Port of Seattle

EXAMINING THE EFFECTS OF RUNWAY DEICING ON DISSOLVED OXYGEN IN RECEIVING WATERS: RESULTS OF THE 1999-2000 WINTER SEASON

Seattle-Tacoma International Airport
Seattle, Washington

January 2001

Volume 2
Technical Appendices

AR 034374

ECY00015742

1 INTRODUCTION

This document presents the technical appendices (Volume 2) to the report entitled "Examining the Effects of Runway Deicing on Dissolved Oxygen in Receiving Waters: Results of the 1999-2000 Winter Season" (Volume 1, Report, November, 2000).

(this page intentionally blank)

2 APPENDIX A PHOTOGRAPHS

AR 034377

ECY00015745

(this page intentionally blank)

1 MILLER CREEK WATERSHED SAMPLING STATIONS

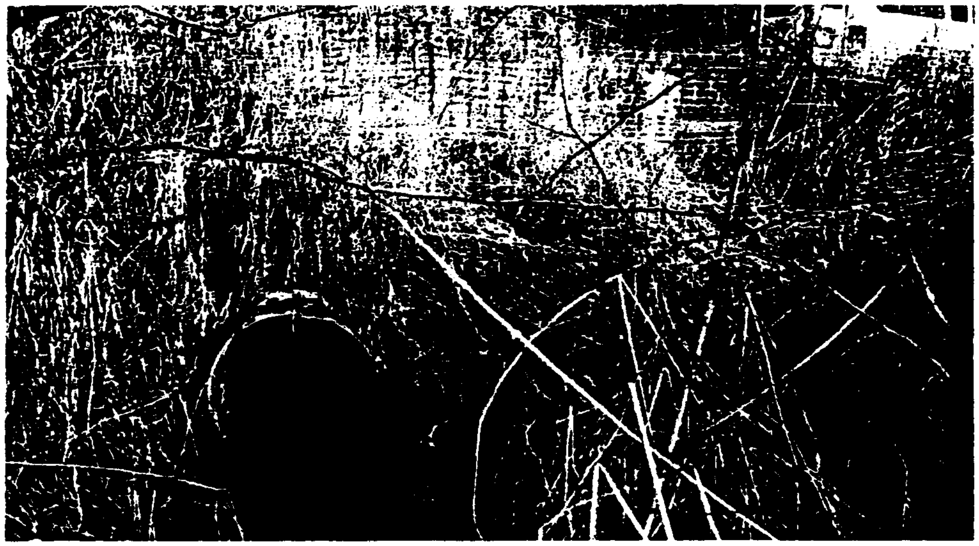


photo 1-1

N1 - culvert outlet

photo 1-2

N1- sampler and flow meter. Culvert outlet is on opposite side of orange fence

photo 1-3

N3N4 - culvert outlet

photo 1-4

N3N4 - Sampler and flowmeter. Culvert outlet on opposite side of orange fence

photo 1-5

NEPL – outlet (south end) of culvert under SR-518

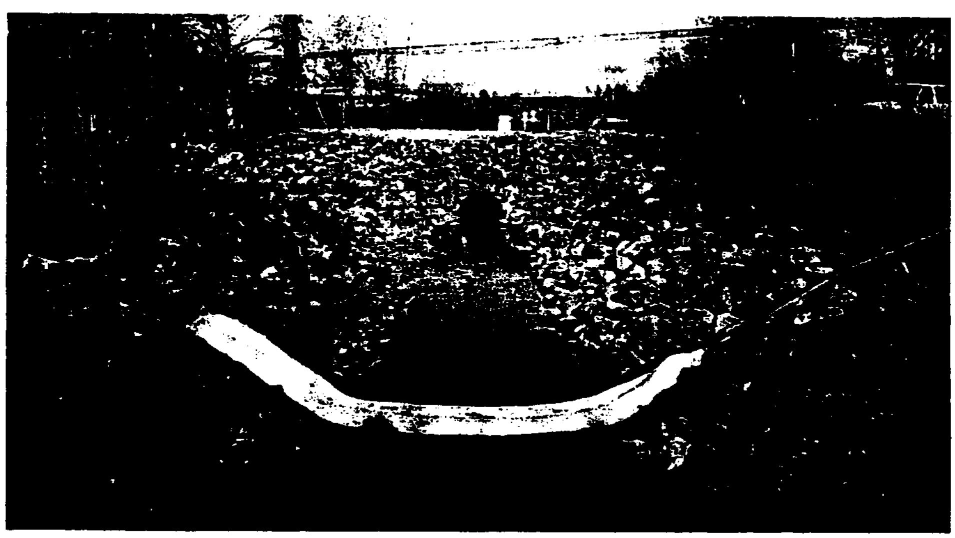


photo 1-6

RebaOut - outlet from control structure where flow measured

AR 034381

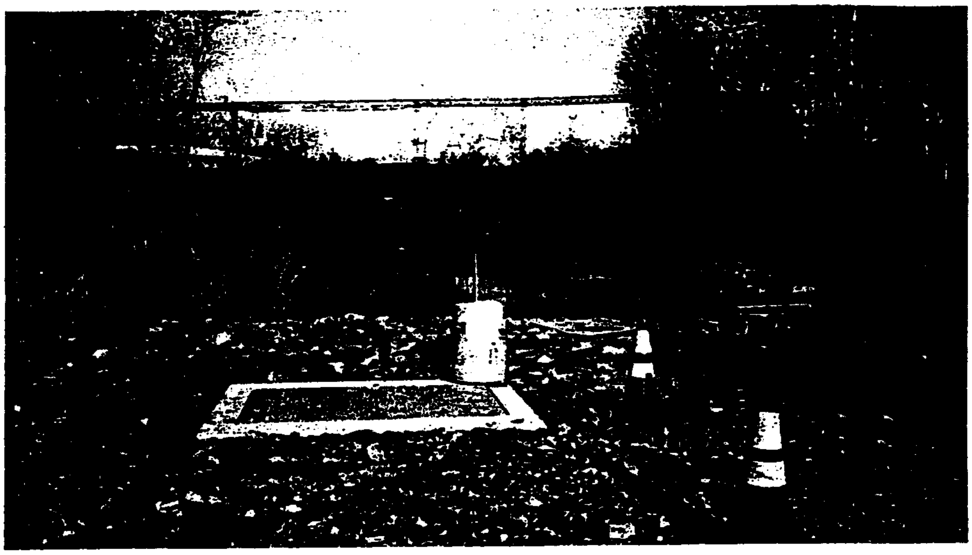


photo 1-7

RebaOut – samples collected in vault where Hydrolab housed

photo 1-8

RebaOut – control structure where samples collected-- white pipe is Hydrolab housing

photo 1-9

Lake Reba 7/31/00, North to right. Outlet at top center, near aircraft wing. N1 and N3N4 inlets near lower left, and NEPL inlet near lower right not visible. Note floating macrophyte growth

photo 1-10

Lake Reba: 9/27/00 looking west from east end

AR 034383

ECY00015751

photo 1-11

MCup –sampler and flowmeter

photo 1-12

MCmouth – stilling well from north bank upstream of bridge on SW 175th Place. Large stilling well is KCDNR station

2 DES MOINES CREEK WATERSHED SAMPLING STATIONS

photo 2-1

NPin – culvert outlet with sampler and flowmeter in the background

AR 034385

ECY00015753

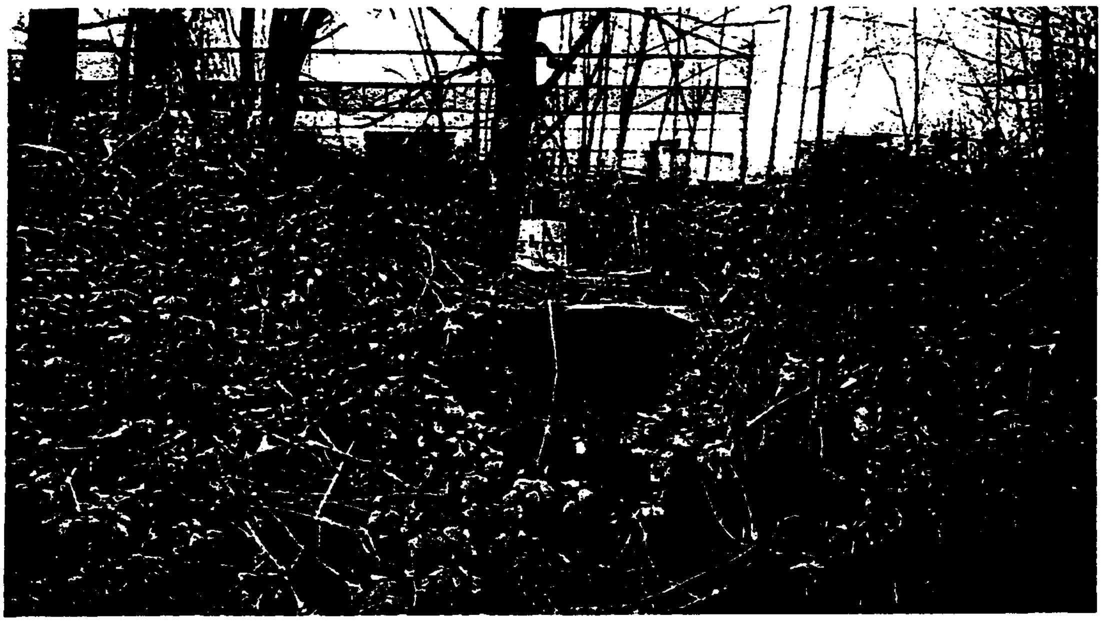


photo 2-2

S567 – culvert outlet with sampler in the background

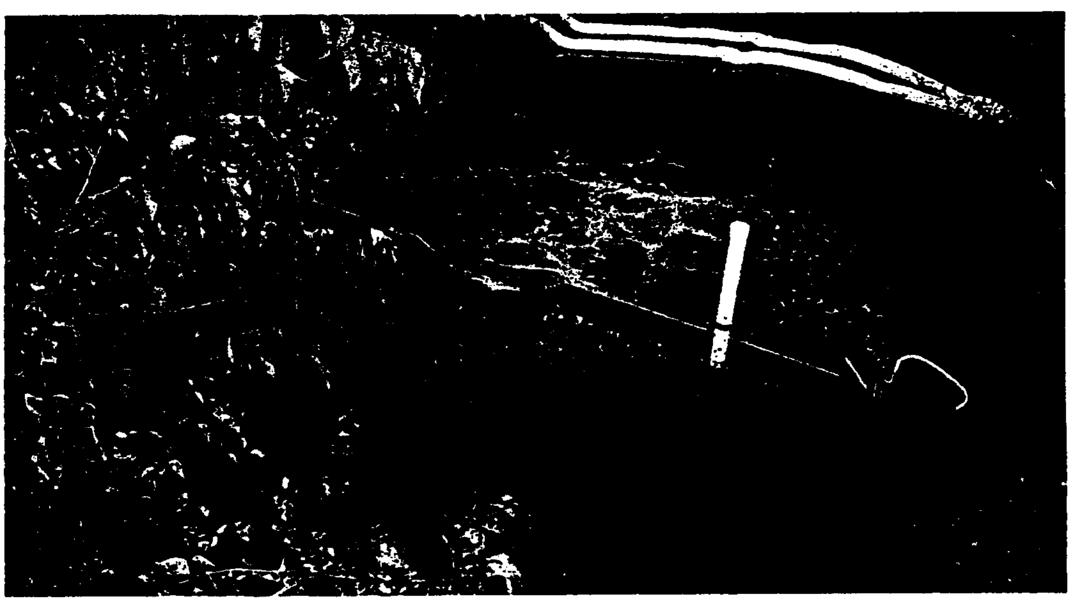


photo 2-3

SDS3 – samples taken from upstream (left side) of weir

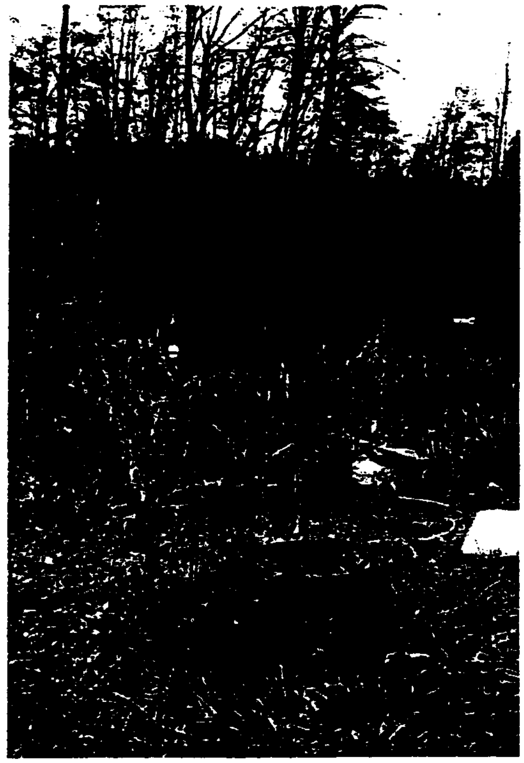


photo 2-4

NP1 – sampler in foreground under bag. Hydrolab buoy in upper right

photo 2-5

NPout - sampler and flowmeter at pond outlet. NP3 Hydrolab station is white buoy in right center

photo 2-6

NPout - outlet of Northwest Pond Cell 3 at culvert just right of center

photo 2-7

Northwest Pond Cell 3 – NP3 Hydrolab station at white buoy in center

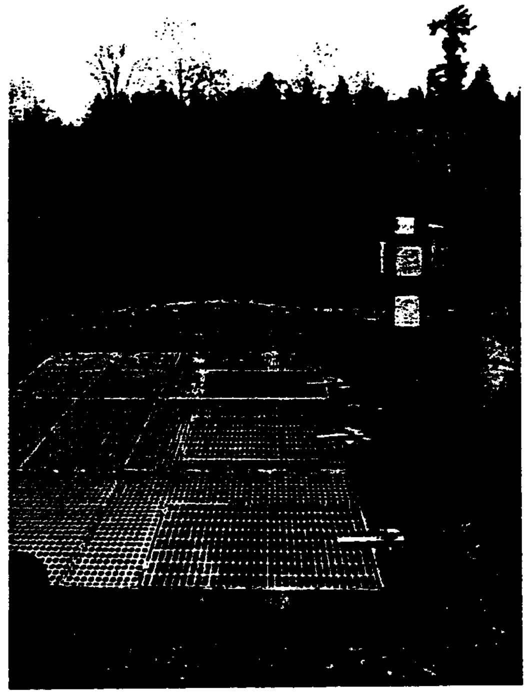


photo 2-8

DME - Tyee Pond control structure vault. KCDNR loggers on right

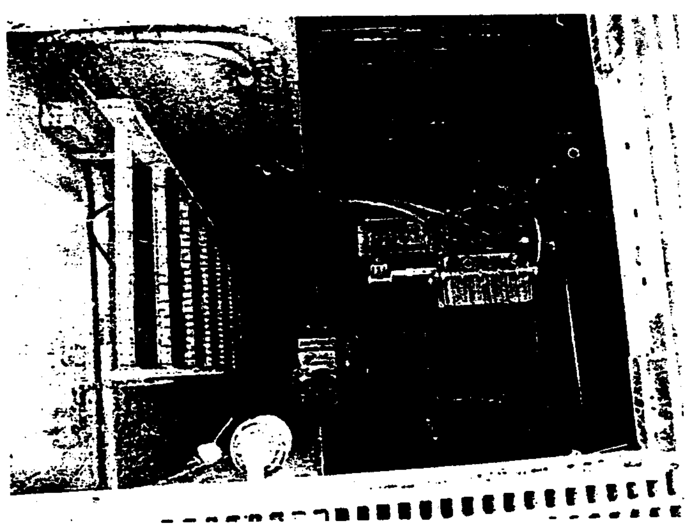


photo 2-9

DME – inside of Tyee Pond control structure

AR 034389

ECY00015757

photo 2-10

DME – instream inlet to control structure on east branch where samples were collected

photo 2-11

DMmouth –sampler housing in white box on right end of footbridge. Large stilling well for KCDNR gage

Photo 2-12

NW Ponds from, Feb 00. North is to right

AR 034391

ECY00015759

photo 2-13

NW Ponds: 9/27/00 looking West-Southwest. Note macrophyte growth ringing cell#3 in foreground. Cell 2 in center, Cell 1 in shadows in center of photo

photo 2-14

Detail near outlet of NW Ponds cell #3, 9/27/00, looking west (upgradient) from outlet structure note considerable macrophyte growth. White buoy left of center is NP3 Hydrolab station

photo 2-15 NWP Cell 2 detail of macrophyte growth, August 2000

photo 2-16 NWP cell 3 macrophyte growth, looking towards outlet, August 2000

3 JANUARY 2000 RUNWAY DEICING EVENT PHOTOS

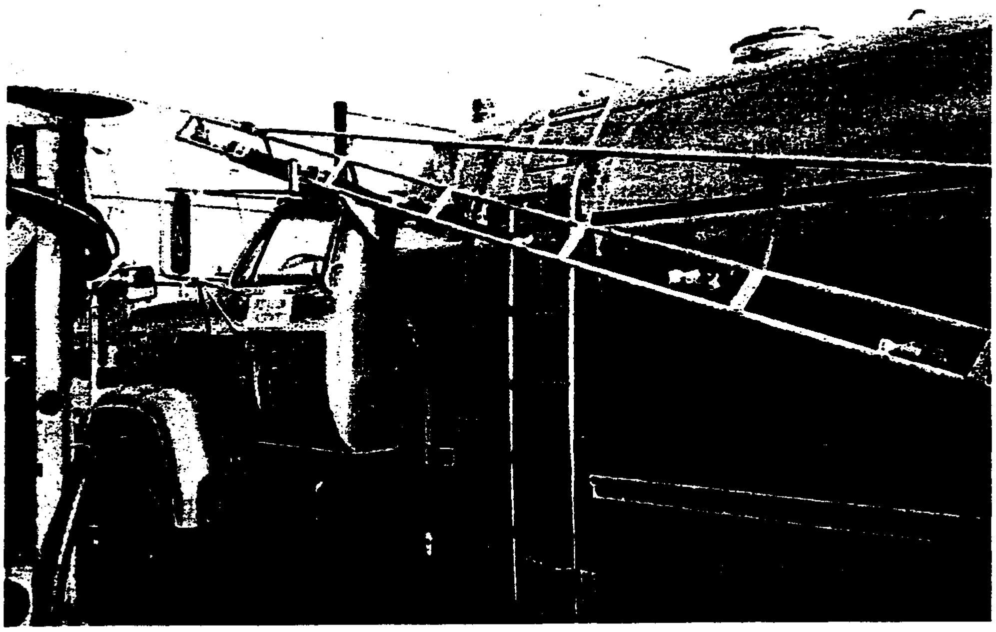


Figure 3-1 Liquid Potassium Acetate Application Truck #10.

Note pink color in vertical tube on tank shows liquid level

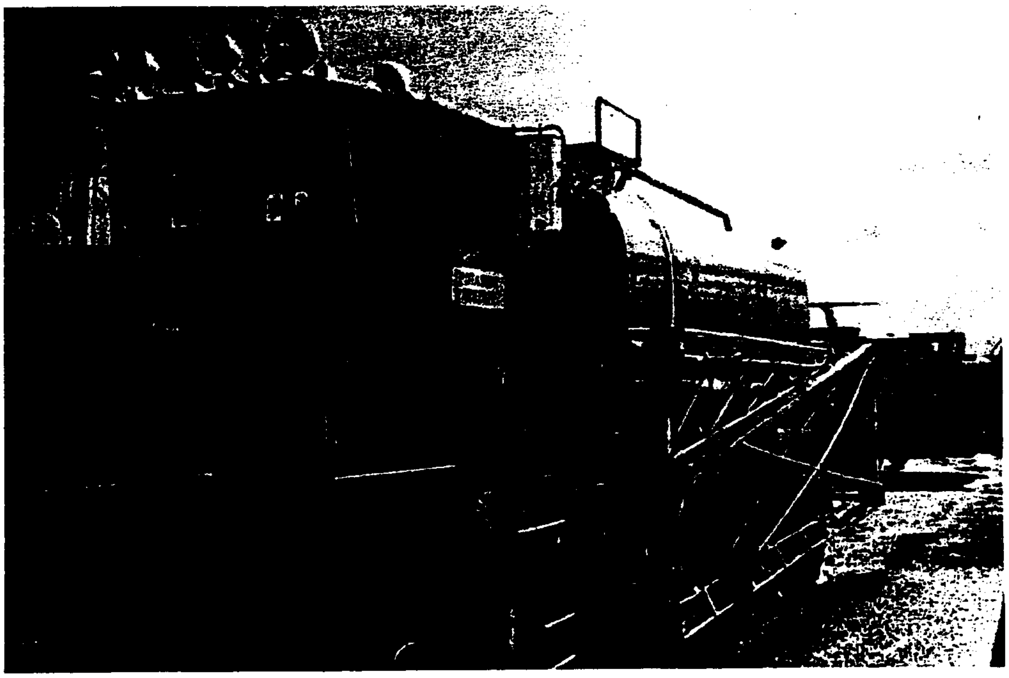


Figure 3-2 Liquid Potassium Acetate Application Truck #11.

Note pink color in vertical tube on tank shows liquid level and approximate volume

Figure 3-3 View NW over airfield during event 1, January 12, 2000,10:19

Taxiway A in foreground. Northbound MD80 aircraft on Taxiway B. Southbound 737 aircraft on takeoff roll on runway 16L. Note minor amount of snow plowed to edge; melting in progress.

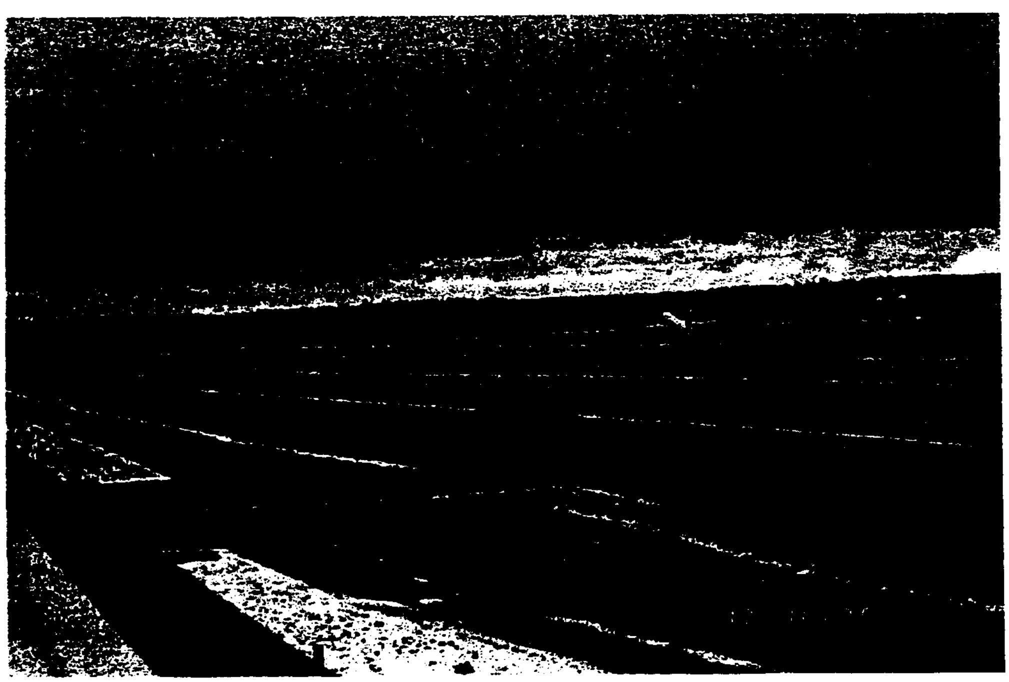


Figure 3-4 View SW over airfield during event1, January 12, 2000, 10:20.

Taxiway A in foreground, southbound 737 aircraft on takeoff roll on runway 16L. Note minor amount of snow plowed to edge; melting in progress.

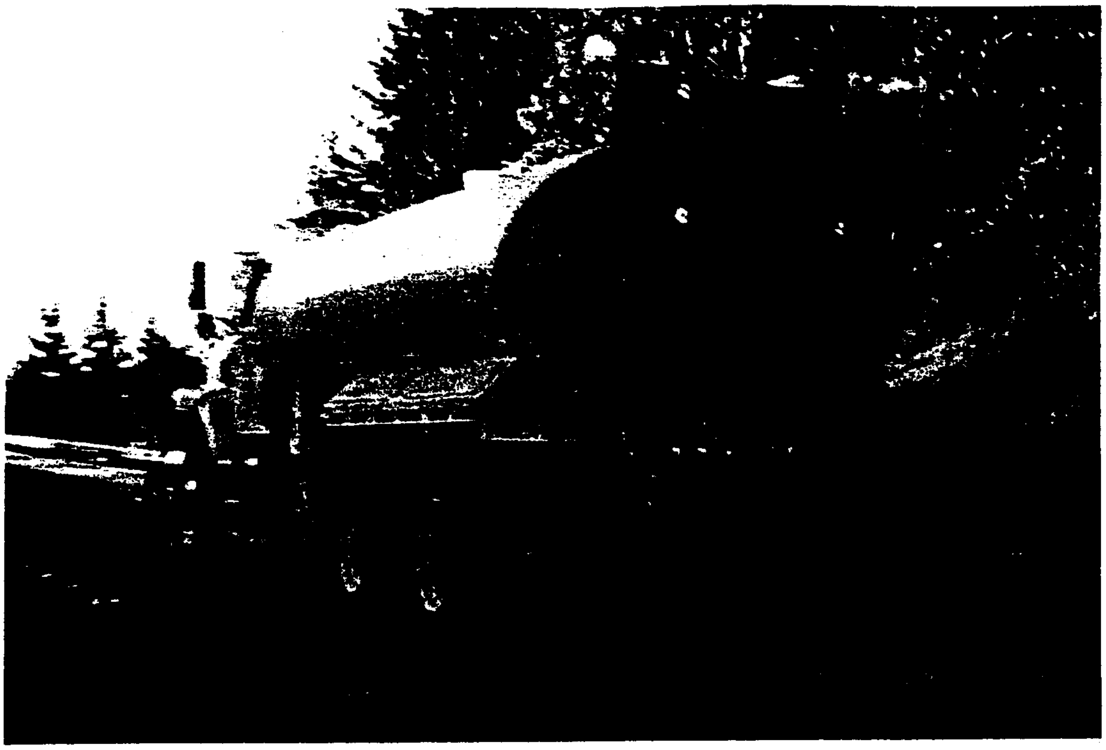


Figure 3-5 Event 2 WSDOT Liquid Deicer Applied on Southbound SR509, January 19, 2000, 07:31.

Figure 3-6 Event 2 WSDOT Liquid Deicer Applied on Southbound SR509, January 19, 2000, 07:30.

Note heavy frost on shoulder breakdown lanes

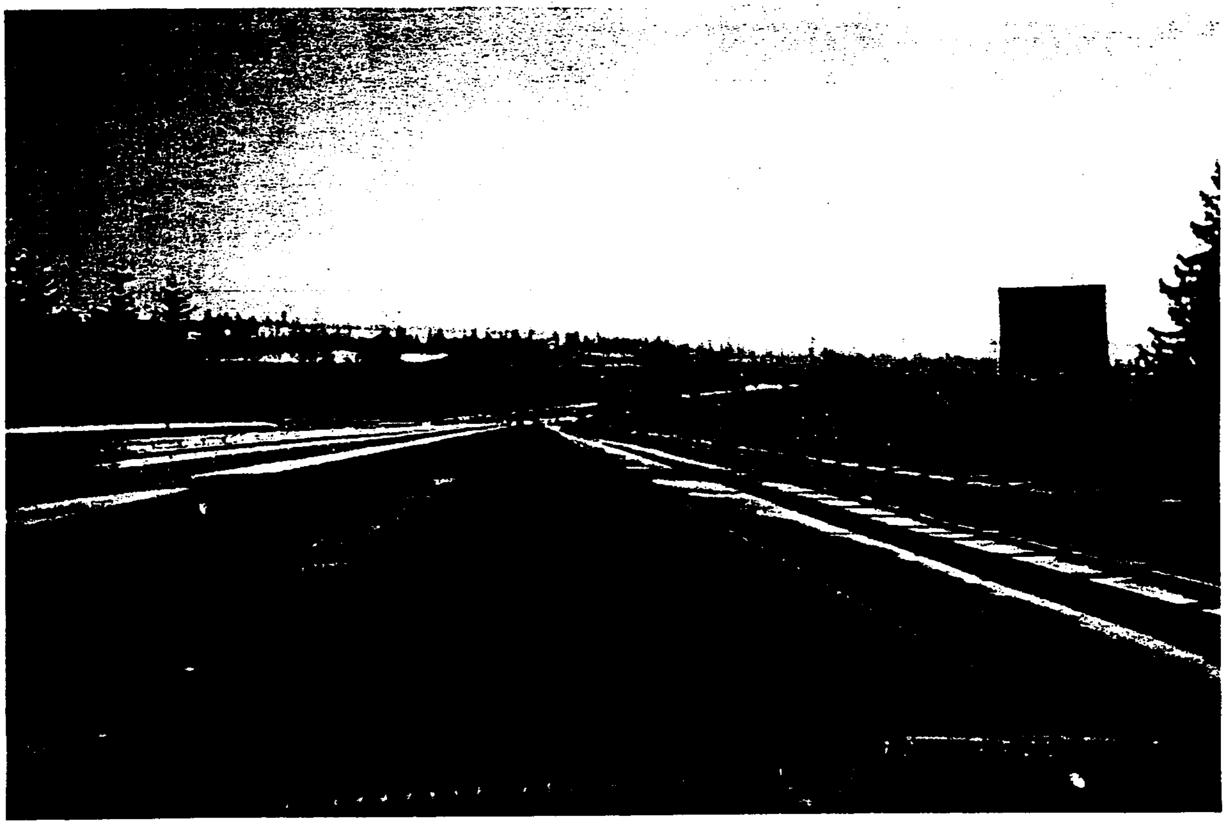


Figure 3-7 Eastbound SR518, January 19, 2000, 07:36.

Note heavy frost on shoulder breakdown lanes

AR 034397

ECY00015765

3 APPENDIX B QA/QC AND FIELD METHODS

3.1 Introduction

This Appendix presents the quality assurance/quality control methods and field installation procedures used during the study. Plots of QC data and profiles of chemical constituent concentrations also appear in this appendix.

3.2 Hydrolab Maintenance, and Quality Control Procedures

Each week the Hydrolabs were removed from the water and were either taken to the stormwater field lab, if they were scheduled to be calibrated, or were cleaned and maintained at the station. At the time each unit was removed, the water depth at the station was measured and water samples were collected for dissolved oxygen and conductivity analysis by a contract laboratory. Water samples were taken using a Van Dorn sampler at the same depth that the sonde had been deployed. A portion of each sample was immediately fixed with reagents for subsequent Winkler DO analysis by the lab.

Dissolved oxygen and temperature were measured at the depth of the sonde using a YSI Model 95 hand held DO meter. When the Hydrolabs were redeployed after maintenance and calibration, these procedures were repeated, except that measurements and water samples were taken from the depth at which the unit would be deployed over the next week. Samples collected when the sondes were taken out were labeled "end", and samples collected when the units were put back were labeled "start".

Data was immediately downloaded from each sonde each time the unit was removed from the water for maintenance. Data was imported into an Excel worksheet and immediately reviewed for any data gaps and errors. The unit was then programmed for redeployment. Sensors were cleaned per the manufacturer's recommendations, battery voltage was checked and batteries were replaced if necessary. All activity was recorded in a weekly Field Log. The sonde was then redeployed, typically within an hour of when it was removed.

Every other week, the DO sensor on each sonde was calibrated according to the Hydrolab manual instructions. Conductivity was calibrated once, immediately prior to the initial deployment of each sonde. For DO calibration, the sondes were taken back to the stormwater laboratory and kept overnight. After each unit was cleaned and inspected, the DO sensor membrane and electrolyte was replaced and the sensor was soaked in deionized water for at least 12 hours prior to calibration. Calibration was performed according to the manufacturer, using the water-saturated air method, which assumes 100% DO saturation at ambient barometric pressure. Data sondes were typically taken out of service for less than 24 hours for calibration.

3.3 Northwest Ponds DO Profile Data Collection Procedures

At each monitoring location in the 3 cells of the Northwest Ponds (NP1, NP2, and NP3), measurements of DO and temperature were taken along vertical profiles using a YSI model 95 hand held DO meter. At NP1 and NP2, measurements were taken at 1-foot intervals along the 10 to 12-foot deep profile. In the shallower cell 3 (6 foot deep), measurements were taken at ½-foot intervals.

Grab samples were collected a short distance horizontally from where the DO measurements were taken to minimize errors from possible water strata mixing. At each station, grab samples were collected at the same depth interval that DO measurements were taken. Sampling proceeded from the surface to the bottom of the water column. A surface sample was collected by dipping the sample bottle directly into the pond. All other samples were collected with a Van Dorn sampler attached to the end of a pole. The sampler was lowered on the pole into the water column at a slight angle from horizontal and once positioned at the appropriate depth, the sampler was triggered to collect a sample. The planar location of the profile sampling varied by up to 20 ft due to boat drift. In each cell, the deepest sample typically contained a significant amount of unconsolidated sediment comprised mostly of fine, dark organic matter.

On two occasions, ORP was measured in every profile sample collected with the Van Dorn sampler. Before any water was removed from the sampler, the top of the cylinder was opened and the ORP probe from an Orion model 1230 pH/redox meter was slowly lowered to the bottom of the sampler and the readings were allowed to stabilize. The ORP readings taken in the first two Van Dorn samples at each station were compared to ORP measurements taken by lowering the probe into the water column. At each station, each pair of ORP measurements were within 5 mV of each other. Before taking the first reading at each cell, the ORP meter was checked against an ORP standard. The probe was rinsed with deionized water before each reading was taken.

3.4 Assessment methods for continuous monitoring data

To assess the success of the field quality control measures used for continuous water quality monitoring at Lake Reba and the Northwest Ponds, the differences between dissolved oxygen measurements obtained concurrently by three methods were calculated. Specifically, the relative percent difference (RPD) between each of the concurrent measurements was determined as follows:

$$RPD = [(M1 - M2) / ((M1+M2/2))] \times 100$$

where-

M1 = DO measurement by first method

M2 = DO measurement by second method

AR 034400

ECY00015768

Three RPDs were calculated for each set of data: 1) the RPD between the Hydrolab and Winkler measurement, 2) the RPD between the Hydrolab and YSI measurement, and 3) the RPD between the Winkler and YSI measurement.

Time series charts of each set of these RPDs are presented for the Lake Reba Outlet, and three locations in NWP (NP1-NP3) in this Appendix. According to the monitoring plan, an RPD no greater than ±20% was considered acceptable, reflecting the measurement error inherent to employing the three methods under these circumstances. An RPD beyond ±20% warranted review of quality control procedures and revision of maintenance and calibration routine if necessary as well as an investigation of whether spatial variability or some other environmental factors were causing substantial differences in the measurements.

3.5 Monitoring Instrument Installations

Isco model 4150 area-velocity flowmeters were used to monitor flow at RebaOut, NEPL, N1, N3N4, NPin, and NP567. Each unit used an area velocity probe to measure water level and velocity. The probe was attached to a scissor-ring that was inserted into the pipe at each station. Each of the flowmeters was programmed to log level, flow, velocity, and sample events.

Isco model 4230 bubbler flow meters were used for continuous flow monitoring at MCup, MCmouth, NPout, SDS3, DME, and DMmouth. At each station, a bubbler line was attached to a section of steel rebar secured in the channel and the level was set using a staff gage or measurement from an established benchmark (tape-down measurement). Each time these instruments were maintained, the meter level was checked against the tape down measurement or staff gage.

Isco model 3700 samplers were deployed to collect water samples. Samplers were configured with 24, 1-liter polypropylene bottles. Sample bottles were washed and rinsed with deionized water prior to deployment. To accomplish level enabling, the samplers were hard-wired to flowmeters everywhere except at NP1. At that station, a level enabling triggering mechanism was installed at the pond's edge and was set to trigger at one-tenth foot above the water surface existing just before event sampling. With a rise in water level at the onset of runoff, the trigger mechanism became submersed, sending an electrical pulse to the sampler, which enabled the unit to begin the sampling routine.

Each sampler was equipped with a 5/8-inch vinyl suction line. At most stream sampling stations, the sampler suction line strainers were positioned mid stream, just above the channel bottom. At MCmouth and DMmouth, the strainers were positioned near the edge of the stream at mid-depth. The strainers were secured with zip-ties either to the flow meter cables, stilling wells, trash racks, or other structures.

At the pond stations the sampler strainers were positioned in a different manner. At NP1, the sampler strainer was suspended six feet below the water surface from a buoy located about 20 feet offshore, near the Hydrolab sonde. At NPout, the strainer was attached to the King County gage stilling well, located adjacent to the outlet culvert, at about mid-depth. At RebaOut the sampler strainer was installed in the vault sump, just below the elevation of the outlet pipe invert, next to the Hydrolab sonde. The strainer was zip-tied to the access ladder to keep it in place.

Twelve-volt deep cycle marine batteries powered all samplers and flowmeters. Each sampler was housed in a shelter or completely covered with a plastic bag to provide additional protection during deployment.

3.6 Constituent Data concurrent with NW Ponds DO Profiles

The table below summarizes the chemical constituents that were analyzed concurrently with DO in samples taken during vertical profile sampling in Northwest Ponds, cells 1-3 (stations NP1, NP2, and NP3). Plots of these profiles appear below. See Volume 1, Section 3.3 for a discussion of sampling methods.

Table 3-1 NW Ponds Profiles: Chemical Constituent Data

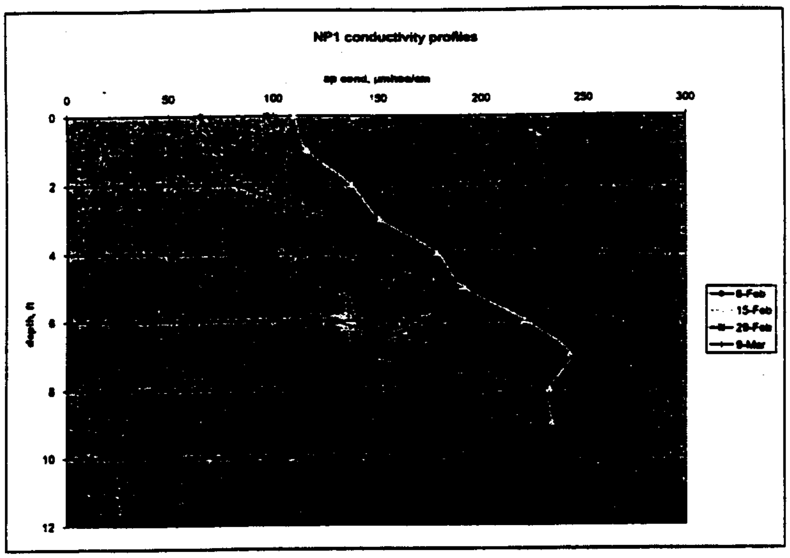
SAMPLE ID	depth, ft	COND (uS/cm)	BOD5 (mg/l)	COD (mg/l)	pH	Ca2+ (mg/l)	K+ (mg/l)	Na2+ (mg/l)
NP1 020800 0	0	65.4		5.0	6.55	8.83	1.10	2.60
NP1 020800 1	1	73.1		13.4	6.61	9.03	2.36	2.93
NP1 020800 2	2	83.5		13.0	6.60	9.80	0.30	4.21
NP1 020800 3	3	129		11.3	6.60	15.5	0.732	6.54
NP1 020800 4	4	133		14.2	6.61	15.4	2.06	7.03
NP1 020800 5	5	195		10.9	6.68	24.2	2.77	9.16
NP1 020800 6	6	172		14.6	6.58	21.6	2.73	7.68
NP1 020800 7	7	149		13.0	6.65	18.8	2.82	6.32
NP1 020800 8	8	237		5.0	6.62	29.8	3.56	10.1
NP1 020800 9	9	237		12.1	6.55	31.2	2.88	9.99
NP1 020800 10	10	178		111	6.54	22.9	3.65	8.71
NP2 020800 0	0	106		20.1	6.57	13.3	1.94	6.16
NP2 020800 1	1	107		21.8	6.56	14.4	1.71	7.47
NP2 020800 2	2	136		15.9	6.71	19.3	1.96	8.81
NP2 020800 3	3	137		12.1	6.47	18.1	2.03	9.01
NP2 020800 4	4	166		10.5	6.45	22.6	3.23	9.33
NP2 020800 5	5	173		18.4	6.46	22.5	4.13	9.81
NP2 020800 6	6	176		23.1	6.52	22.1	3.63	10.0
NP2 020800 7	7	190		15.9	6.64	25.0	1.69	9.09
NP2 020800 8	8	204		16.7	6.63	29.1	3.64	10.9
NP2 020800 9	9	192		16.7	6.71	27.2	2.57	10.7
NP2 020800 10	10	199		106	6.74	22.8	3.64	8.05
NP3 020900 0	0	86.2	4.00	16.3	6.81	8.27	1.04	2.18
NP3 020900 1	1	96.5	2.00	18.0	6.97	7.41	1.54	2.42
NP3 020900 2	2	103	2.00	13.0	6.62	9.06	1.79	2.84
NP3 020900 3	3	117	7.50	36.8	6.73	11.2	2.43	3.51
NP3 020900 4	4	109	27.5	58.3	6.57	8.55	1.87	3.07
NP3 020900 5	5	141	14.3	160	6.72	11.1	1.12	4.06
NP1 021500-0	0	110	2.00	5.0		12.2	1.08	2.76
NP1 021500-1	1	116	2.00	10.1		12.2	1.23	2.86
NP1 021500-2	2	137	2.00	10.5		13.9	1.31	3.30
NP1 021500-3	3	151	2.00	5.0		15.8	1.55	3.98
NP1 021500-4	4	178	2.00	16.3		18.7	1.79	4.79
NP1 021500-5	5	191	2.00	5.0		21.8	1.98	5.64
NP1 021500-6	6	221	4.34	11.3		26.4	2.28	6.30
NP1 021500-7	7	243	2.00	14.6		26.7	2.62	7.23
NP1 021500-8	8	233	2.00	16.7		25.9	2.38	6.70
NP1 021500-9	9	234	2.00	34.6		25.6	2.34	6.45

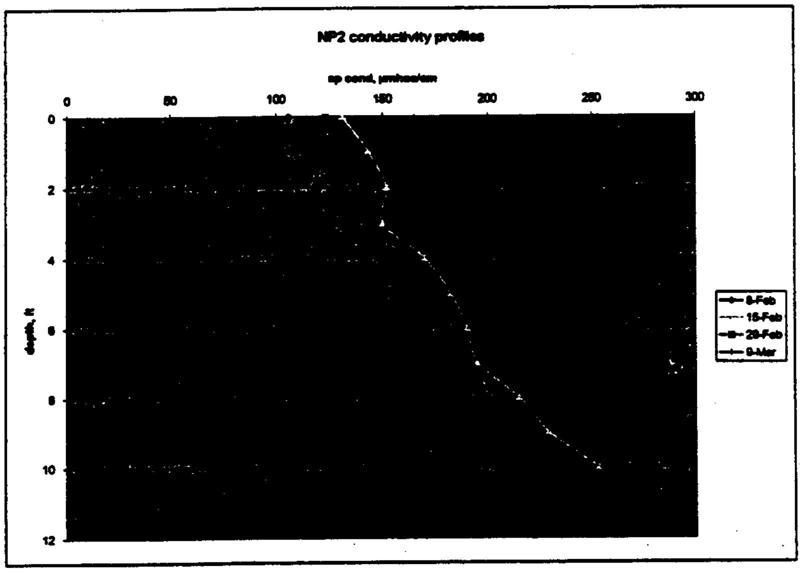
Table 3-1 (continued)

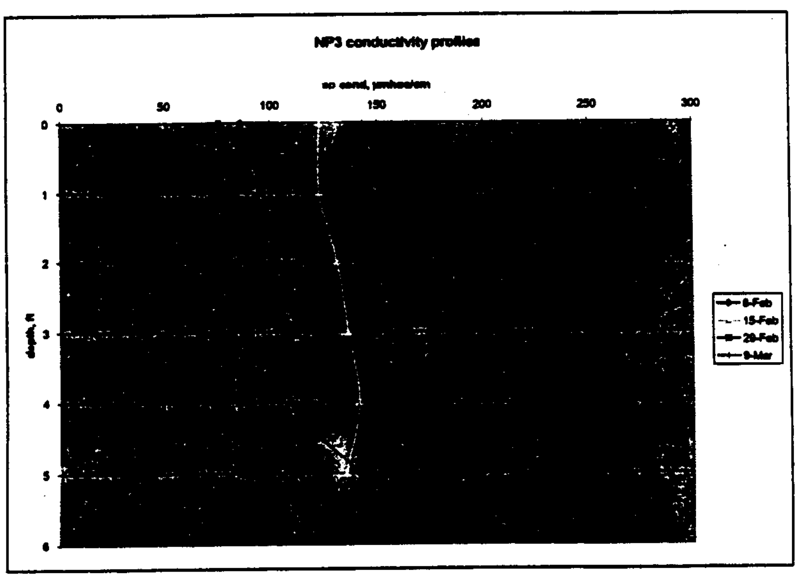
SAMPLE ID	depth, ft	COND (uS/cm)	BOD5 (mg/l)	COD (mg/l)	pH	Ca2+ (mg/l)	K+ (mg/l)	Na2+ (mg/l)
NP2 021500-0	0	131	2.00	19.7		18.8	1.31	3.57
NP2 021500-1	1	143	2.00	14.6		19.7	1.47	4.00
NP2 021500-2	2	152	2.00	10.5		20.8	1.55	4.45
NP2 021500-3	3	150	2.00	14.2		18.3	1.58	4.18
NP2 021500-4	4	170	2.00	11.7		21.9	1.90	5.12
NP2 021500-5	5	182	2.00	18.8		25.1	1.91	5.17
NP2 021500-6	6	190	2.00	5.0		23.5	2.12	5.41
NP2 021500-7	7	195	2.00	5.0		22.5	2.05	5.42
NP2 021500-8	8	215	2.00	12.6		28.9	2.65	6.15
NP2 021500-9	9	229	2.00	16.3		29.3	2.52	6.09
NP2 021500-10	10	253	31.8	178		30.8	2.93	6.66
NP3 021500-0	0	123	15.9	22.2		18.8	2.30	2.90
NP3 021500-1	1	123	15.5	18.0		21.0	2.11	2.91
NP3 021500-2	2	131	12.4	23.5		19.8	2.23	3.17
NP3 021500-3	3	136	11.4	18.8		20.4	2.30	3.30
NP3 021500-4	4	141	11.4	109		21.3	2.31	3.83
NP3 021500-5	5	135	22.9	149		20.7	2.58	3.48
NP1 022900-0	0	96.9	4.16	31.2		9.30	0.973	1.97
NP1 022900-1	1	104	2.00	28.2		10.7	1.04	2.04
NP1 022900-2	2	102	2.00	26.9		10.4	1.13	2.11
NP1 022900-3	3	103	2.00	24.3		10.8	0.820	2.16
NP1 022900-4	4	112	2.00	20.5		10.4	0.943	2.40
NP1 022900-5	5	119	2.00	21.8		11.4	1.20	2.47
NP1 022900-6	6	129	2.00	20.1		13.4	1.36	2.97
NP1 022900-7	7	205	2.00	27.7		22.2	2.22	5.26
NP1 022900-8	8	202	4.20	24.3		22.4	2.11	5.38
NP1 022900-9	9	226	5.58	24.8		23.7	2.26	5.52
NP1 022900-10	10	244	7.40	18.8		26.2	2.41	6.21
NP2 022900-0	0	123	2.00	13.8		10.9	1.09	2.51
NP2 022900-1	1	122	2.00	13.4		12.2	1.22	2.67
NP2 022900-2	2	119	2.00	16.3		12.2	0.911	2.85
NP2 022900-3	3	128	2.00	21.4		13.2	1.73	3.18
NP2 022900-4	4	148	2.00	22.6		16.0	1.51	3.78
NP2 022900-5	5	153	2.00	27.7		15.4	1.59	4.21
NP2 022900-6	6	170	2.00	19.3		17.8	1.65	4.23
NP2 022900-7	7	192	2.00	22.2		20.3	1.84	4.93
NP2 022900-8	8	199	2.00	14.2		22.7	1.97	5.29
NP2 022900-9	9	209	2.00	19.3		23.2	2.19	5.22
NP2 022900-10	10	224	2.00	23.1		26.6	2.28	5.77
NP3 022900-0	0	76.0	4.92	5.0		9.61	1.58	1.08
NP3 022900-1	1	77.3	5.94	5.0		9.30	1.68	1.10
NP3 022900-2	2	79.2	5.46	13.0		9.97	1.63	1.03
NP3 022900-3	3	82.4	4.90	14.2		10.0	1.78	1.22
NP3 022900-4	4	85.4	4.68	12.6		10.4	1.75	1.33
NP3 022900-5	5	86.1	36.4	716		8.78	1.99	1.57

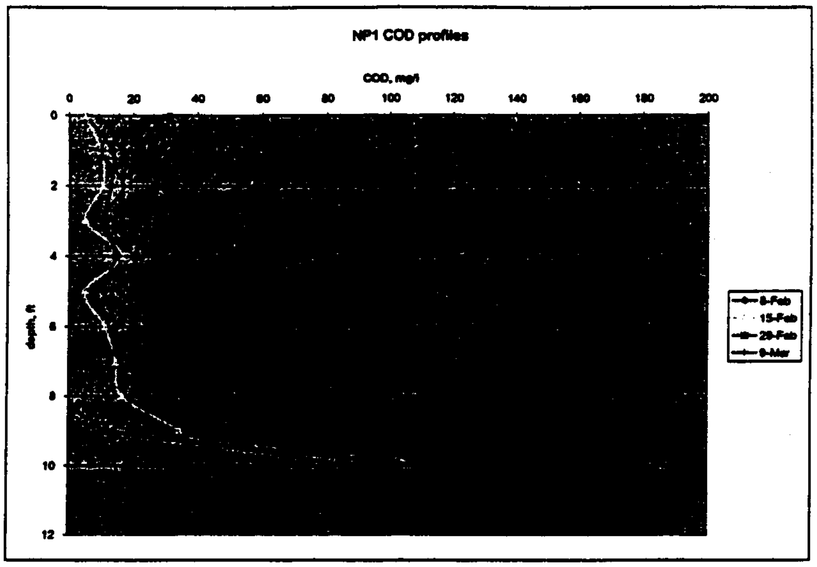
Table 3-1 (continued)

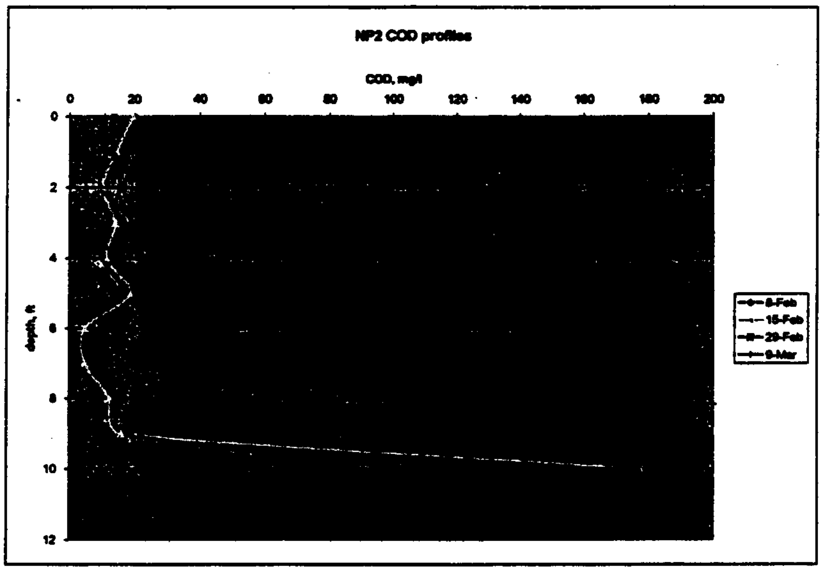
SAMPLE ID	depth, ft	COND (uS/cm)	BOD5 (mg/l)	COD (mg/l)	pH	Ca2+ (mg/l)	K+ (mg/l)	Na2+ (mg/l)
NP1 030900 0	0	194	2.00	15.5		17.5	1.66	5.08
NP1 030900-1	1	200	2.00	10.1		18.7	1.97	5.20
NP1 030900-2	2	200	2.00	16.7		24.9	2.37	6.54
NP1 030900-3	3	204	2.00	10.1		26.0	2.55	6.27
NP1 030900-4	4	219	2.00	15.5		29.8	2.40	6.88
NP1 030900-5	5	204	2.00	15.9		25.7	2.81	6.45
NP1 030900-6	6	242	4.18	26.9		31.1	2.87	6.95
NP1 030900-7	7	275	7.14	24.8		35.0	3.10	7.98
NP1 030900-8	8	270	5.76	19.3		36.1	3.35	8.13
NP1 030900-9	9	293	10.6	24.3		35.0	3.40	8.57
NP1 030900-10	10	288	16.9	87.9		32.4	3.17	8.01
NP2 030900 0	0	165	2.00	10.9		15.8	1.63	3.67
NP2 030900-1	1	170	2.00	11.3		16.9	1.41	3.78
NP2 030900-2	2	176	2.00	9.6		14.6	1.81	3.70
NP2 030900-3	3	184	2.00	19.3		19.1	1.82	4.64
NP2 030900-4	4	187	2.00	13.4		19.0	1.92	4.63
NP2 030900-5	5	198	2.00	9.64		20.1	2.09	5.22
NP2 030900-6	6	205	2.00	10.5		20.7	2.21	4.96
NP2 030900-7	7	220	2.00	16.3		23.2	2.43	5.64
NP2 030900-8	8	256	5.48	63.2		29.0	2.76	6.10
NP2 030900-9	9	243	25.4	1939		22.9	2.42	5.39
NP3 030900 0	0	143	2.00	14.2		15.4	1.68	2.83
NP3 030900-1	1	147	2.00	17.6		15.8	1.66	2.76
NP3 030900-2	2	152	2.00	12.6		16.0	1.69	2.84
NP3 030900-3	3	160	2.00	10.5		17.5	1.96	3.01
NP3 030900-4	4	160	2.00	13.0		16.6	1.91	3.01
NP3 030900-5	5	158	10.7	24.3		16.6	1.92	3.21
not detected: result shown is 1/2 detection limit								

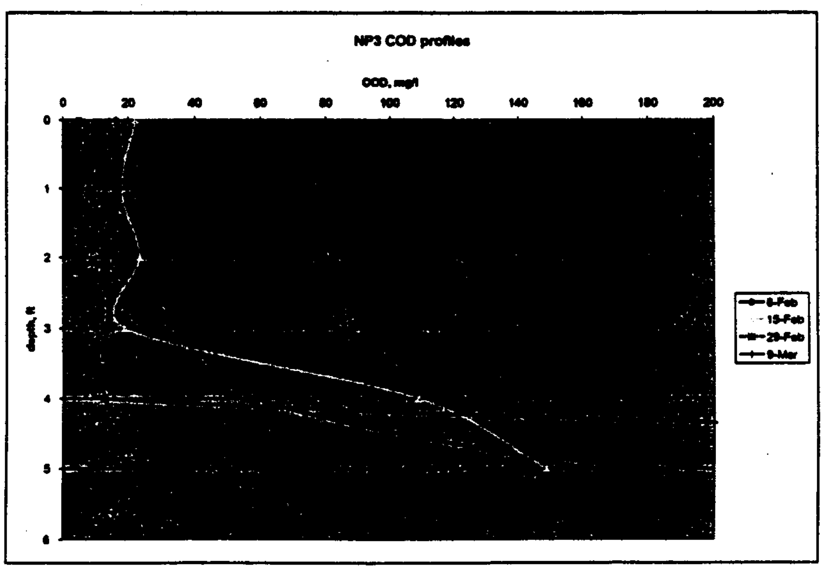

NP1 conductivity profiles
sp cond, µmhos/cm
depth, ft


NP2 conductivity profiles
sp cond, µmhos/cm
depth, ft


NP3 conductivity profiles
sp cond, µmhos/cm
depth, ft

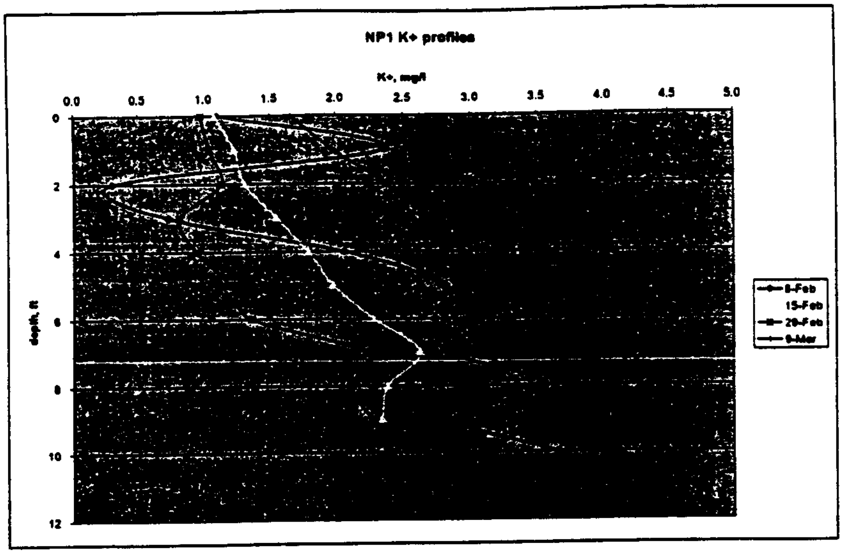


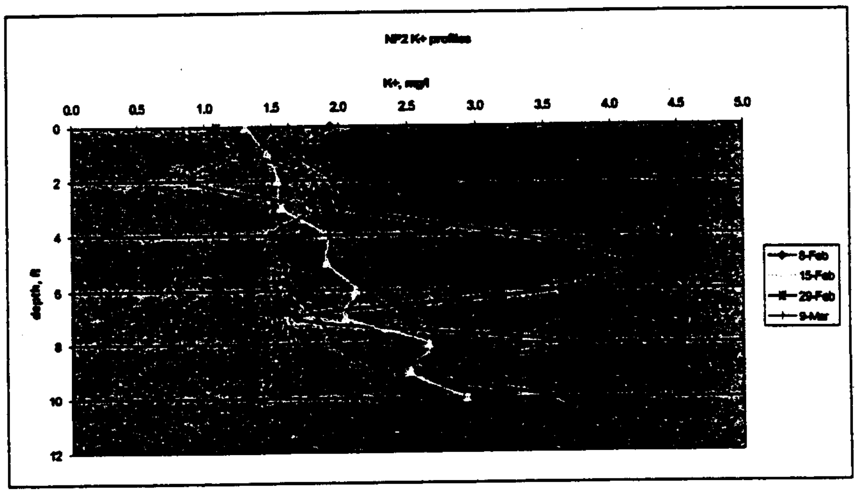


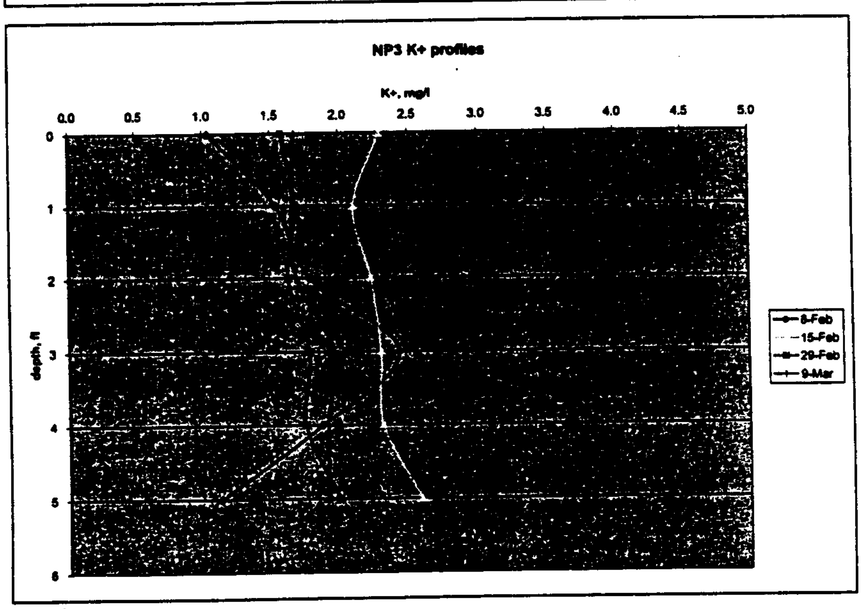


ECY00015775

AR 034407





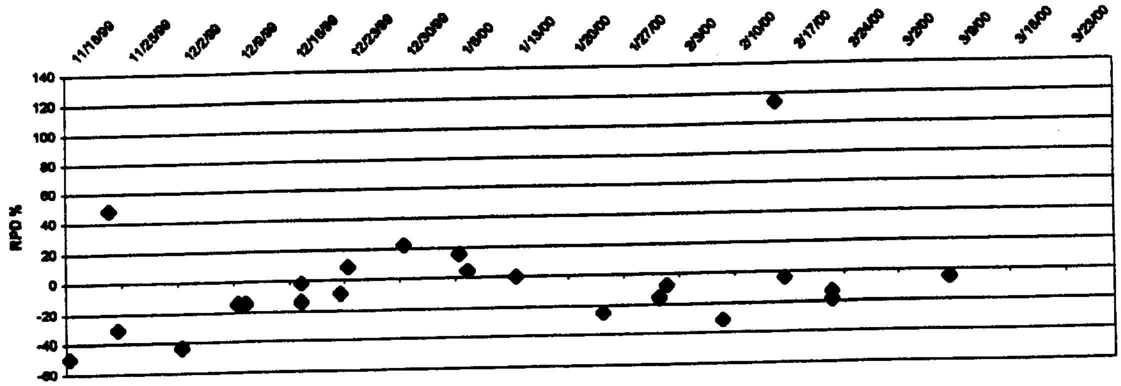


AR 034408

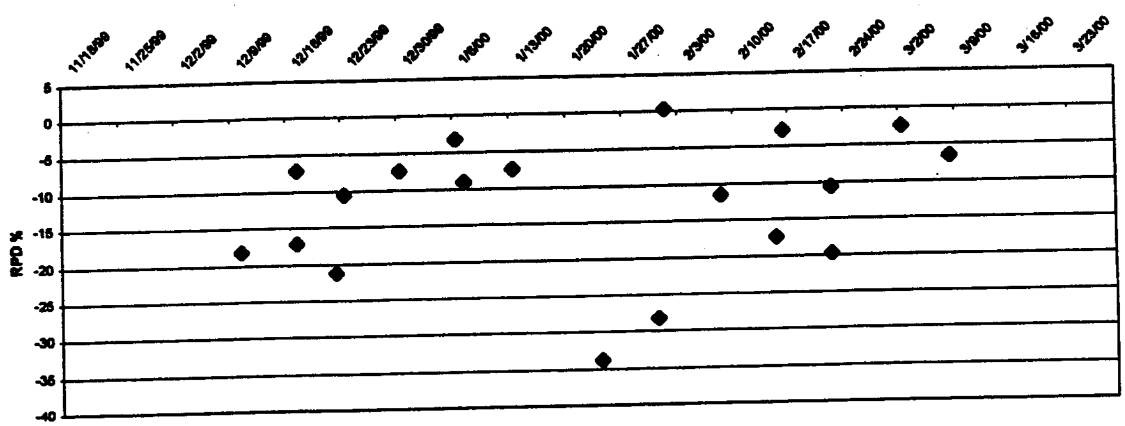
ECY00015776

LAKE REBA
D.O. Measurement Relative Percent Differences (RPDs)

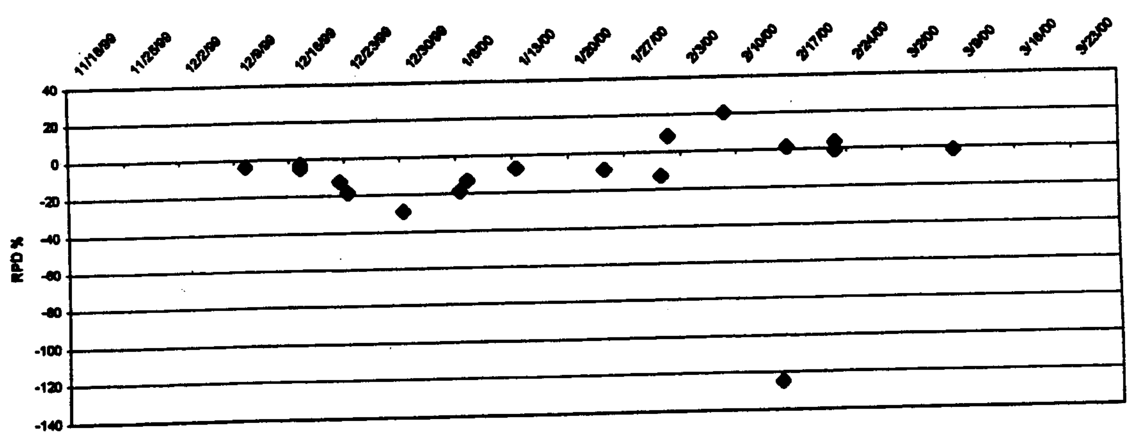
Relative Percent Difference Between Hydrolab D.O and Winkler D.O. at Lake Reba Outlet



Relative Percent Difference Between Hydrolab D.O and YSI D.O. at Lake Reba Outlet



Relative Percent Difference Between Winkler D.O and YSI D.O. at Lake Reba Outlet



ECY00015777

AR 034409

Continuous Monitoring QA/QC Results

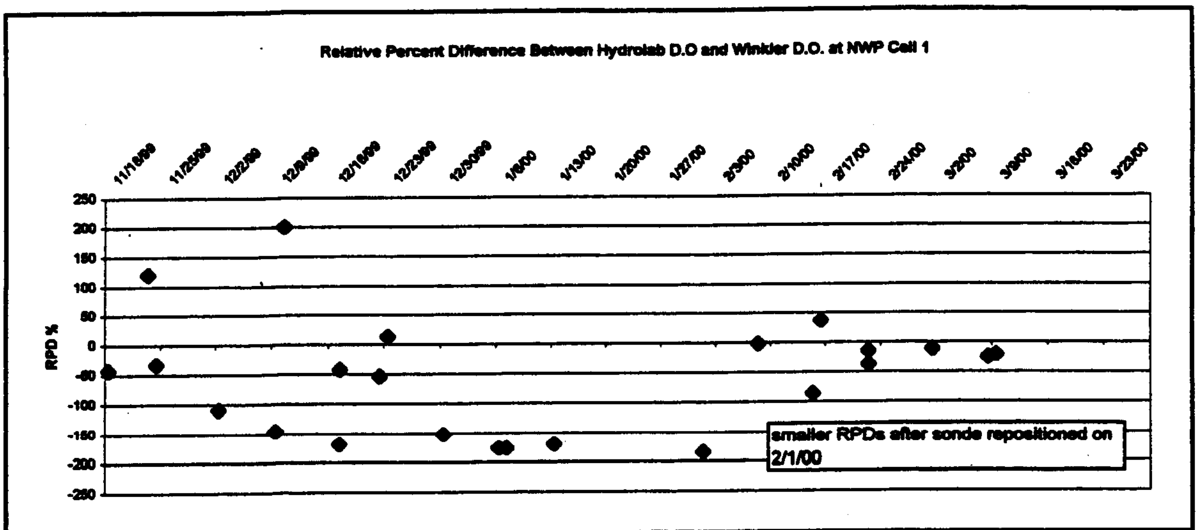
LAKE REBA

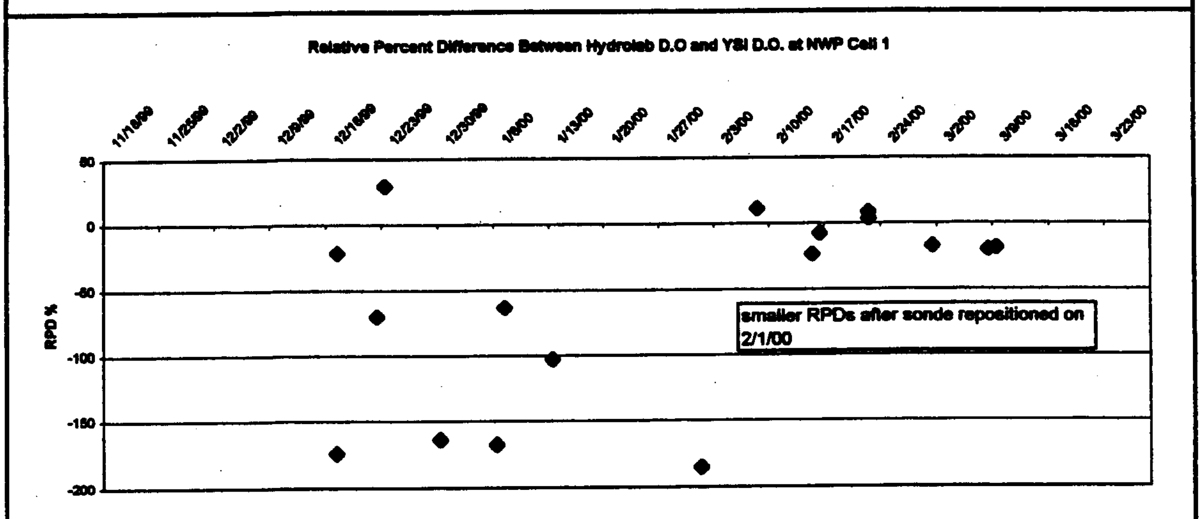
Date	Time	Date/Time	Winkler	YSI	Hydro DO	Conductivity	Hydro Cond.	Hydro Time	RPD Hydolab D.O., Winkler D.O.	RPD Hydolab D.O., YSI D.O.	RPD Winkler D.O., YSI D.O.
11/18/99	11:00	11/18/99 11:00	7.52	N/A	4.53	N/A	166.7	1100	-50		
11/23/99	14:45	11/23/99 14:45	3.3	N/A	5.41	231	164.2	1400	48		
11/24/99	11:32	11/24/99 11:32	8.4	N/A	6.15	191.6	206	1200	-31		
12/2/99	11:00	12/2/99 11:00	10.23	N/A	6.6	183(181)	155.4	1100	-43		
12/9/99	10:20	12/9/99 10:20	9.65	N/A	8.34	179	154.9	1000	-15		
12/10/99	11:00	12/10/99 11:00	8.6	8.92	7.43	N/A	161.5	1100	-15	-18	-4
12/17/99	10:30	12/17/99 10:30	6.95	7.15	6.02	202	175.4	1000	-14	-17	-3
12/17/99	16:00	12/17/99 16:00	7.3	7.67	7.14	205	185.3	1700	-2	-7	-5
12/22/99	13:00	12/22/99 13:00	6.3	7.13	5.76	289	260	800	-9	-21	-12
12/23/99	15:10	12/23/99 15:10	5.4	6.52	5.87	307	288	1600	8	-10	-19
12/30/99	13:16	12/30/99 13:16	4.46	5.99	5.56	339	323	1300	22	-7	-29
1/6/00	11:00	1/6/00 11:00	5.87	7.1	6.87	252	235	9:00	16	-3	-19
1/7/00	12:15	1/7/00 12:15	6.09	6.95	6.35	280	268	12:00	4	-9	-13
1/13/00	10:00	1/13/00 10:00	8.42	9.05	8.4	244	232	1000	0	-7	-7
1/13/00	10:30	1/13/00 10:30	NA	NA	NA	230	NA				
1/24/00	12:00	1/24/00 12:00	7.82	8.54	6.07	310	262	1200	-25	-34	-9
1/31/00	12:49	1/31/00 12:49	7.14	8.11	6.1	334	313	1300	-16	-28	-13
2/1/00	12:00	2/1/00 12:00	11	10.13	10.16	107	74.4	1400	-8	0	8
2/8/00	9:30	2/8/00 9:30	12	9.8	8.74	173	146	1000	-31	-11	20
2/15/00	9:30	2/15/00 9:30	2.25	9.77	8.2	210	158	900	114	-17	-125
2/16/00	12:00	2/16/00 12:00	9.67	9.56	9.29	273	236	1500	-4	-3	1
2/22/00	9:30	2/22/00 9:30	8.76	8.47	7.62	291	NA	9:00	-14	-11	3
2/22/00	9:45	2/22/00 9:45	9.7	9.8	8.04	289	254	900	-19	-20	-1
3/1/00	11:30	3/1/00 11:30	9.08	9.7	NA	155					
3/2/00	11:43	3/2/00 11:43	NA	10.07	9.82	NA				-3	
3/8/00	13:10	3/8/00 13:10	10.7	10.87	10.17	304		14:00	-5	-7	-2
3/28/00	13:00	3/28/00 13:00	9.26	10.26	NA	343					

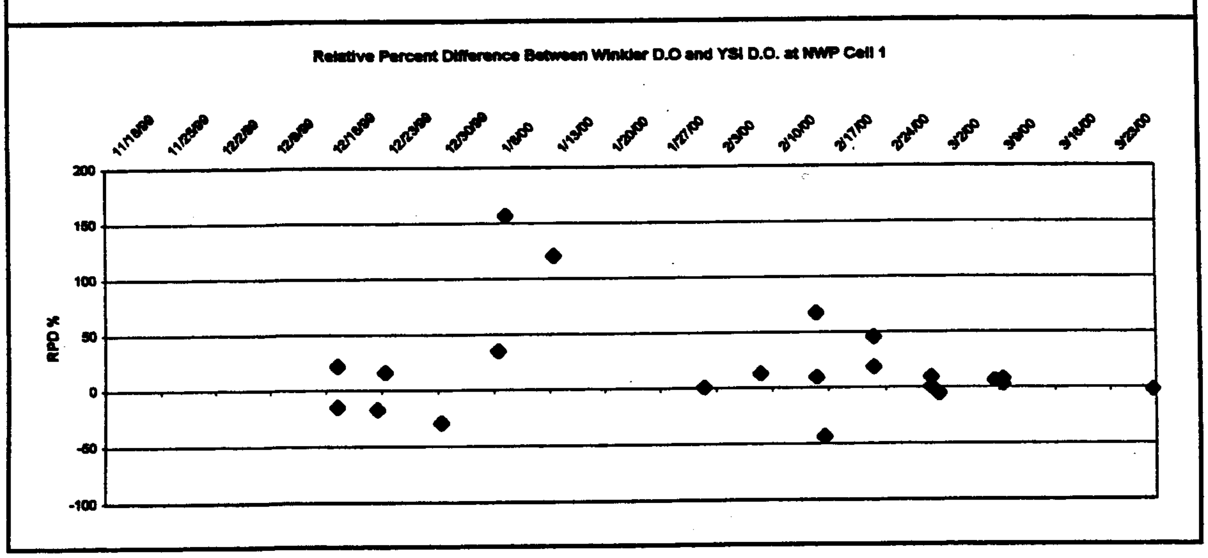
AR 034410

ECY00015778

Northwest Pond Cell 1
D.O. Measurement Relative Percent Differences (RPDs)







Continuous Monitoring QA/QC Results

Northwest Pond Cell 1

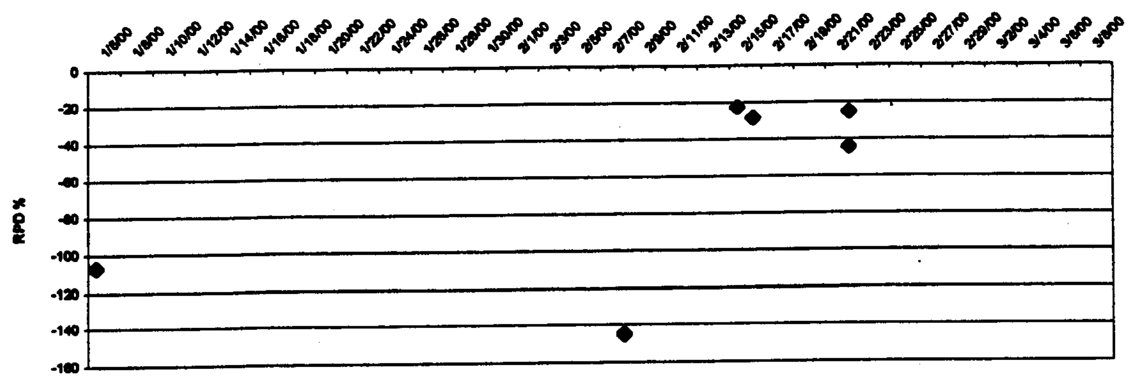
Date	Time	Date/Time	Winkler	YSI	Hydro DO	Conductivity	Hydro Cond.	Hydro Time	RPD Hydolab D.O., Winkler D.O.	RPD Hydolab D.O., YSI D.O.	RPD Winkler D.O., YSI D.O.
11/18/99	13:00	11/18/99 13:00	6.3	N/A	4.08	N/A	201	1400	-43		
11/23/99	13:30	11/23/99 13:30	0.8	N/A	3.23	174	158	1300	121		
11/24/99	12:30	11/24/99 12:30	6.3	N/A	4.49	186	171	1300	-34		
12/2/99	13:40	12/2/99 13:40	8.04	N/A	2.34	131	140.2	1200	-110		
12/9/99	11:30	12/9/99 11:30	1.48	N/A	0.23	185	203	1100	-146		
12/10/99	12:30	12/10/99 12:30	0	N/A	0.49	N/A	212	1500	200		
12/17/99	11:30	12/17/99 11:30	7.53	8.77	0.62	139	168	1100	-170	-174	-15
12/17/99	15:30	12/17/99 15:30	5.98	4.8	3.88	146	169	1800	-43	-21	22
12/22/99	12:00	12/22/99 12:00	4.36	5.2	2.5	193	208	1200	-54	-70	-18
12/23/99	14:10	12/23/99 14:10	4.23	3.58	4.8	205	208	1600	13	29	17
12/30/99	13:16	12/30/99 13:16	4.46	5.99	0.6	107	243	1300	-153	-164	-29
1/6/00	12:30	1/6/00 12:30	4.71	3.3	0.29	203	241	1200	-177	-168	35
1/7/00	14:00	1/7/00 14:00	6.37	0.77	0.4	181	269	1400	-176	-63	157
1/13/00	12:00	1/13/00 12:00	4.12	1.03	0.33	151	250	1200	-170	-103	120
1/13/00	12:30	1/13/00 12:30	1.91	NA	NA	176	NA	NA			
1/24/00	12:10	1/24/00 12:10	2.11	1.49	NA	210	248	NA			
1/31/00	11:53	1/31/00 11:53	1.2	0.71	NA	232	248	NA			
2/1/00	12:00	2/1/00 12:00	9.52	9.45	0.37	93.4	246	1400	-185	-185	1
2/8/00	12:35	2/8/00 12:35	11.5	10.07	11.21	83.8	18	1300	-3	11	13
2/15/00	14:00	2/15/00 14:00	10.2	5.08	4.02	137	201	1200	-87	-23	67
2/15/00	14:00	2/15/00 14:00	2.22	2.01	NA	233	NA	NA			10
2/16/00	13:30	2/16/00 13:30	4.75	7.43	6.87	181	192	1500	36	-8	-44
2/22/00	11:50	2/22/00 11:50	6.49	5.38	5.56	213	226	11:00	-15	3	19
2/22/00	12:00	2/22/00 12:00	9.22	5.8	6.29	195	224	16:00	-38	8	46
2/29/00	14:10	2/29/00 14:10	9.67	8.76	NA	102	NA	NA			10
2/29/00	14:10	2/29/00 14:10	1.91	1.9	NA	202	NA	NA			1
3/1/00	15:21	3/1/00 15:21	9.01	9.51	7.99	146	NA	16:00	-12	-17	-5
3/8/00	12:00	3/8/00 12:00	8.88	8.32	6.8	191	NA	11:00	-27	-20	7
3/9/00	14:01	3/9/00 14:01	6.69	6.5	5.4	200	NA	14:00	-21	-18	3
3/9/00	14:01	3/9/00 14:01	0.13	0.12	NA	270	NA	NA			8
3/28/00	14:20	3/28/00 14:20	6.1	6.23	NA	220	NA	NA			-2

AR 034412

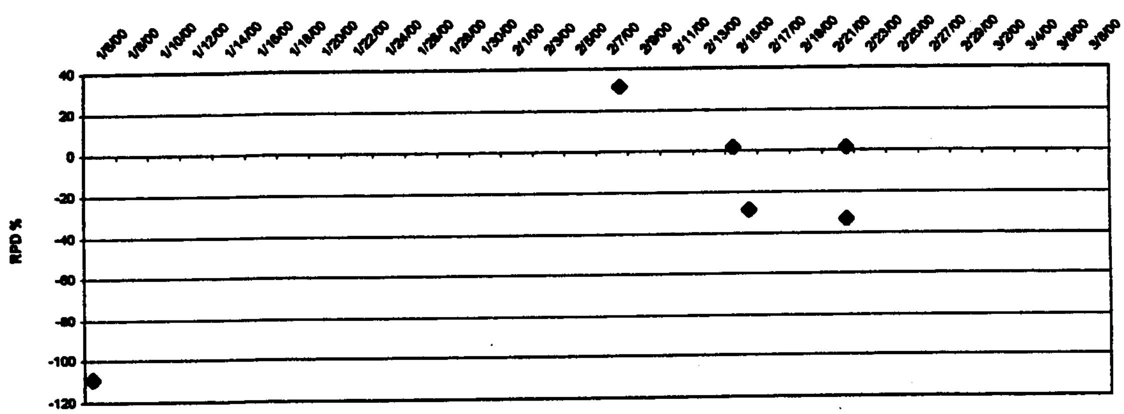
ECY00015780

Northwest Pond Cell 2
D.O. Measurement Relative Percent Differences (RPDs)

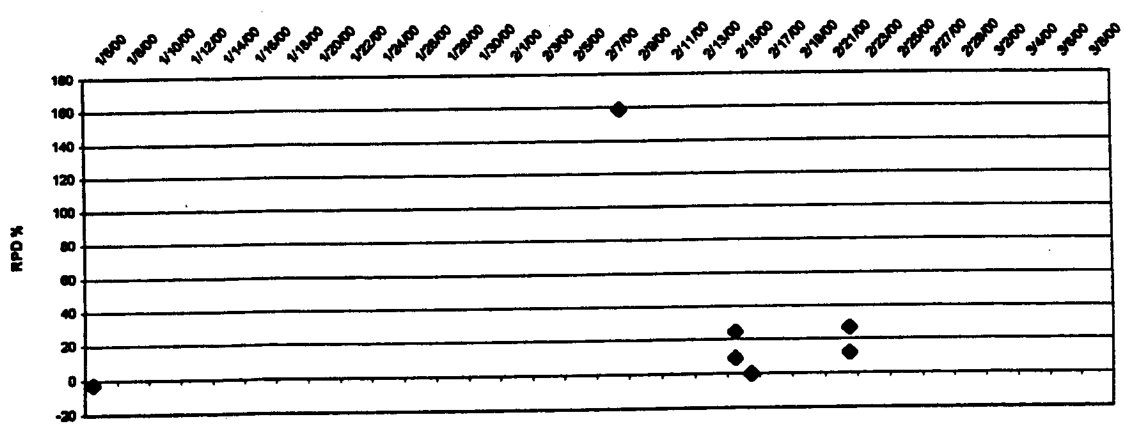
Relative Percent Difference Between Hydrolab D.O and Winkler D.O. at NWP Cell 2



Relative Percent Difference Between Hydrolab D.O and YSI D.O. at NWP Cell 2



Relative Percent Difference Between Winkler D.O and YSI D.O. at NWP Cell 2



AR 034413 ECY00015781

Continuous Monitoring QA/QC Results

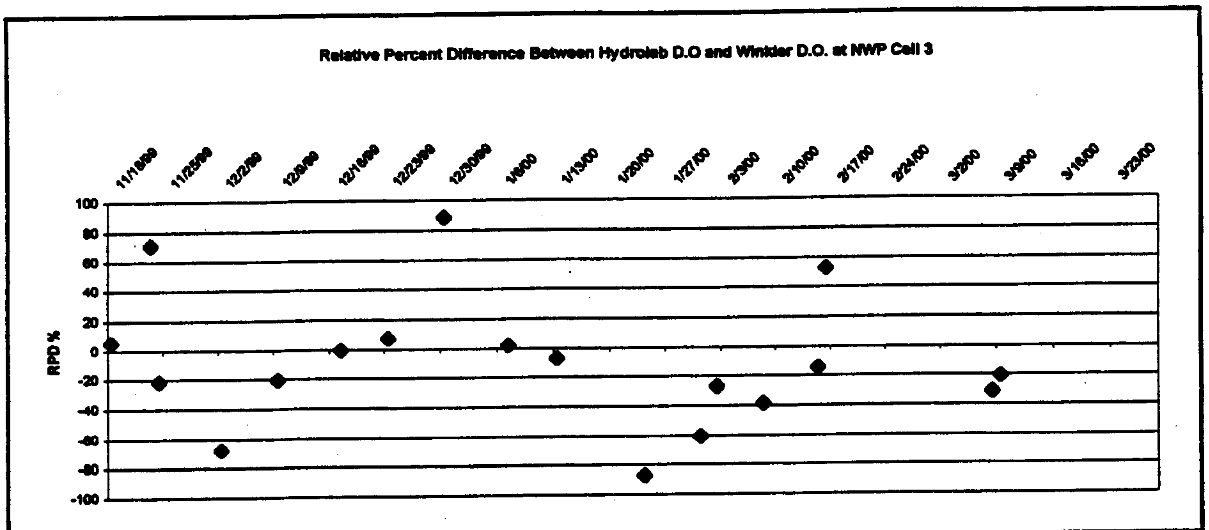
Northwest Pond Cell 2

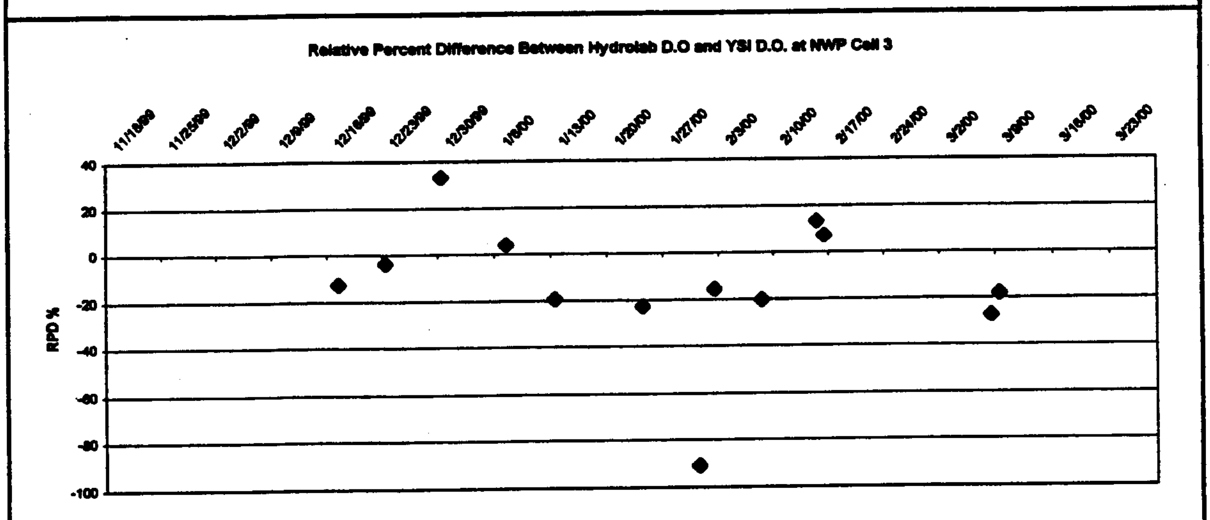
Date	Time	Date/Time	Winkler	YSI	Hydro DO	Conductivity	Hydro Cond.	Hydro Time	RPD Hydolab D.O., Winkler D.O.	RPD Hydolab D.O., YSI D.O.	RPD Winkler D.O., YSI D.O.
1/6/00	12:00	1/6/00 12:00	3.57	3.67	1.08	165	193	12:00	-107	-109	-3
1/7/00			NO HYDROLAB DEPLOYED								
1/13/00											
1/24/00											
1/31/00											
2/1/00	12:30	2/1/00 12:30	N/A	1.36	N/A	147		N/A			
2/8/00	12:30	2/8/00 12:30	9.47	1.1	1.51	126	N/A	1200	-145	31	158
2/15/00	13:30	2/15/00 13:30	6.81	5.33	5.42	152	N/A	1100	-23	2	24
2/15/00	13:30	2/15/00 13:30	0.97	0.89	NA	215	NA	NA			9
2/16/00	13:20	2/16/00 13:20	7.43	7.45	5.57	145	N/A	1500	-29	-29	0
2/22/00	11:39	2/22/00 11:39	6.14	4.7	4.76	188	NA	11:00	-25	1	27
2/22/00	12:00	2/22/00 12:00	6.58	5.85	4.18	194	NA	14:00	-45	-33	12
2/29/00	13:45	2/29/00 13:45	8.75	8.86	NA	123	NA	NA			
2/29/00	13:45	2/29/00 13:45	1.77	1.8	NA	199	NA	NA			
3/9/00	13:10	3/9/00 13:10	8.5	8:38	NA	176	NA	NA			
3/9/00	13:10	3/9/00 13:10	0.1	0.09	NA	256	NA	NA			

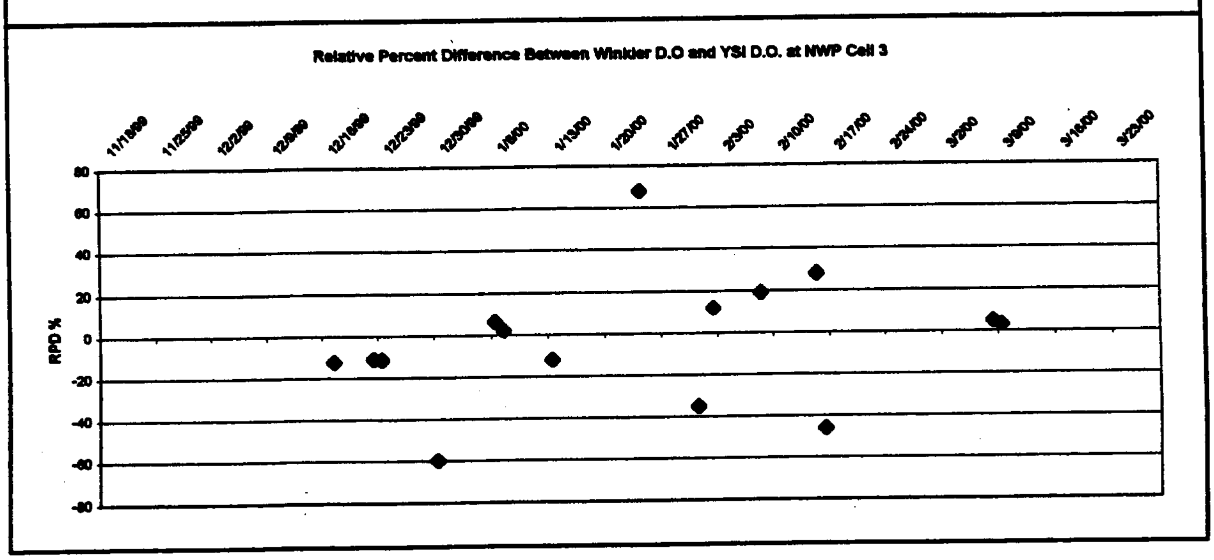
AR 034414

ECY00015782

Northwest Pond Cell 3
D.O. Measurement Relative Percent Differences (RPDs)







AR 034415

ECY00015783

Continuous Monitoring QA/QC Results

Northwest Pond Cell 3

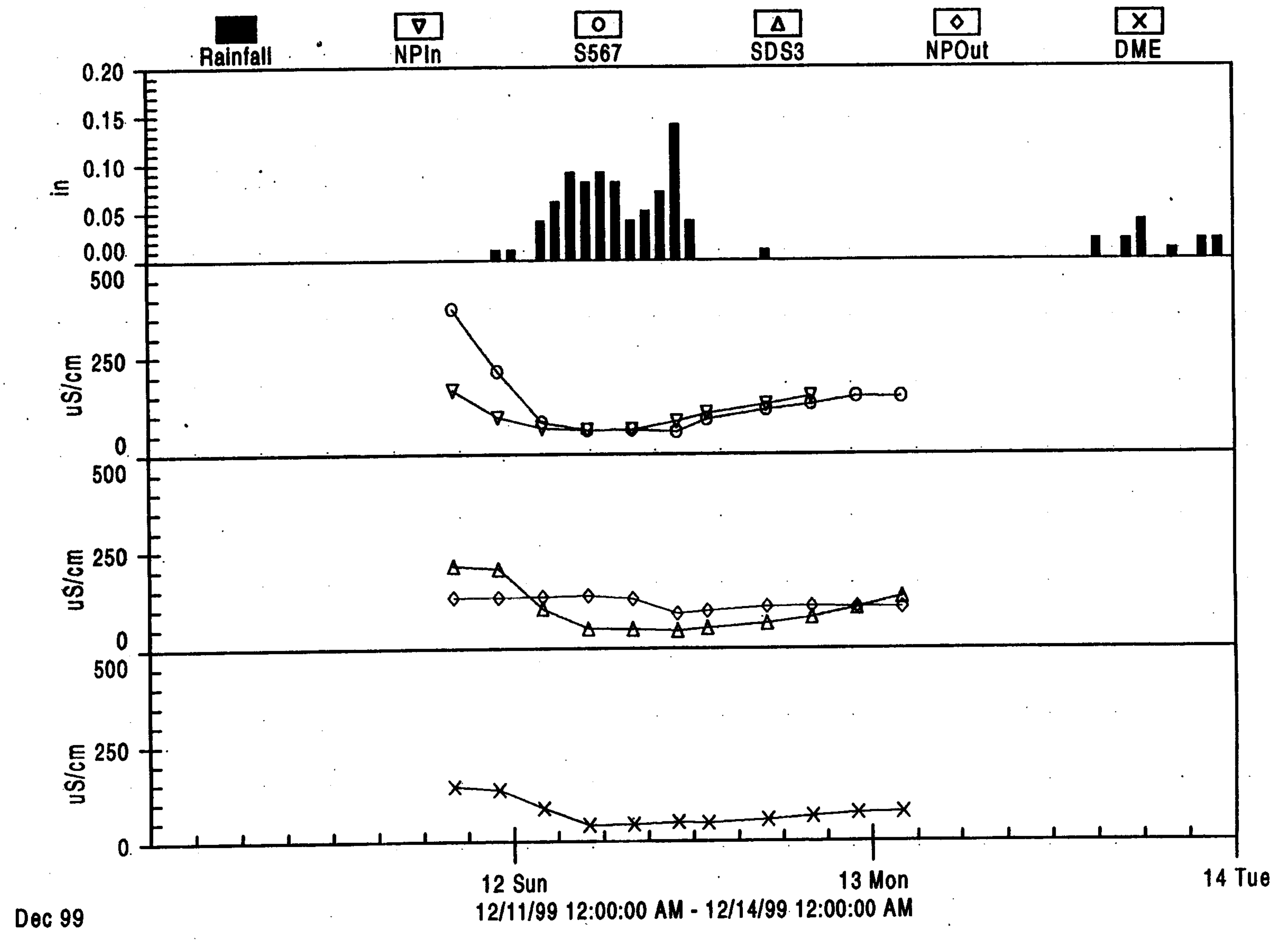
Date	Time	Date/Time	Winkler	YSI	Hydro DO	Conductivity	Hydro Cond.	Hydro Time	RPD Hydolab D.O., Winkler D.O.	RPD Hydolab D.O., YSI D.O.	RPD Winkler D.O., YSI D.O.
11/18/99	12:00	11/18/99 12:00	2.73	N/A	2.88	N/A	105.5	1200	5		
11/23/99	13:00	11/23/99 13:00	1.59	N/A	3.35	141.1	114.4	1200	71		
11/24/99	12:20	11/24/99 12:20	4.5	N/A	3.61	138.3	118.9	1300	-22		
12/2/99	13:10	12/2/99 13:10	11.68	N/A	5.74	87.6	103.5	1100	-68		
12/9/99	11:00	12/9/99 11:00	5.45	N/A	4.41	123.9	106.6	1000	-21		
12/10/99	12:05	12/10/99 12:05	5.14	5.1	N/A	N/A	N/A	N/A			
12/17/99	12:00	12/17/99 12:00	N/A	N/A	N/A	N/A	N/A	N/A			
12/17/99	15:05	12/17/99 15:05	6.01	6.8	5.98	94	76.2	1500	-1	-13	-12
12/22/99	11:00	12/22/99 11:00	4.11	4.6	N/A	133	N/A	N/A			-11
12/23/99	13:40	12/23/99 13:40	3.39	3.8	3.65	140	207	1400	7	-4	-11
12/30/99	12:00	12/30/99 12:00	1.21	2.25	3.14	225	209	1100	89	33	-60
1/6/00	11:30	1/6/00 11:30	5.93	5.56	N/A	108	N/A	N/A			6
1/7/00	14:20	1/7/00 14:20	4.78	4.68	4.87	131	125.7	1500	2	4	2
1/13/00	11:18	1/13/00 11:18	4.52	5.1	4.2	185	145.4	1100	-7	-19	-12
1/13/00	11:30	1/13/00 11:30	2.29	3.1		161					
1/24/00	14:11	1/24/00 14:11	7.82	3.86	3.07	310	156	1500	-87	-23	68
1/31/00	11:00	1/31/00 11:00	0.99	1.41	0.53	195	197	1100	-61	-91	-35
2/1/00	12:00	2/1/00 12:00	NA	NA	8.43		92	1400			
2/2/00	12:00	2/2/00 12:00	8.43	7.49	6.4	81.2	97.2	1300	-27	-16	12
2/8/00	12:18	2/8/00 12:18	7.39	6.11	4.99	113	110.3	1100	-39	-20	19
2/15/00	13:00	2/15/00 13:00	7.63	5.77	6.59	131	138.4	1500	-15	13	28
2/16/00	13:05	2/16/00 13:05	3.84	6.13	6.59	129	NA	1500	53	7	-46
2/22/00	11:00	2/22/00 11:00	5.90	4.3	NA	174	NA	NA			
2/22/00	12:00	2/22/00 12:00	5.87	5.45	NA	172	NA	NA			
2/29/00	12:15	2/29/00 12:15	8.92	9.11	N/A	79.2	NA	NA			
3/1/00	15:04	3/1/00 15:04	7.78	7.12	NA	111	NA	NA			
3/8/00	11:20	3/8/00 11:20	7.81	7.45	5.67	140	NA	1200	-32	-27	5
3/9/00	12:30	3/9/00 12:30	7.36	7.13	5.95	152	NA	1200	-21	-18	3
3/28/00	14:00	3/28/00 14:00	6.79	6.73	NA	173	NA	NA			

4 APPENDIX C PLOTS OF TRACERS FOR EACH MONITORING LOCATION

4.1 Introduction

This appendix contains four families of figures:

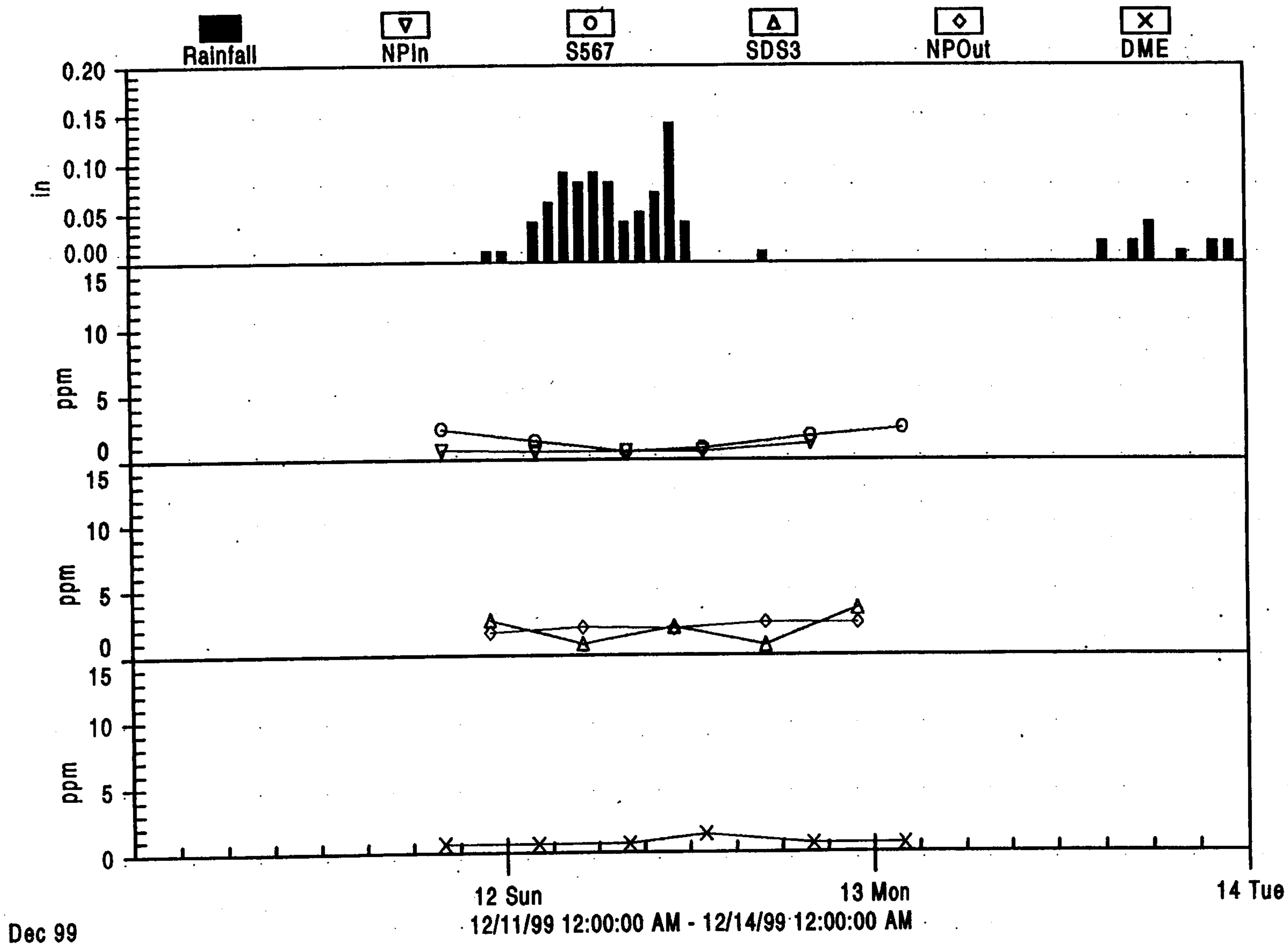
1) Background event (December 11-12, 1999) rainfall, conductivity and tracer ion concentrations for sampling stations in Des Moines and Miller Creek watersheds (several examples of these plots appear in Volume 1, Section 3 in Figures 3-10 through 3-12),
2) Deicing event (all three events in the period January 12-27, 2000) conductivity and corresponding chemical applications (CMA and SA)for sampling stations for both creeks,
3) Deicing event rainfall, water level, tracer ion concentration and corresponding chemical applications for the Lake Reba outlet (Miller Creek).
4) Tracer ion concentrations, chemical presence signal periods and chemical applications corresponding to each station sampled during the three deicing events (January 12-27, 2000).



Des Moines Creek Watershed
Sp Cond (uS/cm) During Background Event

ECY00015786

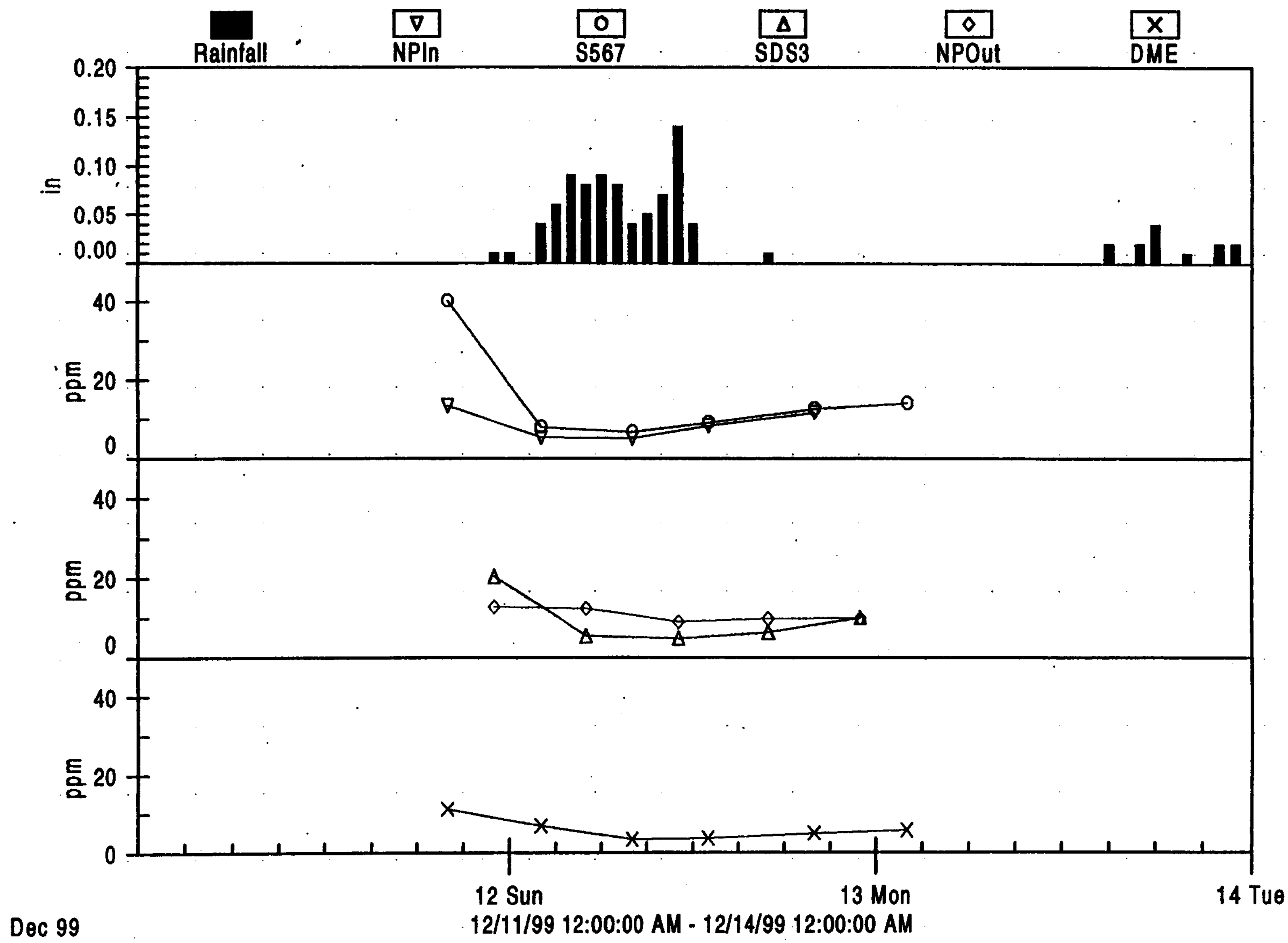
AR 034418



ECY00015787

Des Moines Creek Watershed
Potassium (ppm) During Background Event

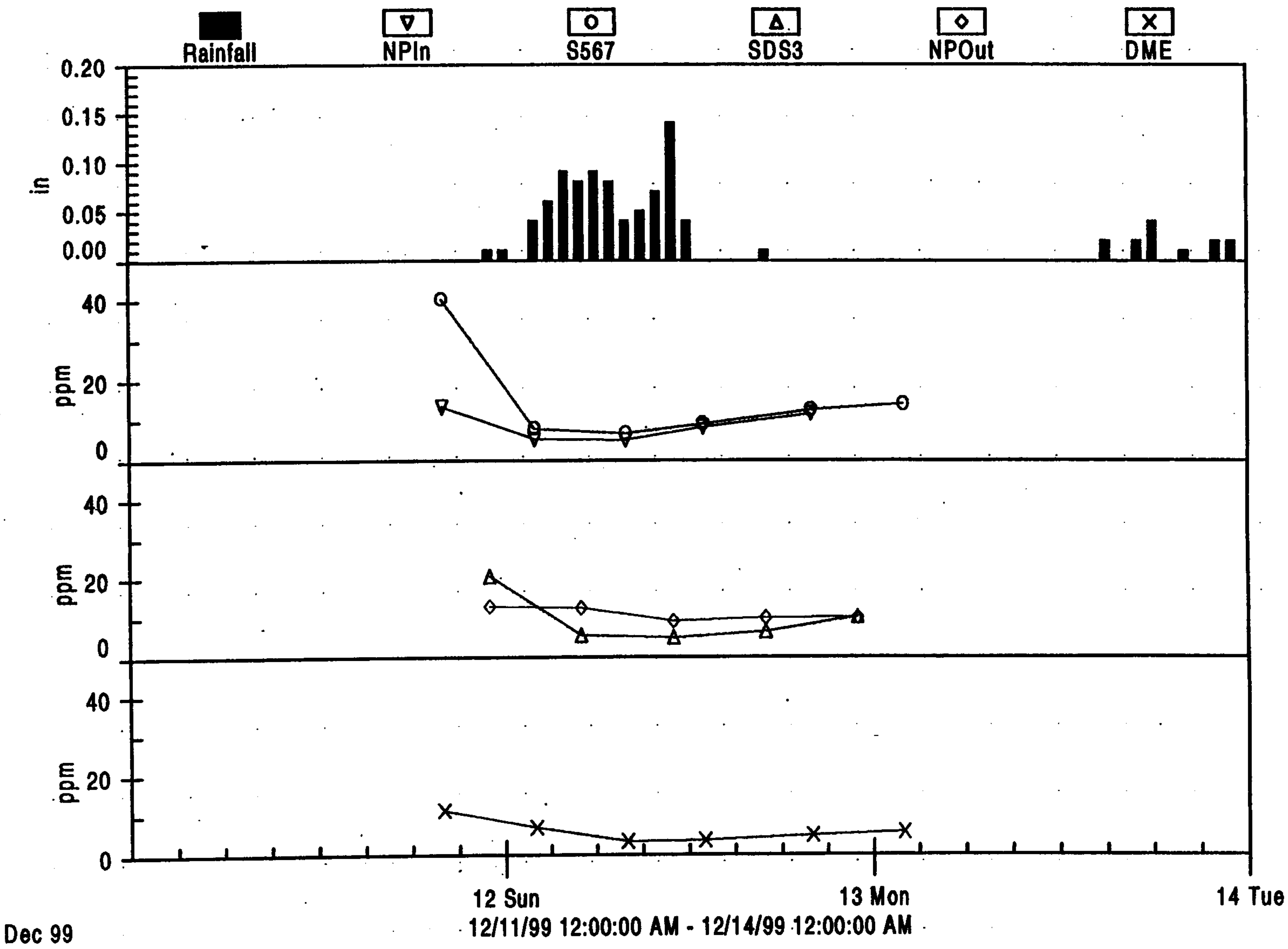
AR 034419



Des Moines Creek Watershed
Calcium (ppm) During Background Event

ECY00015788

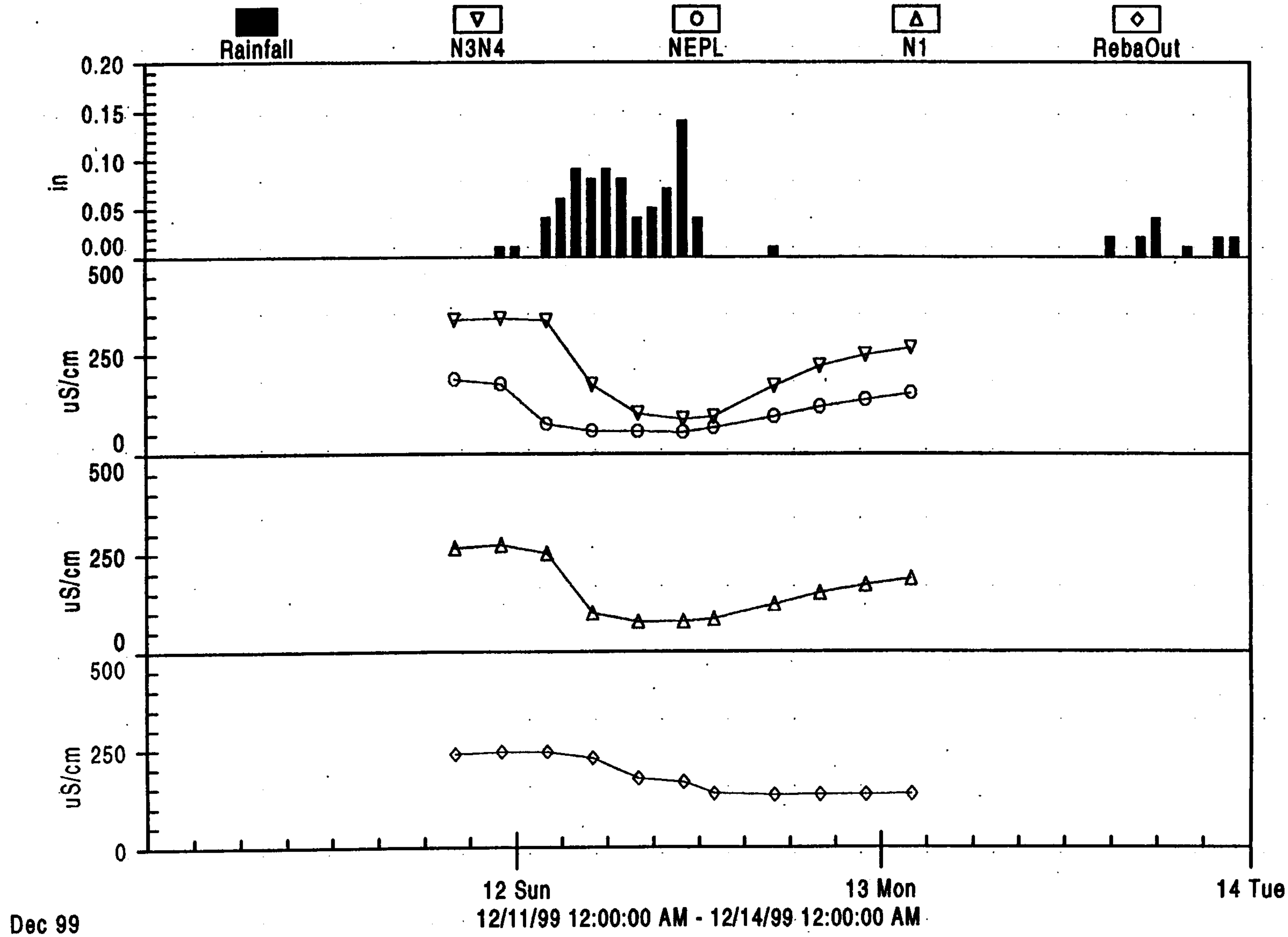
AR 034420



ECY00015789

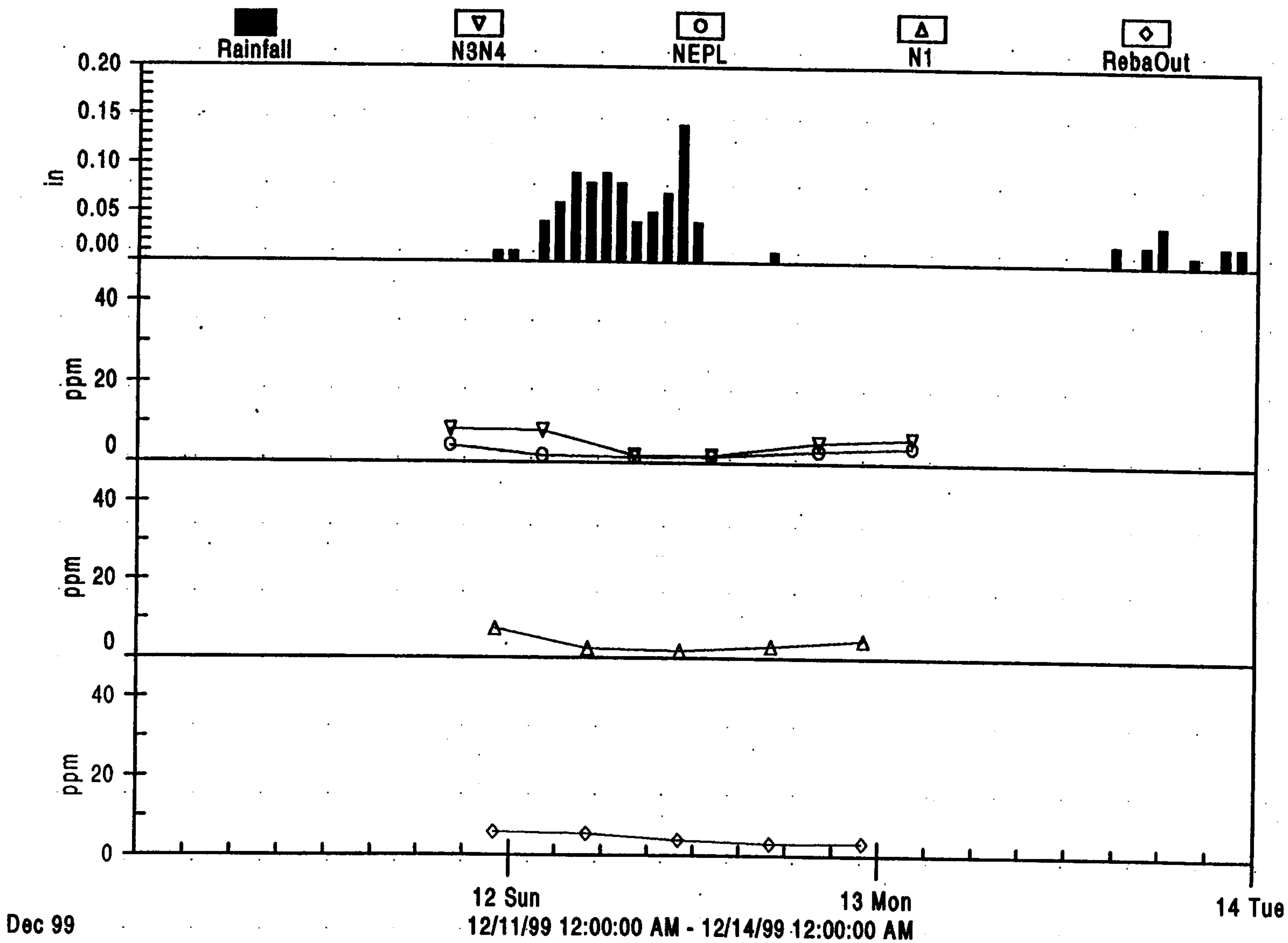
AR 034421

Des Moines Creek Watershed
Sodium (ppm) During Background Event



ECY00015790

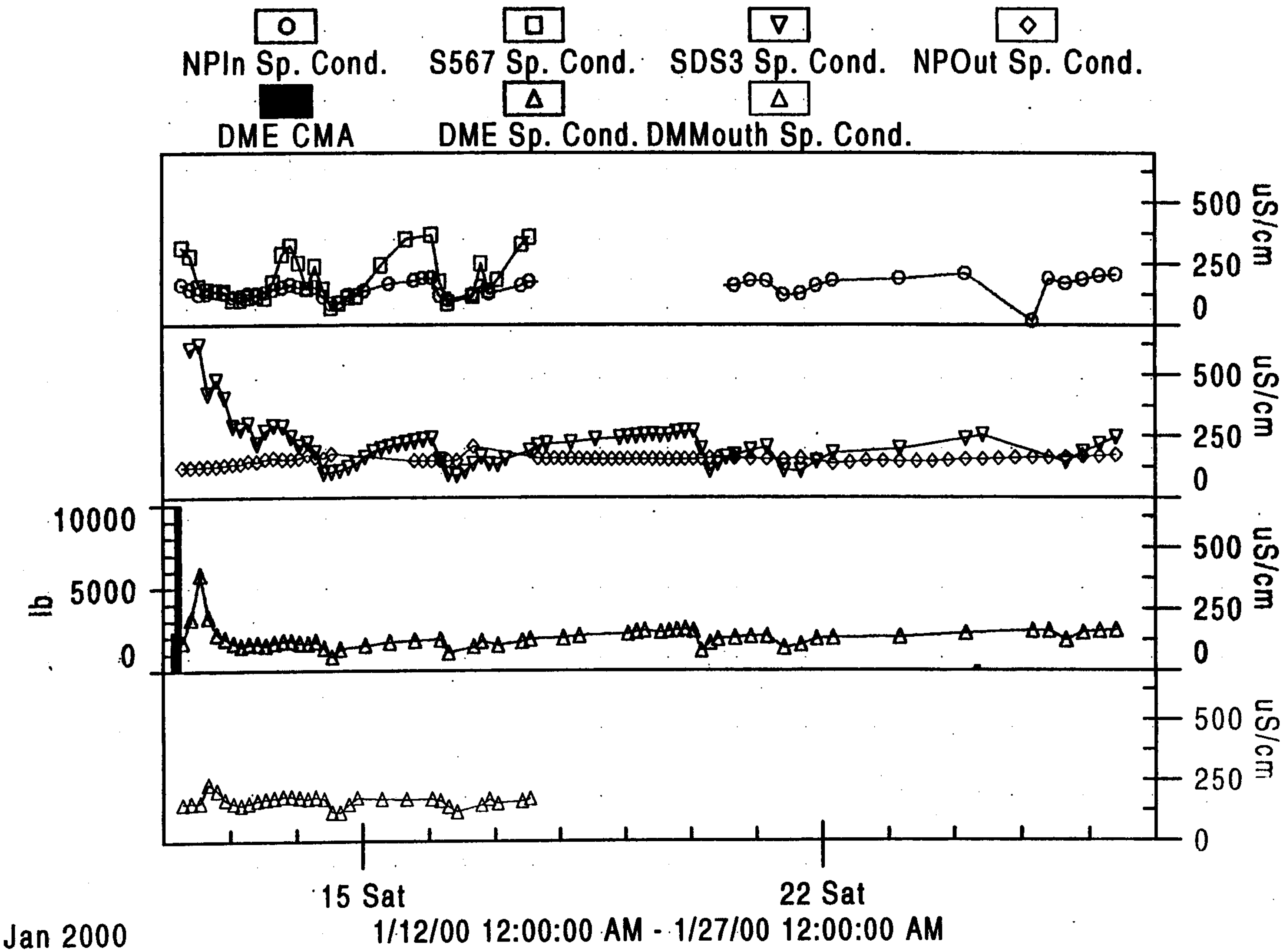
Miller Creek Watershed
Sp Cond (uS/cm) During Background Event



Miller Cree… …ershed
Sodium (ppm) During Background Event

ECY00015791

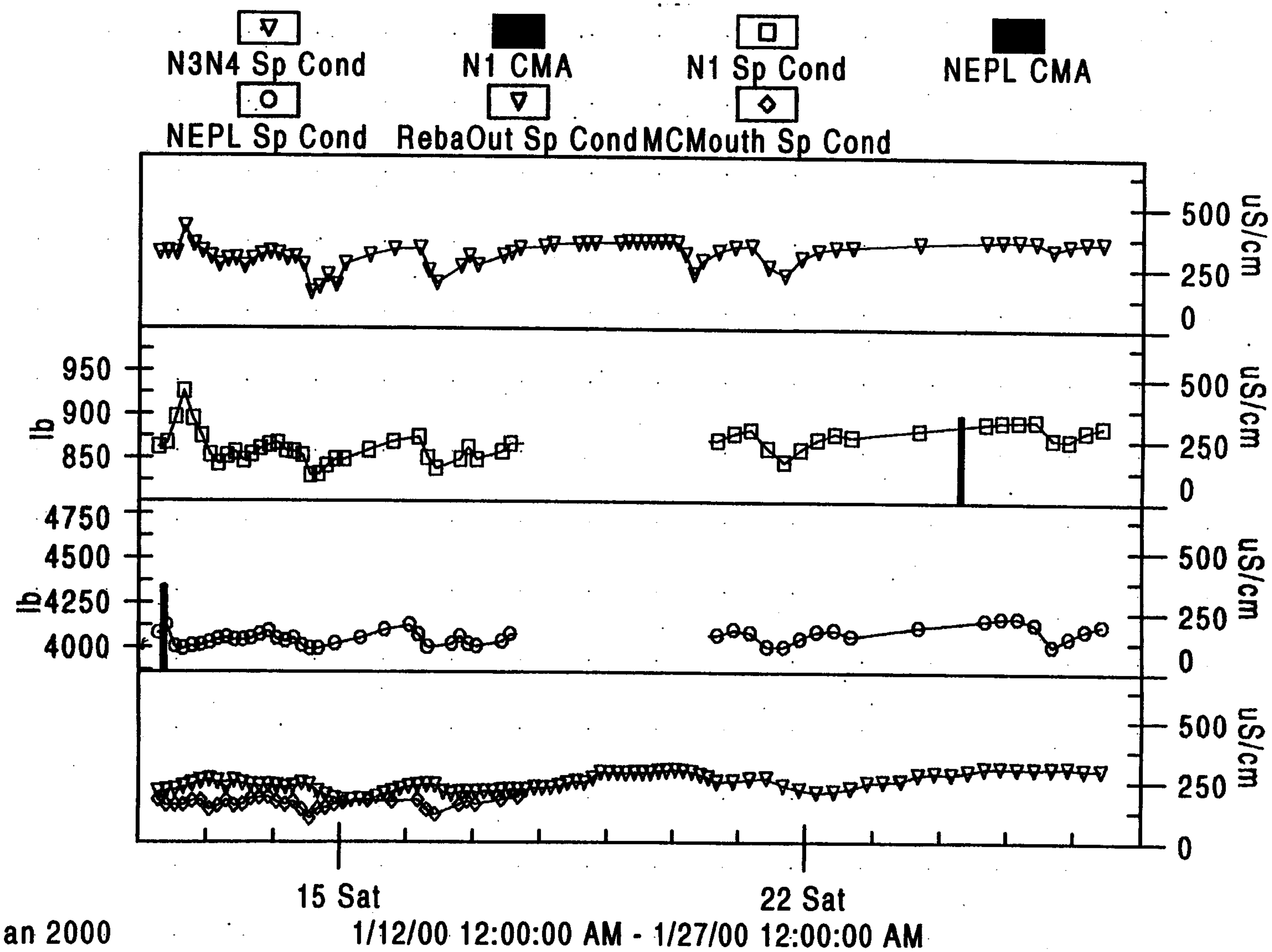
AR 034423



ECY00015792

AR 034424

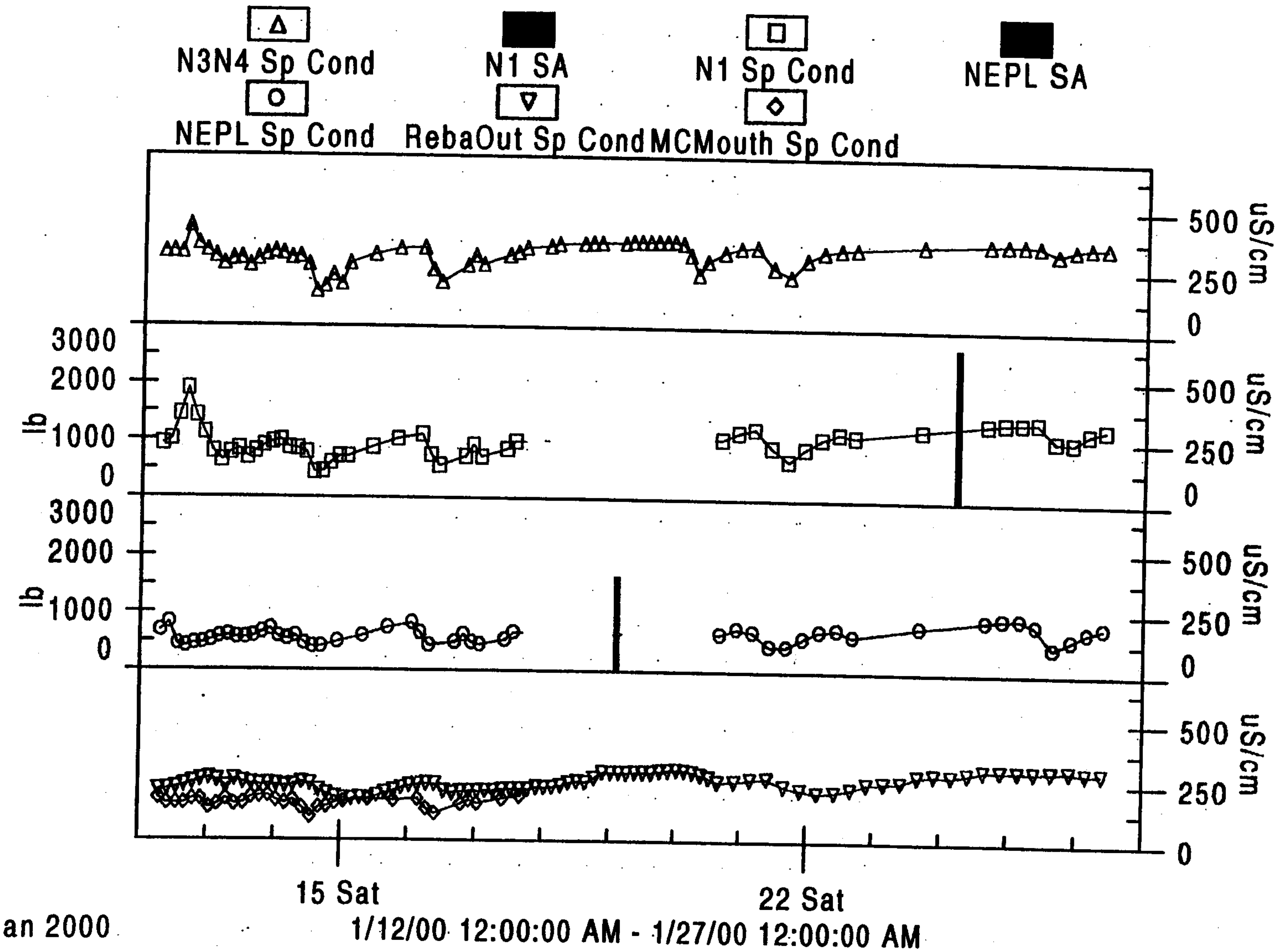
Des Moines Creek Watershed
Ca-Mg Acetate (CA) Application (lb)



ECY00015793

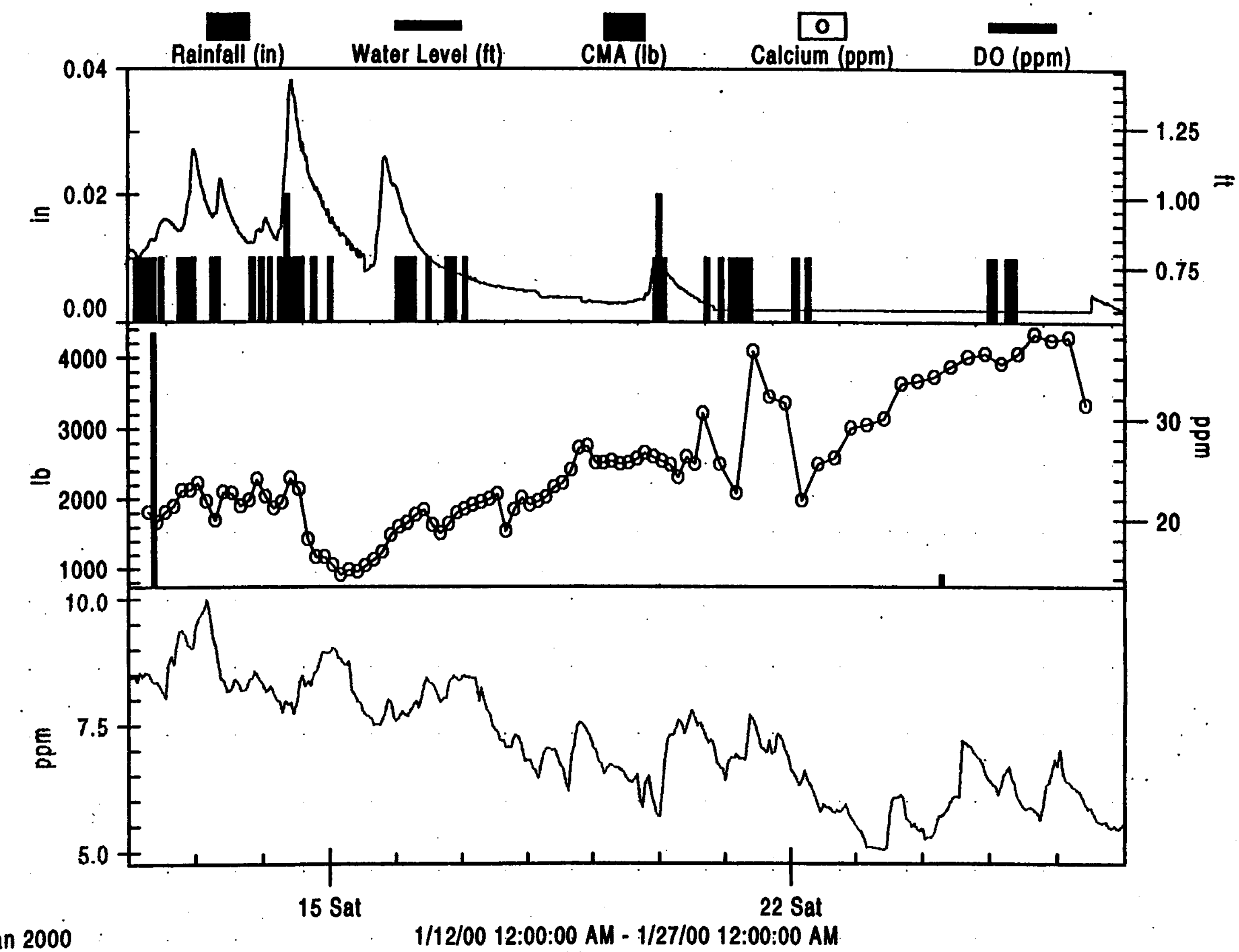
AR 034425

Miller Creek Watershed
Ca-Mg Acetate (CMA) A[illegible]ication (lb)



ECY00015794

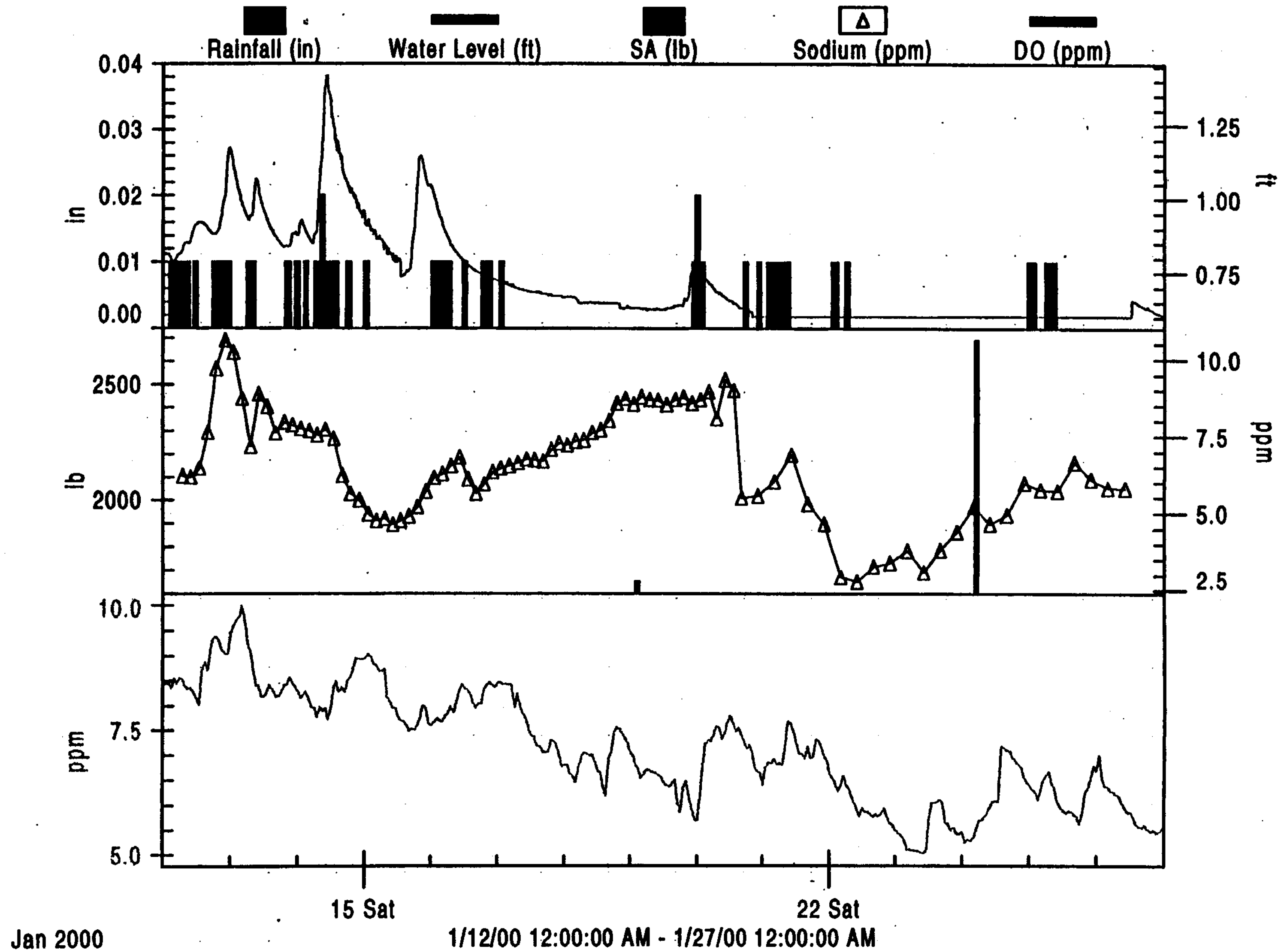
Miller Creek Watershed
Sodium Acetate (SA) Application (lb)



ECY00015795

AR 034427

Lake Reba Outlet (RebaOut)
Calcium Levels After CM/ plications

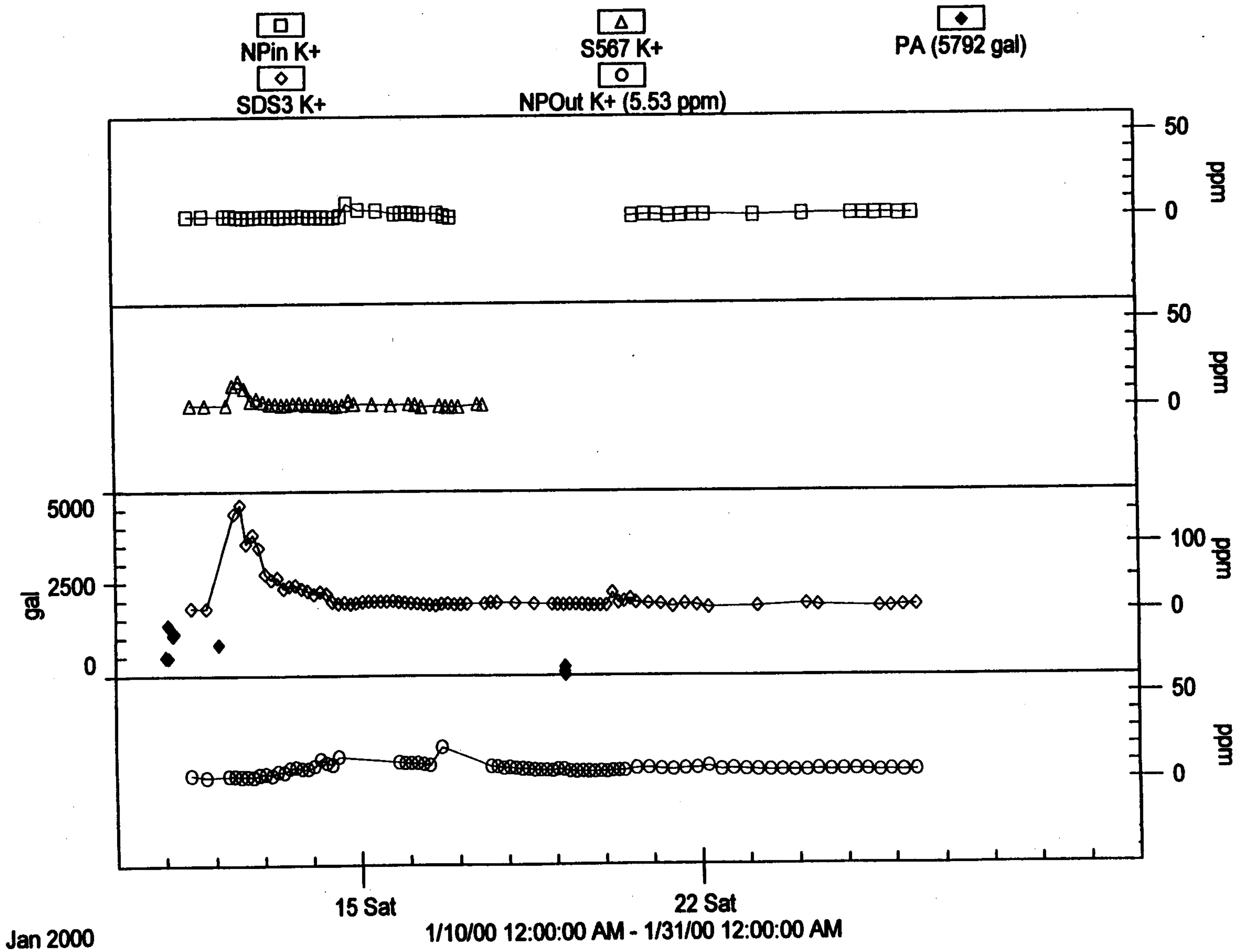


ECY00015796

AR 034428

Lake Reba Outlet (RebaOut)
Sodium Levels After SA Applications

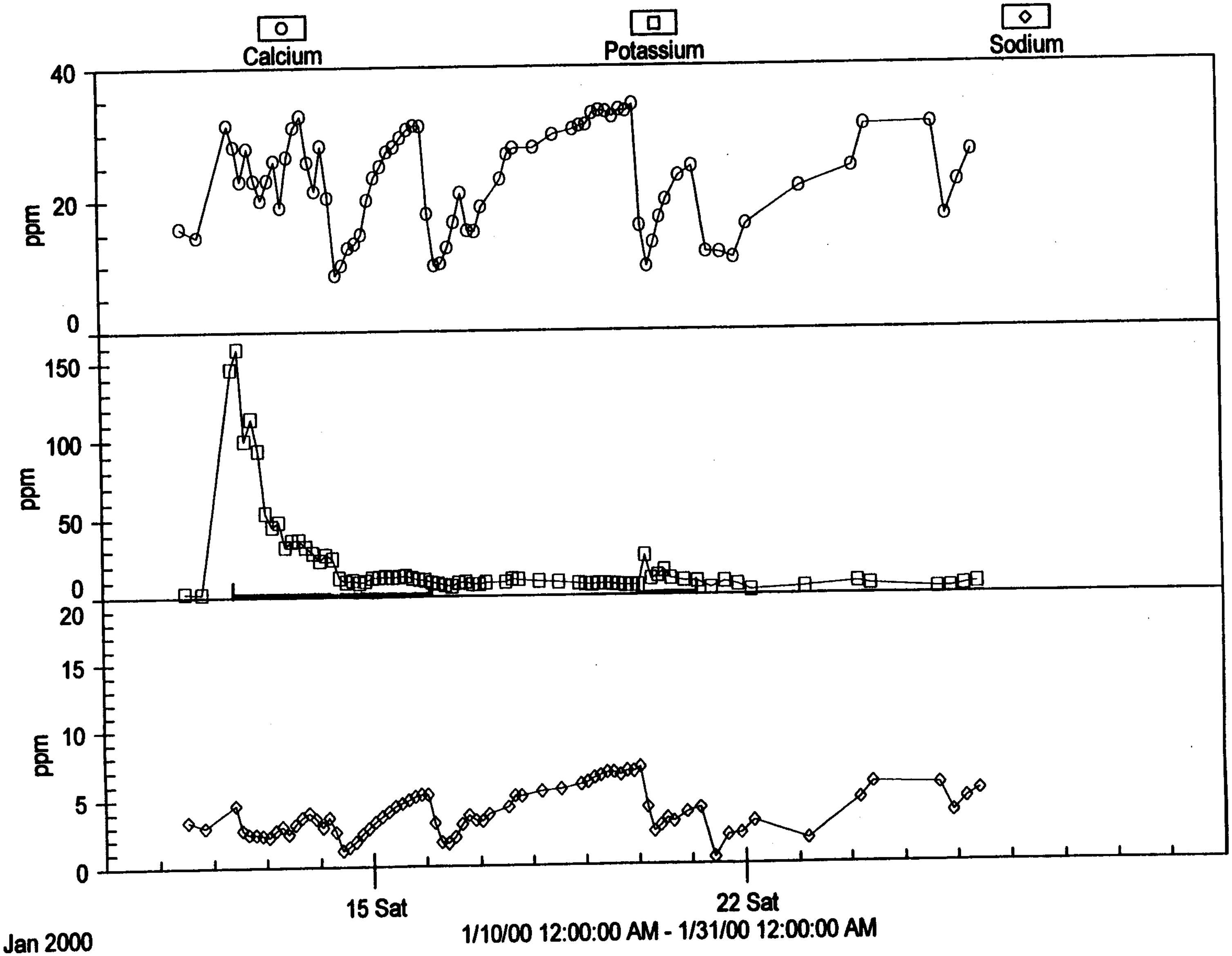
Potassium - Northwest Ponds Basin



AR 034429

ECY00015797

SDS3 Tracers



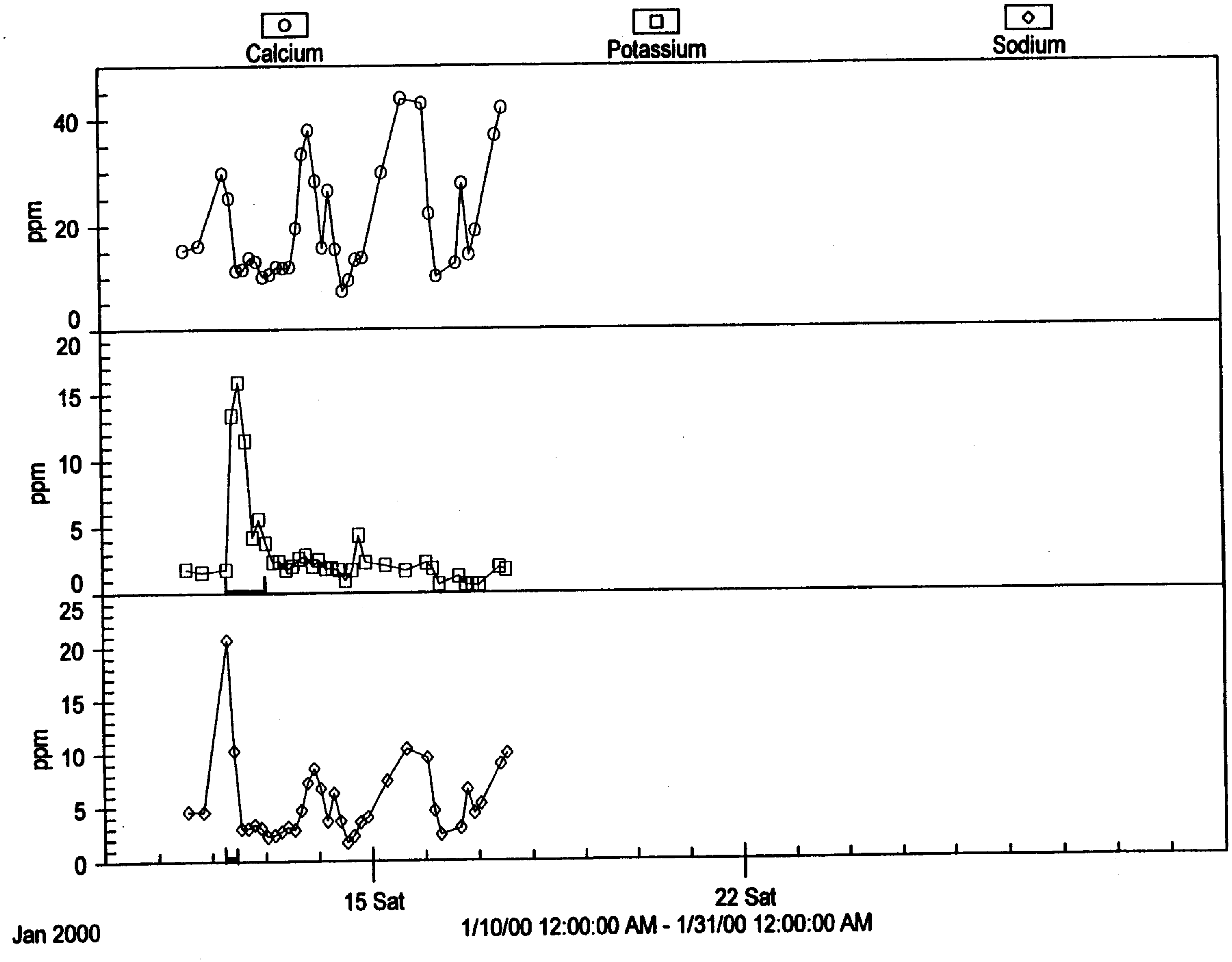
ECY00015798

AR 034430

SDS3

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	N	Y	N
Background Range (ppm)	8.5 - 34.2	2.2 - 13.2	0.4 - 7.2
Number of Signals	0	2	0
First Signal Characteristics			
Signal Start	-	1/12/00 10:00	-
Signal End	-	1/16/00 7:00	-
Signal Duration (hrs)	-	93.0	-
Signal Peak (date/ time)	-	1/12/00 13:00	-
Signal Max (ppm)	-	159.0	-
Signal/Noise	-	20.6	-
Notes	-	-	-
Second Signal Characteristics			
Signal Start	-	1/20/00 4:00	-
Signal End	-	1/21/00 4:00	-
Signal Duration (hrs)	-	24.0	-
Signal Peak (date/ time)	-	1/20/00 4:00	-
Signal Max (ppm)	-	25.5	-
Signal/Noise	-	3.3	-
Notes	-	-	-

S567 Tracers

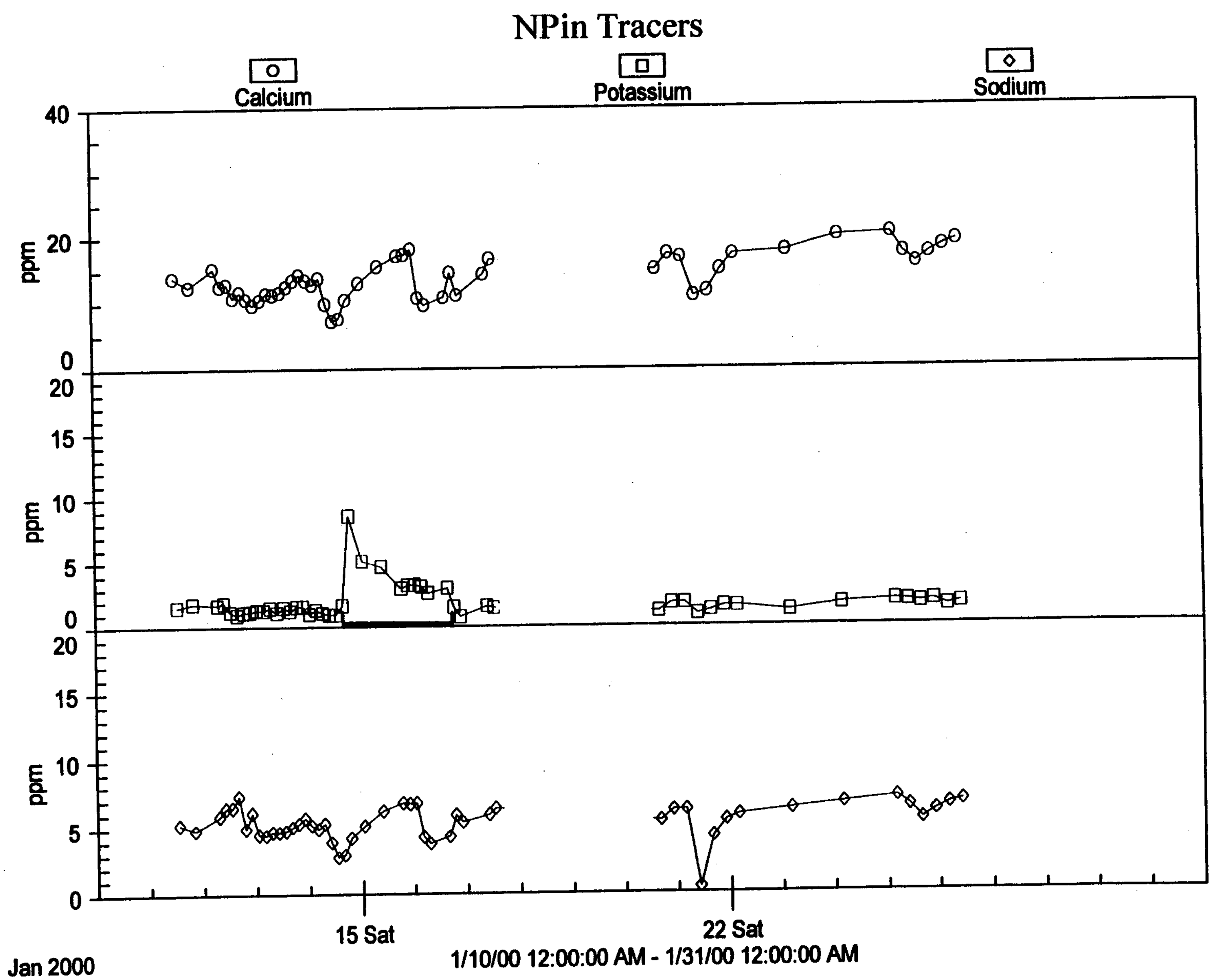


AR 034432

ECY00015800

S567

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	N	N	N
Background Range (ppm)	7 - 44	0.6 - 4.4	1.7 - 10.4
Number of Signals	0	1	1
First Signal Characteristics	-		
Signal Start	-	1/12/00 10:00	1/12/00 7:00
Signal End	-	1/13/00 1:00	1/12/00 10:00
Signal Duration (hrs)		15.0	3.0
Signal Peak (date/ time)	-	1/12/00 13:00	1/12/00 7:00
Signal Max (ppm)	-	15.9	20.7
Signal/Noise	-	6.4	3.5
Notes	-	-	-
Second Signal Characteristics		-	-
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-

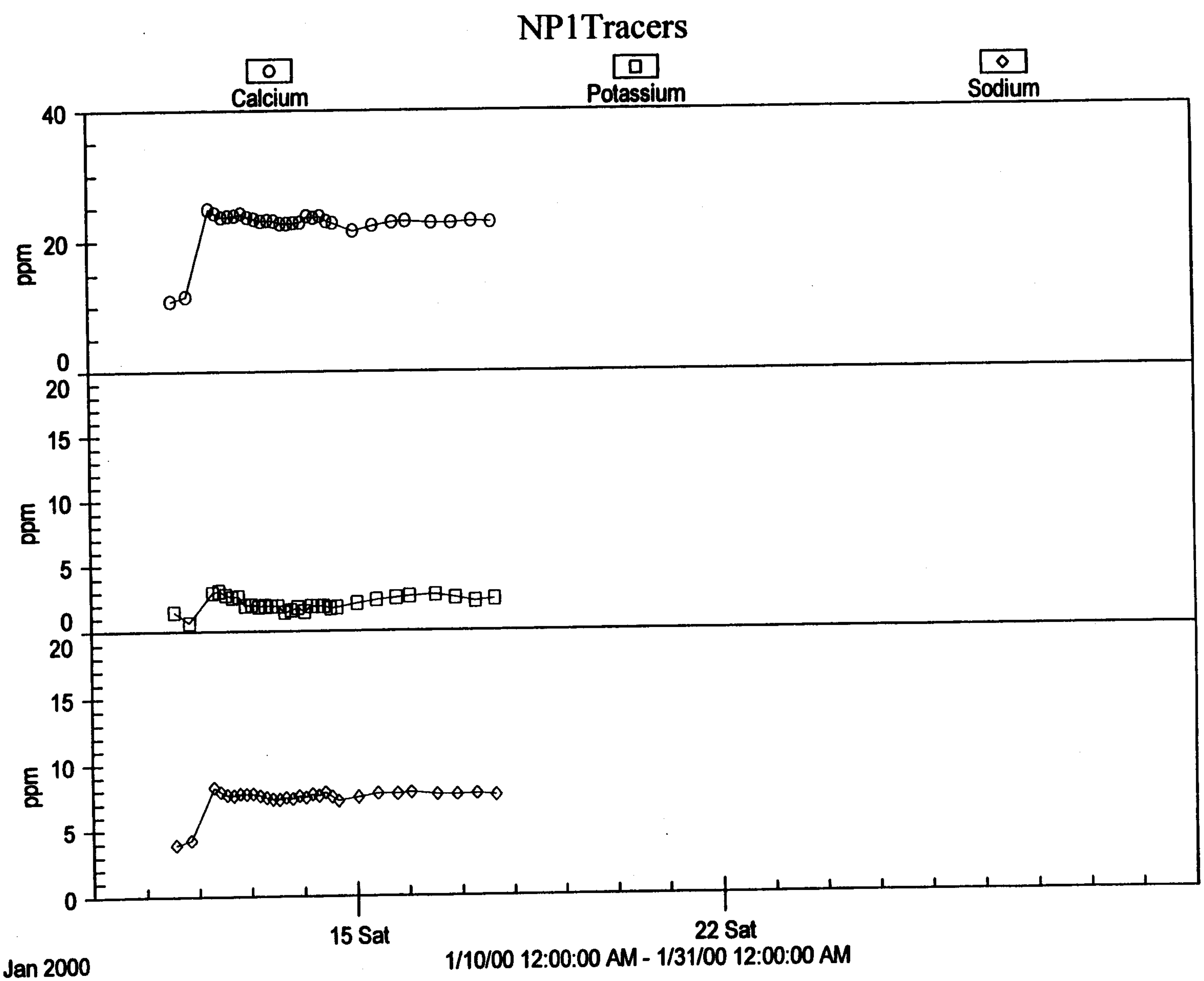


AR 034434

ECY00015802

NPIn

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	N	N	N
Background Range (ppm)	7 - 20	0.6 - 1.9	<1 - 7
Number of Signals	0	1	0
First Signal Characteristics			-
Signal Start	-	1/14/00 16:00	-
Signal End	-	1/16/00 19:00	-
Signal Duration (hrs)		51.0	
Signal Peak (date/ time)	-	1/14/00 19:00	-
Signal Max (ppm)	-	8.6	-
Signal/Noise	-	6.6	-
Notes	-	-	-
Second Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Duration (hrs)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-



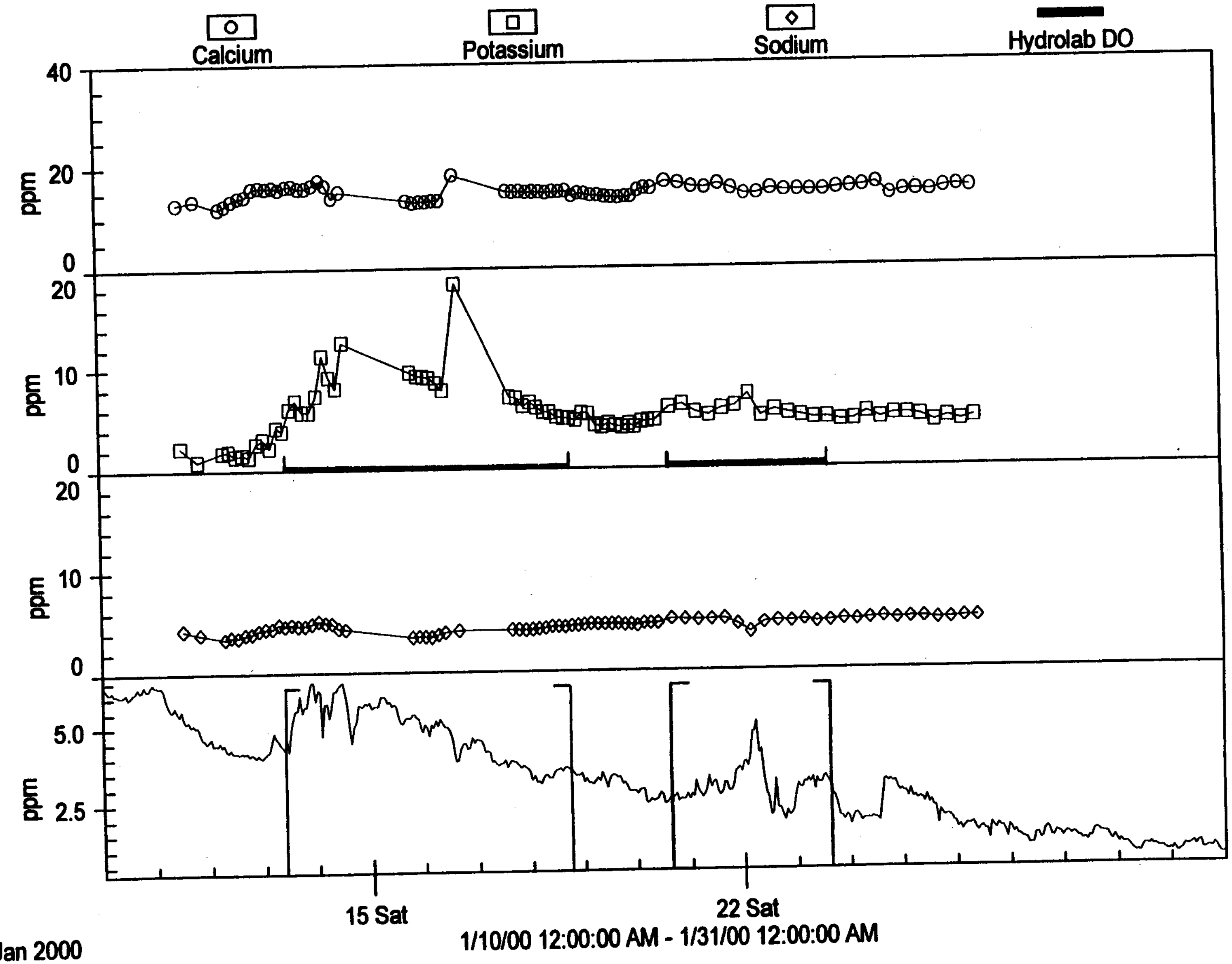
AR 034436

ECY00015804

NP1

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	N	N	N
Background Range (ppm)	10.9 - 24.9	0.6 - 3.0	3.9 - 8.3
Number of Signals	0	0	0
First Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-
Second Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-

NPOut Tracers



AR 034438

ECY00015806

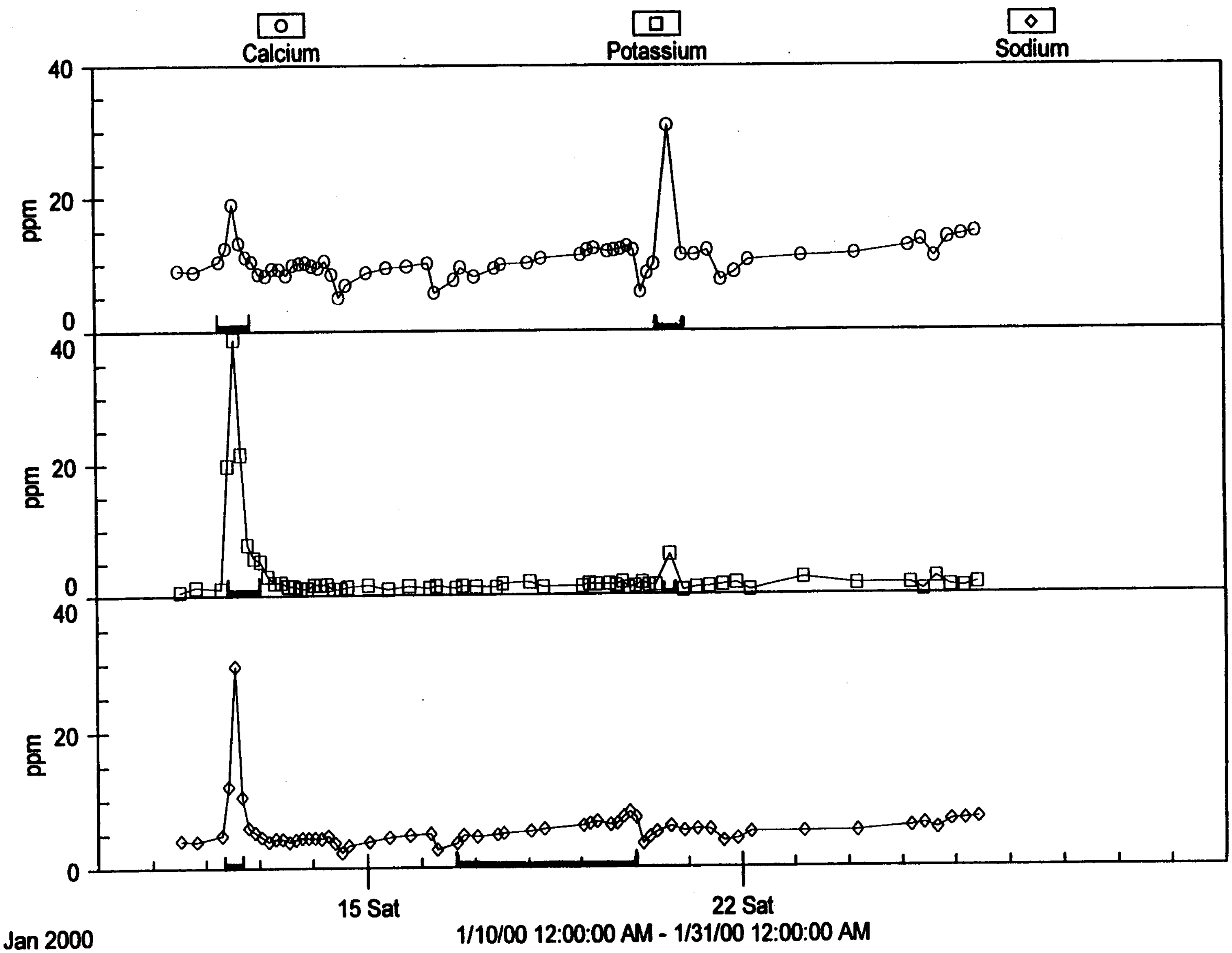
NPOut

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	N	Y	N
Background Range (ppm)	11.9 - 18.1	1 - 5.3	3.4 - 5.1
Number of Signals	0	2	0
First Signal Characteristics			
Signal Start	-	1/13/00 13:00	-
Signal End	-	1/18/00 19:00	-
Signal Duration (hrs)	-	126.0	-
Signal Peak (date/ time)	-	1/16/00 16:00	-
Signal Max (ppm)	-	18.4	-
Signal/Noise	-	3.8	-
Notes	-	Signal defined using average of max/ min values after event (4.8 ppm)	-
Second Signal Characteristics			
Signal Start	-	1/20/00 16:00	-
Signal End	-	1/23/00 16:00	-
Signal Duration (hrs)	-	72.0	-
Signal Peak (date/ time)	-	1/22/00 4:00	-
Signal Max (ppm)	-	7.2	-
Signal/Noise	-	1.5	-
Notes	-	Signal defined using average of max/ min values after event (4.8 ppm)	-

AR 034439

ECY00015807

DME Tracers



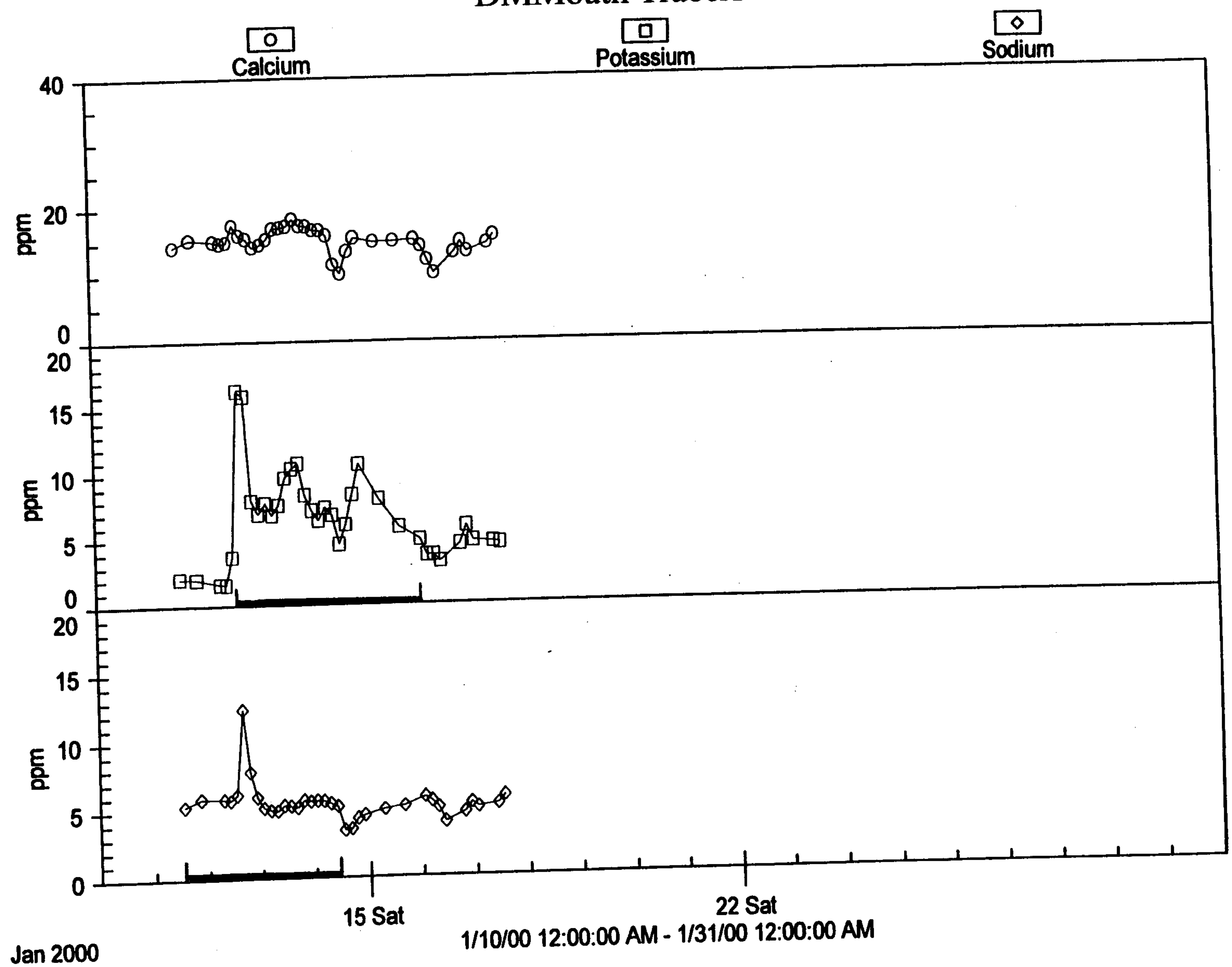
AR 034440

ECY00015808

DME

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	Y	Y	Y
Background Range (ppm)	4.9 - 14.6	0.6 - 2.6	2.2 - 7.1
Number of Signals	1	2	2
First Signal Characteristics			
Signal Start	1/12/00 7:00	1/12/00 10:00	1/12/00 7:00
Signal End	1/12/00 22:00	1/13/00 7:00	1/12/00 22:00
Signal Duration (hrs)	15.0	21.0	15.0
Signal Peak (date/ time)	1/12/00 13:00	1/12/00 13:00	1/12/00 13:00
Signal Max (ppm)	19	38.8	29.6
Signal/Noise	1.9	8.6	6.3
Notes	-	-	First signal prior to documented application
Second Signal Characteristics			
Signal Start	-	1/20/00 16:00	1/16/00 19:00
Signal End	-	1/20/00 16:00	1/20/00 4:00
Signal Duration (hrs)	-	0.0	81.0
Signal Peak (date/ time)	-	1/20/00 16:00	1/19/00 22:00
Signal Max (ppm)	-	6.17	8.09
Signal/Noise	-	3.9	1.7
Notes	Second peak suspect, no incr. in flow, no inc. in cond.	-	Signal starts prior to second applic, could be background

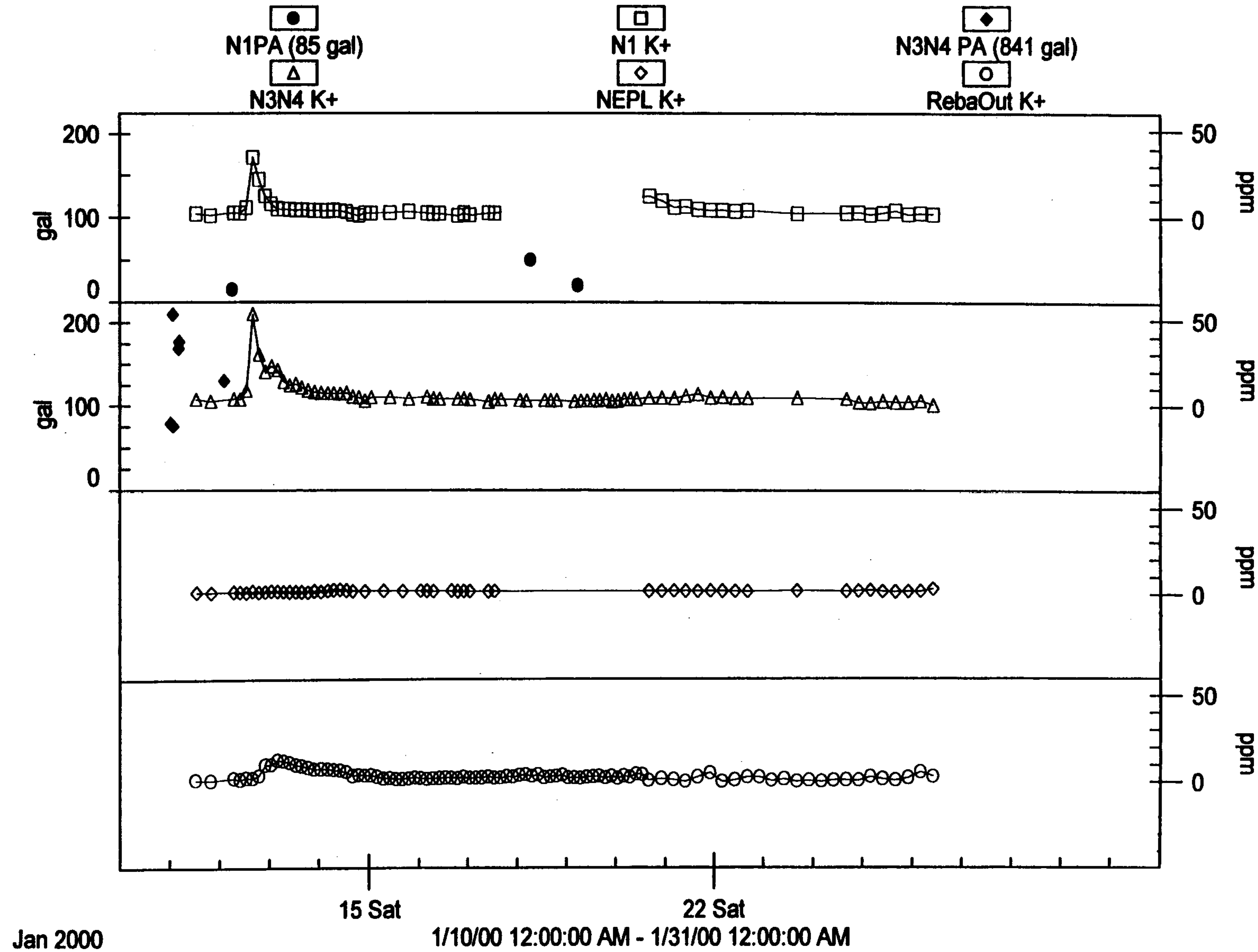
DMMouth Tracers



DMMouth

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	Y	Y	Y
Background Range (ppm)	10.1 - 18.4	1.6 - 5.9	3.5 - 5.8
Number of Signals	0	1	1
First Signal Characteristics			
Signal Start	-	1/12/00 16:00	1/11/00 13:20
Signal End	-	1/16/00 1:00	1/14/00 10:00
Signal Duration (hrs)	-	81.0	68.7
Signal Peak (date/ time)	-	1/12/00 16:00	1/12/00 16:00
Signal Max (ppm)	-	16.3	12.4
Signal/Noise	-	4.3	2.6
Notes	-	signal has 3 peaks	signal prior to documented application
Second Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-

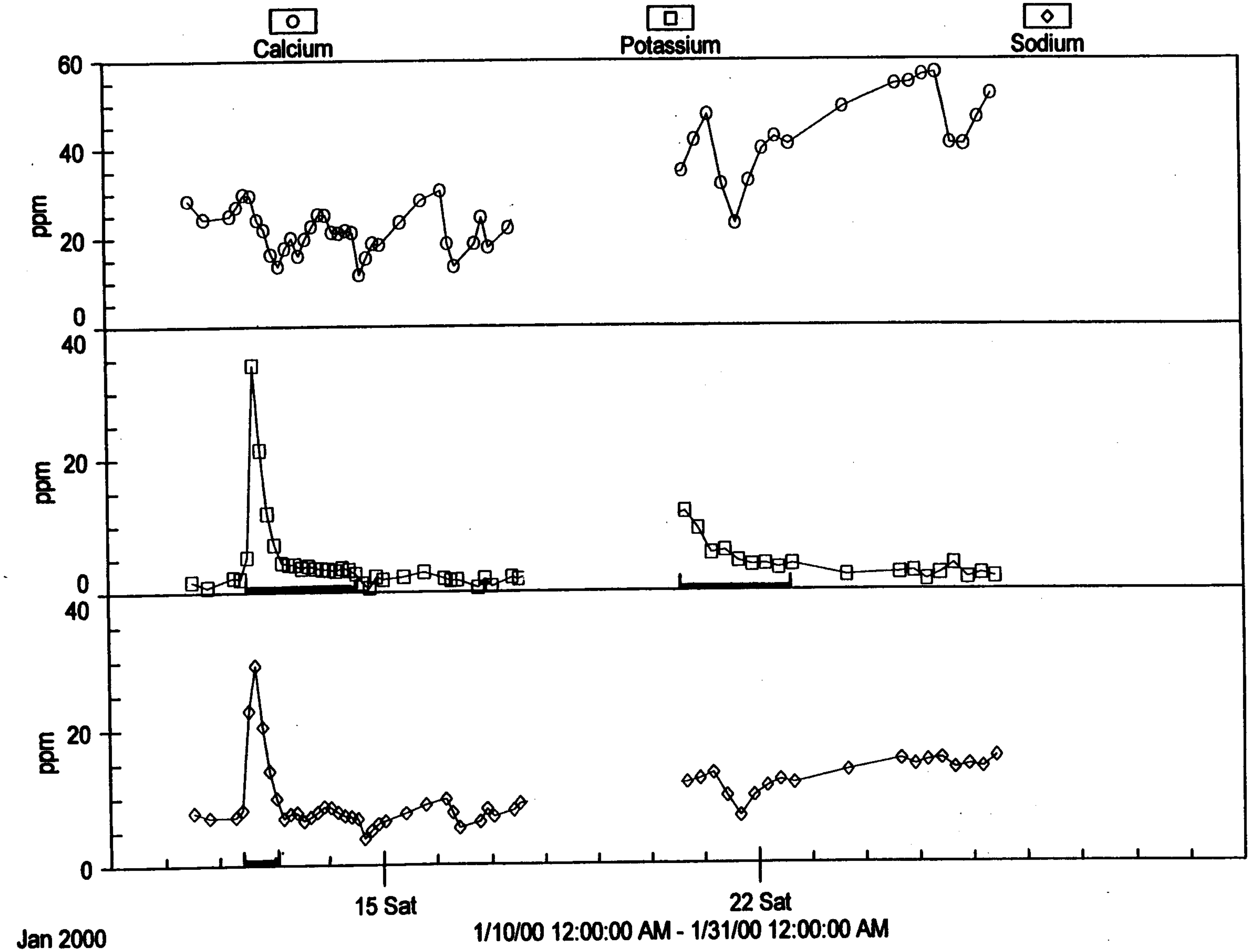
Potassium - Lake Reba Basin



AR 034444

ECY00015812

N1 Tracers



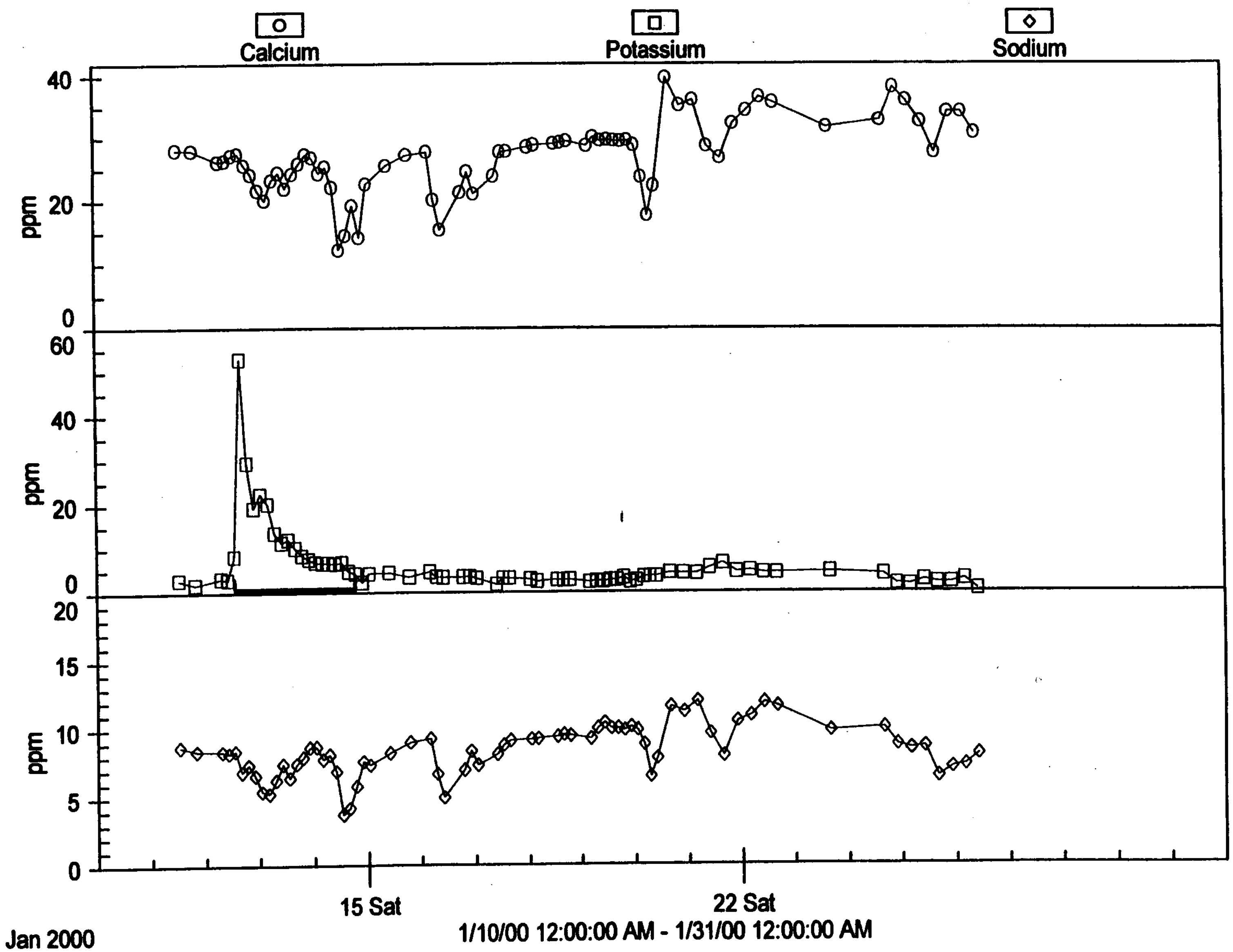
Calcium
Potassium
Sodium
60
40
20
0
ppm
40
20
0
ppm
40
20
0
ppm
Jan 2000
15 Sat
22 Sat
1/10/00 12:00:00 AM - 1/31/00 12:00:00 AM

N1

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	Y	Y	Y
Background Range (ppm)	14 - 55	0.6 - 3.9	3.9 - 15.5
Number of Signals	N	2	1
First Signal Characteristics			
Signal Start	-	1/12/00 13:00	1/12/00 13:00
Signal End	-	1/14/00 13:00	1/13/00 1:00
Signal Duration (hrs)	-	48.0	12.0
Signal Peak (date/ time)	-	1/12/00 16:00	1/12/00 16:00
Signal Max (ppm)	-	34.2	29.4
Signal/Noise	-	15.2	3.0
Notes	peak of 55 during dry after application	First signal prior to documented application	signal prior to documented application
Second Signal Characteristics			-
Signal Start	-	1/20/00 16:00	-
Signal End	-	1/22/00 16:00	-
Signal Duration (hrs)	-	48.0	-
Signal Peak (date/ time)	-	1/20/00 16:00	-
Signal Max (ppm)	-	12	-
Signal/Noise	-	5.2	-
Notes	-	sampled tail-end of second signal	-

AR 034446

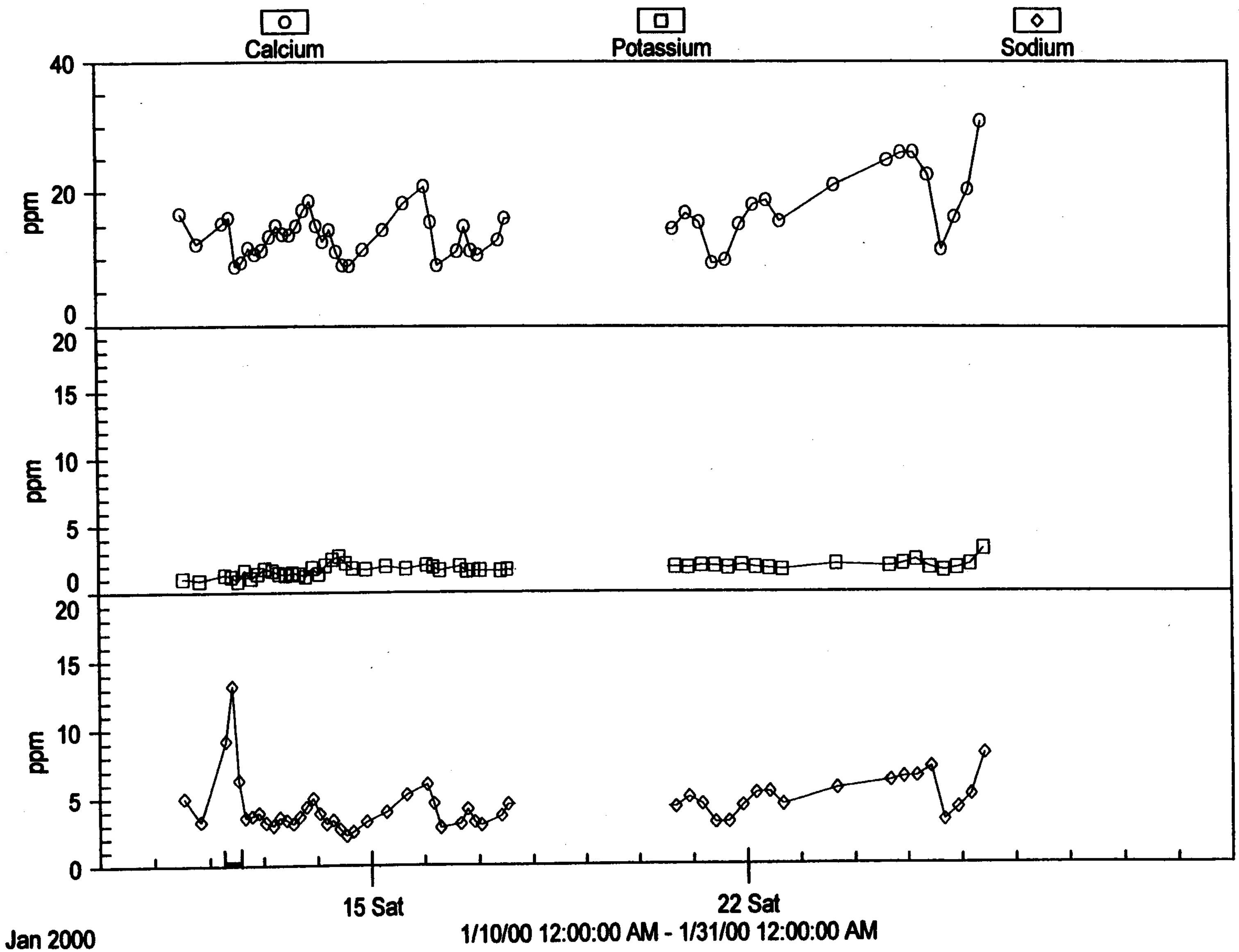
N3N4 Tracers



N3N4

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	N	Y	N
Background Range (ppm)	12 - 40	0.6 - 6.6	4 - 12
Number of Signals	0	1	0
First Signal Characteristics			
Signal Start	-	1/12/00 13:00	-
Signal End	-	1/14/00 19:00	-
Signal Duration (hrs)	-	54.0	-
Signal Peak (date/ time)	-	1/12/00 16:00	-
Signal Max (ppm)	-	52.9	-
Signal/Noise	-	14.7	-
Notes	-	-	-
Second Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-

NEPL Tracers



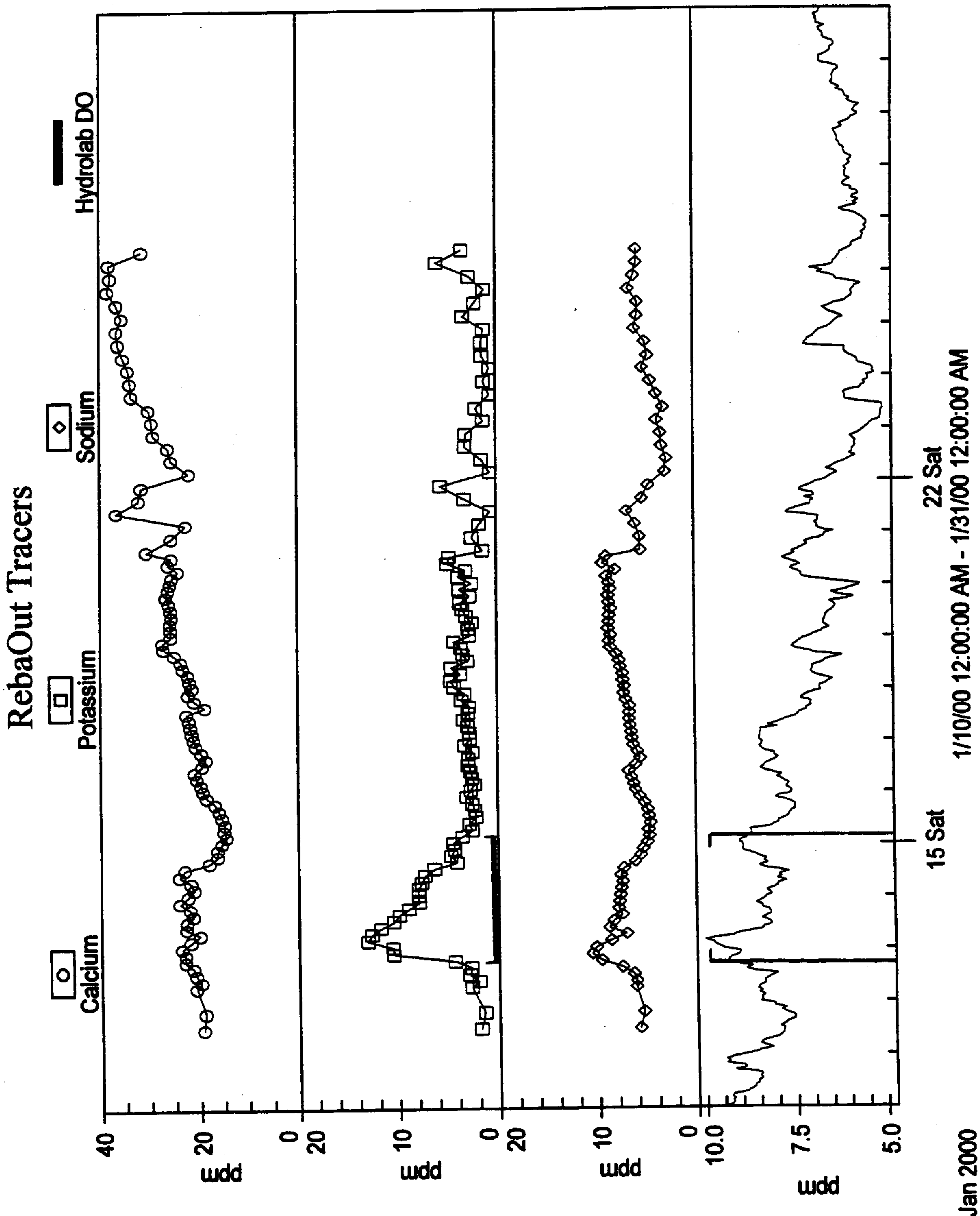
AR 034449

ECY00015817

NEPL

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	Y	N	Y
Background Range (ppm)	8.9 - 30.9	0.9 - 3.3	2.2 - 8.1
Number of Signals	0	0	1
First Signal Characteristics			
Signal Start	-	-	1/12/00 7:00
Signal End	-	-	1/12/00 13:00
Signal Duration (hrs)	-	-	6.0
Signal Peak (date/ time)	-	-	1/12/00 10:00
Signal Max (ppm)	-	-	13.2
Signal/Noise	-	-	2.5
Notes			signal prior to documented application
Second Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-

AR 034450



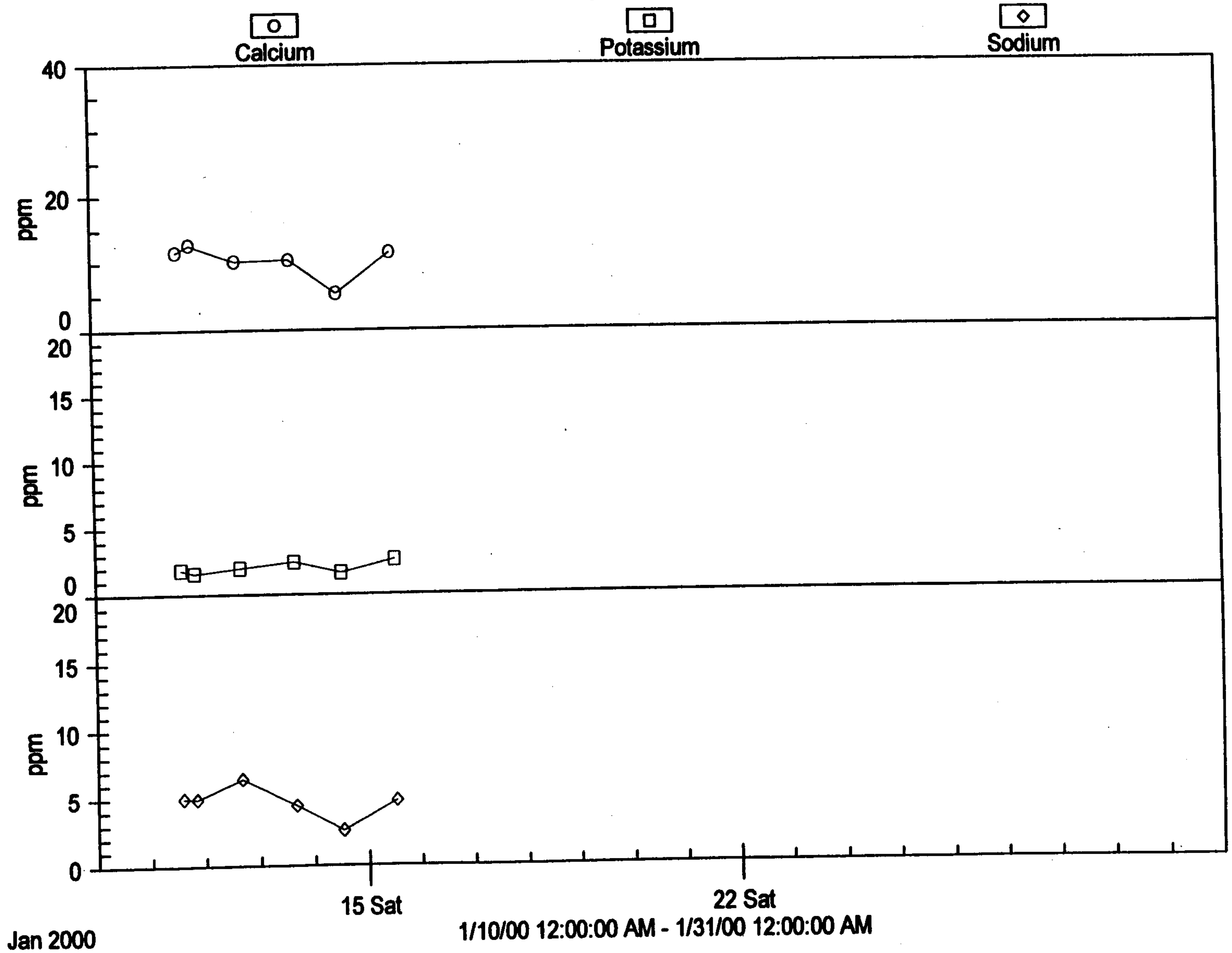
AR 034451

ECY00015819

RebaOut

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	Y	Y	Y
Background Range (ppm)	14.4 - 38.3	0.6 - 5.9	2.8 - 10.6
Number of Signals	0	1	0
First Signal Characteristics			
Signal Start	-	1/12/00 19:00	-
Signal End	-	1/15/00 4:00	-
Signal Duration (hrs)	-	57.0	-
Signal Peak (date/ time)	-	1/13/00 4:00	-
Signal Max (ppm)	-	13.1	-
Signal/Noise	-	4.0	-
Notes	-	-	-
Second Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-

MCUp Tracers



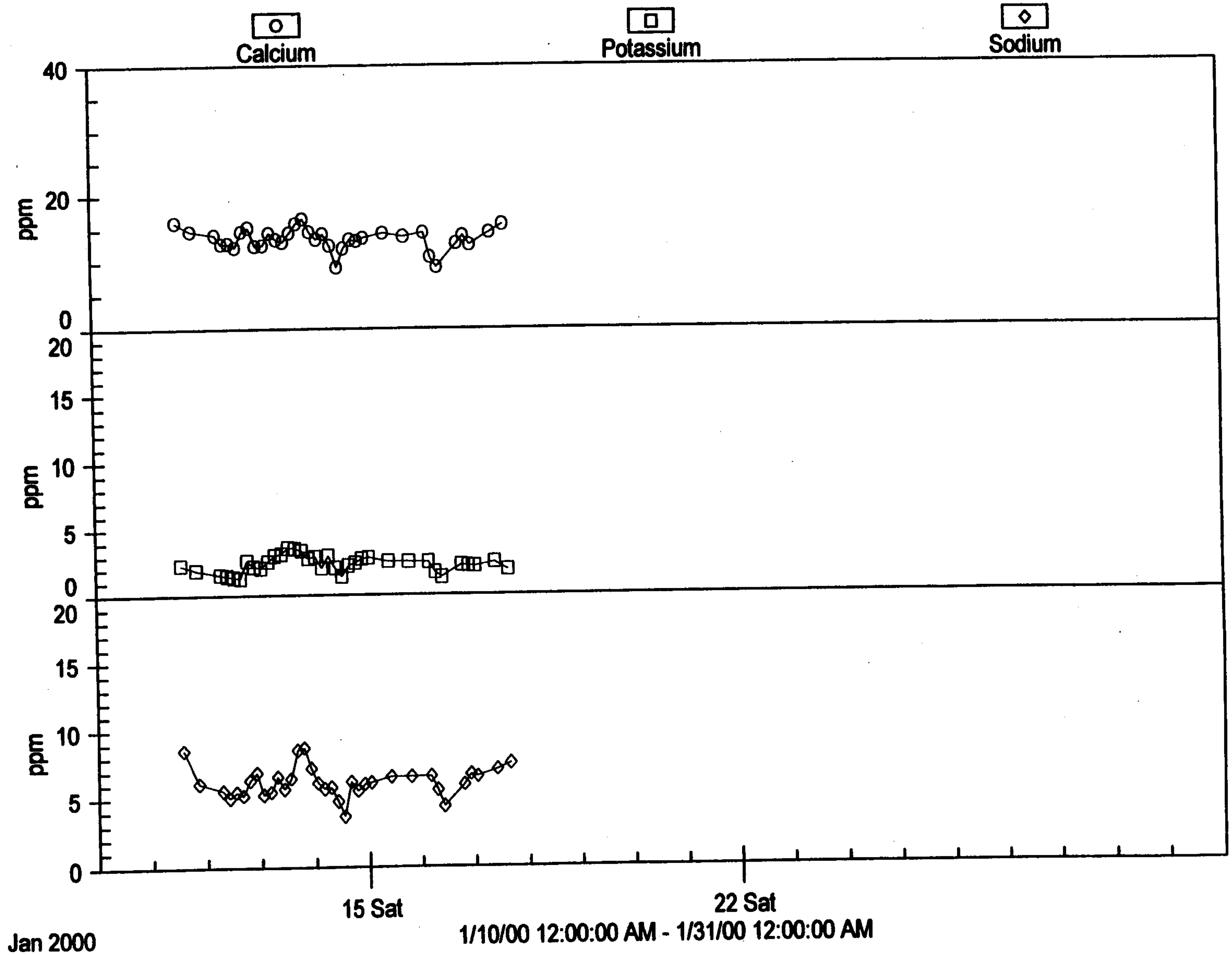
AR 034453

ECY00015821

MCUp

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	N	N	N
Background Range (ppm)	5.3 - 12.7	1.6 - 2.6	2.6 - 6.5
Number of Signals	0	0	0
First Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-
Second Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-

MCMouth Tracers



MCMouth

	CMA/ Calcium	PA/ Potas	SA/ Sodium
Chemical Applied (Y/N)	Y	Y	Y
Background Range (ppm)	9.3 - 16.5	1.3 - 3.6	3.7 - 8.7
Number of Signals	0	0	0
First Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-
Second Signal Characteristics			
Signal Start	-	-	-
Signal End	-	-	-
Signal Duration (hrs)	-	-	-
Signal Peak (date/ time)	-	-	-
Signal Max (ppm)	-	-	-
Signal/Noise	-	-	-
Notes	-	-	-

5 APPENDIX D DATA ANALYSIS METHODS AND RESULTS

5.1 *Introduction*

This Appendix presents a summary of the methods and results of statistical analyses conducted to determine if the presence of deicing chemicals in Lake Reba and Northwest Pond 3 causes a decrease in either the concentration or saturation of dissolved oxygen (DO) in the ponds. The methods and results in this appendix are first summarized with more information about theory, methods, and results presented in Sub-Appendices D1-D7.

Investigation of the effects of deicing chemicals on levels of DO[1] in Northwest ponds and Lake Reba, began with exploratory analyses conducted to visually investigate the range, variance, and temporal distributions of DO levels and changes, over 1, 6, and 8 hour periods, in DO levels. Exploratory analyses were also conducted to investigate the range, variance, and temporal distributions of selected physical variables, and changes in those variables, that were recorded during the monitoring period. These physical variables, including rainfall (as indicated by rising water level in the ponds), conductivity, water temperature, date and time, and presence of deicing chemicals, were considered the "independent" variables that might be used to help explain or predict DO levels.

After the distributions of individual variables had been explored, the relationships between DO levels and the physical variables were explored using scatter plots, correlation analyses, and simple time-series techniques. Exploratory analyses were followed by statistical analyses, including hypothesis testing and simple time-series modeling, designed to test for differences between DO levels when deicing chemicals were present (treatment periods) and were not present (control periods) in the system.

---

[1] The term DO levels will be used to refer to concentration and saturation of DO in Lake Reba and Northwest Ponds. Changes in levels will refer to changes in both concentration and saturation.

Effects of explanatory variables other than deicing chemicals were examined to determine how they could effect the distribution of DO levels and changes in level.

Although the study was originally designed to include "control" and "treatment" ponds and time periods, the highly stratified DO found in the control ponds (NWP cells 1 and 2) indicated that these ponds were not well-suited as controls for the two treatment ponds (NWP cell 3, and Lake Reba). The application of deicing chemicals to runway areas could not be planned so that the nature and timing of the treatment periods was a controlled aspect of the study. Over the course of the monitoring year, the need for application of deicing chemicals to ground surfaces was limited to a two-week period of time that was followed by the longest low rainfall period in the 4-month monitoring period. There was too little separation in time between chemical applications and dissimilar chemical applications for the three events in the two-week period to be considered replicates.

With the unsuitable control ponds, no replication of treatment periods, and no specific thresholds of DO change to test for, the types of analyses available for testing for the potential effects of deicing chemicals were limited and caution was required when interpreting the results(see Table 1). This study did not examine a predefined biologically significant threshold of potential effects (e.g., rate of change or total change in DO over a specific time period.) For these reasons, it was necessary to develop a "weight of evidence approach" to support or not support conclusions that deicing chemicals affect DO levels in the ponds.

Table 5-1. Factors that affected available analytical methods and interpretation of results.

1. Lack of control ponds • Northwest pond cells 1 and 2 (NP1 and NP2), lie upgradient of cell 3 (NP3). Runoff from outfall SDS3 transports the majority of deicing chemicals from the runways to NP3. Thus, NP1 and NP2 were intended to serve as control ponds unaffected by deicing chemicals. During the course of the study, it was discovered that DO in NP1 and NP2 was highly stratified and not comparable to the much more homogeneous DO exhibited in both NP3 or Lake Reba. Therefore, NP1 and NP2 were not well-suited to be considered control ponds.
2. Lack of replicate treatment (deicing) events • Deicing events were not separated sufficiently in time for their effects to be independent and loading quantity and/or chemical types used differed between events. • All deicing events occurred during a unique type of weather pattern: unusually low rainfall. This weather pattern was not repeated at other times during the monitoring program. Furthermore, this type of weather pattern has been shown in this study and previous work to result in naturally falling DO in both NP3 and Lake Reba.
3. Effects of unmeasured variables. • DO levels are affected by complex interactions among factors (variables), some of which were measured in this study (e.g., rainfall, water level, water temperature, conductivity) and some of which were not (e.g., local wind, retention periods of the ponds, etc.). Without replication, it is not possible to describe the nature of these, especially if unmeasured variables had measurable effects. That is, the likely possibility that unmeasured variables did affect DO levels complicates interpretation of results. • For example, the relationships between DO and explanatory variables differed at Lake Reba and NP3. It is likely that physical characteristics such as depth, volume, and turn over rates that differed between the ponds, also affected dissolved oxygen levels. • Within ponds, the distributions of DO levels differed between treatment and control periods. It was not possible to discriminate which factor (e.g., measured or unmeasured variables, including deicing chemical presence) caused these differences.
4. No predefined measure of a significant effect on DO. • Without a pre-specified definition of a threshold that would constitute a "deicing effect" (e.g., a given change in DO), it was difficult to search the data for a deicing effect. If multiple definitions had been created and searched for, the probability of spurious results would have been increased.

5.2 *Exploratory Analyses*

5.2.1 Methods

Exploratory Analyses were conducted to guide and focus statistical analyses of the effects of deicing chemicals on DO levels. In particular, the exploratory phase was designed to:

1) identify signals of deicing event(s) and explore relationships between conductivity and tracer ions during background and treatment periods to demonstrate the efficacy of conductivity as an aggregate tracer,
2) determine which of the measured physical variables, including rainfall, water level, conductivity, temperature, presence of deicing chemicals, and time (including temporal patterns in individual variables or relationships between variables) best predicted DO levels and changes in DO levels,
3) explore temporal scales of change, and
4) identify differences between NP3 and Lake Reba in terms of the relationships between DO and explanatory physical variables.

All analyses were conducted in SPSS for Windows Release 9.0.0. Most data were collected in and/or imported to Flowlink 4.1 software used to program and manage data for the field instrumentation. The Flowlink data were exported and visually checked against data transferred to Excel and SPSS data files. Outliers or missing values in time series plots and exploratory graphs were investigated and corrected as needed to confirm real data and/or missing values.

5.2.1.1 Identify signals of deicing event(s) and explore relationships between conductivity and tracer ion concentrations.

To identify a "signal" of a deicing event (i.e., a beginning and end of a treatment replicate) the following pieces of information were examined:

1. the times during which different deicing chemicals were applied to runways,
2. the quantities of deicing chemicals that were applied, and
3. presence of tracer ions associated with the deicing chemicals and their relationship to conductivity in Lake Reba and NP3

Concentrations of tracer ions (Na^{2+}, K^{+}, and Ca^{2+}), conductivity, and DO were plotted against time during a background (control) event from 12/11/99-12/13/99 and during the treatment period from 1/11/00 – 1/28/00 when deicing chemicals were applied. During the two-week treatment period, a peak in tracer concentration was identified as an isolated high point flanked on either side by progressively smaller concentrations. The magnitude of this peak value had to be substantially higher than the concentrations observed during the background event to be considered a "signal". The onset of a deicing signal was defined as the first tracer ion concentration immediately prior to the signal peak whose value was greater than the background concentration[2]. The end of the signal was defined as the last concentration immediately following the tracer peak whose value was greater than the background concentration. See Appendix C for more details.

Correlations between tracer ion concentrations and conductivity during control (12/11/99-12/13/99) and treatment periods (1/11/00 – 1/28/00) were compared to determine how well the ions correlated with applications of deicing chemicals.

5.2.1.2 Determine the physical variables, including time, that best predict DO levels and changes in DO levels

The variables measured during the study period that might affect DO levels or changes in level included conductivity, water temperature, rain, water level, and time. Although time is not really a causal variable, it can be considered a variable that integrates effects

---

[2] The average of the smallest minimum concentration and largest maximum concentration was used to define the "background" concentration around the tracer signal.

created by other causal variables. In addition, with time-series data, it is important to be certain that there is no correlation among data values before classical hypothesis tests are conducted.

The relationships between the measured physical variables and DO levels were explored using simple time series methods that provide insight into each variable's distribution over time and any temporal structure in relationships between variables. The autocorrelation function (ACF) was used to show how correlation among the data values of a variable is related to their separation in time (details described in Appendix D1). Relationships among variables were explored using the cross-correlation function (CCF) which shows how the correlation between the data values of two different variables is related to their separation in time. These exploratory analyses were largely qualitative; a more formal time series modeling was conducted in the second phase of analysis.

To investigate the potential effects of deicing chemicals, two definitions of a deicing treatment were created so that results using the two definitions could be compared. The first definition was based solely on the presence of deicing chemicals in the ponds as determined by tracer ion analyses (see Appendix C and related figures). According to the tracer ion data a deicing signal was present at the two ponds during the following times:

Lake Reba

- From January 12, 2000 19:00 to January 15, 04:00

NP3

- From January 13, 2000 13:00 to January 18, 19:00 and
- January 20, 2000 16:00 to January 23, 16:00

The periods of signal presence at each pond were defined as the treatment periods for the pond according to the "signal-based" definition of a deicing treatment. At Lake Reba, the treatment period constituted one continuous 2.5-day period. At NP3, the treatment period consisted of two different periods separated by a little less than two days (though it was not certain that the signal from the first event was completely extinguished prior to the onset of the signal associated with the next chemical applications). In each pond, all periods before or after the treatment period(s) were considered control periods.

The second, more conservative definition of a treatment period (the "time-based" definition) was the same at both ponds. Using this definition, all hours between the start of the first signal at Lake Reba and end of the last signal at NP3 (i.e., from January 12, 2000 at 19:00 through January 23, 16:00) were considered the treatment period. Hours outside that twelve-day (approximately two-week) period were considered control hours. The time-based definition excludes the uncertainty that chemicals were completely flushed between successive applications of deicing chemicals.

These two definitions were used to explore how tightly evidence of effects on DO levels were tied to the presence of deicing chemicals *vs.* other factors, besides deicing chemicals, that co-occurred during the treatment period. The interpretation of these analyses was complicated by the fact that each application of deicing chemicals included different volumes and/or types of chemicals applied (PA, SA and CMA)

5.2.1.3 Explore temporal scales of change.

Based on the results of exploratory analyses of the effects of time and temporal patterns, changes in the concentration and saturation of DO over 1 hour, 6 hour, and 8 hour periods were investigated as the measures of "change in DO". Correlations between changes in explanatory variables and changes in DO levels were computed for treatment and control periods using both definitions of treatment.

5.2.1.4 Compare relationships between DO and explanatory variables at NP3 and Lake Reba.

Time series plots of hourly, daily, and moving average data for the two ponds were visually compared for differences in patterns over time and effects of explanatory variables. Plots of DO *vs.* time and DO in NP3 *vs.* Lake Reba use time as a surrogate for interactions among measured and unmeasured causal variables. Comparing DO levels at the two ponds and relationships between DO and explanatory variables helped to determine whether unmeasured might have affected DO levels. Scatter plots of time-paired data from NP3 and Lake Reba and CCFs of data from NP3 and Lake Reba were also used to compare measured variables in the two ponds.

5.2.2 Results/Findings

5.2.2.1 Identify signals of deicing and explore relationships between conductivity and tracer ion concentrations.

Correlations between conductivity and tracer ion concentrations varied between sampling locations and between background and treatment periods. Conductivity was highly and positively correlated with calcium and sodium during both the background and treatment periods. The sign and the strength of the correlation between conductivity and potassium tended to change considerably between treatment and control periods and the nature of the change depended on site.

1. **Background conductivity was best explained by calcium and sodium tracers.** During the background sampling, correlations between sodium, calcium, and conductivity were high ($r > 0.95$) at all sampling locations, although few were statistically significant due to small sample sizes (n = 5-6). Correlation between background levels of conductivity and potassium was generally low, except at SDS3, S567, NPin, N3N4, and Lake Reba where correlation was moderate ($0.50 < r < 0.90$) (Table 2).

2. **The correlation between conductivity and tracer ion concentrations was generally weaker during the treatment period than the background period except at three sites where the strength of the correlation between conductivity and potassium increased during the treatment period.** During the treatment period, correlations between conductivity, calcium, and sodium declined slightly relative to background at all sites. None of the declines were large, especially the decline in the conductivity-calcium correlation at NEPL, N1, and S567, and the decline in the correlation between conductivity and sodium at DME, N1, and, perhaps, S567.

The conductivity-potassium correlation also decreased at some sites during deicing (in Miller Creek system, at Lake Reba and N3N4, in the Des Moines Creek system, at Npin and S567). These decreases were more significant than the declines in the conductivity-calcium-sodium correlations. In contrast, the conductivity-potassium correlation increased considerably at two sites in Des Moines Creek (DME, NPout) and one site in Miller Creek (N1) and less dramatically at SDS3 (De Moines) and NEPL (Miller).

3. **Changes in conductivity-tracer ion correlations were similar at some groups of sites.** Lake Reba and N3N4 in Miller Creek and NPin and S567 in Des Moines Creek responded similarly in that correlations among tracer ions generally declined during the treatment event. At N1 in Des Moines Creek, correlation between conductivity, calcium, sodium, and potassium stayed relatively equal or increased during deicing. N1 and NEPL in Miller Creek and NPout, DME, and SDS3 in Des Moines Creek had similar responses in terms of the direction, though not always the magnitude, of their changes in response.

4. **Deicing signal timing varied among monitoring locations.** Deicing chemicals arrived with different timing at the NP3 and Lake Reba and other sites along Des Moines and Miller Creek. The timing stemmed from the differences in size, imperviousness, and other drainage characteristics of the application areas. These

areas may be deiced at different times with different types and amounts of deicing chemicals. The temporal and chemical features of a deicing signal depend on where, when, which, and how much of the different deicing chemicals are applied. For example, NP3 receives chemicals only from airfield runoff from SDS3 and this year, only PA was applied to SDS3. Lake Reba receives chemicals from N3N4 (this year PA only) and from the landside areas N1 and NEPL (this year, PA, SA and CMA).

Increases in the conductivity-potassium correlation during the deicing period occurred at SDS3, NPout, DME, and N1 and corresponded to PA applications in the respective drainage areas. Though an increase was expected at N3N4, the peak in PA at this location was very brief and conductivity continued to be explained better by calcium and sodium, as it was during background. N1 and NEPL, which received CMA and SA, had very little change from background in the conductivity-calcium and conductivity-sodium correlations.

Table 2. Pearson correlations between conductivity and tracer ions during background and treatment periods.

	Calcium		Potassium		Sodium	
Location	background	deicing	background	deicing	background	deicing
SDS3	0.999	↓↓ 0.618	0.533	↑ 0.860	0.994	↓↓ 0.259
NPin	0.999	↓↓ 0.642	0.601	↓↓ 0.012	0.997	↓↓ 0.494
Npout (NP3)	0.973	↓↓ 0.539	-0.349	↑↑ 0.706	0.995	↓↓ 0.454
DME	0.998	↓↓ 0.572	-0.353	↑↑ 0.808	0.997	≈ 0.950
S567	1.000	≈ 0.979	0.680	↓ -0.011	1.000	↓ 0.832
N1	1.000	≈ 0.962	0.110	↑↑ 0.604	1.000	≈ 0.980
N3N4	0.999	↓ 0.820	0.693	↓ -0.465	0.999	↓↓ 0.618
NEPL	1.000	≈ 0.941	0.246	≈ 0.325	0.984	↓ 0.692
Reba Out	1.000	↓ 0.813	0.735	↓↓ -0.064	1.000	↓↓ 0.348

Arrows indicate whether correlations during the treatment period increased, decreased, or stayed the same relative to background.

5.2.2.2 Determine the physical variables that best predict DO concentration and saturation

1. **Data for all variables were extremely time dependent; each hourly data value was highly correlated with values of the preceding and following hours.** Even 1, 6, and 8 hour changes were autocorrelated. This means that levels of DO and other variables tended to change gradually and continuously over time and did not exhibit frequent, large increases or decreases in the course of an hour. (See Appendix D2 for more details and Appendix D3 for graphs of ACF and PACF functions). For a long time series such as this, autocorrelation coefficients are averages of the correlation between many pairs of values that are separated by different lengths of time. In some cases, relatively large and rapid changes in DO did occur, especially in response to rain. For example, on 11/4/99, DO concentration rose from 1.7 to 3.1 mg/L over one hour at Lake Reba. During the same day, DO concentration changed from 5.41 – 8.47 mg/L at NP3 over 8 hours. Declines in DO in response to dry weather were generally not quite as rapid as rises, but declines of over 2 mg/L in less than 24 hours were not uncommon.

2. **The autocorrelation structure of each variable varied slightly from one variable to the next.** For a given variable, there were some differences in the autocorrelation structure between ponds. Although these results are qualitative, they indicate that the physical and possibly biological processes differ at the two ponds. (Appendix D2, Table 1, and Appendix D3 for ACF/PACF graphs.)

3. **Correlation between variables was not affected by time. That is, there were no differences due to time lag in the cross-correlation functions.** Consequently, correlations among variables were described by nonparametric Spearman Rank correlation coefficients which describes the correlation at time lag 0. None of the correlations between variables were strong although some were significant because of large sample sizes. DO percent saturation was more strongly correlated with other measured variables than was DO concentration. (Appendix D2, Table 3; Appendix D4 for CCF graphs).

4. **Cross-correlations between percent changes in variables did vary with time lag; strong temporal patterns were apparent.** The average magnitude of the cross-correlation coefficients for percent change variables increased with the number of hours over which percent change was estimated. (Appendix D4).

5.2.2.3 Explore temporal scales of change.

As discussed in the previous section, exploratory time-series analyses and graphing indicated that the values of each variable and 1, 6, and 8 hour changes in values, were highly autocorrelated. Plots over time of moving averages of different orders indicated that 2-6 hour moving averages preserved all patterns in the data. Partial autocorrelation coefficients and subsequent statistical analyses also indicated that low-order (1-3 hour) autocorrelation and moving average components were adequate to describe the variability in the data.

Six-hour changes were selected as the period of change for investigations of change and rates of change in the data. Six hours seemed long enough to so that the beginning and end of each period of change would not be completely autocorrelated and small enough to reveal any rapid changes that might occur when temperature or rain patterns made quick shifts.

5.2.2.4 Compare relationships between DO and explanatory variables at NP3 and Lake Reba.

1. **The cross-correlation plots of each variable's values in NP3 and in Lake Reba indicated that there were no consistent lags between ponds in the rises and falls in level of the different measured variables (maximum cross-pond correlation at time lag = 0, Appendix D4).** However, the magnitudes of the cross-pond correlations were not high and indicate that the ponds did not experience identical physical conditions or DO responses.

2. **DO levels and conductivity were higher at Lake Reba than at NP3 during both control and treatment periods.** Median six-hour changes and percent changes in DO concentration and conductivity were approximately equal during control and treatment periods in the two ponds, but the range of changes was slightly higher in Lake Reba. The opposite was true of changes in DO percent saturation; the range was slightly higher in NP3 (Appendix D5 Figures 1-3).

3. **Variance in temperature and changes in temperature were slightly greater in Lake Reba than NP3 during control and treatment periods (Appendix D5 Figure 4).**

4. **Changes in level had a smaller range during the treatment period than the control period at both ponds.** Percent changes in level tended to be higher at NP3 than at Lake Reba (Appendix D5 Figure 5).

5. **During the control period, the relationships among physical variables other than DO were similar at the two ponds.** In general, level and conductivity were inversely related, level and temperature were inversely related, and temperature and conductivity were positively related (Appendix D6). Correlations between variables tended to be stronger at NP3 than at Lake Reba.

6. **During the treatment period, the sign of the cross-correlation coefficients between physical variables (not including DO) changed from the control period.** In addition, treatment cross-correlations showed more of a temporal pattern than did control cross-correlations. Patterns of treatment cross-correlations tended to differ between and the nature of the difference depended on whether the time or the signal based treatment period was used. Although the period that a signal was present at Lake Reba would seem to have no particular meaning with respect to cross-correlations in NP3, this period had consistently different CCFs than the CCFs for time-based and NP3 signal-based treatment periods. For more detail, see Appendix D6.

7. **At both ponds, cross-correlations between DO and water level change sign from control to treatment periods.** There seems to be no clear effect of the definition of deicing period at NP3. The shape of the CCFs during the signal-based and the time-based treatment periods are not identical, but they are generally positive (Appendix D6, Figure 1). At Lake Reba, the time-based and signal-based CCFs appear different, although many of the CCCs during the signal-based treatment period are not signficant (Appendix D6, Figure 2). As with the CCFs of the independent variables, the period of time that a signal was present at Lake Reba also seems to be an unusual time period at NP3 as well (Appendix D6, Figure 1).

8. **The sign changes for the correlation between DO and temperature between the control and treatment periods at NP3 (positive to insignificant or negative for both definitions of treatment) (Appendix D6, Figure 1).** At Lake Reba, time-based treatment and control CCFs completely positive with minimal effects of time. The signal-based treatment CCF, however, shows a strong negative correlation between DO and temperature – especially at time lags of 2-6 hours (Appendix D6, Figure 2). Again, the CCF of NP3 temperature and DO was also different for this period (Appendix D6, Figure 1).

9. **The CCF between DO and conductivity was weakly positive and unaffected by time lag during the control period at NP3.** The CCF remains weakly positive during all definitions of the treatment period with some indication of a time lag effect. The appearance of a pattern is likely due to the fact that, during this shorter time period, there are very few data values with a "mate" that is 16 hours earlier. At Lake Reba, on the other hand, the relationship between DO and conductivity switches from weakly positive to quite strongly negative during the time-based treatment period. It changes back to predominantly positive during the signal-based treatment period (Appendix D6 Figures 1 and 2).

The shapes of the DO-conductivity cross-correlation functions for the control period were quite similar at the two ponds for both treatment period definitions. The control period CCFs were quite flat and low magnitude, indicating only a low level of correlation between the two variables (i.e., lots of variability in the nature of their relationship) and no time lags in the correlations between the two ponds. The CCFs for the treatment period had different shapes than the control CCFs in both ponds. During the treatment period, the shapes of the CCFs were affected by pond and the definition of the treatment period.

At each pond, the DO-conductivity CCF for the two-week treatment period and the CCF for the period of time that a signal was present at NP3 were consistent (since these two time periods were quite similar in length). When the treatment period was defined as the period of signal presence at Lake Reba, a shorter period than the time-based period or the signal-based period at NP3, there was no consistency within or between ponds. The effect of the change in definition of the treatment period was particularly apparent at Lake Reba where even the sign of the correlations changed depending on definition.

Scatterplots may provide some insight into the apparent inconsistencies in the CCFs. The scatterplots indicate that there may be a threshold conductivity value at which the relationship between DO and conductivity changes from negative to positive. For example, a negative relationship may exist between conductivity and DO at Lake Reba at conductivity levels less than approximately 300 μS/cm and a positive relationship at higher conductivity levels. On either side of this potential threshold, considerable heterogeneity can be seen in the relationship. At NP3, a similar type of switch in the sign of the relationship seems to begin at approximately 150-200 μS/cm. Again, it appears that there may be considerable heterogeneity in the relationship through out the range of conductivity that was encountered in the study.

The relationship between DO percent saturation at Lake Reba and NP3 seems to be generally positive except for the period of time that a deicing signal was present at Lake Reba (Appendix D6, Figures 9 and 10, top two rows of graphs). The relationship between conductivity at the two ponds seems to be positive during control periods, but slightly negative and highly variable during treatment periods (Figures 1 and 2; Appendix D6, Figures 9, 10, bottom two rows).

5.2.3 Summary

Exploratory analyses support concepts about how the physical and biological processes at the two ponds differ. For example, levels of DO were generally higher at Lake Reba than at NP3 and changes in variables may occur more frequently and be larger at Lake Reba than at NP3 (see also Figures 1 and 2). There was also evidence that the relationships among the variables change during the treatment period, but it was not clear that the changes were caused by the presence of deicing chemicals.

The type and volumes of chemicals applied, pond depth and volume, and other unmeasured, local, physical factors also differed at the two ponds and interactions among these variables could have caused any of the effects that were seen. For example, it was not clear how the difference between the level-temperature correlations in the control and treatment periods at both ponds could be caused by deicing chemicals. Changes in the level-temperature relationship, however, could have affected the relationship between conductivity (which is affected by level) and DO (which is affected by both temperature and level).

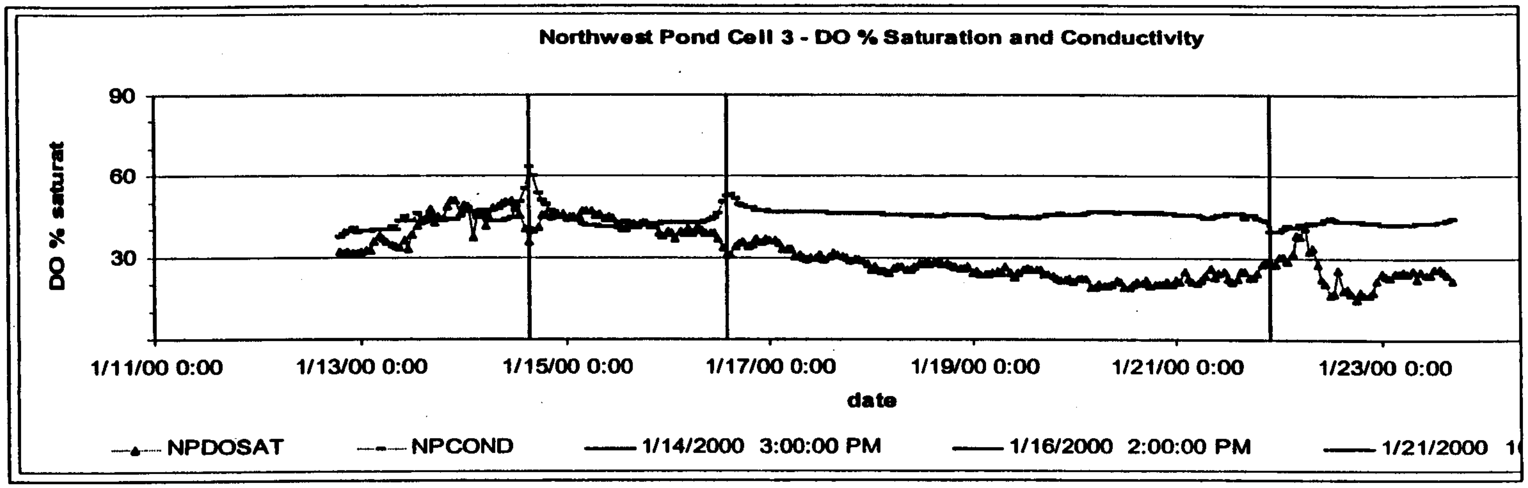


Figure 1. DO % Saturation and Conductivity at NP3 during two-week deicing period. Vertical lines indicate inflection points between different periods of conductivity.

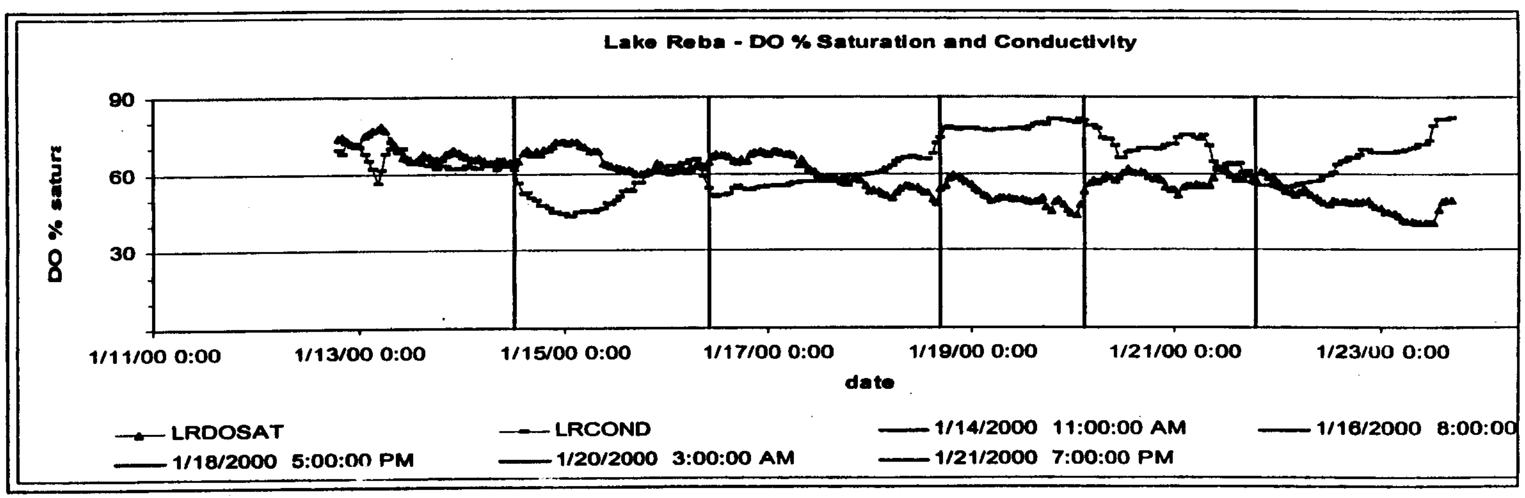


Figure 2. DO % Saturation and Conductivity at Lake Reba during two-week deicing period. Vertical lines indicate inflection points between different periods of conductivity.

5.3 Statistical Analyses.

Analytical methods included two basic approaches.

1) Model/Predict/Explain measured DO concentrations using contemporaneous data collected about physical variables. Models were used to remove variability in DO caused by variables not related to deicing to improve the ability to discern an effect of deicing.

2) Compare means, variances, temporal patterns, and relationships among variables during times with and without deicing chemicals. This approach was used to:

- identify changes in variance and patterns that might not be detected through modeling
- isolate variables used in modeling for more focused analysis
- identify evidence that unmeasured variables may affect DO concentrations

5.3.1 Methods

5.3.1.1 Approach 1: Model/Predict/Explain measured DO concentrations

Because the exploratory analyses showed that the data and their relationships were affected by their proximity in time, it was not appropriate to construct a General Linear Model to predict DO levels[3]. Instead, for each pond, time series models called Integrated Autoregressive Moving Average (ARIMA) models (Diggle, 1990) were fit to DO percent saturation to test for the significance of temporal components[4] and effects of temperature, conductivity, and presence of deicing chemicals (See Appendix D1 for details). Percent saturation was selected as the dependent variable because the

---

[3] General linear models assume that residuals around the model are independent of one another. In time-series models they are correlated in time.

correlations between explanatory variables and percent saturation were found to be larger than correlations with DO concentration in the exploratory analyses.

The Akaiki Information Criterion (AIC) (Akaiki, 1973; Burnham and Anderson, 2000) was used to determine which ARIMA model fit the data best. The AIC is a measure of model fit that considers both the fit of the model and the number of parameters in the model. Models with the same "fit"[5] but fewer parameters are considered stronger models. The ARIMA model with the smallest AIC was considered the best fitting model in that it fit the data best with a minimum number of parameters.

5.3.1.2 *Approach 2 - Compare means, variances, temporal patterns, and relationships among variables during times with and without deicing chemicals.*

Using the second approach, nonparametric comparison of means (Mann Whitney U test)[6] and Levene's test for differences in variance were conducted to determine whether the means and/or variances of any of the variables differed between control and treatment periods. The variables tested included DO concentration, DO percent saturation, temperature, water level, conductivity, as well as change over 6 hour periods and percent change over 6 hour periods in each of those variables. Both definitions of deicing were used in order to discern the effects of deicing chemicals from the effects of other physical variables that affect DO levels.

---

[4] Autoregressive components (AR), difference/change components (I), moving average components (MA). See Appendix AAA.
[5] As measured by the negative log liklihood for the model
[6] Mann Whitney U test compares means of data ranks. By comparing ranks, the test essentially compares the medians of two data sets.

5.3.2 Results/Findings

5.3.2.1 Approach 1. Model/Predict

1) **Over the course of the entire study period, DO percent saturation in both NP3 and Lake Reba was affected by water temperature, conductivity, deicing chemicals, and percent saturation during the previous hour. The nature of the effects of deicing chemicals could not be clearly discriminated from effects of the other variables.**

In both ponds, the best fitting ARIMA (1,1,1) model included a first order (1 hour) autoregressive, difference, and moving average component as well as temperature, conductivity, and presence of a deicing signal[7]. The ARIMA components had the highest significance levels, but all variables were highly significant ($p < 0.0001$). (Appendix D7). These results indicate that the physical variables, temperature, conductivity, and deicing chemicals affect DO levels, and that reactions of DO to these factors will be affected by DO levels in the previous hour. It seems reasonable that DO levels in a pond would respond relatively slowly to changes in environmental conditions, especially if the changes in conditions were also gradual. The autocorrelation seen in all variables in the exploratory analyses indicates that these kinds of gradual changes tend to be the rule. As will be seen in the next set of analyses, however, the nature of the effects by deicing chemicals can be difficult to predict.

5.3.2.2 Approach 2. Directly compare data from control and treatment periods.

2) The significance, magnitude, and direction of differences between hourly DO and 6-hour changes in DO during treatment and control periods depended on how the treatment period was defined. (Appendix D8).

---

[7] That is, after the data were differenced by 1 hour, data were highly related to the data value in the hour previous hour and converting data to moving averages of two hour periods resulted in no significant loss of information.

As explained in Section 5.2.1, the treatment period was defined in two ways to discriminate between effects of deicing chemicals and physical factors on DO. Using the first definition, the treatment period was defined as only those hours when a deicing chemical signal was present in a particular pond. According to the second definition, the treatment period included all hours between the first signal at Lake Reba and last signal at NP3. In the case of NP3, there was little difference between these two definitions and the results of Mann-Whitney tests of differences between the medians of the two periods were similar for both time- and signal-based definitions of the treatment period. At Lake Reba, however, the signal-based period was considerably shorter than the time-based treatment period, and the results of the Mann-Whitney tests tended to depend more on the definition of the treatment period.

The signs and magnitudes of differences between the treatment periods, as well as the significance of the differences, differed between the two ponds with a few exceptions (Appendix D8, Tables 1, 2, 3, 4). Differences between periods may be due to the fact that the number and range of data values during the control periods were considerably larger than during the respective treatment periods (either definition). The control periods were on the order of several months, containing far greater variability in weather patterns than were experienced during the two-week treatment period.

For example, using either treatment definition, median water level was significantly higher during the treatment period than the control period at both ponds. Median water temperature was significantly lower during the treatment periods than during the control period at both ponds. Median conductivity was significantly lower at Lake Reba during the treatment period than the control period but did not differ between control and treatment periods at NP3 using either definition of treatment.

DO levels were lower and six-hour changes in DO were smaller during the treatment period than during the control period at both ponds using the time-based treatment definitions. Using the signal-based definition, DO levels during the treatment period were still lower than DO levels during the control period at NP3 but they were higher than control levels at Lake Reba. Lower conductivity during signal presence at Lake Reba could explain the elevated DO during that period. Consistent conductivity in NP3 was associated with a decrease in DO during signal presence, and indeed, during the entire two-week treatment period.

The results of hypothesis testing and time-series analysis of all the variables measured at the two ponds indicate that temperature, water level (which is driven by rainfall and groundwater), and conductivity (which is affected by level) are dynamic variables that have a strong effect on DO levels in the two ponds. Differences between the mean DO levels in the two ponds, visual inspection of time series and other exploratory graphs of the variables indicate that environmental processes differ between the two ponds. These local processes create different reactions in terms of DO levels. The dynamic nature of the multiple, interacting processes made it difficult to discriminate the effects of deicing chemicals.

5.3.3 Summary

Air temperature and rainfall affect water temperature, water level, and conductivity, which, in turn, affect DO levels in Lake Reba and NP3. Because a relatively unique period of prolonged, low temperatures and low rainfall followed deicing chemical applications, it was difficult to separate the effects of these two variables, and their effects on conductivity, from the effects of deicing chemicals on DO.

At Lake Reba, where a deicing signal was detected during only a subset of the low-rain, low-temperature period, DO levels were actually higher during signal presence than during other times of the year (including other times during the low rain/temperature period). This fact indicates that declines in DO after cessation of the deicing chemical signal were attributable to background processes – most likely, to low rainfall and runoff. Because Lake Reba is shallower than NP3, DO levels may respond more quickly to environmental inputs in Lake Reba than in NP3. Time series graphs from the two ponds also indicated that changes in "state" may occur more frequently in Lake Reba than in NP3 (see Figures 1, 2 for examples).

In general, the number and complexity of co-occurring factors are too complex for ongoing monitoring to effectively detect potential DO effects. These factors are:

- the infrequency of ground-surface deicing,
- the complexity of the natural DO response at the two ponds,
- the differences between the sizes and hydrological processes of the two ponds, and
- the different types of deicing chemicals that are likely to enter each pond.

Any further analyses should involve a risk-assessment approach. Such an approach could evaluate weather patterns that affect the frequency, magnitude, and duration of deicing events and the ability of the system to self correct when rainfall (and runoff) increases. This approach could be aimed to estimate the probability of occurrence for a range of deicing event scenarios and shed further light on the potential for associated adverse affects on DO in the two ponds.

(this page intentionally blank)

AR 034480

ECY00015848

5.4 Appendix D1. Background information about time-series analyses methods.

5.4.1 Methods

A plot of the ACF shows correlation between pairs of values of a single variable (i.e., autocorrelation) and how autocorrelation is related to the separation in time of the paired data values. When data are sampled at regular time intervals, as in this study, the separation in time is called a lag[8]. Autocorrelation coefficients (ACCs) are Pearson correlation coefficients, *r*, that range from negative one to positive one. No correlation is indicated when *r* is not statistically different than zero. Maximum positive correlation is indicated by $r = 1.0$ and maximum inverse correlation $r = -1.0$. The ACC at lag zero (no separation in time) is, by definition, one.

The partial autocorrelation function (PACF) plots the partial correlation coefficient (PACC) over time and shows the autocorrelation between data values when correlation caused by intermediate time lags has been removed.[9] The patterns of autocorrelation and partial autocorrelation are used to determine whether a time series is stationary (Diggle 1990, Cressie 1993) and to identify autoregressive (AR) and moving average (MA) components in the data. The assumption that the data are "stationary" must be met before time series the results of time series methods can be properly interpreted.[10] Stationarity is a relatively complex statistical property, with different levels, that relates to the consistency of temporal processes in the data.

Stationarity can be assessed by examining the patterns of the ACF and PACF for each variable. When necessary, the data can be "transformed" to produce a stationary

---

[8] In this study, data were sampled hourly so a lag is one hour long.
[9] The partial autocorrelation coefficient is analagous to the partial correlation coefficient that looks at the correlation between two variables when the values of other correlated variables are kept constant.
[10] This is analagous to requiring that data be normal before results of general linear models such as Analysis of Variance and regression can be properly interpreted.

series. Differencing (subtracting each data value from the next data value in time) is a commonly used first transformation to produce stationarity. When data are differenced by 1, the time series is converted to a series of the hourly changes in the variable. When data are differenced by 2, they are converted to changes in hourly changes. Autocorrelation and partial correlation functions for each variable were plotted and visually inspected to determine what types of transformations were required to produce stationarity. In all cases, differencing by one was adequate to produce stationarity.

After a time series has been transformed so that it is stationary, patterns in the ACF and the PACF can be used to determine whether the series is predominantly an autoregressive (AR) process (i.e., data values are correlated with other data at certain time lags), a moving average (MA) or exponentially smoothed process, or a combination of both (ARMA). For example, if the ACF shows a rapid cut-off in the value of the ACCs after a certain time lag and/or the lag-one ACC is negative, a MA process of the order of the last significant time period is suggested (Diggle, 1990, Web site). If the ACF decays smoothly, the PACF can be checked. If the PACF shows a sharp cut-off and/or the first coefficient of the ACF is positive, then an AR process is suggested (Diggle, 1990, Web site). If the PACF does not show a cut-off, then an autoregressive-moving average (ARMA) process is suggested (Diggle, 1990). Diggle (p. 169) states "...we reemphasize that model identification as here presented is a subjective process, and that parsimony should be the guiding principle. If in doubt, we should opt for fewer rather than more parameters in the identified model, but include in the...diagnostic checking stage an assessment of whether additional parameters are needed to give an adequate fit."

After investigating the patterns of the stationary series, the series can be coded in terms of the number of lags involved in each process component (AR, I, MA), where the I indicates the number of times the data were differenced. For example, an undifferenced time series with a first-order autoregressive component would be coded (1,0,0). A time series that was differenced once and was a first-order moving average process would be coded (0,1,1).

5.5 *Appendix D2. Results of Time Series Analyses.*

5.5.1 Autocorrelation within variables

5.5.1.1 Whole time series

The Autocorrelation functions (ACFs) of all variables declined very slowly with time lag and coefficients for correlation between data values that were 1 hour apart (i.e., lag of 1) was close to 1 (perfect correlation). The Partial Autocorrelation functions (PACFs) indicated that a correlation between data values, when correlation caused by intervening data values was eliminated, became insignificant once data were 3 to 5 hours apart.

These characteristics indicated the need to difference all the variables to produce a stationary time series before the time series of different variables could be modeled and compared (See Appendix D1). After differencing (I = 1), all of the variables had stationary distributions and most of the variables were either autoregressive of order 1 to 3 or moving average processes of order 1 to 2.

DO and conductivity at NP3 appeared to be predominantly moving average processes (Table 1; Appendix D3, Figures 4,5), but the strength of the autocorrelation was low. DO concentration, DO saturation, and conductivity all hand negative, and very small, first autocorrelation coefficients after the series had been differenced. All variables at Lake Reba and temperature at NP3 had positive first ACCs of weak to moderate magnitude. Temperature has a strong cyclic pattern at both ponds such that temperatures that were 24 hours apart were similar, quite different than the temperature twelve hours earlier. The PACF indicates that a good deal of this pattern was due to

AR 034483

correlation that was "passed" from hour to hour. The magnitude of the PACCs at longer lags was much lower than the magnitude of the ACC at a similar lag.

Table 1. Significant Autoregressive (AR) and Moving Average (MA) components of time series of DO, level, temperature, and conductivity at NP3 and Lake Reba for whole time series after time series were differenced to produce stationarity.

Variable	NP3	LR
DO concentration	MA(1)	AR(1-2)
DO % saturation	MA(2)	AR(2-3)
Level	AR(3)	AR(2)
Temperature	AR(2)	AR(2)
Conductivity	MA(1)	AR(2)

5.5.1.2 Treatment vs. control period

The time series of the treatment period was much shorter than the time series of the control period. In the cases of DO levels, water level, and water temperature at NP3, the autocorrelation pattern of the control period seemed to be repeated during the treatment period but the autocorrelation and partial autocorrelation coefficients became statistically insignificant because the sample size was so small (Table 2). For all other variables (all variables at Lake Reba and temperature and conductivity at NP3, a change in the pattern of the ACF and/or PACF was apparent). Because the sample sizes for the treatment periods were quite small, differences noted between treatment and control periods appeared relatively consistent using both definitions of deicing and it was not possible to distinguish effects of the definition of the treatment period on the ACFs of the variables.

5.5.2 Cross-correlations between variables

Because temporal patterns were not evindent in the CCFs as they were in the ACFs, correlations between variables were summarized using the Spearman Rank

Nonparametric Correlation Coefficient (Table 3). The strongest correlations were between level and temperature (r = -0.46, r = -0.74, Lake Reba and NP3 respectively), level and conductivity (r = -0.80, r = -0.76, Lake Reba and NP3 respectively), and DO percent saturation and temperature (r = 0.52 and r = 0.60, Lake Reba and NP3 respectively). DO concentration was moderately correlated with temperature at NP3 (r = 0.45).

Table 2. Significant Autoregressive (AR) and Moving Average (MA) components of time series of DO, level, temperature, and conductivity at NP3 and Lake Reba for treatment and control periods after time series were differenced to produce stationarity.

Variable	NP3 control	NP3 treatment	LR control	LR treatment
DO concentration	MA(1)	MA(1)*	AR(2)	AR(2)*^
DO % saturation	MA(2)	MA(1)*	AR(3)	AR(1)*^
Level	AR(3)	AR(2)*	AR(2)	AR(2)^
Temperature	AR(2-3)	AR(2)^	AR(2)	AR(1)*^
Conductivity	MA(3)	AR(1)^	AR(2)	AR(1)*^

* similar pattern but not all AR or MA coefficients significant due to small sample size

^ ACFs and PACFs for 2 periods have different shapes

AR 034485

Table 3. Nonparametric Spearman Rank Correlation between variables (equivalent to lag 0 nonparametric cross correlation).

		DO % saturation	Conductivity	Level	Temp
Lake Reba DO	R	**0.95**	**0.10**	**-0.11**	**0.26**
	P	<0.001	<0.001	<0.001	<0.001
	N	3925	3931	2855	3932
Lake Reba DO % saturation	R		**0.20**	**-0.30**	**0.52**
	P		<0.001	<0.001	<0.001
	N		4225	3198	4226
Lake Reba Conductivity	R			**-0.80**	**0.34**
	P			<0.001	<0.001
	N			2855	4233
Lake Reba Level	R				**-0.46**
	P				<0.001
	N				2855
NP3 DO	R	**0.97**	**0.03**	**-0.23**	**0.45**
	P	<0.001	<0.001	<0.001	<0.001
	N	3202	3202	1745	3202
NP3 DO % saturation	R		**0.16**	**-0.43**	**0.60**
	P		<0.001	<0.001	<0.001
	N		3501	2043	3501
NP3 Conductivity	R			**-0.76**	**0.39**
	P			<0.001	<0.001
	N			2325	3783
NP3 Level	R				**-0.74**
	P				<0.001
	N				2325

R: Spearman Rank Correlation Coefficient

P: Probability that Correlation = 0

N: Sample size

5.6 *Appendix D3. Autocorrelation and Partial Autocorrelation Coefficient Graphics*

Appendix D3. Figure 1.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for: DO concentration and DO % saturation in Northwest Pond Cell 3 and Lake Reba: full time series.

Appendix D3. Figure 2.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for: temperature and conductivity in Northwest Pond Cell 3 and Lake Reba: full time series.

Appendix D3. Figure 3.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for: water level in Northwest Pond Cell 3 and Lake Reba: full time series.

Appendix D3. Figure 4.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for: DO concentration and DO % saturation in Northwest Pond Cell 3 and Lake Reba: full time series.

Appendix D3. Figure 5.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for: temperature and conductivity in Northwest Pond Cell 3 and Lake Reba: full time series.

Appendix D3. Figure 6.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for: water level in Northwest Pond Cell 3 and Lake Reba: full time series.

Appendix D3. Figure 7.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for DO concentration in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 8.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for DO percent saturation in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 9.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for water level in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 10.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for water temperature in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 11.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for conductivity in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 12.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for DO concentration in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 13.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for DO % saturation in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 14.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for water level in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 15.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for water temperature in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

Appendix D3. Figure 16.

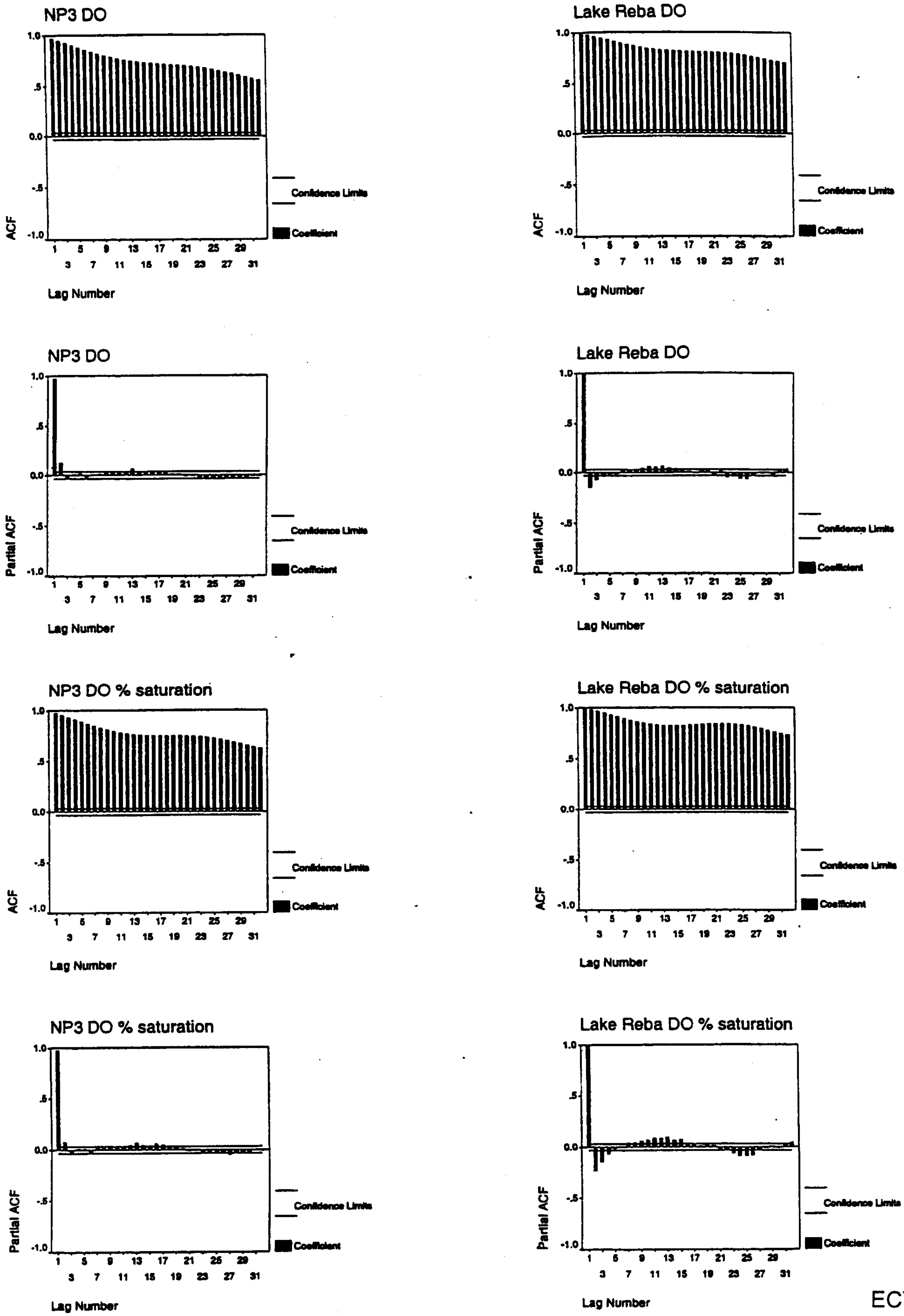
Autocorrelation and partial autocorrelation functions of (differenced) time series data for conductivity in Northwest Pond Cell 3 and Lake Reba: control and treatment period time series.

AR 034489

ECY00015857

(

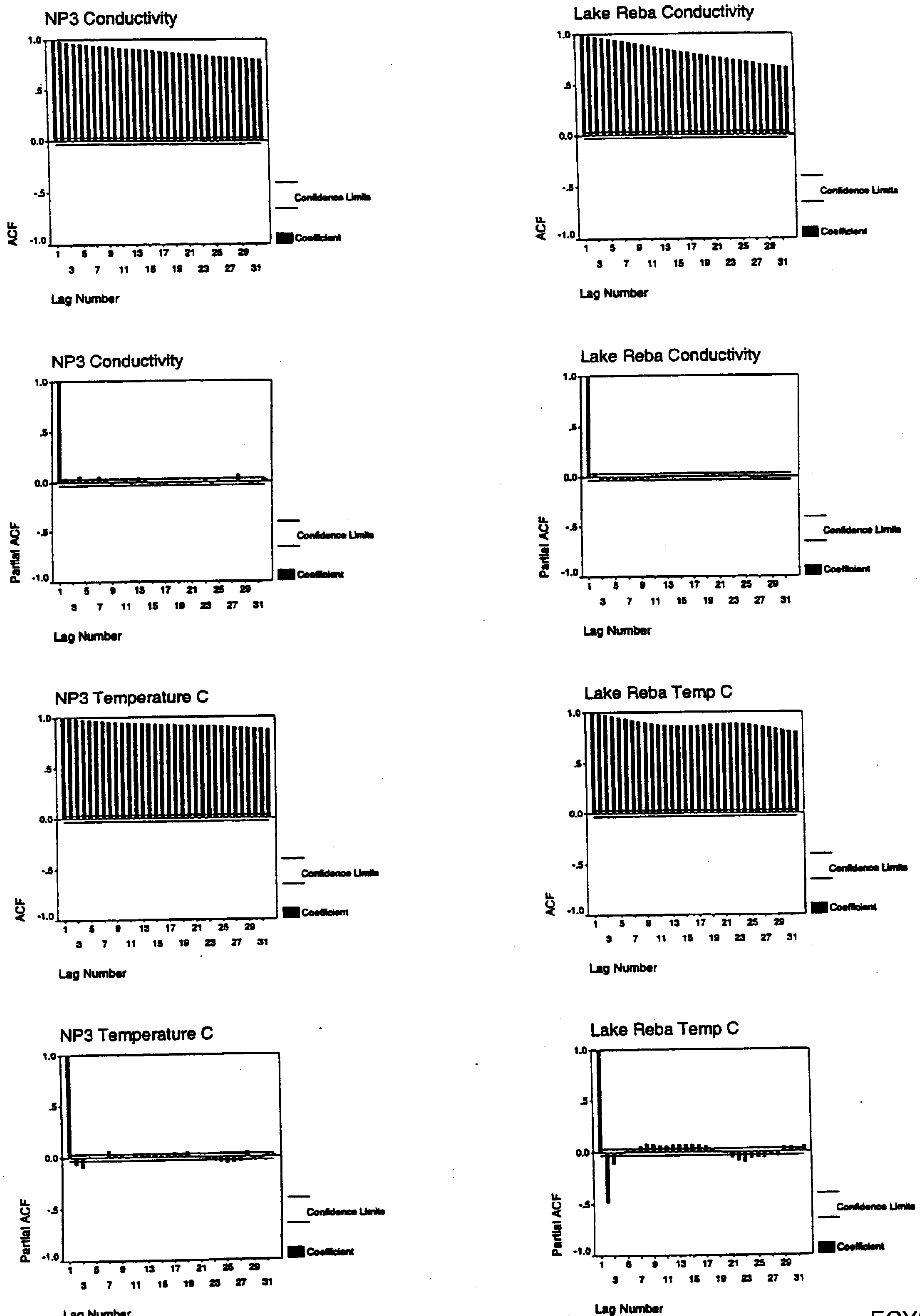
This page intentionally blank)



ECY00015859

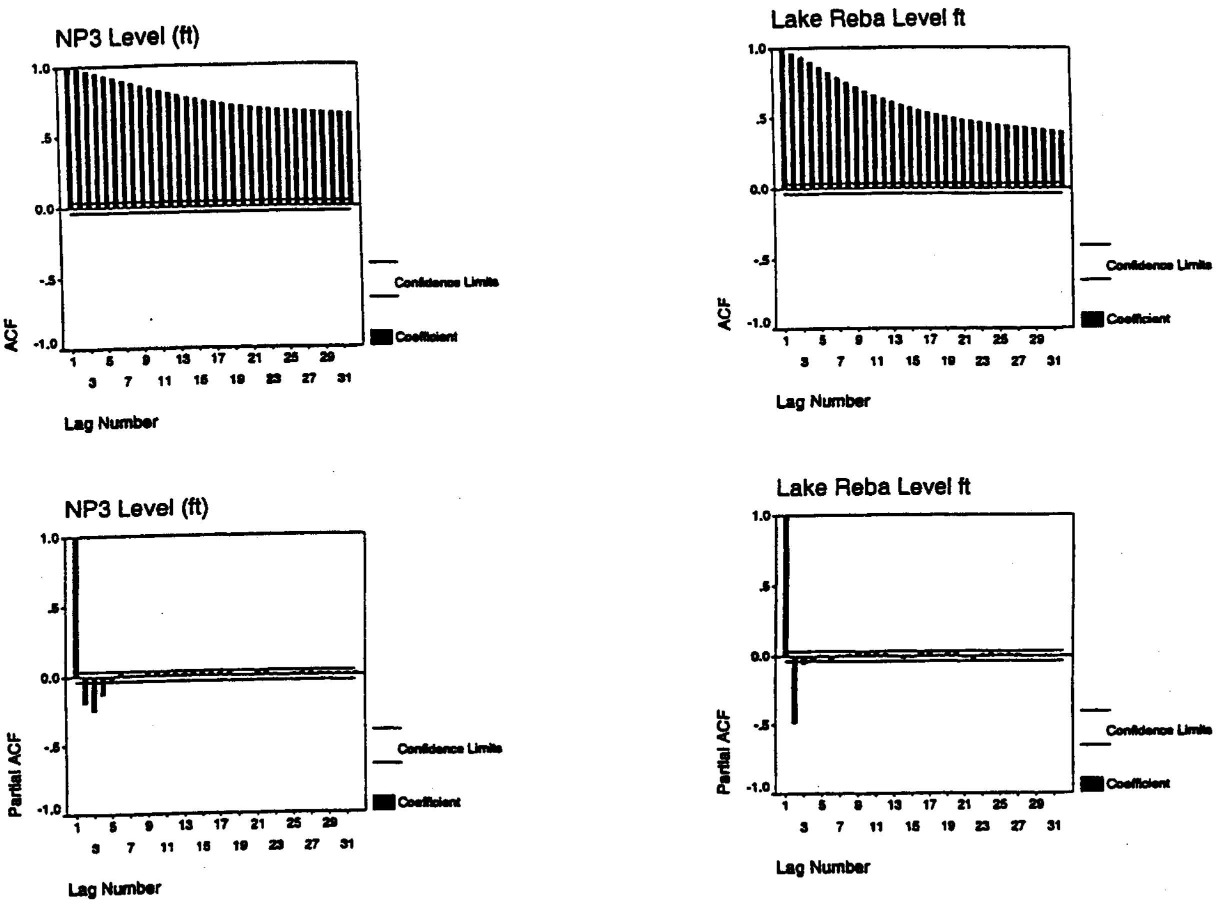
Appendix D3. Figure 1.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for: DO concentration and DO % saturation in Northwest Pond Cell 3 and Lake Reba: full time series.



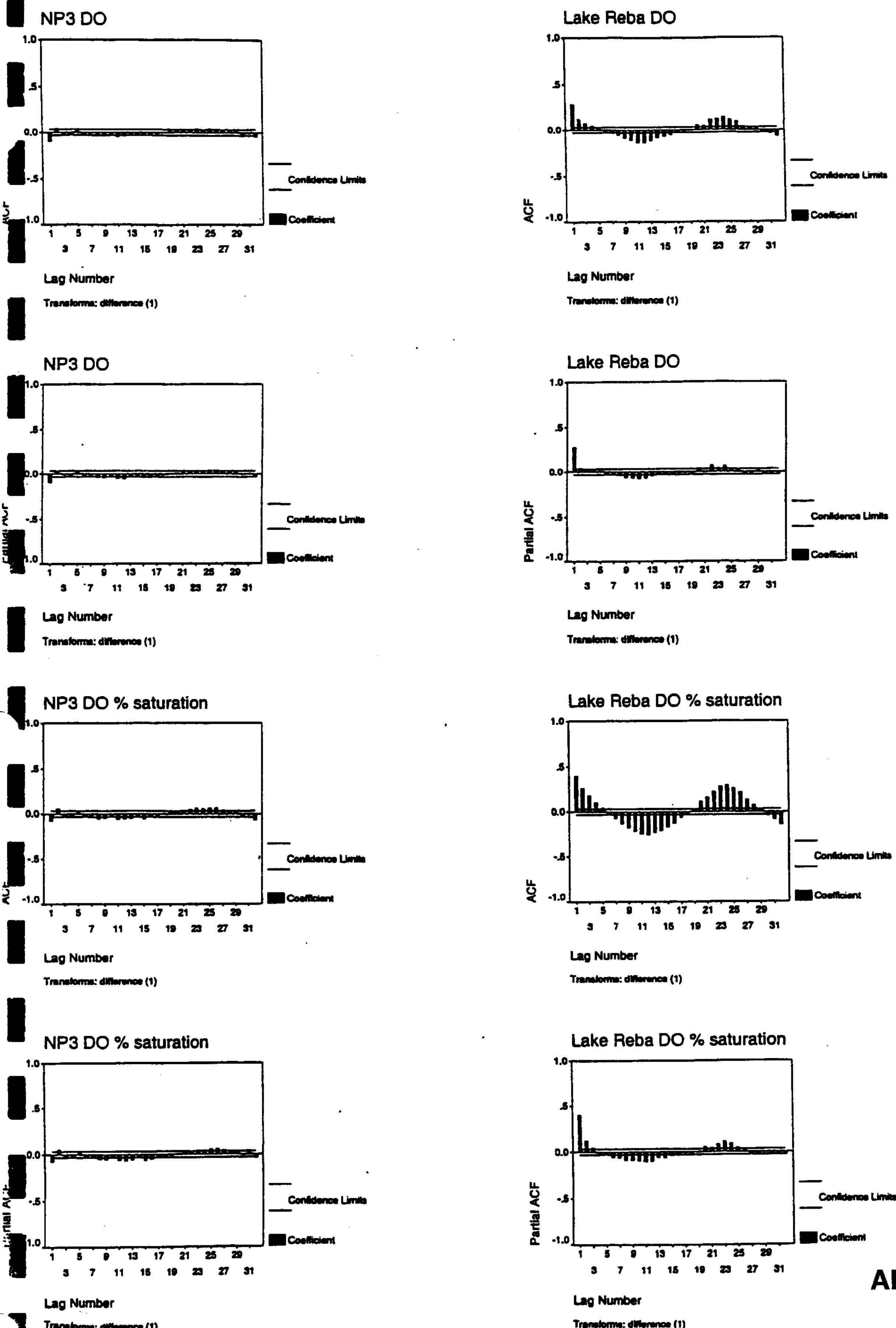
Appendix D3. Figure 2.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for: temperature and conductivity in Northwest Pond Cell 3 and Lake Reba: full time series.



Appendix D3. Figure 3.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for: water level in Northwest Pond Cell 3 and Lake Reba: full time series.

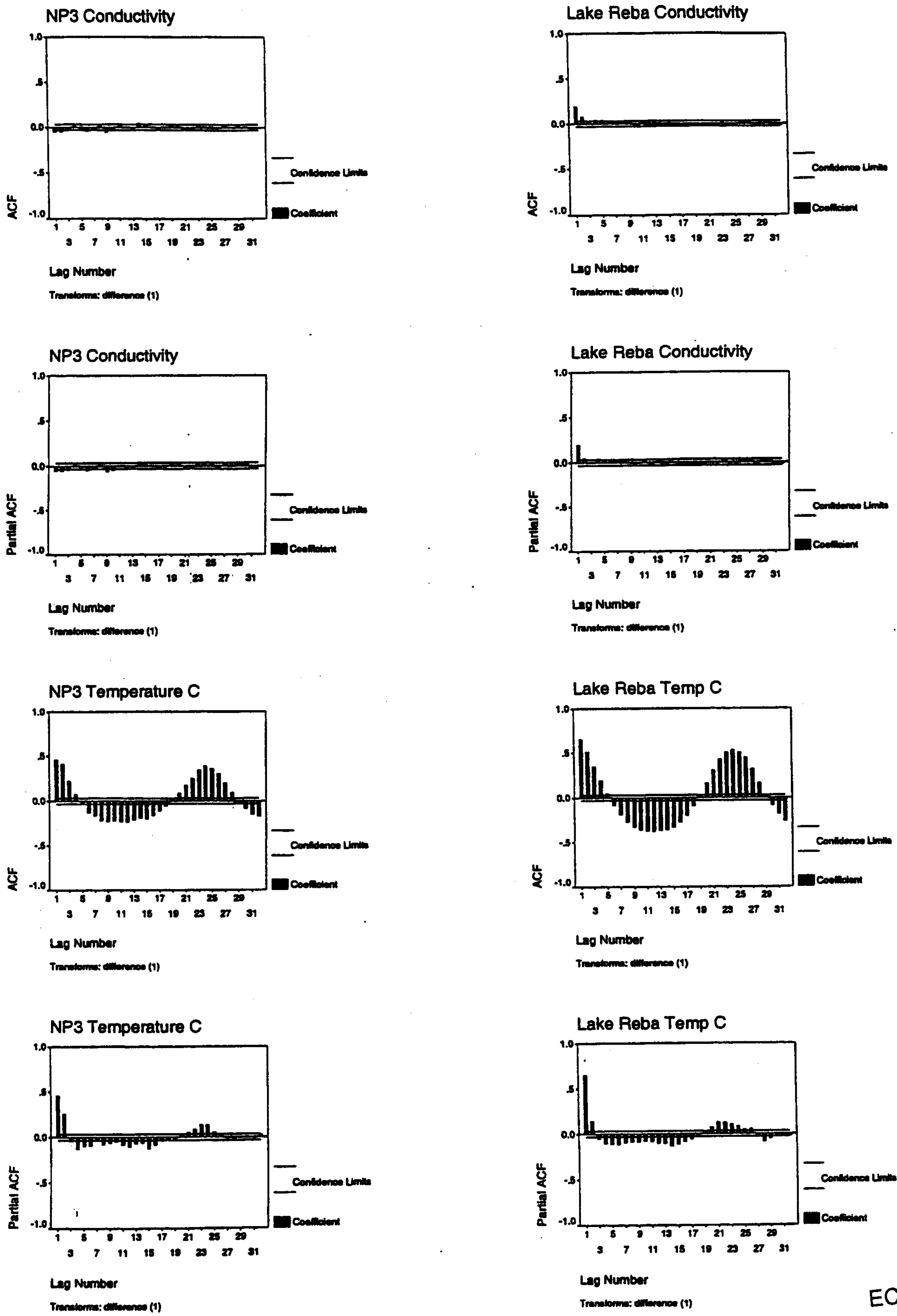


AR 034494

ECY00015862

Appendix D3. Figure 4.

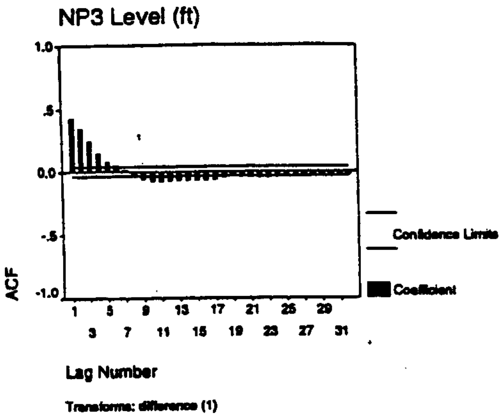
Autocorrelation and partial autocorrelation functions of (differenced) time series data for: DO concentration and DO % saturation in Northwest Pond Cell 3 and Lake Reba: full time series.

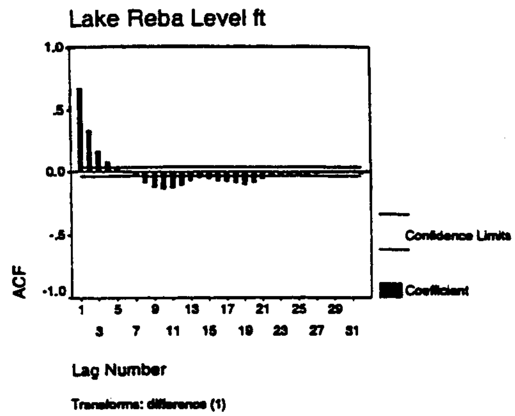


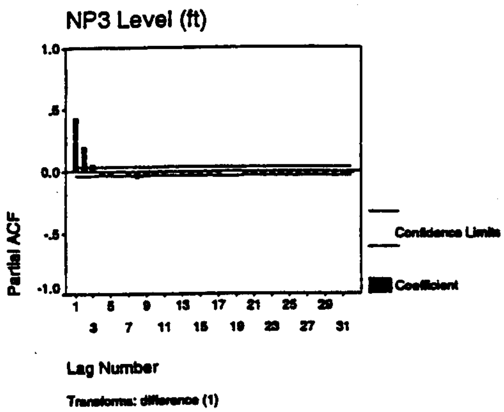
ECY00015863

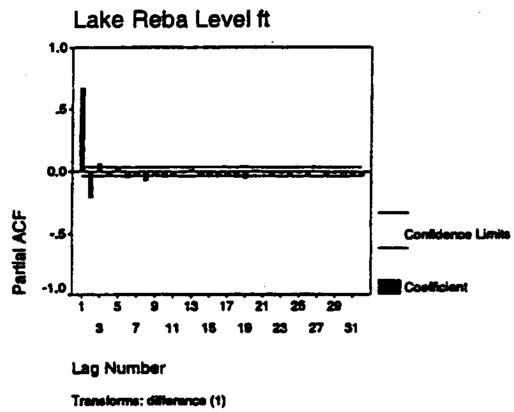
Appendix D3. Figure 5.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for: temperature and conductivity in Northwest Pond Cell 3 and Lake Reba: full time series.



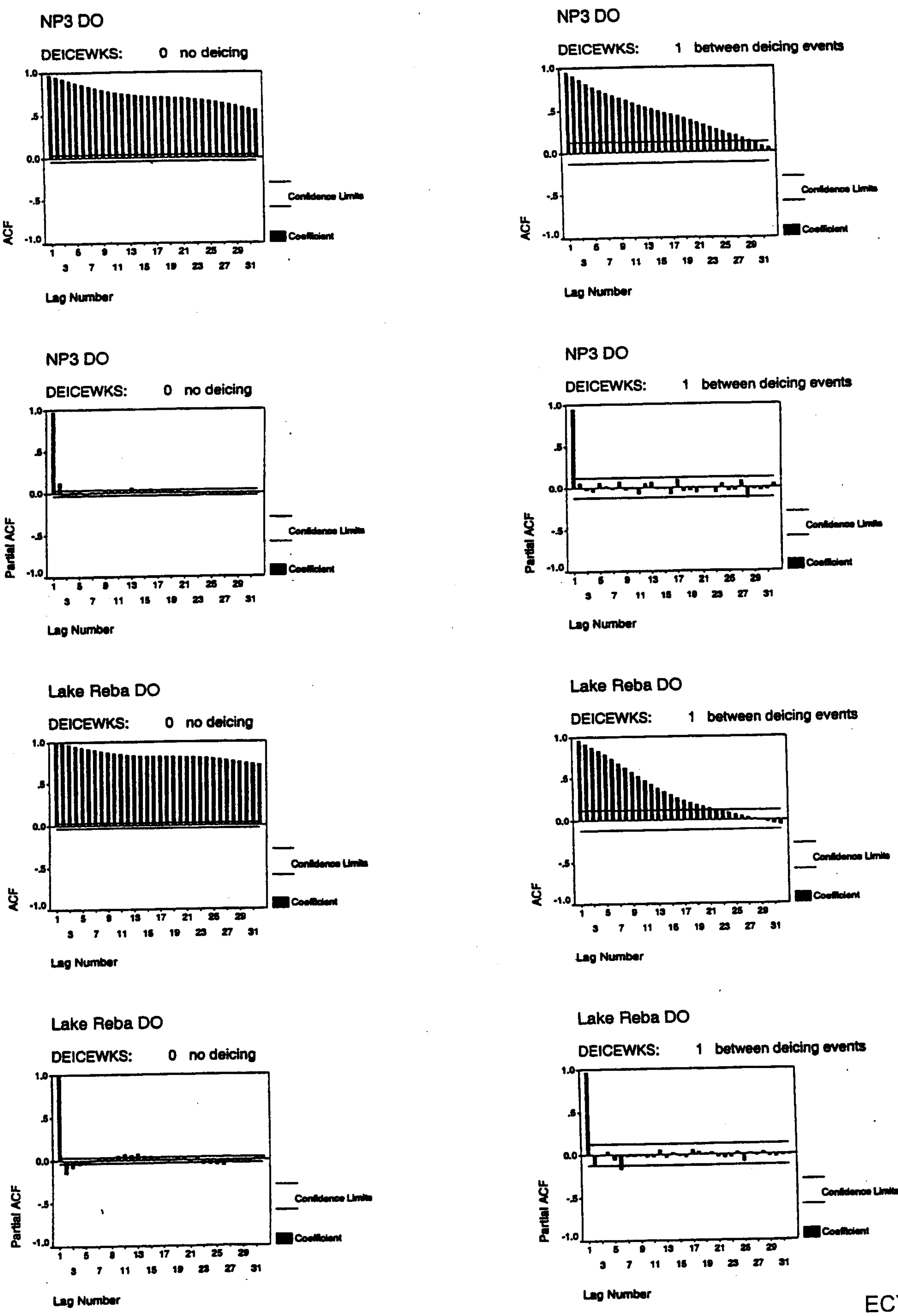






Appendix D3. Figure 6.

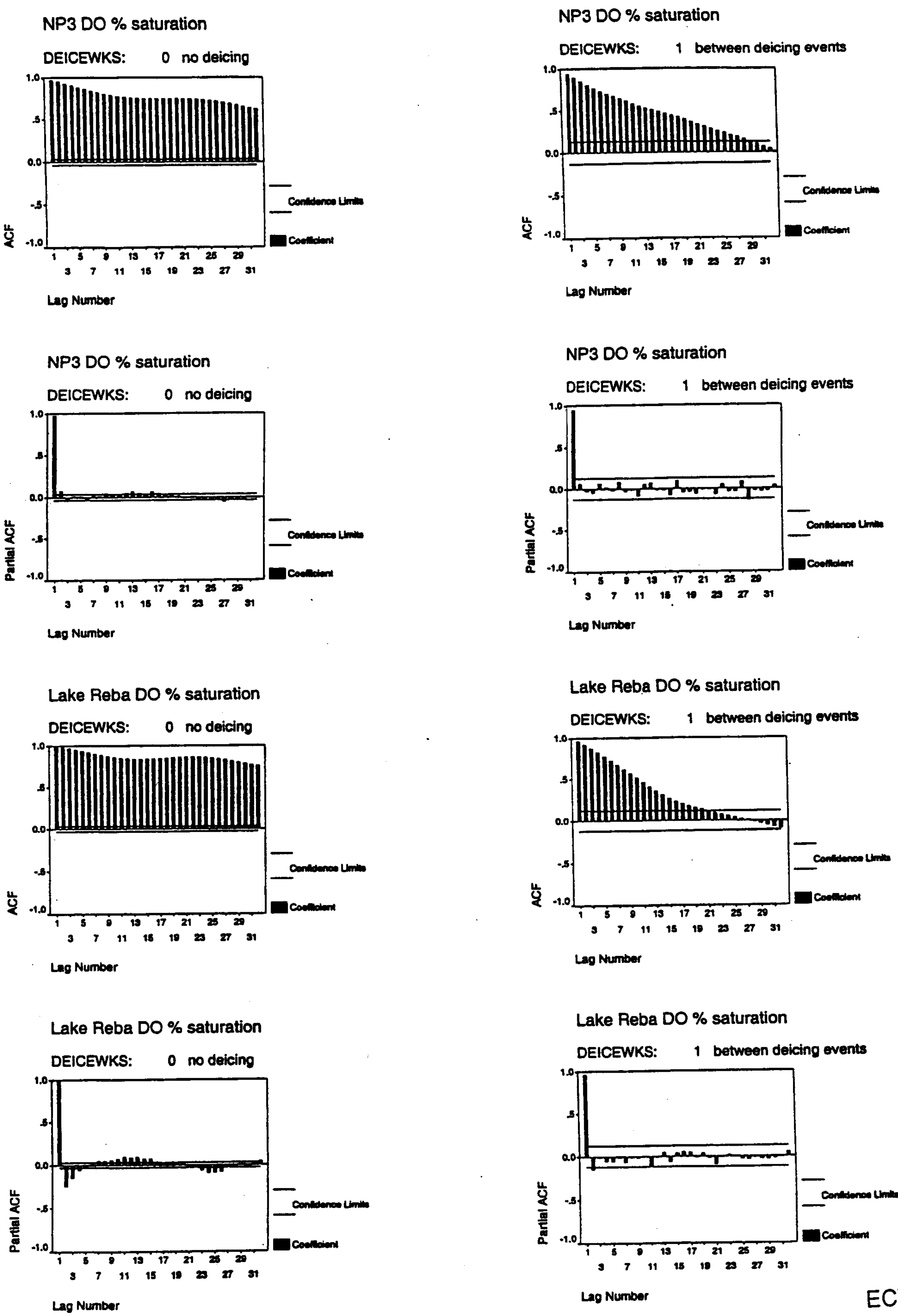
Autocorrelation and partial autocorrelation functions of (differenced) time series data for: water level in Northwest Pond Cell 3 and Lake Reba: full time series.



ECY00015865

Appendix D3. Figure 7.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for DO concentration in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

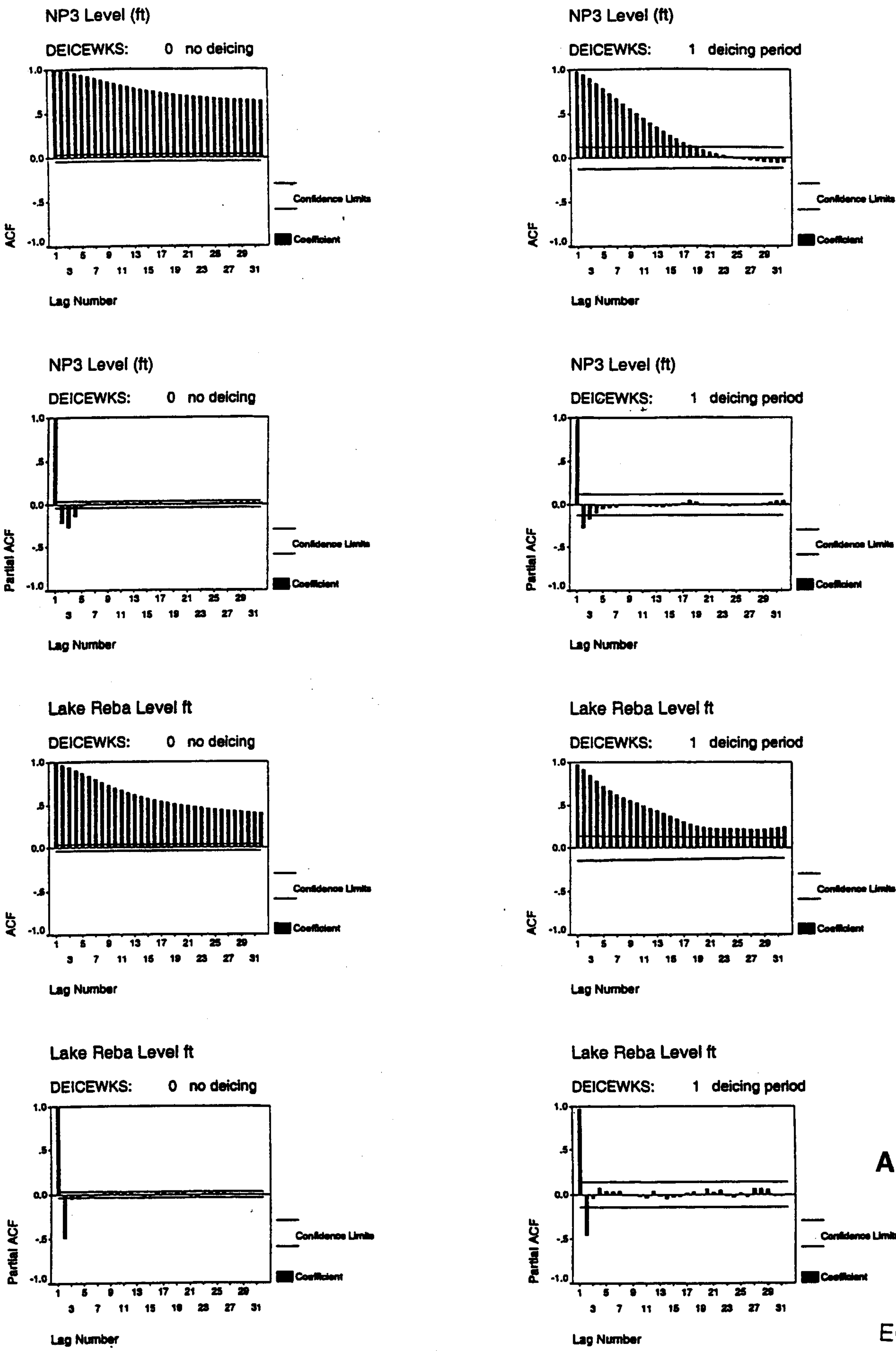


ECY00015866

Appendix D3. Figure 8.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for DO % saturation in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

AR 034498

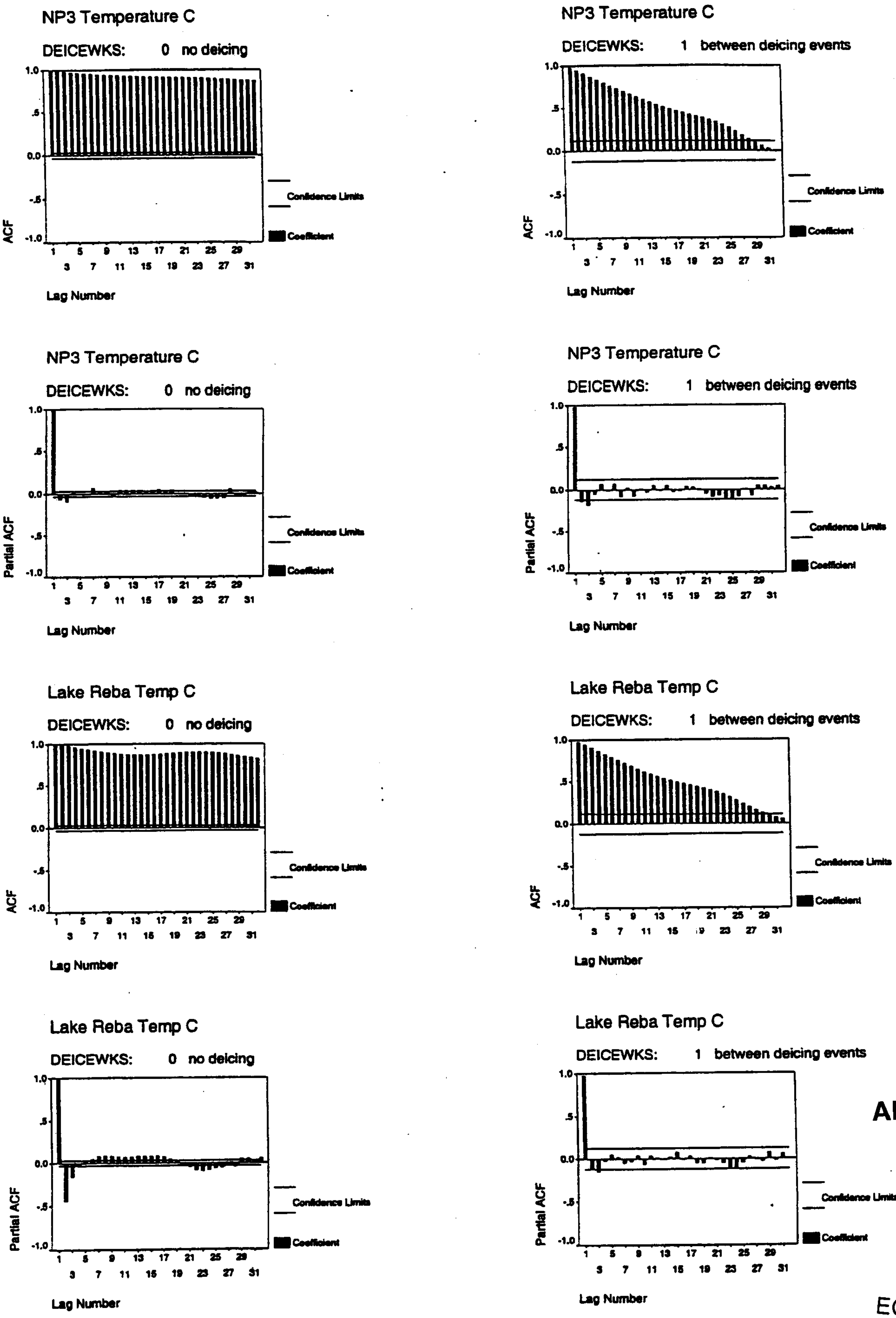


AR 034499

ECY00015867

Appendix D3. Figure 9.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for water level in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

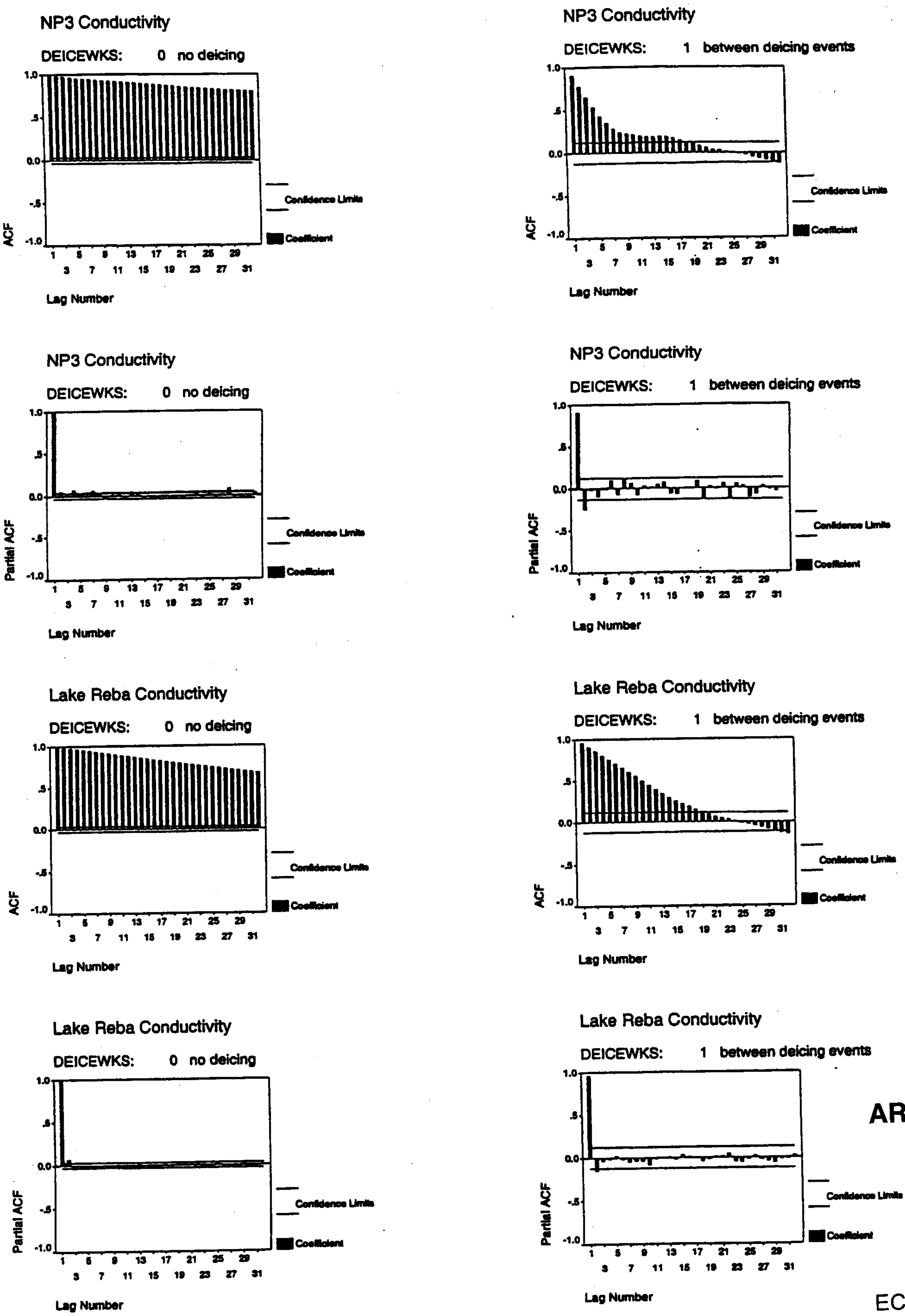


AR 034500

ECY00015868

Appendix D3. Figure 10.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for water temperature in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

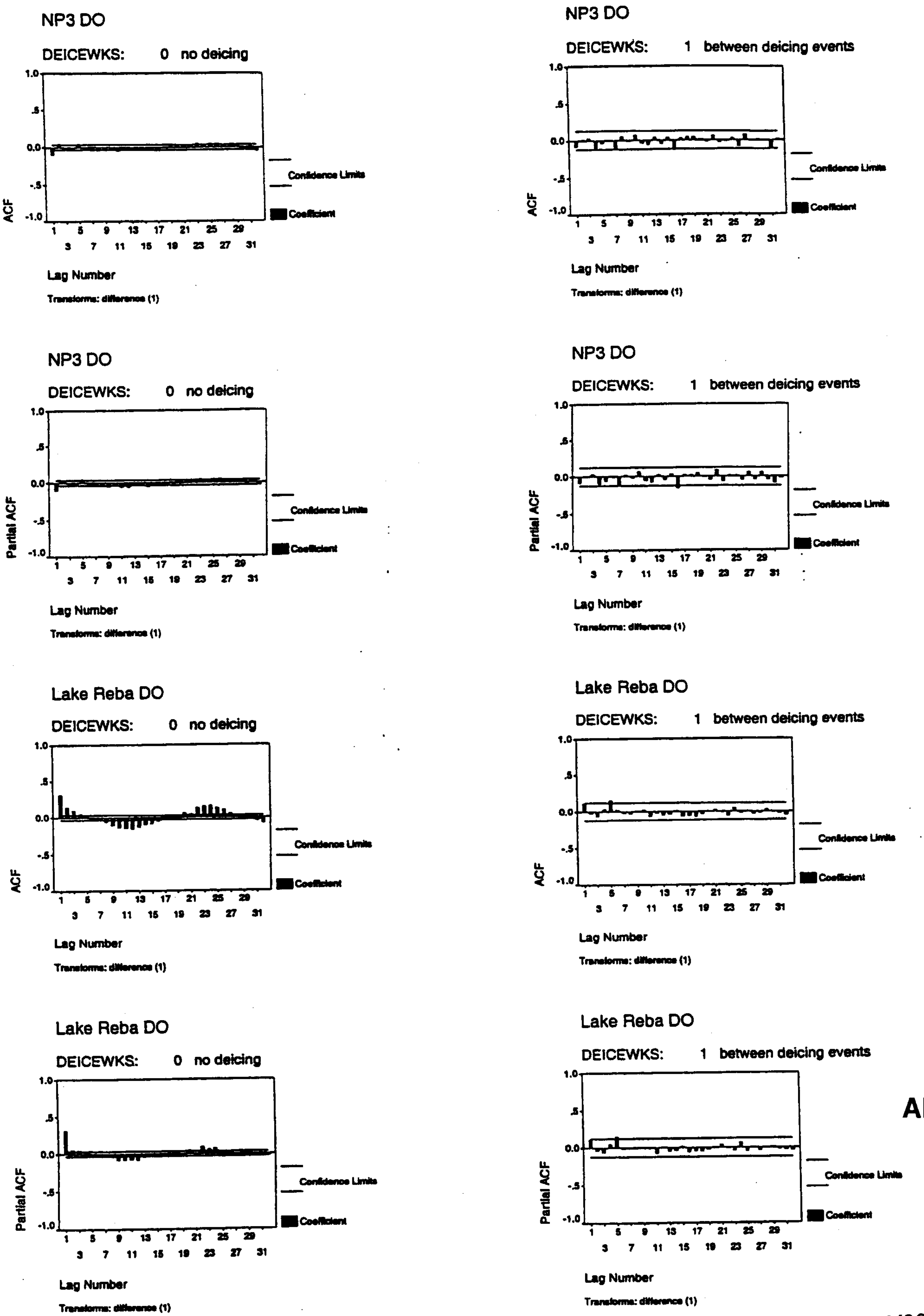


AR 034501

ECY00015869

Appendix D3. Figure 11.

Autocorrelation and partial autocorrelation functions of (untransformed) time series data for conductivity in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

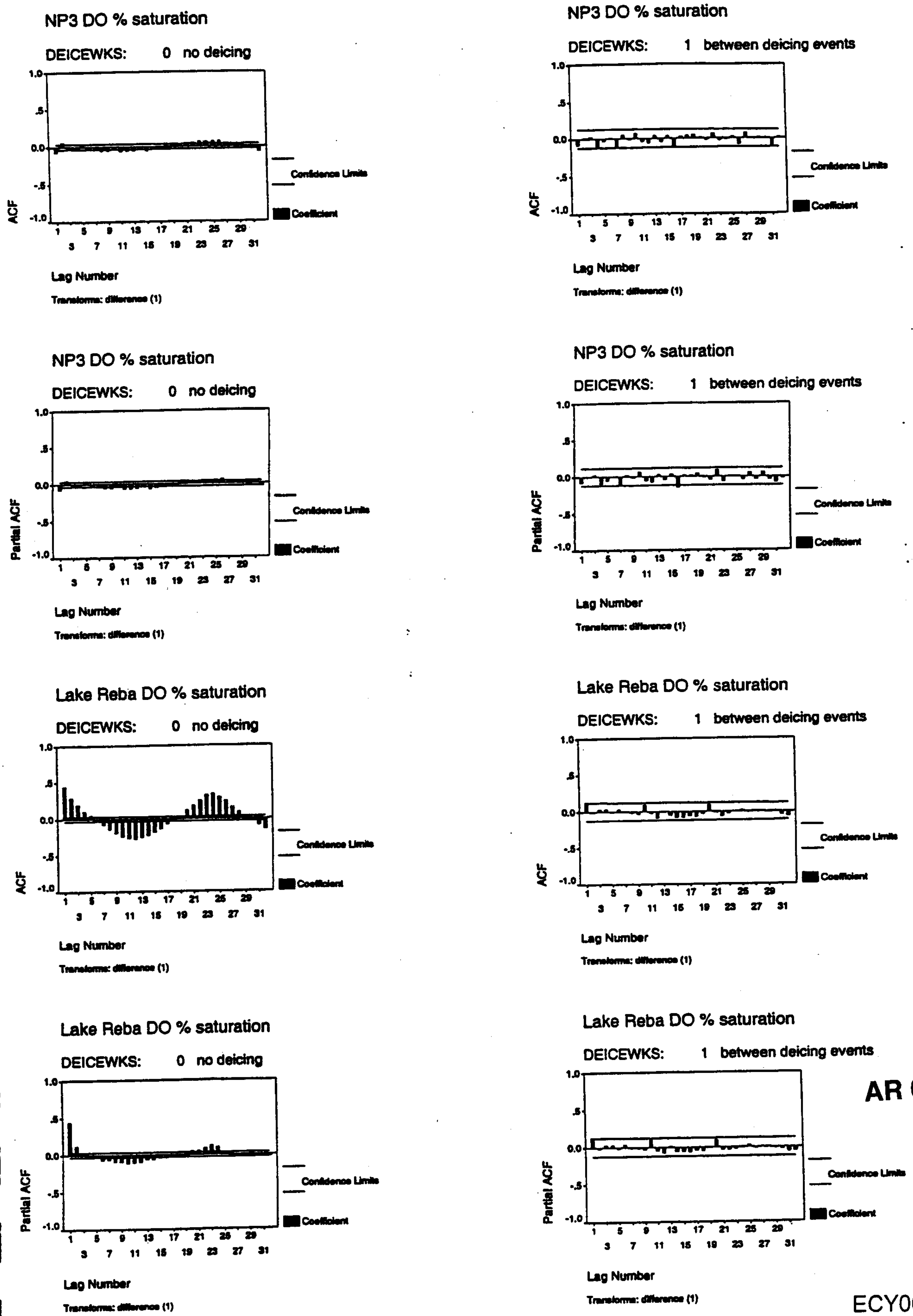


AR 034502

ECY00015870

Appendix D3. Figure 12.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for DO concentration in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

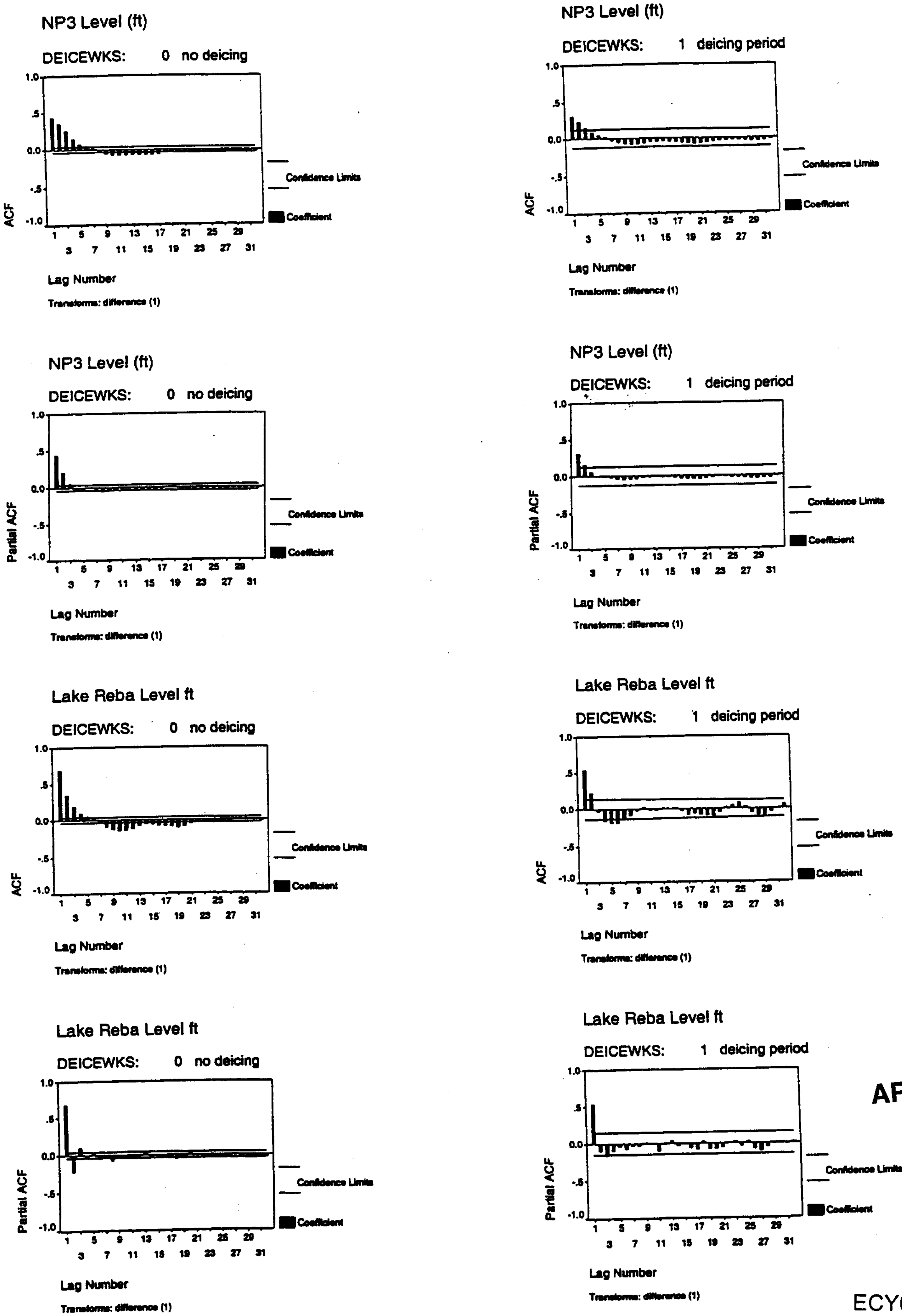


AR 034503

ECY00015871

Appendix D3. Figure 13.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for DO % saturation in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

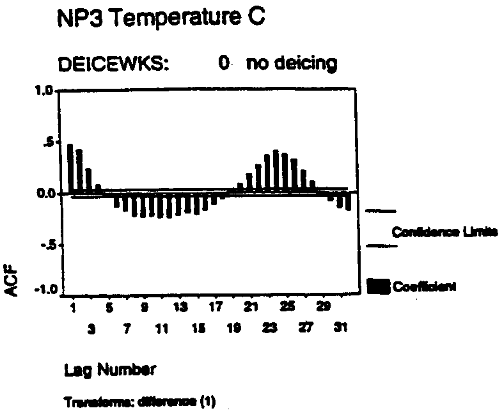


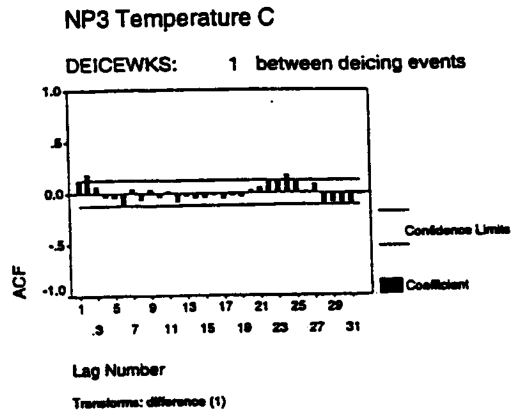
AR 034504

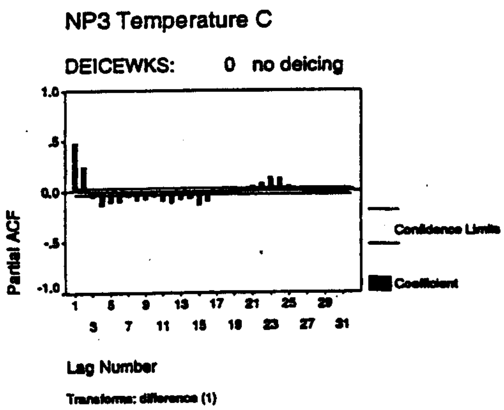
ECY00015872

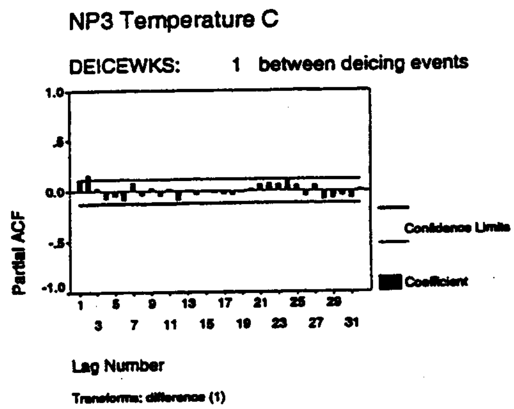
Appendix D3. Figure 14.

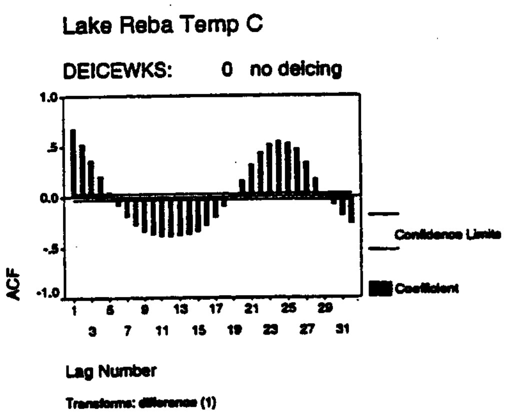
Autocorrelation and partial autocorrelation functions of (differenced) time series data for water level in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

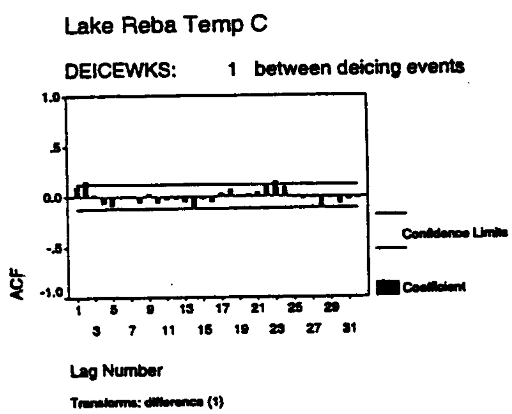


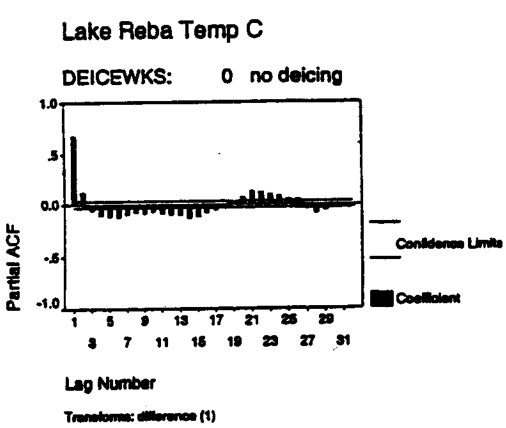


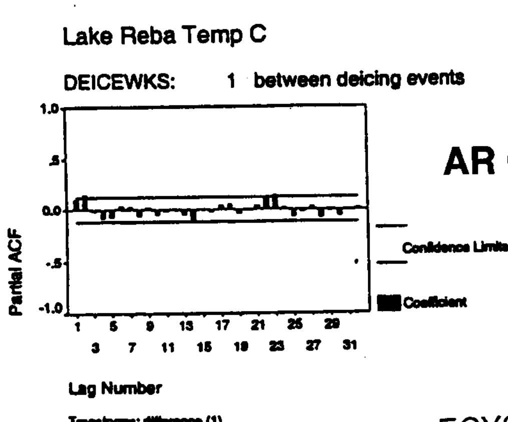






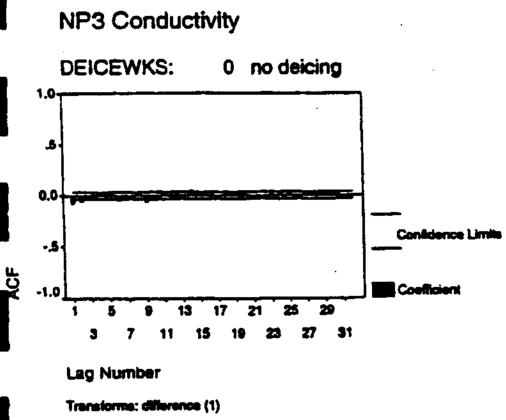


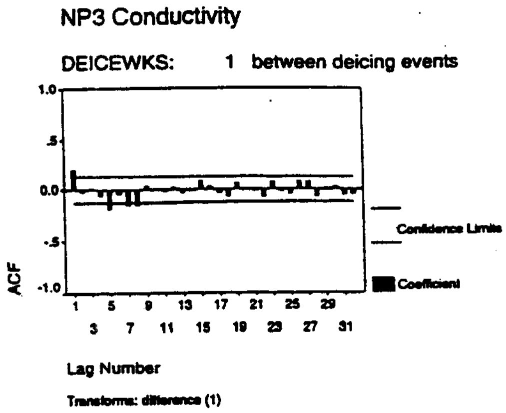


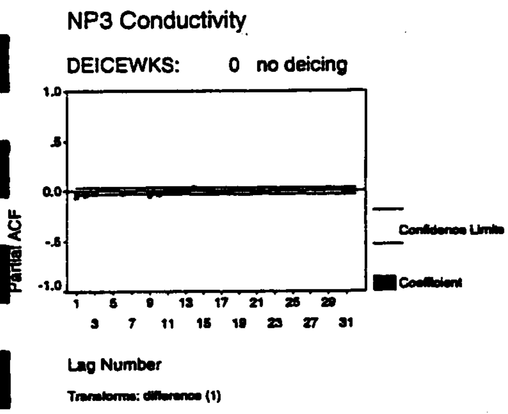


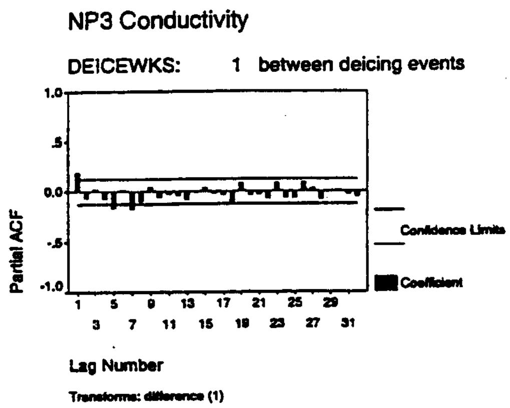
Appendix D3. Figure 15.

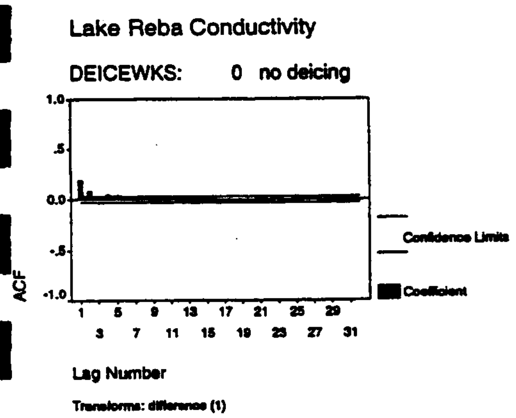
Autocorrelation and partial autocorrelation functions of (differenced) time series data for water temperature in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

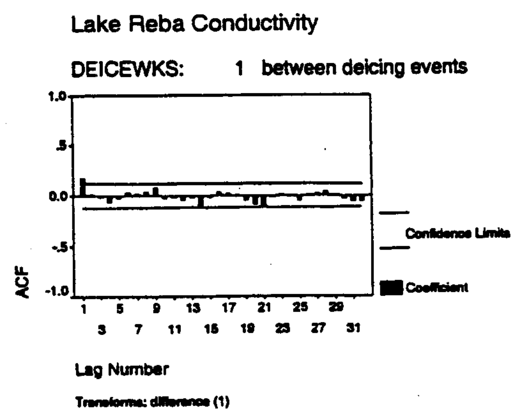


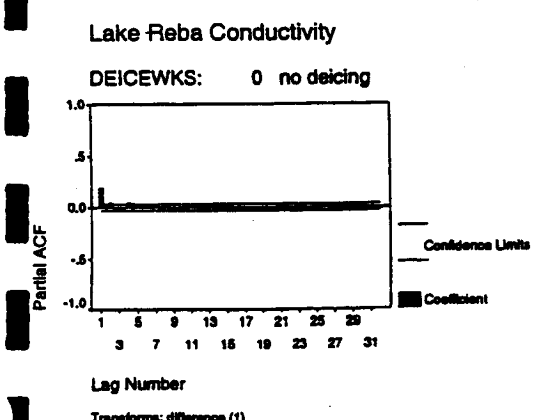


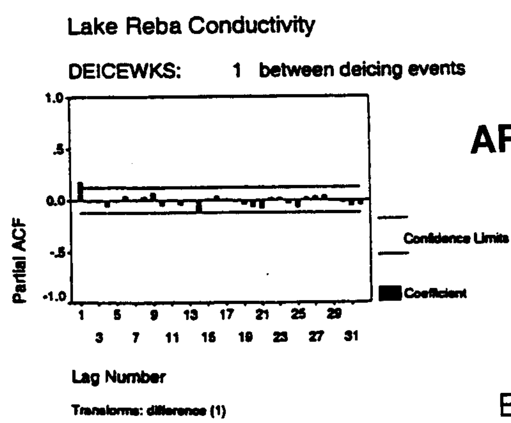












AR 034506

ECY00015874

Appendix D3. Figure 16.

Autocorrelation and partial autocorrelation functions of (differenced) time series data for conductivity in Northwest Pond Cell 3 and Lake Reba: non deicing and deicing period time series.

5.7 Appendix D4. Graphs of Cross Correlation Coefficients

Note: PD = percent change

1, 6, 8 = hours of change

DO = DO concentration

DOS = DO % saturation

T = Temperature

C = Conductivity

L = Level

NP = NP3

LR = Lake Reba

For example:

PD1DONP = percent change over 1 hour intervals in DO concentration at NP3

PD6TLR = percent change over 6 hour intervals in temperature at Lake Reba

Appendix D4. Figure 1.

Cross-correlation functions of (untransformed) time series data for: DO concentration and DO % saturation, water level, temperature, and conductivity in Northwest Pond Cell 3 and Lake Reba.

Appendix D4. Figure 2.

Cross-correlation functions of (untransformed) time series data for: DO % saturation and water level, temperature, and conductivity in Northwest Pond Cell 3 and Lake Reba.

AR 034507

Appendix D4. Figure 3.

Cross-correlation functions of (untransformed) time series data for: temperature, water level, and conductivity in Northwest Pond Cell 3 and Lake Reba.

Appendix D4. Figure 4.

Cross-correlation functions of (untransformed) time series data for percent changes over 1 hour periods in: (column 1) DO concentration with DO % saturation, water level, conductivity, and temperature; (column 2) DO % saturation with water level, conductivity, and temperature; and water level with conductivity for Northwest Pond Cell 3: full time series.

Appendix D4. Figure 5.

Cross-correlation functions of (untransformed) time series data for percent changes over 1 hour periods in: (column 1) water level with temperature, conductivity with temperature in Northwest Pond Cell 3; DO concentration with DO percent saturation, water level in Lake Reba and (column 2) DO concentration with conductivity, and temperature; DO % saturation with water level and conductivity in Lake Reba: full time series.

Appendix D4. Figure 6.

Cross-correlation functions of (untransformed) time series data for percent changes over 1 hour periods in: DO % saturation with temperature and water level; water level with temperature, conductivity with temperature for Lake Reba: full time series.

Appendix D4. Figure 7.

Cross-correlation functions of (untransformed) time series data for percent changes over 6 hour periods in: (column 1) DO concentration with DO % saturation, water level, conductivity, and temperature; (column 2) DO % saturation with water level, conductivity, and temperature; and water level with conductivity for Northwest Pond Cell 3: full time series.

Appendix D4. Figure 8.

Cross-correlation functions of (untransformed) time series data for percent changes over 6 hour periods in: (column 1) water level with temperature, conductivity with temperature in Northwest Pond Cell 3; DO concentration with DO percent saturation, water level in Lake Reba and (column 2) DO concentration with conductivity, and temperature; DO % saturation with water level and conductivity in Lake Reba: full time series.

Appendix D4. Figure 9.

Cross-correlation functions of (untransformed) time series data for percent changes over 6 hour periods in: DO % saturation with temperature and water level; water level with temperature, conductivity with temperature for Lake Reba: full time series.

Appendix D4. Figure 10.

Cross-correlation functions of (untransformed) time series data for percent changes over 8 hour periods in: (column 1) DO concentration with DO % saturation, water level, conductivity, and temperature; (column 2) DO % saturation with water level, conductivity, and temperature; and water level with conductivity for Northwest Pond Cell 3: full time series.

Appendix D4. Figure 11.

Cross-correlation functions of (untransformed) time series data for percent changes over 8 hour periods in: (column 1) water level with temperature, conductivity with temperature in Northwest Pond Cell 3; DO concentration with DO percent saturation, water level in Lake Reba and (column 2) DO concentration with conductivity, and temperature; DO % saturation with water level and conductivity in Lake Reba: full time series.

AR 034509

Appendix D4. Figure 12.

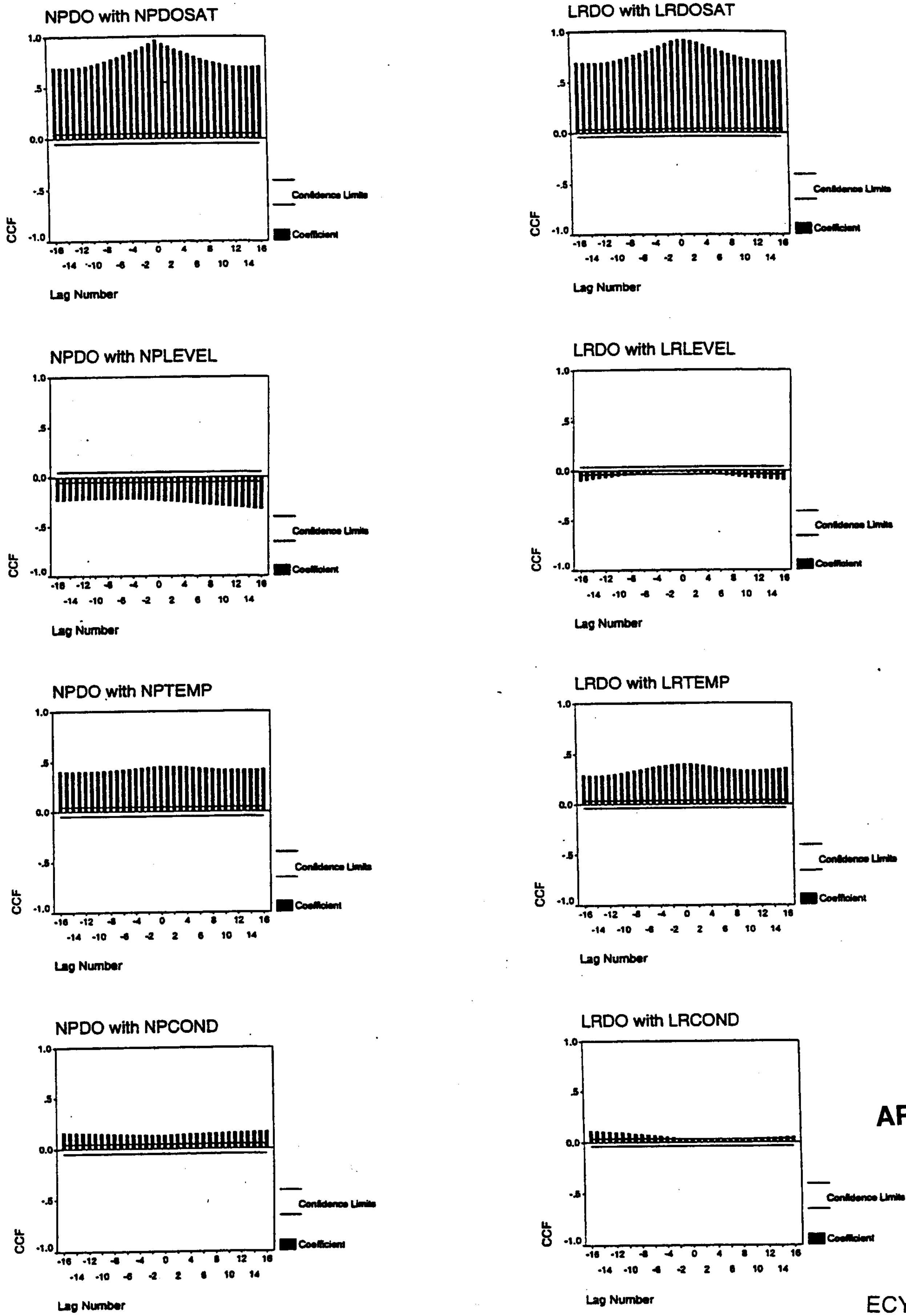
Cross-correlation functions of (untransformed) time series data for percent changes over 8 hour periods in: DO % saturation with temperature and water level; water level with temperature, conductivity with temperature for Lake Reba: full time series.

Appendix D4. Figure 13.

Cross-correlation functions of (untransformed) comparing time series data in NP3 and Lake Reba for: DO concentration, DO % saturation, water level, temperature, and conductivity; full time series.

AR 034510

ECY00015878

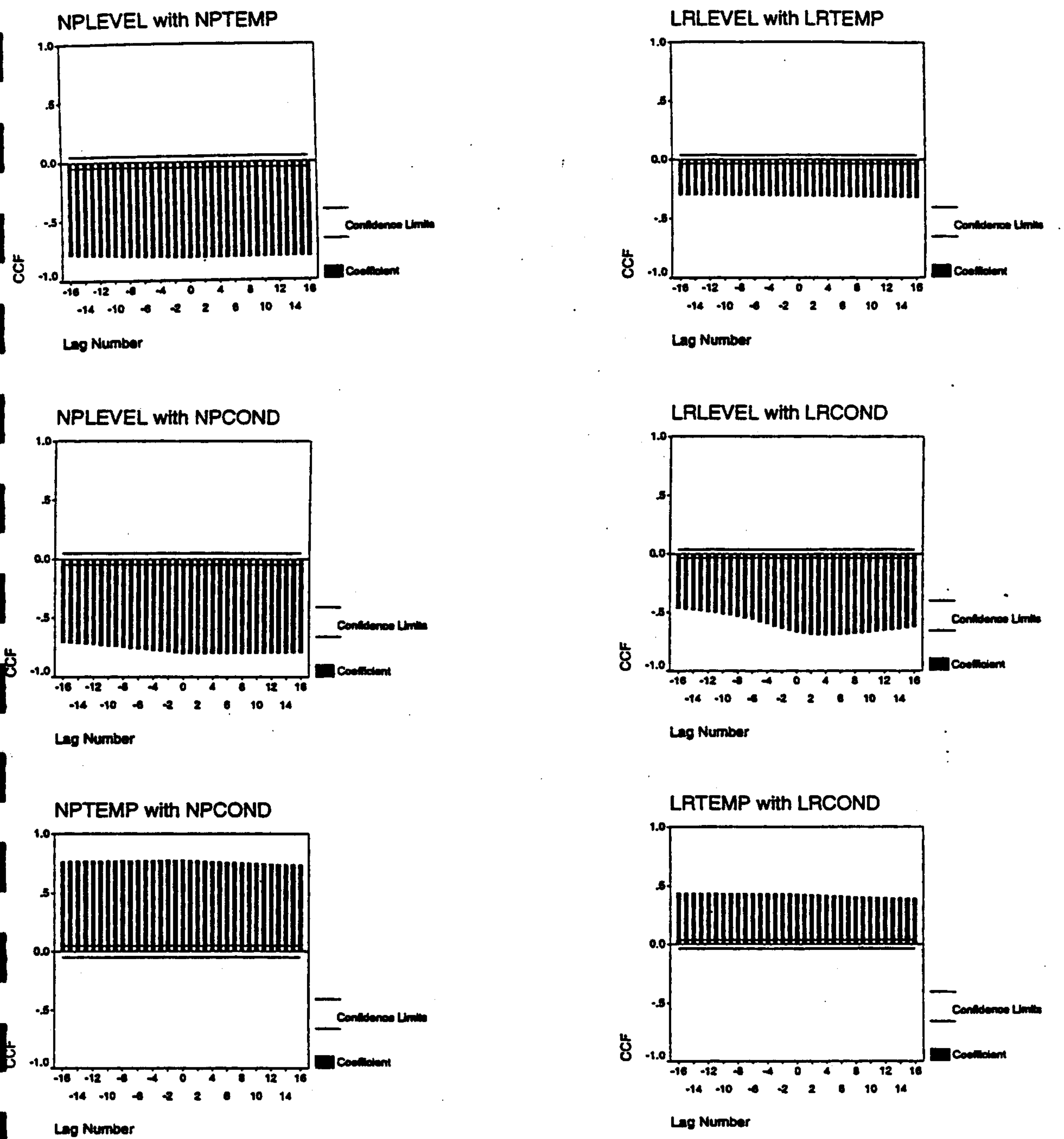


AR 034511

ECY00015879

Appendix D4. Figure 1.

Cross correlation functions of (untransformed) time series data for: DO concentration and DO % saturation, water level, temperature, and conductivity in Northwest Pond Cell 3 and Lake Reba.

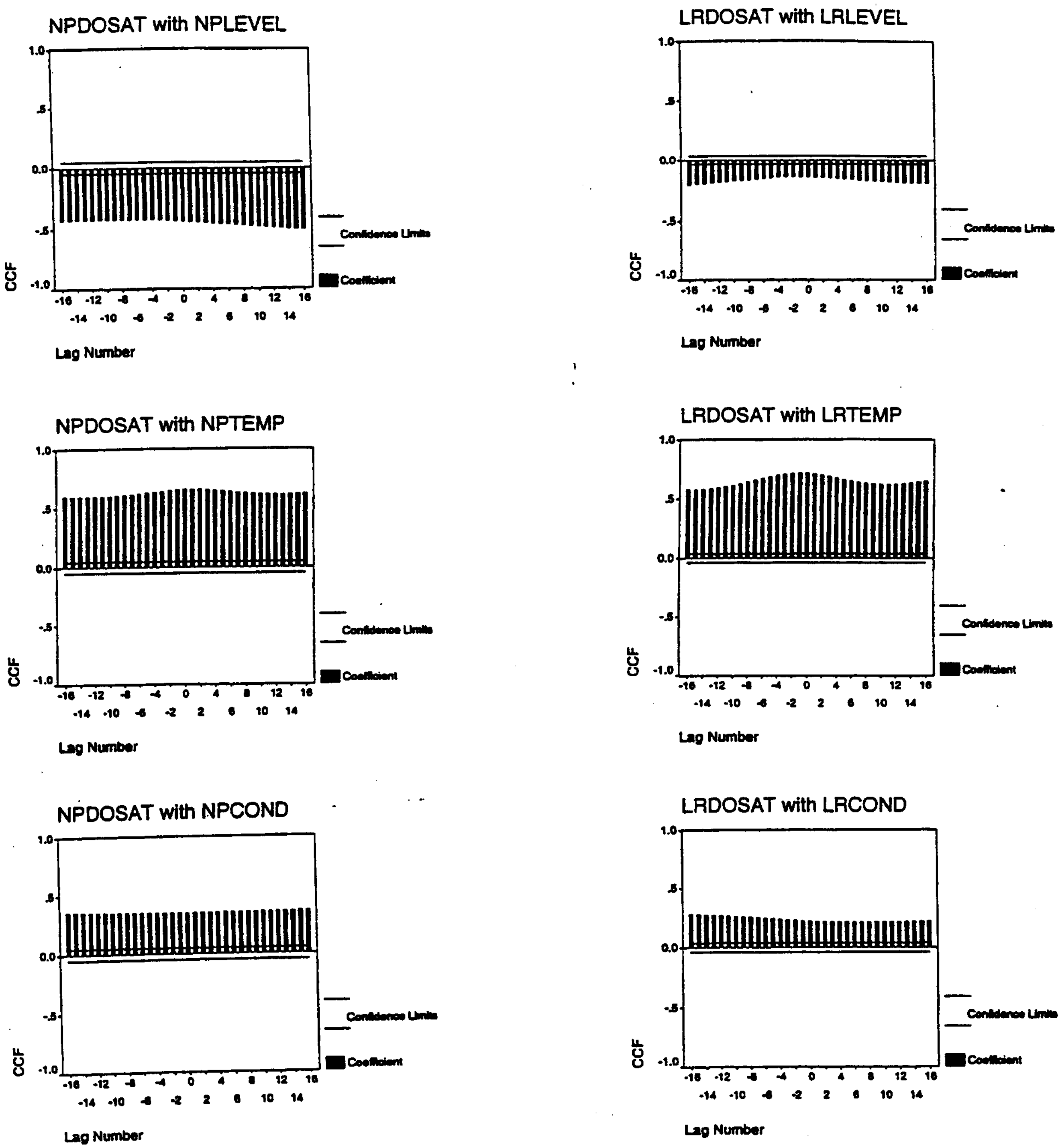


Appendix D4. Figure 2.

Cross correlation functions of (untransformed) time series data for: DO % saturation and water level, temperature, and conductivity in Northwest Pond Cell 3 and Lake Reba.

AR 034512

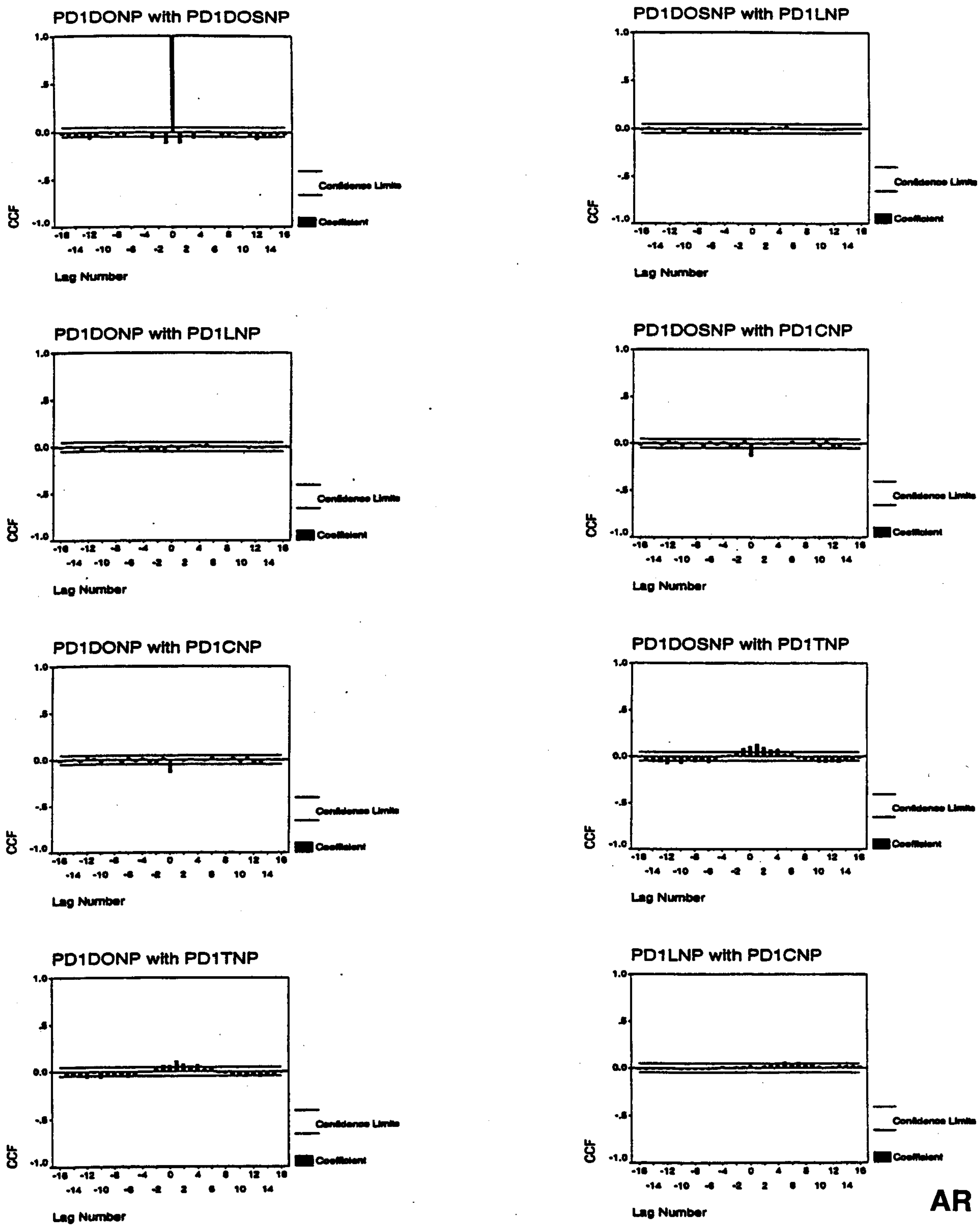
ECY00015880



Appendix D4. Figure 3.

Cross correlation functions of (untransformed) time series data for: temperature, water level, and conductivity in Northwest Pond Cell 3 and Lake Reba.

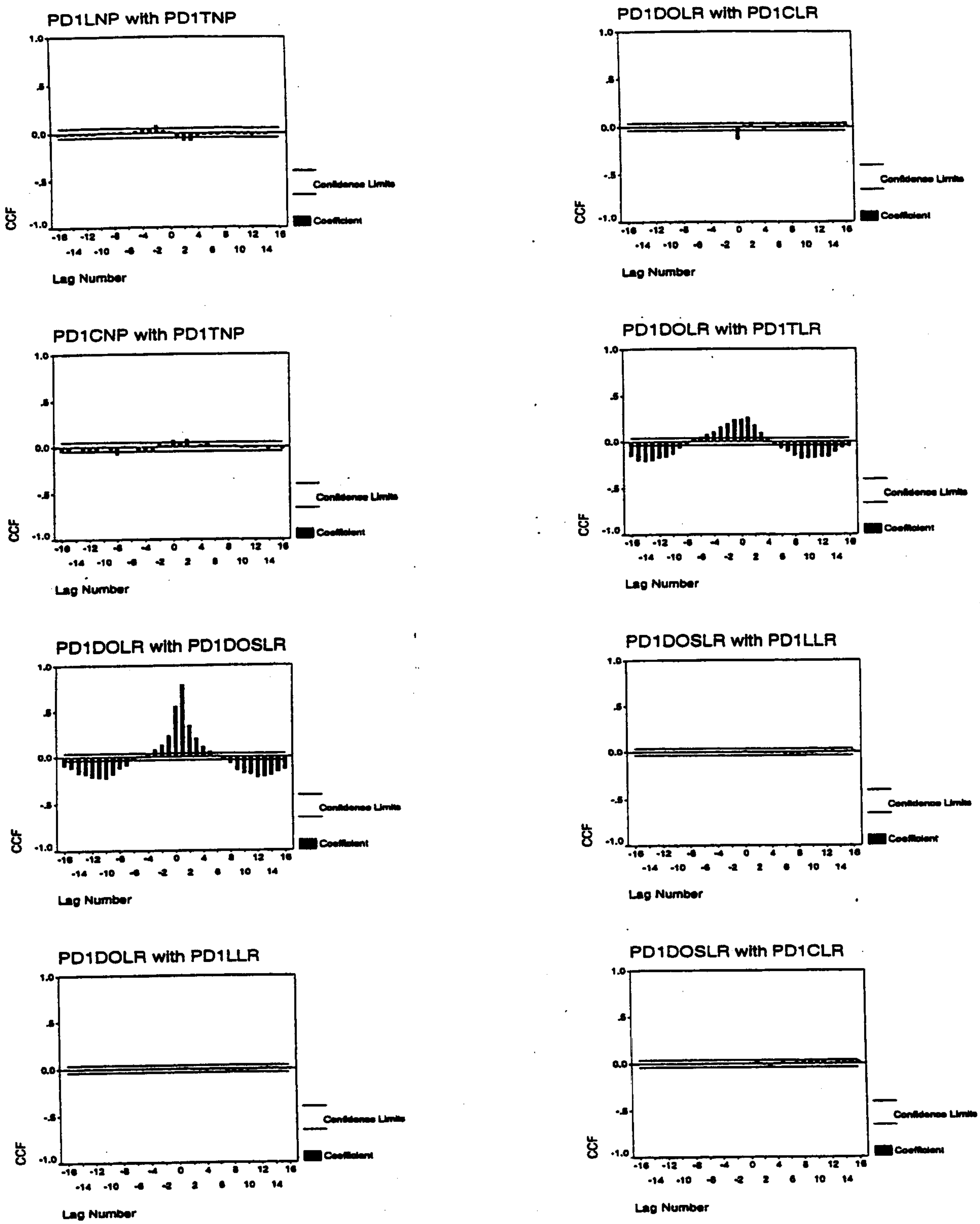
AR 034513



AR 034514

Appendix D4. Figure 4.

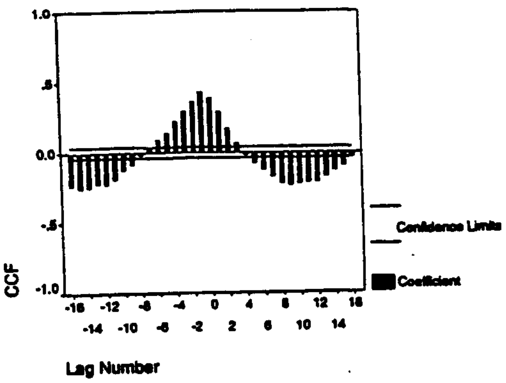
Cross correlation functions of (untransformed) time series data for percent changes over 1 hour periods in: (column 1) DO concentration with DO % saturation, water level, conductivity, and temperature; (column 2) DO % saturation with water level, conductivity, and temperature; and water level with conductivity for Northwest Pond Cell 3: full time series.



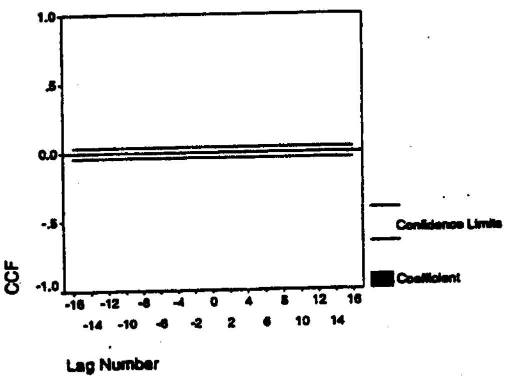
Appendix D4. Figure 5.

Cross correlation functions of (untransformed) time series data for percent changes over 1 hour periods in: (column 1) water level with temperature, conductivity with temperature in Northwest Pond Cell 3; DO concentration with DO percent saturation, water level in Lake Reba and (column 2) DO concentration with conductivity, and temperature; DO % saturation with water level and conductivity in Lake Reba: full time series.

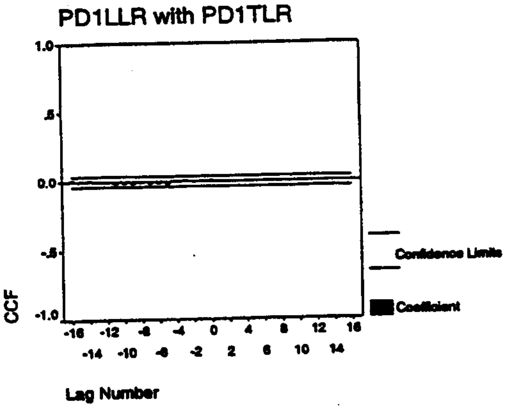
PD1DOSLR with PD1TLR



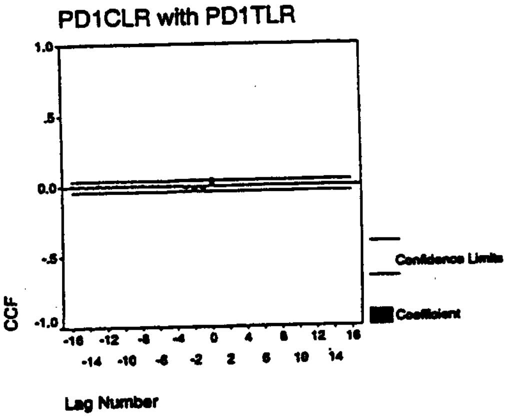
PD1LLR with PD1CLR



PD1LLR with PD1TLR

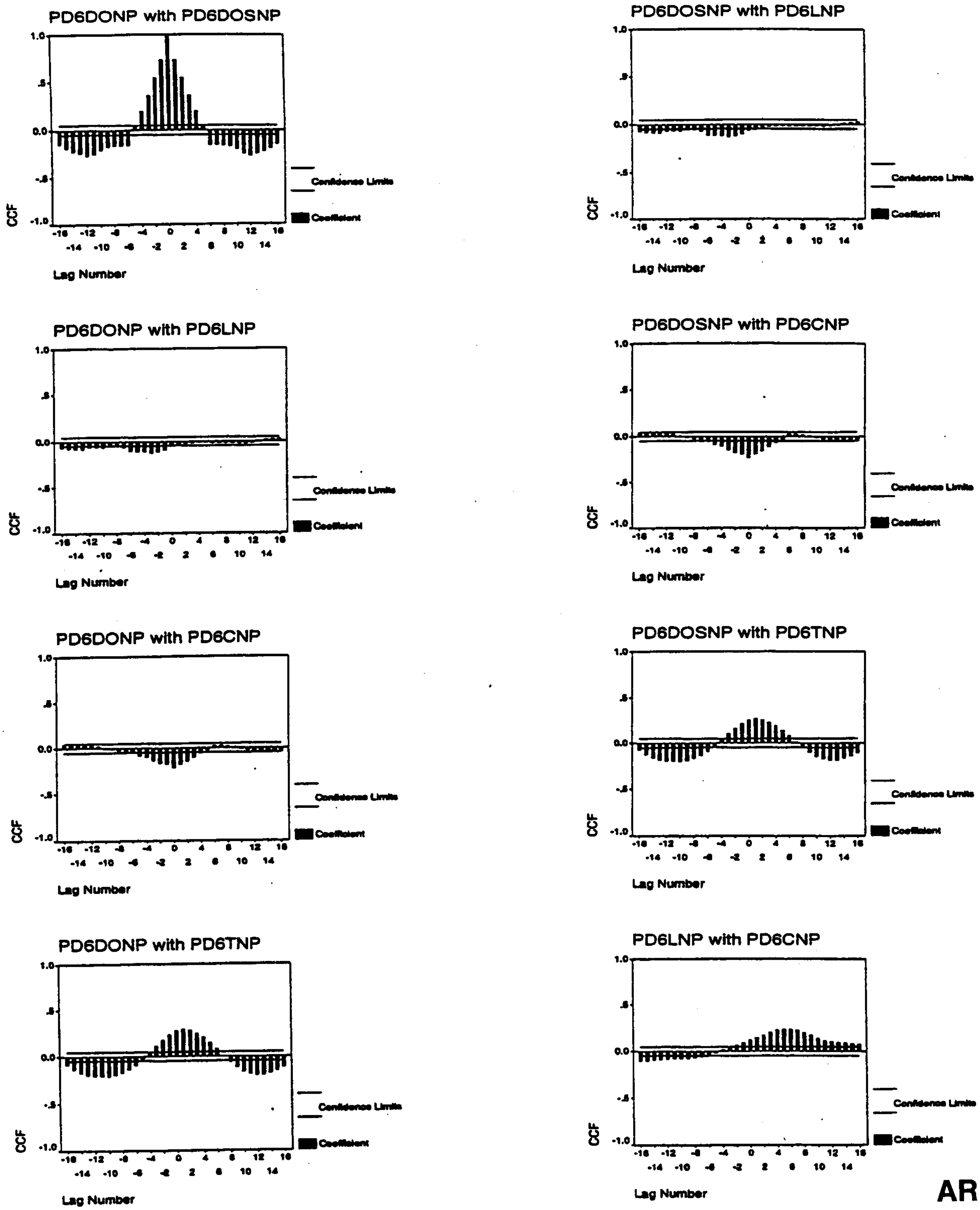


PD1CLR with PD1TLR



Appendix D4. Figure 6.

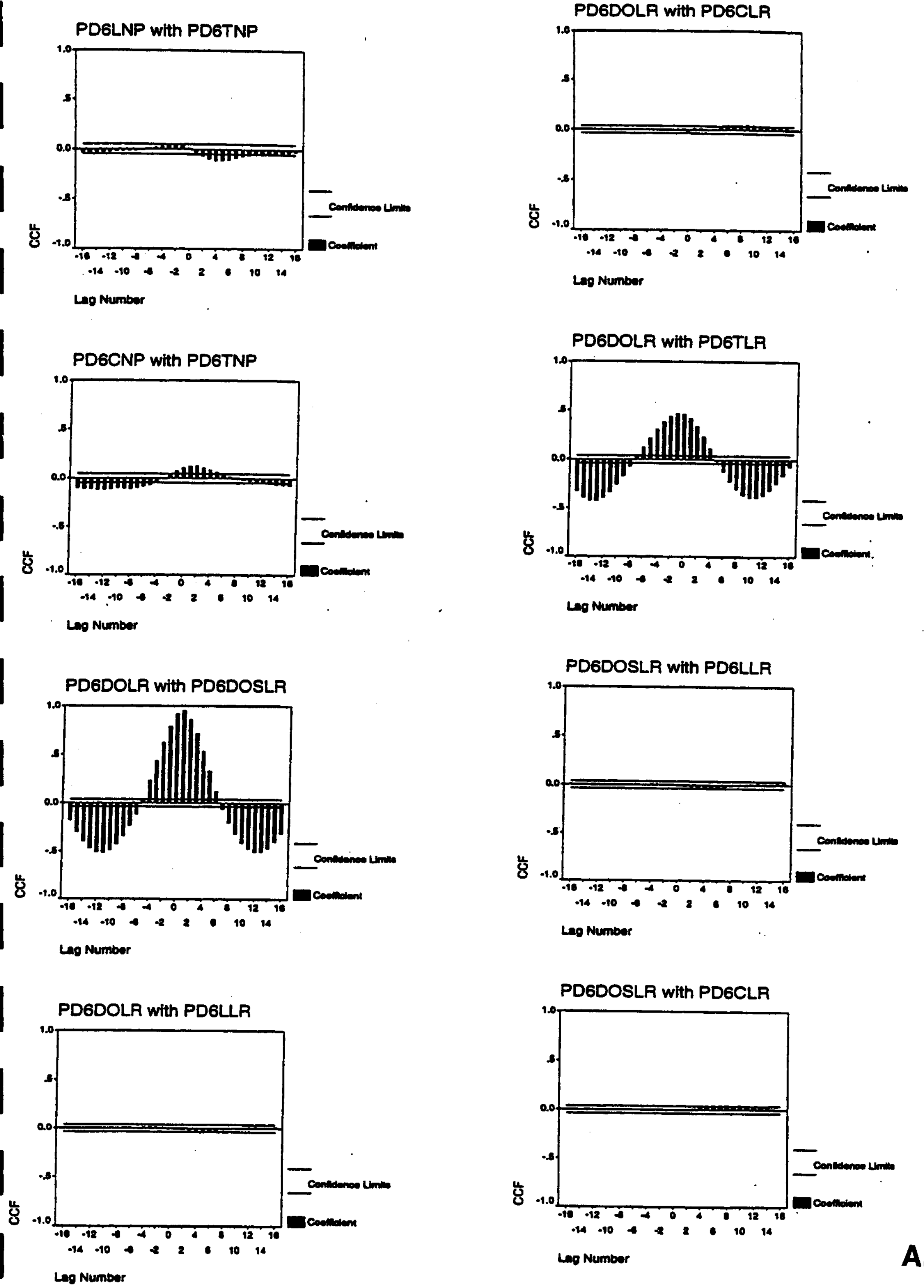
Cross correlation functions of (untransformed) time series data for percent changes over 1 hour periods in : DO % saturation with temperature and water level; water level with temperature, conductivity with temperature for Lake Reba: full time series.



AR 034517

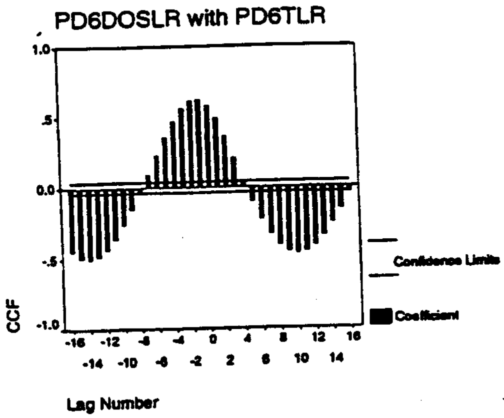
Appendix D4. Figure 7.

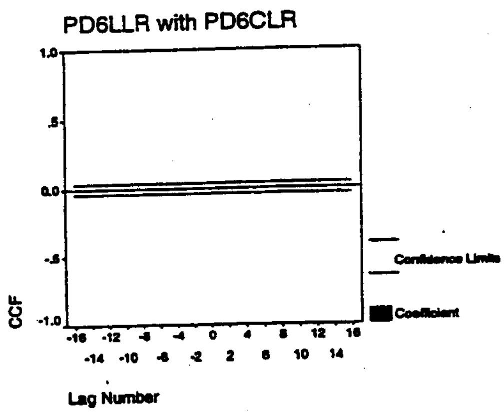
Cross correlation functions of (untransformed) time series data for percent changes over 6 hour periods in: (column 1) DO concentration with DO % saturation, water level, conductivity, and temperature; (column 2) DO % saturation with water level, conductivity, and temperature; and water level with conductivity for Northwest Pond Cell 3: full time series.

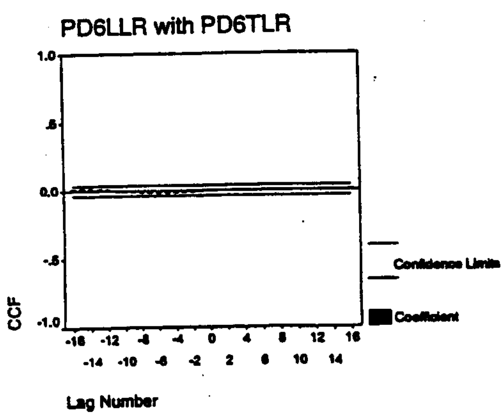


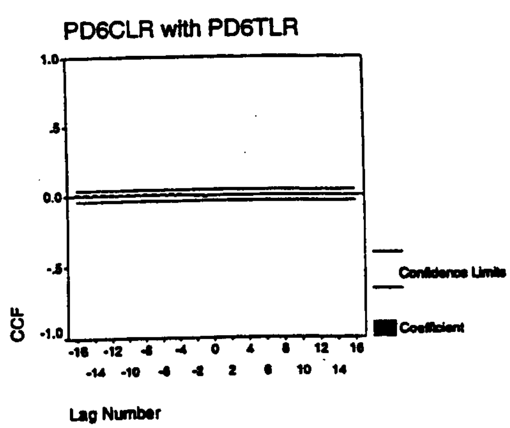
Appendix D4. Figure 8.

Cross correlation functions of (untransformed) time series data for percent changes over 6 hour periods in: (column 1) water level with temperature, conductivity with temperature in Northwest Pond Cell 3; DO concentration with DO percent saturation, water level in Lake Reba and (column 2) DO concentration with conductivity, and temperature; DO % saturation with water level and conductivity in Lake Reba: full time series.







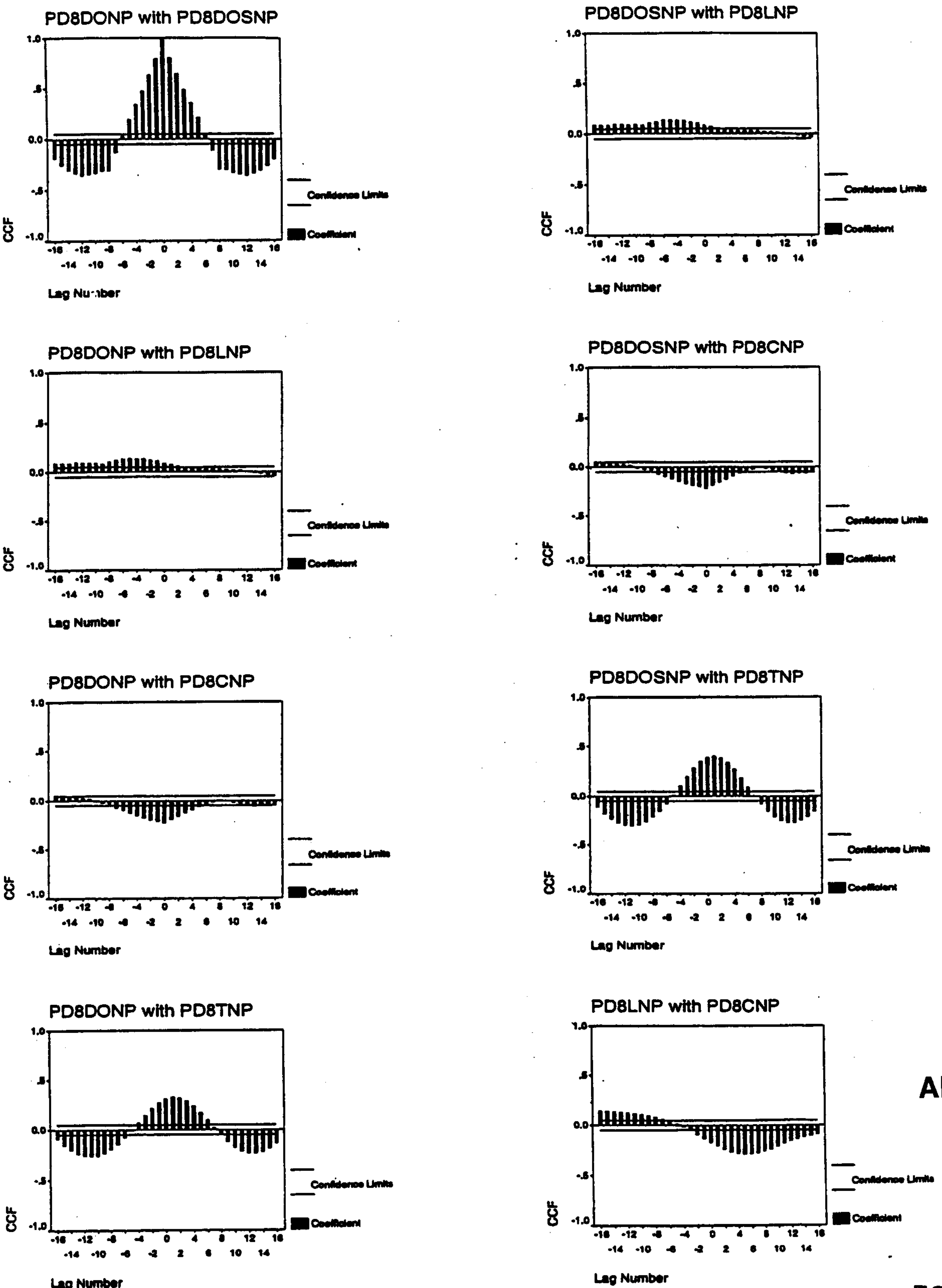


AR 034519

ECY00015887

Appendix D4. Figure 9.

Cross correlation functions of (untransformed) time series data for percent changes over 6 hour periods in : DO % saturation with temperature and water level; water level with temperature, conductivity with temperature for Lake Reba: full time series.

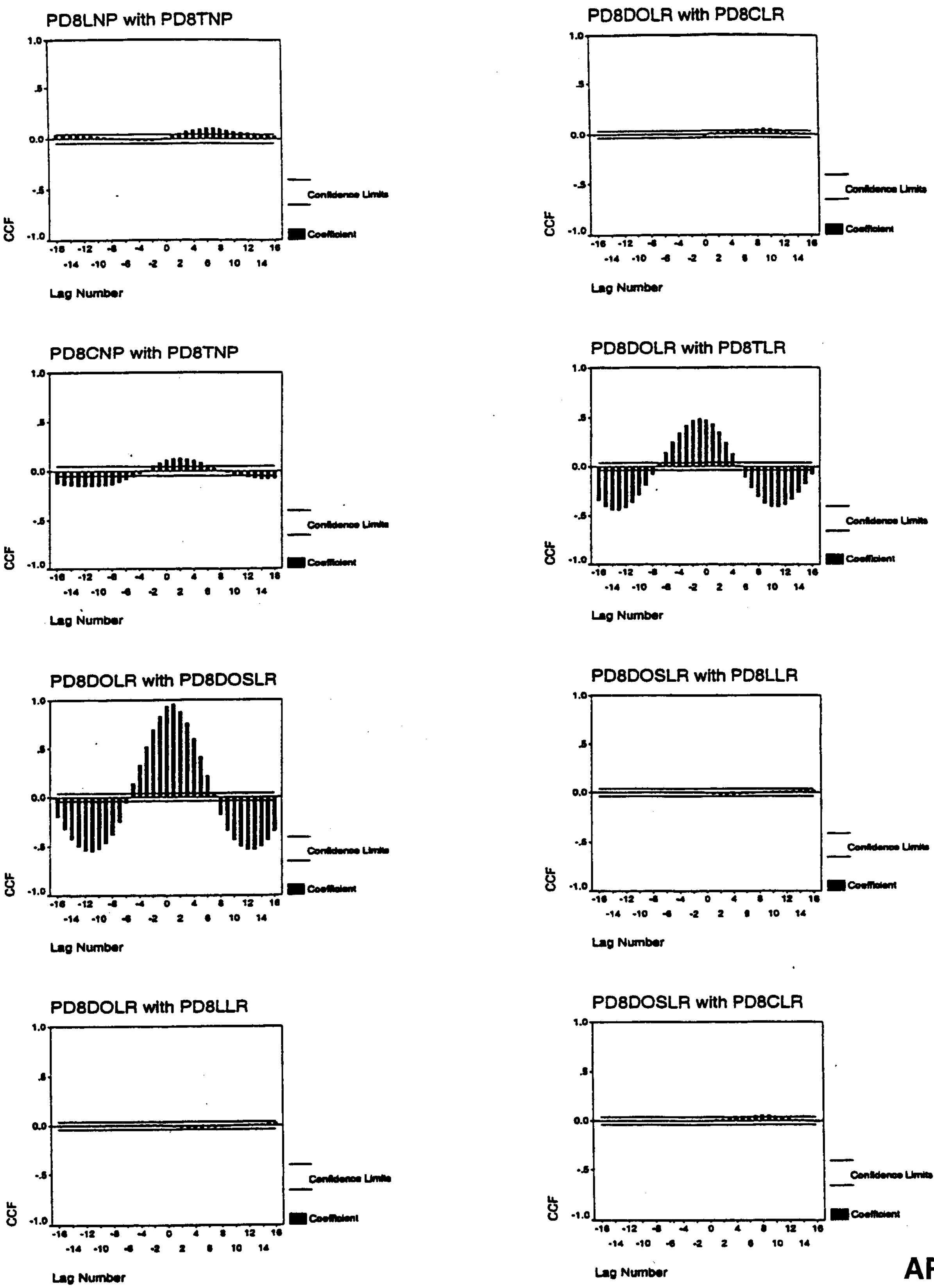


AR 034520

ECY00015888

Appendix D4. Figure 10.

Cross correlation functions of (untransformed) time series data for percent changes over 8 hour periods in: (column 1) DO concentration with DO % saturation, water level, conductivity, and temperature; (column 2) DO % saturation with water level, conductivity, and temperature; and water level with conductivity for Northwest Pond Cell 3: full time series.

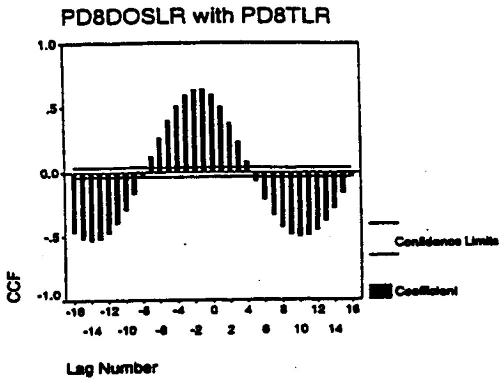


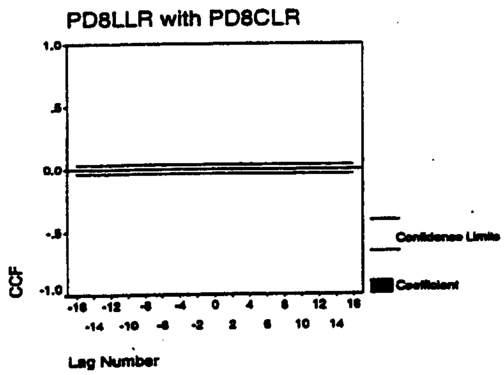
AR 034521

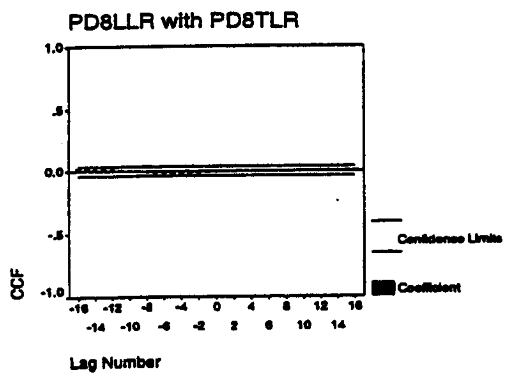
Appendix D4. Figure 11.

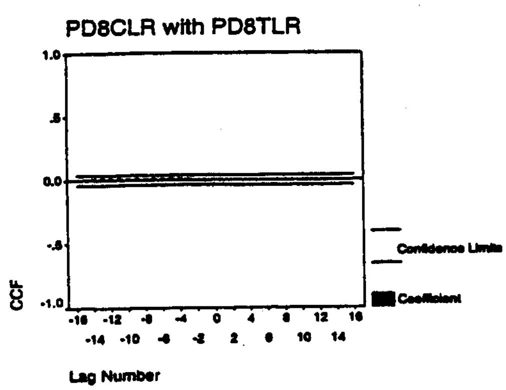
Cross correlation functions of (untransformed) time series data for percent changes over 8 hour periods in: (column 1) water level with temperature, conductivity with temperature in Northwest Pond Cell 3; DO concentration with DO percent saturation, water level in Lake Reba and (column 2) DO concentration with conductivity, and temperature; DO % saturation with water level and conductivity in Lake Reba: full time series.

ECY00015889



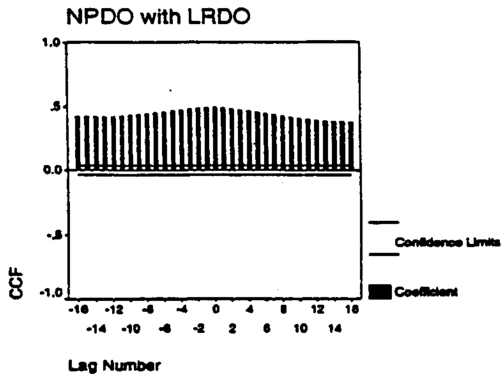


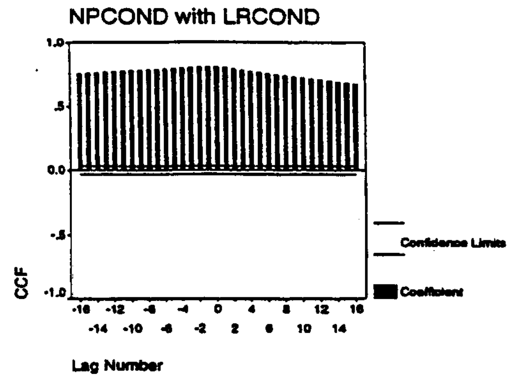


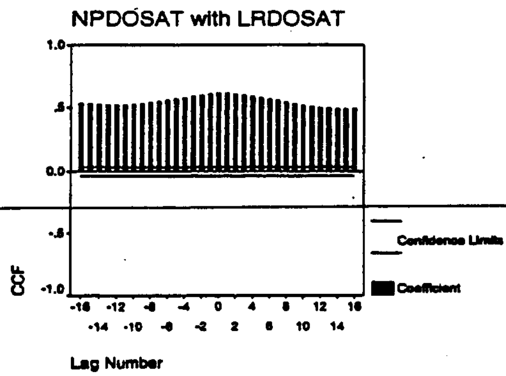


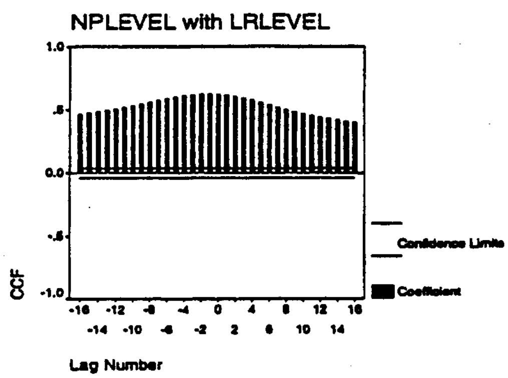
Appendix D4. Figure 12.

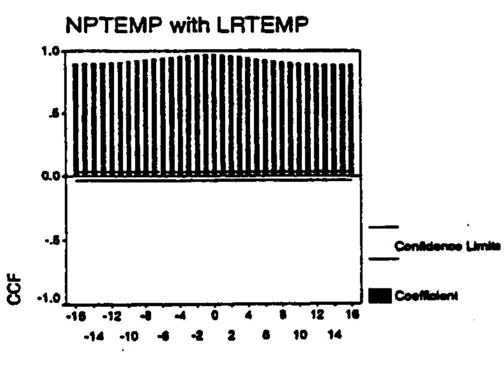
Cross correlation functions of (untransformed) time series data for percent changes over 8 hour periods in : DO % saturation with temperature and water level; water level with temperature, conductivity with temperature for Lake Reba: full time series.











AR 034523

Appendix D4.· Figure 13.

Cross correlation functions of (untransformed) comparing time series data in NP3 and Lake Reba for: DO concentration, DO % saturation, water level, temperature, and conductivity; full time series.

ECY00015891

5.8 *Appendix D5. Box Plots of Lake Reba and NP3 data.*

Appendix D5. Figure 1.

Box plots of DO concentration, 6 hour changes in DO concentration, and 6 hour percent changes in DO concentration at NP3 and Lake Reba during control periods and the two week treatment periods.

Appendix D5. Figure 2.

Box plots of DO percent saturation, 6 hour changes in DO percent saturation, and 6 hour percent changes in DO percent saturation at NP3 and Lake Reba during control periods and the two week treatment periods.

Appendix D5. Figure 3.

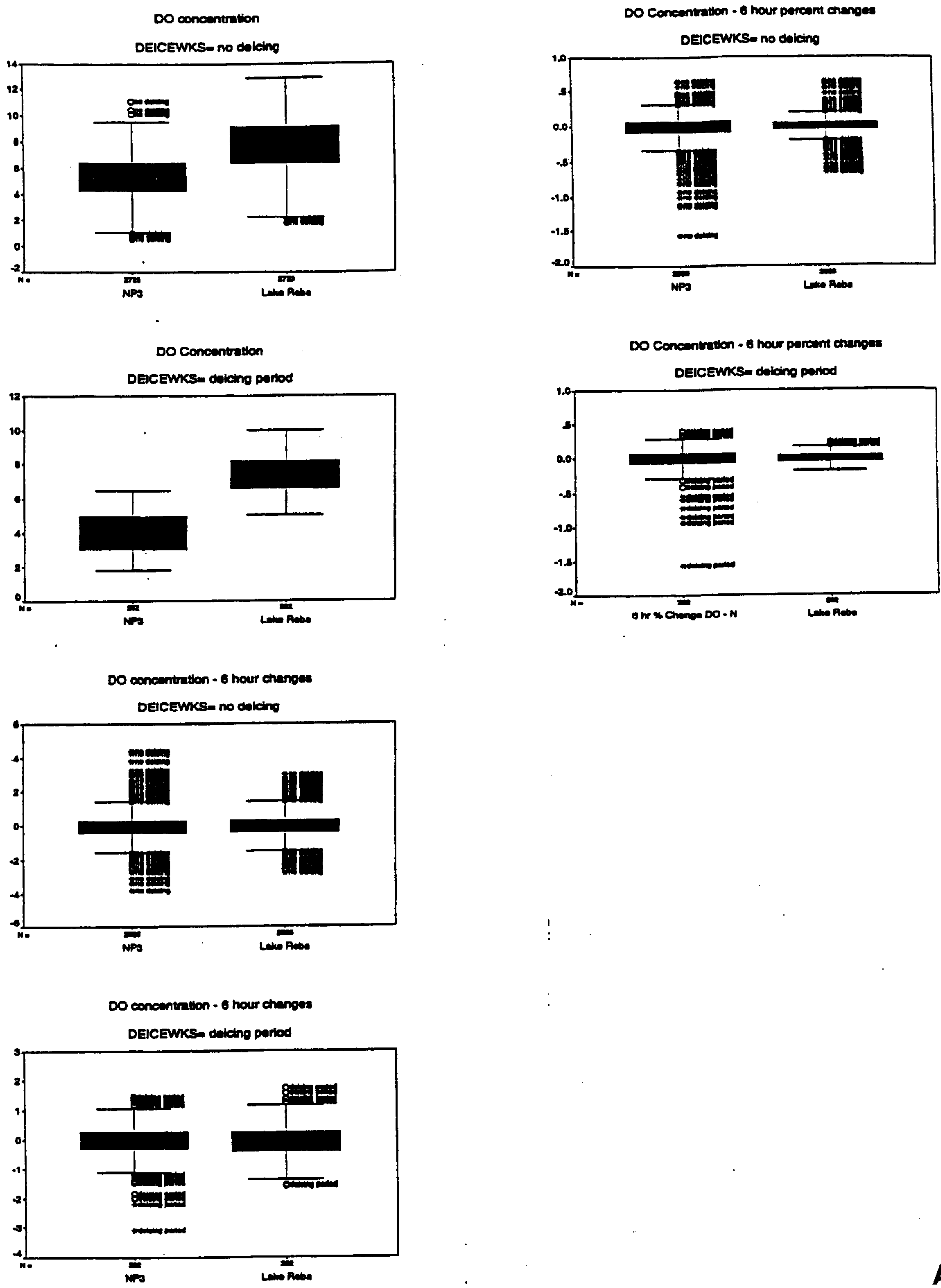
Box plots of conductivity, 6 hour changes in conductivity, and 6 hour percent changes in conductivity at NP3 and Lake Reba during control periods and the two week treatment periods.

Appendix D5. Figure 4.

Box plots of temperature, 6 hour changes in temperature, and 6 hour percent changes in temperature at NP3 and Lake Reba during control periods and the two week treatment periods.

Appendix D5. Figure 5.

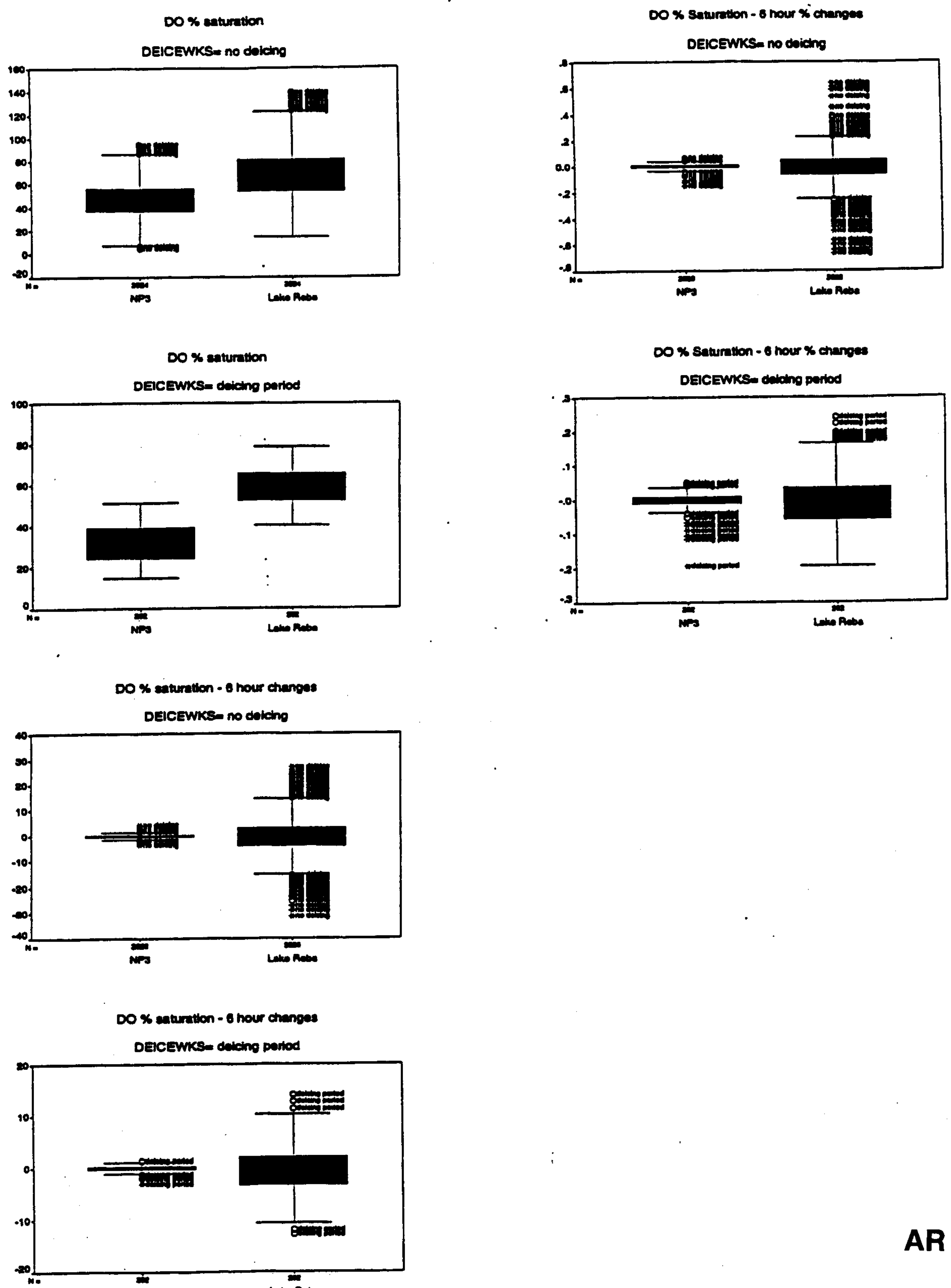
Box plots of water level, 6 hour changes in water level, and 6 hour percent changes in water level at NP3 and Lake Reba during control periods and the two week treatment periods.



AR 034525

Appendix D5. Figure 1.

Box plots of DO concentration, 6 hour changes in DO concentration, and 6 hour percent changes in DO concentration at NP3 and Lake Reba during nondeicing periods and the two week non deicing periods.

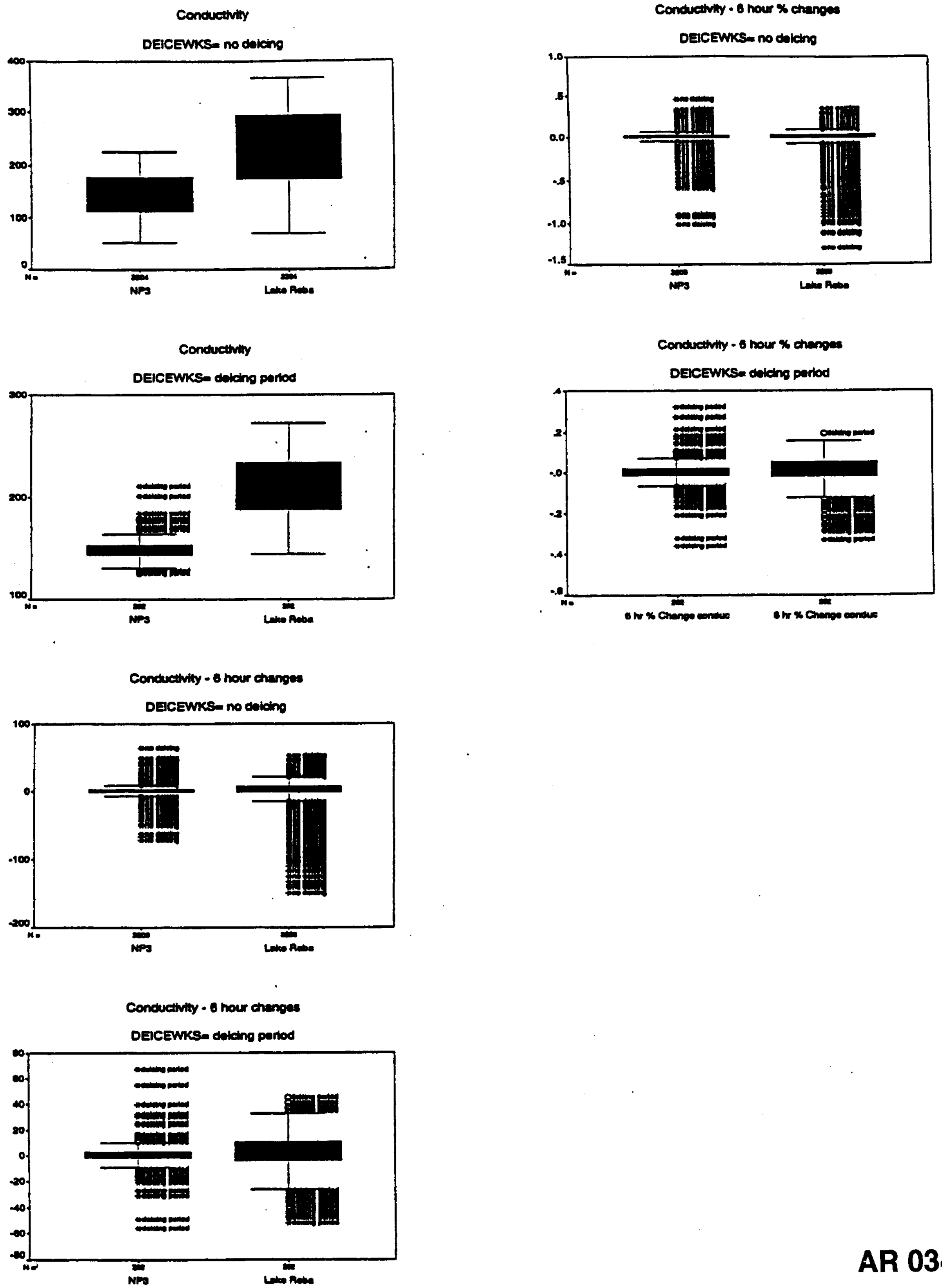


AR 034526

Appendix D5. Figure 2.

Box plots of DO percent saturation, 6 hour changes in DO percent saturation, and 6 hour percent changes in DO percent saturation at NP3 and Lake Reba during nondeicing periods and the two week non deicing periods.

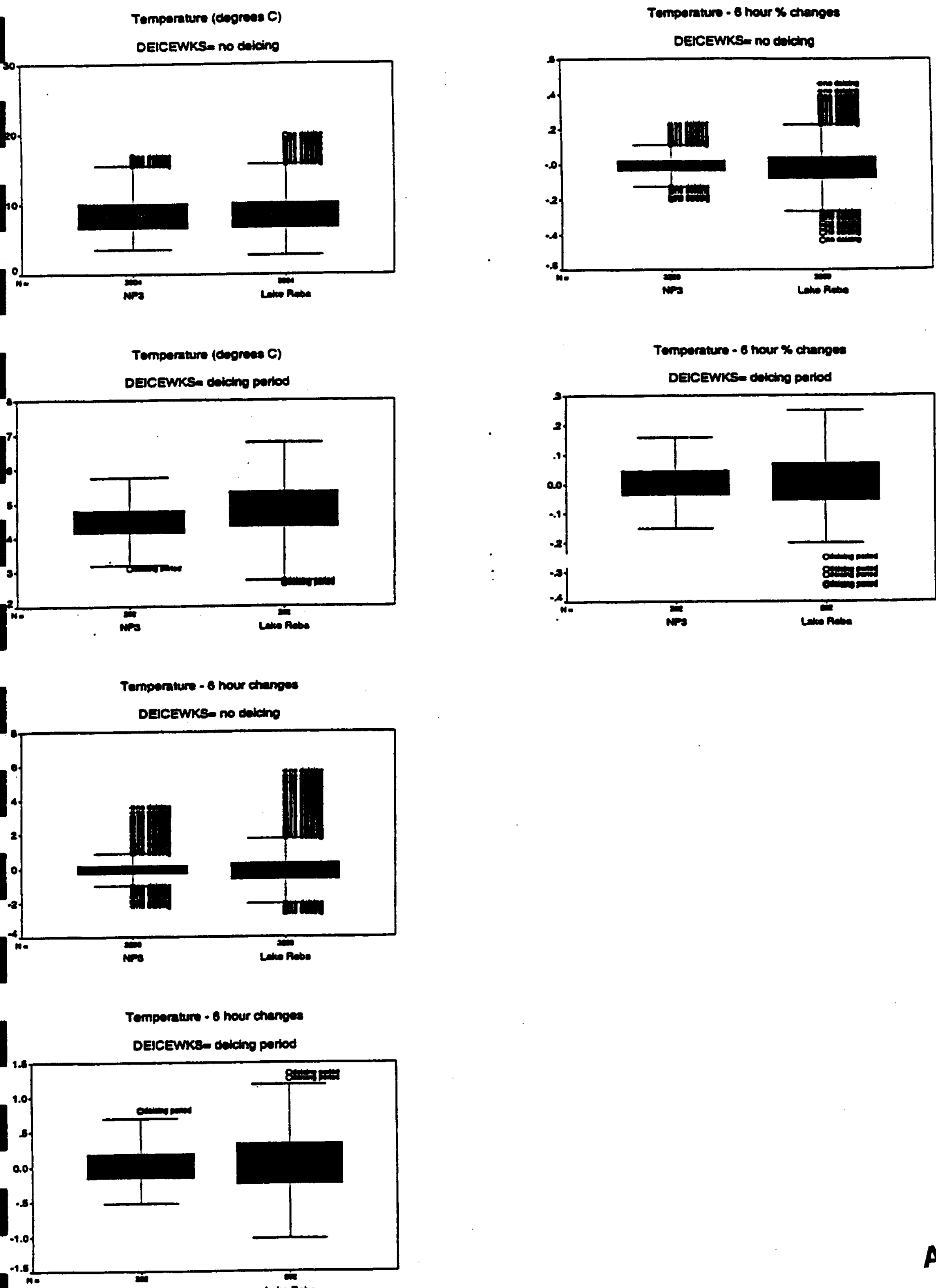
ECY00015894



AR 034527

Appendix D5. Figure 3.

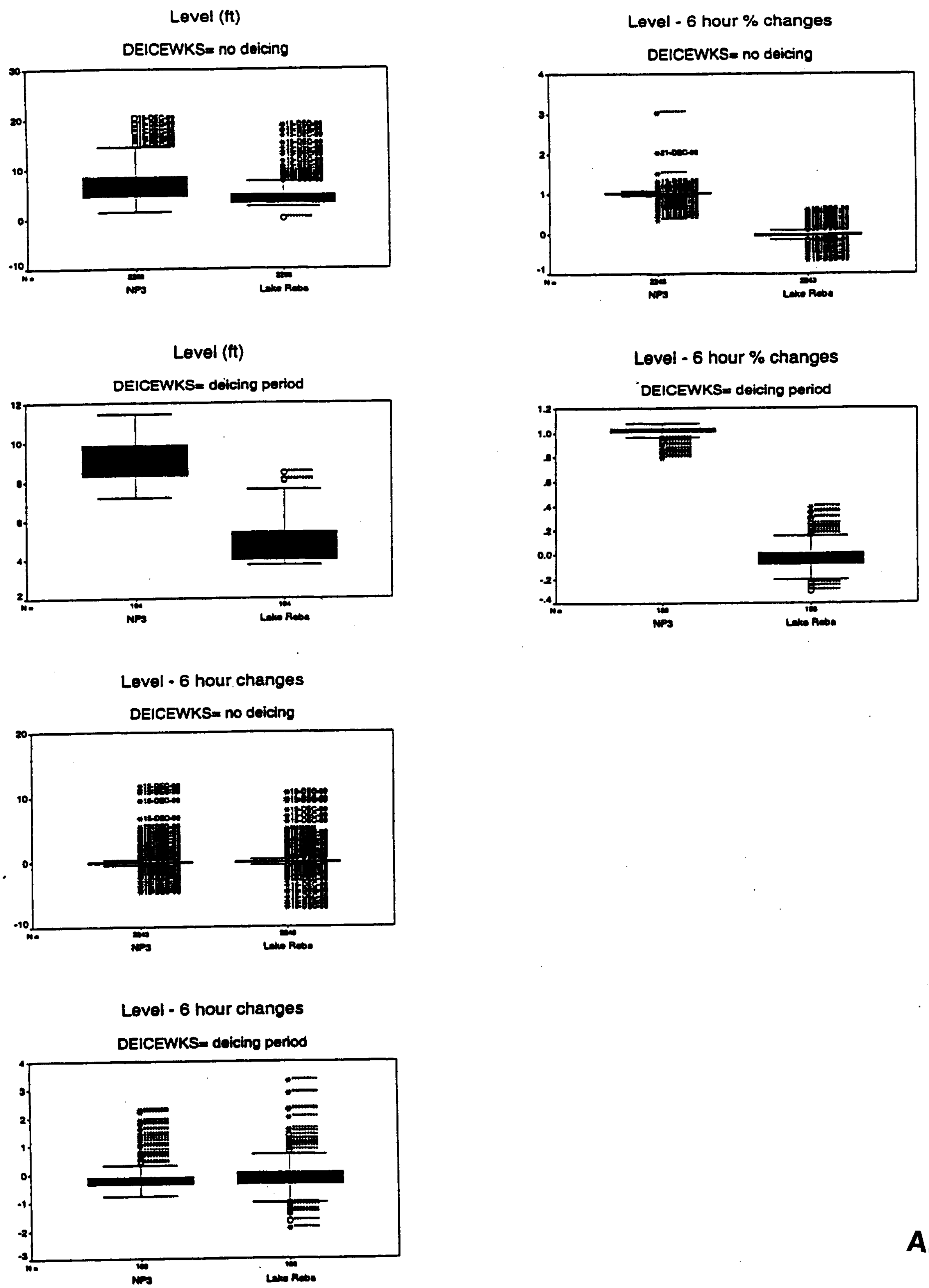
Box plots of conductivity, 6 hour changes in conductivity, and 6 hour percent changes in conductivity at NP3 and Lake Reba during nondeicing periods and the two week non deicing periods.



AR 034528

Appendix D5. Figure 4.

Box plots of temperature, 6 hour changes in temperature, and 6 hour percent changes in temperature at NP3 and Lake Reba during nondeicing periods and the two week non deicing periods.



AR 034529

Appendix D5. Figure 5.

Box plots of water level, 6 hour changes in water level, and 6 hour percent changes in water level at NP3 and Lake Reba during nondeicing periods and the two week non deicing periods.

5.9 Appendix D6. Cross-correlation functions of physical variables and DO

Temperature-level:_Although the correlation between temperature and level was predominantly negative and did not have a strong temporal component during the control period at either pond (Figures 3 and 4), during the two-week treatment period (i.e., temporal definition of deicing), the cross-correlations between time and level were generally positive and appeared to be affected by time. The CCF for the signal-based and time-based treatment periods were quite different at the two ponds (compare columns 2 and 3 in Figure 3 and columns 2 and 4 in Figure 4). It may be interesting that during the time that a signal was present at Lake Reba (Figures 3 and 4, right hand column where LREVENT = 1) the CCFs of the two ponds were quite similar although they were experiencing different amounts of deicing chemicals at this time (i.e., the signal based definition differs between the two sites). This kind of finding may indicate that some other unmeasured variable was controlling the temperature-level relationship.

Level-Conductivity: Because sample sizes vary greatly between the treatment and control periods, it was difficult to know whether the subtle differences among the level-conductivity CCFs at Lake Reba represent real changes in the correlation structure or effects of samples size. At NP3, on the other hand, the CCFs for all the treatment periods (predominantly but weakly positive) were quite different from the CCF for the control period (strongly negative). As with temperature and conductivity, the period of time that a signal was present at Lake Reba seems to be a time that the level-conductivity relationship was different than during the longer time periods of the temporal and signal-based treatment periods at NP3.

Temperature-conductivity: The sign of the cross correlation coefficients changes during the treatment periods (both definitions) at both ponds. In addition, as with the other in Figures 3 and 4, time lag has a greater effect on the cross correlation coefficient during the treatment period than during the control period. Once more, at NP3, the CCF for the period of signal presence at Lake Reba had a markedly different shape than all the other treatment CCFs.

Appendix D6. Figure 1.

Cross-correlation functions of DO percent saturation and DO, water level, temperature, and conductivity at NP3 during control and treatment periods. In Column 1 (deicewks, control) and Column 2, (deicewks, treatment period), the treatment period was the entire two-week treatment period. In Column 3 (Npevent, present), the treatment period was the period of time that a deicing signal was present at NP3. In Column 4 (Lrevent, present), the treatment period was the period of time during which there was a deicing signal present at Lake Reba.

Appendix D6. Figure 2.

Cross-correlation functions of DO percent saturation and DO, water level, temperature, and conductivity at Lake Reba during control and treatment periods. In Column 1 (deicewks, control) and Column 2, (deicewks, treatment period), the treatment period was the entire two-week treatment period. In Column 3 (Npevent, present), the treatment period was the period of time that a deicing signal was present at NP3. In Column 4 (Lrevent, present), the treatment period was the period of time during which there was a deicing signal present at Lake Reba.

Appendix D6. Figure 3.

Cross-correlation functions of water level and conductivity, temperature and conductivity, and water level and temperature at NP3 during control and treatment periods. In Column 1 (deicewks, control) and Column 2, (deicewks, treatment period), the treatment period was the entire two-week treatment period. In Column 3 (Npevent, present), the treatment period was the period of time that a deicing signal was present at NP3. In Column 4 (Lrevent, present), the treatment period was the period of time during which there was a deicing signal present at Lake Reba.

AR 034531

Appendix D6. Figure 4.

Cross-correlation functions of water level and conductivity, temperature and conductivity, and water level and temperature at Lake Reba during control and treatment periods. In Column 1 (deicewks, control) and Column 2, (deicewks, treatment period), the treatment period was the entire two-week treatment period. In Column 3 (Npevent, present), the treatment period was the period of time that a deicing signal was present at NP3. In Column 4 (Lrevent, present), the treatment period was the period of time during which there was a deicing signal present at Lake Reba.

Appendix D6. Figure 5.

Scatter plots of water level and temperature, water level and conductivity at NP3. In Column 1 (deicewks, control , treatment period), the treatment period was the entire two-week treatment period. In Column 2 (Npevent, signal present, signal not present), the treatment period was the period of time that a deicing signal was present at NP3. In Column 3 (LRevent, signal present, signal not present), the treatment period was the period of time during which there was a deicing signal present at Lake Reba.

Appendix D6. Figure 6.

Scatter plots of conductivity and temperature, conductivity and DO % saturation at NP3. In Column 1 (deicewks, control , deicing period), the treatment period was the entire two-week treatment period. In Column 2 (Npevent, signal present, signal not present), the treatment period was the period of time that a deicing signal was present at NP3. In Column 3 (LRevent, signal present, signal not present), the treatment period was the period of time during which there was a deicing signal present at Lake Reba.

Appendix D6. Figure 7.

Scatter plots of water level and temperature, water level and conductivity at Lake Reba. In Column 1 (deicewks, control , deicing period), the treatment period was the entire two-week treatment period. In Column 2 (Npevent, signal present, signal not present), the treatment period was the period of time that a deicing signal was present at NP3. In

Column 3 (LRevent, signal present, signal not present), the treatment period was the period of time during which there was a deicing signal present at Lake Reba.

Appendix D6. Figure 8.

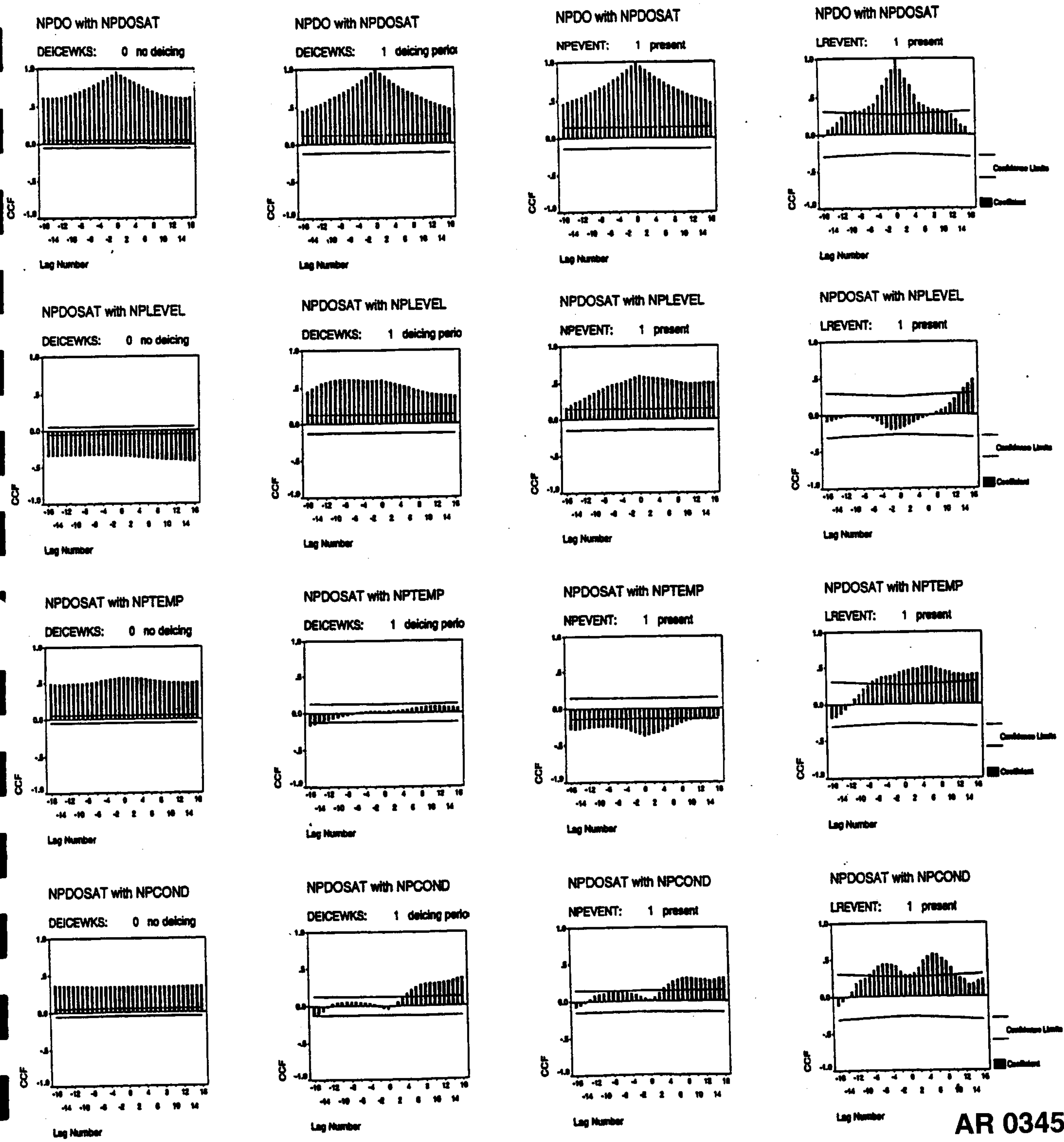
Scatter plots of conductivity and temperature, conductivity and DO % saturation at Lake Reba. In Column 1 (deicewks, control , deicing period), the treatment period was the entire two-week treatment period. In Column 2 (Npevent, signal present, signal not present), the treatment period was the period of time that a deicing signal was present at NP3. In Column 3 (LRevent, signal present, signal not present), the treatment period was the period of time during which there was a deicing signal present at Lake Reba.

Appendix D6. Figure 9.

Cross-correlation functions of DO percent saturation at Lake Reba and NP3 and conductivity at Lake Reba and NP3 during control and treatment periods. In Column 1 (deicewks), the treatment period was the entire two-week treatment period. In Column 2 (LRevent), the treatment period was the period of time during which there was a deicing signal present at Lake Reba. In Column 3 (NPevent), the treatment period was the period of time that a deicing signal was present at NP3.

Appendix D6. Figure 10.

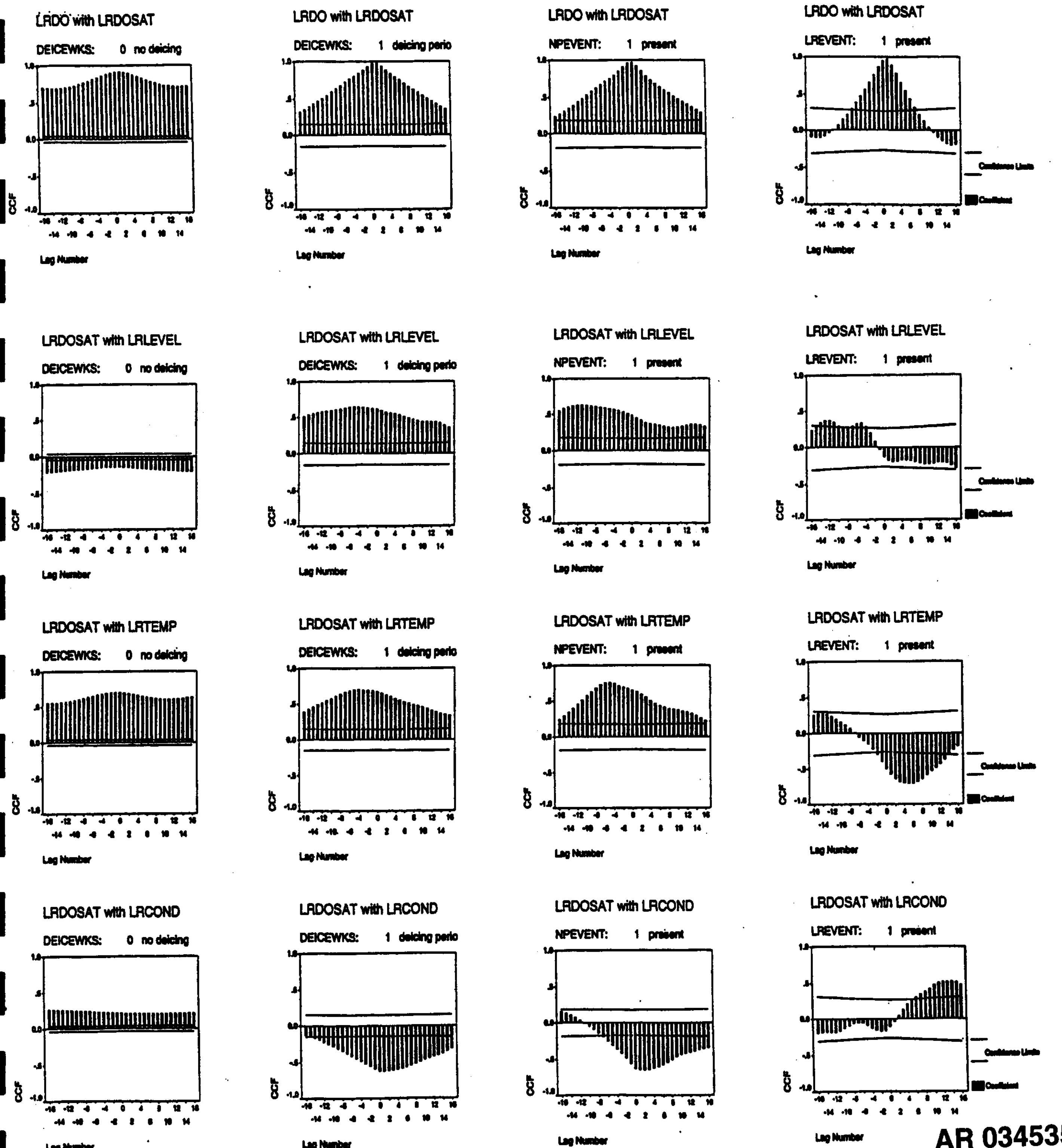
Scatter plots DO percent saturation at Lake Reba and NP3 and conductivity at Lake Reba and NP3 during control and treatment periods. In Column 1 (deicewks), the treatment period was the entire two-week treatment period. In Column 2 (LRevent), the treatment period was the period of time during which there was a deicing signal present at Lake Reba. In Column 3 (NPevent), the treatment period was the period of time that a deicing signal was present at NP3.



AR 034534

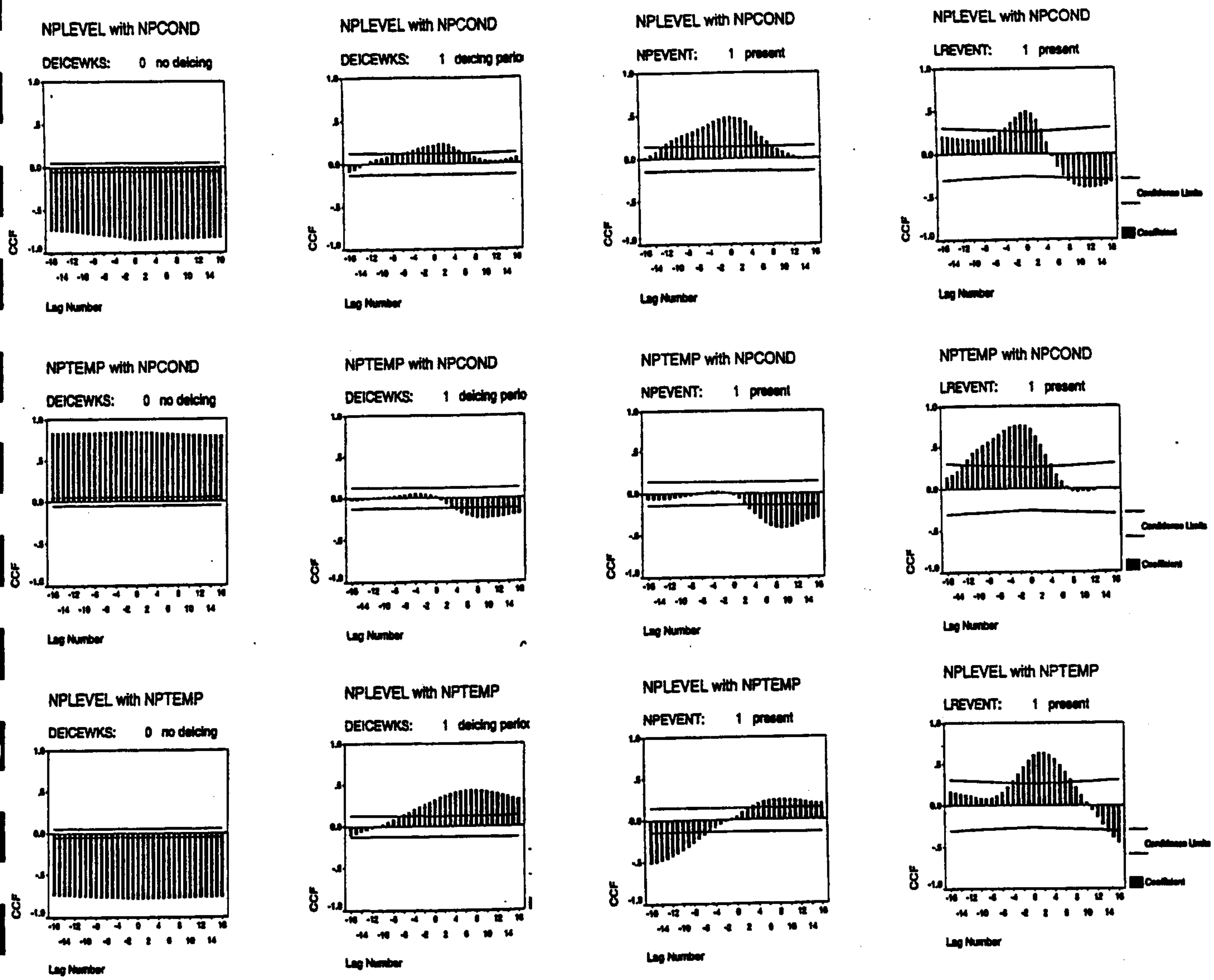
Appendix D6. Figure 1.

Cross-correlation functions of DO percent saturation and DO, water level, temperature, and conductivity at NP3 during non-deicing and deicing periods. In Column 1 (deicewks, no deicing) and Column 2, (deicewks, deicing period), the deicing period was the entire two-week deicing period. In Column 3 (Npevent, present), the deicing period is the period of time that a deicing signal was present at NP3. In Column 4 (Lrevent, present), the deicing period was the period of time during which there was a deicing signal present at Lake Reba.



Appendix D6. Figure 2.

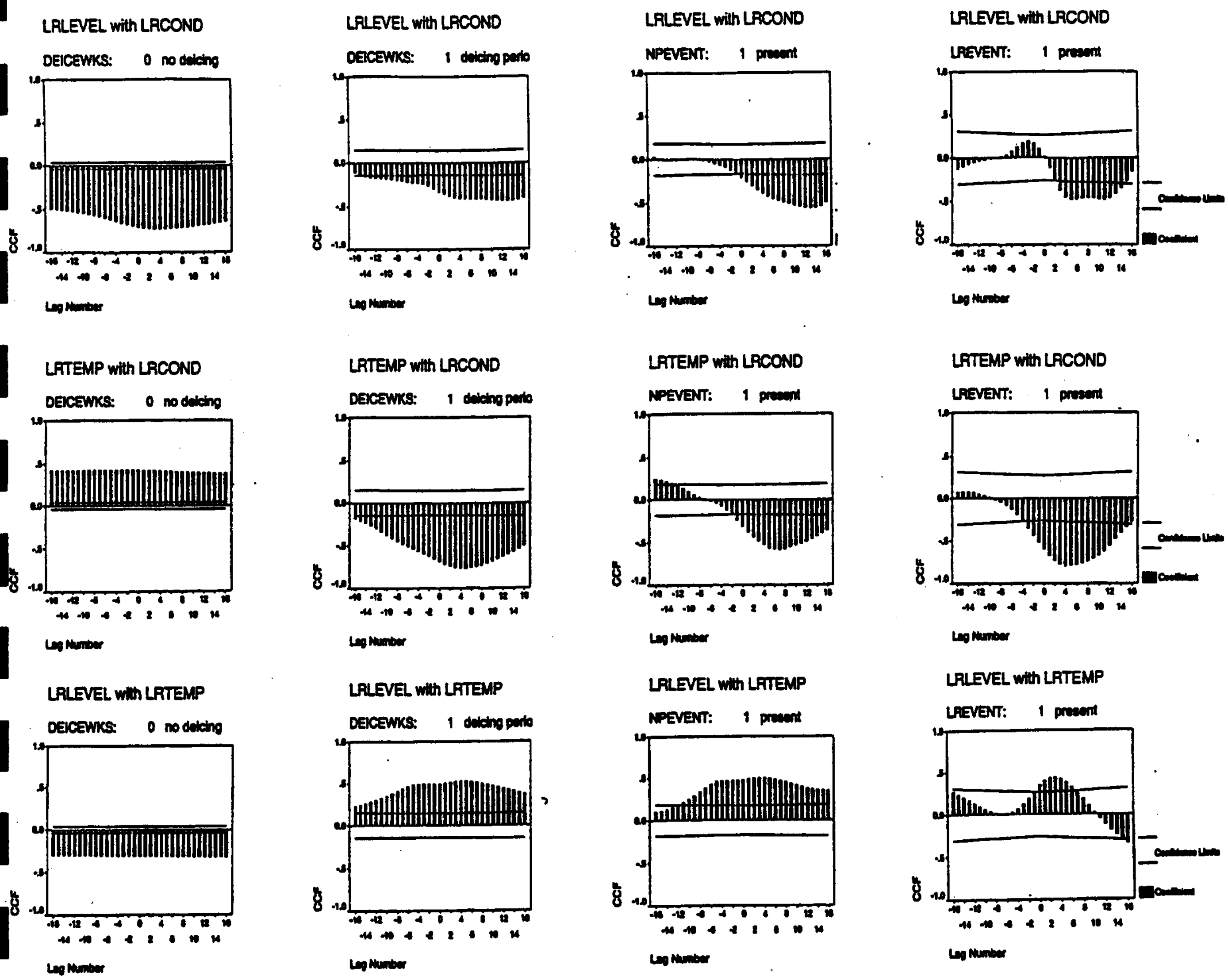
Cross-correlation functions of DO percent saturation and DO, water level, temperature, and conductivity at Lake Reba during non-deicing and deicing periods. In Column 1 (deicewks, no deicing) and Column 2, (deicewks, deicing period), the deicing period was the entire two-week deicing period. In Column 3 (Npevent, present), the deicing period is the period of time that a deicing signal was present at NP3. In Column 4 (Lrevent, present), the deicing period was the period of time during which there was a deicing signal present at Lake Reba.



Appendix D6. Figure 3.

Cross-correlation functions of water level and conductivity, temperature and conductivity, and water level and temperature at NP3 during non-deicing and deicing periods. In Column 1 (deicewks, no deicing) and Column 2, (deicewks, deicing period), the deicing period was the entire two-week deicing period. In Column 3 (Npevent, present), the deicing period is the period of time that a deicing signal was present at NP3. In Column 4 (Lrevent, present), the deicing period was the period of time during which there was a deicing signal present at Lake Reba.

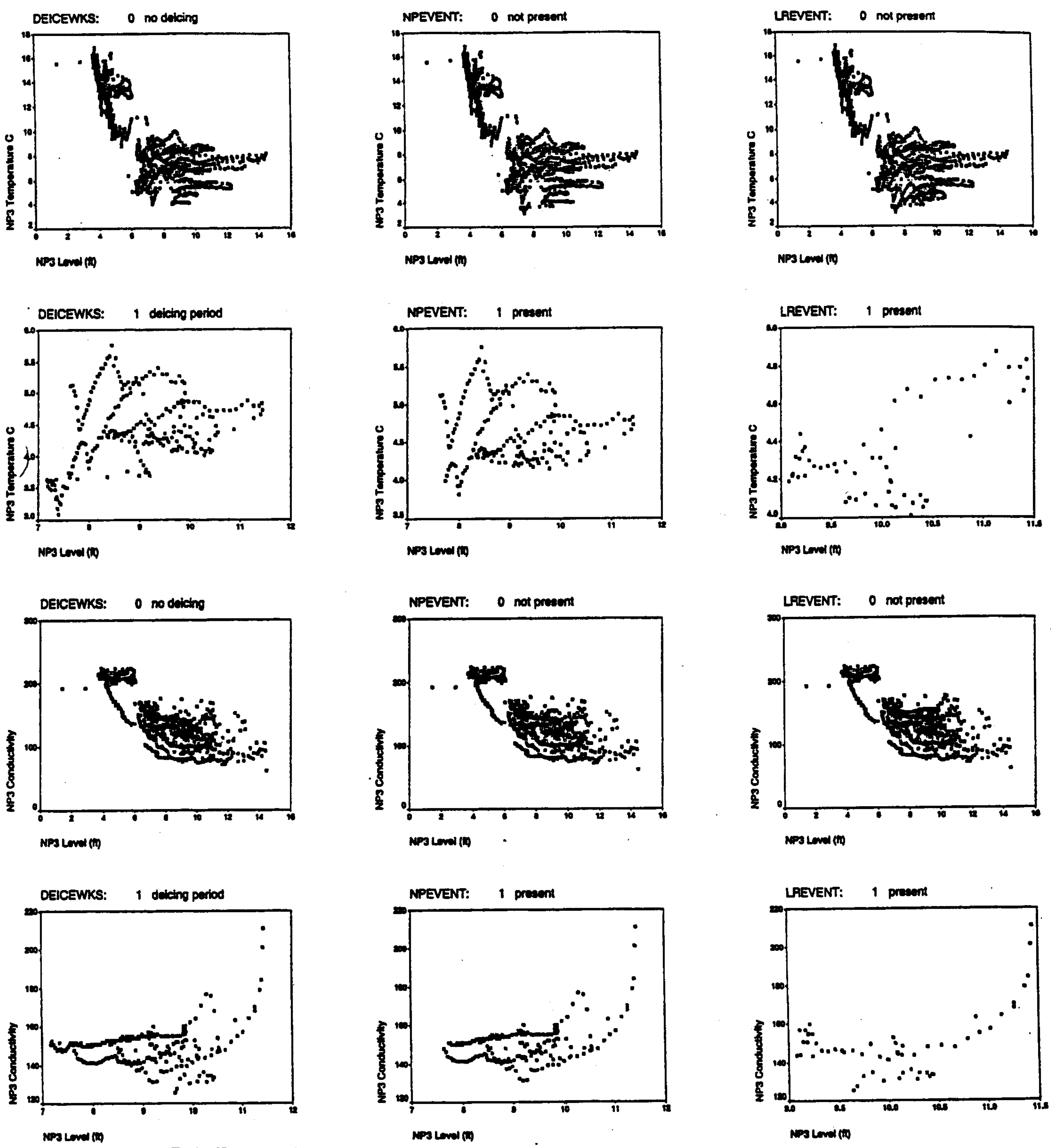
AR 034536



Appendix D6. Figure 4.

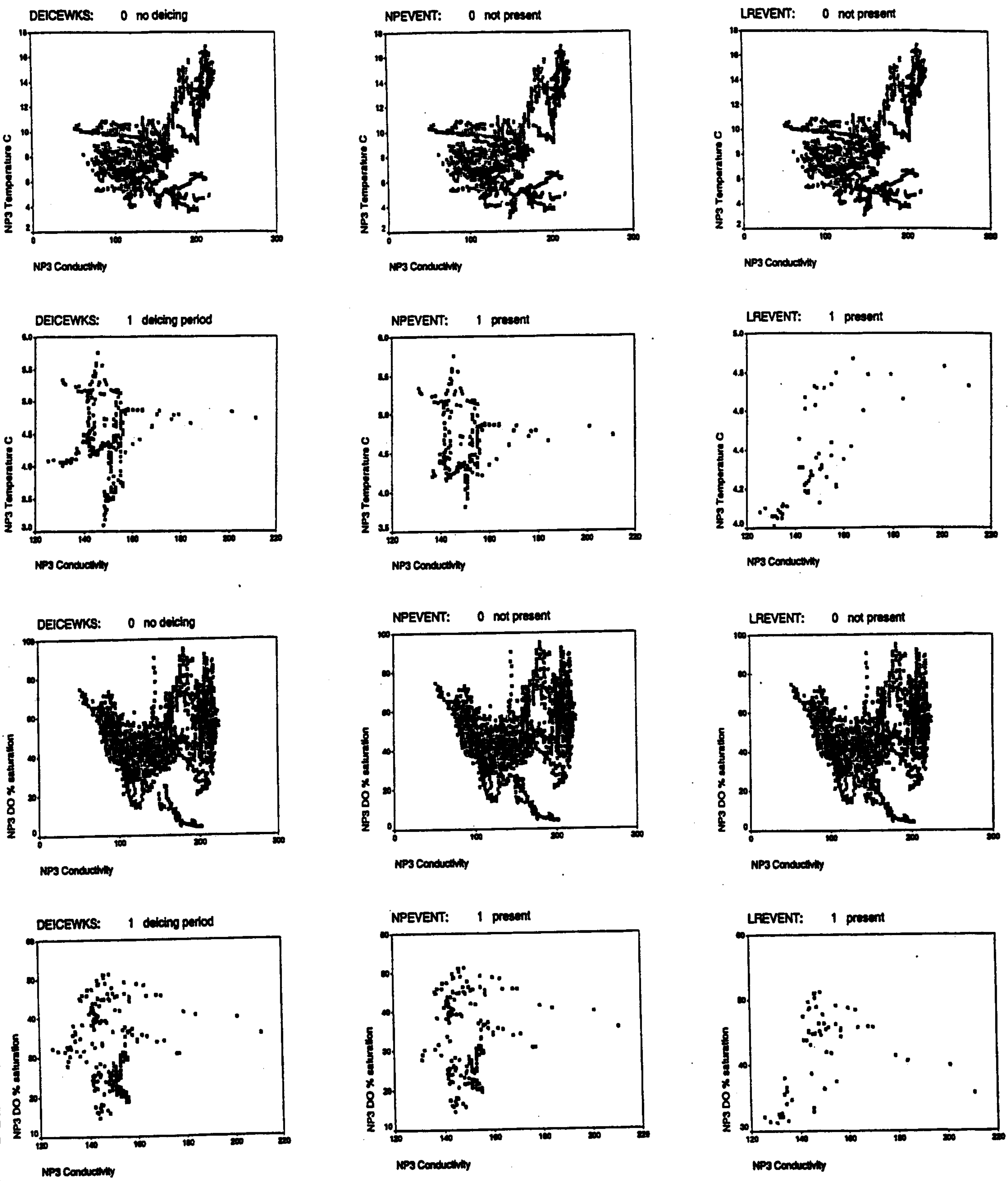
Cross-correlation functions of water level and conductivity, temperature and conductivity, and water level and temperature at Lake Reba during non-deicing and deicing periods. In Column 1 (deicewks, no deicing) and Column 2, (deicewks, deicing period), the deicing period was the entire two-week deicing period. In Column 3 (Npevent, present), the deicing period is the period of time that a deicing signal was present at NP3. In Column 4 (Lrevent, present), the deicing period was the period of time during which there was a deicing signal present at Lake Reba.

AR 034537



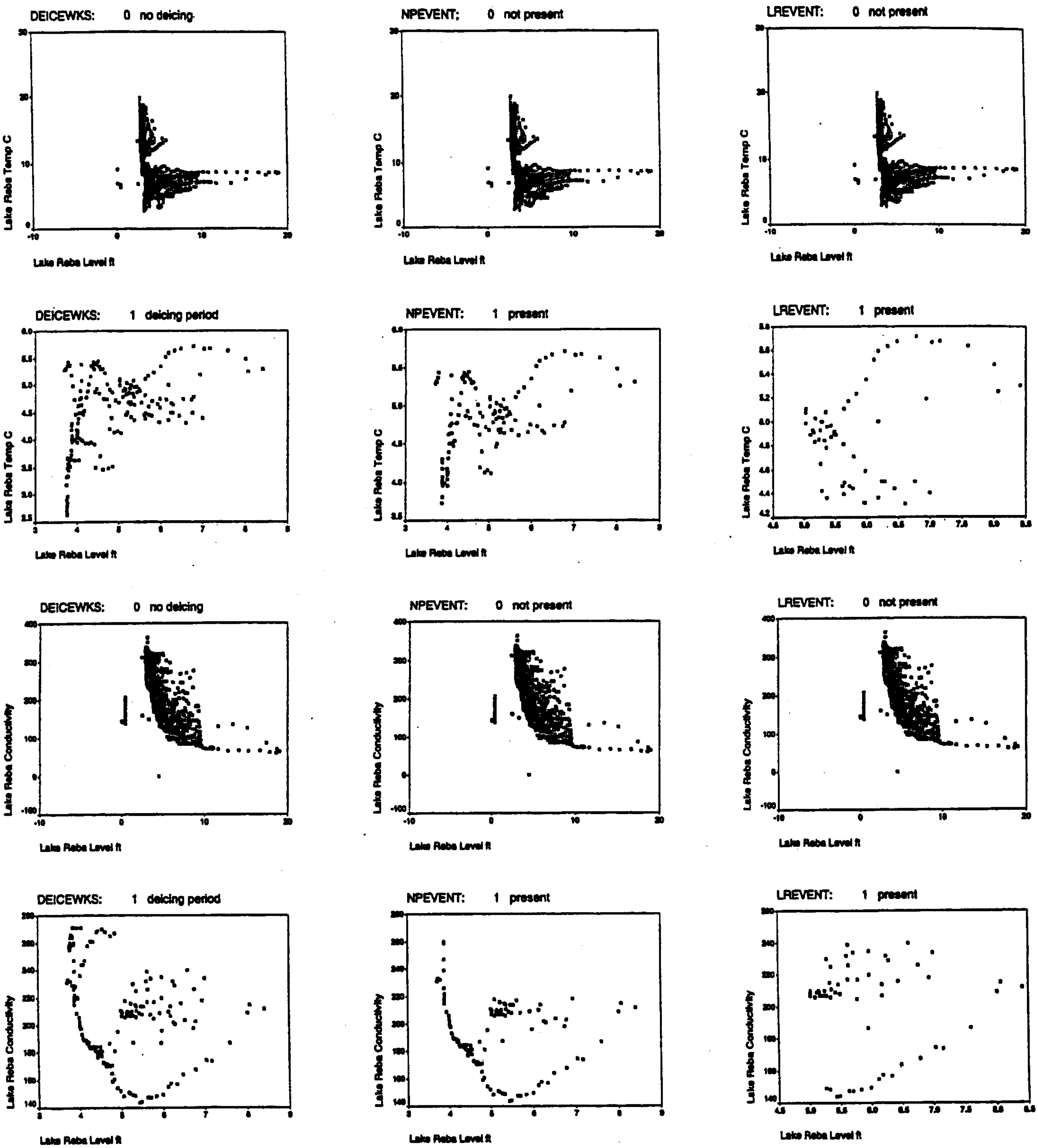
Appendix D6. Figure 5.

Scatter plots of water level and temperature, water level and conductivity at NP3. In Column 1 (deicewks, no deicing, deicing period), the deicing period is the entire two-week deicing period. In Column 2 (Npevent, signal present, signal not present), the deicing period is the period of time that a deicing signal was present at NP3. In Column 3 (LRevent, signal present, signal not present), the deicing period is the period of time during which there was a deicing signal present at Lake Reba.



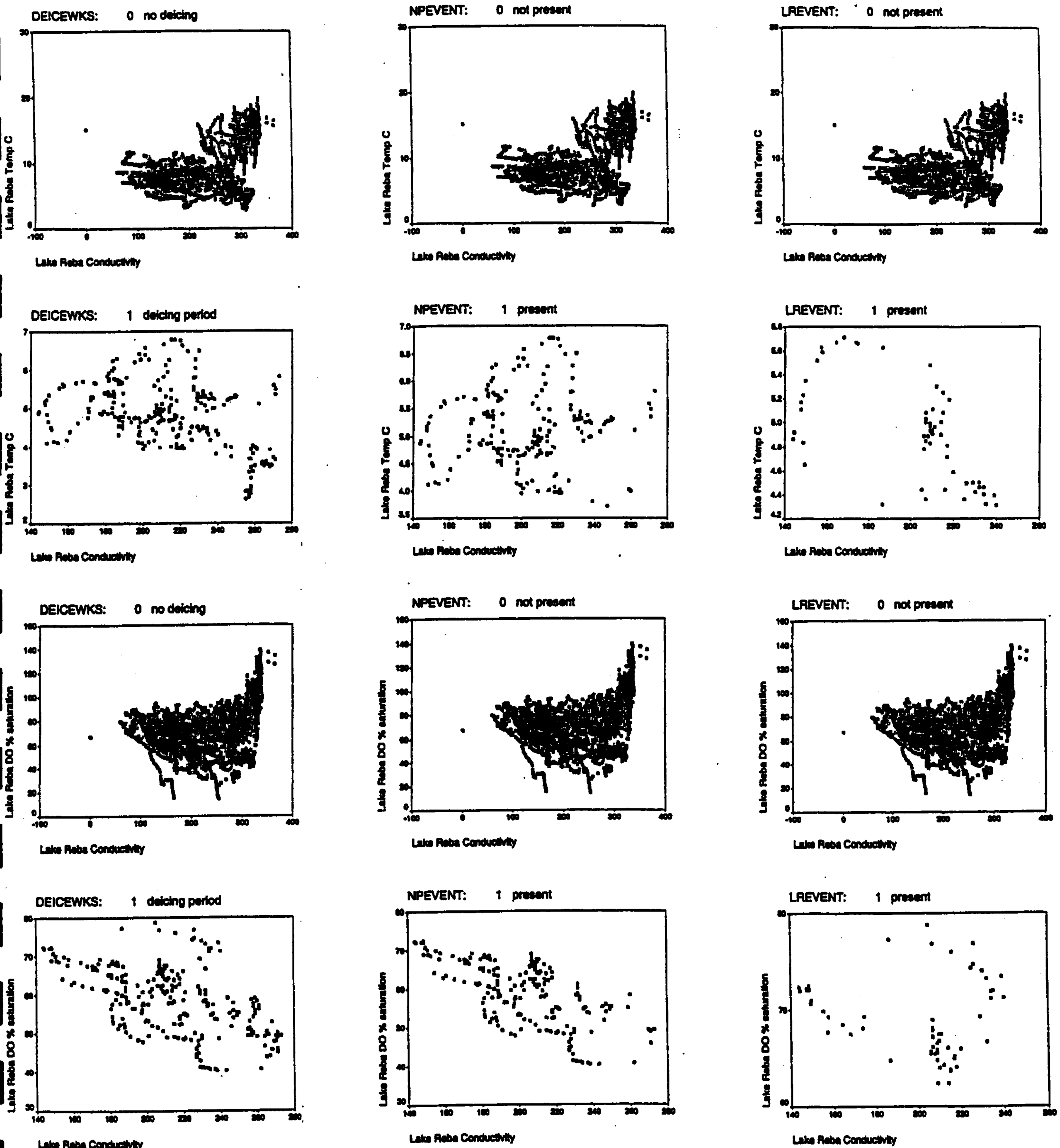
Appendix D6. Figure 6.

Scatter plots of conductivity and temperature, conductivity and DO % saturation at NP3. In Column 1 (deicewks, no deicing, deicing period), the deicing period is the entire two-week deicing period. In Column 2 (Npevent, signal present, signal not present), the deicing period is the period of time that a deicing signal was present at NP3. In Column 3 (LRevent, signal present, signal not present), the deicing period is the period of time during which there was a deicing signal present at Lake Reba.



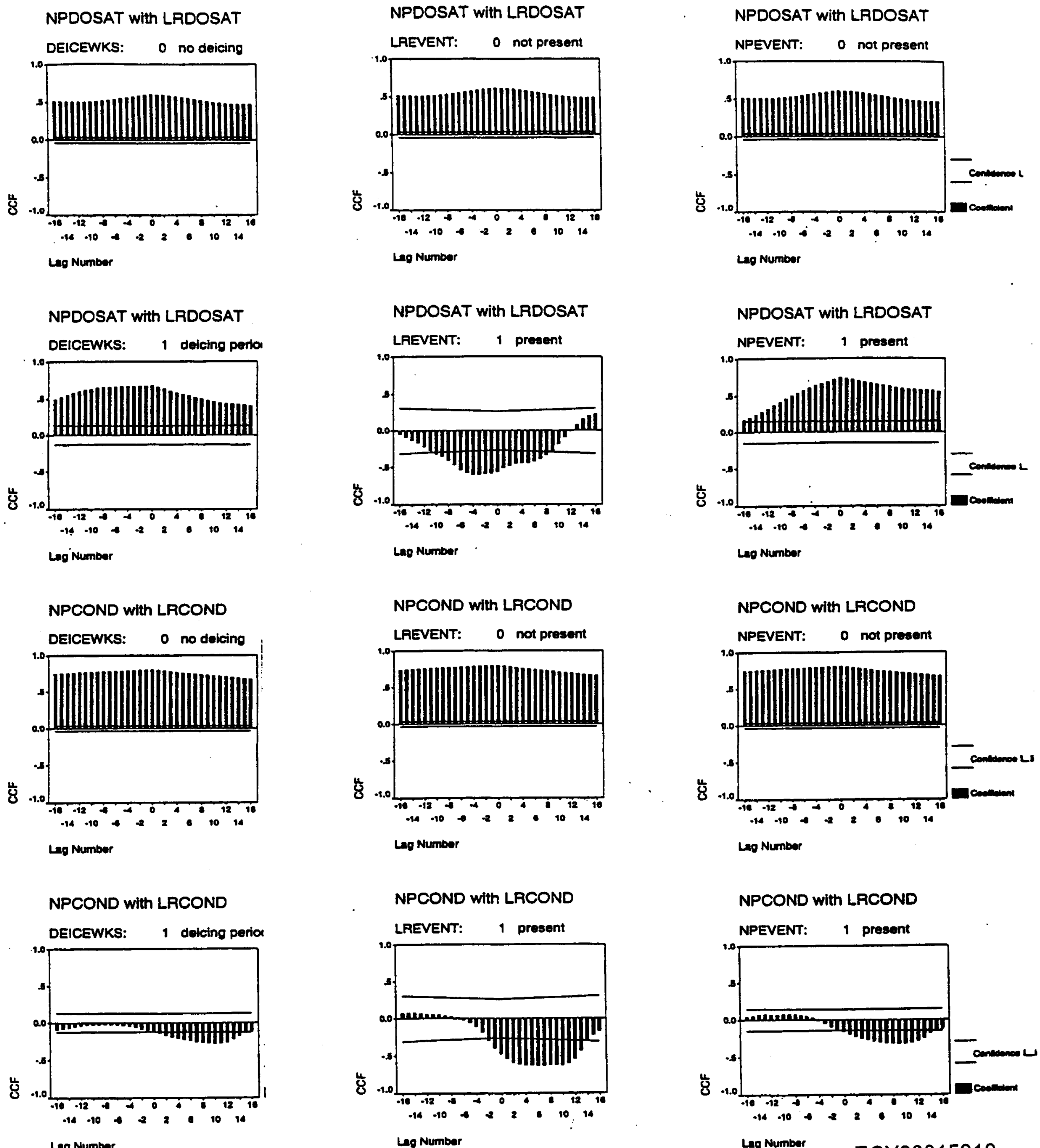
Appendix D6. Figure 7.

Scatter plots of water level and temperature, water level and conductivity at Lake Reba. In Column 1 (deicewks, no deicing, deicing period), the deicing period is the entire two-week deicing period. In Column 2 (Npevent, signal present, signal not present), the deicing period is the period of time that a deicing signal was present at NP3. In Column 3 (LRevent, signal present, signal not present), the deicing period is the period of time during which there was a deicing signal present at Lake Reba.



Appendix D6. Figure 8.

Scatter plots of conductivity and temperature, conductivity and DO % saturation at Lake Reba. In Column 1 (deicewks, no deicing, deicing period), the deicing period is the entire two-week deicing period. In Column 2 (Npevent, signal present, signal not present), the deicing period is the period of time that a deicing signal was present at NP3. In Column 3 (LRevent, signal present, signal not present), the deicing period is the period of time during which there was a deicing signal present at Lake Reba.



ECY00015910

Appendix D6. Figure 9.

Cross-correlation functions of DO percent saturation at Lake Reba and NP3 and conductivity at Lake Reba and NP3 during non-deicing and deicing periods. In Column 1 (deicewks), the deicing period is the entire two-week deicing period. In Column 2 (LRevent), the deicing period is the period of time during which there was a deicing signal present at Lake Reba. In Column 3 (NPevent), the deicing period is the period of time that a deicing signal was present at NP3.

AR 034542

5.10 Appendix D7. Summary of ARIMA model results.

Table 1. Akaiki Information criterion and Residual variance for each ARIMA model fit to the data in each pond.

site	ARIMA parameters	AIC	Standard Error	Residual Variance
LR	1,1,1	16,231.5	1.64	2.69
	1,1,0	16,266.8	1.65	2.72
	0,1,1	16,342.3	1.66	2.77
	1,0,0	16,628.5	1.72	2.96
	0,1,0	16,637.1	1.72	2.97
	0,0,1	29,614.3	8.00	64.09
NP3	1,1,1	17,305.9	2.86	8.18
	0,1,1	17,311.5	2.86	8.19
	1,1,0	17,315.8	2.86	8.20
	1,0,0	17,366.1	2.88	8.32
	0,1,0	17,388.8	2.89	8.37
	0,0,1	24,008.9	7.49	56.13

5.11 *Appendix D8. Results of Mann-Whitney non-parametric t-tests*

This appendix presents results for Mann-Whitney non-parametric t-tests for differences between variable means during treatment and control periods as affected by the definition of the treatment period.

Table 1. Summary of results of Mann-Whitney non-parametric t-test for differences between variable means during treatment and control periods as affected by the definition of the treatment period. The treatment period was defined as (time) the same period of time at both ponds and (signal) as only those hours when a deicing signal was present at the pond (as determined by tracer ions, see text for explanation).

Treatment mean higher by both definitions		**Treatment and control means differ, but direction of difference depends on definition of treatment period**	
	6 hr % Change level - NP3	6 hr Change conductivity - NP3	time says treatment mean higher, signal says treatment mean lower
	6 hr Change level - NP3		
	6 hr Change temperature - LR		
	6 hr Change temperature - NP3		
	Level - LR		
	Level - NP3		
Treatment mean lower by both definitions			
	6 hr Change DO - NP3	6 hr % Change temperature - LR	time says treatment mean lower, signal says treatment mean higher
	6 hr Change DO saturation - NP3	6 hr % Change temperature - NP3	time says treatment mean lower, signal says treatment

			mean higher
	Conductivity - LR	DO - LR	time says treatment mean lower, signal says treatment mean higher
	Temperature - LR		
	DO - NP3		
	DO saturation - NP3		
	Temperature - NP3		
No significant difference by either definition			
	6 hr Change DO - LR		
	6 hr % Change DO - LR		
	Conductivity - NP3		
Treatment mean higher by signal			
	6 hr % Change conductivity - NP3	6 hr Change level - LR	time says treatment mean higher, signal says treatment mean lower
Treatment mean lower by signal			
	6 hr % Change level – LR	DO saturation – LR	time says treatment mean lower, signal says treatment mean higher
Treatment mean higher by time			
	6 hr Change conductivity – LR	6 hr % Change DO saturation – LR	time says treatment mean higher, signal says treatment mean lower
	6 hr Change DO saturation – LR	6 hr % Change DO saturation – NP3	time says treatment mean higher, signal says treatment mean lower
Treatment mean lower by time			
	6 hr % Change conductivity – LR		
	6 hr % Change DO – NP3		

Table 2. Means and standard deviations of selected variables during treatment and control periods using two definitions of deicing.

Pond	Variable	period	N	Mean	Standard deviation	Tracer signal	N	Mean	Standard deviation
NP3	DO	control	2933	5.27	1.73	not present	2995	5.23	1.73
		treatment	262	3.94	1.17	present	200	4.12	1.23
NP3	DO % saturation	control	3281	46.23	16.28	not present	3293	45.85	16.38
		treatment	262	31.16	9.25	present	200	32.70	9.62
NP3	Level (ft)	control	2689	6.95	2.37	not present	2751	6.99	2.37
		treatment	262	8.96	1.01	present	200	9.34	0.91
NP3	Temperature C	control	3513	8.78	2.93	not present	3575	8.70	2.97
		treatment	262	4.43	0.53	present	200	4.64	0.40
NP3	Conductivity	control	3513	149.07	42.48	not present	3575	149.04	42.12
		treatment	262	149.05	9.67	present	200	149.71	9.94
NP3	6 hr Change DO	control	2843	-0.03	0.80	not present	2905	-0.03	0.79
		treatment	262	-0.03	0.59	present	200	-0.01	0.66
NP3	6 hr Change DO saturation	control	2843	-0.03	0.80	not present	2905	-0.03	0.79
		treatment	262	-0.03	0.59	present	200	-0.01	0.66
NP3	6 hr Change temperature	control	3419	-0.01	0.56	not present	3481	-0.01	0.56
		treatment	262	0.02	0.29	present	200	0.03	0.31
NP3	6 hr Change conductivity	control	3419	0.24	8.18	not present	3481	0.27	8.13
		treatment	262	0.47	10.60	present	200	-0.06	11.89
NP3	6 hr Change level	control	2671	0.00	0.96	not present	2733	0.01	0.95
		treatment	262	-0.04	0.60	present	200	-0.11	0.59
NP3	6 hr % Change DO	control	2843	-0.0209	0.16	not present	2905	-0.0210	0.16

Pond	Variable	period	N	Mean	Standard deviation	Tracer signal	N	Mean	Standard deviation
		treatment	262	-0.0208	0.19	present	200	-0.0190	0.21
NP3	6 hr % Change DO sat	control	2843	-0.0024	0.02	not present	2905	-0.0024	0.02
		treatment	262	-0.0026	0.02	present	200	-0.0023	0.03
NP3	6 hr % Change level	control	2671	1.0049	0.10	not present	2733	1.0044	0.10
		treatment	262	1.0062	0.06	present	200	1.0142	0.06
NP3	6 hr % Change cond	control	3419	-0.0005	0.08	not present	3481	-0.0003	0.08
		treatment	262	0.0014	0.06	present	200	-0.0029	0.07
NP3	6 hr % Change temp	control	3419	-0.0034	0.06	not present	3481	-0.0035	0.06
		treatment	262	0.0019	0.07	present	200	0.0039	0.07
LR	DO	control	3670	7.78	1.79	not present	3874	7.74	1.76
		treatment	262	7.35	1.06	present	58	8.61	0.55
LR	DO % saturation	control	3972	69.30	19.04	not present	4176	68.65	18.86
		treatment	262	58.87	8.49	present	58	69.05	4.08
LR	Level ft	control	3230	3.75	2.10	not present	3367	3.78	2.06
		treatment	195	4.80	1.05	present	58	5.93	0.81
LR	Temp C	control	3971	8.85	3.29	not present	4175	8.66	3.33
		treatment	262	4.82	0.87	present	58	4.92	0.41
LR	Conductivity	control	3971	230.16	71.89	not present	4175	229.50	70.04
		treatment	262	212.93	32.05	present	58	199.91	29.08
LR	6 hr Change DO	control	3600	-0.01	0.65	not present	3804	-0.01	0.64
		treatment	262	-0.07	0.53	present	58	0.01	0.58
LR	6 hr Change DO saturation	control	3902	-0.09	7.30	not present	4106	-0.13	7.18
		treatment	262	-0.50	4.37	present	58	0.44	4.76
LR	6 hr Change level	control	3218	0.01	0.94	not present	3355	0.01	0.93
		treatment	195	-0.06	0.76	present	58	0.00	1.10

Pond	Variable	period	N	Mean	Standard deviation	Tracer signal	N	Mean	Standard deviation
LR	6 hr Change temperature	control	3901	-0.01	1.10	not present	4105	0.00	1.08
		treatment	262	0.03	0.47	present	58	0.06	0.31
LR	6 hr Change conductivity	control	3901	0.02	20.85	not present	4105	0.19	20.20
		treatment	262	1.11	18.05	present	58	-7.22	20.32
LR	6 hr % Change DO	control	3600	0.00	0.09	not present	3804	-0.0055	0.09
		treatment	262	-0.01	0.07	present	58	-0.0005	0.07
LR	6 hr % Change DO sat	control	3902	-0.007	0.10	not present	4106	-0.0072	0.10
		treatment	262	-0.012	0.08	present	58	0.0041	0.07
LR	6 hr % Change level	control	2859	-0.042	2.24	not present	2996	-0.0421	2.19
		treatment	195	-0.030	0.19	present	58	-0.0130	0.16
LR	6 hr % Change cond	control	3901	[illegible]	[illegible]	not present	4105	-0.1857	10.57
		treatment	262	0.001	0.09	present	58	-0.0464	0.11
LR	6 hr % Change temp	control	3901	0.008	0.11	not present	4105	-0.0075	0.11
		treatment	262	0.000	0.10	present	58	0.0120	0.06

AR 034548

ECY00015916

Table 3. Ranks of selected variables used in Mann-Whitney U tests of differences between treatment and control periods using two definitions of deicing.

Pond	Variable	period	N	Mean rank	Tracer signal	N	Mean rank
NP3	DO	control	2933	1,663.63	not present	2995	1,639.98
		treatment	262	863.24	present	200	969.40
NP3	DO % saturation	control	3231	1,824.96	not present	3293	1,799.12
		treatment	262	785.56	present	200	888.89
NP3	Level (ft)	control	2689	1,397.46	not present	2751	1,413.40
		treatment	262	2,282.10	present	200	2,337.06
NP3	Temperature C	control	3513	2,009.15	not present	3575	1,975.33
		treatment	262	263.64	present	200	326.99
NP3	Conductivity	control	3513	1,882.31	not present	3575	1,882.88
		treatment	262	1,964.32	present	200	1,979.56
NP3	6 hr Change DO	control	2843	1,542.74	not present	2905	1,543.83
		treatment	262	1,664.36	present	200	1,686.14
NP3	6 hr Change DO saturation	control	2843	1,542.74	not present	2905	1,543.83
		treatment	262	1,664.36	present	200	1,686.14
NP3	6 hr Change temperature	control	2671	1,496.62	not present	2733	1,500.76
		treatment	262	1,165.05	present	200	1,005.72
NP3	6 hr Change conductivity	control	3419	1,825.55	not present	3481	1,829.15
		treatment	262	2,042.57	present	200	2,047.29
NP3	6 hr Change level	control	3419	1,853.03	not present	3481	1,857.90
		treatment	262	1,684.06	present	200	1,546.93
NP3	6 hr % Change DO	control	2848	1,545.13	not present	2905	1,543.86

Pond	Variable	period	N	Mean rank	Tracer signal	N	Mean rank
		treatment	262	1,638.43	present	200	1,685.74
NP3	6 hr % Change DO sat	control	2845	1,545.77	not present	2905	1,543.95
		treatment	262	1,631.44	present	200	1,684.51
NP3	6 hr % Change level	control	2671	1,445.64	not present	2733	1,439.38
		treatment	262	1,684.77	present	200	1,844.45
NP3	6 hr % Change conductivity	control	3419	1,831.16	not present	3481	1,834.12
		treatment	262	1,969.41	present	200	1,960.81
NP3	6 hr % Change temperature	control	3419	1,854.18	not present	3481	1,858.69
		treatment	262	1,669.02	present	200	1,533.05
LR	DO	control	3670	1,988.72	not present	3874	1,956.60
		treatment	262	1,655.28	present	58	2,627.56
LR	DO % saturation	control	3972	2,165.99	not present	4176	2,115.80
		treatment	262	1,382.35	present	58	2,239.97
LR	Level ft	control	2864	1,489.12	not present	3000	1,508.29
		treatment	194	2,125.58	present	58	2,626.24
LR	Temp C	control	3971	2,227.55	not present	4175	2,140.46
		treatment	262	441.42	present	58	427.98
LR	Conductivity	control	3971	2,140.53	not present	4175	2,124.90
		treatment	262	1,760.31	present	58	1,548.44
LR	6 hr Change DO	control	3600	1,936.58	not present	3804	1,928.32
		treatment	262	1,861.66	present	58	2,140.04
LR	6 hr Change DO saturation	control	3902	2,080.84	not present	4106	2,078.07
		treatment	262	2,107.28	present	58	2,396.46
LR	6 hr Change level	control	2845	1,525.28	not present	2981	1,519.46
		treatment	188	1,391.65	present	52	1,375.84

Pond	Variable	period	N	Mean rank	Tracer signal	N	Mean rank
LR	6 hr Change temperature	control	3901	2,064.53	not present	4105	2,075.92
		treatment	262	2,342.07	present	58	2,512.21
LR	6 hr Change conductivity	control	3901	2,077.10	not present	4105	2,091.05
		treatment	262	2,154.89	present	58	1,441.29
LR	6 hr % Change DO	control	3600	1,938.14	not present	3804	1,928.22
		treatment	262	1,840.31	present	58	2,146.38
LR	6 hr % Change DO sat	control	3902	2,084.16	not present	4106	2,078.10
		treatment	262	2,057.80	present	58	2,394.13
LR	6 hr % Change level	control	2845	1,524.51	not present	2981	1,519.39
		treatment	188	1,403.33	present	52	1,379.75
LR	6 hr % Change conductivity	control	3901	2,068.96	not present	4105	2,075.67
		treatment	262	2,276.14	present	58	2,529.73
LR	6 hr % Change temperature	control	3901	2,076.84	not present	4105	2,091.20
		treatment	262	2,158.87	present	58	1,430.84

Table 4. Summary of results of nonparametric Mann-Whitney U tests of differences between control and both defeinitions of treatment periods. P values < 0.05 indicate the difference between the time periods was statistically significant.

Nonparametric test	location	Was the mean greater when the signal was present or not present?	Was the mean greater during the treatment or the control period?	Mann-Whitney P value (signal-basis)	Mann-Whitney P value (time-basis)	summary
DO	NP3	not present	control	0.00	0.00	control mean higher
DO % saturation	NP3	not present	control	0.00	0.00	control mean higher
Level (ft)	NP3	present	treatment	0.00	0.00	treatment mean higher
Temperature C	NP3	not present	control	0.00	0.00	control mean higher
Conductivity	NP3	present	treatment	0.22	0.24	treatment mean higher
6 hr Change DO	NP3	present	treatment	0.03	0.04	treatment mean higher
6 hr Change DO saturation	NP3	present	treatment	0.03	0.04	treatment mean higher
6 hr Change level	NP3	present	treatment	0.00	0.00	treatment mean higher
6 hr Change temperature	NP3	not present	control	0.00	0.01	control mean higher
6 hr Change conductivity	NP3	not present	control	0.00	0.00	control mean higher
6 hr % Change DO	NP3	present	treatment	0.03	0.11	treatment mean higher
6 hr % Change DO sat	NP3	present	treatment	0.03	0.14	treatment mean higher
6 hr % Change level	NP3	present	treatment	0.00	0.00	treatment mean higher
6 hr % Change temperature	NP3	not present	control	0.00	0.01	control mean higher
6 hr % Change conductivity	NP3	present	treatment	0.10	0.04	treatment mean higher
DO	LR	present	control	0.00	0.00	results depend on definition of deicing
DO % saturation	LR	present	control	0.44	0.00	results depend on definition of deicing
Level (ft)	LR	present	treatment	0.00	0.00	treatment mean higher
Temperature C	LR	not present	control	0.00	0.00	control mean higher

Nonparametric test	location	Was the mean greater when the signal was present or not present?	Was the mean greater during the treatment or the control period?	Mann-Whitney P value (signal-basis)	Mann-Whitney P value (time-basis)	summary
Conductivity	LR	not present	control	**0.00**	**0.00**	control mean higher
6 hr Change DO	LR	present	control	0.15	0.29	results depend on definition of deicing
6 hr Change DO saturation	LR	present	treatment	**0.05**	0.73	treatment mean higher
6 hr Change level	LR	not present	control	0.24	**0.04**	control mean higher
6 hr Change temperature	LR	present	treatment	**0.01**	**0.00**	treatment mean higher
6 hr Change conductivity	LR	not present	treatment	**0.00**	0.31	results depend on definition of deicing
6 hr % Change DO	LR	present	control	0.14	0.17	results depend on definition of deicing
6 hr % Change DO sat	LR	present	control	**0.05**	0.73	results depend on definition of deicing
6 hr % Change level	LR	not present	control	0.25	0.06	control mean higher
6 hr % Change temperature	LR	not present	treatment	**0.00**	0.28	results depend on definition of deicing
6 hr % Change conductivity	LR	present	treatment	**0.00**	**0.01**	treatment mean higher

Appendix D References

Cressie, N.A.C. Statistics for Spatial Data. Wiley Series in Probability and Mathematical Statistics. 1993.

Diggle, P.J. Time Series, A Biostatistical Introduction. Clarendon Press, Oxford, England, 1990.

http://www.duke.edu/~rnau/411arim3.htm Identifying the numbers of AR or MA terms , Duke University, School of Business, BA411, Statistical Forecasting. Class notes.

6 APPENDIX E CHEMICAL APPLICATION SUMMARY

This appendix contains the list of chemical applications recorded and supplied by POS Aviation Maintenance. It does not reflect any corrections that the data in this report suggest. Corrections, as indicated by tracer data discussed in the report, are incorporated in the summary tables in the Appendix F. Applications were summarized for each SDS subbasin and drainage area corresponding to the sampling points used in this study. These applications were allocated to SDS subbasins (and drainage areas corresponding to sampling locations use din this project) based upon nomenclature used by POS maintenance for application areas and the corresponding drainage systems as shown on drawing STIA-9918.

(this page intentionally blank)

Summary of 2000 Ground Deicing Chemical Applications

NPDES DO study

CMA (lb)

Potassium Acetate (gal)

Date	Time	Landside applications	AOA applications	Chemical	chem qty	sand lb	subbasin	subbasin
1/12/2000	400	#1 offramp 170th		CMA (1/2)	2300	2300	SDE4	DME
1/12/2000	530	South Employee Lot		CMA (1/2)	10000	10000	NA	DME
1/24/2000	800	Fire Station AOA & Road side		CMA (1/2)	200	200	SDE4	DME
1/12/2000	900	north Lot		CMA (1/2)	4340	4340	NA	NEPL
1/24/2000	700	North Empl. lot to 160th Aircargo		CMA (1/2)	900	900	SDN1	N1
1/24/2000	900	160th East to Hy 99 & back		CMA (1/2)	1200	1200	NA	NA
1/11/2000	30		16/R-34/L	E-36	635		AF	AF
1/11/2000	130		16/L-34R	E-36	1697		AF	AF
1/11/2000	154		16/L-34R	E-36	612		AF	AF
1/11/2000	415		16/L-34R	E-36	1362		AF	AF
1/11/2000	435		16/R-34/L &TW/Q &TW/	E-36	1430		AF	AF
1/12/2000	215		16/R-34/L	E-36	1047		AF	AF
1/19/2000	430	Touchdown area 34/R		E-36	204		SDS4, SD	AF
1/19/2000	445	Touchdown area 34/L		E-36	237		SDS3	AF
1/19/2000	500	South end B/TW over 188th tunnel		E-36	31		SDS4, SD	AF
1/11/2000	315		TW/A	E-36	443		SDE4	DME
1/12/2000	115		Gate E-100	E-36	50		SDE4	DME
1/12/2000	215		AOA rd - So Hard stand	E-36	25		SDE4	DME
1/12/2000	245	170th Brg to Clock freeway N&S		E-36	125		SDE4	DME
1/12/2000	300		Hill behind D concourse	E-36	75		SDE4	DME
1/12/2000	305		B/TW & A/TW	E-36	1195		SDE4	DME
1/12/2000	400	Bus Route		E-36	150		SDE4	DME
1/12/2000	605		So. Sat & No. Sat & N/T	E-36	717		SDS1	DME
1/12/2000	620	Upper Dr		E-36	15		SDE4	DME
1/12/2000	630	Lower Dr		E-36	25		SDE4	DME
1/12/2000	645	170th Brg no		E-36	25		SDE4	DME
1/12/2000	700	170th Brg so		E-36	5		SDE4	DME
1/19/2000	229	Aircargo 4 to 161th east		E-36	3		SDE4	DME
1/19/2000	231	Aircargo 4 parking lot		E-36	1		SDE4	DME
1/28/2000	500	Upper Dr south		E-36	5		SDE4	DME
1/12/2000	608	160th Brg		E-36	15		SDN1	N1
1/18/2000	600	Aircargo road 160th to 154th		E-36	50		SDN1	N1
1/19/2000	525	Aircargo Rd 160th north to 154th		E-36	10		SDN1	N1
1/19/2000	525	Aircargo Rd 154th to 160th		E-36	10		SDN1	N1
1/11/2000	100	Parking G. spirals No & So		E-36	100		IWS	NA
1/11/2000	130	Parking G. Exit lane 1-10		E-36	10		IWS	NA
1/11/2000	200	Parking G. Exit from oversize lot		E-36	5		IWS	NA
1/11/2000	230	Parking G. Exit toll plaza		E-36	10		IWS	NA
1/11/2000	300	Parking G. taxi lot		E-36	10		IWS	NA
1/11/2000	315	Parking G. 3rd floor enterance		E-36	10		IWS	NA
1/11/2000	330	Dan Baker road (3rd floor enter.)		E-36	5		IWS	NA
1/12/2000	130		Gate E-185	E-36	50		IWS	NA
1/12/2000	200		South Hard Stand	E-36	25		SDS4	NA
1/12/2000	230		Cargo 4	E-36	25		IWS	NA
1/19/2000	225		Aircargo 4 fuel pumps	E-36	1		IWS	NA
1/19/2000	200	160th street east & west		SA (1/2)	250	250	NA	NA
1/19/2000	230	North Emploee lot		SA (1/2)	1650	1650	NA	NEPL
1/19/2000	630	Upper Dr south		SA	350		SDE4	DME
1/19/2000	630	From 170th bridge north to clock		SA	2125		SDE4	DME
1/19/2000	630	Upper dr. So		SA	350		SDE4	DME
1/19/2000	630	170th bridge No & So to clock		SA	4250		SDE4	DME
1/19/2000	645	From clock south to 170th bridge		SA	4000		SDE4	DME
1/19/2000	645	From 170th bridge north to clock		SA	4000		SDE4	DME
1/19/2000	645	on ramp 170th		SA	50		SDE4	DME
1/19/2000	645	off ramp 170th		SA	50		SDE4	DME
1/19/2000	645	From clock south to 170th bridge		SA	4000		SDE4	DME
1/19/2000	645	From 170th bridge north to clock		SA	4000		SDE4	DME
1/19/2000	645	on ramp 170th		SA	50		SDE4	DME
1/19/2000	645	off ramp 170th		SA	50		SDE4	DME
1/24/2000	500	Aircargo Rd 160th north to 154th		SA	1345		SDN1	N1
1/24/2000	500	North Empl. lot to 160th Aircargo		SA	1345		SDN1	N1
12/3/1999	400	So Empl Lot				1	NA	DME

Summary of 2000 Ground Deicing Chemical Applications

NPDES [illegible]

SAND (lbs) with minor chemical (PA) added to prevent freezing

Date	Time	Landside application	AOA application	Chemical	chem qty	sand lb	subbasin	subbasin
12/8/1999	915	So Empl Lot				1700	NA	DME
1/11/2000	430	Multi Lane-R/lane				100	SDE4	DME
1/12/2000	30	Upper & Lower Dr				11,000	SDE4	DME
1/12/2000	30	Upper & Lower Dr				11,000	SDE4	DME
1/12/2000	300	Upper & Lower Dr				11000	SDE4	DME
1/12/2000	300	Upper & Lower Dr				11000	SDE4	DME
1/12/2000	400	South remote Lot				1475	NA	DME
1/12/2000	430	Gate E-100				75	SDE4	DME
1/12/2000	500	South Lot				50	SDE4	DME
1/19/2000	645	188th No to Tunnel on Aircargo rd				845	NA	DME
1/19/2000	655	Aircargo rd So Tunnel to 188th st				845	NA	DME
1/19/2000	800	South Parking lot				800	SDE4	DME
1/19/2000	845	South enterance to parking				820	SDE4	DME
1/19/2000	900	Lower DR & Upper DR				1000	SDE4	DME
1/19/2000	900	North enterance to parking garage				200	SDE4	DME
1/19/2000	900	down ramp to parking garage				820	SDE4	DME
1/28/2000	2200	South GT lot				30	SDE4	DME
12/27/1999	600	160th Brige				50	SDN1	N1
1/11/2000	530	Aircargo Rd north				6000	SDN1	N1
1/12/2000	500	Biffy Dump				50	IWS	NA
1/12/2000	500	E-185				50	IWS	NA
1/12/2000	515	Delta Emplolee Lot				50	IWS	NA
1/15/2000	530	in front of g Bus - Limo lot 160th st				100	NA	NA
1/12/2000	300	north Lot				1525	NA	NEPL
1/12/2000	430	North Lot				50	NA	NEPL
1/18/2000	635	North Emploee Parking lot				3200	NA	NEPL
1/19/2000	800	North Emploee lot				3320	NA	NEPL

1. "CMA (1/2)" and SA (1/2) mean 50/50 sand/chemical mixture applied (solid)
2. Sand used on "roadside" had minor amount of liquid E36 (potassium acetate) sprayed on to prevent freezing.
3. Chemical application trucks used on the AOA have "dickey box" computer controller/flowmeters that calculate quantities to higher precision, hence the number of significant figures on some PA qtys.
4. applications were allocated to SDS subbasins (and drainage areas corresponding to sampling locations use din this project) based upon nomenclature used for application areas and corresponding drainage systems as shown on drawing STIA-9918.
5. All times indicated for January 11th are assumed to be for January 12th given that first notice of chemical applications was given on January 12, 01:39 AM. There were no freezing temperatures nor frozen precipitation recorded by the NWS on January 11th.
6. All chemical applications to the airfield (runways and taxiways as indicated in this table) were lumped into one volume and allocated amongst the SDS3, SDS4, SDN3 and SDN4 subbasins according to the percent of impervious area for each subbasin relative to the total impervious area of the entire airfield drainage.

E-36: Potassium Acetate E-36
SA: Sodium Acetate
CMA: Calcium Magnesium Acetate

AR 034557

7 APPENDIX F BOD ESTIMATES

This appendix summarizes methods used to estimate theoretical BOD loads described in this report. Importantly, the estimates of BOD attributable to ground-deicing chemicals are based only on the volumes applied, as recorded and summarized in Appendix E and tables in the main body of the report. That is, the load estimates do not necessarily reflect what occurred in discharges. All BOD estimates are based upon the actual data obtained by Horner (1996) for BOD rates of PA and CMA tested at 4°C over periods of one to 35 days. BOD attributable to SA is assumed to be similar to CMA, which is supported by the manufacturer's MSDS (Cryotech, 1999) and other literature (Horner, 1996b).

BOD estimates are the product of chemical volume (either reported or calculated otherwise) and the BOD values (g BOD per g chemical) listed in the tables, converted to pounds using the appropriate specific gravity listed on the suppliers' MSDS. Glycol volumes estimated in SDS3 and SDE4 discharges are the products of sample glycol concentration and total discharge volume that occurred during the sampling period.

Tables 7-1 through 7-4 show estimates of BOD for the January 11-12, 2000 ground-deicing event. Tables 7-4 and 7-7 compare the BOD attributable to glycols found in stormwater samples with BOD estimated for all chemicals applied during the January 2000 and December 1998 events, respectively. These two tables highlight the relevant BOD_{5+} estimates cited in the text of Volume 1, Executive Summary and Section 2.4. Tables 7-5 through 7-7 show BOD estimates for the December 24, 1998 event that are cited in the text of Volume 1, Section 2.4.

AR 034558

ECY00015926

Table 7-1 Total Volumes of Ground Deicers and ADAFs (glycols) during the January 11-12, 2000 event

total volumes reported	area	*PA, lb	CMA, lb	SA, lb	EG, gal	PG, gal	PA, gal
	DME (SDE4)	30160	12300	0			2850
	NWP (SDS3)	57548	0	0			5438
	LR (N1, N3/N4)	9048	4340	0			855
	IWS	2381	0	0			225
	other	0	0	0			0
	sum	99,137	16,640	-	17	571	9,368
	*uses speicific gravity per MSDS of			1.275			

note: Ethylene (EG) and Propylene (PG) glycol volumes estimated using results from Jan 11-12 samples taken at SDS3 and SDE4. See Table 7-2 below.

Table 7-2 Estimates of Glycol Volumes from January 11-12, 2000 Deicing Event Stormwater Sample Results

	sample results, mg/l				estimated loads (gal)			ADAFs applied (gal)**			% escape to SDS		
outfall	EG	PG	total glycols	stormwater discharge volume*, gal	EG	PG	total glycols	EG	PG	total	EG	PG	total glycols
SDE4	4.5	7.47	12	303,417	1	2	4	734	14904	15638	0.2%	0.02%	0.02%
SDS3	9.47	355	364	1,600,973	15	568	583	734	14904	15638	2.1%	3.8%	3.7%
								3 day totals Jan 11-13					
				Sum:	17	571	586				2.3%	3.8%	3.7%

*From Flowlink 4.1 data: volume discharged during flow-weighted composite sampling period

**as reported to POS by airlines, includes totals in dry period prior to first runoff sampled

AR 034559

ECY00015927

Table 7-3 BOD5 Estimates for Ground Deicing Chemicals Applied in January 2000

BOD5 (lb) Estimates for Jan 11-12 event only								
	PA*	% of total	CMA	% of total	SA	% of total	sum	% of total
L. Reba	2,440	8%	790	3%	-	0%	3,230	11%
NW Ponds	15,540	52%	-	0%	-	0%	15,540	52%
DME	8,140	27%	2,250	8%	-	0%	10,390	35%
IWS	640	2%	-	0%	-	0%	640	2%
other	-	0%	-	0%	-	0%	-	0%
total	26,760	90%	3,040	10%	-	0%	29,800	100%

* using specific gravity per MSDS of 1.275

BOD5 (lb) Estimates for all events of January 2000								
	PA*	% of total	CMA	% of total	SA	% of total	sum	% of total
L. Reba	2,640	7%	960	3%	790	2%	4,390	11%
NW Ponds	16,210	42%	-	0%	-	0%	16,210	42%
DME	10,360	27%	2,290	6%	4,260	11%	16,910	44%
IWS	650	2%	-	0%	-	0%	650	2%
other	-	0%	220	1%	50	0%	270	1%
total	29,860	78%	3,470	9%	5,100	13%	38,400	

BOD rates from literature review and actual tests conducted by Horner (1996)

	% of ult BOD as f(time) @ 4°C**			
type	1	5	10	20
PA	51%	30%	56%	87%
CMA	51%	30%	56%	87%
SA	51%	30%	56%	87%

	g BOD/g compound @ 4°C		
type	BOD1	BOD5	ult BOD
PA	0.46	0.27	0.9
CMA	0.31	0.18	0.61
SA	0.31	0.18	0.61

**note: above values are as measured and include distinct lag phase

note: SA and CMA assumed to have similar lag to PA

AR 034560

ECY00015928

Table 7-4 BOD Estimates for ground deicers and ADAFs (glycols) applied during January 11-12, 2000 event

	drainage area	BOD1	BOD2	BOD3	BOD4	BOD5	BOD10	BOD20	BOD26	ult BOD
total BOD	DME (SDE4)	17709	14629	12704	8469	10394	19248	30027	33107	34647
	NWP (SDS3)	26472	21868	18991	12661	15538	28774	44888	49491	51793
	LR (N1, N3/N4)	5515	4556	3957	2638	3237	5995	9352	10311	10790
	IWS	1095	905	786	524	643	1191	1857	2048	2143
	other	0	0	0	0	0	0	0	0	0
	sum (lb)	50,790	41,960	36,440	24,290	29,810	55,210	86,120	94,960	99,370
BOD from glycols	EG*	46	11	9	9	59	126	172	172	172
	EG % TG	1%	1%	1%	4%	3%	2%	2%	2%	2%
	EG % grand	0.1%	0.03%	0.02%	0.04%	0.2%	0.2%	0.2%	0.2%	0.2%
	PG*	3712	1237	742	247	1683	6434	9601	10146	10393
	TG sum	3758	1249	751	257	1741	6560	9773	10318	10565
	TG%grand	6.9%	2.9%	2.0%	1.0%	[redacted]	10.6%	10.2%	9.8%	9.6%
	grand total (lb)	54,550	43,210	37,190	24,550	31,550	61,770	95,890	105,280	109,940
	*uses specific gravity per MSDS of			1.045						
		values used in table above: gBOD/g compound @4°C (source: Homer, 1996)								
	chem type	BOD1	BOD2	BOD3	BOD4	BOD5	BOD10	BOD20	BOD26	ult BOD
g BOD/g	PA	[redacted]								
	CMA	0.31	0.26	0.22	0.15	0.18	0.34	0.53	0.58	[redacted]
	SA	0.31	0.26	0.22	0.15	0.18	0.34	0.53	0.58	0.61
	EG	[redacted]								
	PG									
% ult	PA	51%	42%	37%	24%	30%	56%	87%	96%	100%
	CMA	51%	42%	37%	24%	30%	56%	87%	96%	100%
	SA	51%	42%	37%	24%	30%	56%	87%	96%	100%
	EG	27%	7%	5%	5%	34%	73%	100%	100%	100%
	PG	36%	12%	7%	2%	16.2%	62%	92%	98%	100%

[redacted]

assume CMA and SA have decay rates similar to PA (use same %of ult BOD)
assume SA has same ultimate BOD as CMA

Table 7-5 Total Volumes of Ground Deicers and ADAFs (glycols) during December 24, 1998 event

	drainage area	PA*, lb	CMA, lb	SA, lb	EG, gal	PG, gal	PA, gal
total volumes reported	DME (SDE4)	58760	0	20000			5553
	NWP (SDS3)	112118	6000	0			10595
	LR (N1, N3/N4)	17628	800	4000			1666
	IWS	4639	0	0			438
	other	515	0	0			49
	sum	193,660	6,800	24,000	83	212	18,300
	*uses speicific gravity per MSDS of			1.275			

note: Ethylene (EG) and Propylene (PG) glycol volumes estimated using results from Dec. 24, 1998 samples taken at SDS3 and SDE4. See Table 7-6 below.

Table 7-6 Estimates of Glycol Volumes from December 24, 1998 Deicing Event Stormwater Samples

	sample results, mg/l				estimated loads (gal)			ADAFs applied (gal)**			% escape to SDS		
outfall	EG	PG	total glycols	stormwater discharge volume*, gal	EG	PG	total glycols	EG	PG	total	EG	PG	total glycols
SDE4	13	31	44	500,000	7	16	22	2280	39214	41494	0.3%	0.04%	0.05%
SDS3	32	82	113	2,400,000	77	197	271	2280	39214	41494	3.4%	0.50%	0.65%
				Sum:	83	212	293	8 day total Dec 18-25			3.7%	0.54%	0.71%

*From Flowlink 4.1 data: volume discharged during flow-weighted composite sampling period

**as reported to POS by airlines, includes 7-day period of dry-weather prior to first runoff sampled

Table 7-7 BOD Estimates for ground deicers and ADAFs (glycols) applied during December 24, 1998 event

	area	BOD1	BOD2	BOD3	BOD4	BOD5	BOD10	BOD20	BOD26	ult BOD
total BOD	DME (SDE4)	33265	27480	23864	15909	19525	36158	56406	62191	65084
	NWP (SDS3)	53445	44150	38341	25561	31370	58093	90624	99919	104567
	LR (N1, N3/N4)	9605	7935	6891	4594	5638	10440	16287	17958	18793
	IWS	2134	1763	1531	1021	1253	2319	3618	3989	4175
	other	237	196	170	113	139	258	402	443	464
	sum	98,690	81,520	70,800	47,200	57,920	107,270	167,340	184,500	193,080
BOD from glycols	EG*	231	55	41	45	283	608	830	830	830
	EG % TG	15%	11%	14%	34%	32%	21%	20%	19%	18%
	EG % grand	0.2%	0.07%	0.06%	0.09%	0.5%	0.6%	0.5%	0.4%	0.4%
	PG*	1322	441	264	88	599	2291	3418	3612	3700
	TG sum	1553	496	306	133	883	2899	4248	4442	4530
	TG% grand	1.5%	0.6%	0.4%	0.3%	[redacted]	2.6%	2.5%	2.4%	2.3%
	grand total	100,240	82,020	71,110	47,330	58,800	110,170	171,590	188,940	197,610
	*uses specific gravity per MSDS of		1.045							

this table uses same BOD rates as shown in the lower half of Table 7-4 above.

AR 034562

ECY00015930

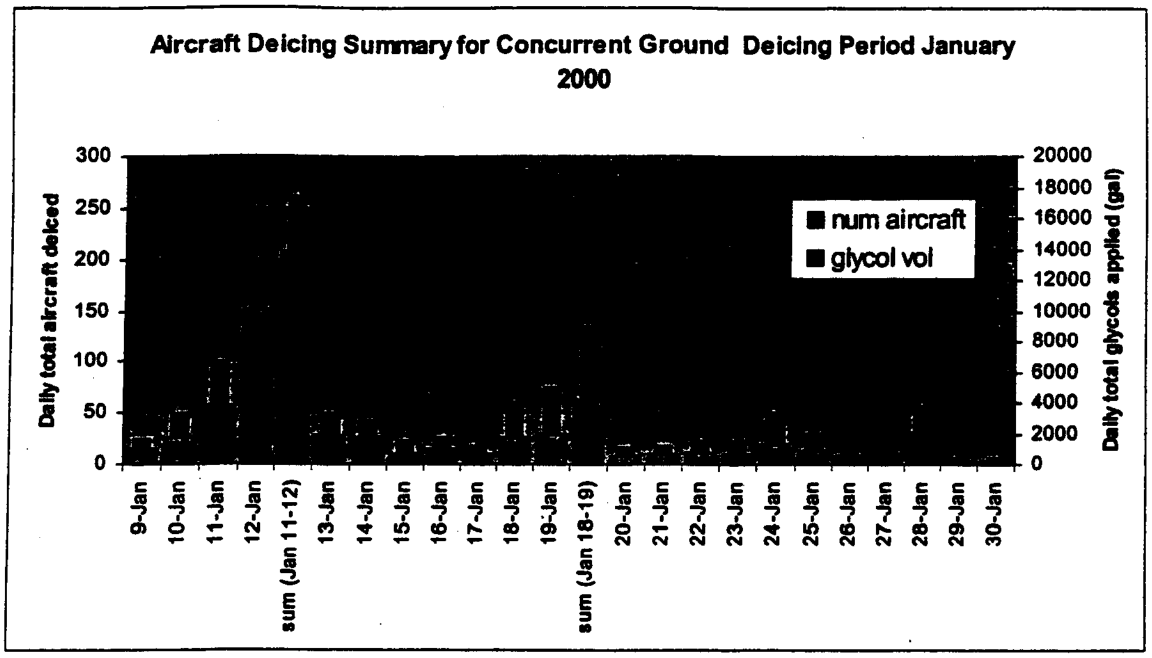


Figure 7-1 Aircraft Deicing Summary for January 2000 Deicing Event Period