

**KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 2002-71**

**ANALYSES OF DATA FROM VENT WELLS AROUND YAGGY GAS
STORAGE FACILITY, HUTCHINSON, KANSAS**

by

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**Analyses of data from vent wells around Yaggy Gas Storage
facility, Hutchinson Kansas**

**Kansas Geological Survey
Open File Report No. 2002- 71
(In preparation for publication)**

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Introduction

This report is a follow-up to KGS OFR 2001-68. The vent wells located in Hutchinson city and around the Yaggy Gas Storage facility were monitored through 2002. Shut-in pressures were recorded at the surface for both Group 1 and Group 2 wells. In addition, fluid columns were recorded under shut-in conditions for both the groups. These data were analyzed to map the sub-surface pressure in the 3-Fingers zone. Recommendations were designed, based on these analyses, to plug wells that were considered as ineffective vents.

Analyses of data – Group 1 wells

Wells included in this group had either flowed gas and/or still record pressures at the surface upon shut-in. These wells were shut-in for periods varying between 70-96 hrs in January 2002, and surface pressures were recorded along with standing fluid columns. In most wells, this shut-in period was extended to about 400 hrs, and this was followed by another round of recording of surface shut-in pressures along with fluid level measurements (February 2002 survey). Tables 1 and 2 list the recorded shut-in pressures at the surface with the corresponding fluid levels in the surveys carried out in January and February 2002. For purposes of comparisons, the shut-in pressures and fluid columns recorded in Aug 2001, and January 2002, and February 2002 are listed in Table 3.

$$\text{Pressure in 3-Fingers (psi)} = \text{surface shut-in pressure (psi)} + (\text{height of fluid column above 3-Fingers, ft}) * 0.5 \quad (\text{A})$$

The average water gradient, measured in multiple surveys in these wells, was found to be close to 0.5 psi/ft. It becomes apparent from Table 3, the significant increases in surface pressures occur in only three wells, namely DDV #36, #42, and OB #3 when the shut-in period is extended beyond 76.8, 73, and 95.5 hours respectively. Thus, for the vast majority of wells, a shut-in time close to (or above) 70 hours is sufficient to record a stable surface pressures. For the 3 wells (mentioned above) that do show an increase,

future shut-in periods must be accordingly adjusted in order to obtain stabilized surface pressure readings. Table 3 also tabulates the wells, in a descending order, according to the changes in pressures at the 3-Fingers zone between August 2001 and January 2002. The January 2002 readings were used in this comparison as opposed to February 2002 because the shut-in time periods in the August and January surveys were similar. It appears that all the wells listed between DDV #5 and #53 show a pressure increase greater than 5 psi. This increase in the calculated pressure at the 3-Fingers can occur due to an increase in gas pressure in the zone and/or due to increase in the fluid columns standing in the wells (possibly due to seepage from uncased intervals above the 3-Fingers zone). However when the THSP (tubing head shut-in pressure) is greater than 0 psi, the increase in calculated pressure in the 3-Fingers is certainly due to increase in gas pressure in this zone. Thus, the increases in the sub-surface pressures in the 3-Fingers zone at DDV #5, #17, #4, and #44 are due to higher standing fluid columns in the wells in January 2002 as opposed to August 2001. Cross-checking the well history files revealed that DDV #5, #17, and #4 were indeed filled up with water in order to run wireline logs. For the wells DDV #43, #54, #67, #36, #42, #12, #55, and #53, the sub-surface gas pressure increased from anywhere between 6 psi to 74 psi. For wells DDV #64, #68, #70, and OB #3, and #2, there was a decline in the sub-surface gas pressure in the 3-Fingers zone between August 2001 and January 2002. However, when these wells were shut-in for periods exceeding 70 hours, a THSP greater than 10 psi (and as high as 191 psi) was recorded in each of these wells even as late as January 2002. Thus despite gas pressure declines in the 3-Fingers zone, these wells still show significant shut-in pressures at the surface. The distribution of sub-surface shut-in pressures in the 3-Fingers zone, as of January 2002, is shown in Figure 1. This map shows that few pressure pockets remain in the 3-Fingers under the city of Hutchinson. However, the pressures in these pockets are sub-hydrostatic. The sub-surface gas pressure in the 3-Fingers is highest under the area that extends from the northwestern boundary of the city to the Yaggy storage facility. However, it is important to note that though the pressures are relatively higher here, it is still remains sub-hydrostatic.

Table 4 lists the results of the shut-in survey carried out in July 2002. As before, the THSPs and the fluid column above the 3-Fingers zone were used (equation A) to calculate the sub-surface gas pressure. For wells where THSP = 0 (or close to zero), the calculated pressure for the 3-Fingers zone could be representative of the fluid column standing in the well. A comparison of the sub-surface pressures calculated in January 2002 with that in July 2002 reveals that pressures declined for an overwhelming majority of the wells. DDV#55 was the only well, with a non-zero THSP, where the calculated pressure increased by 25 psi. This indicates that the vent wells were bleeding off sub-surface pressure albeit very slowly. Figure 2 maps the distribution of calculated sub-surface pressure in the 3-Fingers as of July 2002. Figure 3 provides a perspective comparison of the sub-surface pressure maps in the study area between March 2001 and July 2002.

An effort was made to identify wells in the Group 1 list that could be considered as candidates for plugging. Table 5 lists the Group 1 wells in an ascending order as per the calculated shut-in pressures in the 3-Fingers zone. The selection criteria for active wells was that the calculated sub-surface pressure should be greater than 100 psi with the THSP being greater than 0 psi. These wells were regarded as “active” in the sense that the pressure in the 3-Fingers in their vicinity was above 100 psi (though sub-hydrostatic). Also, upon shut-in these well recorded a non-zero THSP (> zero) which implied that some gas was still managing to flow into the well bore by overcoming the back pressure created by the standing fluid column in the well. Thus, the active wells which would be kept open for further observation includes all the OB wells and also DDV # 53, # 64, #67, #12, #36, #5, #68, and #42. All wells in Group 1 other than these active wells were recommended for plugging.

Analyses of data – Group 2 wells

These wells had never flowed any measurable quantities of gas and/or recorded a significant THSP upon shut-in since the time of their drilling. Table 6 lists the shut-in pressures at the surface along with the fluid levels standing in these wells. The shut-in

surface pressure and the fluid column were used (equation A) to calculate the pressure in the 3-Fingers zone. As stated earlier, this calculated pressure could be attributed to gas present in the vicinity of the well only when the THSP at the well was greater than zero (with the non-zero reading being above the resolution of the scale of the pressure gauge). For wells with THSP = 0 psi, this analysis cannot be used to determine if gas is present in the vicinity of the well bore. All the calculated pressures were sub-hydrostatic. Drilling records indicate that all Group 2 wells were unloaded after completion of drilling. However, none of them flowed measurable quantities of gas at the surface under unloaded conditions. Thus, it was decided that all but 4 wells would be recommended for plugging. Wells recommended to be kept open for further observation included DDV #2, #26, #45, and #50. THSPs at these wells varied between 4 to 32 psi, and these values were comparatively higher than what was recorded for the vast majority of wells in Group 2.

The Group 2 wells were kept shut-in since December 2001, and were tested for THSPs in July 2002 after more than 4500 hrs of shut-in. However, K-Gas (Kansas Gas Service) did not record fluid levels at these wells during this survey. Thus, the recorded data could not be used to calculate the pressure at the 3-Fingers zone as of July 2002.

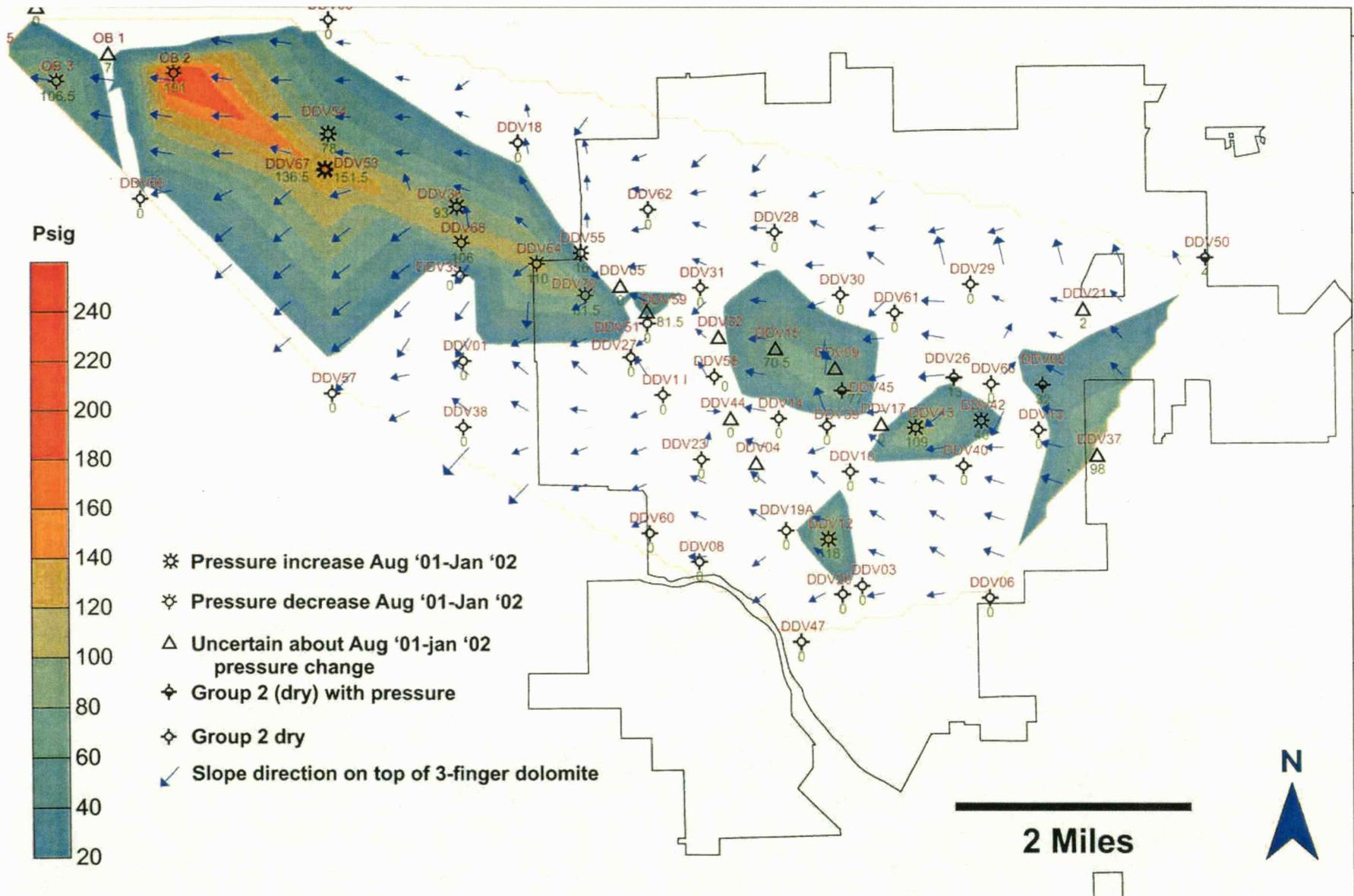


Figure 1

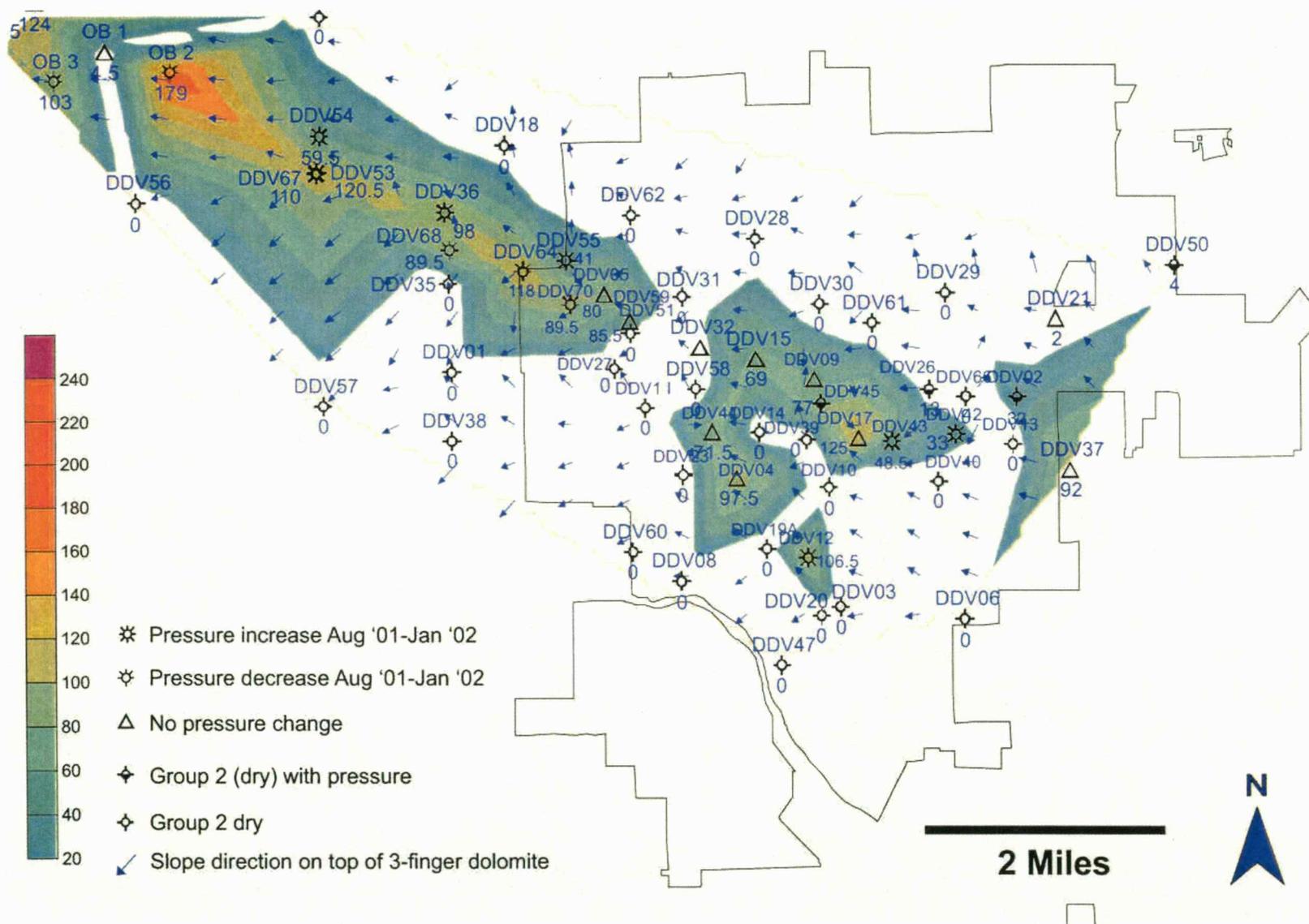


Figure 2

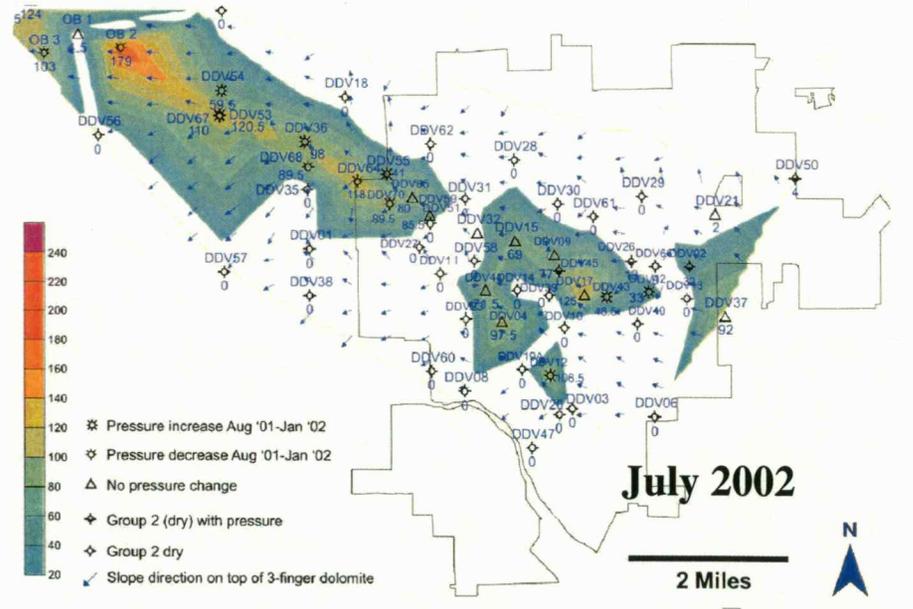
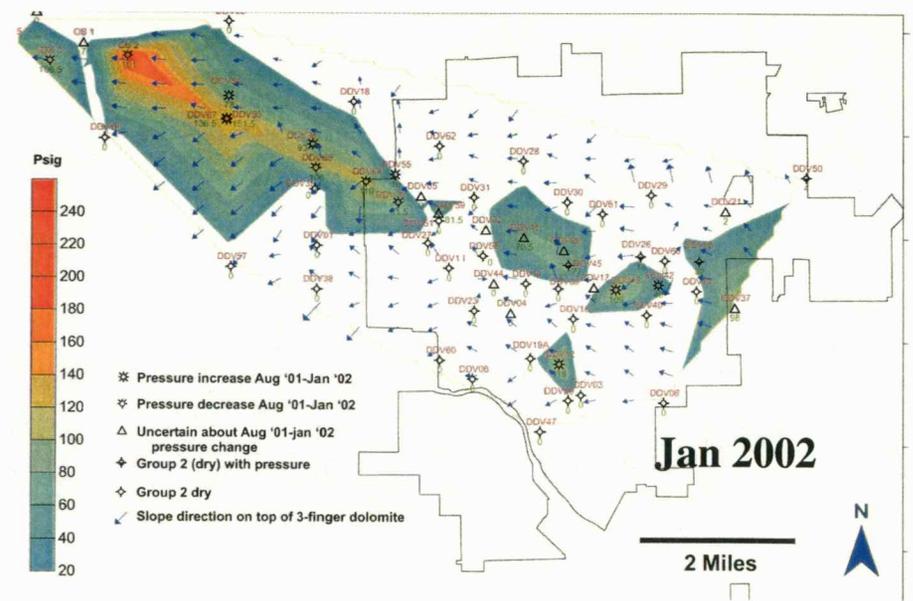
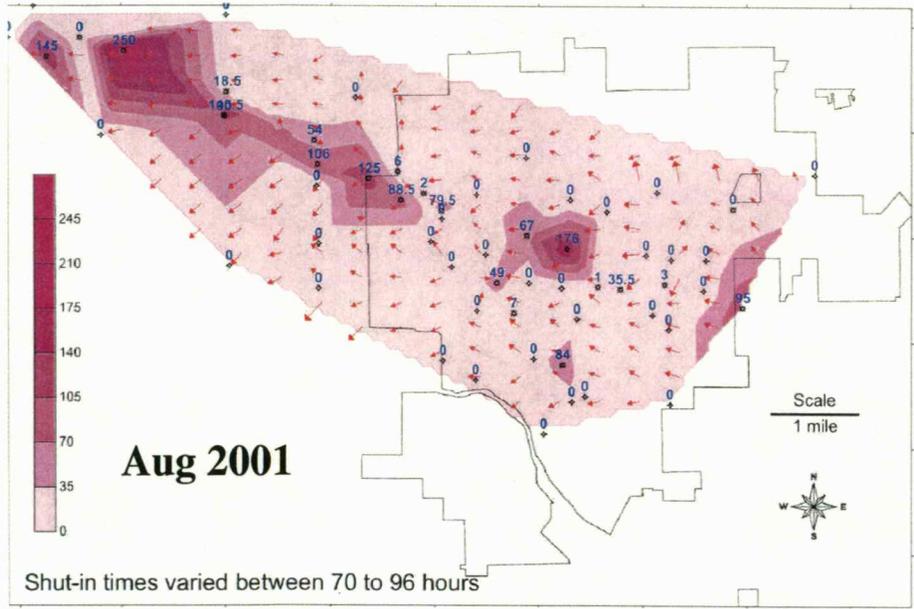
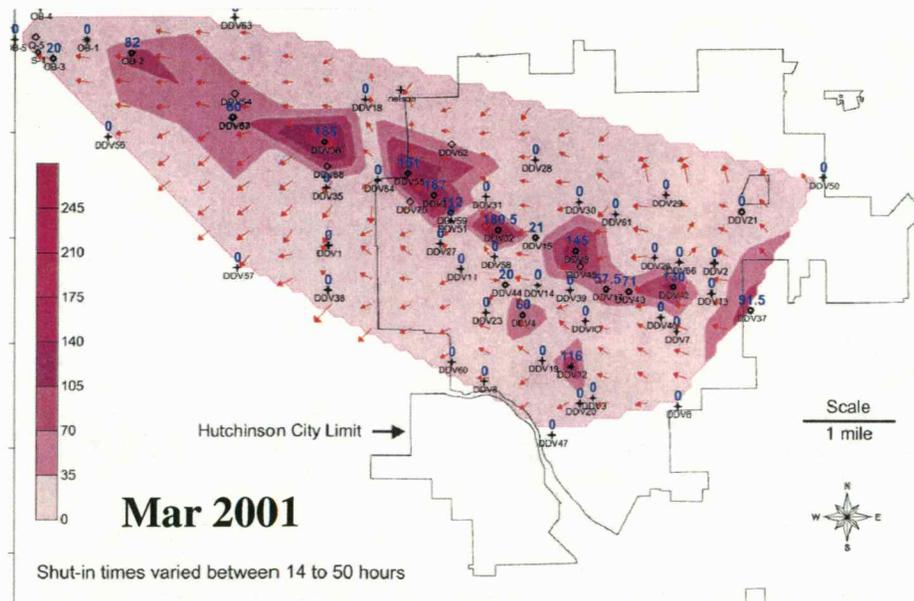


Figure 3

Table 1														
Results from Jan 2002 tests														
Well	Elevation	Csg depth, ft	TD reached ft	SI time hrs	THSP/CHSP		BHSP		Data quality check		Top of 3F ft	Wtr column above Gas, ft	Pr @ 3F zone, psi	Comments
					Surface Pr shutin, psig	Water level, ft	Static Pr at TD, psig	BHSP- (THSP+wtr col)						
DDV #4	1529	243	574	74.08	0	55	280	21	278	223	112			
DDV #5	1540	201	561	75.08	0	20	265	-6	310	290	145			
DDV #9	1532	201		81.00	43			-43	286					
DDV #12	1523	201	204	73.92	12	50	72	-17	262	212	118		3F>>TD. TD, Wtr level, pr @ TD N/A.	
DDV #15	1535	205	546	74.58	4	153	204	4	286	133	71		3F >>TD	
DDV #17	1529	201	558	73.67	0	15	282	11	270	255	128			
DDV #21	1522	216	478	72.00	2	295	77	-17	235	0	2			
DDV #32									299				No above grd well head	
DDV #36	1547	201	571	76.83	37	210	222	5	322	112	93			
DDV #37	1522	201	546	72.67	0	38	264	10	234	196	98			
DDV #42	1525	202	550	73.00	40	270	162	-18	248	0	40			
DDV #43	1528	202	551	73.25	17	78	227	-27	262	184	109			
DDV #44	1532	202	536	74.33	0	130	194	-9	291	161	81			
DDV #53	1559	202	585	94.33	96	230	248	-26	341	111	152			
DDV #54	1557	202	570	94.67	7	200	167	-25	342	142	78			
DDV #55	1546	208	482	75.67	6	295	87	-13	315	20	16			
DDV #59	1537	202	170	75.00	1	139	17	1	300	161	82		3F>>TD	
DDV #64	1541	201	582	76.00	35	150	268	17	300	150	110			
DDV #67	1556	201	569	98.30	104	273	240	-12	338	65	137			
DDV #68	1545	201	524	76.33	77	253	200	-13	311	58	106			
DDV #70	1540	202	548	75.33	10	165	213	12	308	143	82			
OB #1	1569	250	454	95.17	0	380	33	-4	394	14	7			
OB #2	1564	536	460	95.00	191		187	-4	387	0	191			
OB #3	1579	537	599	95.50	19	232			407	175	107			
OB #4	1574	539	550	96.17	0	217			427	210	105			
OB #5	1570	538	612	95.92	1	310			430	120	61			

NOTE :These fluid levels are from the casing-tubing annulus because the 3-Fingers is open to the annulus in OB #2 to #5.

Table 2														
Results from Feb 2002 tests														
Well	Elevation	Csg depth, ft	TD reached ft	SI time hrs	THSP/CHSP		BHSP		Data quality check		Top of 3F ft	Wtr column above Gas, ft	Pr @ 3F zone, psi	Comments
					Surface Pr shutin, psig	Water level, ft	Static Pr at TD, psig	BHSP- (THSP+wtr col)						
DDV #4	1529	243	574	410.50	0	44	265	0	0	278	234	117		
DDV #5	1540	201	561	432.92	0	40	245	-16	310	270	135			
DDV #9	1532	201	60	413.00	43	10	70	2	286	276	181	3F >> TD. Wtr level present - unsure		
DDV #12	1523	201	204	410.33	23	34	80	-28	262	228	137	3F >> TD. Wtr level available		
DDV #15	1535	205	546	411.17	20	182	192	-10	286	104	72			
DDV #17	1529	201	558	410.00	0	33	276	14	270	237	119			
DDV #21	1522	216	478	408.67	2	332	79	4	235	0	2			
DDV #32									299				No above grd well head	
DDV #36	1547	201	571	434.00	104	260	250	-10	322	62	135			
DDV #37	1522	201	546	409.80	0	15	264	-2	234	219	110			
DDV #42	1525	202	550	409.42	93	306	208	-7	248	0	93			
DDV #43	1528	202	551	409.67	30	106	233	-20	262	156	108			
DDV #44	1532	202	536	410.83	11	132	203	-10	291	159	91			
DDV #53	1559	202	585	434.22	119	304	247	-13	341	37	138			
DDV #54	1557	202	570	434.67	28	220	182	-21	342	122	89			
DDV #55	1546	208	482	433.00	36	309	116	-7	315	6	39			
DDV #59	1537	202	170	432.75	19	165	28	7	300	135	87	3F >> TD		
DDV #64	1541	201	582	433.42	53	160	270	6	300	140	123			
DDV #67	1556	201	569	292.33	125				338			125	Buildup for 292hrs. Wtr level not recorded	
DDV #68	1545	201	524	76.33	77	253	200	-13	311	58	106		Buildup for 76 hrs only	
DDV #70	1540	202	548	434.25	22	200	212	16	308	108	76			
OB #1	1569	250	453	452.93	0	383	34	-1	394	11	6			
OB #2	1564	536	460	436.50	191		187	-4	387	0	191			
OB #3	1579	537	599	453.50	82	248			407	159	162			
OB #4	1574	539	550	434.33	0	217			427	210	105			
OB #5	1570	538	614	435.17	2	310			430	120	62			

NOTE :These fluid levels are from the casing-tubing annulus because the 3-Fingers is open to the annulus in OB #2 to #5.

Table 3																				
Well	Aug-01			Aug-01			Jan-02			Jan-02			Feb-02		Feb-02		Jan-Feb 02		Jan02 Aug 01	
	SI time	wtr col	THSP	Pr @ 3F	SI time	wtr col	THSP	Pr @ 3F	SI time	THSP	Pr @ 3F	SI time	THSP	Pr @ 3F	Increase 3F Pr					
	hrs	above 3F		zone, psi	hrs	above 3F		zone, psi	hrs		zone, psi	hrs		zone, psi	fr 70+ to 400+					
DDV #5	75	0	2	2	75.08	290	0	145	432.92	0	135				-10					143
DDV #17	73	0	1	1	73.67	255	0	128	410.00	0	119				-9					127
DDV #4	74	0	7	7	74.08	223	0	112	410.50	0	117				6					105
DDV #43	73	67	2	36	73.25	184	17	109	409.67	30	108				-1					74
DDV #54	77	17	10	19	94.67	142	7	78	434.67	28	89				11					60
DDV #67	77	0	90	90	98.30	65	104	137	292.33	125	125	atleast. Wtr n/a			-12					47
DDV #36	76	102	3	54	76.83	112	37	93	434.00	104	135				42					39
DDV #42	72	0	3	3	73.00	0	40	40	409.42	93	93				53					37
DDV #12	73	132	18	84	73.92	212	12	118	410.33	23	137									34
DDV #44	70	96	1	49	74.33	161	0	81	410.83	11	91				10					32
DDV #55	76	0	6	6	75.67	20	6	16	433.00	36	39				23					10
OB #1	96	0	0	0	95.17	14	0	7	452.93	0	6				-2					7
DDV #53	76	81	105	146	94.33	111	96	152	434.22	119	138				-14					6
DDV #15	74	104	15	67	74.58	133	4	71	411.17	20	72				2					4
DDV #37	71	174	8	95	72.67	196	0	98	409.80	0	110				12					3
DDV #21	72	0	0	0	72.00	0	2	2	408.67	2	2				0					2
DDV #59	75	135	12	80	75.00	161	1	82	432.75	19	87				5					2
DDV #32	well head n/a								0.00											0
DDV #68	75		106	106	76.33	58	77	106	76.33	77		shutin<430 hrs								0
DDV #70	75	143	17	89	75.33	143	10	82	434.25	22	76				-6					-7
OB #4	97	248	0	124	96.17	210	0	105	434.33	0	105				0					-19
OB #5	96	186	0	93	95.92	120	1	61	435.17	2	62				1					-32
OB #2	95	0	0	250	95.00	0	191	191	436.50	191	191				0					-59
DDV #64	0		197	197	76.00	150	35	110	433.42	53	123				13					-87
OB #3	96	194	145	242	95.50	175	19	107	453.50	82	162				55					-136
DDV #9	>75 hrs	286	33	176	81.00		43		413.00	43	181									-176

Wells where sub-surface gas pressure increased in the 3-Fingers zone between Aug 2001 and January 2002.

Despite decline in sub-surface pressure in the 3-Fingers, these wells still show significant THSP as of January 2002.

Table 4														
Results from July 2002 tests														
Well	Elevation	Csg depth, ft	TD reached ft	SI time hrs	THSP/CHSP		BHSP		Data quality check		Top of 3F ft	Wtr column above Gas, ft	Pr @ 3F zone, psi	Comments
					Surface Pr shutin, psig	Water level, ft	Static Pr at TD, psig	BHSP- (THSP+wtr col)						
DDV #4	1529	243	574	74.00	11	105	247	2	278	173	98			
DDV #5	1540	201	561	75.00	0	150	212	7	310	160	80			
DDV #9	1532	201	63		39	1	64	-6	286				3F>>TD.	
DDV #12	1523	201	204	74.00	3	55	69	-9	262	207	107		3F >>TD	
DDV #15	1535	205	546	75.00	1	150	204	5	286	136	69			
DDV #17	1529	201	558	73.00	0	20	245	-24	270	250	125			
DDV #21	1522	216	478	72.00	2	310	101	15	235	0	2			
DDV #32									299				No above grd well head	
DDV #36	1547	201	571	93.00	37	200	219	-4	322	122	98			
DDV #37	1522	201	546	73.00	0	50	260	12	234	184	92			
DDV #42	1525	202	550	73.00	33	255	196	16	248	0	33			
DDV #43	1528	202	551	73.00	0	165	221	28	262	97	49			
DDV #44	1532	202	536	74.00	1	150	204	10	291	141	72			
DDV #53	1559	202	585	93.00	80	260	245	3	341	81	121			
DDV #54	1557	202	570	94.00	6	235	174	1	342	107	60			
DDV #55	1546	208	482	76.00	6	245	126	2	315	70	41			
DDV #59	1537	202	170	75.00	8	145	26	6	300	155	86		3F>>TD	
DDV #64	1541	201	582	76.00	18	100	267	8	300	200	118			
DDV #67	1556	201	569	93.00	66	250	217	-9	338	88	110			
DDV #68	1545	201	524	93.00	79	290	221	25	311	21	90			
DDV #70	1540	202	548	76.00	3	135	207	-3	308	173	90			
OB #1	1569	250	454	95.00	0	385	40	6	394	9	5			
OB #2	1564	536	460	95.00	179				387		179		No water in the well	
OB #3	1579	537	599	95.00	6	213			407	194	103		Annulus water level	
OB #4	1574	539	550	96	0	179			427	248	124		Annulus water level	
OB #5	1570	538	614	95	0	244			430	186	93		Annulus water level	

Table 5

Plugging candidates - Group 1 wells

Well	Elevation	Csg depth, ft	TD reached ft	SI time hrs	THSP/CHSP Surface Pr shutin, psig	Water level, ft	BHSP Static Pr at TD, psig	Data quality check BHSP- (THSP+wtr col)	Top of 3F ft	Wtr column above Gas, ft	Pr @ 3F zone, psi	Comments	
OB #2	1564	536	460	95.00	179				387		179	No water in the well	
DDV #17	1529	201	558	73.00	0	20	245		-24	270	250	125	
OB #4	1574	539	550	96	0	179				427	248	124	Annulus water level
DDV #53	1559	202	585	93.00	80	260	245		3	341	81	121	
DDV #64	1541	201	582	76.00	18	100	267		8	300	200	118	
DDV #67	1556	201	569	93.00	66	250	217		-9	338	88	110	
DDV #12	1523	201	204	74.00	3	55	69		-9	262	207	107	3F >>TD
OB #3	1579	537	599	95.00	6	213				407	194	103	Annulus water level
DDV #36	1547	201	571	93.00	37	200	219		-4	322	122	98	
DDV #4	1529	243	574	74.00	11	105	247		2	278	173	98	
OB #5	1570	538	614	95	0	244				430	186	93	Annulus water level
DDV #37	1522	201	546	73.00	0	50	260		12	234	184	92	
DDV #68	1545	201	524	93.00	79	290	221		25	311	21	90	
DDV #70	1540	202	548	76.00	3	135	207		-3	308	173	90	
DDV #59	1537	202	170	75.00	8	145	26		6	300	155	86	3F >>TD
DDV #5	1540	201	561	75.00	0	150	212		7	310	160	80	
DDV #44	1532	202	536	74.00	1	150	204		10	291	141	72	
DDV #15	1535	205	546	75.00	1	150	204		5	286	136	69	
DDV #54	1557	202	570	94.00	6	235	174		1	342	107	60	
DDV #43	1528	202	551	73.00	0	165	221		28	262	97	49	
DDV #55	1546	208	482	76.00	6	245	126		2	315	70	41	
DDV #42	1525	202	550	73.00	33	255	196		16	248	0	33	
OB #1	1569	250	454	95.00	0	385	40		6	394	9	5	
DDV #21	1522	216	478	72.00	2	310	101		15	235	0	2	
DDV #9	1532	201	63		39	1	64		-6	286			3F >>TD.
DDV #32										299			No above grd well head

