CYCLES 0 & 1.
Station = G-2889

Cycle Testing Results for the Aquifer Storage and Recovery System at the Broward County Office of Environmental Services 2A Water Treatment Plant

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Introduction

The Broward County Office of Environmental Resources (BCOES) 2A Water Treatment Plant (WTP) aquifer storage and recovery (ASR) system was completed in 1997. The ASR system was designed and constructed to store raw Biscayne aquifer water during periods when excess water is available and to recover the stored water during periods of high demand. Figures 1 and 2 provide a location map and site plan of the 2A WTP and associated ASR system, respectively.

The Florida Department of Environmental Protection (FDEP) issued approval to begin cycle testing of the ASR system on April 9, 1998. Cycle testing was conducted to evaluate the hydraulic performance of the ASR system and determine the water quality effects of recharge of fresh water into the relatively saline water of the ASR zone. Cycle testing typically consists of several cycles, each of which include a period of recharging water into the ASR zone followed by recovery of water from the ASR zone until a predetermined recovered water quality threshold has been reached. A short storage period between the recharge and recovery periods may also be included in a cycle.

Prior to beginning true cycle testing, a brief mini-cycle (Cycle 0) was conducted to allow equipment testing of the ASR system and allow a quick appraisal of the water quality effects resulting from recharge of water into the ASR zone. Cycle 1 was conducted following completion of Cycle 0. The purpose of this Technical Memorandum is to present the results of Cycle 0 and Cycle 1.

Background

The ASR system consists of an ASR well and single-zone monitor well, both of which are completed into the Floridan aquifer system. The ASR well was constructed with 16-inch steel casing to a depth of 995 feet below pad level (bpl) and an open hole interval to a depth of 1,200 feet bpl. The single-zone monitor well was constructed approximately 275 due west of the ASR well with 6-5/8 inch steel casing to a depth of 990 feet bpl and an open hole interval to 1,200 feet bpl. The monitor well was constructed to monitor the water quality of the stored water within the ASR zone. Figure 3 provides a completion diagram of the ASR well and single-zone monitor well.

Cycle 0

Cycle 0 was conducted from July 9, 1998 through July 21, 1998, and consisted of a 10 day recharge period and a 2 day recovery period. The recharge and recovery rates were both approximately 2 million gallons per day (mgd). Approximately 20 million gallons were recharged into the ASR zone and approximately 4 million gallons were recovered during Cycle 0. All of the equipment and instrumentation associated with the ASR system were found to be operating properly during Cycle 0.

WTP personnel collected water samples from the ASR well and monitor well twice a day throughout Cycle 0. Samples underwent analysis for chloride, conductivity, total hardness, calcium hardness, total alkalinity, iron, color, turbidity, temperature and pH. A summary of the water quality data for Cycle 0 is provided in Attachment A. Water sampling was conducted to evaluate the quality of water being recharged and recovered at the ASR well and to monitor water quality changes at the monitor well.

Figures 4 through 9 present graphs of the water quality for the ASR well for the entire cycle. Water quality at the ASR well was consistent throughout the recharge period except for minor fluctuations in iron and color. An increasing trend in chloride, conductivity, hardness, and turbidity and a decreasing trend in iron and color took place in the recovered water shortly after recovery began. These water quality changes at the ASR well reflect the recovery of water that is a mixture of recharged water and native Floridan aquifer water. Alkalinity, temperature, and pH of the recharge water and the native Floridan aquifer water are similar, therefore, these parameters remained consistent at the ASR well throughout both the recharge and recovery periods of Cycle 0.

Graphs presenting water quality for the monitor well during Cycle 0 are presented in Figures 10 through 15. Water quality fluctuations at the monitor well during the first 4 days of the recharge period of Cycle 0 are related to natural fluctuations in water quality and precision of analytical equipment. A freshening trend at the monitor well is evident after the 4th day of recharge. This freshening trend reflects a mixing of recharge water with native Floridan aquifer water. The freshening trend began to reverse approximately one half day after recovery began, however, water quality parameters at the monitor well did not return to background levels prior to the completion of Cycle 0.

Cycle 1

Prior to beginning Cycle 1, a target water quality criteria of 250 mg/L of chloride in the recovered water was selected as the recovery cut-off criteria at which recovery should cease. The cut-off criteria of 250 mg/L of chloride corresponds to the primary drinking water standard limit for chloride.

A total of 171 million gallons of raw Biscayne aquifer water was recharged into the ASR zone over the period from July 27, 1998 to October 26, 1998. Recovery took place from October 26, 1998 to November 12, 1998. The rate of recharge and recovery was approximately 2.0 mgd.

Water quality samples were collected twice a day at the ASR well and monitor well throughout Cycle 1. A summary of the water quality data for Cycle 1 is provided in Attachment B. Graphs presenting water quality data from the ASR well for Cycle 1 are

provided in Figures 16 through 21. Generally, water quality at the ASR well during recharge was stable with the exception of minor fluctuations in hardness and alkalinity and a few peaks in iron, color, and turbidity. Water quality remained stable and similar to that of the recharge water through the first 5 days of the 20-day recovery period. An increasing trend in chloride, conductivity, and hardness of the recovered water at the ASR well began to take place after the 5th day of recovery. The increasing trend in these parameters is an indication that the recovered water contains an increasing proportion of native Floridan aquifer water. Recovery took place until the chloride concentration of the recovered water neared 250 mg/L, at which time recovery ceased.

Figures 22 through 27 present water quality data from the monitor well for Cycle 1. Water quality fluctuations at the monitor well during the first several days of the recharge period represent natural fluctuations in water quality. Reported chloride values are greater than the reported conductivity values between the second sampling event on August 3, 1998 and the first sampling event on August 6, 1998. This suggests that the reported values for one of these parameters are inaccurate. Several days into the recharge period a decrease in chloride, conductivity, hardness, color and turbidity occurred at the monitor well. This is the result of relatively fresh recharge water mixing with native Floridan aquifer water. The increase in color and turbidity which took place approximately half way through Cycle 1 is probably related to a small amount of solids being produced from the monitor well. Alkalinity, temperature, and pH remained stable throughout Cycle 1.

An increase in chloride, conductivity, and hardness began to take place approximately 5 days into the 20-day recovery period at the monitor well. The increase in these parameters represents a decrease in the proportion of fresh recharge water at the monitor well.

As shown in Figure 24, an increase in iron concentration took place at the monitor well about half way through Cycle 1. Iron concentrations for the second half of the cycle average approximately 4 mg/L, which is about twice that of the recharge water and significantly higher than the native Floridan aquifer water. These data suggests that the steel casing of the monitor well may be contributing iron to the samples collected from the monitor well. This phenomenon will be evaluated further during subsequent cycles.

Recovery efficiency is the percentage of the water volume that was recharged into the ASR zone that is subsequently recovered prior to reaching a predetermined target water quality criteria for the recovered water. As mentioned above, a target water quality criteria of 250 mg/L of chloride was established for the recovered water. This target criteria was reached after recovering a volume of 36 million gallons of water. The resultant recovery efficiency for Cycle 1 is 21.1%. A recovery efficiency of 21.1% for the first full cycle is very good and improvement is anticipated with each subsequent cycle.

Summary and Conclusions

Cycles 0 and 1 have been completed at the BCOES 2A ASR system. Cycle 0 took place between July 9, 1998 and July 21, 1998 and was conducted to allow testing of equipment and instrumentation. All equipment and instrumentation were found to be operating properly. Water sampling at the ASR well indicated stable recharge water quality during the recharge portion of Cycle 0. A freshening trend was evident at monitor well after 4 days of recharging. This freshening trend represents the mixing of native Floridan aquifer water

with fresh recharge water at the monitor well. The freshening trend was reversed shortly after beginning to recover water at the ASR well. An increase in chloride, conductivity, and hardness in the recovered water at the ASR well took place shortly after beginning recovery.

Cycle 1 took place between July 27, 1998 and November 12, 1998. A total of 171 million gallons of water were recharged into the ASR zone during the recharge portion of Cycle 1. Thirty-six million gallons of water were recovered at the ASR well prior to reaching the target water quality criteria threshold of 250 mg/L chloride in the recovered water. The resultant recovery efficiency was 21.1%. Water quality at the monitor well demonstrated a freshening trend during the recharge portion of Cycle 1. This trend was reversed during recovery.

Results of the above discussed cycle testing indicate the ASR system will prove to be an efficient and effective component of the BCOES water supply system. A recovery efficiency of 21.1% for Cycle 1 is very good and improvements in recovery efficiency are anticipated with each subsequent cycle. Data from both of the cycles discussed above indicate there are no adverse geochemical affects from storing raw Biscayne aquifer water in the ASR zone.

Discuss recommendations/plans for Cycle 2

Figures

N.T.S.

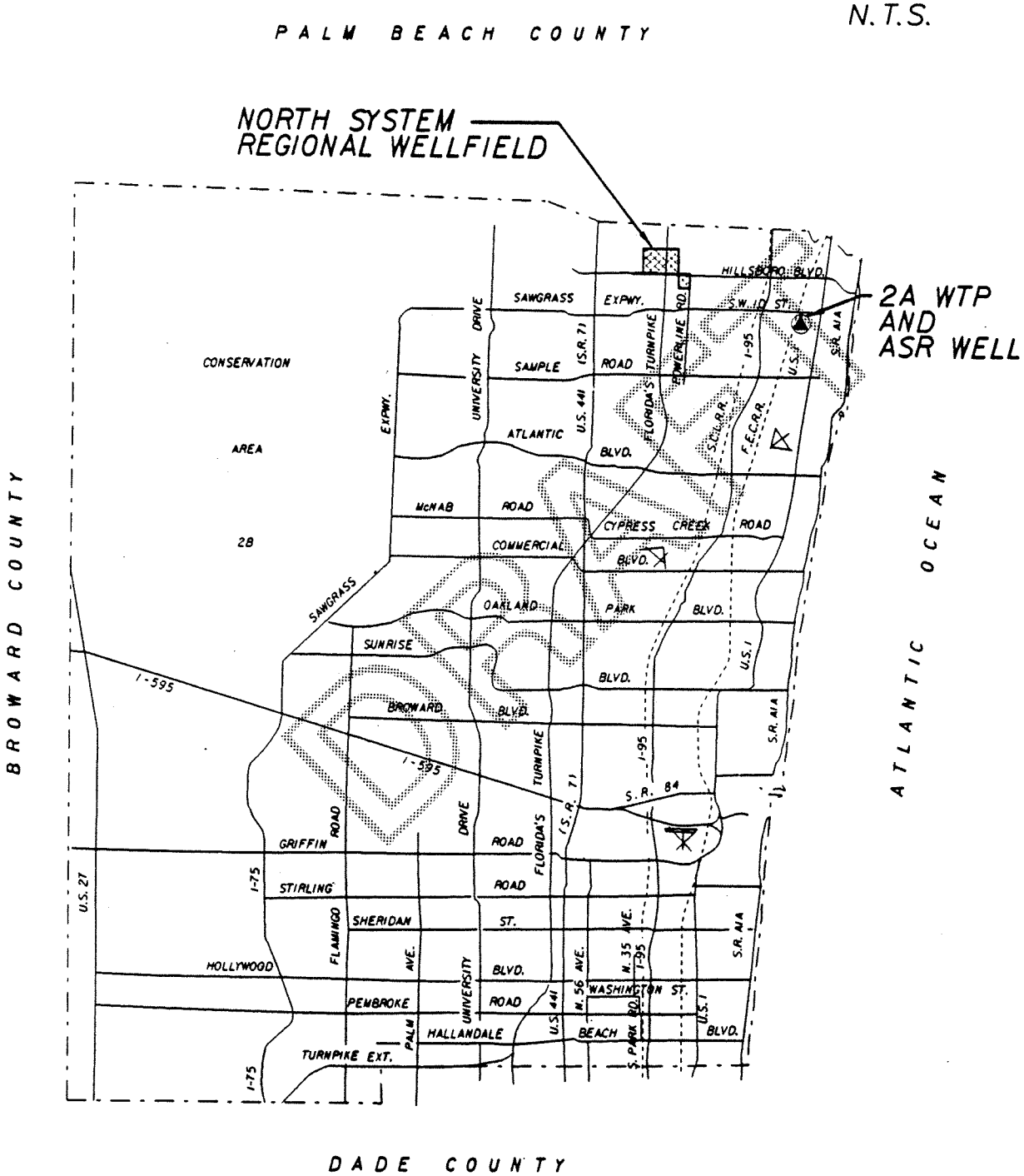

FIGURE 1
LOCATION MAP

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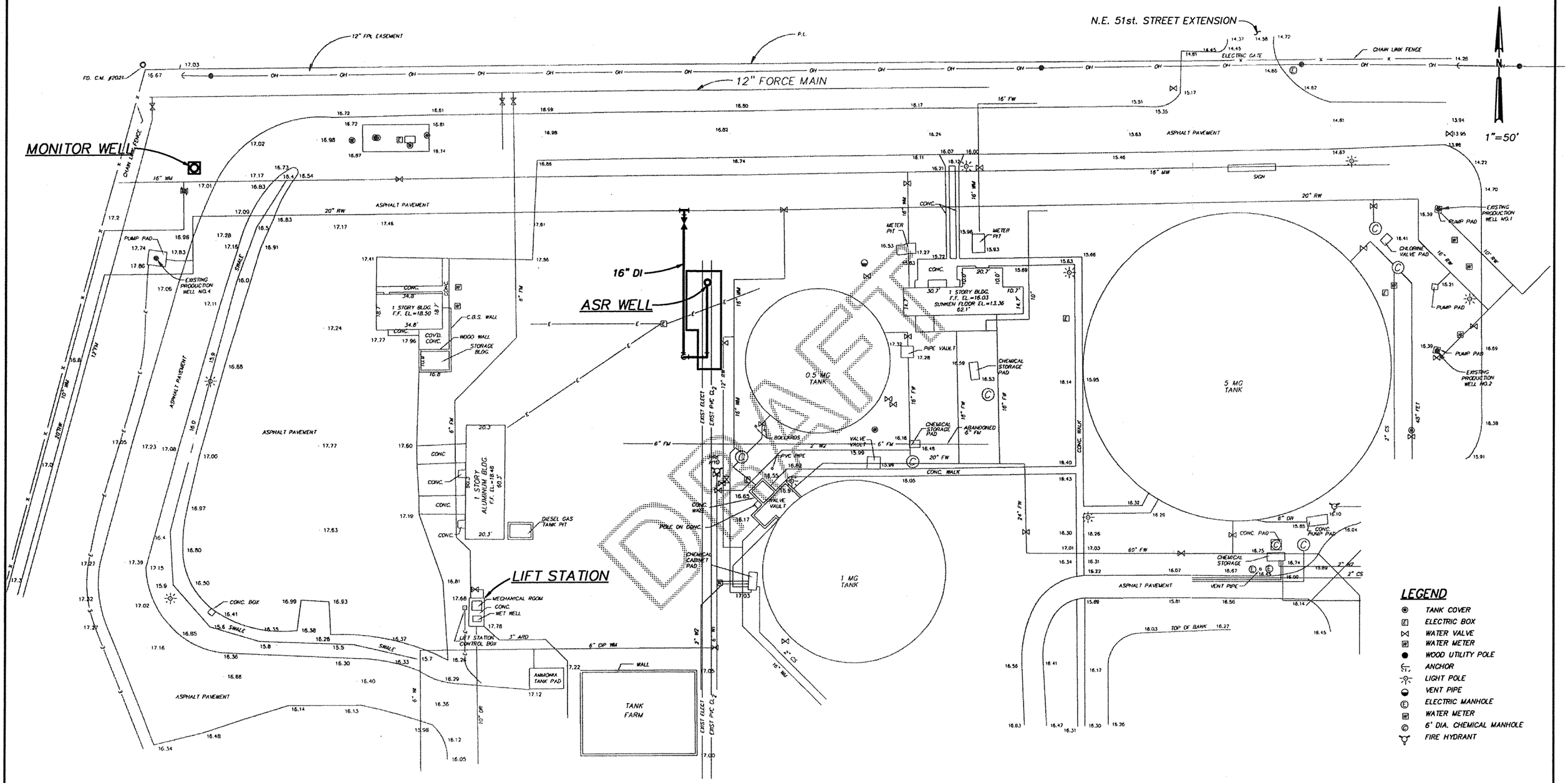

FIGURE 2
SITE PLAN

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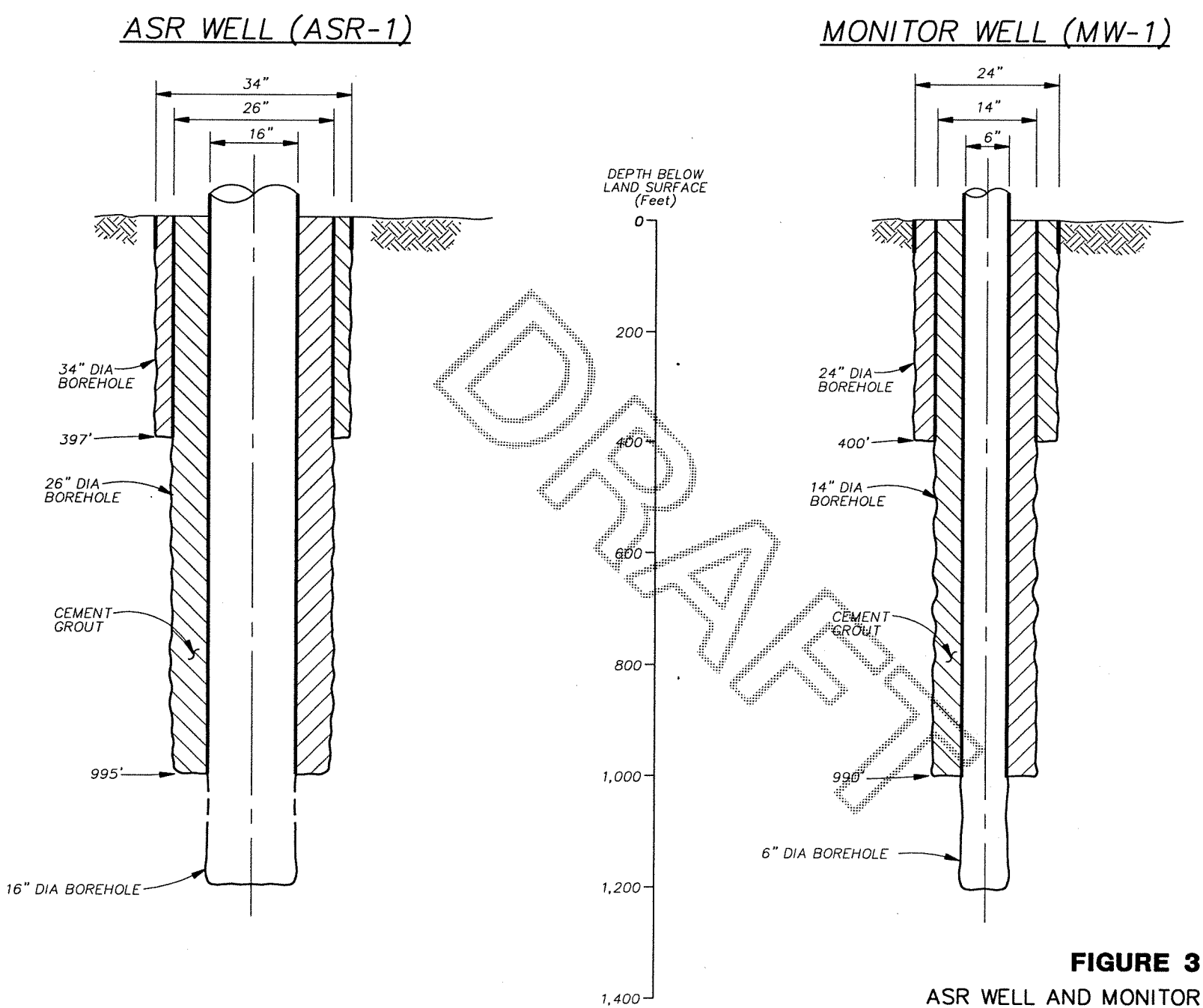

FIGURE 3

ASR WELL AND MONITOR WELL COMPLETION DIAGRAM

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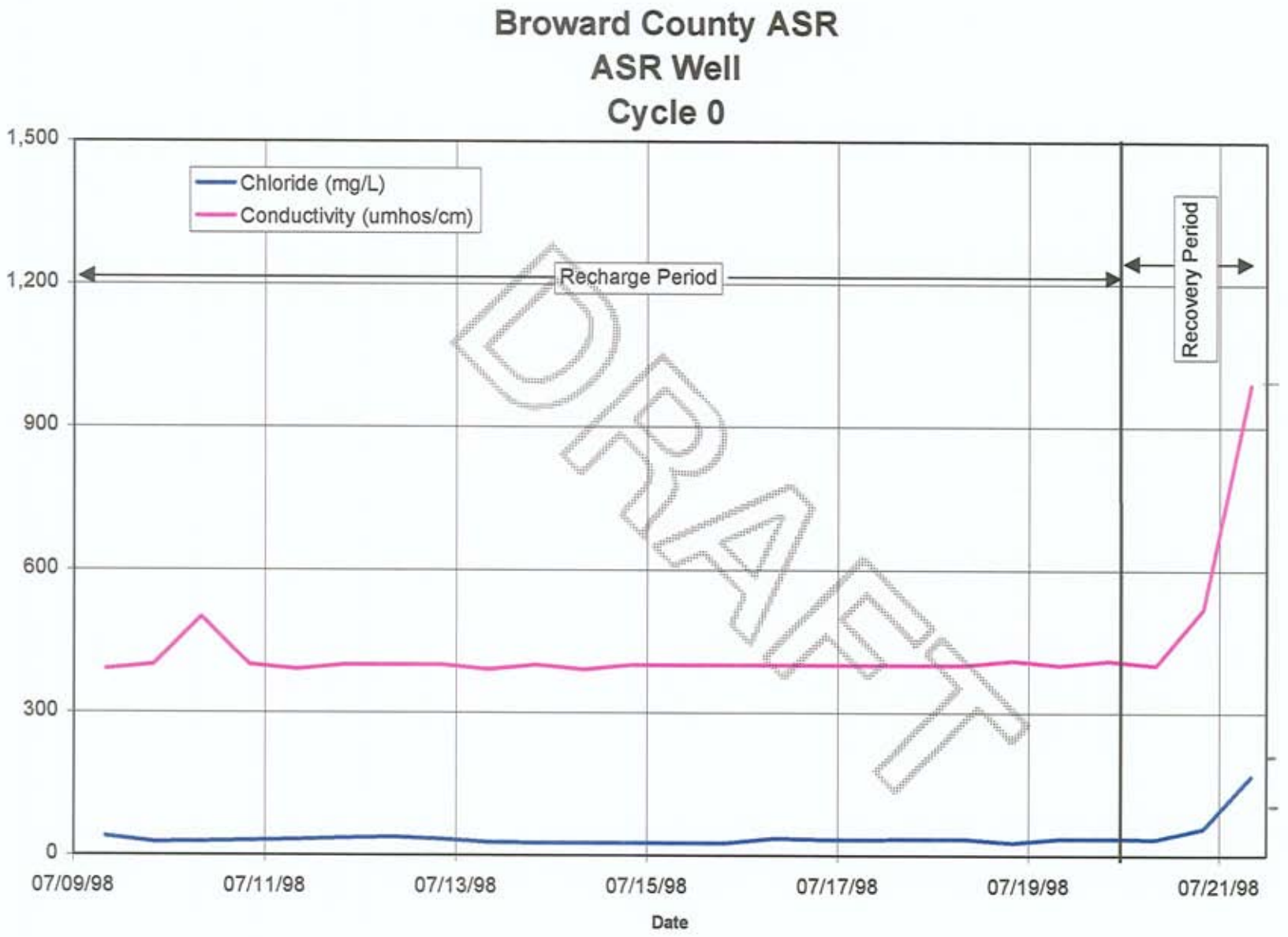


Figure 4. Cycle 0 ASR Well Chloride and Conductivity Data

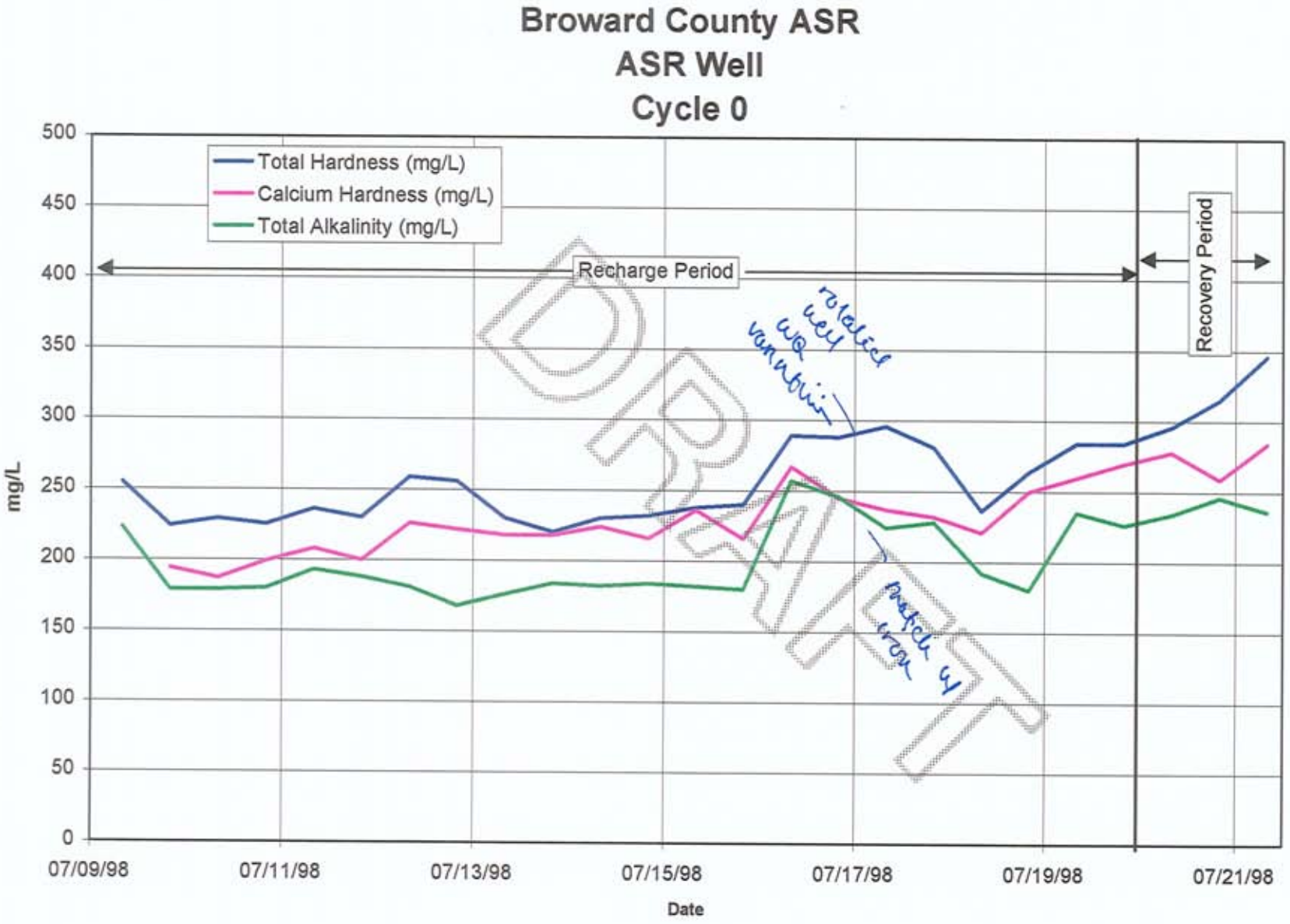


Figure 5. Cycle 0 ASR Well Hardness and Alkalinity Data

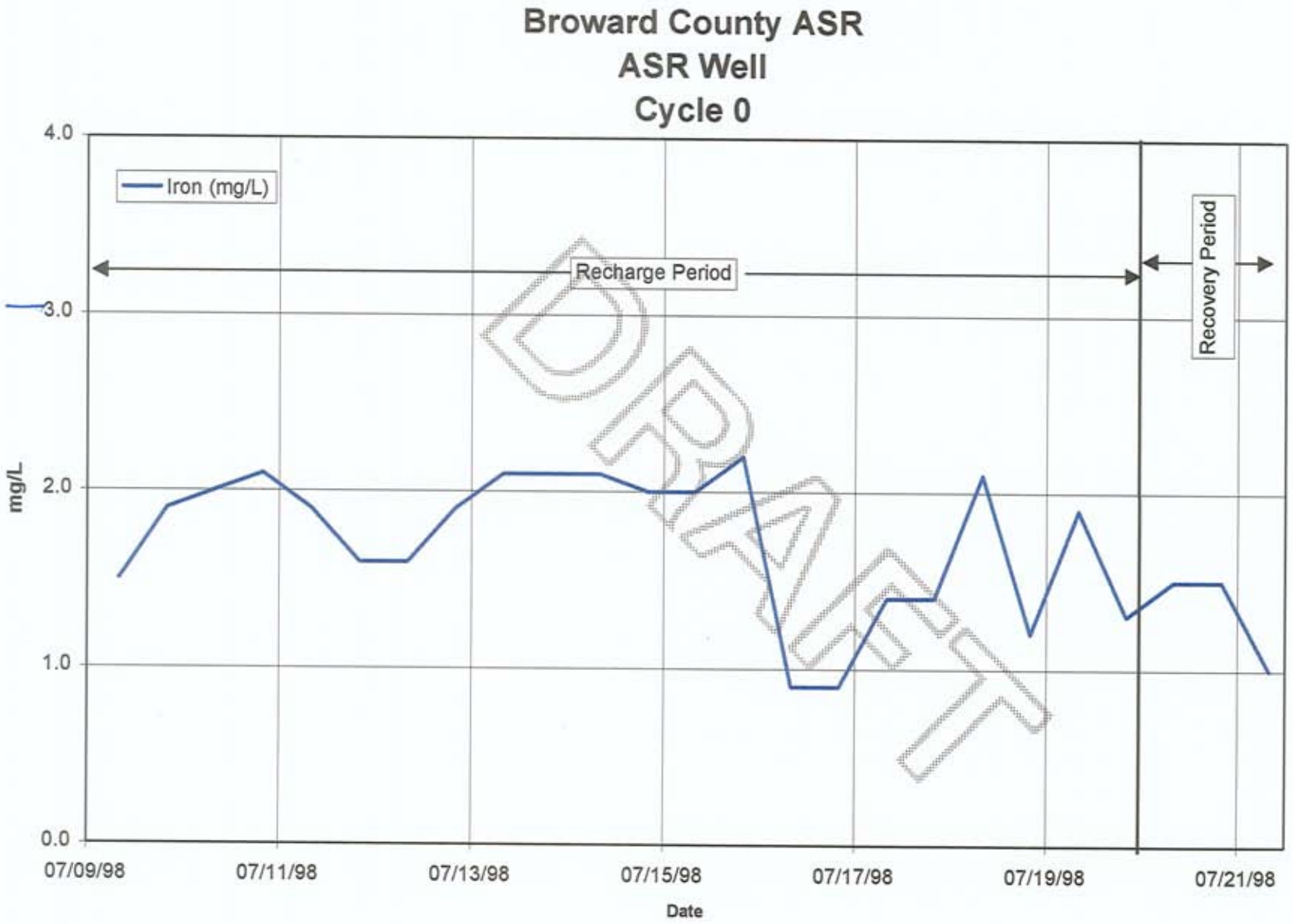


Figure 6. Cycle 0 ASR Well Iron Data

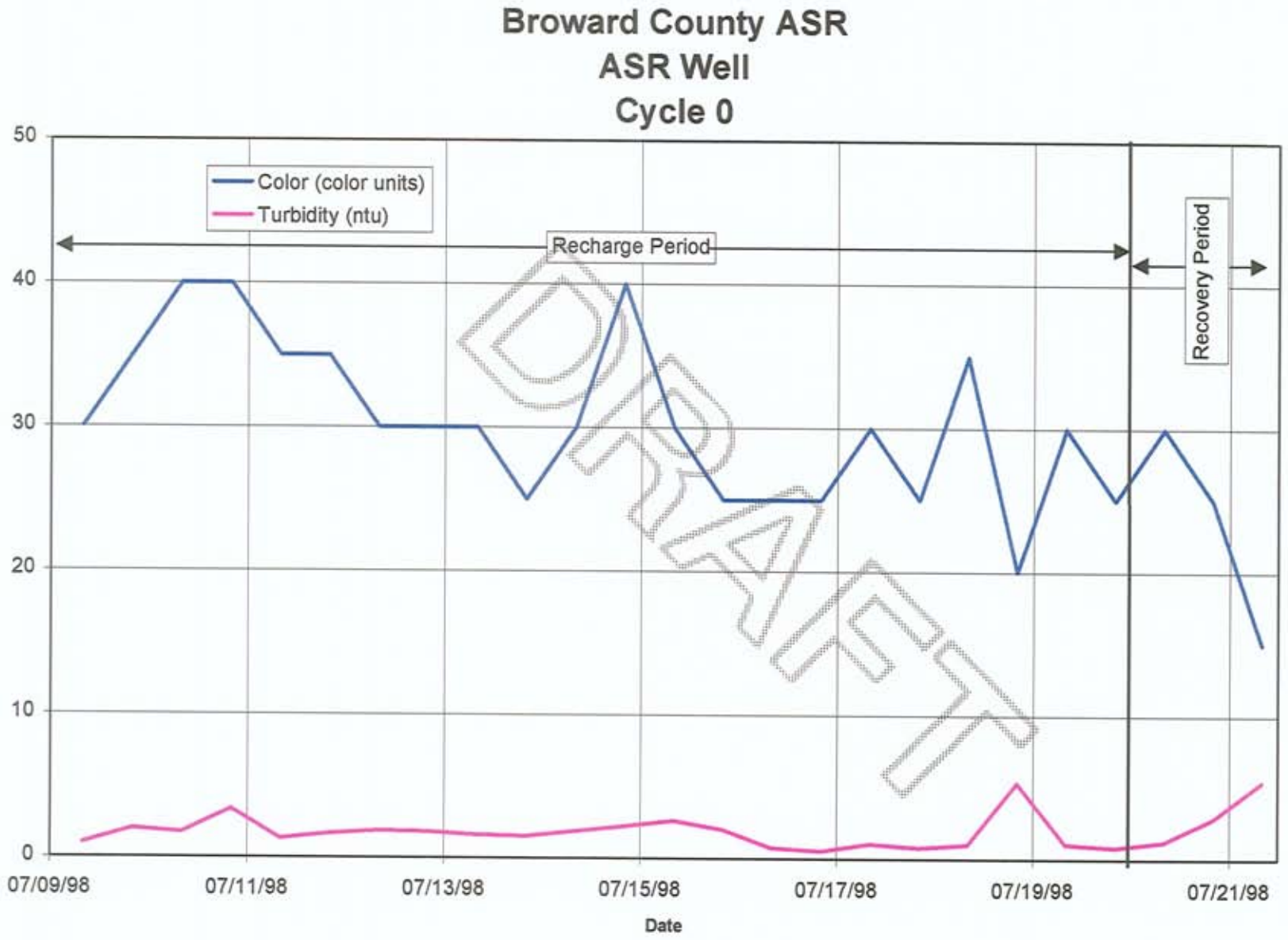


Figure 7. Cycle 0 ASR Well Color and Turbidity Data

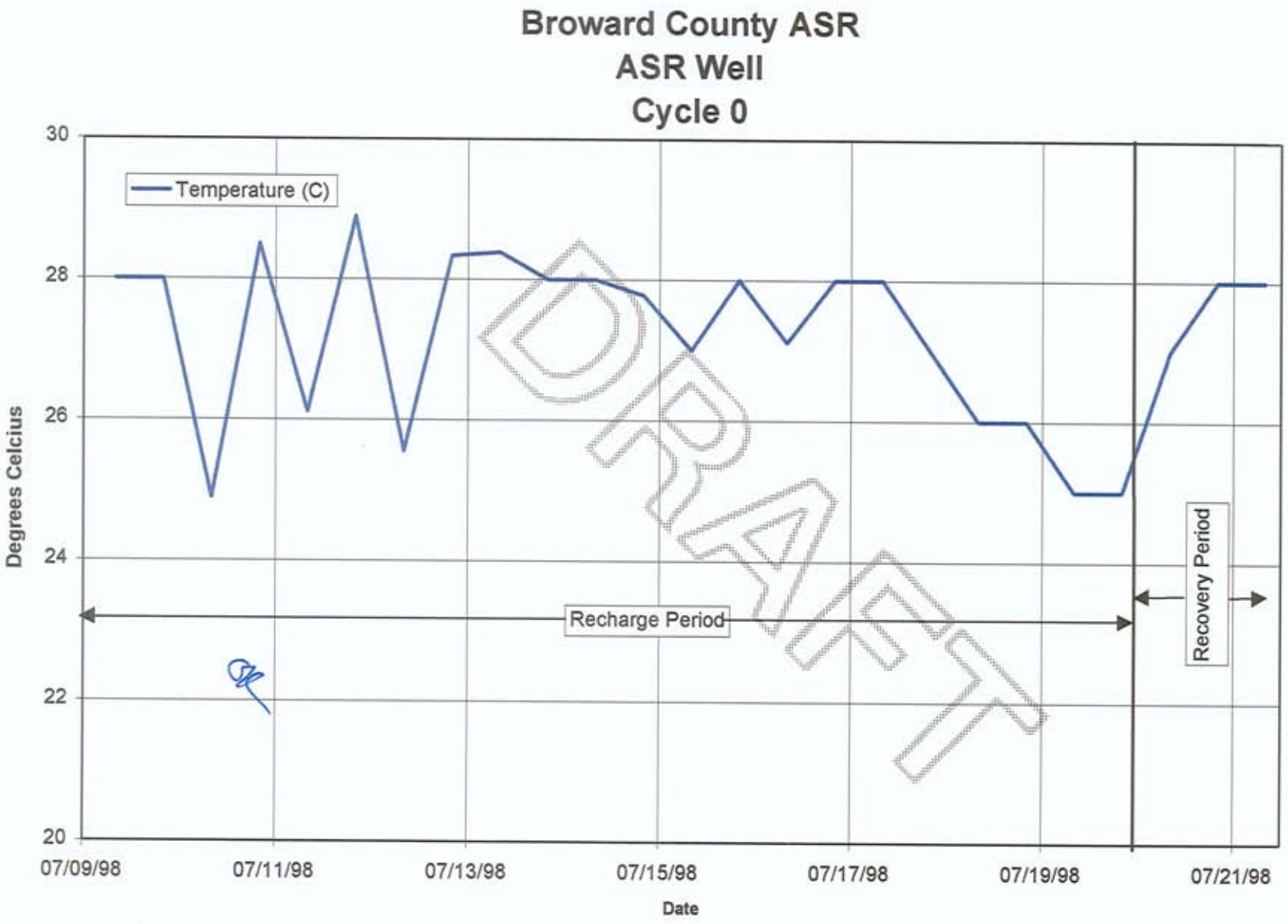


Figure 8. Cycle 0 ASR Well Temperature Data

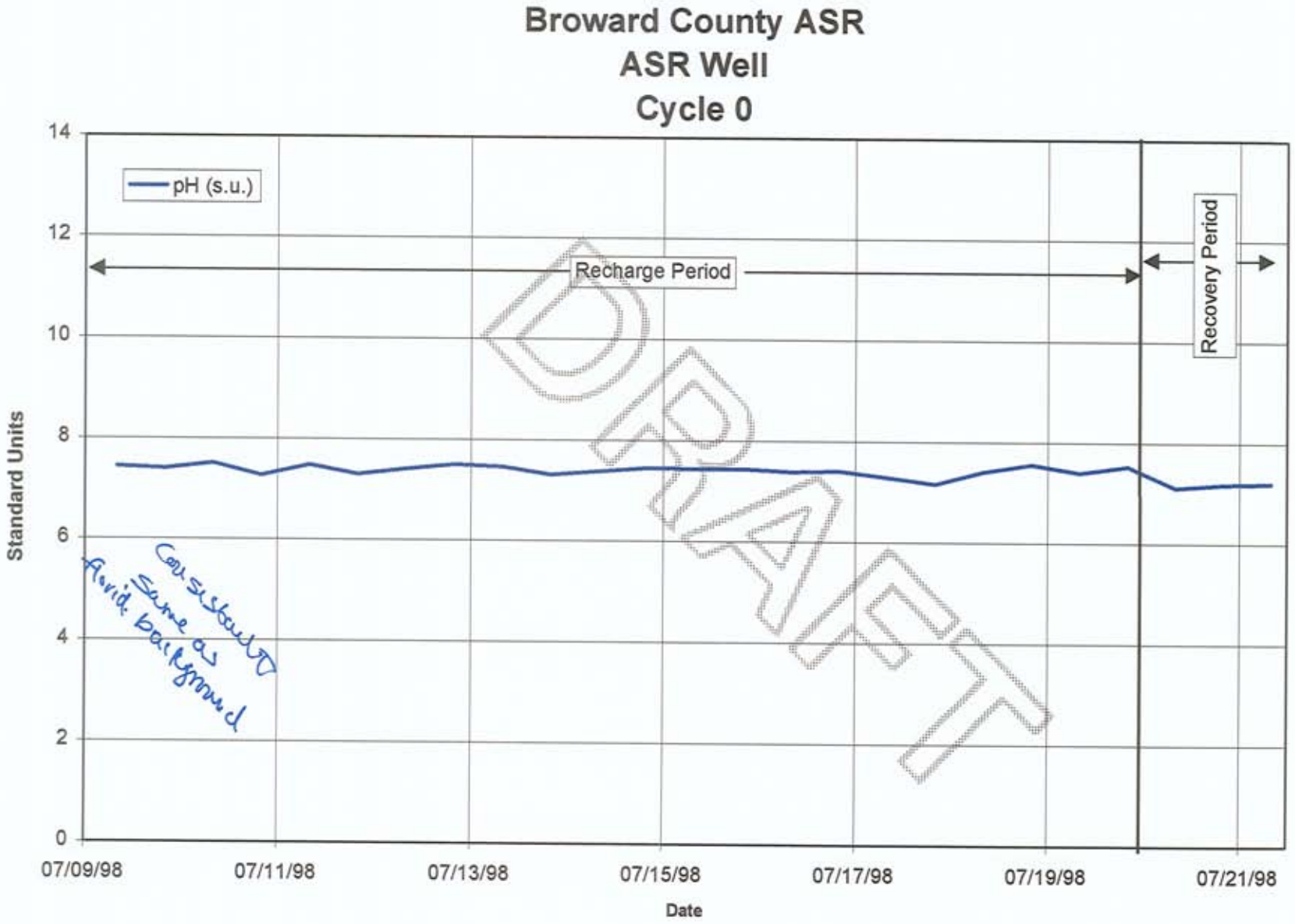


Figure 9. Cycle 0 ASR Well pH Data

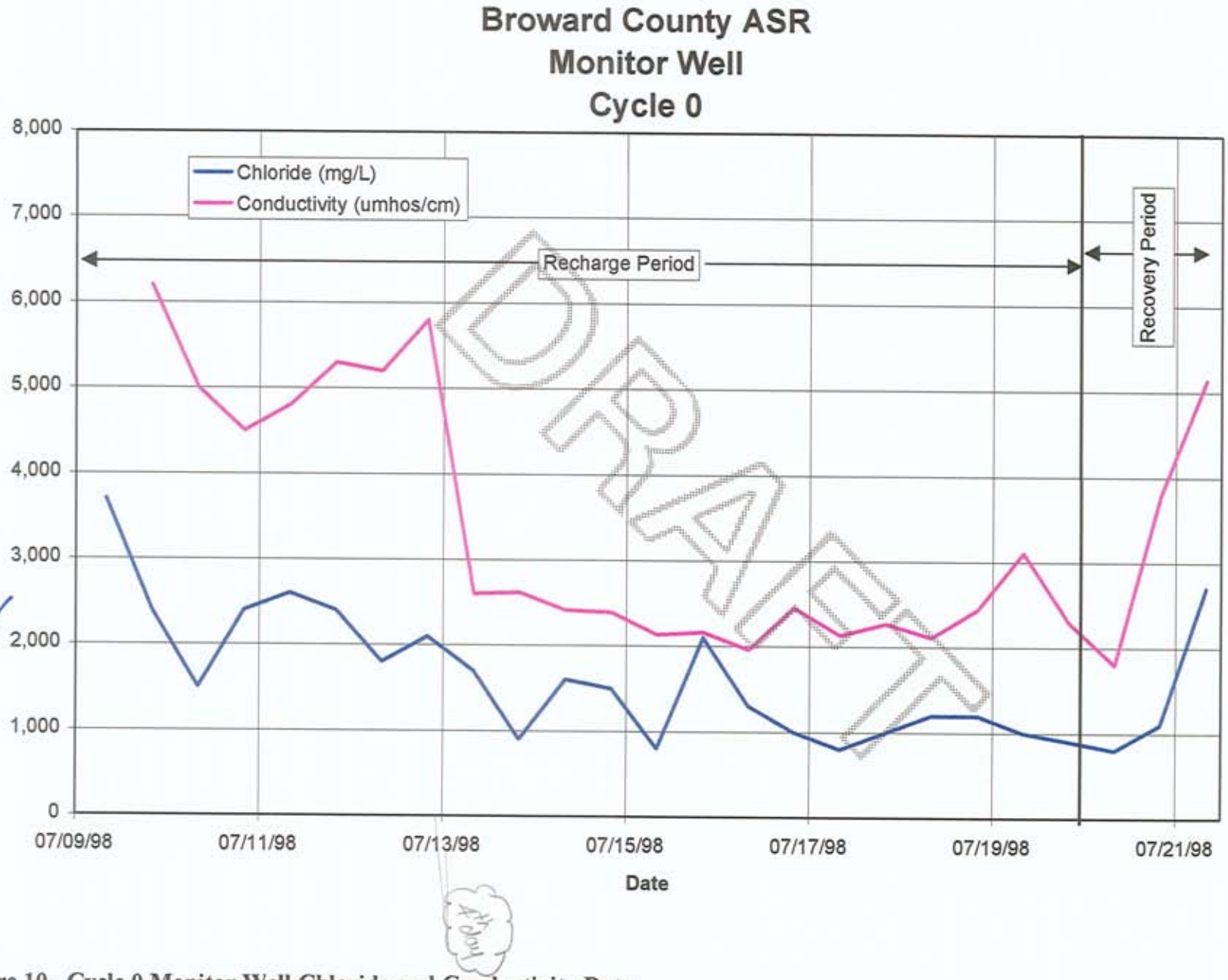


Figure 10. Cycle 0 Monitor Well Chloride and Conductivity Data

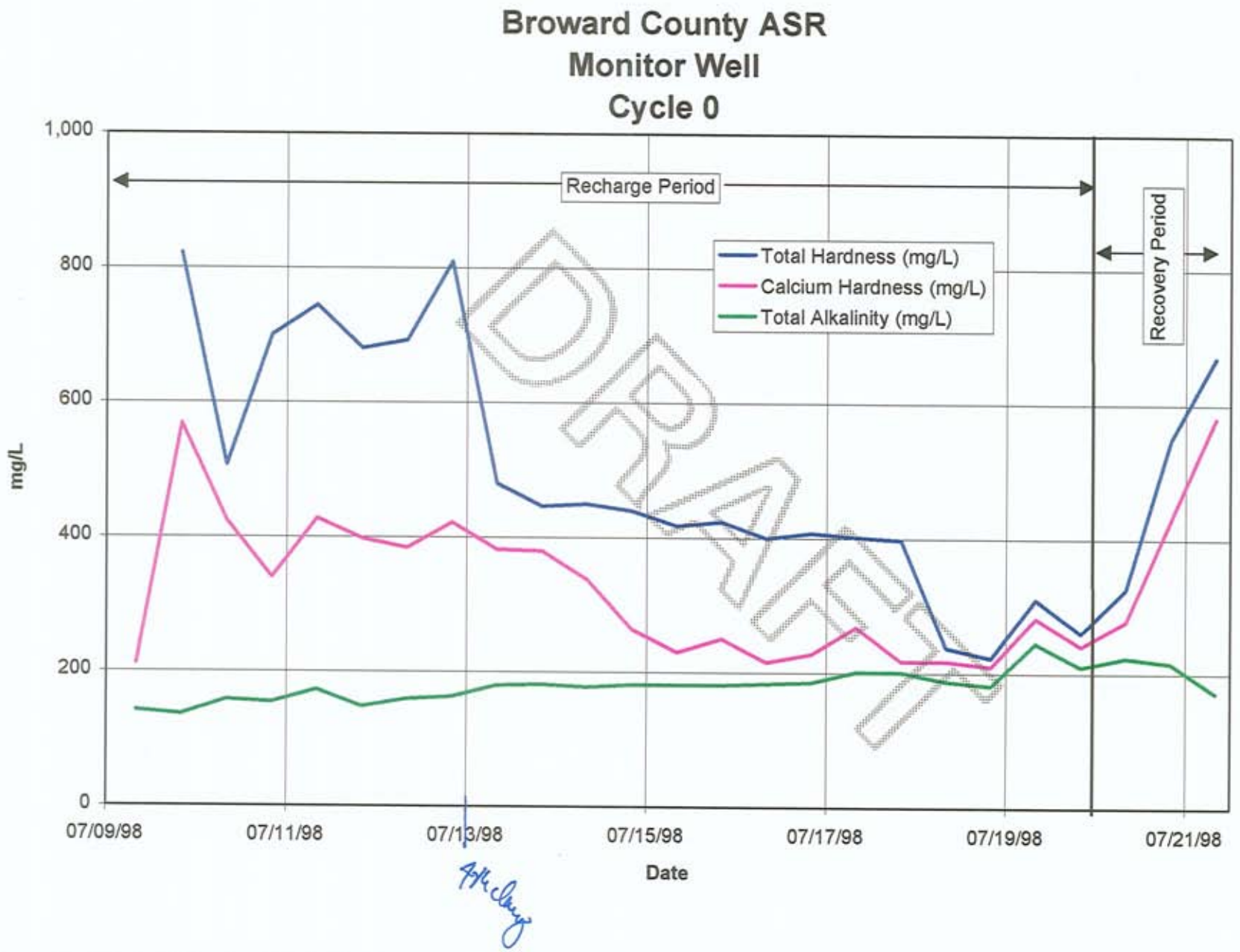


Figure 11. Cycle 0 Monitor Well Hardness and Alkalinity Data

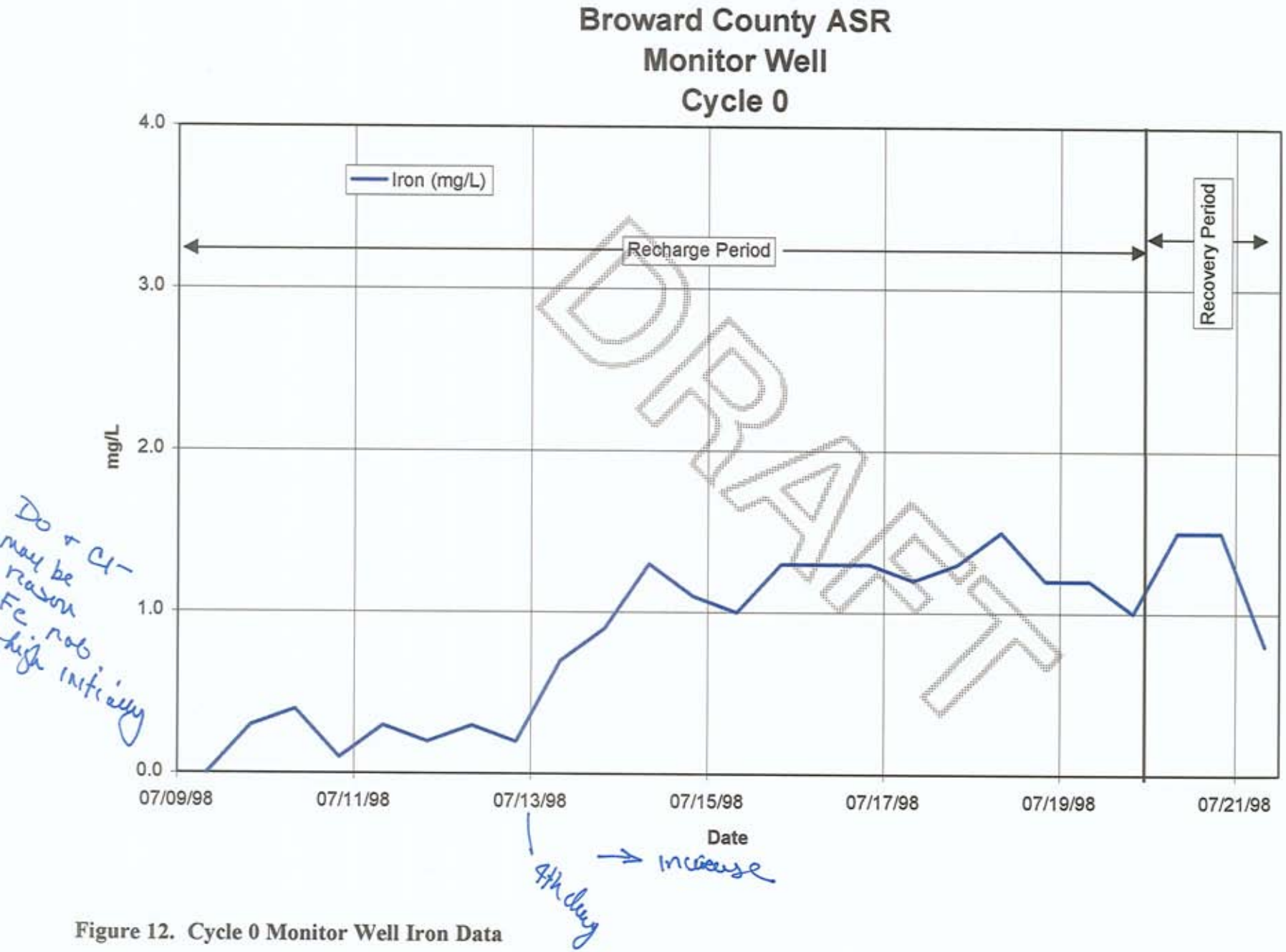


Figure 12. Cycle 0 Monitor Well Iron Data

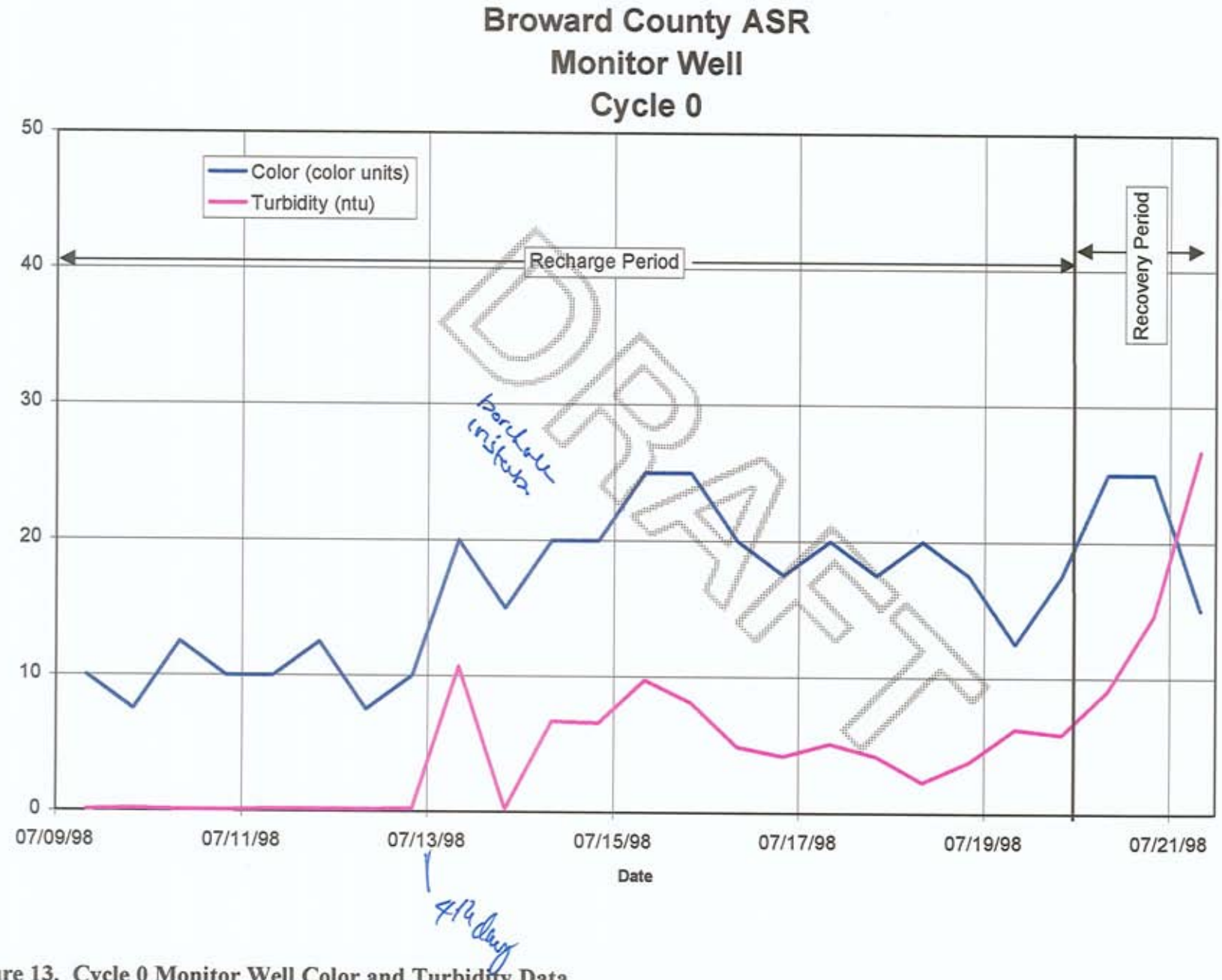


Figure 13. Cycle 0 Monitor Well Color and Turbidity Data

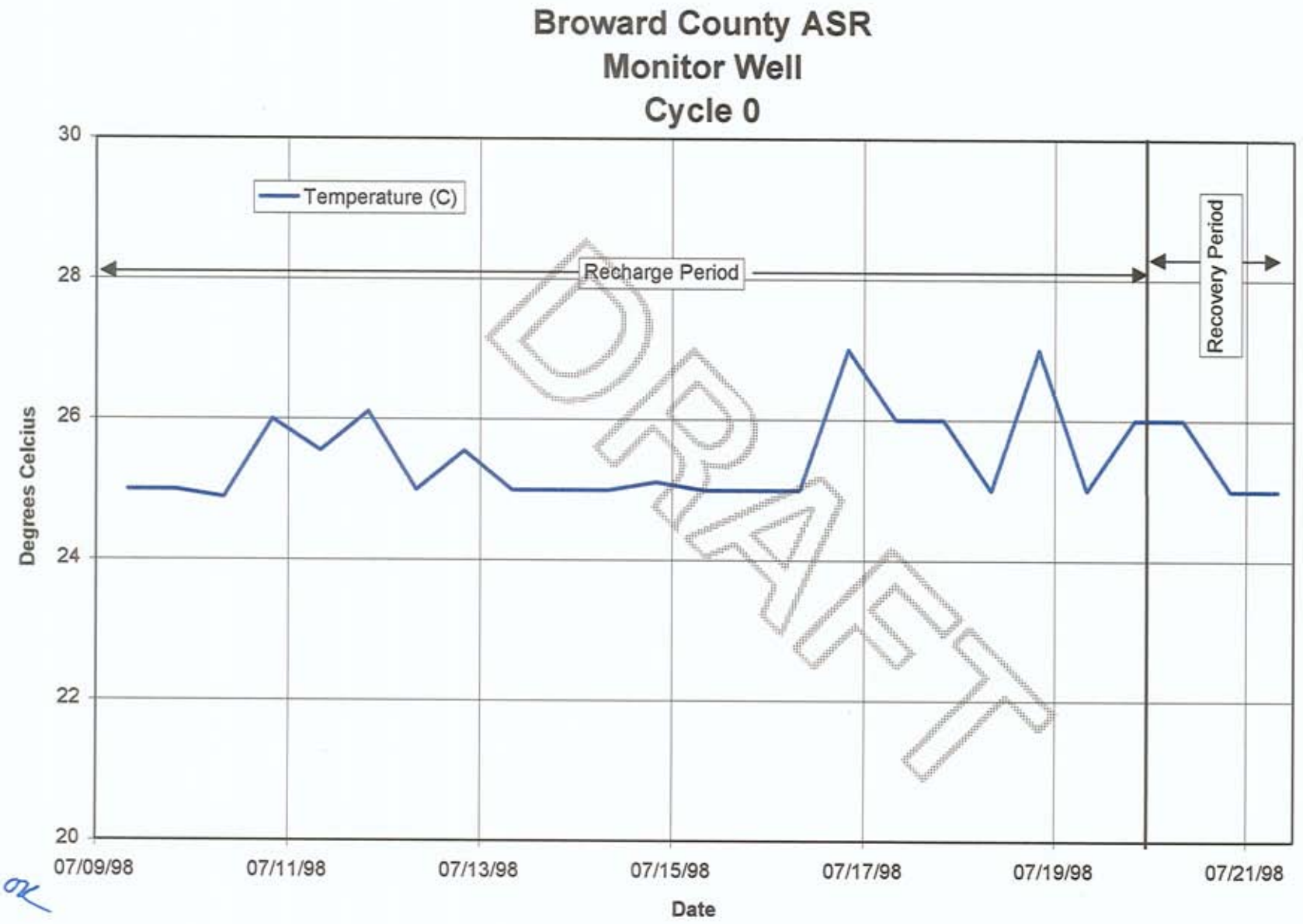
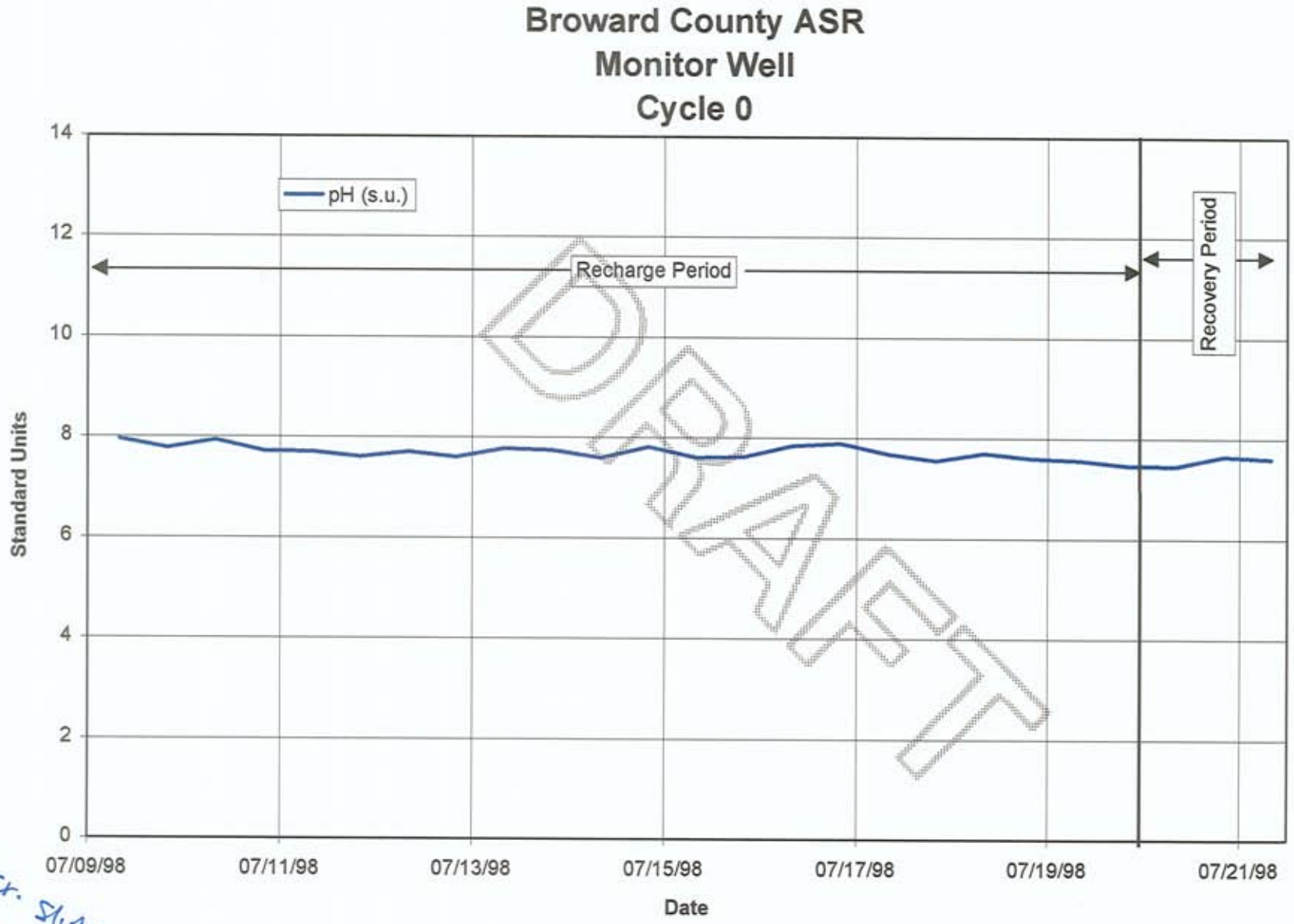


Figure 14. Cycle 0 Monitor Well Temperature Data



incr. slightly 7.3 to 7.8

Figure 15. Cycle 0 Monitor Well pH Data

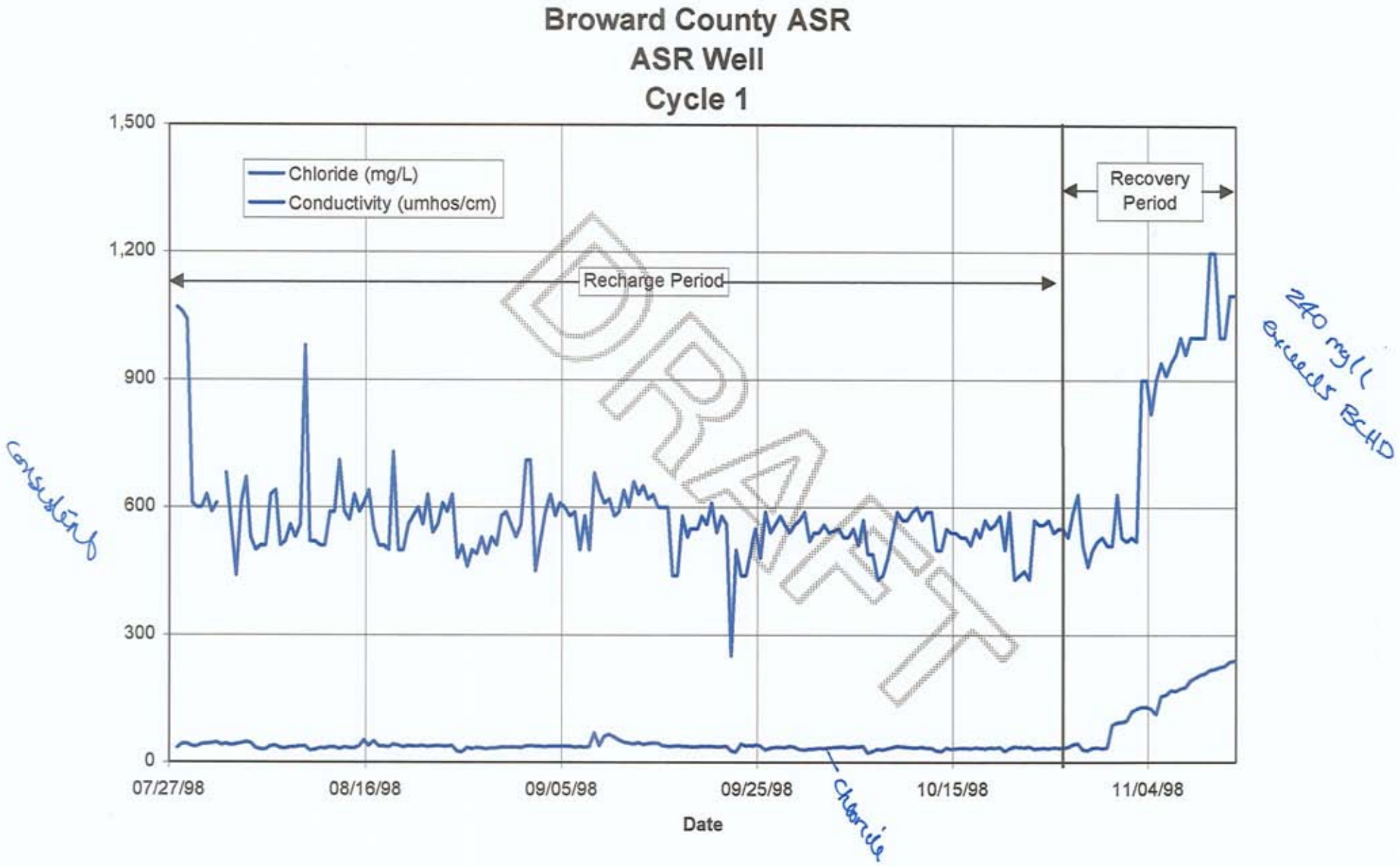


Figure 16. Cycle 1 ASR Well Chloride and Conductivity Data

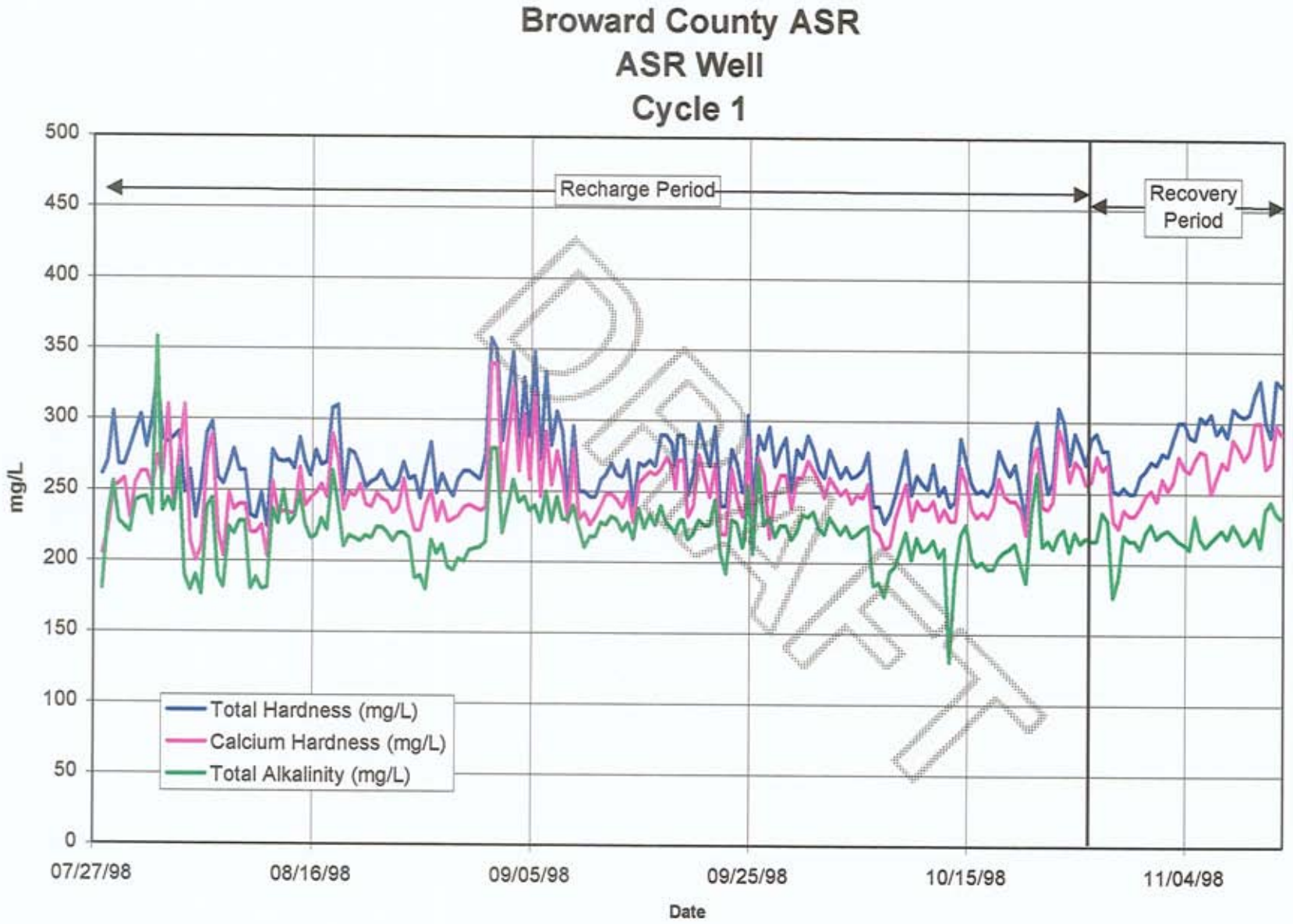


Figure 17. Cycle 1 ASR Well Hardness and Alkalinity Data

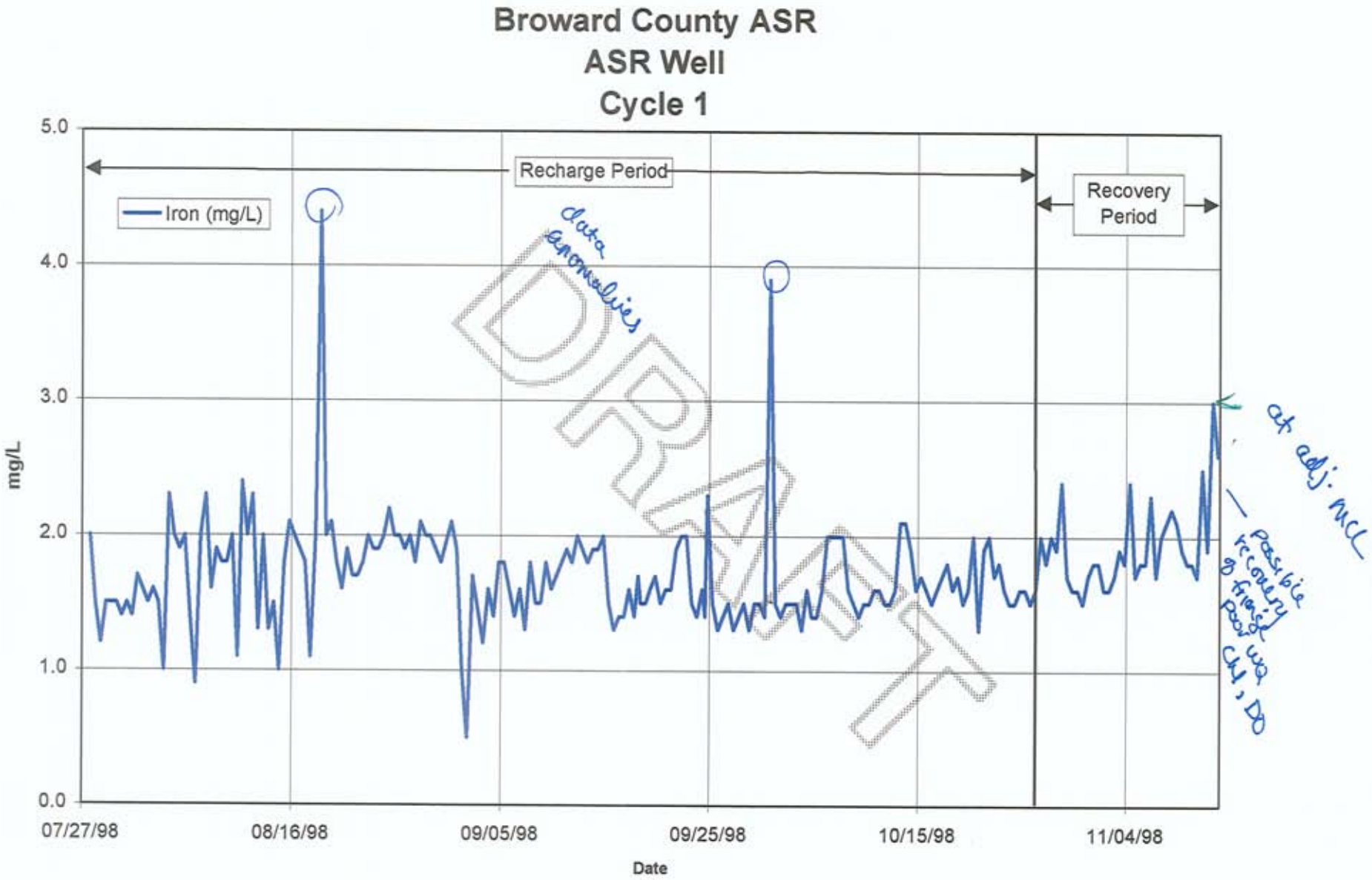


Figure 18. Cycle 1 ASR Well Iron Data

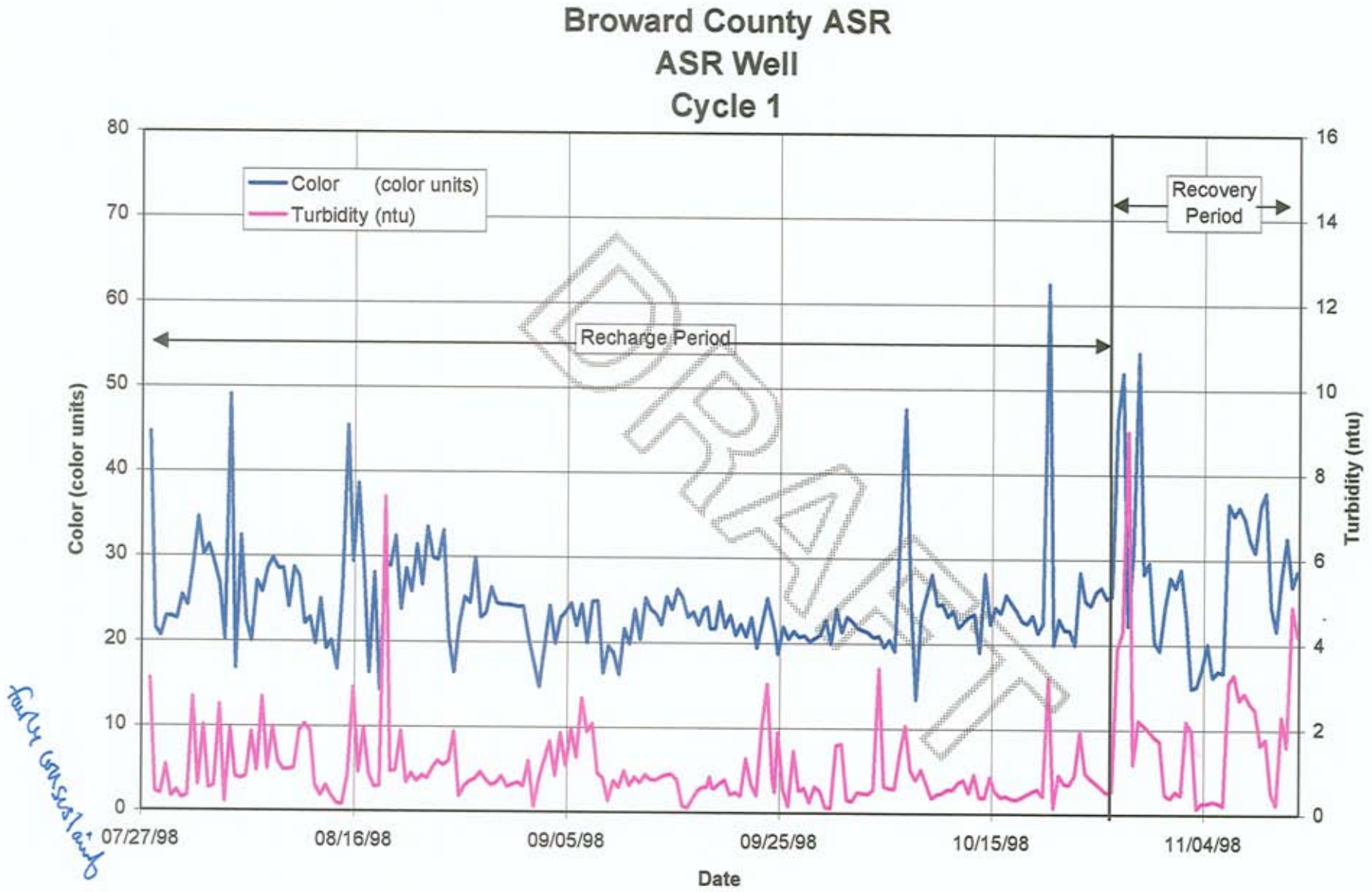


Figure 19. Cycle 1 ASR Well Color and Turbidity Data

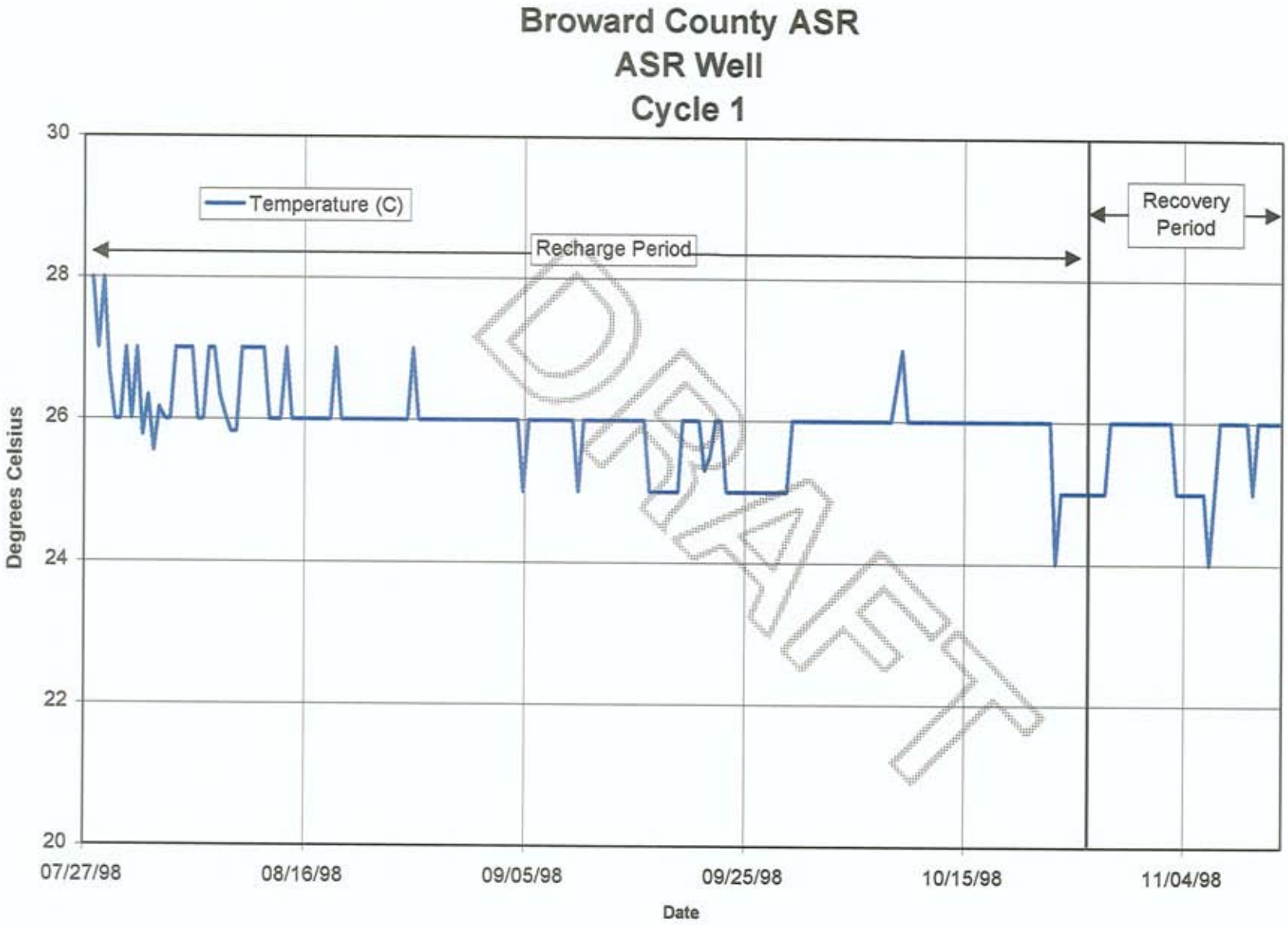


Figure 20. Cycle 1 ASR Well Temperature Data

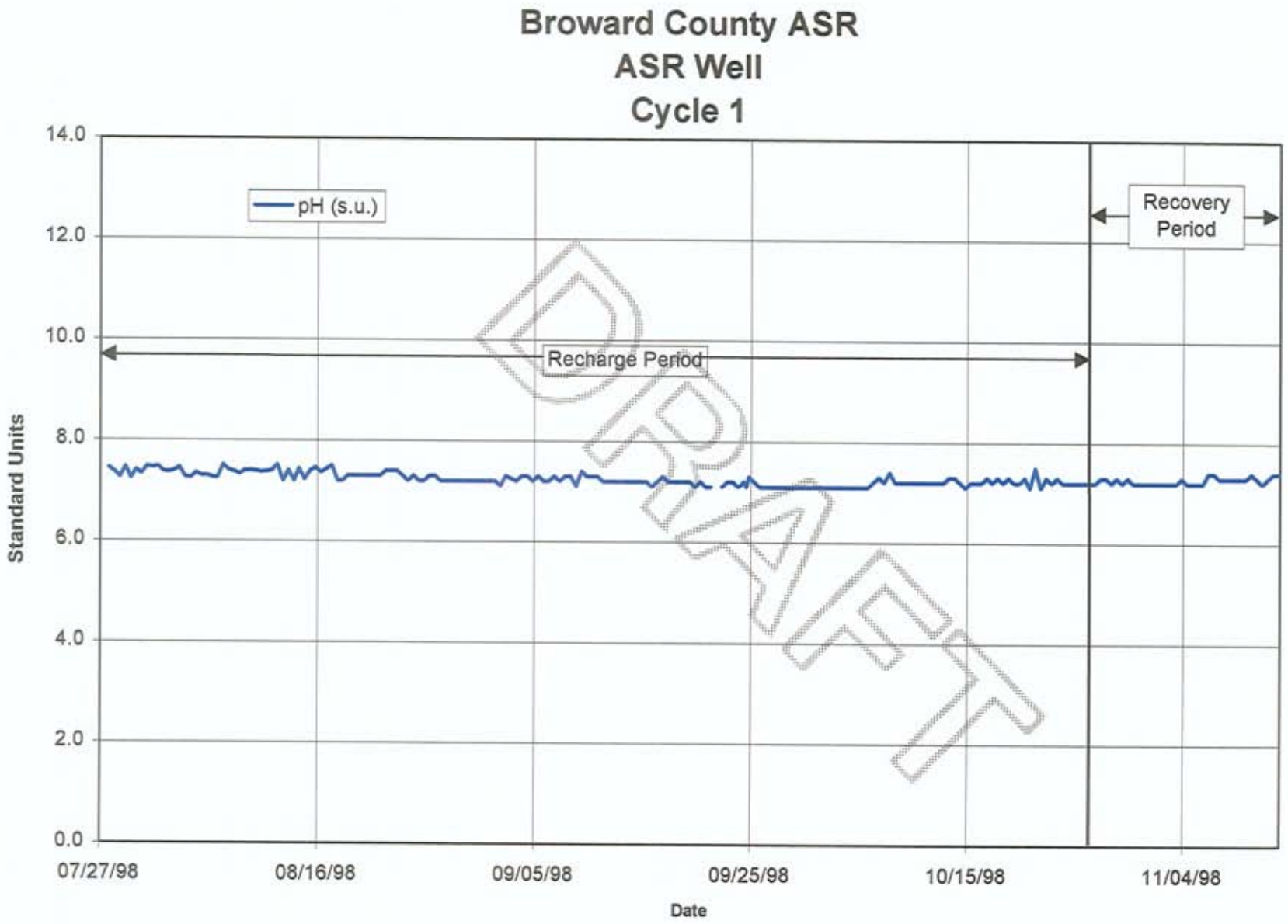


Figure 21. Cycle 1 ASR Well pH Data

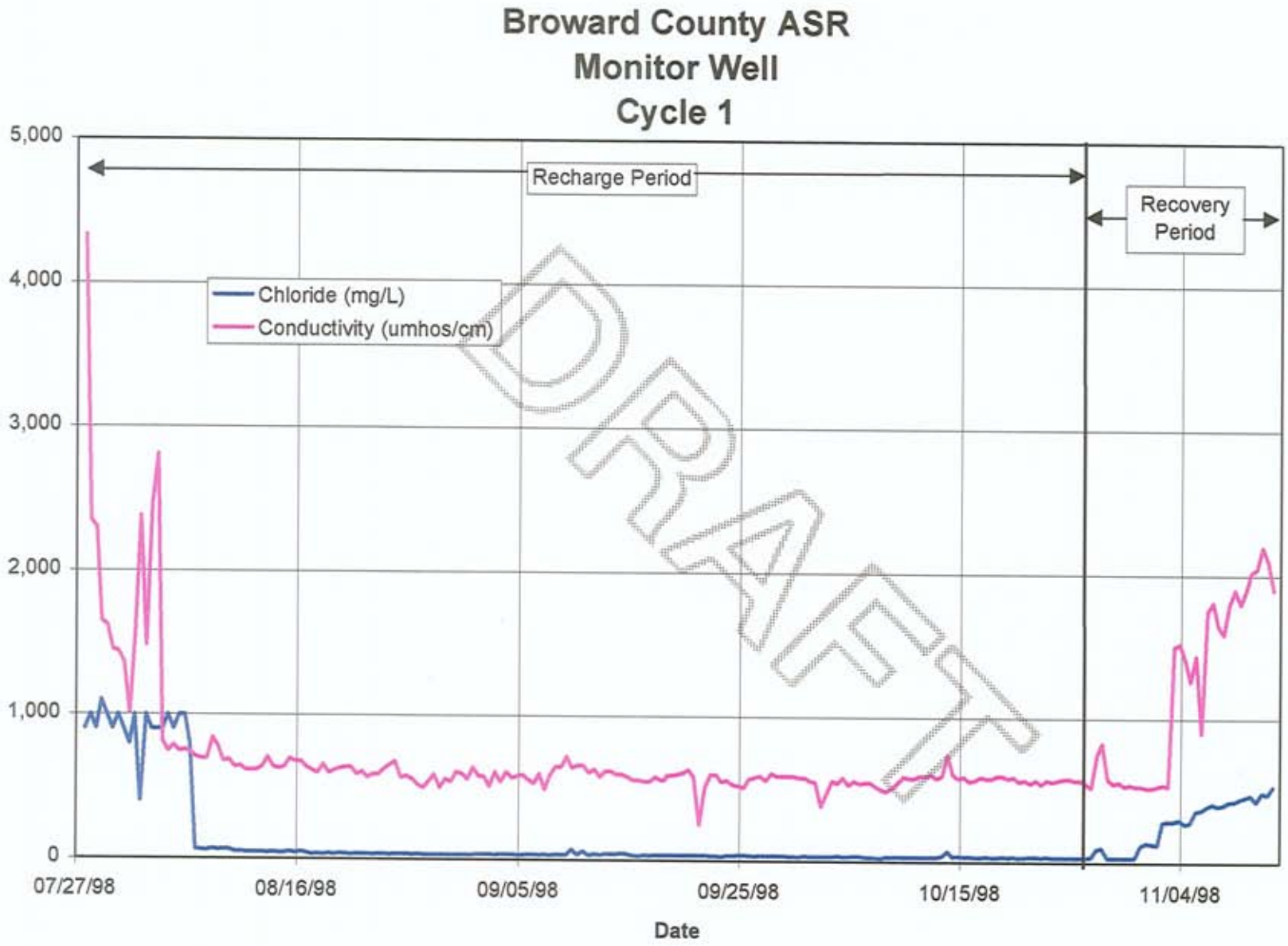


Figure 22. Cycle 1 Monitor Well Chloride and Conductivity Data

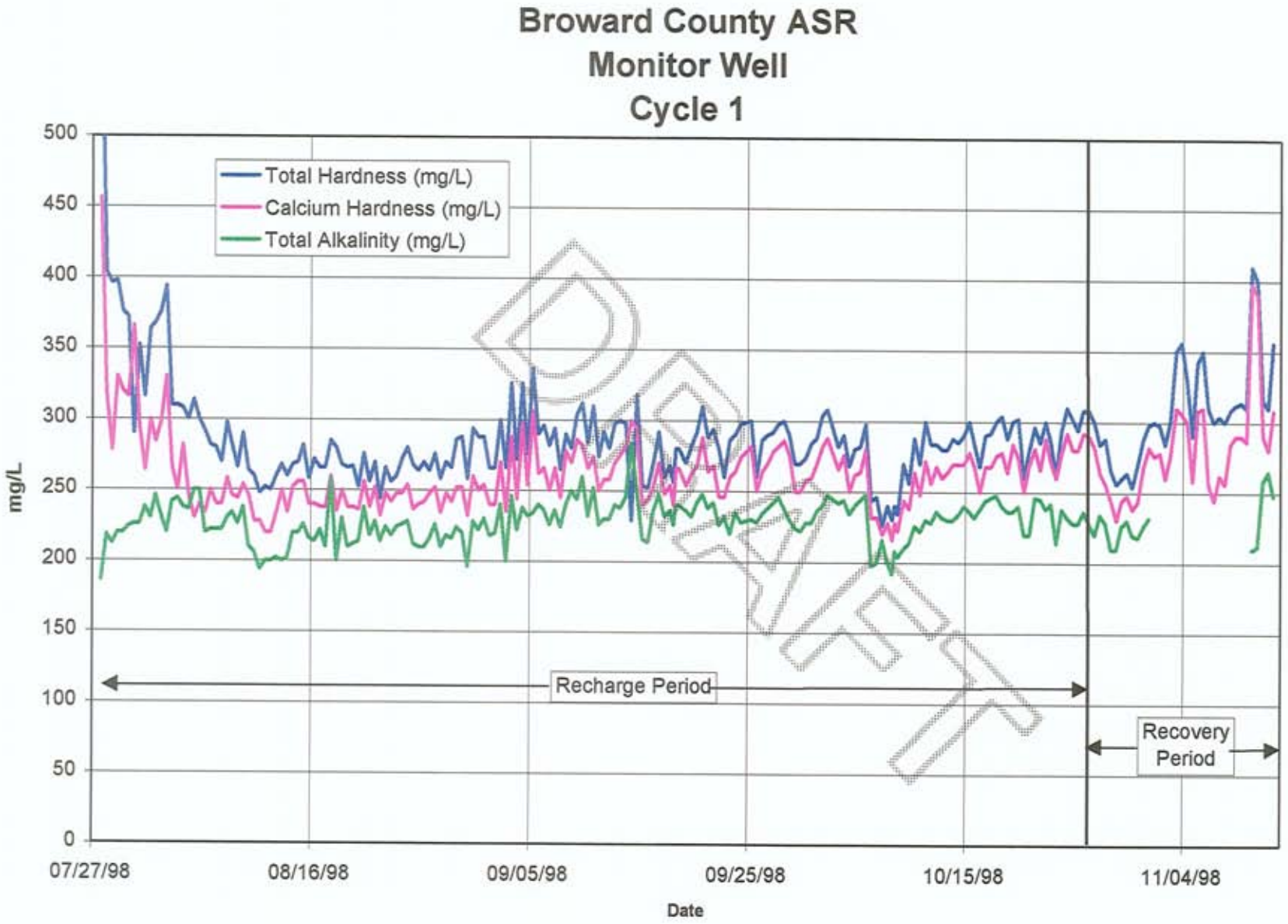


Figure 23. Cycle 1 Monitor Well Hardness and Alkalinity Data

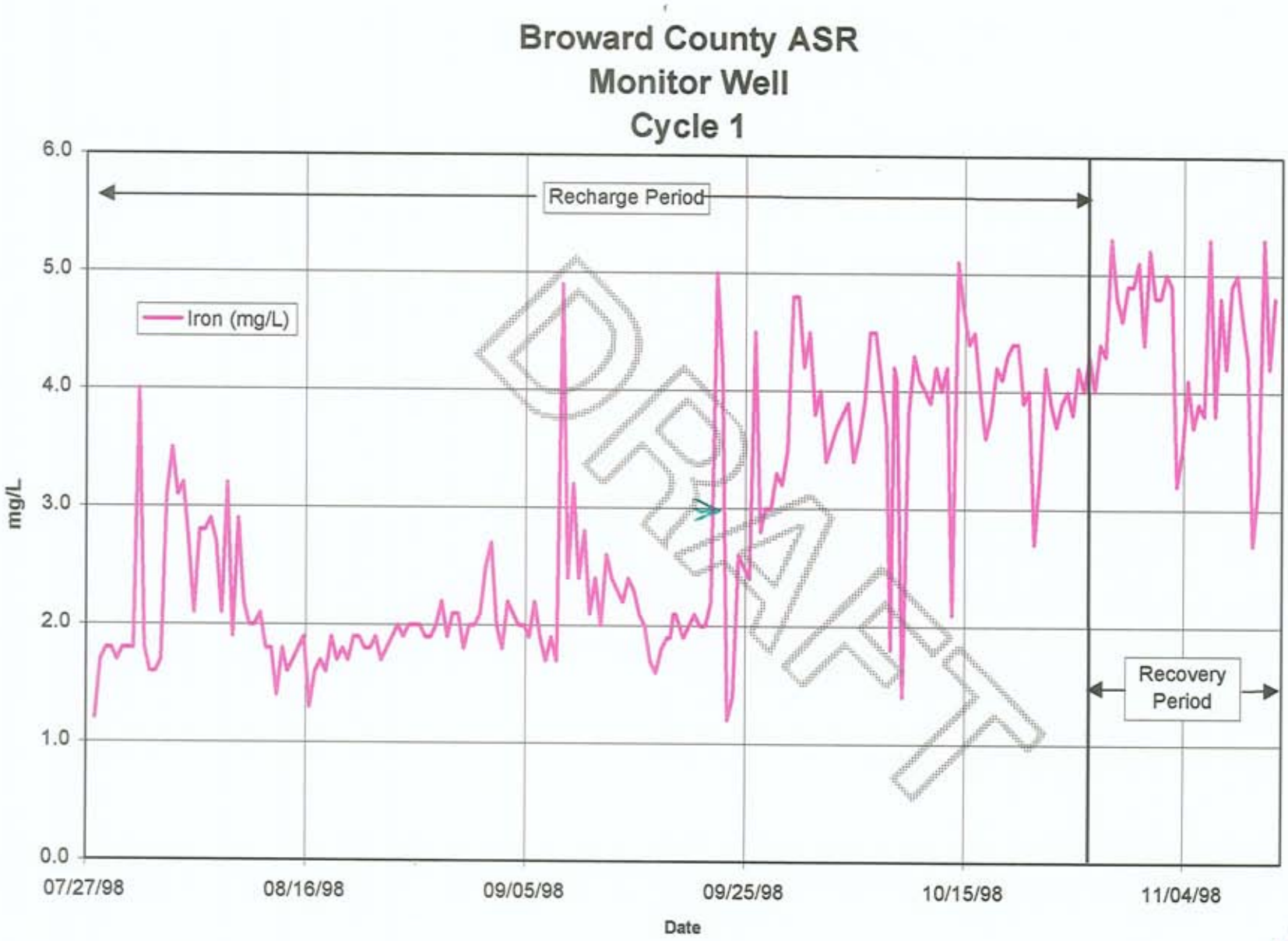


Figure 24. Cycle 1 Monitor Well Iron Data

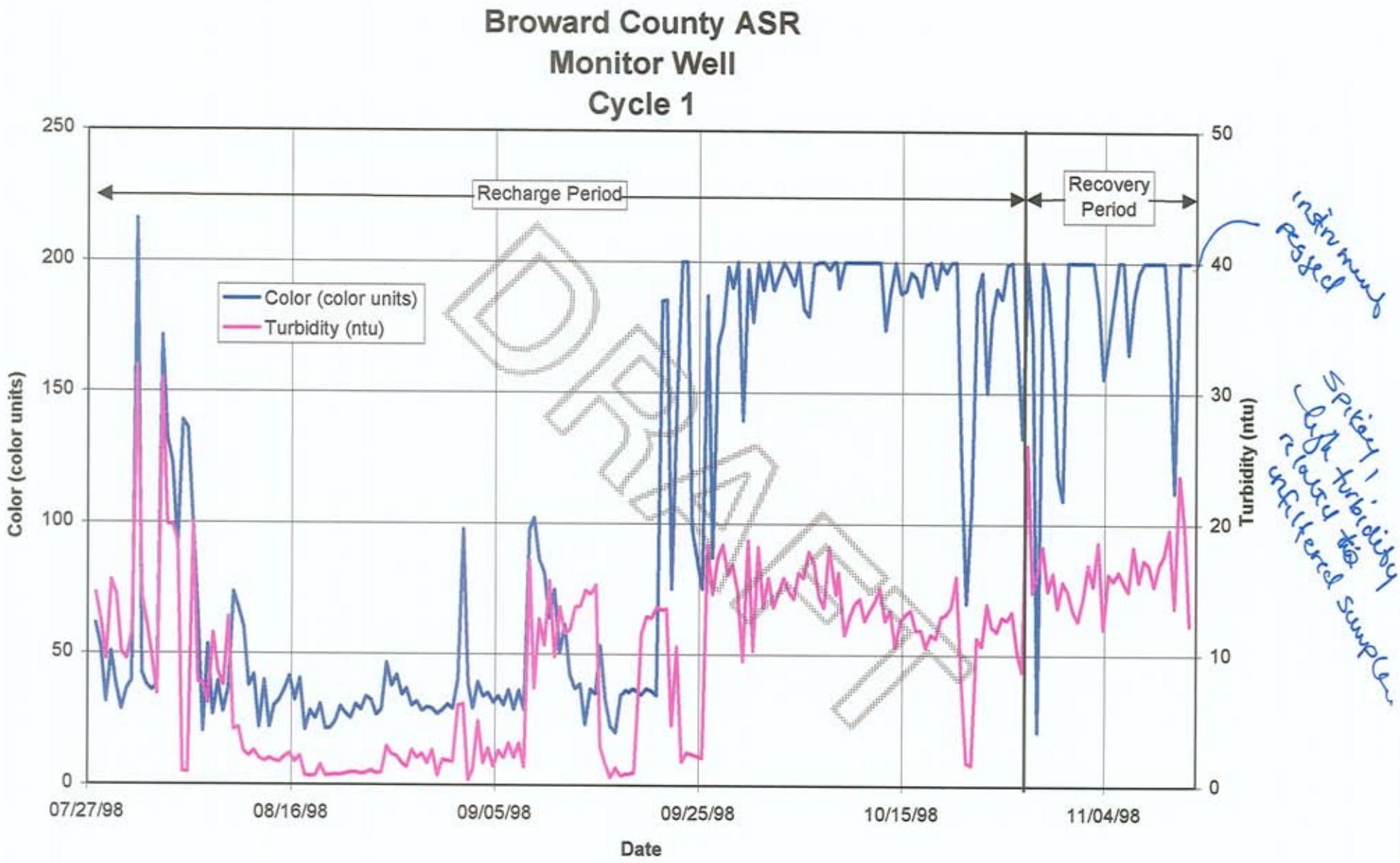


Figure 25. Cycle 1 Monitor Well Color and Turbidity Data

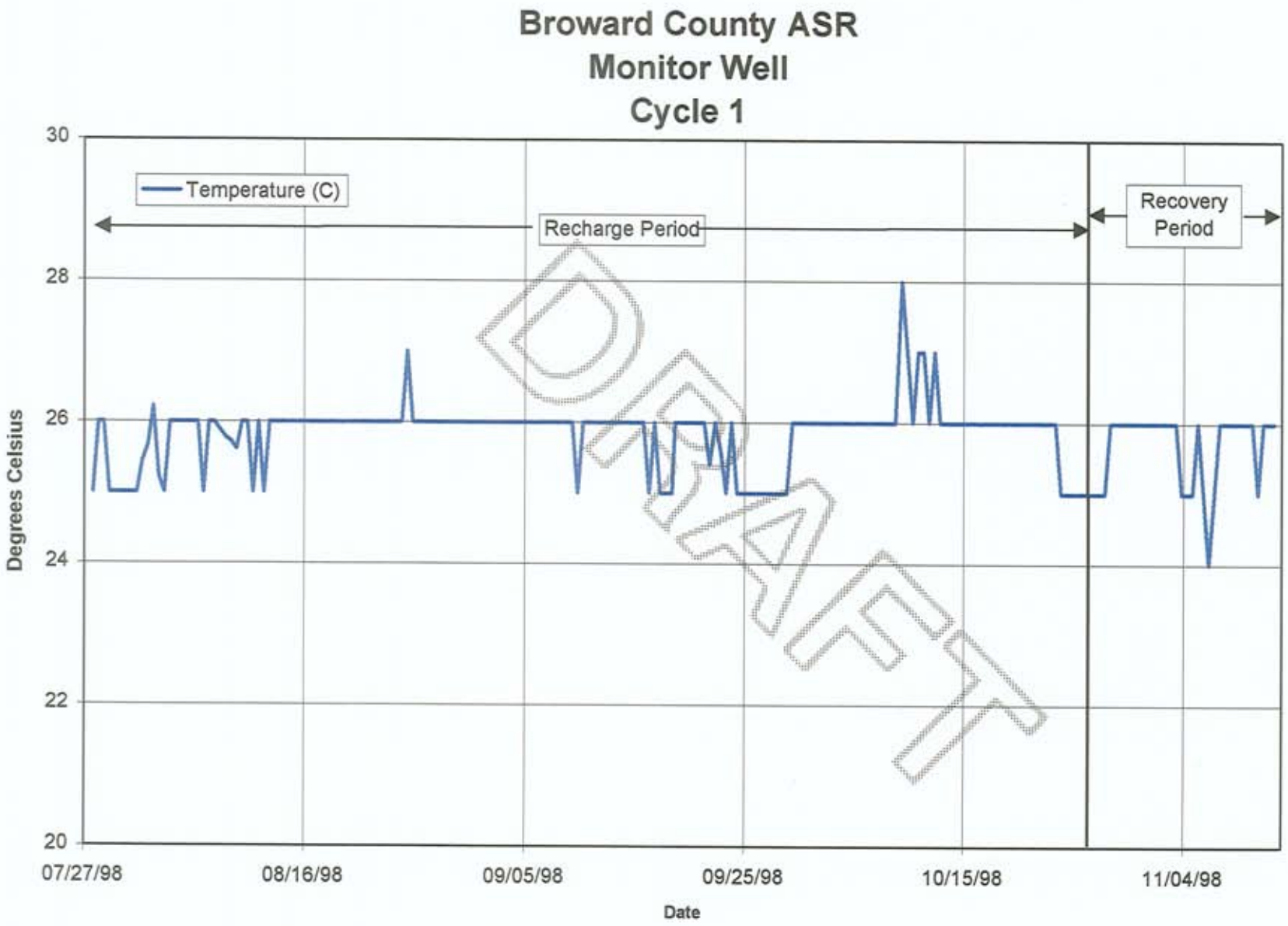


Figure 26. Cycle 1 Monitor Well Temperature Data

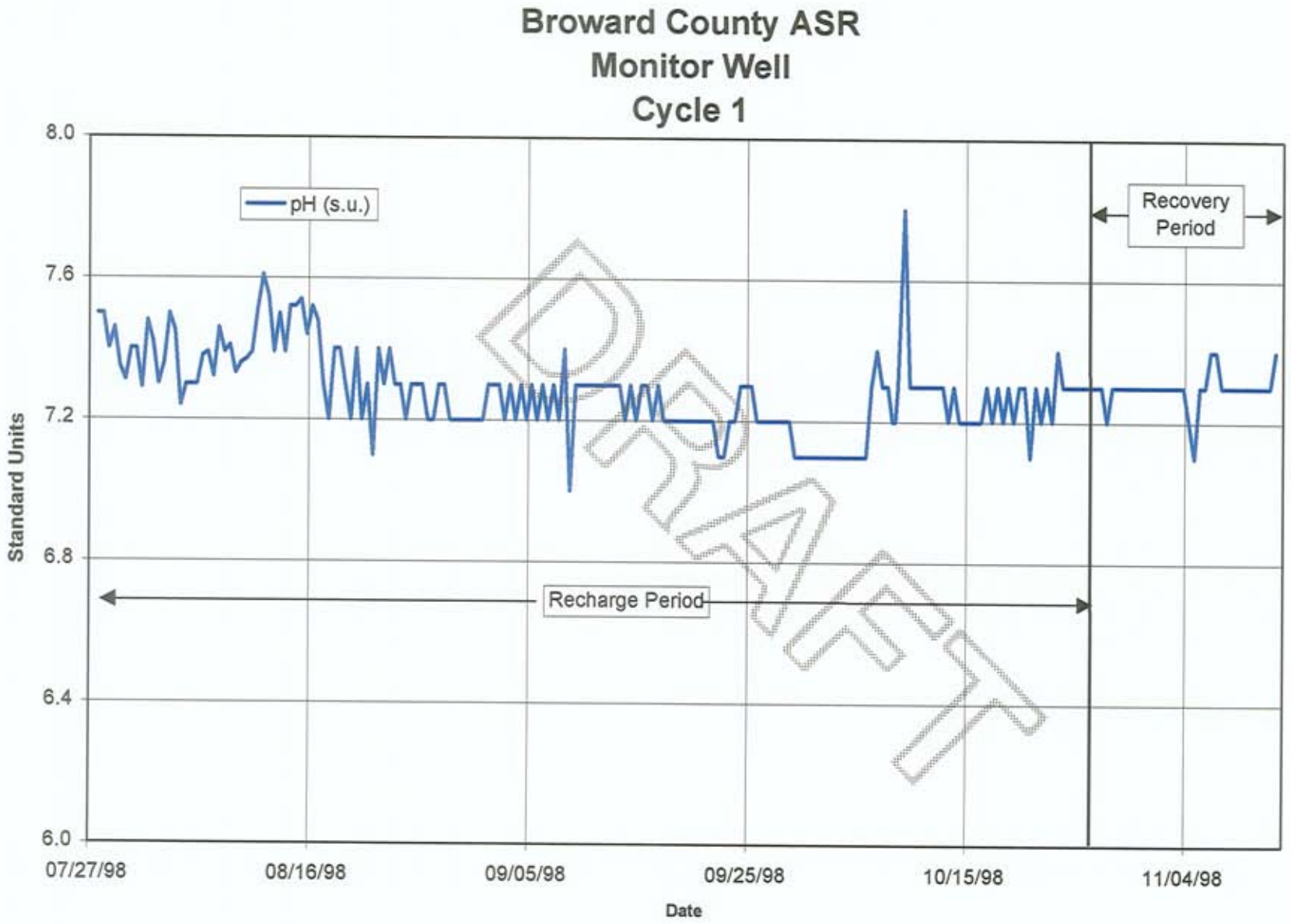


Figure 27. Cycle 1 Monitor Well pH Data

Attachment A

Cycle 0 Water Quality Data

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 0 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
7/9/98 8:00	40	390	28.0	7.44	30.0	1.5	255		223	1.00
7/9/98 20:00	28	400	28.0	7.40	35.0	1.9	224	194	179	1.98
7/10/98 8:00	29	500	24.9	7.51	40.0	2.0	229	187	179	1.75
7/10/98 20:00	31	400	28.5	7.27	40.0	2.1	225	199	180	3.38
7/11/98 8:00	33	390	26.1	7.48	35.0	1.9	236	208	193	1.30
7/11/98 20:00	36	400	28.9	7.30	35.0	1.6	230	200	188	1.66
7/12/98 8:00	38	400	25.6	7.41	30.0	1.6	259	226	181	1.90
7/12/98 20:00	34	400	28.3	7.50	30.0	1.9	256	222	168	1.83
7/13/98 8:00	28	390	28.4	7.46	30.0	2.1	230	218	176	1.59
7/13/98 20:00	27	400	28.0	7.31	25.0	2.1	220	218	184	1.53
7/14/98 8:00	27	390	28.0	7.38	30.0	2.1	230	224	182	1.88
7/14/98 20:00	27	400	27.8	7.45	40.0	2.0	232	216	184	2.24
7/15/98 8:00	27	400	27.0	7.44	30.0	2.0	238	236	182	2.62
7/15/98 20:00	27	400	28.0	7.44	25.0	2.2	240	216	180	2.03
7/16/98 8:00	36	400	27.1	7.39	25.0	0.9	289	267	257	0.78
7/16/98 20:00	34	400	28.0	7.41	25.0	0.9	288	245	246	0.56
7/17/98 8:00	34	400	28.0	7.29	30.0	1.4	296	237	224	1.08
7/17/98 20:00	35	400	27.0	7.16	25.0	1.4	281	232	228	0.82
7/18/98 8:00	35	400	26.0	7.41	35.0	2.1	236	221	192	1.02
7/18/98 20:00	28	410	26.0	7.56	20.0	1.2	264	250	180	5.33
7/19/98 8:00	36	400	25.0	7.40	30.0	1.9	284	260	235	1.07
7/19/98 20:00	36	410	25.0	7.53	25.0	1.3	284	270	226	0.87
7/20/98 8:00	35	400	27.0	7.11	30.0	1.5	296	278	234	1.26
7/20/98 20:00	58	520	28.0	7.18	25.0	1.5	315	259	246	2.86
7/21/98 8:00	168	990	28.0	7.20	15.0	1.0	346	284	236	5.40

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
MONITOR WELL
CYCLE 0 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Alkalinity (mg/L)	Turbidity (ntu)
7/9/98 8:00	3,700		25.0	7.95	10.0	0.0		212	142	0.12
7/9/98 20:00	2,400	6,200	25.0	7.77	7.5	0.3	822	568	136	0.18
7/10/98 8:00	1,500	5,000	24.9	7.93	12.5	0.4	506	424	158	0.11
7/10/98 20:00	2,400	4,500	26.0	7.71	10.0	0.1	700	340	155	0.12
7/11/98 8:00	2,600	4,800	25.6	7.70	10.0	0.3	744	428	173	0.16
7/11/98 20:00	2,400	5,300	26.1	7.60	12.5	0.2	680	398	148	0.19
7/12/98 8:00	1,800	5,200	25.0	7.70	7.5	0.3	692	384	160	0.19
7/12/98 20:00	2,100	5,800	25.6	7.60	10.0	0.2	810	422	163	0.21
7/13/98 8:00	1,700	2,600	25.0	7.77	20.0	0.7	480	382	180	10.70
7/13/98 20:00	900	2,620	25.0	7.74	15.0	0.9	446	380	182	0.21
7/14/98 8:00	1,600	2,410	25.0	7.59	20.0	1.3	450	338	178	6.68
7/14/98 20:00	1,500	2,390	25.1	7.81	20.0	1.1	440	264	182	6.57
7/15/98 8:00	800	2,130	25.0	7.60	25.0	1.0	418	230	182	9.73
7/15/98 20:00	2,100	2,160	25.0	7.62	25.0	1.3	424	250	182	8.12
7/16/98 8:00	1,300	1,960	25.0	7.84	20.0	1.3	400	216	184	4.86
7/16/98 20:00	1,000	2,450	27.0	7.89	17.5	1.3	408	228	186	4.18
7/17/98 8:00	800	2,130	26.0	7.68	20.0	1.2	402	268	202	5.12
7/17/98 20:00	1,000	2,270	26.0	7.55	17.5	1.3	398	218	202	4.18
7/18/98 8:00	1,200	2,110	25.0	7.70	20.0	1.5	238	218	188	2.30
7/18/98 20:00	1,200	2,440	27.0	7.60	17.5	1.2	223	210	182	3.81
7/19/98 8:00	1,000	3,110	25.0	7.56	12.5	1.2	310	282	245	6.21
7/19/98 20:00	900	2,300	26.0	7.46	17.5	1.0	260	241	210	5.82
7/20/98 8:00	800	1,800	26.0	7.45	25.0	1.5	326	278	224	9.06
7/20/98 20:00	1,100	3,780	25.0	7.65	25.0	1.5	548	430	216	14.60
7/21/98 8:00	2,700	5,140	25.0	7.60	15.0	0.8	670	580	172	26.70

Attachment B

Cycle 1 Water Quality Data

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
7/27/98 20:00	34	1,070	28.0	7.45	44.6	2.0	261	205	180	3.11
7/28/98 8:00	44	1,060	27.0	7.37	21.5	1.5	270	222	231	0.46
7/28/98 20:00	44	1,040	28.0	7.26	20.6	1.2	305	252	256	0.40
7/29/98 8:00	38	610	26.7	7.47	22.9	1.5	268	254	228	1.08
7/29/98 20:00	37	600	26.0	7.24	22.9	1.5	268	258	224	0.33
7/30/98 8:00	43	600	26.0	7.41	22.6	1.5	280	230	220	0.48
7/30/98 20:00	44	630	27.0	7.33	25.4	1.4	292	255	242	0.30
7/31/98 8:00	45	590	26.0	7.48	24.2	1.5	303	263	244	0.37
7/31/98 20:00	47	610	27.0	7.46	28.8	1.4	280	263	245	2.68
8/1/98 8:00	42		25.8	7.48	34.6	1.7	300	252	232	0.62
8/1/98 20:00	44	680	26.3	7.38	30.2	1.6	332	274	358	2.02
8/2/98 8:00	41	560	25.6	7.37	31.3	1.5	286	260	235	0.54
8/2/98 20:00	43	440	26.2	7.40	29.2	1.6	284	310	244	0.60
8/3/98 8:00	45	610	26.0	7.46	26.8	1.5	287	235	235	2.50
8/3/98 20:00	48	670	26.0	7.27	20.2	1.0	291	276	266	0.22
8/4/98 8:00	46	530	27.0	7.25	49.0	2.3	248	310	190	1.95
8/4/98 20:00	34	500	27.0	7.35	16.8	2.0	264	214	179	0.81
8/5/98 8:00	31	510	27.0	7.30	32.4	1.9	230	200	190	0.77
8/5/98 20:00	31	510	27.0	7.30	22.4	2.0	254	210	176	0.82
8/6/98 8:00	38	630	26.0	7.26	20.0	1.4	290	274	238	1.86
8/6/98 20:00	40	640	26.0	7.26	27.1	0.9	298	290	244	0.95
8/7/98 8:00	34	510	27.0	7.51	25.8	2.0	259	221	189	2.68
8/7/98 20:00	33	520	27.0	7.41	28.6	2.3	254	203	181	0.99
8/8/98 8:00	36	560	26.3	7.38	29.8	1.6	266	248	224	1.99
8/8/98 20:00	36	530	26.1	7.33	28.6	1.9	279	236	219	1.16
8/9/98 8:00	39	560	25.8	7.40	28.6	1.8	264	240	228	0.98
8/9/98 20:00	39	980	25.8	7.40	24.0	1.8	264	240	228	0.98
8/10/98 8:00	29	520	27.0	7.39	28.7	2.0	232	220	180	1.02
8/10/98 20:00	30	520	27.0	7.37	27.6	1.1	230	220	188	1.89
8/11/98 8:00	34	510	27.0	7.38	22.1	2.4	248	225	180	2.05
8/11/98 20:00	33	510	27.0	7.40	22.8	2.0	224	203	181	1.89

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
8/12/98 8:00	36	590	27.0	7.51	19.7	2.3	278	256	237	0.60
8/12/98 20:00	36	590	26.0	7.19	25.0	1.3	271	234	226	0.37
8/13/98 8:00	32	710	26.0	7.40	19.1	2.0	270	235	250	0.61
8/13/98 20:00	36	590	26.0	7.19	20.1	1.3	271	234	226	0.37
8/14/98 8:00	34	570	27.0	7.44	16.7	1.5	265	233	231	0.18
8/14/98 20:00	34	630	26.0	7.22	26.4	1.0	287	266	248	0.17
8/15/98 8:00	38	590	26.0	7.39	45.4	1.8	270	239	226	0.86
8/15/98 20:00	52	610	26.0	7.46	29.4	2.1	260	244	216	2.92
8/16/98 8:00	40	640	26.0	7.36	38.6	2.0	278	248	218	0.93
8/16/98 20:00	50	550	26.0	7.43	29.0	1.9	268	254	230	1.98
8/17/98 8:00	38	510	26.0	7.50	16.3	1.8	270	245	222	0.88
8/17/98 20:00	39	510	26.0	7.20	28.1	1.1	308	290	264	0.58
8/18/98 8:00	36	500	26.0	7.20	14.3	2.0	310	272	240	0.61
8/18/98 20:00	43	730	27.0	7.30	29.4	4.4	246	236	210	7.40
8/19/98 8:00	41	500	26.0	7.30	28.9	2.0	278	248	218	0.95
8/19/98 20:00	36	500	26.0	7.30	32.4	2.1	276	246	216	0.97
8/20/98 8:00	40	560	26.0	7.30	23.8	1.8	266	254	214	1.90
8/20/98 20:00	38	580	26.0	7.30	28.6	1.6	252	240	218	0.69
8/21/98 8:00	38	600	26.0	7.30	25.9	1.9	256	238	216	0.90
8/21/98 20:00	40	560	26.0	7.30	31.4	1.7	258	248	224	0.72
8/22/98 8:00	37	630	26.0	7.40	26.7	1.7	264	244	224	0.86
8/22/98 20:00	38	540	26.0	7.40	33.5	1.8	254	242	220	0.79
8/23/98 8:00	40	560	26.0	7.40	29.9	2.0	250	234	214	1.03
8/23/98 20:00	39	610	26.0	7.30	29.7	1.9	256	238	220	1.20
8/24/98 8:00	38	590	26.0	7.20	33.1	1.9	270	258	220	1.10
8/24/98 20:00	40	630	26.0	7.30	20.6	2.0	258	236	216	1.19
8/25/98 8:00	27	480	26.0	7.20	16.4	2.2	260	222	188	1.88
8/25/98 20:00	25	510	27.0	7.20	22.1	2.0	244	222	190	0.36
8/26/98 8:00	35	460	26.0	7.30	25.3	2.0	266	240	180	0.60
8/26/98 20:00	32	500	26.0	7.30	24.6	1.9	284	250	215	0.72
8/27/98 8:00	35	490	26.0	7.20	29.9	2.0	248	228	205	0.78

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
8/27/98 20:00	34	530	26.0	7.20	22.9	1.8	262	242	212	0.94
8/28/98 8:00	32	490	26.0	7.20	23.4	2.1	252	228	196	0.76
8/28/98 20:00	34	530	26.0	7.20	26.4	2.0	246	230	194	0.63
8/29/98 8:00	34	510	26.0	7.20	24.6	2.0	258	232	202	0.69
8/29/98 20:00	36	580	26.0	7.20	24.4	1.9	264	238	200	0.84
8/30/98 8:00	36	590	26.0	7.20	24.4	1.8	264	240	208	0.59
8/31/98 8:00	36	530	26.0	7.20	24.2	2.1	258	236	210	0.70
8/31/98 20:00	35	560	26.0	7.20	24.2	1.9	276	238	214	0.61
9/1/98 8:00	39	710	26.0	7.20	20.5	1.0	358	340	280	1.20
9/1/98 20:00	40	710	26.0	7.10	17.6	0.5	350	340	280	0.12
9/2/98 8:00	38	450	26.0	7.30	14.7	1.7	285	250	220	0.78
9/3/98 8:00	37	590	26.0	7.20	24.3	1.2	348	324	258	1.67
9/3/98 20:00	39	630	26.0	7.30	19.8	1.6	280	264	242	0.86
9/4/98 8:00	38	580	26.0	7.30	22.9	1.4	330	304	246	1.86
9/4/98 20:00	38	610	25.0	7.20	23.6	1.8	288	258	236	1.09
9/5/98 8:00	39	600	26.0	7.30	24.6	1.8	348	320	240	1.98
9/5/98 20:00	38	580	26.0	7.20	21.9	1.6	272	246	228	1.29
9/6/98 8:00	36	590	26.0	7.20	24.5	1.4	334	292	250	2.68
9/6/98 20:00	37	500	26.0	7.30	19.9	1.6	282	254	228	1.89
9/7/98 8:00	36	580	26.0	7.20	24.8	1.3	306	278	246	2.09
9/7/98 20:00	37	500	26.0	7.30	24.9	1.8	292	260	230	0.93
9/8/98 8:00	70	680	26.0	7.30	16.4	1.5	240	228	230	0.81
9/8/98 20:00	40	640	26.0	7.10	19.6	1.5	296	280	240	0.27
9/9/98 8:00	62	610	26.0	7.40	18.7	1.8	250	230	224	0.74
9/9/98 20:00	66	620	25.0	7.30	16.2	1.6	250	235	210	0.58
9/10/98 8:00	60	580	26.0	7.30	21.6	1.7	246	226	218	0.98
9/10/98 20:00	54	590	26.0	7.30	19.8	1.8	246	232	218	0.63
9/11/98 8:00	48	640	26.0	7.20	23.9	1.9	258	240	228	0.83
9/11/98 20:00	46	600	26.0	7.20	20.3	1.8	262	248	226	0.70
9/12/98 8:00	44	660	26.0	7.20	25.3	2.0	270	248	232	0.89
9/12/98 20:00	47	630	26.0	7.20	23.9	1.9	262	244	230	0.78

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
9/13/98 8:00	43	650	26.0	7.20	23.4	1.8	260	238	222	0.76
9/13/98 20:00	45	620	26.0	7.20	22.1	1.9	272	250	228	0.84
9/14/98 8:00	46	630	26.0	7.20	25.4	1.9	240	228	216	0.89
9/14/98 20:00	46	600	26.0	7.20	23.9	2.0	270	256	238	0.90
9/15/98 8:00	40	600	26.0	7.20	26.3	1.5	268	260	224	0.76
9/15/98 20:00	39	600	26.0	7.10	25.3	1.3	272	264	234	0.16
9/16/98 8:00	38	440	25.0	7.20	23.0	1.4	268	262	226	0.11
9/16/98 20:00	40	440	25.0	7.30	23.6	1.4	290	266	240	0.34
9/17/98 8:00	39	580	25.0	7.20	22.1	1.6	290	274	228	0.54
9/17/98 20:00	38	530	25.0	7.20	23.9	1.4	284	268	224	0.61
9/18/98 4:00	37	550	25.0	7.20	24.2	1.7	268	252	220	0.60
9/18/98 10:00	37	550	25.0	7.20	21.7	1.5	290	272	226	0.84
9/18/98 16:00	37	550	25.0	7.20	21.7	1.5	290	272	230	0.58
9/18/98 22:00	37	550	25.0	7.20	21.7	1.5	290	272	230	0.58
9/19/98 8:00	39	580	26.0	7.20	24.9	1.6	248	232	216	0.68
9/19/98 20:00	38	560	26.0	7.10	21.8	1.7	262	240	220	0.78
9/20/98 8:00	38	610	26.0	7.20	23.3	1.5	298	276	230	0.43
9/20/98 20:00	37	540	26.0	7.10	20.9	1.6	282	260	226	0.48
9/21/98 8:00	37	580	25.3	7.10	22.2	1.6	268	246	226	0.40
9/21/98 20:00	39	560	25.5		20.7	1.9	296	270	244	1.28
9/22/98 8:00	28	250	26.0	7.10	23.0	2.0	240	220	206	0.67
9/22/98 20:00	25	500	26.0	7.20	19.4	2.0	240	220	192	0.41
9/23/98 8:00	44	440	25.0	7.20	22.3	1.5	280	256	230	2.01
9/23/98 20:00	40	440	25.0	7.10	25.3	1.4	270	245	228	3.04
9/24/98 8:00	41	500	25.0	7.20	22.6	1.6	250	232	210	0.83
9/24/98 14:00	39	530	25.0	7.10	21.3	1.4	250	238	218	0.49
9/24/98 20:00	42	550	25.0	7.30	18.7	2.3	304	288	254	1.90
9/25/98 8:00	40	480	25.0	7.20	21.9	1.5	240	228	206	0.56
9/25/98 20:00	30	590	25.0	7.10	20.5	1.3	290	274	270	0.16
9/26/98 8:00	34	540	25.0	7.10	21.4	1.4	280	262	226	1.46
9/26/98 20:00	36	560	25.0	7.10	20.7	1.5	296	217	232	0.52

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
9/27/98 8:00	36	580	25.0	7.10	20.9	1.3	268	250	218	0.58
9/27/98 20:00	35	560	25.0	7.10	20.2	1.4	280	262	226	0.25
9/28/98 8:00	38	540	25.0	7.10	20.6	1.5	288	262	226	0.63
9/28/98 20:00	36	560	25.0	7.10	21.0	1.3	250	238	216	0.51
9/29/98 8:00	31	570	26.0	7.10	22.7	1.5	280	260	222	0.14
9/29/98 20:00	30	590	26.0	7.10	20.0	1.5	274	260	234	0.12
9/30/98 8:00	32	520	26.0	7.10	24.1	1.4	290	272	232	1.60
9/30/98 20:00	32	540	26.0	7.10	21.3	3.9	280	265	236	1.63
10/1/98 8:00	34	540	26.0	7.10	23.1	1.5	266	258	224	0.32
10/1/98 20:00	33	560	26.0	7.10	22.6	1.4	260	246	220	0.29
10/2/98 8:00	35	540	26.0	7.10	21.8	1.5	280	260	232	0.49
10/3/98 8:00	36	550	26.0	7.10	21.3	1.5	260	248	220	0.46
10/3/98 20:00	37	530	26.0	7.10	20.7	1.3	268	252	226	0.56
10/4/98 8:00	35	530	26.0	7.10	20.9	1.6	260	242	218	3.40
10/4/98 20:00	36	550	26.0	7.10	19.6	1.4	262	248	220	0.64
10/5/98 8:00	37	510	26.0	7.10	20.4	1.4	266	246	224	0.59
10/5/98 20:00	38	570	26.0	7.10	19.1	1.6	278	256	226	0.58
10/6/98 8:00	23	490	26.0	7.20	33.4	2.0	240	224	184	1.39
10/6/98 20:00	27	490	26.0	7.30	47.6	2.0	240	220	186	2.07
10/7/98 8:00	32	430	26.0	7.20	25.4	2.0	228	210	176	1.01
10/7/98 20:00	30	440	26.0	7.40	13.4	2.0	235	212	194	0.79
10/8/98 8:00	33	480	26.0	7.20	23.4	1.6	248	232	198	1.04
10/9/98 8:00	38	590	27.0	7.20	28.2	1.4	280	256	222	0.37
10/9/98 20:00	37	570	26.0	7.20	24.6	1.5	248	230	202	0.46
10/10/98 8:00	36	570	26.0	7.20	24.7	1.5	262	244	218	0.49
10/10/98 20:00	35	590	26.0	7.20	23.2	1.6	256	238	208	0.57
10/11/98 8:00	35	600	26.0	7.20	23.9	1.6	252	238	210	0.57
10/11/98 20:00	36	570	26.0	7.20	21.9	1.5	270	244	216	0.73
10/12/98 8:00	34	590	26.0	7.20	22.6	1.5	248	230	204	0.80
10/12/98 20:00	34	590	26.0	7.20	23.2	1.6	254	238	210	0.49
10/13/98 8:00	28	500	26.0	7.30	23.5	2.1	240	230	130	0.93

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
10/13/98 20:00	27	500	26.0	7.30	19.0	2.1	244	230	192	0.40
10/14/98 8:00	34	550	26.0	7.20	28.3	1.9	288	268	220	0.38
10/14/98 20:00	32	540	26.0	7.10	22.3	1.6	272	256	227	0.87
10/15/98 8:00	33	540	26.0	7.20	24.3	1.7	256	238	204	0.53
10/15/98 20:00	34	530	26.0	7.20	23.6	1.6	250	232	198	0.40
10/16/98 8:00	34	530	26.0	7.20	25.8	1.5	252	236	201	0.42
10/16/98 20:00	33	510	26.0	7.30	24.8	1.6	248	232	196	0.36
10/17/98 8:00	35	550	26.0	7.20	23.9	1.7	256	240	196	0.34
10/17/98 20:00	34	530	26.0	7.30	22.7	1.8	280	260	204	0.40
10/18/98 8:00	33	570	26.0	7.20	22.4	1.6	270	248	208	0.47
10/18/98 20:00	35	550	26.0	7.30	23.4	1.7	262	244	210	0.54
10/19/98 8:00	34	560	26.0	7.20	21.3	1.5	270	244	214	0.58
10/19/98 20:00	36	580	26.0	7.20	22.5	1.6	250	238	200	0.42
10/20/98 8:00	27	500	26.0	7.30	62.4	2.0	230	220	186	3.21
10/20/98 20:00	33	590	26.0	7.10	19.9	1.3	286	270	236	0.15
10/21/98 8:00	37	430	26.0	7.50	23.0	1.9	300	282	264	0.92
10/21/98 20:00	36	440	26.0	7.10	21.7	2.0	273	240	212	0.72
10/22/98 8:00	35	450	26.0	7.30	21.6	1.7	250	238	216	0.70
10/22/98 20:00	37	430	26.0	7.20	19.9	1.8	258	244	210	0.92
10/23/98 8:00	32	570	24.0	7.30	28.5	1.6	310	295	220	1.93
10/23/98 20:00	33	560	25.0	7.20	25.1	1.5	300	284	224	0.98
10/24/98 8:00	34	560	25.0	7.20	24.6	1.5	270	258	208	0.84
10/24/98 20:00	33	570	25.0	7.20	26.2	1.6	292	272	222	0.74
10/25/98 8:00	35	540	25.0	7.20	26.7	1.6	282	268	214	0.63
10/25/98 20:00	34	550	25.0	7.20	25.4	1.5	270	256	218	0.51
10/26/98 8:00	34	550	25.0	7.20	25.7	1.6	288	258	216	0.55
10/26/98 20:00	36	530	25.0	7.20	46.5	2.0	292	276	216	3.90
10/27/98 8:00	43	590	25.0	7.30	51.9	1.8	280	266	236	4.30
10/27/98 20:00	45	630	25.0	7.30	22.2	2.0	280	270	230	9.00
10/28/98 8:00	30	510	26.0	7.20	30.7	1.9	252	230	176	1.17
10/28/98 20:00	29	460	26.0	7.30	54.3	2.4	250	225	190	2.21

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
10/29/98 8:00	34	500	26.0	7.20	28.3	1.7	254	238	220	2.10
10/29/98 20:00	35	520	26.0	7.30	29.6	1.6	250	234	216	1.98
10/30/98 8:00	33	530	26.0	7.20	20.3	1.6	250	234	216	1.83
10/30/98 20:00	35	510	26.0	7.20	19.3	1.5	262	240	210	1.74
10/31/98 8:00	89	510	26.0	7.20	24.4	1.7	266	248	222	0.48
10/31/98 20:00	94	630	26.0	7.20	27.9	1.8	272	252	228	0.39
11/1/98 8:00	95	530	26.0	7.20	26.7	1.8	270	244	218	0.54
11/1/98 20:00	98	520	26.0	7.20	28.9	1.6	278	260	222	0.46
11/2/98 8:00	120	530	26.0	7.20	23.3	1.6	276	252	224	2.19
11/2/98 20:00	126	520	26.0	7.20	14.9	1.7	288	258	220	1.98
11/3/98 8:00	130	900	25.0	7.20	15.1	1.9	300	276	216	0.15
11/3/98 20:00	130	900	25.0	7.30	17.2	1.8	300	268	214	0.27
11/4/98 8:00	126	820	25.0	7.20	20.1	2.4	290	265	210	0.27
11/4/98 20:00	113	900	25.0	7.20	16.2	1.7	288	274	234	0.32
11/5/98 8:00	156	940	25.0	7.20	16.9	1.8	304	280	218	0.29
11/5/98 20:00	159	910	25.0	7.20	16.7	1.8	300	278	212	0.22
11/6/98 8:00	170	940	24.0	7.40	36.6	2.3	306	250	216	3.10
11/6/98 20:00	168	960	25.0	7.40	35.2	1.7	292	261	220	3.30
11/7/98 8:00	174	1,000	26.0	7.30	36.2	2.0	298	272	224	2.71
11/7/98 20:00	178	960	26.0	7.30	34.9	2.1	290	268	218	2.86
11/8/98 8:00	194	1,000	26.0	7.30	32.3	2.2	310	288	228	2.63
11/8/98 20:00	200	1,000	26.0	7.30	30.9	2.1	306	282	222	2.48
11/9/98 8:00	206	1,000	26.0	7.30	36.3	1.9	304	274	214	1.64
11/9/98 20:00	210	1,000	26.0	7.30	37.9	1.8	306	280	218	1.78
11/10/98 8:00	218	1,200	25.0	7.40	24.6	1.8	320	300	226	0.52
11/10/98 20:00	220	1,200	26.0	7.30	21.6	1.7	330	300	212	0.23
11/11/98 8:00	225	1,000	26.0	7.20	28.1	2.5	300	268	239	2.30
11/11/98 20:00	228	1,000	26.0	7.30	32.6	1.9	290	272	244	1.60
11/12/98 8:00	238	1,100	26.0	7.40	26.9	3.0	330	298	236	4.90
11/12/98 20:00	240	1,100	26.0	7.40	28.7	2.6	326	292	232	4.20
11/13/98 8:00	40	600	26.0	7.30	32.6	1.7	300	288	252	1.87

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
ASR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
11/13/98 20:00	38	600	26.0	7.10	27.7	1.4	300	275	240	12.10
11/14/98 8:00	39	500	26.0	7.30	28.9	1.5	268	248	218	3.96
11/14/98 20:00	40	400	26.0	7.30	30.4	1.6	274	252	214	4.20

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
MONITOR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
7/27/98 20:00	900	4,330	25.0	7.50	61.5	1.2	586	456	186	14.60
7/28/98 8:00	1,000	2,350	26.0	7.50	52.5	1.7	404	318	218	12.50
7/28/98 20:00	900	2,300	26.0	7.40	31.5	1.8	396	278	212	9.59
7/29/98 8:00	1,100	1,650	25.0	7.46	50.7	1.8	398	330	220	15.60
7/29/98 20:00	1,000	1,620	25.0	7.35	38.0	1.7	376	320	220	14.50
7/30/98 8:00	900	1,450	25.0	7.31	28.6	1.8	372	316	224	10.10
7/30/98 20:00	1,000	1,440	25.0	7.40	36.4	1.8	290	366	226	9.57
7/31/98 8:00	900	1,360	25.0	7.40	39.7	1.8	352	294	226	11.60
7/31/98 20:00	800	1,010	25.0	7.29	215.6	4.0	316	264	238	32.00
8/1/98 8:00	1,000	1,550	25.4	7.48	42.6	1.8	364	300	230	14.30
8/1/98 20:00	400	2,380	25.7	7.42	38.2	1.6	368	284	246	12.40
8/2/98 8:00	1,000	1,480	26.2	7.30	36.0	1.6	376	298	232	9.80
8/2/98 20:00	900	2,460	25.2	7.36	38.0	1.7	394	330	220	6.90
8/3/98 8:00	900	2,810	25.0	7.50	171.2	3.1	310	266	242	31.00
8/3/98 20:00	900	820	26.0	7.45	132.2	3.5	310	250	244	19.90
8/4/98 8:00	1,000	750	26.0	7.24	122.8	3.1	308	282	238	19.90
8/4/98 20:00	900	790	26.0	7.30	90.8	3.2	300	246	236	18.60
8/5/98 8:00	1,000	750	26.0	7.30	139.0	2.7	314	230	250	1.00
8/5/98 20:00	1,000	760	26.0	7.30	136.0	2.1	300	240	250	0.98
8/6/98 8:00	800	740	26.0	7.38	100.3	2.8	292	234	220	20.00
8/6/98 20:00	69	710	25.0	7.39	65.2	2.8	282	250	222	7.84
8/7/98 8:00	64	700	26.0	7.32	20.3	2.9	280	240	222	7.77
8/7/98 20:00	61	700	26.0	7.46	53.5	2.7	270	240	222	6.23
8/8/98 8:00	70	840	25.9	7.39	26.7	2.1	298	258	230	11.60
8/8/98 20:00	65	780	25.8	7.41	39.4	3.2	282	246	234	8.64
8/9/98 8:00	66	680	25.7	7.33	27.8	1.9	266	244	226	7.60
8/9/98 20:00	68	690	25.6	7.36	36.7	2.9	290	254	238	12.80
8/10/98 8:00	54	640	26.0	7.37	73.6	2.2	264	246	210	4.22
8/10/98 20:00	54	650	26.0	7.39	67.4	2.0	260	228	206	4.38
8/11/98 8:00	50	620	25.0	7.51	60.3	2.0	248	228	194	2.57
8/11/98 20:00	51	620	26.0	7.61	37.7	2.1	252	220	200	2.20
8/12/98 8:00	50	620	25.0	7.55	42.0	1.8	250	220	200	2.60

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
MONITOR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
8/12/98 20:00	49	640	26.0	7.39	22.0	1.8	260	234	202	2.04
8/13/98 8:00	46	710	26.0	7.50	40.0	1.4	268	250	200	1.80
8/13/98 20:00	49	640	26.0	7.39	22.0	1.8	260	234	202	2.04
8/14/98 8:00	48	630	26.0	7.52	30.1	1.6	268	252	220	1.86
8/14/98 20:00	47	640	26.0	7.52	32.5	1.7	270	256	220	1.75
8/15/98 8:00	52	700	26.0	7.54	36.4	1.8	282	256	226	2.14
8/15/98 20:00	48	680	26.0	7.44	41.6	1.9	258	240	216	2.39
8/16/98 8:00	54	680	26.0	7.52	32.3	1.3	272	240	214	1.79
8/16/98 20:00	46	640	26.0	7.48	40.6	1.6	266	238	222	2.21
8/17/98 8:00	36	620	26.0	7.30	21.1	1.7	266	238	210	0.72
8/17/98 20:00	38	600	26.0	7.20	28.3	1.6	285	260	258	0.66
8/18/98 8:00	36	660	26.0	7.40	25.3	1.9	280	235	200	0.70
8/18/98 20:00	41	600	26.0	7.40	30.9	1.7	268	250	230	1.52
8/19/98 8:00	36	620	26.0	7.30	21.3	1.8	266	238	210	0.73
8/19/98 20:00	42	630	26.0	7.20	21.7	1.7	267	238	212	0.76
8/20/98 8:00	38	640	26.0	7.40	24.6	1.9	252	236	214	0.79
8/20/98 20:00	37	640	26.0	7.20	29.9	1.9	276	256	238	0.79
8/21/98 8:00	39	590	26.0	7.30	27.2	1.8	256	238	218	0.84
8/21/98 20:00	38	610	26.0	7.10	25.4	1.8	270	252	228	0.98
8/22/98 8:00	40	570	26.0	7.40	30.9	1.9	244	232	214	0.98
8/22/98 20:00	37	590	26.0	7.30	28.6	1.7	266	248	224	0.86
8/23/98 8:00	38	590	26.0	7.40	33.6	1.8	256	242	218	0.94
8/23/98 20:00	40	630	26.0	7.30	32.4	1.9	260	248	224	1.10
8/24/98 8:00	37	660	26.0	7.30	26.8	2.0	272	248	226	0.89
8/24/98 20:00	39	680	26.0	7.20	28.9	1.9	280	254	228	0.97
8/25/98 8:00	39	570	27.0	7.30	46.7	2.0	268	236	212	2.95
8/25/98 20:00	40	580	26.0	7.30	37.7	2.0	264	240	210	2.35
8/26/98 8:00	37	560	26.0	7.30	42.1	2.0	270	242	210	2.22
8/26/98 20:00	38	520	26.0	7.20	34.4	1.9	264	248	216	1.67
8/27/98 8:00	36	500	26.0	7.20	36.8	1.9	276	252	226	1.36
8/27/98 20:00	35	540	26.0	7.30	30.3	2.0	258	234	210	2.67
8/28/98 8:00	37	590	26.0	7.30	31.9	2.2	270	248	218	2.08

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
MONITOR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
8/28/98 20:00	36	500	26.0	7.20	28.4	1.9	266	242	216	2.40
8/29/98 8:00	35	560	26.0	7.20	29.8	2.1	286	252	224	1.68
8/29/98 20:00	35	540	26.0	7.20	29.3	2.1	288	252	220	2.68
8/30/98 8:00	34	610	26.0	7.20	27.1	1.8	258	232	196	0.73
8/30/98 20:00	37	600	26.0	7.20	28.6	2.0	294	260	228	1.96
8/31/98 8:00	37	560	26.0	7.20	30.9	2.0	288	250	222	1.86
8/31/98 20:00	36	640	26.0	7.20	29.3	2.1	288	254	230	1.79
9/1/98 8:00	40	580	26.0	7.30	40.3	2.5	266	240	218	6.10
9/1/98 20:00	39	580	26.0	7.30	97.7	2.7	266	240	220	6.20
9/2/98 8:00	40	510	26.0	7.30	38.4	2.0	300	270	240	0.40
9/2/98 20:00	36	610	26.0	7.20	29.3	1.8	266	235	200	1.21
9/3/98 8:00	39	540	26.0	7.30	39.4	2.2	326	288	246	4.90
9/3/98 20:00	38	610	26.0	7.20	33.9	2.1	272	244	222	1.69
9/4/98 8:00	38	570	26.0	7.30	35.3	2.0	326	298	238	2.80
9/4/98 20:00	37	580	26.0	7.20	31.6	2.0	276	254	232	1.42
9/5/98 8:00	37	590	26.0	7.30	34.1	1.9	336	306	234	2.64
9/5/98 20:00	39	560	26.0	7.20	30.4	2.2	290	262	240	2.10
9/6/98 8:00	40	530	26.0	7.30	36.3	1.9	296	266	236	3.20
9/6/98 20:00	36	600	26.0	7.20	28.8	1.7	282	250	226	2.10
9/7/98 8:00	38	490	26.0	7.30	36.1	1.9	294	266	236	3.21
9/7/98 20:00	36	590	26.0	7.20	28.6	1.7	265	245	224	1.39
9/8/98 8:00	40	650	26.0	7.40	97.5	4.9	290	278	240	17.20
9/8/98 20:00	40	650	26.0	7.00	102.1	2.4	280	270	250	7.40
9/9/98 8:00	38	720	26.0	7.30	86.3	3.2	304	286	244	12.70
9/9/98 20:00	74	640	25.0	7.30	81.3	2.4	312	282	260	10.70
9/10/98 8:00	39	660	26.0	7.30	63.8	2.8	284	266	232	15.60
9/10/98 20:00	63	660	26.0	7.30	74.6	2.1	310	274	252	9.80
9/11/98 8:00	37	610	26.0	7.30	50.4	2.4	274	250	226	13.60
9/11/98 20:00	46	630	26.0	7.30	61.4	2.0	292	258	230	11.60
9/12/98 8:00	39	580	26.0	7.30	42.4	2.6	280	258	230	11.90
9/12/98 20:00	48	620	26.0	7.30	36.9	2.4	298	270	240	13.60
9/13/98 8:00	48	620	26.0	7.30	38.6	2.3	300	276	238	13.70

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
MONITOR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
9/13/98 20:00	46	600	26.0	7.20	23.1	2.2	298	282	246	14.90
9/14/98 8:00	49	600	26.0	7.30	36.7	2.4	229	300	284	14.60
9/14/98 20:00	48	580	26.0	7.20	34.9	2.3	318	294	250	15.30
9/15/98 8:00	36	560	26.0	7.30	53.2	2.1	254	240	216	2.97
9/15/98 20:00	33	560	26.0	7.30	32.8	2.0	252	244	214	1.65
9/16/98 8:00	40	550	25.0	7.20	22.6	1.7	270	254	236	0.62
9/16/98 20:00	36	550	26.0	7.30	20.1	1.6	292	270	248	1.33
9/17/98 8:00	38	580	25.0	7.20	34.3	1.8	260	248	232	0.76
9/17/98 20:00	39	560	25.0	7.20	36.4	1.9	268	254	236	0.88
9/18/98 4:00	39	560	25.0	7.20	35.4	1.9	256	240	226	0.84
9/18/98 10:00	40	590	25.0	7.20	36.7	2.1	280	266	240	0.98
9/18/98 16:00	40	590	26.0	7.20	36.7	2.1	280	266	240	0.98
9/19/98 8:00	40	600	26.0	7.20	34.6	1.9	270	254	236	11.60
9/19/98 20:00	40	610	26.0	7.20	36.9	2.0	282	262	232	12.90
9/20/98 8:00	40	630	26.0	7.20	36.1	2.1	292	268	242	12.80
9/20/98 20:00	39	580	26.0	7.20	34.3	2.0	310	288	248	13.60
9/21/98 8:00	39	250	26.0	7.20	184.9	2.0	288	264	238	13.40
9/21/98 20:00	40	510	25.4	7.20	185.4	2.2	294	268	242	13.50
9/22/98 8:00	37	600	26.0	7.10	75.0	5.0	280	246	226	4.57
9/22/98 20:00	37	600	25.6	7.10	147.1	4.2	260	246	232	10.60
9/23/98 8:00	28	550	25.0	7.20	200.0	1.2	286	260	220	1.80
9/23/98 20:00	38	560	26.0	7.20	200.0	1.4	290	264	235	2.50
9/24/98 8:00	40	530	25.0	7.30	98.0	2.6	298	274	228	2.40
9/25/98 8:00	42	510	25.0	7.30	75.0	2.4	300	282	230	2.10
9/25/98 20:00	38	570	25.0	7.20	187.0	4.5	260	250	228	18.40
9/26/98 8:00	37	580	25.0	7.20	87.0	2.8	286	264	234	14.60
9/26/98 20:00	39	590	25.0	7.20	168.0	3.0	290	270	238	17.40
9/27/98 8:00	38	560	25.0	7.20	176.0	3.0	292	278	242	18.40
9/27/98 20:00	40	610	25.0	7.20	198.0	3.3	298	282	246	16.10
9/28/98 8:00	39	590	25.0	7.20	190.0	3.2	300	286	238	16.90
9/28/98 20:00	39	590	25.0	7.20	200.0	3.5	290	276	230	14.80
9/29/98 8:00	35	590	26.0	7.10	139.4	4.8	270	250	224	9.50

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
MONITOR WELL
CYCLE 1 WATER QUALITY DATA

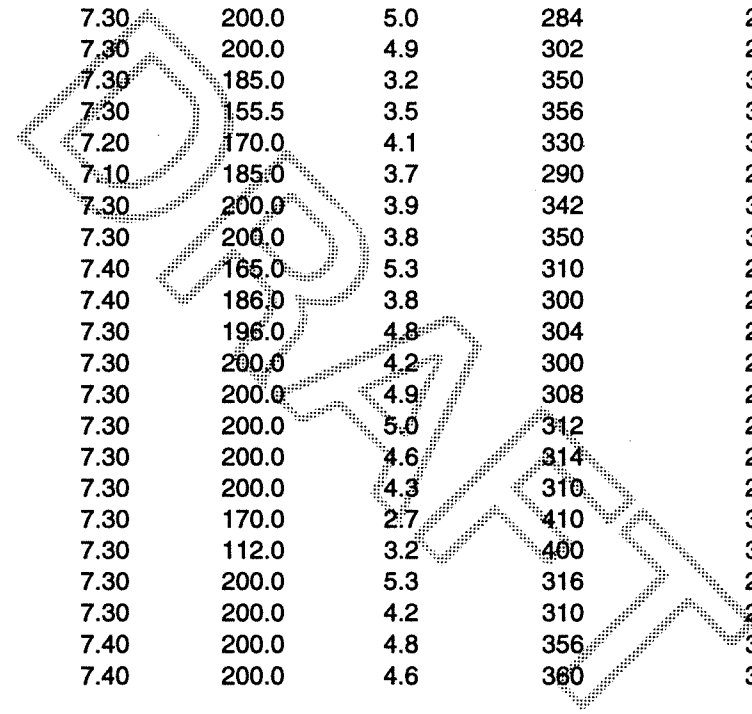
Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
9/29/98 20:00	37	590	26.0	7.10	197.0	4.8	270	250	222	18.70
9/30/98 8:00	32	580	26.0	7.10	177.0	4.2	274	258	228	10.30
9/30/98 20:00	38	580	26.0	7.10	199.0	4.5	284	260	228	18.20
10/1/98 8:00	35	560	26.0	7.10	189.0	3.8	288	270	236	13.60
10/1/98 20:00	36	550	26.0	7.10	200.0	4.0	304	282	240	15.90
10/2/98 8:00	35	380	26.0	7.10	189.0	3.4	308	288	248	13.60
10/3/98 8:00	37	560	26.0	7.10	200.0	3.7	282	266	242	15.90
10/3/98 20:00	39	540	26.0	7.10	196.0	3.8	290	276	244	14.90
10/4/98 8:00	36	580	26.0	7.10	191.0	3.9	268	250	234	14.30
10/4/98 20:00	37	530	26.0	7.10	200.0	3.4	280	262	240	16.30
10/5/98 8:00	39	560	26.0	7.10	182.0	3.6	282	264	244	15.90
10/5/98 20:00	39	540	26.0	7.10	179.0	3.9	298	280	248	17.90
10/6/98 8:00	32	550	26.0	7.30	199.0	4.5	244	232	198	17.10
10/6/98 20:00	33	550	26.0	7.40	200.0	4.5	246	232	200	14.50
10/7/98 8:00	28	520	26.0	7.30	200.0	4.1	226	220	216	13.60
10/7/98 20:00	26	500	26.0	7.30	197.0	3.7	240	228	200	18.30
10/8/98 6:00	34	490	26.0	7.20	200.0	1.8	230	216	192	15.92
10/8/98 12:00	33	500	26.0	7.20	200.0	4.2	240	228	208	14.60
10/8/98 18:00	35	510	26.0	7.30	190.0	4.1	234	222	204	16.30
10/9/98 8:00	34	550	28.0	7.80	200.0	1.4	270	244	210	11.50
10/9/98 20:00	35	590	27.0	7.30	200.0	3.8	256	238	214	12.90
10/10/98 8:00	37	580	26.0	7.30	200.0	4.3	288	264	226	13.90
10/10/98 20:00	36	580	27.0	7.30	200.0	4.1	270	248	222	14.30
10/11/98 8:00	37	600	27.0	7.30	200.0	4.0	300	272	230	12.60
10/11/98 20:00	37	590	26.0	7.30	200.0	3.9	284	256	228	13.40
10/12/98 8:00	36	610	27.0	7.30	200.0	4.2	284	268	236	14.10
10/12/98 20:00	35	580	26.0	7.30	200.0	4.0	280	260	232	15.10
10/13/98 8:00	42	600	26.0	7.20	174.0	4.2	280	264	230	12.60
10/13/98 20:00	75	740	26.0	7.30	189.0	2.1	288	270	230	13.40
10/14/98 8:00	40	610	26.0	7.20	200.0	5.1	285	270	234	10.60
10/14/98 20:00	44	580	26.0	7.20	188.0	4.7	290	270	240	12.60
10/15/98 8:00	38	590	26.0	7.20	189.0	4.4	300	278	236	13.10

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
MONITOR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
10/15/98 20:00	40	560	26.0	7.20	196.0	4.5	284	268	232	13.40
10/16/98 8:00	37	570	26.0	7.20	194.0	4.0	268	250	238	11.90
10/16/98 20:00	37	590	26.0	7.30	187.0	3.6	290	268	244	11.90
10/17/98 8:00	38	580	26.0	7.20	199.0	3.8	292	268	246	10.60
10/17/98 20:00	37	580	26.0	7.30	200.0	4.2	300	276	248	11.60
10/18/98 8:00	37	600	26.0	7.20	190.0	4.1	304	278	240	11.30
10/18/98 20:00	40	600	26.0	7.30	200.0	4.3	288	264	236	12.90
10/19/98 8:00	36	580	26.0	7.20	196.0	4.4	300	284	236	13.10
10/19/98 20:00	38	590	26.0	7.30	200.0	4.4	302	274	240	13.70
10/20/98 8:00	33	560	26.0	7.30	200.0	3.9	260	250	220	16.00
10/20/98 20:00	34	570	26.0	7.10	124.3	4.0	280	270	220	8.20
10/21/98 8:00	39	550	26.0	7.30	69.7	2.7	296	281	246	1.82
10/21/98 20:00	39	570	26.0	7.20	107.3	3.3	285	266	245	1.61
10/22/98 8:00	37	540	26.0	7.30	188.0	4.2	300	288	238	11.30
10/22/98 20:00	39	570	26.0	7.20	196.0	3.9	286	272	242	10.70
10/23/98 8:00	34	560	26.0	7.40	150.0	3.7	262	260	214	13.90
10/23/98 20:00	35	570	25.0	7.30	179.0	3.9	294	278	238	12.20
10/24/98 8:00	36	580	25.0	7.30	190.0	4.0	310	292	232	11.80
10/24/98 20:00	35	580	25.0	7.30	186.0	3.8	302	280	228	12.90
10/25/98 8:00	36	570	25.0	7.30	199.0	4.2	294	280	228	12.70
10/25/98 20:00	37	570	25.0	7.30	200.0	4.0	308	292	236	13.30
10/26/98 8:00	37	550	25.0	7.30	168.0	4.3	308	290	228	10.30
10/26/98 20:00	38	520	25.0	7.30	133.0	4.0	300	282	220	8.74
10/27/98 8:00	97	750	25.0	7.30	200.0	4.4	284	264	234	26.00
10/27/98 20:00	102	830	25.0	7.20	172.3	4.3	288	256	228	14.80
10/28/98 8:00	35	580	26.0	7.30	20.6	5.3	266	244	210	16.30
10/28/98 20:00	35	550	26.0	7.30	200.0	4.8	256	230	210	18.30
10/29/98 8:00	36	560	26.0	7.30	190.0	4.6	260	244	226	14.90
10/29/98 20:00	37	530	26.0	7.30	163.3	4.9	264	248	230	16.30
10/30/98 8:00	35	540	26.0	7.30	119.0	4.9	254	238	220	13.60
10/30/98 20:00	34	530	26.0	7.30	109.0	5.1	270	244	218	15.60
10/31/98 8:00	122	530	26.0	7.30	200.0	4.4	288	268	226	14.90

BROWARD COUNTY OFFICE OF ENVIRONMENTAL SERVICES 2A WATER TREATMENT PLANT
MONITOR WELL
CYCLE 1 WATER QUALITY DATA

Date/Time	Chloride (mg/L)	Conductivity (umhos/cm)	Temperature (C)	pH (s.u.)	Color (color units)	Iron (mg/L)	Total Hardness (mg/L)	Calcium Hardness (mg/L)	Total Alkalinity (mg/L)	Turbidity (ntu)
10/31/98 20:00	138	520	26.0	7.30	200.0	5.2	298	282	232	13.40
11/1/98 8:00	132	520	26.0	7.30	200.0	4.8	300	276		12.60
11/1/98 20:00	126	530	26.0	7.30	200.0	4.8	298	278		14.30
11/2/98 8:00	280	540	26.0	7.30	200.0	5.0	284	260		16.90
11/2/98 20:00	288	530	26.0	7.30	200.0	4.9	302	278		15.30
11/3/98 8:00	290	1,500	26.0	7.30	185.0	3.2	350	310		18.60
11/3/98 20:00	300	1,520	25.0	7.30	155.5	3.5	356	306		12.00
11/4/98 8:00	270	1,410	25.0	7.20	170.0	4.1	330	300		16.20
11/4/98 20:00	280	1,260	25.0	7.10	185.0	3.7	290	258		15.70
11/5/98 8:00	360	1,440	26.0	7.30	200.0	3.9	342	308		16.40
11/5/98 20:00	368	900	25.0	7.30	200.0	3.8	350	310		15.60
11/6/98 8:00	392	1,750	24.0	7.40	165.0	5.3	310	256		14.90
11/6/98 20:00	410	1,810	25.0	7.40	186.0	3.8	300	244		18.30
11/7/98 8:00	396	1,650	26.0	7.30	196.0	4.8	304	262		15.60
11/7/98 20:00	402	1,590	26.0	7.30	200.0	4.2	300	256		17.30
11/8/98 8:00	424	1,800	26.0	7.30	200.0	4.9	308	284		16.90
11/8/98 20:00	428	1,900	26.0	7.30	200.0	5.0	312	290		15.30
11/9/98 8:00	446	1,800	26.0	7.30	200.0	4.6	314	290		16.90
11/9/98 20:00	458	1,900	26.0	7.30	200.0	4.3	310	286		17.70
11/10/98 8:00	472	2,020	26.0	7.30	170.0	2.7	410	398	210	19.60
11/10/98 20:00	428	2,050	25.0	7.30	112.0	3.2	400	390	212	13.60
11/11/98 8:00	488	2,200	26.0	7.30	200.0	5.3	316	290	258	23.70
11/11/98 20:00	478	2,100	26.0	7.30	200.0	4.2	310	280	265	19.70
11/12/98 8:00	530	1,900	26.0	7.40	200.0	4.8	356	308	248	12.30
11/12/98 20:00	550	1,900	26.0	7.40	200.0	4.6	360	332	240	15.60



August 24, 1999

Mr. Mike Scotty, P.E.
Broward County Office of Environmental Services
2555 West Copans Road
Pompano Beach, Florida 33069

SUBJECT: Broward County Office of Environmental Services
District 2A Water Treatment Plant
Aquifer Storage and Recovery Well System
Request to Continue Cycle Testing

Dear Mr. Calas:

Montgomery Watson is pleased to present the following information, on behalf of the Broward County Office of Environmental Services (BCOES), regarding recent analyses that have been performed during cycle testing of the Aquifer Storage and Recovery well system at the above referenced facility. These analyses are presented in support of a request to continue with cycle testing of the system and to perform field filtration of water samples collected from the on-site monitoring well MW-1 for analysis of iron and color. As the consultant for the BCOES, Montgomery Watson presents the following justifications for continuation of cycle testing:

- The information collected from the facility indicates that elevated concentrations of iron and color in water collected from the monitor well are the result of reactions taking place inside the well casing, and are not representative of concentrations of these constituents in the aquifer.

- As a result, continued operation and testing of the 2A WTP ASR system does not represent a threat to water quality in the Floridan aquifer system, the public health or other operating ASR well facilities.

- Sufficient information has been collected to substantiate performance of field filtration of water samples collected from MW-1 prior to analysis for iron and odor in compliance with FDEP technical guidance criteria.

- A core issue that remains to be resolved is the economic feasibility of implementation of ASR technology at the District 2A WTP facility. Therefore cycle testing at the facility should be allowed to continue.

- Monitoring of the ASR system (with appropriate revisions) will ensure protection of the environment while also providing BCOES with a valuable water resource management tool.

BACKGROUND

The District 2A WTP ASR well system was completed in 1997. The system was issued approval for cycle testing using raw Biscayne aquifer water on April 9, 1998. In support of use of raw groundwater for the system, a Water Quality Criteria Exemption (WQCE) was obtained for the constituents of color, iron and odor (OGC File No. 96-3218). The WQCE allowed for maximum concentration of 100 units for color, 3 milligrams per liter (mg/L) for iron and 6 threshold units for odor, as measured at the location of the deep monitor well (MW-1) at the facility. MW-1 is completed with a 6-inch (inner) diameter steel casing set at a depth of 990 feet below land surface (bls) and an open hole extending to a depth of 1,200 feet bls. MW-1 is located approximately 275 feet due west of the ASR well.

CYCLE TESTING SUMMARY

To date, the ASR well system has undergone Cycle Tests 0, 1 and 2. A total of 387 million gallons of water have been recharged into the ASR well and 91 million gallons of water have been recovered. The information collected during these tests is presented in a letter dated April 23, 1999 to Mr. Jose Calas from Mr. David McNabb at CH2M Hill. Included below is a brief summary of those tests.

Cycle 0 (July 9, 1998 to July 21, 1998)

During Cycle 0, recharge took place for 10 days at a rate of 2 million gallons per day (mgd) and recovery took place for 2 days (also at a rate of 2 mgd). Recovery took place until the chloride concentration in the recovered water reached a concentration of 225 mg/L. Iron concentrations in the recharge and recovered water (as measured at the ASR well) varied between 0.9 mg/L and 2.1 mg/L throughout the entire recharge and recovery periods.

During the fourth day of recharge, concentrations of chloride and conductivity in water collected from MW-1 declined sharply, indicating the passage of the "front" of the fresh water bubble from the ASR well. At that time, approximately 8 million gallons of water had been injected into the aquifer. Iron concentrations in water collected from MW-1 began to increase from pre-injection concentrations of approximately 0.2 mg/L to 1.2 mg/L throughout the cycle.

Cycle 1 (July 27, 1998 to November 12, 1998)

Cycle 1 began immediately following the completion of the recovery portion of Cycle 0. During Cycle 1, recharge took place for 86 days at a rate of 2 mgd and recovery took place for 18 days at a rate of 2 mgd, until the concentration of chlorides in the recovered water reached 225 mg/L. The recovery efficiency of this cycle was 21%. Except for brief periods (two data points) of exceedance during recharge, the iron concentration of recharged and recovered water remained below 2 mg/L measured at the ASR well.

Approximately 58 days into the recharge period, iron concentrations in water collected

from MW-1 increased from approximately 2 mg/L to above 4 mg/L. Color concentrations increased from approximately 25 color units to 200 units. A rust colored tint of the samples collected from MW-1 was also observed to begin at that time. The concentrations of both iron and color did not change from these values during the recovery period.

At that time, it was hypothesized that rust from inside the steel casing of MW-1 was the most likely source of observed variations in water quality. It was thought that the dissolved oxygen (DO) in the recharge water was causing an oxidation reaction with the casing. Water collected from the wellhead of MW-1 was capturing particles of rust from the casing during purging of the well for sample collection, resulting in the observed water quality variations. An expanded set of analyses were then performed during the subsequent recharge and recovery period (Cycle 2) to confirm the hypothesis.

Cycle 2 (November 13, 1998 to March 11, 1999)

Cycle 2 consisted of an 88 day period of recharge, a 9 day period of storage and a 23 day period of recovery. Recovery took place until the chloride concentration of recovered water 225 mg/L was achieved. The recovery efficiency of the cycle was 26%. During the recharge period, iron concentrations of the injected raw Biscayne aquifer water varied generally between 1mg/L and 2mg/L and color and odor concentrations remained below the WQCE limit concentrations. At the location of MW-1, iron concentrations remained at or above the concentration of 5 mg/L throughout the recharge and recovery periods. The color of water collected from MW-1 varied largely between 100 and 200 color units throughout the recharge and recovery periods.

EXPANDED ANALYSES

At present, cycle testing has been halted because iron and color concentrations in water collected from MW-1 have increased to above the 3 mg/L and 100 color unit limits, respectively, specified in the WQCE. Over the past several months, additional analyses of the data collected during the cycle tests have been performed, to determine the cause of elevated concentrations of iron and color in water collected from MW-1.

Recharge and Stored Water Chemical Characterization

Characterization of the water recharged and stored at the facility included sampling water from the ASR well and MW-1 for dissolved oxygen (DO), oxidation reduction potential (ORP), and the Langlier Index during the first 2 weeks of recovery for Cycle 2. Results of the characterization demonstrated that the water is aggressive to steel, with an average DO value of 3.72 mg/L at the ASR well and 3.66 mg/L at MW-1 during the sampling period. These data indicate that the DO concentration of recharge water remains relatively high in the storage zone after injection. The slight reduction in DO observed at MW-1 when compared to that of the ASR well is likely to be related to a reduction in DO that occurs inside the casing of MW-1, as a result of oxidation of iron in the steel casing.

Bacteria Testing
A water sample from MW-1 was also collected and analyzed for iron related bacteria to determine if the observed water quality trends were the result of a bacterial infestation in MW-1. The analysis demonstrated that iron related bacteria are not present in water from MW-1, which indicates that the source of elevated concentrations of iron are the result of chemical reactions taking place in the vicinity of the well.

Filtered Sample Analyses
Analytical results indicate a significant reduction in both color and iron values for samples from MW-1 when the samples are filtered in the field. The unfiltered samples (representing total iron concentrations) had average values of 4.6 mg/L and 157.7 units for iron and color, respectively, over a 6-day sampling period. The filtered samples (passed through a 45 micron-size filter prior to acidification) had average values of 1.3 mg/L and 16.5 units for iron and color, respectively.

Unfiltered iron and color values from the ASR well over the same 6-day period averaged 1.6 mg/L and 28.3 units, respectively. It is important to note the relative similarity of the concentrations of iron and color in water collected from the ASR well and the monitor well when the water from MW-1 is filtered.

Visual Examination of Wellhead Samples
Water recovered from MW-1 was visually observed to emit a reddish-brown rust color typical of iron in the oxidized state. After filtration of the water sample in the field, the filter material was observed to contain a layer of reddish-brown residue that appeared to have been deposited colloidal rust. Water samples recovered from the ASR well did not exhibit a reddish-brown color at all.

Purging Rate Analyses
Further evidence to support the theory that the elevated parameters are the result of oxidation of the steel casing in MW-1 is provided by the effect that a change in purging practices at MW-1 had on iron and color values. Prior to February 10, 1999, MW-1 was continuously purged at a rate of approximately 5 to 10 gallon per minute (gpm). This purge rate is equivalent to a velocity of 0.11 feet per second (ft/s) and water has a residence time of 150 minutes as it travels up, through the casing. It was thought that the extended residence time of the water in the casing of MW-1 may have been a contributing factor for the elevated iron and color parameters. Therefore, the purging rate of MW-1 was increased to approximately 100 gpm on February 10, 1999. This purging rate is equivalent to a velocity of 1.1 ft/s and water has a residence time of 15 minutes as it travels up, through the casing. This purging rate was maintained throughout the completion of Cycle 2. Upon the initiation of the increased purge rate, iron concentrations in water from MW-1 declined from approximately 7 mg/L to 4 mg/L. Color concentrations declined from approximately 400 color units to less than 200 color units.

Thief Sampling Event

MW-1 was most recently sampled on July 1, 1999. For the sampling event, a thief sampling device was utilized to collect samples from discreet depths. This device allows for depth-specific sample collection in wells through the use of an electronically-controlled sampling port that opens and closes by a instruction from a wireline geophysical operator.

Prior to collection of the first thief sample, two initial samples were collected from the wellhead sampling tap, after water from the well was allowed to flow at a rate of approximately 100 gallons per minute for a period of one week. This represents a total volume of approximately 1,000,000 gallons. The volume of the casing is approximately 1,450 gallons. This sample, "Surface 1" contained a total iron concentration of 27.2 milligrams per liter (mg/L). A second sample (Surface B) from the wellhead tap was collected approximately 50 minutes later, and the total iron concentration of 5.53 mg/L. Although total iron concentrations were high, dissolved iron concentrations remained very low throughout the sampling event, indicating that particulate material (rust) was the most likely cause of elevated iron concentrations. Table 1 presents a summary of the sampling results.

Table 1. Summary of July 1 sampling event results.

Sample I.D.	Depth (fbls)	Turbidity (NTU)	Total Iron (mg/L)	Dissolved Iron (mg/L)
Surface 1	Flowing Wellhead	38.4	27.2	0.504
Surface B	Flowing Wellhead	26.8	5.53	0.535
Thief 1	995	8.7	2.40	0.174
Surface 2	Flowing Wellhead	37.3	8.02	0.539
Thief 2	995	29.8	15.6	0.774
Surface 3	Flowing Wellhead	35.9	9.65	0.993
Thief 3	993	54.6	13.4	0.151
Thief 4	993	23.4	5.05	0.099

The first sample collected with the thief device was located at a depth of 995 feet below land surface (bls), which was approximately 5 feet below the base of the 6.625-inch (outer) diameter well casing. This sample (Thief 1) exhibited an iron concentration of 2.40 mg/L. These results further support the hypothesis that the elevated iron concentrations are from the well casing and that water within the formation (below the casing) does not contain elevated total iron concentrations. A flowing wellhead sample (Surface 2) was collected twelve minutes later, and revealed an iron concentration of 8.02 mg/L, again showing the contribution of iron from the well casing.

Iron-rich encrusting material on the casing walls may have been disturbed during the process of raising and lowering the thief sampling device in the well. As a result, samples collected after the initial thief event were impacted by a "cloud" of iron-rich water within the well.

When the thief device was lowered to 995 bls again, the sample results (Thief 2) revealed an iron concentration of 15.6 mg/L. A subsequent wellhead sample (Surface 3) revealed an iron concentration of 9.65 mg/L. A subsequent thief sample (Thief 3) collected from the open hole revealed iron concentration of 13.4 mg/L, continuing to show impacts from the iron-rich cloud. Twenty minutes later, the final thief sample collected during the event (Thief 4) indicated a concentration of 5.05 mg/L, revealing that the cloud may have been settling within the open borehole.

Radius of Influence Analysis

As mentioned in the discussion of the Cycle 0 test results, a distinct freshening trend was observed in water collected from MW-1 after 4 days of recharge (at a rate of 2 mgd) had taken place. At that time, approximately 8 million gallons of water had been injected into the aquifer through the ASR well. This freshening trend has been interpreted to signify the passage of the "front" of the freshwater bubble of injected into the aquifer. MW-1 is located a distance of 275 feet away from the ASR well.

The water quality trends observed at MW-1 indicate that after 4 days of injection, recharge water is placed beyond the distance of the monitor well at the facility. Conversely, after 4 days of recovery (at a rate of 2 mgd) the ASR well withdraws water that has been placed beyond the distance of the monitor well within the storage zone. This is significant because total iron and color concentrations in water collected from the ASR well (including those collected during and beyond the fourth day of recovery) do not show elevated concentrations. Water recharged and recovered from great distances from the ASR well within the storage zone does not show evidence of reactions that degrade water quality. Therefore, the reactions that are causing elevated concentrations of iron and color in water recovered from MW-1 appear to be restricted to phenomena that are occurring within the monitor well casing.

REQUEST TO ALLOW FILTRATION OF WATER SAMPLES FROM MW-1

Based on the multiple demonstrations that support oxidation of the casing as the source of elevated concentrations of iron and color in water collected from MW-1, BCOES respectfully requests the Department to allow the performance of field filtration of water samples collected from MW-1 during cycle testing. The field filtered samples will be analyzed for iron and color only, as the concentrations of these two constituents are related to each other. That is, samples containing relatively high concentrations of particulate iron also display high concentrations of color as a result of the particulate matter.

To support the request to perform field filtration, the 1994 FDEP technical document entitled "Determining Representative Ground Water Samples, Filtered or Unfiltered" was reviewed. The document contains a list of criteria statements and requests that must be addressed before acceptance can be granted, as per Rule 62-520.300(6) of the Florida Administrative Code. The remainder of this correspondence responds to each of the

criteria items listed in the FDEP technical document.

1. The monitor wells are completed in a surficial or intermediate aquifer.

The monitor well for this project is not completed in a surficial or intermediate aquifer. However, the text of the guidance document deals primarily with problems associated with insufficiently developed, small diameter monitor wells completed in low yield aquifers. The text does not exclude the fact that such conditions could exist in deeper, confined aquifers.

The open hole of MW-1 is completed in the upper Floridan aquifer between the depths of 990 feet bls and 1,200 feet bls. The geological material comprising the storage zone is described as a white to gray colored chalky limestone in the report dated 1997 entitled "Engineering Report on the Construction and Testing of the Aquifer Storage and Recovery (ASR) System at the BCOES 2A Water Treatment Plant". The limestone is fossiliferous and exhibits multiple thin layers of low permeability, hard micrite between porous, water bearing zones. Porosity was visually estimated to be intergranular, interparticle and secondary moldic and ranged between 15% to 40%. These materials are relatively competent and are not expected to contain high concentrations of colloidal matter and/or iron.

2. The request to use filtered samples is restricted to the metals and radionuclides (excluding radon).

The request to perform field filtration is restricted to the constituents of iron and color. Because samples containing relatively high concentrations of particulate iron also display high concentrations of color as a result of the particulate matter, these two parameters are related. Testing conducted to date indicates that when field filtration is performed, the concentrations of iron and color in water recovered from MW-1 closely correspond to the concentrations present in water recharged and recovered from the ASR well.

3. The responsible party provides a statement, signed and sealed by the professional geologist or professional engineer who prepared or approved it, documenting that the monitor wells were properly constructed and developed in accordance with standard practices described in EPA Document 600/4-89/034, 1989 Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells, Sections 4, 5, 6, and 7 and Appendix A, or ASTM D 5092-90, Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers, and the applicable water management district's regulations on water well construction.

The 1997 report by CH2M Hill documenting the construction and development of

MW-1 was signed and sealed by Peter Kwiatkowski, P.G., the project manager and Robert W. Hungate, P.E. the project engineer. The monitoring well was properly constructed and developed utilizing deep water well industry standard methods as per the technical specifications, contract drawings and the construction permit, which were reviewed by members of the FDEP, the EPA, the South Florida Water Management District, the United States Geological Survey, and the Broward County Public Health Unit. The materials and methods implemented during the construction of the monitor well are in compliance with those methods described in the EPA Document 570/9-75-001 "Manual of Water Well Construction Practices" and the "AWWA Standard for Water Wells" Chapter A100-90.

4. The ground water samples were collected and analyzed according to a Department approved quality assurance plan and any specific permit requirements.

Throughout the diagnostic testing that has been performed to date at the site, water sample collection and analyses have been performed by the BCOES Analytical Laboratories located in Pompano Beach, Florida, under a state-approved quality assurance plan (Drinking Water Certification #56074 and Environmental Certification #E56441). Water sample collection and analysis during the thief sampling events were performed by Precision Environmental Laboratory located in Miramar, Florida under a state-approved CompQAP (#990102) and HRS Certification (#E86349, 86413).

5. Good faith efforts have been undertaken to remove contributing factors and minimize any persistent turbidity problems in the monitor well water samples. These can include well redevelopment, sampling using a slow well-purging technique during sample collection, and low impact sampling procedures. To demonstrate that a good faith effort has been taken, a document shall be submitted by the professional geologist or professional engineer documenting the well construction, well development, and the steps taken to reduce the turbidity of the samples from the monitor wells, and providing field turbidity measurements taken during well development and purging. It is anticipated that an attempt will be made to purge and sample the well at a very slow, constant pumping rate of e.g., <0.2 gallons per minute. The use of bailers to purge wells has been shown to contribute high turbidity to many monitor well samples and these are not recommended for this purpose. Any pertinent observations which the responsible party desires to discuss should be included.

The multiple demonstrations of evidence described in the first section of this correspondence provide documentation of the good faith efforts that the BCOES has undertaken to determine the cause of high iron and color concentrations in water collected from MW-1. Among the demonstrations were performance of depth-specific (thief) sampling and variation of the pumping rate of the wellhead

sampling equipment. These demonstrations have demonstrated that the source of elevated concentrations of iron and color in water collected from MW-1 is from contact with the steel casing of the well. Field filtration of water samples collected from MW-1 will eliminate the source of the spurious concentrations, and provide a more accurate representation of reactions that are occurring within the storage zone. For future events, water samples from MW-1 will be collected from the wellhead tap, after at least three well volumes of water have been evacuated from the well.

6. Submission of analytical results on filtered and unfiltered samples from a representative number of monitor wells, including the background well. Turbidity measurements must be determined within five minutes of sample collection, and the samples shall be filtered in accordance with this Department technical document.

For the purposes of this project, water that has been recharged, stored and recovered through the ASR well is considered to be most representative of background conditions at the site. A total of 387 million gallons of water has been recharged into the ASR well and 91 million gallons of water have been recovered through the well. Therefore, the ASR well can serve as an appropriate background well for the facility. Analytical results of unfiltered water collected from the ASR well have been included in the Cycle Testing Reports and supporting correspondences that have been submitted to the FDEP. All of the water recharged and recovered from the ASR well (with the exception of a few isolated events) has exhibited total iron concentrations of between 1 mg/L and 3 mg/L. Unfiltered color concentrations from the ASR well (except for a few isolated events) have ranged between 20 units and 40 units. Turbidity concentrations have all been less than or equal to 9 units. As previously described in the thief sampling results, water collected from MW-1 exhibits similar concentrations when subjected to field filtration.

The BCOES would like to resume cycle testing at the WTA 2A ASR facility within the next few weeks. Therefore, we request the Department and TAC review and comment regarding BCOES's request to resume cycle testing and filtration of water samples collected from MW-1 for iron and color analysis as soon as possible. If you have any questions, please contact us at 561-586-8830.

Very truly yours,
MONTGOMERY WATSON

Robert T. Verrastro, P.G.

Senior Hydrogeologist

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