Aquifer-Test Report for WW-4A, Area 6, Nevada Test Site

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INTRODUCTION

The U.S. Geological Survey (USGS) proposed to the U.S. Department of Energy (DOE) that an aquifer test be conducted using wells WW-4 and WW-4A (fig. 1). These wells produce water from the same welded tuff aquifer and are about 1,200 feet apart. The transmissivity and storage of the welded tuff aquifer were estimated to constrain hydraulic parameters used in ground-water models at the Nevada Test Site. The aquifer-test was analyzed with the Moench dual-porosity solution (Moench, 1984).

TEST DESCRIPTION

The aquifer test started when well WW-4A began pumping at 08:43 Pacific Standard Time on February 19, 2002. Water levels in wells WW-4 and WW-4A had recovered for about 114 hours prior to this test. During this test, an average of 620 gallons per minute was discharged from WW-4A for approximately 56 hours. Water levels were monitored at one-minute intervals in both wells WW-4 and WW-4A for the duration of the test.

Water level changes in both WW-4 and WW-4A were measured from 11/15/01 to 03/08/02 with pressure transducers. The manufacturer provided accuracy of these transducers was ±0.007 ft. The transducers were calibrated by the USGS under laboratory and field conditions. Water temperature and barometric pressure were also measured at each well site. Discharge from well WW-4A was measured with an in-line flowmeter that was accurate to 2 percent of total discharge.

AQUIFER TEST SITE

Water Wells WW-4 and WW-4A are located at 36°54´18´´N.; 116 ° 01´26´´W. and 36°54´12´´N.; 116 °01´38´´W., respectively, in Area 6 of the Nevada Test Site (fig. 1). WW-4 is approximately 1,184 feet northeast of WW-4A.

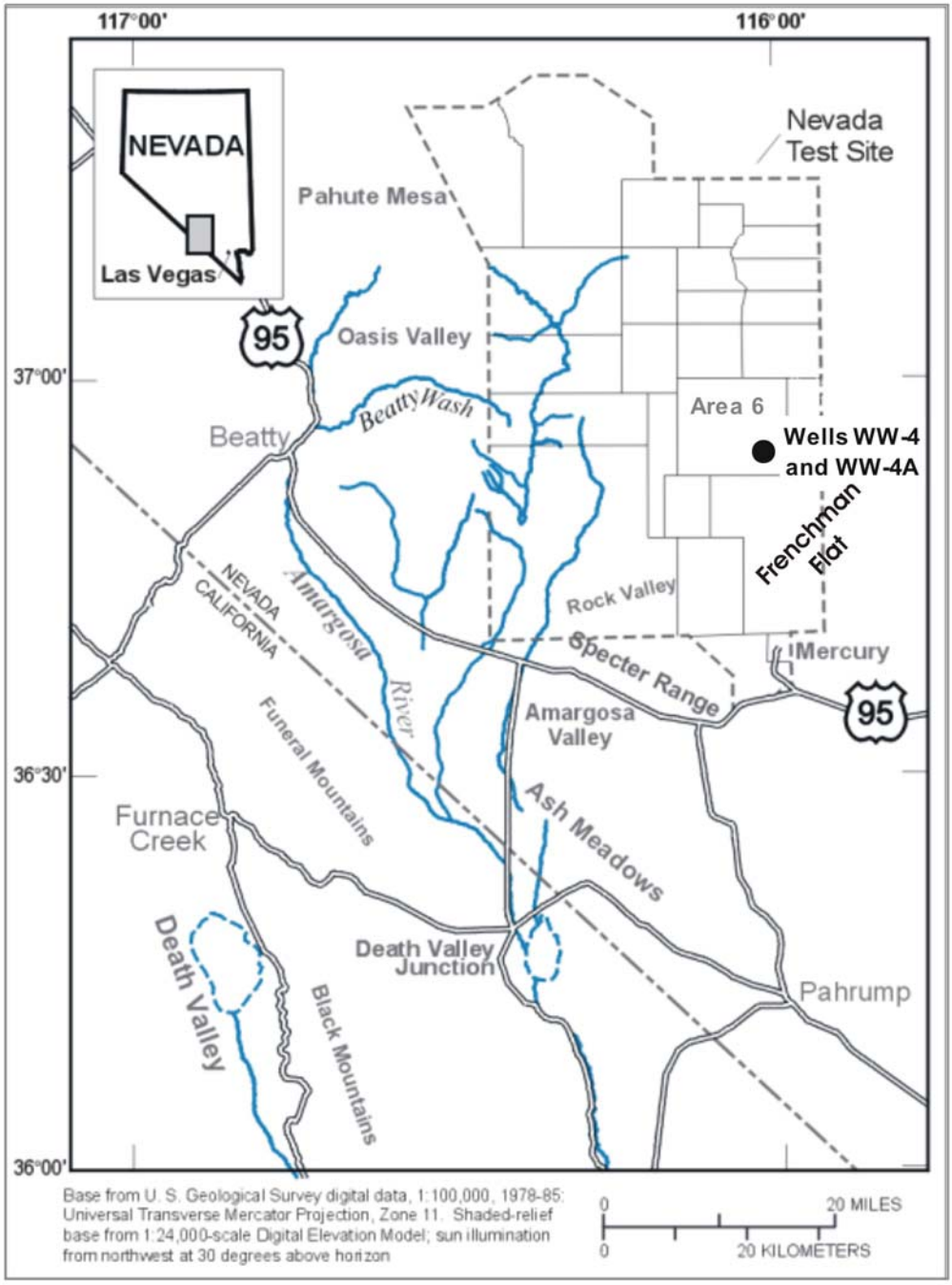

Figure 1. Location of wells WW-4 and WW-4A on the Nevada Test Site.

CONSTRUCTION

Wells WW-4 and WW-4A were drilled in the Frenchman Flat area as water-supply wells. Wells WW-4 and WW-4A were completed, respectively, on November 23, 1981 and February 22, 1990. Figure 2 provides detailed information about well construction.

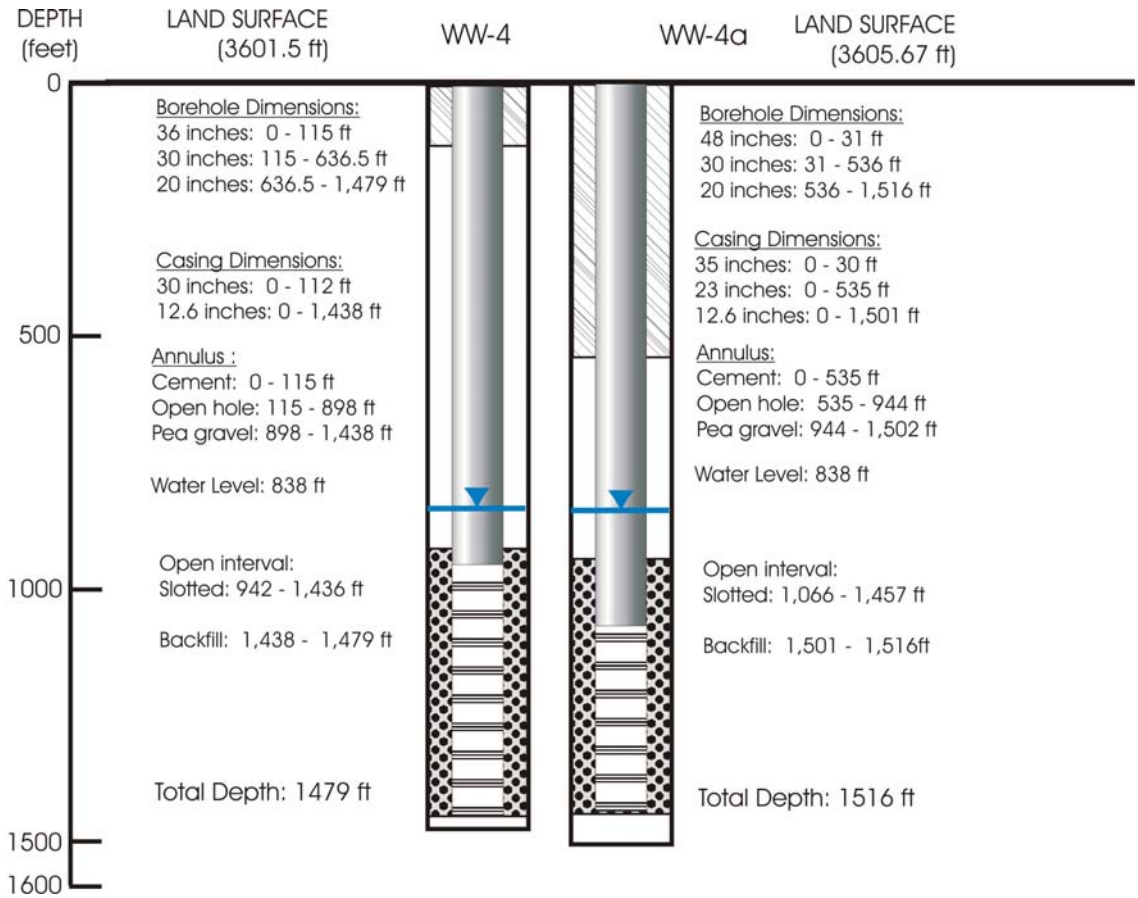

Figure 2. Construction of wells WW-4 and WW-4A at time of February 19-21, 2002 aquifer test.

HYDROGEOLOGIC CHARACTERISTICS

Wells WW-4 and WW-4A were completed in Tertiary volcanic rocks (fig. 3). In northern Frenchman Flat, these rocks, where saturated, form both aquifers and confining units. The Ammonia Tanks Member of the Timber Mountain Tuff and the less welded upper section of the Rainier Mesa Member of the Timber Mountain Tuff form a tuff-confining unit. Below this confining unit is a welded-tuff aquifer. This welded-tuff aquifer is characterized by high fracture permeability and generally consists of moderately welded to densely welded ash-flow tuffs of the Rainier Mesa Member of the Timber Mountain Tuff and Topopah Springs Member of the Paintbrush Tuff. The uppermost densely welded ash-flow tuff in the Rainier Mesa Member was chosen as the top of this welded tuff aquifer. Bedded and less-welded volcanic rocks below the welded-tuff aquifer were chosen to represent a lower tuff-confining unit (Laczniak and others, 1996, p.25-26).

Thickness of the welded-tuff aquifer is variable but was assumed to be a uniform 350 ft thick for the purposes of estimating hydraulic conductivity. Aquifer thickness is about 400 and 290 ft, respectively, in wells WW-4 and WW-4A. These differences have been attributed to faulting (P.H. Thompson, written communication, 1990).

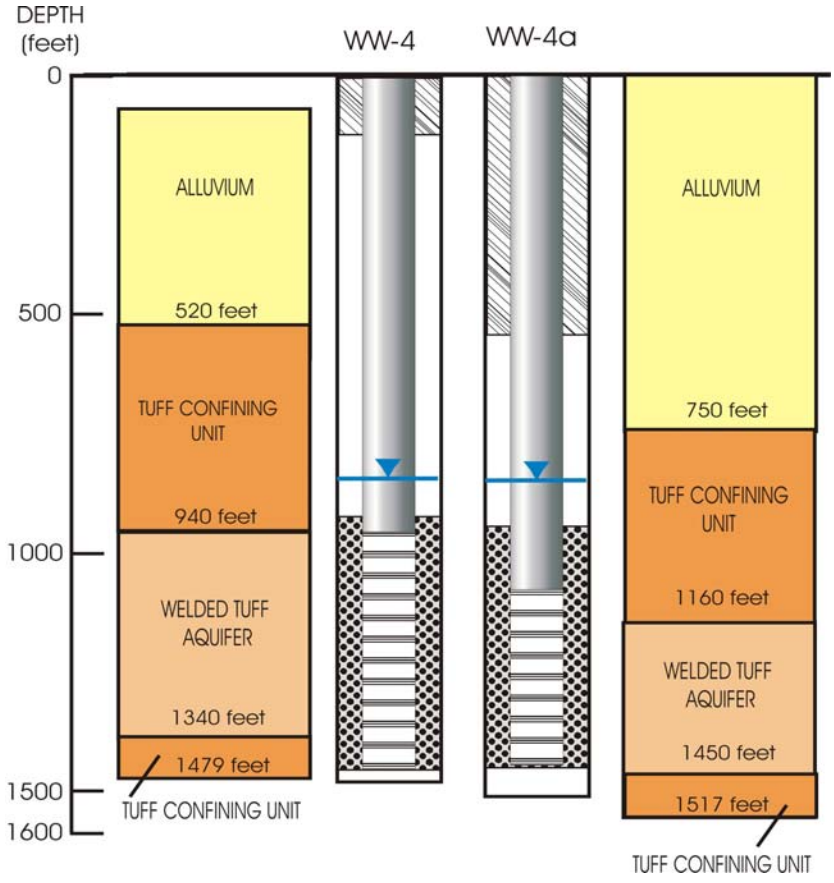

Figure 3. Well construction and hydrogeologic units at WW-4 and WW-4A.

DRAWDOWN ESTIMATION

Drawdowns in wells WW-4 and WW-4A owing strictly to the pumping stress could not be computed by subtracting the water level at the start of pumping from measured water levels. Stresses other than pumping, such as barometric changes and earth tides, were known to have affected water levels. A general linear trend also existed prior to and during the pumping test that probably was due to continued recovery from prior pumping of wells WW-4 and WW-4A.

Drawdowns in both wells were estimated by subtracting a surrogate for the unpumped water level from the measured water level (fig. 4A). Surrogate water levels were computed for each well by summing linear, barometric, and earth tide trends (fig. 4B). Surrogate water levels were fitted to measured water levels during the 2 days prior to pumping well WW-4A. Vertical offset, temporal slope, barometric amplitude, earth-tide amplitude, and earth-tide phase shift were adjusted to minimize the difference between surrogate and measured water levels. Shifting the phase of the barometric signal was tested and found to be insignificant. The earth-tide amplitudes and phases were computed from a finite-serious Fourier regression of sines and cosines using the precise frequencies of the 6 principal earth tides (Galloway and Rojstacter, 1989).

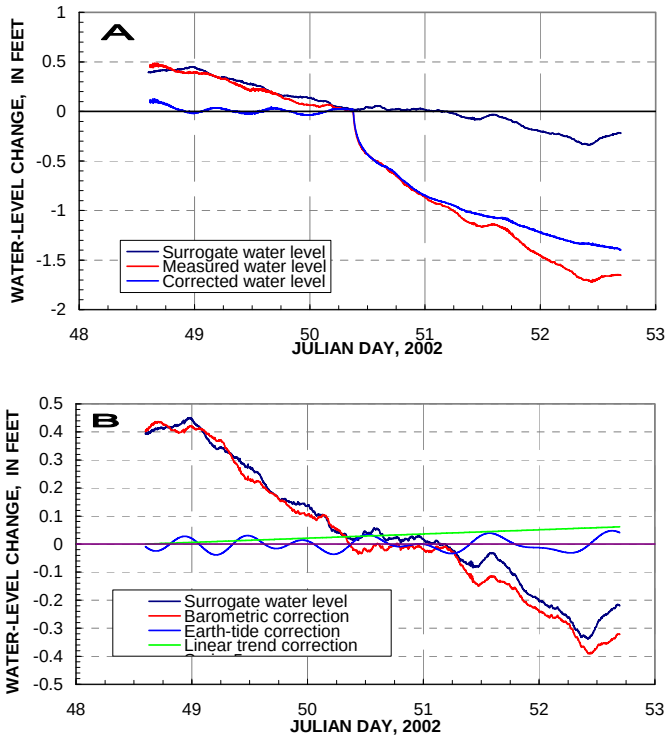

Figure 4. Estimated drawdown in well WW-4, February 17-21, 2002 (julian days 48-53). (A) Computing corrected water level from surrogate and measured water levels. (B) Computing surrogate water levels from linear, barometric, and earth tide trends.

AQUIFER TEST ANALYSIS

The Moench solution for fractured, confined aquifers was used to analyze aquifer test data in wells WW-4 and WW-4A. The Moench solution assumes that aquifers are laterally infinite, homogeneous and isotropic, and bounded by impermeable confining units. Production and observation wells are assumed to be fully penetrating so that all flow is horizontal. Analysis of the aquifer test results was performed with AQTESOLV software, version 3.01 (Duffield, 2000).

Hydraulic properties were estimated by minimizing the sum-of-squares differences between simulated and measured drawdowns. Drawdowns from the first 10 minutes of pumping in WW-4A were not used in the analysis because wellbore storage affected these measurements. Recovery data was not used because the uncertainty of the drawdown estimates was greater during this phase of the test than during the pumping phase of the test.

Simulated drawdowns matched measured drawdowns within about 0.1 ft in both wells WW-4 and WW-4A (fig. 5). The fit between simulated and measured drawdowns was generally better for later times of drawdown (greater than 600 minutes).

Transmissivity could be reliably estimated from water level responses in wells WW-4 and WW-4A using the Moench solution. The best estimate of transmissivity and storage are considered to be 27,000 ft^2/d and 0.0003, respectively. A transmissivity of 27,000 ft^2/d could be estimated equally well with the Cooper-Jacob method (fig. 5). Lateral hydraulic conductivity of the welded-tuff aquifer was about 80 ft/d if the aquifer was assumed to be about 350 ft thick.

The aquifer matrix was assumed to be parallel slabs that could range from 25 to 200 ft thick. Final estimates of specific storage of matrix (Ss'), wellbore skin (Sw), and fracture skin (Sf) were 9E-7 ft^{-1}, 7.3, and 1.2, respectively, and were independent of assumed slab thickness. Estimates of matrix hydraulic conductivity (K') were dependent on assumed slab thickness. Doubling the assumed slab thickness caused estimates of K' to increase fourfold. Matrix hydraulic conductivity estimates ranged from 0.009 to 0.6 ft/d for slab thickness that ranged from 25 to 200 ft, respectively.

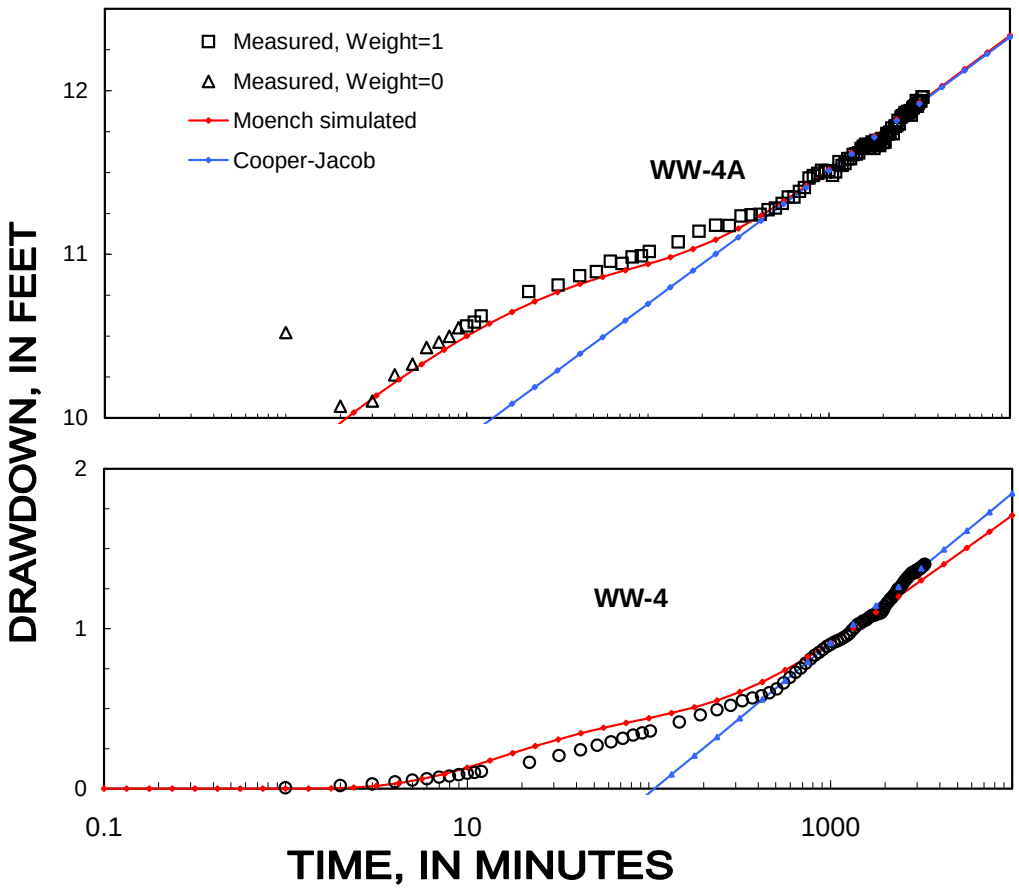

Figure 5. Measured and simulated drawdowns for wells WW-4 and WW4A.

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APPENDIX A –DRAWDOWN RECORDS for wells WW-4A and WW-4

	DRAWDOWN, IN FEET			
	WW-4A		WW-4	
DATE TIME	SIMPLE	CORRECTED	SIMPLE	CORRECTED
2/19/2002 8:43	0.00	0.00	0.00	0.00
2/19/2002 8:44	10.52	10.52	0.00	0.00
2/19/2002 8:45	10.07	10.07	0.02	0.02
2/19/2002 8:46	10.10	10.10	0.03	0.03
2/19/2002 8:47	10.26	10.26	0.04	0.04
2/19/2002 8:48	10.33	10.33	0.05	0.05
2/19/2002 8:49	10.43	10.43	0.06	0.06
2/19/2002 8:50	10.47	10.46	0.07	0.07
2/19/2002 8:51	10.51	10.50	0.08	0.08
2/19/2002 8:52	10.56	10.55	0.09	0.09
2/19/2002 8:53	10.57	10.56	0.10	0.10
2/19/2002 8:55	10.63	10.62	0.11	0.11
2/19/2002 9:05	10.79	10.77	0.17	0.16
2/19/2002 9:15	10.83	10.81	0.21	0.21
2/19/2002 9:25	10.89	10.87	0.25	0.24
2/19/2002 9:35	10.91	10.89	0.27	0.27
2/19/2002 9:45	10.97	10.96	0.30	0.29
2/19/2002 9:55	10.96	10.94	0.32	0.31
2/19/2002 10:05	11.00	10.98	0.34	0.34
2/19/2002 10:15	11.00	10.99	0.35	0.35
2/19/2002 10:25	11.03	11.02	0.37	0.36
2/19/2002 11:10	11.09	11.08	0.42	0.42
2/19/2002 11:55	11.13	11.14	0.44	0.46
2/19/2002 12:40	11.18	11.18	0.48	0.49
2/19/2002 13:25	11.17	11.18	0.50	0.52
2/19/2002 14:10	11.22	11.23	0.52	0.55
2/19/2002 14:55	11.23	11.24	0.54	0.57
2/19/2002 15:40	11.25	11.24	0.58	0.58
2/19/2002 16:25	11.30	11.27	0.61	0.60
2/19/2002 17:10	11.31	11.28	0.63	0.62
2/19/2002 17:55	11.33	11.31	0.66	0.66
2/19/2002 18:40	11.37	11.35	0.69	0.69
2/19/2002 19:25	11.39	11.35	0.74	0.73
2/19/2002 20:10	11.41	11.38	0.76	0.75
2/19/2002 20:55	11.44	11.41	0.79	0.78
2/19/2002 21:40	11.49	11.47	0.80	0.81
2/19/2002 23:10	11.52	11.49	0.85	0.85
2/19/2002 23:55	11.55	11.51	0.87	0.87
2/20/2002 0:40	11.55	11.50	0.90	0.89
2/20/2002 1:25	11.56	11.51	0.92	0.90
2/20/2002 2:10	11.53	11.48	0.93	0.91
2/20/2002 2:55	11.54	11.50	0.93	0.92
2/20/2002 4:25	11.59	11.54	0.97	0.94
2/20/2002 5:10	11.61	11.55	0.99	0.96

2/20/2002 5:55	11.65	11.59	1.01	0.97
2/20/2002 6:40	11.67	11.59	1.05	0.99
2/20/2002 7:25	11.71	11.61	1.08	1.01
2/20/2002 8:20	11.73	11.61	1.11	1.03
2/20/2002 9:05	11.74	11.62	1.13	1.03
2/20/2002 9:50	11.78	11.65	1.14	1.05
2/20/2002 10:35	11.80	11.66	1.15	1.05
2/20/2002 11:20	11.82	11.67	1.16	1.06
2/20/2002 12:05	11.80	11.67	1.16	1.07
2/20/2002 12:50	11.78	11.66	1.15	1.08
2/20/2002 13:35	11.78	11.69	1.14	1.08
2/20/2002 14:20	11.74	11.65	1.14	1.09
2/20/2002 15:05	11.80	11.70	1.16	1.09
2/20/2002 15:50	11.79	11.68	1.18	1.10
2/20/2002 16:35	11.79	11.66	1.19	1.10
2/20/2002 17:20	11.85	11.71	1.22	1.12
2/20/2002 18:05	11.85	11.68	1.26	1.14
2/20/2002 18:50	11.87	11.69	1.29	1.16
2/20/2002 19:35	11.94	11.74	1.32	1.17
2/20/2002 20:20	11.96	11.74	1.35	1.18
2/20/2002 21:05	12.00	11.75	1.38	1.19
2/20/2002 21:50	12.04	11.77	1.41	1.21
2/20/2002 22:35	12.01	11.74	1.43	1.22
2/20/2002 23:20	12.06	11.78	1.45	1.23
2/21/2002 0:05	12.08	11.79	1.47	1.25
2/21/2002 0:50	12.12	11.82	1.48	1.25
2/21/2002 1:35	12.11	11.80	1.51	1.27
2/21/2002 2:20	12.15	11.84	1.52	1.28
2/21/2002 3:05	12.17	11.85	1.54	1.29
2/21/2002 3:50	12.17	11.85	1.55	1.30
2/21/2002 4:35	12.20	11.87	1.58	1.31
2/21/2002 5:20	12.21	11.86	1.60	1.32
2/21/2002 6:05	12.23	11.87	1.61	1.33
2/21/2002 6:50	12.24	11.86	1.64	1.34
2/21/2002 7:35	12.28	11.88	1.68	1.35
2/21/2002 8:20	12.27	11.85	1.69	1.35
2/21/2002 9:05	12.32	11.89	1.70	1.35
2/21/2002 9:50	12.34	11.90	1.71	1.35
2/21/2002 10:35	12.34	11.91	1.72	1.37
2/21/2002 11:20	12.35	11.94	1.70	1.37
2/21/2002 12:05	12.28	11.90	1.68	1.38
2/21/2002 12:50	12.28	11.92	1.66	1.38
2/21/2002 13:35	12.28	11.93	1.66	1.38
2/21/2002 14:20	12.28	11.94	1.66	1.39
2/21/2002 15:50	12.28	11.96	1.65	1.40