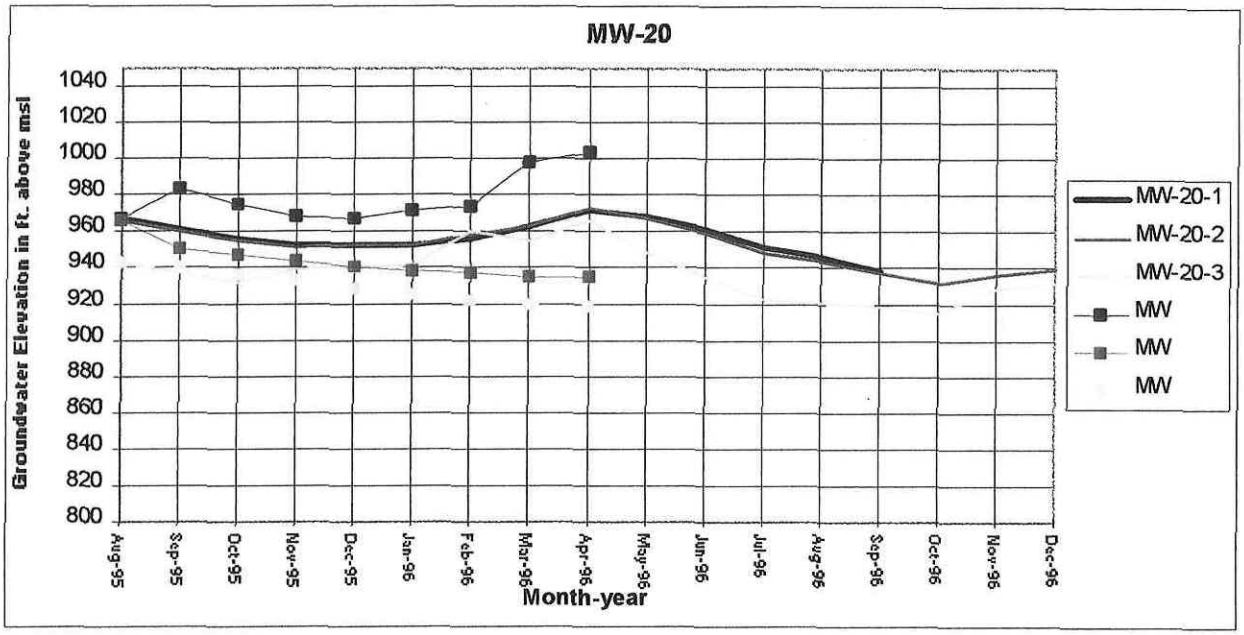
Observed vs. Simulated Piezometric Elevations-Refined Three Dimensional Calibration, Geologic Layers 1,2,3

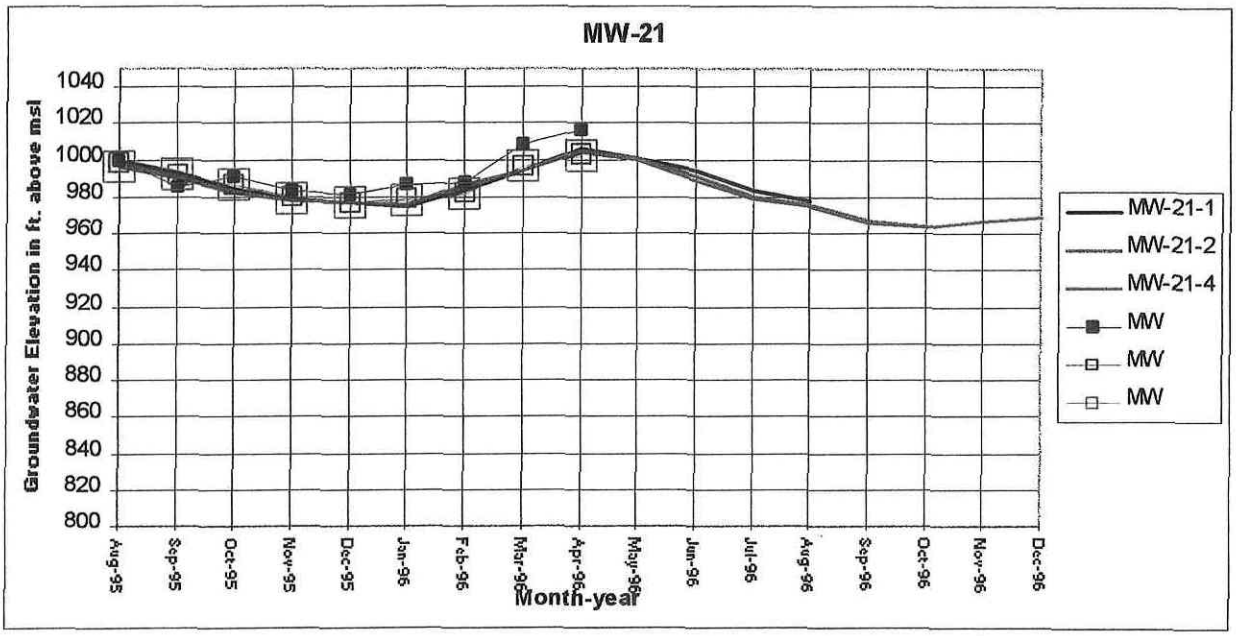
Model Layers	Color
1	
2	
3	
4	
5	
6	

Observed Values (line)
Simulated Values (symbol)

Port	1	2	3
CORRELATION	.68089	.10471	-.77402

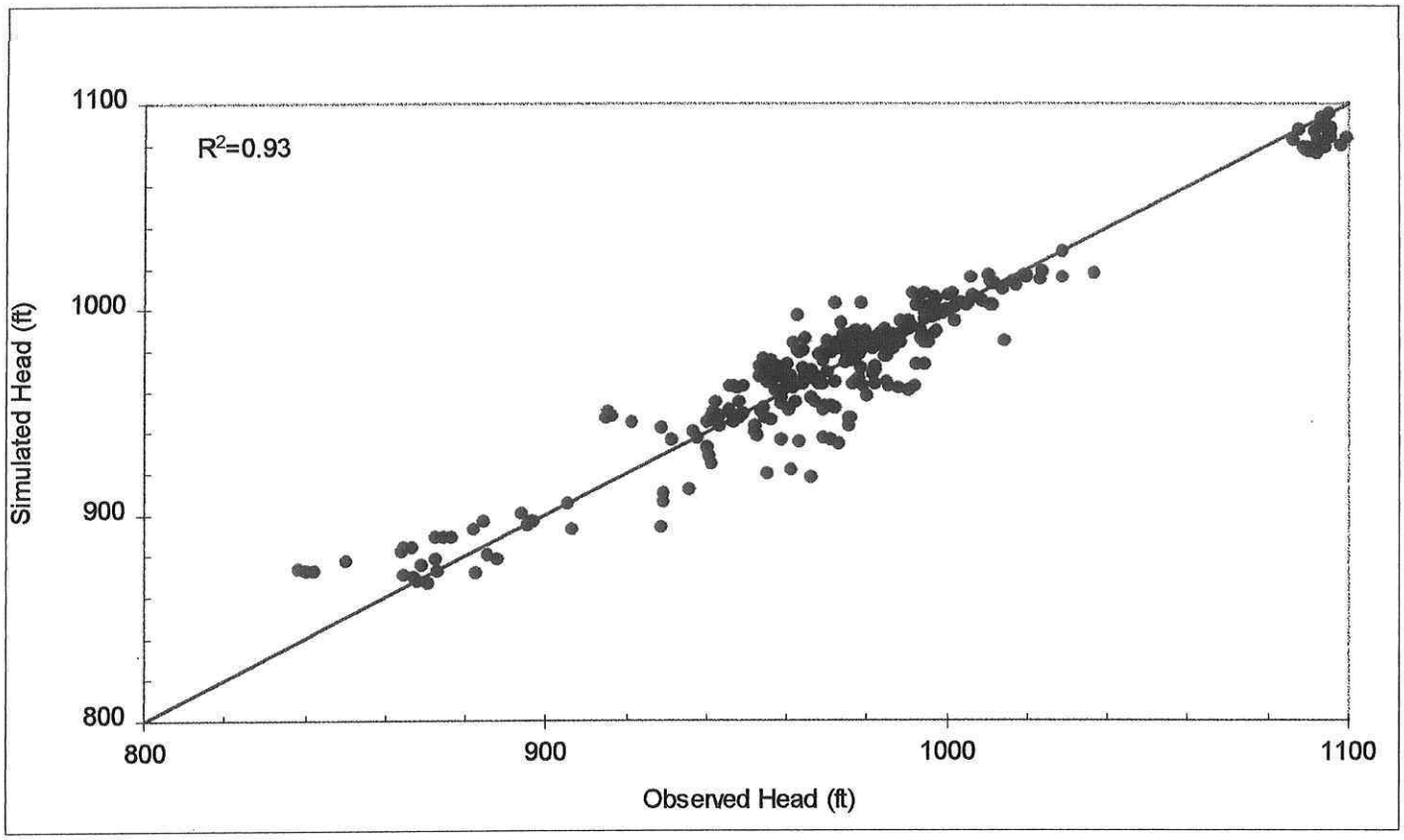


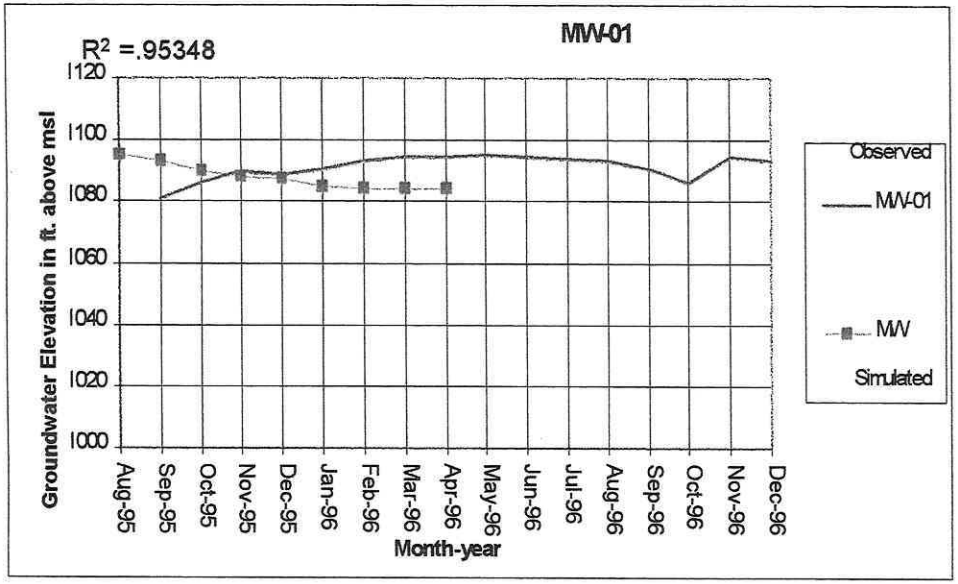
Port	1	2	4
CORRELATION	.85353	.97516	.96027

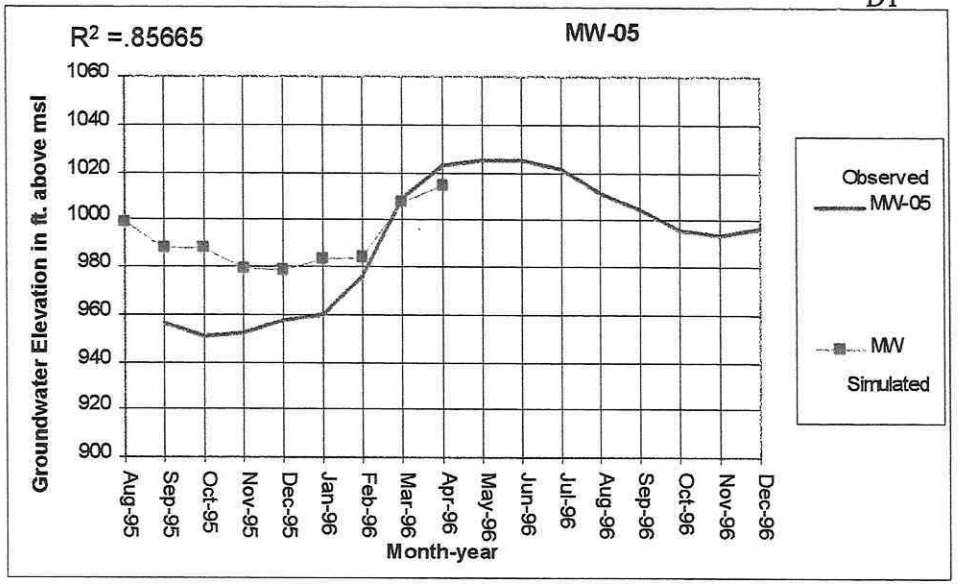


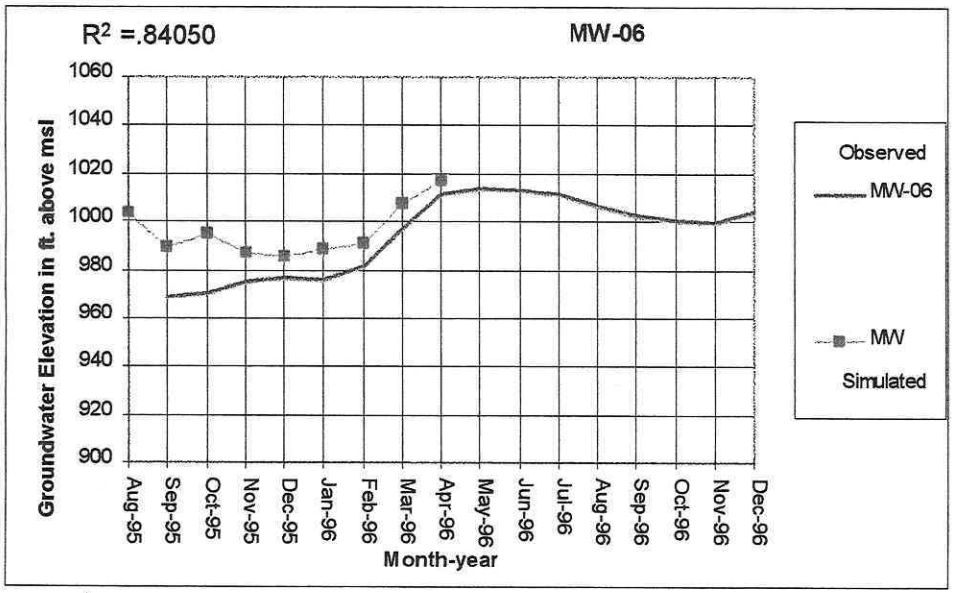
*Note: Refined Three-Dimensional Model Simulations Ran through April 1,1996

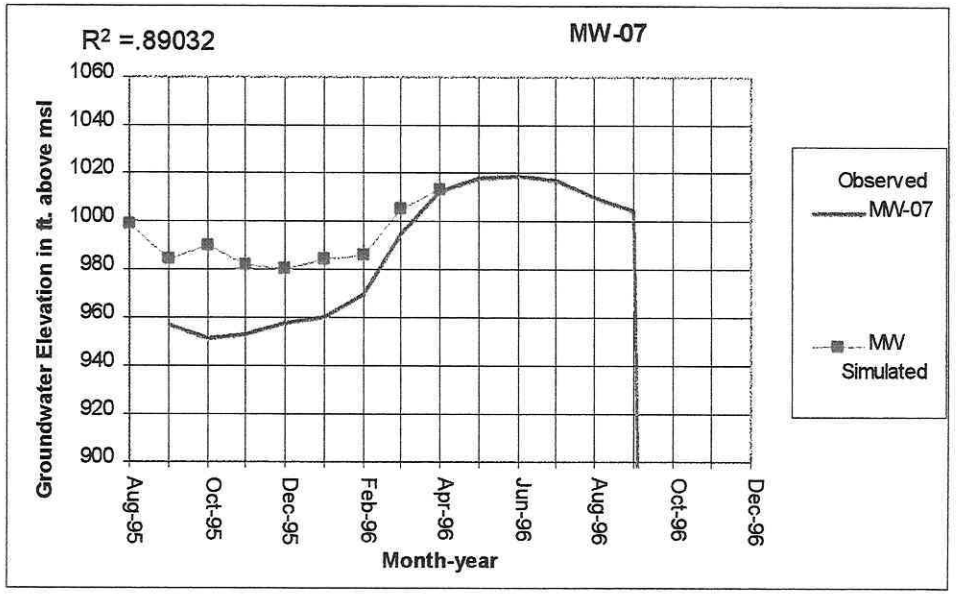
Residual Plot of All JPL Wells- Refined Calibration Period, August 1995-April 1996





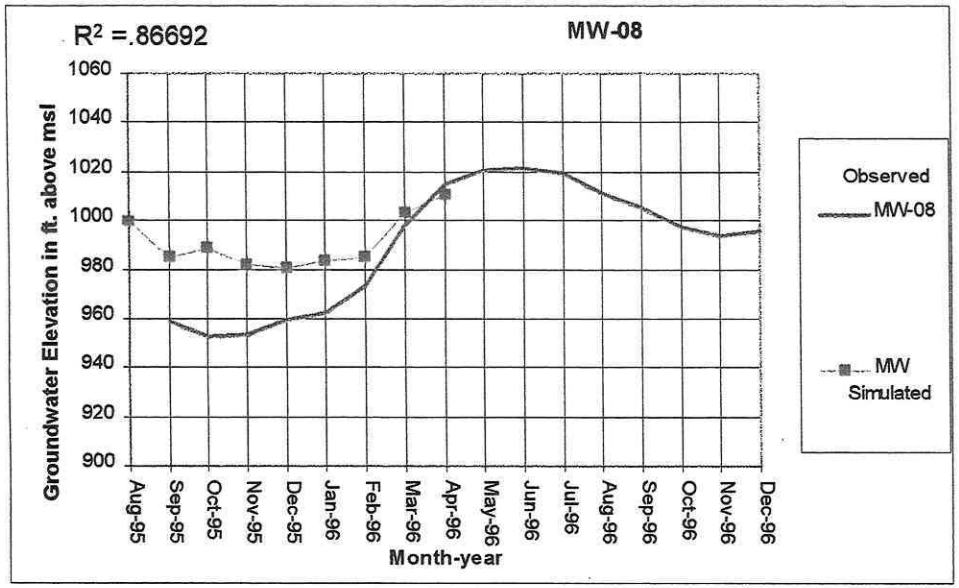


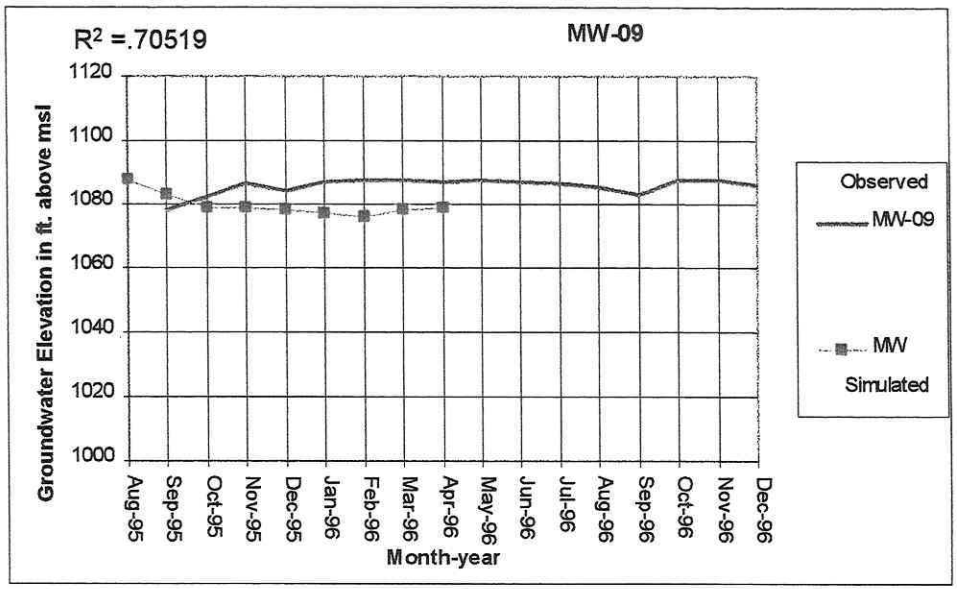


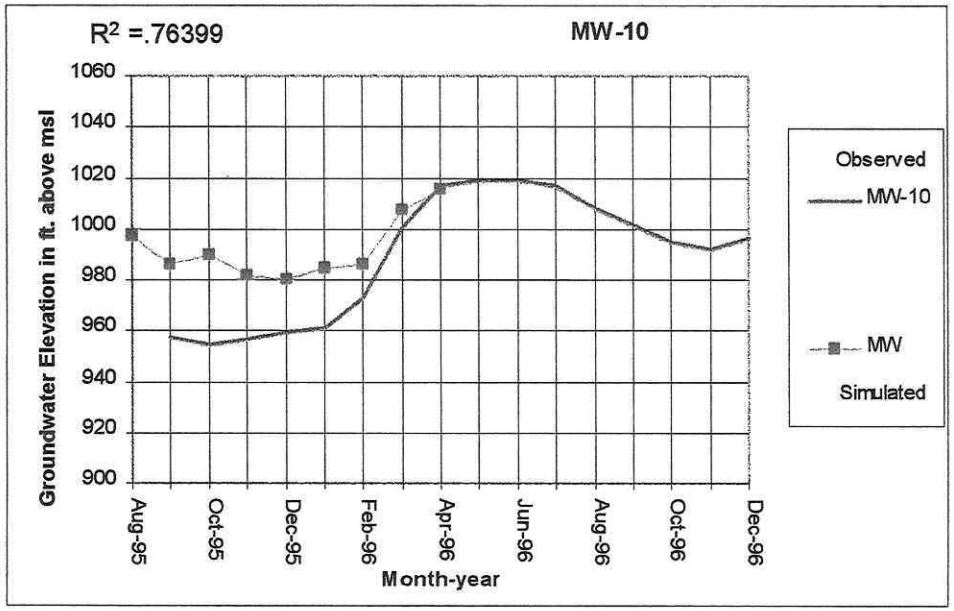


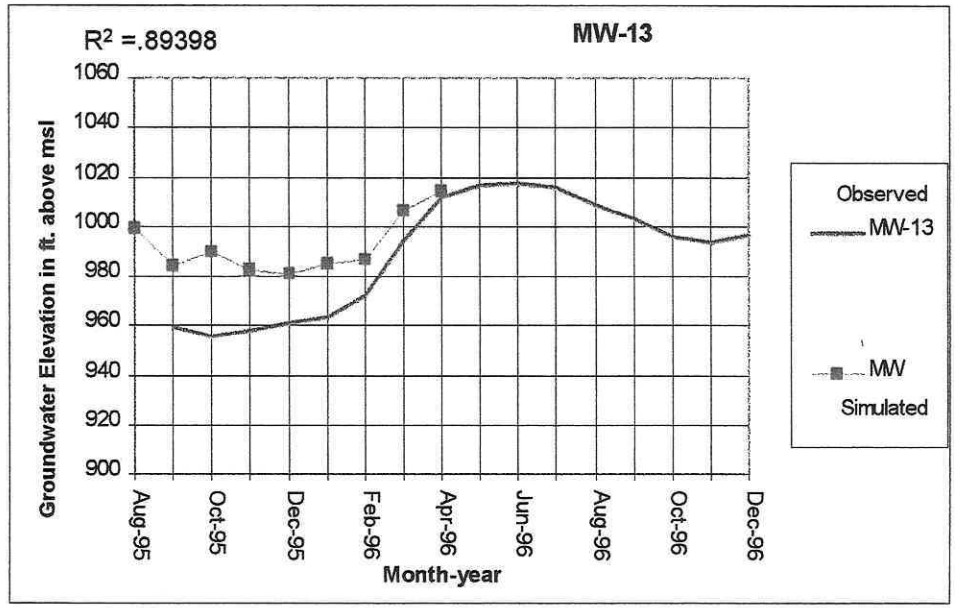
Observed vs. Simulated Piezometric Elevations-Verification of Refined Three-Dimensional Calibration Results

*Note: Refined Three-Dimensional Model Simulations Ran through April 1,1996. Observed Values Sep. 1997-April 1998 plotted against Simulated Values Sep. 1995-April 1996.



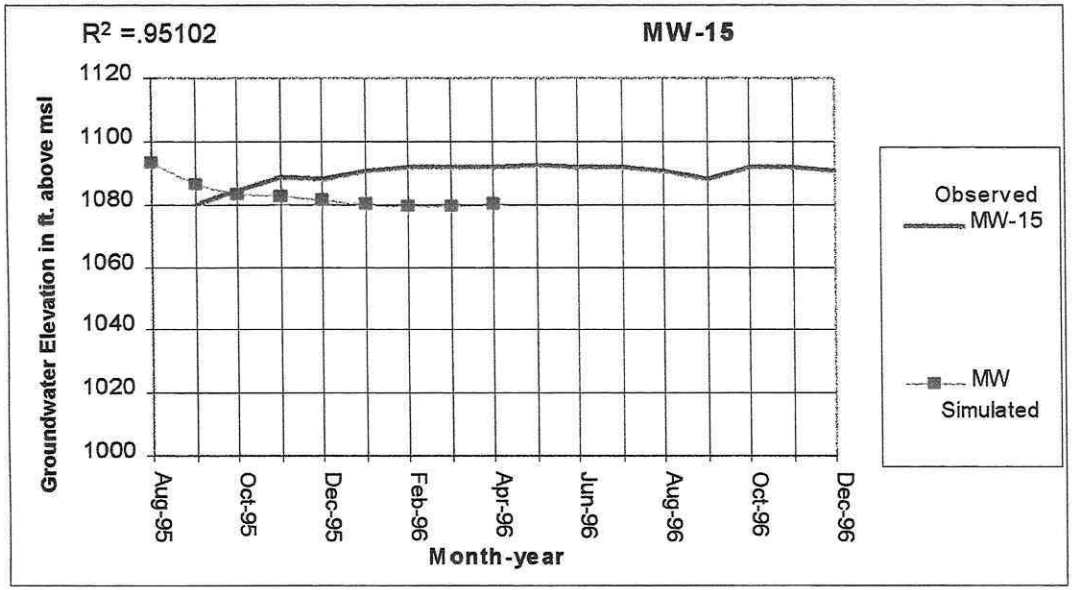


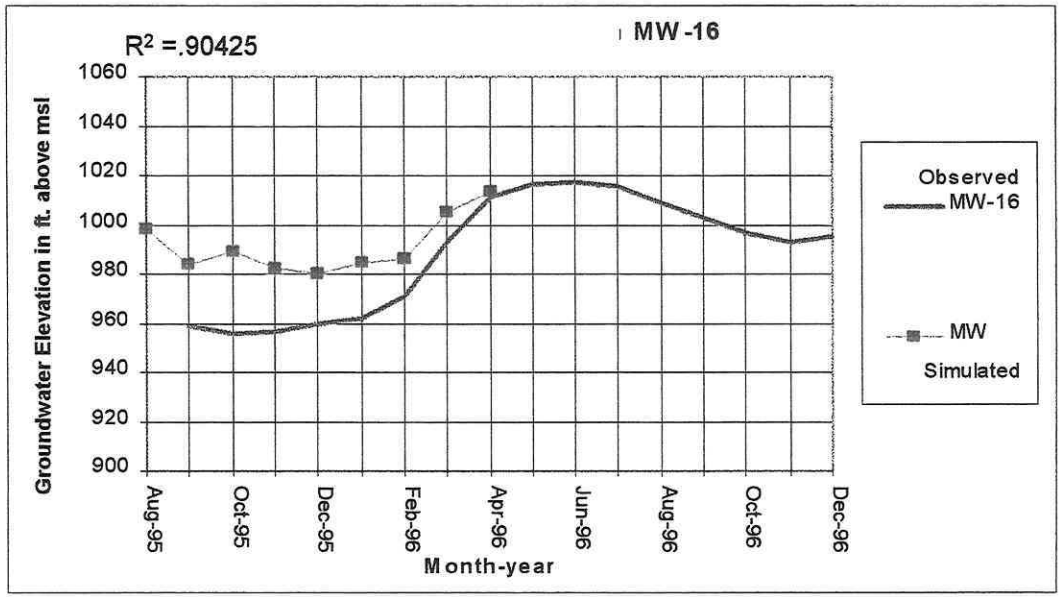




Observed vs. Simulated Piezometric Elevations-Verification of Refined Three-Dimensional Calibration Results

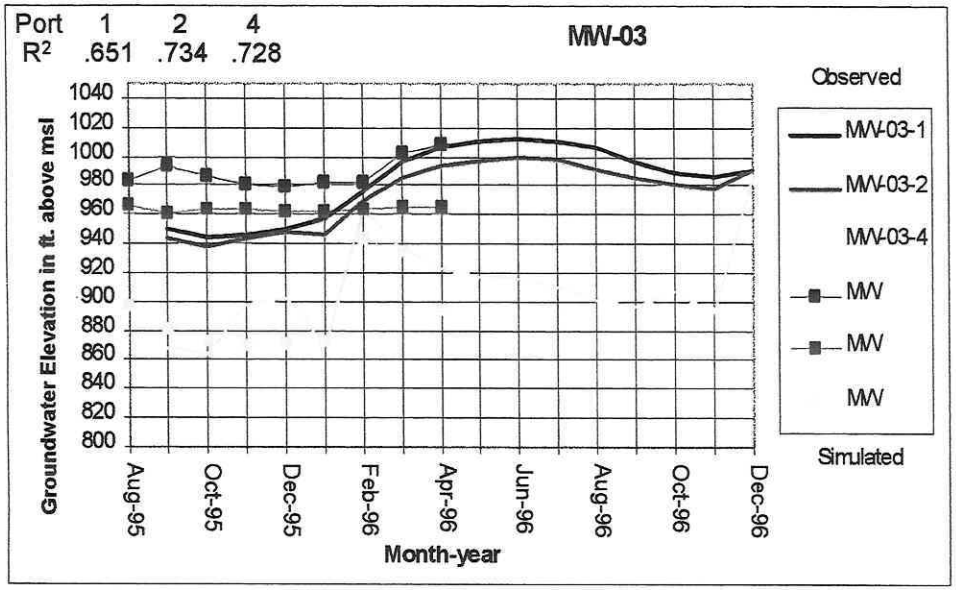
*Note: Refined Three-Dimensional Model Simulations Ran through April 1,1996. Observed Values Sep. 1997-April 1998 plotted against Simulated Values Sep. 1995-April 1996.

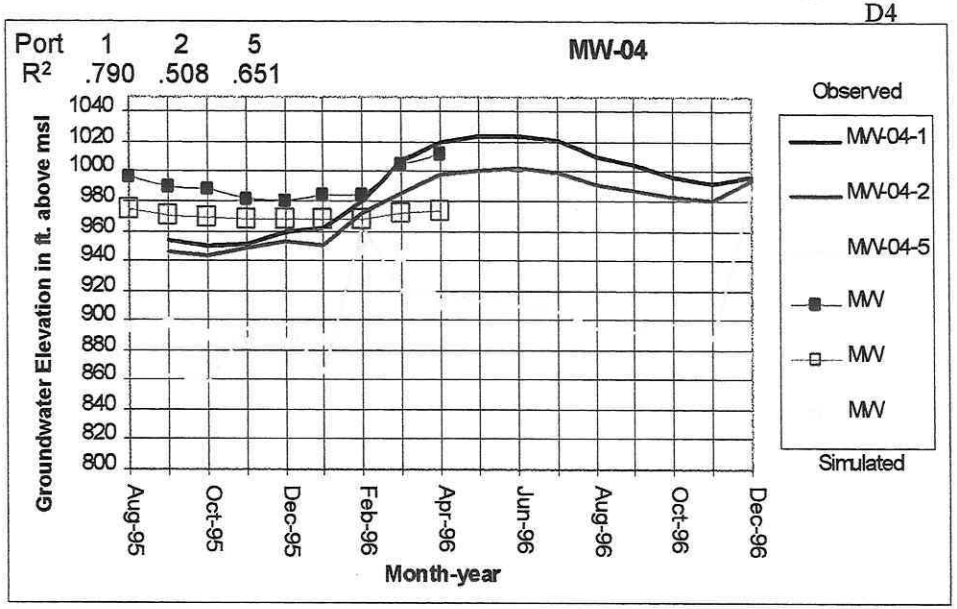


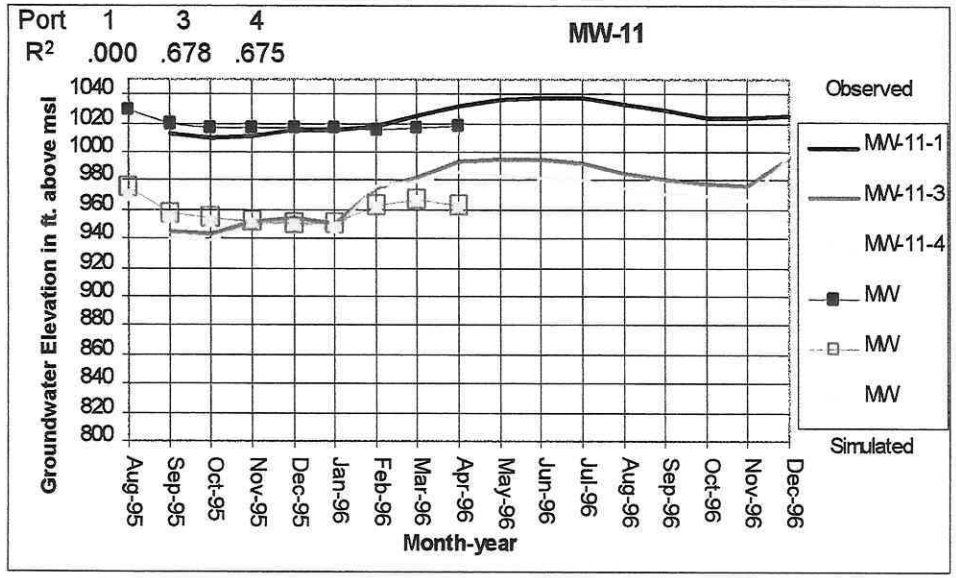


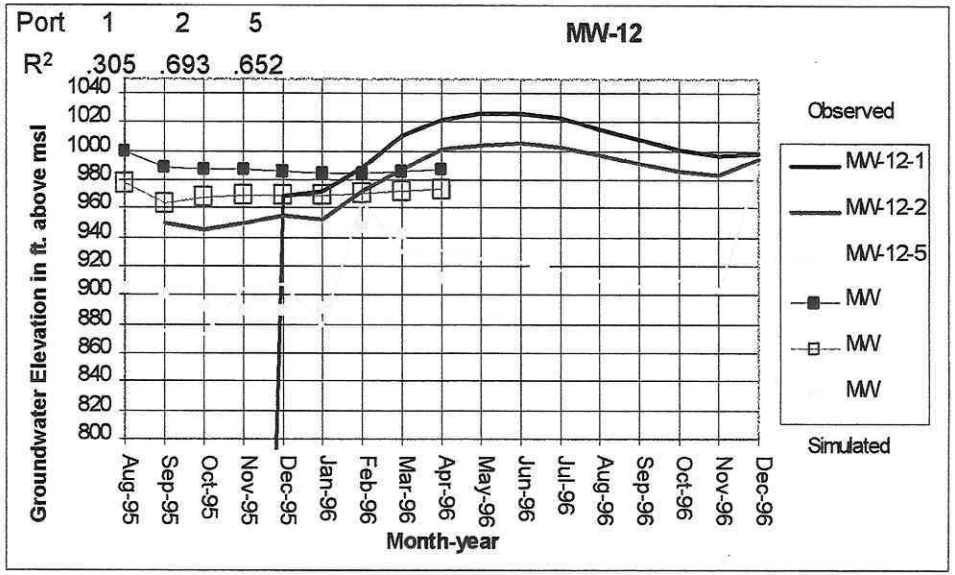
Observed vs. Simulated Piezometric Elevations-Verification of Refined Three-Dimensional Calibration Results

*Note: Refined Three-Dimensional Model Simulations Ran through April 1,1996. Observed Values Sep. 1997-April 1998 plotted against Simulated Values Sep. 1995-April 1996.









Model Layers	Color		
1		4	
2		5	
3		6	

Observed Values (line)
Simulated Values (symbol)

Observed vs. Simulated Piezometric Elevations-Verification of Refined Three-Dimensional Calibration Results, Geologic Layers 1,2,3

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*Note: Refined Three-Dimensional Model Simulations Ran through April 1,1996. Observed Values Sep. 1997-April 1998 plotted against Simulated Values Sep. 1995-April 1996.

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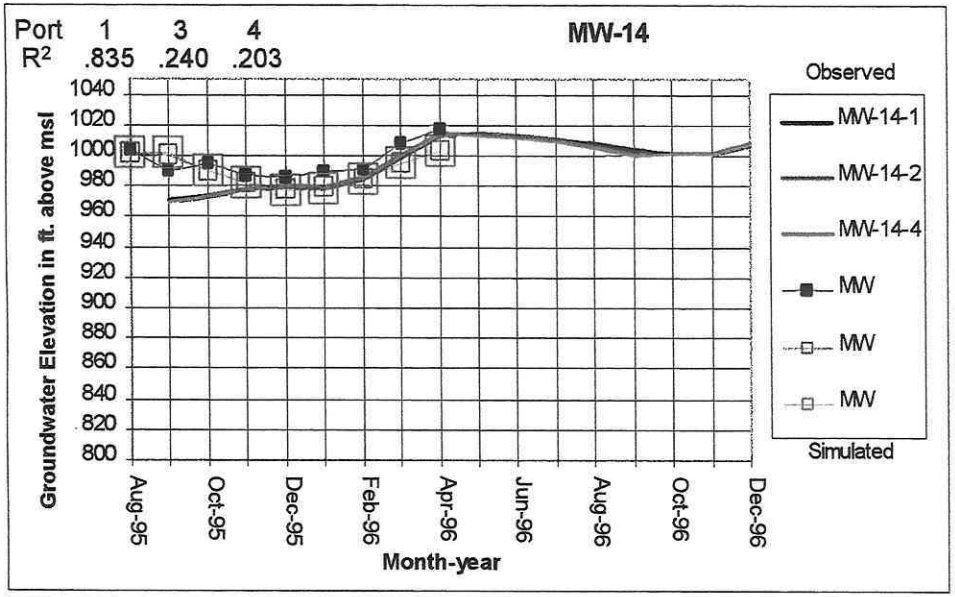

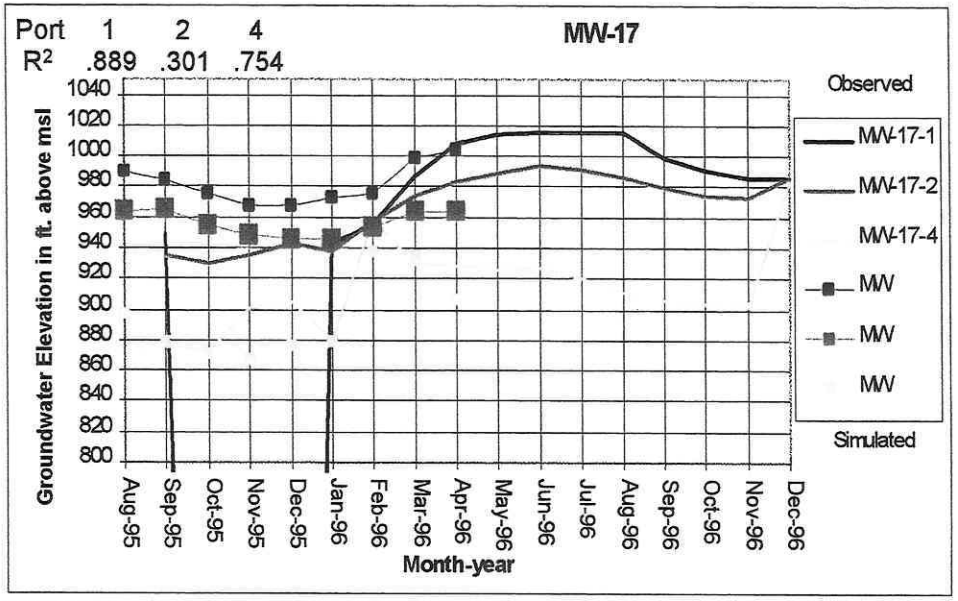

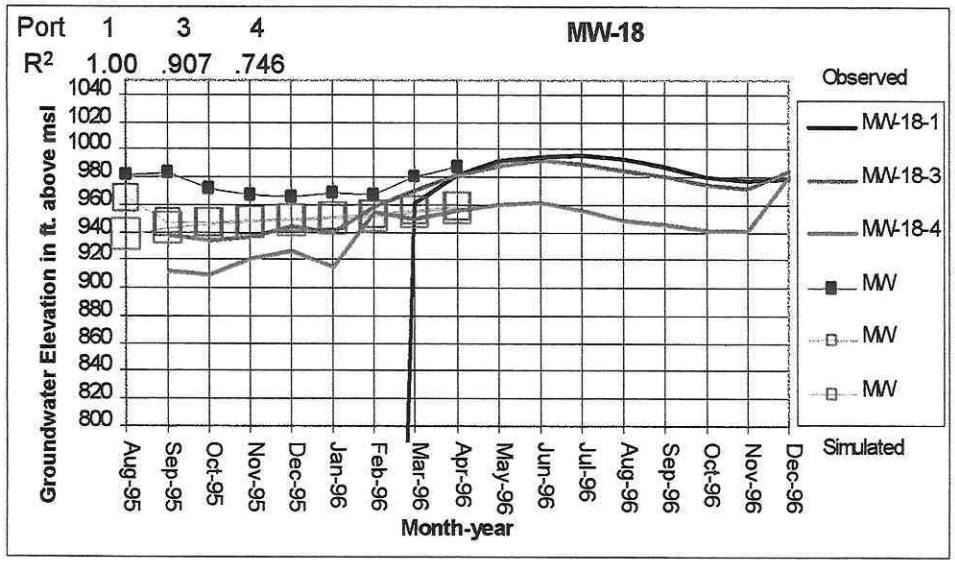

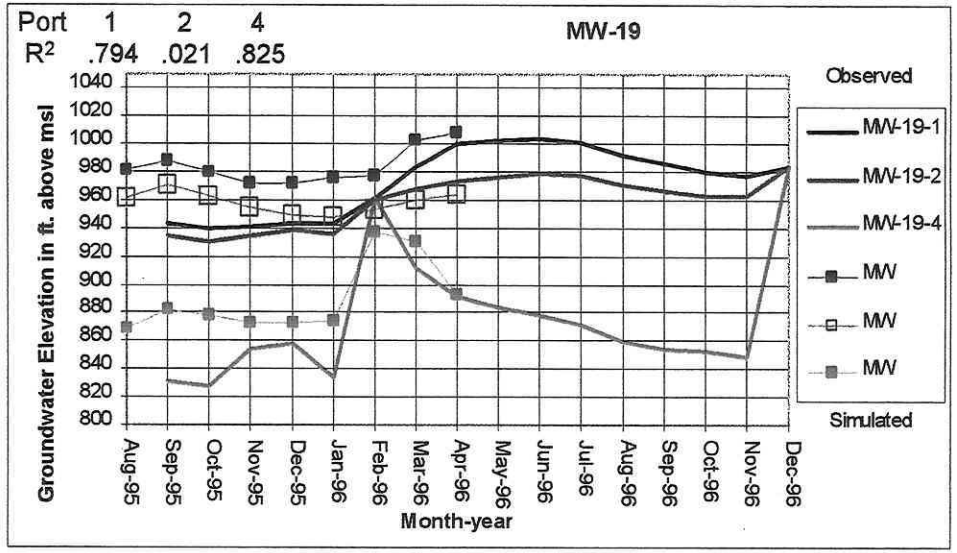

Model Layers	Color		
1		4	
2		5	
3		6	

Observed Values (line)
Simulated Values (symbol)

Observed vs. Simulated Piezometric Elevations-Verification of Refined Three-Dimensional Calibration Results, Geologic Layers 1,2,3

*Note: Refined Three-Dimensional Model Simulations Ran through April 1,1996. Observed Values Sep. 1997-April 1998 plotted against Simulated Values Sep. 1995-April 1996.

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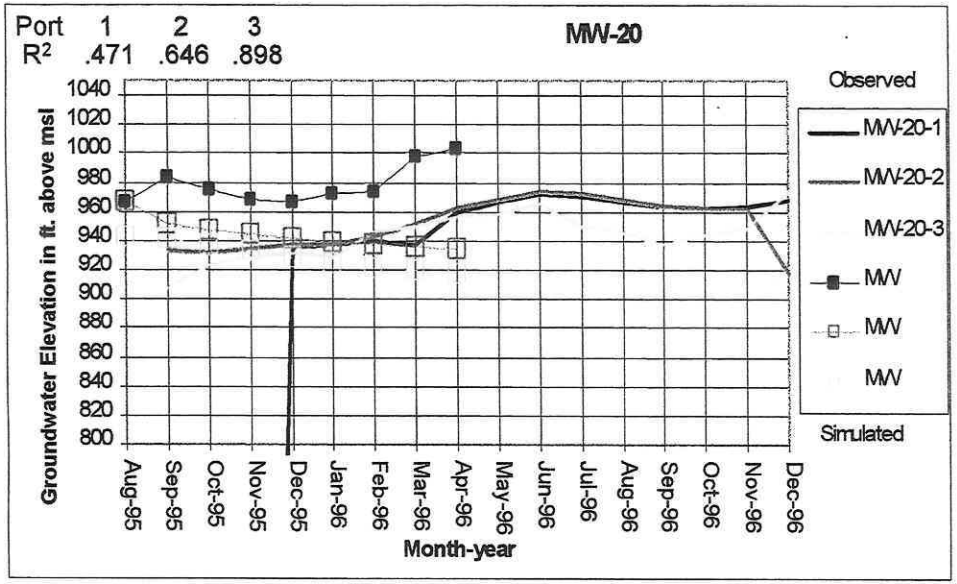

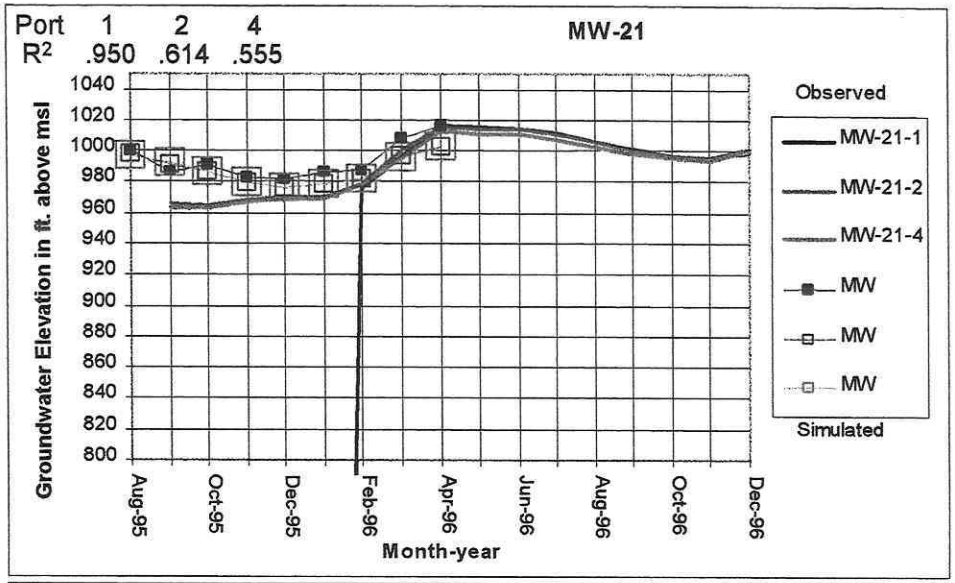

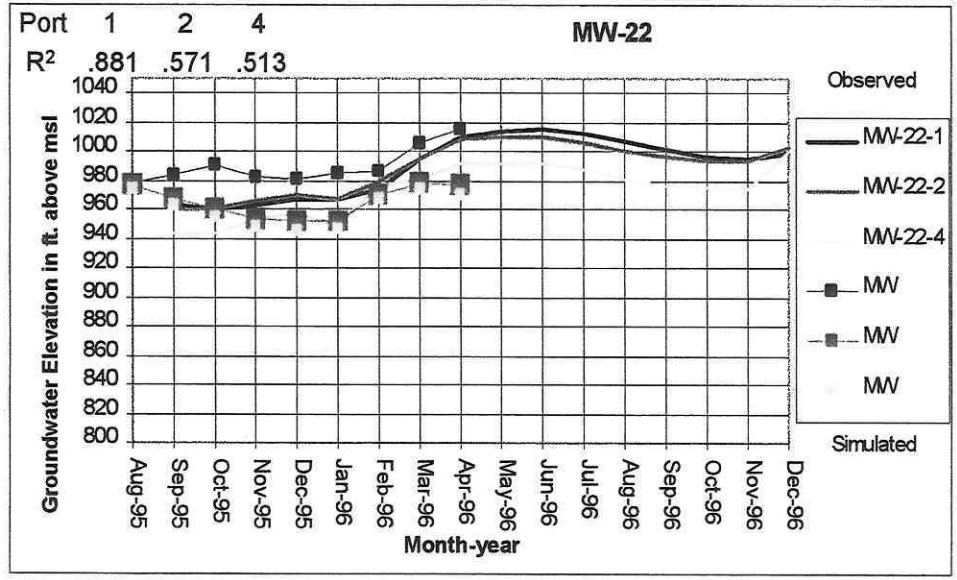

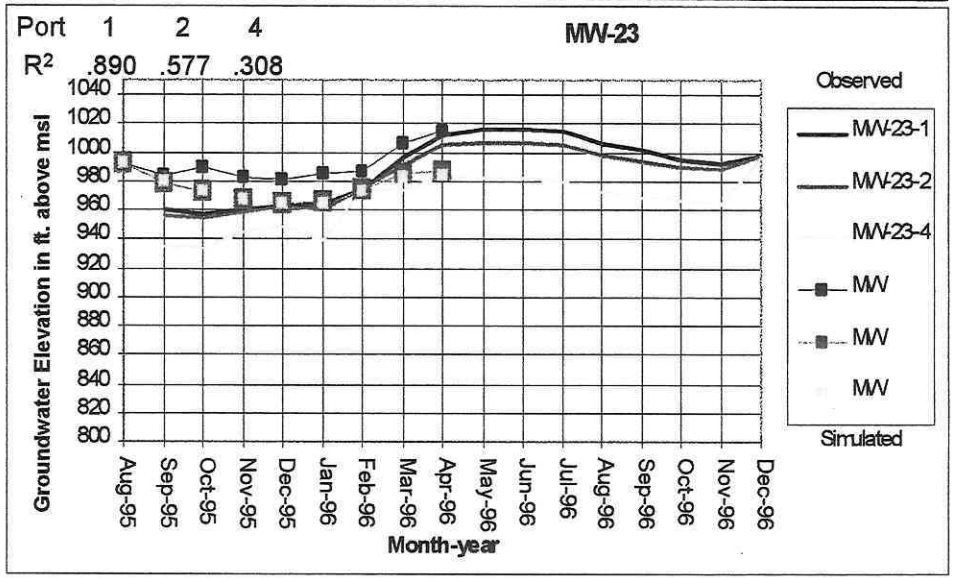

Model Layers	Color		
1		4	
2		5	
3		6	

Observed Values (line)
Simulated Values (symbol)

Observed vs. Simulated Piezometric Elevations-Verification of Refined Three-Dimensional Calibration Results, Geologic Layers 1,2,3

*Note: Refined Three-Dimensional Model Simulations Ran through April 1,1996. Observed Values Sep. 1997-April 1998 plotted against Simulated Values Sep. 1995-April 1996.

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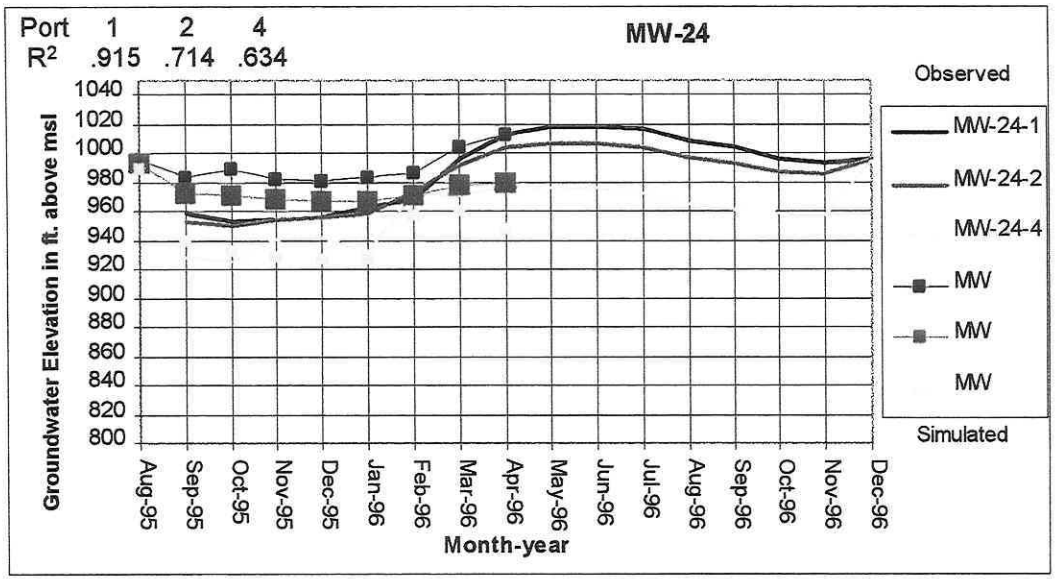

Model Layers	Color
1	
2	
3	
4	
5	
6	

Observed Values (line)
Simulated Values (symbol)

Observed vs. Simulated Piezometric Elevations-Verification of Refined Three-Dimensional Calibration Results, Geologic Layers 1,2,3

*Note: Refined Three-Dimensional Model Simulations Ran through April 1,1996. Observed Values Sep. 1997-April 1998 plotted against Simulated Values Sep. 1995-April 1996.

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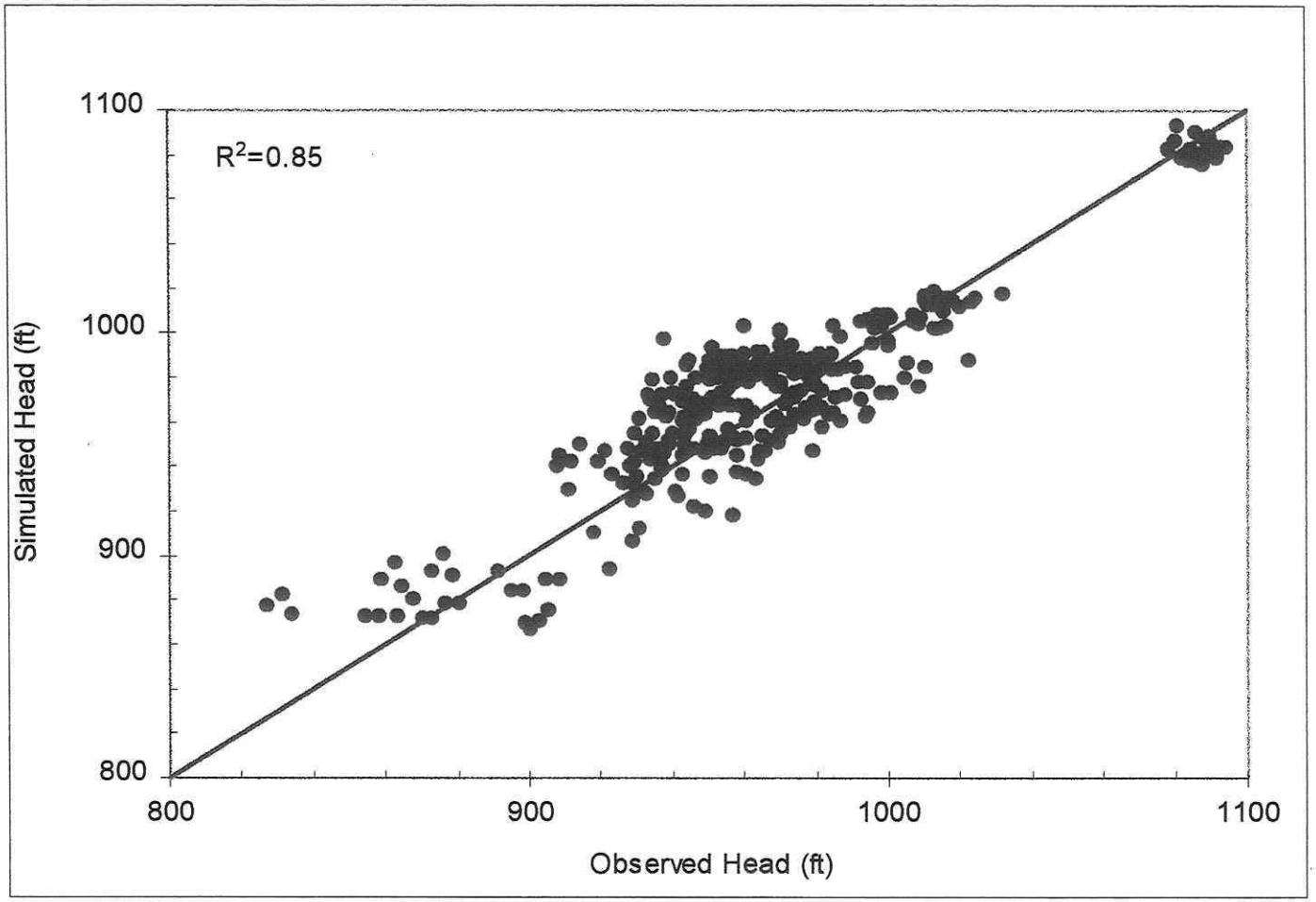


Residual Plot of all JPL Wells-Data Verified from
September 1997 to April 1998

APPENDIX D

OBSERVED VS. SIMULATED PIEZOMETRIC ELEVATIONS IN DEEP AND SHALLOW JPL WELLS AND RESIDUAL PLOT FOR VERIFICATION OF THE REFINED THREE-DIMENSIONAL CALIBRATION

APPENDIX H

RESULTS OF GROUNDWATER MODEL SIMULATIONS

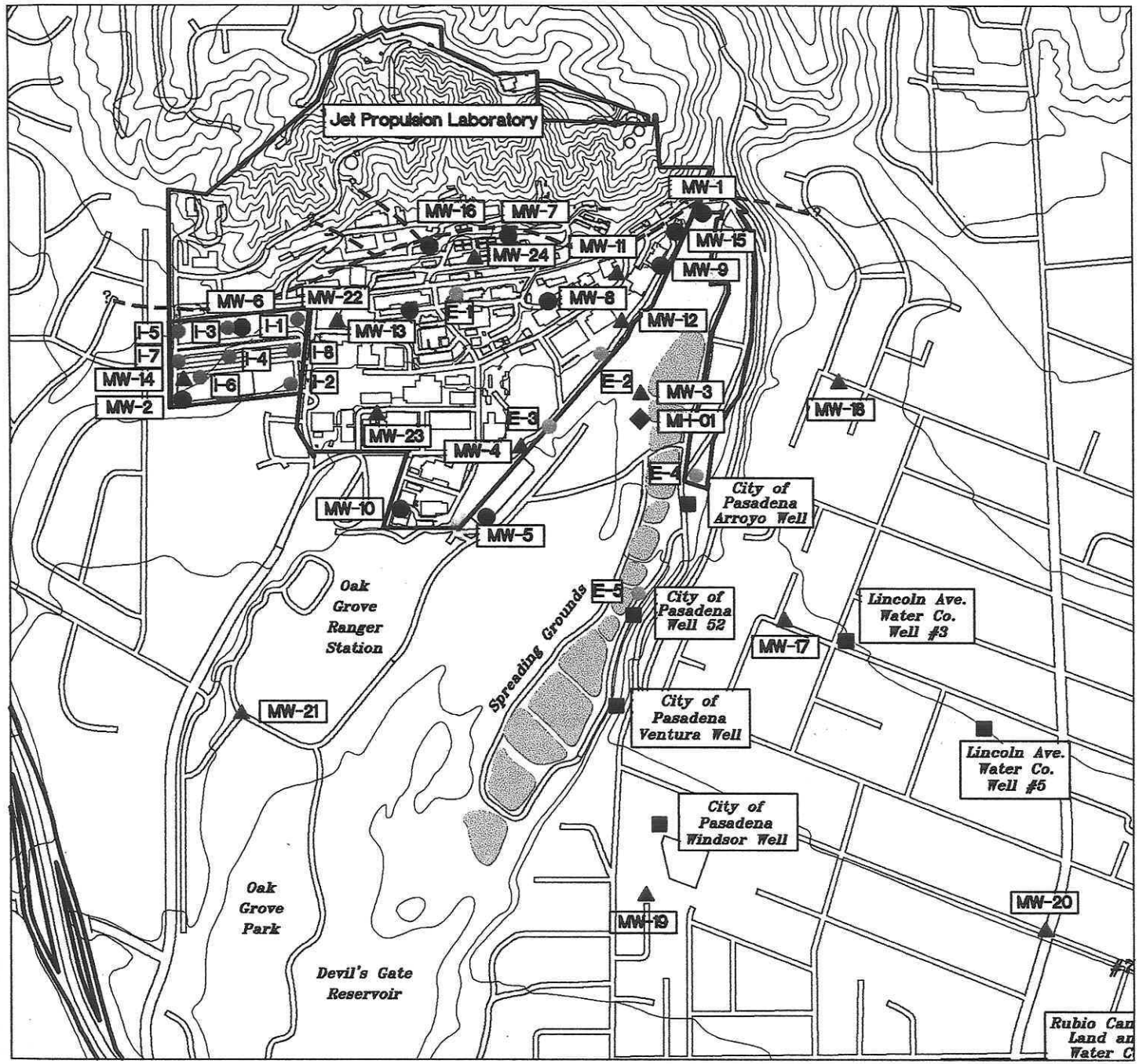
TABLE H-1

SUMMARY OF EXTRACTION AND INFILTRATION RATES USED FOR GROUNDWATER MODEL SIMULATIONS JET PROPULSION LABORATORY

Simulation No.	Remedial Alternative	Extraction Wells					Infiltration Wells							
		Layers 1&2	Layers 2&3				Vadose Zone							
		E-1	E-2	E-3	E-4	E-5	I-1	I-2	I-3	I-4	I-5	I-6	I-7	I-8
01	2	250					250							
02	2	500					500							
03	2	750					375	375						
04	3	1000	2000	2000			625	625	625	625	625	625	625	625
05	3	1000	2500	2500			750	750	750	750	750	750	750	750
06	3	1000	3000	3000			875	875	875	875	875	875	875	875
07	4(1)				1000	1000	500	500	500	500				
08	4(1)				1000	1500	420	420	420	420	420	420		
09	4(1)				1500	1500	375	375	375	375	375	375	375	375
10	4(1)				1000	2000	375	375	375	375	375	375	375	375
11	4(1)				1500	2000	440	440	440	440	440	440	440	440
12	4(1)				2000	2000	500	500	500	500	500	500	500	500
13	5(1)	1000			2000	2000	625	625	625	625	625	625	625	625
14	5(1)	1250			2000	2000	660	660	660	660	660	660	660	660
15	5(1)	1500			2000	2000	690	690	690	690	690	690	690	690
16	5(1)	2000			2000	2000	750	750	750	750	750	750	750	750

Notes:

: Flow rates for all nearby municipal production wells during simulations match those in Table 4-1.
: Results from simulations for months of September (low-water levels) and March (high-water levels) were post-processed.
: Infiltration wells assumed to be 135 feet deep and contain 100 feet of screen.
: All layers refer to geologic layers (Foster Wheeler, 1999).
(1): E-4 and E-5 are near the same locations as the Arroyo well and Well 52, respectively. It is assumed the Arroyo Well and Well 52 have been replaced with new extraction wells 4 and 5.



Explanation

- JPL Shallow Monitoring Wells
- JPL Deep Multi–Port Monitoring Wells
- Municipal Production Wells
- City of Pasadena Monitoring Well
- JPL Thrust Fault
- JPL Property Line
- Extraction Wells
- Infiltration Wells

N

1000 500 0 1000

SCALE IN FEET

Source: USGS, 7.5 Minute Topographic Map Pasadena, CA 1966, Revised 1988, 1994.

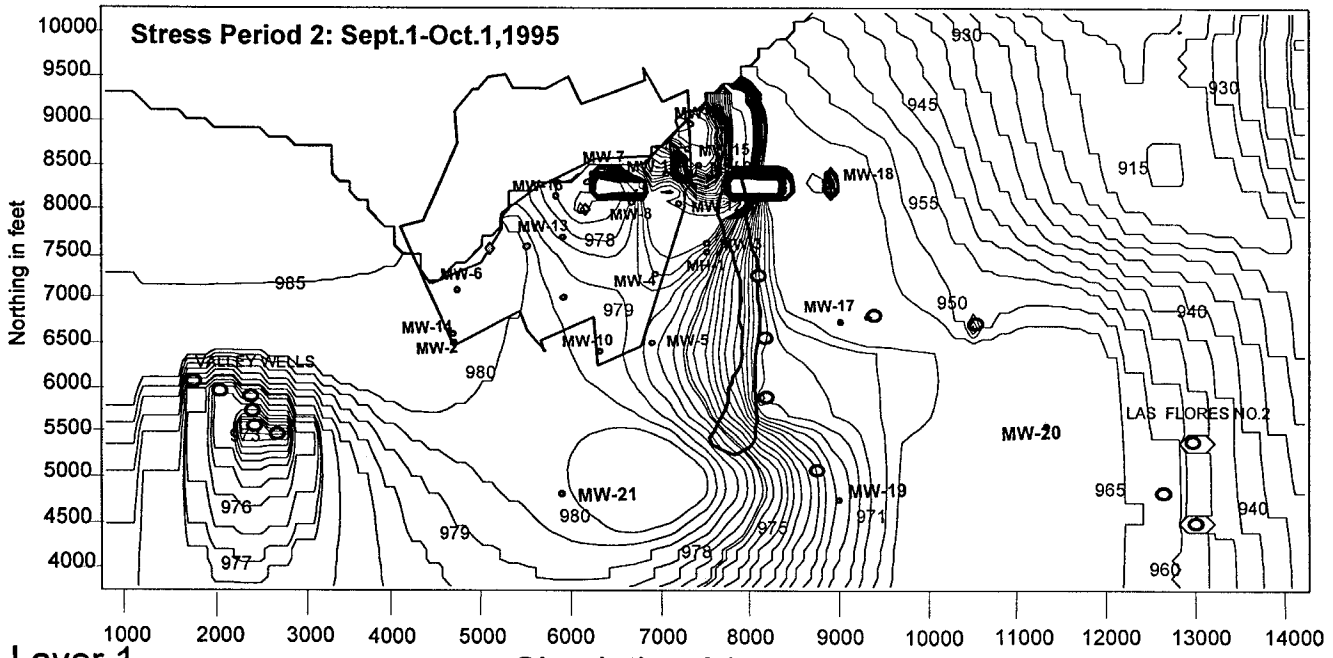
FIGURE H–1

LOCATION OF EXTRACTION (E) AND INFILTRATION (I) WELLS USED FOR GROUNDWATER MODEL SIMULATIONS

Jet Propulsion Laboratory
Pasadena, California

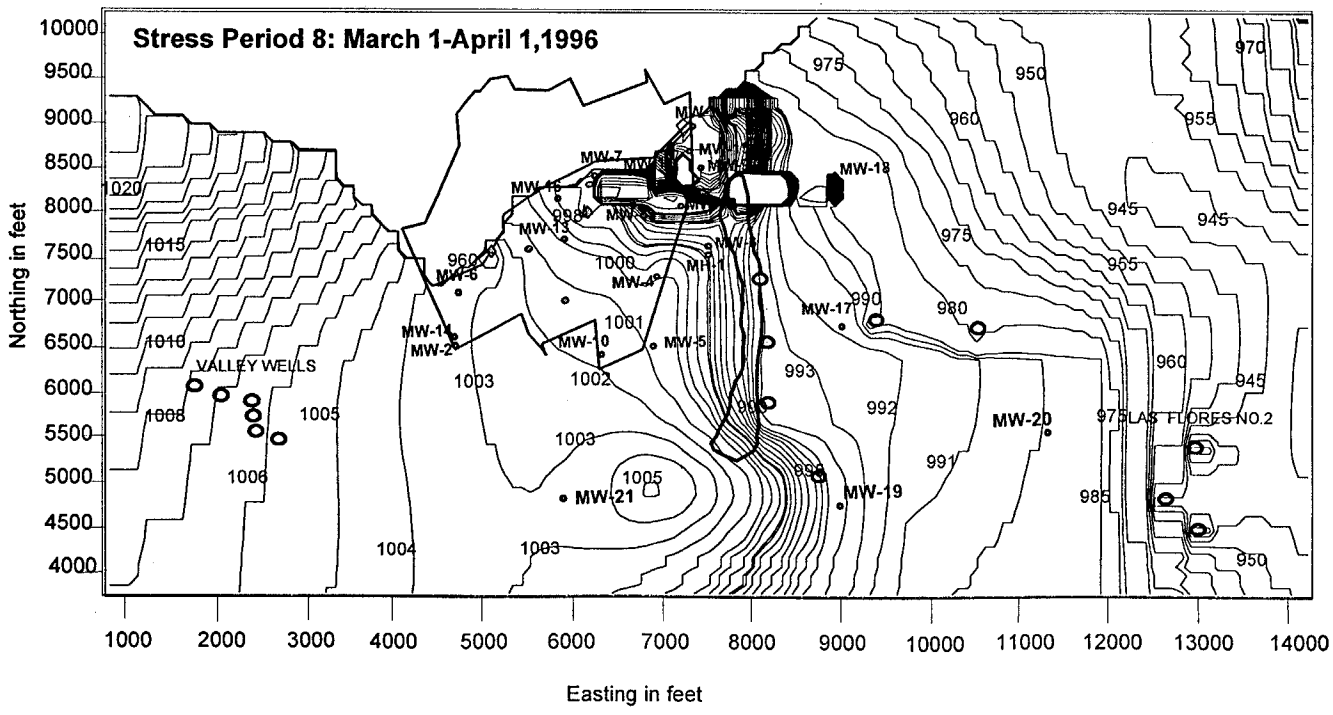
FOSTER WHEELER ENVIRONMENTAL CORPORATION

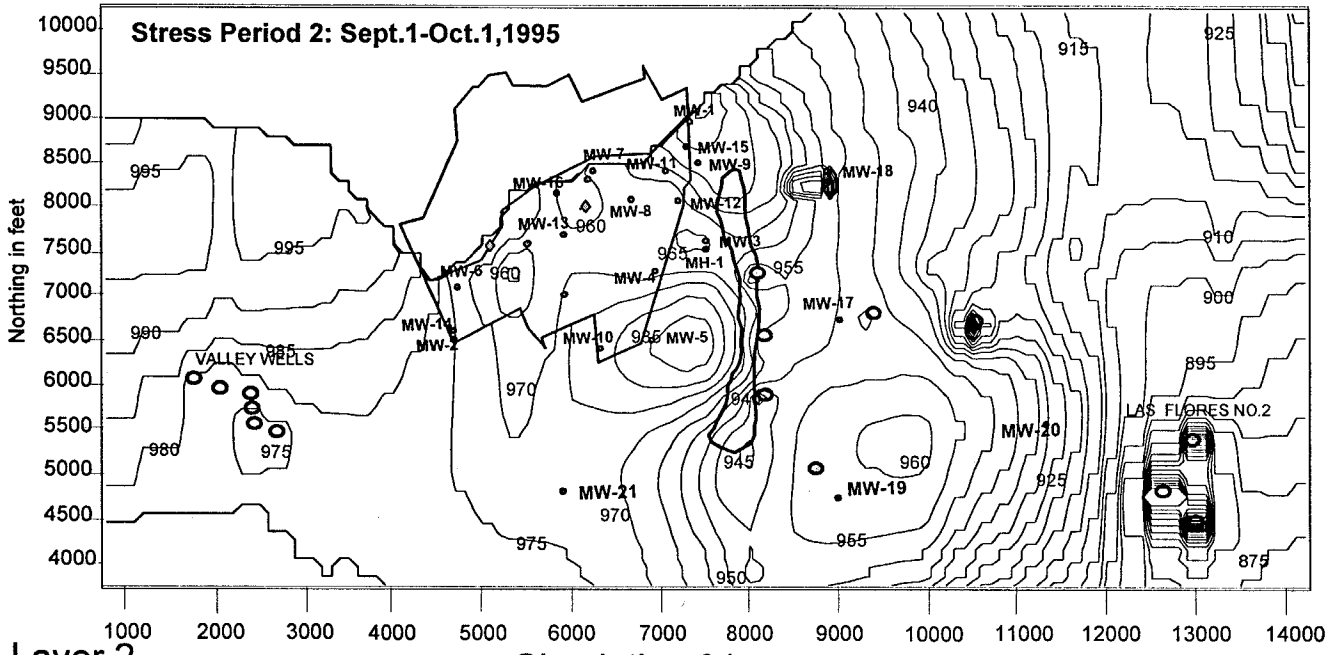
PLOT/UPDATE OCT 05 1998 08:56:28



Geologic Layer 1

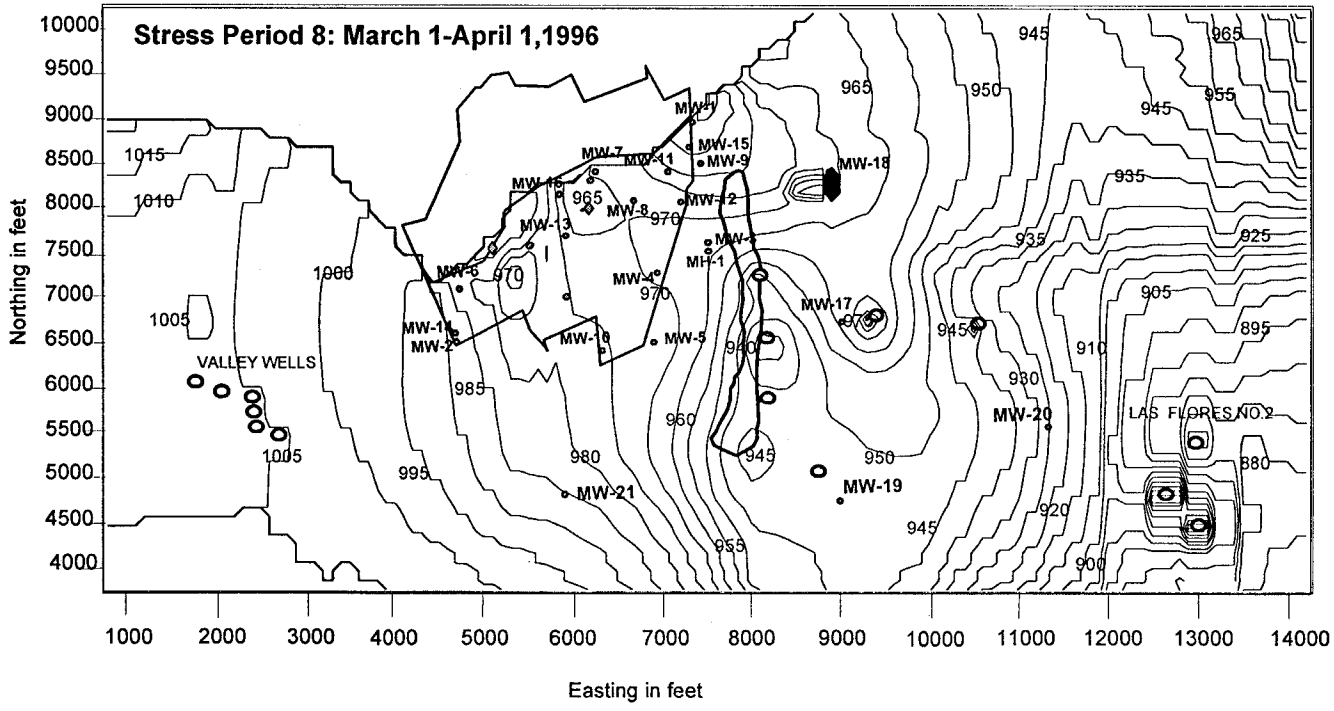
Simulation 01

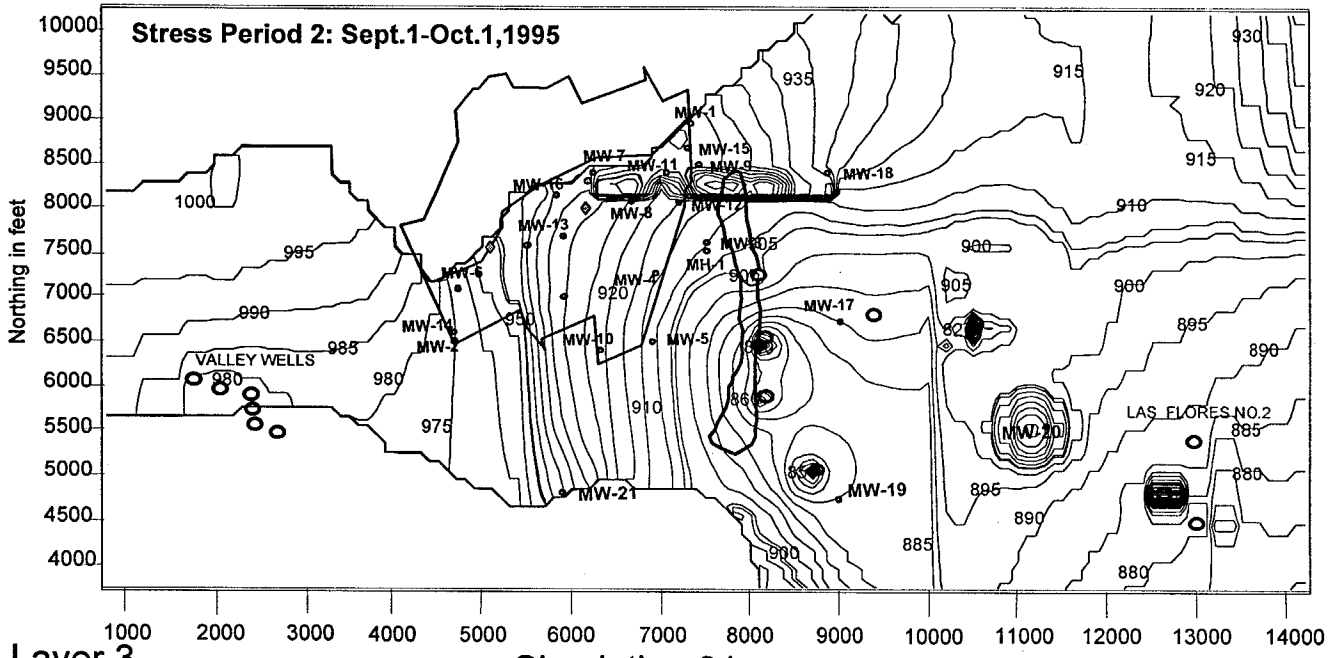




Geologic Layer 2

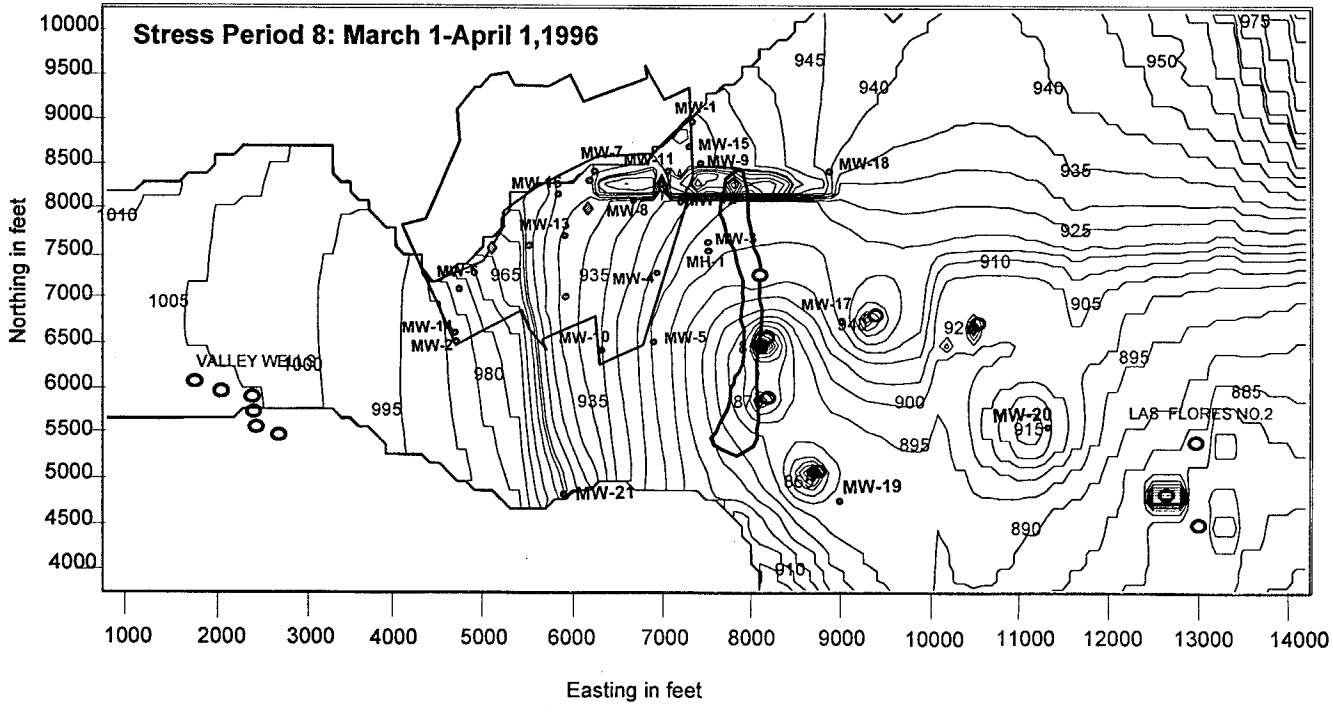
Simulation 01

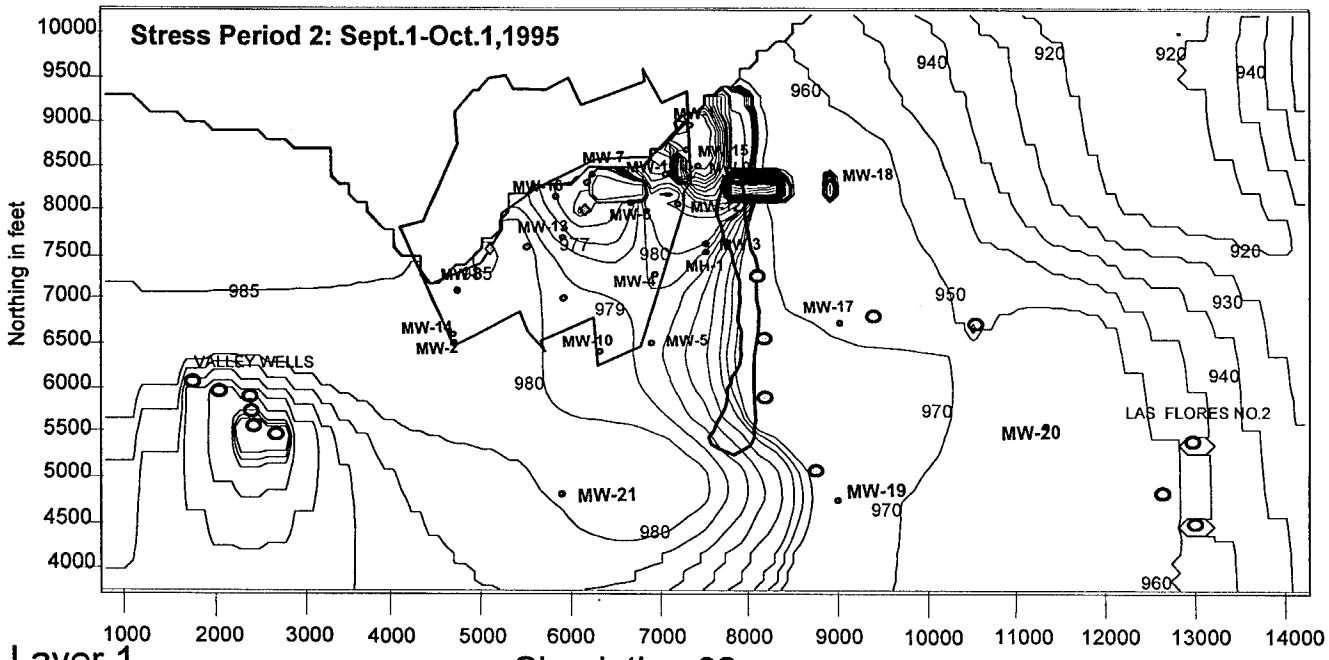




Geologic Layer 3

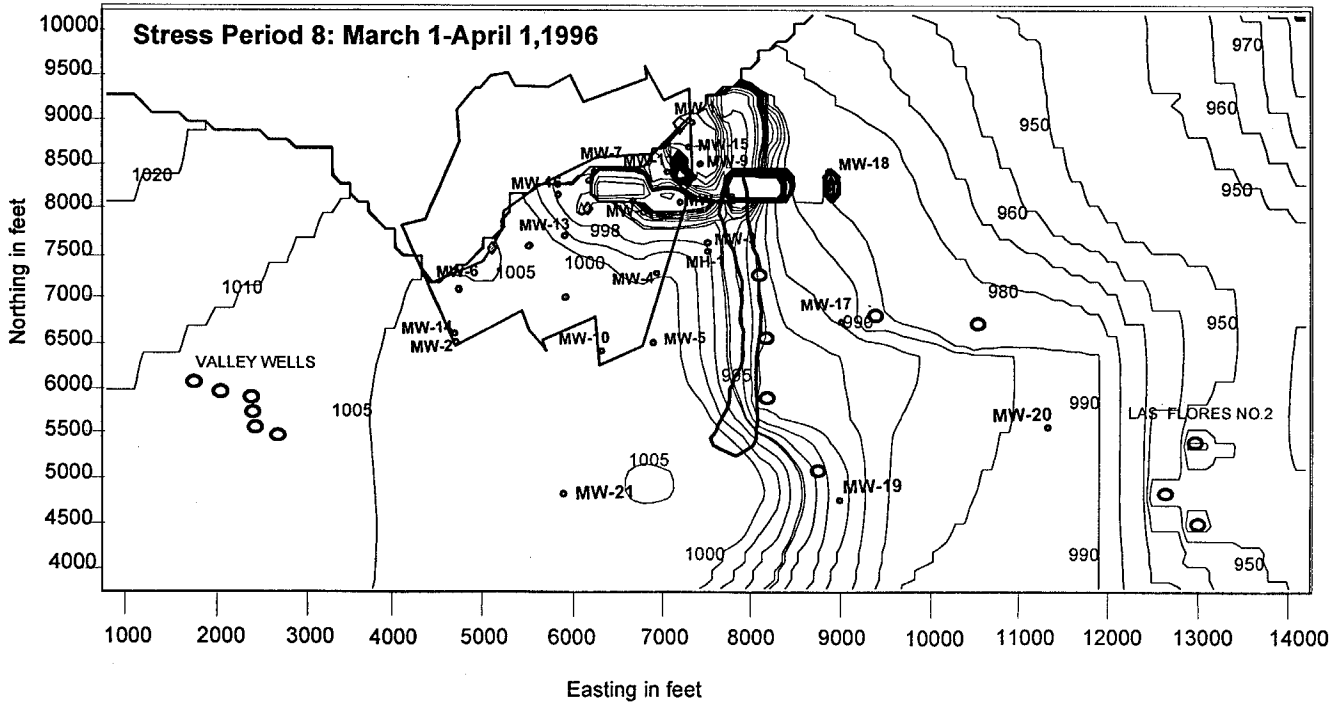
Simulation 01

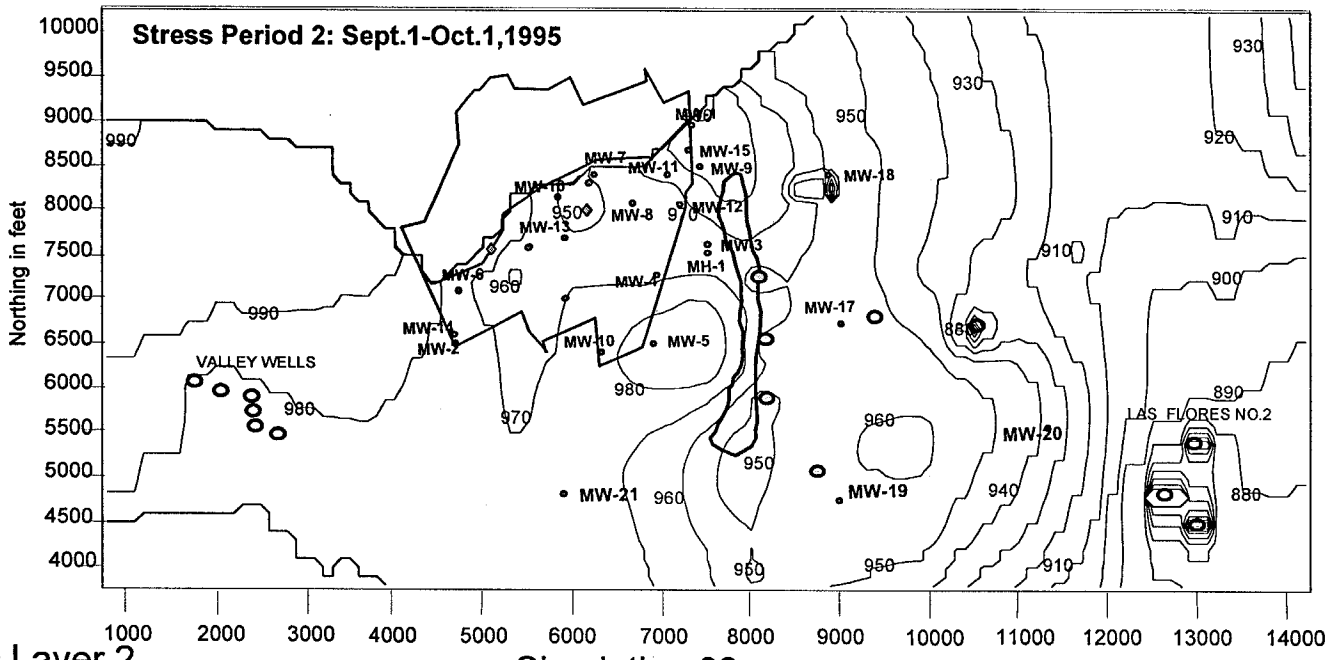




Geologic Layer 1

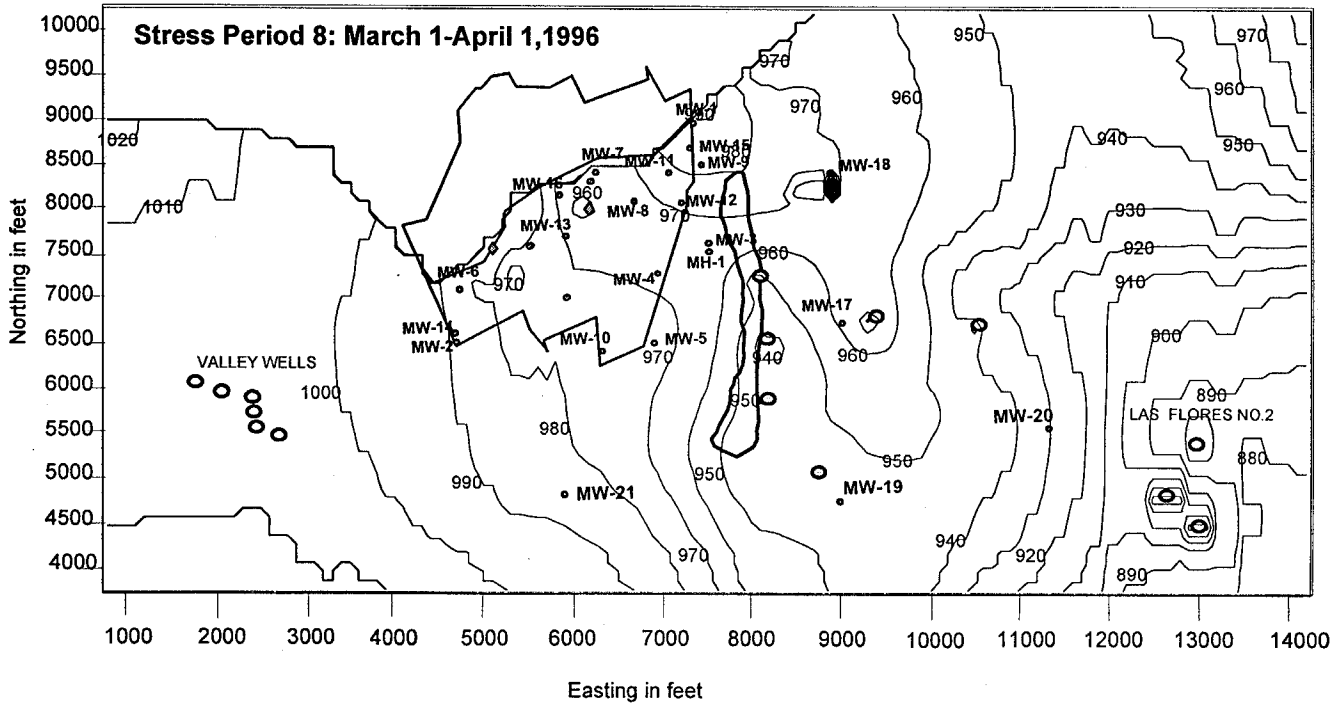
Simulation 02

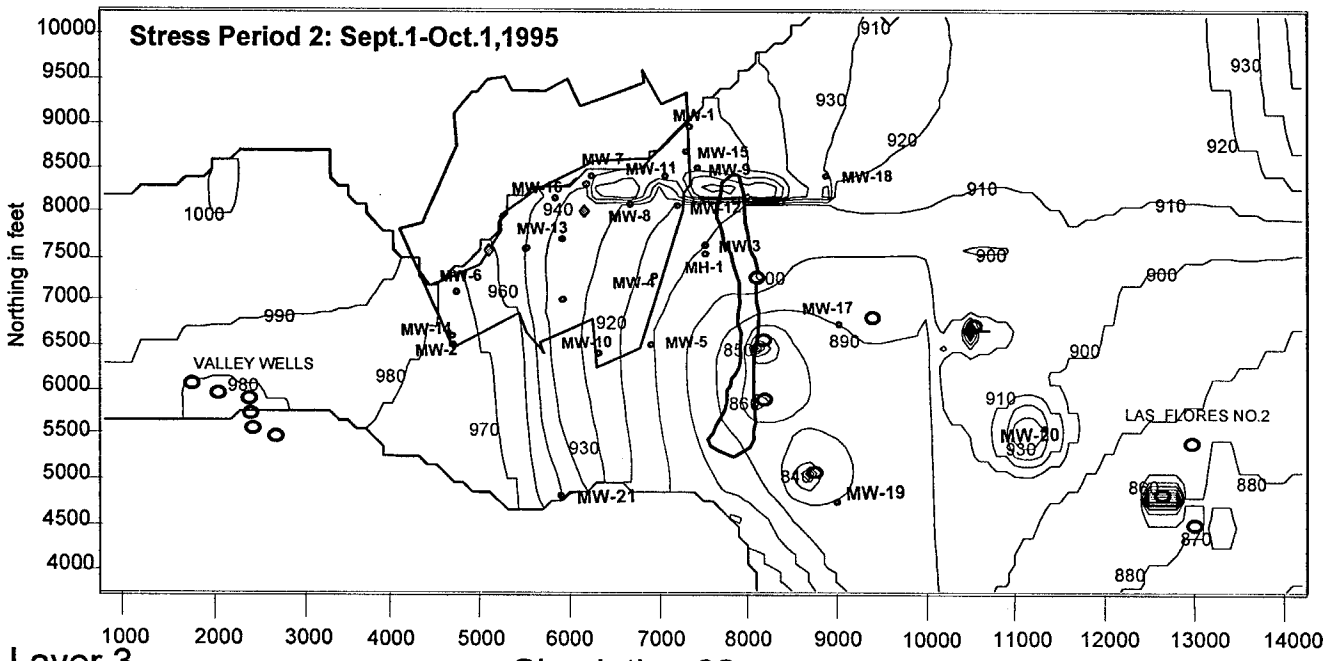




Geologic Layer 2

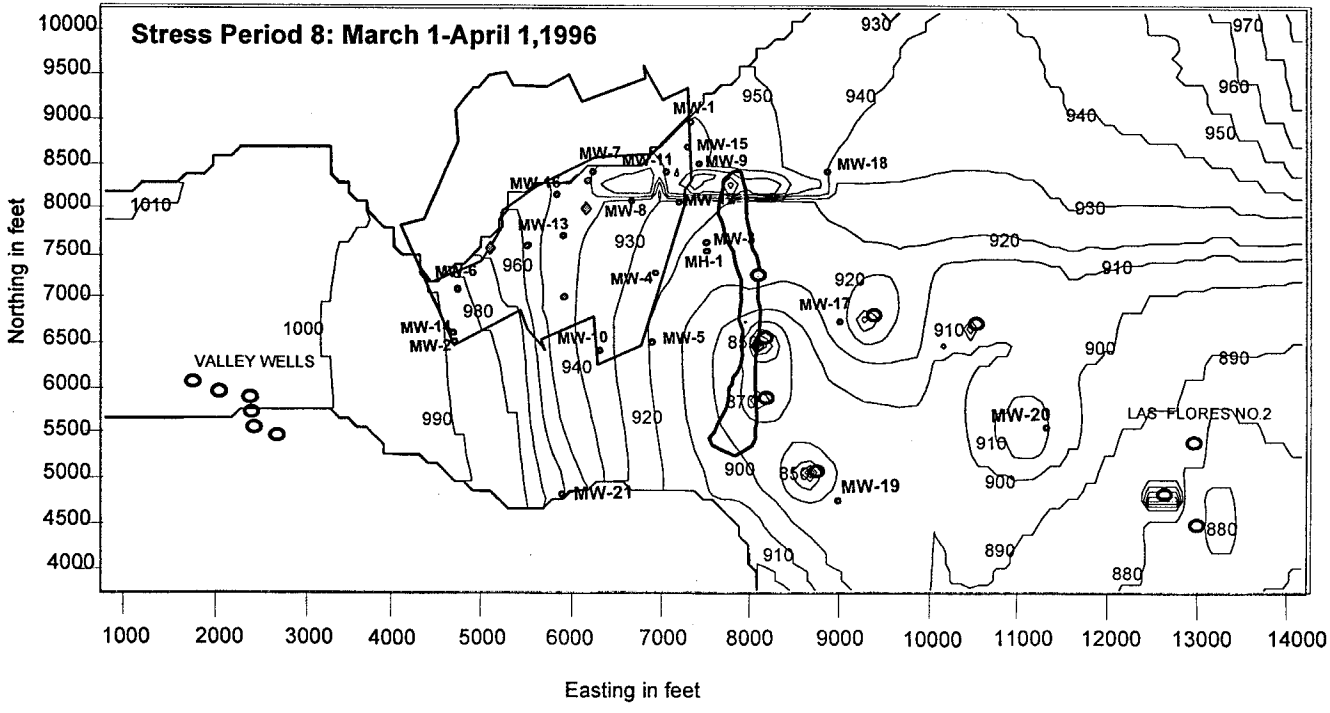
Simulation 02

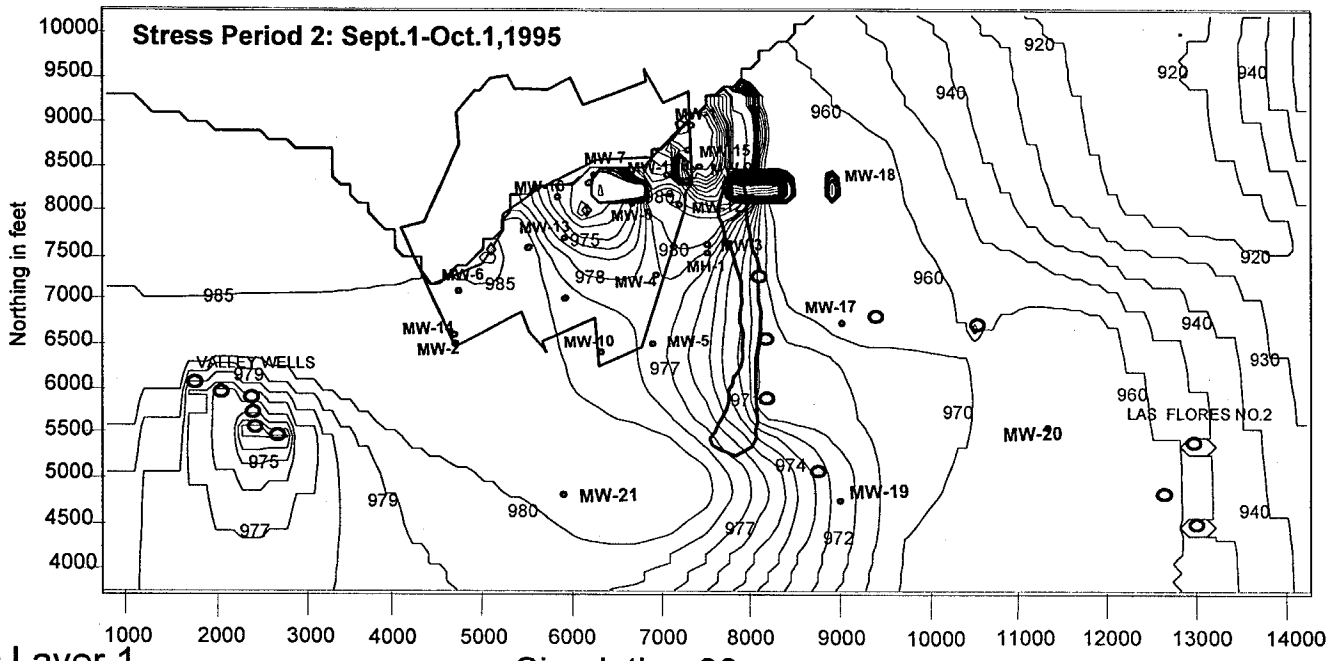




Geologic Layer 3

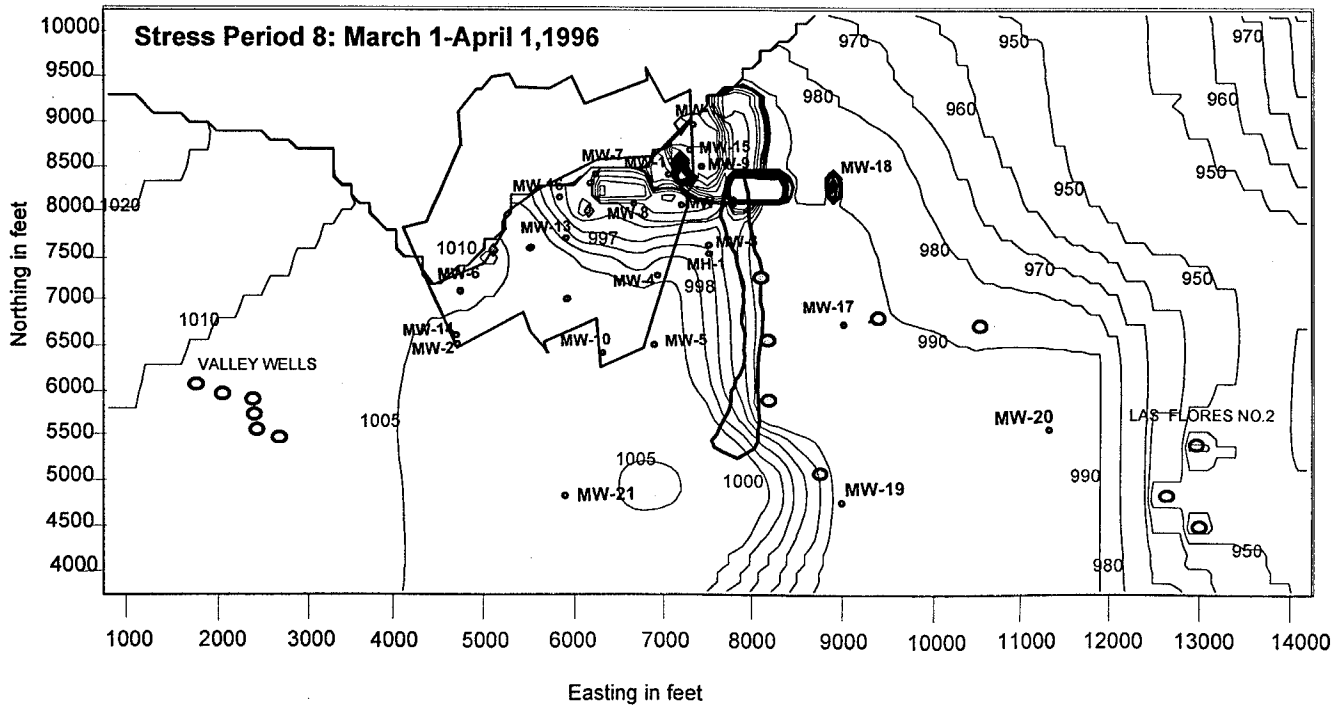
Simulation 02

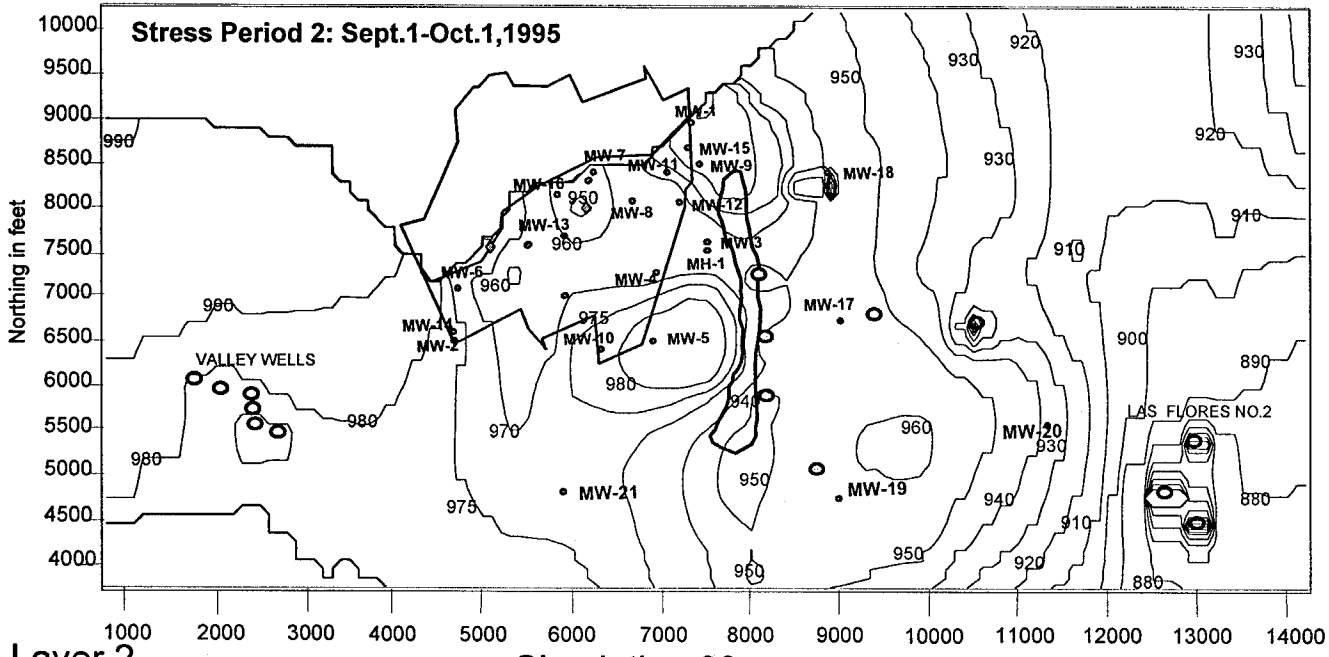




Geologic Layer 1

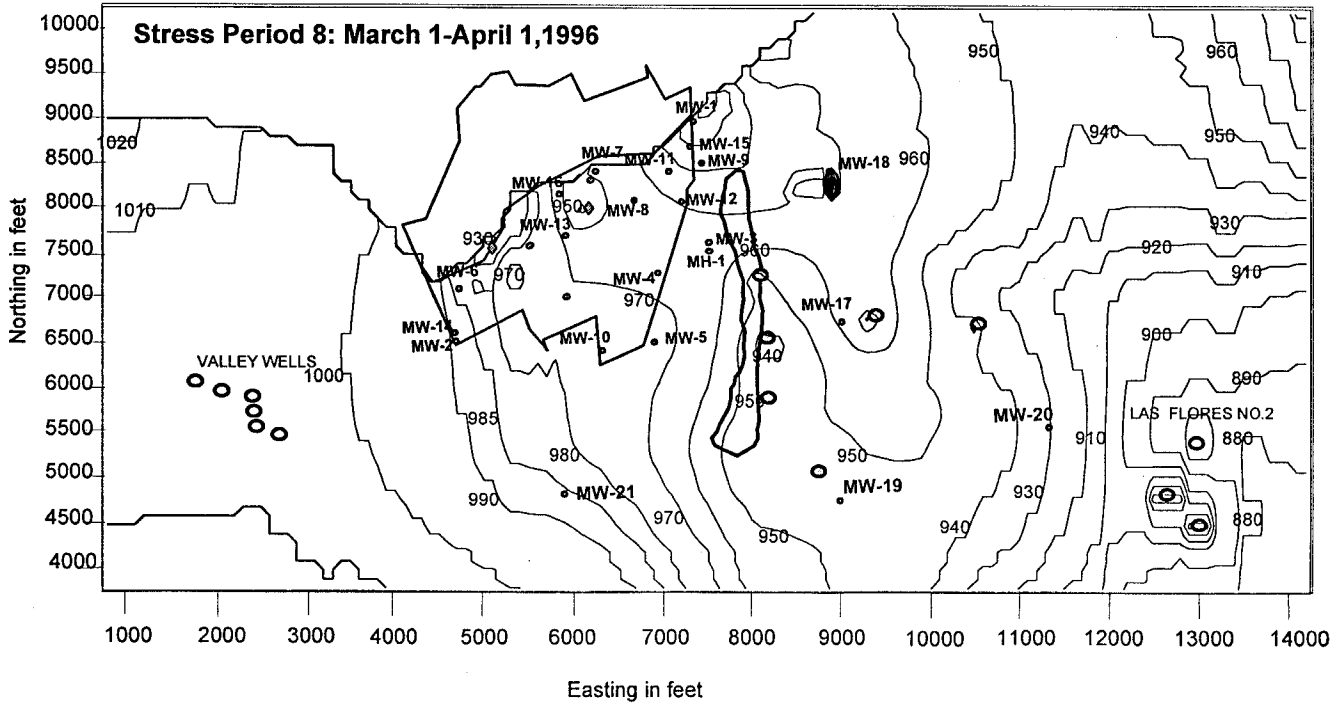
Simulation 03

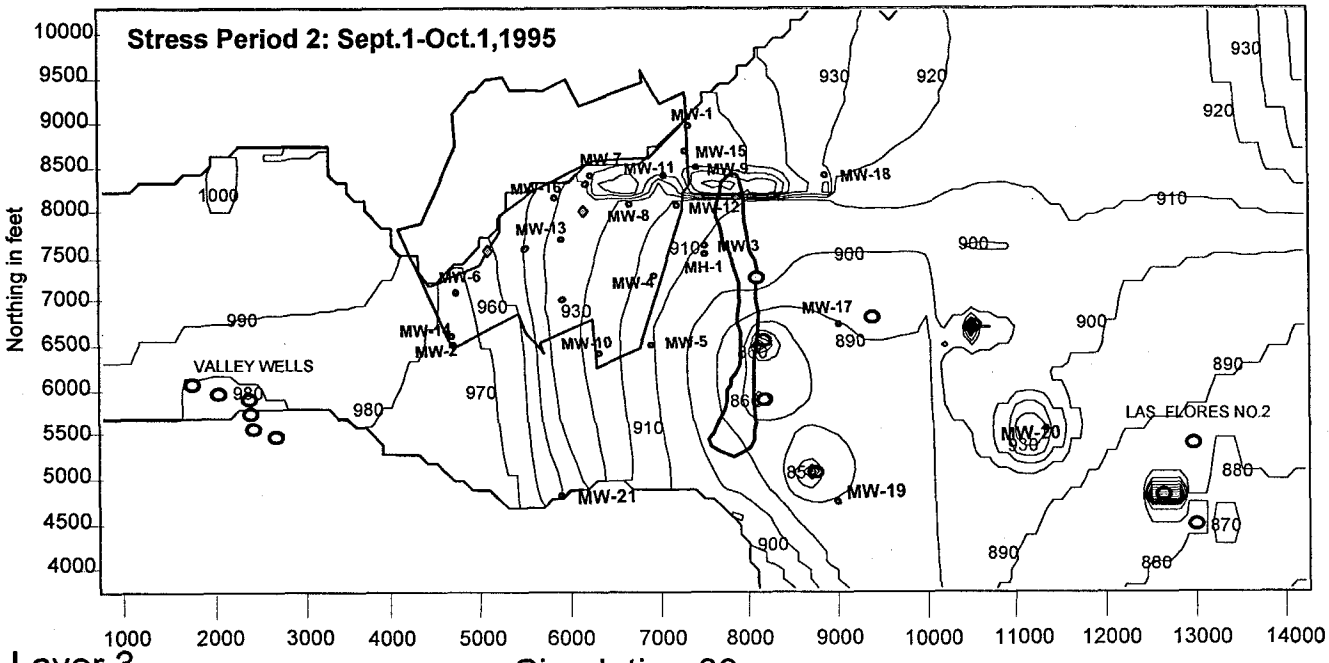




Geologic Layer 2

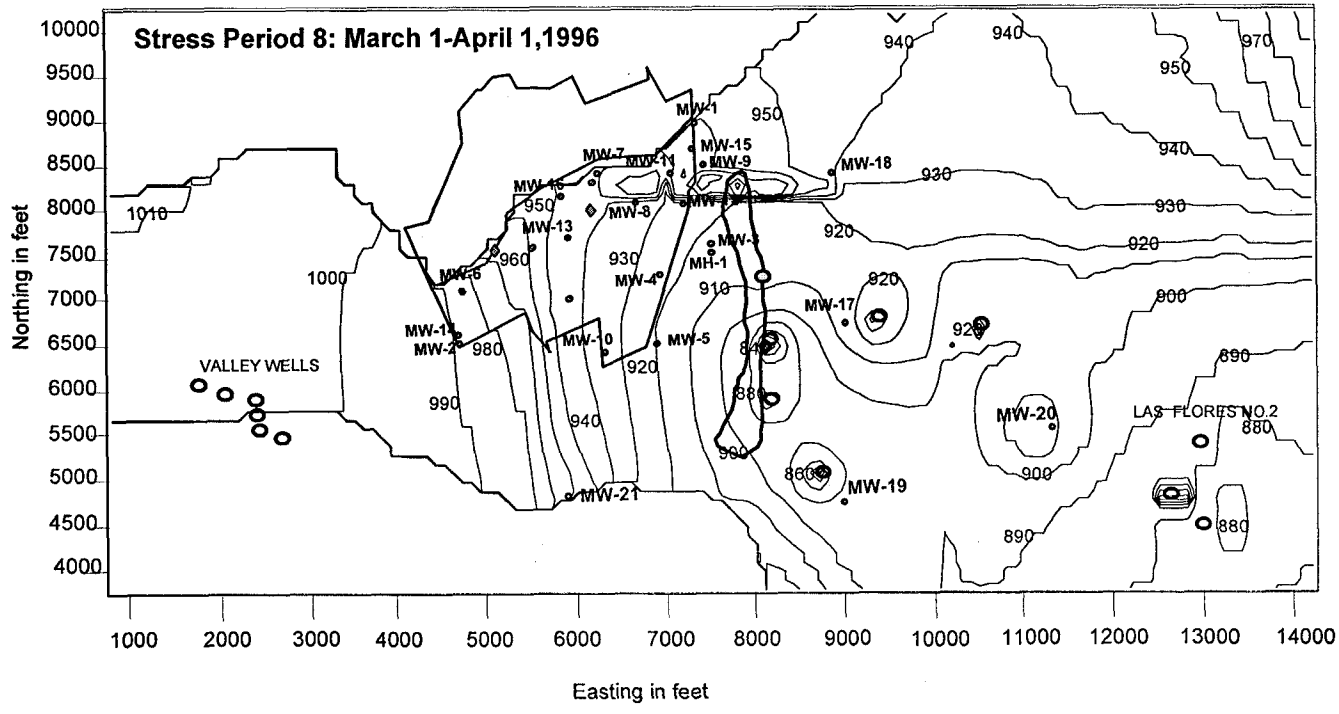
Simulation 03

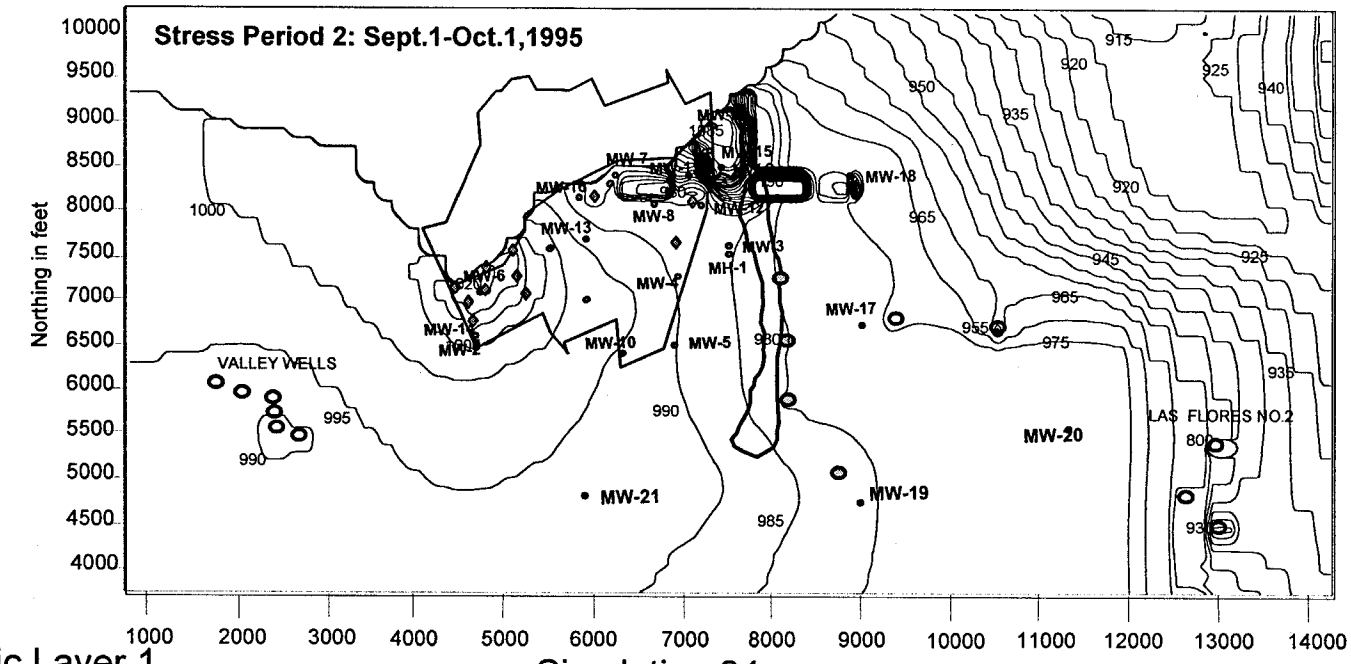




Geologic Layer 3

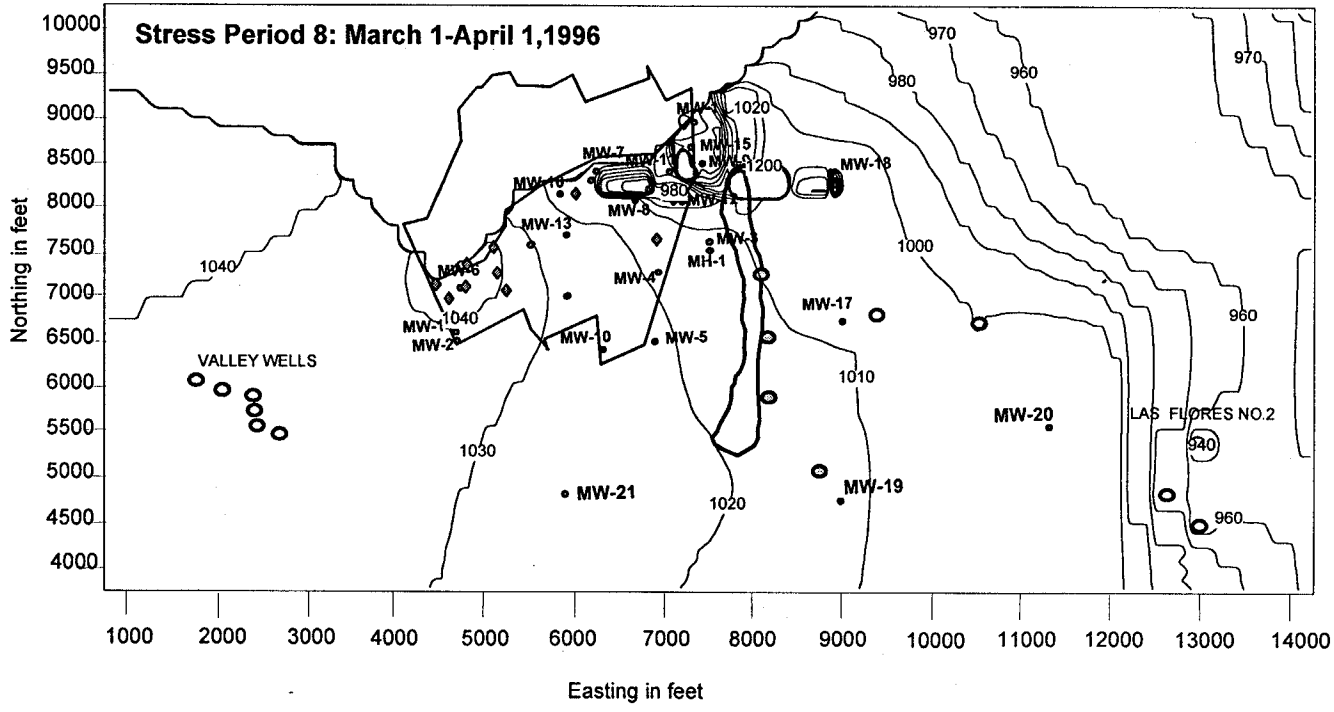
Simulation 03

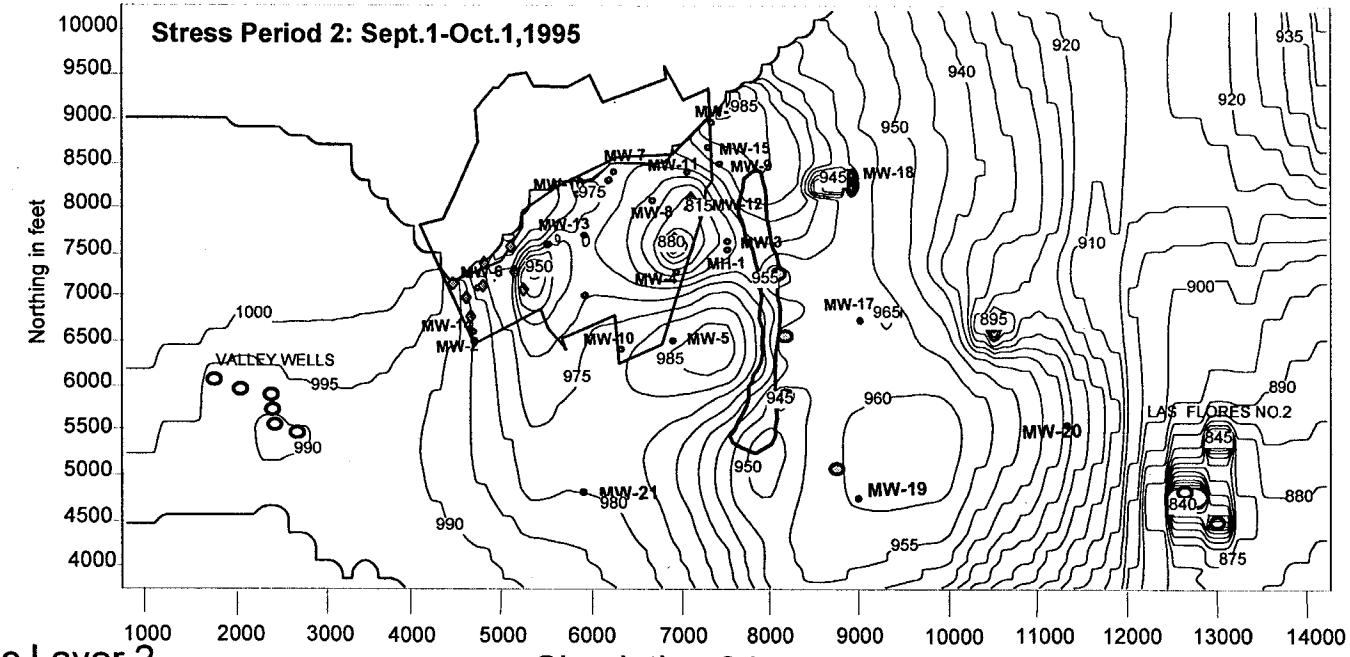




Geologic Layer 1

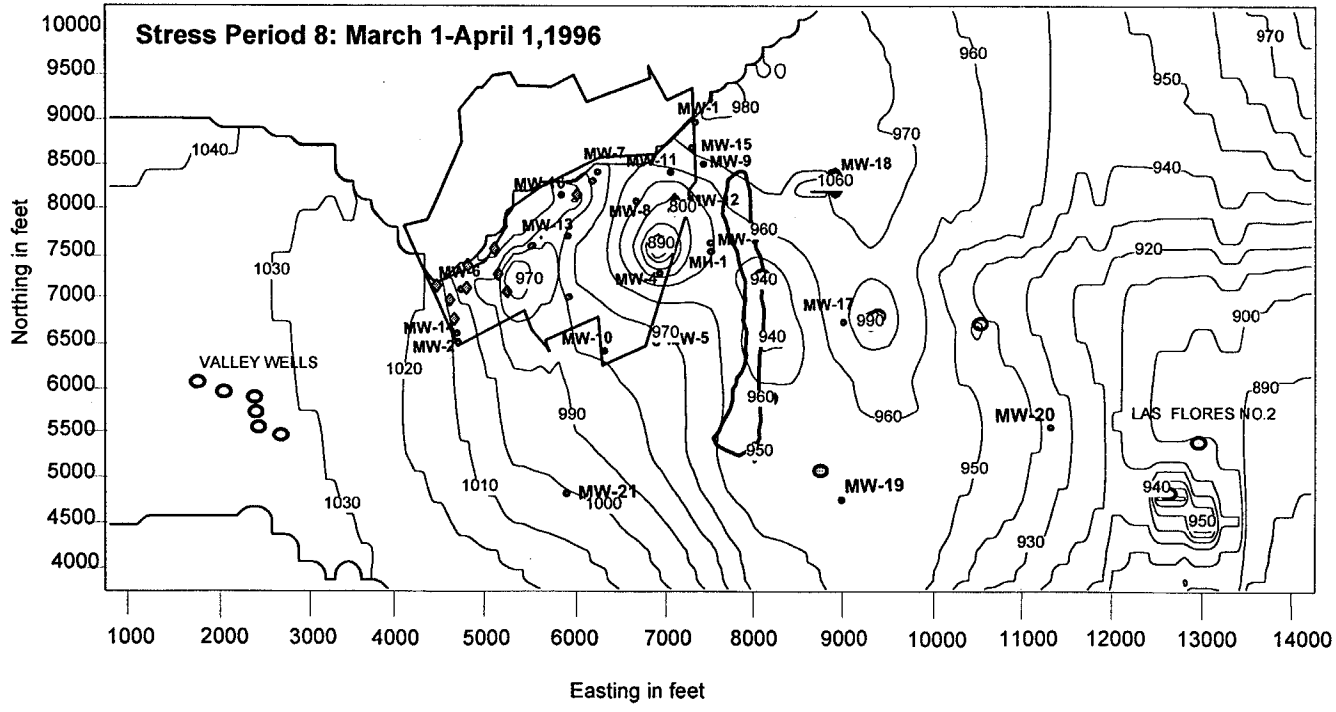
Simulation 04

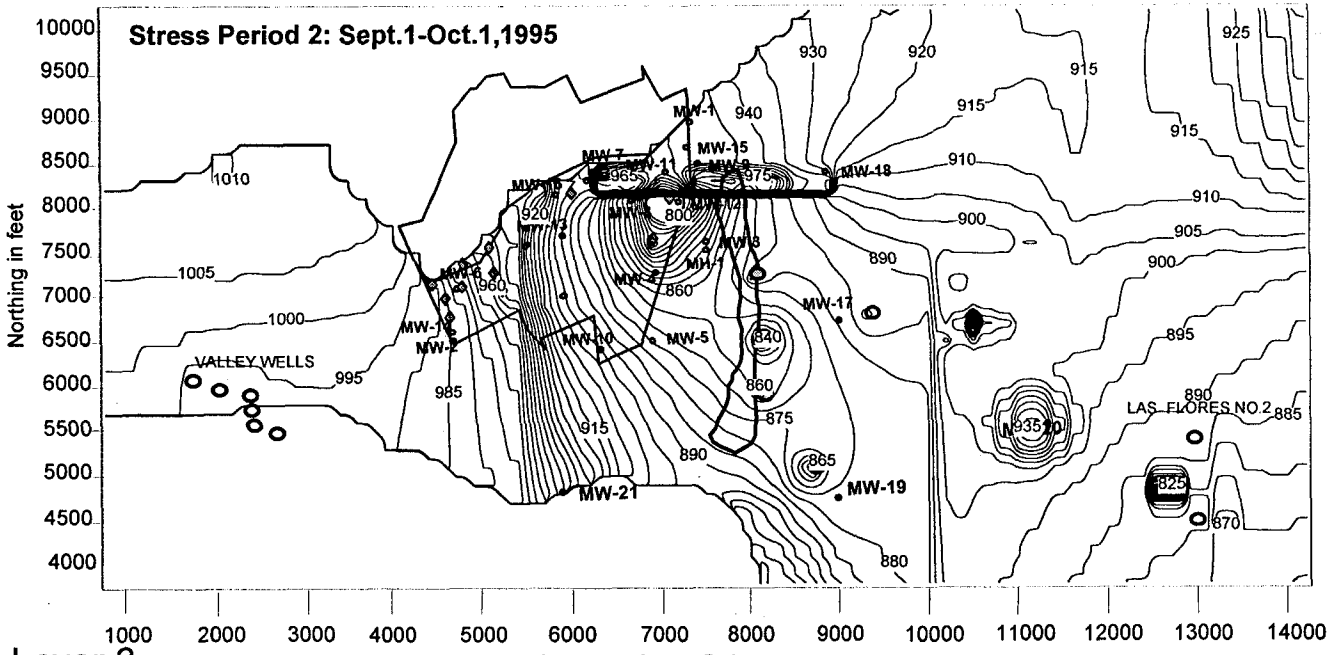




Geologic Layer 2

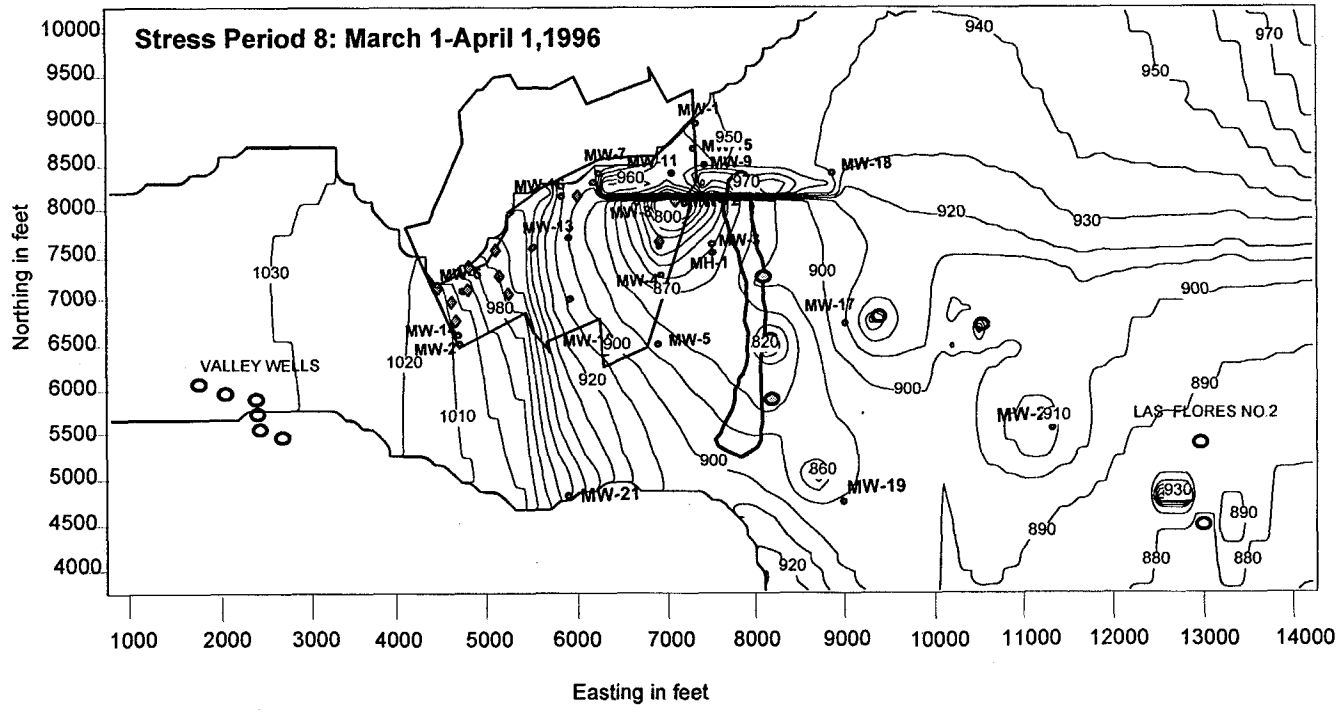
Simulation 04

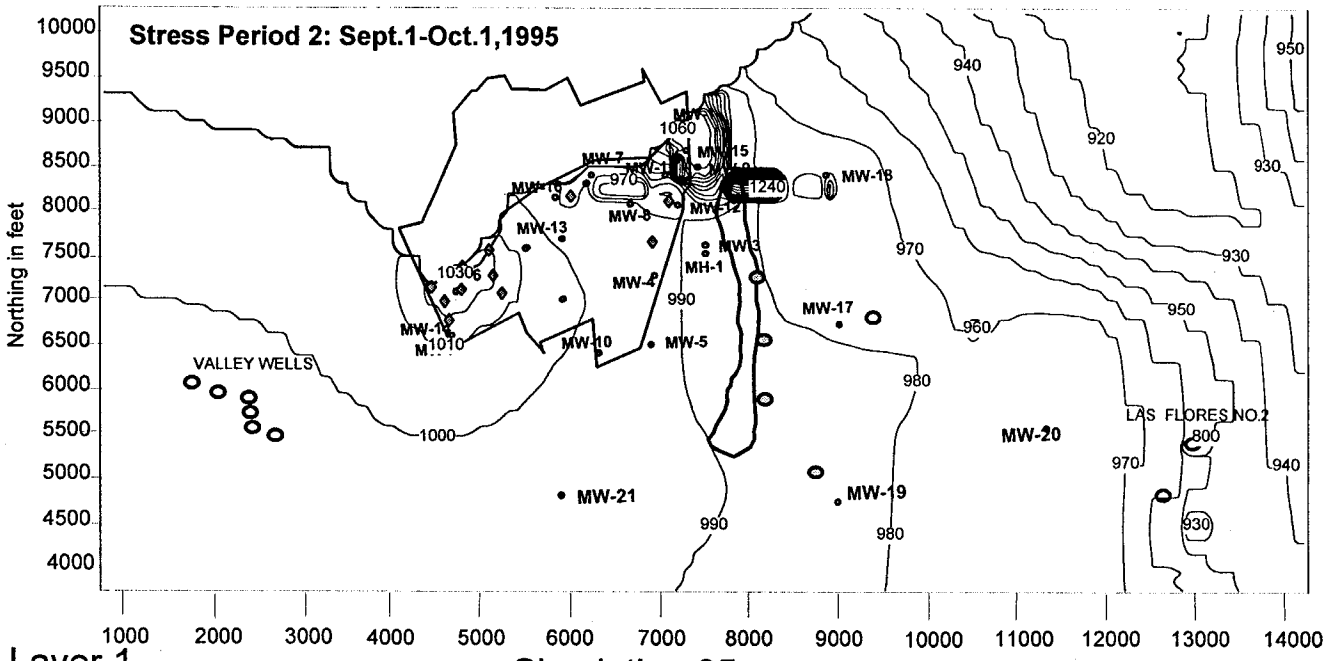




Geologic Layer 3

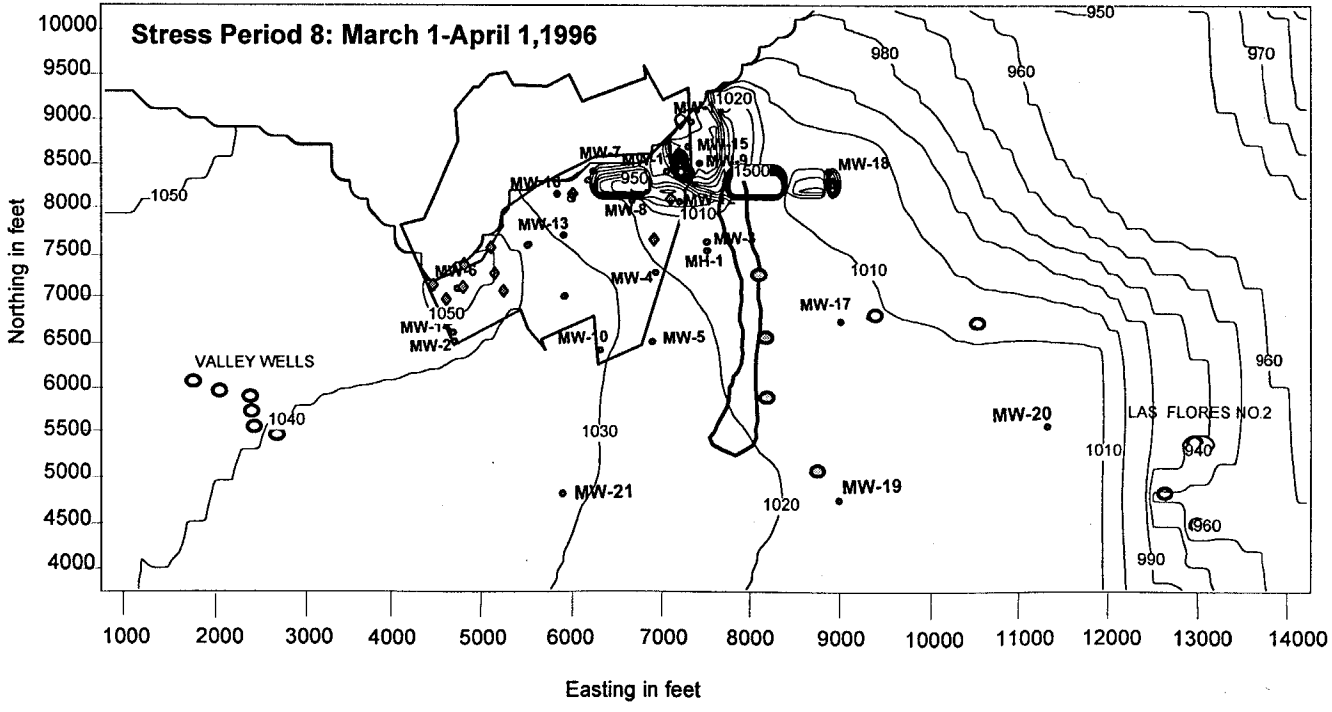
Simulation 04

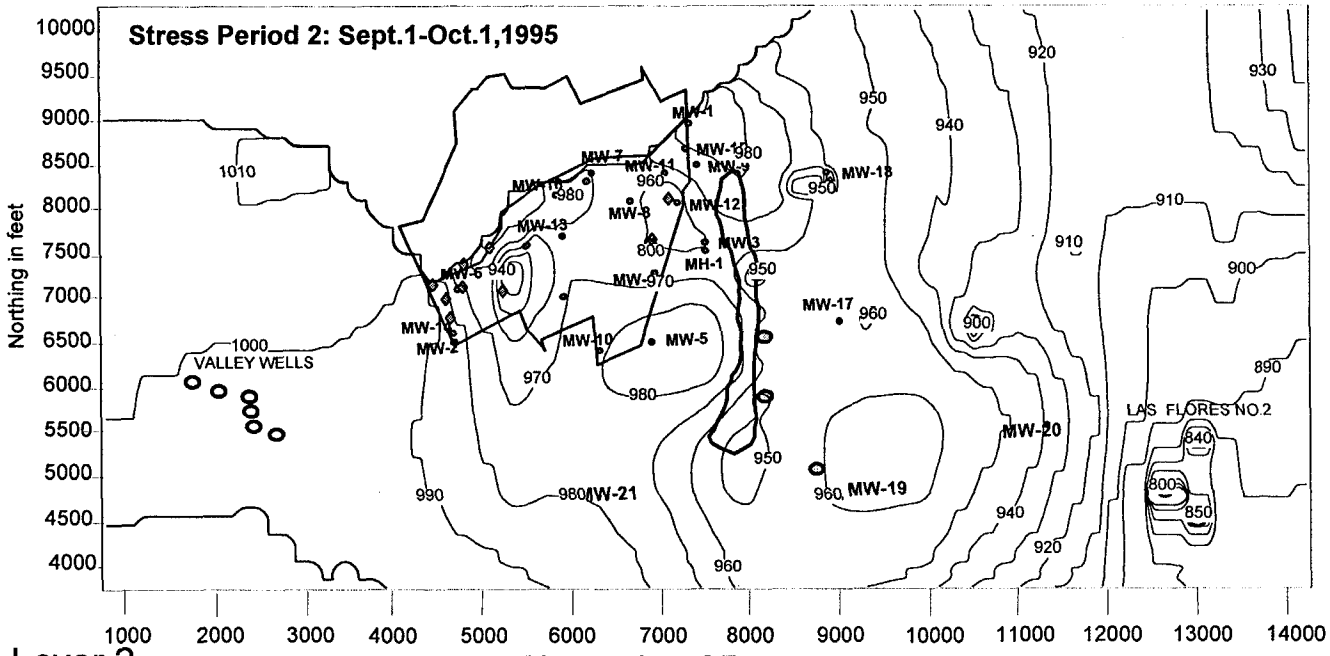




Geologic Layer 1

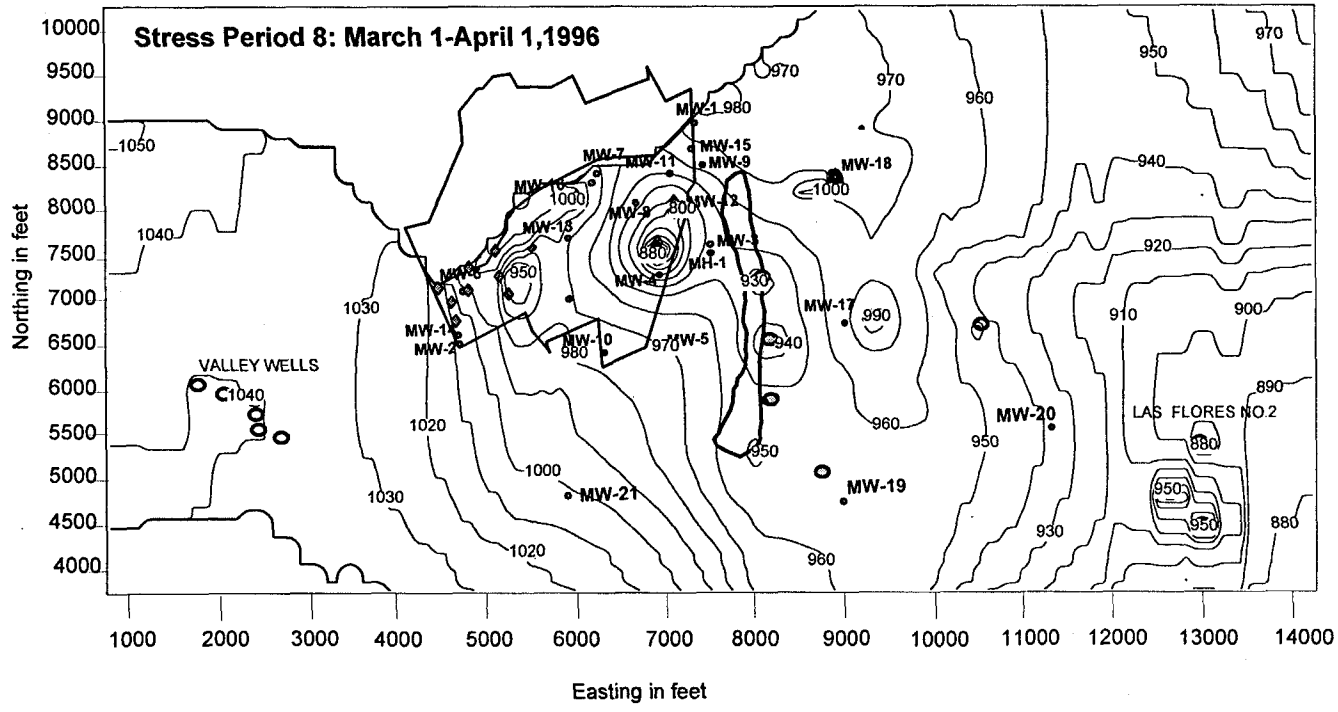
Simulation 05

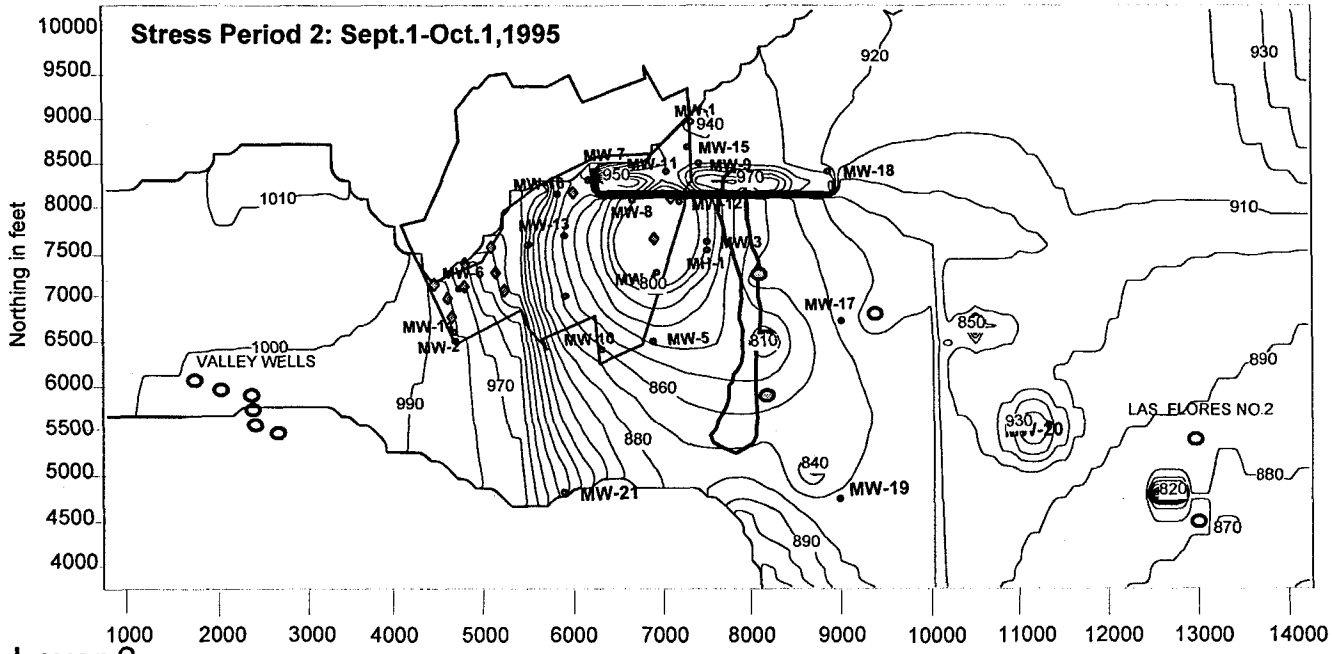




Geologic Layer 2

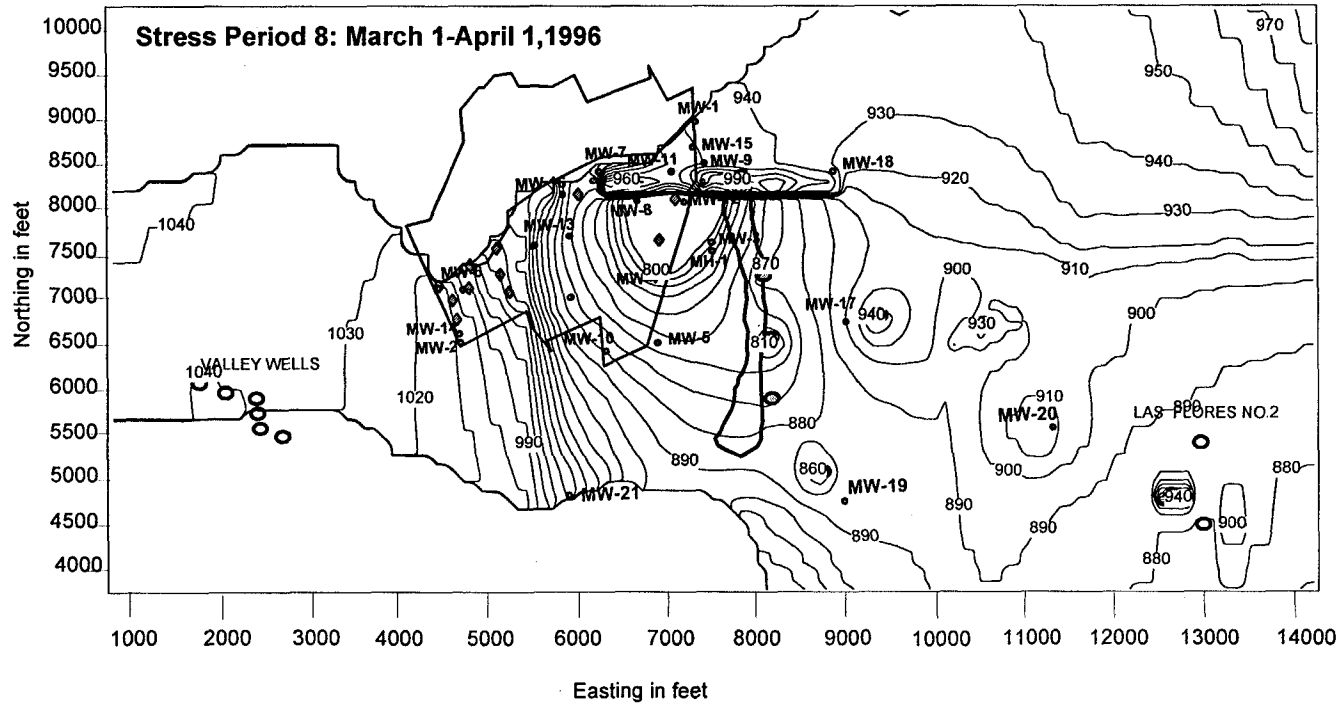
Simulation 05

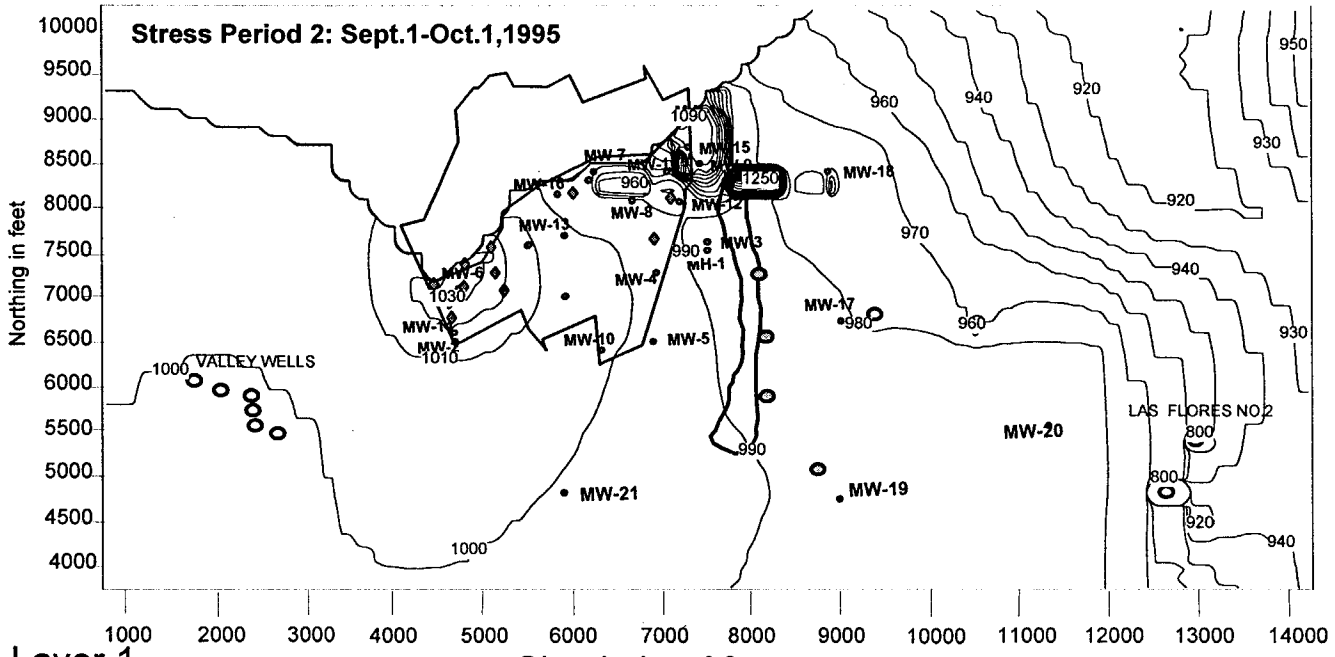




Geologic Layer 3

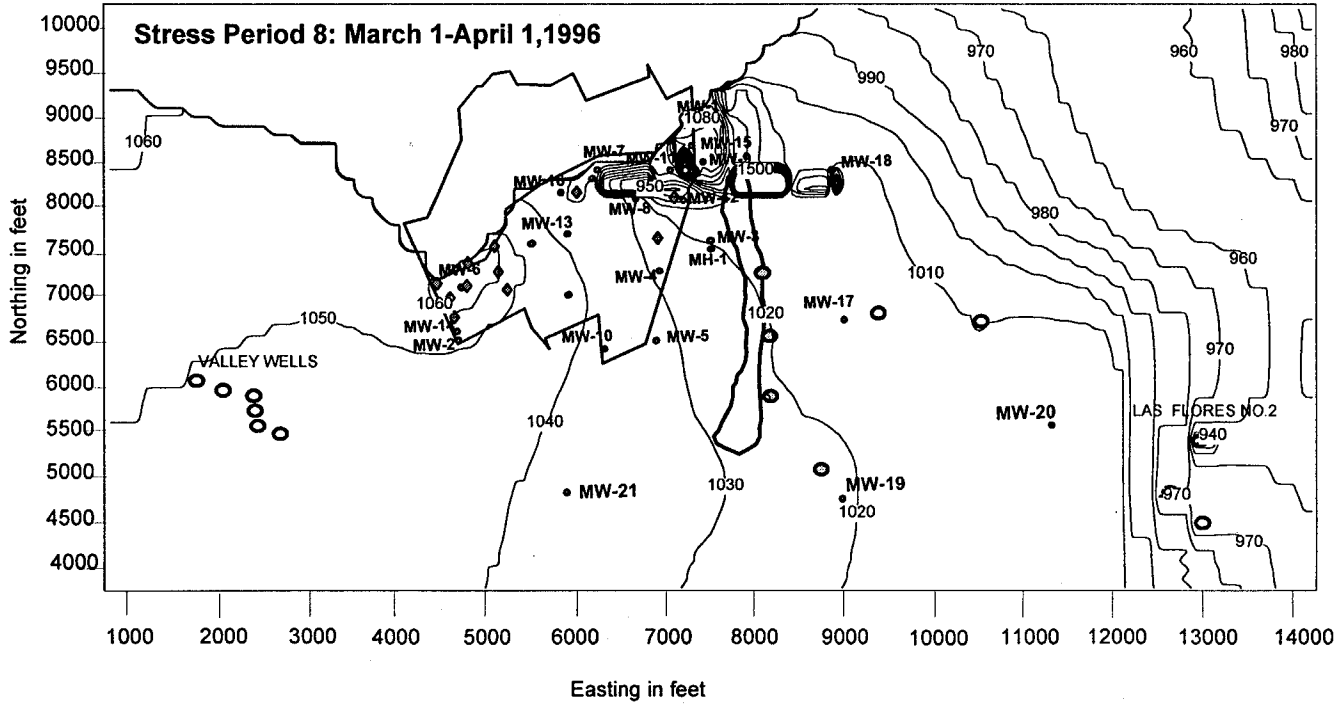
Simulation 05

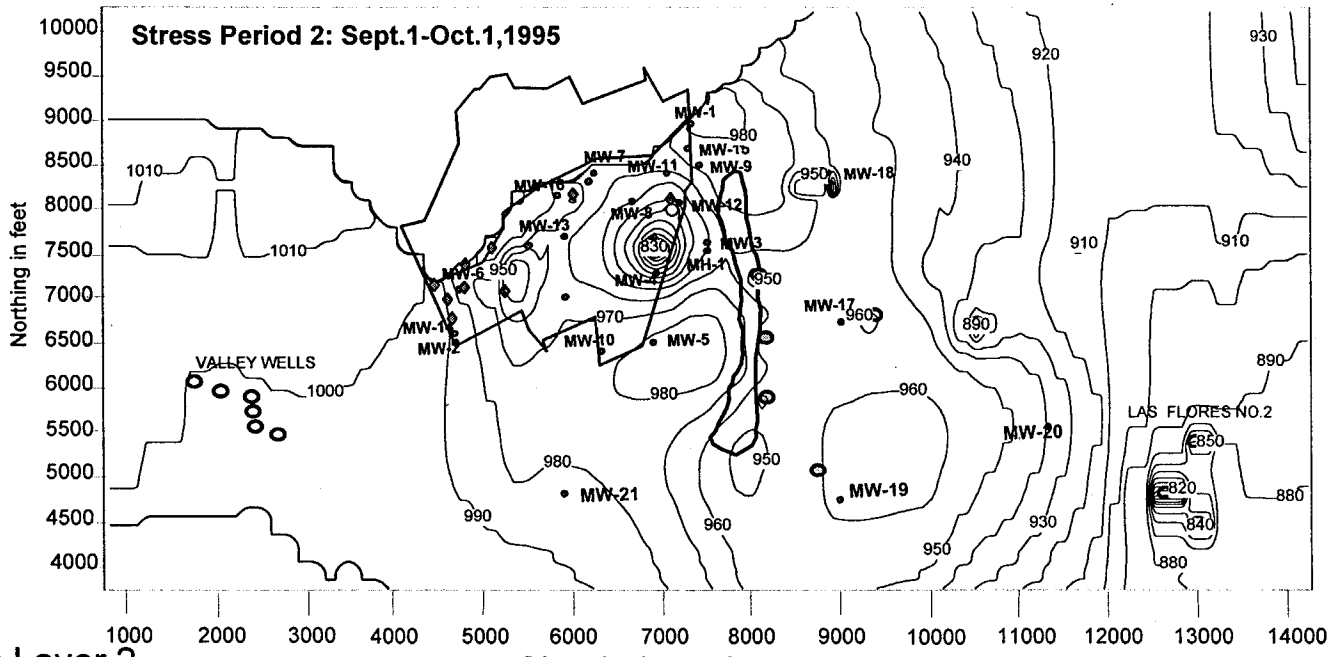




Geologic Layer 1

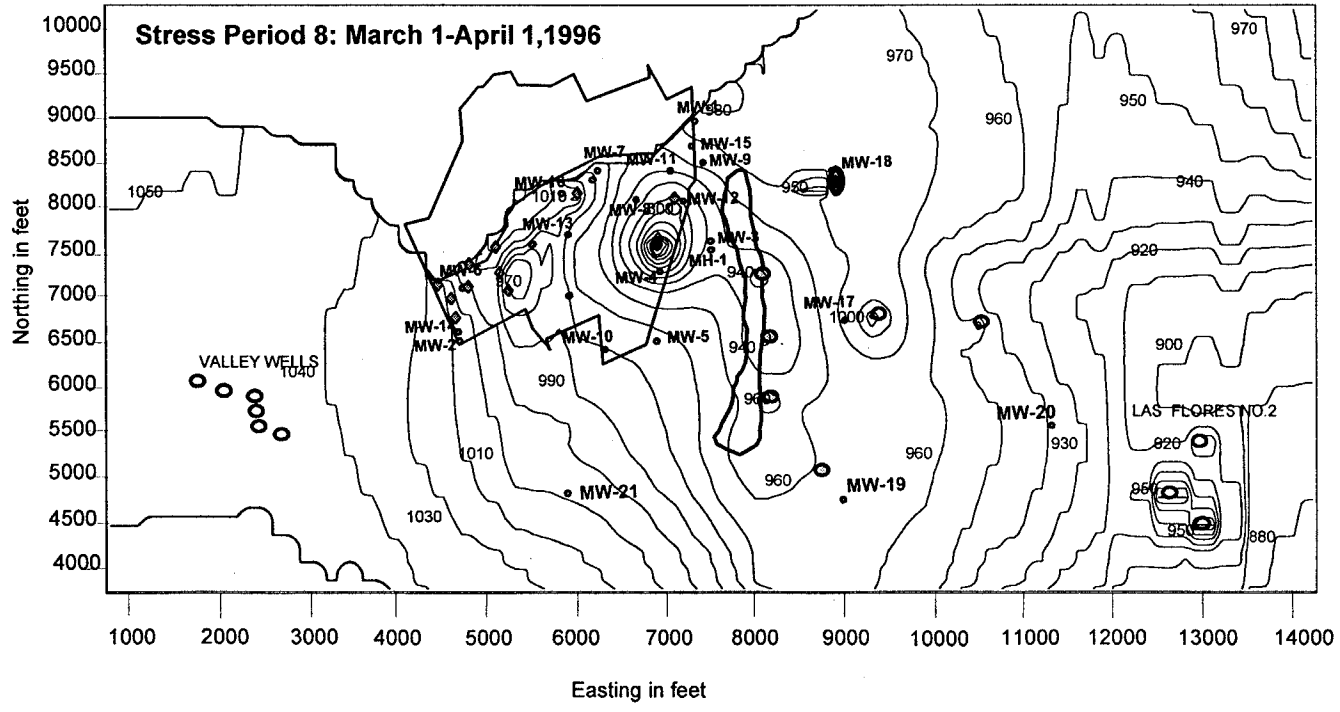
Simulation 06

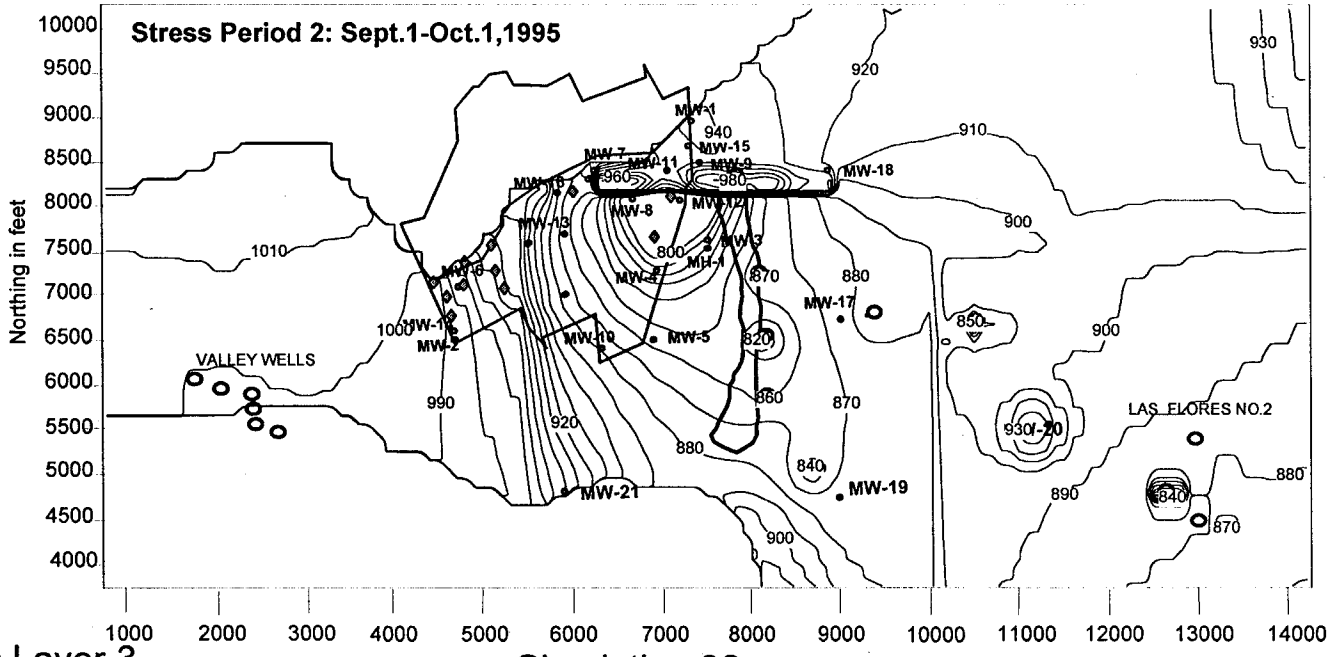




Geologic Layer 2

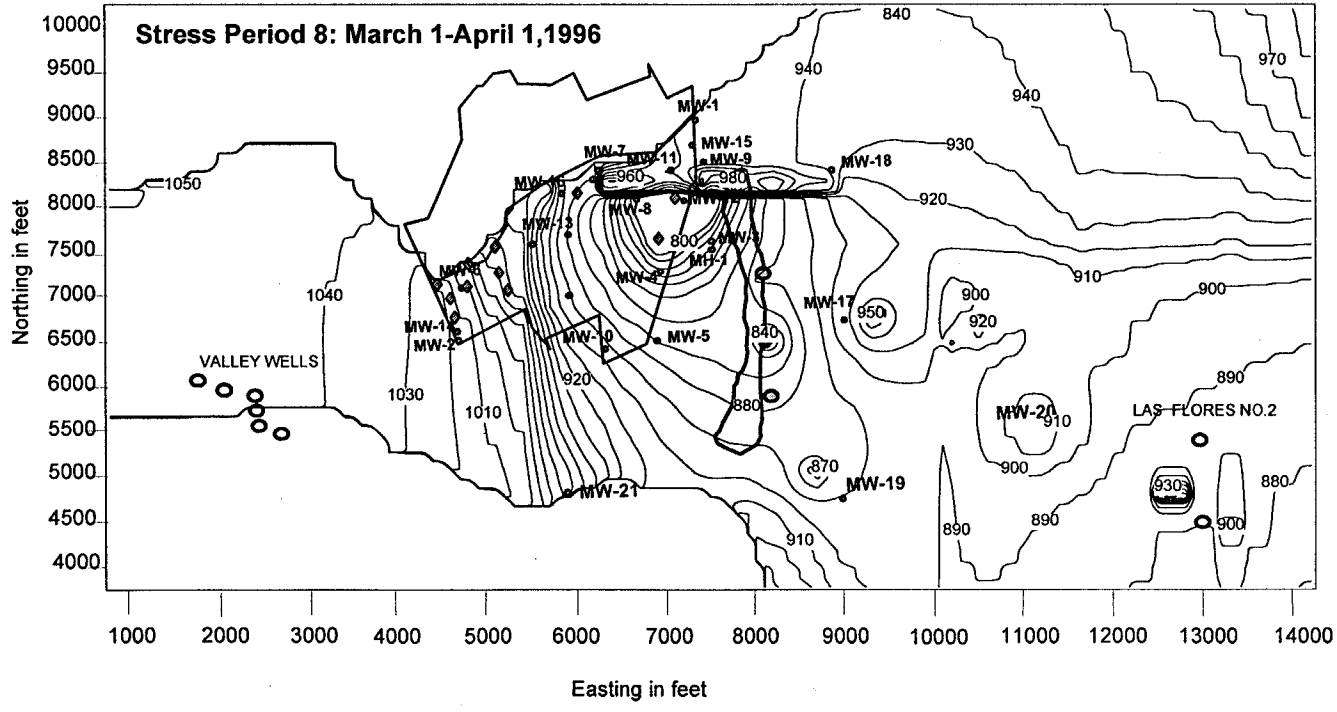
Simulation 06

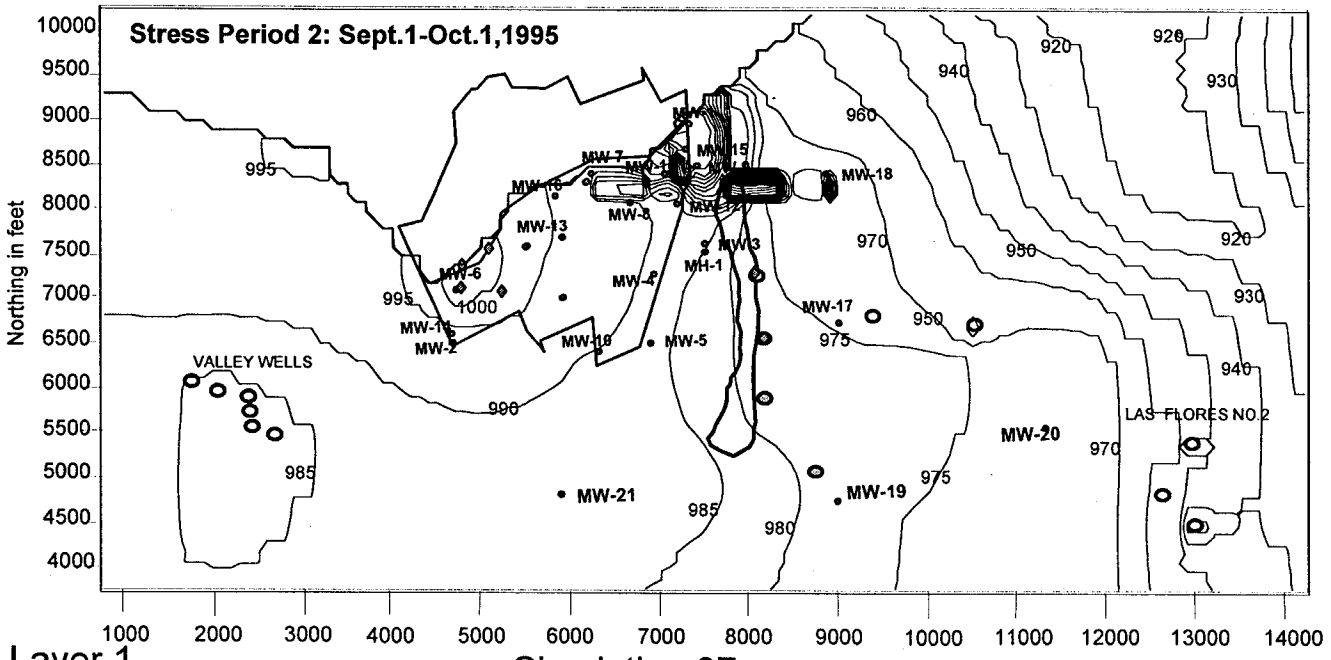




Geologic Layer 3

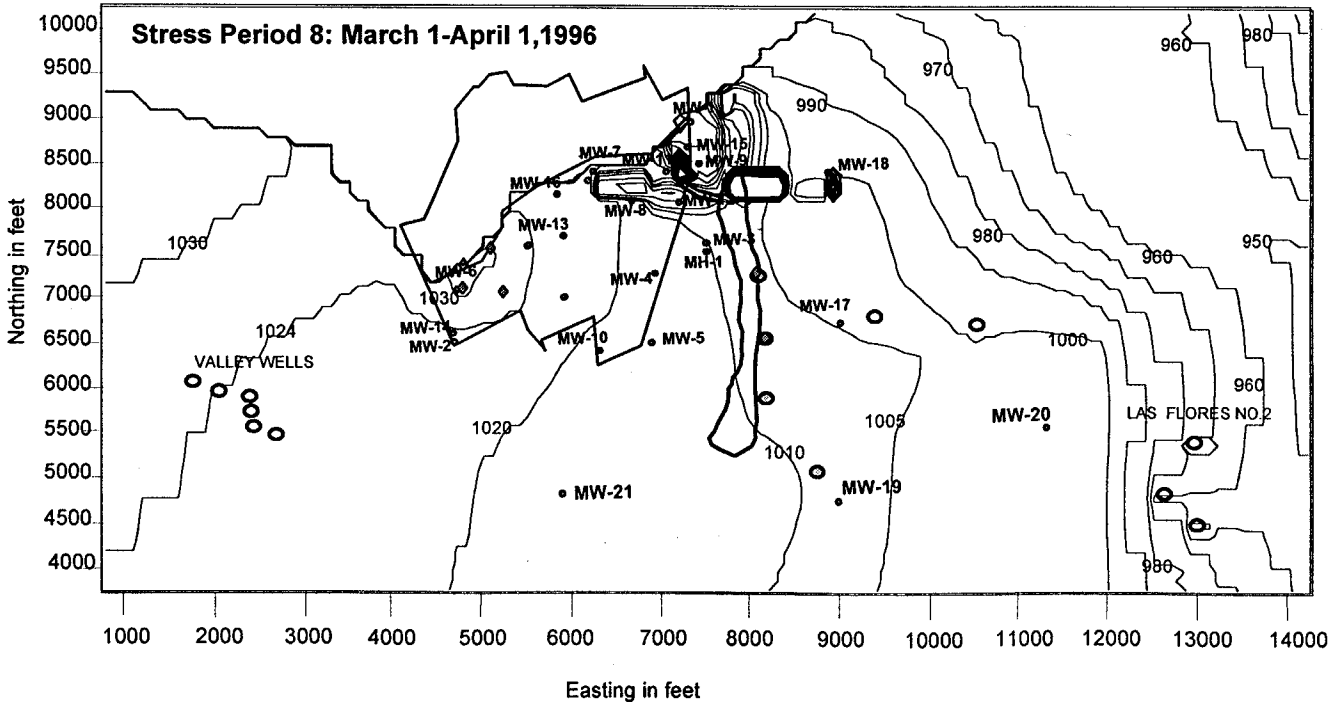
Simulation 06

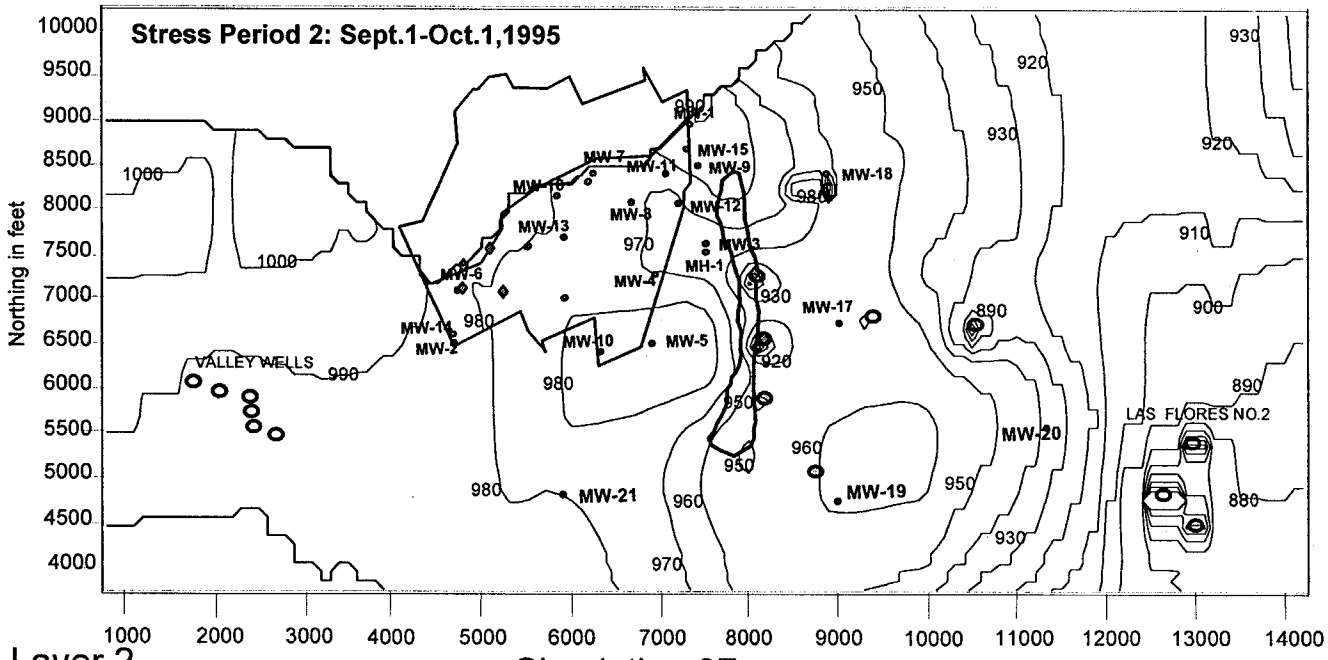




Geologic Layer 1

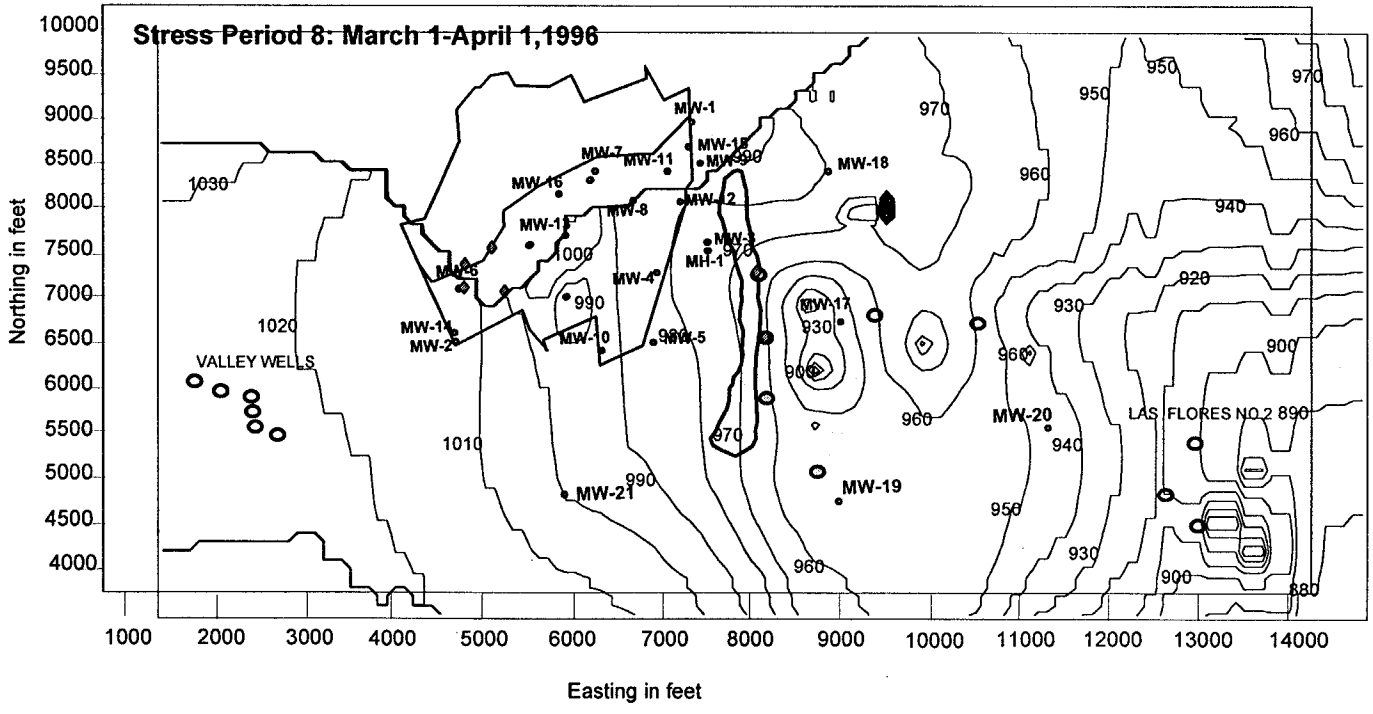
Simulation 07

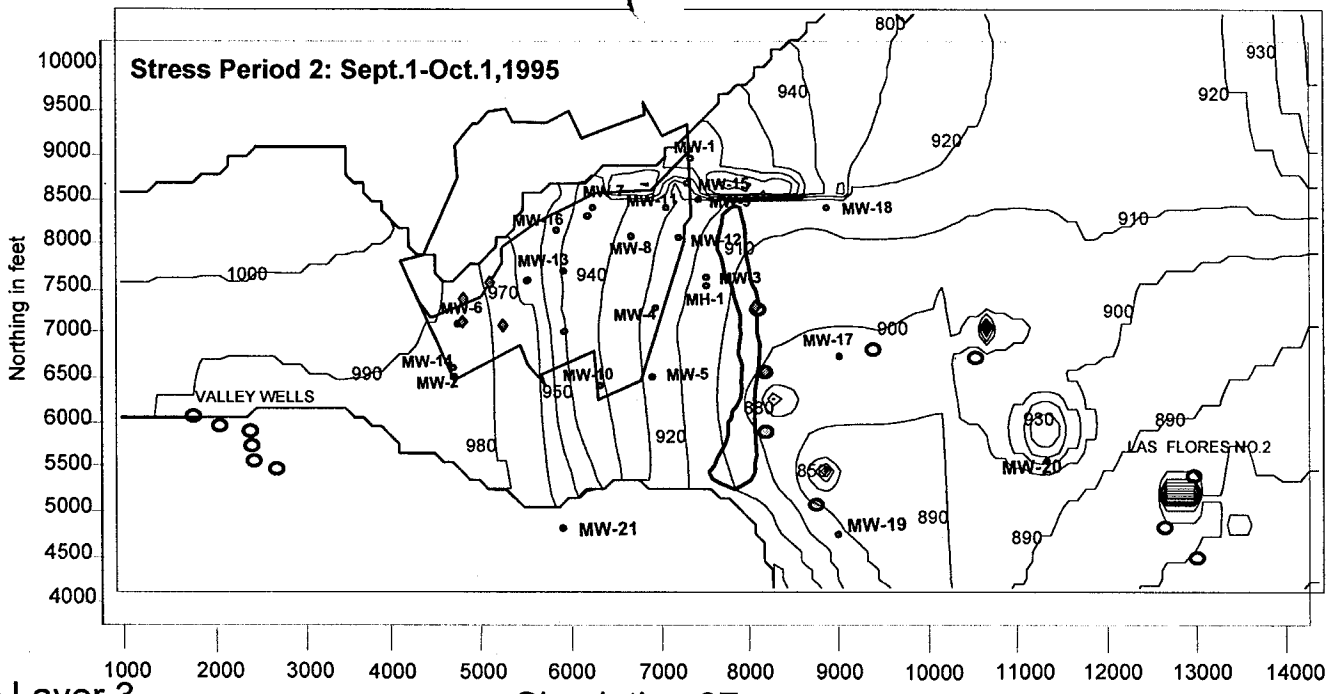




Geologic Layer 2

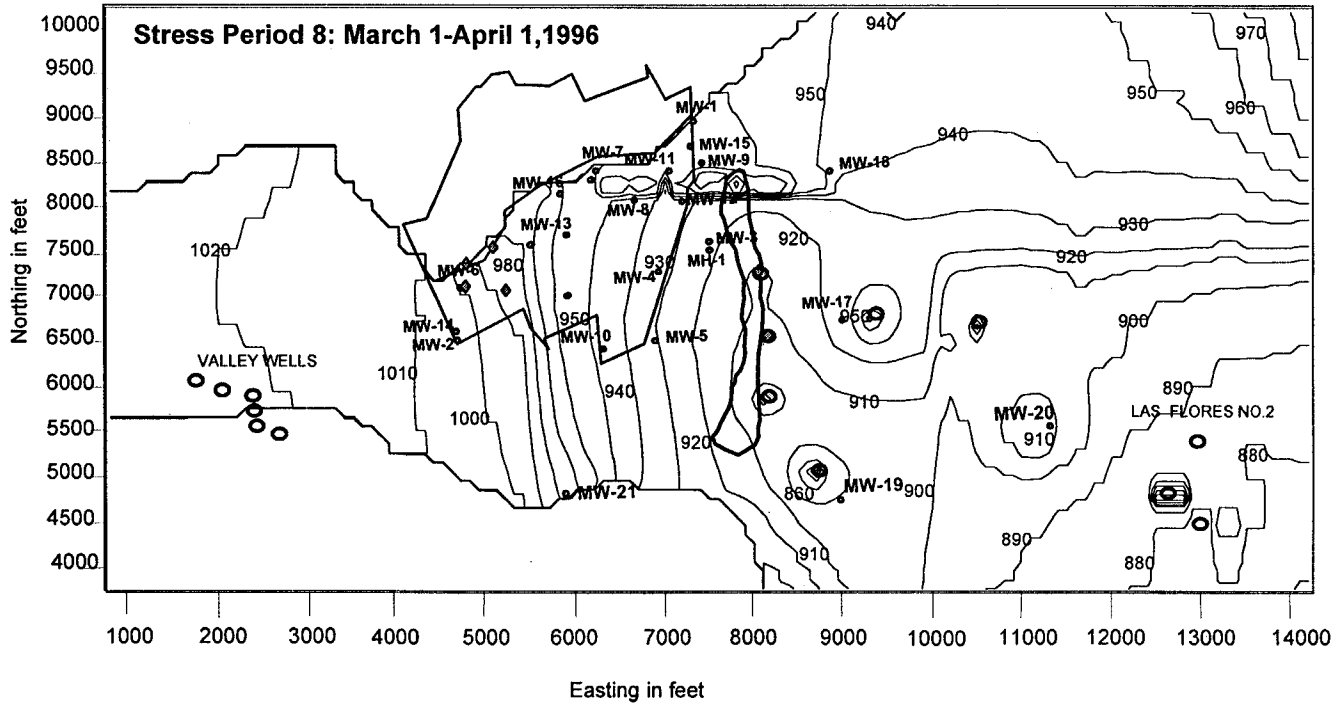
Simulation 07

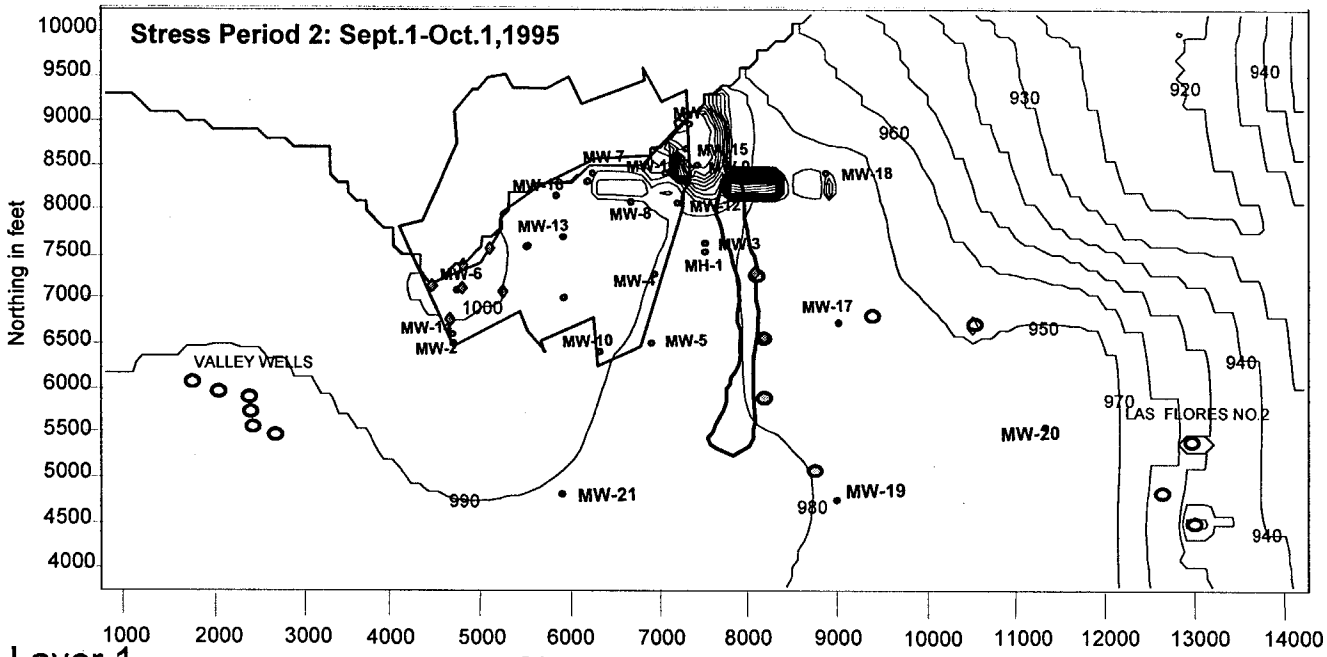




Geologic Layer 3

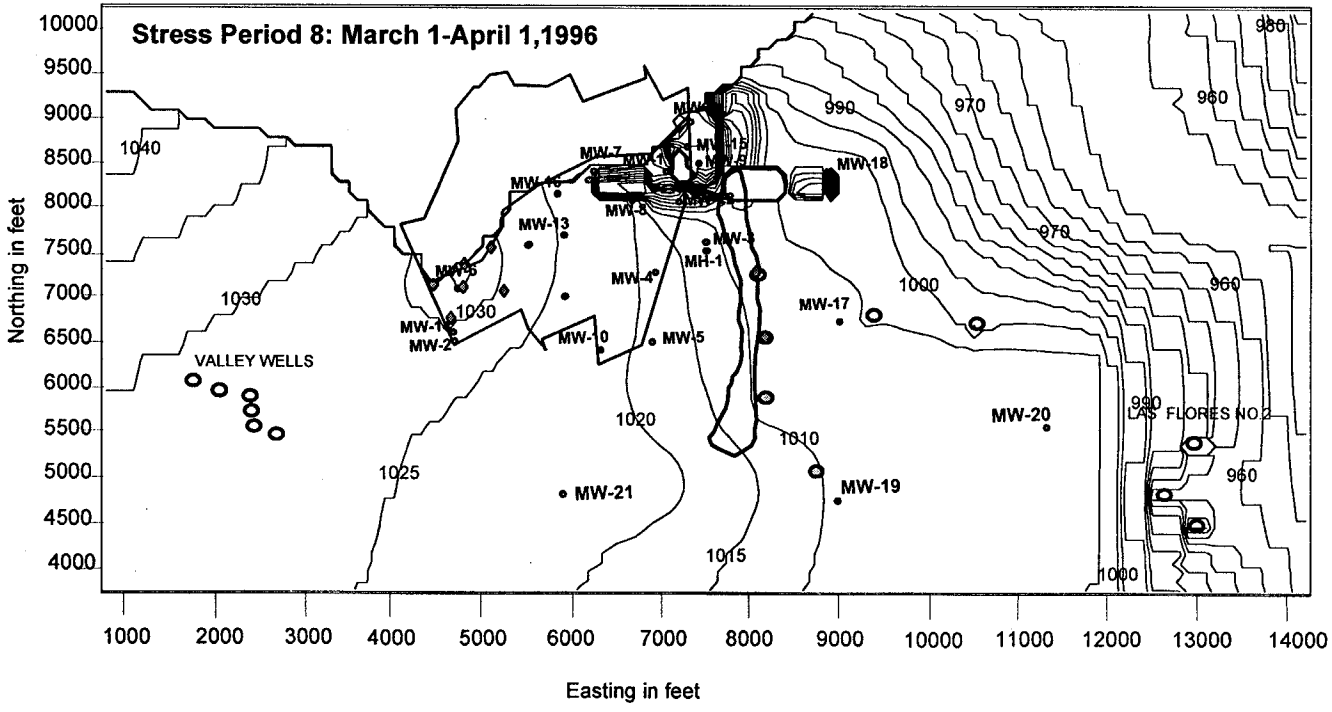
Simulation 07

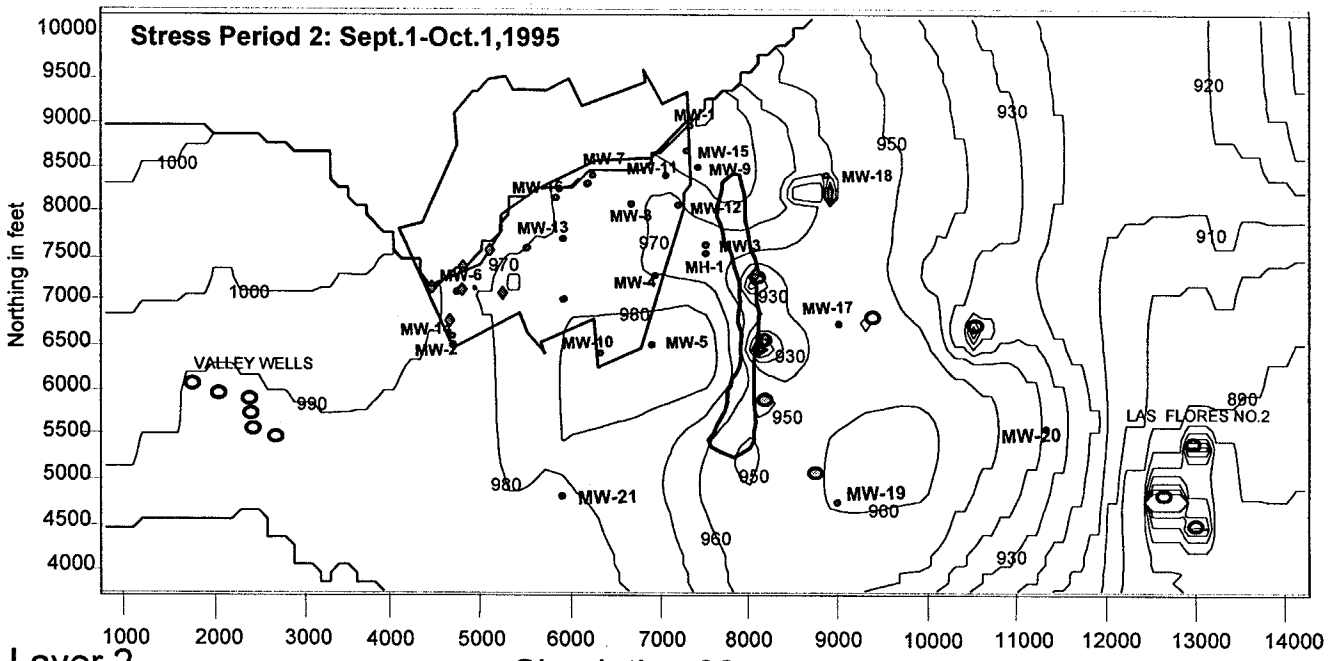




Geologic Layer 1

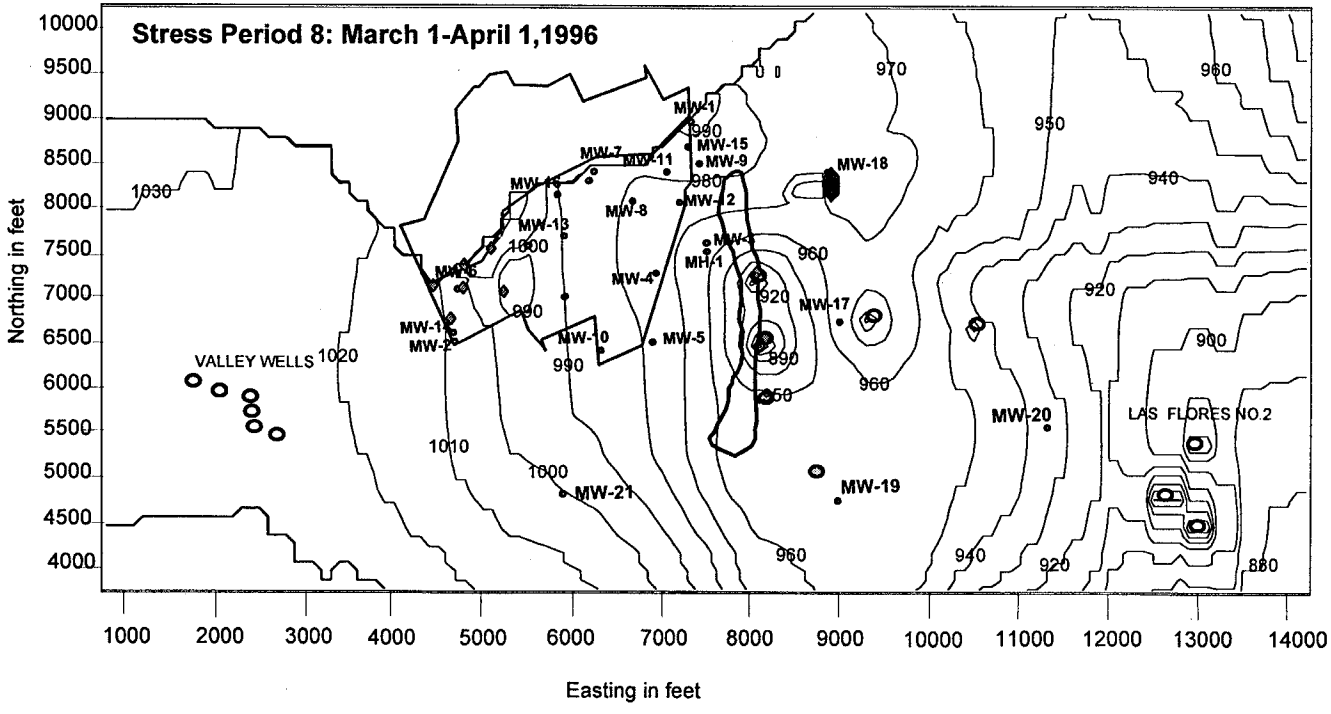
Simulation 08

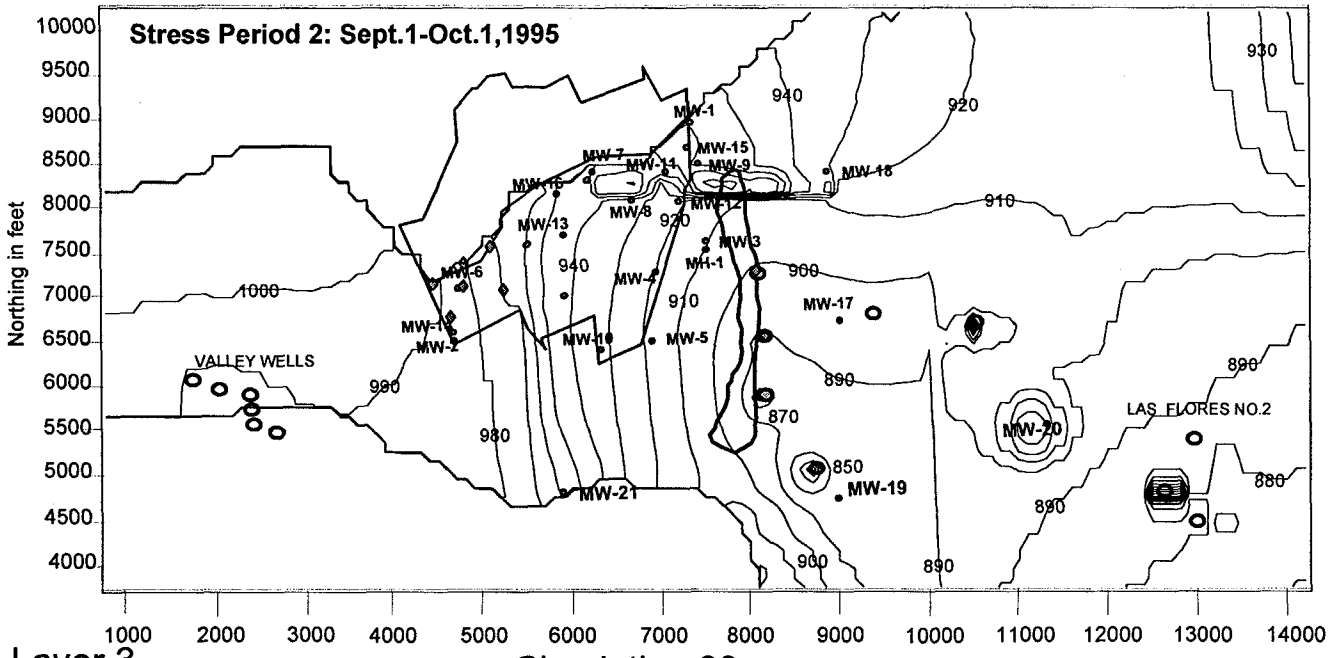




Geologic Layer 2

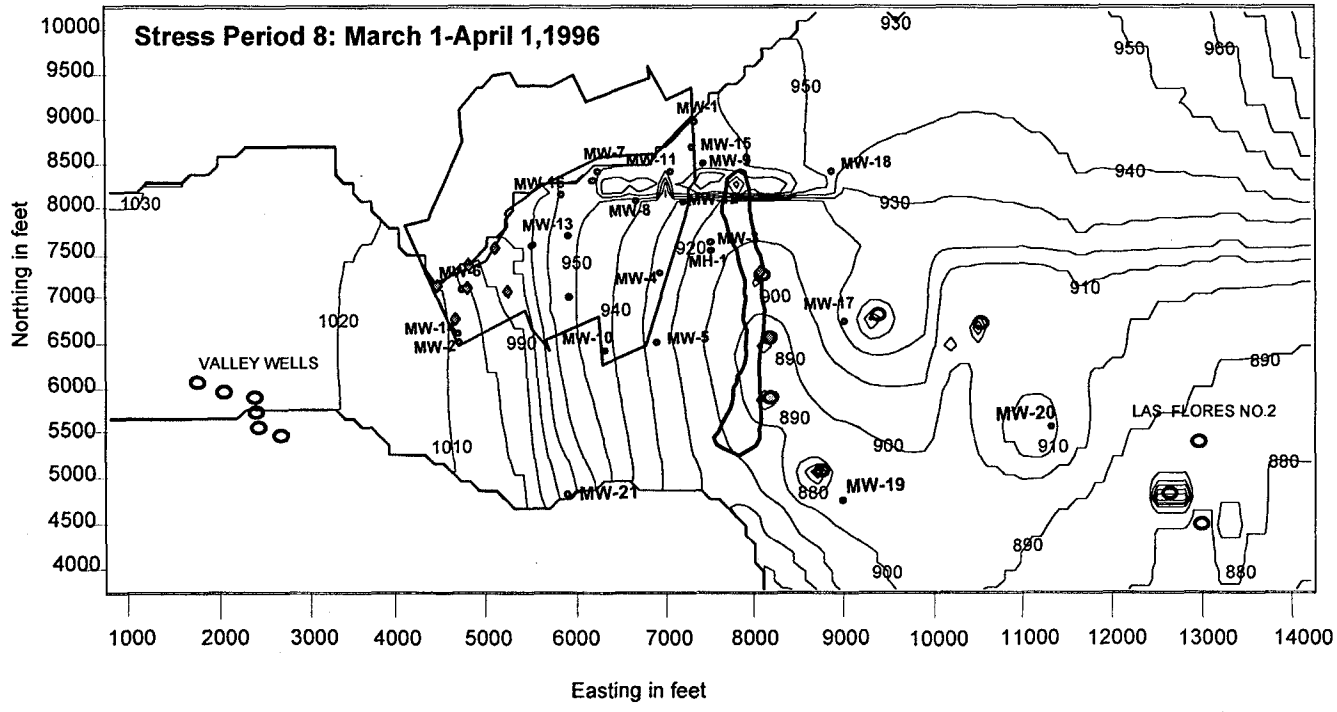
Simulation 08

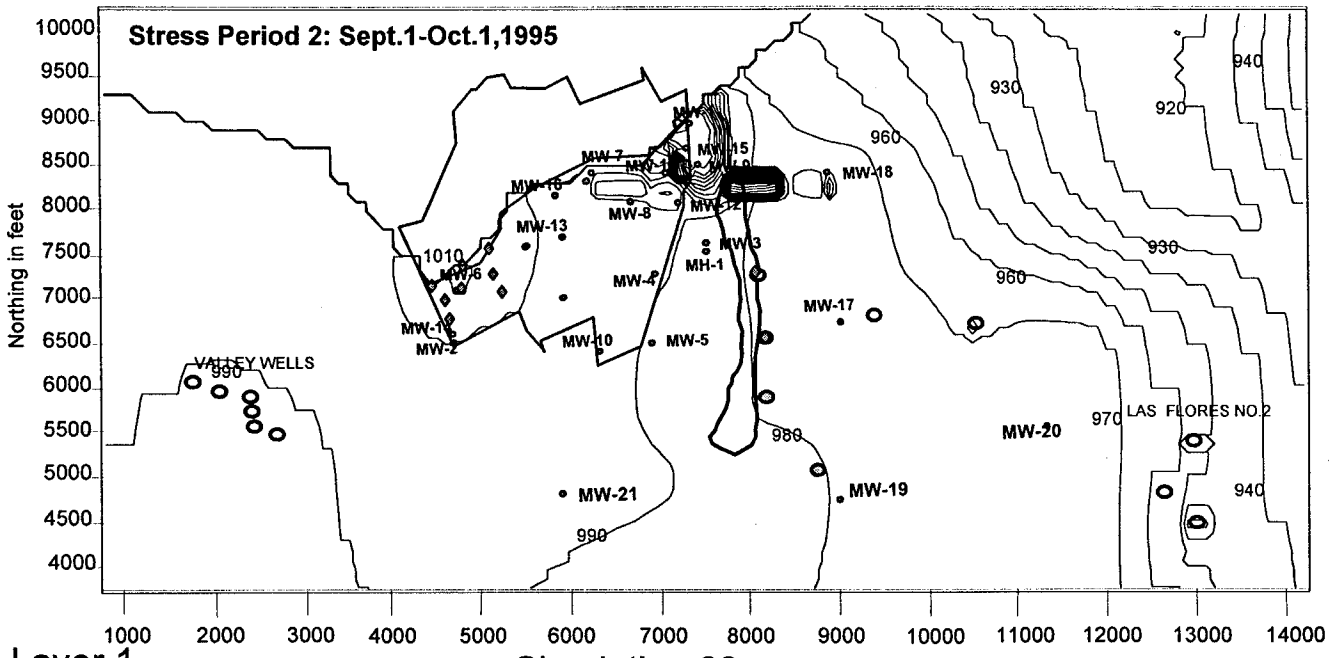




Geologic Layer 3

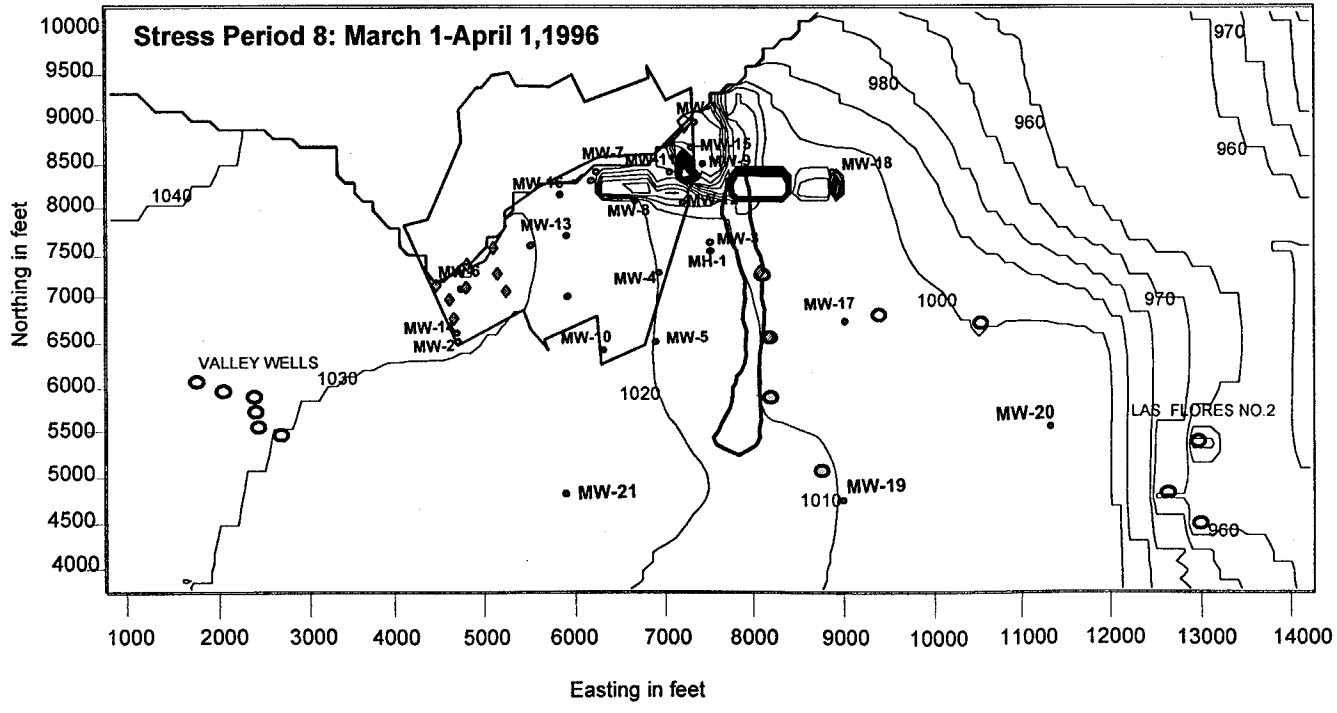
Simulation 08

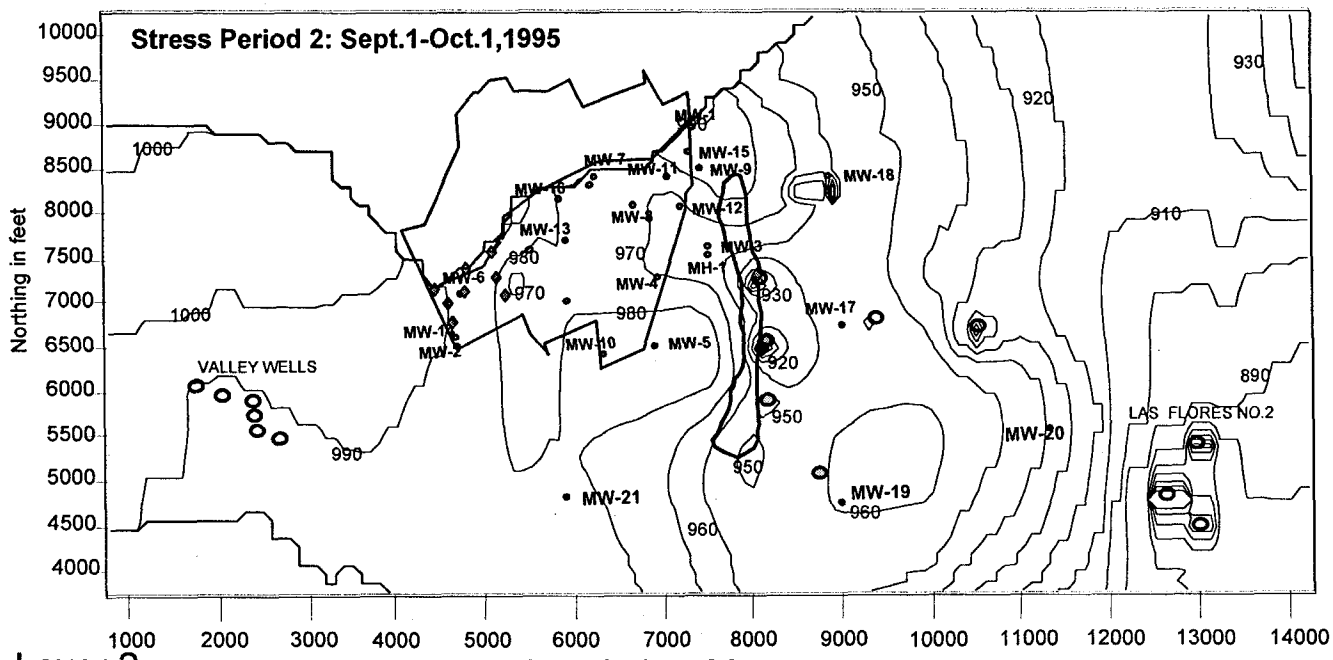




Geologic Layer 1

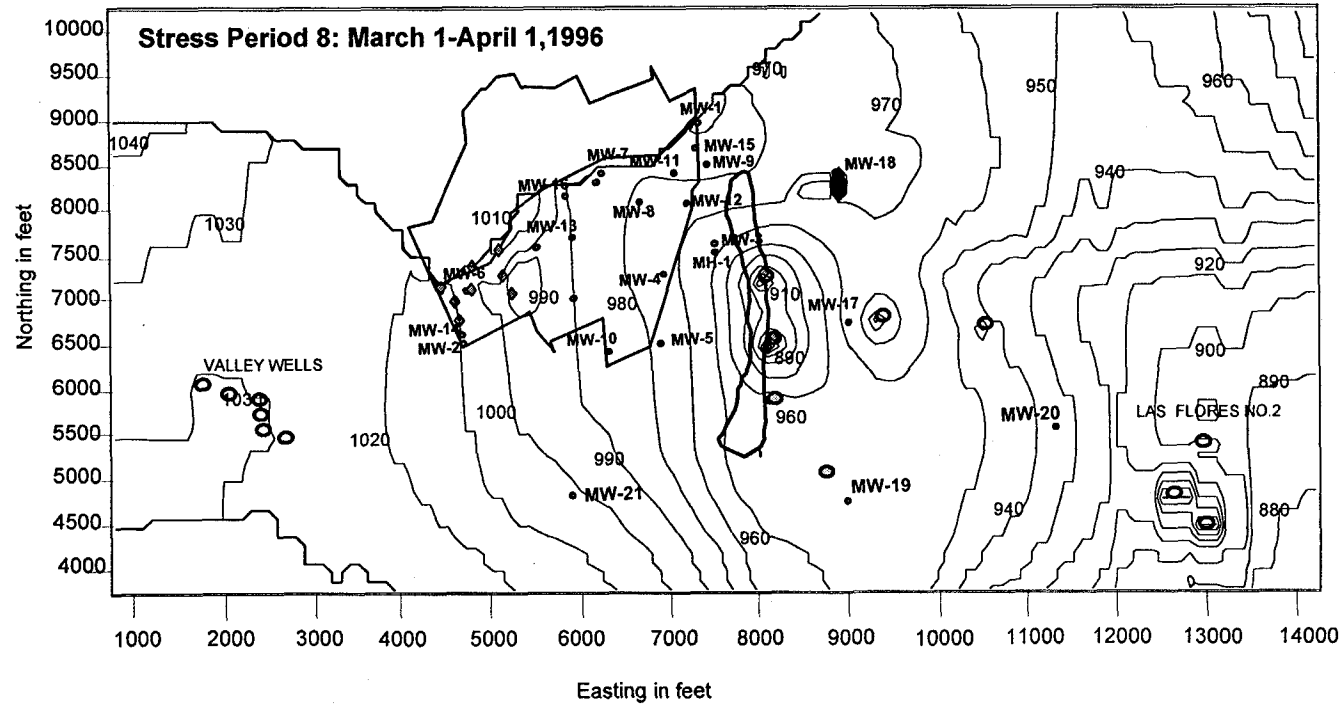
Simulation 09

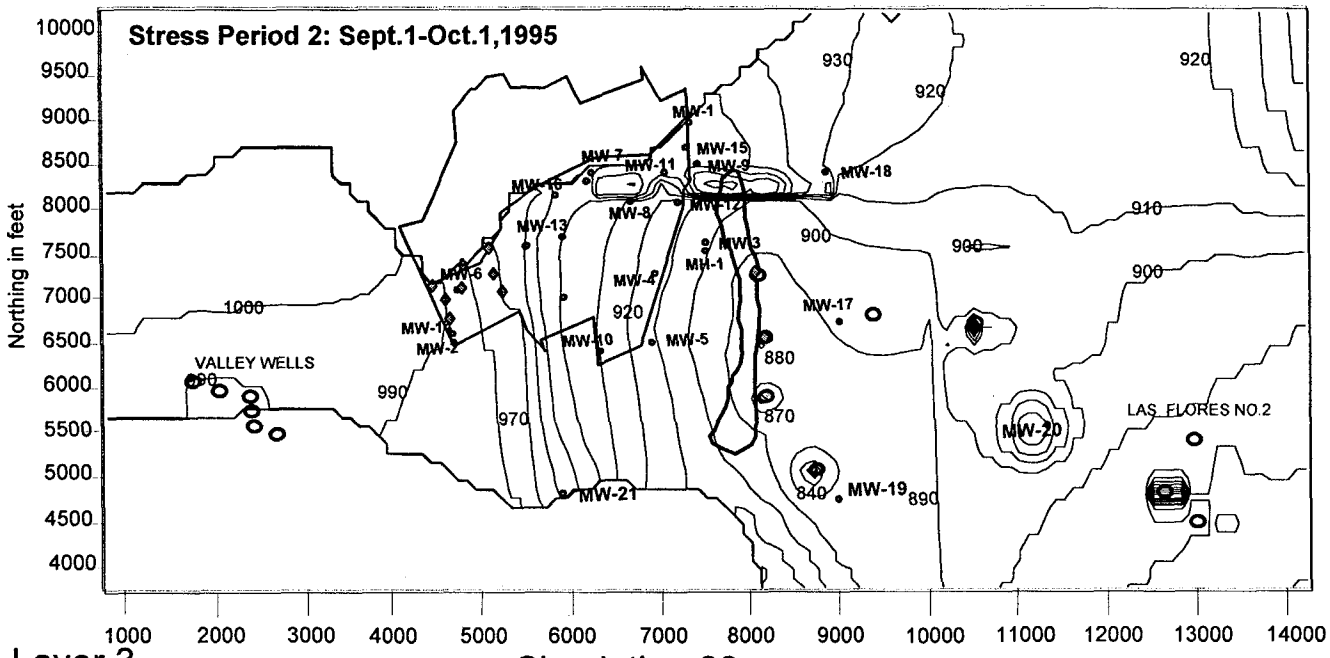




Geologic Layer 2

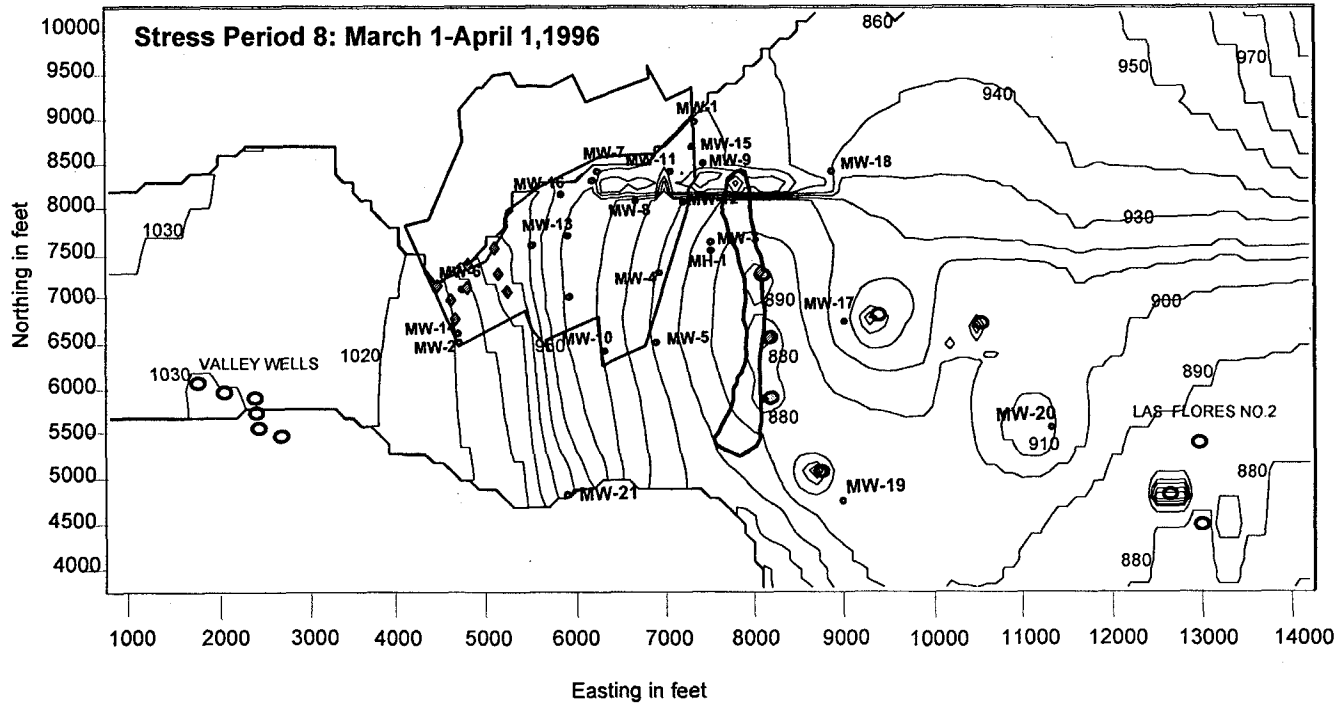
Simulation 09

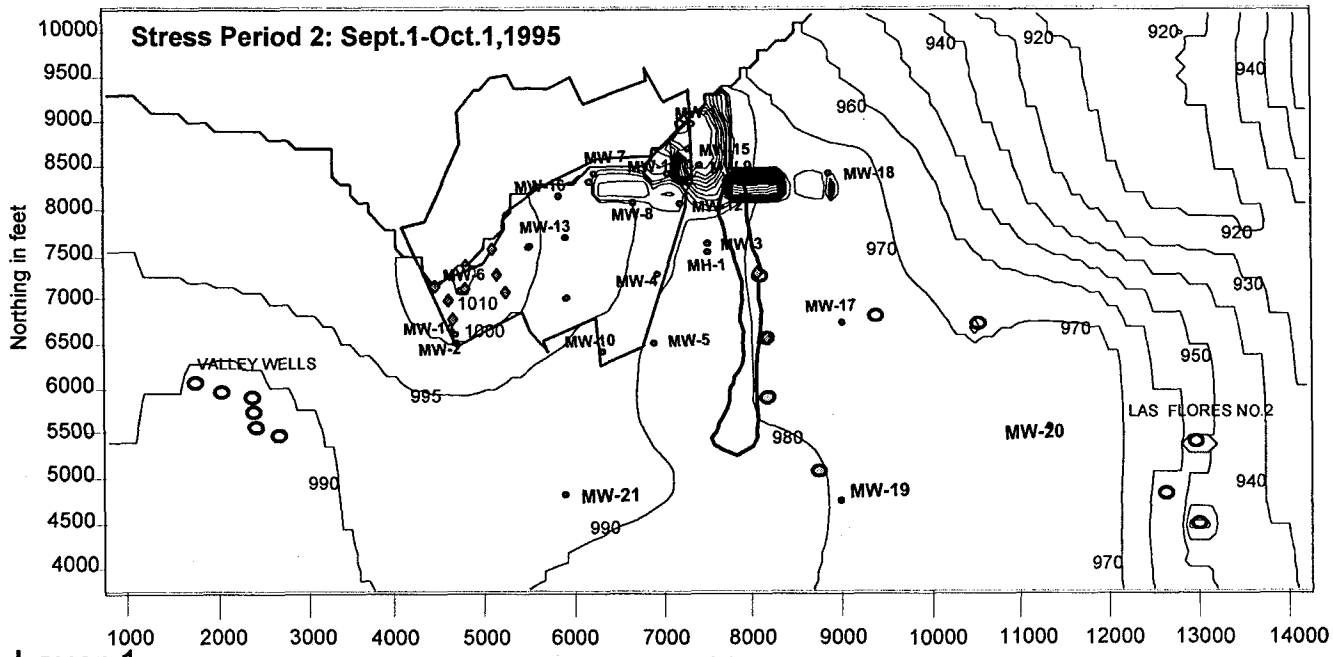




Geologic Layer 3

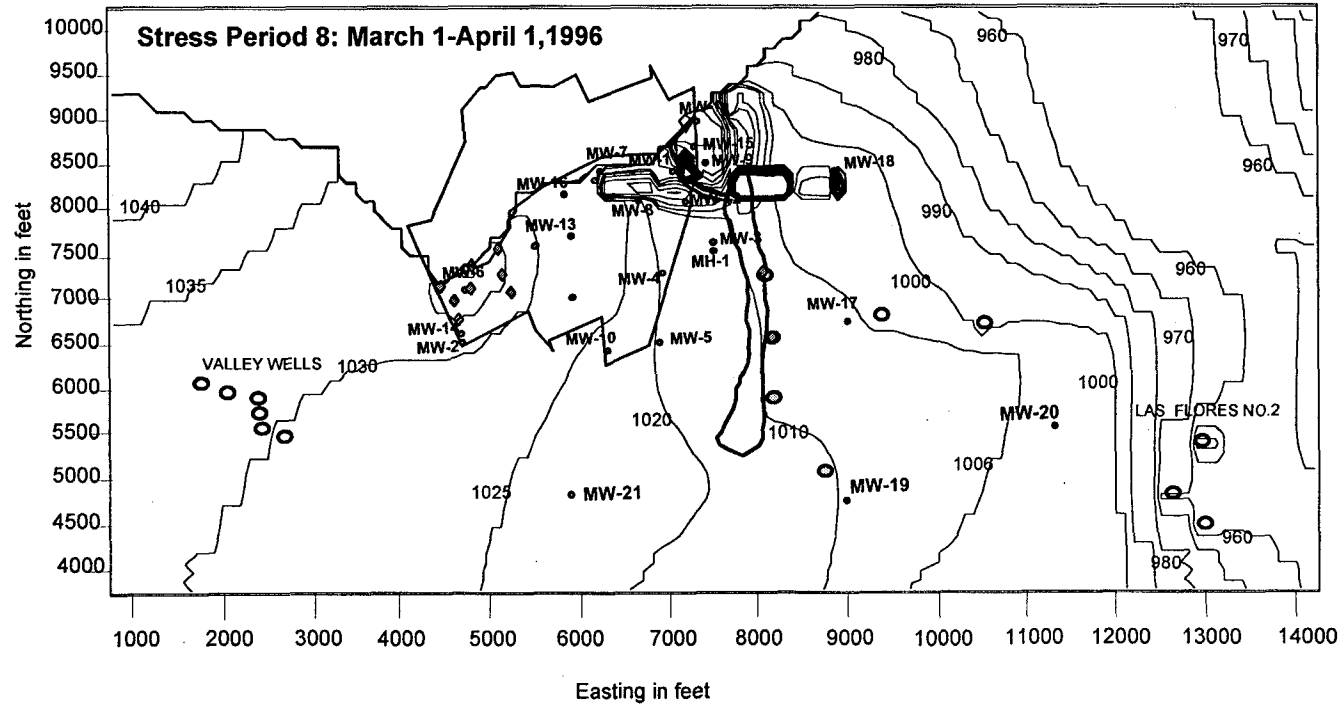
Simulation 09

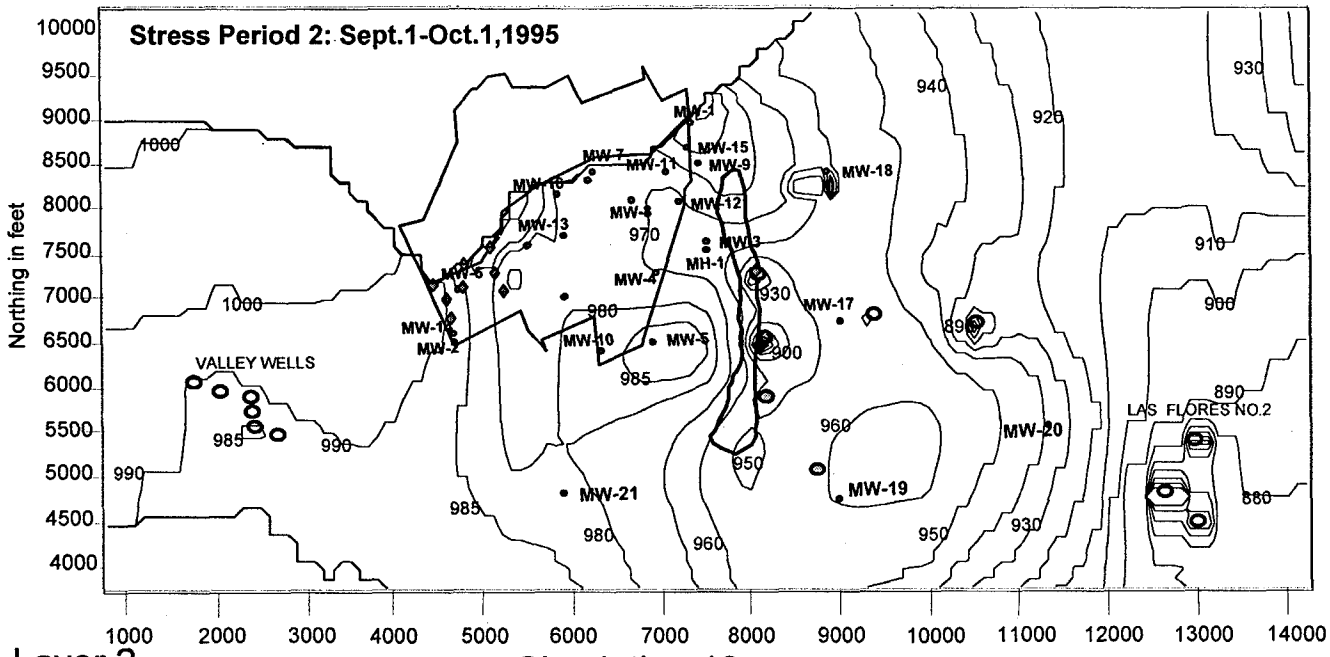




Geologic Layer 1

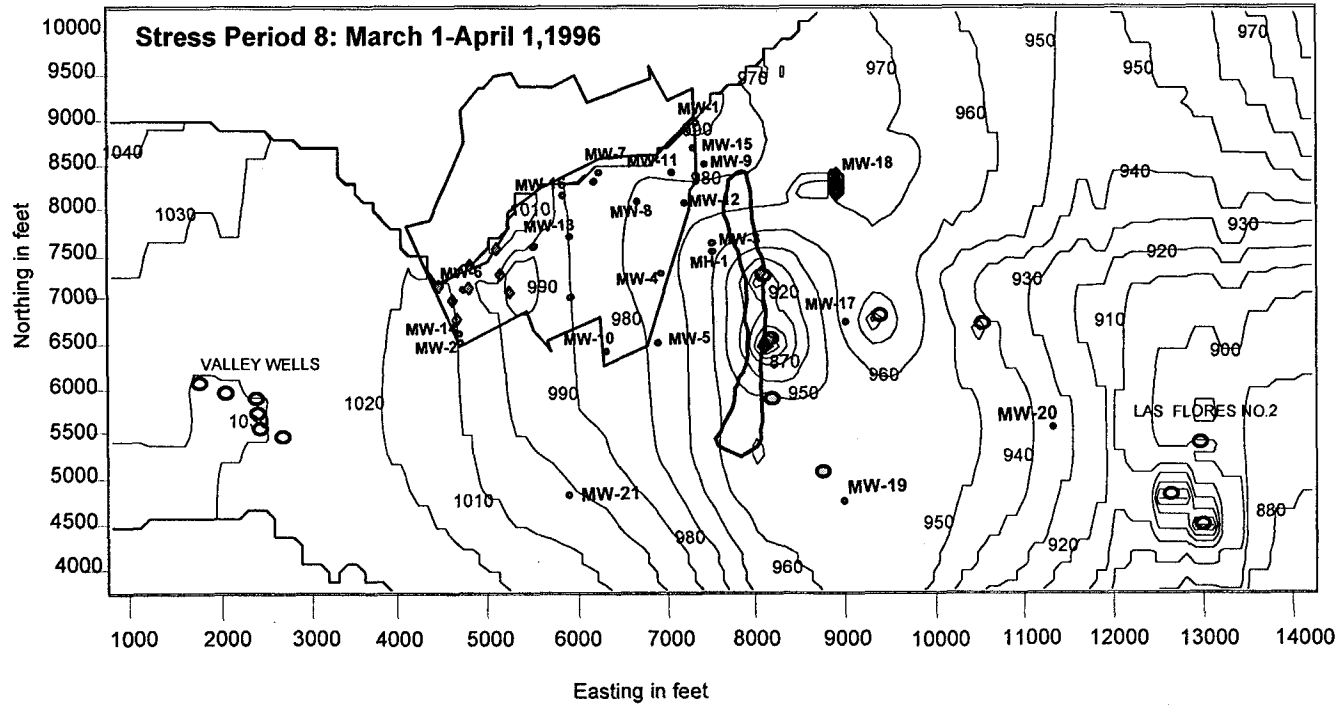
Simulation 10

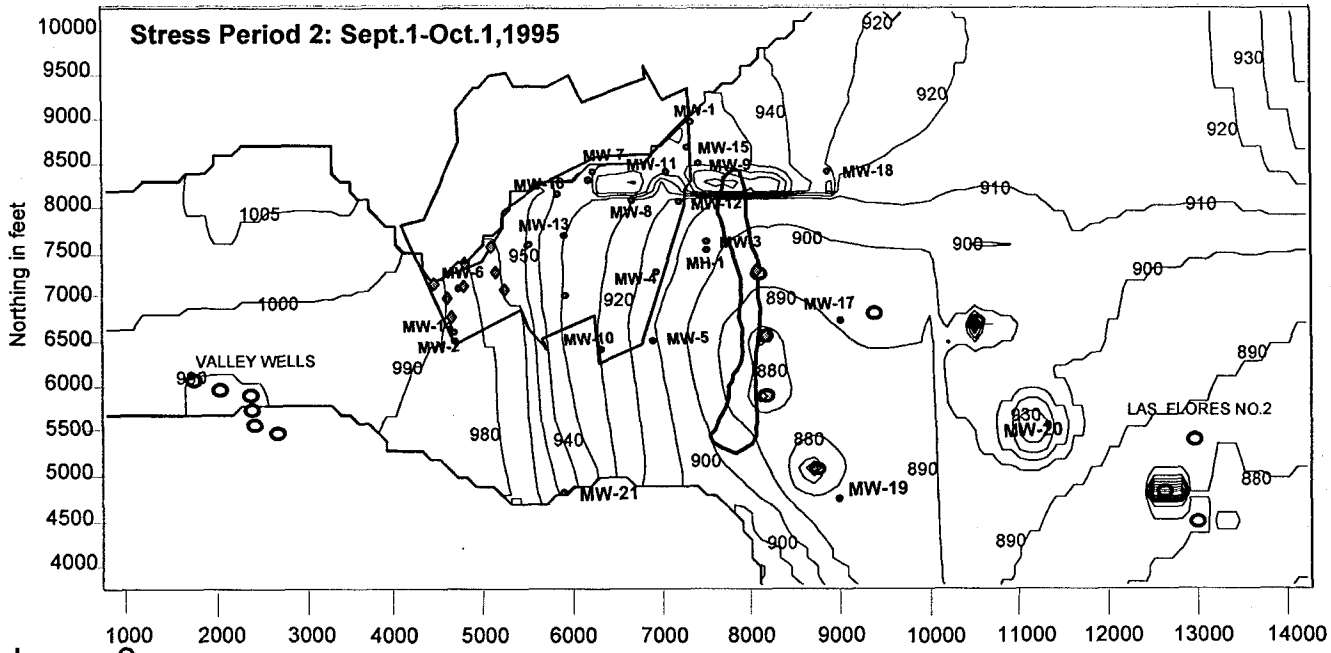




Geologic Layer 2

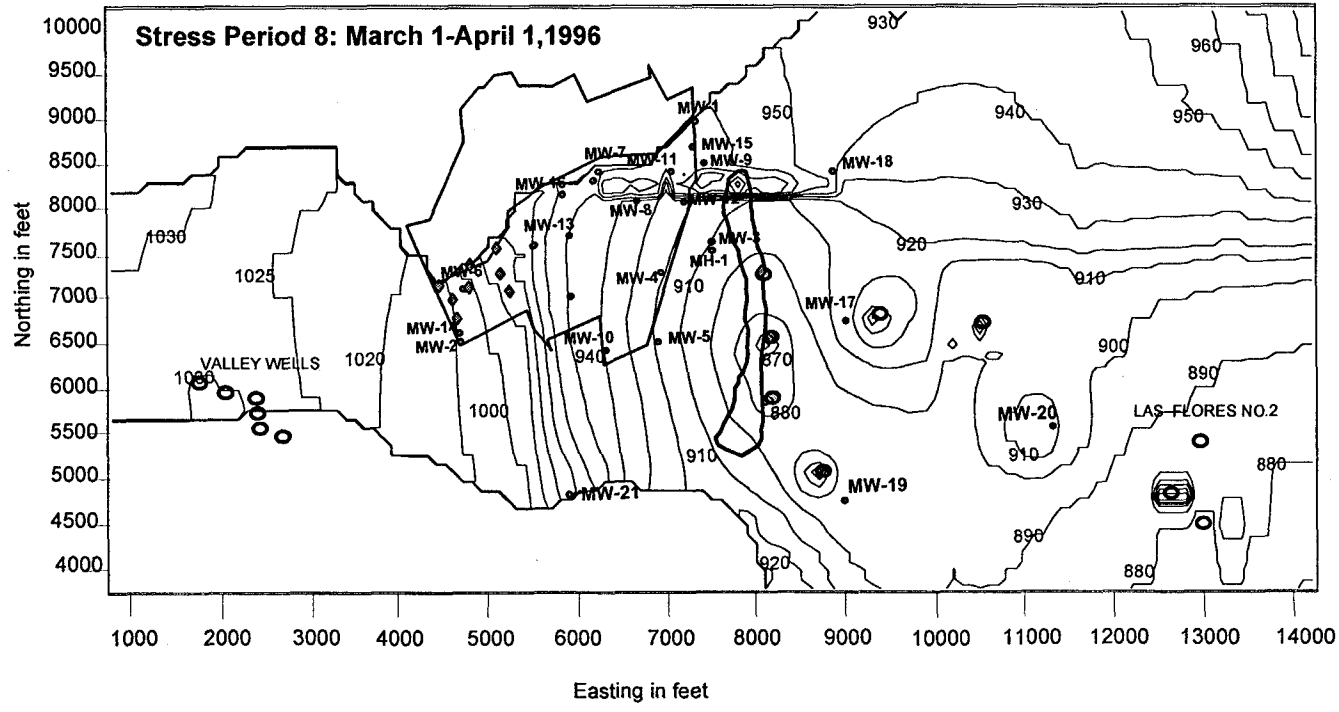
Simulation 10

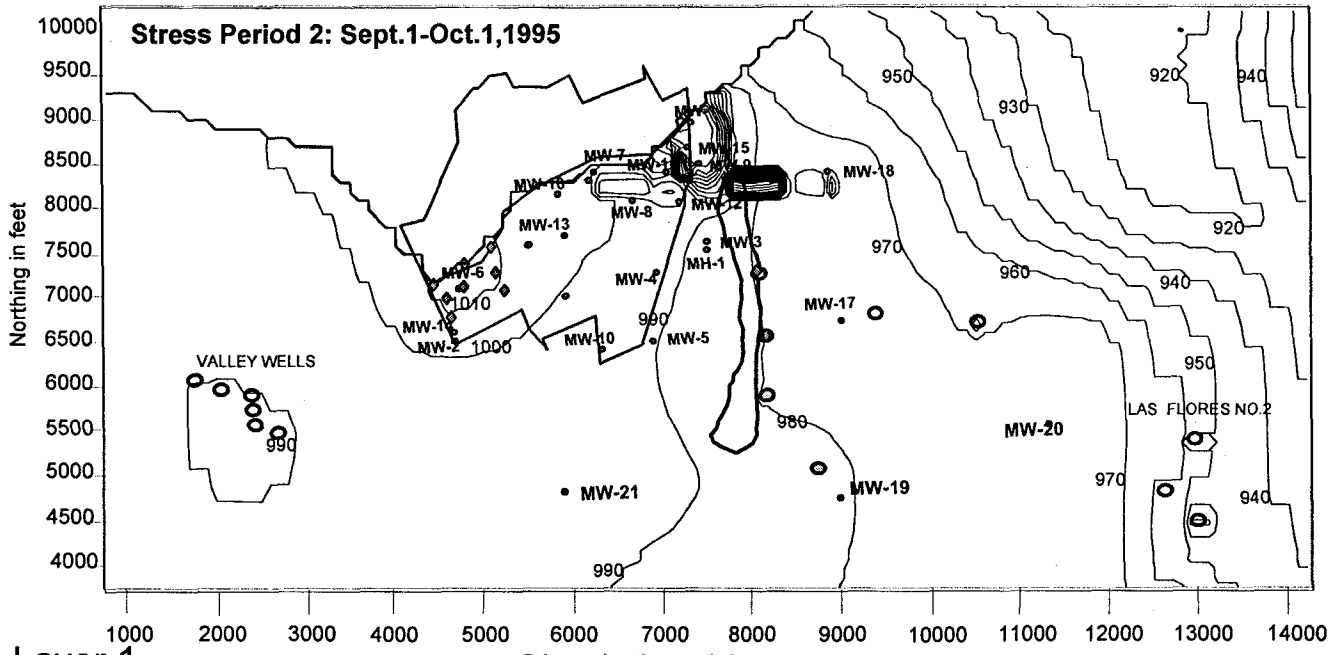




Geologic Layer 3

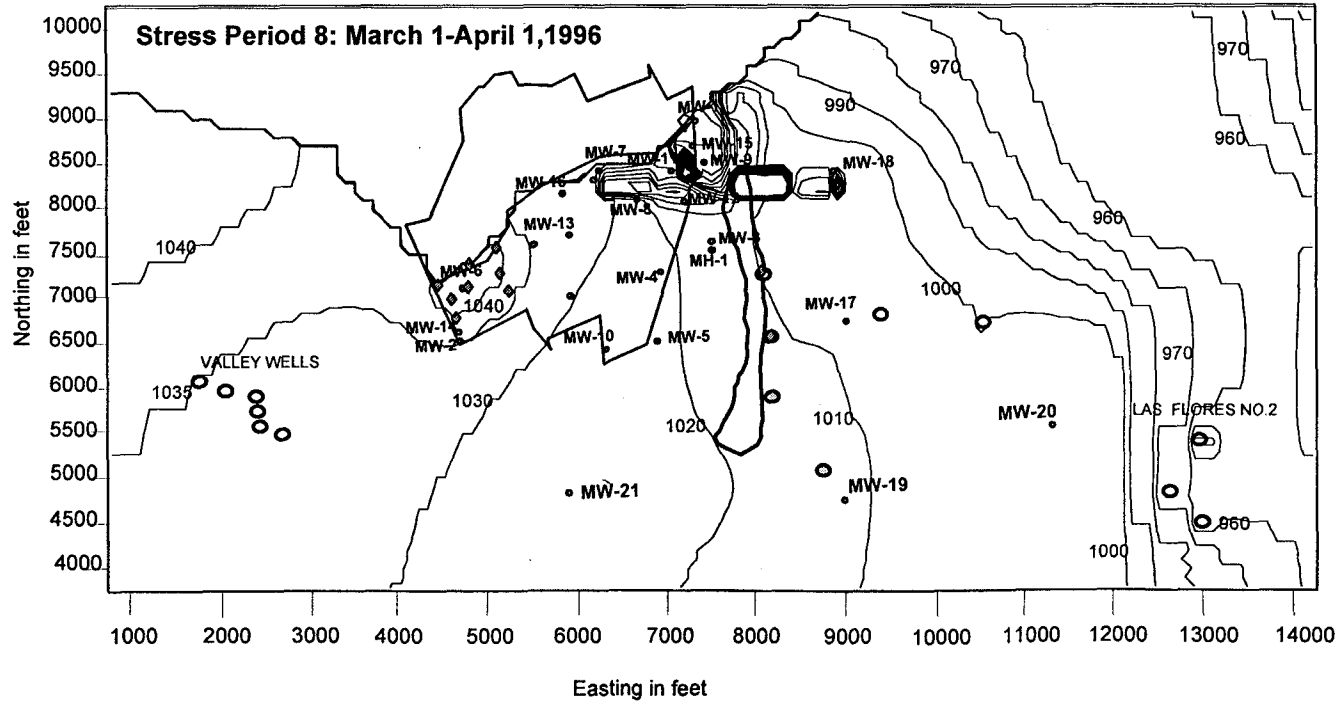
Simulation 10

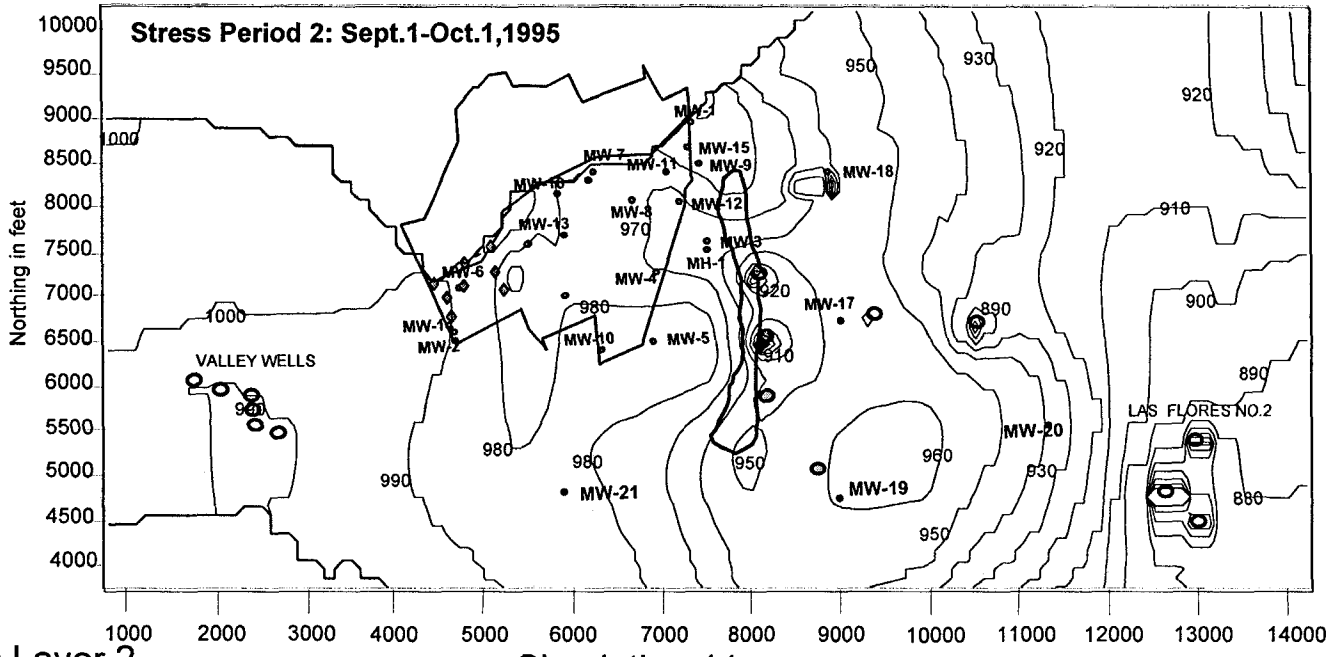




Geologic Layer 1

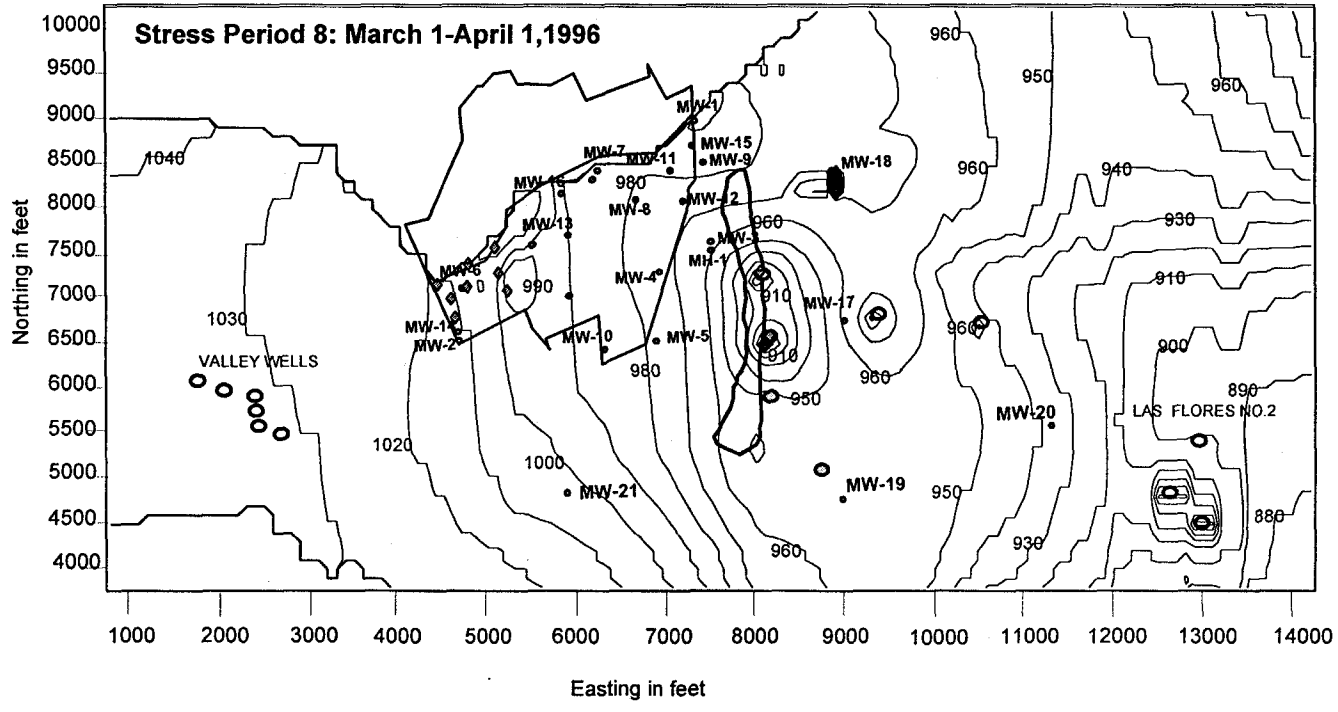
Simulation 11

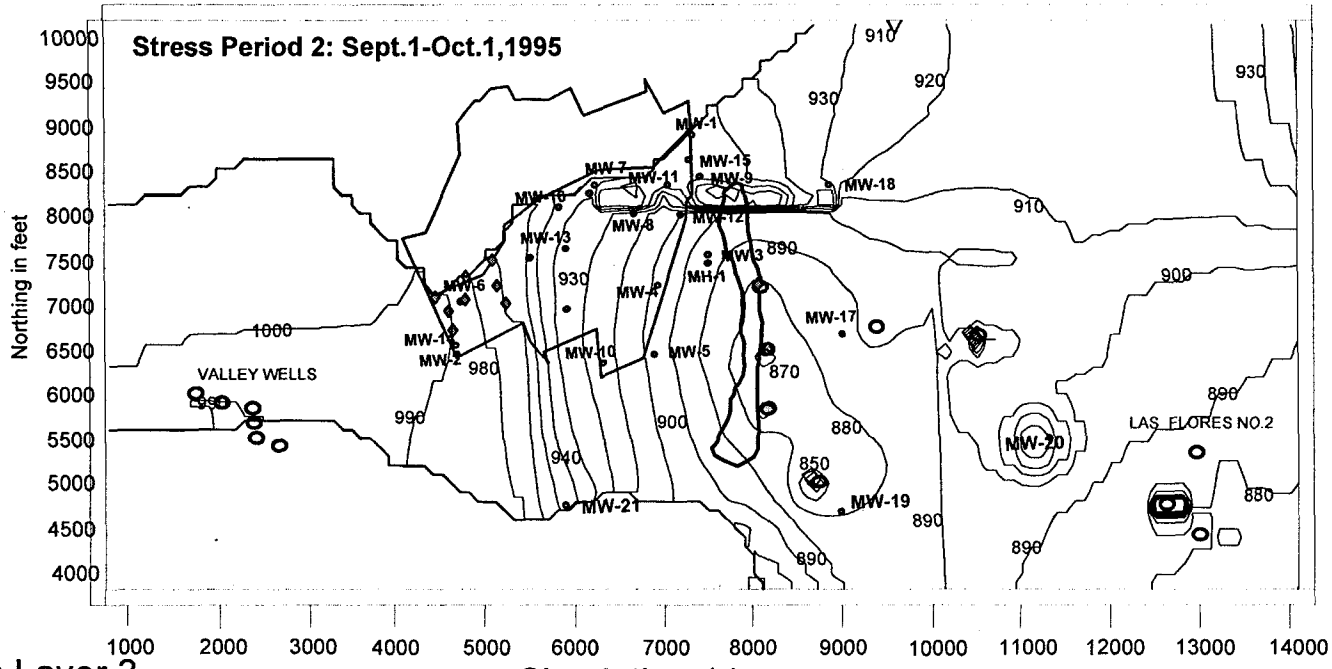




Geologic Layer 2

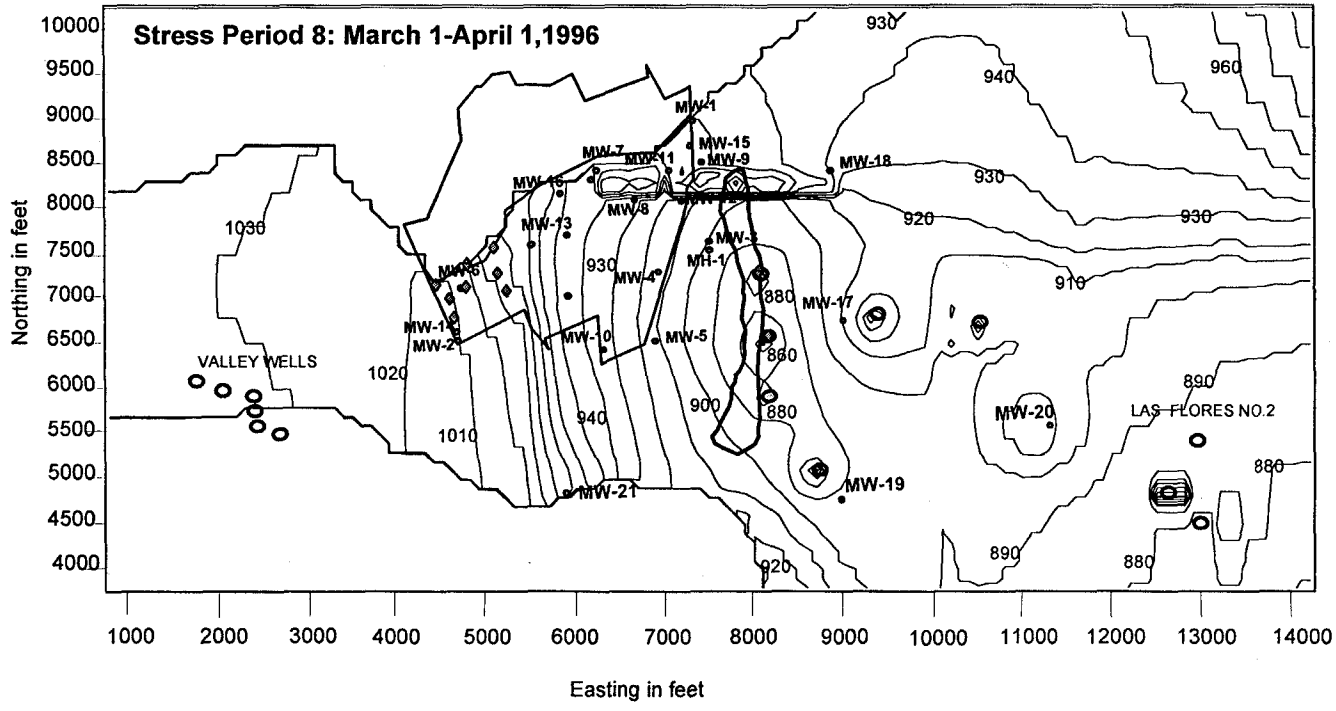
Simulation 11

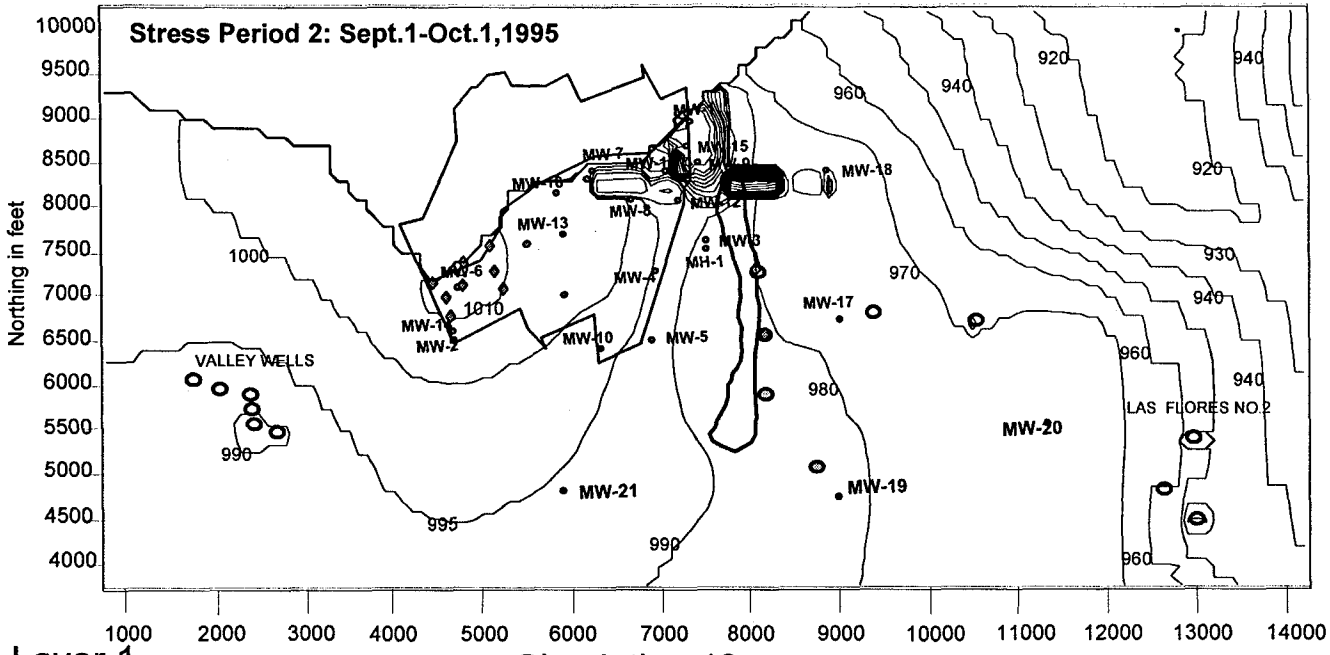




Geologic Layer 3

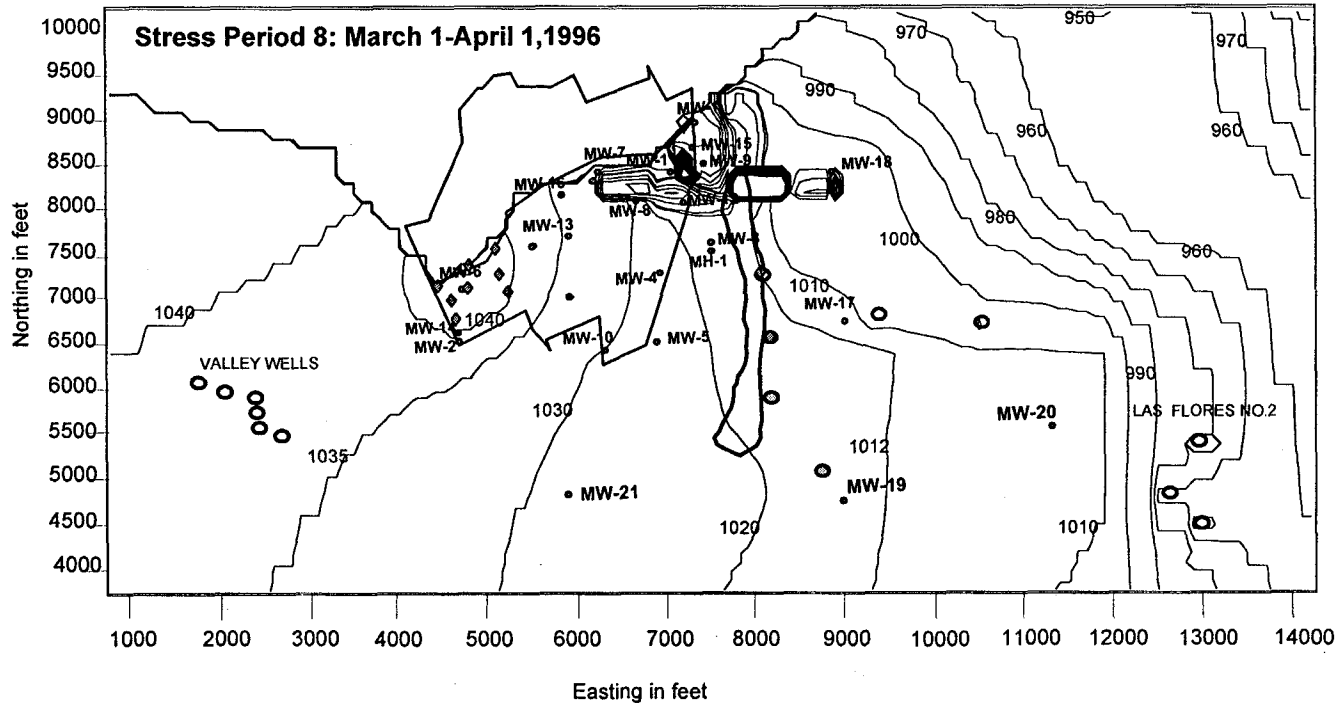
Simulation 11

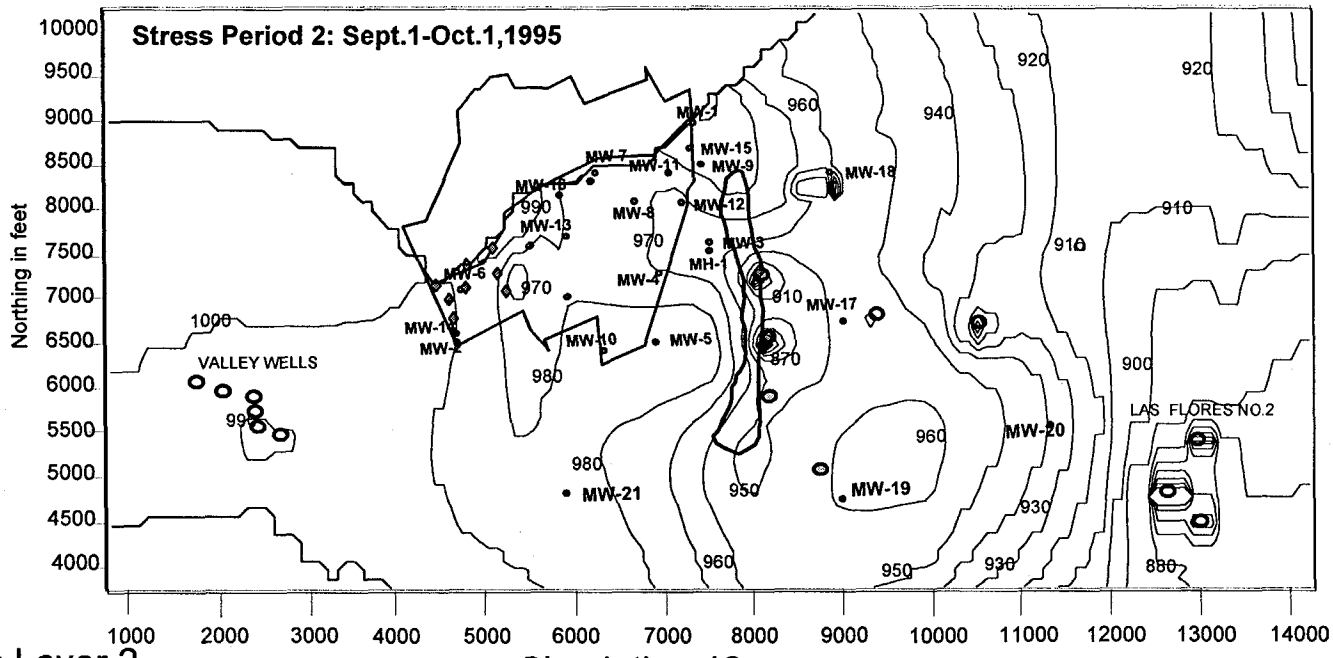




Geologic Layer 1

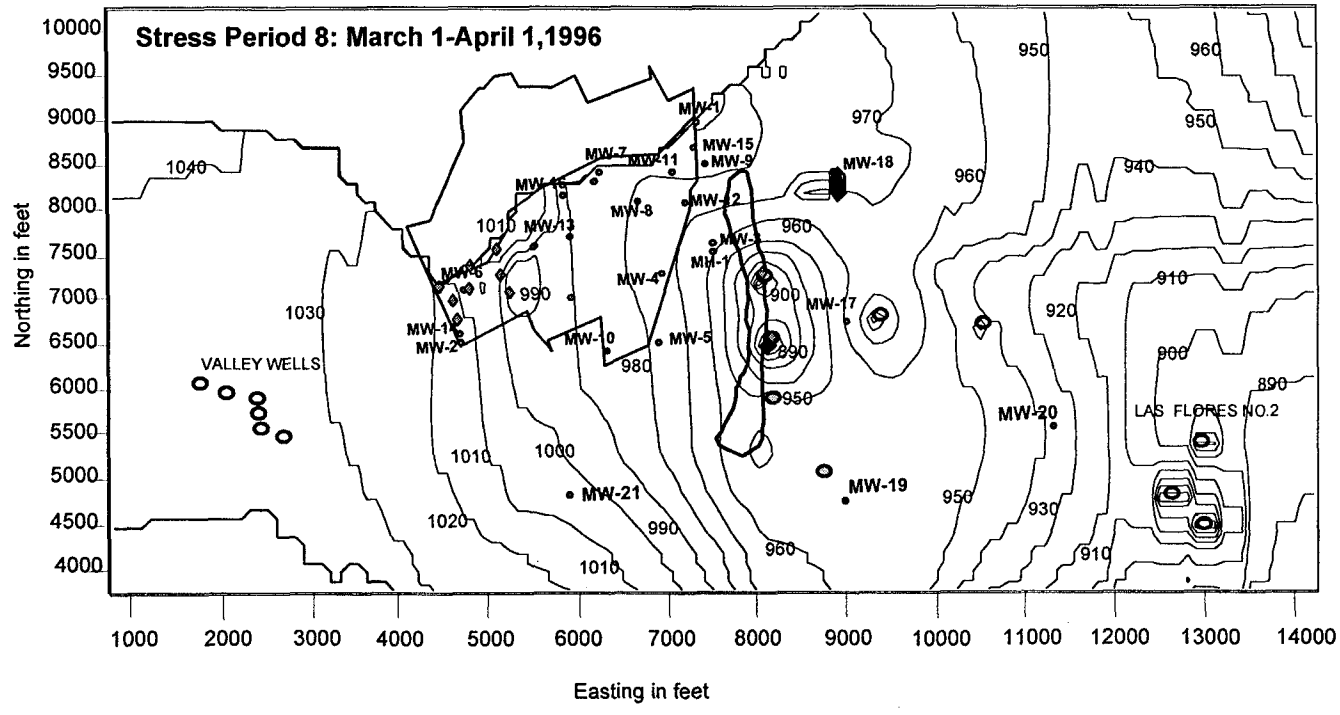
Simulation 12

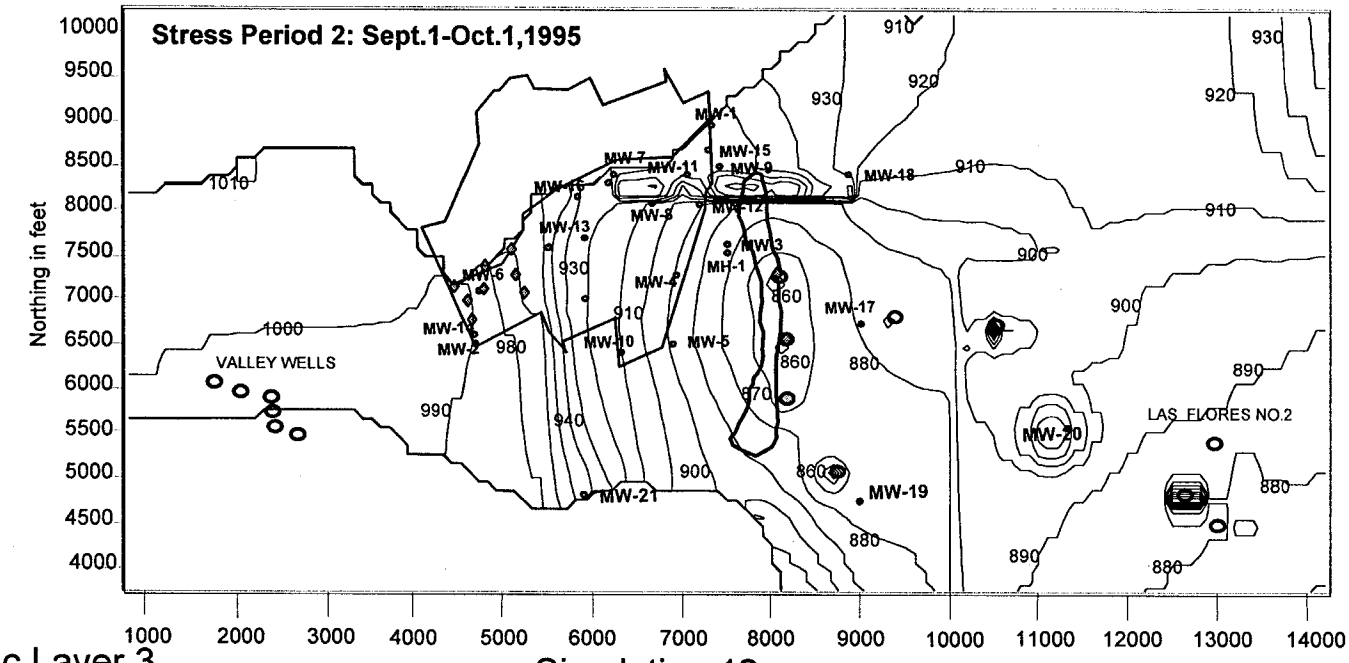




Geologic Layer 2

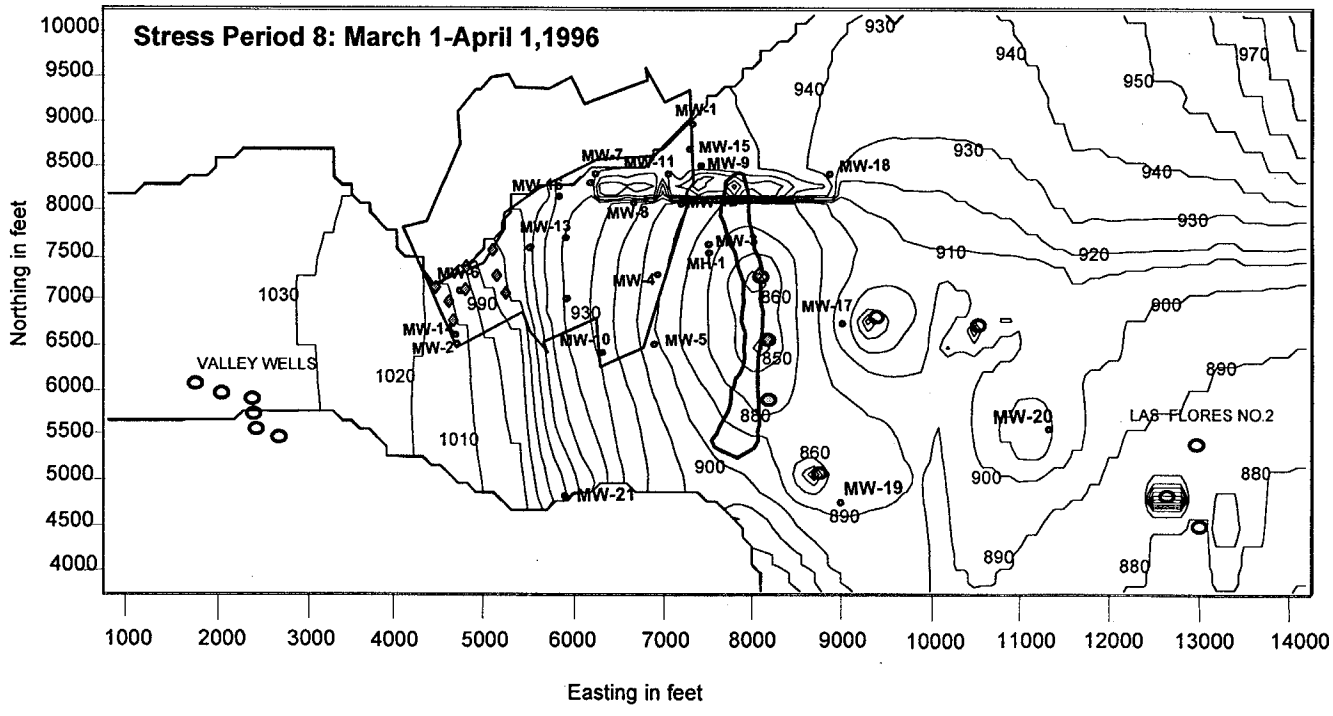
Simulation 12

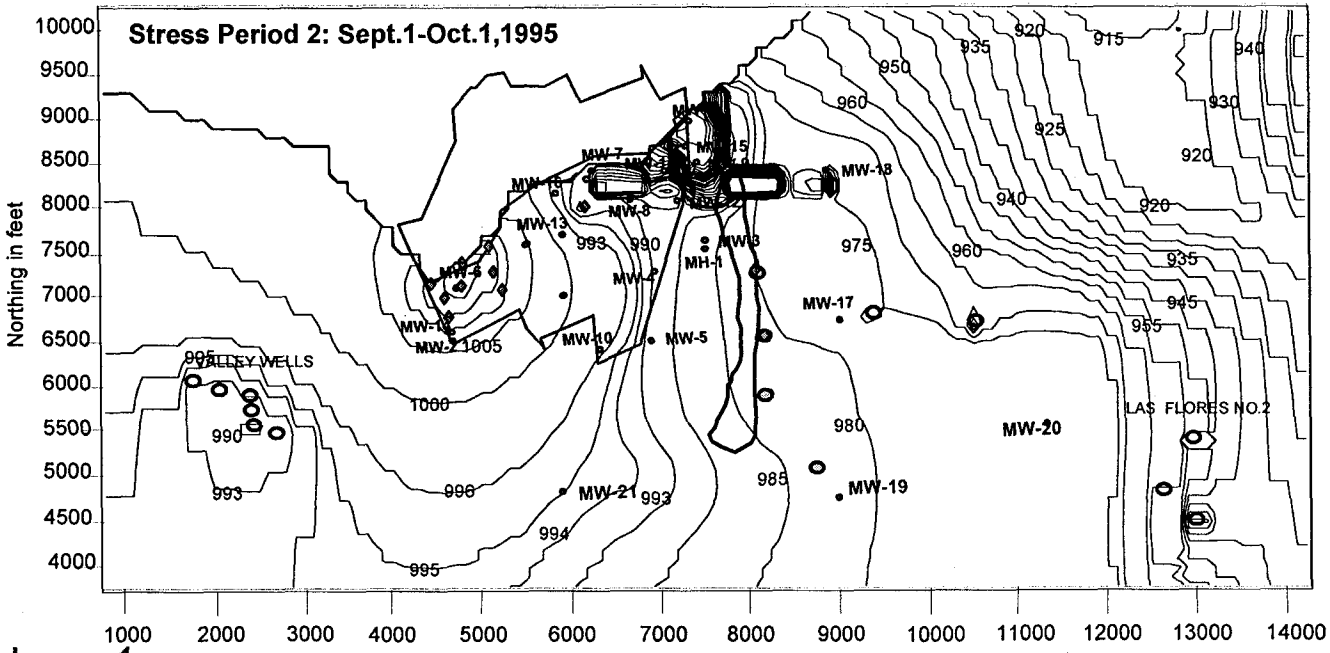




Geologic Layer 3

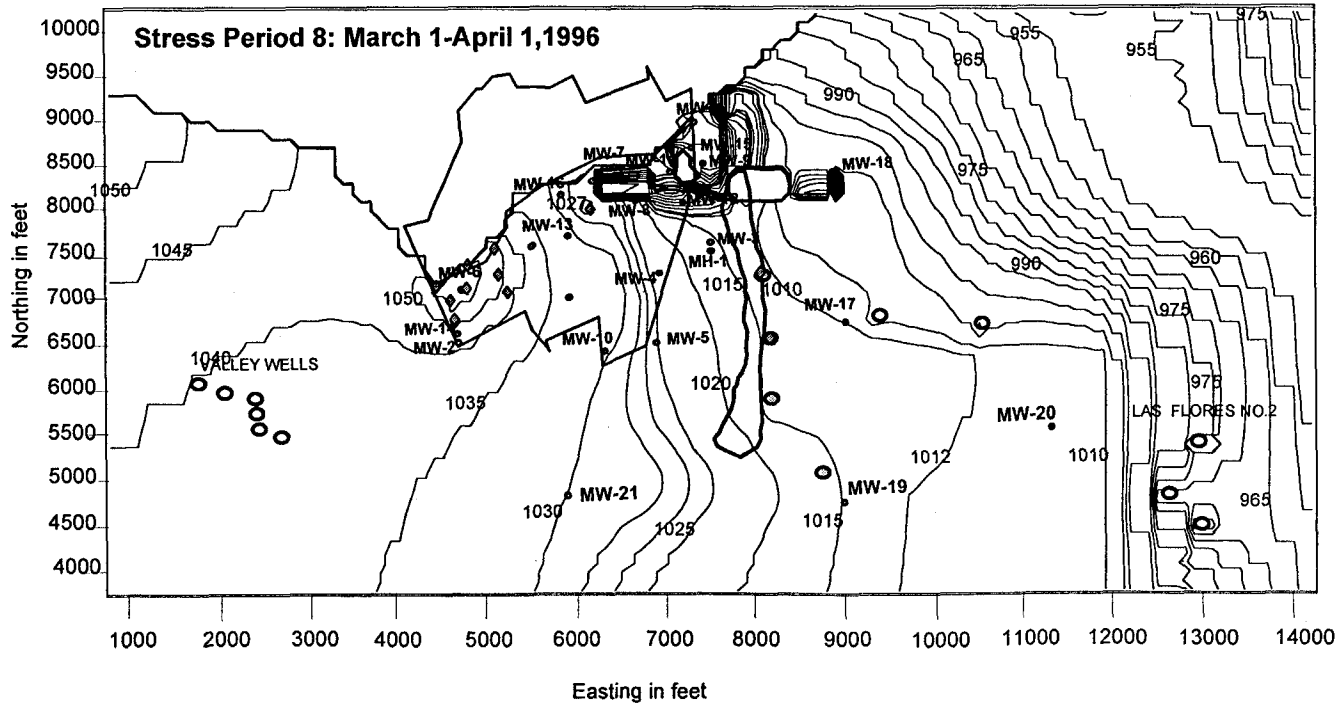
Simulation 12

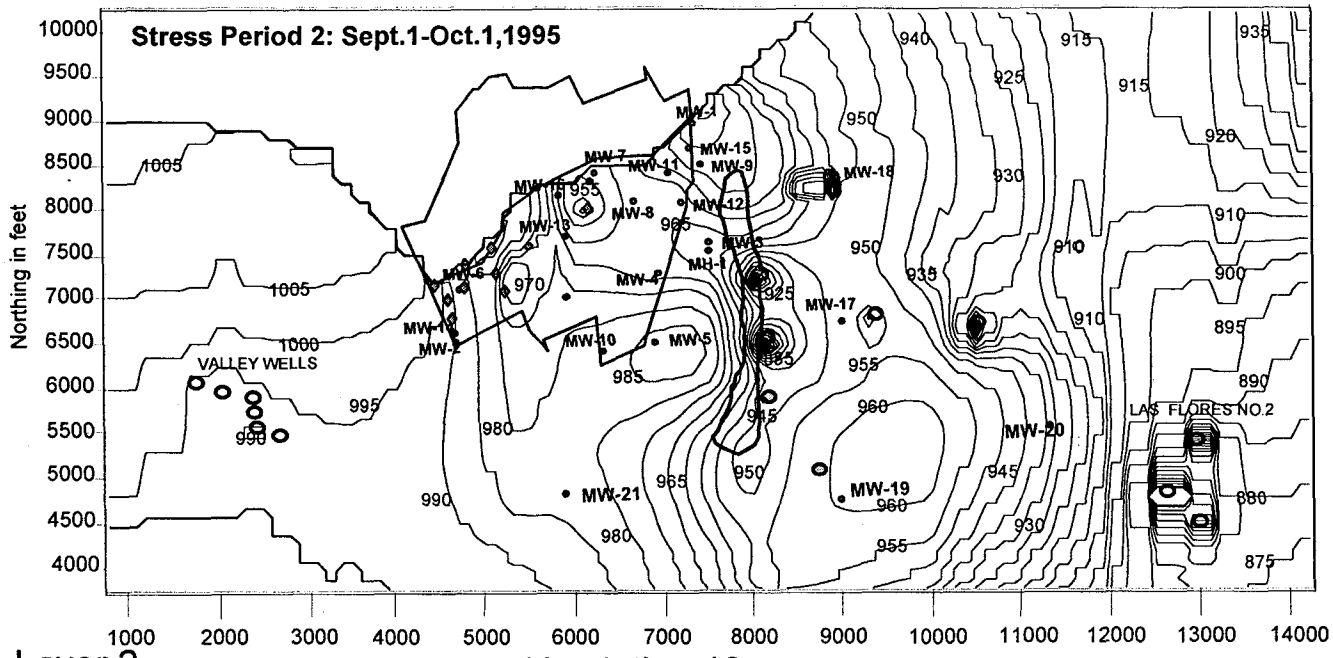




Geologic Layer 1

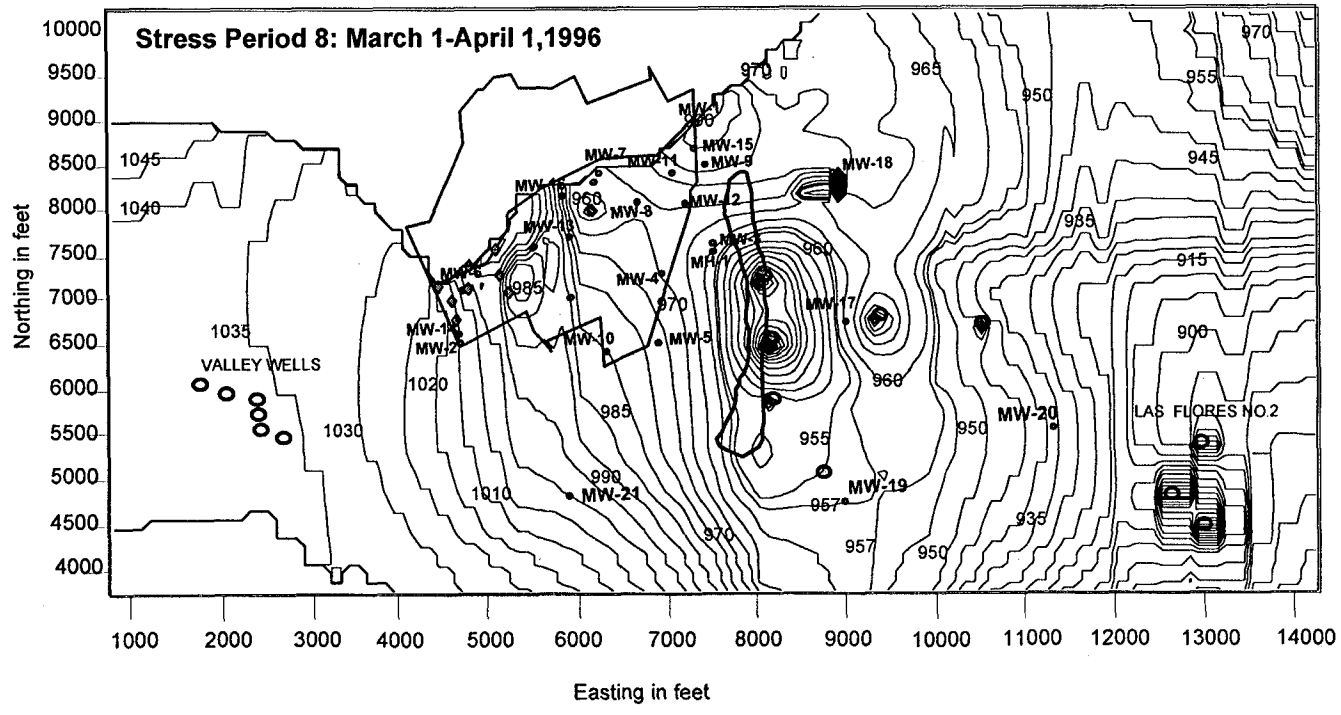
Simulation 13

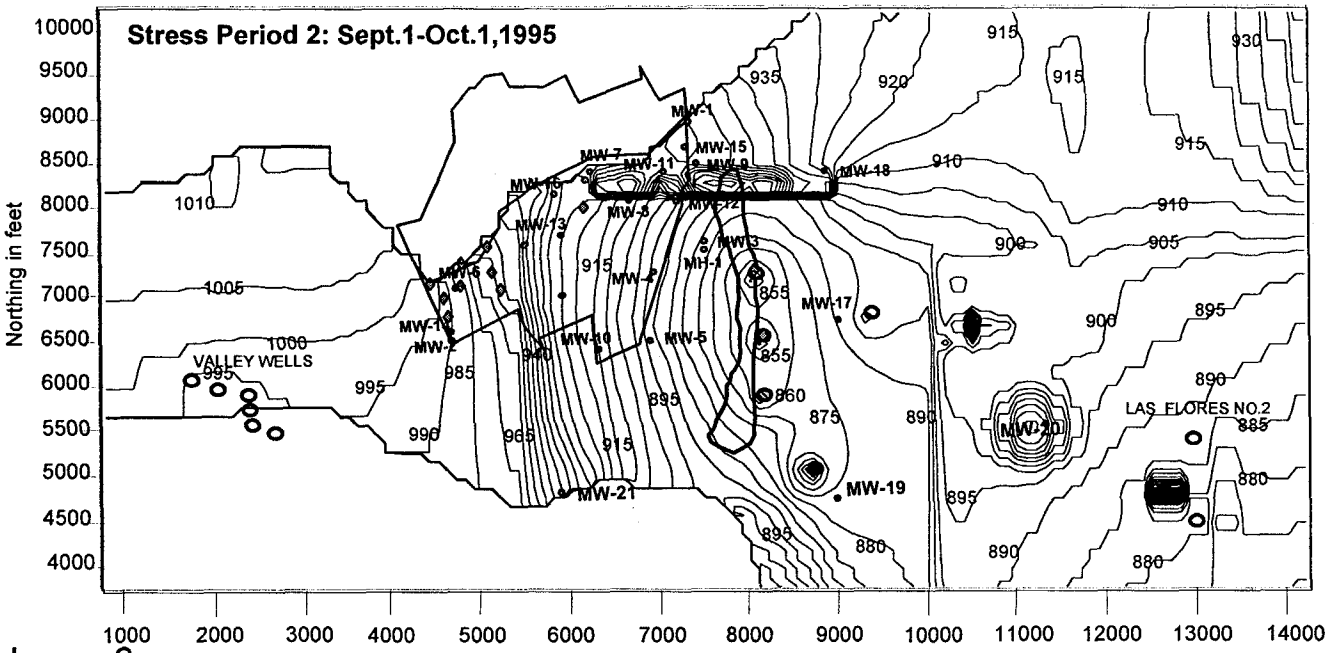




Geologic Layer 2

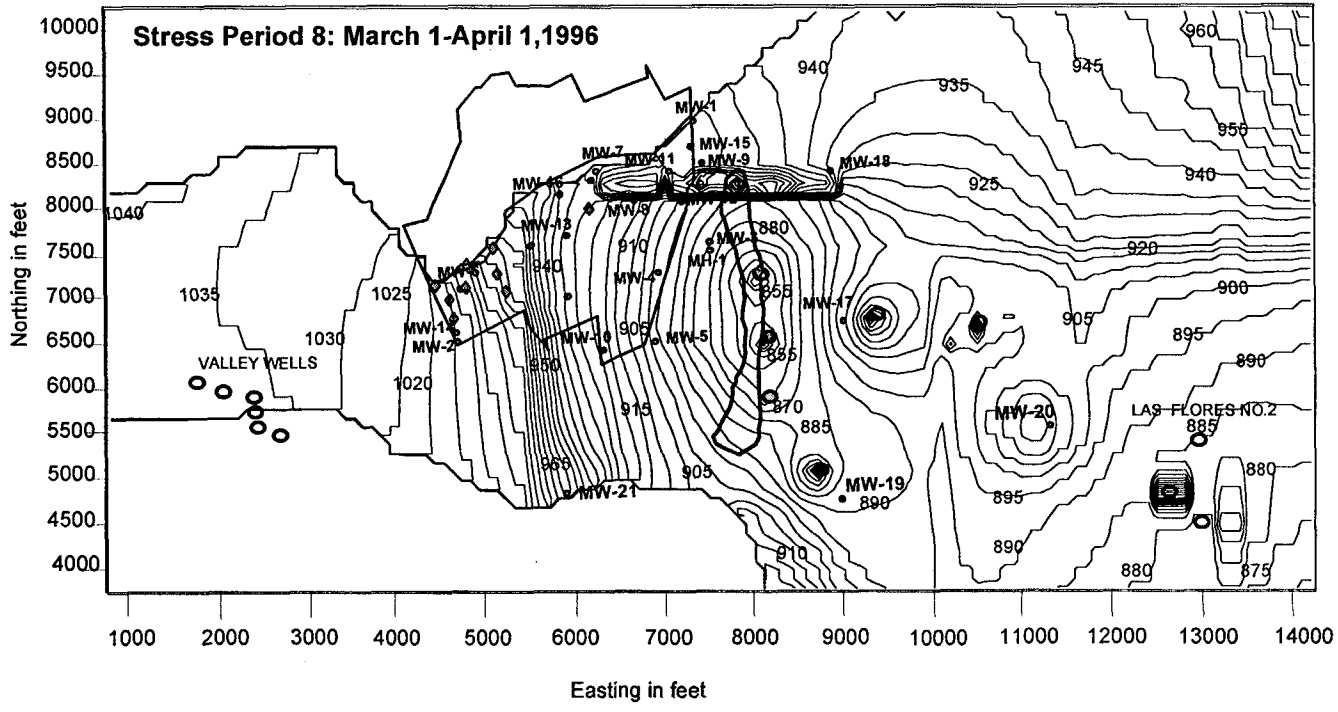
Simulation 13

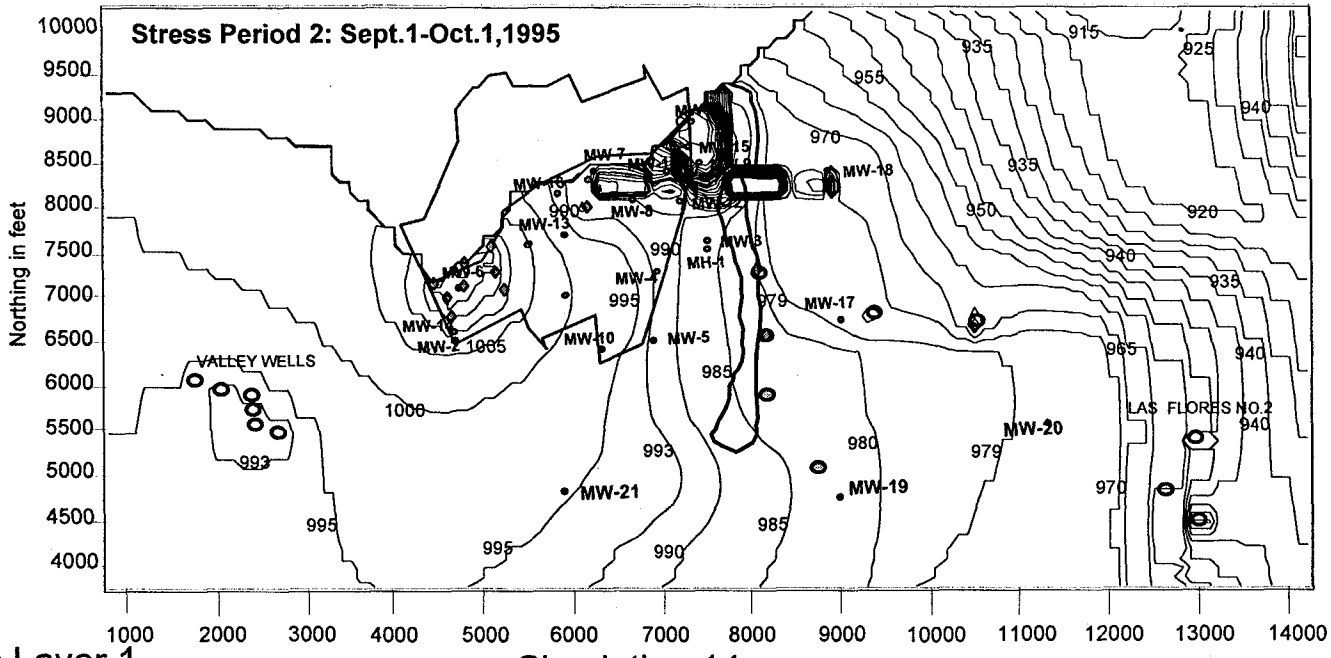




Geologic Layer 3

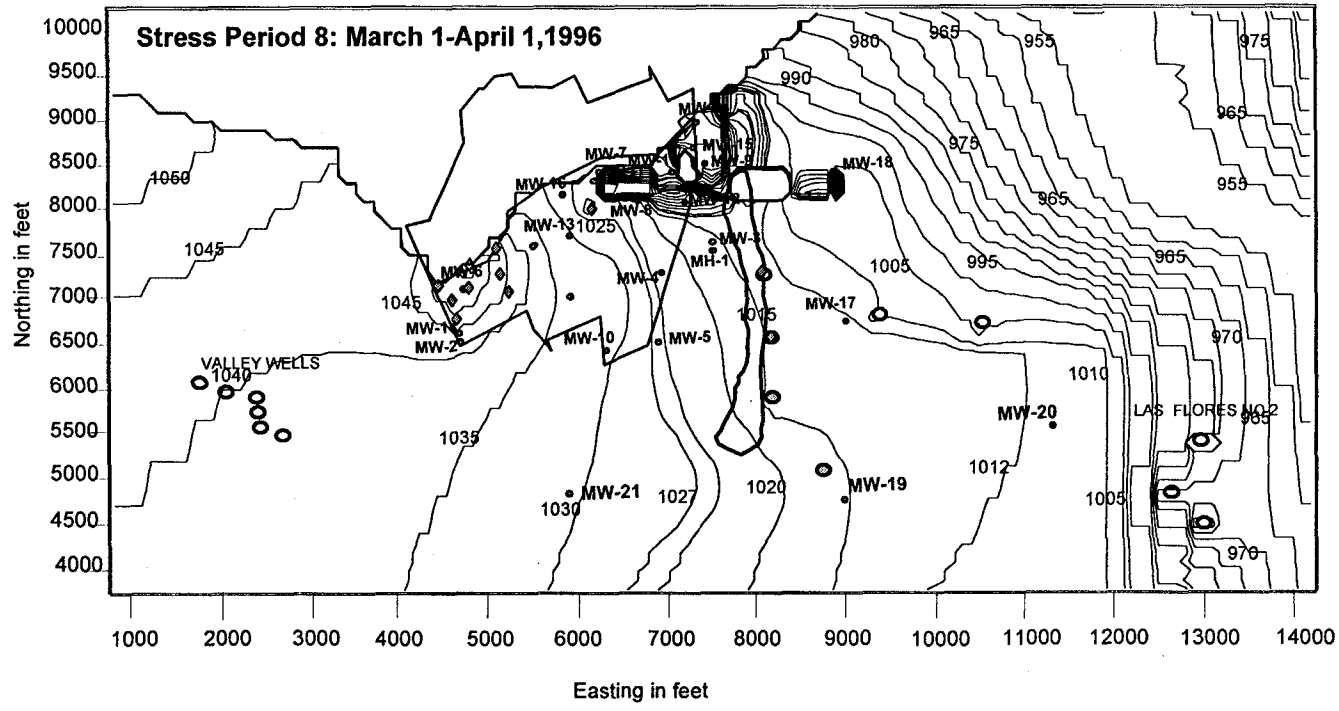
Simulation 13

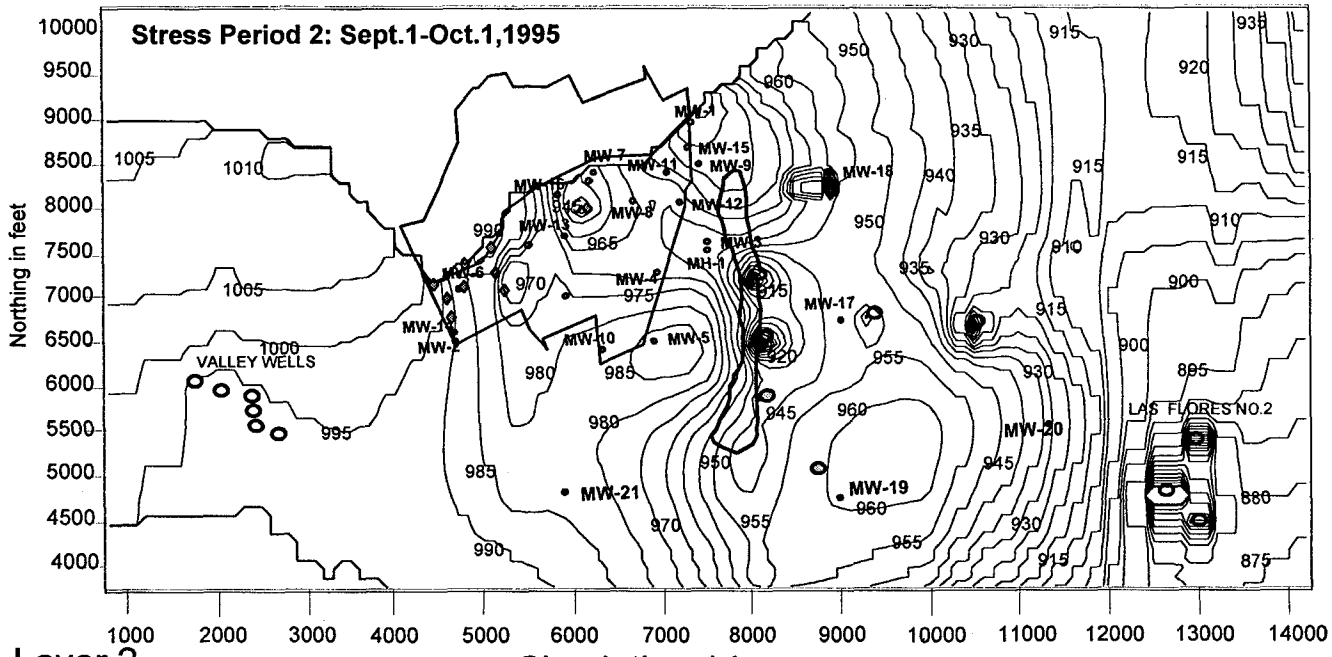




Geologic Layer 1

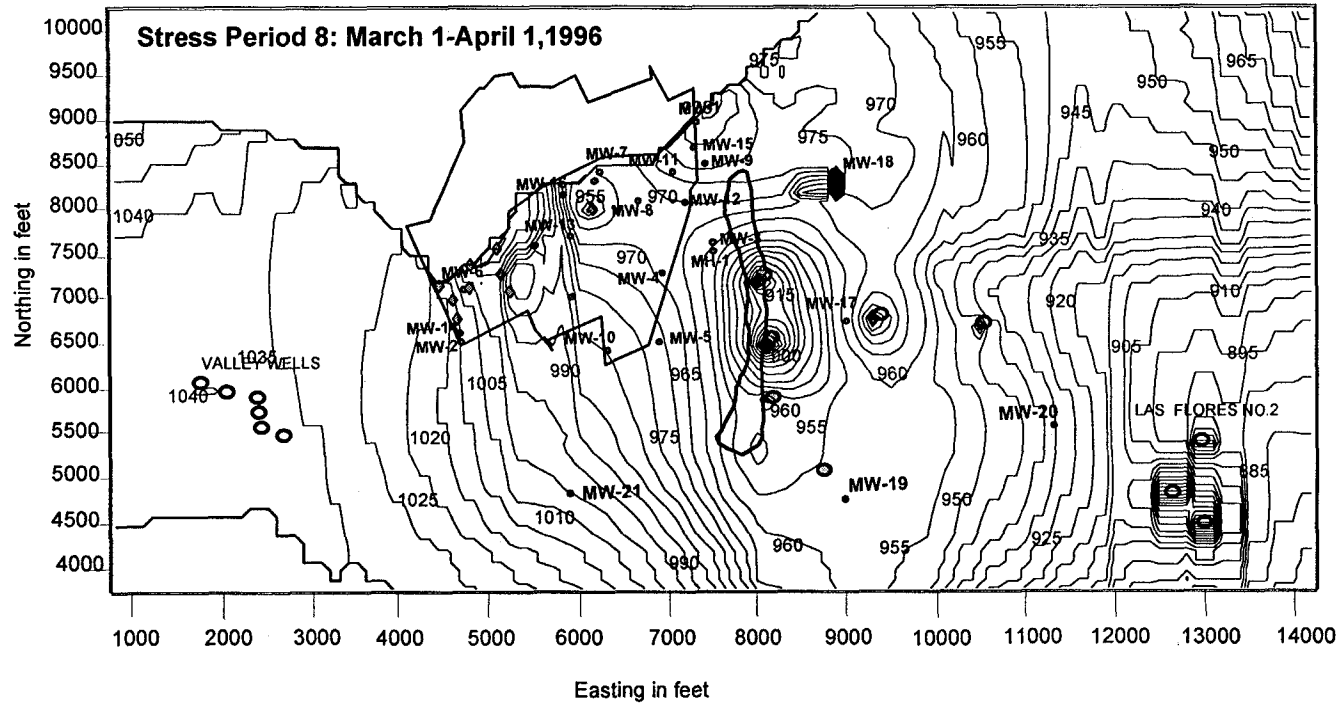
Simulation 14

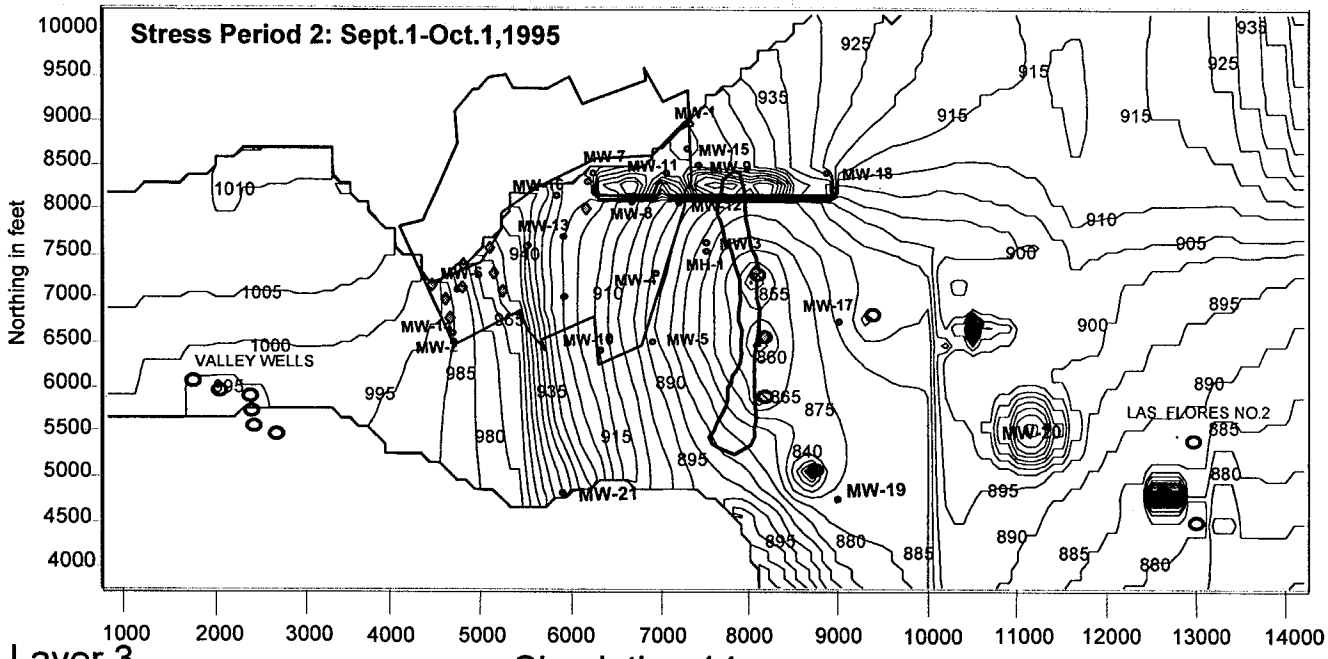




Geologic Layer 2

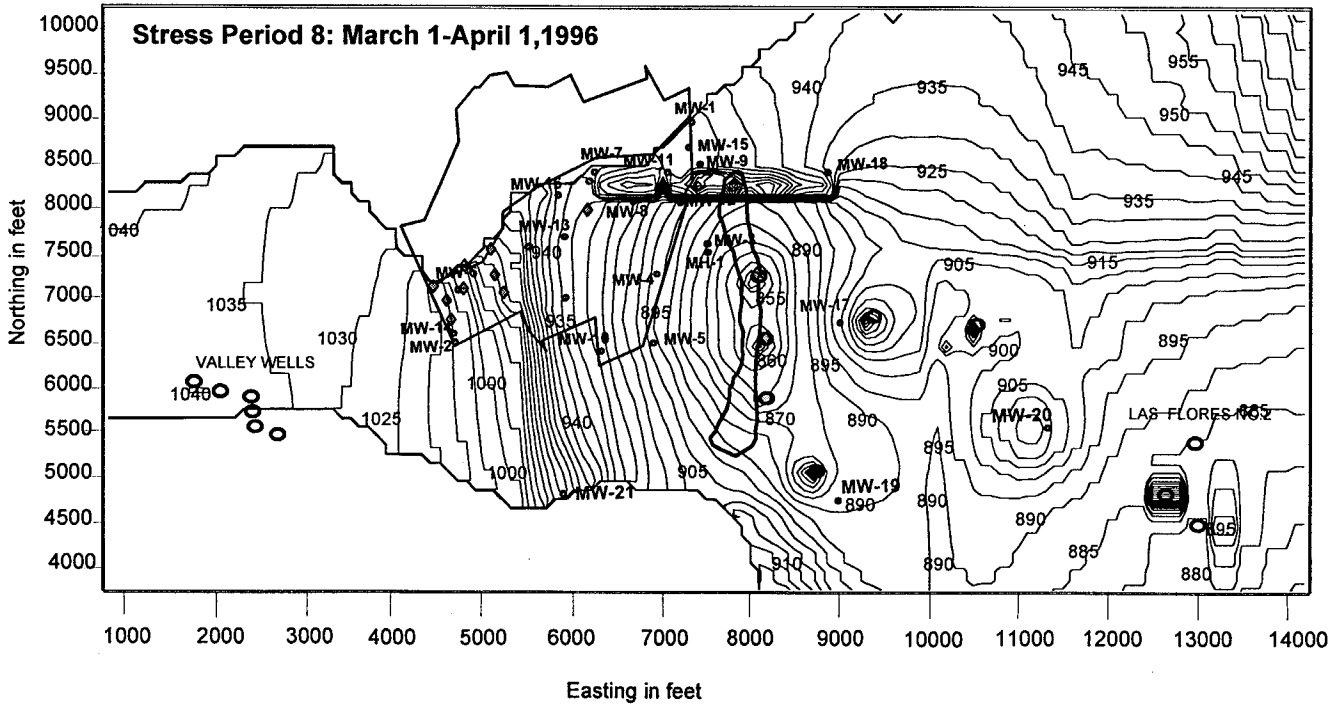
Simulation 14

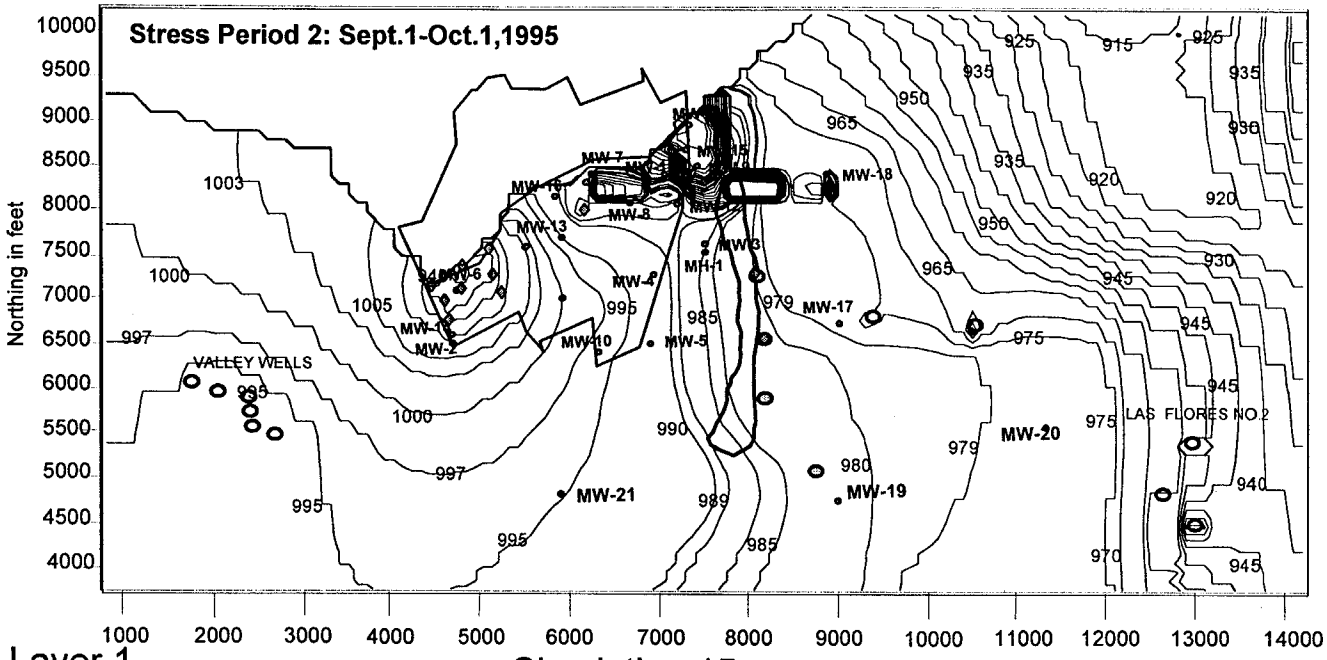




Geologic Layer 3

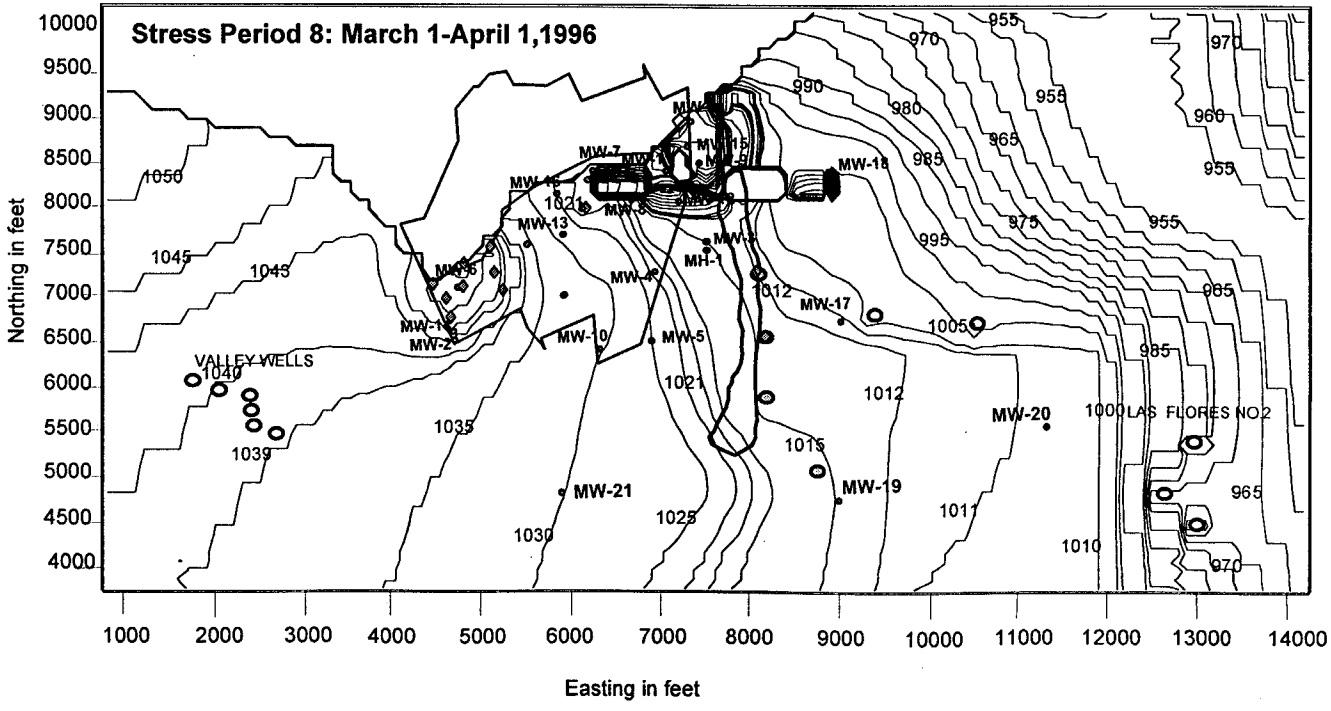
Simulation 14

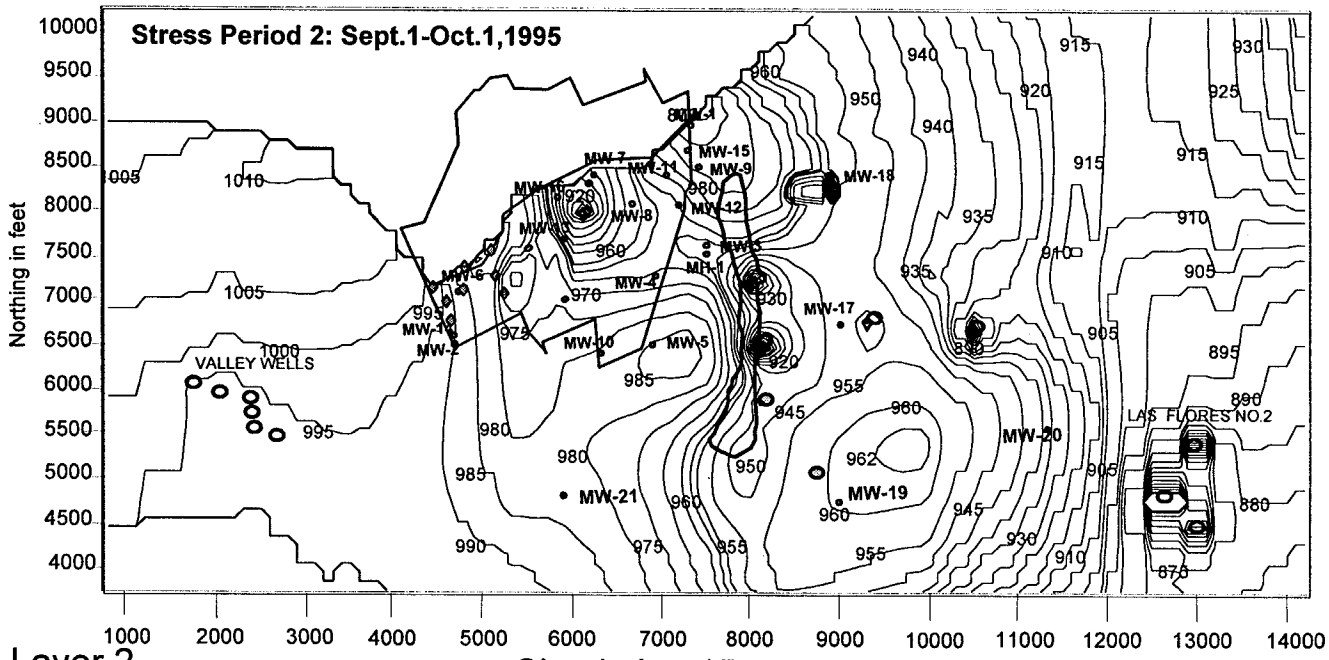




Geologic Layer 1

Simulation 15





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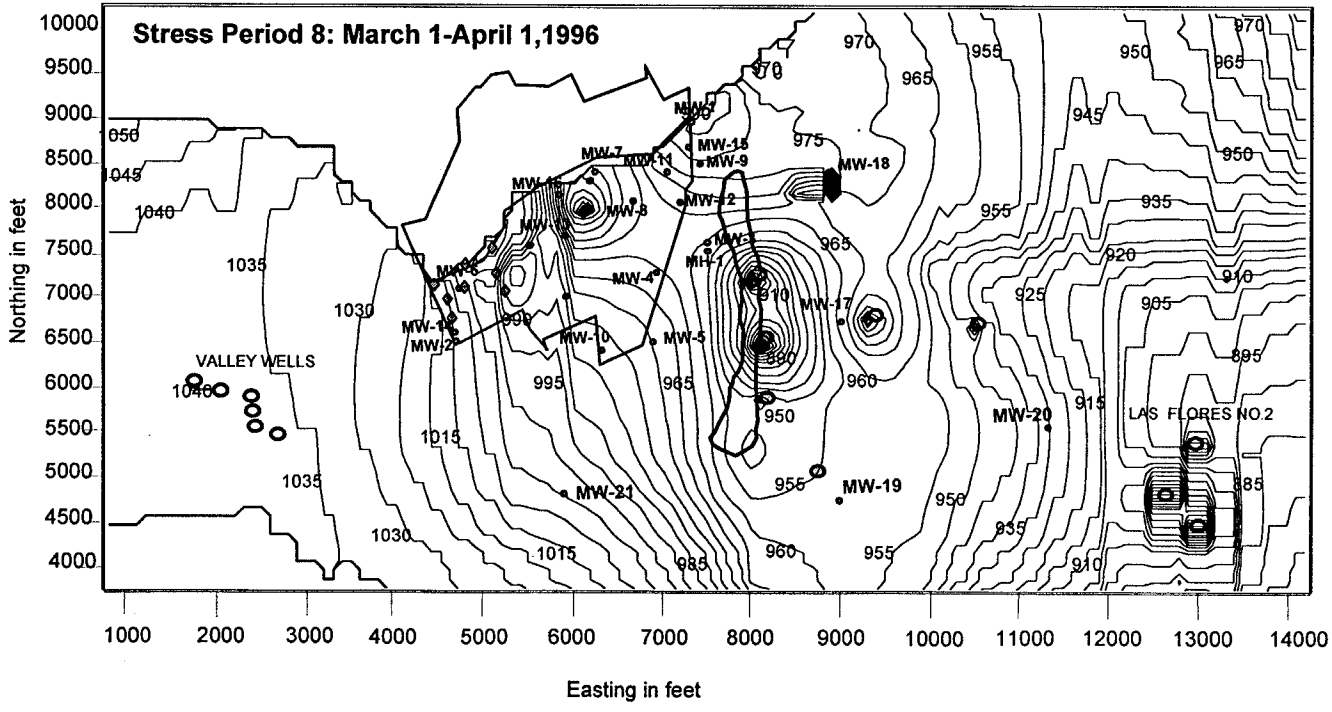
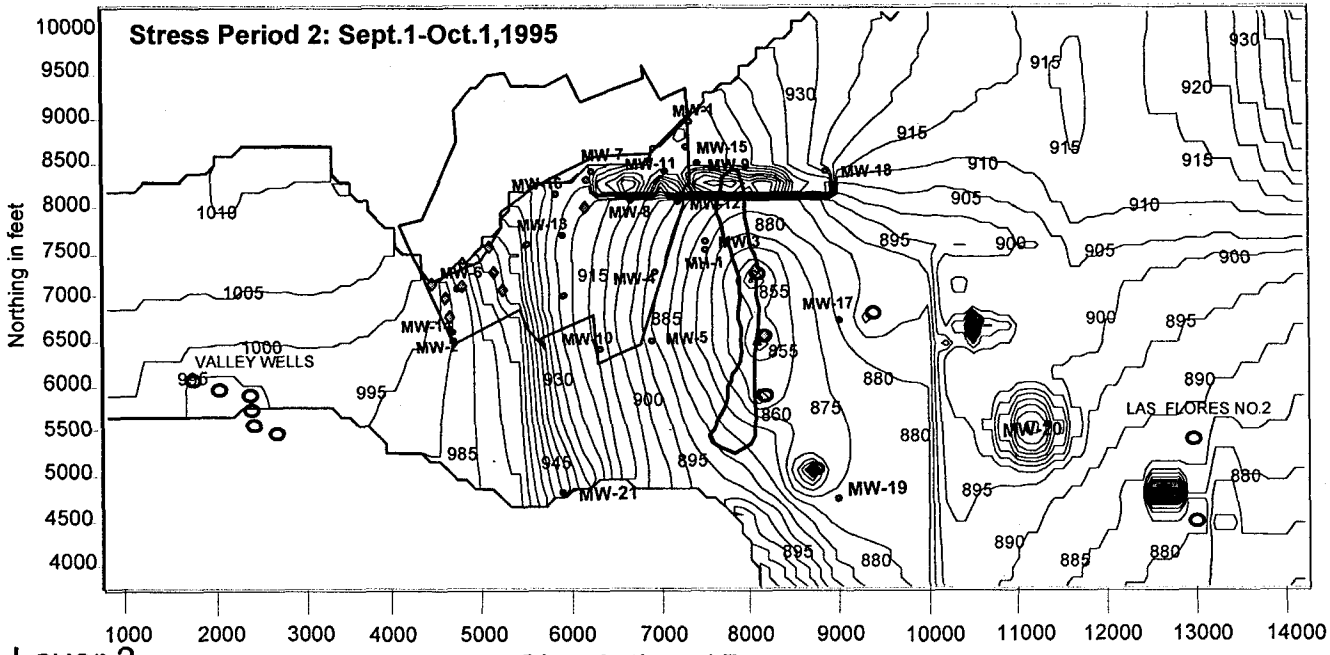
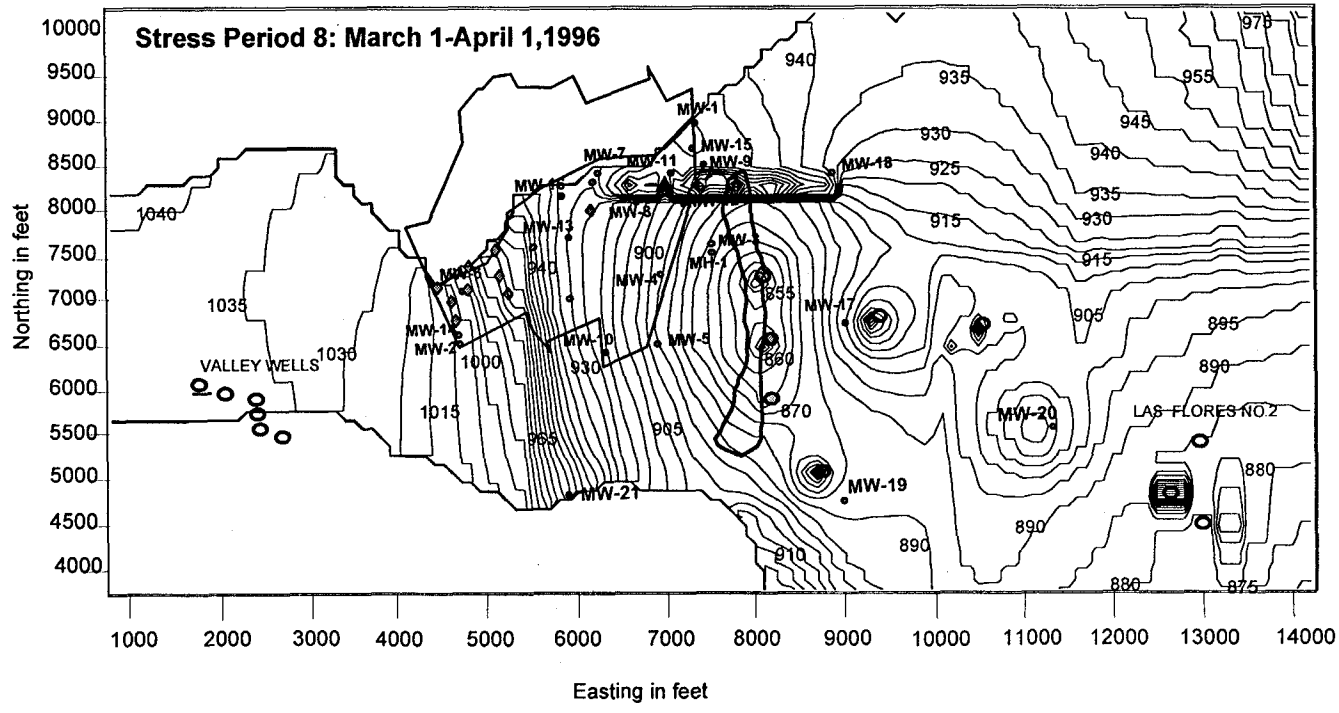
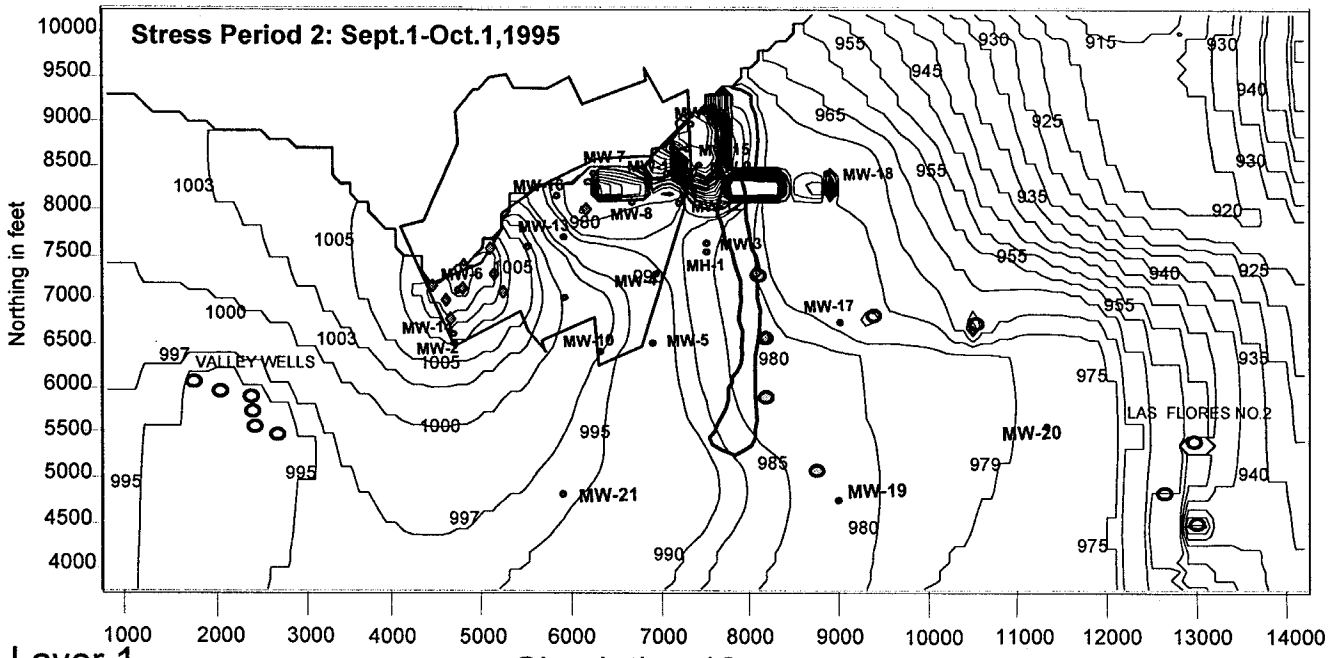




Geologic Layer 3

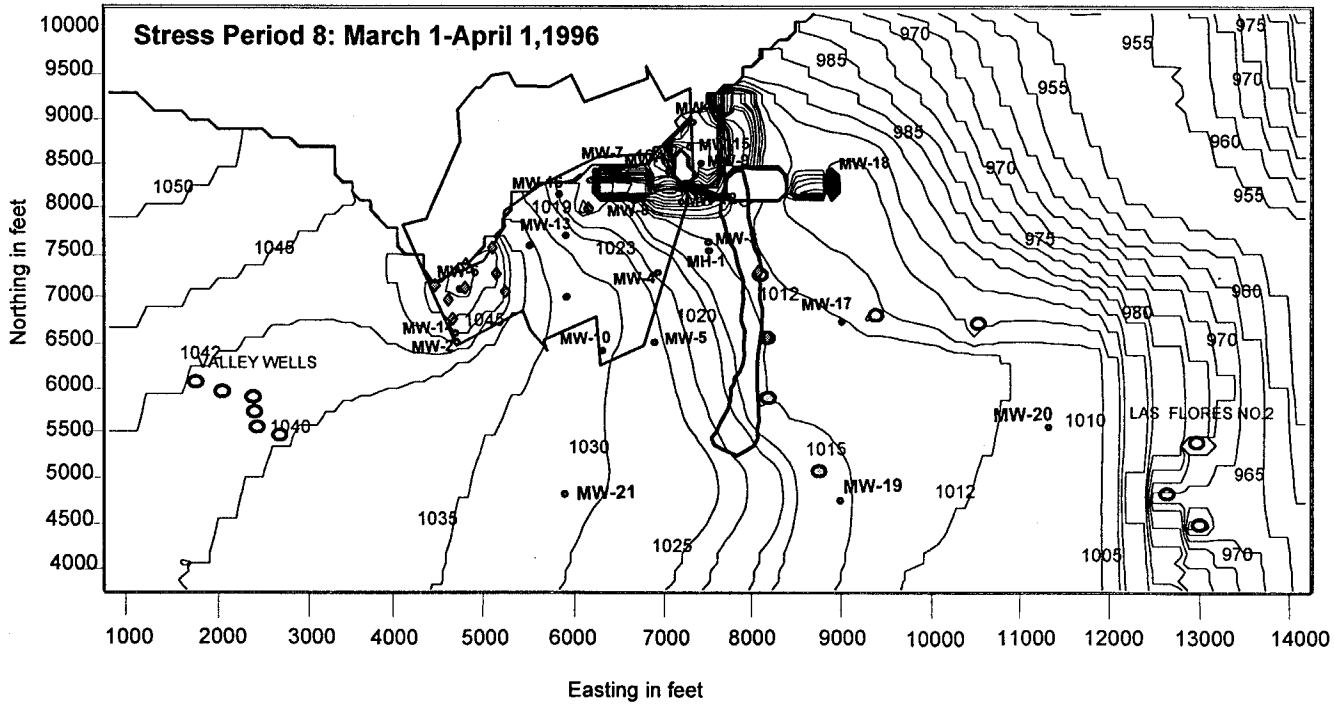
Simulation 15

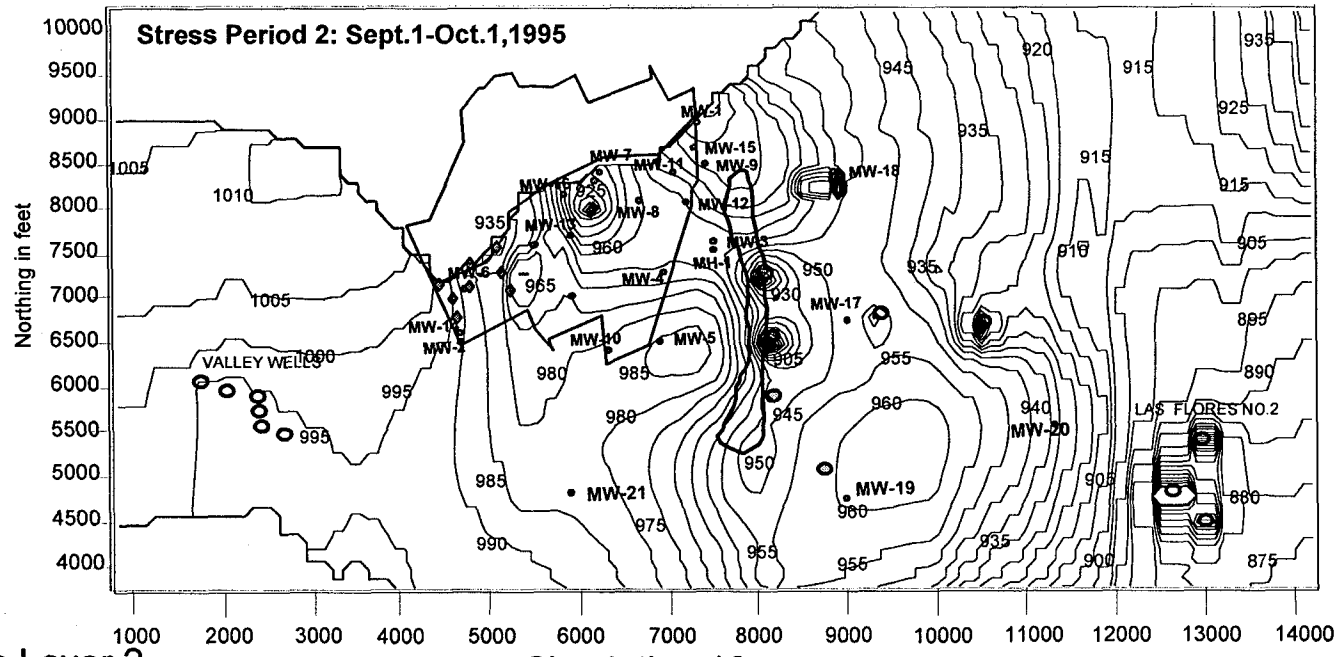




Geologic Layer 1

Simulation 16





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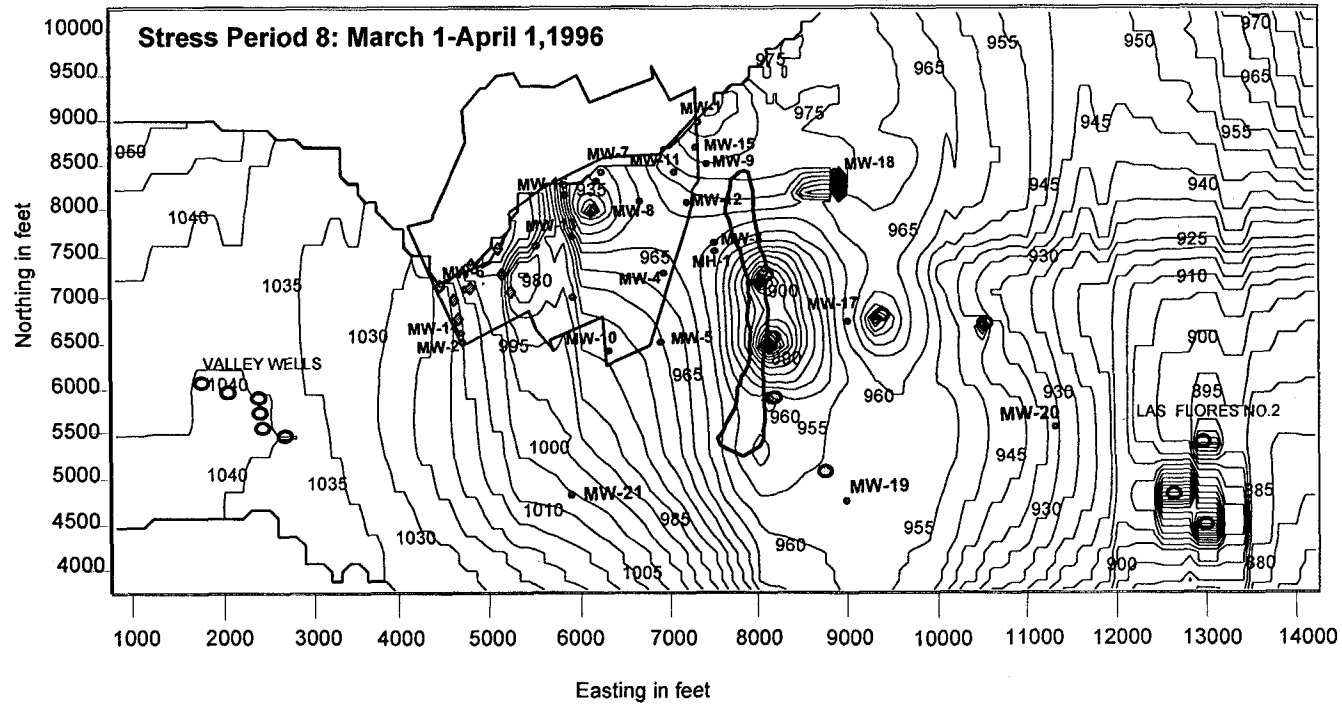

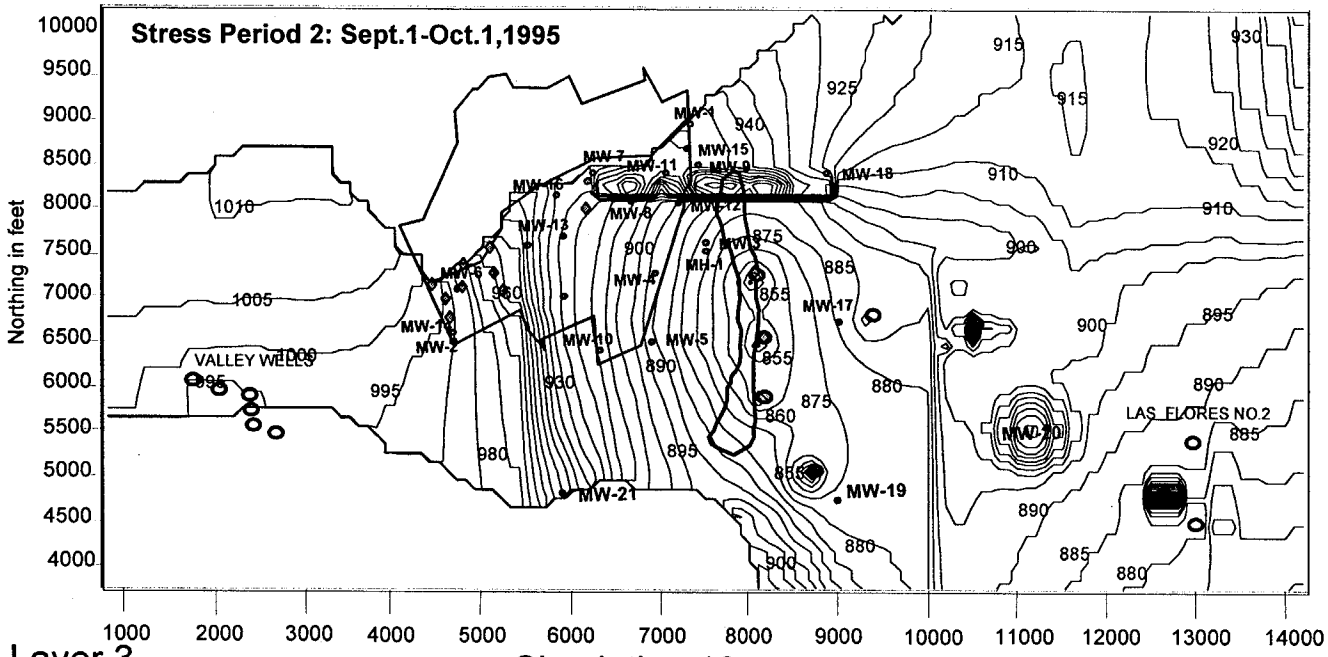

Geologic Layer 3

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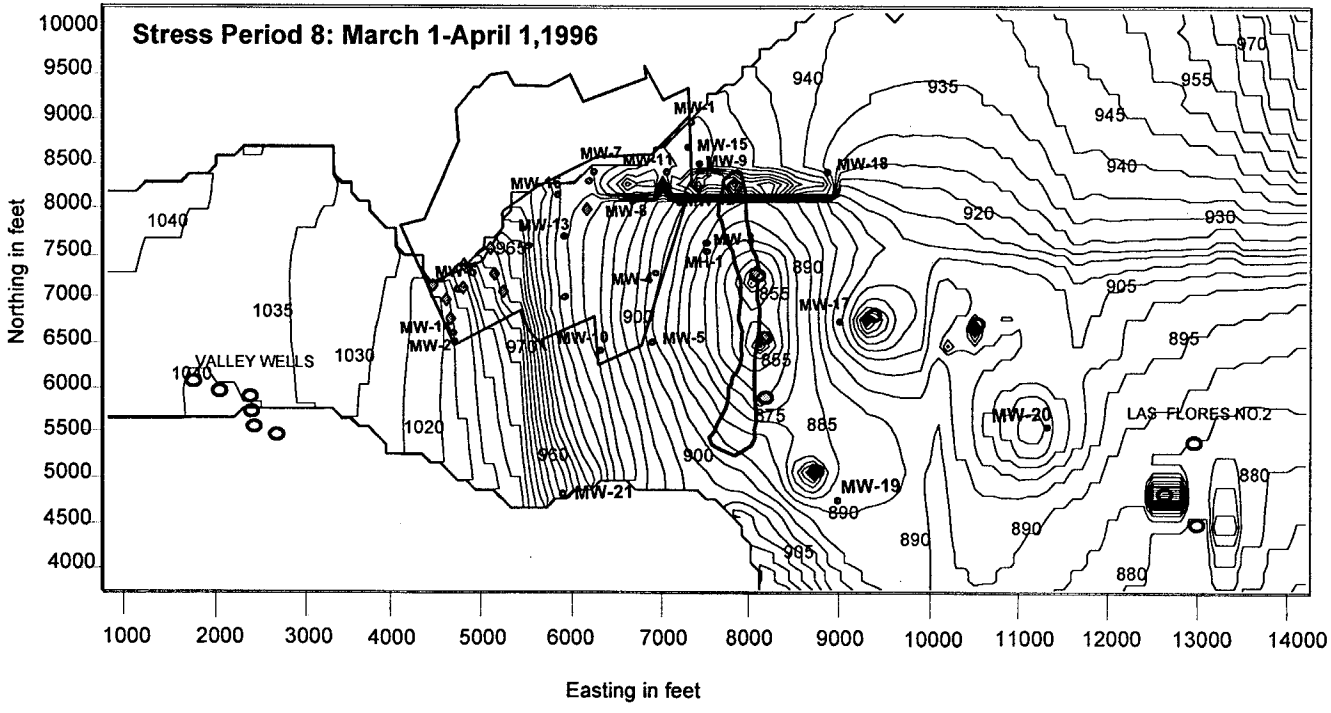

APPENDIX I

REMEDIAL ALTERNATIVE COST ESTIMATES

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TABLE I-1: SUMMARY OF COST ESTIMATES
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

	Alternative-------->	2	3	4	5	6[A]	Comments
COLLECTION							
A. Capital							
	Extraction Wells	$ 400,650	$ 1,443,750	$ 1,043,100	$ 1,443,750	$ 1,043,100	See Table I-2
	Piping (EW to TP)	$ 336,600	$ 752,400	$ 1,287,183	$ 1,683,183	$ 1,287,183	See Table I-3
	TOTAL	**$ 737,250**	**$ 2,196,150**	**$ 2,330,283**	**$ 3,126,933**	$ 2,330,283	
B. O & M Cost							
	Extraction Wells	$ 40,319	$ 564,468	$ 322,553	$ 443,510	$ 322,553	See Table I-2
	Piping (EW to TP)	$ 10,200	$ 22,800	$ 62,001	$ 74,001	$ 62,001	See Table I-3
	TOTAL	$ 50,519	$ 587,268	$ 384,553	$ 517,511	$ 384,553	
	PRESENT WORTH	**$ 776,603**	**$ 9,027,743**	**$ 5,911,530**	**$ 7,955,410**	**$ 5,911,530**	
TREATMENT							
A. Capital							
	Air Stripper	$ 92,488	$ 657,758	$ 383,800	$ 620,927	$ 383,800	See Table I-4
	LGAC	$ 602,000	$ 3,220,000	$ 1,925,000	$ 2,828,000	$ 1,925,000	See Table I-5
	Air Stripper/LGAC Total	*$ 694,488*	*$ 3,877,758*	*$ 2,308,800*	*$ 3,448,927*	$ 2,308,800	
	RO/Biotreatment Total	*$ 2,141,434*	*$ 23,858,374*	*$ 10,853,618*	*$ 17,107,664*		See Table I-6
	Ion Exchange	*$ 3,137,131*	*$ 12,604,000*	*$ 9,225,300*	*$ 10,697,875*		See Table I-7
	{25% reduction - see note (B)}	*(1,319,641.35)*	*(9,115,593.60)*	*(5,019,729.40)*	*(6,951,384.75)*		
	TOTAL	**$ 4,653,412**	**$ 31,224,539**	**$ 17,367,988**	**$ 24,303,081**	**$ 2,308,800**	
B. O & M Cost							
	Air Stripper	$ 88,941	$ 708,481	$ 421,024	$ 568,124	$ 421,024	See Table I-4
	LGAC	$ 170,194	$ 604,110	$ 388,193	$ 547,008	$ 388,193	See Table I-5
	Air Stripper/LGAC Total	*$ 259,135*	*$ 1,312,592*	*$ 809,217*	*$ 1,115,132*	$ 809,217	
	Reverse Osmosis	$ 223,497	$ 2,410,259	$ 1,534,606	$ 2,045,222		See Table I-6
	Biotreatment	$ 45,490	$ 617,237	$ 344,297	$ 490,578		See Table I-6
	RO/Biotreatment Total	*$ 268,987*	*$ 3,027,496*	*$ 1,878,903*	*$ 2,535,800*		
	Ion Exchange	*$ 193,456*	*$ 999,651*	*$ 1,060,661*	*$ 1,189,953*		See Table I-7
	{25% reduction - see note (B)}	*(115,610.75)*	*(1,006,786.82)*	*(734,891.04)*	*(931,438.18)*		
	TOTAL	**$ 605,968**	**$ 4,332,952**	**$ 3,013,891**	**$ 3,909,447**	**$ 809,217**	
	PRESENT WORTH[C]	**$ 9,315,208**	**$ 66,608,095**	**$ 46,330,886**	**$ 60,097,780**	**$ 12,439,656**	
RE-INJECTION & DISPOSAL							
A. Capital							
	Infiltration Wells	$ 453,900	$ 1,815,600	$ 1,815,600	$ 1,815,600	$ 1,815,600	See Table I-2
	Piping (TP to IW)	$ 1,045,358	$ 4,643,025	$ 3,556,556	$ 3,564,694	$ 3,556,556	See Table I-3
	Piping (TP to sewer)	$ 382,800	$ 1,039,683	$ 765,600	$ 1,036,738		See Table I-3
	Connection Fees	$ 397,579	$ 5,566,111	$ 3,180,635	$ 4,373,373		See Table I-8
	TOTAL	**$ 2,279,637**	**$ 13,064,420**	**$ 9,318,391**	**$ 10,790,405**	**$ 5,372,156**	

TABLE I-1: SUMMARY OF COST ESTIMATES
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

	Alternative--------->	2	3	4	5	6[A]	Comments
B. O & M Cost							
	Infiltration Wells	$ 40,319	$ 564,468	$ 322,553	$ 443,510	$ 322,553	See Table I-2
	Piping (TP to IW)	$ 40,876	$ 301,663	$ 245,744	$ 314,976	$ 245,744	See Table I-3
	Piping (TP to sewer)	$ 11,600	$ 40,704	$ 23,200	$ 40,614		See Table I-3
	Waste Surcharge	$ 85,375	$ 1,195,251	$ 683,000	$ 939,125		See Table I-8
	TOTAL	$ 178,170	$ 2,102,084	$ 1,274,498	$ 1,738,226	$ 568,297	
	PRESENT WORTH[C]	**$ 2,738,904**	**$ 32,314,190**	**$ 19,592,153**	**$ 26,720,795**	**$ 8,736,123**	
GROUNDWATER MONITORING		$ 750,000	$ 750,000	$ 750,000	$ 750,000	$ 750,000	See Table I-9
	PRESENT WORTH[D]	**$ 11,598,889**	**$ 11,598,889**	**$ 11,598,889**	**$ 11,598,889**	**$ 11,598,889**	
TOTAL CAPITAL		**$ 7,670,299**	**$ 46,485,108**	**$ 29,016,663**	**$ 38,220,419**	**$ 10,011,240**	
TOTAL PRESENT WORTH O&M, GW MONITORING		**$ 24,429,604**	**$ 119,548,917**	**$ 83,433,457**	**$ 106,372,874**	**$ 38,686,198**	
GRAND TOTAL		**$ 32,099,903**	**$ 166,034,025**	**$ 112,450,120**	**$ 144,593,293**	**$ 48,697,438**	

Note
(A) Costs for this Alternative were estimated from those for Alternative 4, and are not included in the Tables showing backups.
(B) Costs were estimated for the Reverse Osmosis and Ion Exchange systems independently. However, it is expected that the use of both systems in conjunction will result either in elimination or down-sizing of certain elements. The final system (and costs) will depend on the outcome of the 500 gpm pilot test.
(C) Based on a 30 year period, and a 5% discount factor.
(D) Includes 5 year reviews, see Table I-9.

TABLE I-2: W INSTALLATION
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

UNIT PRICES							
Item No.	Bid Item	Quantity (E-2 to E-5)	Quantity (E-1)	Units	Rate	Amount (E-1)	Amount (E-2 to E-5)
1	Mob/demob one reverse circulation drill rig	1	1	LS	$ 50,000	$ 50,000	$ 50,000
2	Install 36-inch conductor casing and sanitary seal	50	50	ft	$ 250	$ 12,500	$ 12,500
3	Pilot hole drilling; drill nominal 17.5 in pilot hole	600	350	ft	$ 45	$ 15,750	$ 27,000
4	Borehole reaming; ream pilot hole to 28-inches	600	350	ft	$ 35	$ 12,250	$ 21,000
5	Steel well casing	200	100	ft	$ 46	$ 4,600	$ 9,200
6	Slotted well casing	450	300	ft	$ 70	$ 21,000	$ 31,500
7	Gravel pack	450	300	ft	$ 120	$ 36,000	$ 54,000
8	Cement sanitary seal (from top of gravel pack to gs)	150	100	ft	$ 50	$ 5,000	$ 7,500
9	Well development	40	40	hours	$ 325	$ 13,000	$ 13,000
10	Roll-off bin delivery	2	2	ea	$ 750	$ 1,500	$ 1,500
11	Roll-off bin rental	60	60	bin/days	$ 20	$ 1,200	$ 1,200
12	Frac-tank delivery	2	2	ea	$ 750	$ 1,500	$ 1,500
13	Frac-tank rental (two 500-barrel tanks)	60	60	bin/days	$ 50	$ 3,000	$ 3,000
14	Development pumping; install & remove test pump	1	1	LS	$ 10,000	$ 10,000	$ 10,000
15	Perform development pumping	40	40	hours	$ 120	$ 4,800	$ 4,800
16	Extraction Pump, Controls, and housing					$ 75,000	$ 100,000
	Total Estimate					$ 267,100	$ 347,700

Infiltration Wells: Drilling and Installation Costs

Item	Bid Item	Quantity	Unit	Unit Cost	Total Amount
1	Mobilization/Demobilization	1	LS	$ 50,000	$ 50,000
2	Conductor Casing and Sanitary Seal; drill 30-inch min. hole and install 24-inch conductor casing	50	ft	$ 180	$ 9,000
3	Pilot Hole Drilling (drill pilot hole to 12 to 18 inches)	85	ft	$ 45	$ 3,825
4	Borehole Reaming (ream pilot hole to 22-inches)	85	ft	$ 35	$ 2,975
5	Steel Well Casing (12-inch blank steel)	75	ft	$ 42	$ 3,150
6	Stainless Steel Well Screen (12 inch wire-wrap)	40	ft	$ 130	$ 5,200
7	Stainless Steel Blank Well Casing (12 inch)	20	ft	$ 130	$ 2,600
8	Gravel Pack	50	ft	$ 120	$ 6,000
9	Grout Seal (install around production casing)	85	ft	$ 50	$ 4,250
10	Well Development (conduct surge block and air-lift well development using drill rig)	8	hours	$ 325	$ 2,600
11	Well Head; construct well head and appurtenances	1	LS	$ 2,500	$ 2,500
12	Roll-off Bin Delivery/Pickup	2	Bin	$ 750	$ 1,500
13	Roll-off Bin Rental	60	Bin-day	$ 20	$ 1,200
14	Baker Tank Delivery/Pickup	2	Tank	$ 750	$ 1,500
15	Baker Tank Rental	60	Tank-day	$ 50	$ 3,000
16	Standby Time	8	hours	$ 250	$ 2,000
17	Pump, Controls, and Housing				$ 50,000

	Total Estimate				$ 151,300		

Capital Costs	Alternative ---->	2	3	4	5
	Extraction Well Costs	$ 267,100	$ 962,500	$ 695,400	$ 962,500
	Construction Management (25%)	$ 66,775	$ 240,625	$ 173,850	$ 240,625
	Health & Safety (25%)	$ 66,775	$ 240,625	$ 173,850	$ 240,625
	TOTAL EW COST	**$ 400,650**	**$ 1,443,750**	**$ 1,043,100**	**$ 1,443,750**
	Infiltration Well Costs	$ 302,600	$ 1,210,400	$ 1,210,400	$ 1,210,400
	Construction Management (25%)	$ 75,650	$ 302,600	$ 302,600	$ 302,600
	Health & Safety (25%)	$ 75,650	$ 302,600	$ 302,600	$ 302,600
	TOTAL IW COST	**$ 453,900**	**$ 1,815,600**	**$ 1,815,600**	**$ 1,815,600**
Operation & Maintenance Costs					
Flow (gal)	gpm	500	7000	4000	5500
Flow (acre foot)	AFY	806	11,289	6,451	8,870
Unit Cost ($/af)	50				
Cost per year	**$/yr**	**$ 40,319**	**$ 564,468**	**$ 322,553**	**$ 443,510**

Notes:
1. Well installation costs are based on quote from licensed well drilling contractor.
2. Pumping costs of $50/af are approximate and based on experience.

		Alternative -->	2	2	2	2
			E-1 to Treatment Plant	Treatment Plant to Injection Well I-2	I-2 to I-1	From TP to sewer
Capital Costs						
1	Flow, gpm	gpm	500	450.0	225	100.0
2	Flow, MGD	MGD	0.72	0.65	0.32	0.14
2	Pipe Dia, inches	inches	8	8	4	4
3	Frict. Loss/ft	ft	0.008276	0.006810	0.055070	0.012285
4	Length	ft	850	3450	450	2900
5	Friction Loss (includes SF of 2)	ft	14	47	50	71
6	Elevation Difference	ft	0	65	45	40
7	Total Loss	psi	6	48	41	48
8	Total Loss	ft	14	112	95	111
9	pump hydraulic horsepower	whp	2	13	5	3
10	pump brake horsepower	bhp	3	18	8	4
11	Pump Station Costs			2@20hp		
	Pumps			$ 5,550		
	Pump Station Building			$ 40,000		
12	Piping Installation ($20/inch/linear foot)	Cost/ft	$ 160	$ 160	$ 80	$ 80
	Steel piping	Cost	$ 136,000	$ 552,000	$ 36,000	$ 232,000
	Additional for on-site piping	50%	$ 68,000	$ 276,000	$ 18,000	$ 116,000
13	Total Capital Cost/Piping		$ 204,000	$ 597,550	$ 36,000	$ 232,000
	Other Costs	Design (40%)	$ 81,600	$ 239,020	$ 14,400	$ 92,800
		Construction Mgmt. (15%)	$ 30,600	$ 89,633	$ 5,400	$ 34,800
		Permitting (10%)	$ 20,400	$ 59,755	$ 3,600	$ 23,200
	Total Capital		$ 336,600	$ 985,958	$ 59,400	$ 382,800
Operation & Maintenance Costs						
	Maintenance	cost/yr	$ 10,200	$ 29,878	$ 1,800	$ 11,600
	Electricity Usage	kWh/yr		131400		
	Electricity Cost	$/yr		$ 9,198		
	Total O&M		$ 10,200	$ 39,076	$ 1,800	$ 11,600

		Alternative -->	3	3	3	3	3	3	3	3
			E-1 to Treatment Plant	E-2 to Treatment Plant	E-3 to Treatment Plant	TP to I-2	I-2 to I-1	I-2 to I-3	I-2 to I-5	TP to Sewer
Capital Costs										
1	Flow, gpm	gpm	1000	3000	3000	6300	3150	3150	3150	1400
2	Flow, MGD	MGD	1.44	4.32	4.32	9.07	4.54	4.54	4.54	2.02
2	Pipe Dia, inches	inches	12	18	18	24	24	18	18	10
3	Frict. Loss/ft	ft	0.004149	0.004404	0.004404	0.004286	0.001189	0.004820	0.004820	0.018773
4	Length	ft	850	450	250	3450	450	750	1150	2900
5	Friction Loss (includes SF of 2)	ft	7	4	2	30	1	7	11	109
6	Elevation Difference	ft	0	0	5	65	45	45	45	40
7	Total Loss	psi	3	2	3	41	20	23	24	64
8	Total Loss	ft	7	4	7	95	46	52	56	149
9	pump hydraulic horsepower	whp	2	3	5	151	37	42	45	53
10	pump brake horsepower	bhp	3	4	8	215	52	59	64	75
11	Pump Station Costs					3@100hp	2@50hp	2@50hp	2@50hp	2@50hp
	Pumps					$ 22,565	$ 15,167	$ 10,111	$ 10,111	$ 10,111
	Pump Station Building					$ 50,000	$ 50,000	$ 50,000	$ 50,000	$ 40,000
12	Piping Installation ($20/inch/linear foot)	Cost/ft	$ 240	$ 360	$ 360	$ 480	$ 480	$ 360	$ 360	$ 200
	Steel piping	Cost	$ 204,000	$ 162,000	$ 90,000	$ 1,656,000	$ 216,000	$ 270,000	$ 414,000	$ 580,000
	Additional for on-site piping	50%	$ 102,000	$ 81,000	$ 45,000	$ 828,000	$ 108,000	$ 135,000	$ 207,000	$ 290,000
13	Total Capital Cost/Piping		$ 204,000	$ 162,000	$ 90,000	$ 1,728,565	$ 281,167	$ 330,111	$ 474,111	$ 630,111
	Other Costs	Design (40%)	$ 81,600	$ 64,800	$ 36,000	$ 691,426	$ 112,467	$ 132,044	$ 189,644	$ 252,044
		Construction Mgmt. (15%)	$ 30,600	$ 24,300	$ 13,500	$ 259,285	$ 42,175	$ 49,517	$ 71,117	$ 94,517
		Permitting (10%)	$ 20,400	$ 16,200	$ 9,000	$ 172,857	$ 28,117	$ 33,011	$ 47,411	$ 63,011
	Total Capital		$ 336,600	$ 267,300	$ 148,500	$ 2,852,133	$ 463,925	$ 544,683	$ 782,283	$ 1,039,683
Operation & Maintenance Costs										
	Maintenance	cost/yr	$ 10,200	$ 8,100	$ 4,500	$ 86,428	$ 14,058	$ 16,506	$ 23,706	$ 31,506
	Electricity Usage	kWh/yr				1314000	328500	328500	328500	131400
	Electricity Cost	$/yr				$ 91,980	$ 22,995	$ 22,995	$ 22,995	$ 9,198
	Total O&M		$ 10,200	$ 8,100	$ 4,500	$ 178,408	$ 37,053	$ 39,501	$ 46,701	$ 40,704

		Alternative -->	4	4	4	4	4	4
			E-5/E-4 to TP	TP to I-2	I-2 to I-1	I-2 to I-3	I-2 to I-5	TP to Sewer
Capital Costs								
1	Flow, gpm	gpm	4000	3600	1800	1800	1800	800
2	Flow, MGD	MGD	5.76	5.18	2.59	2.59	2.59	1.15
2	Pipe Dia, inches	inches	18	18	14	14	14	8
3	Frict. Loss/ft	ft	0.007499	0.006171	0.005814	0.005814	0.005814	0.019744
4	Length	ft	2000	3450	450	750	1150	2900
5	Friction Loss (includes SF of 2)	ft	30	43	5	9	13	115
6	Elevation Difference	ft	0	65	45	45	45	40
7	Total Loss	psi	13	47	22	23	25	67
8	Total Loss	ft	30	108	50	54	58	155
9	pump hydraulic horsepower	whp	30	98	23	24	27	31
10	pump brake horsepower	bhp	43	140	33	35	38	45
11	Pump Station Costs		2@50hp		2@50hp	2@50hp	2@50hp	
	Pumps		$ 10,111	$ 25,155	$ 10,111	$ 10,111	$ 10,111	
	Pump Station Building		$ 50,000	$ 50,000	$ 50,000	$ 50,000	$ 50,000	
12	Piping Installation ($20/inch/linear foot)	Cost/ft	$ 360	$ 360	$ 280	$ 280	$ 280	$ 160
	Steel piping	Cost	$ 720,000	$ 1,242,000	$ 126,000	$ 210,000	$ 322,000	$ 464,000
	Additional for on-site piping	50%		$ 621,000	$ 63,000	$ 105,000	$ 161,000	$ 232,000
13	Total Capital Cost/Piping		$ 780,111	$ 1,317,155	$ 186,111	$ 270,111	$ 382,111	$ 464,000
	Other Costs	Design (40%)	$ 312,044	$ 526,862	$ 74,444	$ 108,044	$ 152,844	$ 185,600
		Construction Mgmt. (15%)	$ 117,017	$ 197,573	$ 27,917	$ 40,517	$ 57,317	$ 69,600
		Permitting (10%)	$ 78,011	$ 131,715	$ 18,611	$ 27,011	$ 38,211	$ 46,400
	Total Capital		$ 1,287,183	$ 2,173,305	$ 307,083	$ 445,683	$ 630,483	$ 765,600
Operation & Maintenance Costs								
	Maintenance	cost/yr	$ 39,006	$ 65,858	$ 9,306	$ 13,506	$ 19,106	$ 23,200
	Electricity Usage	kWh/yr	328500	985500	328500	328500	328500	
	Electricity Cost	$/yr	$ 22,995	$ 68,985	$ 22,995	$ 22,995	$ 22,995	
	Total O&M		$ 62,001	$ 134,843	$ 32,301	$ 36,501	$ 42,101	$ 23,200

		Alternative -->	5	5	5	5	5	5	5
			E-1 to TP	E-5/E-4 to TP	TP to I-2	I-2 to I-1	I-2 to I-3	I-2 to I-5	TP to Sewer
Capital Costs									
1	Flow, gpm	gpm	1500	4000	4950	2475	2475	2475	1100
2	Flow, MGD	MGD	2.16	5.76	7.13	3.56	3.56	3.56	1.58
2	Pipe Dia, inches	inches	12	18	18	14	14	14	10
3	Frict. Loss/ft	ft	0.008784	0.007499	0.011122	0.010479	0.010479	0.010479	0.012016
4	Length	ft	1000	2000	3450	450	750	1150	2900
5	Friction Loss (includes SF of 2)	ft	18	30	77	9	16	24	70
6	Elevation Difference	ft	0	0	65	45	45	45	40
7	Total Loss	psi	8	13	61	24	26	30	47
8	Total Loss	ft	18	30	142	54	61	69	110
9	pump hydraulic horsepower	whp	7	30	177	34	38	43	31
10	pump brake horsepower	bhp	10	43	253	49	54	62	44
11	Pump Station Costs			2@50hp		2@50hp	2@50hp	2@100hp	3@20hp
	Pumps			$ 10,111	$ 25,155	$ 10,111	$ 10,111	$ 15,044	$ 8,326
	Pump Station Building			$ 50,000	$ 50,000	$ 50,000	$ 50,000	$ 50,000	$ 40,000
12	Piping Installation ($20/inch/linear foot)	Cost/ft	$ 240	$ 360	$ 360	$ 280	$ 280	$ 280	$ 200
	Steel piping	Cost	$ 240,000	$ 720,000	$ 1,242,000	$ 126,000	$ 210,000	$ 322,000	$ 580,000
	Additional for on-site piping	50%	$ 120,000		$ 621,000	$ 63,000	$ 105,000	$ 161,000	$ 290,000
13	Total Capital Cost/Piping		$ 240,000	$ 780,111	$ 1,317,155	$ 186,111	$ 270,111	$ 387,044	$ 628,326
	Other Costs	Design (40%)	$ 96,000	$ 312,044	$ 526,862	$ 74,444	$ 108,044	$ 154,817	$ 251,330
		Construction Mgmt. (15%)	$ 36,000	$ 117,017	$ 197,573	$ 27,917	$ 40,517	$ 58,057	$ 94,249
		Permitting (10%)	$ 24,000	$ 78,011	$ 131,715	$ 18,611	$ 27,011	$ 38,704	$ 62,833
	Total Capital		$ 396,000	$ 1,287,183	$ 2,173,305	$ 307,083	$ 445,683	$ 638,622	$ 1,036,738
Operation & Maintenance Costs									
	Maintenance	cost/yr	$ 12,000	$ 39,006	$ 65,858	$ 9,306	$ 13,506	$ 19,352	$ 31,416
	Electricity Usage	kWh/yr		328500	1642500	328500	328500	657000	131400
	Electricity Cost	$/yr		$ 22,995	$ 114,975	$ 22,995	$ 22,995	$ 45,990	$ 9,198
	Total O&M		$ 12,000	$ 62,001	$ 180,833	$ 32,301	$ 36,501	$ 65,342	$ 40,614

Note:
1. Piping design is approximate and based on the figures in Section 4.0 showing the piping layout for each alternative. Flows to the sewer are conservative, and are based on a single stage RO. These flows would reduce significantly if only ion exchange were to be used. This would be determined upon completion of the pilot study.
2. Unit costs of $20/inch/foot are conservative, and a 1.5 safety factor is used for piping on the JPL site due to presence of buried utilities.
3.Piping material is assumed to be steel (30+ year design life).
4. Depth to piping is assumed to be 10 feet when crossing the Arroyo to account for scouring during possible flood events.
5. Design costs are assumed to be 40% of capital, which is higher than typical, to account for the complexity of the site.

TABLE I-4. AIR STRIPPING
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

	Alternative----->		2	3	4	5
Design	Air Stripper					
	Flow, gpm	gpm	500	7000	4000	5500
		cfm	66.85	935.9	534.8	735.35
	VOC Loading	ppm	0.3	0.2	0.2	0.2
		lbs/yr	657.5256	6136.9056	3506.8032	4821.8544
	Blower	hp	7.5	30	40	20
	Flowrate	cfm	3350	37434	26738	29412
	Power	kwh	52560	210240	280320	140160
	Adsorber Loading	lb/ft3	3.73433E-07	3.11909E-07	2.49533E-07	3.11914E-07
		ug/L	5.98239403	4.996781536	3.997510659	4.996854345
		ppM	0.933815252	0.779967148	0.623987053	0.779978513
	Amount of Carbon	1.5%	43835.04	409127.04	233786.88	321456.96
Capital Cost	Adsorber		$ 6,163	$ 58,800	$ 42,767	$ 58,800
	Air Stripper		$ 49,850	$ 298,725	$ 151,162	$ 296,483
	Demisters		$ 10,050	$ 112,302	$ 80,214	$ 88,236
	Total Capital		$ 66,063	$ 469,827	$ 274,143	$ 443,519
	5% of Capital (Piping)		$ 3,303	$ 23,491	$ 13,707	$ 22,176
	10% of Capital (Foundation)		$ 6,606	$ 46,983	$ 27,414	$ 44,352
	25% of Capital (Installation)		$ 16,516	$ 117,457	$ 68,536	$ 110,880
	FINAL TOTAL		**$ 92,488**	**$ 657,758**	**$ 383,800**	**$ 620,927**
Operation & Maintenance Costs						
	Labor Cost	$/hr	50	50	50	50
	Cost of Power (Stripper)	$/kwh	$ 0.07	$ 0.07	$ 0.07	$ 0.07
	Carbon Replacement	$/lb	1.5	1.5	1.5	1.5
	Laboratory	$/yr	$ 6,000	$ 6,000	$ 6,000	$ 6,000
	Labor per month	hrs	16	16	16	16

TABLE I-4: AIR STRIPPING
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

	Alternative----->		2	3	4	5
	Labor	$	$ 9,600	$ 9,600	$ 9,600	$ 9,600
	Blower Electrical Cost	$	$ 3,679	$ 14,717	$ 19,622	$ 9,811
	Carbon cost	$	$ 65,753	$ 613,691	$ 350,680	$ 482,185
	System Maintenance/Repairs	15%	$ 9,909	$ 70,474	$ 41,121	$ 66,528
	TOTAL O & M COST	**$/yr**	**$ 88,941**	**$ 708,481**	**$ 421,024**	**$ 568,124**
		$/KGAL	$ 0.338	$ 0.193	$ 0.200	$ 0.197

Notes:
1. Capital and O&M costs based on quotes from CarbonAir Environmental Systems.
2. Offgases from stripper to be treated using vapor phase granular activated carbon.
3. Due to the high air flows, no heating of offgases was assumed to be required. This would result in high moisture content in the influent to the carbon vessels, which would result in more frequent change-out of the primary vessel.

TABLE I-5: LIQUID PHASE GAC
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

	Alternative------->		2	3	4	5
Design						
	Flow	gpm	500	7000	4000	5500
	No. of trains (2 per, series-parallel)		2	10	6	9
	Carbon per train	lb	40000	40000	40000	40000
	Equalization Tank RT	minutes	15	15	15	15
	Volume		7500	105000	60000	82500
Unit Costs						
	Carbon Trains	ea	$165,000	$165,000	$165,000	$165,000
	Tank	gal	2	2	2	2
	Piping/valves/instruments	train	$15,000	$15,000	$15,000	$15,000
	Pump	train	$20,000	$20,000	$20,000	$20,000
CAPITAL COSTS						
	Carbon vessels		$330,000	$1,650,000	$990,000	$1,485,000
	Piping/valves/instruments		$30,000	$30,000	$25,000	$25,000
	Equalization Tank		$15,000	$210,000	$120,000	$165,000
	Holding Tank		$15,000	$210,000	$120,000	$165,000
	Transfer Pumps		$40,000	$200,000	$120,000	$180,000
	Total		$430,000	$2,300,000	$1,375,000	$2,020,000
	5% of Capital (Piping)		$21,500	$115,000	$68,750	$101,000
	10% of Capital (Foundation)		$43,000	$230,000	$137,500	$202,000
	25% of Capital (Installation)		$107,500	$575,000	$343,750	$505,000
	FINAL TOTAL		**$602,000**	**$3,220,000**	**$1,925,000**	**$2,828,000**
OPERATION & MAINTENANCE COSTS						
Design						
	Flow	gpm	500	7000	4000	5500
		mgd	0.72	10.08	5.76	7.92
	Avg VOC	ppm	0.01	0.01	0.01	0.01

TABLE I-5: LIQUID PHASE GAC
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

	Alternative------->		2	3	4	5
	VOC mass/yr	lb	21.91752	306.84528	175.34016	241.09272
	Carbon Efficiency	%, decimal	0.01	0.01	0.01	0.01
	Carbon consumed/yr	lb	2191.752	30684.528	17534.016	24109.272
	Pump HP	train	100	100	100	100
	Total HP		200	1000	600	900
	Samples per month		5	9	7	8.5
	Labor per week	hr	20	20	20	20
Unit Cost						
	Carbon Replacement	$/lb	$0.95	$0.95	$0.95	$0.95
	Power	$/kWh	$ 0.07	$ 0.07	$ 0.07	$ 0.07
	Sample Analysis	$/ea	$ 300	$ 300	$ 300	$ 300
	Labor	$/hr	$ 50	$ 50	$ 50	$ 50
Costs/yr						
	Carbon Replacement/yr		$ 2,082	$ 29,150	$ 16,657	$ 22,904
	Power		$ 98,112	$ 490,560	$ 294,336	$ 441,504
	Laboratory		$ 18,000	$ 32,400	$ 25,200	$ 30,600
	Labor		$ 52,000	$ 52,000	$ 52,000	$ 52,000
	Total O&M Costs		**$ 170,194**	**$ 604,110**	**$ 388,193**	**$ 547,008**

Notes:
1. Capital costs based on quotes from USFilter/Westates.

	Alternative---->		2	3	4	5	Comments
A. REVERSE OSMOSIS SYSTEM							
RO SYSTEM (Method 1)							
Stage 1							
Design	Feed Flow	gpm	500	7000	4000	5500	
	Product Flow	gpm	400	5600	3200	4400	
		mgd	0.576	8.064	4.608	6.336	
	%R		0.8	0.8	0.8	0.8	
	Membrane Feed pressure	psi	150	150	150	150	
	Mass Transfer Coefficient		0.15	0.15	0.15	0.15	
	Pump/Motor Efficiency		0.7	0.7	0.7	0.7	
Cost Factors	Filters		0.09375	0.09375	0.09375	0.09375	
	Feed Pumps		0.276	0.116	0.139	0.125	
	Membrane Units		0.444444444	0.444444444	0.444444444	0.444444444	
	Degasification		0.05	0.05	0.05	0.05	
	Chemicals		0.16875	0.16875	0.16875	0.16875	
	Distribution Pumping/Storage		0.357735685	0.24683801	0.263031178	0.253451467	
	Misc.		0.4	0.4	0.4	0.4	
Capital Cost	Factor		1.790705428	1.519320931	1.558948226	1.535505127	
	Cost		$ 1,000,000	$ 12,300,000	$ 7,200,000	$ 9,700,000	
Stage 2							
Design	Feed Flow	gpm	100	1400	800	1100	
	Product Flow	gpm	50	700	400	550	
		mgd	0.072	1.008	0.576	0.792	
	%R		0.5	0.5	0.5	0.5	
	Membrane Feed pressure	psi	300	300	300	300	
	Mass Transfer Coefficient		0.15	0.15	0.15	0.15	
	Pump/Motor Efficiency		0.7	0.7	0.7	0.7	
Cost Factors	Filters		0.15	0.15	0.15	0.15	
	Feed Pumps		1.195	0.500	0.602	0.542	
	Membrane Units		0.22	0.22	0.22	0.22	
	Chemicals		0.225	0.225	0.225	0.225	
	Distribution Pumping/Storage		0.545836354	0.325573056	0.357735685	0.338708606	
	Misc.		0.4	0.4	0.4	0.4	
Capital Cost	Factor		2.738199369	1.823056476	1.956684734	1.877631637	
	Cost		$ 197,000	$ 1,838,000	$ 1,127,000	$ 1,487,000	
TOTAL CAPITAL			$ 1,197,000	$ 14,138,000	$ 8,327,000	$ 11,187,000	
$/gpd			$ 2	$ 1	$ 1	$ 1	
	5% of Capital (Piping)		$ 59,850	$ 706,900	$ 416,350	$ 559,350	
	10% of Capital (Foundation)		$ 119,700	$ 1,413,800	$ 832,700	$ 1,118,700	
	25% of Capital (Installation)		$ 299,250	$ 3,534,500	$ 2,081,750	$ 2,796,750	

	Alternative---->		2	3	4	5	Comments
FINAL TOTAL			**$ 1,675,800**	**$ 19,793,200**	**$ 11,657,800**	**$ 15,661,800**	
RO SYSTEM (Method 2)							
Stage 1							
Design	Flow	gpm	500	7,000	4,000	5,500	
	Annual Flow	Kgal	262,800	3,679,200	2,102,400	2,890,800	
	Annual Flow	Acre-feet	806	11,289	6,451	8,870	
	No. of ROs		2	32	16	24	Based on USFilter
	Arrays/RO		2	2	2	2	Based on USFilter
	Configuration		6x4	6x4	6x4	6x4	Based on USFilter
	Membranes/vessel		6	6	6	6	Based on USFilter
	Total membranes		120	1,920	960	1,440	Based on USFilter
Stage 2							
Design	Flow	gpm	100	1,400	800	1,100	
	No. of ROs		1	6	4	6	Based on USFilter
	Arrays/RO		1	2	1	2	Based on USFilter
	Configuration		3	6x4	6	6x4	Based on USFilter
	Membranes/vessel		6	6	6	6	Based on USFilter
	Total		18	360	240	360	Based on USFilter
Cost Factors	6x4-6M		$ 130,715	$ 130,715	$ 130,715	$ 130,715	Based on USFilter
	3-6M		$ 84,050	$ 84,050	$ 84,050	$ 84,050	Based on USFilter
	6-6M		$ 104,616	$ 104,616	$ 104,616	$ 104,616	Based on USFilter
	CIP-225		$ 22,562	$ 22,562	$ 22,562	$ 22,562	Based on USFilter
Capital Cost							
	First Stage RO		$ 522,860	$ 8,365,760	$ 4,182,880	$ 6,274,320	
	Second Stage RO		$ 84,050	$ 1,568,580	$ 418,464	$ 1,568,580	
	CIP-225 (Clean-in-Place eqpt)		$ 67,686	$ 857,356	$ 451,240	$ 676,860	
	Tanks		$ 25,000	$ 150,000	$ 100,000	$ 100,000	Assumed
	Controls		$ 50,000	$ 100,000	$ 100,000	$ 100,000	Assumed
Total for RO			$ 749,596	$ 11,041,696	$ 5,252,584	$ 8,719,760	
$/gpd			$ 1	$ 1	$ 1	$ 1	
	5% of Capital (Piping)		$ 37,480	$ 552,085	$ 262,629	$ 435,988	
	10% of Capital (Foundation)		$ 74,960	$ 1,104,170	$ 525,258	$ 871,976	
	25% of Capital (Installation)		$ 187,399	$ 2,760,424	$ 1,313,146	$ 2,179,940	
FINAL TOTAL (Method 2)			**$ 1,049,434**	**$ 15,458,374**	**$ 7,353,618**	**$ 12,207,664**	
B. BIOTREATMENT CAPITAL COSTS							
Design	Flow	gpm	50	700	400	550	
Capital Cost			$ 780,000	$ 6,000,000	$ 2,500,000	$ 3,500,000	Based on USFilter
SUBTOTAL CAPITAL (METHOD 1)			$ 1,977,000	$ 14,138,000	$ 8,327,000	$ 11,187,000	
SUBTOTAL CAPITAL (METHOD 2)			$ 1,529,596	$ 17,041,696	$ 7,752,584	$ 12,219,760	

	Alternative---->		2	3	4	5	Comments
TOTAL CAPITAL (METHOD 1)			$ 1,977,000	$ 14,138,000	$ 8,327,000	$ 11,187,000	
5% of Capital (Piping)			$ 98,850	$ 706,900	$ 416,350	$ 559,350	
10% of Capital (Foundation)			$ 197,700	$ 1,413,800	$ 832,700	$ 1,118,700	
25% of Capital (Installation)			$ 494,250	$ 3,534,500	$ 2,081,750	$ 2,796,750	
FINAL TOTAL (METHOD 1)			**$ 2,767,800**	**$ 19,793,200**	**$ 11,657,800**	**$ 15,661,800**	
TOTAL CAPITAL (METHOD 2)			$ 1,529,596	$ 17,041,696	$ 7,752,584	$ 12,219,760	
5% of Capital (Piping)			$ 76,480	$ 852,085	$ 387,629	$ 610,988	
10% of Capital (Foundation)			$152,960	$ 1,704,170	$ 775,258	$ 1,221,976	
25% of Capital (Installation)			$382,399	$ 4,260,424	$ 1,938,146	$ 3,054,940	
FINAL TOTAL (METHOD 2)			**$ 2,141,434**	**$ 23,858,374**	**$ 10,853,618**	**$ 17,107,664**	
C. OPERATING COSTS							
C1 Method 1							
	Flowrate	gal/yr	262800	3679200	2102400	2890800	
	Electrical cost	$/kwh	$ 0.07	$ 0.07	$ 0.07	$ 0.07	
	Percent Recovery		0.9	0.9	0.9	0.9	
	Pump Efficiency		0.7	0.7	0.7	0.7	
	Membrane Feed Pressure	psig	100.0	100.0	100.0	100.0	
$0.00441	Microfiltration	$/gal	$ 1,159	$ 16,229	$ 9,274	$ 12,752	
$0.08822	Membrane Feed Pumping	$/gal	$ 23,185	$ 324,587	$ 185,478	$ 255,033	
$0.18300	Membrane Replacement	$/gal	$ 48,092	$ 673,294	$ 384,739	$ 529,016	
$0.15144	Chemical Addition	$/gal	$ 39,800	$ 557,194	$ 318,397	$ 437,796	
$1,000	Operating Labor	$wk	$ 52,000	$ 52,000	$ 52,000	$ 52,000	
$0.10000	Maintenance	$/gal	$ 26,280	$ 367,920	$ 210,240	$ 289,080	
$1,000.42708	**TOTAL**	$/yr	$ 190,516	$ 1,991,225	$ 1,160,128	$ 1,575,676	
C2 Method 2							
	No. of Pumps		2	28	16	22	
	HP each		100.00	100.00	100.00	100.00	
	kWh		1401600	19622400	11212800	15417600	
	Membrane Changes (1 per 4 yrs)		35	570	300	450	Typical 3 to 5 yrs
	Unit Costs						
	kWh		0.07	0.07	0.07	0.07	
	Membrane	quote	823.00	823.00	823.00	823.00	Based on USFilter
	Chemicals	$/kgal	$ 0.08	$ 0.08	$ 0.08	$ 0.08	Assumed (model)-
	Operating Labor & Maintenance	$/kgal	$ 0.20	$ 0.07	$ 0.15	$ 0.12	assumed 0.25,
	Analytical	$/month	$ 2,000	$ 2,000	$ 2,000	$ 2,000	
	Total Cost						
	Power		$ 98,112	$ 1,373,568	$ 784,896	$ 1,079,232	
	Membranes		$ 28,394	$ 469,110	$ 246,900	$ 370,350	
	Chemicals		$ 20,431	$ 286,037	$ 163,450	$ 224,744	
	Operating Labor & Maintenance		$ 52,560	$ 257,544	$ 315,360	$ 346,896	
	Analytical		$ 24,000	$ 24,000	$ 24,000	$ 24,000	

	Alternative---->		2	3	4	5	Comments
	Total RO O&M		**$ 223,497**	**$ 2,410,259**	**$ 1,534,606**	**$ 2,045,222**	
	Cost per Kgal	$/Kgal	$ 0.850	$ 0.655	$ 0.730	$ 0.707	
	Cost per Acre-feet	$/acre ft	$ 277	$ 213	$ 238	$ 231	
C3 Biotreatment System							
	Flow	gpm	50	700	400	550	
	HP		20	240	120	200	
	kWh		140160	1681920	840960	1401600	
	Ethanol	gpd	58	805	460	633	
	Unit Costs						
	Power	$/kwh	$ 0.07	$ 0.07	$ 0.07	$ 0.07	
	Ethanol	$/gal	$ 1.70	$ 1.70	$ 1.70	$ 1.70	
	Total						
	Power		$ 9,811	$ 117,734	$ 58,867	$ 98,112	
	Ethanol		$ 35,679	$ 499,503	$ 285,430	$ 392,466	
	Labor (included under RO)						
	Total Biotreatment O&M		$ 45,490	$ 617,237	$ 344,297	$ 490,578	
TOTAL O&M (Method 2)			**$ 268,987**	**$ 3,027,496**	**$ 1,878,903**	**$ 2,535,800**	
Cost per Acre-feet			$ 333.57	$ 268.17	**$ 291.26**	**$ 285.88**	

Note:
1. Method 1 is based on a mathematical cost model(Cost Optimization Model for Low Pressure Membrane Applications, G.W. Dunkelberger and J.S. Taylor, AWWA Conference, 1991). Method 2 is based on cost estimates provided by USFilter. As can be seen, the costs obtained from the 2 methods are comparable. Method 2 was used in the Summary in Table I-1.
2. A double stage RO system is assumed, in order to reduce the amount of waste generated. However, all piping for conveyance of these wastes, and sewer connection fees/annual surcharges are based on a single stage RO system.
3. The final design would depend on the results of the pilot study.
4. Biotreatment costs provided by USFilter and assume fluidized bed reactor. If a CSTR or MBFR from ARA is used, capital and operating costs may be higher.
5. Both capital and O&M unit costs were compared with published literature and found to be comparable.

TABLE I-7: IX, EXCHANGE
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

	Alternative---------->		2	3	4	5
CAPITAL COST						
Design	Water Treatment Plant:					
	Flow	gpm	500	7000	4000	5500
	Flow	AF	806	11,289	6,451	8,870
	Waste Brine	gpm	6.25	87.5	50	68.75
		gpd	9000	126000	72000	99000
	Waste Brine Factor		1.25%	1.25%	1.25%	1.25%
	Brine Regeneration Module:					
	Empty bed contact time	min	15	15	15	15
	Catalyst bulk density	lb/gal	10.5	10.5	10.5	10.5
	Catalyst on stream	gal	93.75	1312.5	750	1031.25
		lbs	984.375	13781.25	7875	10828.125
	Brine recovery		90%	90%	90%	90%
	Brine to dispose		10%	10%	10%	10%
	Waste brine to disposal	gpm	0.625	8.75	5	6.875
		gpd	900	12600	7200	9900
	Ethanol flow	gpm	0.0132086	0.1849225	0.10567	0.14529625
		gpd	19.020384	266.2884	152.1648	209.2266
Cost Factors	*ISEP Unit:*					
	ISEP equipment, FOB job site		$ 925,000	$ 3,850,000	$ 3,200,000	$ 3,300,000
	Equipment installation (50%)	50%	$ 462,500	$ 1,925,000	$ 1,600,000	$ 1,650,000
	Brine Regeneration Module:					
	Equipment, FOB job site		$ 946,700	$ 2,400,000	$ 1,582,000	$ 2,100,000
	Equipment installation	20%	$ 189,340	$ 480,000	$ 316,400	$ 420,000
	Engineering		$ 46,900	$ 100,000	$ 63,600	$ 100,000
	Catalyst - initial fill @ $160/lb		$ 157,500	$ 2,205,000	$ 1,260,000	$ 1,732,500
Capital Cost	ISEP Unit		$ 1,387,500	$ 5,775,000	$ 4,800,000	$ 4,950,000
	Brine Regeneration Module		$ 1,340,440	$ 5,185,000	$ 3,222,000	$ 4,352,500
Capital Cost			$ 2,727,940	$ 10,960,000	$ 8,022,000	$ 9,302,500
	5% of Capital (Piping)		$ 136,397	$ 548,000	$ 401,100	$ 465,125
	10% of Capital (Foundation)		$ 272,794	$ 1,096,000	$ 802,200	$ 930,250
FINAL TOTAL CAPITAL COST			**$ 3,137,131**	**$ 12,604,000**	**$ 9,225,300**	**$ 10,697,875**

	Alternative---------->		2	3	4	5
Operation & Maintenance Costs						
	ISEP Unit:					
	Operating Cost excluding brine		$ 30,441	$ 120,000	$ 243,532	$ 243,532
	Makeup brine @ $70/ton		$ 6,756	$ 33,600	$ 54,046	$ 54,046
	Brine Regeneration Module:					
	Annual membrane operating cost (based on 3 yr)		$ 11,170	$ 11,170	$ 11,170	$ 11,170
	Electric power @ $0.07/Kwh		$ 46,834	$ 309,856	$ 374,665	$ 374,665
	Ethanol @ $1.70/gal		$ 11,317	$ 56,575	$ 90,538	$ 124,490
	Equipment maintenance @ 3% of capital		$ 35,488	$ 89,400	$ 58,860	$ 78,600
	Labor @ $75/day		$ 26,250	$ 26,250	$ 26,250	$ 26,250
	Waste brine disposal $80/1000 gal		$ 25,200	$ 352,800	$ 201,600	$ 277,200
	ISEP O&M Cost		$ 37,197	$ 153,600	$ 297,578	$ 297,578
	Brine Regeneration O&M Cost		$ 156,259	$ 846,051	$ 763,083	$ 892,375
	TOTAL O&M COSTS		**$ 193,456**	**$ 999,651**	**$ 1,060,661**	**$ 1,189,953**
	O&M/AF		$ 239.91	$ 88.55	$ 164.42	$ 134.15

Note:
1. Costs were based on quotes from Calgon Carbon Corporation (CCC) for their ISEP+ system.
2. Unit costs could not be compared with literature values, since ISEP+ is a proprietary system. Capital costs were higher than conventional units - however conventional units will result in higher waste quantities.
3. The final design will depend on the results of the pilot study.
4. CCC is in the process of refining/changing their design for the PNDM to use ammonia instead of ethanol (as of 12/99). Above costs do not reflect this change.

TABLE I-8 SEWAGE
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

	Alternative ----->	2	3	4	5
Flow	gpm	100	1400	800	1100
	gpd	144000	2016000	1152000	1584000
	mgd	0.144	2.016	1.152	1.584
	mgy	52.56	735.84	420.48	578.16
COD	mg/L	200	200	200	200
SS	mg/L	500	500	500	500
COD	Klbs/yr	87.67008	1227.38112	701.36064	964.37088
SS	Klbs/yr	219.1752	3068.4528	1753.4016	2410.9272
Surcharge/yr	$	$ 85,375	$ 1,195,251	$ 683,000	$ 939,125
Fees					
Connection fee	$	$ 397,579	$ 5,566,111	$ 3,180,635	$ 4,373,373

Note:
1. The flow was assumed based on a single stage RO system, although as shown in Table I-6, a two stage RO system may be considered to reduce the amount of waste discharge. Initial discussions with the Department of Public Works at the City of Pasadena indicate that these flows can likely be accomodated. Also, depending on the outcome of the pilot study, the amount of flow could be significantly lower, particularly if only ion exchange is used.
2. Sewage connection fees and annual surcharges based on cost equations provided by Los Angeles County Sanitation District.
3. The equation used to estimate fees (based on District guidance documents):
Connection Fee = R * [X*(Flow, gpd)/260 + Y * (COD/1.22) + Z * (SS/0.59)]
Where R = $1,100, X = 0.6, Y =0.2, Z = 0.2
COD & SS are in pounds per day.
Conservative values for SS & COD are assumed.
4. Sewage fees - The equation used to estimate fees (based on District guidance):
Surcharge = $405 * (V, mgy) + $71.60 * (COD, Kilopounds/yr) + $202.4 * (SS, Kilopounds/yr)
+ $53.8 * 2.5log (P/A) * P
where P = peak flow, gpm; A = average flow, gpm
Since a conservative flow value was assumed (see Note 1), P was assumed to be equal to A

TABLE I.-9 : GROUNDWATER MONITORING
FEASIBILITY STUDY REPORT - OU-1
JET PROPULSION LABORATORY, PASADENA

		Alternative---->	2	3	4	5
Cost per Event						
		Labor	$ 120,000	$ 120,000	$ 120,000	$ 120,000
		Laboratory	$ 40,000	$ 40,000	$ 40,000	$ 40,000
		ODCs	$ 27,500	$ 27,500	$ 27,500	$ 27,500
		Total per event	$ 187,500	$ 187,500	$ 187,500	$ 187,500
		Total per year	**$ 750,000**	**$ 750,000**	**$ 750,000**	**$ 750,000**

Present Worth Calculations				
Interest, I	0.05			
Year, n	1 to 30			
PW	FW/(1+I)^n			
Year	Monitoring	5-year Review	Cash Flow	Present Worth
1	$ 750,000		$ 750,000	$ 714,286
2	$ 750,000		$ 750,000	$ 680,272
3	$ 750,000		$ 750,000	$ 647,878
4	$ 750,000		$ 750,000	$ 617,027
5	$ 750,000	$ 25,000	$ 775,000	$ 607,233
6	$ 750,000		$ 750,000	$ 559,662
7	$ 750,000		$ 750,000	$ 533,011
8	$ 750,000		$ 750,000	$ 507,630
9	$ 750,000		$ 750,000	$ 483,457
10	$ 750,000	$ 25,000	$ 775,000	$ 475,783
11	$ 750,000		$ 750,000	$ 438,509
12	$ 750,000		$ 750,000	$ 417,628
13	$ 750,000		$ 750,000	$ 397,741
14	$ 750,000		$ 750,000	$ 378,801
15	$ 750,000	$ 25,000	$ 775,000	$ 372,788
16	$ 750,000		$ 750,000	$ 343,584
17	$ 750,000		$ 750,000	$ 327,223
18	$ 750,000		$ 750,000	$ 311,640
19	$ 750,000		$ 750,000	$ 296,800
20	$ 750,000	$ 25,000	$ 775,000	$ 292,089
21	$ 750,000		$ 750,000	$ 269,207
22	$ 750,000		$ 750,000	$ 256,387
23	$ 750,000		$ 750,000	$ 244,178
24	$ 750,000		$ 750,000	$ 232,551
25	$ 750,000	$ 25,000	$ 775,000	$ 228,860
26	$ 750,000		$ 750,000	$ 210,931
27	$ 750,000		$ 750,000	$ 200,886
28	$ 750,000		$ 750,000	$ 191,320
29	$ 750,000		$ 750,000	$ 182,210
30	$ 750,000	$ 25,000	$ 775,000	$ 179,318
Total				**$ 11,598,889**

Note:
1. Costs are based on costs incurred for the ongoing groundwater monitoring conducted for OU-1 and OU-3.
2. Number of wells is assumed to remain the same regardless of the Alternative.