GBT ARCHIVE L0560
FILE: LASER RANGING
KEYS: CALIBRATION, EXPERIMENTAL DATA, HYDROSTATIC LEVEL, LASER RANGING, MEASUREMENT PROGRAM, POINTING, PRECISION POINTING, SURVEYS

November 30, 1999

To: Distribution
From: David H. Parker
Subject: First NPH6 hydrostatic level field measurements and future plans

Attached are results of the first monument-to-monument hydrostatic level measurements made with the NRAO enhanced version of the Pellissier H5 Hydrostatic Level, the NPH6. The measurements were made by Brian Ellison, David Parker and John Shelton, with the cooperation of COMSAT, on the evenings of November 8, 9, and 10, under moderately cooling temperatures, and calm wind conditions.

Recall that the Pellissier H5 (see GBT Memo 116 and file L0523) was used in the fall of 1992 to establish 16 bench marks on the foundation, which closed to better than 0.050 mm. These bench marks were used to reference short shots with the N3 optical level to set the track wear plates to an accuracy of better than 0.175 mm, as noted in memo A0092 by Dave Seaman.

Modifications to the Pellissier H5 instrument were initiated in May 1993 (L0197) in order to extend the 50 foot hose to facilitate future measurements of the GBT track and foundation from a central radial location near the pintle room. Due to the untimely death of Pierre Pellissier, this project was picked up by the GBT Antenna Metrology Group as a low priority skunkworks project in July 1997. After Bill Radcliff built the motor control and detection system; interface, software, and experimental work was carried on by summer students and co-op students (Petticrew, Matheny, Sumner and Ray). The final integration, testing and "making it work" fell on John Shelton, Brian Ellison, Mike Hedrick, and David Parker. The evolutionary development is documented in memos L0340, L0472, L0486, and L0507.

Each set of measurements between pairs of laser monuments (62 meters apart) were made in a single set-up with an automated instrument on each monument connected by two 100-foot coaxial hoses, a vent line, and serial interface. The hoses were supported on 20-foot sections of Unistrut which were supported on stands, and leveled with a masonry line, in order to minimize the U tube error (0.070 mm/m°C). The hoses were then covered with a reflective sheet to minimize radiation heating, and flushed to remove bubbles. The wells were also purged to remove bubbles.

Starting in the late afternoon, measurement cycles were repeated 4 to 5 times in order to measure the impact of moderate sun-vs-evening conditions and to check the repeatability. All control was through a CMT handheld computer interfaced to each instrument and pump control system via a RS485 serial line.

On operator command, an automatic measurement cycle was initiated by closing the solenoid valves connecting the sense line to the wells, opening the solenoid valves connecting the sense line to the pump and return line, and starting the pump. Water was circulated through the inner sense line and returned to the reservoir through the outer return line until the reservoir supply and return temperatures reached equillibrium, which typically occurred with the return temperature about 0.3 °C cooler than the supply temperature. With 200 feet of hose, the pump delivers about 4 GPM and the hose contains about 18 gallons of water, so the exchange rate was about every 4.5 minutes. While circulating water, the lines were purged to insure that no bubbles were trapped between the solenoid valve and well by momentarily opening the solenoid valve at each instrument (under operator command) and flushing the lines.

While circulating water, the maximum pressure can reach around 50 PSIG–which slightly expands the wire reinforced hose. After the pump was shut down, the solenoid valves automatically remained open for about 30 seconds in order to vent the water displaced by the sense line returning to its unexpanded diameter.

On operator command; the measurement cycle closed the solenoid valves connecting the sense line to the return line, opened the solenoid valves connecting the sense line to the instrument wells, and cycled the motor-driven contact probes about 2.5 times per minute. The water level in the wells were checked to insure that the initial height plus the exponential decay rate contraction of the hose, and thus rise of the water level in the well (typically less than 5 mm), would not exceed the travel of the digital indicator (12.5 mm). If required, adjustments were made in the water level and the measurement cycle was restarted–otherwise the measurements continued.

Calibration measurements of the NPH6 were conducted before and after the field measurements. The instrument constant was measured in the calibration lab using a short connecting hose. The instruments were placed about 250 mm apart on matched v-blocks resting on a surface plate which was leveled before each calibration to about 2 seconds, i.e., the maximum error due to the surface plate = 0.0025 mm. The indicators were checked 10/6 and 10/26 by noting the indicated readings when they were against their stops. The A indicator changed by 0.002 mm, but the B indicator did not change. Repeatability was also checked in the lab with the 200-foot hose coiled on a table next to the surface plate, and the two instruments resting next to each other on the level surface plate.

The attached data shows the average instrument constant to be 0.784 mm, with a standard deviation of 0.006 mm, i.e., A-B=0.784 mm for two level points. There was a shift of 0.011 mm between the measurements before and after taking the instrument to the field. This is significantly higher than the 0.001 mm standard deviation between consecutive measurements or the 0.002 mm shift in the A indicator. This is suspect and we are looking for the cause of this shift.

The attached plots show (for each experiment): differential (A-B) measurements, the 10 minutes of data (≈25 points) used for the statistics highlighted in red, the well temperatures, the individual A and B measurements, A+B, and expanded scale A and B measurements for the 10 minutes of data used. Plots are also included for the lab calibrations. Tables are included for the data analysis with the average and standard deviation of each measurement and elevations of ZY103, ZY104, ZY105 and ZY106. Elevations are included for Wild N3 levels measured 6/4/97 (ZY103-ZY104) and 5/5/99 (ZY104-ZY105, ZY105-ZY106). Note that the two methods differ in a non-systematic way by as much as 0.7 mm.

Note that the A-B measurements typically show a settling time of about 15 minutes after circulating the water. This is due to the hose relaxation, as confirmed by the A+B plots, i.e., A+B tracks the water rising in the wells. Note that the indicator reading increases for a longer distance to the water, i.e., a smaller number indicates a rising water level. Note that there are several outlier points on the short side. These are usually due to a drop of water clinging to the platinum tip and premature contact with the water. Outlier points on the long side usually indicate contamination floating on the water. No data points were rejected from the plots.

Note that data taken before sundown are more erratic and disagree with the evening measurements by about 50 microns. The afternoon data were rejected in the data analysis, but all evening data was used. The tradeoff between waiting for the hose relaxation to decay and transients introduced by thermal changes is clear in the A+B plots. Note that for evening measurements the A+B curves decay into a flat region much longer than the afternoon measurements.

If everything were symmetric and the probes made contact simultaneously, the hose relaxation would not affect the differential measurements. In these measurements, the pump was connected to the A end sense line, which resulted in a pressure gradient in the sense line in the B direction, and the return was also at the A end, which resulted in a pressure gradient in the return line in the A direction, i.e., the A end expanded more than the B end and introduced an asymmetry in the hydraulic system.

The motor driven probes are systematically synchronized by the CMT software to better than 500 ms. For a uniform rise in the wells of 0.5 mm/min, this would result in a systematic error less than 0.004 mm. We are going to look at the systematic time delay and minimize it. Another idea is to increase the well size from 2.625 inch diameter and thus reduce the sensitivity of the level change by the square of the diameter. Of course, the hose decay could be further optimized by using a stronger reinforced hydraulic line or a larger diameter (lower pressure drop) hose.

At this time we don't see much advantage in persuing this for the GBT applications, since the 15-minute delay is not significant compared to the time required to set up and level the hose between stations (typically about 8 man hours for easy paths and potentially much more for stations on the north side of the telescope, which are as much as 10 feet above the ground).

Michael Goldman calculated the natural frequency of the oscillation between the wells, in memo L0315, to have a period of around 59 seconds. With the measurement period of around 24 seconds, oscillations should be resolved. Note on the expanded A and B plots that some do show slight 180 degree phase shifts, but it looks like the oscillations have damped well before the 15 minute settling time.

Note that the standard deviation for ZY106–ZY105 = 0.0046 mm, ZY105–ZY104 = 0.0038 mm, and ZY104–ZY103 = 0.0075 mm. The instrument constant standard deviation = 0.0056 mm. For the worst case (ZY104–ZY103), this yields an RSS error of around 0.0093 mm. To put this in perspective, a 0.0093 mm error at 62 meters would be around 0.03 seconds.

An interesting aside is, due to the curvature of the earth, a correction of

$$y = \frac{d^2}{2R} \tag{1}$$

where y is the height difference between a tangent and the geoid, d is the distance between the points, and $R = 6\ 372\ 161$ meters (the radius of the earth). Since the laser system works in a Cartesian coordinate system, monuments at 120 meters from the center of the GBT will require an elevation correction of 1.129 mm.

We do not plan on making any additional monument-to-monument measurements until next spring, when all 12 monuments will be calibrated—starting with these 4. We are very confident of the NPH6 measurements, so we will be looking for changes in elevations of these 4 over the winter. From length measurements on test cylinders, which Bill Radcliff has been making since 11/96, the concrete has cured and length changes are dominated by environmental conditions. Great care was taken to insure symmetry in the monument design in order to minimize relative motion between monuments. This experiment will measure the performance of the design.

If these monuments remain relatively stable, we are confident that calibration of the monument elevations with respect to the local gravity vector, combined with the published NGS DEFLECT program data on the deflection of the local gravity vector and calibration of cardinal points on the GBT, will allow the GBT to be pointed via dead reckoning, as outlined in GBT Memo 195, to better than 1 second—a first for radio astronomy.

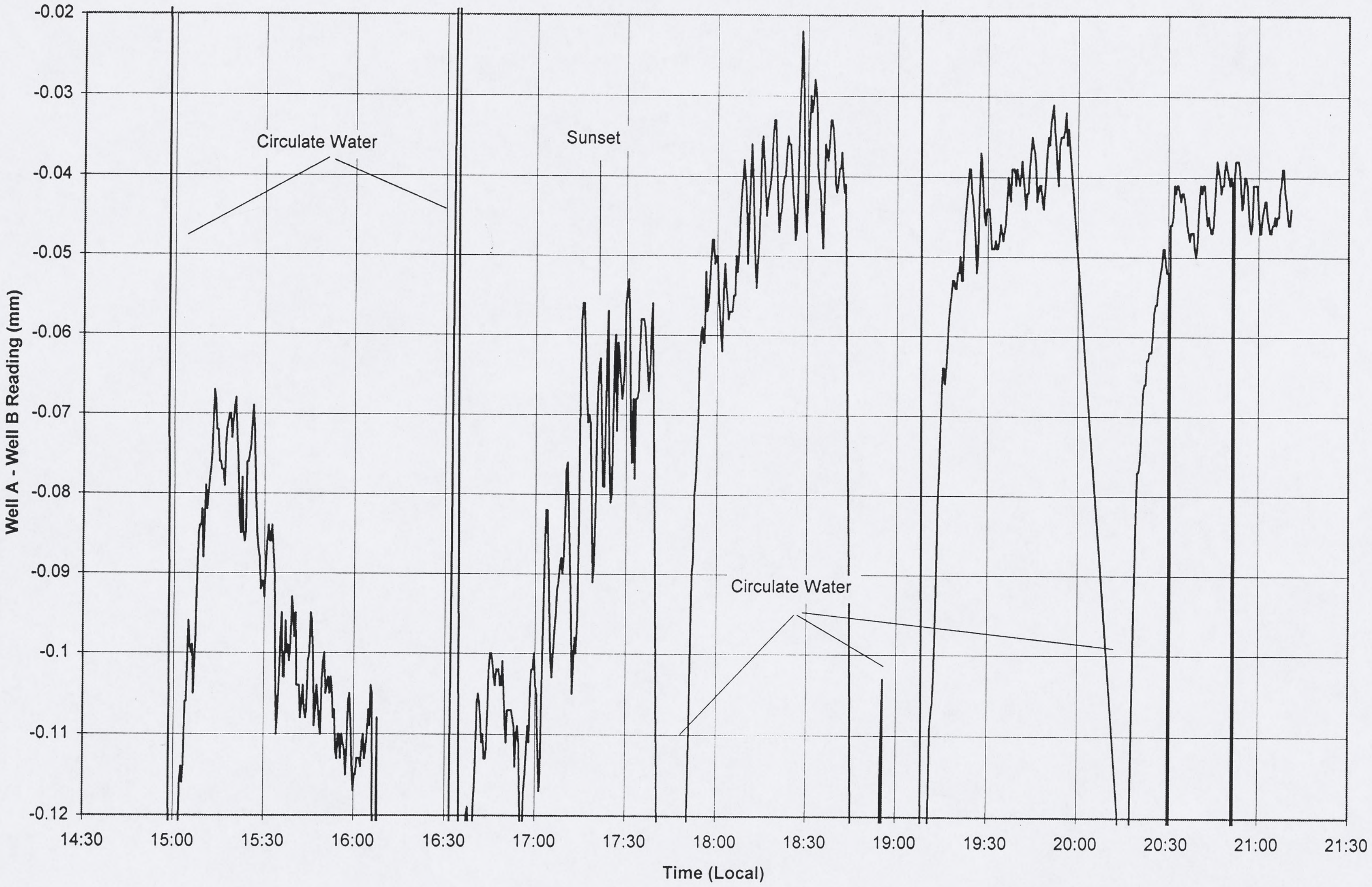
The effort for the remainder of the fall will concentrate on setting 8 equally-spaced bench marks on the GBT track foundation, and setting 2 next to the pintle room for the performance measurement program outlined in GBT memo 191. The objective is to get a baseline to determine how the foundation is moving under load and time. For example, 4 of the track points are on the grade beams, and the other 4 are midway between the grade beams. Next spring we want to measure the foundation at each point under 4.25 million pound loads vs no-load conditions. Symmetric deflections would indicate a healthy foundation and bearing on the rock. Deflections could also be checked against the design predictions. Symmetric settling over the years would also indicate a healthy bearing on the rock. Detailed measurements should be conducted on each side of the vertical cracks in the wall (if we know the locations).

Working from the 8 bench marks, the elevation of the track with respect to the foundation can be measured. These measurements could insure rust is not forming between the track and grout, as well as assure the condition of the grout and measure track wear. As documented in Seaman's memo A0092, the track was set to an accuracy of better than 0.175 mm in 1992/1993. It will be interesting to see what 7 years and 17 000 000 pounds have done to that accuracy.

cc: Dana Balser
Martin Barkley
Joe Brandt
Jim Condon
Ray Creager
Brian Ellison
Rick Fisher
Michael Goldman
Bob Hall
Dave Hogg
Mike Hedrick
Gareth Hunt
Phil Jewell
Lee King
Jay Lockman
Ron Maddalena
Pat Matheny
Mark McKinnon
Roger Norrod
John Payne
Bill Radcliff
Jason Ray
Fred Schwab
Amy Shelton
John Shelton
S. Srikanth
Mike Sumner
Paul Vanden Bout
Don Wells
gbtarchive
M1118_1

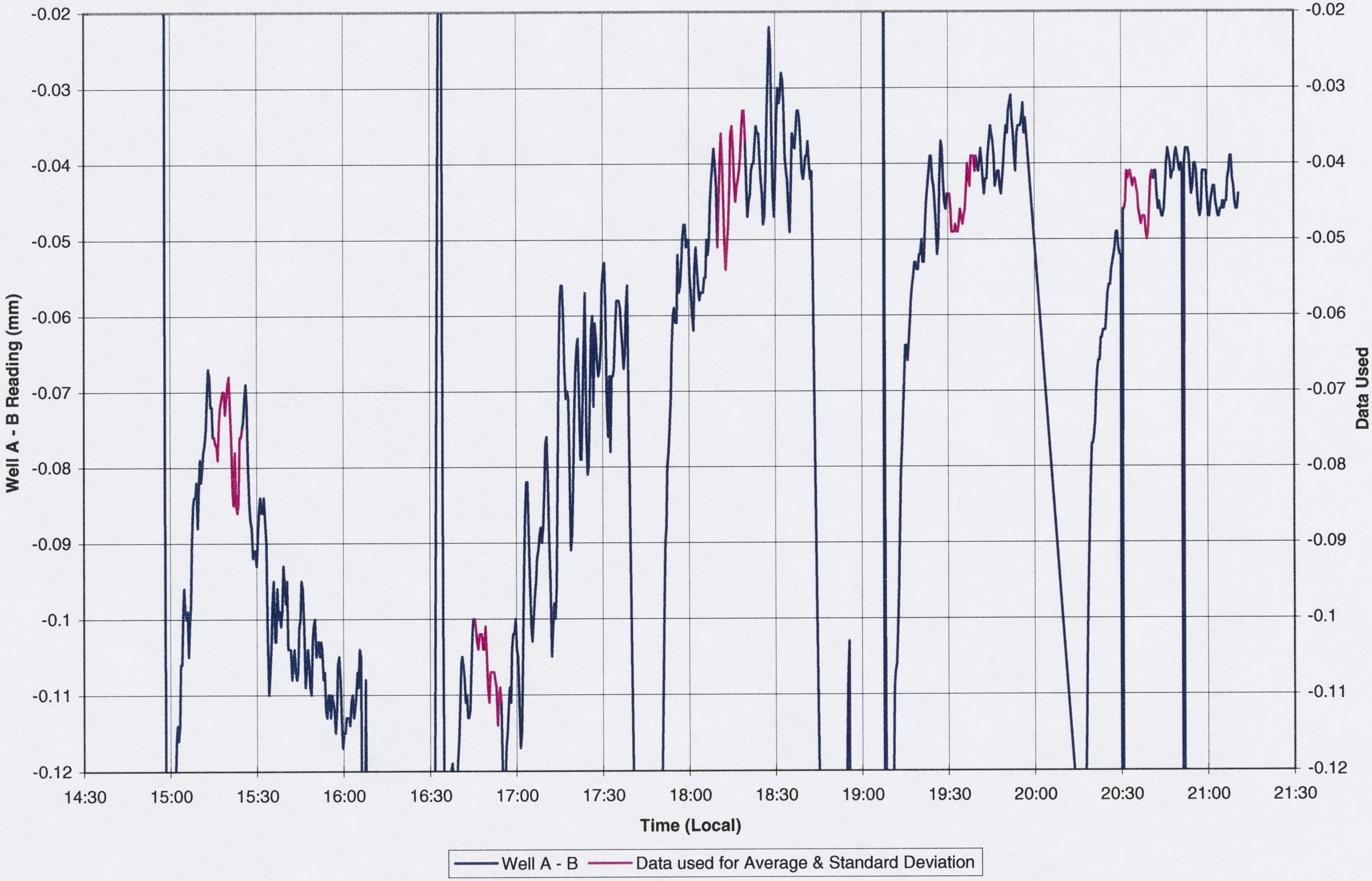
Hydrostatic Level Data 11-08-1999 Well A on ZY105 - Well B on ZY106

File: 1108.xls Disk: B298



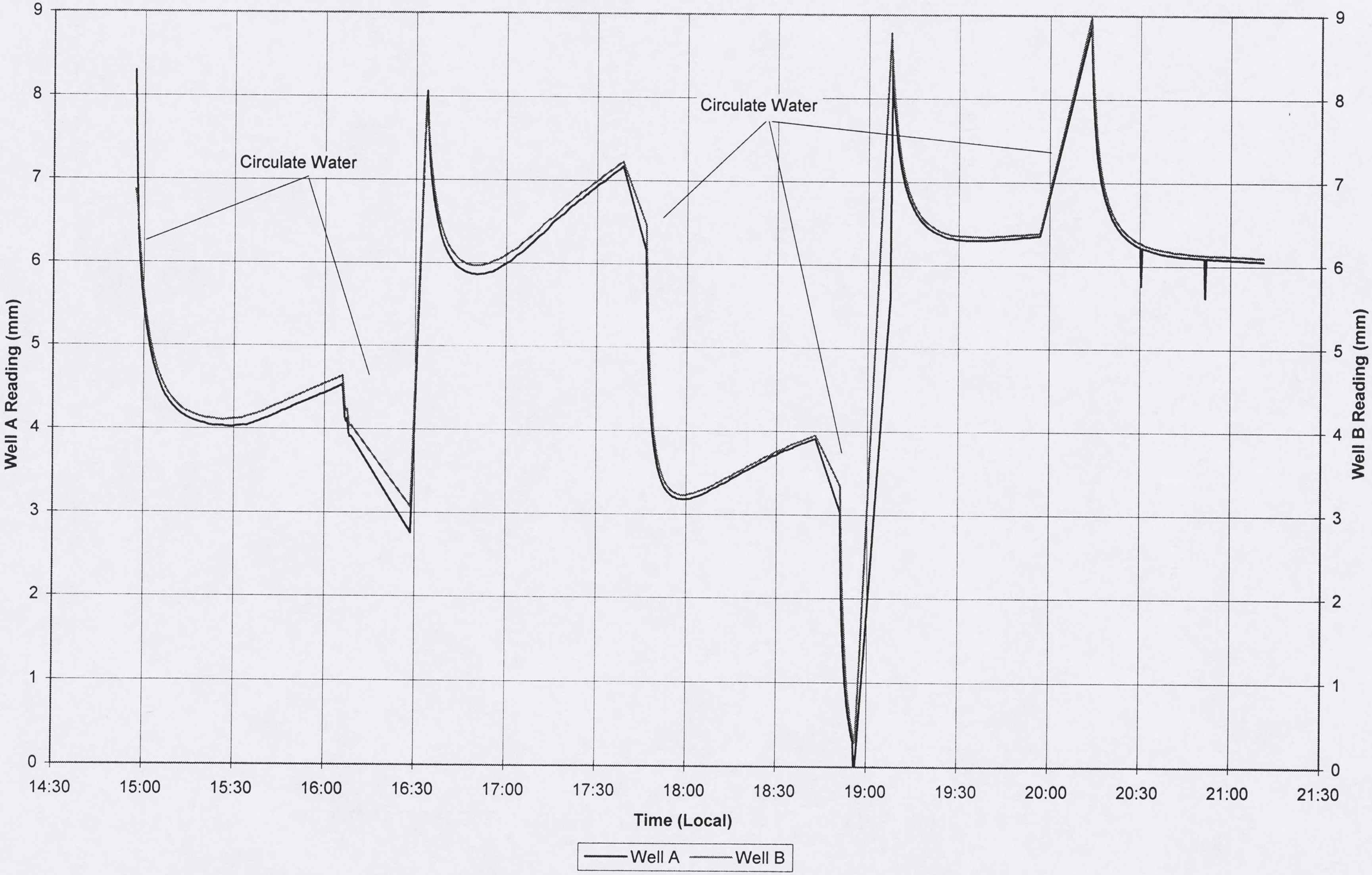
Hydrostatic Level Data 11-08-1999 Well A on ZY105 - Well B on ZY106

File: 1108.xls Disk: B298



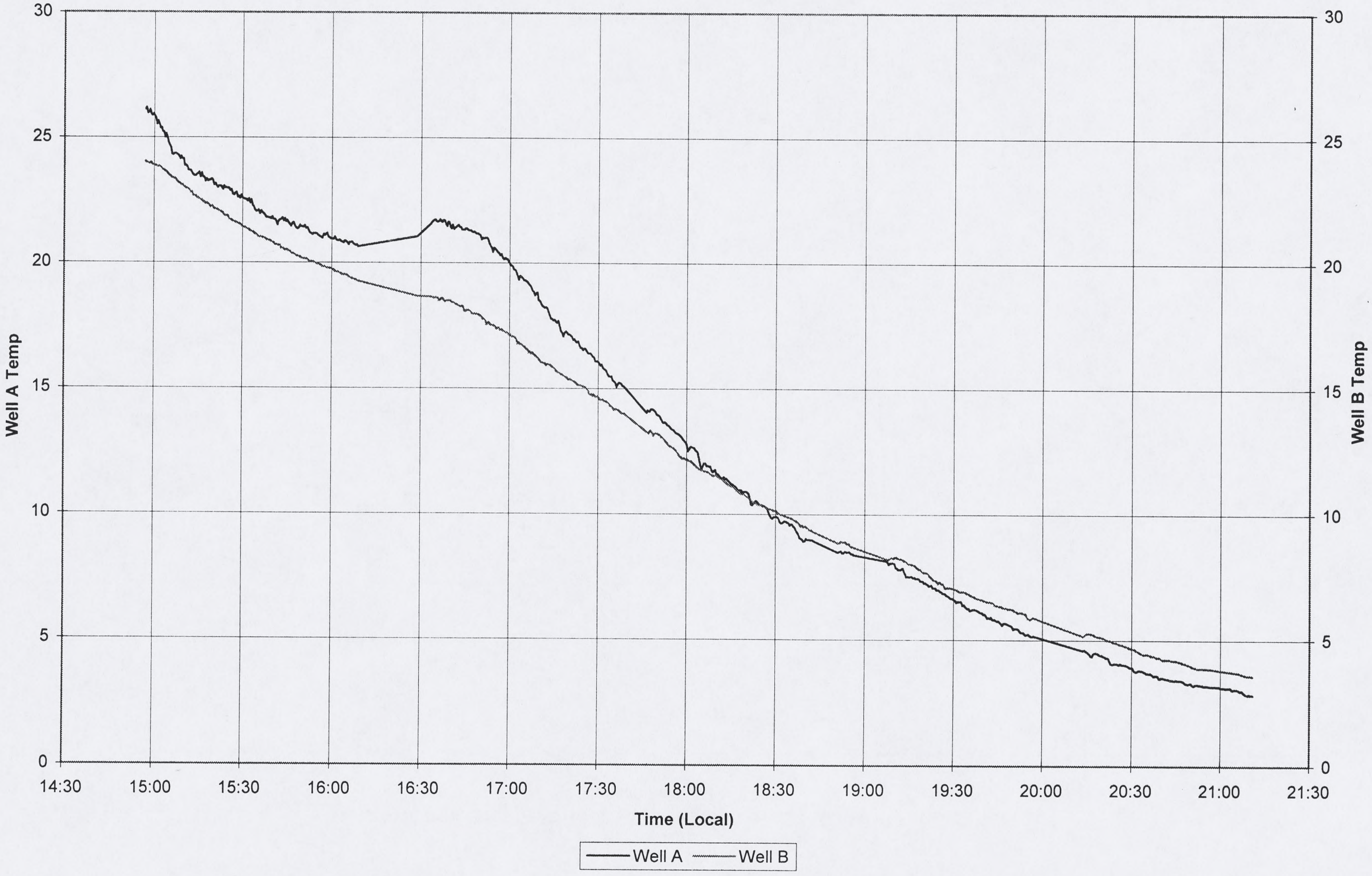
Hydrostaic Level Data 11-08-1999 Well A on ZY105 Well B on ZY106

File: 1108.xls Disk: B298



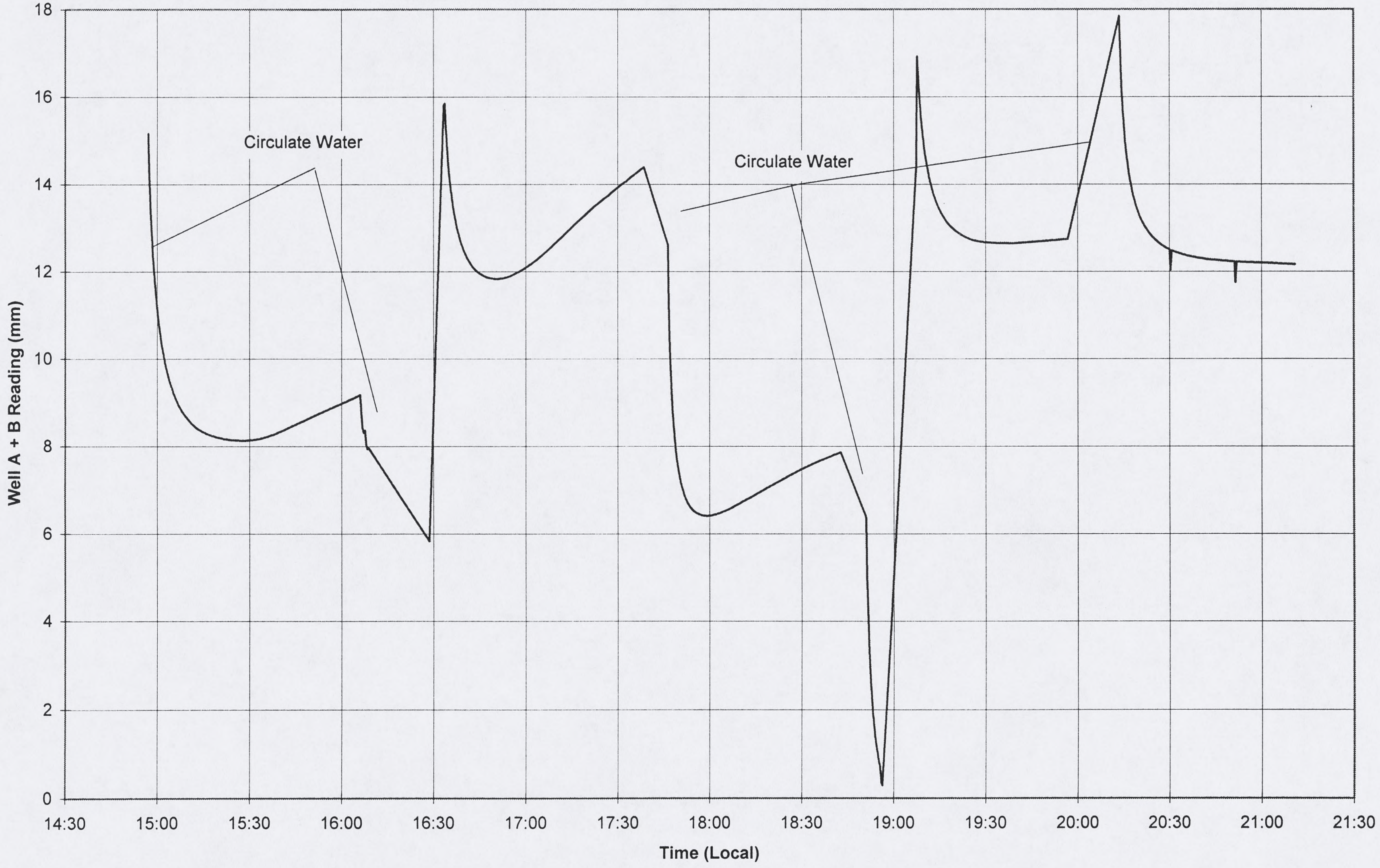
Hydrostatic Level Data 11-08-1999 Well A on ZY105 & Well B on ZY106 Temperatures

File: 1108.xls Disk: B298



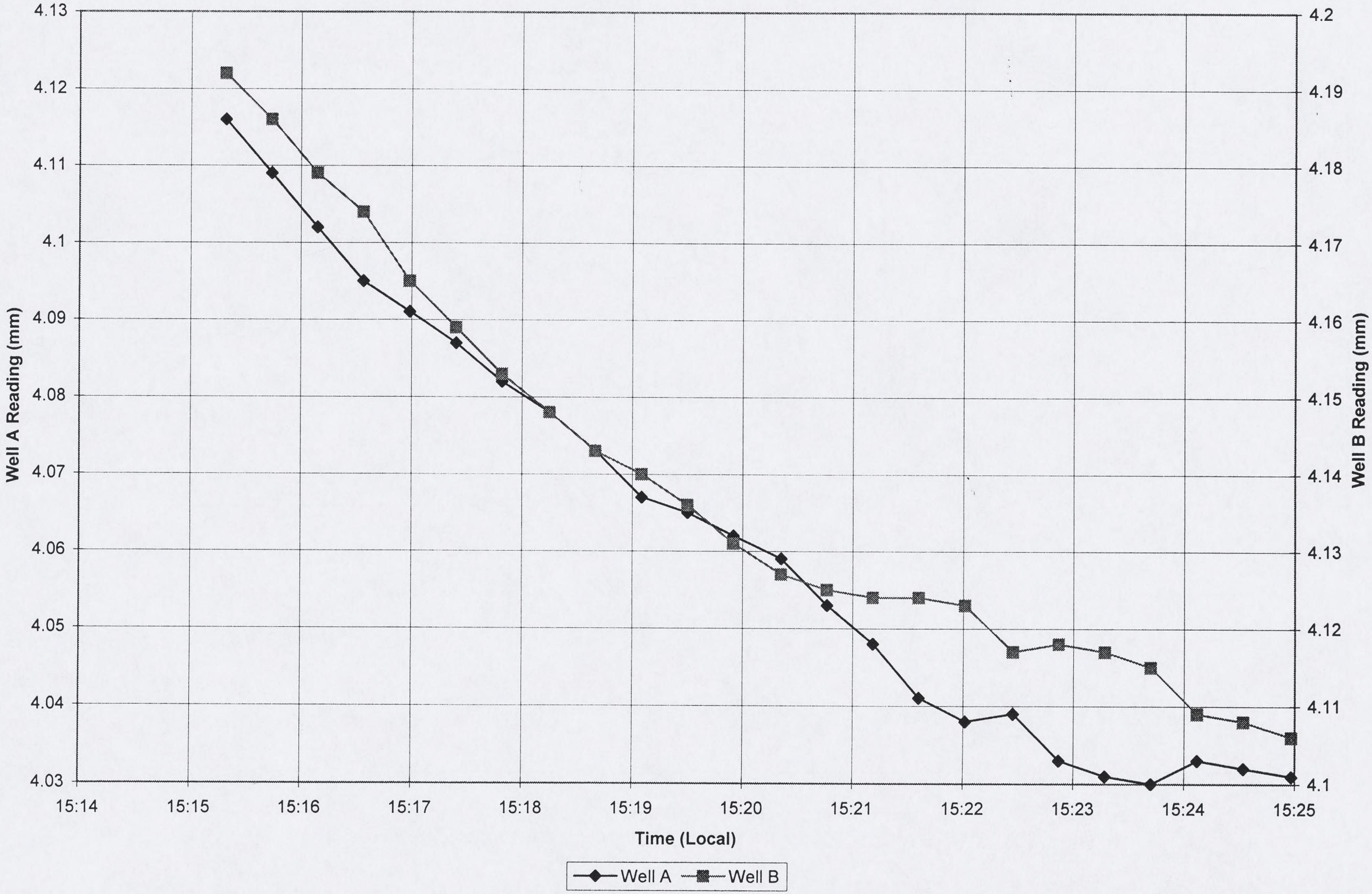
Hydrostatic Level Data 11-08-1999 Well A on ZY105 + Well B on ZY106

File: 1108.xls Disk: B298



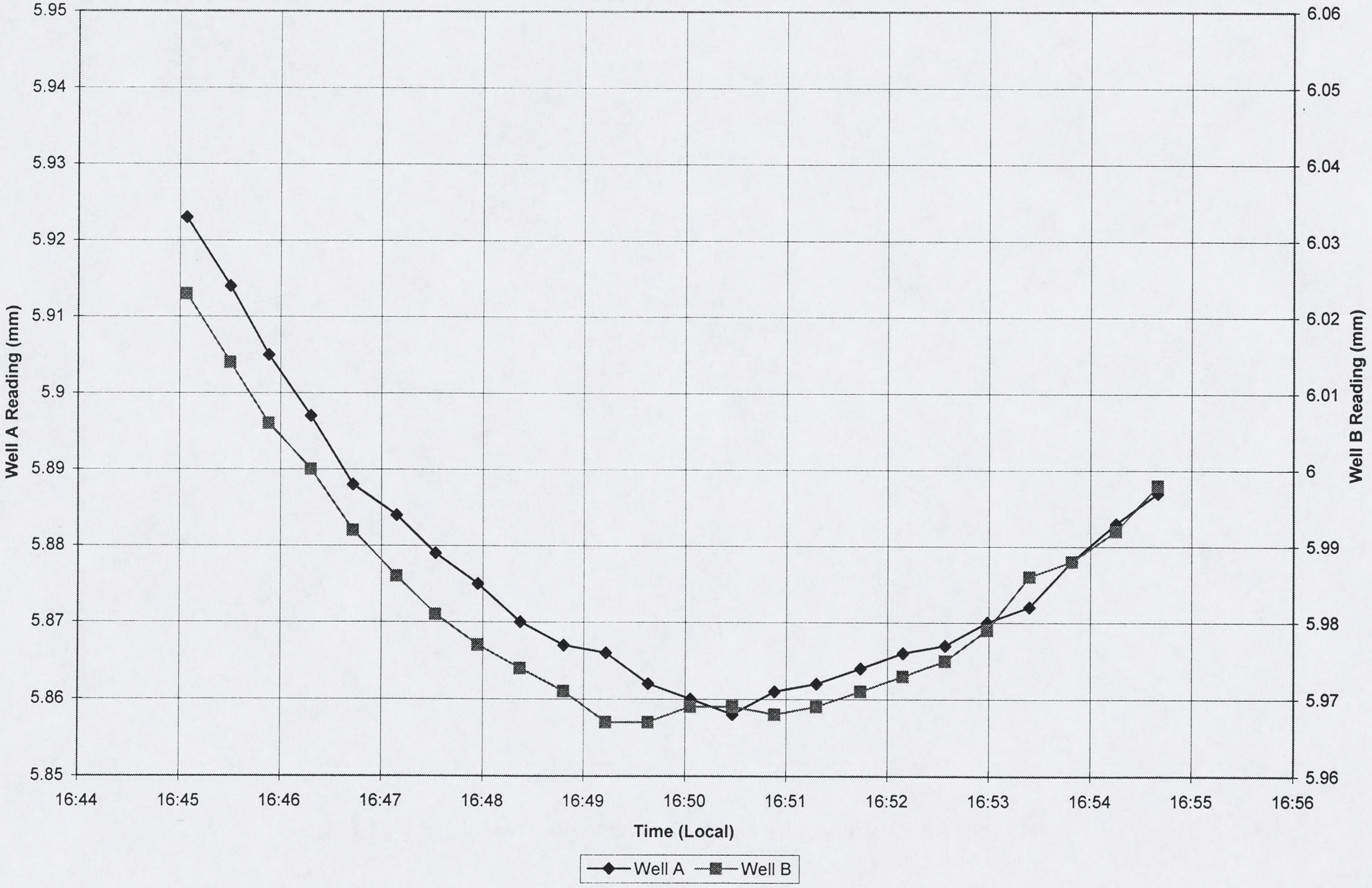
Hydrostatic Level Data 11-08-1999 Well A on ZY105 & Well B on ZY106

File: 1108.xls Disk: B298



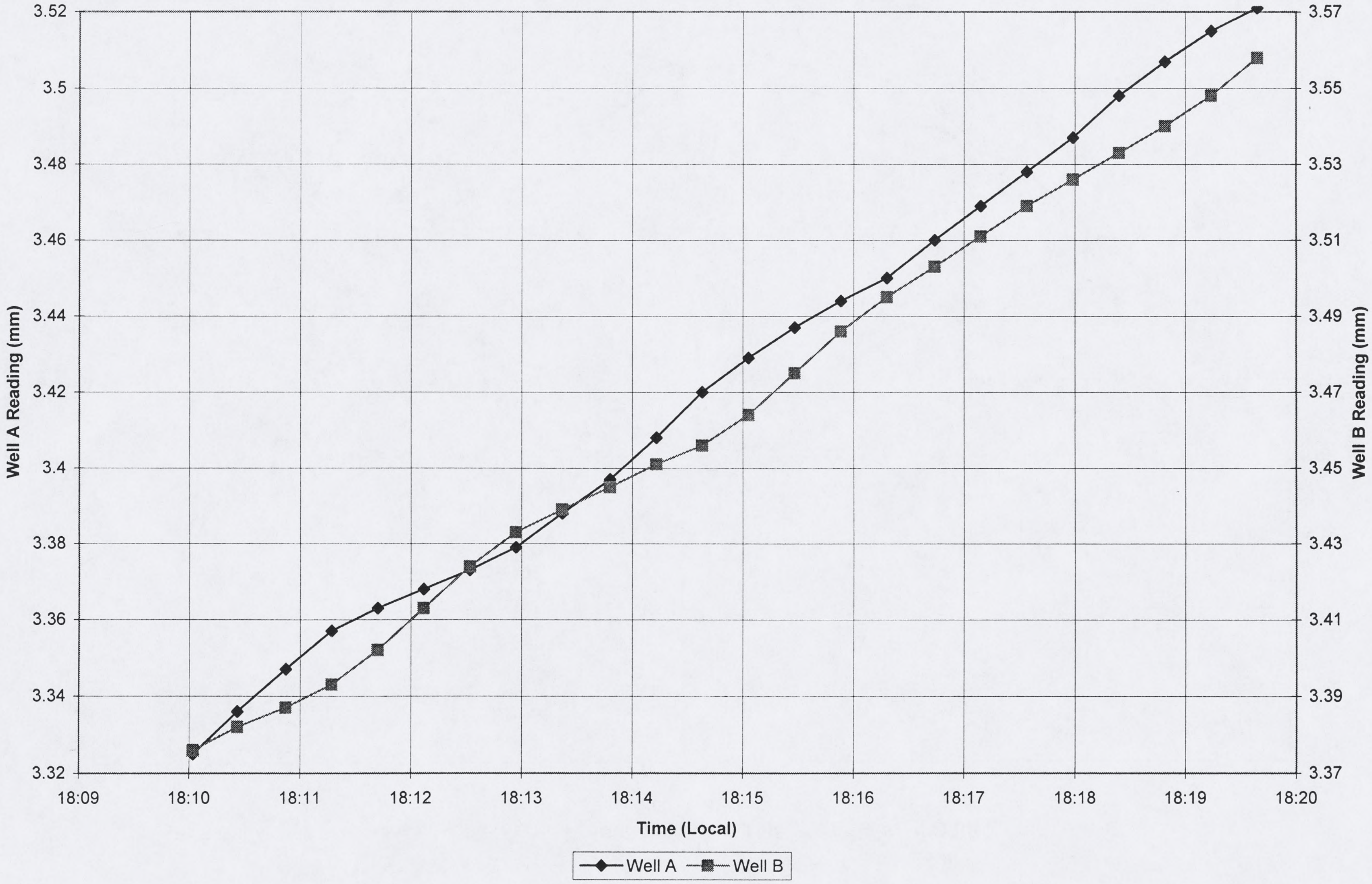
Hydrostatic Level Data 11-08-1999 Well A on ZY105 & Well B on ZY106

File: 1108.xls Disk: B298



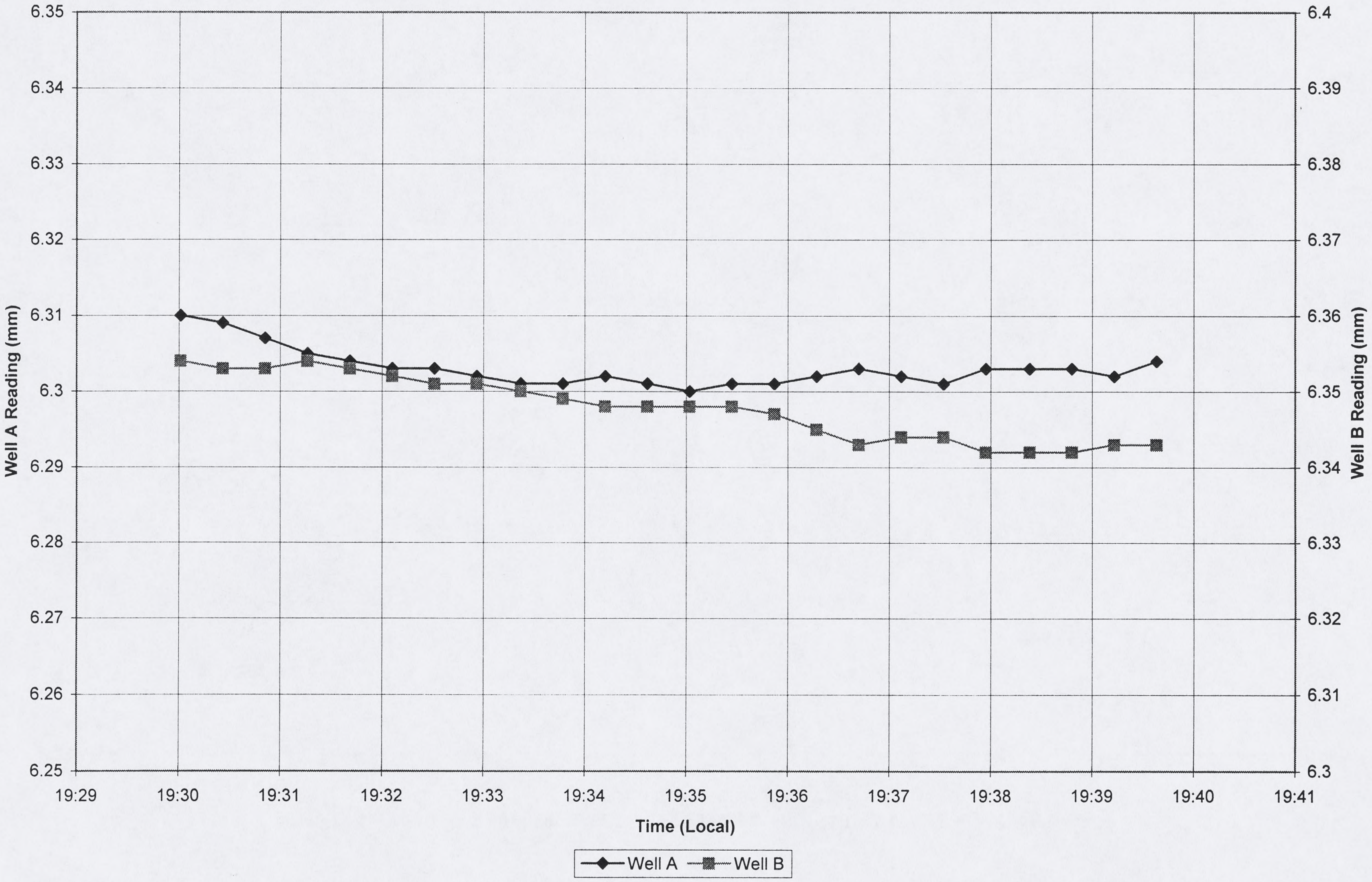
Hydrostaic Level Data 11-08-1999 Well A on ZY105 & Well B on ZY106

File: 1108.xls Disk: B298



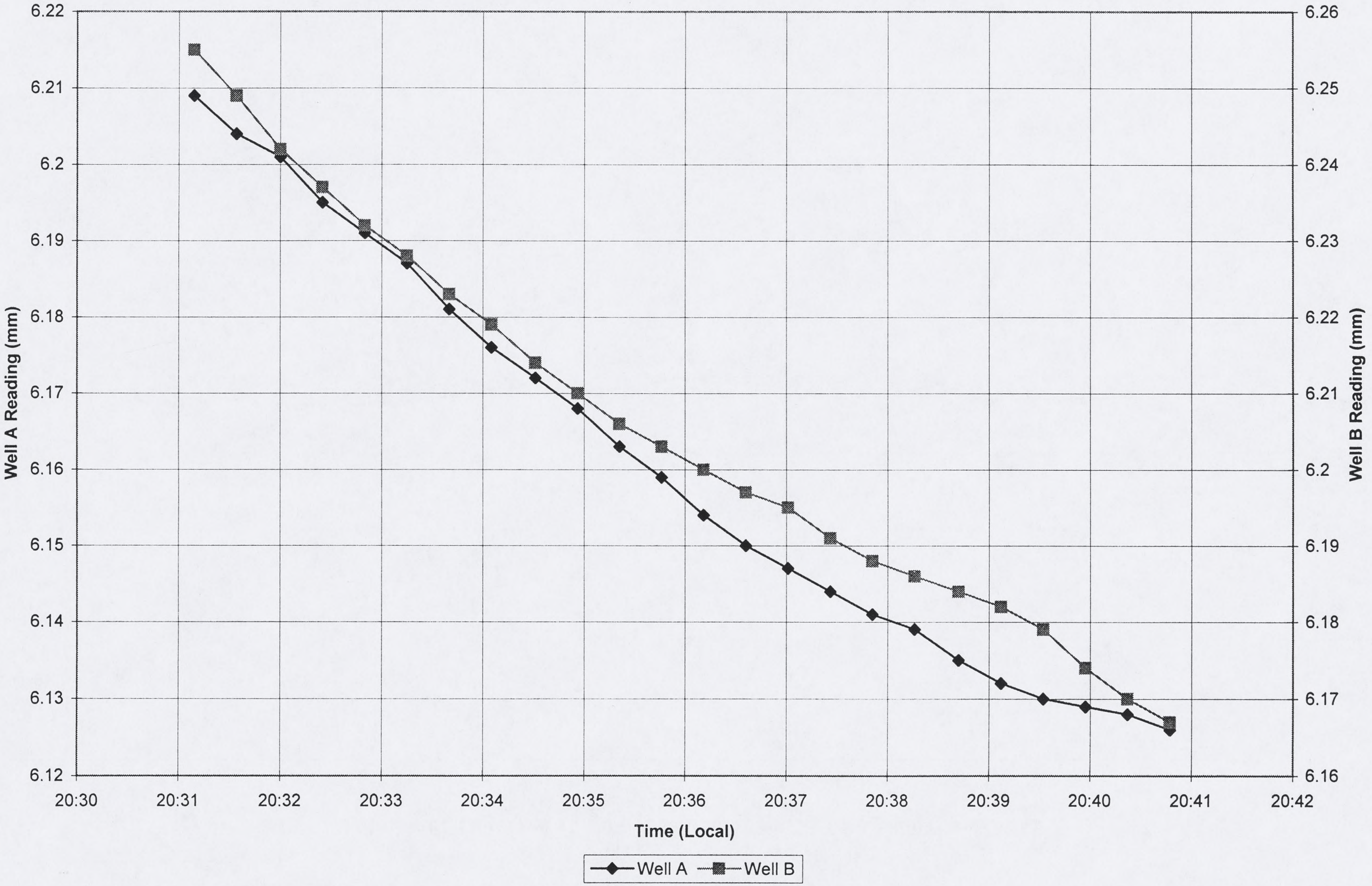
Hydrostatic Level Data 11-08-1999 Well A on ZY105 & Well B on ZY106

File: 1108.xls Disk: B298



Hydrostatic Level Data 11-08-1999 Well A on ZY105 & Well B on ZY106

File: 1108.xls Disk: B298



Well A on ZY105 Well B on ZY106 11-08-1999

15:15:19	-0.076
15:15:44	-0.077
15:16:09	-0.077
15:16:34	-0.079
15:16:59	-0.074
15:17:24	-0.072
15:17:49	-0.071
15:18:15	-0.07
15:18:40	-0.07
15:19:05	-0.073
15:19:30	-0.071
15:19:55	-0.069
15:20:21	-0.068
15:20:46	-0.072
15:21:11	-0.076
15:21:36	-0.083
15:22:01	-0.085
15:22:27	-0.078
15:22:52	-0.085
15:23:17	-0.086
15:23:42	-0.085
15:24:07	-0.076
15:24:32	-0.076
15:24:58	-0.075
15:25:23	-0.074
16:45:04	-0.1
16:45:30	-0.1
16:45:53	-0.101
16:46:18	-0.103
16:46:43	-0.104
16:47:09	-0.102
16:47:32	-0.102
16:47:57	-0.102
16:48:22	-0.104
16:48:48	-0.104
16:49:13	-0.101
16:49:38	-0.105
16:50:03	-0.109
16:50:28	-0.111
16:50:53	-0.107
16:51:18	-0.107
16:51:44	-0.107
16:52:09	-0.107
16:52:34	-0.108
16:52:59	-0.109
16:53:24	-0.114
16:53:49	-0.11

	Average	Standard Deviation
Experiment # 1 *	-0.07592	0.005369
Experiment # 2 *	-0.10571	0.003928
Experiment # 3	-0.04179	0.006093
Experiment # 4	-0.04475	0.003733
Experiment # 5	-0.04458	0.002933
Selected Data	-0.04371	0.004604

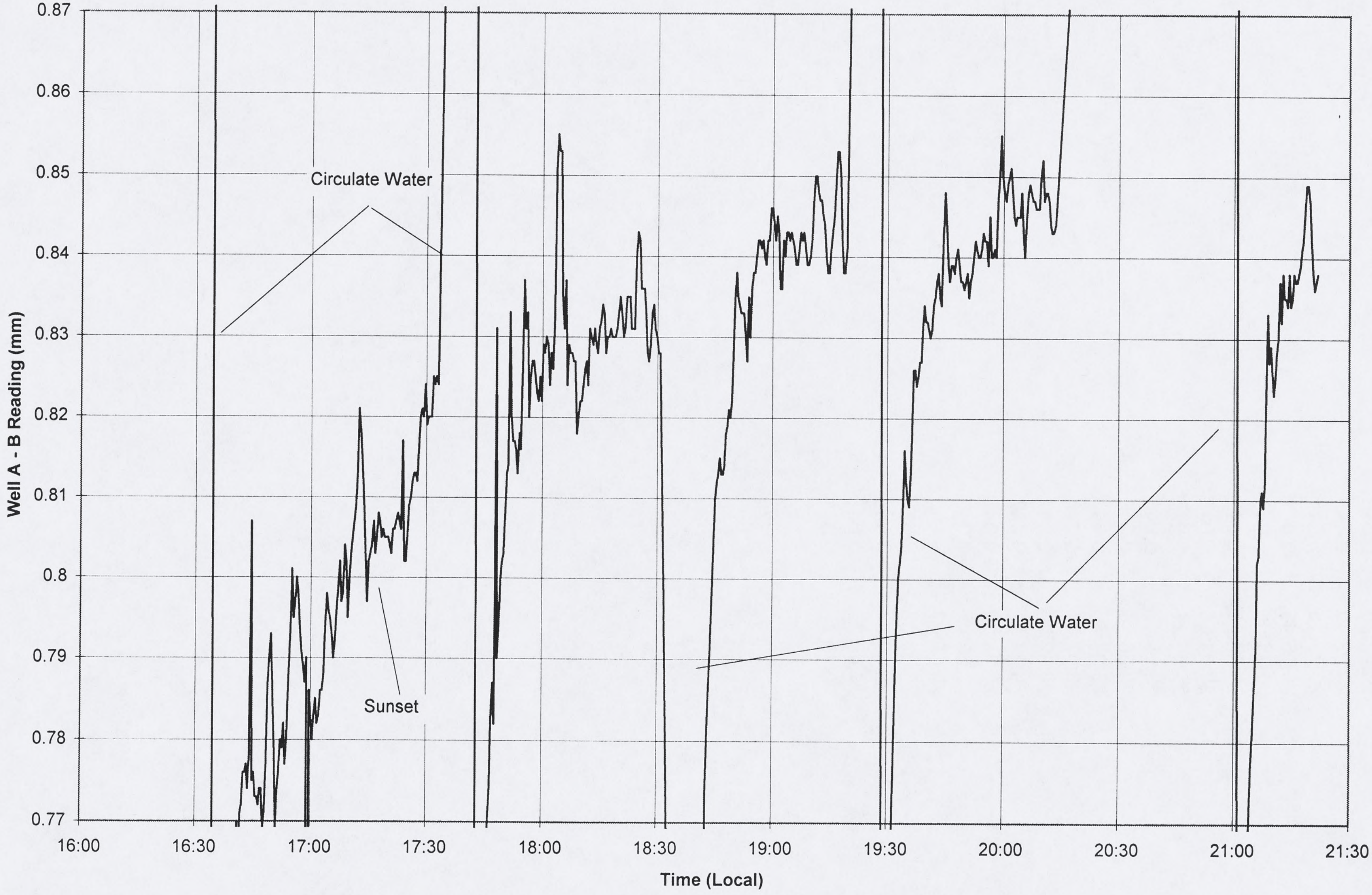
* = Did not use in selected data

16:54:15	-0.109
16:54:40	-0.111
18:10:02	-0.051
18:10:26	-0.046
18:10:52	-0.04
18:11:17	-0.036
18:11:42	-0.039
18:12:07	-0.045
18:12:32	-0.051
18:12:57	-0.054
18:13:22	-0.051
18:13:48	-0.048
18:14:13	-0.043
18:14:38	-0.036
18:15:03	-0.035
18:15:28	-0.038
18:15:53	-0.042
18:16:18	-0.045
18:16:44	-0.043
18:17:09	-0.042
18:17:34	-0.041
18:17:59	-0.039
18:18:24	-0.035
18:18:49	-0.033
18:19:14	-0.033
18:19:39	-0.037
19:30:01	-0.044
19:30:26	-0.044
19:30:51	-0.046
19:31:16	-0.049
19:31:41	-0.049
19:32:06	-0.049
19:32:31	-0.048
19:32:56	-0.049
19:33:22	-0.049
19:33:47	-0.048
19:34:12	-0.046
19:34:37	-0.047
19:35:02	-0.048
19:35:27	-0.047
19:35:52	-0.046
19:36:17	-0.043
19:36:42	-0.04
19:37:07	-0.042
19:37:32	-0.043
19:37:57	-0.039
19:38:23	-0.039
19:38:48	-0.039
19:39:13	-0.041
19:39:38	-0.039
20:31:09	-0.046
20:31:34	-0.045

20:32:00	-0.041
20:32:25	-0.042
20:32:50	-0.041
20:33:15	-0.041
20:33:40	-0.042
20:34:05	-0.043
20:34:31	-0.042
20:34:56	-0.042
20:35:21	-0.043
20:35:46	-0.044
20:36:11	-0.046
20:36:36	-0.047
20:37:01	-0.048
20:37:26	-0.047
20:37:51	-0.047
20:38:16	-0.047
20:38:42	-0.049
20:39:07	-0.05
20:39:32	-0.049
20:39:57	-0.045
20:40:22	-0.042
20:40:47	-0.041

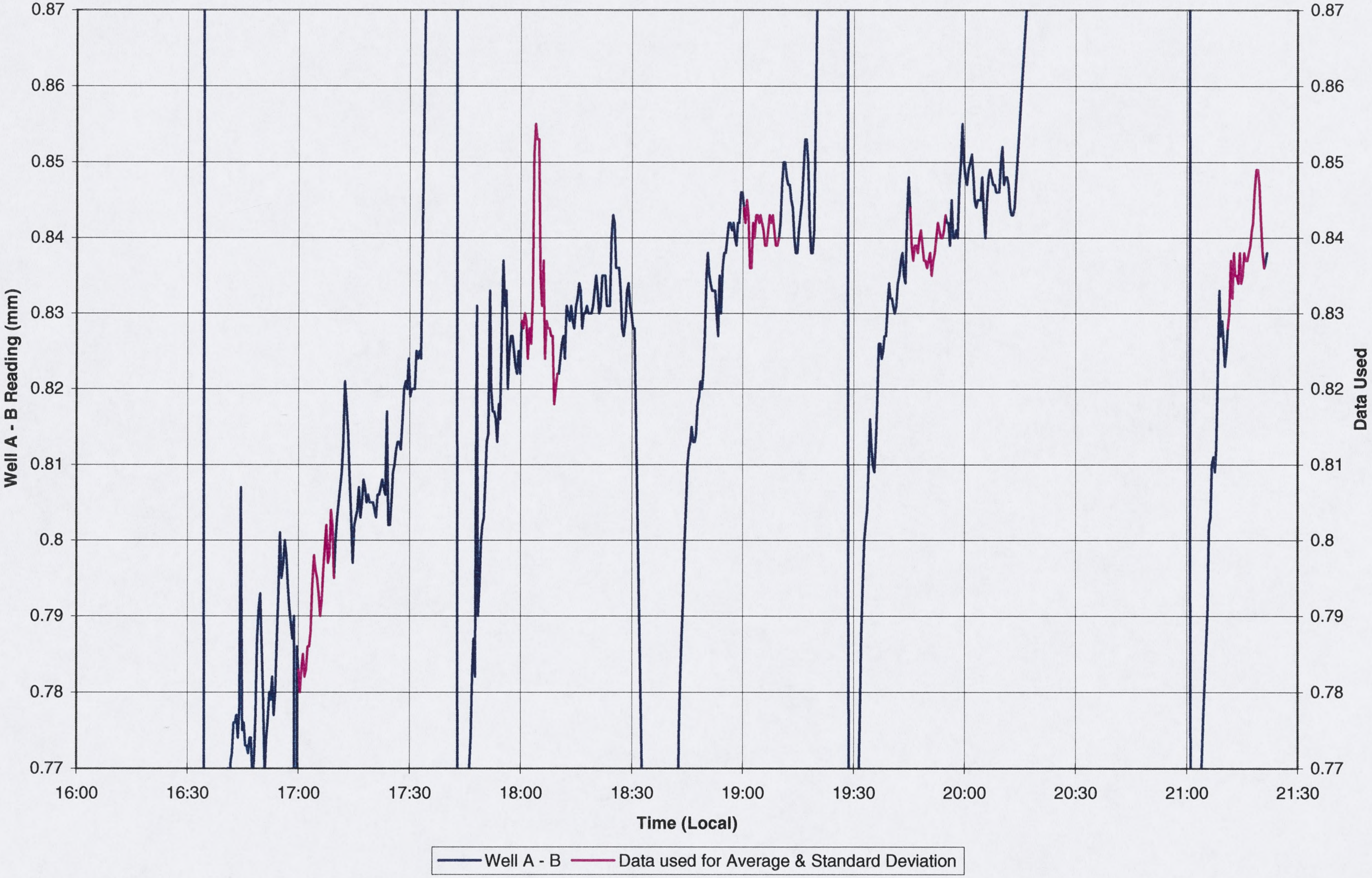
Hydrostatic Level Data 11-09-1999 Well A on ZY105 - Well B on ZY104

File: 1109-2.xls Disk: B298



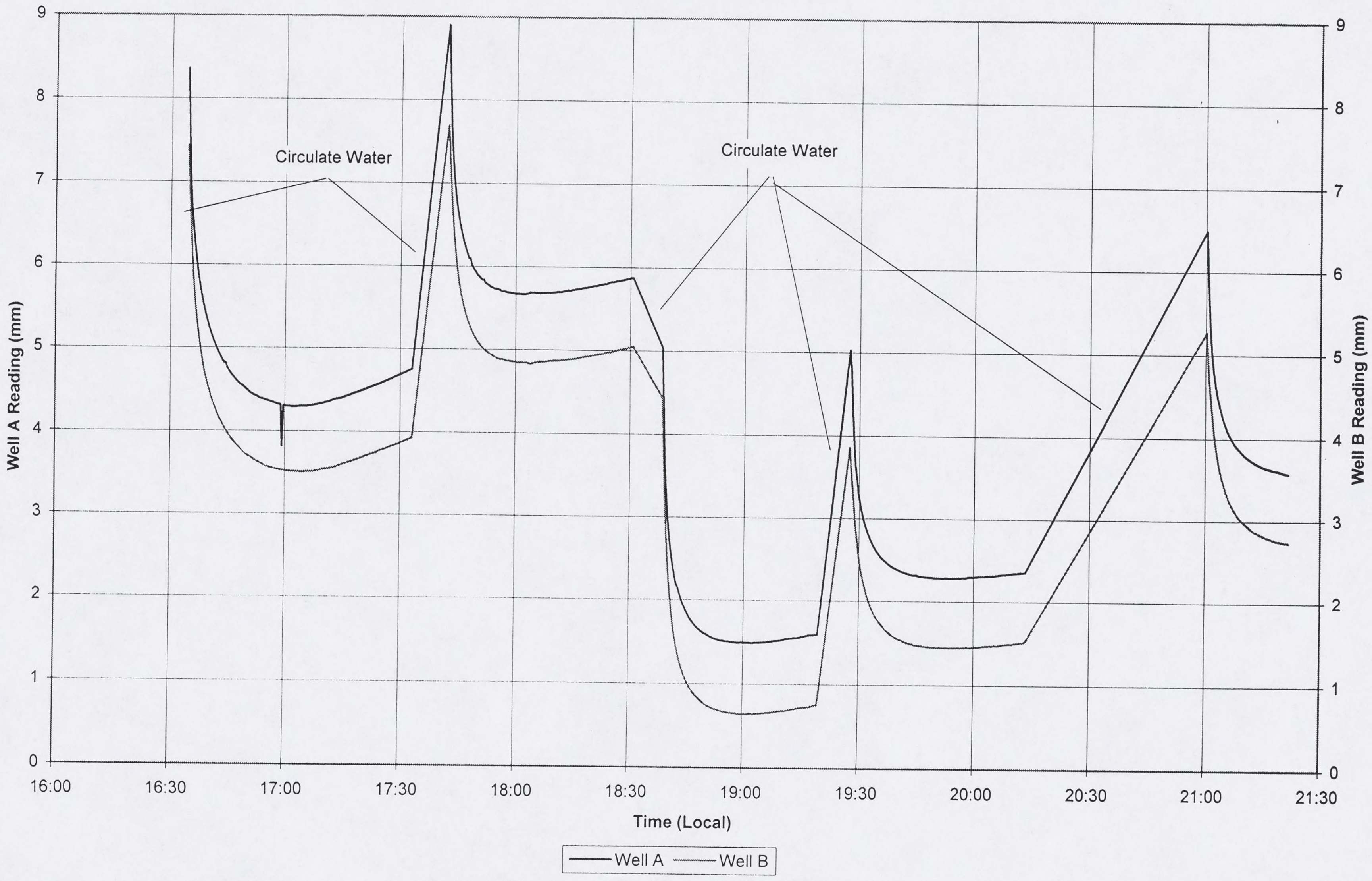
Hydrostatic Level Data 11-09-1999 Well A on ZY105 - Well B on ZY104

File: 1109-2.xls Disk: B298



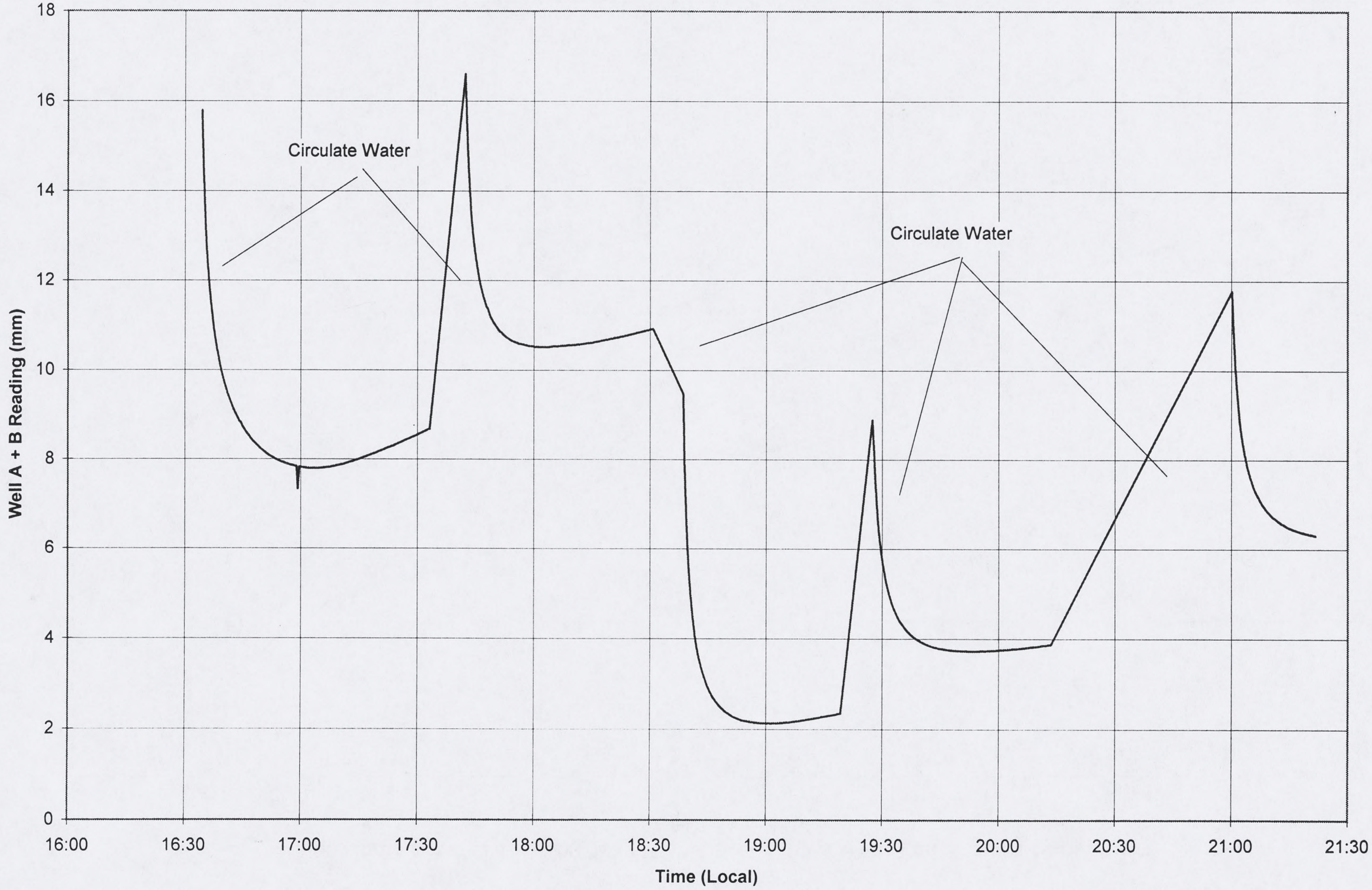
Hydrostatic Level Data 11-09-1999 Well A on ZY105 Well B on ZY104

File: 1109-2.xls Disk: B298



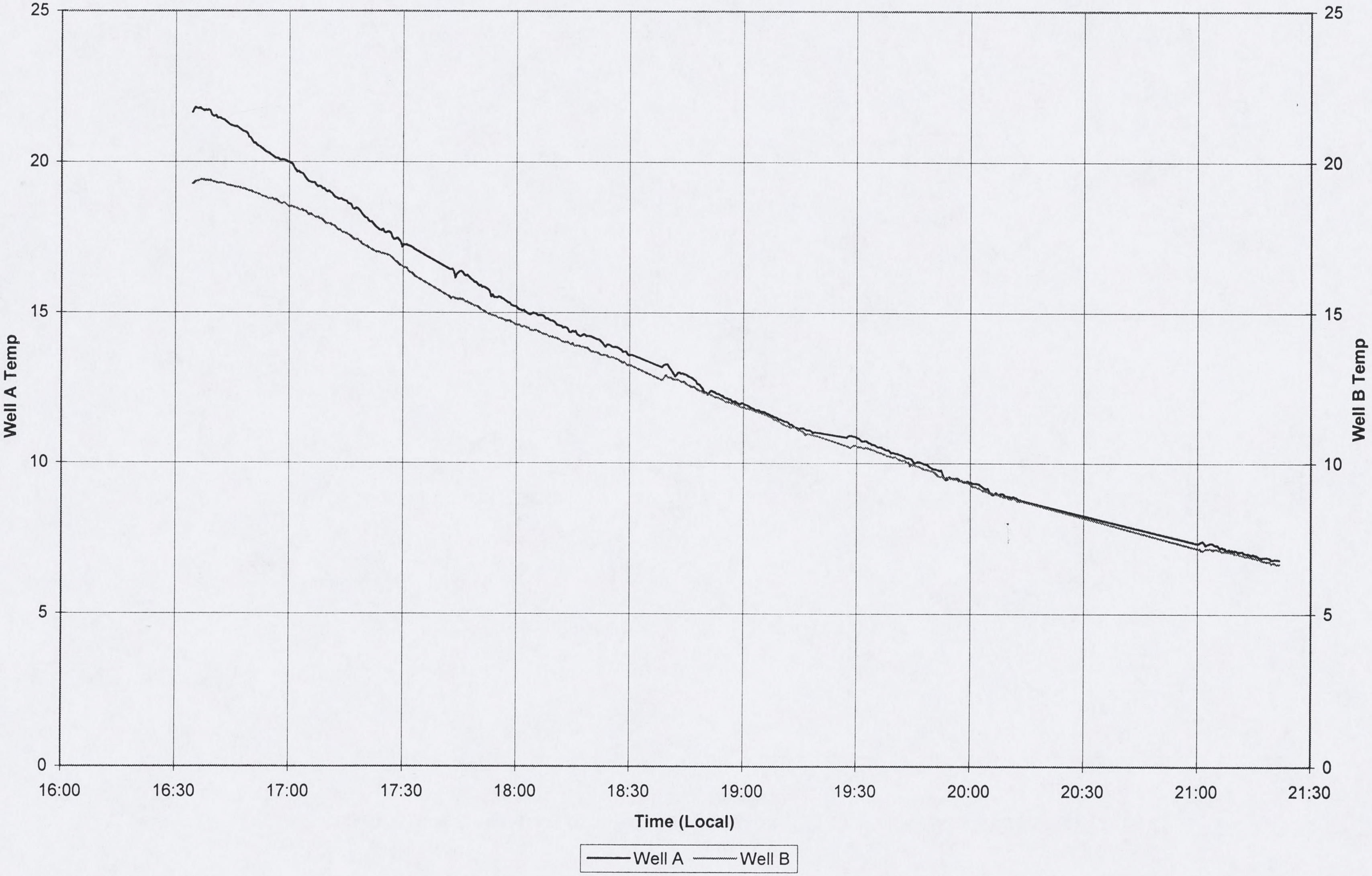
Hydrostatic Level Data 11-09-1999 Well A on ZY105 + Well B on ZY104

File: 1109-2.xls Disk: B298



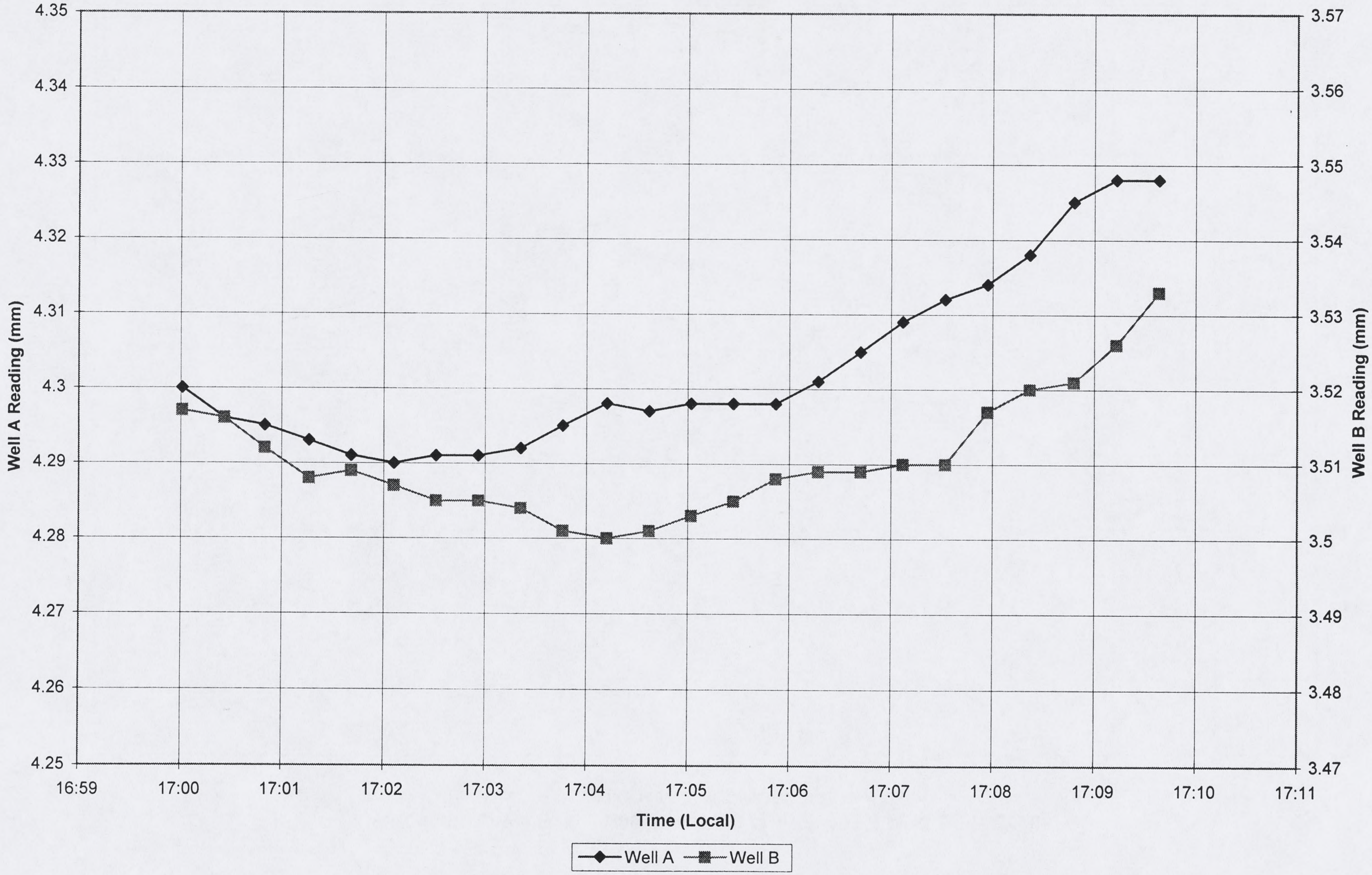
Hydrostatic Level Data 11-09-1999 Well A on ZY105 & Well B on ZY104 Temperatures

File: 1109-2.xls Disk: B298



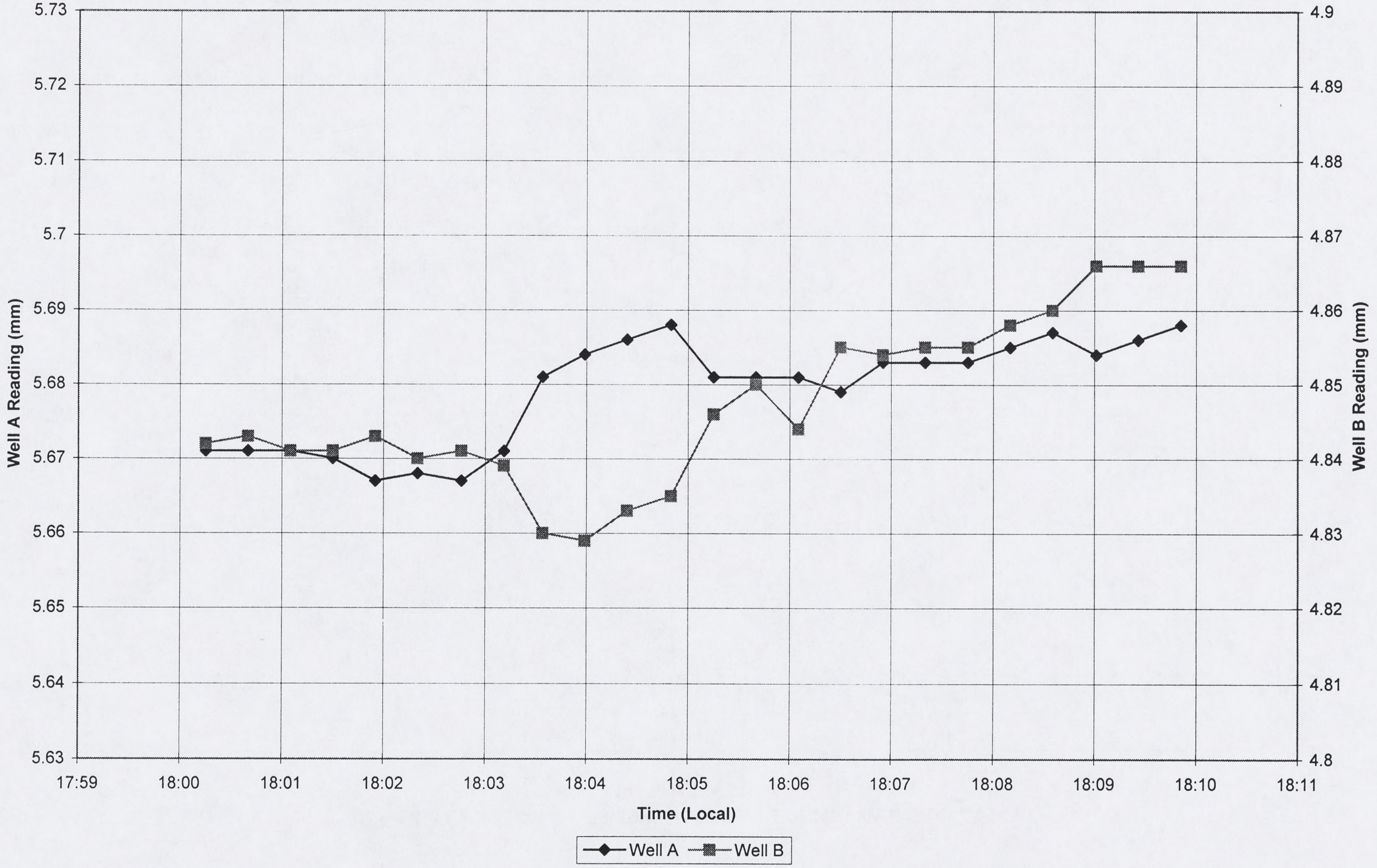
Hydrostatic Level Data 11-09-1999 Well A on ZY105 & Well B on ZY104

File: 1109-2.xls Disk: B298



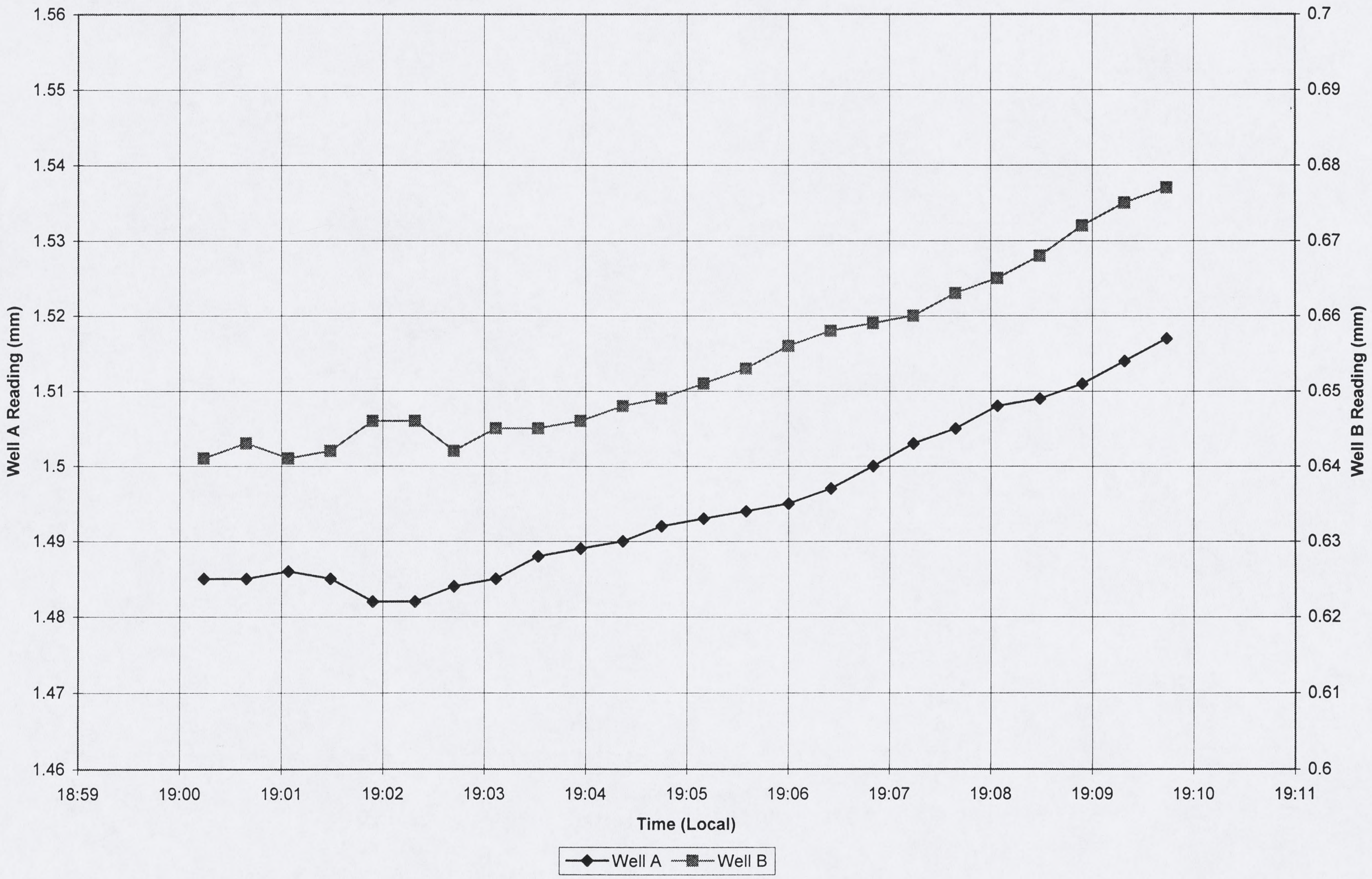
Hydrostatic Level Data 11-09-1999 Well A on ZY105 & Well B on ZY104

File: 1109-2.xls Disk: B298



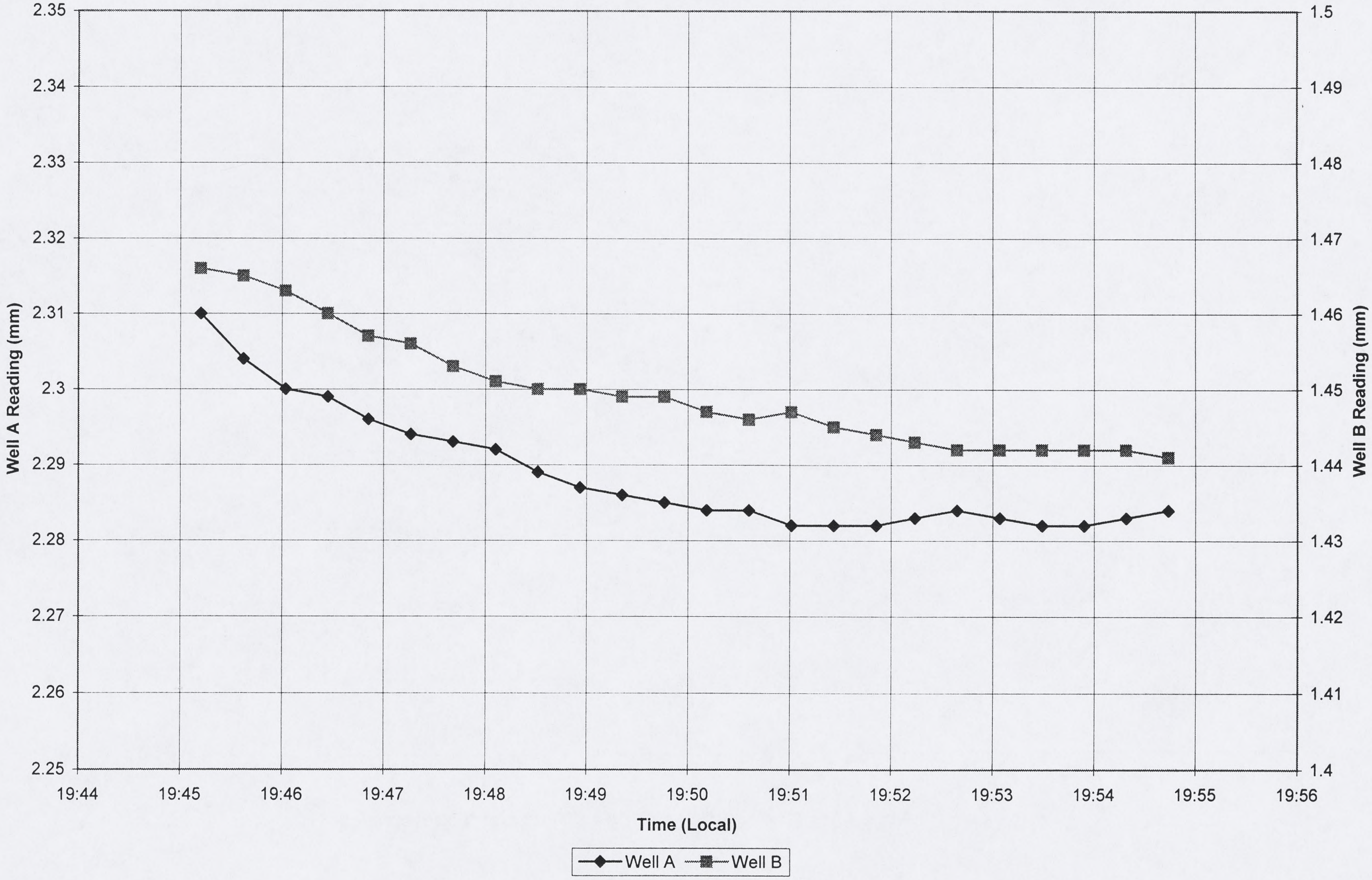
Hydrostatic Level Data 11-09-1999 Well A on ZY105 & Well B on ZY104

File: 1109-2.xls Disk: B298



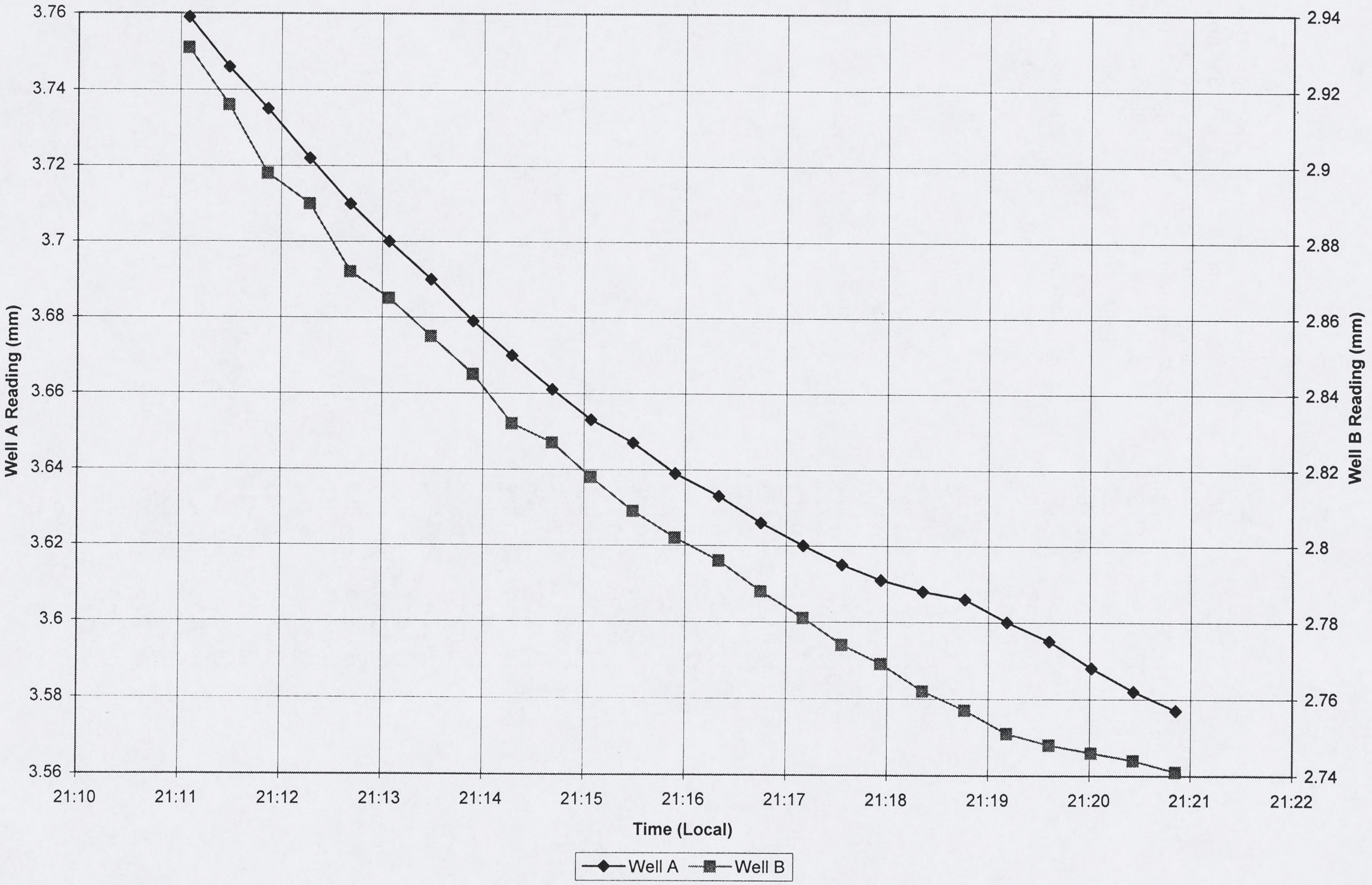
Hydrostatic Level Data 11-09-1999 Well A on ZY105 & Well B on ZY104

File: 1109-2.xls Disk: B298



Hydrostatic Level Data 11-09-1999 Well A on ZY105 & Well B on ZY104

File: 1109-2.xls Disk: B298



Well A on ZY105 Well B on ZY104 11-09-1999

17:00:01	0.783
17:00:26	0.78
17:00:50	0.783
17:01:16	0.785
17:01:41	0.782
17:02:06	0.783
17:02:31	0.786
17:02:56	0.786
17:03:21	0.788
17:03:46	0.794
17:04:12	0.798
17:04:37	0.796
17:05:02	0.795
17:05:27	0.793
17:05:52	0.79
17:06:17	0.792
17:06:42	0.796
17:07:07	0.799
17:07:32	0.802
17:07:57	0.797
17:08:22	0.798
17:08:48	0.804
17:09:13	0.802
17:09:38	0.795
18:00:15	0.829
18:00:40	0.828
18:01:05	0.83
18:01:30	0.829
18:01:55	0.824
18:02:20	0.828
18:02:46	0.826
18:03:11	0.832
18:03:34	0.851
18:03:59	0.855
18:04:24	0.853
18:04:50	0.853
18:05:15	0.835
18:05:40	0.831
18:06:05	0.837
18:06:30	0.824
18:06:55	0.829
18:07:20	0.828
18:07:45	0.828
18:08:10	0.827
18:08:35	0.827
18:09:01	0.818

	Average	Standard Deviation
Experiment # 1 *	0.791958	0.007141
Experiment # 2 *	0.831833	0.01054
Experiment # 3	0.841167	0.002297
Experiment # 4	0.839083	0.002225
Experiment # 5	0.8382	0.005377
Selected Data	0.839466	0.003805

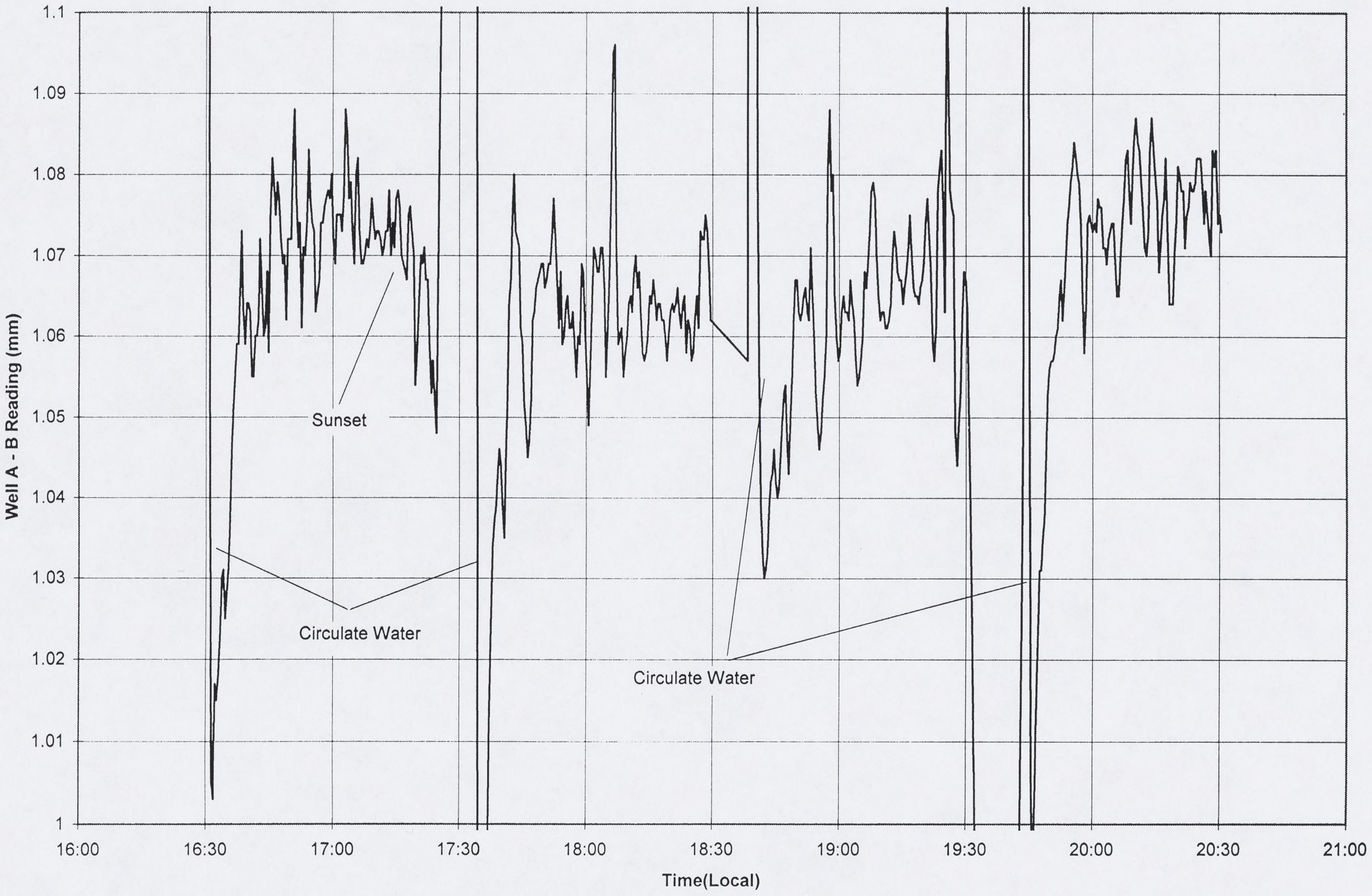
* = Did not use in selected data

18:09:26	0.82
18:09:51	0.822
19:00:14	0.844
19:00:39	0.842
19:01:04	0.845
19:01:29	0.843
19:01:54	0.836
19:02:19	0.836
19:02:42	0.842
19:03:07	0.84
19:03:32	0.843
19:03:57	0.843
19:04:22	0.842
19:04:45	0.843
19:05:10	0.842
19:05:35	0.841
19:06:00	0.839
19:06:25	0.839
19:06:50	0.841
19:07:14	0.843
19:07:39	0.842
19:08:04	0.843
19:08:29	0.841
19:08:54	0.839
19:09:19	0.839
19:09:44	0.84
19:45:12	0.844
19:45:37	0.839
19:46:02	0.837
19:46:27	0.839
19:46:51	0.839
19:47:16	0.838
19:47:41	0.84
19:48:06	0.841
19:48:31	0.839
19:48:56	0.837
19:49:21	0.837
19:49:46	0.836
19:50:11	0.837
19:50:36	0.838
19:51:01	0.835
19:51:26	0.837
19:51:51	0.838
19:52:14	0.84
19:52:39	0.842
19:53:04	0.841
19:53:29	0.84
19:53:54	0.84
19:54:19	0.841
19:54:44	0.843
21:11:05	0.828
21:11:29	0.83

21:11:52	0.837
21:12:17	0.832
21:12:41	0.838
21:13:04	0.835
21:13:29	0.835
21:13:54	0.834
21:14:17	0.838
21:14:41	0.834
21:15:04	0.835
21:15:29	0.838
21:15:54	0.837
21:16:20	0.837
21:16:45	0.838
21:17:10	0.839
21:17:33	0.841
21:17:56	0.842
21:18:21	0.846
21:18:46	0.849
21:19:11	0.849
21:19:36	0.847
21:20:01	0.842
21:20:26	0.838
21:20:51	0.836

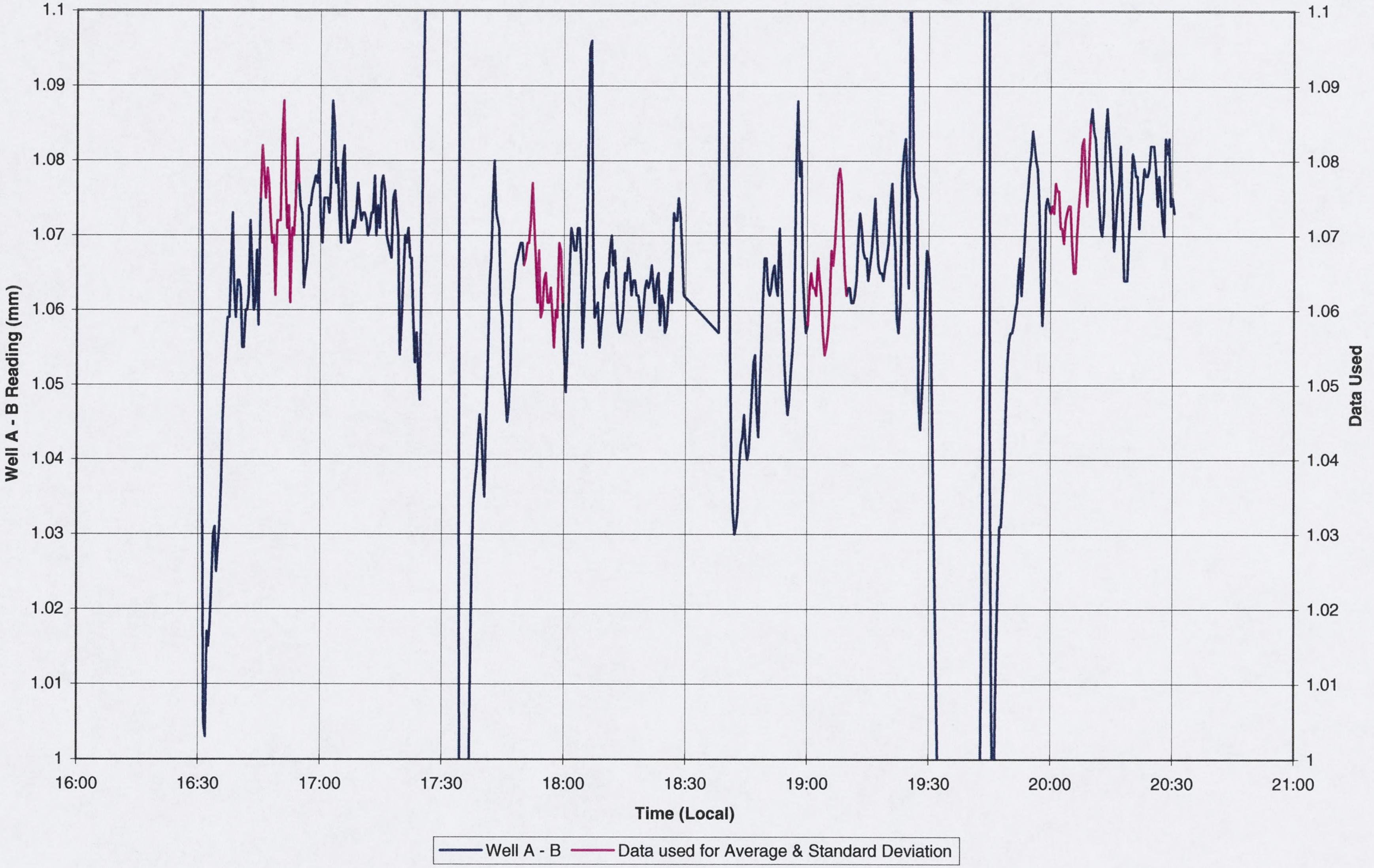
Hydrostatic Level Data 11-10-1999 Well A on ZY103 - Well B on ZY104

File: 1110.xls Disk: B298



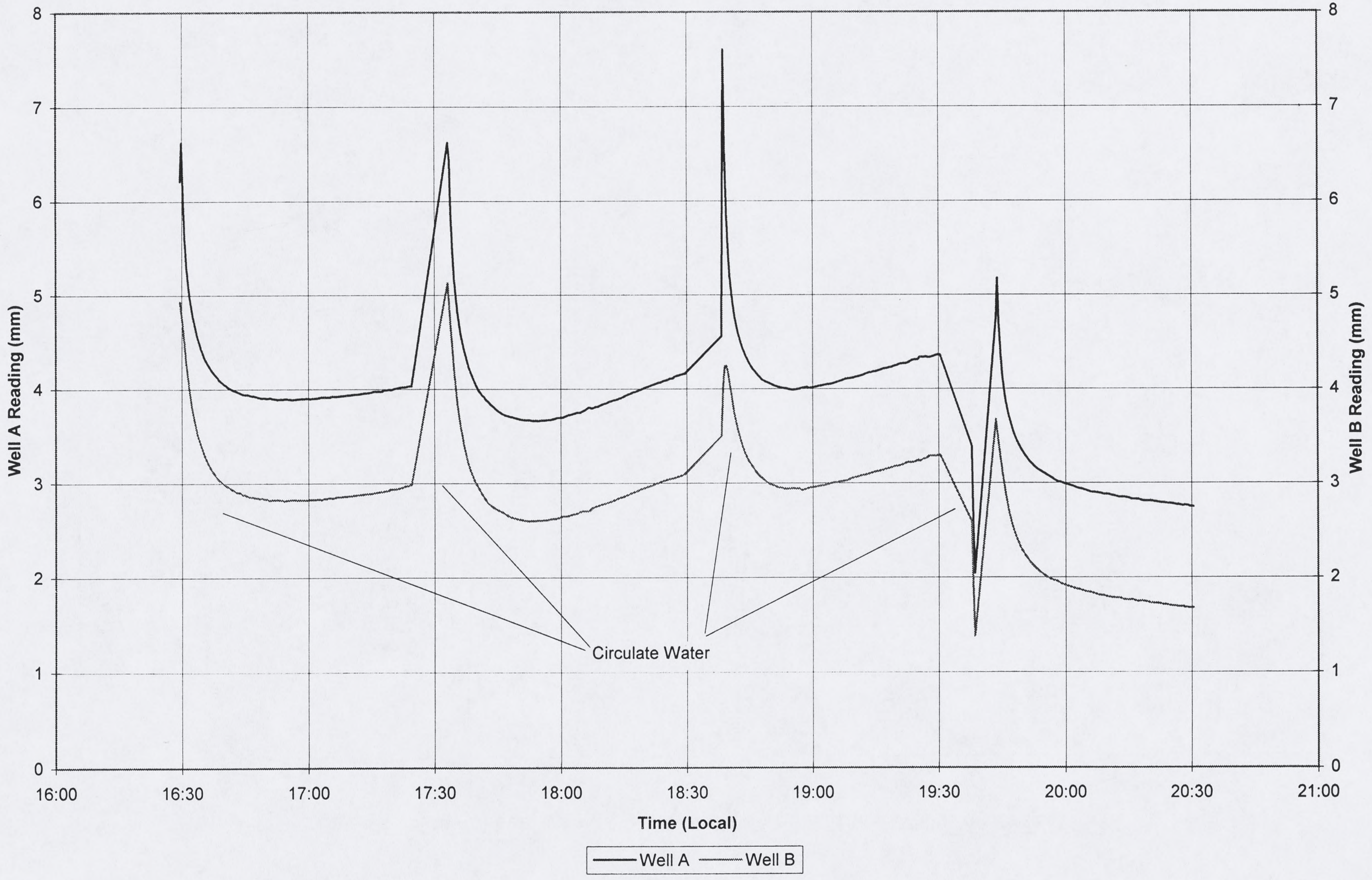
Hydrostatic Level Data 11-10-1999 Well A on ZY103 - Well B on ZY104

File: 1110.xls Disk: B298



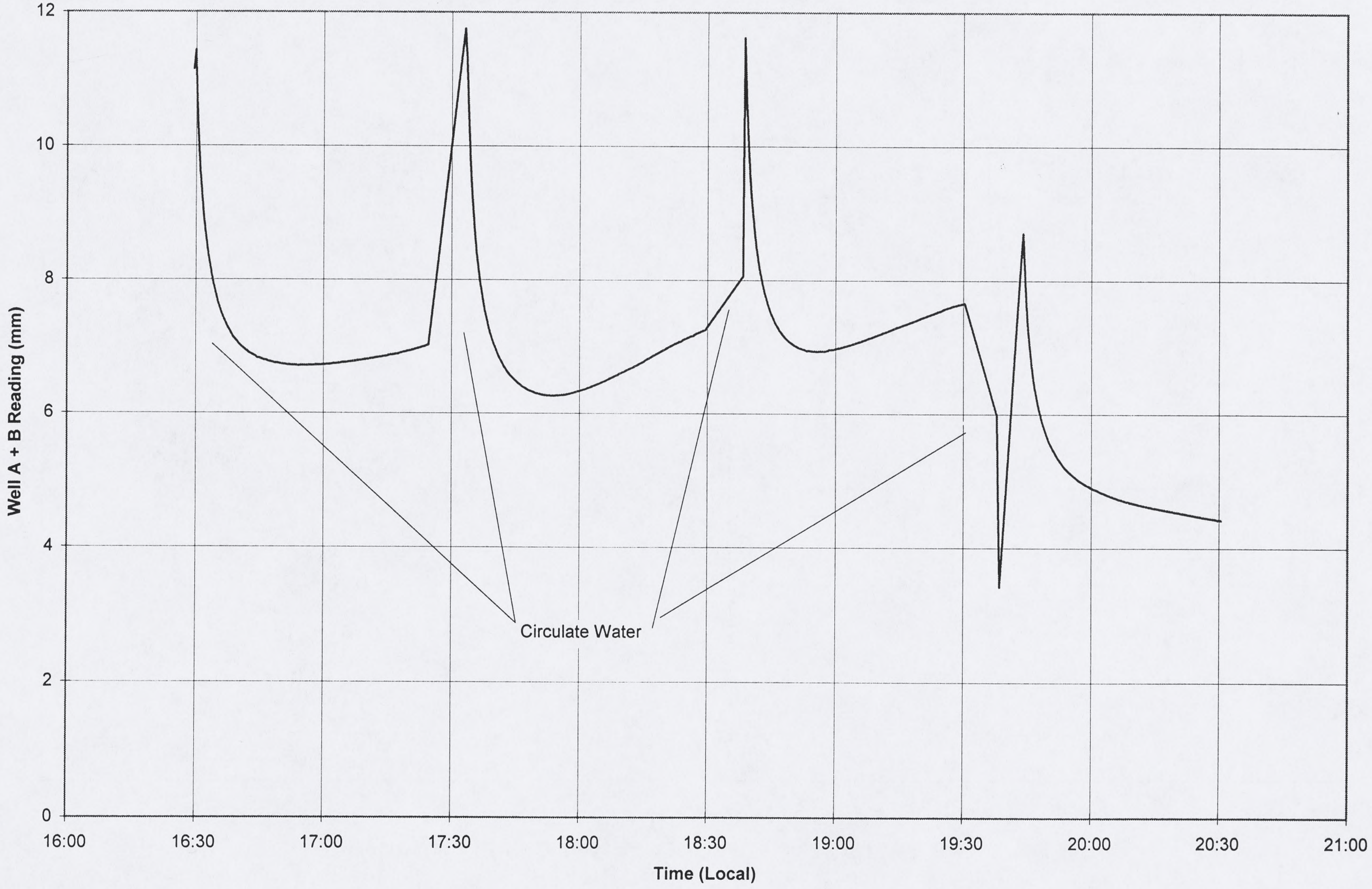
Hydrostatic Level Data 11-10-1999 Well A on ZY104 Well B on ZY104

File: 1110.xls Disk: B298



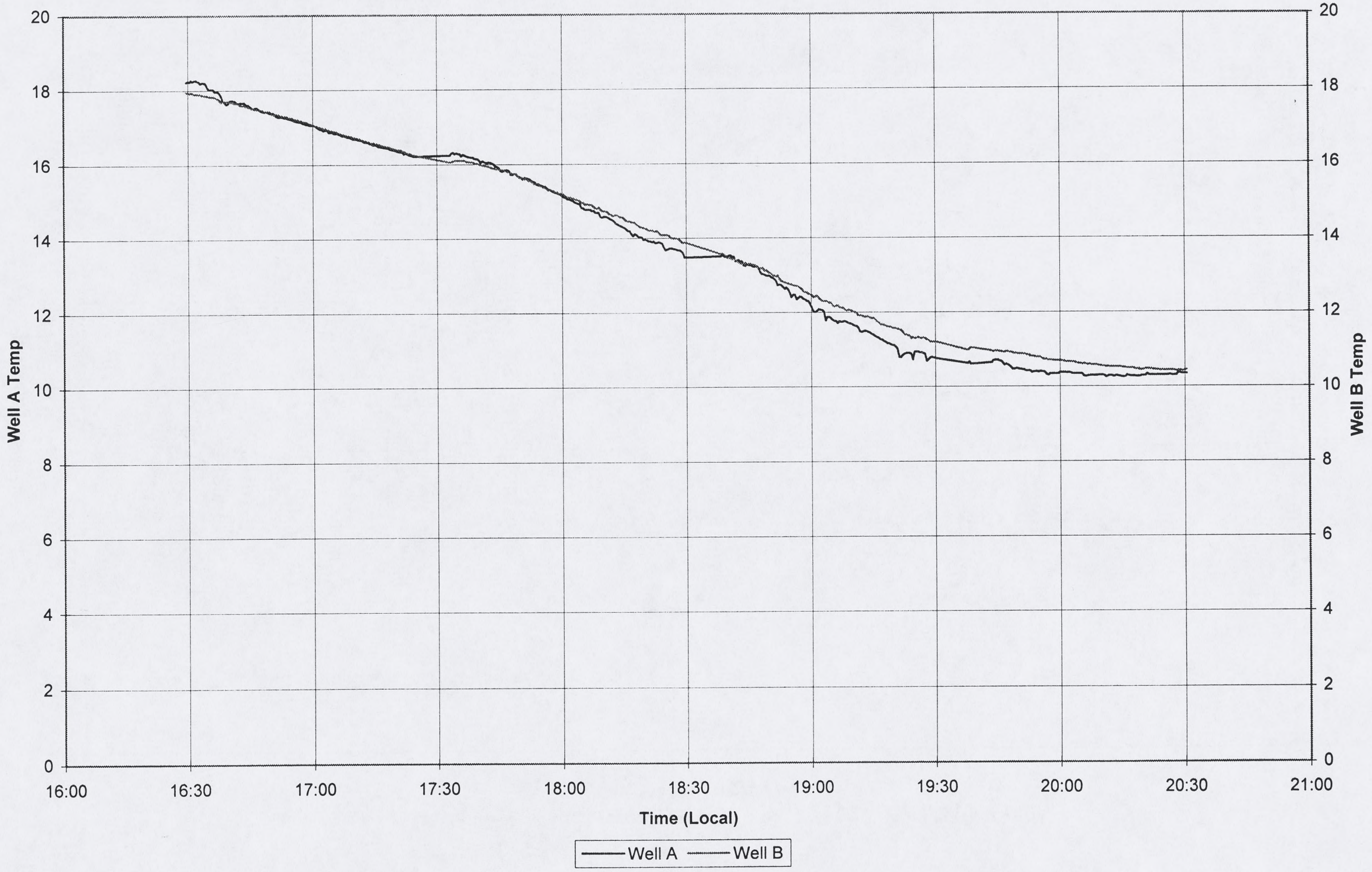
Hydrostatic Level Data 11-10-1999 Well A on ZY103 + Well B on ZY104

File: 1110.xls Disk: B298



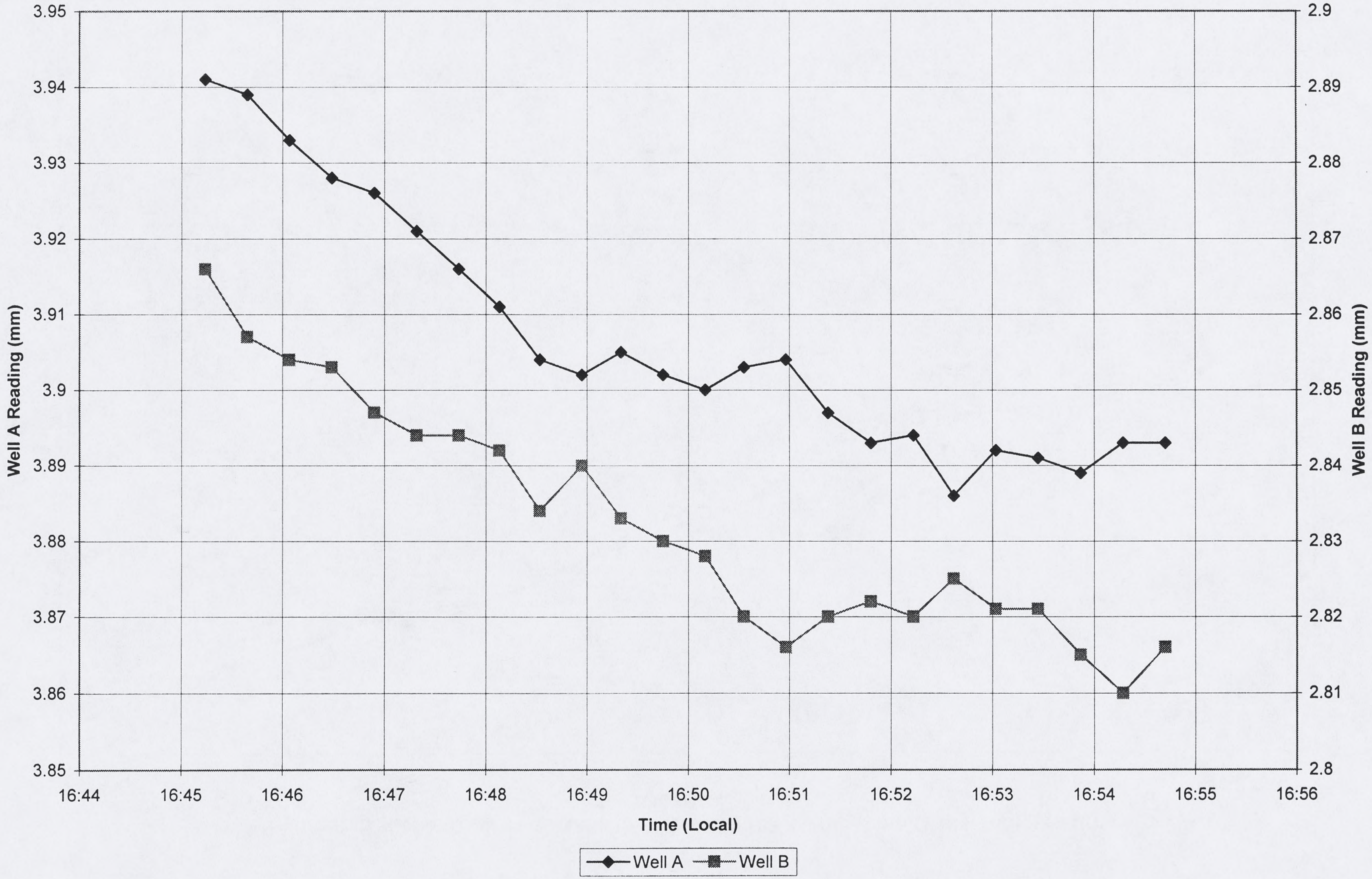
Hydrostatic Level Data 11-10-1999 Well A on ZY103 & Well B on ZY104 Temperatures

File: 1110.xls Disk: B298



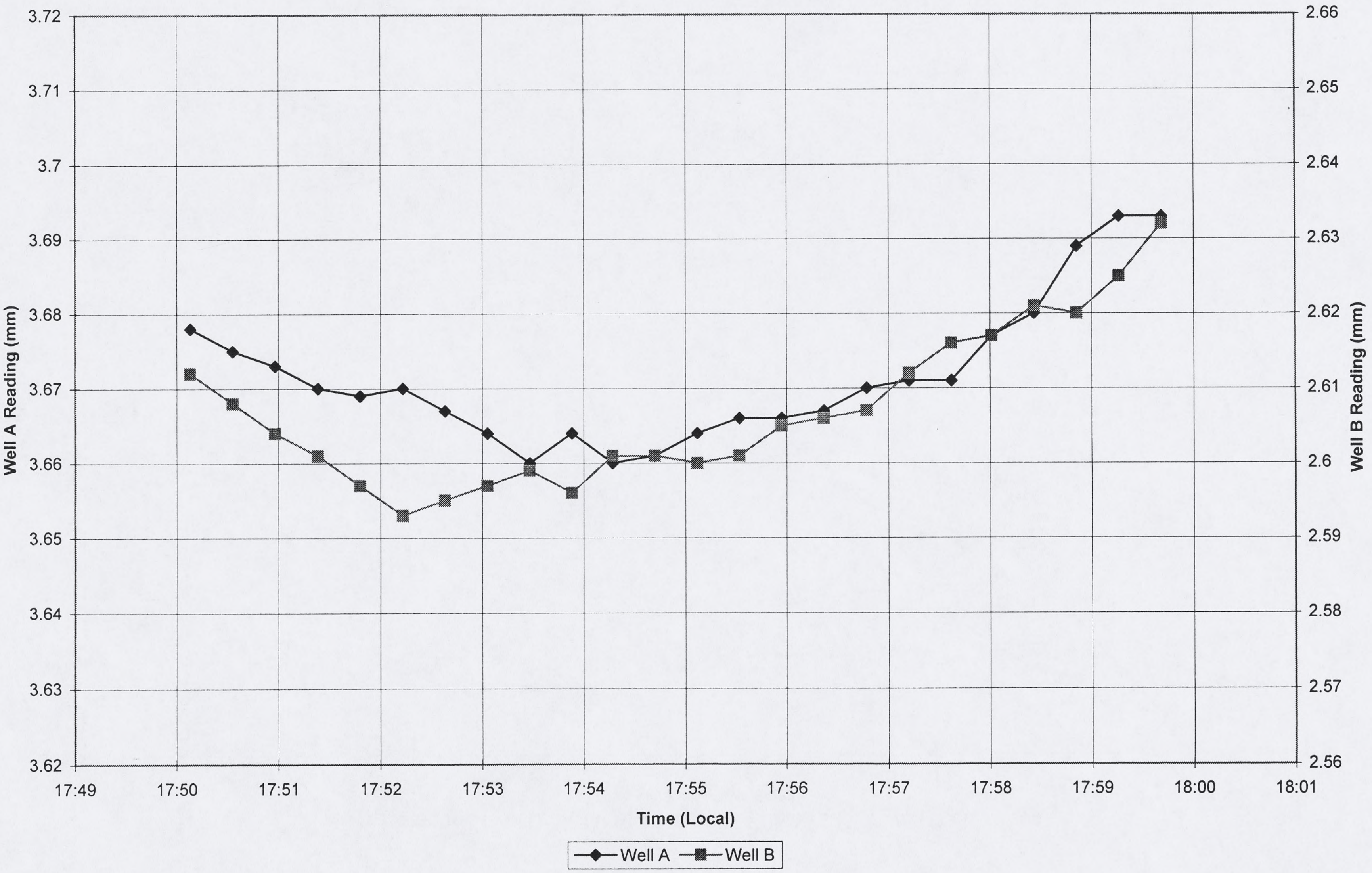
Hydrostatic Level Data 11-10-1999 Well A on ZY103 & Well B on ZY104

File: 1110.xls Disk: B298



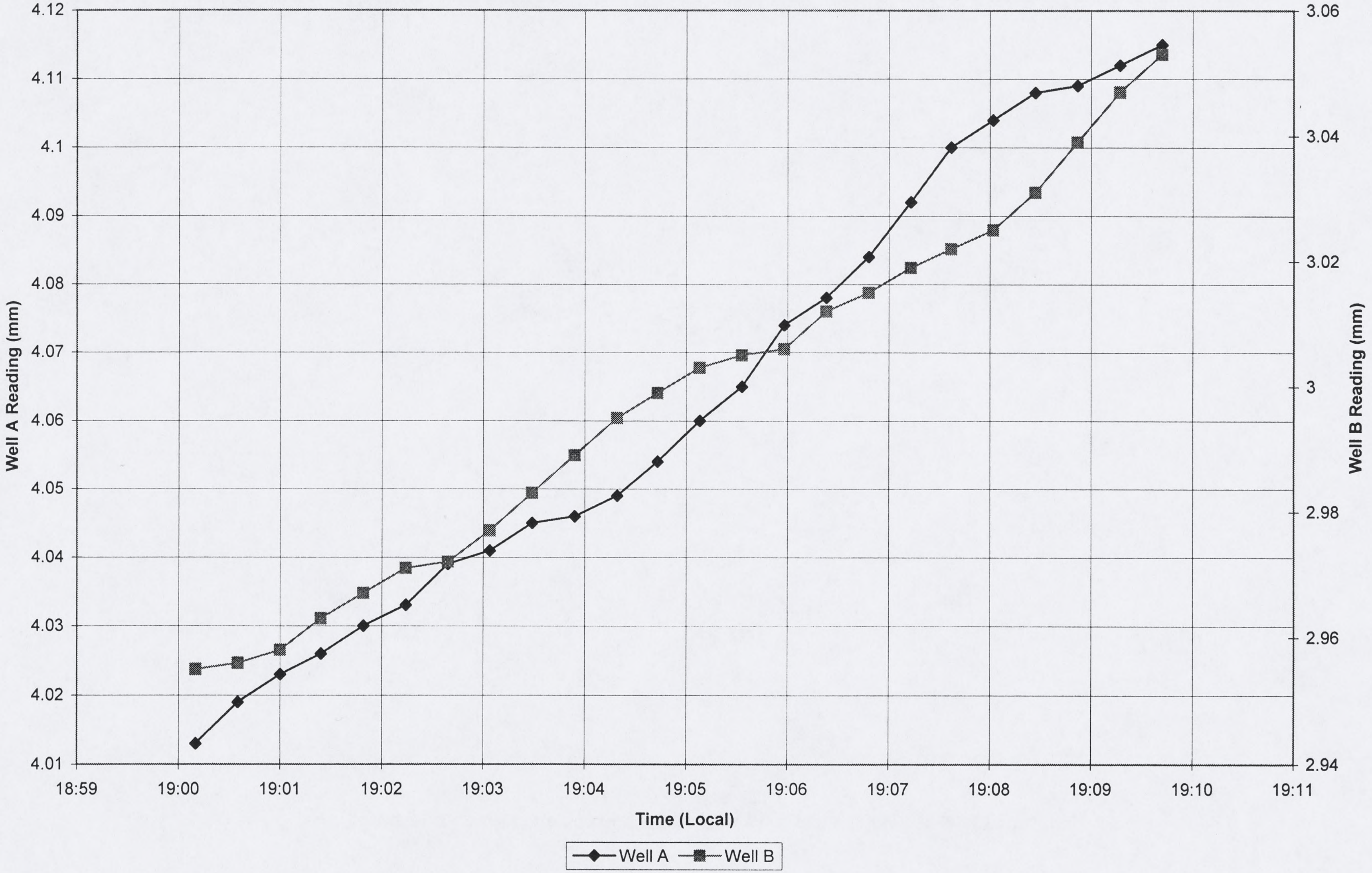
Hydrostatic Level Data 11-10-1999 Well A on ZY103 & Well B on ZY104

File: 1110.xls Disk: B298



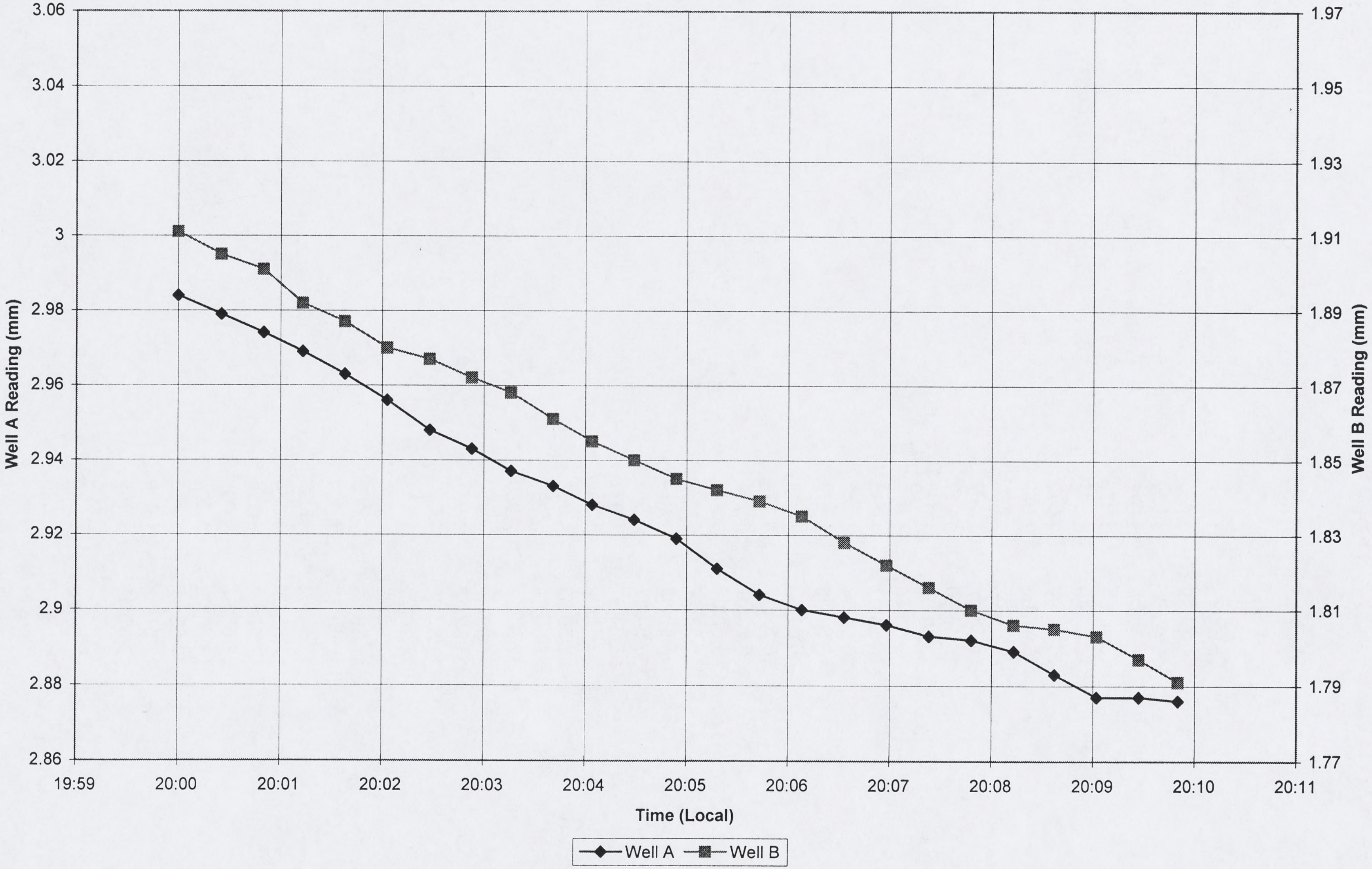
Hydrostatic Level Data 11-10-1999 Well A on ZY103 & Well B on ZY104

File: 1110.xls Disk: B298



Hydrostatic Level Data 11-10-1999 Well A on ZY103 & Well B on ZY104

File: 1110.xls Disk: B298



Well A on ZY103 Well B on ZY104 11-10-1999

16:45:14	1.075
16:45:39	1.082
16:46:04	1.079
16:46:29	1.075
16:46:54	1.079
16:47:19	1.077
16:47:44	1.072
16:48:08	1.069
16:48:32	1.07
16:48:57	1.062
16:49:20	1.072
16:49:45	1.072
16:50:10	1.072
16:50:33	1.083
16:50:58	1.088
16:51:23	1.077
16:51:48	1.071
16:52:13	1.074
16:52:37	1.061
16:53:02	1.071
16:53:27	1.07
16:53:52	1.074
16:54:17	1.083
16:54:42	1.077
17:50:08	1.066
17:50:33	1.067
17:50:58	1.069
17:51:23	1.069
17:51:48	1.072
17:52:13	1.077
17:52:38	1.072
17:53:03	1.067
17:53:28	1.061
17:53:53	1.068
17:54:17	1.059
17:54:42	1.06
17:55:07	1.064
17:55:32	1.065
17:55:57	1.061
17:56:22	1.061
17:56:47	1.063
17:57:12	1.059
17:57:37	1.055
17:58:01	1.06
17:58:26	1.059
17:58:51	1.069

	Average	Standard Deviation
Experiment # 1	1.074375	0.006261
Experiment # 2	1.064667	0.005281
Experiment # 3	1.064875	0.006886
Experiment # 4	1.0742	0.004983
Selected Data	1.069577	0.007518

17:59:16	1.068
17:59:41	1.061
19:00:10	1.058
19:00:35	1.063
19:01:00	1.065
19:01:24	1.063
19:01:49	1.063
19:02:14	1.062
19:02:39	1.067
19:03:04	1.064
19:03:29	1.062
19:03:54	1.057
19:04:19	1.054
19:04:43	1.055
19:05:08	1.057
19:05:33	1.06
19:05:58	1.068
19:06:23	1.066
19:06:48	1.069
19:07:13	1.073
19:07:37	1.078
19:08:02	1.079
19:08:27	1.077
19:08:52	1.07
19:09:17	1.065
19:09:42	1.062
20:00:00	1.073
20:00:25	1.074
20:00:50	1.073
20:01:13	1.077
20:01:38	1.076
20:02:03	1.076
20:02:28	1.071
20:02:53	1.071
20:03:16	1.069
20:03:41	1.072
20:04:04	1.073
20:04:29	1.074
20:04:54	1.074
20:05:18	1.069
20:05:43	1.065
20:06:08	1.065
20:06:33	1.07
20:06:58	1.074
20:07:23	1.077
20:07:48	1.082
20:08:13	1.083
20:08:37	1.078
20:09:02	1.074
20:09:27	1.08
20:09:50	1.085

Well A - Well B Both Wells on Surface Plate 11-05-1999

		Average	Standard Deviation
Experiment # 1		0.779958	0.000908
Experiment # 2		0.777417	0.000584
Selected Data		0.778688	0.00149

15:55:00	0.781
15:55:25	0.782
15:55:50	0.781
15:56:15	0.781
15:56:40	0.781
15:57:05	0.78
15:57:31	0.781
15:57:56	0.781
15:58:21	0.78
15:58:46	0.78
15:59:11	0.78
15:59:36	0.78
16:00:02	0.779
16:00:27	0.78
16:00:52	0.78
16:01:17	0.779
16:01:42	0.78
16:02:08	0.779
16:02:33	0.779
16:02:58	0.779
16:03:23	0.779
16:03:48	0.779
16:04:13	0.779
16:04:39	0.779
16:20:24	0.779
16:20:49	0.778
16:21:14	0.778
16:21:39	0.777
16:22:04	0.778
16:22:29	0.778
16:22:54	0.778
16:23:19	0.777
16:23:44	0.777
16:24:09	0.777
16:24:34	0.777
16:24:59	0.778
16:25:24	0.778
16:25:49	0.777
16:26:14	0.777
16:26:39	0.777
16:27:04	0.777
16:27:29	0.778
16:27:54	0.777
16:28:19	0.777
16:28:44	0.777
16:29:09	0.777
16:29:34	0.777
16:29:58	0.777

Well A - Well B Both Wells on Surface Plate 11-11-1999

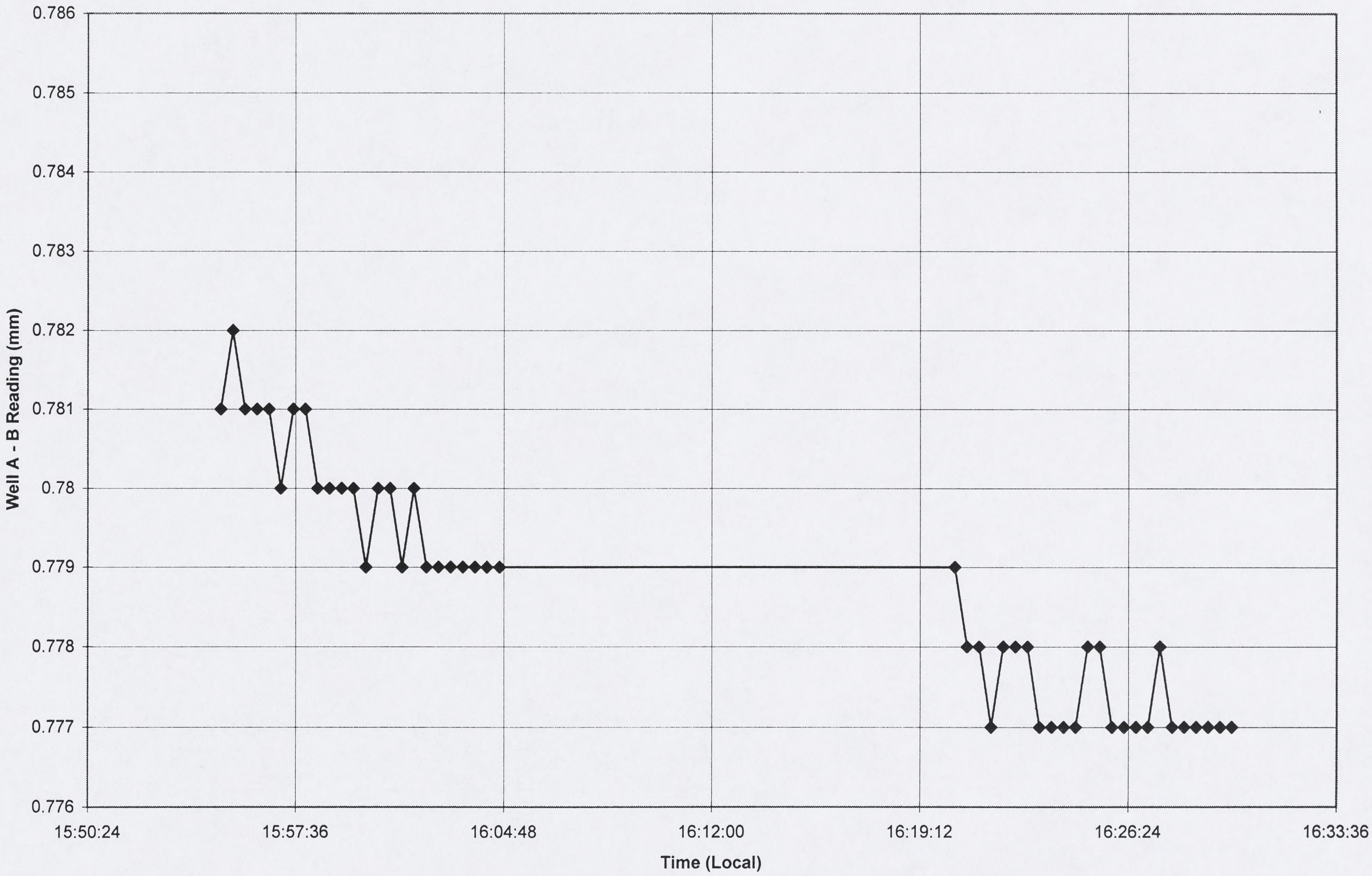
11:25:20	0.787	11:30:22	0.788

11:25:20	0.787
11:25:46	0.787
11:26:11	0.788
11:26:36	0.789
11:27:01	0.791
11:27:26	0.79
11:27:51	0.789
11:28:16	0.789
11:28:42	0.788
11:29:07	0.788
11:29:32	0.789
11:29:57	0.788
11:30:22	0.788
11:30:47	0.79
11:31:12	0.79
11:31:37	0.791
11:32:02	0.791
11:32:27	0.791
11:32:53	0.791
11:33:18	0.792
11:33:43	0.791
11:34:08	0.792
11:34:33	0.792
11:34:58	0.79
13:15:20	0.79
13:15:45	0.79
13:16:10	0.791
13:16:35	0.791
13:17:00	0.79
13:17:25	0.789
13:17:50	0.788
13:18:15	0.789
13:18:40	0.789
13:19:06	0.789
13:19:31	0.789
13:19:56	0.79
13:20:21	0.79
13:20:45	0.79
13:21:10	0.79
13:21:35	0.789
13:22:01	0.788
13:22:26	0.79
13:22:51	0.789
13:23:16	0.79
13:23:41	0.789
13:24:06	0.789
13:24:31	0.791
13:24:56	0.789

	Average	Standard Deviation
Experiment # 1	0.789667	0.001579
Experiment # 2	0.789542	0.000833
Selected Data	0.789604	0.00125
Selected Data From 11-05&11-1999	0.784146	0.005655

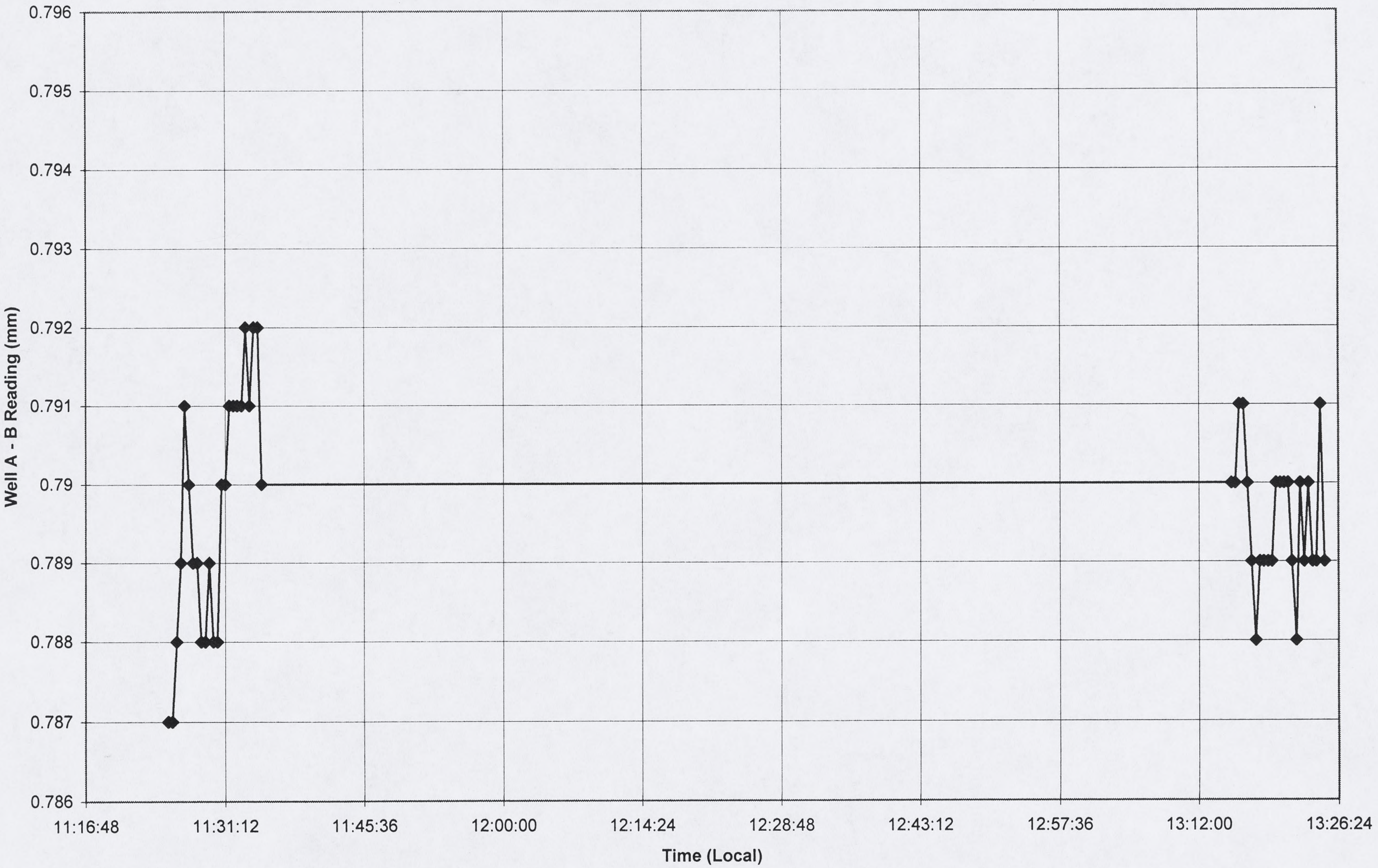
Hydrostatic Level Data 11-05-1999 Well A & B on Surface Plate

File: 1105.xls Disk: B298



Hydrostatic Level Data 11-11-1999 Well A & B on Surface Plate

File: 1111.xls Disk: B298



	(+) BS	(-) FS	Elevation	N 3
ZY106	-0.043708333		0	0
ZY105			-0.827854167	-.615
ZY104	1.06957732	0.839465753	-0.883174087	-.120
ZY103			-0.597742601	-1,08
Instrument Constant		0.784145833		