APPENDIX A

FIELD INVESTIGATIONS

As part of the UW29 Manganese Assessment the following field investigation activities were completed:

- Time series sampling at UW 29
- Time series sampling of UW 12 and UW 29
- Conversion of Redox to Eh
- Water level monitoring at Sycamore Landfill

A short summary of the methods, materials, and observations during this investigation are included in this appendix.

Time Series Sampling at UW 29

On January 8, 2007, UW 29 was instrumented for sampling and then turned on for a period of approximately 5 hours for sampling. The well pump's variable frequency drive was set to its lowest setting, to pump at its slowest rate for the first 2 hours and 15 minutes of pumping. This lowest setting was used to slow down potential changes in water quality when first starting to pump the well. After this initial period, the pumping rate was increased to its maximum rate to discharge the maximum amount of water during the pumping period.

Samples were collected from the sample tap located just downstream of the well pump and gate valve. The sample tap valve was removed and replaced with a brass and Teflon tubing arrangement to split flow between a flow through cell and a valve for sample collection. A flow through cell was used for measurement of pH, conductivity, redox, and temperature. The flow through cell was maintained in a water bath of water from the well to maintain uniform temperature.

The well discharge was diverted to the hydrant adjacent to the pump house and discharge to a storm sewer by water utility personnel. Discharge of the well and the head in the well was recorded from the SCADA panel in the well house by water utility personnel. These data are recorded in Table A1.

Time series sampling was conducted to determine water quality changes as water was withdrawn from the aquifer. The volume of water contained within the well is calculated and

subtracted from the total volume of water withdrawn from the well to determine how much water is being withdrawn from the aquifer. These calculations assume that water is withdrawn from the well before water from the aquifer is withdrawn. However, mixing of water in the well and from the aquifer occurs. These calculations are approximate and used as a guide to indicate when water is being withdrawn primarily from the well and when water is withdrawn primarily from the aquifer.

The results of the field parameter monitoring is shown in Figure A1, with notes on when water was being produced from the aquifer, when the well was turned off to increase its flow rate, and the time when each sample for lab analyses were collected.

The size of the pump riser and annulus are shown in Table A1 and used to calculate the volume of water contained in these zones. The volume removed from the pump riser and annulus were calculated for the amount of drawdown that occurred in the water level in these zones. These volumes were subtracted from the total volume pumped to estimate the volume of water removed from the aquifer and the radius of capture from the sandstone aquifer. The radius of capture assumes plug flow through the entire thickness of the open zone of the aquifer (i.e., from the bottom of the casing, at 342 ft to the bottom of the aquifer, 815 ft) and an effective porosity of 10%).

Results of the analyses from the flow through cell (pH, DO, redox and temperature) are shown on Figure A1. The time series results for each parameter are affected by the pump and the meter response. Monitoring of the meter response began before water entered the flow through cell, so each probe was exposed to the air. As water entered into the flow through cell each probe began to equilibrate to the water. Within the first 10 minutes of monitoring, each probe shows a large degree of change.

The redox probe shows the largest change, dropping to a redox of approximately -250 mv before rising to a stable redox (of approximately -88mv) during the first pumping rate. The source of this large drop in redox is not known.

Over the same time frame as the redox drop and rise, the pH rose to 8.3 and then dropped to its steady state value of approximately 7.17. The source of this change in pH is also not known. The change in pH and redox approximately parallels the eH-pH diagram (see Figure A2) line between Fe^{2+} and $Fe(OH)_3$, staying on the $Fe(OH)_s$ side. It is of interest to note, that the samples collected and analyzed over this time frame showed little change in water quality parameters, in particular, iron changed very little, consistent with the observation that the Eh-pH stayed within the insoluble iron zone.

The DO probe shows a drop from high DO and starts to equilibrate at a value of 4.35 mg/L. This is consistent with starting the test with air in the flow through cell. The drop from a value of 4.35 mg/L to its final DO of 0.11 mg/L is probably due to the observation that there were air bubbles coming through the flow through cell for approximately 10 minutes. The fittings were

re-checked to confirm they were tight, demonstrating that no air could be entering the system. The air bubbles gradually dissipated with time. The source of the air bubbles was probably air in the riser pipe and air trapped inside part of the large gate valve. This trapped air may have been released through time. This rise and dissipation of DO was seen again after shutting down the well for approximately 40 minutes to increase its pumping rate.

Results of the time series sampling at UW 29 demonstrates that there were several changes that occurred in very early times when the well was turned on. DO changes are explained by effects of air trapped in the plumbing. The source pH and redox changes are not known, but follow the boundary between iron solubility/insolubility.

Time Series Sampling at UW 12 and UW 30

Field parameters (DO, pH, redox, and specific conductance) were measured at UW 12 and UW 30 to compare with UW 29. The same sampling arrangement was used at UW 12 and UW 30 as used at UW 29, using the same flow through cell. Data from UW 12 and UW 30 are presented in Figures A2 and A3.

The pump at UW 30 was running when the flow through cell was connected and continued running throughout the monitoring period. The pump at UW 12 was running when the flow through cell was connected, but then shut down and started again, as shown on Figure A3. It can be reasonably assumed that water quality being pumped from both these wells was not changing during the time when sampling occurred and that any changes were due to probe equalization or changes due to pump shut down (only at UW 12).

The data collected at UW 30, see Figure A3, show a gradual change in each probe to equilibrium conditions. DO is shown to require approximately 5 minutes to equilibrate from an air filled cell. Specific conductance requires a very short period of time to equilibrate. pH is shown to change quickly, but then requires more then 17 minutes to come to within 0.05 pH units of the final value. Redox is similar to pH, in that it changes dramatically early on, but then requires more than 15 minutes to come to within 20% of the final value measured at approximately 40 mintues.

The data collected at UW 12 is a combination of observations at UW 30 (i.e., a well that had been continuously pumped) and UW 29 (i.e., measurements at startup). The changes in DO initially followed the observation at UW 30, in that DO was equilibrating quickly. However, when the pump cycled off then on, the DO bounced around again, probably due to air in the lines being dissipated.

Conversion of Redox to Eh

The reduction/oxidation potential measured by the YSI probe can be converted to Eh by first correcting the values measured to the standard Zobell solution and then correction from the silver chloride solution to the standard hydrogen electrode (SHE). The standard Zobell solution was measured in the field at each well measured. The correction from the measured redox values to Eh is requires adding 185 mv to the measured redox values to obtain Eh.

Table A1
UW 29 Pumping Records

Depth to Water (ft)	Pump rate (gpm)	Volume pumped in time interval (gal)	Cumulative volume pumped (gal)	Riser volume removed?	Volume removed from annulus & riser (gal)	Volume from aquifer (gal)	Volume from aquifer (ft^3)	Capture Radius (ft)
105.6	0			N				
120.8	1,000	1,000	1,000	N				
120.8	800	900	1,900	Y	1,058	842	113	0.9
120.8	750	775	2,675	Y	1,058	1,617	216	1.2
120.8	710	730	3,405	Y	1,058	2,347	314	1.5
122.4	710	2,840	6,245	Y	1,290	4,955	662	2.1
125	710	16,330	22,575	Y	1,667	20,908	2,795	4.3
126.1	710	7,100	29,675	Y	1,827	27,848	3,723	5.0
127.8	700	15,510	45,185	Y	2,073	43,112	5,764	6.2
129	690	20,850	66,035	Y	2,247	63,788	8,528	7.6
129	690	28,980	95,015	Y	2,247	92,768	12,402	9.1
112	-		95,015	Y	UW 29 shut down from 11:47 to 12:24 to increase rate.			
136	2,770	19,390	114,405	Y	3,262	111,143	14,859	10.0
163.5	2,700	35,555	149,960	Y	7,250	142,710	19,079	11.3
171.7	2,700	40,500	190,460	Y	8,439	182,021	24,334	12.8
174.8	2,600	26,500	216,960	Y	8,888	208,072	27,817	13.7
182.6	2,600	106,600	323,560	Y	10,019	313,541	41,917	16.8
184.3	2,500	51,000	374,560	Y	10,266	364,294	48,702	18.1
186.5	2,500	67,500	442,060	Y	10,585	431,475	57,684	19.7
188.5	2,500	70,000	512,060	Y	10,875	501,185	67,003	21.2
190	2,500	25,000	537,060	Y	11,092	525,968	70,317	21.8

Figure A1. Field Parameters UW 29
January 8, 2007

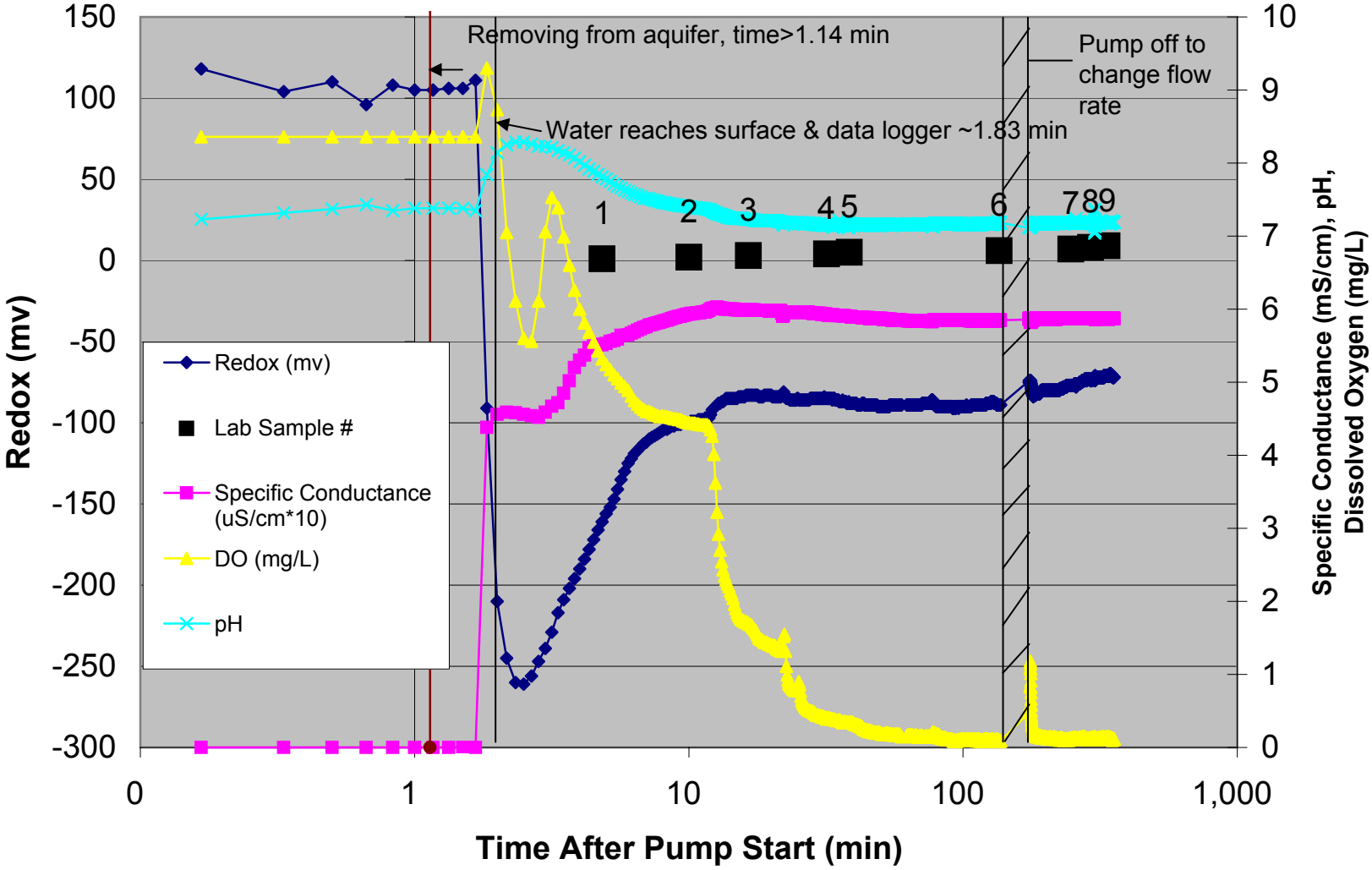

Figure A2. Field Parameters UW 12
January 10, 2007

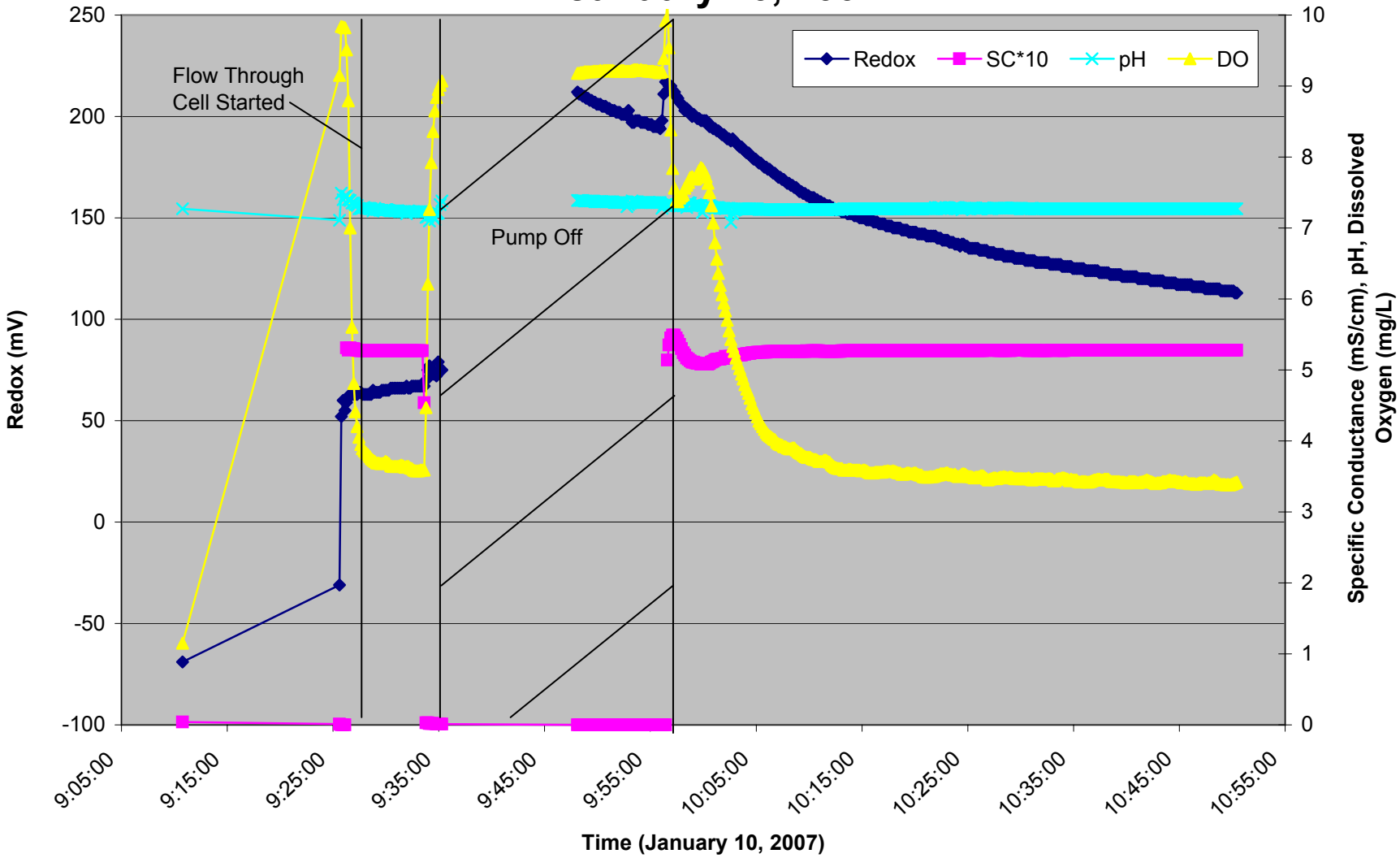

Figure A3. Field Parameters UW 30
January 10, 2007