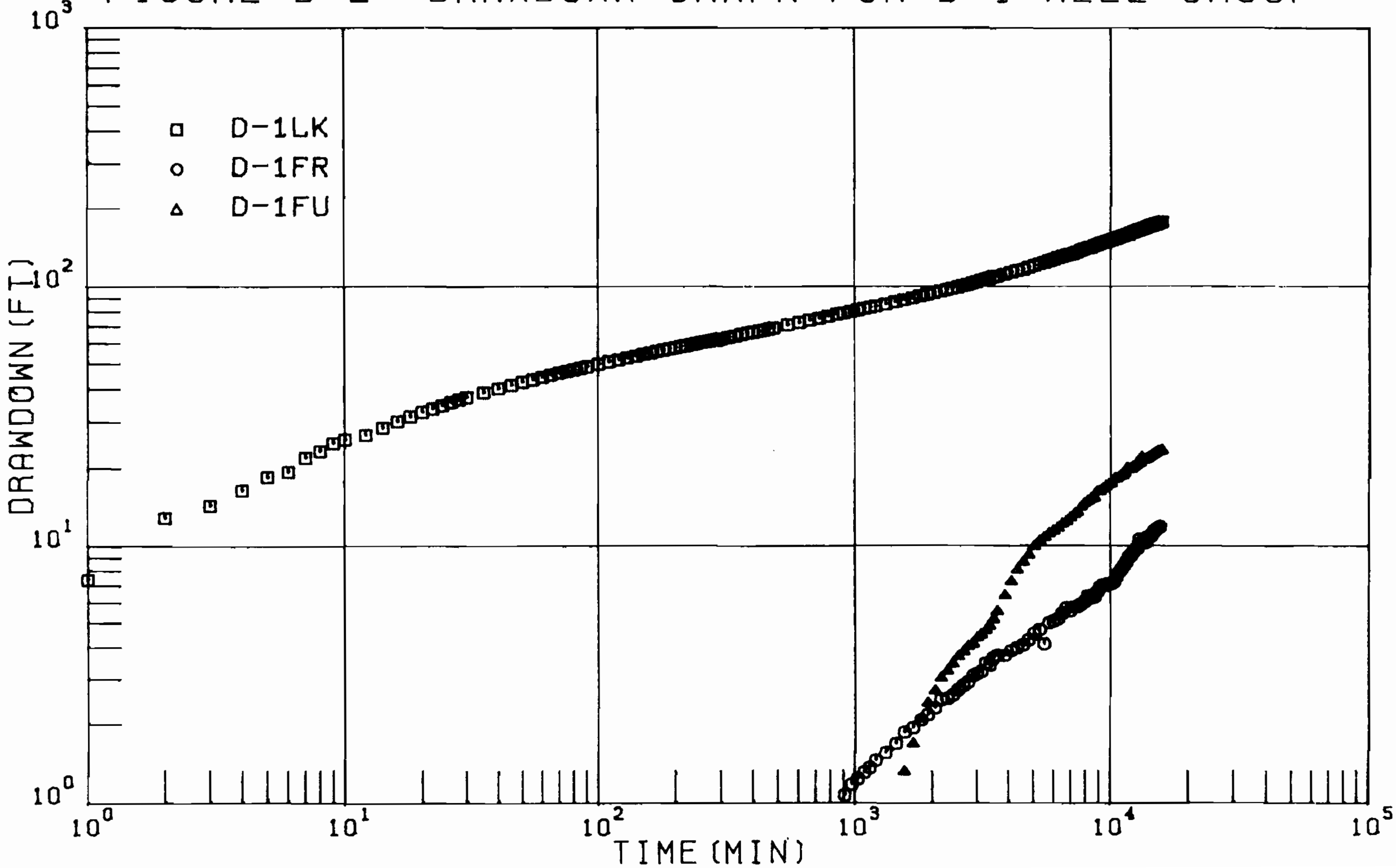
WR28-2-520-128.B-1

FIGURE B-1: DRAWDOWN GRAPH FOR WELL D-PW



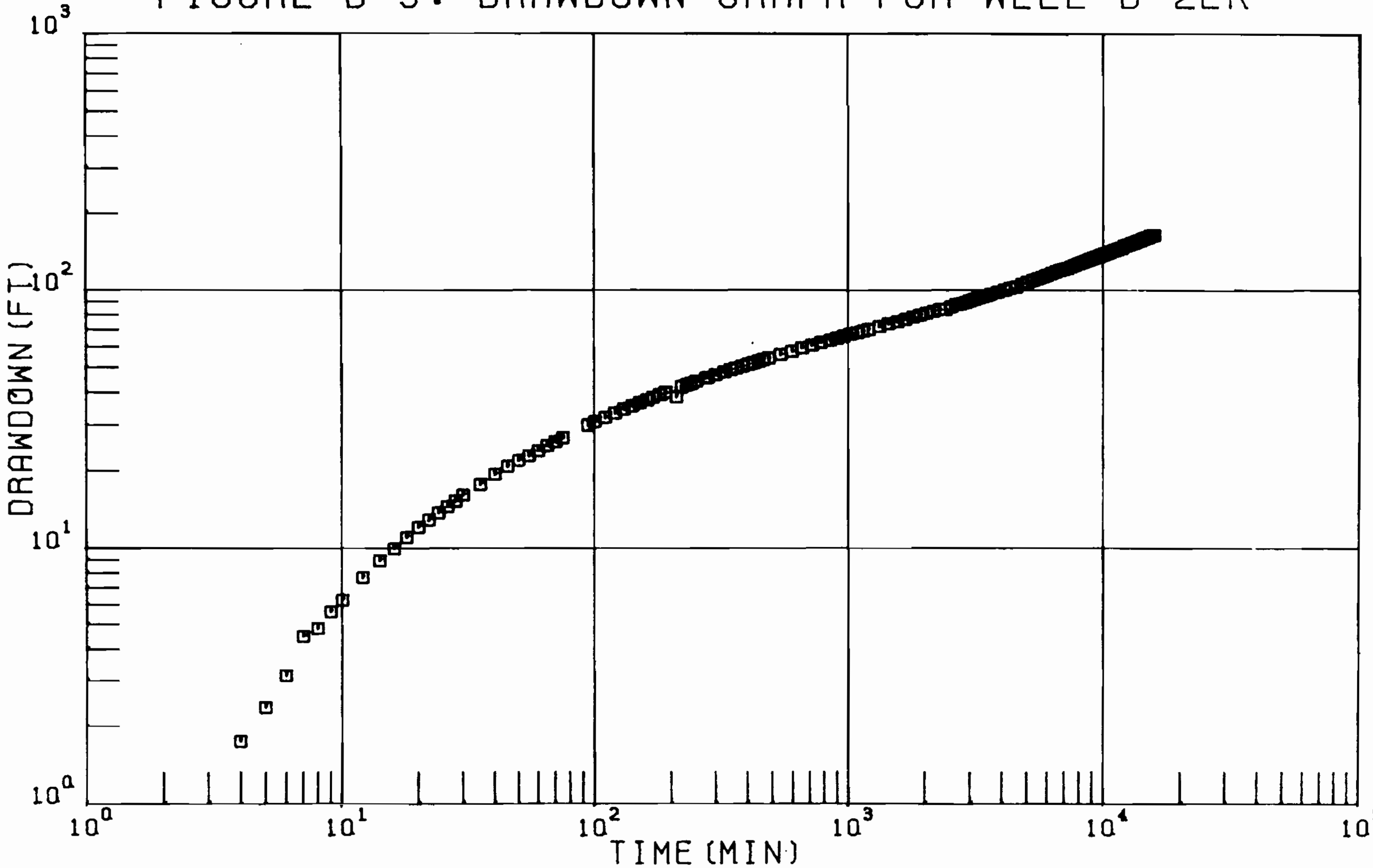
WR28-2-520-128.B-2

FIGURE B-2: DRAWDOWN GRAPH FOR D-1 WELL GROUP



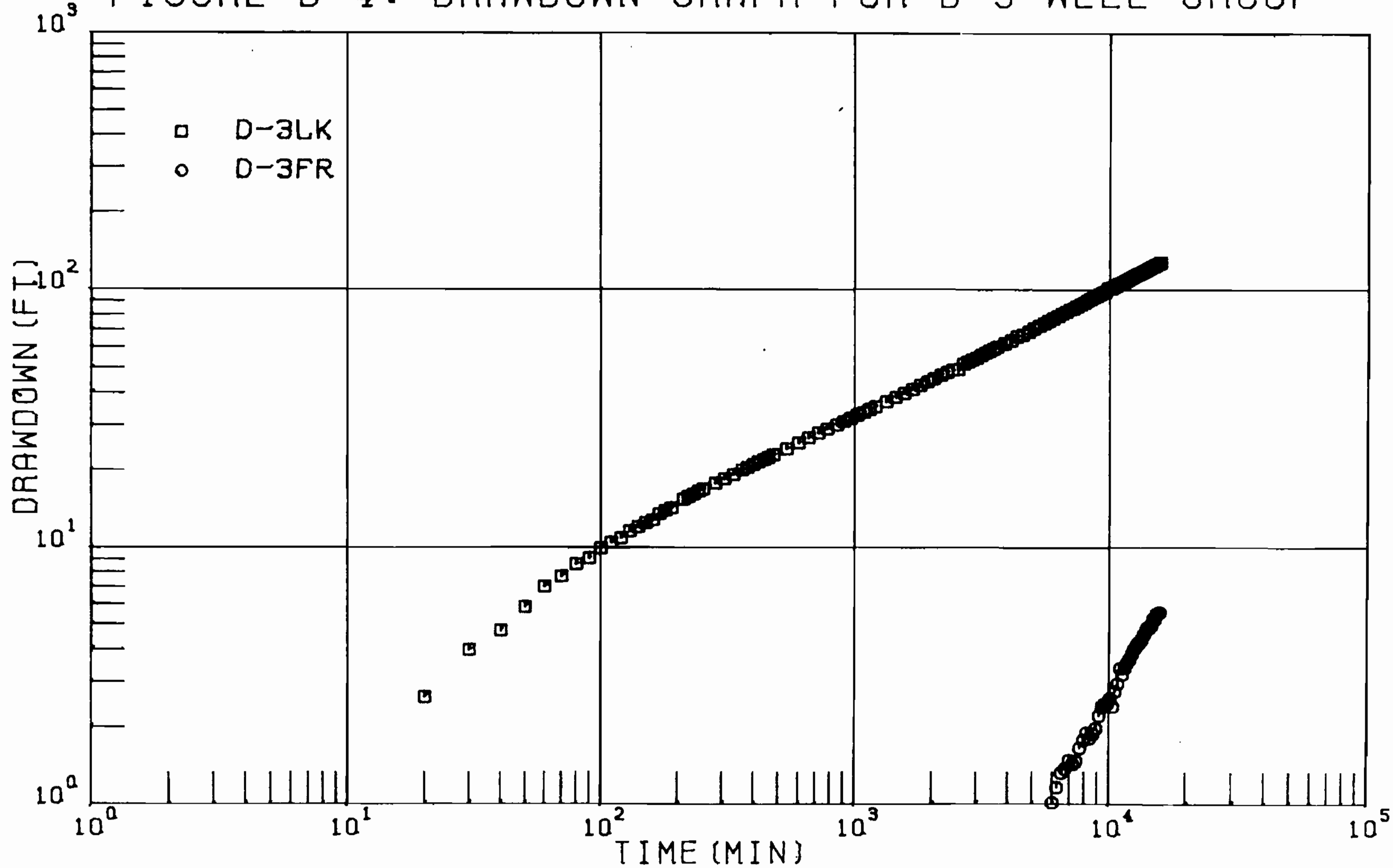
W..28-2-.20-.28.B-3

FIGURE B-3: DRAWDOWN GRAPH FOR WELL D-2LK



WR28-2-520-128.B-4

FIGURE B-4: DRAWDOWN GRAPH FOR D-3 WELL GROUP



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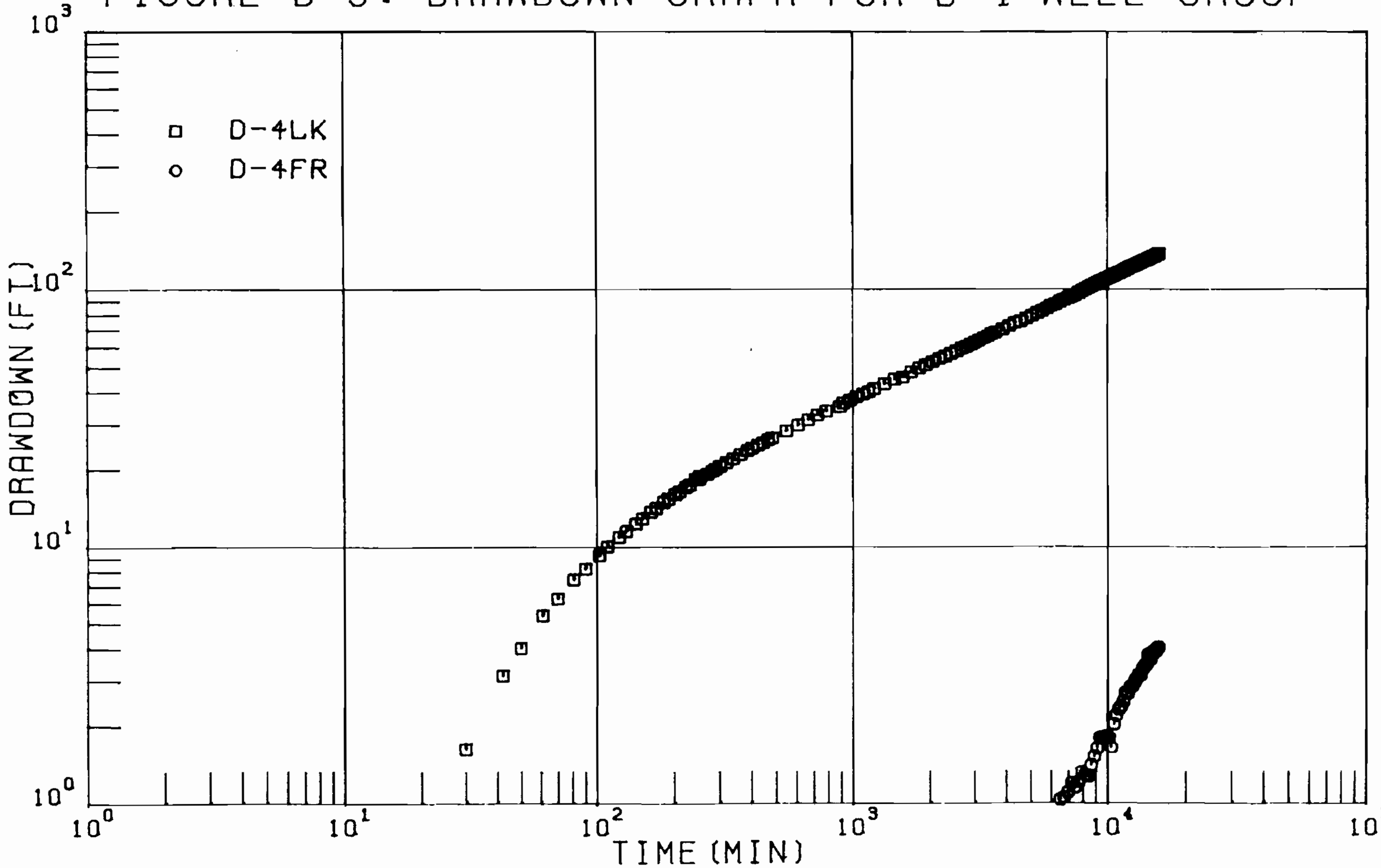
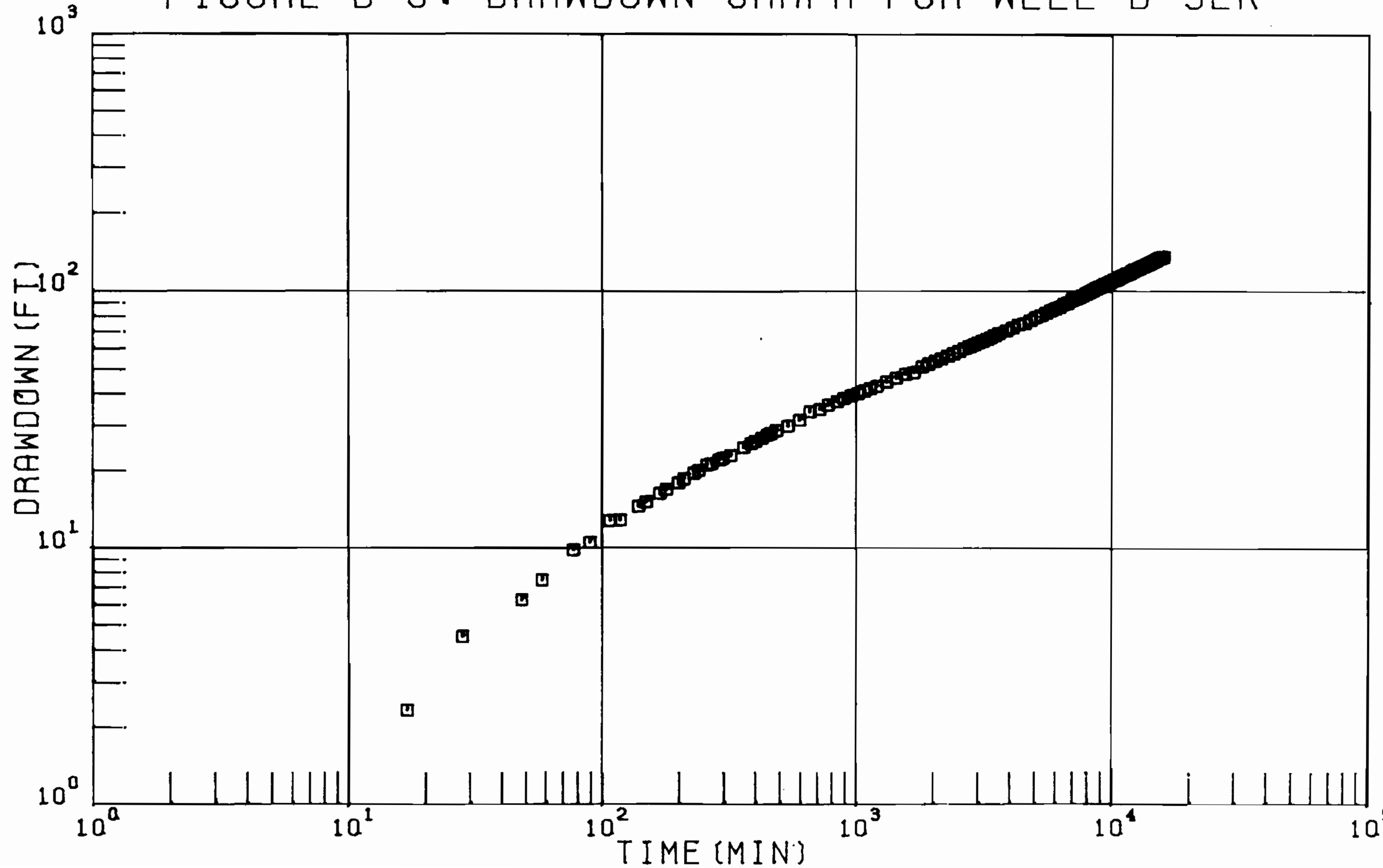
WR28-2-520-128.B-5

FIGURE B-5: DRAWDOWN GRAPH FOR D-4 WELL GROUP



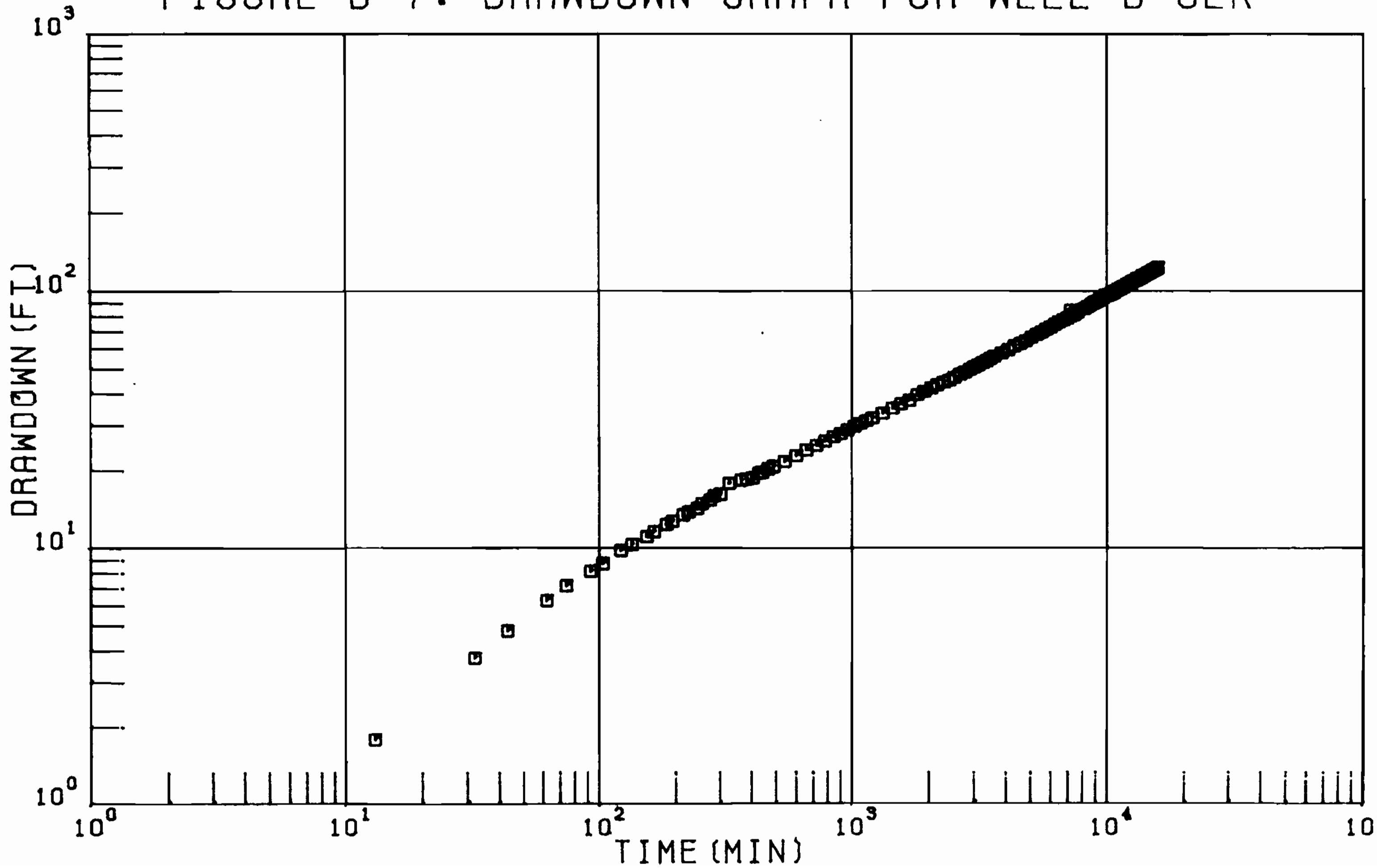
Wr28-2-520-128.B-6

FIGURE B-6: DRAWDOWN GRAPH FOR WELL D-5LK



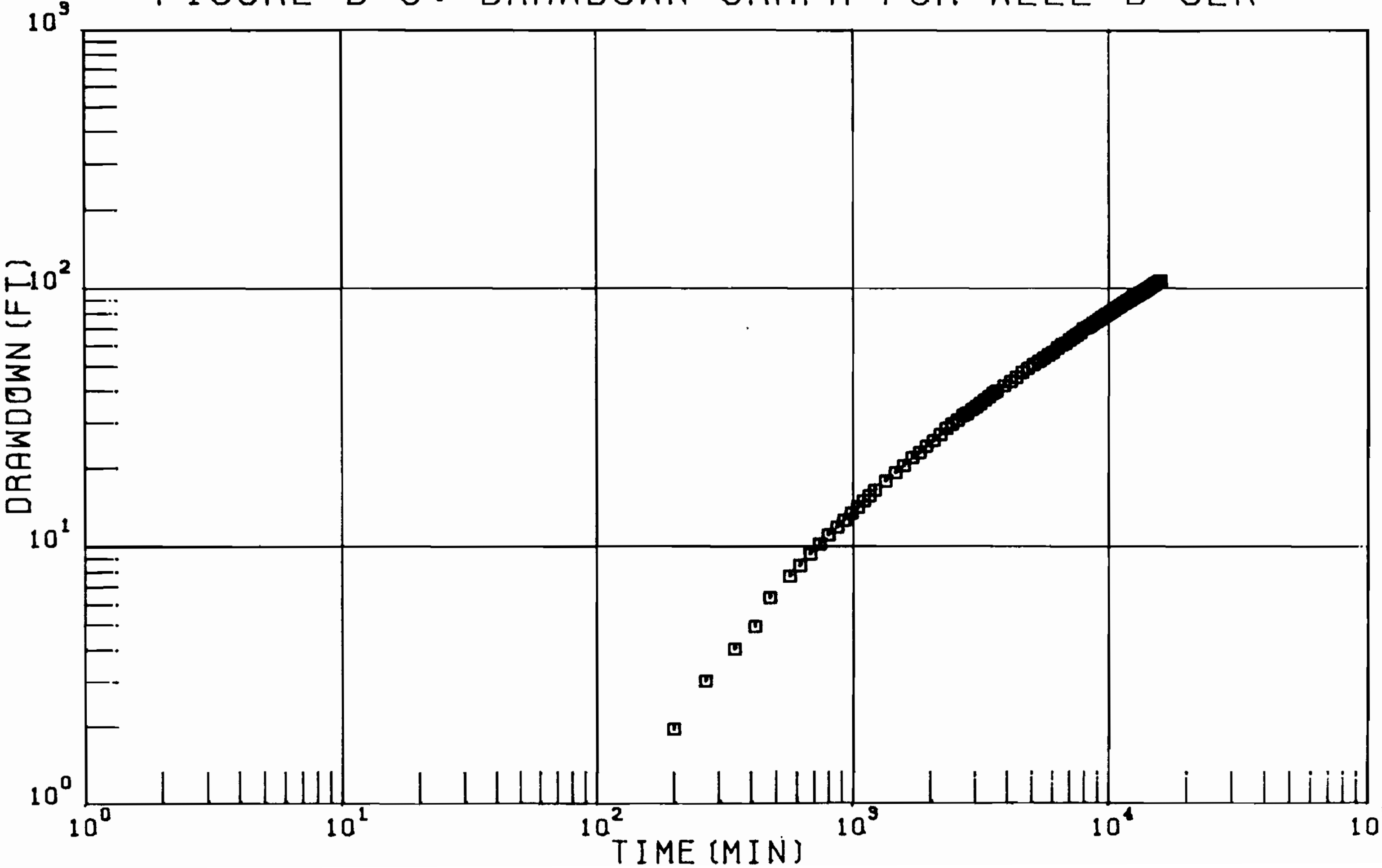
WR28-2-520-128.B-7

FIGURE B-7: DRAWDOWN GRAPH FOR WELL D-6LK



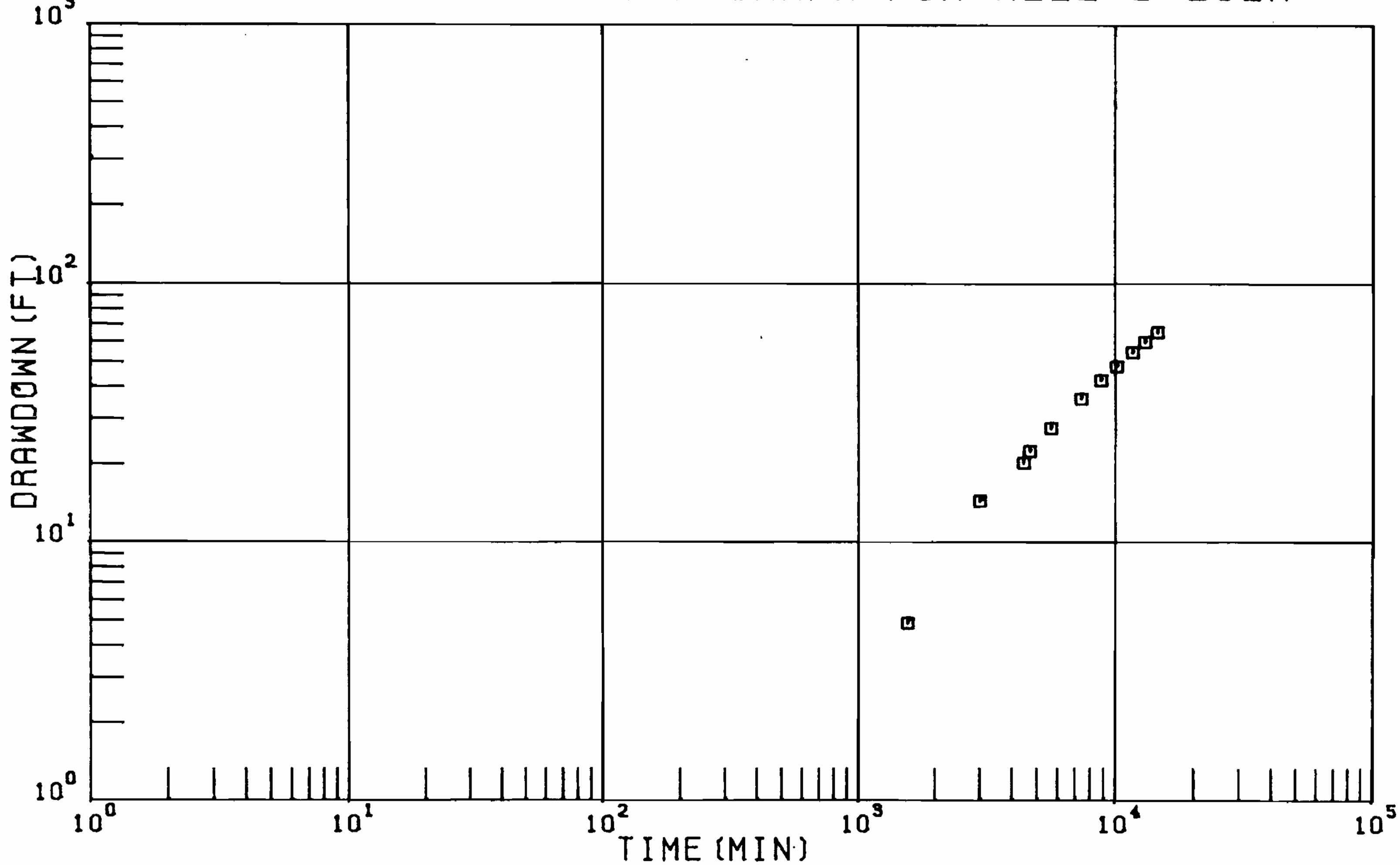
WR28-2-520-128.B-8

FIGURE B-8: DRAWDOWN GRAPH FOR WELL D-8LK



W ..-2 ..0-I...3-9

FIGURE B-9: DRAWDOWN GRAPH FOR WELL D-20LK

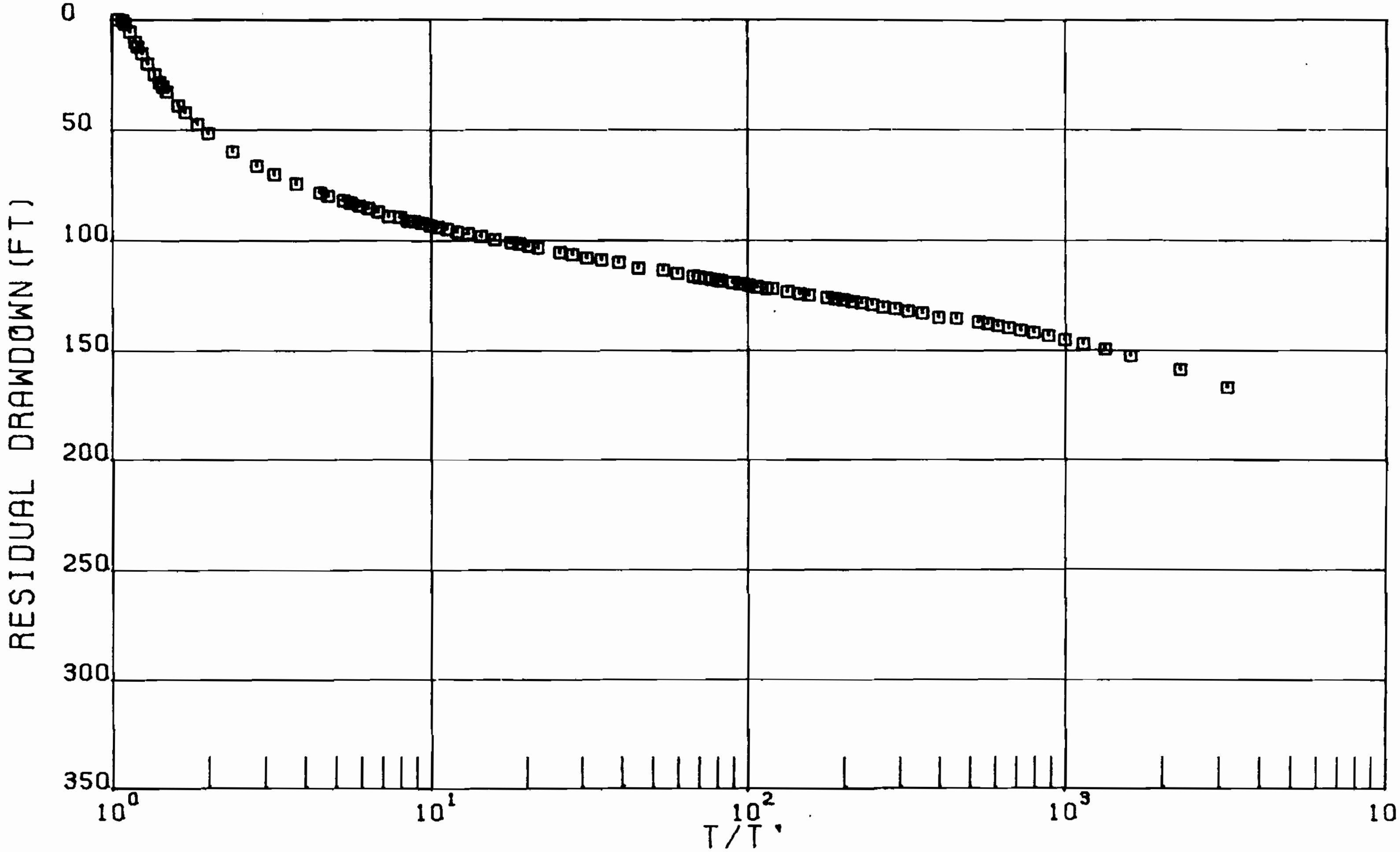


APPENDIX C

SEMILOGARITHMIC TIME-RESIDUAL DRAWDOWN GRAPHS

WR28-2-520-128.C-1

FIGURE C-1: RECOVERY GRAPH FOR WELL D-PW



WR28-2-520-128.C-2

FIGURE C-2: RECOVERY GRAPH FOR D-1 WELL GROUP

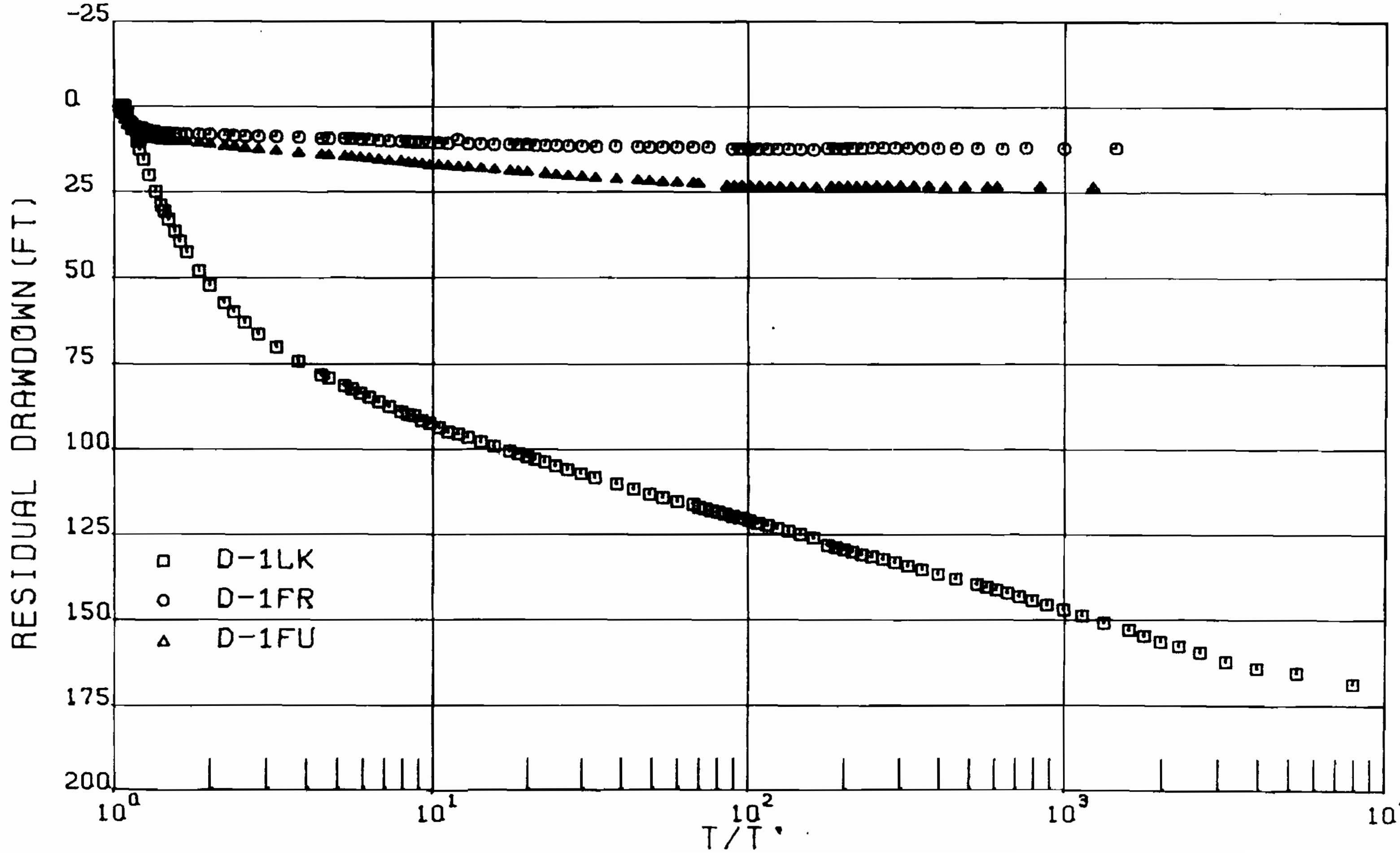
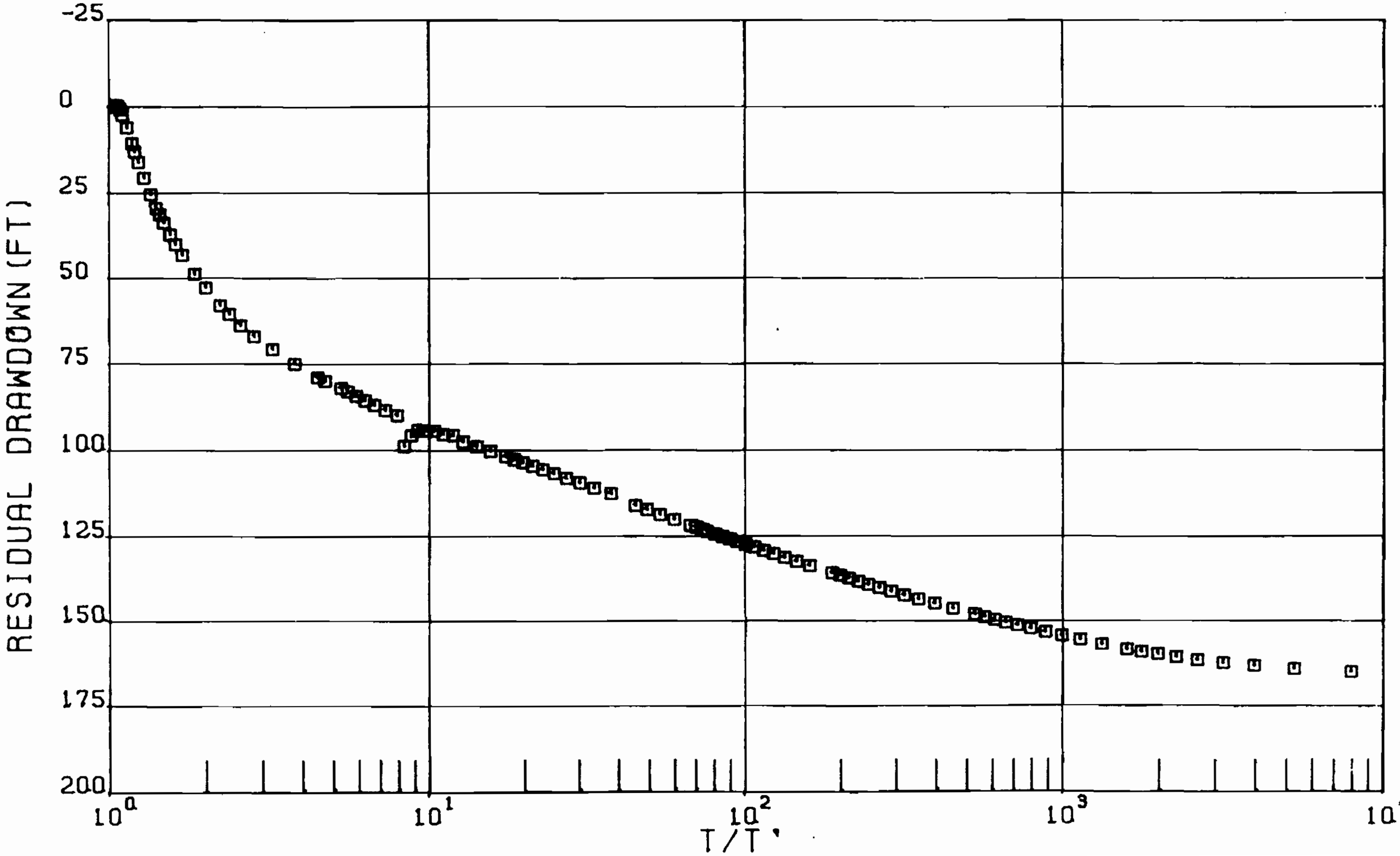
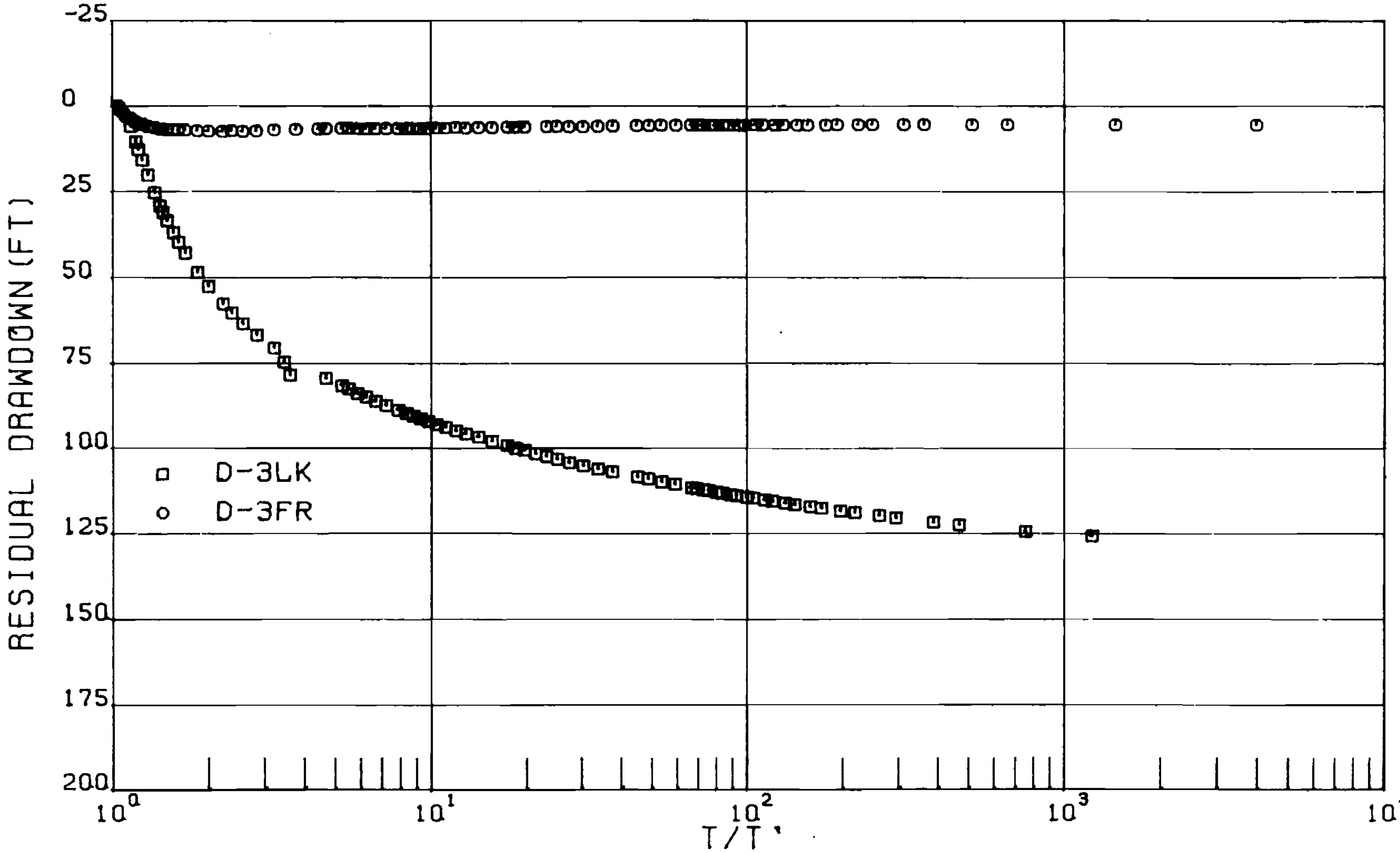


FIGURE C-3: RECOVERY GRAPH FOR WELL D-2LK



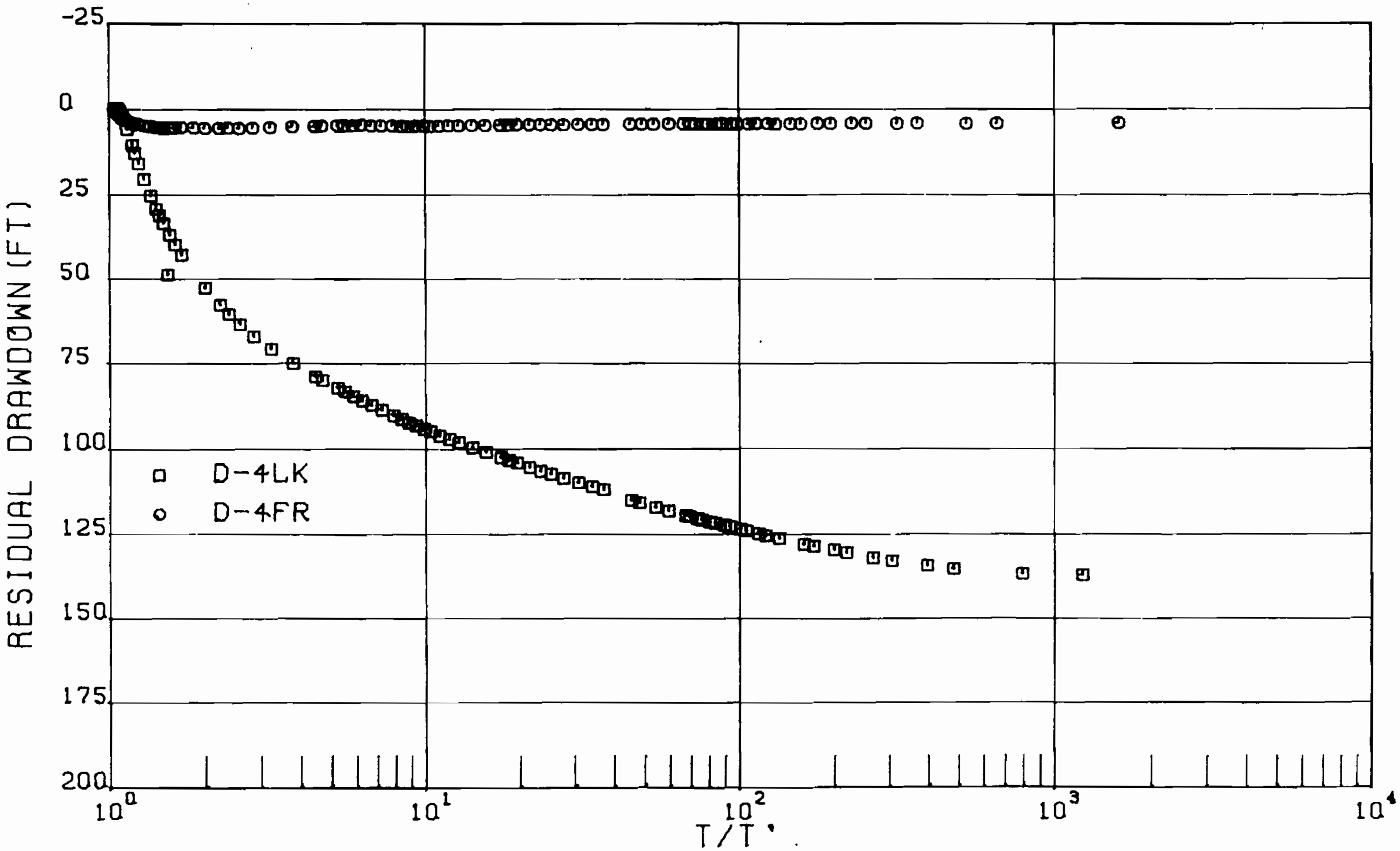
WR28-2-520-128.C-4

FIGURE C-4: RECOVERY GRAPH FOR D-3 WELL GROUP



wn28-c-320-128.C-5

FIGURE C-5: RECOVERY GRAPH FOR D-4 WELL GROUP



WR28-520-128.C-6

FIGURE C-6: RECOVERY GRAPH FOR WELL D-5LK

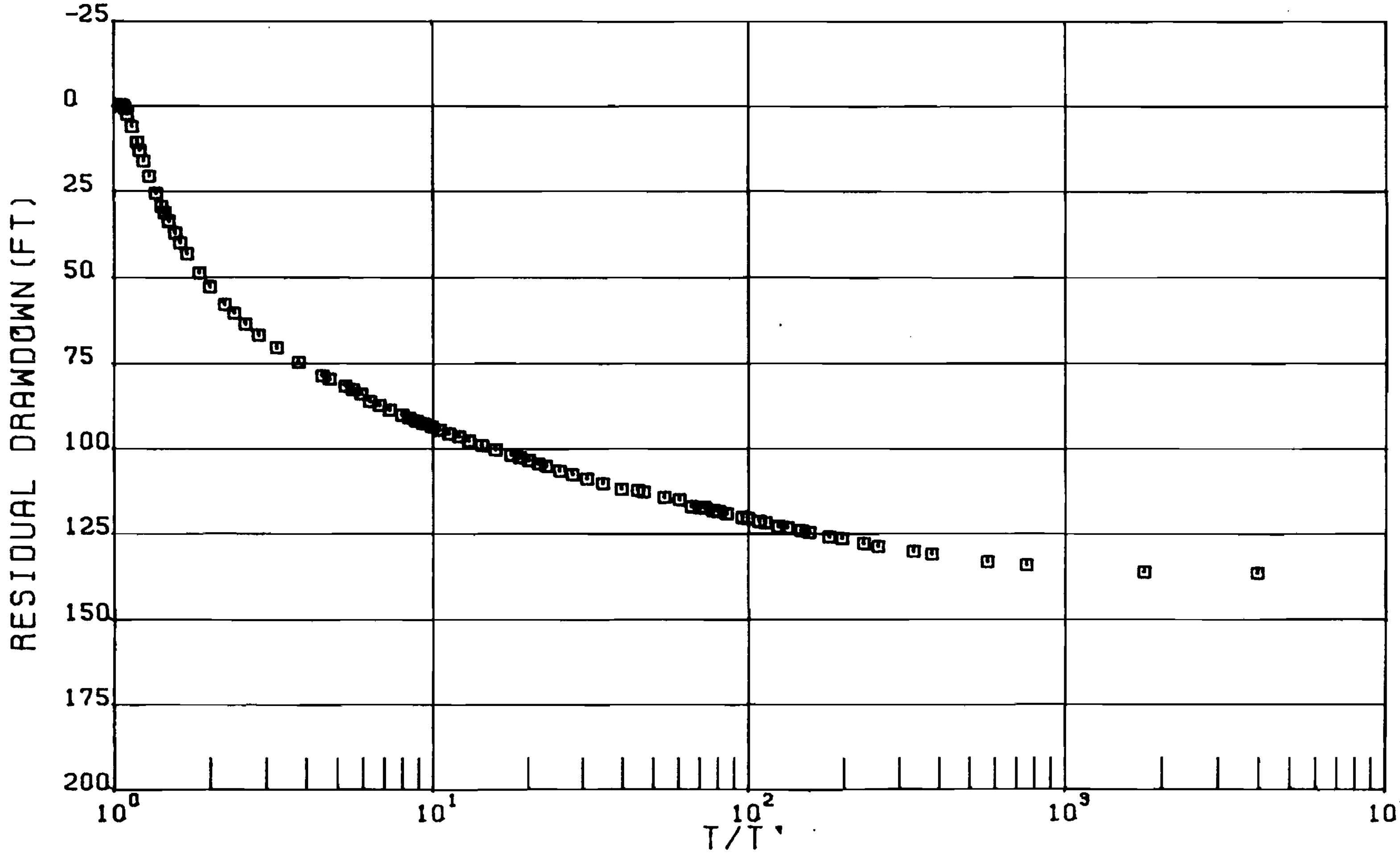


FIGURE C-7: RECOVERY GRAPH FOR WELL D-6LK

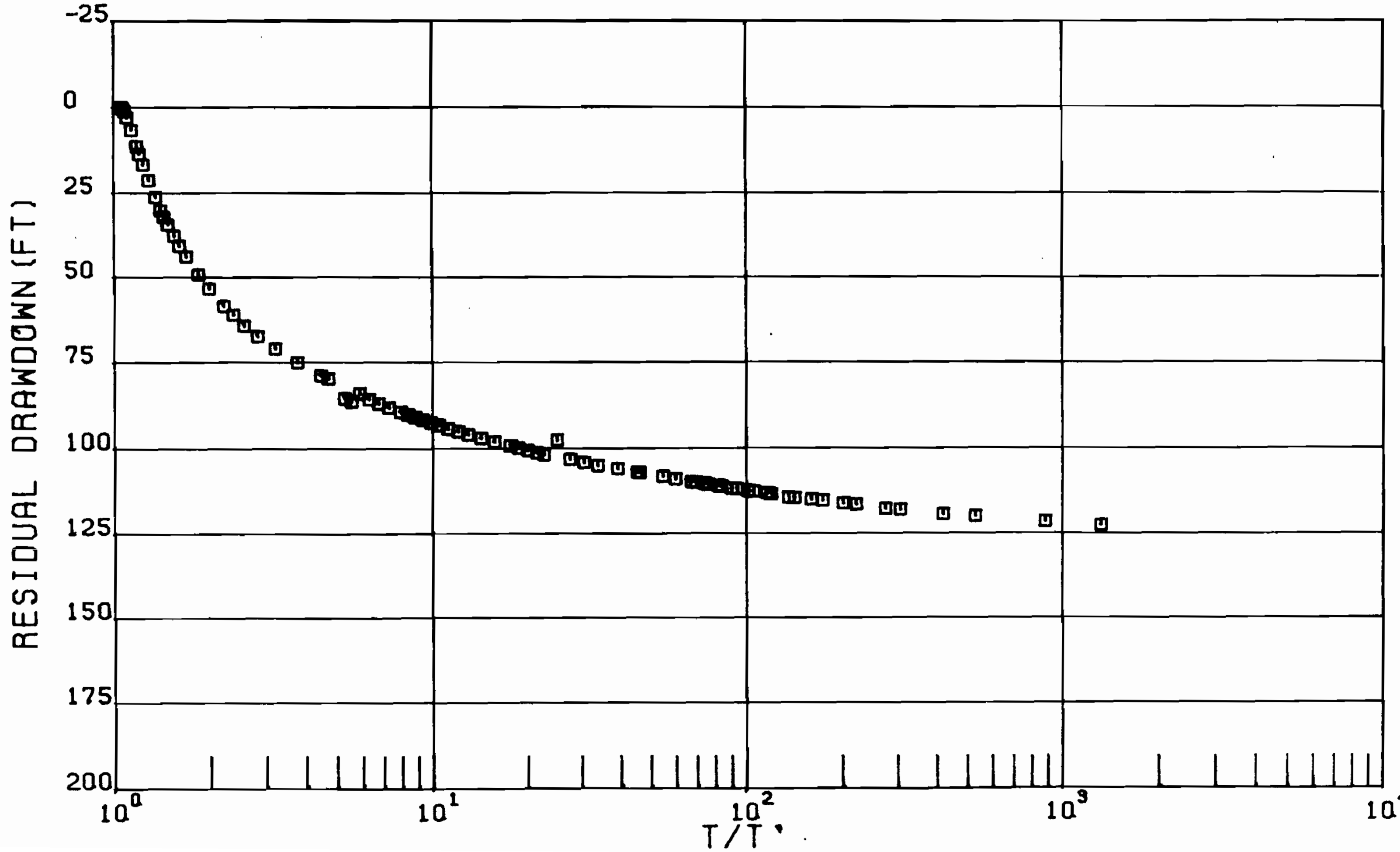


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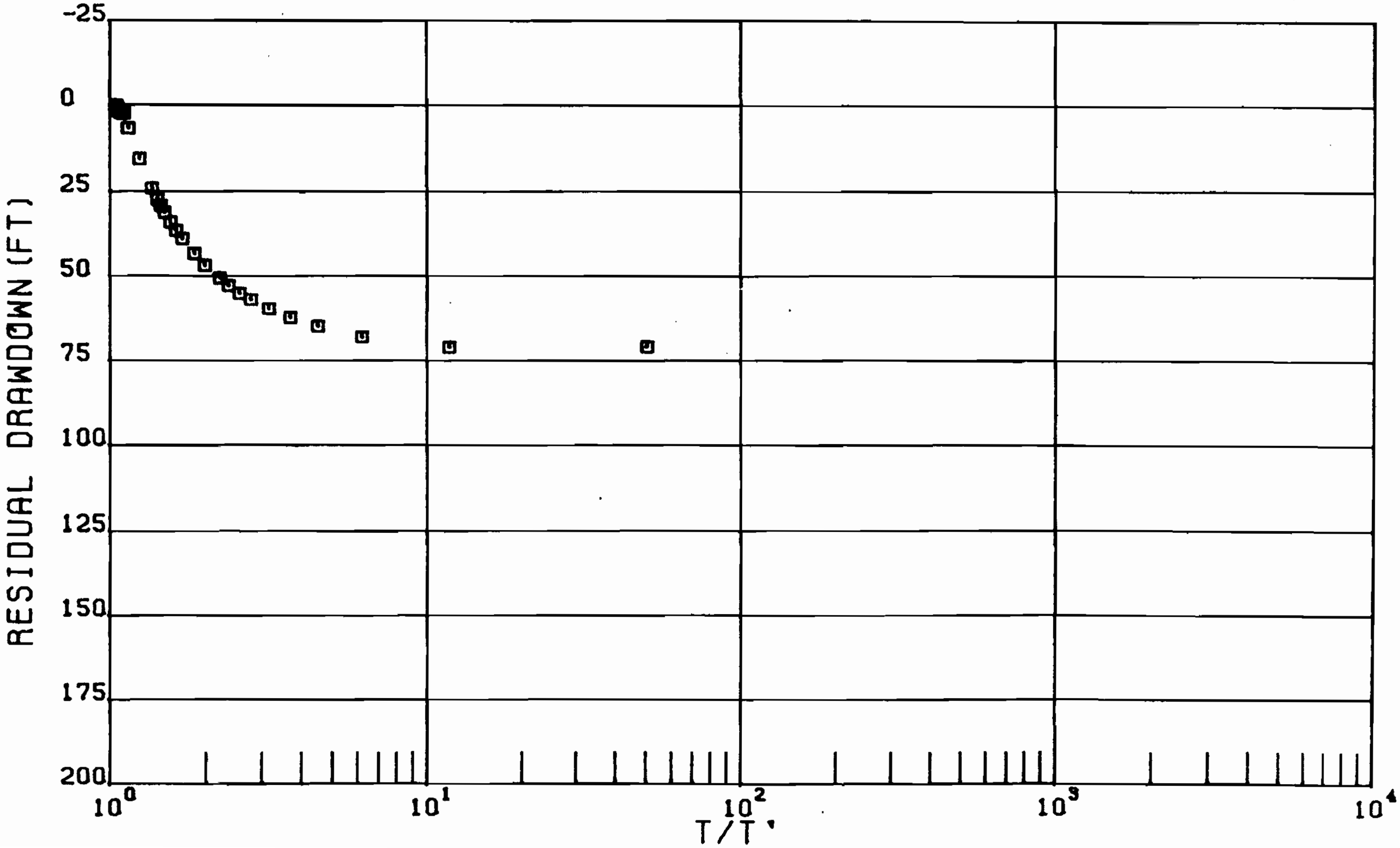
FIGURE C-9: RECOVERY GRAPH FOR WELL D-20LK



APPENDIX 2.7-L

Class V UIC Application

UIC PERMIT APPLICATION

Class V Non-Hazardous Injection Wells

Powertech (USA) Inc.

Dewey-Burdock Project

Custer and Fall River Counties, South Dakota

EPA Permit # TBD

March 2010

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APPENDIX C ELECTRONIC COPY OF PERMIT APPLICATION

APPENDIX D HISTORICAL PHOTO, CITY OF EDGEMONT WATER WELL

USEPA PERMIT FORMS

FORM 7520-6 PROPOSED WELLS UIC PERMIT APPLICATION

FORM 7520-14 PROPOSED WELLS PLUGGING AND ABANDONMENT

1.0 PERMIT APPLICATION AND INTRODUCTION

Through the submittal of this application, Powertech (USA) Inc. [Powertech], requests an Area Permit and authorization from the US Environmental Protection Agency (USEPA) to install and operate four to eight non-hazardous Class V disposal wells located at the Dewey-Burdock Project, pursuant to the applicable Underground Injection Control (UIC) regulations. The number of wells is to be determined and is dependent upon well capacity. Powertech requests authorization to inject a total of 300 gallons per minute (gpm) in a maximum of eight Class V disposal wells. These wells are to be located in Custer and Fall River Counties, South Dakota, within the limits of the proposed Class V permit area within the Dewey-Burdock Project boundary. Proposed locations for the first four wells are shown on Figure B-2. The Project is located approximately 13 miles north-northwest of Edgemont, South Dakota, and straddles the area between northern Fall River and southern Custer County line. The project boundary encompasses approximately 10,580 acres (4,282 ha) of mostly private land on either side of County Road 6463 and includes portions of Sections 1-5, 10-12, 14 and 15, Township 7 South, Range 1 East and Sections 20, 21, 27, 28, 29 and 30-35, Township 6 South, Range 1 East. Approximately 240 acres (~2%) (97.1 ha) are under the control of the Bureau of Land Management (BLM) located in portions of Sections 3, 10, 11, and 12. A map identifying the general project location is included as Figure 1.

A completed copy of USEPA UIC 7520-6, "Underground Injection Control Permit Application" for the wells is included in this application, and required attachments to this form are also included in this document. In this application, the initial four planned wells are referred to individually as Dewey-Burdock Disposal Well Nos. 1, 2, 3, and 4, (DW Nos. 1, 2, 3, and 4) or collectively with additional disposal wells as the Dewey-Burdock Disposal Wells. All depths discussed in this application are below ground surface (bgs) unless otherwise noted.

The proposed Powertech facility in South Dakota will operate between four and eight Class V Non-Hazardous Disposal Wells for underground injection of fluids from an in-situ leach (ISL) uranium mining project. Fresh water aquifers in the vicinity of the wells are to be protected by casing and cement. Injected fluids will be delivered to the Minnelusa and Deadwood Formations in separate wells under positive pressure injection through tubing and a packer. The wells are to have one cemented long string protective casing extending into the injection interval. The wellbores are to be perforated completions within the injection interval. The annulus area between the protective casings and injection tubing strings will be filled with inhibited fresh water. Annulus pressure will be continuously monitored to detect any potential leaks in the tubing or casing strings and annulus pressures will be maintained at more than 100 psi above the tubing pressure.

Relevant administrative data regarding the permit are summarized as follows.

Applicant:	Powertech (USA) Inc.
State:	South Dakota
Counties:	Custer and Fall River
Facility Address:	310 2nd Avenue Edgemont, SD 57735
Mailing Address:	5575 DTC Parkway, Suite 140, Greenwood Village, CO 80111
Location of Planned Wells:	Site 1: NE ¼ of NW ¼ of SW ¼ of Section 2, T7S, R1E DW No. 1: Lat: -103.971938654 Long: 43.469772181 DW No. 2: Lat: -103.971859557 Long: 43.4696483743 Site 2: SE ¼ of NW ¼ of SW ¼ of Section 29, T6S, R1E DW No. 3: Lat: -104.031570321 Long: 43.4971737527 DW No. 4: Lat: -104.031436264 Long: 43.4970792287

Location of Additional Wells:	To be determined
USEPA ID Nos.:	Dewey-Burdock Disposal Well Nos. 1, 2, 3, 4, and additional wells- TBD
Contact:	Mr. Richard Blubaugh, Vice President

OMB No. 2040-0042 Approval Expires 12/31/2011

EPA

United States Environmental Protection Agency

Underground Injection Control
Permit Application

(Collected under the authority of the Safe Drinking Water Act. Sections 1421, 1422, 40 CFR 144)

I. EPA ID Number

	T/A	C
U		

Read Attached Instructions Before Starting

For Official Use Only

Application approved (mo day year)	Date received (mo day year)	Permit Number	Well ID	FINDS Number

II. Owner Name and Address

Owner Name			
Powertech (USA) Inc.			
Street Address: 5575 DTC Parkway, Suite 140		Phone Number: (303) 790-7528	
City: Greenwood Village	State: CO	ZIP CODE: 80111	

III. Operator Name and Address

Owner Name			
Powertech (USA) Inc.			
Street Address: 5575 DTC Parkway, Suite 140		Phone Number: (303) 790-7528	
City: Greenwood Village	State: CO	ZIP CODE: 80111	

IV. Commercial Facility

- [ ] Yes
- [x] No

V. Ownership

- [x] Private
- [ ] Federal
- [ ] Other

VI. Legal Contact

- [x] Owner
- [ ] Operator

VII. SIC Codes

SIC: 1094
NAISC: 212291

VIII. Well Status *(Mark "x")*

- [ ] A. Operating — Date Started: mo day year
- [ ] B. Modification/Conversion
- [x] C. Proposed

IX. Type of Permit Requested *(Mark "x" and specify if required)*

A. Individual	B. Area	Number of Existing Wells	Number of Proposed Wells	Name(s) of field(s) or project(s)
[ ]	[x]	0	4 - 8	Dewey-Burdock

X. Class and Type of Well *(see reverse)*

A. Class(es) (enter code(s))	B. Type(s) (enter code(s))	C. If class is "other" or type is code 'x,' explain	D. Number of wells per type (if area permit)
Other	N/A	Class V, permitted under 40 CFR 144.12	4 - 8

XI. Location of Well(s) or Approximate Center of Field or Project

Latitude Deg	Latitude Min	Latitude Sec	Longitude Deg	Longitude Min	Longitude Sec	Sec	Twp	Range	1/4 Sec	Feet From	Line	Feet From	Line
103	59	43	43	28	55	34	6S	1E	SW	93.0	W	1403	S

XII. Indian Lands (Mark 'x')

- [ ] Yes
- [x] No

XIII. Attachments

(Complete the following questions on a separate sheet(s) and number accordingly; see instructions)

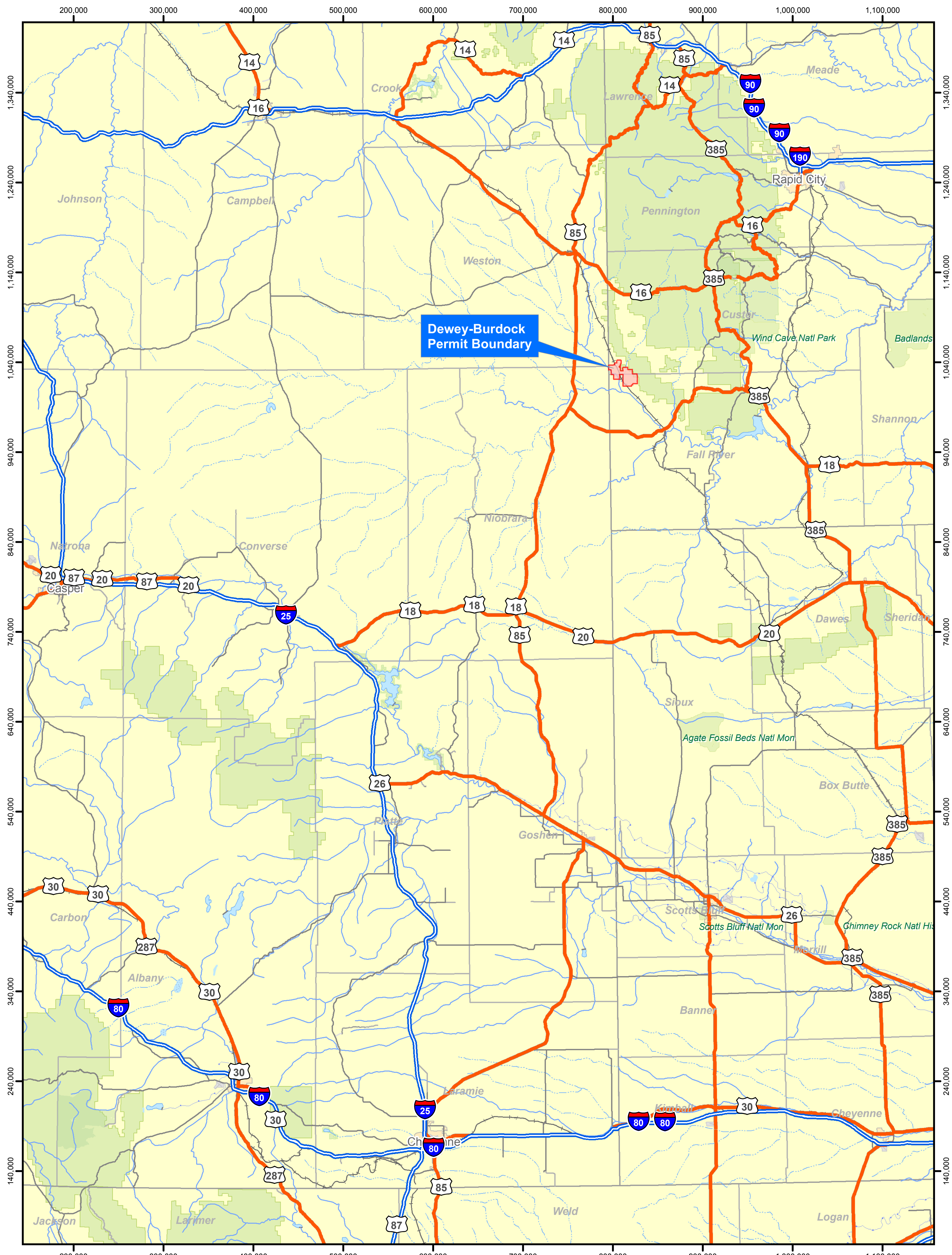
For Classes I, II, III, (and other classes) complete and submit on a separate sheet(s) Attachments A--U (pp 2-6) as appropriate. Attach maps where required. List attachments by letter which are applicable and are included with your application.

XIV. Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possiblity of fine and imprisonment. (Ref. 40 CFR 144.32)

A. Name and Title *(Type or Print)*	B. Phone No. *(Area Code and No.)*
Richard Blubaugh, Vice President - Environmental	(303) 790-7528
C. Signature	D. Date Signed

EPA Form 7520-6 (Rev. 12-08)



Legend

Dewey-Burdock Permit Boundary

N

Miles
0 10 20 30 40

POWERTECH (USA) INC.

Figure 1
Site Location Map
2010 Dewey-Burdock Class V Permit

Scale: 1:1,250,000	Date: March 2010
2010_DB_Class_V_Fig_01.mxd	By: JLM / Checked: HD

Petrotek
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2.0 USEPA FORM 7520-6 PERMIT APPLICATION ATTACHMENTS

2.A AREA OF REVIEW METHODS

Give the methods and, if appropriate, the calculations used to determine the size of the area of review (fixed radius or equation). The area of review shall be a fixed radius of ¼-mile from the well bore unless the use of an equation is approved in advance by the Director.

RESPONSE

In the meeting held on November 24, 2009, EPA Region 8 instructed Powertech to generally follow Class I standards and approach for this application. As such, the radius of investigation used in this permit request has been based on standard practices applied historically to Class I wells in Region 8. Under Section 146.6 of the UIC regulations (40CFR), the area of review (AOR) for a non-hazardous Class I injection well is defined as either the calculated zone of endangering influence or a fixed radius of not less than one-fourth mile.

The South Dakota Department of Environment and Natural Resources (DENR) has guidance for Class V wells but does not require separate state approval for Class V well installation. The guidelines for Class V wells are outlined in a letter received from DENR which is included as Appendix A.

The critical pressure rise, cone-of-influence (COI), radius of fluid displacement (ROFD) calculations for this permit application are based on the formation parameters derived from the correlation of three separate type logs. The location of these wells is shown on Figure A-1. Type Log #1 (Figure A-2) is from the Earl Darrow #1 (T7S, R1E, Sec 2) which penetrates the top of the Minnelusa and is located within the Dewey-Burdock Project boundary near the well locations of DW Nos. 1 and 2. Type Log #2 (Figure A-3) is from the Lance-Nelson Estate #1 (T7S, R1E, Sec 21) which penetrates the top of the Madison and is located just south of the project boundary. Type Log #3 (Figure A-4), from the #1 West Mule Creek (T39, R61W, Sec 2), penetrates to the top of the Precambrian and is located in eastern Wyoming to the southwest of the Project. This is the closest log available that penetrates the Deadwood Formation. Additionally, tops for shallow formations from the logs of various uranium exploration wells within the Project boundary were used in conjunction with the type logs to determine surface elevation and formation depths at each well site.

DW Nos. 1 and 2 target the Minnelusa and Deadwood Formations, respectively, and are located near the main plant site (Site 1). DW Nos. 3 and 4 target the Minnelusa and Deadwood, respectively, and will be located at Site 2. While formation parameters are expected to be similar at each site, formations are expected to occur at greater depth at Site 2 due to geologic structure. Separate critical pressure rise and COI calculations for the Minnelusa and Deadwood at each site are included in this application and are presented in Tables A-1 through A-4. In addition, ROFD calculations for the Minnelusa and Deadwood are presented in Tables A-5 and A-6, respectively.

Because the calculated ROFD and COI are significantly smaller than the statutory minimum, a fixed radius of 1,320' (¼ mile) has been used for evaluation of all artificial penetrations for Class V injection into the Minnelusa Formation for DW Nos. 1 and 3. Based on COI calculations, a radius of 1,355' has been used for evaluation of all artificial penetrations for Class V injection into the Deadwood Formation for DW Nos. 2 and 4. The Class V permit area has been conservatively defined by applying the maximum calculated AOR of 1,355' as an offset from the Dewey-Burdock Project boundary and the oil and gas wells permitted within that boundary.

In the event that additional disposal wells are required to inject the requested 300 gpm, similar AORs are expected for subsequent Dewey-Burdock Disposal Wells located within the proposed Class V permit area. The input parameters used to calculate the AORs are based on formation parameters derived from limited data and will be verified during the drilling, testing, and completion process. If the input parameters that have been used are found to yield projections that are insufficiently conservative, the AORs will be recalculated.

The COI for injection is defined as that area around a well within which increased injection zone pressures caused by injection could be sufficient to drive fluids into an underground source of drinking water (USDW). The pathway for this theoretical fluid movement is assumed to be a hypothetical, open abandoned well, which penetrates the confining zone for injection. Information used in the following calculations has been estimated from available geophysical well logs and will be verified through formation testing during the drilling process.

Critical Pressure Rise

For this permit application, three critical pressure rise calculations are required at each site. One is applied for the rise from the Minnelusa to the Unkpapa/Sundance, one for the rise from the Minnelusa to the Madison, and one for the rise from the Deadwood to the Madison.

To calculate the COI, a value must first be assigned for the pressure increase in the injection interval that would be sufficient to cause injection zone brine to rise in a hypothetical open pathway to the base of the lowermost USDW. This applies individually to the rise from the Minnelusa (injection zone) to the Unkpapa/Sundance (USDW) and for rise from the Deadwood (injection zone) to the Madison (USDW). The COI will also be applied to the transfer of injection zone brine from the base of the effective Minnelusa in a hypothetical open pathway down to the top of the Madison Formation. This critical pressure rise, Pc, is assigned as indicated in Figure A-5.

The pressure required at the top of the injection interval to support injection zone brine in the configuration indicated is, in psi units:

$$P = 0.433\ [y_B D_B + y_w(D_w - L)]$$

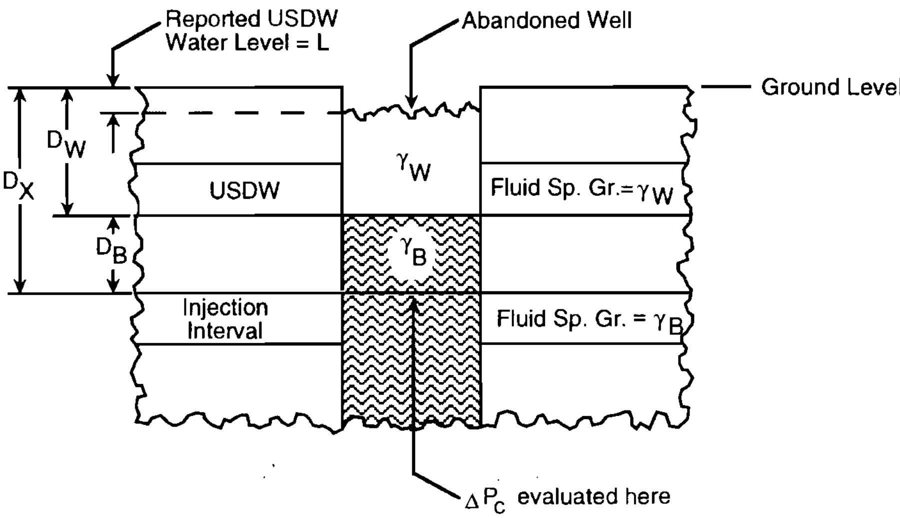
where: $D_B = D_x - D_w$

and the pressure rise is then:

$$Pc = 0.433\ [y_B D_B + y_w(D_w - L)] - Po$$

where Po is the original, pre-injection value for pressure at the top of the injection interval expressed in psi units.

FIGURE A-5 CRITICAL PRESSURE RISE



MINNELUSA TO UNKPAPA/SUNDANCE AND MINNELUSA TO MADISON FOR DW NO. 1 – SITE 1

Minnelusa – Unkpapa/Sundance

Original pressure in the Minnelusa has been calculated based on a depth to water of 1,415' above top of the Minnelusa from USGS potentiometric maps (Figure D-14, Driscoll et al., 2002). For the estimated top of the injection interval of 1,615' (See Response F, Table F-2), a gradient of 0.433 psi/ft * 1.008 (SG of approximately 15,000 mg/l TDS brine) yields a pressure of 617.6 psi at the top of the Minnelusa (1,615'). The same gradient applied to the effective base of the Injection Zone at 2,205 yields a pressure 875.1 psi. The effective base refers to the lowermost zone of effective porosity in the Minnelusa that will be targeted for injection in DW No. 1 as discussed in Section 2.F of this document.

In assigning the critical pressure rise and calculating the cone-of-influence (Tables A-1 and A-3) at this site, the base of the overlying USDW, the Unkpapa/Sundance, is assigned as 920', as discussed in Response 2.D of this document. The potentiometric surface of Unkpapa/Sundance near the Dewey-Burdock Project is projected to be approximately 29 feet above ground surface (Figure D-14a, Powertech 2008). Therefore, in these calculations, it is assumed that the water table in the Unkpapa/Sundance is at approximately 589 feet above the top of the formation. The result is a calculated critical pressure rise for Minnelusa to Unkpapa/Sundance of 97.1 psi (Table A-1).

The values in Table A-1 were used in the pressure rise equation to compute the critical pressure rise for Minnelusa to Unkpapa/Sundance as follows:

$$Pc = 0.433[1.008(1{,}615-920) + 1.001(920-(-29))] - 617.6 \text{ psi}$$

or:

$$Pc = 97.1 \text{ psi}$$

Minnelusa - Madison

The top of the underlying USDW is the Madison Formation at 2,765' as discussed in Response 2.D of this document. Original pressure in the Madison has been calculated based on an artesian aquifer condition with a water level of approximately 200' above ground surface. This head is based on historical water well data for the City of Edgemont water wells completed in the Madison Formation (Appendix D). Based on an estimated shut-in pressure of 150 psi and a minimum surface elevation of 3,450', the potentiometric surface of the Madison at Edgemont is 3,745' (345' above ground surface). It is noted that surface elevation at Edgemont wells may be as high as 3,650'. Given the elevation increase of approximately 100' to 300' from Edgemont to the Dewey-Burdock Project, it is reasonable to assume a potentiometric level of approximately 3,900' AMSL (~200' above ground surface) at Dewey-Burdock. USGS potentiometric maps for this formation are regional and based on little (if any) local data (Figure D-10, Driscoll et al., 2002). The result is a calculated critical pressure rise for the Minnelusa to Madison of 165.6 psi (Table A-1). It is noted that formation parameters have been estimated from available data and will be verified through formation testing during the drilling process.

The values in Table A-1 were used in the pressure rise equation to compute the critical pressure rise for Minnelusa to top of Madison as follows:

$$Pc = 0.433[1.008(2{,}205-2{,}765) + 1.001(2{,}765-(-200))] - 875.1 \text{ psi}$$

or:

$$Pc = 165.6 \text{ psi}$$

Cone-of-Influence

Based on the calculated value for the critical pressure rise, the cone-of-influence can be calculated for DW No.1 over a ten-year period of injection. At DW No. 1 there is projected to be a 13.2' cone-of-influence for continuous injection at a rate of 75 gpm (2,571 bwpd) in the Minnelusa Formation (Table A-2). This is the value at which pressure at distance intersects the critical pressure rise of 97.1 psi from the Minnelusa to the Unkpapa/Sundance (Figure A-6). Since the critical pressure rise for the Minnelusa to the over-pressured Madison is never intersected, even at the well bore, there is no COI and no potential exists for contamination of the Madison. As such, the fixed radius of 1,320' (¼ mile) will be used for the Minnelusa Formation at Site 1. Pressure rise has been evaluated in an infinite acting reservoir with a line source well using the log-approximation of the radial flow diffusivity equation (Lee, 1982).

$$dP = -70.6\, Bq\mu / kh * \ln ([1{,}688\, \phi\, \mu c_t r^2 / kt] - 2s)$$

where the values listed in Table A-3 have been assigned based on site-specific information.

Calculations for pressure rise due to ten years of injection have been based on a rate of 75 gpm. Well capacities will be verified during the drilling, testing, and completion process.

MINNELUSA TO UNKPAPA/SUNDANCE AND MINNELUSA TO MADISON FOR DW NO. 3 – SITE 2

Minnelusa – Unkpapa/Sundance

Original pressure in the Minnelusa has been calculated based on a depth to water of 1,750' above the top of the Minnelusa from USGS potentiometric maps (Figure D-14, Driscoll et al., 2002). For the estimated top of the injection interval of 1,950' (See Response F, Table F-2), a gradient of 0.433

psi/ft * 1.008 (SG of approximately 15,000 mg/l TDS brine) yields a pressure of 763.8 psi at the top of the Minnelusa. The same gradient applied to the effective base of the Injection Zone at 2,540 yields a pressure 1,021.3 psi. (Table A-2).The effective base refers to the lowermost porous zone that will be targeted for injection as discussed in Section 2.F of this document.

In assigning the critical pressure rise and calculating the cone-of-influence (Tables A-2 and A-3) at this site, the base of the overlying USDW, the Unkpapa/Sundance, is assigned as 1,255', as discussed in Response 2.D of this document. The lowest potentiometric surface near the Dewey-Burdock Project is projected to be approximately 29 feet above ground surface (Figure D-14a, Powertech 2008). Therefore, in these calculations, it is assumed that the water table in the Unkpapa/Sundance is at approximately 924' above the top of the formation. The result is a calculated critical pressure rise for Minnelusa to Unkpapa/Sundance of 96.1 psi (Table A-2).

The values in Table A-2 were used in the pressure rise equation to compute the critical pressure rise for Minnelusa to Unkpapa/Sundance as follows:

$$Pc = 0.433[1.008(1{,}950-1{,}255) + 1.001(1{,}255-(-29))] - 763.8 \text{ psi}$$

or:

$$Pc = 96.1 \text{ psi}$$

Minnelusa - Madison

The top of the underlying USDW is the Madison Formation at 3,100' as discussed in Response 2.D of this document. Original pressure in the Madison has been calculated based on an artesian aquifer condition with a water level of approximately 200' above ground surface. This head is based on historical water well data for the City of Edgemont water wells completed in the Madison Formation (Appendix D). Based on an estimated shut-in pressure of 150 psi and a minimum surface elevation of 3,450', the potentiometric surface of the Madison at Edgemont is 3,745' (345' above ground surface). It is noted that surface elevation at Edgemont wells may be as high as 3,650'. Given the elevation increase of approximately 100' to 300' from Edgemont to the Dewey-Burdock Project, it is reasonable to assume a potentiometric level of approximately 3,900' AMSL (~200' above ground surface) at Dewey-Burdock. USGS potentiometric maps for this formation are regional and based on little (if any) local data (Figure D-10, Driscoll et al., 2002). The result is a calculated critical pressure rise for the Minnelusa to Madison of 164.6 psi (Table A-2). It is noted that formation parameters have been estimated from available data and will be verified through formation testing during the drilling process.

The values in Table A-2 were used in the pressure rise equation to compute the critical pressure rise for Minnelusa to Madison as follows:

$$Pc = 0.433[1.008(2{,}540-3{,}100) + 1.001(3{,}100-(-200))] - 1{,}021.3 \text{ psi}$$

or:

$$Pc = 164.6 \text{ psi}$$

Cone-of-Influence

Based on the calculated value for the critical pressure rise, the cone-of-influence can be calculated for DW No. 3 over a ten-year period of injection. At DW No. 3, there is projected to be a 14.4' cone-of-influence for continuous injection at a rate of 75 gpm (2,571 bwpd) in the Minnelusa Formation (Table A-3). This is the value at which pressure at distance intersects the critical pressure rise of 96.1 psi from the Minnelusa to the Unkpapa/Sundance (Figure A-6). Since the critical pressure rise for the Minnelusa to the over-pressured Madison is never intersected, even at the well bore, there is no COI and no potential exists for contamination of the Madison. As such, the fixed radius of 1,320' (1/4 mile) will be used. Pressure rise has been evaluated in an infinite acting reservoir with a line source well using the log-approximation of the radial flow diffusivity equation (Lee, 1982).

$$dP = -70.6\ Bq\mu\ /kh * \ln\left(\left[\ 1{,}688\ \phi\ \mu c_t r^2\ /kt\ \right] - 2s\right)$$

where the values listed in Table A-3 have been assigned based on site-specific information.

Calculations for pressure rise due to ten years of injection have been based on a rate of 75 gpm. Well capacities will be verified during the drilling, testing, and completion process.

DEADWOOD TO MADISON FOR DW NO. 2 – SITE 1

Original pressure in the Deadwood has been calculated based on an estimated formation fluid level of 2,900' above the top of the Deadwood. For the estimated top of the injection interval of 3,100' (See Response F, Table F-2), a gradient of 0.433 psi/ft * 1.008 (SG of 15,000 mg/l TDS brine) yields a pressure of 1,265.7 psi at the top of the Deadwood.

In assigning the critical pressure rise and calculating the cone-of-influence (Tables A-1 and A-4) at this site, the base of the overlying USDW, the Madison Formation, is assigned as 3,060', as discussed in Response 2.D of this document. Original pressure in the Madison has been calculated based on an artesian aquifer condition with a water level of approximately 200' above ground surface. This head is based on historical water well data for the City of Edgemont water wells completed in the Madison Formation (Appendix D). Based on an estimated shut-in pressure of 150 psi and a minimum surface elevation of 3,450', the potentiometric surface of the Madison at Edgemont is 3,745' (345' above ground surface). It is noted that surface elevation at Edgemont wells may be as high as 3,650'. Given the elevation increase of approximately 100' to 300' from Edgemont to the Dewey-Burdock Project, it is reasonable to assume a potentiometric level of approximately 3,900' AMSL (~200' above ground surface) at Dewey-Burdock. USGS potentiometric maps for this formation are regional and based on little (if any) local data (Figure D-10, Driscoll et al., 2002). The result is a calculated critical pressure rise for the Minnelusa to Madison of 164.7 psi (Table A-1). It is noted that formation parameters have been estimated from available data and will be verified through formation testing during the drilling process.

The values in Table A-1 were used in the pressure rise equation to compute the critical pressure rise for Deadwood to Madison as follows:

$$Pc = 0.433[1.008(3{,}100-3{,}060) + 1.001(3{,}060-(-200))] - 1{,}265.7 \text{ psi}$$

or:

$$Pc = 164.7 \text{ psi}$$

Cone-of-Influence

Based on the calculated value for the critical pressure rise, the cone-of-influence can be calculated for the DW No. 2 over a ten-year period of injection. At DW No. 2, there is projected to be a 1,210' cone-of-influence for continuous injection at a rate of 75 gpm (2,571 bwpd) in the Deadwood Formation (Table A-4). This is the value at which pressure at distance intersects the critical pressure rise of 164.7 psi from the Deadwood to the Madison (Figure A-7). Pressure rise has been evaluated in an infinite acting reservoir with a line source well using the log-approximation of the radial flow diffusivity equation (Lee, 1982).

$$dP = -70.6\ Bq\mu\ /kh * \ln\left(\left[\ 1{,}688\ \phi\ \mu c_t r^2\ /kt\ \right] - 2s\right)$$

where the values listed in Table A-4 have been assigned based on site-specific information.

Calculations for pressure rise due to ten years of injection have been based on a rate of 75 gpm. Well capacities will be verified during the drilling, testing, and completion process.

DEADWOOD TO MADISON FOR DW NO. 4 – SITE 2

Original pressure in the Deadwood has been calculated based on an estimated formation fluid level of 3,235' above the top of the Deadwood. For the estimated top of the injection interval of 3,435' (See Response F), a gradient of 0.433 psi/ft * 1.008 (SG of 15,000 mg/l TDS brine) yields a pressure of 1,412.0 psi at the top of the Deadwood.

In assigning the critical pressure rise and calculating the cone-of-influence (Tables A-2 and a-4) at this site, the base of the overlying USDW, the Madison Formation, is assigned as 3,395', as discussed in Response 2.D of this document. Original pressure in the Madison has been calculated based on an artesian aquifer condition with a water level of approximately 200' above ground surface. This head is based on historical water well data for the City of Edgemont water wells completed in the Madison Formation (Appendix D). Based on an estimated shut-in pressure of 150 psi and a minimum surface elevation of 3,450', the potentiometric surface of the Madison at Edgemont is 3,745' (345' above ground surface). It is noted that surface elevation at Edgemont wells may be as high as 3,650'. Given the elevation increase of approximately 100' to 300' from Edgemont to the Dewey-Burdock Project, it is reasonable to assume a potentiometric level of approximately 3,900' AMSL (~200' above ground surface) at Dewey-Burdock. USGS potentiometric maps for this formation are regional and based on little (if any) local data (Figure D-10, Driscoll et al., 2002). The result is a calculated critical pressure rise for the Minnelusa to Madison of 163.7 psi (Table A-2). It is noted that formation parameters have been estimated from available data and will be verified through formation testing during the drilling process.

The values in Table A-2 were used in the pressure rise equation to compute the critical pressure rise for Deadwood to Madison as follows:

$$Pc = 0.433[1.008(3,435-3,395) + 1.001(3,395-(-200))] - 1,412.0 \text{ psi}$$

or:

$$Pc = 163.7 \text{ psi}$$

Cone-of-Influence

Based on the calculated value for the critical pressure rise, the cone-of-influence can be calculated for the DW No. 2 over a ten-year period of injection. At DW No. 4, there is projected to be a 1,242' cone-of-influence for continuous injection at a rate of 75 gpm (2,571 bwpd) in the Deadwood Formation (Table A-4). This is the value at which pressure at distance intersects the critical pressure rise of 163.7 psi from the Deadwood to the Madison (Figure A-7). Pressure rise has been evaluated in an infinite acting reservoir with a line source well using the log-approximation of the radial flow diffusivity equation (Lee, 1982).

$$dP = -70.6\ Bq\mu /kh * \ln ([1,688\ \phi\ \mu c_t r^2 /kt] -2s)$$

where the values listed in Table A-4 have been assigned based on site-specific information.

Calculations for pressure rise due to ten years of injection have been based on a rate of 75 gpm. Well capacities will be verified during the drilling, testing, and completion process.

Radius of Fluid Displacement

Minnelusa

The same formation parameters for each formation that were used in the COI calculations were used to calculate the ROFD. Using a porosity of 21% and an effective thickness of 164', the calculated ROFD is 698' after 10 years of constant rate injection at 75 gpm. The effect of an estimated hydraulic gradient of 10 ft/mile alters the maximum ROFD by 8.12' which yields a total calculated ROFD of approximately 706' (Table A-5). The ROFD in the Minnelusa is presented on Figure B-2.

Deadwood

Using a porosity of 11% and an effective thickness of 85', the calculated ROFD is 1,339' after 10 years of constant rate injection at 75 gpm. The effect of an estimated hydraulic gradient of 10 ft/mile alters the maximum ROFD by 15.50' which yields a total calculated ROFD of approximately 1,355' (Table A-6). The ROFD in the Deadwood is presented on Figure B-2a.

Final AORs

The calculated COIs for DW Nos. 1, 2, 3, and 4 are 13.2', 1,210', 14.4', and 1,242', respectively. The distances for DW Nos. 1 and 3 are less than the calculated ROFDs for the Minnelusa (706') and less than a fixed radius of ¼ mile or 1,320'. As such, a radius of 1,320' has been used for evaluation of all artificial penetrations for Class V injection into the Minnelusa Formation for DW No. 1 and DW No. 3 (Figure B-2).

The calculated COIs for DW Nos. 2 and 4 are less than the calculated ROFDs for the Deadwood (1,355') and greater than a fixed radius of ¼ mile or 1,320'. As such, a radius of 1,355' has been used for DW No. 2 and DW No. 4 for evaluation of all artificial penetrations for Class V injection into the Deadwood Formation (Figure B-2a). Figure B-2b presents the final AORs of the four planned wells relative to the Class V permit area and oil and gas wells near the project. The Class V permit area is defined conservatively by applying the maximum calculated AOR of 1,355' as an offset from the Dewey-Burdock Project boundary and the oil and gas wells permitted within that boundary.

The input parameters used to calculate the AORs are based on formation parameters derived from limited data and will be verified during the drilling, testing, and completion process. If the input parameters that have been used are found to yield projections that are insufficiently conservative, the AORs will be recalculated.

Pressure Rise at the Dewey Fault

The Dewey Fault shown on Figure B-2b is located in excess of 4,000' to the northwest of the nearest corner of the proposed Class V permit area. While some authors have mapped it as dipping to the southeast, it is shown at the same location relative to the Dewey-Burdock Project at surface and at depth (Figures D-1, D-8, D-10, D-14, and D-15). As such, it is more likely a near vertical fault in proximity to the site. The pressure rise at a distance of 4,000' due to injection in the Minnelusa would be approximately 34 psi. This is less than the calculated critical pressure rise of 96.1 psi (Minnelusa to Unkpapa/Sundance) and 164.6 psi (Minnelusa to Madison). The pressure rise at a distance of 4,000' due to injection into the Deadwood would be approximately 119 psi. This is less than the calculated critical pressure rise of 163.7 psi necessary to transmit fluid from the Deadwood to the Madison along any hypothetical open pathway. It can thus be concluded that the Dewey Fault could not act as a conduit for fluid to rise to a USDW due to injection into the Minnelusa or

Deadwood in the vicinity of the proposed Class V permit area.

TABLE A-1 Critical Pressure Rise - Site 1

Pc=0.433(YbDb+Yw(Dw-L))-Po				Inj. Zone DTW (ft;bgs)	Yb (Inj. Z)	Confining Zone Db (feet; bgs)	SG of USDW Yw (USDW)	Top Inj. Zone Dx (feet; bgs)	Base/Top Inj. Zone Dw (feet; bgs)	USDW DTW L (feet; bgs)	Inj. Zone Po (psi)
Minnelusa to Unkpapa/Sundance				200	1.008	695	1.001	1615	920	-29	617.6
Pc =	97.1	psi									
Minnelusa to Madison				200	1.008	-560	1.001	2205	2765	-200	875.1
Pc =	165.6	psi									
Deadwood to Madison				200	1.008	40	1.001	3100	3060	-200	1,265.7
Pc =	164.7	psi									

Po calculated based on a depth to water of 1,400' above top of Minnelusa; fluid gradient of Minnelusa and Deadwood = 0.433 psi/ft x 1.008 (SG)

TABLE A-2 Critical Pressure Rise - Site 2

Pc=0.433(YbDb+Yw(Dw-L))-Po			Inj. Zone DTW (ft;bgs)	Yb (Inj. Z)	Confining Zone Db (feet; bgs)	SG of USDW Yw (USDW)	Top Inj. Zone Dx (feet; bgs)	Base/Top Inj. Zone Dw (feet; bgs)	USDW DTW L (feet; bgs)	Inj. Zone Po (psi)
Minnelusa to Unkpapa/Sundance			200	1.008	695	1.001	1950	1255	-29	763.8
Pc =	96.1	psi								
Minnelusa to Madison			200	1.008	-560	1.001	2540	3100	-200	1,021.3
Pc =	164.6	psi								
Deadwood to Madison			200	1.008	40	1.001	3435	3395	-200	1,412.0
Pc =	163.7	psi								

Po calculated based on a depth to water of 1,400' above top of Minnelusa; fluid gradient of Minnelusa and Deadwood = 0.433 psi/ft x 1.008 (SG)

TABLE A-3 Calculated Pressure Rise vs. Distance (Diffusivity Equation) - Minnelusa Formation

Injection Rate (gpm) 75

Based on Equation 1.11 (Lee, 1982; P. 5)

dp = -70.6(qBu/kh)[ln(1,688.388*por*u*ct*rw^2/kt)-2s]

Where

dp =	pressure differential	Solve	psi
q =	flowrate (STB/d)	2,571.43	bbl/d
B =	formation volume factor (RB/STB)	1.01	RB/STB
u =	viscosity (cp)	0.74	cp
k =	permeability (md)	150	md
h =	reservior thickness (feet)	164	feet
por =	formation effective porosity (percent)	0.21	fraction
ct =	total matrix and fluid compressibility (1/psi)	6.50E-06	psi-1
rw =	radius (feet)	Variable	feet
t =	injection time (hours)	87660.0	hours = 10.00 years
s =	skin factor (units)	0.0	

Term 1 -70.6(qBu/kh)

Term 2 (por*u*ct*rw^2/kt)

Injection Rate (gpm) = 75

dp = Term 1 * ln(1688.388*Term 2)

	Radius (ft)	Term 1	Term 2	[ln (term 2) - 2s]	dp (psi)	
rw	0.26042	-5.51566	5.2098E-15	-25.45671	140.4	Minn-Madison NO COI At 165.6 (DW No. 1) or 164.6 (DW No. 3)
no skin	0.5	-5.51566	1.9205E-14	-24.15208	133.2	
	1	-5.51566	7.6820E-14	-22.76579	125.6	
	5	-5.51566	1.9205E-12	-19.54691	107.8	
	13.2	-5.51566	1.3385E-11	-17.60535	97.1	Minn-Unkpapa/Sundance Pc=97.1 psi (DW No. 1)
	14.4	-5.51566	1.5929E-11	-17.43133	96.1	Minn-Unkpapa/Sundance Pc=96.1 psi (DW No. 3)
	22.6	-5.51566	3.9236E-11	-16.52989	91.2	
	25	-5.51566	4.8012E-11	-16.32804	90.1	
	35	-5.51566	9.4104E-11	-15.65509	86.3	
	48.5	-5.51566	1.8070E-10	-15.00266	82.7	
	50.5	-5.51566	1.9591E-10	-14.92184	82.3	
	75	-5.51566	4.3211E-10	-14.13081	77.9	

TABLE A-3 Calculated Pressure Rise vs. Distance (Diffusivity Equation) - Minnelusa Formation

100	-5.51566	7.6820E-10	-13.55545	74.8
125	-5.51566	1.2003E-09	-13.10916	72.3
150	-5.51566	1.7284E-09	-12.74452	70.3
172	-5.51566	2.2726E-09	-12.47080	68.8
200	-5.51566	3.0728E-09	-12.16915	67.1
225	-5.51566	3.8890E-09	-11.93359	65.8
250	-5.51566	4.8012E-09	-11.72287	64.7
275	-5.51566	5.8095E-09	-11.53225	63.6
300	-5.51566	6.9138E-09	-11.35822	62.6
325	-5.51566	8.1141E-09	-11.19814	61.8
350	-5.51566	9.4104E-09	-11.04992	60.9
375	-5.51566	1.0803E-08	-10.91194	60.2
400	-5.51566	1.2291E-08	-10.78286	59.5
425	-5.51566	1.3876E-08	-10.66161	58.8
450	-5.51566	1.5556E-08	-10.54729	58.2
500	-5.51566	1.9205E-08	-10.33657	57.0
625	-5.51566	3.0008E-08	-9.89028	54.6
750	-5.51566	4.3211E-08	-9.52564	52.5
1000	-5.51566	7.6820E-08	-8.95028	49.4
1250	-5.51566	1.2003E-07	-8.50399	46.9
1500	-5.51566	1.7284E-07	-8.13935	44.9
1830	-5.51566	2.5726E-07	-7.74165	42.7
2020	-5.51566	3.1345E-07	-7.54408	41.6
2250	-5.51566	3.8890E-07	-7.32842	40.4
2400	-5.51566	4.4248E-07	-7.19934	39.7
3000	-5.51566	6.9138E-07	-6.75305	37.2
3500	-5.51566	9.4104E-07	-6.44475	35.5
4000	-5.51566	1.2291E-06	-6.17769	34.1
4500	-5.51566	1.5556E-06	-5.94212	32.8
5280	-5.51566	2.1416E-06	-5.62243	31.0
6000	-5.51566	2.7655E-06	-5.36676	29.6
6600	-5.51566	3.3463E-06	-5.17614	28.5
6700	-5.51566	3.4484E-06	-5.14606	28.4
6800	-5.51566	3.5521E-06	-5.11643	28.2
6900	-5.51566	3.6574E-06	-5.08723	28.1
7000	-5.51566	3.7642E-06	-5.05846	27.9
7100	-5.51566	3.8725E-06	-5.03009	27.7
7200	-5.51566	3.9823E-06	-5.00212	27.6
7300	-5.51566	4.0937E-06	-4.97453	27.4
7400	-5.51566	4.2066E-06	-4.94732	27.3
7500	-5.51566	4.3211E-06	-4.92047	27.1
7600	-5.51566	4.4371E-06	-4.89398	27.0
7700	-5.51566	4.5546E-06	-4.86784	26.8
7800	-5.51566	4.6737E-06	-4.84203	26.7
7900	-5.51566	4.7943E-06	-4.81655	26.6
8000	-5.51566	4.9164E-06	-4.79139	26.4

TABLE A-3 Calculated Pressure Rise vs. Distance (Diffusivity Equation) - Minnelusa Formation

8100	-5.51566	5.0401E-06	-4.76655	26.3
8200	-5.51566	5.1653E-06	-4.74201	26.2
8300	-5.51566	5.2921E-06	-4.71777	26.0
8400	-5.51566	5.4204E-06	-4.69381	25.9
8500	-5.51566	5.5502E-06	-4.67015	25.8
9000	-5.51566	6.2224E-06	-4.55583	25.1
10000	-5.51566	7.6820E-06	-4.34511	24.0
10560	-5.51566	8.5664E-06	-4.23613	23.4
11000	-5.51566	9.2952E-06	-4.15449	22.9

TABLE A-4 Calculated Pressure Rise vs. Distance (Diffusivity Equation) - Deadwood Formation

Injection Rate (gpm) 75

Based on Equation 1.11 (Lee, 1982; P. 5)

dp = -70.6(qBu/kh)[ln(1,688.388*por*u*ct*rw^2/kt)-2s]

Where

dp =	pressure differential	Solve	psi
q =	flowrate (STB/d)	2,571.43	bbl/d
B =	formation volume factor (RB/STB)	1.01	RB/STB
u =	viscosity (cp)	0.67	cp
k =	permeability (md)	75	md
h =	reservior thickness (feet)	85	feet
por =	formation effective porosity (percent)	0.11	fraction
ct =	total matrix and fluid compressibility (1/psi)	7.00E-06	psi-1
rw =	radius (feet)	Variable	feet
t =	injection time (hours)	87660.0	hours = 10.00 years
s =	skin factor (units)	0.0	

Term 1 -70.6(qBu/kh)

Term 2 (por*u*ct*rw^2/kt)

Injection Rate (gpm) 75

dp = Term 1 * ln(1688.388*Term 2)

	Radius (ft)	Term 1	Term 2	[ln (term 2) - 2s]	dp (psi)
rw	0.26042	-19.27060	5.3217E-15	-25.43545	490.2
no skin	0.5	-19.27060	1.9617E-14	-24.13083	465.0
	1	-19.27060	7.8470E-14	-22.74453	438.3
	5	-19.27060	1.9617E-12	-19.52566	376.3
	10	-19.27060	7.8470E-12	-18.13936	349.6
	15	-19.27060	1.7656E-11	-17.32843	333.9
	22.6	-19.27060	4.0079E-11	-16.50863	318.1
	25	-19.27060	4.9044E-11	-16.30678	314.2
	35	-19.27060	9.6126E-11	-15.63384	301.3

TABLE A-4 Calculated Pressure Rise vs. Distance (Diffusivity Equation) - Deadwood Formation

48.5	-19.27060	1.8458E-10	-14.98140	288.7	
50.5	-19.27060	2.0012E-10	-14.90059	287.1	
75	-19.27060	4.4139E-10	-14.10956	271.9	
100	-19.27060	7.8470E-10	-13.53419	260.8	
125	-19.27060	1.2261E-09	-13.08790	252.2	
150	-19.27060	1.7656E-09	-12.72326	245.2	
172	-19.27060	2.3215E-09	-12.44954	239.9	
200	-19.27060	3.1388E-09	-12.14790	234.1	
225	-19.27060	3.9725E-09	-11.91233	229.6	
250	-19.27060	4.9044E-09	-11.70161	225.5	
275	-19.27060	5.9343E-09	-11.51099	221.8	
300	-19.27060	7.0623E-09	-11.33697	218.5	
325	-19.27060	8.2884E-09	-11.17688	215.4	
350	-19.27060	9.6126E-09	-11.02867	212.5	
375	-19.27060	1.1035E-08	-10.89068	209.9	
400	-19.27060	1.2555E-08	-10.76160	207.4	
425	-19.27060	1.4174E-08	-10.64035	205.0	
450	-19.27060	1.5890E-08	-10.52604	202.8	
500	-19.27060	1.9617E-08	-10.31532	198.8	
625	-19.27060	3.0652E-08	-9.86903	190.2	
715	-19.27060	4.0116E-08	-9.59997	185.0	
1000	-19.27060	7.8470E-08	-8.92902	172.1	
1210	-19.27060	1.1489E-07	-8.54778	164.7	Deadwood-Madison Pc=164.7 psi at DW No. 2
1242	-19.27060	1.2104E-07	-8.49558	163.7	Deadwood-Madison Pc=163.7 psi at DW No. 4
1750	-19.27060	2.4031E-07	-7.80979	150.5	
2000	-19.27060	3.1388E-07	-7.54273	145.4	
2124	-19.27060	3.5401E-07	-7.42242	143.0	
2180	-19.27060	3.7292E-07	-7.37037	142.0	
3000	-19.27060	7.0623E-07	-6.73180	129.7	
3500	-19.27060	9.6126E-07	-6.42350	123.8	
4000	-19.27060	1.2555E-06	-6.15643	118.6	
4500	-19.27060	1.5890E-06	-5.92087	114.1	
5280	-19.27060	2.1876E-06	-5.60117	107.9	
6000	-19.27060	2.8249E-06	-5.34550	103.0	
6600	-19.27060	3.4181E-06	-5.15488	99.3	
6700	-19.27060	3.5225E-06	-5.12481	98.8	
6800	-19.27060	3.6284E-06	-5.09518	98.2	
6900	-19.27060	3.7359E-06	-5.06598	97.6	
7000	-19.27060	3.8450E-06	-5.03720	97.1	
7100	-19.27060	3.9557E-06	-5.00883	96.5	
7200	-19.27060	4.0679E-06	-4.98086	96.0	
7300	-19.27060	4.1817E-06	-4.95327	95.5	
7400	-19.27060	4.2970E-06	-4.92606	94.9	

TABLE A-4 Calculated Pressure Rise vs. Distance (Diffusivity Equation) - Deadwood Formation

7500	-19.27060	4.4139E-06	-4.89922	94.4
7600	-19.27060	4.5324E-06	-4.87273	93.9
7700	-19.27060	4.6525E-06	-4.84658	93.4
7800	-19.27060	4.7741E-06	-4.82077	92.9
7900	-19.27060	4.8973E-06	-4.79530	92.4
8000	-19.27060	5.0221E-06	-4.77014	91.9
8100	-19.27060	5.1484E-06	-4.74529	91.4
8200	-19.27060	5.2763E-06	-4.72075	91.0
8300	-19.27060	5.4058E-06	-4.69651	90.5
8400	-19.27060	5.5368E-06	-4.67256	90.0
8500	-19.27060	5.6694E-06	-4.64889	89.6
9000	-19.27060	6.3561E-06	-4.53457	87.4
10000	-19.27060	7.8470E-06	-4.32385	83.3
10560	-19.27060	8.7505E-06	-4.21488	81.2
11000	-19.27060	9.4949E-06	-4.13323	79.6

Table A-5 Radius of Fluid Displacement Calculation - Minnelusa Formation

Porosity = 0.21
Formation Thickness = 164 ft
Injection Rate = 75 gpm

r = radius of fluid displacement   Q = injection volume (ft^3)

r = (Q/((pi)*h*porosity))^0.5

Elapsed Time (yrs)	Qt (ft3)	r (ft)	r (miles)
1	5,270,055	221	0.04
5	26,350,275	493	0.09
10	52,700,550	698	0.13

EFFECT OF REGIONAL HYDRAULIC GRADIENT

ASSUME: Regional gradient = 0.0001 ft/ft (10 ft/mile)

Linear velocity (vl):
vl = (KI)/porosity where I = hydraulic gradient
K = 4.670 ft/d

Hyd. Gradient Displacement = (vl)*(time)

Elapsed Time (yrs)	Injection Displacement Ri (ft)	Hyd. Grad. Displ. Rg (ft)	Total Fluid Displacment Rt (ft)
1	221	0.81	221.51
5	493	4.06	497.56
10	698	8.12	706.03

NOTE: The additional displacement due to the regional hydraulic gradient is independent of injection rate.

Table A-6 Radius of Fluid Displacement Calculation - Deadwood Formation

Porosity = 0.11
Formation Thickness = 85 ft
Injection Rate = 75 gpm

r = radius of fluid displacement   Q = injection volume (ft^3)

r = (Q/((pi)*h*porosity))^0.5

Elapsed Time (yrs)	Qt (ft3)	r (ft)	r (miles)
1	5,270,055	424	0.08
5	26,350,275	947	0.18
10	52,700,550	1339	0.25

EFFECT OF REGIONAL HYDRAULIC GRADIENT

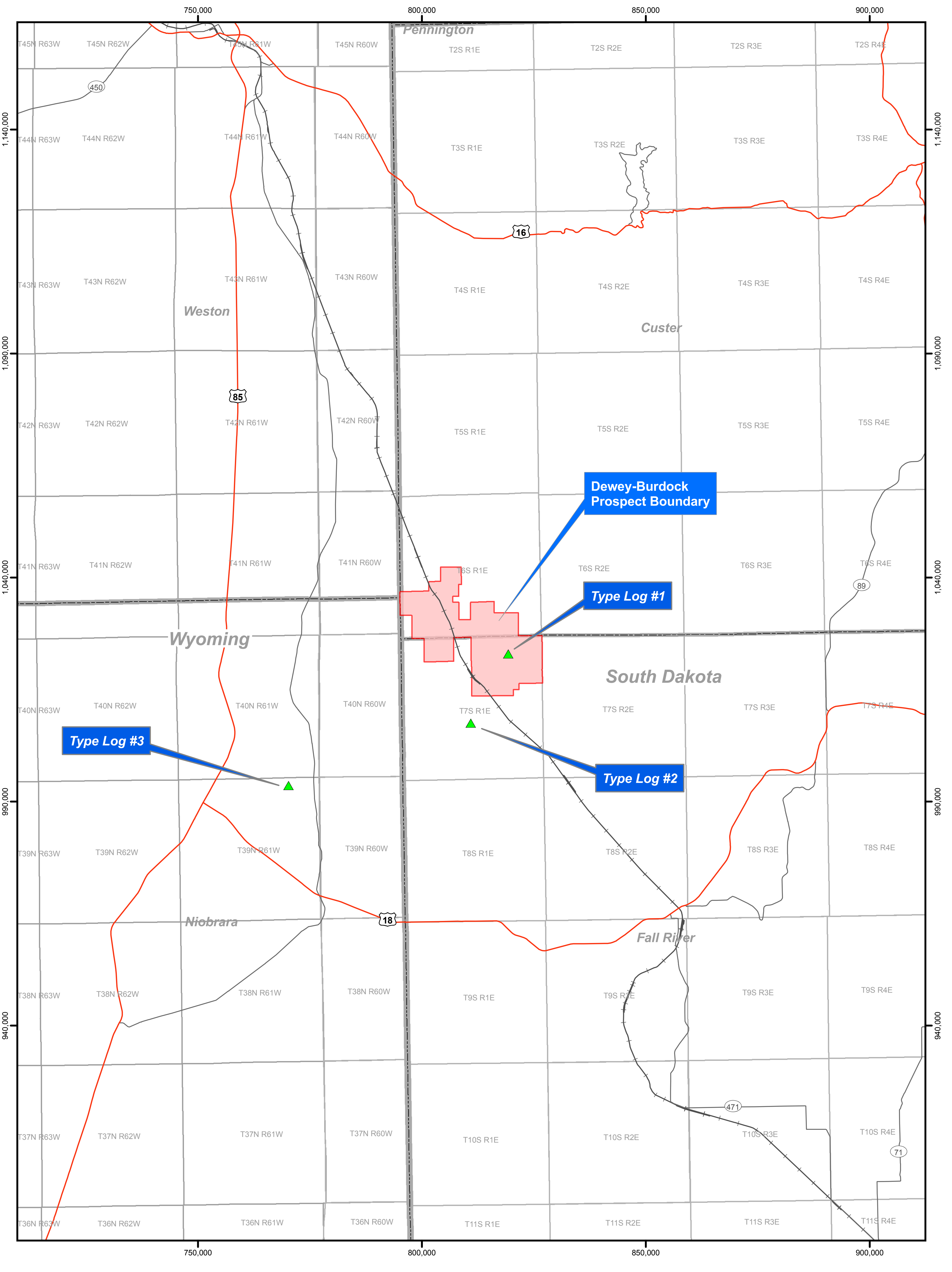
ASSUME: Regional gradient = 0.0001 ft/ft (10 ft/mile)

Linear velocity (vl):
vl = (KI)/porosity where I = hydraulic gradient
K = 4.670 ft/d

Hyd. Gradient Displacement = (vl)*(time)

Elapsed Time (yrs)	Injection Displacement Ri (ft)	Hyd. Grad. Displ. Rg (ft)	Total Fluid Displacment Rt (ft)
1	424	1.55	425.12
5	947	7.75	954.88
10	1339	15.50	1354.95

NOTE: The additional displacement due to the regional hydraulic gradient is independent of injection rate.



Legend

Dewey-Burdock Permit Boundary

Type Log Location

N

0 2 4 6 8 Miles

POWERTECH (USA) INC.

Figure A-1
Area of Interest
Showing Location of Type Logs
2010 Dewey-Burdock Class V Permit

Scale: 1:250,000	Date: March 2010
2010_DB_Class_V_Fig_A-01.mxd	By: JLM / Checked: HD

Petrotek
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Littleton, Colorado 80127-4239 USA
303-290-9414
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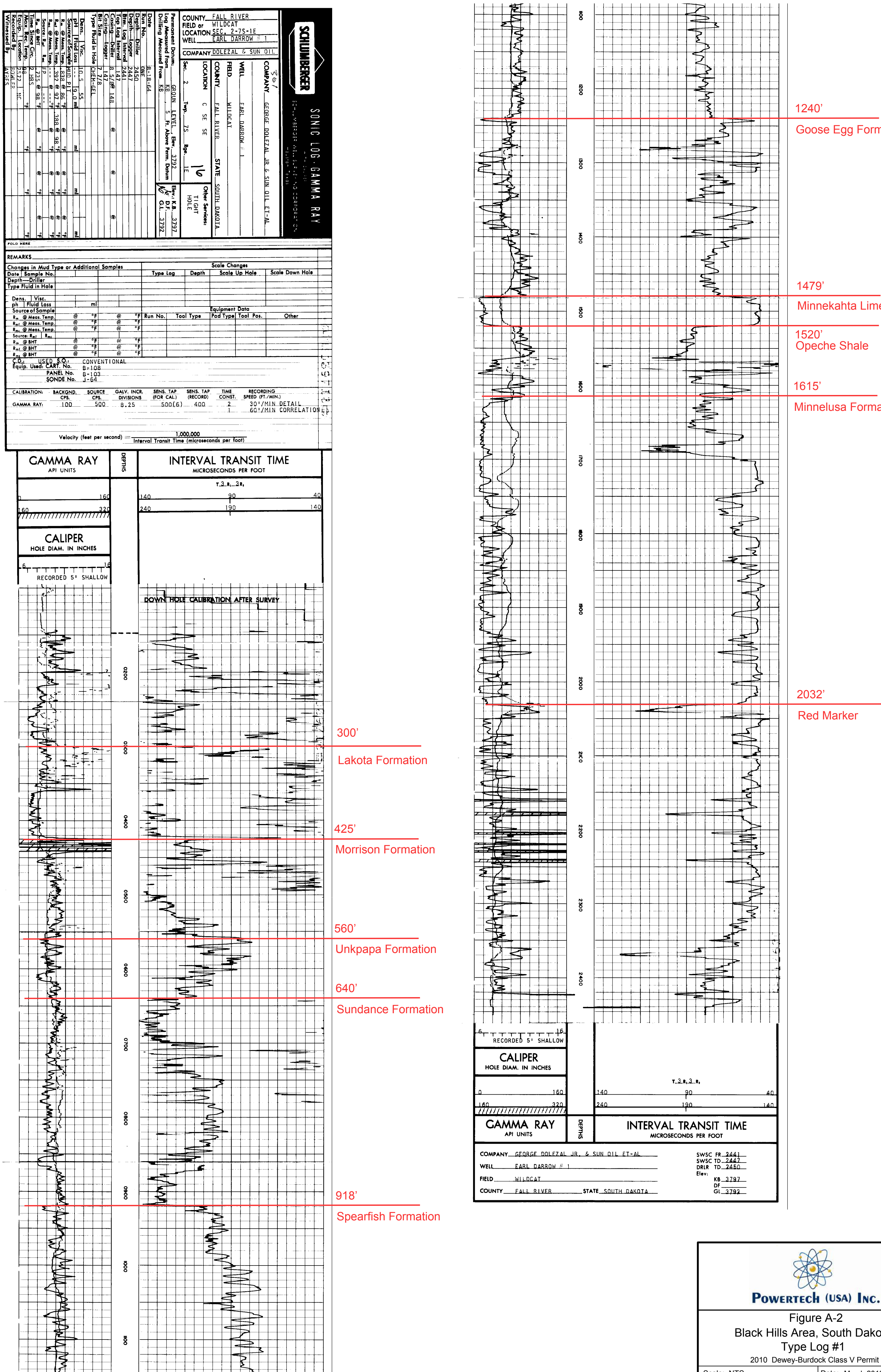

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Figure A-2
Black Hills Area, South Dakota
Type Log #1
2010 Dewey-Burdock Class V Permit

Scale: NTS	Date: March 2010
2010_DB_Class_V_Fig_A-02.ai	By: JLM / Checked: HD

Petrotek
10288 West Chatfield Ave., Suite 201
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303-290-9414
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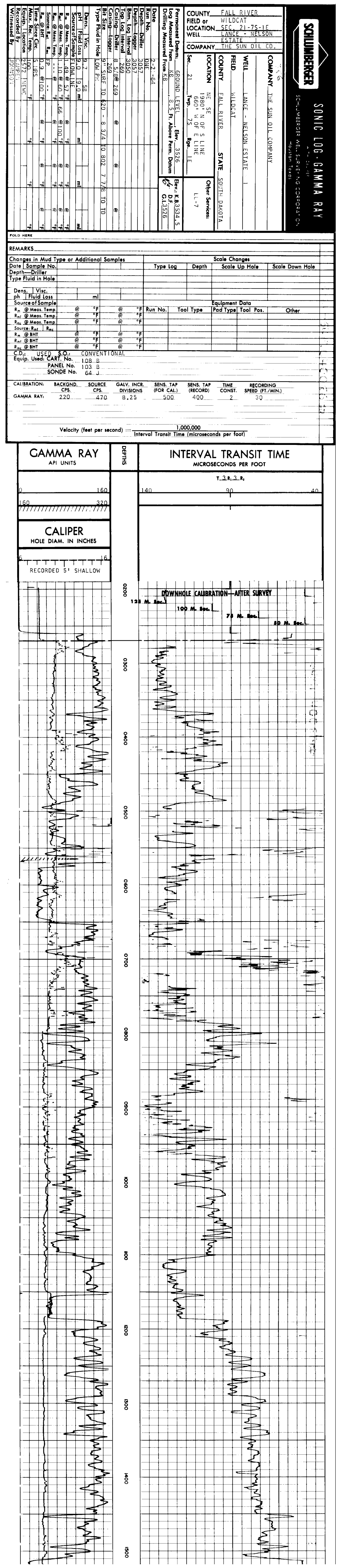

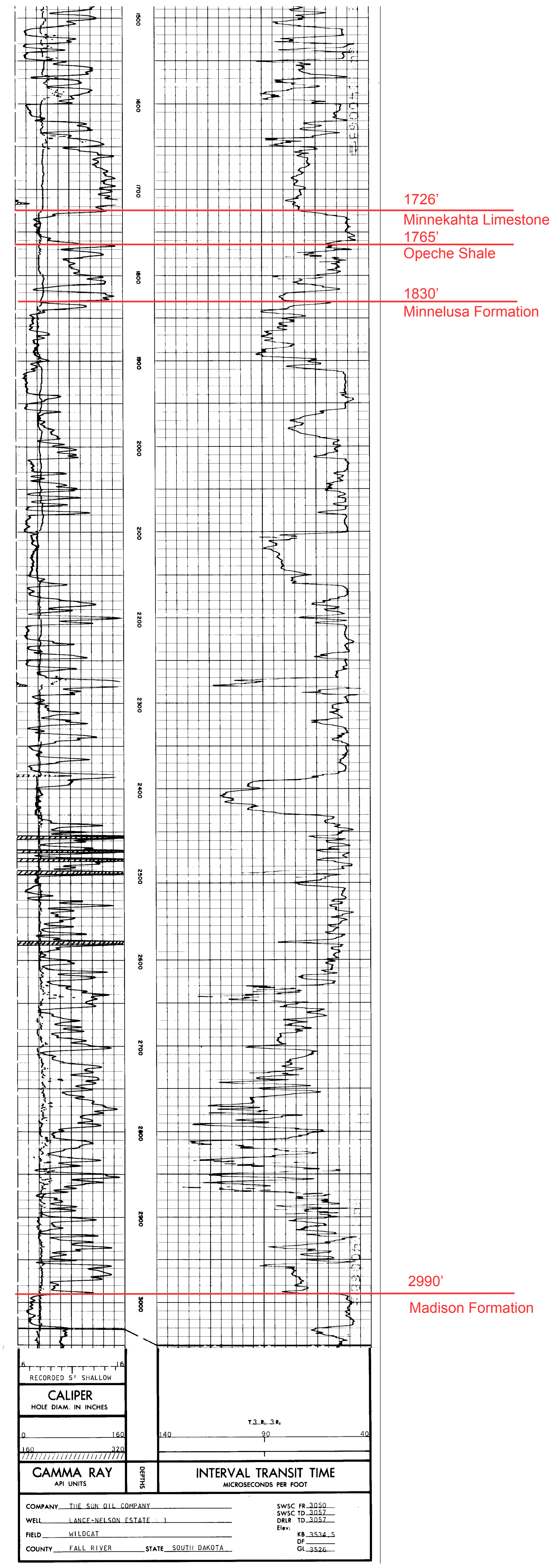

POWERTECH (USA) INC.

Figure A-3
Black Hills Area, South Dakota
Type Log #2
2010 Dewey-Burdock Class V Permit

Scale: NTS	Date: March 2010
2010_DB_Class_V_Fig_A-03.ai	By: JLM / Checked: HD

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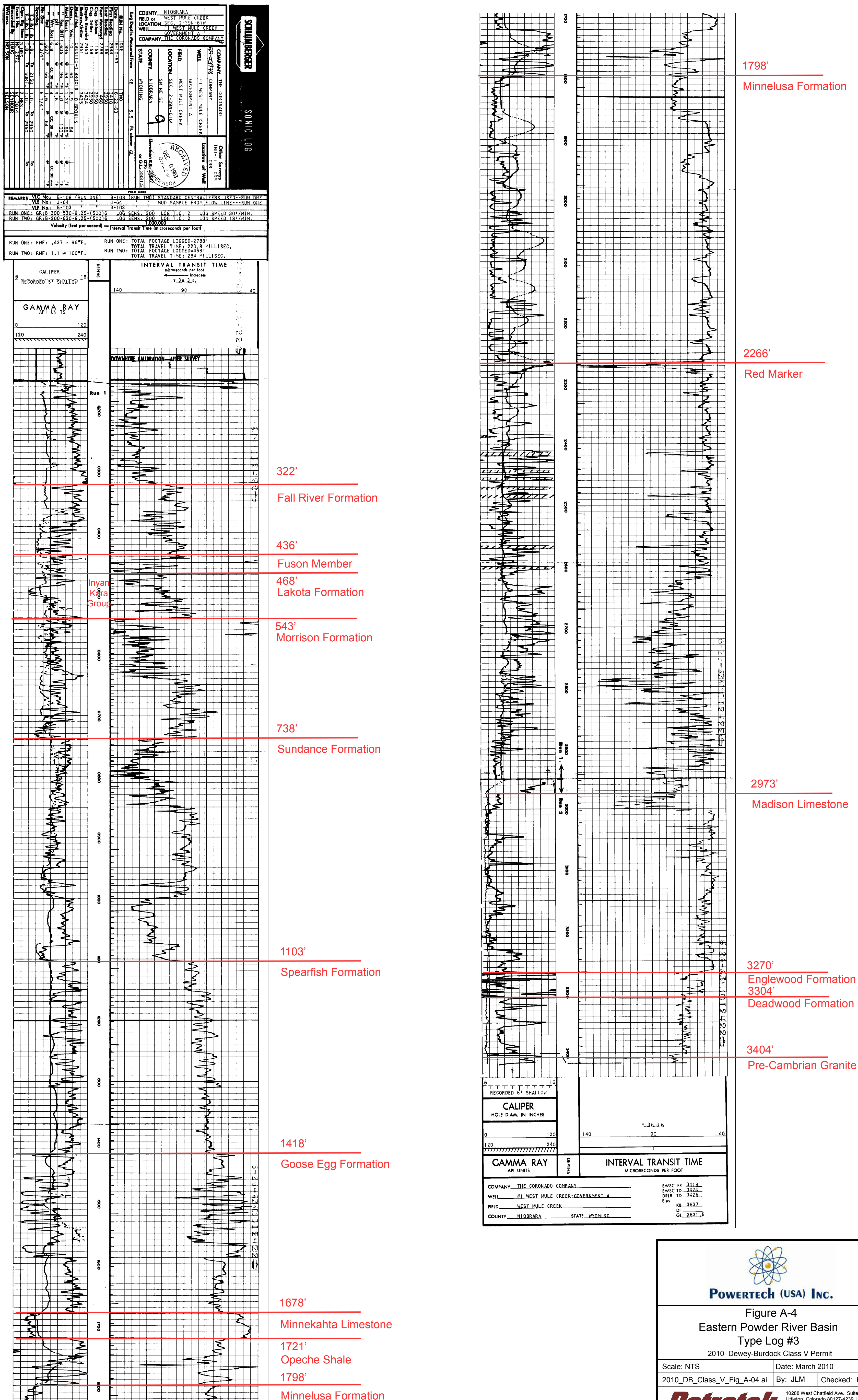

POWERTECH (USA) INC.

Figure A-4
Eastern Powder River Basin
Type Log #3
2010 Dewey-Burdock Class V Permit

Scale: NTS	Date: March 2010
2010_DB_Class_V_Fig_A-04.ai	By: JLM / Checked: HD

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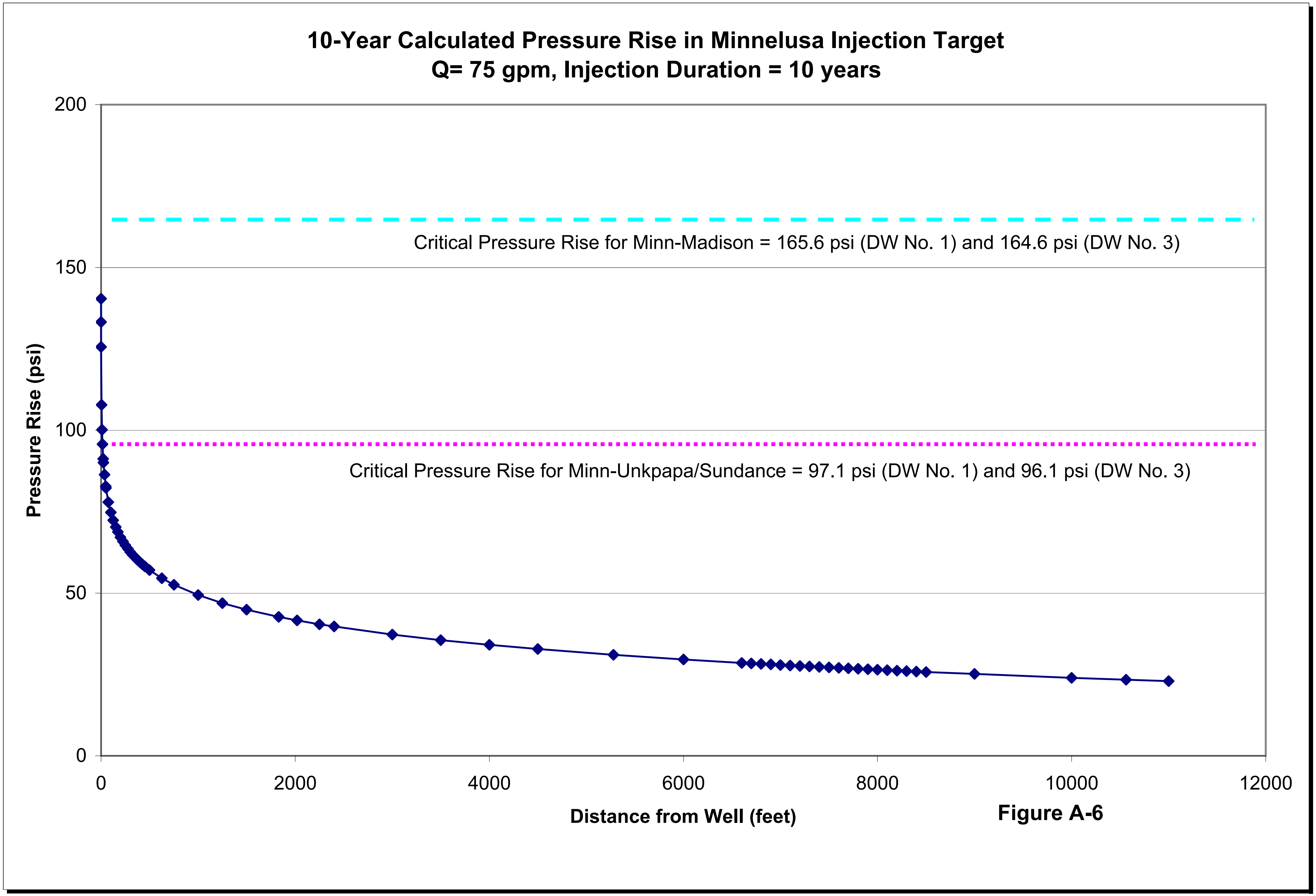

10-Year Calculated Pressure Rise in Minnelusa Injection Target
Q= 75 gpm, Injection Duration = 10 years
Pressure Rise (psi)
200
150
100
50
0
Critical Pressure Rise for Minn-Madison = 165.6 psi (DW No. 1) and 164.6 psi (DW No. 3)
Critical Pressure Rise for Minn-Unkpapa/Sundance = 97.1 psi (DW No. 1) and 96.1 psi (DW No. 3)
0
2000
4000
6000
8000
10000
12000
Distance from Well (feet)

Figure A-6

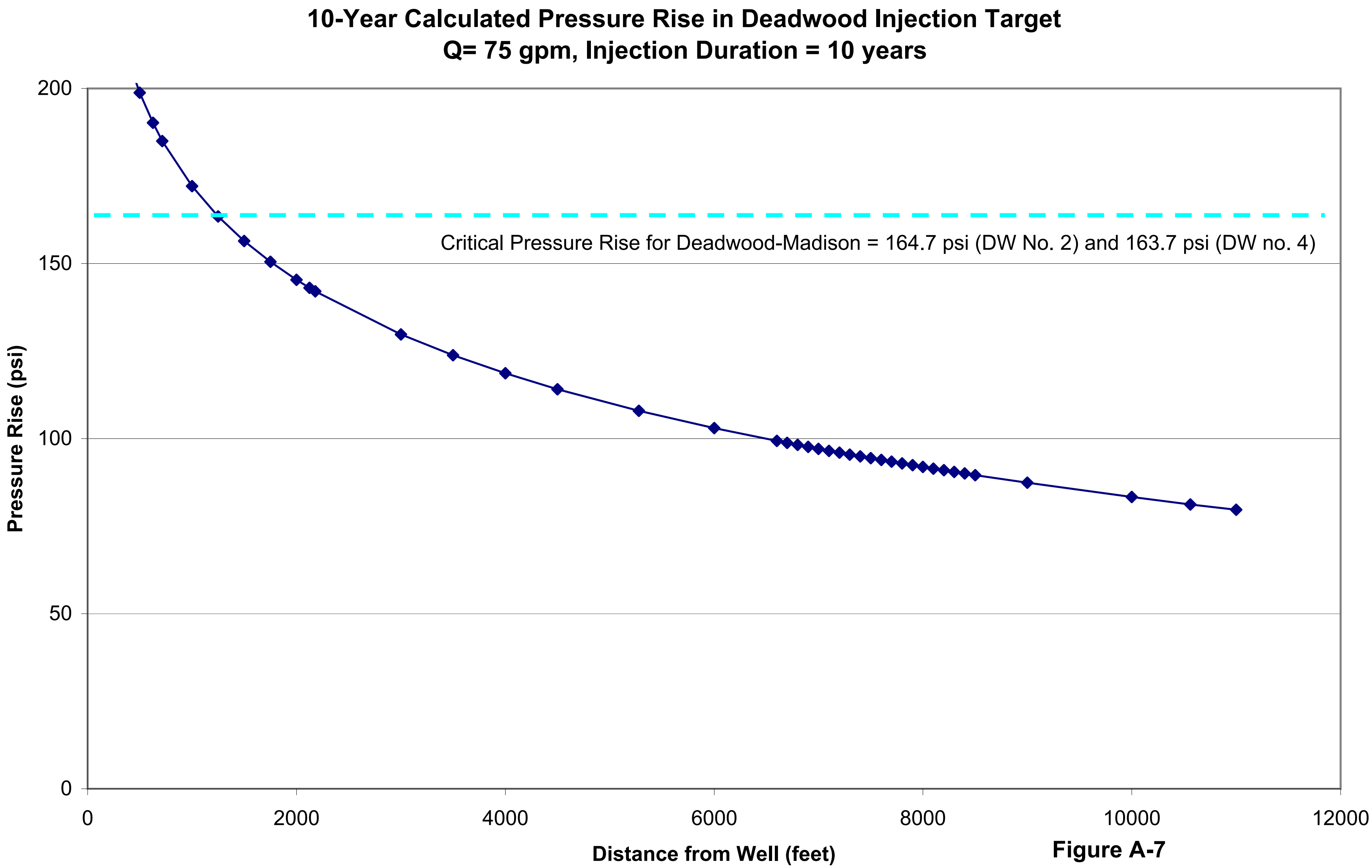

10-Year Calculated Pressure Rise in Deadwood Injection Target
Q= 75 gpm, Injection Duration = 10 years
Critical Pressure Rise for Deadwood-Madison = 164.7 psi (DW No. 2) and 163.7 psi (DW no. 4)
Pressure Rise (psi)
200
150
100
50
0
0
2000
4000
6000
8000
10000
12000
Distance from Well (feet)

Figure A-7

2.B MAPS OF WELLS IN AREA AND AREA OF REVIEW

Submit a topographic map, extending one mile beyond the property boundaries, showing the injection well(s) or project area for which a permit is sought and the applicable area of review. The map must show all intake and discharge structures and all hazardous waste, treatment, storage, or disposal facilities. If the application is for an area permit, the map should show the distribution manifold (if applicable) applying injection fluid to all wells in the area, including all system monitoring points. Within the area of review, the map must show the following:

The number, or name, and location of all producing well, injection well, abandoned well, dry holes, surface bodies of water, springs, mines (surface and subsurface), quarries, and other pertinent surface features, including residences and roads, and faults, if known or suspected. In addition, the map must identify those well, springs, other surface water bodies, and drinking water wells located within one-quarter mile of the facility property boundary. Only information of public record is required to be included on this map.

RESPONSE

Maps based on available public records have been prepared and submitted in this Response as summaries of the required data.

Topographic Map

A copy of the USGS Topographic map available with the outline of the Dewey-Burdock Project boundary superimposed on the map is included as Figure B-1. In addition, the map shows the location of all known surface bodies of water, springs, mines, quarries, residencies and roads.

Artificial Penetrations

There are two artificial penetrations identified in the areas of review surrounding Site 1 and one in the areas of review surrounding Site 2. Figures B-2 and B-2a show the artificial penetrations within the AORs for DW Nos. 1 through 4 for the Minnelusa and the Deadwood, respectively.

Figure B-2b, a map generated using regional data provided by the state of South Dakota, shows the Proposed Class V permit area, the location of the required AORs for four of the proposed Dewey-Burdock Disposal Wells, and the locations of surrounding oil and gas wells. Figure B-2c presents the location of all known water wells within the proposed Class V permit area.

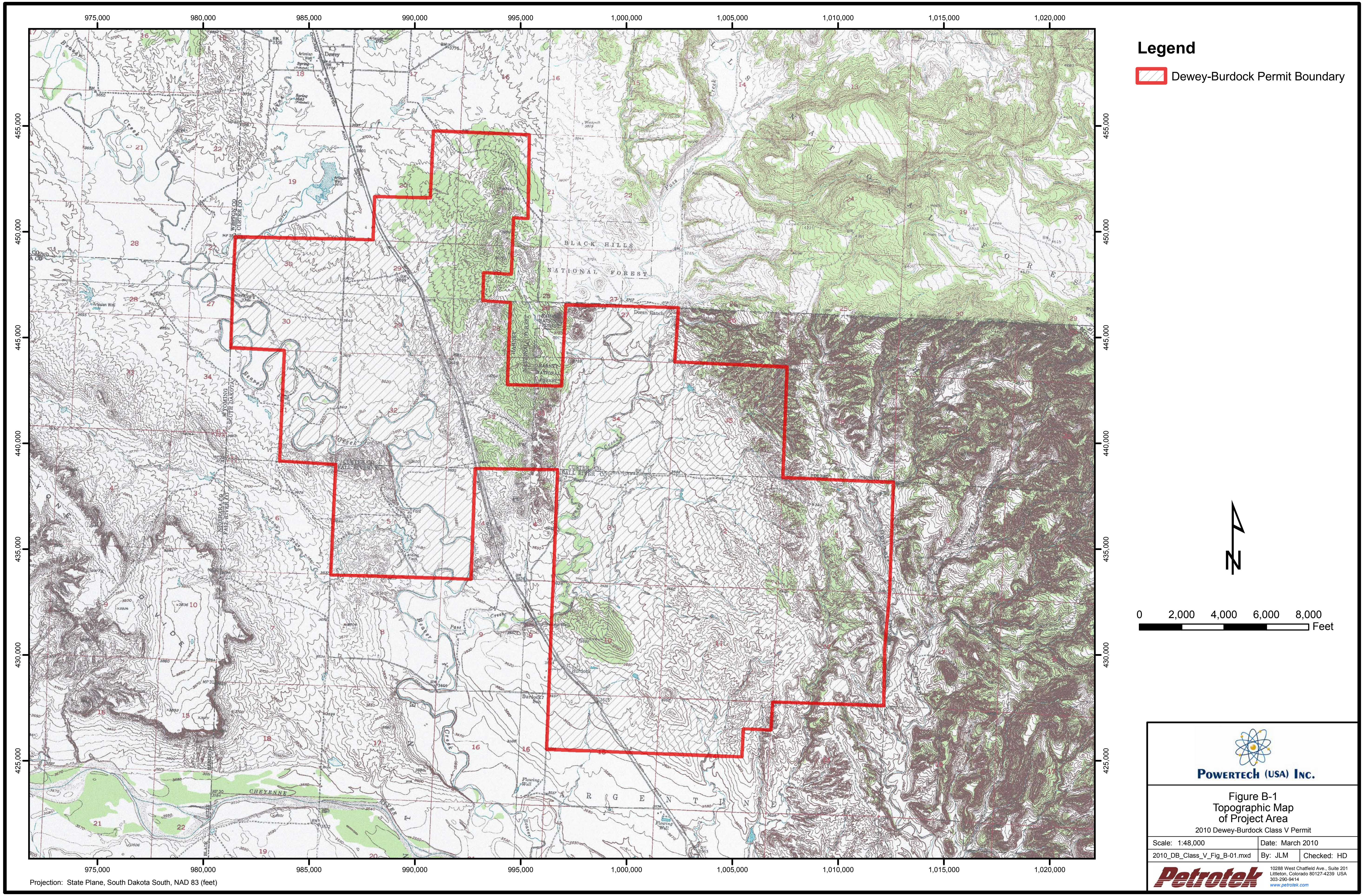
Table C-1 is a tabulation of the known water wells located within the Class V permit area. The deepest formation penetrated by any of these wells is the Unkpapa/Sundance. Due to the absence of wells within the Class V permit area that penetrate the injection zones, there is little potential for causing any endangerment to a USDW.

Table C-2 is a tabulation of the three oil and gas wells permitted within the Dewey-Burdock Project area. The plugging records for these well are included as Appendix B. According to the records obtained from DENR, each of the wells is plugged to a sufficient depth so as not to allow transmission of fluids from the targeted injection zones to overlying USDWs. Note that none of these wells are located within the proposed Class V permit area. As such, they will not be encompassed in any prospective AORs of proposed Dewey-Burdock Disposal Wells.

Property Ownership and Public Notice

Figure B-3 shows the surface property owners in the Dewey-Burdock Project area and Figure B-4 shows the mineral ownership within the Dewey-Burdock Project boundary.

For the purpose of public notice, newspaper service is available from several publishers in the area including the closest paper to the proposed facility, the Edgemont Herald Tribune.


Legend
Dewey-Burdock Permit Boundary
0 2,000 4,000 6,000 8,000 Feet
N
BLACK HILLS
NATIONAL FOREST
CHEYENNE
Projection: State Plane, South Dakota South, NAD 83 (feet)
POWERTECH (USA) INC.
Figure B-1
Topographic Map
of Project Area
2010 Dewey-Burdock Class V Permit
Scale: 1:48,000
Date: March 2010
2010_DB_Class_V_Fig_B-01.mxd
By: JLM
Checked: HD
Petrotek
10288 West Chatfield Ave., Suite 201
Littleton, Colorado 80127-4239 USA
303-290-9414
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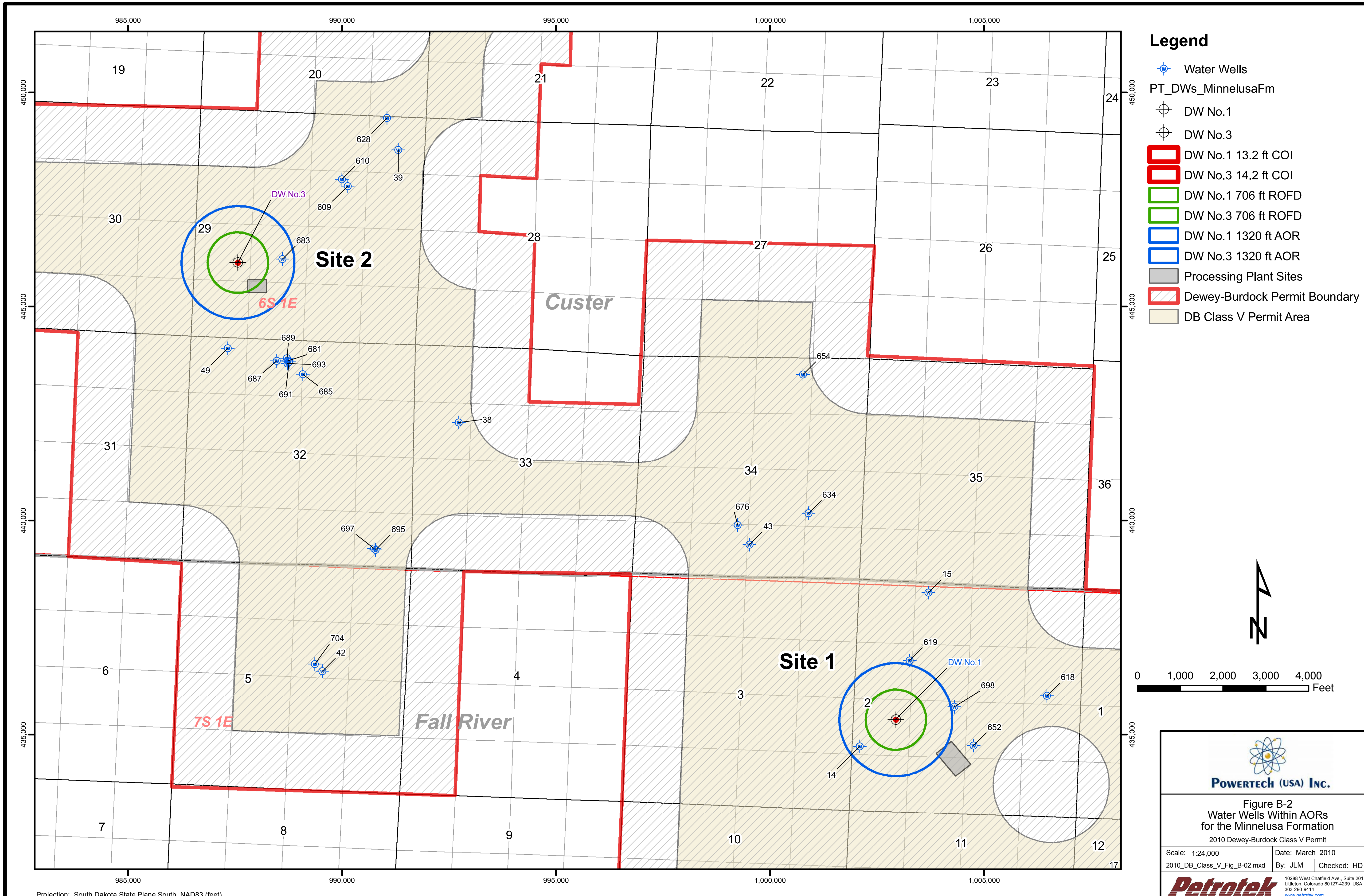
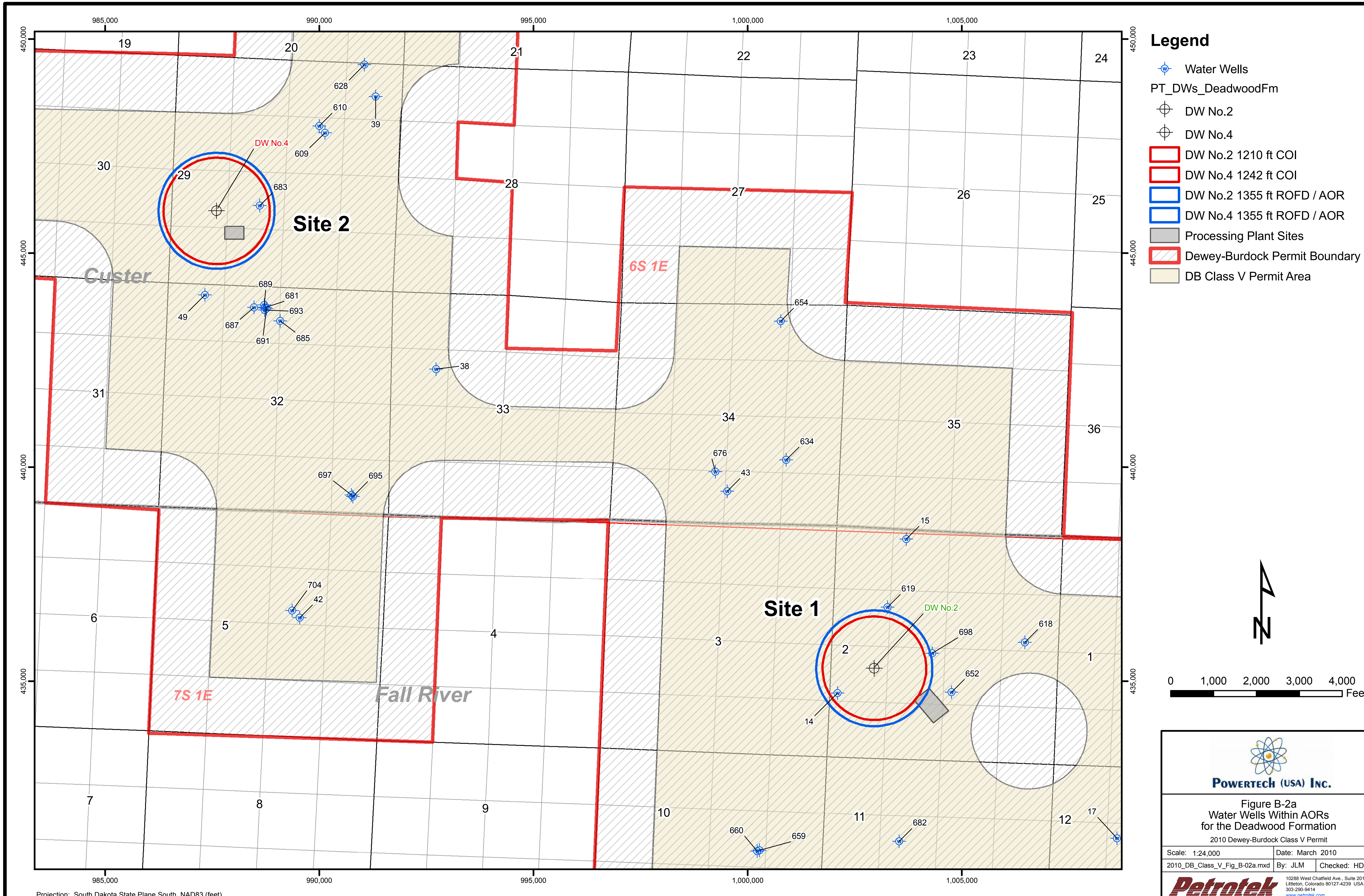
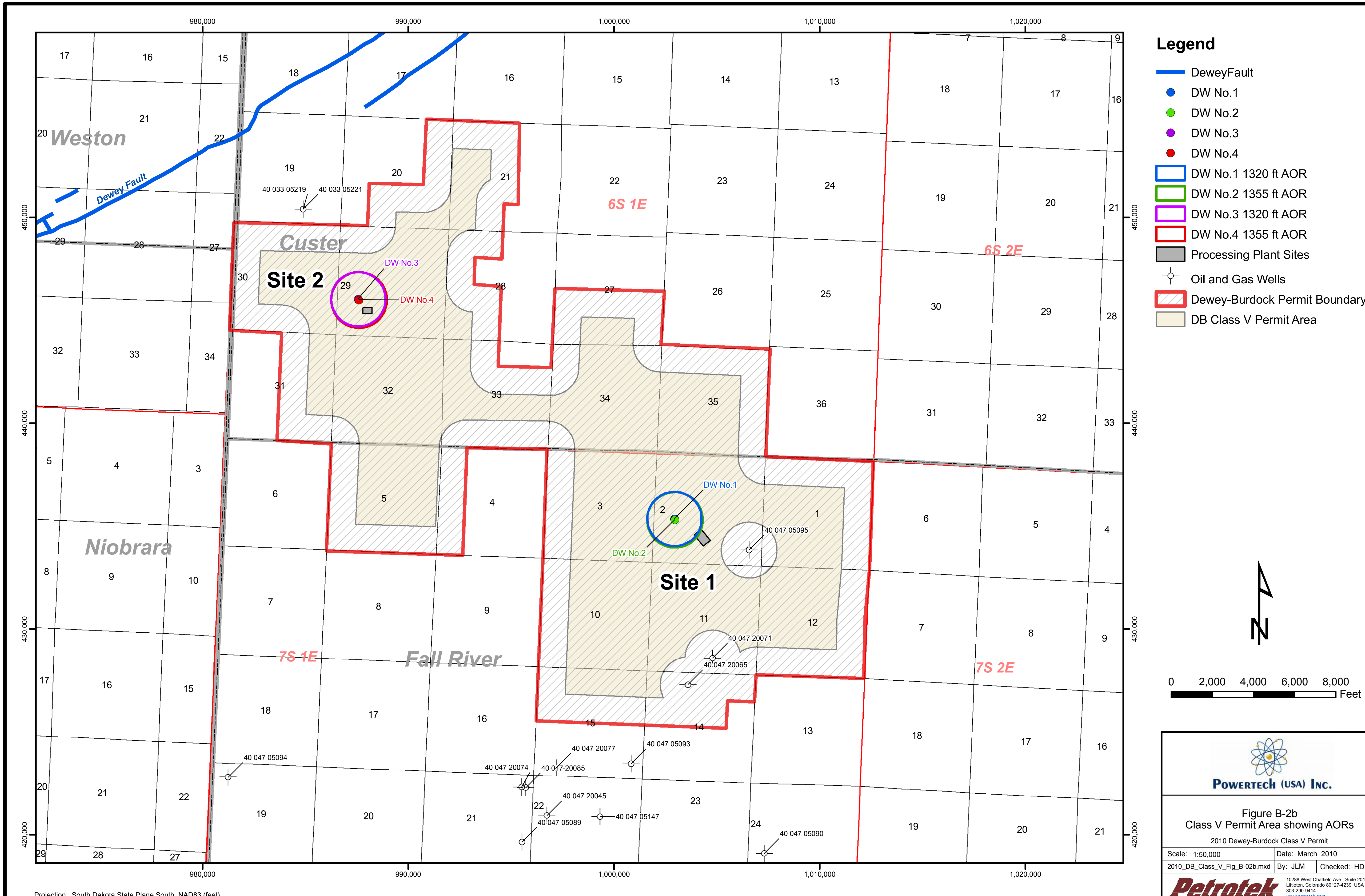
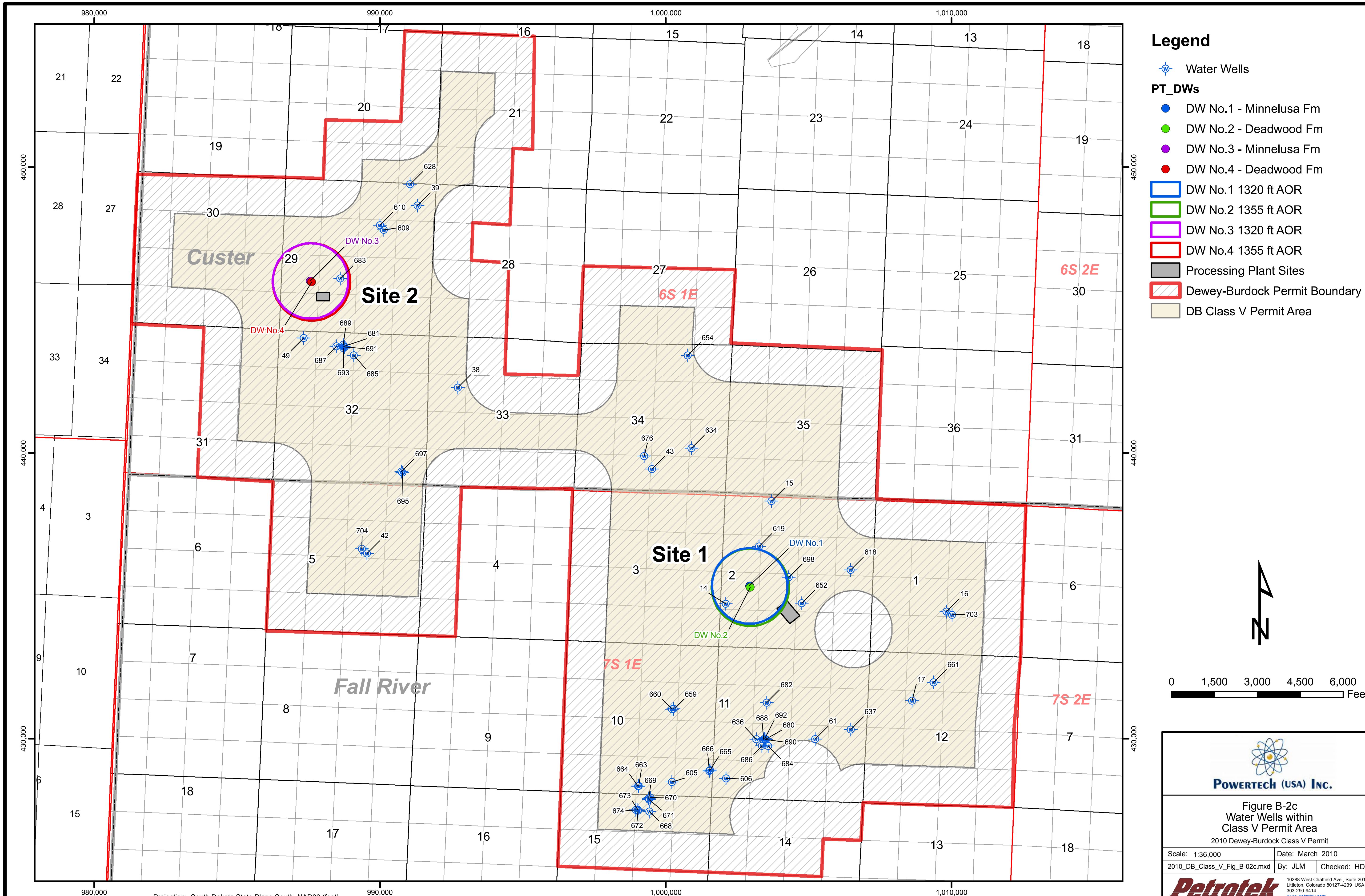
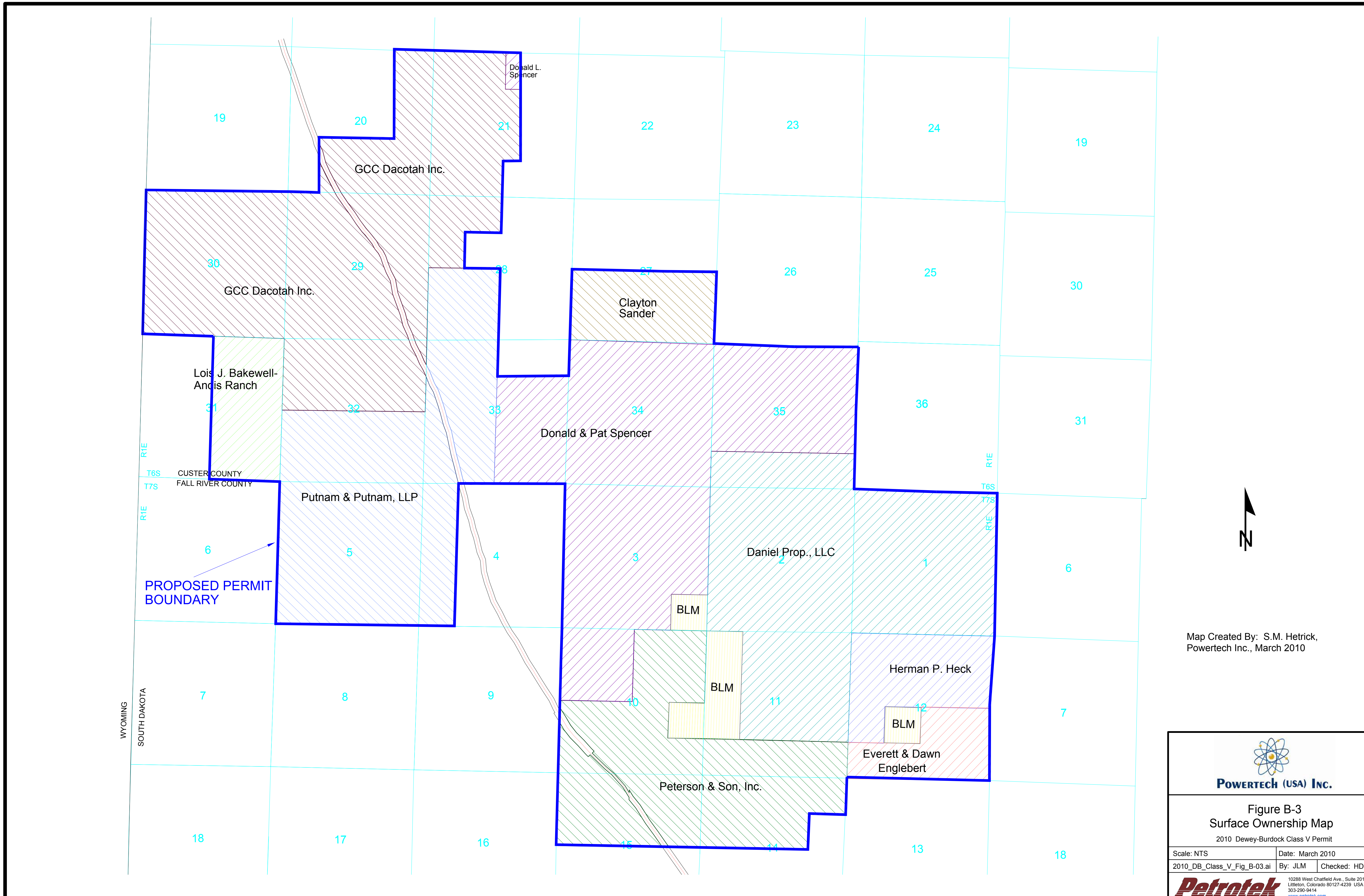

Legend
Water Wells
PT_DWs_MinnelusaFm
DW No.1
DW No.3
DW No.1 13.2 ft COI
DW No.3 14.2 ft COI
DW No.1 706 ft ROFD
DW No.3 706 ft ROFD
DW No.1 1320 ft AOR
DW No.3 1320 ft AOR
Processing Plant Sites
Dewey-Burdock Permit Boundary
DB Class V Permit Area
Site 2
Site 1
Custer
Fall River
6S 1E
7S 1E
DW No.3
DW No.1
985,000
990,000
995,000
1,000,000
1,005,000
450,000
445,000
440,000
435,000
0 1,000 2,000 3,000 4,000 Feet
N
Projection: South Dakota State Plane South, NAD83 (feet)
POWERTECH (USA) INC.
Figure B-2
Water Wells Within AORs
for the Minnelusa Formation
2010 Dewey-Burdock Class V Permit
Scale: 1:24,000
Date: March 2010
2010_DB_Class_V_Fig_B-02.mxd
By: JLM
Checked: HD
Petrotek

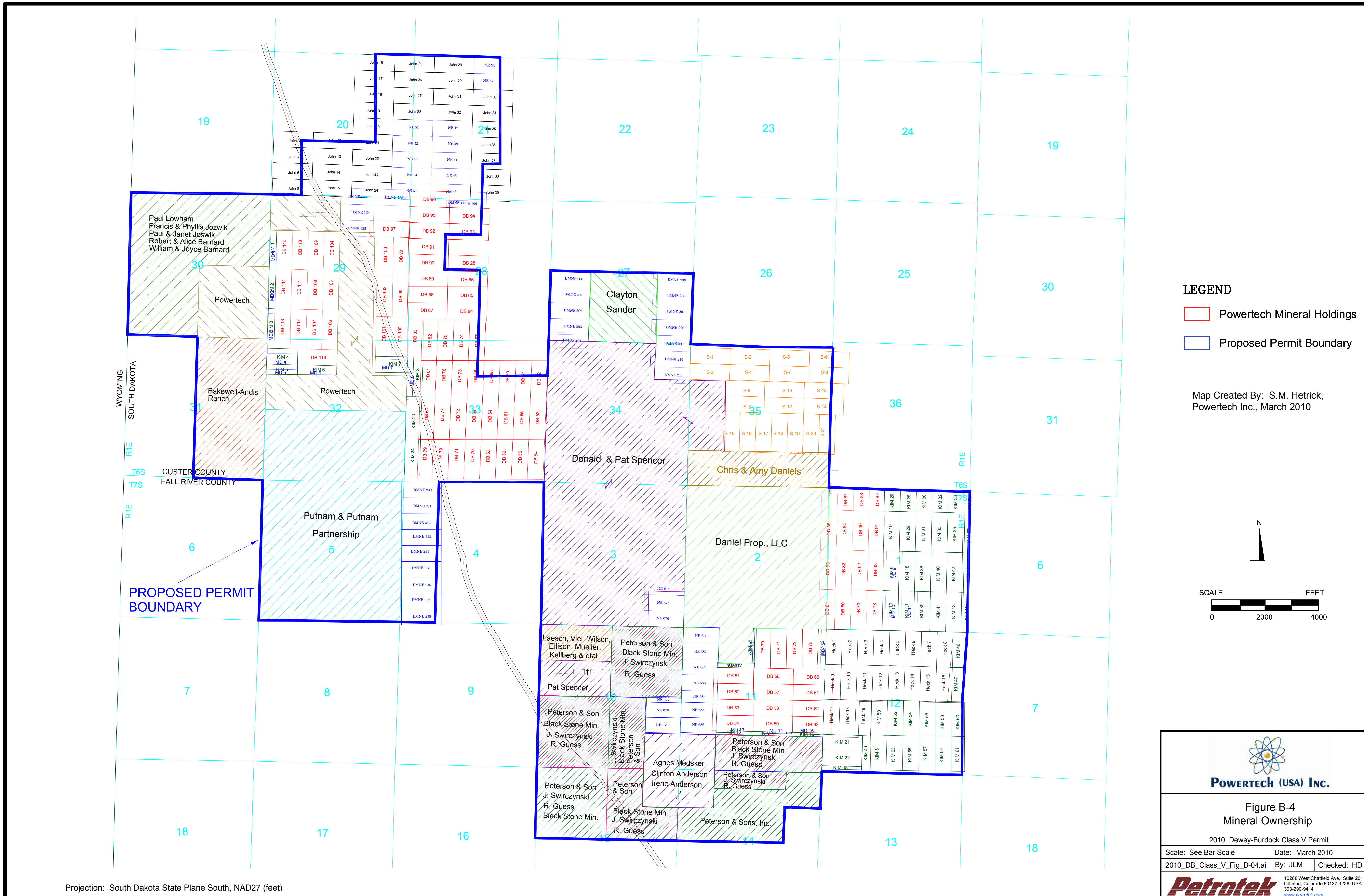

Legend
Water Wells
PT_DWs_DeadwoodFm
DW No.2
DW No.4
DW No.2 1210 ft COI
DW No.4 1242 ft COI
DW No.2 1355 ft ROFD / AOR
DW No.4 1355 ft ROFD / AOR
Processing Plant Sites
Dewey-Burdock Permit Boundary
DB Class V Permit Area
Site 1
Site 2
DW No.2
DW No.4
Custer
Fall River
6S 1E
7S 1E
0 1,000 2,000 3,000 4,000 Feet
POWERTECH (USA) INC.
Figure B-2a
Water Wells Within AORs
for the Deadwood Formation
2010 Dewey-Burdock Class V Permit
Scale: 1:24,000
Date: March 2010
2010_DB_Class_V_Fig_B-02a.mxd
By: JLM
Checked: HD
Petrotek
Projection: South Dakota State Plane South, NAD83 (feet)



Legend
DeweyFault
DW No.1
DW No.2
DW No.3
DW No.4
DW No.1 1320 ft AOR
DW No.2 1355 ft AOR
DW No.3 1320 ft AOR
DW No.4 1355 ft AOR
Processing Plant Sites
Oil and Gas Wells
Dewey-Burdock Permit Boundary
DB Class V Permit Area
Weston
Custer
Niobrara
Fall River
Dewey Fault
Site 1
Site 2
6S 1E
6S 2E
7S 1E
7S 2E
DW No.1
DW No.2
DW No.3
DW No.4
40 033 05219
40 033 05221
40 047 05095
40 047 20071
40 047 20065
40 047 05094
40 047 20077
40 047 20074
40 047-20085
40 047 05093
40 047 20045
40 047 05089
40 047 05147
40 047 05090
0 2,000 4,000 6,000 8,000
Feet
N
Powertech (USA) Inc.
Figure B-2b
Class V Permit Area showing AORs
2010 Dewey-Burdock Class V Permit
Scale: 1:50,000
Date: March 2010
2010_DB_Class_V_Fig_B-02b.mxd
By: JLM
Checked: HD
Petrotek
Projection: South Dakota State Plane South, NAD83 (feet)


Legend
Water Wells
PT_DWs
DW No.1 - Minnelusa Fm
DW No.2 - Deadwood Fm
DW No.3 - Minnelusa Fm
DW No.4 - Deadwood Fm
DW No.1 1320 ft AOR
DW No.2 1355 ft AOR
DW No.3 1320 ft AOR
DW No.4 1355 ft AOR
Processing Plant Sites
Dewey-Burdock Permit Boundary
DB Class V Permit Area
0 1,500 3,000 4,500 6,000 Feet
Custer
Fall River
Site 1
Site 2
DW No.1
DW No.2
DW No.3
DW No.4
6S 1E
7S 1E
6S 2E
7S 2E
980,000
990,000
1,000,000
1,010,000
450,000
440,000
430,000
Projection: South Dakota State Plane South, NAD83 (feet)
POWERTECH (USA) INC.
Figure B-2c
Water Wells within
Class V Permit Area
2010 Dewey-Burdock Class V Permit
Scale: 1:36,000
Date: March 2010
2010_DB_Class_V_Fig_B-02c.mxd
By: JLM
Checked: HD
Petrotek
10288 West Chatfield Ave., Suite 201
Littleton, Colorado 80127-4239 USA
303-290-9414
www.petrotek.com


GCC Dacotah Inc.
GCC Dacotah Inc.
Donald L. Spencer
Clayton Sander
Lois J. Bakewell-Andis Ranch
Donald & Pat Spencer
Putnam & Putnam, LLP
Daniel Prop., LLC
BLM
BLM
BLM
Herman P. Heck
Everett & Dawn Englebert
Peterson & Son, Inc.
PROPOSED PERMIT BOUNDARY
CUSTER COUNTY
FALL RIVER COUNTY
T6S
T7S
R1E
WYOMING
SOUTH DAKOTA
N
Map Created By: S.M. Hetrick, Powertech Inc., March 2010
POWERTECH (USA) INC.
Figure B-3
Surface Ownership Map
2010 Dewey-Burdock Class V Permit
Scale: NTS
Date: March 2010
2010_DB_Class_V_Fig_B-03.ai
By: JLM
Checked: HD
Petrotek



LEGEND
Powertech Mineral Holdings
Proposed Permit Boundary
Map Created By: S.M. Hetrick, Powertech Inc., March 2010
PROPOSED PERMIT BOUNDARY
WYOMING
SOUTH DAKOTA
CUSTER COUNTY
FALL RIVER COUNTY
Paul Lowham
Francis & Phyllis Jozwik
Paul & Janet Joswik
Robert & Alice Barnard
William & Joyce Barnard
Powertech
Bakewell-Andis Ranch
Putnam & Putnam Partnership
Clayton Sander
Donald & Pat Spencer
Chris & Amy Daniels
Daniel Prop., LLC
Laesch, Viel, Wilson, Ellison, Mueller, Kellberg & etal
Pat Spencer
Peterson & Son
Black Stone Min.
J. Swirczynski
R. Guess
Agnes Medsker
Clinton Anderson
Irene Anderson
Peterson & Sons, Inc.
SCALE
FEET
0
2000
4000
N
Projection: South Dakota State Plane South, NAD27 (feet)
POWERTECH (USA) INC.
Figure B-4
Mineral Ownership
2010 Dewey-Burdock Class V Permit
Scale: See Bar Scale
Date: March 2010
2010_DB_Class_V_Fig_B-04.ai
By: JLM
Checked: HD
Petrotek

2.C CORRECTIVE ACTION PLAN AND WELL DATA

Submit a tabulation of data reasonably available from public records or otherwise known to the applicant on all wells within the area of review, including those on the map required in Attachment B, which penetrate the proposed injection zone. Such data shall include the following:

A description of each well's type, construction, date drilled, location, depth, record of plugging and/or completion, and any additional information the Director may require. In the case of a new injection well, include the corrective action proposed to be taken by the applicant under 40 CFR 144.55.

RESPONSE

Corrective Action

A corrective action plan is not required for any of the artificial penetrations within the AORs of the proposed Dewey-Burdock wells or the Class V permit area because there are no artificial penetrations to the injection zone within the Class V permit area. If a corrective action plan for any neighboring well becomes necessary in the future, it will be developed according to appropriate regulatory standards and guidelines.

The corrective action plan which would be proposed by Powertech should the potential for fluid migration to occur through the confining layer develop via any future well likely would include the following:

1. The impacted Dewey-Burdock Project Disposal Well will be shut-in.
2. The USEPA, Region 8 UIC Section and the SD DENR will be notified.
3. Following well shut-in, liquid 11e2 waste will be shipped to alternative permitted facilities for off-site treatment and/or disposal as necessary.
4. A contingency plan will be prepared as follows:
    a. Locate well and identify present operator or owner, if any.
    b. Identify mode of failure.
    c. Prepare remedial plan outlining course of action.
    d. The remedial plan will be submitted to the USEPA, Region 8 and SD DENR for approval.
    e. Upon authorization, the remedial plan will be implemented.

Water Wells within AORs

Table C-1 is a tabulation of the known artificial penetrations (water wells) located within the Class V permit area. The deepest formation penetrated by any of these wells is the Unkpapa/Sundance. Due to the absence of wells within the Class V permit area that penetrate either of the targeted injection zones, there is no potential from artificial penetrations for causing any endangerment to a USDW.

Area of Review Oil and Gas Well Data

Table C-2 is a tabulation of the three oil and gas wells permitted within the Dewey-Burdock Project area that are outside the assigned AORs. The plugging records for these wells are included as Appendix B. Plugging records obtained from DENR indicate that each of the wells is plugged to a sufficient depth so as not to allow transmission of fluids from the targeted injection zones to overlying USDWs. Note that none of these wells are located within the proposed Class V permit area. As such, they will not be encompassed in any prospective future AORs of proposed additional Dewey-Burdock Disposal Wells.

TABLE C-1 Known Water Wells Within Class V Permit Area

Well ID	Well Depth (ft)	Formation	Abandoned	Depth to Water (ft)
605	Unknown	Inyan Kara	no	Unknown
606	Unknown	Lakota	yes	0
42	600	Lakota	no	-10
61	525	Lakota	unknown	Unknown
16	330	Lakota	no	158
618	Unknown	Unknown	no	Unknown
15	495	Lakota	yes	0
634	Unknown	Unknown	yes	Unknown
43	350	Lakota	yes	Unknown
14	470	Lakota	unknown	-1
636	Unknown	Unknown	yes	Unknown
637	Unknown	Unknown	no	Unknown
17	156	Fall River	no	Unknown
39	Unknown	Unknown	unknown	Unknown
652	280	Inyan Kara	yes	Unknown
654	Unknown	Inyan Kara	yes	Unknown
659	Unknown	Fall River	yes	Unknown
660	Unknown	Lakota	yes	Unknown
661	Unknown	Lakota	unknown	Unknown
663	550	Lakota	unknown	Unknown
664	360	Fall River	unknown	Unknown
665	252	Fall River	unknown	Unknown
666	441	Lakota	unknown	Unknown
669	550	Lakota	unknown	Unknown
670	395	Fuson	unknown	Unknown
671	350	Fall River	unknown	Unknown
672	376	Fall River	unknown	Unknown
673	440	Fuson	unknown	Unknown
674	570	Lakota	unknown	Unknown
676	23	Alluvial	no	Unknown
683	650	Fall River	no	5
687	608	Fall River	no	Unknown
685	595	Fall River	no	Unknown
682	460	Lakota	no	Unknown
686	428	Lakota	no	Unknown
684	423	Lakota	no	Unknown
690	623	Unkpapa/Sundance	no	-29
692	327	Lakota	no	Unknown
38	494	Lakota	no	-14
609	1000	Lakota	no	7
610	Unknown	Fall River	no	Unknown
619	280	Lakota	no	19
628	Unknown	Inyan Kara	no	Unknown
668	574	Inyan Kara	no	Unknown
698	205	Fall River	no	Unknown
704	955	Unkpapa/Sundance	no	Unknown
703	525	Unkpapa/Sundance	no	Unknown
695	508	Fall River	no	Unknown

TABLE C-1 Known Water Wells Within Class V Permit Area

Well ID	Well Depth (ft)	Formation	Abandoned	Depth to Water (ft)
697	682	Lakota	no	Unknown
691	505	Fall River	no	Unknown
693	910	Unkpapa/Sundance	no	-138
689	730	Lakota	no	-59
681	600	Fall River	no	-13
49	600	Fall River	no	Unknown
688	255	Fall River	no	37
680	436	Lakota	no	39

Source: 2009 Powertech Dewey-Burdock NRC Application

TABLE C-2 Oil and Gas Wells Within Project Area

Well API	Name	Well Depth (ft)	Formation	Well Status
40-047-05095	Earl Darrow #1	2,450	Minnelusa	Plugged and Abandonded
40-047-20071	#34-11 Peterson	2,250	Minnelusa	Plugged and Abandonded
40-047-20065	Lenore Peterson #21-14	2,266	Minnelusa	Plugged back to 850'

2.D MAPS AND CROSS SECTIONS OF USDWs

Submit maps and cross sections indicating the vertical limits of all underground sources of drinking water within the area of review (both vertical and lateral limits for Class I), their position relative to the injection formation and the direction of water movement, where known, in every underground source of drinking water which may be affected by the proposed injection activities.

RESPONSE

The major bedrock aquifers in the Black Hills area include the Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara (Carter et al, 2003). These aquifers are regionally extensive in areas surrounding the Black Hills as shown on Figure D-1 (Driscoll et al., 2002). A regional east-west geologic cross section across the Black Hills Uplift is shown on Figure D-2. The location of the cross section A-A' is indicated on Figure D-1. Ground-water flow in the regional aquifer system in the Paleozoic aquifer units (i.e., Deadwood, Madison, Minnelusa, and Minnekahta Formations) is generally interpreted to be radially outward from the outcrops surrounding the Black Hills (Figure D-3). Groundwater recharge from the Black Hills area comingles with groundwater in the Powder River Basin to the west and then migrates northeastward into the Williston Basin where it eventually discharges at lower elevations to the land surface in eastern North Dakota and along the outcrop of the Canadian Shield in Canada.

Only two of these major aquifers, the Madison and Inyan Kara, are considered to be USDWs within the AORs of the Dewey-Burdock Disposal Wells. As discussed below, the Deadwood, Minnelusa, and Minnekahta do not supply water wells in the Dewey-Burdock area and are not considered to be USDWs locally. Further, due to local total dissolved solids (TDS) concentrations in excess of 10,000 mg/l, (shown Table D-1 from the USGS Produced Waters Database [http://energy.cr.usgs.gov/prov/prodwat/data2.htm]), the Minnelusa is not a USDW.

Minor aquifers in the area include the Sundance formation (Driscoll et al., 2002). While some authors differentiate geologically between the Sundance and overlying Unkpapa Formation, they are thought to be hydrogeologically connected and are referred to as the Unkpapa/Sundance in this document. Further, the Unkpapa/Sundance is considered to be the lower-most USDW above the Madison below the Dewey-Burdock Project area.

Deadwood Formation

The Cambrian-age Deadwood Formation consists of massive to thinly-bedded, brown to light-gray sandstone; greenish glauconitic shale; dolomite; and flat-pebble limestone conglomerate. Sandstone with conglomerate occurs locally at the base of the formation. The Deadwood ranges in thickness from 0 to 500 feet (Carter et al., 2003) in the area. Generally, groundwater flow in the Cambrian-Ordovician aquifer system is from the high-altitude recharge areas on the top of the Black Hills radially outward (Figure D-4). Regionally the Deadwood is confined by the Precambrian basement (Williamson and Carter, 2001). It overlies the Precambrian basement and granite wash (where present) and outcrops approximately 20 miles to the northeast of the Dewey-Burdock Project (Figure D-1). As stated previously, the Deadwood is not considered to be a local USDW. Based on available data, there are no known water wells supplied by the Deadwood Formation in the Dewey-Burdock Project area. There are no water quality data available in the area, but it is suspected that water quality declines with depth and distance down-gradient from the recharge at the outcrop. As a result, it is likely that the Deadwood contains dissolved solids in excess of 10,000 mg/l below Sites 1 and 2 and will not meet the USEPA criteria for a USDW. An isopach map of the Deadwood is included as Figure D-5.

Madison Formation

The Mississippian Madison aquifer is contained within the limestones, siltstones, sandstones, and dolomite of the Madison Limestone or Group. Generally, water in the Madison is confined except in outcrop areas and can frequently demonstrate artesian conditions. Groundwater flow in this aquifer system generally is from the recharge areas radially outward from the Black Hills (Figure D-6). Water in the Madison is typically fresh only near the recharge areas, becoming slightly saline to saline as it moves down-gradient (Figure D-7). In the deeper parts of the Williston Basin, the water is a brine with dissolved solids concentrations greater than 300,000 mg/L (Driscoll et al., 2002). Local water quality for the Madison is summarized by analysis of the Edgemont city wells and is presented in Table D-1. Structure contour and isopach maps of the Madison are included as Figures D-8 and D-9, respectively. A potentiometric surface map of the Madison Formation is presented as Figure D-10.

Minnelusa Formation

The Pennsylvanian- and Permian-age Minnelusa Formation consists of yellow to red, cross-stratified sandstone, limestone, dolomite, and shale. The Minnelusa Aquifer occurs primarily in sandstone and anhydrite beds in the upper part of the formation (Williamson and Carter, 2001). Water in this aquifer moves from recharge areas radially outward from the Black Hills and to the northeast to discharge areas in eastern South Dakota (Figure D-6). It is confined above by the Opeche Shale and below by layers of lower permeability in the Minnelusa Formation.

The Minnelusa is referred to as an aquifer but is an oil and gas producer in the Dewey-Burdock area. Table D-2 and Figure D-11 present local water quality data from the USGS Produced Waters Database for the Minnelusa Formation that shows TDS concentrations in excess of 10,000 mg/l in the Dewey-Burdock area. In addition, this formation does not supply water to any local water wells. As such, it is not considered to be a USDW in the Dewey-Burdock area. Structure contour and isopach maps of the Minnelusa are included as Figures D-12 and D-13, respectively. A potentiometric surface map of the Minnelusa Formation is presented as Figure D-14.

It has been postulated that in the vicinity of the Black Hills, there may be communication between the Madison and Minnelusa Formations and even communication from the Minnelusa to the surface via breccia pipes. However, this communication is thought to occur near the outcrop in areas where these formations are near surface. These areas are located well to the north and east of the Project area and up-gradient in the system. Evidence of regional isolation is the contrast between water quality in the Madison and Minnelusa. There is no evidence to suggest that there is communication between these formations locally.

Minnekahta Formation

The Permian-age Minnekahta Limestone is a thin to medium-bedded, fine-grained, purple to gray laminated limestone, which ranges in thickness from 25 to 65 feet (Driscoll et al., 2002). The Minnekahta is considered a major aquifer in parts of the Black Hills area but does not supply any known water wells locally.

Unkpapa/Sundance Formation

The Sundance Formation consists of greenish-gray shale with thin limestone lenses; glauconitic sandstone, with red sandstone near the middle of the formation. The Sundance ranges from 250 to 450 feet thick (Carter et al., 2003). The Unkpapa Sandstone is a massive fine-grained sandstone, 0 to 225 feet thick (Carter et al., 2003). A potentiometric surface map of the Unkpapa is presented as figure D-14a. The Unkpapa/Sundance is considered a minor aquifer in the area. Local water quality data from wells located within the Dewey-Burdock Project are presented in Table D-3.

Inyan Kara Group

Several sandstone units compose the lower Cretaceous aquifer, which is known as the Inyan Kara aquifer in South Dakota. These units are the Lakota and Fall River Formations and the Lakota is divided into the Chilson, Minnewaste, and Fuson Members. Some authors include the Minnewaste Limestone Member regionally, but it is not present below the project area. Generally, water in the Inyan Kara is confined by several thick shale layers of the Graneros Group (including the Skull Creek Shale), except in outcrop areas around structural uplifts, such as the Black Hills Uplift. Regionally, groundwater in the Inyan Kara moves from high-altitude recharge areas to discharge areas in eastern North Dakota and South Dakota. Although the aquifer is wide-spread, it contains little fresh water except in small areas in central and south-central Montana and north and east of the Black Hills uplift. Water in the Inyan Kara is saline in the deeper parts of the Williston and Powder River Basins (Driscoll et al., 2002). Table D-4 presents local water quality data from wells located within the Dewey-Burdock Project. A structure contour map of the Inyan Kara is included as Figure D-15. Isopach maps of each of the units that compose the Inyan Kara are included as Figures D-16, D-17, and D-18. A potentiometric surface map of the Fall River Aquifer is presented as Figure D-19.

Figure D-20 is a cross-section location map that shows A - A' (Figure D-21) and B - B' (Figure D-22) which show the vertical extent of the USDWs across the project area. The lowermost formations (Madison, Englewood, and Deadwood) are not shown due to the lack of deep well logs.

TABLE D-1 Local Water Quality Data - Madison Formation

Summary of Madison well data, Edgemont city water														
		Well ID	BNR/TVA	well 2	well 4	well 5	TVA	well 2	well 4	well 5	Mean	Minimum	Maximum	Std. Dev
		Sample Date	11/6/2002	11/6/2002	11/6/2002	11/6/2002	5/23/2000	5/23/2000	5/23/2000	5/23/2000				
Component		**units**												
Physical properties														
Conductivity	Cond.	umhos/cm	1154	1671	1785	2140	1300	1700	1800	2300	1731.3	1154.0	2300.0	382.1
Hardness			406	503	528	580	410	460	500	560	493.4	406.0	580.0	64.3
pH	pH		7.81	7.7	7.73	7.66	7.15	7.23	7.26	7.37	7.5	7.2	7.8	0.3
TDS	TDS	mg/L	726	1047	1101	1333	690	980	940	1000	977.1	690.0	1333.0	205.0
TSS	TSS	mg/L												
Turbidity	Turbidity	NTU												
Acidity	Acidity													
Alkalinity	CaCO3		188	181	182	180	170	160	160	170	173.9	160.0	188.0	10.5
Carbonate	CO3	mg/L												
Bicarbonate	HCO3	mg/L	229	221	222	220	210	200	200	210	214.0	200.0	229.0	10.7
Chloride	Cl	mg/L	185	255	300	385	150	250	270	360	269.4	150.0	385.0	79.7
Cyanide	CN	mg/L												
Flouride	F	mg/L	0.843	1.1	1.07	1.32	0.9	1.05	1.03	1.2	1.1	0.8	1.3	0.2
Nitrogen, Ammonia	NH3	mg/L												
Nitrogen, Nitrate	NO3	mg/L	0.211	0.086	0.063	<.05	0.15	0.16	0.16	<.1	0.1	0.1	0.2	0.1
Nitrogen, Nitrite	NO2	mg/L					<.01	<.01	<.01	<.01		0.0	0.0	
Sulfate	SO4	mg/L	211	295	309	353	210	300	340	390	301.0	210.0	390.0	64.0
Metals														
Aluminum	Al	mg/L												
Arsenic	As	mg/L	0.006	0.01	0.01	0.008					0.0085	0.0	0.0	0.0019
Calcium	Ca	mg/L	115	150	156	175	100	120	130	140	135.8	100.0	175.0	24.4
Iron	Fe	mg/L	0.05	0.091	<.05	2.53	<0.05	0.09	<.05	2.6	1.1	0.1	2.6	1.4
Magnesium	Mg	mg/L	28.8	31.1	33.7	34.8	30	32	35	36	32.7	28.8	36.0	2.6
Manganese	Mn	mg/L	0.05	0.05	<.05	<.05	<.03	<.03	<.03	0.05	0.05	0.1	0.1	0.00
Mercury	Hg	mg/L												
Lead	Pb	mg/L												
Molybdenum	Mo	mg/L												
Potassium	K	mg/L	10.6	17.3	17.9	23	12	19	20	24	18.0	10.6	24.0	4.7
Selenium	Se	mg/L												
Sodium	Na	mg/L	86.9	161	174	228	88	150	170	200	157.2	86.9	228.0	49.4

Source: Summary of Madison well data, Edgemont city water http://www.sdgs.usd.edu/other/db.html

TABLE D-2 Local Water Quality Data - Minnelusa Formation

API Number	Location					County	Formation Sampled	Sample Method	Test Interval		TDS (mg/L)
	Section	Township	Range	Latitude	Longitude				Top (feet)	Bottom (feet)	
4003305005	34	6S	2E	43.48664	-103.86925	Custer	Minnelusa	DST	1,338	1,375	18,814
4003305010	34	6S	2E	43.48814	-103.86781	Custer	Minnelusa	Production	1,368	1,388	13,512
4003305010	34	6S	2E	43.48814	-103.86781	Custer	Minnelusa	Wellhead	1,356	--	7,740
4003305015	34	6S	2E	43.49021	-103.86926	Custer	Minnelusa	Separator	713	--	7,429
4003305035	30	5S	2E	43.58112	-103.93146	Custer	Minnelusa	Bailer	845	851	4,288
4004705067	15	9S	2E	43.26232	-103.87392	Fall River	Minnelusa	DST	2,692	2,707	24,823
4004705067	15	9S	2E	43.26232	-103.87392	Fall River	Minnelusa	DST	2,692	2,707	24,422
4004705067	15	9S	2E	43.26232	-103.87392	Fall River	Minnelusa	WLT	2,230	2,234	9,803
4004705089	21	7S	1E	43.42595	-103.99711	Fall River	Minnelusa	DST	2,390	2,400	21,391
4004705089	21	7S	1E	43.42595	-103.99711	Fall River	Minnelusa	DST	2,390	2,400	17,279
4004705089	21	7S	1E	43.42595	-103.99711	Fall River	Minnelusa	DST	2,390	2,400	16,652
4004705092	21	7S	2E	43.42964	-103.88318	Fall River	Minnelusa	Unknown	1,415	1,418	10,183
40000185	34	6S	2E	43.48480	-103.86630	Custer	Minnelusa	Separator	713	--	7,427
40000183	34	6S	2E	43.48480	-103.86630	Custer	Minnelusa	Separator	680	--	6,968

Notes:
-- - Data not provided.
Shading indicates duplicate samples.
Source: USGS Produced waters Database; http://energy.cr.usgs.gov/prov/prodwat/data.htm

TABLE D-3 Local Water Quality Data - Unkpapa/Sundance Formation

Well #635				
Analyte	**9/26/07 18:08**	**11/27/07 8:25**	**2/10/08 14:55**	**4/29/08 19:00**
A/C Balance (± 5) (%)	-1.14	-0.831	-0.25	3.52
Alkalinity-Total as CaCO3 (mg/L)	124	118	120	118
Aluminum-Dissolved (mg/L)	<0.1	<0.1	<0.1	<0.1
Ammonia (mg/L)	0.1	0.4	0.5	0.5
Anions (meq/L)	30.4	31.6	33.7	32.8
Antimony-Total (mg/L)			<0.003	<0.003
Arsenic-Dissolved (mg/L)	<0.001	<0.001	<0.001	<0.001
Arsenic-Total (mg/L)			<0.001	0.001
Barium-Dissolved (mg/L)	<0.1	<0.1	<0.1	<0.1
Barium-Total (mg/L)			<0.1	<0.1
Beryllium-Total (mg/L)			<0.001	<0.001
Bicarbonate as HCO3 (mg/L)	151	144	146	144
Boron-Dissolved (mg/L)	0.4	0.4	0.5	0.4
Boron-Total (mg/L)			0.5	0.4
Cadmium-Dissolved (mg/L)	<0.005	<0.005	<0.005	<0.005
Cadmium-Total (mg/L)			<0.005	<0.005
Calcium-Dissolved (mg/L)	110	120	132	136
Carbonate as CO3 (mg/L)	<5	<5	<5	<5
Cations (meq/L)	29.8	31.1	33.5	35.2
Chloride (mg/L)	24	23	26	20
Chromium-Dissolved (mg/L)	<0.05	<0.05	<0.05	<0.05
Chromium-Total (mg/L)			<0.05	<0.05
Conductivity @ 25 C (umhos/cm)	2890	2830	2950	2810
Copper-Dissolved (mg/L)	<0.01	<0.01	<0.01	<0.01
Copper-Total (mg/L)			<0.01	<0.01
Fluoride (mg/L)	0.3	0.3	0.4	0.4
Gross Alpha-Dissolved (pCi/L)	2.5	4.4	14.8	13.2
Gross Beta-Dissolved (pCi/L)	4.3	6.3	10	-8
Gross Gamma-Dissolved (pCi/L)	960	1000	91	
Iron-Dissolved (mg/L)	<0.03	<0.03	<0.03	<0.03
Iron-Total (mg/L)			1.11	1.08
Lead 210-Dissolved (pCi/L)	<1	1.7	<1	
Lead 210-Suspended (pCi/L)	<1	5.1	<1	-9.6
Lead 210-Total (pCi/L)	<1			
Lead-Dissolved (mg/L)	<0.001	0.003	<0.001	<0.001
Lead-Total (mg/L)			<0.001	<0.001
Magnesium-Dissolved (mg/L)	44.3	49	52.3	54.1
Manganese-Dissolved (mg/L)	0.06	0.07	0.06	0.06
Manganese-Total (mg/L)			0.06	0.05
Mercury-Dissolved (mg/L)	<0.001	<0.001	<0.001	<0.001
Mercury-Total (mg/L)	<0.0002	<0.001	<0.001	<0.001
Molybdenum-Dissolved (mg/L)	<0.1	<0.1	<0.1	<0.1
Molybdenum-Total (mg/L)			0.01	<0.1
Nickel-Dissolved (mg/L)	<0.05	<0.05	<0.05	<0.05
Nickel-Total (mg/L)			<0.05	<0.05
Nitrogen, Nitrate as N (mg/L)	<0.1	<0.1	<0.1	<0.05
Nitrogen, Nitrite as N (mg/L)	<0.1	<0.1	<0.1	<0.05
Oxidation-Reduction Potential (mV)		270	129.4	180
pH	7.72	7.64	7.91	8.2
Polonium 210-Dissolved (pCi/L)	<1	1.9	<1	1.1
Polonium 210-Suspended (pCi/L)	<1	<1	<1	
Polonium 210-Total (pCi/L)	<1			
Potassium-Dissolved (mg/L)	7.8	8.3	8.2	7.3
Radium 226-Dissolved (pCi/L)	1.6	0.8	1.3	
Radium 226-Suspended (pCi/L)	0.8	<0.2	0.6	0.3
Radium 226-Total (pCi/L)	2.4			

TABLE D-3 Local Water Quality Data - Unkpapa/Sundance Formation

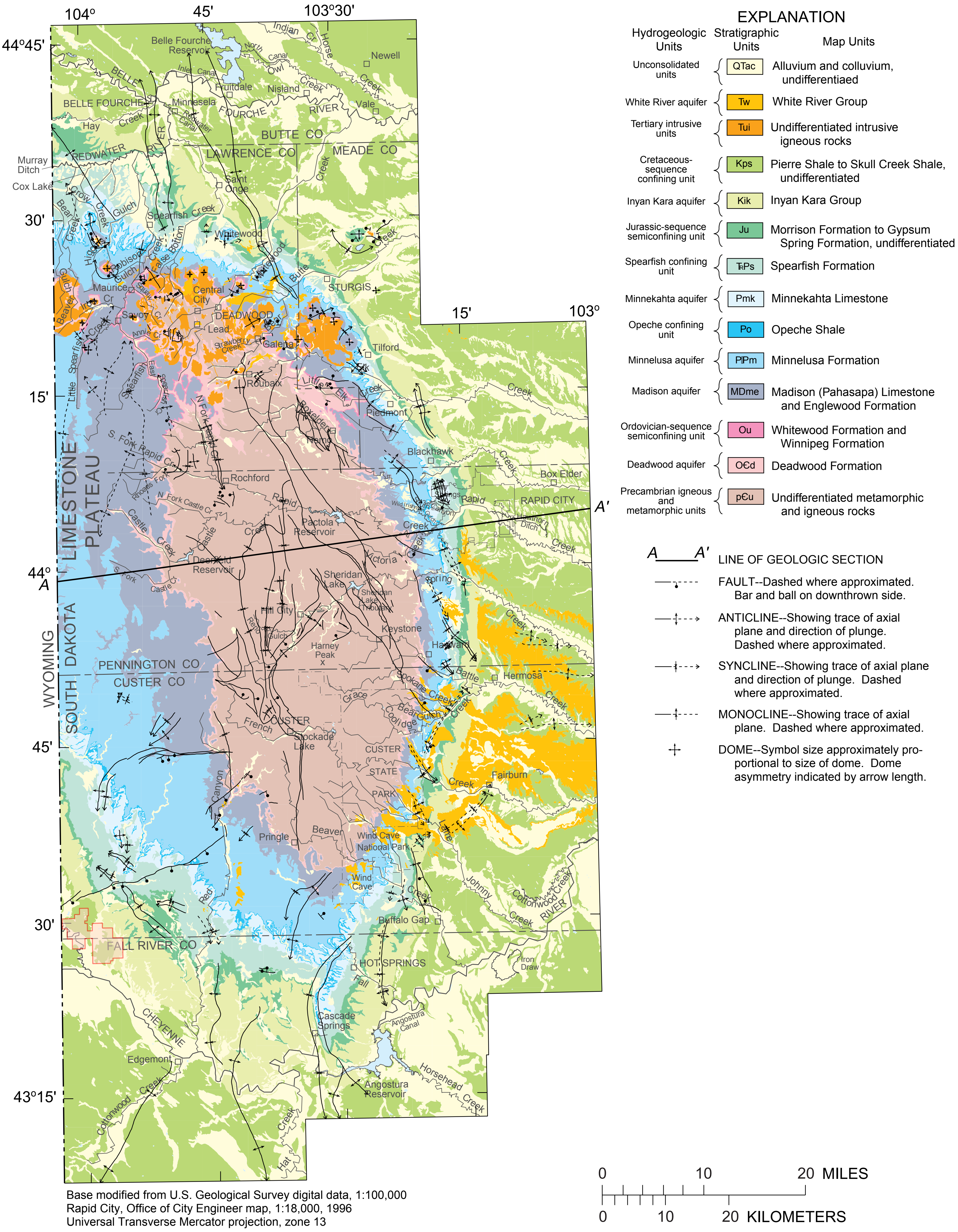
Well #635				
Analyte	**9/26/07 18:08**	**11/27/07 8:25**	**2/10/08 14:55**	**4/29/08 19:00**
Radon 222-Total (pCi/L)		902	806	1070
Selenium-Dissolved (mg/L)	0.001	<0.001	<0.001	<0.001
Selenium-IV-Dissolved (mg/L)		0.001	<0.001	<0.001
Selenium-Total (mg/L)			<0.001	0.001
Selenium-VI-Dissolved (mg/L)		<0.001	<0.001	<0.001
Silica-Dissolved (mg/L)	8.6	9	10	4.9
Silver-Dissolved (mg/L)	<0.005	<0.005	<0.005	<0.005
Silver-Total (mg/L)			<0.005	<0.005
Sodium Adsorption Ratio (SAR) (meq/L)		9.3	9.6	10
Sodium-Dissolved (mg/L)	470	480	515	545
Solids-Total Dissolved Calculated (mg/L)	2040	2120	2270	2280
Solids-Total Dissolved TDS @ 180 C (mg/L)	2200	2300	2300	2200
Strontium-Total (mg.L)			4.2	4.6
Sulfate (mg/L)	1500	1370	1470	1430
TDS Balance (0.80 - 1.20) (dec.%)	1.09	1.08	1.03	0.98
Thallium-Total (mg/L)			<0.001	<0.001
Thorium 230-Dissolved (pCi/L)	<0.2	<0.2	<0.2	0.2
Thorium 230-Suspended (pCi/L)	<0.2	<0.2	<0.2	0.1
Thorium 230-Total (pCi/L)	<0.2			
Thorium 232-Dissolved (pCi/L)	<0.005	<0.005	<0.005	<0.005
Uranium-Dissolved (mg/L)	0.002	0.002	0.0021	0.0017
Uranium-Suspended (mg/L)	<0.0003	<0.0003	<0.0003	<0.0003
Uranium-Total (mg/L)	0.002		0.0021	0.0017
Vanadium-Dissolved (mg/L)	<0.1	<0.1	<0.1	<0.1
Zinc-Dissolved (mg/L)	<0.01	0.02	<0.01	<0.01
Zinc-Total (mg/L)			<0.01	<0.01

Source: Powertech 2008 Class III UIC Permit Application, Appendix F

TABLE D-4 Local Water Quality Data - Inyan Kara Group (Lakota and Fall River Formations)

		Mean			Minimum			Maximum		
	Well	Powertech	TVA	RPD	Powertech	TVA	RPD	Powertech	TVA	RPD
Alkalinity as CaCO3, mg/L	2	181	219	19%	88	200	78%	214	242	12%
	7	171	181	6%	170	171	1%	176	191	8%
	8	166	178	7%	156	166	6%	178	194	9%
	13	159	173	8%	142	160	12%	170	196	14%
	16	153	152	1%	148	144	3%	160	157	2%
	18	179	196	9%	172	180	5%	184	238	26%
	42	178	188	5%	174	179	3%	180	204	13%
	4002	140	158	12%	138	144	4%	144	202	34%
	7002	261	261	0%	250	210	17%	280	300	7%
Conductivity, uS/cm	2	2285	1547	39%	1500	1450	3%	4400	1750	86%
	7	1542	1338	14%	1440	1325	8%	1650	1350	20%
	8	1450	1385	5%	1420	1285	10%	1560	1450	7%
	13	1292	1274	1%	1140	1100	4%	1420	1400	1%
	16	1063	1162	9%	925	1150	22%	1260	1175	7%
	18	1412	1379	2%	1330	1300	2%	1470	1420	3%
	42	1408	1353	4%	1310	1200	9%	1510	1400	8%
	4002	1220	1161	5%	1130	1100	3%	1340	1195	11%
	7002	2328	2339	0%	2200	1925	13%	2480	2500	1%
pH	2	7.91	7.7	3%	7.85	7.16	9%	7.94	8.2	3%
	7	8.11	8.5	5%	8.05	8.3	3%	8.17	8.7	6%
	8	7.95	7.87	1%	7.93	7.59	4%	7.97	8.5	6%
	13	7.9	7.76	2%	7.75	7.48	4%	8.05	8.1	1%
	16	7.46	7.34	2%	7.38	7.31	1%	7.57	7.39	2%
	18	8.08	7.94	2%	8.02	7.69	4%	8.11	8.4	4%
	42	8.02	7.94	1%	7.95	7.67	4%	8.08	8.4	4%
	4002	7.83	7.75	1%	7.65	7.51	2%	8.02	8.5	6%
	7002	7.36	7.44	1%	7.22	7.14	1%	7.56	8	6%
Total Dissolved Solids	2	1750	1043	51%	1100	1004	9%	3600	1113	106%
	7	999	1081	8%	896	1058	17%	1050	1104	5%
	8	1000	965	4%	940	860	9%	1100	1130	3%
	13	878	886	1%	850	792	7%	890	1006	12%
	16	814	846	4%	760	796	5%	940	894	5%
	18	958	909	5%	940	520	58%	990	1118	12%
	42	950	939	1%	930	888	5%	980	1033	5%
	4002	818	773	6%	790	740	7%	850	805	5%
	7002	1875	1843	2%	1800	1690	6%	1900	1970	4%
RPD (Relative Percent Difference) = The absolute difference divided by the average.										

Source: Table 2.7-45: Comparison of Statistics for Selected Constituents between Historic TVA Data and current Powertech Data (2009 Powertech NRC Application)



Legend

Dewey-Burdock Permit Boundary

N

From:
Water-Resources Investigations Report 01-4194
by Joyce E. Williamson and Janet M. Carter, 2001

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Figure D-1
Distribution of Hydrogeologic Units
in the Black Hills Area
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_Fig_D-01.ai	By: JLM	Checked: HD

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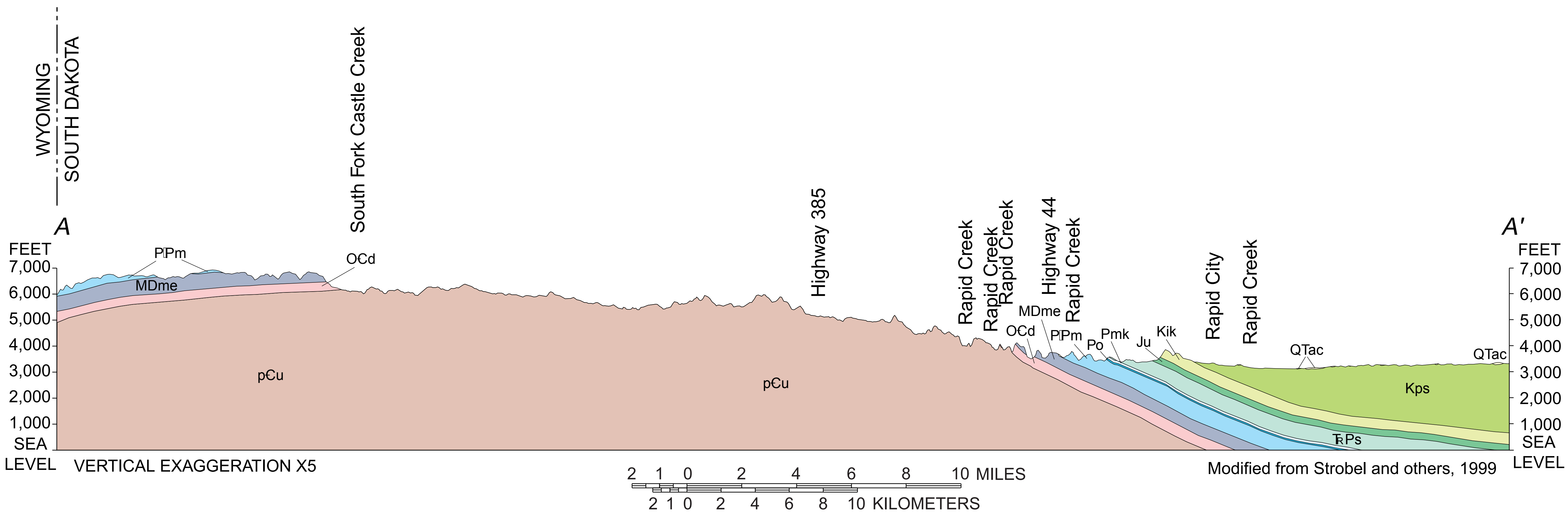

EXPLANATION

Hydrogeologic Units	Stratigraphic Units	Map Units
Unconsolidated units	QTac	Alluvium and colluvium, undifferentiaed
White River aquifer	Tw	White River Group
Tertiary intrusive units	Tui	Undifferentiated intrusive igneous rocks
Cretaceous-sequence confining unit	Kps	Pierre Shale to Skull Creek Shale, undifferentiated
Inyan Kara aquifer	Kik	Inyan Kara Group
Jurassic-sequence semiconfining unit	Ju	Morrison Formation to Gypsum Spring Formation, undifferentiated
Spearfish confining unit	TRPs	Spearfish Formation
Minnekahta aquifer	Pmk	Minnekahta Limestone
Opeche confining unit	Po	Opeche Shale
Minnelusa aquifer	PPm	Minnelusa Formation
Madison aquifer	MDme	Madison (Pahasapa) Limestone and Englewood Formation
Ordovician-sequence semiconfining unit	Ou	Whitewood Formation and Winnipeg Formation
Deadwood aquifer	OCd	Deadwood Formation
Precambrian igneous and metamorphic units	pCu	Undifferentiated metamorphic and igneous rocks

From:
Water-Resources Investigations Report 01-4194
(after Stobel et al., 1999, Modified by Driscoll et al., 2002)

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Figure D-2
Generalized East-West Geologic Cross Section through Black Hills Uplift (A-A')
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-2.ai	By: JLM	Checked: HD

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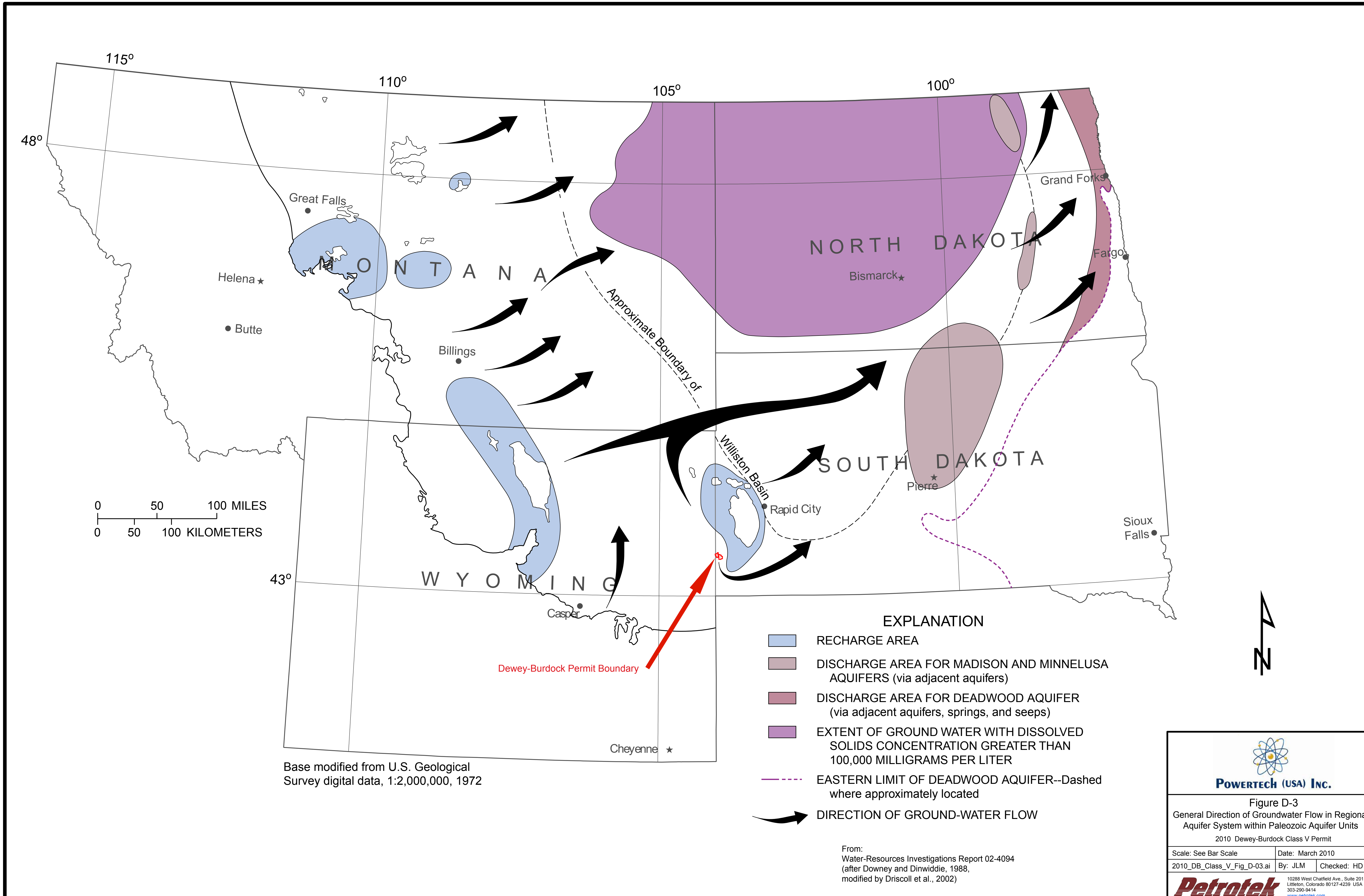
115°
110°
105°
100°
48°
43°
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
Great Falls
Helena
Butte
Billings
Bismarck
Grand Forks
Fargo
Pierre
Rapid City
Sioux Falls
Casper
Cheyenne
Approximate Boundary of Williston Basin
Dewey-Burdock Permit Boundary
0 50 100 MILES
0 50 100 KILOMETERS
N
EXPLANATION
RECHARGE AREA
DISCHARGE AREA FOR MADISON AND MINNELUSA AQUIFERS (via adjacent aquifers)
DISCHARGE AREA FOR DEADWOOD AQUIFER (via adjacent aquifers, springs, and seeps)
EXTENT OF GROUND WATER WITH DISSOLVED SOLIDS CONCENTRATION GREATER THAN 100,000 MILLIGRAMS PER LITER
EASTERN LIMIT OF DEADWOOD AQUIFER--Dashed where approximately located
DIRECTION OF GROUND-WATER FLOW
Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972
From:
Water-Resources Investigations Report 02-4094
(after Downey and Dinwiddie, 1988,
modified by Driscoll et al., 2002)
POWERTECH (USA) INC.
Figure D-3
General Direction of Groundwater Flow in Regional Aquifer System within Paleozoic Aquifer Units
2010 Dewey-Burdock Class V Permit
Scale: See Bar Scale
Date: March 2010
2010_DB_Class_V_Fig_D-03.ai
By: JLM
Checked: HD
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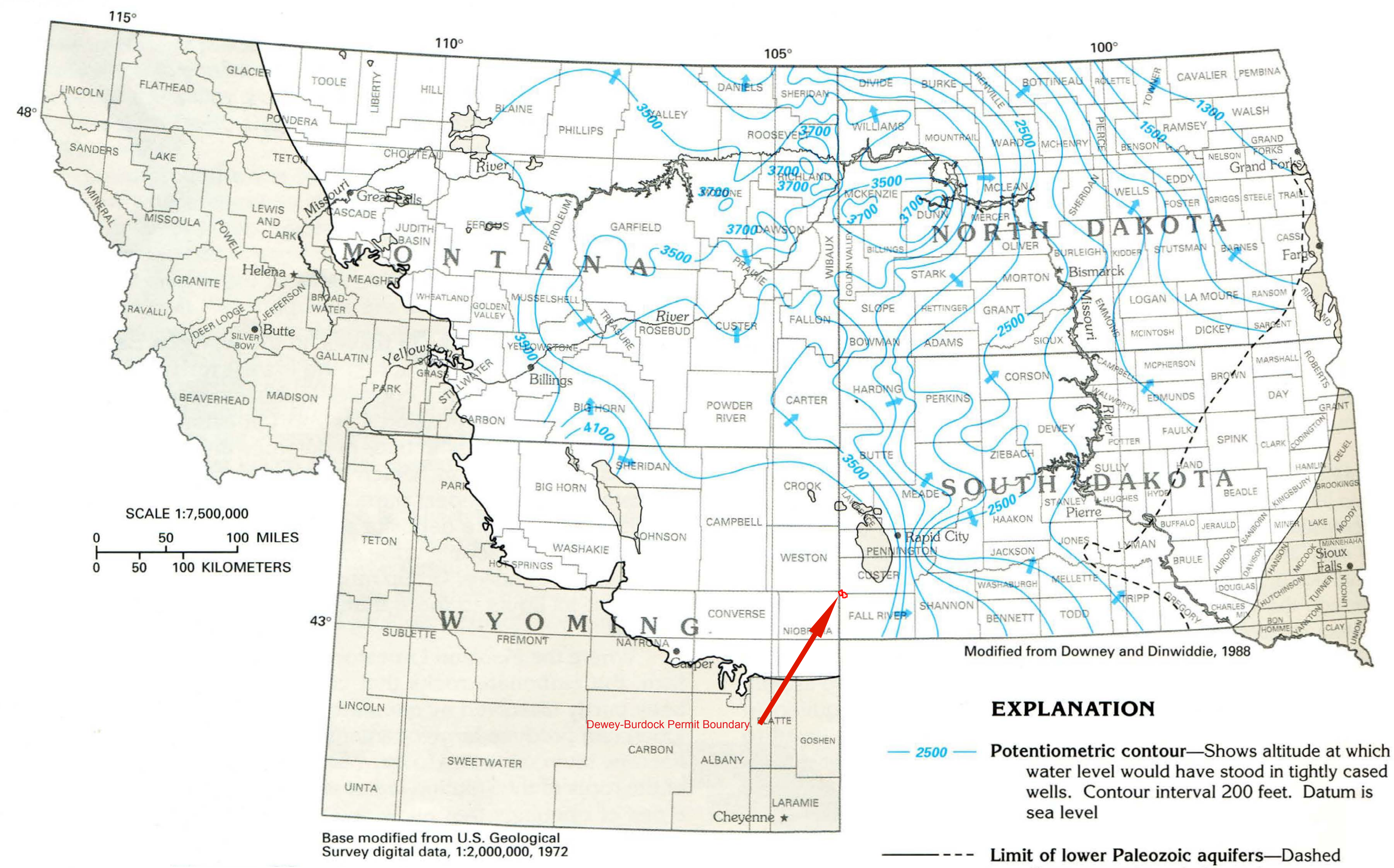

EXPLANATION

— 2500 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Contour interval 200 feet. Datum is sea level

——— - - - **Limit of lower Paleozoic aquifers**—Dashed where approximately located

Direction of ground-water movement

From:
Ground Water Atlas of the United States,
Segment 8 MT, SD. ND & WY,
Hydrologic Investigations Atlas 730-I USGS
(by Whitehead, 1996)

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Figure D-4
Regional Groundwater Flow in Lower Paleozoic Aquifer System, Powder River and Williston Basins

2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_D-04.ai	By: JLM / Checked: HD

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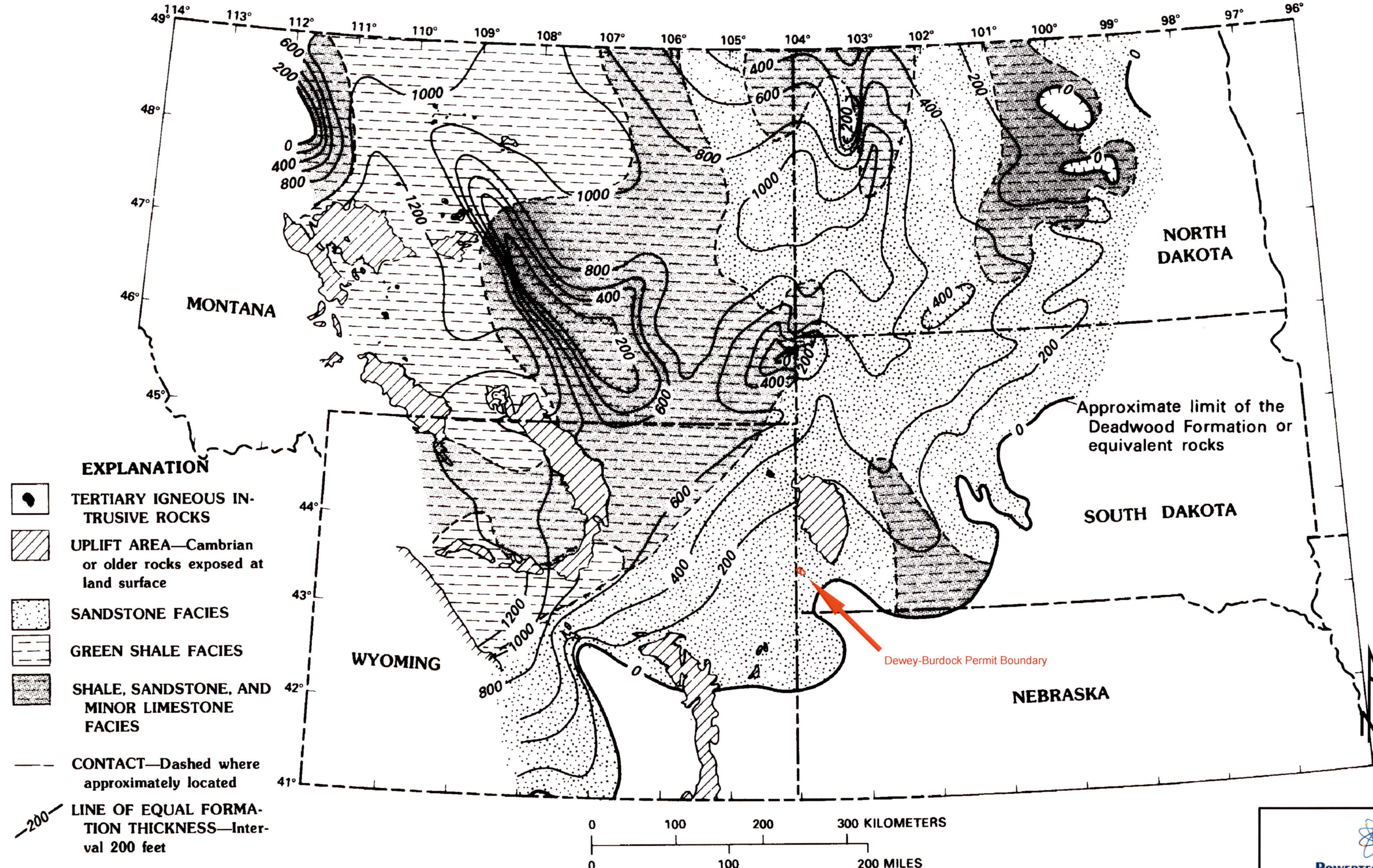

From:
Geological Survey Professional Paper 1273-A
Peterson, 1984

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Figure D-5
Isopach Map,
Deadwood Formation
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-05.ai	By: JLM	Checked: HD

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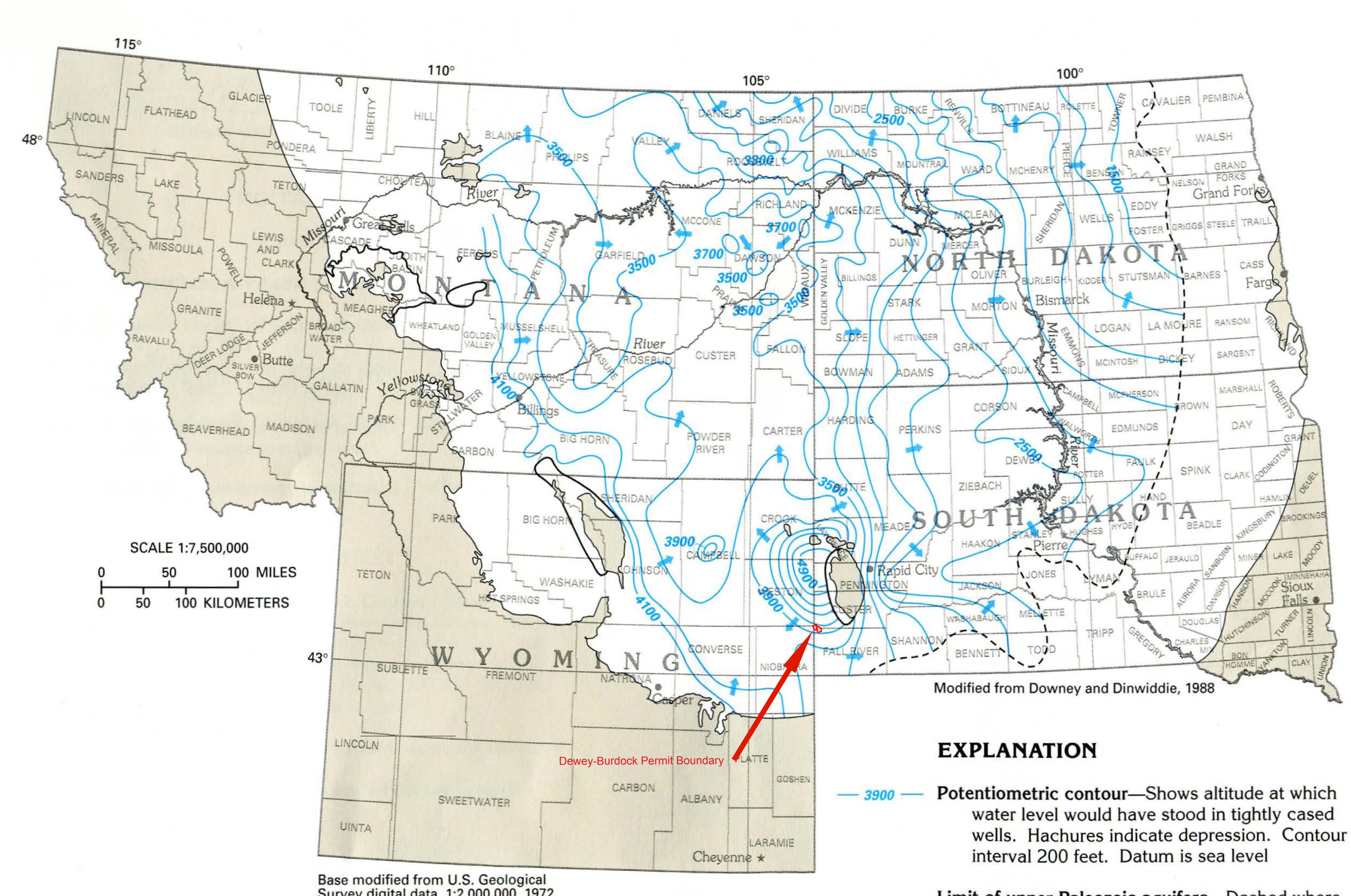

EXPLANATION

— 3900 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Hachures indicate depression. Contour interval 200 feet. Datum is sea level

——— - - - **Limit of upper Paleozoic aquifers**—Dashed where approximately located

➡ **Direction of ground-water movement**

From:
Ground Water Atlas of the United States, Segment 8 MT, SD. ND & WY, Hydrologic Investigations Atlas 730-I USGS (by Whitehead, 1996)

POWERTECH (USA) INC.

Figure D-6
Regional Groundwater Flow Pattern in Upper Paleozoic Aquifer System, Powder River and Williston Basins
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_D-06.ai	By: JLM / Checked: HD

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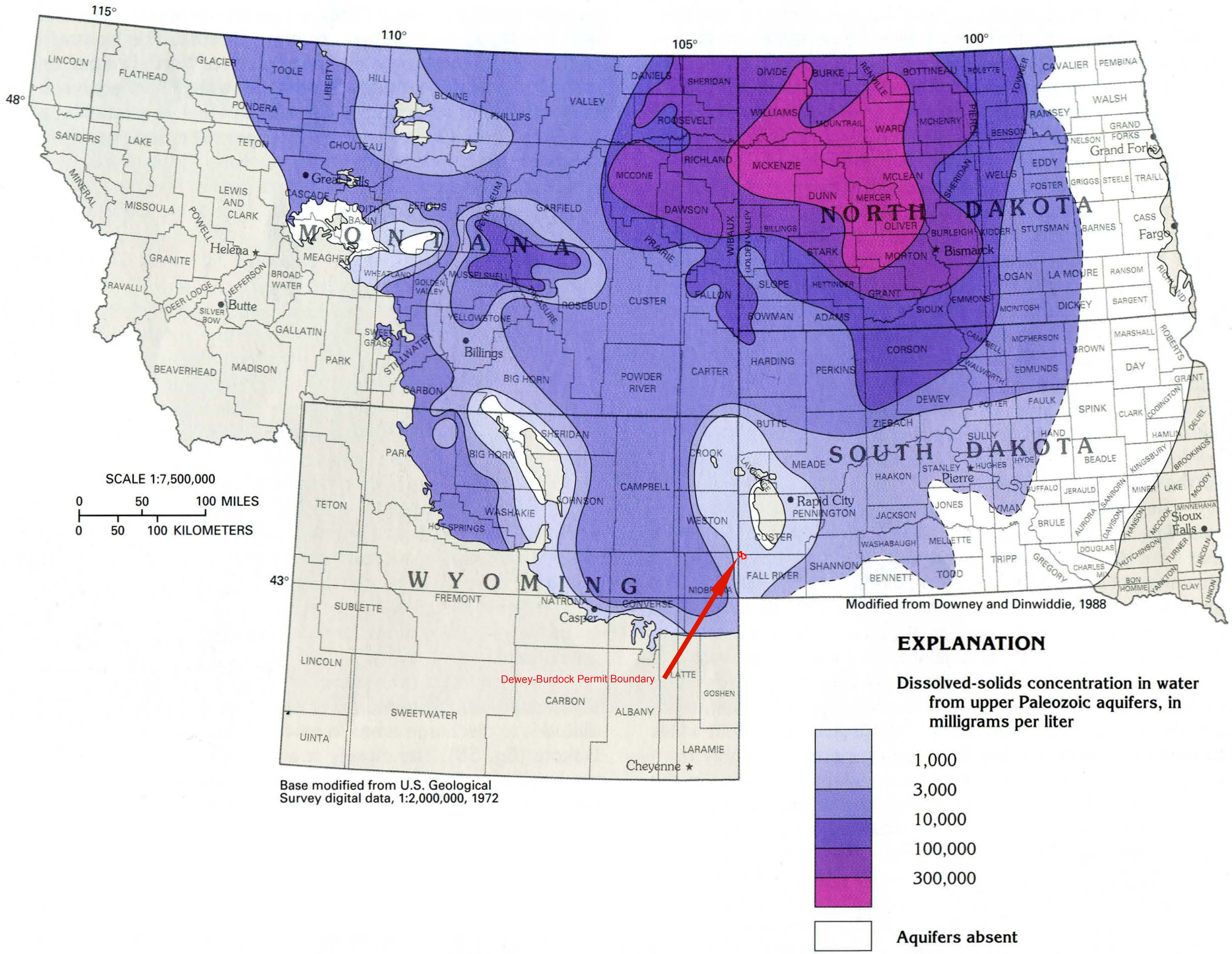

From:
Ground Water Atlas of the United States,
Segment 8 MT, SD. ND & WY,
Hydrologic Investigations Atlas 730-I USGS
(by Whitehead, 1996)

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Figure D-7
Dissolved Solids Concentrations in Upper Paleozoic Aquifer System, Powder River and Williston Basins
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-07.ai	By: JLM	Checked: HD

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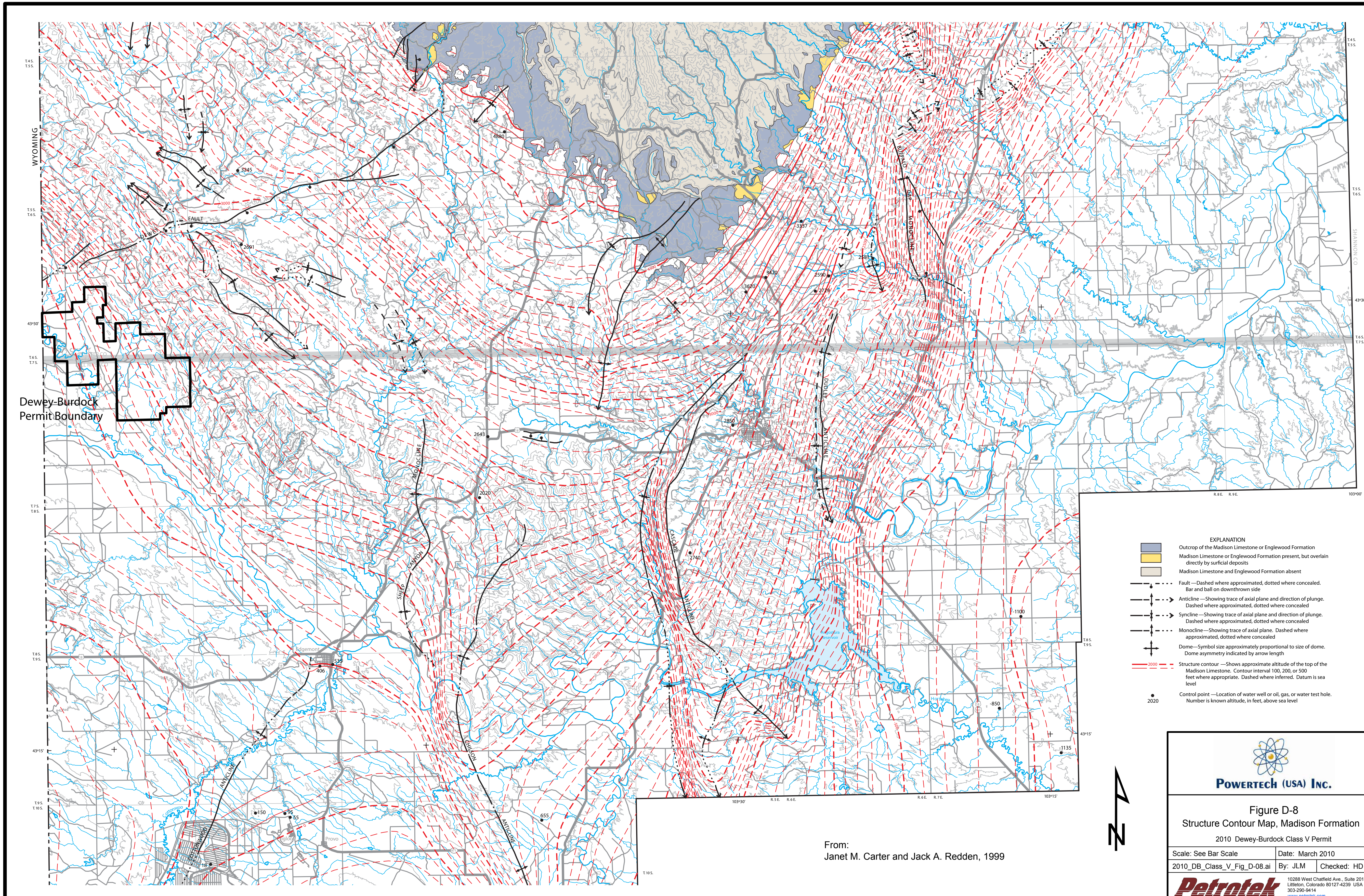
WYOMING
Dewey-Burdock
Permit Boundary
FAULT
DEWEY
MONOCLINE
SHEEP CANYON
CHILSON
ANTICLINE
CASCADE
DUDLEY
BUFFALO GAP
COTTONWOOD
Edgemont
Provo
SHANNON CO
From:
Janet M. Carter and Jack A. Redden, 1999
EXPLANATION
Outcrop of the Madison Limestone or Englewood Formation
Madison Limestone or Englewood Formation present, but overlain directly by surficial deposits
Madison Limestone and Englewood Formation absent
Fault —Dashed where approximated, dotted where concealed. Bar and ball on downthrown side
Anticline —Showing trace of axial plane and direction of plunge. Dashed where approximated, dotted where concealed
Syncline —Showing trace of axial plane and direction of plunge. Dashed where approximated, dotted where concealed
Monocline—Showing trace of axial plane. Dashed where approximated, dotted where concealed
Dome—Symbol size approximately proportional to size of dome. Dome asymmetry indicated by arrow length
2000
Structure contour —Shows approximate altitude of the top of the Madison Limestone. Contour interval 100, 200, or 500 feet where appropriate. Dashed where inferred. Datum is sea level
2020
Control point —Location of water well or oil, gas, or water test hole. Number is known altitude, in feet, above sea level
N
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Figure D-8
Structure Contour Map, Madison Formation
2010 Dewey-Burdock Class V Permit
Scale: See Bar Scale
Date: March 2010
2010_DB_Class_V_Fig_D-08.ai
By: JLM
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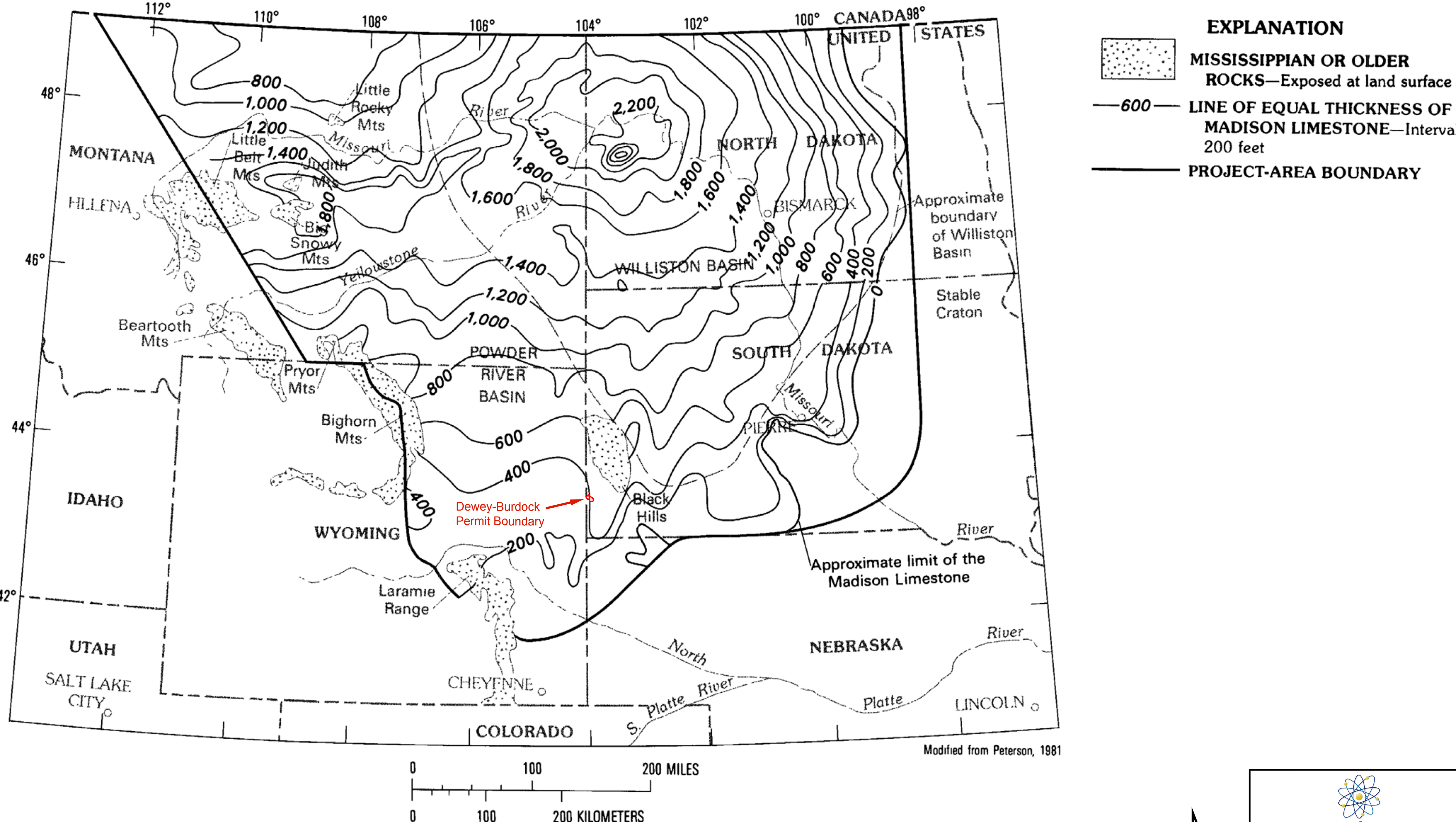

From:
USGS Professional Paper #1402 F

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Figure D-9
Isopach Map, Madison Formation
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-09.ai	By: JLM	Checked: HD

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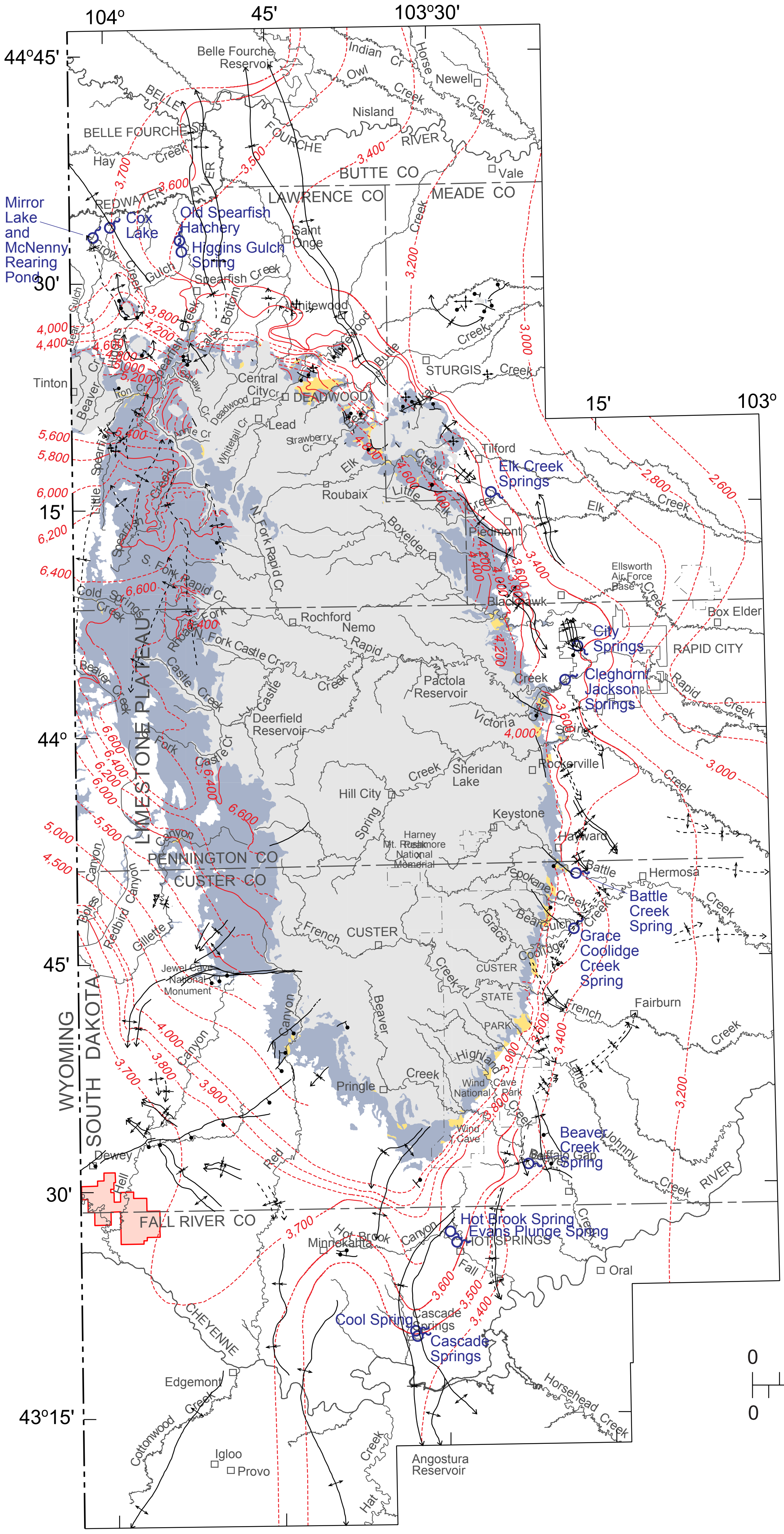

Base modified from U.S. Geological Survey digital data, 1:100,000, 1977, 1979, 1981, 1983, 1985
Rapid City, Office of City Engineer map, 1:18,000, 1996
Universal Transverse Mercator projection, zone 13

EXPLANATION

- OUTCROP OF MADISON LIMESTONE (from Strobel and others, 1999)
- MADISON LIMESTONE PRESENT, BUT OVERLAIN BY SURFICIAL DEPOSITS (from Carter and Redden, 1999d)
- MADISON LIMESTONE ABSENT (from Carter and Redden, 1999d)
- 3,000 POTENTIOMETRIC CONTOUR--Shows altitude at which water would have stood in tightly cased, nonpumping wells (modified from Strobel and others, 2000a). Contour interval 100, 200, or 500 feet, where appropriate. Dashed where inferred. Datum is sea level
- FAULT--Dashed where approximated. Bar and ball on downthrown side
- ANTICLINE--Showing trace of axial plane and direction of plunge. Dashed where approximated
- SYNCLINE--Showing trace of axial plane and direction of plunge. Dashed where approximated
- MONOCLINE--Showing trace of axial plane. Dashed where approximated
- DOME--Symbol size approximately proportional to size of dome. Dome asymmetry indicated by arrow length
- ARTESIAN SPRING

Legend

Dewey-Burdock Permit Boundary

From:
Water-Resources Investigations Report 02-4094
(modified by Driscoll et al., 2002)

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Figure D-10
Potentiometrc Surface of the Madison Formation and Locations of Major Artesian Springs
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_D-10.ai	By: JLM	Checked: HD

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