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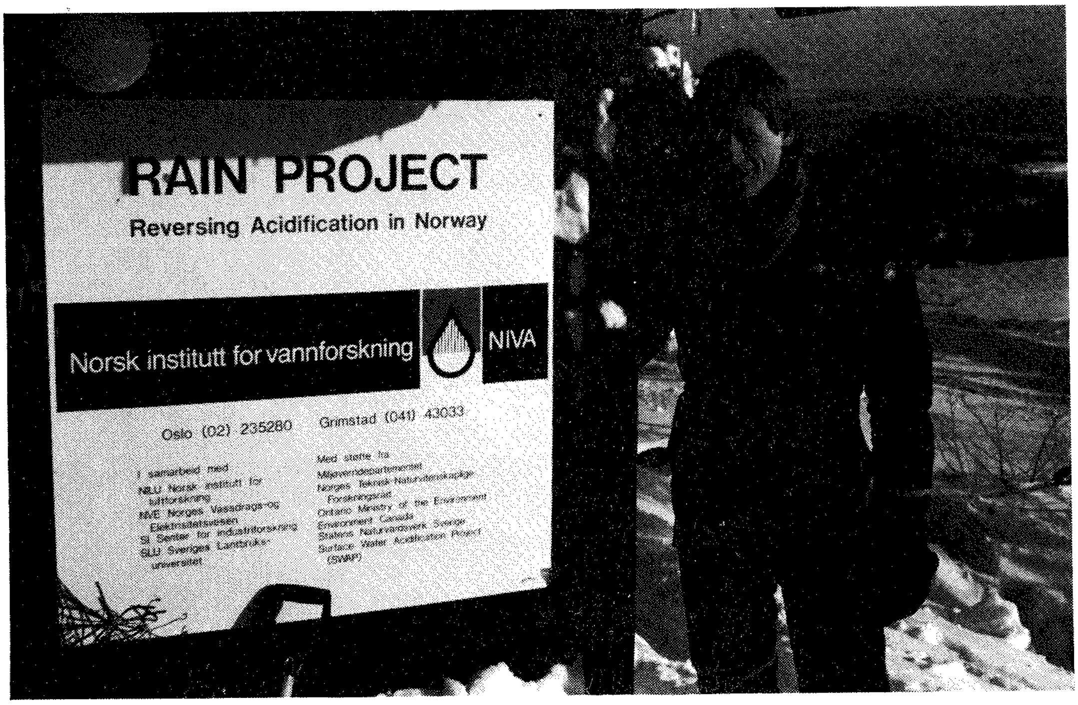
Acid Rain Research

REPORT 16/1988

RAIN–project. Annual report for 1987



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Abstract:

The RAIN project (Reversing Acidification in Norway) is an international research project aimed at investigating the effect on water and soil chemistry of changing acid deposition to whole catchments. The results from 1987 represent 4 years of treatment from Sogndal and 3 1/2 years at Risdalsheia. The original 5-year project period will be extended an additional 3 years through June 1991. Sulfate concentrations have increased from about 20-25 µeq/l to 50-57 µeq/l at SOG2 (H_2SO_4 addition) and 35-45 µeq/l at SOG4 (H_2SO_4 + HNO_3 addition). These levels are about 50% of the expected steady-state concentrations. Addition of HNO_3 has caused only minor increases in nitrate in runoff. At Risdalsheia acid-exclusion has resulted in lower concentrations of the strong acid anions NO_3 (from 35 to 7 µeq/l) and SO_4 (from 110 to 53 µeq/l) relative to both the roofed control catchment and open catchment. The input-output budgets indicate that the acid exclusion has reversed soil acidification at Risdalsheia. The effect of organic acids on the pH of runoff has increased in importance as the acid-exclusion experiment has proceeded.

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NORWEGIAN INSTITUTE FOR WATER RESEARCH

RAIN PROJECT

0-82073

Annual report for 1987

Oslo, May 1988

Richard F. Wright

ABSTRACT

The RAIN project (Reversing Acidification in Norway) is an international research project aimed at investigating the effect on water and soil chemistry of changing acid deposition to whole catchments. The project comprises two parallel large-scale experimental manipulations -- artificial acidification at Sogndal and exclusion of acid rain at Risdalsheia. The project began in June 1983 with treatments beginning in 1984. The results from 1987 represent 4 years of treatment from Sogndal and 3 1/2 years at Risdalsheia. The original 5-year project period will be extended an additional 3 years through June 1991.

Acid addition at Sogndal has caused major changes in runoff chemistry. Acid addition gives short-term episodes of acid, aluminum-rich runoff with recovery between episodes. Sulfate concentrations have increased from about 20-25 µeq/l to 50-57 µeq/l at SOG2 (H_2SO_4 addition) and 35-45 µeq/l at SOG4 (H_2SO_4 + HNO_3 addition). These levels are about 50% of the expected steady-state concentrations. Addition of HNO_3 has caused only minor increases in nitrate in runoff. The increased sulfate concentrations are compensated about 50% by increased concentrations of base cations (mainly Ca and Mg) and about 50% by decreased alkalinity. Acid addition could result in significant soil acidification within a few decades.

At Risdalsheia acid-exclusion has resulted in lower concentrations of the strong acid anions NO_3 (from 35 to 7 µeq/l) and SO_4 (from 110 to 53 µeq/l) relative to both the roofed control catchment and open catchment. The decline in strong acid anion concentrations is compensated partially by a decrease in concentrations of base cations (55%) and partially by an increase in alkalinity (45%). The input-output budgets indicate that the acid exclusion has reversed soil acidification at Risdalsheia. The effect of organic acids on the pH of runoff has increased in importance as the acid-exclusion experiment has proceeded. The acid-exclusion experiment shows that chemical changes caused by acid deposition are largely reversible.

PREFACE

A large number of individuals and institutes have cooperated in the RAIN project in 1987. Scientists active in the project during 1987 included D.F. Brakke, E. Lotse, T. Frogner, E. Gjessing, S.A. Norton, A. Semb, and R.F. Wright. Technical staff included A. Andersen, H. Efraimsen, M.-B. Flaten, R. Høgberget, T. Mindrebø, R. Nilsen, A. Rogne, and R. Storhaug. NILU, NIVA and the Department of Soil Sciences, SLU, provided technical support.

The RAIN project would not be possible without the generous cooperation of landowners at both sites. We thank N. Knagenhjelm, Sogn Televerk, and Arendal Televerk for permission to use private roads. N. Dalaker, H. Haukås, and A. Risdal provided local assistance.

Financial support in 1987 came from the Norwegian Ministry of Environment, The Royal Norwegian Council for Scientific and Industrial Research, the Ontario Ministry of the Environment, Environment Canada, the Swedish National Environmental Protection Board, and from internal research funds from NILU and NIVA.

This annual report is based largely on a draft manuscript by R.F. Wright, E. Lotse and A. Semb that was submitted to the journal Nature in April 1988.

In 1987 several auxillary projects were associated with the RAIN project (Appendix 1). These include 2 projects financed by the Surface Water Acidification Programme (SWAP) (The Royal Society, the Norwegian Academy of Science and Letters, and the Royal Swedish Academy of Sciences), modelling the acidification process (N. Christophersen, principal investigator), weathering studies in conjunction with project RAIN (R. Wright and E. Lotse, co-principal investigators), fish studies in conjunction with project RAIN (financed by Central Electricity Generating Board, R. Wright, principal investigator), a study of aluminum in soils (financed by Electric Power Research Institute, R. A. Parnell, principal investigator), and heavy metals in soils and vegetation (financed by the Royal Norwegian Council for Industrial Research and the Swedish National Environmental Protection Board, E. Steinnes, principal investigator). In 1987 one dr. scient. student (T. Frogner) was associated with the RAIN project under a fellowship from the Royal Norwegian Council for Scientific and Industrial Research.

INTRODUCTION

Acid deposition, acidification of surface waters, and loss of fish populations occur over large regions of Europe and eastern North America (Overrein et al. 1980, Wright 1983, Schindler 1988). International efforts to reduce the emissions of SO_2 and NOx are in part based on the premise that such reductions will restore acidified waters. To test this premise we are conducting whole-catchment manipulations in which the acid loading is changed experimentally. The RAIN project (Reversing Acidification In Norway) comprises two experiments: artifical acidification of 2 pristine catchments in western Norway (Sogndal site) and exclusion of ambient acid deposition at an acidified catchment in southernmost Norway (Risdalsheia site) (Figure 1).

The RAIN project began in June 1983 with the first year devoted to selection of sites, collection of pre-treatment data, and design, construction and installation of roofs, watering systems, weirs and sampling devices. The scientific program includes measurements of precipitation volume and chemical composition, soil chemistry, and runoff volume and chemical composition. The RAIN project design, organization, site descriptions and results obtained through 1986 are described in the annual reports for 1984 (Wright 1985), 1985 (Wright and Gjessing 1986) and 1986 (Wright 1987). Soils data are reported by Lotse and Otabbong (1985). In addition a data report covering the period 1983-85 is available (Wright et al. 1986). A complete list of RAIN project publications is given on the inside back cover of this document.

SOGNDAL: ACID ADDITION

The Sogndal site is a pristine but sensitive area in western Norway presently receiving only minor acid deposition (precipitation pH 4.8). The site is located 900 m above sea level and characterized by gneissic bedrock, patchy, thin (average depth 30 cm) and poorly-developed soils (Lithic Haplumbrept) with pH (H_2O) 4.5-5.5, and alpine vegetation (Lotse and Otabbong 1985). Four catchments are studied; catchment SOG2 (7220 m^2) receives H_2SO_4, catchment SOG4 (1940 m^2) receives a 1:1 mixture of H_2SO_4 + HNO_3, and catchments SOG1 (96300 m^2) and SOG3 (43200 m^2) serve as untreated controls (Table 1). The H_2SO_4 treatment provides information on the effect of sulfuric acid alone; the H_2SO_4 + HNO_3 treatment simulates a future acid deposition scenario in which SO_2 emissions are reduced but NOx emissions continue unabated. The treated catchments receive identical loadings of acid.

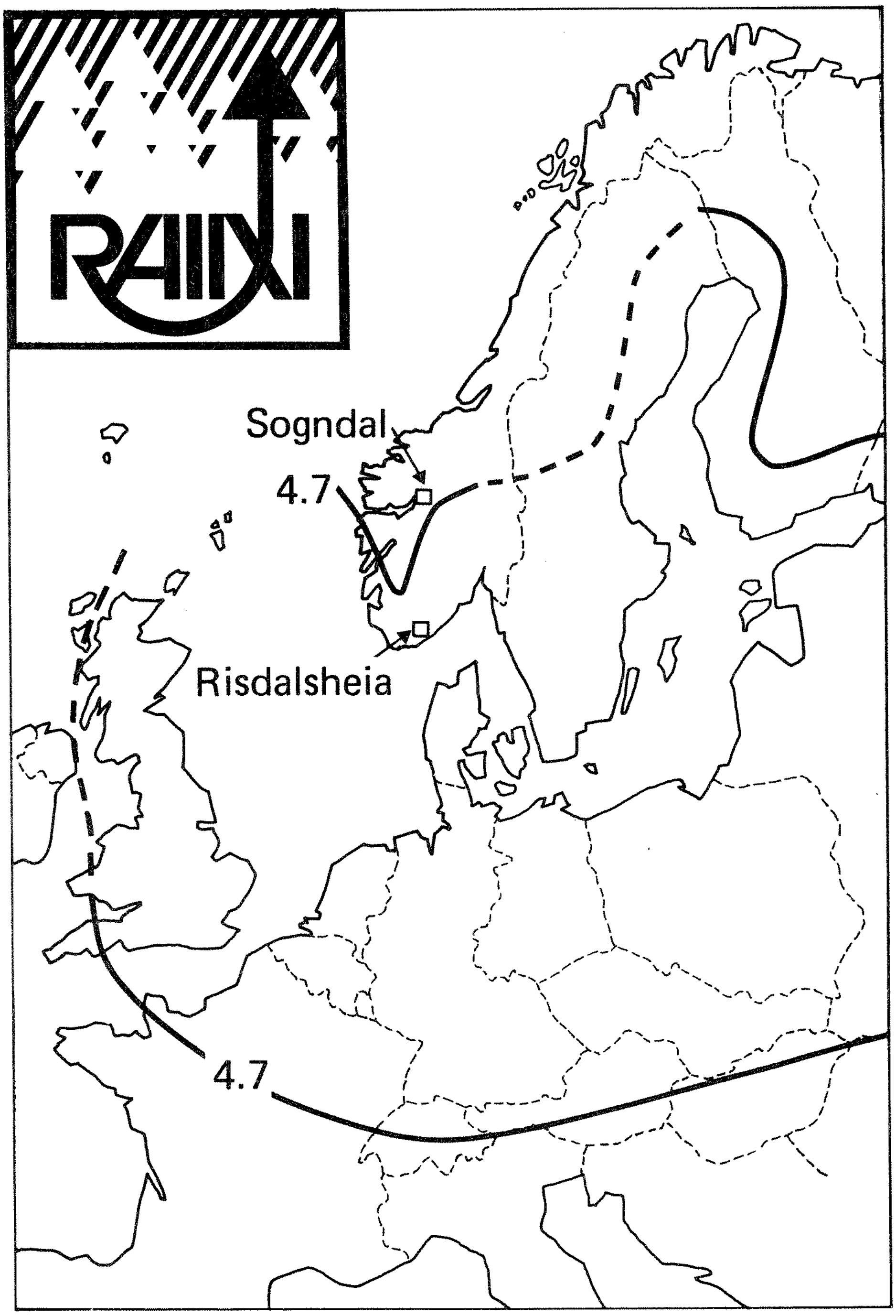

Figure 1. Location of the experimental catchments in project RAIN. Areas within the pH 4.7 isoline receive precipitation with a yearly weighted-average pH below 4.7.

Table 1. RAIN project. Overview of the experimental catchments and treatments.

Sogndal. Acid addition experiments.

Catchment	Treatment	Area
SOG1	control	96300 m^2
SOG2	H_2SO_4	7220 m^2
SOG3	control	43200 m^2
SOG4	H_2SO_4+HNO_3	1940 m^2

Risdalsheia. Acid exclusion experiments.

Catchment	Treatment	Area
KIM	roof, clean rain	860 m^2
EGIL	roof, acid rain	400 m^2
ROLF	no roof, acid rain	220 m^2

Table 2. Summary of Sogndal treatments through 1987.

Catchment SOG2.

Date	Pre-treatment Time	mm	Acid application Time	mm	Post-treatment Time	mm	Acid dose meq/m^2 H^+	SO_4	NO_3
840401			to snowpack	0,01			25.0	25.0	0
840828	1200-1350	3.9	1353-1835	11.0	1840-1910	1.0	11.2	11.2	0
840912	1420-1520	2.2	1520-2005	9.8	2005-2045	1.7	11.2	11.2	0
840926	0720-0820	2.2	0820-1310	11.0	1320-1430	1.9	11.2	11.2	0
841002	0715-0810	2.2	0810-1255	11.0	1255-1350	2.2	11.2	11.2	0
	(total added in 1984 meq/m^2: H^+ 69.8, 3.2 Na, 0.2 K, 1.0 Ca, 0.7 Mg, 3.2 Cl, 69.8 SO_4; 60 mm H_2O)								
850329			to snowpack	0.01			45.0	45.0	0
850611	1335-1405	1.1	1410-1900	11.0	1930-2035	2.1	11.2	11.2	0
850821	0800-0900	2.2	0915-1415	11.0	none		11.2	11.2	0
850821	none		1630-2100	11.0	none		11.2	11.2	0
850828	1030-1125	2.2	1125-1655	11.0	1655-1735	1.9	11.2	11.2	0
851001	none		0645-1145	11.0	none		11.2	11.2	0
	(total added in 1985 meq/m^2: H^+ 101.0, 2.4 Na, 0.1 K, 0.7 Ca, 0.6 Mg, 1.7 Cl, 102.6 SO_4; 61 mm H_2O)								
860325			to snowpack	0.01			45.0	45.0	0
860619	none		1030-1515	11.0	1515-1600	2.1	11.2	11.2	0
860819	0800-0820	2.2	0820-1250	11.0	1250-1335	2.2	11.2	11.2	0
860820	0620-0720	1.8	0740-1220	11.0	1220-1335	1.0	11.2	11.2	0
860903	0620-0720	1.8	0720-1200	11.0	1200-1235	1.5	11.2	11.2	0
860930	1410-1500	1.4	1500-2010	11.0	none		11.2	11.2	0
	(total added in 1986 meq/m^2: H^+ 101.0, 2.7 Na, 0.1 K, 1.4 Ca, 0.7 Mg, 2.4 Cl, 103.0 SO_4; 68 mm H_2O)								
870326			to snowpack	0.01			45.0	45.0	0
870617	0630-0745	2.2	0745-1225	11.0	1225-1320	2.2	11.2	11.2	0
870721	0700-0745	2.2	0745-1325	11.0	1325-1350	2.2	11.2	11.2	0
870819	1320-1415	2.2	1415-1900	11.0	1900-2000	2.2	11.2	11.2	0
870820	0640-0725	2.2	0725-1215	11.0	1215-1310	2.2	11.2	11.2	0
870930	1040-1140	2.2	1140-1620	11.0	1620-1700	1.4	11.2	11.2	0
	(total added in 1987 meq/m^2: H^+ 101.0, 2.7 Na, 0.1 K, 1.3 Ca, 0.8 Mg, 2.3 Cl, 102.7 SO_4; 76 mm H_2O)								

Table 2 (cont.)

Catchment SOG4.

Date	Pre-treatment		Acid application		Post-treatment		Acid dose meq/m^2		
	Time	mm	Time	mm	Time	mm	H^+	SO_4	NO_3
840402			to snowpack	0.01			25.0	12.5	12.5
840829	0730-0840	2.6	0840-1325	11.2	1325-1400	0.5	11.2	5.6	5.6
840912	0730-0830	2.6	0830-1310	9.6	1315-1350	1.4	11.2	5.6	5.6
840926	1405-1450	1.8	1450-1935	11.2	1935-2010	1.8	11.2	5.6	5.6
841002	1400-1445	2.0	1445-1930	11.1	1930-2010	2.0	11.2	5.6	5.6
	(Total added in 1984 meq/m^2: H^+ 69.8, 3.1 Na, 0.2 K, 1.0 Ca, 0.7 Mg, 3.1 Cl, 33.6 SO_4, 22.4 NO_3; 58 mm H_2O)								
850329			to snowpack	0.01			45.0	22.5	22.5
850612	0815-0855	1.8	0930-1400	10.8	1410-1435	1.7	11.2	5.6	5.6
850822	none		0950-1450	10.8	1450-1550	2.0	11.2	5.6	5.6
850823	none		0715-1115	10.8	1115-1215	2.0	11.2	5.6	5.6
850827	1400-1500	1.8	1505-1930	10.8	1930-2030	1.8	11.2	5.6	5.6
851001	none		1235-1735	10.8	none		11.2	5.6	5.6
	(Total added in 1985 meq/m^2: H^+ 101.0, 2.5 Na, 0.1 K, 0.7 Ca, 0.6 Mg, 1.8 Cl, 52.3 SO_4, 50.5 NO_3; 65 mm H_2O)								
860325			to snowpack	0.01			45.0	22.5	22.5
860619	1700-1745	1.7	1745-2200	10.1	2200-2300	2.2	11.2	5.6	5.6
860819	1700-1745	1.7	1745-2200	10.3	2200-2300	3.0	11.2	5.6	5.6
860820	1500-1540	2.0	1540-2020	11.0	2020-2105	2.0	11.2	5.6	5.6
860902	1450-1545	2.0	1545-2025	11.0	2025-2115	2.0	11.2	5.6	5.6
861001	0630-0715	1.4	0715-1320	11.0	1320-1405	1.8	11.2	5.6	5.6
	(Total added in 1986 meq/m^2: H^+ 101.0, 2.9 Na, 0.1 K, 1.5 Ca, 0.7 Mg, 2.6 Cl, 52.7 SO_4, 50.6 NO_3; 73 mm H_2O)								
870327			to snowpack	0.01			45.0	22.5	22.5
870617	1345-1430	2.0	1430-1915	11.0	1915-2030	2.0	11.2	5.6	5.6
870719	1500-1600	2.2	1600-2100	12.1	2100-2130	0.8	11.2	5.6	5.6
870818	1450-1540	2.0	1540-2020	11.0	2020-2110	2.0	11.2	5.6	5.6
870819	0650-0740	2.0	0740-1220	11.0	1220-1310	2.0	11.2	5.6	5.6
870930	1710-1740	1.5	1740-2230	11.0	2230-2310	1.3	11.2	5.6	5.6
	(Total added in 1987 meq/m^2: H^+ 101.0, 2.6 Na, 0.1 K, 1.3 Ca, 0.7 Mg, 2.2 Cl, 52.2 SO_4, 50.5 NO_3; 74 mm H_2O)								

Acid-addition began in April 1984 and consists of application to the snowpack of 0.02 mm pH 1.9 acid and 4-5 events of 11 mm pH 3.2 acid during the snowfree months. Added water is acidified lakewater from SOG1 and is applied at 2 mm/hr by means of commerical irrigation equipment. Prior to and following each acid addition 2 mm of unacidified lakewater were added to wet up and wash down the vegetation, respectively. The experiment is designed such that acid addition is obtained with a minimum of extra water (about 60 mm added to about 1000 mm natural precipitation) added at an acidity that does not cause direct damage to vegetation. Acid addition was 70 meq/m^2/yr in 1984 and 100 meq/m^2/yr in 1985, 1986 and 1987 (Table 2). Annual acid loading is at levels currrently typical for acidified areas in southernmost Norway.

Volume and chemical composition of natural precipitation at Sogndal are measured in weekly bulk samples collected at Haukås farm, 500 m above sealevel and 3 km from the experimental catchments. In addition the water equivalent and chemical composition of the snowpack at the 4 catchments is measured in late winter each year. Because of the high relief in the area, precipitation volume differs substantially over short distances due to snow drifting and orographic effects. We assume that the snowcourse measurements give the best estimate of winter precipitation, and that the gauge at Haukås farm the best estimate of summer precipitation (Table 3).

Discharge is gauged continuously by weir and level recorder at the outlet of catchments SOG1, SOG2, and SOG4. Discharge from SOG3 is not gauged and assumed proportional to that at SOG1. Runoff samples for chemical analysis are collected at least weekly at the outlet of each catchment; sampling frequency is increased to 2-7 times weekly during snowmelt. Additional samples from SOG2 and SOG4 are collected every 2 hours during and immediately following acid additions, and daily for the 5 days following acid addition (see Wright 1985, Wright and Gjessing 1985, and Wright 1987 for details).

Four years of acid addition at Sogndal have resulted in major changes in runoff chemistry (Table 4, Figure 2). Each incident of acid addition gives a short-term episode of acid, aluminum-rich runoff. Recovery between episodes was rapid and full the first year but increasingly slower and less complete in subsequent years. Volume-weighted mean sulfate concentrations have increased from about 20-25 μeq/l (control catchments SOG1, SOG3) to 50-57 μeq/l at SOG2 and 35-45 μeq/l at SOG4. These levels are about 50% of the expected steady-state concentrations at which sulfate output in runoff equals sulfate input in wet and dry deposition. Sulfate outputs equal inputs

Table 3. Hydrologic budgets for the Sogndal catchments. SOG3 is assumed to have the same hydrologic budgets as SOG1.

	SOG1					SOG2							SOG4						
	IN				OUT	IN				OUT			IN				OUT		
	measured Haukås	snow-pack	corr.	factor		added	total	snow-pack	corr.	meas.	corr.	factor	added	total	snow-pack	corr.	meas.	corr.	factor
Period	mm	mm	mm		mm	mm	mm	mm	mm	mm	mm		mm	mm	mm	mm	mm	mm	
830901-831114	411	-	320	0.78	320	0	411	-	320	406	320	0.79	0	411	-	320	600	320	0.53
831115-840630	493	-	656	1.35	656	0	493	-	656	725	656	0.90	0	493	-	656	980	656	0.67
840701-841112	520	-	470	0.90	370	60	580	-	530	586	430	0.73	58	578	-	528	350	428	1.23
841113-850616	345	390	476	1.38	476	0	345	302	476	570	476	0.84	0	345	265	476	925	476	0.51
850617-851101	342	-	452	1.32	352	61	403	-	513	394	415	1.05	65	407	-	517	275	417	1.51
851102-860618	337	520	458	1.36	458	0	337	395	458	457	458	1.00	0	337	384	458	827	458	0.55
860619-861112	441	-	499	1.13	399	68	509	-	567	304	467	1.54	73	514	-	572	743	472	0.64
861113-870614	427	348	570	1.33	590	0	361	138	361	722	365	0.51	0	391	168	391	377	395	1.05
870615-871115	364	-	364	1.00	200	76	364	-	440	318	318	1.00	74	364	-	438	460	323	0.70

Table 4. Volume-weighted mean concentrations of major ions in precipitation and runoff at the Sogndal catchments. The periods refer to pre-treatment 830901-831114 (pre), 831115-841112 (1984), 841113-851101 (1985), 851102-861112 (1986), and 861112-871115 (1987). Treatment began in April 1984. Al is measured as reactive Al and non-labile monomeric Al (NLAL); labile monomeric Al is obtained by difference (Røgeberg and Henriksen 1985); concentrations of ionic Al species are calculated using the procedure of Schecher and Driscoll (1987); values here are sum of all positively-charged species. Alkalinity (alk) is defined as sum of base cations (Na, K, Ca, Mg, and NH_4) less sum of strong acid anions (NO_3, Cl, and SO_4). Dash (-) indicates no data.

Units: µeq/l, H_2O mm.

	precipitation SOG1, SOG3					runoff SOG1 control					runoff SOG3 control					runoff SOG2 H_2SO_4 addition					runoff SOG4 H_2SO_4+HNO_3 addition				
	pre	1984	1985	1986	1987	pre	1984	1985	1986	1987	pre	1984	1985	1986	1987	pre	1984	1985	1986	1987	pre	1984	1985	1986	1987
H_2O	320	1126	928	957	925	320	1026	828	857	790	320	1026	828	857	790	320	1086	891	925	683	320	1086	891	930	718
H^+	12	20	15	11	18	1	2	2	1	2	3	4	1	1	2	3	8	4	8	7	1	4	4	6	4
pH	4.9	4.7	4.8	5.0	4.7	6.0	5.7	5.7	6.0	5.8	5.5	5.4	6.0	6.0	5.7	5.5	5.1	5.4	5.1	5.1	6.0	5.4	5.4	5.2	5.4
Na	44	72	32	22	28	38	88	35	33	38	50	74	33	30	38	53	59	31	35	38	38	51	19	29	37
K	6	6	4	6	6	0	11	2	2	4	0	2	1	0	1	3	4	2	2	5	3	2	1	2	3
Ca	6	9	4	3	6	19	20	16	18	20	19	19	16	18	19	19	22	22	28	29	22	26	20	27	26
Mg	9	16	4	5	5	9	15	8	8	10	9	17	8	8	11	12	13	11	14	13	9	12	9	11	10
Al	-	-	-	-	-	0	1	0	0	0	0	0	0	0	1	0	3	2	2	3	0	1	0	1	3
NH_4	3	9	6	7	14	0	6	5	-	-	0	1	0	-	-	0	3	0	-	-	0	1	1	-	-
NO_3	3	9	8	5	11	3	2	1	1	1	0	2	0	0	0	3	4	1	1	2	0	4	1	6	3
Cl	47	81	26	25	30	34	89	26	28	37	41	78	25	27	36	62	60	26	34	36	38	57	26	26	35
SO_4	16	31	16	20	24	22	28	22	27	21	22	23	22	23	23	22	40	38	57	50	19	26	24	45	36
HCO_3	-	-	-	-	-	9	15	13	4	12	6	1	5	4	8	9	5	2	0	0	12	6	6	1	8
Sum+	80	132	65	54	77	67	143	68	62	74	81	117	59	57	72	90	112	72	89	95	73	97	54	76	83
Sum-	66	126	50	48	65	68	134	65	60	71	69	104	52	54	75	96	109	67	92	88	69	93	57	78	82

Added to SOG2: 1984 60 mm, 70 meq/m^2 H_2SO_4;
1985 61 mm, 100 meq/m^2 H_2SO_4;
1986 68 mm, 100 meq/m^2 H_2SO_4;
1987 76 mm, 100 meq/m^2 H_2SO_4.

Added to SOG4: 1984 58 mm, 35 meq/m^2 H_2SO_4 + 35 meq/m^2 HNO_3;
1985 65 mm, 50 meq/m^2 H_2SO_4 + 50 meq/m^2 HNO_3;
1986 73 mm, 50 meq/m^2 H_2SO_4 + 50 meq/m^2 HNO_3;
1987 74 mm, 50 meq/m^2 H_2SO_4 + 50 meq/m^2 HNO_3.

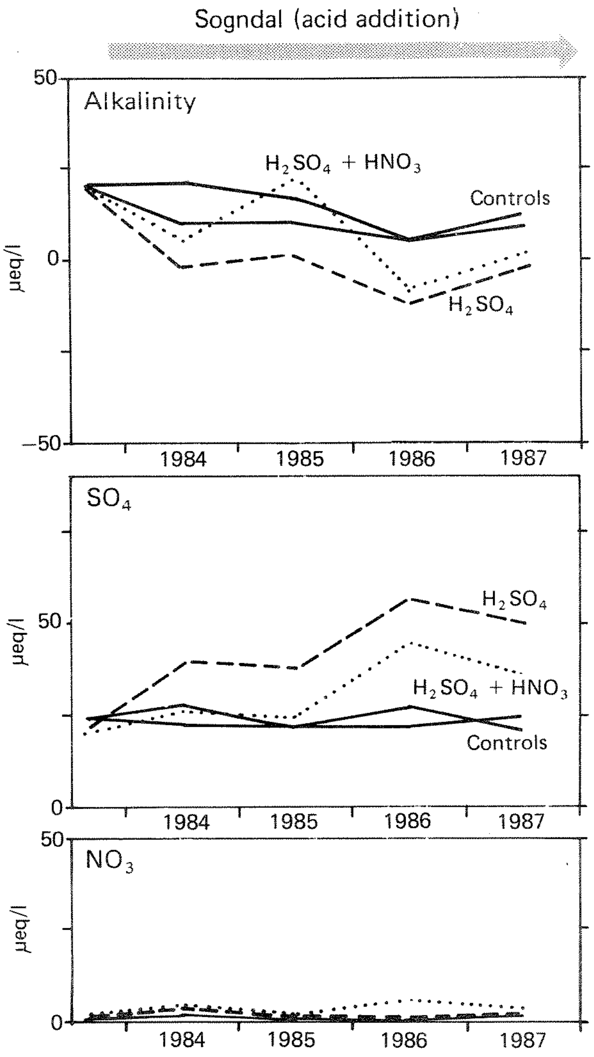

Figure 2. Alkalinity (upper panel), sulfate (middle panel), and nitrate in runoff (volume-weighted annual mean concentrations) at the Sogndal catchments. Alkalinity is defined as sum of charges of base cations less sum of charges of strong acid anions. Acid addition was 70 meq/m^2/yr in 1984 and 100 meq/m^2/yr in 1985-87 either as H_2SO_4 (SOG2) or 1:1 mixture of H_2SO_4+HNO_3 (SOG4). SOG1 and SOG3 are untreated controls.

at the untreated control catchments SOG1 and SOG3 (Table 4), a characteristic of catchments in glaciated regions receiving acid deposition in Europe and North America (Wright and Johannessen 1980, Wright 1984, Kramer et al 1986, Rochelle et al. 1987).

Addition of HNO_3, on the other hand, has caused only minor increases in nitrate in runoff at SOG4. Although a short-term pulse of nitrate occurs during each acid addition, mass budget calculations indicate that > 90% of the added nitrate is retained in the catchment. The efficient retention of nitrate is probably due to uptake by the terrestrial vegetation; nitrogen is the growth-limiting nutrient for these ecosystems.

About 80% of the sulfate added to catchment SOG2 over the 4-year period 1984-87 has been retained and apparently stored in the soil. This sulfate addition is sufficient to increase the pool of readily-available SO_4 (adsorbed and water-soluble SO_4) by about 70% from the 420 ± 310 meq/m^2 measured in August 1984 (Table 5). Resampling in August 1986 indicates that the pool of readily-available sulfate in the soil had increased by about 440 ± 720 meq/m^2; the increase is significant at the 95% level. The relatively large uncertainties in these estimates of pool size are due to spatial heterogenity in soil chemistry within the catchment. At catchment SOG4 about 85% of the 185 meq/m^2 added has been retained; this amounts to a 35% increase in readily-available SO_4 (Table 5). Resampling indicates no significant change in sulfate pool. As the treatments continue, future measurements of sulfur fractions in the soils will reveal whether the retained sulfate is stored in the readily-available pool or transformed to other sulfur forms. At both catchments the change in pool size inferred from the input-output budgets and the increase in sulfate concentrations in runoff over the 4-yr. treatment period are consistent with the assumption that sulfate adsorption is the major soil-chemical process determining the long-term trends in sulfate concentration in runoff.

The increased sulfate concentrations in runoff at both catchments are compensated about 50% by increased concentrations of base cations (mainly Ca and Mg) and about 50% by decreased alkalinity (defined as difference in sum of charges of base cations minus sum of charges of strong acid anions) (Table 4). By the third year of acid addition alkalinity was chronically negative at both SOG2 and SOG4; bicarbonate levels were negligible and labile monomeric Al was of increasing importance (Figure 3).

Table 5. Pools of total sulfur and readily-available sulfate in soil and sulfate fluxes at the experimental catchments at Sogndal (acid addition). Soil data are from samples collected early autumn 1984 (Sogndal) and 1986. Readily-available sulfate is taken as sum of water-soluble and adsorbed sulfate. Samples are collected at 15-cm depth intervals and weighted for soil bulk-density and volume. Number of samples given by n. P refers to statistical significance of paired t-test of change in pool size. Treatment began in April 1984 at Sogndal.

Units: meq SO_4/m^2.

SOGNDAL															
	SOG1 (control)					SOG2 (H_2SO_4)					SOG4 (H_2SO_4+HNO_3)				
	1984	1986	Δ86-84	n	p	1984	1986	Δ86-84	n	p	1984	1986	Δ86-84	n	p
soil pools															
total S	4500±500	3800±800	-700±800	4	n.s.	2660±1130	3790±1990	1200±1640	14	.025	4000±1000	4400±1200	400±1400	4	n.s.
water-soluble + adsorbed SO_4	370±390	220±80	-150±420	4	n.s.	420±310	860±960	440±720	14	.05	440±300	380±320	-50±180	4	n.s.
fluxes 1984-86	In 69 Out 70 ΔIn-Out -1					In 339 Out 130 ΔIn-Out 209					In 204 Out 91 ΔIn-Out 113				

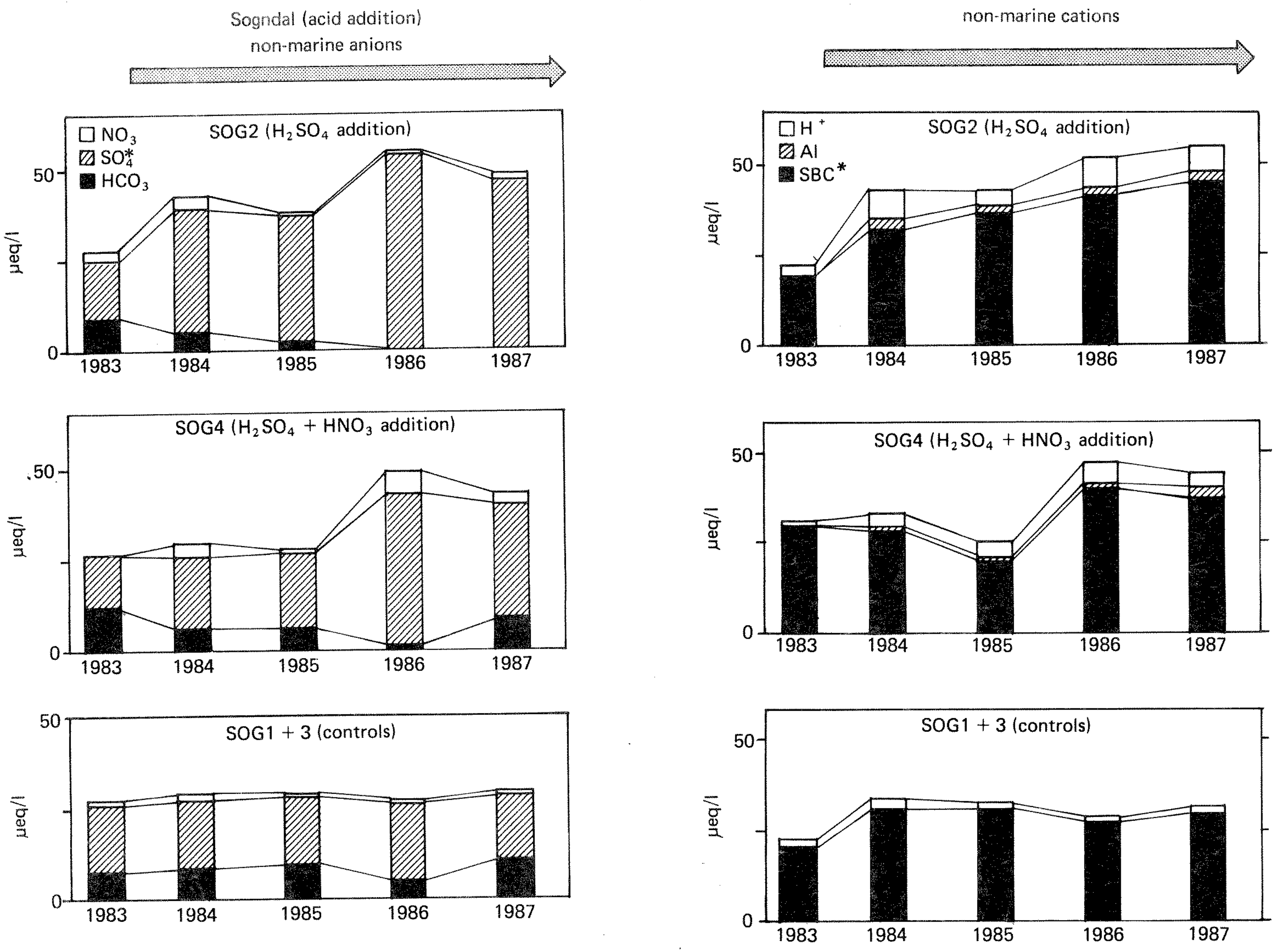

Figure 3. Concentrations of the non-marine fraction of anions and cations in runoff (volume-weighted annual mean concentrations) at the Sogndal catchments. The non-marine fraction is defined as the total concentration less the marine fraction as estimated from Cl and the ion proportions in seawater.

The concentrations of inorganic monomeric labile aluminum (Ali) increased dramatically with decreasing pH, but are not explained by solubility with respect to a single solid phase of aluminum hydroxide. In 1984, the first year of treatment, the relationship log(Ali) = logK - b(pH) had an intercept logK = 9.0 and slope of 3, as would be expected for waters in equilibrium with natural gibbsite (Schecher and Driscoll 1987) (Figure 4). In 1985 and 1986, however, Ali concentrations were markedly lower at the same pH, and the slope was < 3 (Figure 4). Then in 1987 Ali levels were again higher, and the relationship was similar to that in 1984.

The action of several independent processes in the soils and stream may explain these data. The high levels of relatively-soluble Al observed during the first acid additions in 1984 may reflect mobilization and release of Al from the streambed. Circumneutral streams such as those at Sogndal contain a substantial store of Al that is rapidly released during acid episodes (Norton et al. 1987, Hall and Likens 1981). This aluminum is believed to originate in soil solution containing elevated levels of CO_2. As soil solution enters the stream, CO_2 degasses, the pH increases, and aluminum hydroxide precipitates (Norton and Henriksen 1983). Acid addition during the first year at Sogndal caused pulses of strong acid which then quickly redissolved this aluminum. An experiment conducted in July 1987 in which sulfuric acid was added directly to a small stream at an adjacent catchment at Sogndal demonstrated that inorganic Al is readily released (S.A. Norton, pers. comm.). The log(Ali) - pH relationship had an intercept of 9.0 and slope of 3.0, very similar to the 1984 data (Figure 4).

The data from 1985 and 1986 indicate that this streambed store of inorganic Al was depleted. Al concentrations in runoff may now reflect more complex relationships in the catchment soils. Several studies of Al in soil extracts have reported log(Ali) - pH relationships with slopes less than 3 (Misra et al. 1974, Bloom and Grigal 1985). The return to higher Al levels and higher apparent Al solubility in 1987 is more difficult to explain, but may reflect the resupply of streambed Al during the rather dry and warm summer.

Most of the increased flux of base cations in runoff from the acidified catchments at Sogndal is exhibited by Ca and Mg (Table 4). Input-output budgets at the pristine control catchments provide an estimate of chemical weathering rate of base cations given the assumption that the catchments are at steady-state with no significant change in cations stored in living or dead biomass or in the soil. The 4-year data indicate that base cations are released by weathering at

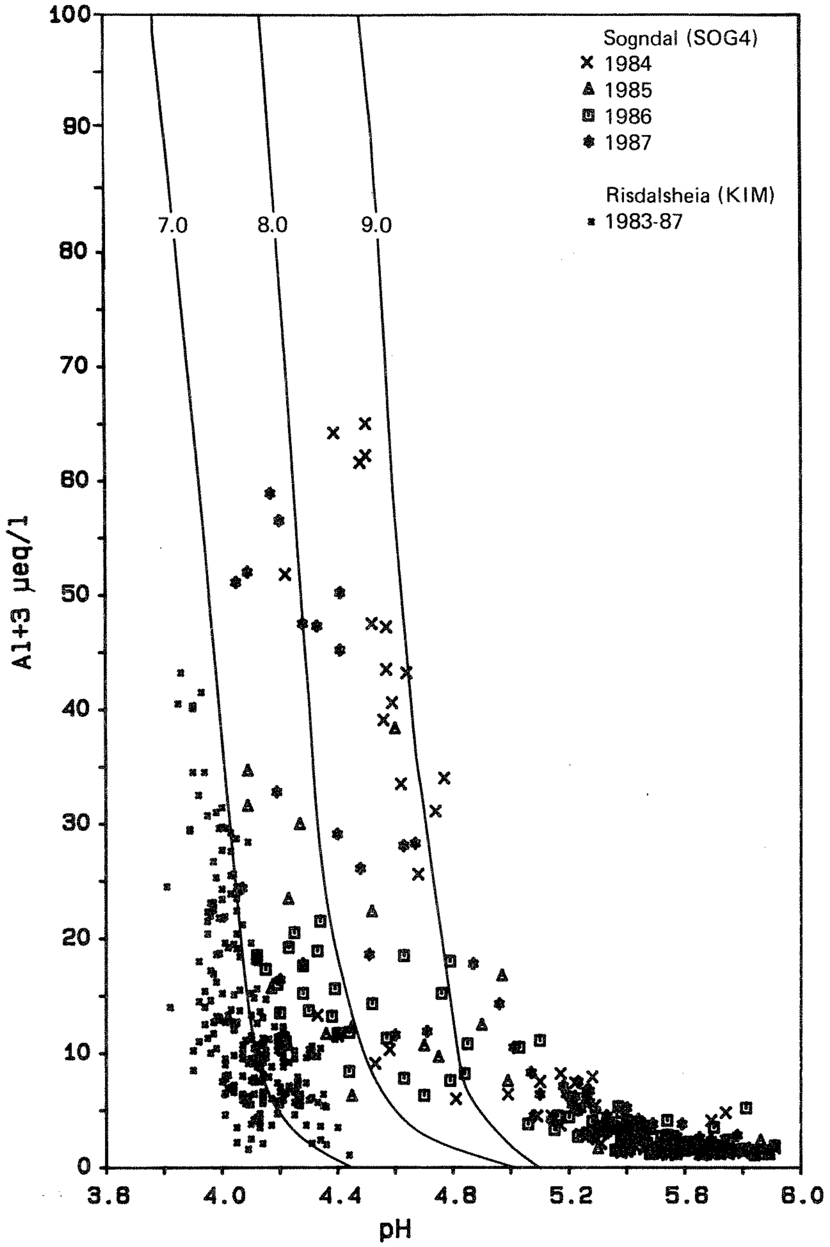

Figure 4. Concentrations of Al^{3+} and pH in runoff at catchments SOG4 (H_2SO_4 + HNO_3 addition) at Sogndal and KIM (acid exclusion) at Risdalsheia. Labile monomeric Al was determined by difference of reactive monomeric Al and non-labile monomeric Al measured by the procedure of Røgeberg and Henriksen (1985). Concentrations of AL^{3+} were determined by the procedure of Schecher and Driscoll (1987). Also shown are curves of log Al^{3+} = logK -3pH for logK = 7.0, 8.0, and 9.0. Natural gibbsite has log K of 9.1 at 25°C.

about 15 meq/m^2/yr, 10 meq/m^2/yr of which is Ca and Mg. The weathering estimate for Na is uncertain because of the high natural flux of seasalt Na. The weathering rate at Sogndal is low relative to that reported from other ecosystems with similar soils and bedrock (Coleman and Dethier 1986).

The net flux of Ca and Mg from the treated catchments SOG2 and SOG4 is about 50% higher than that of the control catchments. Given the assumptions that the weathering rate is identical at all catchments and that the acid additions have not changed the rate, then this additional loss must come from the pool of exchangeable base cations in the soil. We have estimated the size of this pool in 1984 at catchments SOG1, SOG2, and SOG4 by soil surveys and measurements of amounts of exchangeable bases. The increased leaching of Ca and Mg due to acid addition during the 4-years of treatment amounts to about 1.7% of the exchange pool at SOG2 and 2.0% at SOG4. Depletion of the pool will accelerate as the flux of sulfate through the soil increases. This process could result in significant change in soil base saturation after a few decades of acid deposition.

Results obtained during 4-yr of treatment indicate that these pristine, acid-sensitive catchments respond rapidly to increases of acid deposition. Indeed a single severe episode of acid precipitation may be sufficient to acidify runoff to the point at which the low pH, high Al water is toxic to fish. These catchments are typical of large regions of southern Norway. Over 50% of Norway is characterized by barren rock and soils less than 70 cm in depth (Overrein et al. 1980). The chronic acidification of runoff at Sogndal during the third and fourth year of treatment is caused entirely by an increase in acid deposition to levels typical for southernmost Norway; neither land-use change or any other environmental change need be invoked.

RISDALSHEIA: ACID EXCLUSION

The Risdalsheia site is located in a sensitive area in southernmost Norway presently receiving high loading of acid deposition (precipitation pH 4.2; sulfate load wet and dry is 100 meq/m^2/yr) (Figure 1). The catchments are situated 300 m above sealevel and characterized by exposed granitic bedrock (30-50% of surface) and thin, organic-rich, truncated podzolic soils (average depth 10-15 cm, maximum depth 50 cm, 30-50% exposed bedrock) with pH 3.9-4.5, and sparse cover of pine (Pinus sylvestris L.) and birch (Betula pubescens L.) (Lotse and Otabbong 1985). Acid-exclusion is accomplished by means of a 1200-m^2 transparent roof that completely covers the 860-m^2 KIM catchment. Incoming precipitation is collected from the roof, pumped through a filter and ion-exchange system, and automatically applied beneath the roof above the canopy by means of a sprinkler system. Seawater salts at ambient levels are readded prior to sprinkling. Watering rate is fixed at 2 mm/hr. An adjacent 400-m^2 catchment (EGIL) has also been covered with a roof and receives ambient acid precipitation by means of an identical sprinkling system. The watering systems are shut down during the winter. Artificial snow is added beneath the roofs each year by means of commercial snow-making equipment. Water from a nearby pond is ion-exchanged and seasalts added to make clean snow at KIM. Sulfuric acid is also added to make acid snow at EGIL (in 1985), or ambient acid snow is blown under the roof at EGIL by means of snowblower (in 1986 and 1987). Water equivalent of snow added was 115 mm in 1985 (KIM and EGIL), 180 mm (KIM) and 110 mm (EGIL) in 1986, and 150 mm (KIM) and 250 (EGIL) mm in 1987. A third uncovered catchment (ROLF) serves as reference (Table 1). Treatment began in June 1984 (Table 6).

Precipitation volume and chemical composition site are measured in weekly bulk samples collected on site. The volume of water applied to the 2 roofed catchments is measured continuously by meters installed in the sprinkler systems. All runoff from the three catchments is collected at fibreglass weirs and conducted in large-dimension hoses to 500-l tanks. The tanks are fitted with automatic valve and data-logging systems by which the total volume of water leaving each catchment is continuously recorded. Samples for chemical analysis are collected from each 10-20 mm of runoff (minimum once weekly) by automatic samplers. More frequent samples are collected following dry periods (see Wright 1985, Wright and Gjessing 1985, and Wright 1987 for details).

Acid-exclusion at KIM catchment has resulted in lower concentrations of the strong acid anions NO_3 and SO_4 relative to both the roofed control catchment EGIL and open ROLF catchment (Table 7, Figure 5). Nitrate concentrations decreased 60% within two weeks after onset of treatment. (That this decrease is due to the exclusion of nitrate inputs in precipitation was demonstrated by a 1-week period in October 1984 during which a technical failure of the ion-exchange columns resulted in application of 50 mm water with 50 µeq/l NO_3. Nitrate concentrations in runoff jumped immediately from 2 to 25 µeq/l and then declined back to 3-4 µeq/l within 3 weeks (Wright 1985).) Sulfate concentrations show a general decline beginning about 4 months after onset of treatment, and after 3.5 years of treatment are now about 50% of that at EGIL (Table 7, Figure 5).

Table 6. Risdalsheia. Major changes in operation

Date	Operation
23 March 1984	Runoff volume measurements begin at KIM and EGIL
13 June 1984	Treatment begins at KIM and EGIL
1 August 1984	New dam at EGIL; all runoff now collected
31 October 1984	Runoff measurements begin at ROLF
19 December 1984	Sprinkler systems closed for winter at EGIL and KIM
29 April 1985	Sprinkler systems opened again at EGIL and KIM
27 July 1985	New dam at KIM; all runoff now collected
15 November 1985	Sprinkler systems closed for winter at EGIL and KIM
10 May 1986	Sprinkler systems opened again at EGIL and KIM
7-20November 1986	Failure of ion-exchange columns KIM
18 December 1986	Sprinkler systems closed for winter at EGIL and KIM
13 May 1987	Sprinkler systems opened again at EGIL and KIM
14-20October 1987	Failure of ion-exchange columns KIM
23 November 1987	Sprinkler systems closed for winter at EGIL and KIM

Table 7. Volume-weighted mean concentrations of major ions in precipitation and runoff at the Risdalsheia catchments. Precipitation data for 1984 are for 1/2 yr only and begin 13 June. The periods refer to pre-treatment 840325-840612 (pre), 840613-841213 (1984), 841214-851114 (1985), 851115-861218 (1986), and 861219-871123 (1987). Organic anions (A^-) are determined by difference from the ionic balance. Organic acid charge density (c.d. in units μeq/mg C) is defined as A^- divided by total organic carbon (TOC). Deposition includes wet and dry with concentrations obtained by dividing total flux by mm of precipitation. Dry deposition is estimated for seasalts from chloride budget at EGIL catchment, for sulfate and nitrate from concentrations of SO_2 gas, SO_4 particulates, and NO_2 gas measured daily at the station Birkenes, 5 km west of Risdalsheia (SFT 1986), NH_4 from dry deposit of SO_4 particulates and a molar ratio of 1.5, and H^+ by ionic balance (Wright and Gjessing 1986). Runoff data from 1984 for ROLF catchment are incomplete and not included. Deposition data for ROLF catchment in 1984-85 are daily samples from Birkenes (SFT 1986). Dash (-) indicates no data. Units μeq/l, H_2O mm/yr, NLAL μgAl/l, TOC mg C/l, charge density μeq/mg C. See also text to Table 1.

	EGIL catchment (roof, acid rain)									KIM catchment (roof, clean rain)									ROLF catchment (no roof, acid rain)							
	deposition				runoff					deposition				runoff					deposition				runoff			
	1984	1985	1986	1987	pre	1984	1985	1986	1987	1984	1985	1986	1987	pre	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987
H_2O	654	692	771	1134	417	547	545	570	1103	506	596	686	905	417	410	425	531	786	872	1409	1516	1524	-	999	1388	1324
H^+	58	84	83	71	77	110	75	88	78	28	47	39	30	89	95	72	72	77	53	72	77	63	-	87	93	70
pH	4.2	4.1	4.1	4.2	4.1	4.0	4.1	4.1	4.1	4.6	4.3	4.4	4.5	4.1	4.0	4.1	4.1	4.1	4.3	4.1	4.1	4.2	-	4.1	4.0	4.2
Na	78	68	62	96	101	91	75	93	96	75	92	96	71	134	83	99	89	86	73	56	102	60	-	84	101	85
K	5	4	4	4	10	5	7	10	8	0	0	3	3	10	5	12	8	7	5	5	5	3	-	4	4	3
Ca	9	9	9	10	14	15	15	19	19	4	2	6	4	19	12	14	13	11	9	8	12	8	-	15	20	15
Mg	17	16	18	22	29	24	20	28	25	16	22	20	16	31	15	19	19	18	16	11	25	17	-	25	30	21
Al	-	-	-	-	24	20	10	15	14	-	-	-	-	17	5	8	9	10	-	-	-	-	-	8	12	12
NH_4	43	53	39	37	24	9	22	33	26	4	8	6	8	17	2	12	13	6	41	44	42	36	-	14	14	6
NO_3	47	53	43	46	72	37	22	38	37	14	20	9	12	62	5	9	17	7	44	50	49	40	-	31	29	14
Cl	84	75	83	101	91	117	81	111	103	89	111	105	84	120	117	132	104	106	79	56	119	69	-	92	130	108
SO_4	81	85	82	73	106	112	99	131	106	26	37	35	25	137	73	68	64	53	79	77	87	66	-	104	108	68
A^-	-	-	-	-	10	12	24	11	20	-	-	-	-	0	22	29	38	49	-	-	-	-	-	14	6	22
Sum+	210	234	215	240	279	276	225	288	266	127	171	171	132	317	217	237	223	215	197	196	263	187	-	238	274	212
Sum-	212	213	208	220	279	276	225	288	266	129	168	149	121	319	217	237	223	215	202	183	255	175	-	240	273	212
NLAL					101	188	231	191	112					149	280	289	233	185					-	157	125	97
TOC					5.3	9.1	14.1	10.7	9.4					8.4	17.3	19.8	15.6	15.4					-	12.9	10.1	9.7
c.d.					1.9	1.3	1.7	1.0	1.2					0	1.3	1.5	2.4	2.5					-	0.9	0.8	2.3
alk					-91	-122	-63	-97	-72					-108	-78	-53	-43	-38					-	-85	-98	-60

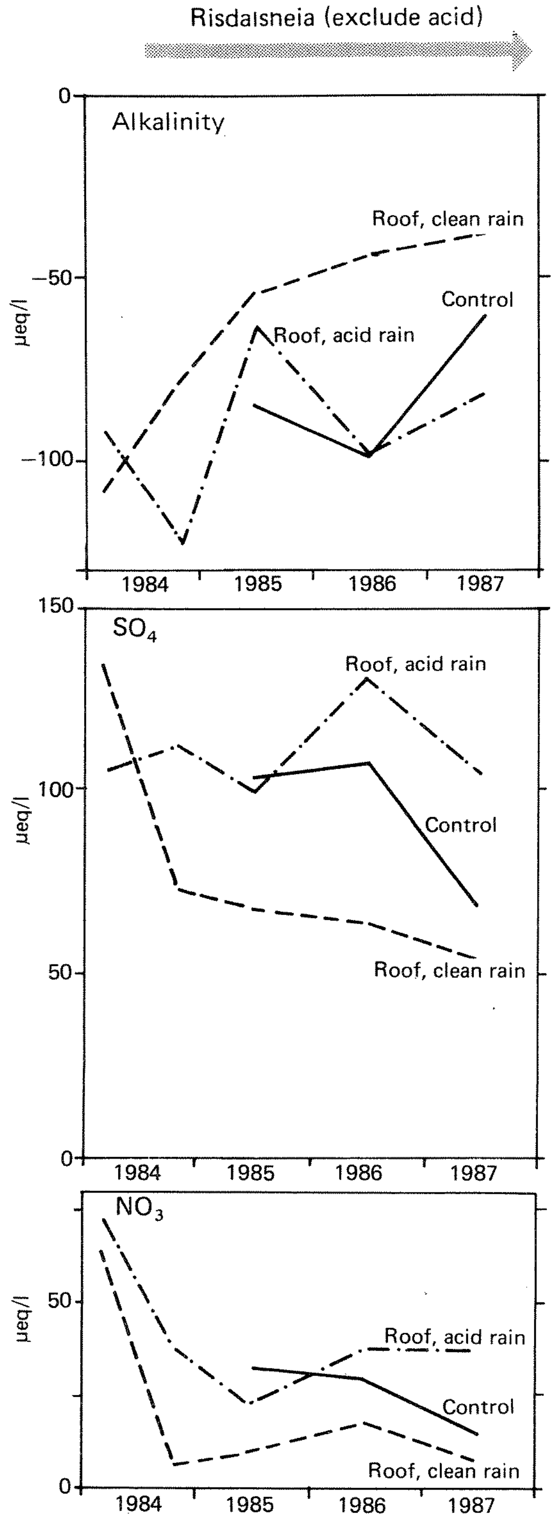

Figure 5. Alkalinity (upper panel), sulfate (middle panel), and nitrate (lower panel) in runoff at Risdalsheia (volume-weighted annual mean concentrations). Alkalinity is defined as sum of charges of base cations less sum of charges of strong acid anions. KIM catchment (860 m^2) is covered by roof and receives "clean" precipitation. EGIL catchment (400 m^2) is also roofed but receives recycled ambient acid precipitation. ROLF catchment (220 m^2) is open and receives ambient acid precipitation.

At KIM catchment sulfate output continues to exceed inputs in wet and dry deposition. Net loss of sulfate during the first 3.5 yrs has been 53 meq/m^2. This is equivalent to about 45% of the pool of readily-available sulfate in the soil prior to treatment (Table 8).

The decline in strong acid anion concentrations is compensated partially by a decrease in concentrations of base cations (55%) and partially by an increase in alkalinity (45%). Changes in the concentrations of base cations are masked in part by year-to-year and catchment-to-catchment differences in the inputs of seawater salts. We estimate the seasalt component from Cl concentrations and the ionic composition of seawater. The non-marine fraction of base cations (denoted by asterisks) has decreased to 0-15 µeq/l during the 3.5 years of treatment, and was negative during the second half of 1984 (Figure 6). Concentrations of ammonium in runoff are also lower than at the untreated control catchment (Table 7).

At Risdalsheia the concentrations of labile monomeric Al at a given pH are much lower than at Sogndal, and the log(Ali) - pH relationship approximately follows a line with intercept logK=6.8 and slope of 3 (Figure 4). The very low pH levels in runoff at Risdalsheia preclude major pH change due to degassing of CO_2, and thus little Al should precipitate out in the streambed. Al in runoff at Risdalsheia probably reflect cation exchange in the soils. Because concentrations of inorganic monomeric Al are negligible at pH levels above 4.4, as the acid-exclusion treatment proceeds and pH increases, concentrations of inorganic Al at Risdalsheia should fall below levels toxic to salmonid fish.

The input-output budgets indicate that relative to the control catchments the acid-exclusion catchment is retaining a portion of the base cations deposited in precipitation and released from weathering; the pool of exchangeable base cations is being replenished. The magnitude of this replenishment depends upon estimates for weathering rates in these catchments. Weathering rates cannot be obtained directly from input-output budgets at the control catchments because a fraction of the base cations in runoff may come from the pool of exchangeable cations on the soil.

As the acid-exclusion experiment has proceeded organic acids have become increasingly important for the pH of runoff. We estimate the concentrations of organic anions by difference from the ionic balance. These estimates are thus uncertain by about ± 10 µeq/l. Runoff from these shallow organic soils contains 10-20 mg/l total organic C (Table 7). At the acid-exclusion catchment the concentration of organic

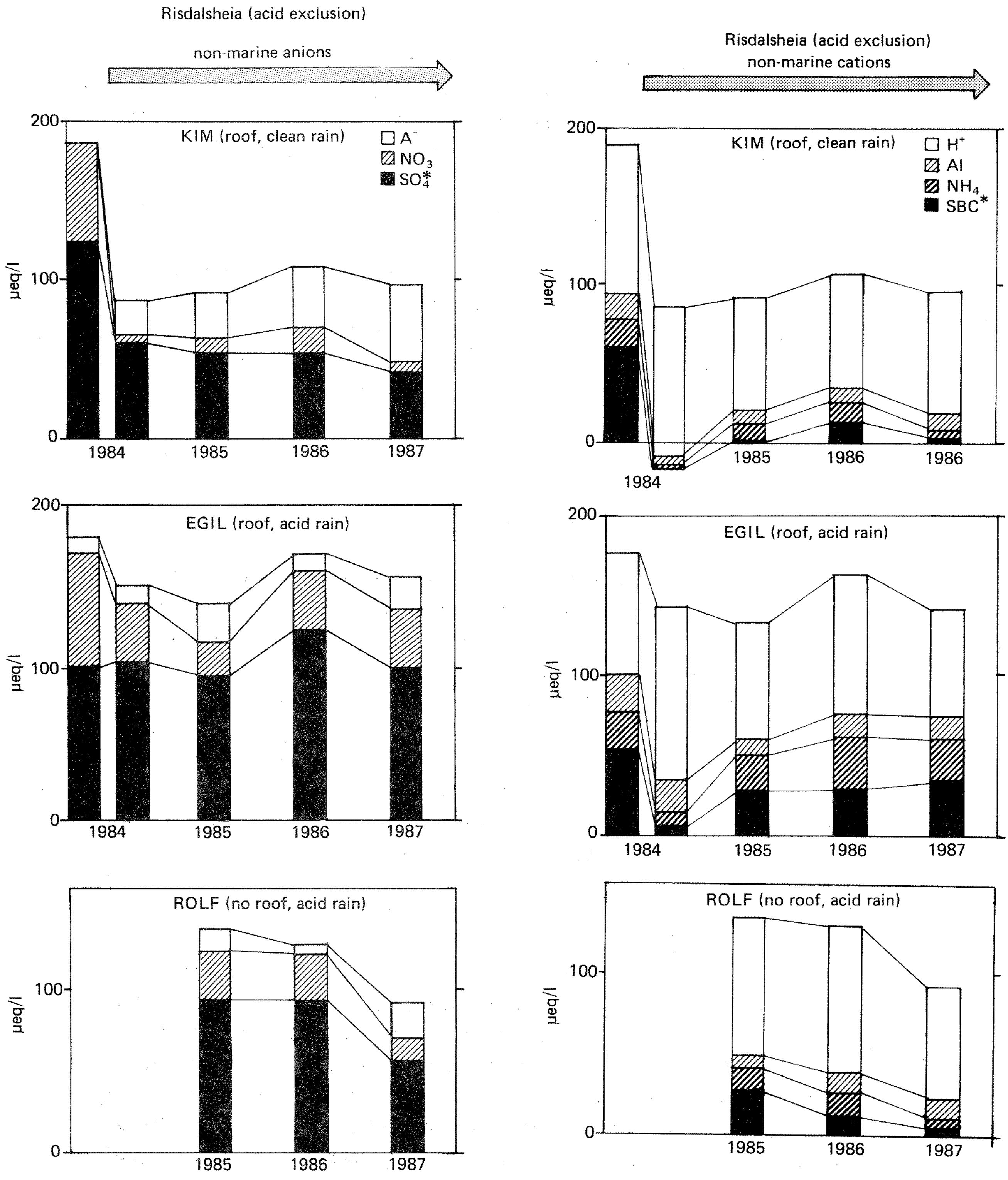

Figure 6. Concentrations of the non-marine fraction of anions and cations in runoff (volume-weighted annual mean concentrations) at the Risdalsheia catchments. The non-marine fraction is defined as the total concentration less the marine fraction as estimated from Cl and the ion proportions in seawater.

Table 8. Pools of total sulfur and readily-available sulfate in soil and sulfate fluxes at the experimental catchments at Risdalsheia (acid exclusion). Soil data are from samples collected early autumn 1983 (Risdalsheia), 1984 (Sogndal) and 1986. Readily-available sulfate is taken as sum of water-soluble and adsorbed sulfate. Samples are collected at 15-cm depth intervals and weighted for soil bulk-density and volume. Number of samples given by n. P refers to statistical significance of paired t-test of change in pool size. Treatment began mid-1984 at Risdalsheia. Units: meq SO_4/m^2.

	RISDALSHEIA									
	KIM (roof, clean rain)					EGIL (roof, acid rain)				
	1983	1986	Δ86-83	n	p	1983	1986	Δ86-83	n	p
soil pools										
total S	1700±1000	910±450	-800±450	9	.01	1070±70	880±210	-190±100	6	.01
water-soluble + adsorbed SO_4	82±36	57±28	-35±30	9	.01	40±15	46±12	6±14	6	n.s.
fluxes* 1984-86	In 59	Out 93	ΔIn-Out -34			In 175	Out 190	ΔIn-Out -15		

*2.5-yr. only from 13 June 1984.

anions has increased as the experiment has proceeded from about 22 µeq/l in 1984 to 49 µeq/l in 1987. This increase is due to increased dissociation of the organic acids and not to change in concentration of TOC; the charge density has increased from about 1.3 in 1984 to 2.5 in 1987 (Figure 7). The organic carbon apparently has a maximum charge density of about 4.5 µeq/mg C and pK of about 4.2 (Wright 1987), similar to that reported from podzolic soils in New York, USA (Cronan and Aitken 1985). When fully dissociated 15 mg C/l will thus contribute approximately 70 µeq/l of organic anions. As the concentration of non-marine strong acid anions ($SO_4^* + NO_3$) declines to a new steady-state of about 25 µeq/l, and with non-marine base cation concentrations of about 20 µeq/l, this pK and level of TOC will result in pH of about 4.6.

At Risdalsheia the acid-exclusion experiment shows that chemical changes caused by acid deposition are largely reversible. The mobile strong acid anions SO_4 and NO_3 in runoff respond rapidly to changes in input. At KIM catchment this decrease in mobile anions has been accompanied in part by an increase in alkalinity, but not by a major increase in pH because of buffering by organic acids. The treatment catchment KIM is by necessity very small and thus has extremely thin and highly organic soils. Runoff contains high concentrations of organic carbon. In this region of Norway streams and lakes draining catchments with thicker, more mineral-rich soils generally have much lower levels of TOC, and organic anions play a minor role (Brakke et al. 1987). In Norway about 90% of lakes in the 1986 1000-lake survey have TOC levels below 6 mg C/l (SFT 1987). In addition base cation concentrations are generally higher due to higher rates of chemical weathering. Our data from the acid-exclusion experiment at Risdalsheia show that reduction in acid deposition results in decreased concentrations of strong acid anions in runoff. In clearwater lakes and streams in southern Norway a major reduction in the flux of strong acid anions will be reflected in major change in pH and inorganic aluminum; the water will be less toxic to fish and other aquatic organisms.

CONCLUDING REMARKS

The changes in runoff chemistry observed at the RAIN project sites can be explained qualtitatively by the interaction of key soil-chemical processes such as sulfate adsorption, cation exchange, dissolution of CO_2, mobilization of aluminum, and buffering by organic acids. These processes are central in understanding soil and water acidification by acid deposition (Reuss and Johnson 1986, Reuss et al. 1987, Brakke et al. 1987). A process-oriented model of soil and water acidification

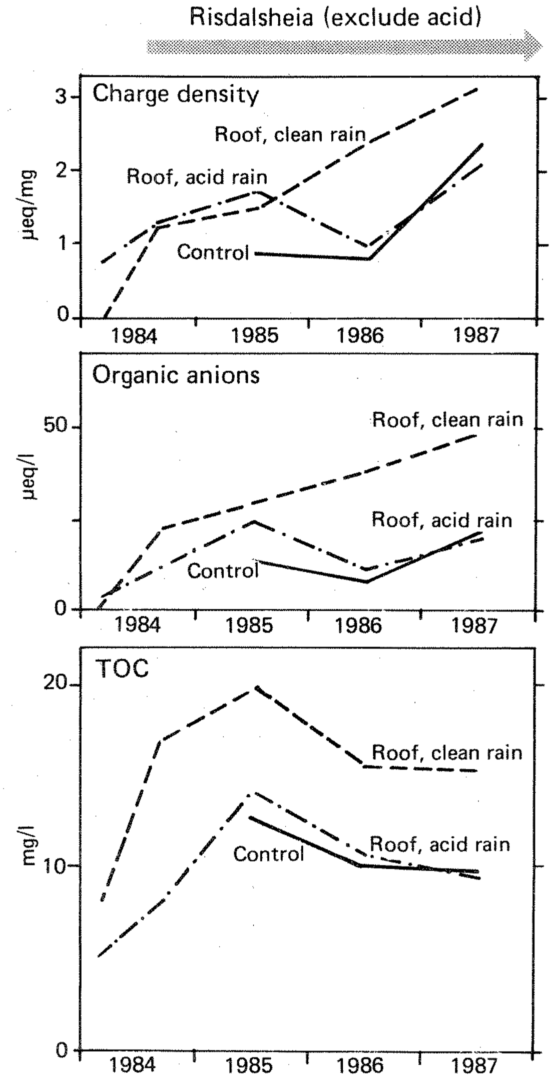

Figure 7. Volume-weighted concentrations of total organic carbon (TOC) (lower panel), organic anions (A^-) (middle panel), and charge density (upper panel) in runoff from the experimental catchments at Risdalsheia. Organic anion concentrations are determined by difference from the ionic balance; charge density is defined as A^-/TOC.

al. 1987). A process-oriented model of soil and water acidification (MAGIC) applied to the first 2-yr data generally predicted the observed changes (Wright and Cosby 1987). The RAIN project provides a unique data set for the calibration and evaluation of such predictive models.

At both Sogndal and Risdalsheia runoff from the treated catchments now differs substantially in chemical composition from that of the control catchments. Runoff at Sogndal has been acidified to levels toxic to fish, and runoff at Risdalsheia has begun to recover to "pre-acidification" chemical composition. Acid addition at Sogndal has caused soil acidification, whereas acid exclusion at Risdalsheia has initiated reversal of ongoing soil acidification.

The RAIN project thus far shows that within a few years changes in acid deposition cause major changes in surface water chemistry at sensitive sites typical of large areas of southern Norway. The reversibility of acidification demonstrated here agrees with empirical data from Canada, the United States, and Scotland (Battarbee et al. 1988, Dillon et al. 1986, Hauhs and Wright in press, Keller et al. 1986, Schindler 1988). As the RAIN project continues the treated catchments will approach new "steady-state", and provide information as to whether acidification of soil and runoff chemistry is indeed fully reversible.

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APPENDICES.

Appendix 1. Satellite projects to the RAIN project in 1987.

Appendix 2. Visitors to the RAIN project in 1987.

Appendix 3. Input-output budgets at Risdalsheia and Sogndal 1984-87.

Appendix 4. Risdalsheia discharge data.

Appendix 5. Risdalsheia runoff chemistry.

Appendix 6. Risdalsheia precipitation data.

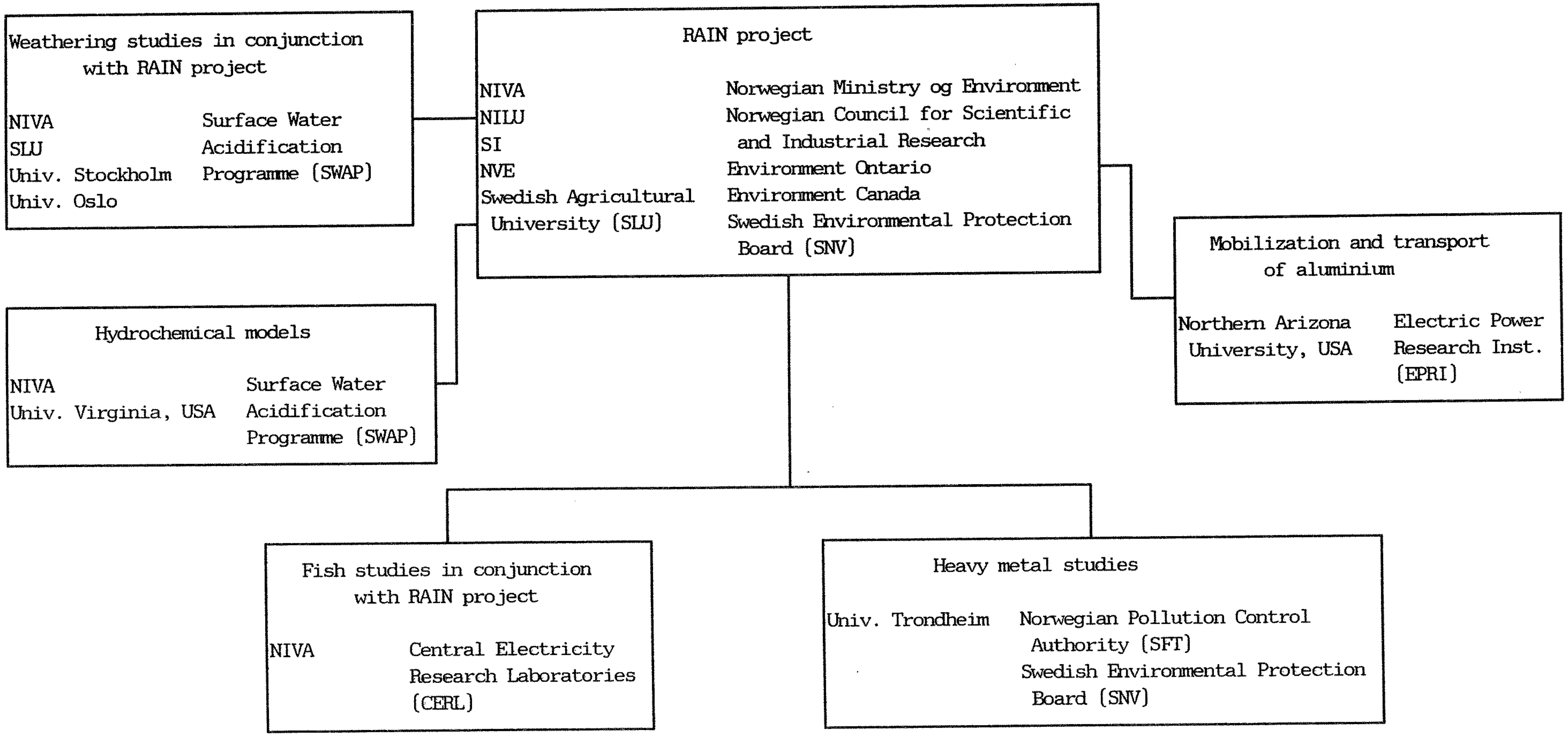
Appendix 7. Sogndal discharge data.

Appendix 8. Sogndal runoff chemistry.

Appendix 9. Sogndal precipitation data.

APPENDIX 1. RAIN PROJECT AND ASSOCIATED SATELLITE PROJECTS IN 1987

Within each box are listed the participating institutions (left) and the funding agencies (right).



APPENDIX 2. VISTORS TO THE RAIN PROJECT IN 1987.

Date	Visitor
27 November 1986	Christopher Wren, Guelph, Canada Tor Punsvik, Miljøvernavd., Vest-Agder
10 December 1986	3 students from Drammen Gymnas
2 April 1987	Mike Hornung, Soil scientist from the Institute of Terrestrial Ecology, U.K.
23 April 1987	20 chemistry students from ADH, Kristiansand. Instructor K. Dye.
13 May 1987	12 biology and 11 chemistry students from Grimstad Gymnas led by Stig Olsen.
22 May 1987	Thames Television filmed for a youth program on acid rain for use in the U.K.
26 May 1987	Department of Forest Ecology, NISK.
11 June 1987	57 students from 7th grade, Evje junior high school
11 June 1987	Louis Portella, EPRI, Calif., USA John Huckabee, EPRI, Calif., USA Steve Lindberg, Oak Ridge National Laboratory, USA Dale Johnson, ----------- " ---------- Ernest Bondietti, ----------- " ---------- Arne Stuanes, NISK Gunnar Abrahamsen, NLH
23 June 1987	Damage project - Norwegian/British cooperation at grade school level, acid rain phenomenon 5 persons
11 August 1987	Central Electricity Generating Board, Film & Video Branch, U.K. inspection of site for future filming
12 August 1987	British and Norwegian Ministries of Environment led by A. Henriksen, NIVA (5 pers.).
20 August 1987	Avis D. Newell, EPA, Corvallis, USA

27 August 1987	BNC Broadcast (video producer company, Oslo) filmed for the video "Det er vårt valg" (It's our choice) on behalf of Lunner Naturvernforening and Norges Naturvernforbund
28 August 1987	NVE, hydrology department - 6 persons.
3 September 1987	English/Norwegian teachers participating in the grade school project on acid rain - 11 persons
9 September 1987	ITV, U.K., filmed for an English breakfast TV series on the environment
18 September 1987	CEGB, Film & Video Branch filmed for a video 5 pers. led by Charles Dunstan.
18 September 1987	Skogskadeutvalget: (Forest Damage Commission) Fylkesskogsjefen, Aust-Agder Skogdirektøren, Landbruksdep. Fylkesmannen, Aust-Agder Miljøverndep. 2 pers. SFT 2 pers. NISK 2 pers. Sekretæren i TEFA-gruppen NRK-Sørlandet v/Skomedal Journalist from Dagbladet led by R. Wright NIVA and 3 scientists.
1 October 1987	20 students from Telemark DH, natural science and environment, led by Arne Lande.
12 October 1987	4 scientists from SWAP-project led by Nils Christophersen
14 October 1987	P. Lloyd, London, editor at "Nature", led by R. Wright, NIVA

20 October 1987	Several organizations from the U.K: Aboricultural Association Friends of the Earth National Federation of Anglers National Trust for Places of Historic Interest or Natural Beauty National Trust for Scotland National Union of Townswomen's Guide Royal Society for the Protection of Birds The National Farmers Union Royal Forestry Society of England, Wales and Northern Ireland World Wildlife Found Norsk MD Fylkesskogsjefen, Aust-Agder Thomas Eid, TEFA-gruppen Stig Olsen Snorre Tønset, NRK, Oslo led by Tor Traaen, NIVA
2 November 1987	Aust-Agder Faglærerlag, 15 pers.
4 November 1987	Representatives of the county environmental authorities and Ministry of Environment - excursion in conjunction with "National conference for state employees who work with pollution issues" ca. 100 pers.
6 November 1987	Anna Fielder, Consumers Association, Holiday Magazine, London - background material for an article to appear early in 1988.
6 November 1987	Espen Hoell, NORCEM CEMENT A/S
12 November 1987	Holt Landbruksskoles agr.tek.klasse - 10 pers.

APPENDIX 3. INPUT-OUTPUT BUDGETS AT RISDALSHEIA AND SOGNDAL 1984-87.

Input-output budgets for water and major ions at EGIL and KIM catchments for the $1^1/_2$ year treatment period 13 June 1984 - 14 November 1985. Organic anions (A^-) are obtained by difference from the ionic balance. Units: meq/m^2; NLAL mgAl/m^2; TOC gC/m^2.

1984-85

	EGIL						KIM			
	Input					Out	Input			Out
	Wet	Dry			Total		Wet	Dry	Total	
		marine part.	Acid part.	gases						
H_2O	1346					1092	1102			835
H^+	64	0	2	23	89	102	10	25	35	72
Na	65	32	0	0	97	91	61	32	93	77
K	6	1	0	0	7	8	1	1	2	6
Ca	12	1	0	0	13	15	3	1	4	11
Mg	16	7	0	0	23	24	14	7	21	14
Al	0	0	0	0	0	18	0	0	0	11
NH_4	57	0	6	0	63	16	0	6	6	6
NO_3	50	0	0	8	58	32	1	8	9	6
Cl	70	38	0	0	108	108	72	38	110	104
SO_4	86	4	8	15	113	115	8	27	35	58
A^-	0	0	0	0	0	18	0	0	0	28
Σ^+	220	41	8	23	292	274	89	72	161	197
Σ^-	206	42	8	23	279	273	81	73	154	196
NLAL						229				238
TOC						12.7				15.5

Input-output budgets for water and major ions at EGIL, KIM and ROLF catchments for the period 15 November 1985 - 18 December 1986. Organic anions (A^-) are obtained by difference from the ionic balance. Units: meq/m^2; NLAL mgAl/m^2; TOC gC/m^2. Fluxes for KIM are corrected for the period 31 October - 20 November during which the ion-exchange columns failed.

1986

	EGIL				KIM				ROLF			
	Input			Out	Input			Out	Input			Out
	Wet	Dry	Total		Wet	Dry	Total		Wet	Dry	Total	
H_2O	771			570	686			531	1516			1388
H^+	47	17	64	50	10	17	27	38	100	17	117	129
Na	27	21	48	54	45	21	66	47	71	83	154	140
K	2	0	3	6	2	0	2	4	5	2	7	6
Ca	6	1	7	11	3	1	4	7	14	4	18	28
Mg	9	5	4	16	9	5	14	10	19	19	38	41
Al	0	0	0	10	0	0	0	5	0	0	0	16
NH_4	27	3	30	19	1	3	4	7	61	3	64	19
NO_3	27	6	33	22	0	6	6	9	62	6	74	40
Cl	39	24	64	64	48	24	72	56	84	97	181	181
SO_4	45	16	63	76	8	16	24	34	107	10	132	150
A^-	0	0	0	5	0	0	0	19	0	0	0	8
Σ^+	119	47	166	166	70	47	117	118	270	127	398	379
Σ^-	111	46	160	166	56	46	102	118	253	127	386	379
NLAL				109				124				174
TOC				6.1				8.3				14.0

Input-output budgets for water and major ions at EGIL, KIM and ROLF catchments for the period 19 December 1986 - 23 November 1987. Organic anions (A^-) are obtained by difference from the ionic balance. Units: meq/m^2; NLAL mgAl/m^2; TOC gC/m^2. Fluxes for KIM are corrected for the period 16-20 October during which the ion-exchange columns failed.

1987

	EGIL						KIM				ROLF			
	Input					Out	Input			Out	Input			Out
	Wet	Dry			Total		Wet	Dry	Total		Wet	Dry	Total	
		marine part.	acid part.	gases										
H_2O	1134					1103	905			786	1524			1324
H^+	60	0	1	19	80	86	8	20	28	60	76	20	96	92
Na	59	40	0	0	109	106	27	40	67	68	74	51	125	113
K	4	1	0	0	5	9	2	1	3	5	5	1	6	4
Ca	9	2	0	0	11	21	2	2	4	9	11	2	13	20
Mg	16	9	0	0	25	28	6	9	15	14	22	12	33	28
Al	0	0	0	0	0	15	0	0	0	8	0	0	0	16
NH_4	40	0	4	0	63	29	5	4	8	5	51	4	55	8
NO_3	41	0	0	11	52	41	1	11	12	6	50	11	61	18
Cl	67	47	0	0	114	114	32	47	80	83	83	60	143	143
SO_4	65	5	5	8	83	117	6	18	24	41	85	19	104	90
A^-	0	0	0	0	0	18	0	0	0	39	0	0	0	30
Σ^+	188	52	5	19			50	76	125	169	239	90	328	281
Σ^-	173	52	5	19			39	76	116	169	218	90	308	281
NLAL						124				146				128
TOC						10.7				12.1				12.9
SiO_2						2.1				2.0				1.5

Input-output budgets for water and major ions at the Sogndal catchments for the periods 831115-841113 (1984), 841114-851101 (1985), 851102-861112 (1986), and 861113-871115 (1987). Precipitation inputs have been corrected such that inputs equal outputs for SOG1. Values thus differ somewhat from those in Wright and Gjessing (1986). Units: H_2O in mm; ions in meq/m^2/yr.; TOC in g C/m^2/yr; SiO_2 in g SiO_2/m^2/yr.

Fluxes. - 1984 -

	SOG1		SOG2		SOG3		SOG4	
	control		H_2SO_4		control		H_2SO_4 + HNO_3	
	In	Out	In	Out	In	Out	In	Out
H_2O	1126	1026	1186	1086	1126	1026	1186	1086
H^+	22	2	89	9	22	4	92	4
Na	81	90	84	64	81	80	84	55
K	7	11	7	4	7	2	7	2
Ca	10	21	11	24	10	21	11	28
Mg	18	15	17	14	18	19	18	13
Al	-	1	-	3	-	0	-	1
NH_4	10	6	10	3	10	1	10	1
NO_3	10	2	11	4	10	2	45	4
Cl	91	91	95	65	91	85	94	62
SO_4	35	29	105	43	35	25	70	28
HCO_3	0	15	0	5	0	1	0	7
Σ^+	148	146	218	121	148	127	222	104
Σ^-	136	138	211	113	136	113	209	101
TOC	-	4.4	-	2.7	-	0.8	-	2.9
SiO_2	-	-	-	-	-	-	-	-

Fluxes. - 1985 -

	SOG1 control		SOG2 H_2SO_4		SOG3 control		SOG4 H_2SO_4 + HNO_3	
	In	Out	In	Out	In	Out	In	Out
H_2O	928	828	991	891	928	828	991	891
H^+	14	2	116	4	14	1	116	4
Na	30	29	32	28	30	27	33	37
K	4	2	5	2	4	1	5	1
Ca	4	13	5	20	4	13	5	18
Mg	4	7	4	10	4	7	4	8
Al	-	0	-	2	-	0	-	0
NH_4	6	4	6	0	6	0	6	1
NO_3	7	1	7	1	7	0	59	1
Cl	24	24	26	23	24	21	22	23
SO_4	15	18	118	34	15	18	66	21
HCO_3	0	11	0	2	0	4	0	6
Σ^+	62	58	168	64	62	49	169	69
Σ^-	46	54	151	59	46	43	147	51
TOC	-	1.2	-	1.4	-	0.8	-	2.5
SiO_2	-	0.7	-	1.2	-	0.8	-	1.6

Fluxes. - 1986 -

	SOG1 control		SOG2 H_2SO_4		SOG3 control		SOG4 H_2SO_4 + HNO_3	
	In	Out	In	Out	In	Out	In	Out
H_2O	957	857	1025	925	957	857	1030	930
H^+	11	1	112	7	11	1	112	6
Na	21	28	25	32	21	26	26	27
K	6	2	6	2	6	0	6	2
Ca	3	15	4	26	3	15	5	25
Mg	5	7	6	13	5	7	6	10
Al	-	0	-	2	-	0	-	1
NH_4	7	0	7	0	7	0	7	0
NO_3	5	1	5	1	5	0	55	6
Cl	24	24	26	31	24	23	26	24
SO_4	19	23	122	53	19	20	71	42
HCO_3	0	3	0	0	0	3	0	1
Σ^+	53	53	160	82	53	49	162	71
Σ^-	48	50	153	85	48	46	152	73
TOC	-	0.8	-	1.5	-	0.7	-	1.4
SiO_2	-	0.9	-	1.5	-	1.2	-	1.7

Fluxes. - 1987 -

	SOG1 control		SOG2 H_2SO_4		SOG3 control		SOG4 H_2SO_4 + HNO_3	
	In	Out	In	Out	In	Out	In	Out
H_2O	925	790	791	683	925	790	819	718
H^+	16	1	112	5	16	2	114	3
Na	26	30	21	26	26	30	22	27
K	6	3	4	4	6	1	5	2
Ca	5	16	6	20	5	15	6	19
Mg	5	8	4	9	5	8	4	8
Al	-	0	-	2	-	1	-	2
NH_4	13	-	9	-	13	-	9	-
NO_3	10	1	6	2	10	0	57	2
Cl	28	30	21	25	28	29	22	25
SO_4	23	16	119	34	23	18	69	26
HCO_3	0	10	0	5	0	6	0	1
Σ^+	71	58	156	68	71	57	160	61
Σ^-	61	57	146	66	61	53	148	54
NLAL	-	7		8		8		12
TOC	-	1.0	-	1.2	-	0.6	-	2.3
SiO_2	-	0.8	-	1.0	-	1.0	-	1.3

APPENDIX 4. RISDALSHEIA DISCHARGE DATA.

RISDALSHEIA DISCHARGE. UNITS: MM/DAY

DATE	EGIL	KIM	ROLF
861219		0.00	0.00
861220		0.00	0.00
861221		0.00	0.00
861222		0.00	0.00
861223		0.00	0.00
861224		0.00	0.00
861225		0.00	0.00
861226		0.00	0.00
861227		0.00	0.00
861228		0.00	0.00
861229		0.00	0.00
861230		0.00	0.00
861231		0.00	0.00
870101		0.00	0.00
870102		0.00	0.00
870103		0.00	0.00
870104		0.00	0.00
870105		0.00	0.00
870106		0.00	0.00
870107		0.00	0.00
870108		0.00	0.00
870109		0.00	0.00
870110		0.00	0.00
870111		0.00	0.00
870112		0.00	0.00
870113		0.00	0.00
870114		0.00	0.00
870115		0.00	0.00
870116		0.00	0.00
870117		0.00	0.00
870118		0.00	0.00
870119		0.00	0.00
870120		0.00	0.00
870121		0.00	0.00
870122		0.00	0.00
870123		0.00	0.00
870124		0.00	0.00
870125		0.78	1.62

	EGIL	KIM	ROLF
870126		0.00	0.00
870127		0.00	0.00
870128		0.78	1.62
870129		0.00	0.00
870130		1.16	0.00
870131		0.00	0.00
870201		0.00	0.00
870202		0.00	0.00
870203		0.00	0.00
870204		0.00	0.00
870205		0.00	0.00
870206		1.94	0.00
870207		0.00	0.00
870208		0.00	0.00
870209		0.39	0.00
870210		0.00	0.00
870211		0.00	0.00
870212		0.00	0.00
870213		0.39	0.00
870214		0.00	0.00
870215		0.00	0.00
870216		0.00	0.00
870217		0.00	0.00
870218		0.00	0.00
870219		0.00	0.00
870220		0.00	1.62
870221		0.78	0.00
870222		1.94	0.00
870223		1.16	0.00
870224		0.78	0.00
870225		0.39	0.00
870226		0.39	1.62
870227		0.00	0.00
870228		0.39	0.00
870301		0.00	0.00
870302		0.00	0.00
870303		0.00	0.00
870304		0.00	0.00
870305		0.00	0.00
870306		0.00	0.00
870307		0.00	0.00
870308		0.00	0.00
870309		0.00	0.00
870310		0.00	0.00
870311		0.00	0.00

	EGIL	KIM	ROLF
870312		0.00	1.62
870313		0.00	0.00
870314		0.00	0.00
870315		0.00	0.00
870316		0.00	0.00
870317		0.00	0.00
870318		0.00	0.00
870319		0.00	0.00
870320		0.00	0.00
870321		0.00	0.00
870322		0.00	0.00
870323		0.00	0.00
870324		0.00	0.00
870325		0.00	1.62
870326		0.39	0.00
870327		0.00	3.24
870328		0.39	0.00
870329		0.78	3.24
870330		3.89	8.09
870331		5.06	11.34
870401		2.33	3.24
870402		0.78	1.62
870403		0.78	1.62
870404		8.07	32.39
870405		0.00	0.00
870406		0.00	0.00
870407		0.00	0.00
870408		0.00	0.00
870409		9.35	8.09
870410		2.33	1.62
870411		0.39	0.00
870412		0.00	0.00
870413		0.00	0.00
870414		5.06	4.86
870415		7.01	3.24
870416		7.40	1.62
870417		7.01	1.62
870418		5.45	0.00
870419		2.72	1.62
870420		0.00	0.00
870421		9.74	0.00
870422		0.00	0.00
870423		0.00	0.00
870424		1.30	0.00
870425		5.06	0.00

	EGIL	KIM	ROLF
870426		3.89	0.00
870427		4.28	0.00
870428		2.33	0.00
870429		0.78	0.00
870430		0.39	0.00
870501		2.33	0.00
870502		4.28	0.00
870503		2.72	1.62
870504		1.55	0.00
870505		0.78	0.00
870506		0.39	0.00
870507		0.39	0.00
870508		0.39	0.00
870509		0.78	0.00
870510		0.39	0.00
870511		0.39	0.00
870512		0.78	0.00
870513		0.39	0.00
870514	0.00	0.00	0.00
870515	0.93	0.00	0.00
870516	0.00	0.39	0.00
870517	0.00	0.39	1.62
870518	0.93	0.00	0.00
870519	0.93	0.78	1.62
870520	0.00	0.39	0.00
870521	0.00	0.39	0.00
870522	0.00	0.00	0.00
870523	0.00	0.00	0.00
870524	0.00	0.00	0.00
870525	0.00	0.00	0.00
870526	0.00	0.00	0.00
870527	6.51	6.24	6.48
870528	1.86	1.95	1.62
870529	0.93	0.78	1.62
870530	0.00	0.00	0.00
870531	0.00	0.00	0.00
870601	0.00	0.39	0.00
870602	0.00	0.39	0.00
870603	0.00	0.00	0.00
870604	0.93	0.00	0.00
870605	0.00	0.00	1.62
870606	6.51	5.07	8.09
870607	1.86	1.95	1.62
870608	0.93	1.56	1.62
870609	1.86	1.95	1.62

	EGIL	KIM	ROLF
870610	0.93	1.17	1.62
870611	0.93	1.17	3.24
870612	3.72	2.73	0.00
870613	1.86	1.95	1.62
870614	0.93	0.78	0.00
870615	1.86	0.39	1.62
870616	1.86	1.95	1.62
870617	7.44	5.07	3.24
870618	5.58	3.90	4.86
870619	3.72	3.12	1.62
870620	1.86	2.73	1.62
870621	1.86	1.56	1.62
870622	1.86	0.78	1.62
870623	0.00	0.00	0.00
870624	0.00	0.00	0.00
870625	0.00	0.00	0.00
870626	0.00	0.00	0.00
870627	0.00	0.00	0.00
870628	0.00	0.00	0.00
870629	0.00	0.00	0.00
870630	0.00	0.00	0.00
870701	0.00	0.00	0.00
870702	0.93	0.00	0.00
870703	0.93	0.39	0.00
870704	0.00	0.00	0.00
870705	0.00	0.00	0.00
870706	0.00	0.00	0.00
870707	0.00	0.00	0.00
870708	0.00	0.00	0.00
870709	0.00	0.00	0.00
870710	0.00	0.00	0.00
870711	0.00	0.00	0.00
870712	0.00	0.00	0.00
870713	0.00	0.00	0.00
870714	0.00	0.00	0.00
870715	0.00	0.00	0.00
870716	0.00	0.00	0.00
870717	0.00	0.00	0.00
870718	24.17	5.07	22.68
870719	9.30	2.34	19.43
870720	5.58	1.95	6.48
870721	4.65	0.00	1.62
870722	0.00	0.00	1.62
870723	0.00	0.00	0.00
870724	0.00	0.00	0.00

	EGIL	KIM	ROLF
870725	0.00	0.00	0.00
870726	0.00	0.00	0.00
870727	0.00	0.00	0.00
870728	0.00	0.00	0.00
870729	0.00	0.00	0.00
870730	0.00	1.17	0.00
870731	0.00	0.78	0.00
870801	0.00	0.39	1.62
870802	0.00	0.00	0.00
870803	0.00	0.00	1.62
870804	0.00	0.78	3.24
870805	0.00	0.78	3.24
870806	0.00	0.78	3.24
870807	0.00	3.12	8.09
870808	9.30	15.20	27.54
870809	6.51	11.31	24.29
870810	4.65	7.80	16.19
870811	3.72	7.41	11.34
870812	1.86	3.51	8.09
870813	0.93	3.51	8.09
870814	0.00	3.51	1.62
870815	1.86	0.00	1.62
870816	0.93	0.78	1.62
870817	0.93	0.39	1.62
870818	4.65	2.73	1.62
870819	4.65	3.12	3.24
870820	4.65	2.73	1.62
870821	0.93	0.78	1.62
870822	19.52	8.19	16.19
870823	5.58	4.29	6.48
870824	5.58	4.29	4.86
870825	10.23	8.19	4.86
870826	19.52	15.98	16.19
870827	4.65	8.19	4.86
870828	4.65	6.63	6.48
870829	0.00	0.00	6.48
870830	0.00	0.00	0.00
870831	0.00	0.00	0.00
870901	0.00	0.00	0.00
870902	0.00	0.00	0.00
870903	0.00	0.00	0.00
870904	0.00	0.00	0.00
870905	6.51	5.07	4.86
870906	11.16	9.36	9.71
870907	6.51	5.07	4.86

	EGIL	KIM	ROLF
870908	1.86	1.56	3.24
870909	6.51	5.07	3.24
870910	5.58	5.07	3.24
870911	6.51	5.07	4.86
870912	2.79	3.12	1.62
870913	3.72	3.12	3.24
870914	2.79	3.12	3.24
870915	3.72	3.12	3.24
870916	2.79	3.12	3.24
870917	2.79	3.12	3.24
870918	2.79	3.12	3.24
870919	3.72	2.34	3.24
870920	1.86	2.34	1.62
870921	1.86	1.95	1.62
870922	3.72	2.73	1.62
870923	3.72	3.51	3.24
870924	7.44	4.68	6.48
870925	1.86	1.95	1.62
870926	0.93	0.78	0.00
870927	0.00	0.00	0.00
870928	0.00	0.00	0.00
870929	0.00	0.00	0.00
870930	0.00	0.00	0.00
871001	0.00	0.00	0.00
871002	0.00	0.00	0.00
871003	0.00	0.00	0.00
871004	0.00	0.00	0.00
871005	20.45	12.09	19.43
871006	31.61	18.71	30.77
871007	15.80	10.53	24.29
871008	34.40	17.55	48.59
871009	13.94	15.98	12.95
871010	18.59	7.80	11.34
871011	18.59	7.80	12.95
871012	18.59	7.80	12.95
871013	18.59	7.41	12.95
871014	29.75	7.80	11.34
871015	29.75	25.34	53.45
871016	29.75	23.39	53.45
871017	13.94	7.80	8.09
871018	4.65	4.29	1.62
871019	1.86	1.17	0.00
871020	0.93	1.17	0.00
871021	0.00	1.17	0.00
871022	4.65	7.80	6.48

	EGIL	KIM	ROLF
871023	4.65	5.85	6.48
871024	4.65	5.85	4.86
871025	3.72	5.85	4.86
871026	12.09	13.64	11.34
871027	17.66	13.64	16.19
871028	8.37	9.75	4.86
871029	13.01	13.64	11.34
871030	8.37	9.75	8.09
871031	0.93	7.80	0.00
871101	0.93	8.19	1.62
871102	0.93	7.80	1.62
871103	0.93	1.95	1.62
871104	0.93	1.95	0.00
871105	0.93	1.56	1.62
871106	0.93	1.95	1.62
871107	0.93	1.95	1.62
871108	0.93	1.56	0.00
871109	0.93	1.95	1.62
871110	0.93	1.95	0.00
871111	0.93	1.95	1.62
871112	15.80	15.59	11.34
871113	16.73	15.59	14.57
871114	18.59	12.48	6.48
871115	18.59	12.48	6.48
871116	18.59	12.48	6.48
871117	8.37	5.85	8.09
871118	8.37	5.85	6.48
871119	9.30	5.85	6.48
871120	8.37	5.85	6.48
871121	9.30	5.85	8.09
871122	8.37	5.85	6.48
871123	9.30	5.85	6.48
871124	0.00	0.78	

APPENDIX 5. RISDALSHEIA RUNOFF CHEMISTRY.

Units: µeq/l; µg Al/l; mg C/l; mg SiO_2/l.

EGIL RUNOFF 1987

Date	pH	Na	K	Ca	Mg	NH_4	NO_3	Cl	SO_4	NLAL	LAL	TOC	SiO_2
870206	4.08	167.9	18.4	31.9	41.1	78.5	70.0	141.0	177.0	59	161	7.2	1.6
870226	4.08	139.6	11.3	26.4	37.8	33.9	49.3	143.9	158.2	134	196	7.3	3.3
870330	4.13	144.4	26.1	44.9	56.8	107.1	103.5	132.6	226.9	-99	-99	7.6	1.7
870402	4.03	137.9	24.5	38.9	55.9	89.2	103.9	138.2	208.2	85	138	6.3	2.1
870409	4.30	62.6	12.5	10.5	16.5	35.7	33.6	64.9	79.1	95	44	6.9	1.1
870414	4.49	38.3	8.9	9.0	9.0	23.9	21.4	45.1	47.9	80	28	6.5	.6
870420	4.41	43.1	9.5	7.0	9.0	27.1	17.8	45.1	47.9	120	27	8.6	.9
870430	4.37	45.7	9.7	8.0	9.0	25.0	21.4	45.1	45.8	165	53	10.5	1.1
870521	4.06	86.6	10.5	17.0	23.9	14.3	30.7	95.9	104.1	220	134	9.9	3.8
870610	4.10	83.1	7.2	13.5	19.7	17.5	17.8	70.5	112.4	37	296	11.9	2.6
870617	4.09	83.5	6.6	16.0	20.6	12.5	9.4	81.8	110.3	242	100	13.0	3.2
870619	4.26	53.9	2.8	12.5	11.5	20.3	6.0	28.2	60.4	242	35	19.1	2.1
870716	4.24	83.5	5.1	18.0	20.6	39.3	17.8	56.4	108.3	173	154	13.5	4.6
870719	4.05	77.9	5.6	22.5	28.8	23.2	38.2	53.6	131.2	133	196	13.2	3.6
870721	4.16	44.8	2.6	10.5	14.0	5.4	11.5	22.6	81.2	127	91	12.3	1.7
870814	4.09	58.3	2.0	14.5	18.9	4.6	6.1	48.0	97.9	167	51	13.2	3.6
870827	4.14	37.0	2.6	10.5	13.2	4.6	20.7	16.9	75.0	133	115	12.9	1.5
870911	4.21	30.9	2.0	10.5	12.3	6.8	6.9	25.4	54.1	152	69	13.6	1.5
870918	4.09	53.5	2.0	15.5	18.9	7.9	18.2	90.3	54.1	142	142	12.8	2.1
871008	4.11	59.6	5.9	13.5	16.5	7.9	18.6	93.1	62.5	73	89	9.2	.7
871014	4.12	80.9	7.4	12.5	14.8	12.5	57.5	76.2	68.7	57	55	6.2	.5
871022	3.77	376.3	14.3	60.9	81.4	53.5	121.4	462.6	258.2	50	384	6.0	.9
871030	3.98	161.8	11.8	25.0	36.2	53.5	95.3	172.1	177.0	62	216	6.0	.9
871111	3.99	160.1	11.0	23.0	30.4	21.4	30.7	200.3	122.8	95	204	7.1	2.9
871123	4.21	86.1	6.4	11.0	14.0	16.1	29.3	87.5	56.2	123	93	8.6	1.6

KIM RUNOFF 1987

Date	pH	Na	K	Ca	Mg	NH_4	NO_3	Cl	SO_4	NLAL	LAL	TOC	SiO_2
870130	3.98	199.7	19.4	28.9	42.8	15.4	13.2	324.4	68.7	97	178	11.0	6.0
870206	4.05	163.1	17.6	30.9	37.8	17.1	18.6	253.9	79.1	49	210	8.8	4.1
870213	3.98	175.7	17.6	33.9	41.1	11.8	23.6	259.5	104.1	99	341	10.6	4.9
870226	4.10	144.4	10.0	16.0	31.3	19.3	27.8	205.9	81.2	164	216	8.7	5.0
870330	4.02	136.2	13.6	21.5	29.6	20.3	24.4	203.1	104.1	-99	-99	11.7	5.4
870402	4.04	129.2	17.4	21.0	29.6	23.2	35.7	169.3	102.0	185	132	11.2	4.1
870409	4.17	97.9	15.3	12.5	17.3	17.1	20.0	107.2	68.7	165	66	11.3	2.5
870414	4.29	217.1	13.6	10.0	12.3	15.4	16.4	76.2	56.2	154	41	10.3	1.8
870420	4.34	67.0	10.2	9.0	11.5	17.8	15.4	62.1	52.0	183	40	11.9	1.7
870430	4.40	47.8	7.7	5.0	6.6	7.9	7.2	36.7	31.2	172	38	12.3	1.2
870521	4.22	85.7	9.2	13.5	14.8	5.7	7.6	79.0	56.2	305	72	19.6	3.5
870529	4.11	89.2	4.9	10.5	19.7	3.2	15.0	87.5	81.2	224	114	12.4	3.8
870610	4.09	89.2	6.1	10.5	20.6	5.4	8.6	95.9	70.8	298	68	17.7	3.9
870617	4.23	68.7	4.6	8.5	13.2	2.5	4.0	76.2	41.6	262	76	13.1	3.3
870619	4.11	87.9	5.1	10.5	18.1	4.6	2.4	87.5	52.0	290	70	17.6	3.9
870716	4.25	61.3	6.4	17.0	17.3	17.8	9.7	56.4	64.5	147	105	13.4	2.6
870719	4.35	43.9	6.1	10.5	13.2	15.0	10.1	39.5	54.1	92	70	9.3	1.6
870721	4.12	75.3	2.6	12.0	19.7	6.1	25.0	64.9	79.1	135	172	12.6	4.3
870807	4.19	101.8	2.6	17.5	22.2	1.8	3.9	138.2	47.9	51	81	6.7	1.7
870814	4.11	64.4	2.3	9.0	14.0	3.9	1.2	67.7	41.6	179	114	19.3	3.1
870828	4.22	50.5	3.1	6.0	8.2	1.8	1.0	48.0	16.7	201	128	20.0	2.3
870911	4.16	59.2	2.8	8.5	10.7	2.5	.9	53.6	22.9	242	87	24.4	2.5
870918	4.14	61.8	3.3	8.0	13.2	2.9	1.0	70.5	22.9	223	23	23.9	2.3
871008	4.12	57.4	4.6	7.5	11.5	1.8	1.9	67.7	41.6	136	97	17.5	1.4
871014	4.14	53.1	4.3	7.0	10.7	2.1	1.6	76.2	52.0	138	64	14.2	1.1
871015	4.08	61.3	6.9	9.0	12.3	2.5	2.8	95.9	43.7	91	62	11.9	.8
871015	4.12	55.2	6.6	7.5	10.7	2.5	3.1	93.1	33.3	77	48	10.1	.6
871022	3.89	198.8	9.2	39.4	55.9	28.9	32.5	361.1	81.2	71	323	6.6	1.7

ROLF RUNOFF 1987

Date	pH	Na	K	Ca	Mg	NH_4	NO_3	Cl	SO_4	NLAL	LAL	TOC	SiO_2
870206	4.10	121.4	4.1	14.5	22.2	8.9	36.1	90.3	110.3	75	111	7.8	1.3
870226	4.15	122.2	6.1	13.0	18.9	10.7	8.0	93.1	106.2	165	66	12.0	2.4
870330	4.03	146.6	9.2	21.0	32.9	31.4	61.4	138.2	135.3	120	96	7.6	1.6
870331	4.03	147.5	10.2	20.5	32.9	25.7	51.1	146.7	133.2	131	103	7.8	1.9
870409	4.09	124.0	8.2	18.5	29.6	28.6	69.6	87.5	129.1	118	103	7.8	1.3
870421	4.29	51.3	4.3	10.0	9.9	13.2	23.9	31.0	62.5	101	22	8.1	.6
870430	4.32	47.0	5.6	12.0	9.9	10.0	11.4	28.2	62.5	165	34	13.1	.8
870521	4.14	68.7	8.9	21.0	23.0	16.1	33.6	50.8	87.4	224	63	18.1	2.1
870610	4.04	77.9	1.0	13.0	20.6	1.8	9.5	70.5	95.8	176	47	12.8	1.8
870617	4.18	55.7	1.0	10.0	13.2	1.8	.9	48.0	50.0	220	51	20.3	2.3
870618	4.15	63.5	.5	10.5	13.2	2.9	1.3	39.5	60.4	226	33	16.8	2.4
870716	4.07	81.3	10.5	26.9	32.9	50.0	31.1	73.3	141.6	127	151	20.2	1.9
870719	3.94	75.7	9.5	23.0	31.3	16.1	24.6	76.2	133.2	88	143	15.4	2.0
870721	4.18	36.1	1.0	6.5	9.0	6.1	1.6	19.7	64.5	90	48	11.8	.9
870807	3.94	53.5	.8	11.5	14.0	2.5	.4	67.7	45.8	139	110	21.3	2.8
870814	4.22	35.7	.5	6.5	8.2	3.2	.4	31.0	35.4	119	46	14.2	1.2
870826	4.10	46.5	.8	8.5	11.5	3.2	3.6	22.6	72.9	140	90	19.0	1.6
870911	4.14	49.2	.8	11.5	15.6	1.1	.4	53.6	45.8	196	90	22.3	2.8
870918	4.08	64.4	2.0	12.0	16.5	6.1	4.5	93.1	33.3	172	137	22.0	3.2
871008	4.11	53.1	1.0	9.0	11.5	1.4	6.2	81.8	52.0	73	78	8.5	.7
871014	4.14	49.2	1.8	8.0	10.7	4.3	11.1	76.2	54.1	46	24	7.2	.3
871022	3.48	565.5	5.9	151.7	249.2	5.7	38.9	1325.9	193.6	70	1640	5.9	1.3
871030	3.72	334.9	5.1	48.9	78.1	7.5	46.8	490.9	185.3	62	434	6.7	1.3
871112	3.83	269.7	4.1	29.9	51.0	7.5	52.8	282.1	229.0	87	249	9.3	1.9
871123	4.22	123.1	2.3	7.5	10.7	3.6	5.0	104.4	54.1	130	55	14.2	1.3

APPENDIX 6. RISDALSHEIA PRECIPITATION DATA.

Units: µeq/l.

EGIL PRECIPITATION 1986-87

DATE ON	DATE OFF	MM	PH	NA	K	CA	MG	NH4	NO3	CL	SO4
861219	870512	253	4.32	45.5	4.7	7.1	9.9	49.0	50.2	49.0	62.1
870514	870520	16.9	4.04	7.0	.8	4.5	2.6	4.3	35.7	7.3	71.8
870521	870528	19.4	4.33	57.4	7.4	18.5	17.4	55.7	45.7	70.2	81.8
870529	870603	2.6	3.94	28.7	30.4	19.5	15.8	285.6	72.8	29.6	201.1
870604	870610	41.1	4.29	18.3	1.0	1.0	4.8	25.7	24.3	21.4	58.1
870611	870616	4.8	4.43	17.4	1.5	2.0	1.2	7.1	23.6	.6	30.0
870617	870624	16.2	5.06	17.4	.8	1.0	.2	2.9	.7	46.3	6.7
870625	870702	10.8	4.10	17.4	1.5	4.0	5.1	5.7	20.7	9.3	68.7
870710	870716	2.3	3.83	68.7	12.5	24.5	20.6	142.8	50.0	55.0	223.0
870717	870723	55.1	4.60	13.1	2.3	8.0	4.3	22.8	6.4	9.3	37.5
870724	870728	1.1	6.03	7.8	8.2	3.5	3.9	142.8	.7	7.9	19.4
870729	870806	10.1	5.31	23.5	1.8	3.5	52.6	2.9	.7	21.2	6.9
870807	870813	42.2	4.46	33.9	1.8	2.5	7.7	2.9	13.6	40.6	30.6
870814	870820	21.7	4.66	3.5	1.3	3.0	1.5	5.7	8.6	7.1	20.0
870821	870826	71.8	4.07	2.6	1.8	8.0	2.0	47.1	54.3	8.2	85.6
870827	870903	2.3	3.91	40.9	15.3	34.9	18.9	85.7	73.5	37.8	160.5
870904	870910	53.4	4.20	17.4	1.3	3.5	31.3	4.3	27.1	18.3	39.3
870911	870917	36.3	4.22	58.3	3.1	6.0	14.0	21.4	37.8	65.7	50.0
870918	870923	24.6	4.05	22.6	3.8	10.5	5.8	58.5	59.3	25.1	79.3
870924	870930	3.4	4.22	60.0	4.9	11.0	15.1	40.0	45.7	58.4	52.5
871001	871007	90.0	4.28	18.7	.8	3.5	4.4	24.3	22.8	21.2	53.7
871008	871013	78.9	4.32	89.6	2.0	5.5	19.4	24.3	37.8	96.8	15.0
871014	871021	101.1	4.39	221.9	6.9	11.5	50.2	24.3	23.6	259.2	66.2
871022	871029	64.0	3.97	38.3	6.1	30.9	11.8	110.0	77.1	42.9	124.9
871030	871105	5.0	3.88	47.8	8.2	34.9	15.5	157.1	155.7	57.8	193.6
871106	871111	4.5	4.09	54.4	2.8	7.0	14.0	74.3	76.4	75.3	101.2
871112	871118	77.4	4.48	43.5	1.0	3.0	10.5	7.1	19.3	57.0	28.7
871119	871125	24.3	4.31	15.7	2.3	3.5	5.6	35.7	31.4	18.9	63.7

KIM PRECIPITATION 86-87

DATE ON	DATE OFF	MM	PH	NA	K	CA	MG	NH4	NO3	CL	SO4
861219	870512	149	5.00	26.0	2.0	2.0	6.0	2.0	1.0	30.0	6.0
870513	870610	61.0	5.13	51.3	14.6	2.0	6.6	2.9	1.4	62.6	12.5
870611	870616	11.6	5.30	45.2	3.1	3.5	9.5	2.9	.7	53.0	6.9
870617	870624	12.4	5.22	38.3	.8	3.5	9.2	2.9	.7	.3	6.7
870625	870702	5.1	5.22	45.2	.8	4.0	11.4	2.9	.7	23.4	8.1
870710	870716	7.0	5.13	44.4	4.9	4.0	11.2	2.9	.7	40.3	10.8
870717	870723	19.0	4.86	40.0	2.0	3.5	9.5	2.9	.7	38.1	6.9
870724	870728	3.7	6.36	44.4	29.7	5.5	15.5	271.3	.7	43.4	20.0
870729	870806	25.8	5.07	32.2	2.6	2.5	7.4	2.9	.7	31.3	4.4
870807	870813	60.3	5.23	27.8	1.5	2.0	6.3	2.9	.7	36.4	3.7
870814	870820	17.2	5.18	27.8	2.0	3.0	5.8	2.9	.7	34.4	1.9
870821	870826	62.7	5.05	22.6	1.0	2.5	5.4	2.9	.7	34.4	3.1
870827	870903	5.2	4.93	25.2	4.1	3.0	7.6	2.9	.7	34.1	3.1
870904	870910	48.3	5.16	19.1	1.5	3.0	3.5	4.3	1.4	21.2	3.7
870911	870917	32.2	5.01	47.8	1.3	3.5	10.4	4.3	1.4	59.0	7.5
870918	870923	21.5	5.36	40.0	1.5	2.5	8.4	4.3	1.4	43.7	8.1
870924	870930	4.1	5.36	40.9	3.1	5.0	8.7	4.3	1.4	40.1	6.9
871001	871007	55.3	5.30	34.8	1.3	3.5	8.2	2.9	.7	38.6	8.7
871008	871013	46.3	4.73	32.6	.3	1.5	7.2	2.9	.7	39.5	5.6
871014	871021	75.5	3.77	80.0	.8	2.5	10.0	2.9	.7	242.3	8.7
871022	871029	65.0	5.04	21.3	.3	.5	4.3	2.9	.7	27.4	6.2
871030	871105	34.6	4.97	22.6	.5	2.0	5.8	2.9	.7	23.7	8.7
871106	871111	22.4	4.96	19.1	.3	2.5	5.3	2.9	.7	28.2	6.2
871112	871118	88.8	5.09	27.4	.5	2.5	6.9	2.9	.7	38.9	5.6
871119	871125	46.5	5.07	19.6	1.5	3.0	5.6	2.9	.7	28.5	4.4

ROLF PRECIPITATION 86-87

DATE ON	DATE OFF	MM	PH	NA	K	CA	MG	NH4	NO3	CL	SO4
861223	861231	31.8	4.70	37.0	4.1	7.5	12.5	40.0	40.0	40.0	30.0
870107	870113	8.3	4.13	23.9	3.1	14.5	5.3	27.1	57.8	17.5	70.6
870129	870205	3.5	4.54	78.3	14.8	29.9	15.1	42.8	49.3	93.9	70.0
870206	870212	57.0	4.52	13.1	2.0	4.0	3.3	5.7	23.6	16.6	21.9
870312	870318	39.8	4.33	63.5	4.6	7.0	13.0	47.1	41.4	65.7	66.2
870319	870325	48.4	4.09	33.1	5.1	8.5	6.1	100.0	90.7	34.7	103.7
870326	870401	72.6	4.47	42.6	2.8	2.5	8.6	34.3	35.0	45.7	41.2
870402	870408	4.9	4.08	240.1	44.0	44.4	35.7	128.5	102.1	200.9	245.5
870409	870415	2.9	3.55	478.5	30.7	44.4	107.6	514.1	382.0	574.1	540.3
870430	870507	5.2	4.05	65.3	2.0	23.0	26.0	20.0	73.5	90.0	96.8
870514	870520	19.9	4.04	7.0	.8	4.5	2.6	4.3	35.7	7.3	71.8
870521	870528	31.2	4.33	57.4	7.4	18.5	17.4	55.7	45.7	70.2	81.8
870529	870603	5.3	3.94	28.7	30.4	19.5	15.8	285.6	72.8	29.6	201.1
870604	870610	67.5	4.29	18.3	1.0	1.0	4.8	25.7	24.3	21.4	58.1
870611	870616	18.2	4.43	17.4	1.5	2.0	1.2	7.1	23.6	.6	30.0
870617	870624	15.3	5.06	17.4	.8	1.0	.2	2.9	.7	46.3	6.7
870625	870702	10.3	4.10	17.4	1.5	4.0	5.1	5.7	20.7	9.3	68.7
870710	870716	6.7	3.83	68.7	12.5	24.5	20.6	142.8	50.0	55.0	223.0
870717	870723	145.2	4.60	13.1	2.3	8.0	4.3	22.8	6.4	9.3	37.5
870724	870728	4.5	6.03	7.8	8.2	3.5	3.9	142.8	.7	7.9	19.4
870729	870806	53.3	5.31	23.5	1.8	3.5	52.6	2.9	.7	21.2	6.9
870807	870813	102.9	4.46	33.9	1.8	2.5	7.7	2.9	13.6	40.6	30.6
870814	870820	21.0	4.66	3.5	1.3	3.0	1.5	5.7	8.6	7.1	20.0
870821	870826	81.8	4.07	2.6	1.8	8.0	2.0	47.1	54.3	8.2	85.6
870827	870903	1.7	3.91	40.9	15.3	34.9	18.9	85.7	73.5	37.8	160.5
870904	870910	57.3	4.20	17.4	1.3	3.5	31.3	4.3	27.1	18.3	39.3
870911	870917	34.4	4.22	58.3	3.1	6.0	14.0	21.4	37.8	65.7	50.0
870918	870923	24.5	4.05	22.6	3.8	10.5	5.8	58.5	59.3	25.1	79.3
870924	870930	3.5	4.22	60.0	4.9	11.0	15.1	40.0	45.7	58.4	52.5
871001	871007	136.9	4.28	18.7	.8	3.5	4.4	24.3	22.8	21.2	53.7
871008	871013	78.3	4.32	89.6	2.0	5.5	19.4	24.3	37.8	96.8	15.0
871014	871021	129.0	4.39	221.9	6.9	11.5	50.2	24.3	23.6	259.2	66.2
871022	871029	45.9	3.97	38.3	6.1	30.9	11.8	110.0	77.1	42.9	124.9
871030	871105	20.7	3.88	47.8	8.2	34.9	15.5	157.1	155.7	57.8	193.6
871106	871111	19.4	4.09	54.4	2.8	7.0	14.0	74.3	76.4	75.3	101.2
871112	871118	71.0	4.48	43.5	1.0	3.0	10.5	7.1	19.3	57.0	28.7
871119	871125	34.4	4.31	15.7	2.3	3.5	5.6	35.7	31.4	18.9	63.7

APPENDIX 7. SOGNDAL DISCHARGE DATA.

Units: mm/day. Corrected data.

	SOG1	SOG2	SOG4
861113	4.63	4.68	5.78
861114	3.96	3.24	4.00
861115	6.09	4.68	4.00
861116	6.88	7.20	4.00
861117	6.09	4.68	4.00
861118	4.63	4.68	4.00
861119	3.96	3.24	4.00
861120	2.84	3.24	4.00
861121	2.84	3.24	4.00
861122	2.39	1.80	4.00
861123	1.95	1.80	4.00
861124	1.95	1.80	4.00
861125	1.95	1.80	4.00
861126	2.39	3.24	4.00
861127	2.84	3.24	4.00
861128	7.79	7.20	0.89
861129	11.99	13.20	12.01
861130	6.09	7.20	5.78
861201	4.63	4.68	5.78
861202	3.96	3.24	5.78
861203	5.30	4.68	4.00
861204	9.75	7.20	4.00
861205	6.09	4.68	4.00
861206	5.30	4.68	4.00
861207	3.40	3.24	4.00
861208	2.84	3.24	4.00
861209	10.80	7.20	5.78
861210	10.80	13.20	12.01
861211	5.30	7.20	5.78
861212	3.96	4.68	4.00
861213	3.40	3.24	4.00
861214	2.84	3.24	4.00
861215	3.29	3.24	4.00
861216	1.95	3.24	2.22
861217	1.95	3.24	0.00
861218	1.95	1.80	0.00
861219	1.95	1.80	0.00
861220	1.60	0.00	0.00
861221	0.00	0.00	0.00

	SOG1	SOG2	SOG 4
861222	0.00	0.00	0.00
861223	0.00	0.00	0.00
861224	0.00	0.00	0.00
861225	0.00	0.00	0.00
861226	0.00	0.00	0.00
861227	0.00	0.00	0.00
861228	0.00	0.00	0.00
861229	0.00	0.00	0.00
861230	0.00	0.00	0.00
861231	0.00	0.00	0.00
870101	0.00	0.00	0.00
870102	0.00	0.00	0.00
870103	0.00	0.00	0.00
870104	0.00	0.00	0.00
870105	0.00	0.00	0.00
870106	0.00	0.00	0.00
870107	0.00	0.00	0.00
870108	0.00	0.00	0.00
870109	0.00	0.00	0.00
870110	0.00	0.00	0.00
870111	0.00	0.00	0.00
870112	0.00	0.00	0.00
870113	0.00	0.00	0.00
870114	0.00	0.00	0.00
870115	0.00	0.00	0.00
870116	0.00	0.00	0.00
870117	0.00	0.00	0.00
870118	0.00	0.00	0.00
870119	0.00	0.00	0.00
870120	0.00	0.00	0.00
870121	0.00	0.00	0.00
870122	0.00	0.00	0.00
870123	0.00	0.00	0.00
870124	0.00	0.00	0.00
870125	0.00	0.00	0.00
870126	0.00	0.00	0.00
870127	0.00	0.00	0.00
870128	0.00	0.00	0.00
870129	0.00	0.00	0.00
870130	0.00	0.00	0.00
870131	0.00	0.00	0.00
870201	0.00	0.00	0.00
870202	0.00	0.00	0.00
870203	0.00	0.00	0.00
870204	0.00	0.00	0.00

	SOG1	SOG2	SOG4
870205	0.00	0.00	0.00
870206	0.00	0.00	0.00
870207	0.00	0.00	0.00
870208	0.00	0.00	0.00
870209	0.00	0.00	0.00
870210	0.00	0.00	0.00
870211	0.00	0.00	0.00
870212	0.00	0.00	0.00
870213	0.00	0.00	0.00
870214	0.00	0.00	0.00
870215	0.00	0.00	0.00
870216	0.00	0.00	0.00
870217	0.00	0.00	0.00
870218	0.00	0.00	0.00
870219	0.00	0.00	0.00
870220	0.00	0.00	0.00
870221	0.00	0.00	0.00
870222	0.00	0.00	0.00
870223	0.00	0.00	0.00
870224	0.00	0.00	0.00
870225	0.00	0.00	0.00
870226	0.00	0.00	0.00
870227	0.00	0.00	0.00
870228	0.00	0.00	0.00
870301	0.00	0.00	0.00
870302	0.00	0.00	0.00
870303	0.00	0.00	0.00
870304	0.00	0.00	0.00
870305	0.00	0.00	0.00
870306	0.00	0.00	0.00
870307	0.00	0.00	0.00
870308	0.00	0.00	0.00
870309	0.00	0.00	0.00
870310	0.00	0.00	0.00
870311	0.00	0.00	0.00
870312	0.00	0.00	0.00
870313	0.00	0.00	0.00
870314	0.00	0.00	0.00
870315	0.00	0.00	0.00
870316	0.00	0.00	0.00
870317	0.00	0.00	0.00
870318	0.00	0.00	0.00
870319	0.00	0.00	0.00
870320	0.00	0.00	0.00
870321	0.00	0.00	0.00

	SOG1	SOG2	SOG4
870322	0.00	0.00	0.00
870323	0.00	0.00	0.00
870324	0.00	0.00	0.00
870325	0.00	0.00	0.00
870326	0.00	0.00	0.00
870327	0.00	0.00	0.00
870328	0.00	0.00	0.00
870329	0.00	0.00	0.00
870330	0.00	0.00	0.00
870331	0.00	0.00	0.00
870401	0.00	0.00	0.00
870402	0.00	0.00	0.00
870403	0.00	0.00	0.00
870404	0.00	0.00	0.00
870405	0.00	0.00	0.00
870406	0.00	0.00	0.00
870407	0.00	0.00	0.00
870408	0.00	0.00	0.00
870409	0.00	0.00	0.00
870410	0.00	0.00	0.00
870411	0.00	0.00	0.00
870412	0.00	0.00	0.00
870413	0.00	0.00	0.00
870414	0.00	0.00	0.00
870415	0.00	0.00	0.00
870416	0.00	0.00	0.00
870417	0.00	0.00	0.00
870418	0.00	0.00	0.00
870419	0.00	0.00	0.00
870420	0.00	0.00	0.00
870421	0.00	0.00	0.00
870422	0.00	0.00	0.00
870423	0.00	0.00	0.00
870424	0.00	0.00	0.00
870425	0.00	0.39	0.44
870426	1.60	2.57	2.96
870427	1.60	2.57	2.96
870428	2.84	3.43	3.94
870429	14.50	13.59	15.62
870430	20.42	22.11	25.43
870501	31.66	32.87	37.80
870502	13.18	11.44	13.16
870503	6.09	2.57	2.96
870504	4.63	1.16	1.33
870505	3.96	1.16	1.33

	SOG1	SOG2	SOG4
870506	3.96	1.16	1.33
870507	3.96	1.16	1.33
870508	3.96	1.16	1.33
870509	5.30	0.64	0.74
870510	6.09	0.64	0.74
870511	6.09	0.64	0.74
870512	4.63	1.16	1.33
870513	4.63	0.64	0.74
870514	3.96	1.67	1.92
870515	4.63	2.57	2.96
870516	7.79	3.43	3.94
870517	11.99	7.63	8.77
870518	15.83	7.63	8.77
870519	10.80	7.63	8.77
870520	6.88	2.57	2.96
870521	8.71	3.43	3.94
870522	13.18	7.63	8.77
870523	18.78	5.91	6.80
870524	20.42	7.63	8.77
870525	18.78	5.91	6.80
870526	15.83	4.71	5.42
870527	10.80	3.43	3.94
870528	6.88	1.67	1.92
870529	6.09	1.67	1.92
870530	7.79	1.67	1.92
870531	9.75	1.67	1.92
870601	7.79	2.57	2.96
870602	8.71	2.57	2.96
870603	7.79	2.57	2.96
870604	7.79	2.57	2.96
870605	6.88	1.16	1.33
870606	6.88	1.16	1.33
870607	6.88	1.16	1.33
870608	4.63	0.64	0.74
870609	3.96	0.64	0.74
870610	3.96	0.64	0.74
870611	4.63	1.16	1.33
870612	3.96	0.64	0.74
870613	3.40	0.64	0.74
870614	2.84	0.39	0.44

	SOG1	SOG2	SOG4
870615	2.39	1.08	0.31
870616	2.39	1.08	0.31
870617	1.60	1.80	0.31

	SOG1	SOG2	SOG4
870618	1.24	1.80	1.55
870619	1.24	1.80	0.31
870620	1.24	1.08	0.31
870621	1.24	1.08	0.31
870622	0.99	1.08	0.31
870623	0.99	1.08	0.31
870624	0.99	1.80	1.55
870625	0.99	1.80	0.31
870626	0.99	1.80	1.55
870627	0.99	1.80	0.31
870628	0.72	1.08	0.31
870629	0.72	1.08	0.31
870630	0.72	1.08	0.31
870701	0.72	1.80	0.31
870702	0.99	3.24	1.55
870703	0.99	1.80	1.55
870704	1.24	1.80	1.55
870705	25.12	16.56	4.67
870706	13.18	9.60	1.55
870707	6.88	9.60	8.41
870708	3.40	3.24	4.05
870709	2.39	1.80	1.55
870710	1.95	1.80	0.31
870711	1.24	1.08	0.31
870712	1.24	1.80	1.55
870713	1.24	3.24	1.55
870714	1.24	1.80	1.55
870715	1.24	1.08	0.31
870716	0.72	0.36	0.31
870717	0.72	0.36	0.31
870718	0.54	0.24	0.31
870719	0.54	0.24	0.31
870720	0.35	0.00	0.31
870721	0.24	0.00	1.55
870722	0.13	0.24	0.31
870723	0.13	0.00	0.31
870724	0.13	0.24	0.00
870725	0.08	0.24	0.31
870726	0.08	0.24	0.31
870727	0.08	0.00	0.00
870728	0.08	0.00	0.00
870729	0.03	0.00	0.00
870730	0.03	0.00	0.00
870731	0.03	0.00	0.00
870801	0.03	0.00	0.00

	SOG1	SOG2	SOG 4
870802	0.03	0.00	0.00
870803	0.02	0.00	0.00
870804	0.02	0.00	0.00
870805	0.02	0.00	0.00
870806	0.02	0.00	0.00
870807	0.02	0.00	0.00
870808	0.02	0.00	0.00
870809	0.02	0.00	0.00
870810	0.02	0.00	0.00
870811	0.02	0.00	0.00
870812	0.02	0.00	0.00
870813	0.02	0.00	0.00
870814	0.02	0.00	0.00
870815	0.02	0.00	0.00
870816	0.02	0.00	0.00
870817	0.03	0.00	0.00
870818	0.03	0.00	0.00
870819	0.03	3.24	0.31
870820	0.03	7.20	4.05
870821	0.03	4.68	4.05
870822	0.03	1.80	4.05
870823	0.03	1.08	1.55
870824	0.03	1.08	1.55
870825	0.03	1.08	0.31
870826	0.03	3.24	0.31
870827	0.03	1.80	1.55
870828	0.13	1.80	1.55
870829	0.13	1.80	4.05
870830	0.35	3.24	1.55
870831	0.72	1.80	4.05
870901	0.72	1.80	4.05
870902	0.54	1.08	1.55
870903	0.35	1.08	1.55
870904	0.35	1.08	1.55
870905	0.35	1.08	1.55
870906	0.24	3.24	1.55
870907	0.35	3.24	1.55
870908	0.54	3.24	4.05
870909	0.99	4.68	4.05
870910	2.84	7.20	4.05
870911	4.63	3.24	8.41
870912	2.39	7.20	8.41
870913	5.30	7.20	4.05
870914	6.09	7.20	8.41
870915	4.63	3.24	8.41

	SOG1	SOG2	SOG4
870916	2.84	1.80	8.41
870917	1.60	3.24	4.05
870918	2.84	9.60	4.05
870919	7.79	9.60	4.05
870920	6.88	4.68	8.41
870921	3.96	4.68	8.41
870922	3.96	4.68	4.05
870923	3.40	4.68	4.05
870924	4.63	3.24	4.05
870925	2.84	1.80	8.41
870926	1.60	1.80	4.05
870927	1.24	1.80	4.05
870928	1.24	1.08	1.55
870929	0.99	1.08	1.55
870930	0.72	3.24	1.55
871001	0.72	3.24	1.55
871002	0.72	1.80	4.05
871003	0.72	1.80	1.55
871004	0.72	1.08	1.55
871005	0.54	1.80	0.31
871006	0.54	3.24	1.55
871007	0.54	3.24	1.55
871008	0.99	1.80	4.05
871009	0.99	3.24	4.05
871010	0.99	1.80	4.05
871011	0.99	1.80	4.05
871012	0.99	1.80	4.05
871013	0.72	1.80	1.55
871014	0.72	1.80	1.55
871015	0.72	3.24	1.55
871016	1.24	4.68	1.55
871017	2.39	3.24	4.05
871018	2.39	1.80	4.05
871019	1.60	1.80	4.05
871020	0.99	1.08	4.05
871021	0.72	1.08	4.05
871022	0.72	1.08	1.55
871023	0.72	1.08	1.55
871024	0.72	1.08	1.55
871025	0.54	1.08	1.55
871026	0.35	1.08	1.55
871027	0.35	1.80	1.55
871028	0.35	3.24	1.55
871029	0.54	1.80	1.55
871030	0.54	1.80	4.05

	SOG1	SOG2	SOG4
871031	0.54	4.68	1.55
871101	0.54	1.80	1.55
871102	0.54	1.08	1.55
871103	0.54	1.08	1.55
871104	0.54	1.80	1.55
871105	0.72	1.80	1.55
871106	0.72	1.80	4.05
871107	0.72	1.80	4.05
871108	0.72	1.80	4.05
871109	0.72	1.80	4.05
871110	0.72	1.08	4.05
871111	0.72	1.08	1.55
871112	0.54	1.08	1.55
871113	0.35	1.08	4.05
871114	0.35	1.08	1.55
871115	0.24	1.08	1.55

APPENDIX 8. SOGNDAL RUNOFF CHEMISTRY.

Units: µeq/l, µg Al/l, mg C/l, mg SiO_2/l.

SOG1 RUNOFF 1987

Date/Time	pH	Na	K	Ca	Mg	NO_3	Cl	SO_4	ALKX	LAL	NLAL	TOC	SiO_2
8611130000	5.70	42.2	1.3	22.5	12.3	.4	50.8	22.9	1.6	7	10	.5	1.3
8611190000	5.74	42.2	1.0	21.5	12.3	.8	45.1	22.9	2.9	0	10	.5	0.0
8611220000	5.87	41.3	1.0	21.0	12.3	.2	50.8	25.0	5.3	0	10	.8	1.4
8611280000	5.97	49.2	2.8	37.9	15.6	.2	45.1	25.0	.0	0	10	1.6	-99
8701270000	5.81	56.1	2.3	31.9	17.3	1.7	59.2	31.2	7.6	8	10	.6	2.0
8704280000	5.47	74.4	32.2	19.5	6.6	12.4	76.2	22.9	20.7	0	10	4.0	.2
8704290000	5.91	64.8	11.8	24.5	14.8	3.6	73.3	20.8	24.0	9	11	1.7	.8
8705210000	5.67	18.7	4.1	4.0	2.5	1.8	19.7	2.1	8.7	0	10	2.0	.1
8705220000	5.67	34.8	5.1	24.5	12.3	1.3	36.7	35.4	17.5	6	11	2.2	1.4
8705230000	5.48	26.1	1.5	20.0	9.9	.6	25.4	29.1	9.8	17	11	1.2	1.1
8705310000	5.59	22.2	.5	10.5	5.8	.9	22.6	10.4	7.6	1	10	.9	.9
8706060000	5.84	26.5	1.5	14.5	6.6	.1	25.4	14.6	4.1	1	10	.9	1.0
8706080000	5.75	27.8	1.3	13.5	6.6	.7	25.4	18.7	1.6	1	10	1.2	1.0
8706140000	5.90	32.6	1.0	18.0	9.0	.1	31.0	18.7	9.8	0	10	.6	1.0
8706210000	5.93	27.8	1.3	15.5	8.2	.1	25.4	20.8	9.8	0	10	1.0	1.0
8706280000	5.79	30.0	1.3	13.5	8.2	.1	25.4	18.7	7.6	0	10	.9	1.0
8707050000	5.96	32.6	2.0	16.0	8.2	1.9	28.2	20.8	7.6	0	10	1.3	1.0
8707120000	5.86	31.3	1.5	16.0	9.0	.2	28.2	22.9	9.8	0	10	.9	1.1
8707190000	5.90	33.1	1.3	15.0	9.0	.1	25.4	22.9	.0	0	10	1.0	1.1
8707191000	5.58	33.1	1.3	15.5	9.9	.1	28.2	22.9	14.2	0	10	1.3	1.1
8707260000	5.90	36.5	1.8	15.5	9.0	.1	33.9	35.4	1.6	0	10	1.2	1.0
8708020000	5.91	38.3	2.3	16.5	9.0	.2	33.9	25.0	2.9	6	10	1.5	.9
8708090000	6.00	36.1	1.3	17.0	9.0	.1	31.0	25.0	.0	0	10	.7	1.0
8708160000	5.81	38.7	2.0	17.5	10.7	.1	33.9	27.1	8.7	0	10	1.1	.9
8708230000	5.82	36.1	1.8	16.5	10.7	.2	33.9	27.1	7.6	0	10	1.3	.8
8708300000	5.80	36.5	1.8	19.0	11.5	.1	31.0	31.2	8.7	0	10	1.1	1.0
8709060000	5.92	36.5	1.5	20.0	11.5	.1	31.0	29.1	4.1	0	10	1.2	1.1
8709130000	6.04	35.7	1.3	20.0	10.7	.3	31.0	33.3	5.3	0	10	1.0	1.2
8709200000	5.97	34.8	.5	17.5	9.9	.1	28.2	27.1	13.1	0	10	1.0	1.3
8709270000	6.34	34.8	1.0	19.5	9.0	.1	25.4	20.8	10.9	0	10	.8	1.8
8710040000	5.79	34.8	1.0	21.0	9.0	.1	28.2	27.1	392.6	0	10	1.0	1.6
8710110000	5.86	35.7	1.5	21.5	9.0	.1	31.0	43.7	9.8	0	10	1.4	1.6
8710180000	5.91	36.5	1.0	20.5	9.9	.4	28.2	27.1	9.8	0	10	.7	1.5
8710250000	5.98	36.5	1.3	21.0	9.0	.3	25.4	27.1	14.2	0	10	.8	1.6
8710310000	6.38	36.5	1.0	25.4	9.9	.7	28.2	31.2	13.1	0	10	.5	1.3
8711070000	6.06	36.1	1.3	25.4	9.9	.5	28.2	29.1	9.8	0	10	.8	1.6

SOG2 RUNOFF 1987

Date/Time	pH	Na	K	Ca	Mg	NO_3	Cl	SO_4	ALKX	LAL	NLAL	TOC	SiO_2
8611190000	5.60	58.3	5.4	26.9	17.3	2.8	59.2	37.5	14.2	2	10	4.5	-99
8611220000	5.51	61.8	9.7	33.9	18.1	.7	70.5	43.7	9.8	23	10	3.9	2.0
8611280000	5.80	53.5	5.4	47.9	18.9	1.9	48.0	39.6	32.5	11	16	3.4	-99
8704280000	4.04	45.2	12.5	15.0	6.6	12.2	45.1	152.0	0.0	43	11	2.1	.1
8704290000	4.68	44.8	11.5	19.0	11.5	8.9	45.1	70.8	.0	24	10	1.1	.3
8704300000	4.72	48.3	27.4	15.5	6.6	8.7	64.9	52.0	.0	24	10	2.4	.1
8705010000	4.89	43.1	19.2	14.5	7.4	7.6	45.1	60.4	.0	69	10	1.4	.1
8705210000	5.67	18.7	4.1	4.0	2.5	1.8	19.7	2.1	8.7	0	10	2.0	.1
8705220000	5.32	18.3	3.6	2.0	1.6	3.5	19.7	8.3	.0	0	10	1.0	.1
8705230000	5.59	14.4	4.1	2.0	.8	1.4	14.1	2.1	5.3	0	10	.7	.1
8705240000	5.33	10.0	1.8	2.0	1.6	2.4	11.3	2.1	.0	2	10	.7	.1
8705290000	5.43	17.0	.5	35.4	6.6	1.4	16.9	20.8	4.1	10	10	.8	.8
8705300000	5.45	19.6	.5	14.5	7.4	1.0	19.7	14.6	4.1	4	10	.8	.8
8705310000	5.50	18.3	1.3	11.5	5.8	1.2	19.7	14.6	6.4	4	10	.8	.8
8706010000	5.33	17.8	.5	13.5	7.4	.9	16.9	22.9	2.9	22	11	.8	.9
8706020000	5.49	21.8	1.0	16.5	7.4	.7	19.7	25.0	1.6	10	10	1.0	1.0
8706030000	5.47	18.7	.5	17.0	7.4	.6	16.9	27.1	1.6	9	11	.7	1.0
8706040000	5.52	19.6	.8	16.5	6.6	.4	22.6	20.8	.0	1	10	.9	1.0
8706050000	5.40	18.7	.5	16.0	6.6	.4	16.9	20.8	.0	10	10	1.0	1.0
8706060000	5.42	21.3	.8	18.0	7.4	.1	22.6	22.9	.0	9	11	1.2	1.1
8706070000	5.43	20.4	.5	17.5	7.4	.2	19.7	27.1	.0	6	10	1.0	1.1
8706080000	5.86	23.5	.8	26.9	8.2	.2	19.7	20.8	5.3	2	10	1.1	1.2
8706130000	5.92	22.2	.8	20.0	9.0	.3	22.6	31.2	12.0	0	10	1.0	1.3
8706140000	5.60	22.2	.5	19.5	8.2	.1	19.7	31.2	1.6	8	10	.8	1.3
8706150000	5.57	22.2	.5	20.0	9.0	.1	22.6	29.1	1.6	8	10	.9	1.4
8706170700	5.66	23.5	.5	19.5	9.9	.1	22.6	29.1	.0	15	10	1.4	1.4
8706170900	5.44	24.4	.5	20.5	9.9	.1	22.6	35.4	.0	12	10	1.2	1.4
8706171000	5.22	23.9	.5	21.5	9.9	.1	22.6	41.6	.0	27	10	1.2	1.4
8706171100	5.28	23.9	.5	21.0	9.9	.1	22.6	35.4	.0	21	10	1.3	1.4
8706171200	5.23	24.4	.5	20.5	9.9	.1	22.6	39.6	.0	36	10	1.4	1.4
8706171300	5.23	24.4	.5	20.5	9.9	.1	19.7	37.5	.0	27	10	1.1	1.4
8706171955	5.26	25.2	.5	22.5	10.7	.1	22.6	41.6	.0	29	10	1.2	1.5
8706180800	5.32	25.7	.5	23.0	11.5	.1	22.6	41.6	.0	29	10	1.2	1.5
8706190000	5.49	26.5	.5	25.9	12.3	.1	25.4	41.6	.0	18	10	1.1	1.5
8706200000	5.39	29.1	.5	26.9	12.3	.1	25.4	43.7	.0	27	10	1.0	1.5
8706210000	5.38	27.4	.5	26.4	12.3	.1	25.4	43.7	.0	27	10	.9	1.5
8706220000	5.61	27.8	.5	29.9	13.2	.1	25.4	45.8	.0	8	10	1.3	1.5
8706230000	5.41	29.1	.5	26.4	12.3	.1	28.2	45.8	.0	21	10	1.1	1.6
8706240000	5.22	31.3	1.8	24.0	12.3	.3	25.4	47.9	.0	15	10	1.5	1.5
8706250000	5.26	29.6	.5	24.5	12.3	.2	25.4	47.9	.0	19	10	1.2	1.5
8706260000	5.33	30.0	.5	25.9	12.3	.1	25.4	47.9	.0	26	10	1.2	1.6

Date/Time	pH	Na	K	Ca	Mg	NO_3	Cl	SO_4	ALKX	LAL	NLAL	TOC	SiO_2
8706270000	5.36	30.0	1.0	24.5	12.3	.2	28.2	52.0	.0	23	10	1.2	1.5
8706280000	5.31	29.1	.5	24.5	13.2	.1	28.2	47.9	.0	29	10	1.1	1.5
8706290000	5.38	31.3	.8	25.9	13.2	.2	28.2	47.9	.0	15	10	1.2	1.5
8706300000	5.47	33.9	2.0	25.4	13.2	.1	28.2	47.9	.0	19	10	1.1	1.5
8707050000	5.52	32.6	.8	28.9	13.2	.1	28.2	45.8	.0	5	10	1.4	1.5
8707120000	5.41	31.3	1.0	28.4	14.0	.3	28.2	45.8	2.9	23	10	1.2	1.6
8707190000	5.45	35.2	1.3	27.9	14.8	.1	28.2	45.8	.0	15	10	1.0	1.7
8707191000	5.36	36.1	1.5	27.9	14.8	.1	33.9	45.8	2.9	29	10	1.7	1.7
8707220000	5.33	34.4	1.0	29.9	15.6	.1	31.0	52.0	.0	29	10	1.2	1.8
8707260000	5.47	39.1	1.3	31.9	16.5	.4	33.9	60.4	.0	26	10	1.7	1.8
8708020000	5.52	41.3	2.8	30.9	14.0	.3	42.3	58.3	.0	23	10	1.2	1.8
8708090000	5.38	40.9	1.3	30.4	14.8	.1	36.7	56.2	.0	31	10	.9	1.8
8708150000	5.39	40.9	1.5	31.4	16.5	.2	36.7	58.3	.0	15	10	1.2	1.9
8708160000	5.35	40.9	1.8	30.9	16.5	.2	36.7	58.3	8.7	15	10	1.1	1.8
8708170000	5.40	41.3	1.5	30.9	16.5	.2	36.7	60.4	.0	15	10	1.0	1.8
8708191400	5.40	41.3	1.5	28.9	16.5	.2	36.7	58.3	.0	8	10	1.4	1.8
8708191800	5.24	40.9	1.5	30.4	17.3	.2	36.7	64.5	.0	15	10	1.3	1.8
8708192000	5.06	42.2	2.0	31.4	17.3	.1	36.7	70.8	.0	29	10	1.3	1.8
8708200645	5.15	40.9	1.5	32.4	18.1	.3	36.7	72.9	.0	48	10	1.1	1.8
8708201000	5.12	40.9	1.5	32.9	18.1	.4	36.7	72.9	.0	55	10	1.2	1.9
8708201500	5.03	41.3	1.5	35.9	18.9	.2	36.7	81.2	0.0	70	10	1.2	1.9
8708210000	4.95	40.9	2.0	35.4	18.1	.7	39.5	83.3	.0	126	10	1.1	1.8
8708220000	4.94	42.6	3.3	38.4	18.9	1.0	39.5	93.7	.0	167	10	1.1	1.9
8708230000	5.02	41.3	2.0	37.4	18.9	.0	36.7	87.4	.0	145	10	1.1	1.9
8708240000	5.07	40.0	1.8	38.9	18.9	.3	36.7	85.4	.0	139	10	.9	1.9
8708250000	5.19	47.0	2.8	38.9	19.7	.6	42.3	85.4	.0	97	11	1.4	2.0
8708260000	5.04	41.8	1.8	39.9	19.7	.1	36.7	87.4	.0	121	10	1.3	2.0
8708270000	5.12	40.9	1.8	39.9	19.7	.1	36.7	87.4	.0	115	10	1.0	2.0
8708280000	5.03	40.5	1.5	39.4	19.7	2.2	33.9	91.6	.0	117	10	1.3	2.0
8708290000	5.20	40.5	1.5	38.9	20.6	.6	33.9	85.4	.0	68	10	1.2	2.0
8708300000	5.09	42.6	1.5	38.9	19.7	.4	39.5	91.6	.0	111	10	.9	2.0
8708310000	5.13	40.0	1.5	37.4	18.9	.6	33.9	79.1	.0	102	10	.9	1.9
8709060000	5.26	39.6	1.3	38.9	18.9	.1	33.9	79.1	.0	66	10	.9	2.1
8709130000	5.40	35.2	1.3	35.4	16.5	.5	31.0	68.7	.0	44	10	.9	2.1
8709200000	5.51	30.9	.5	27.9	14.8	.6	25.4	50.0	10.9	29	10	.9	1.8
8709260000	5.57	30.9	.8	32.4	14.8	.6	25.4	52.0	.0	36	13	.8	2.1
8709301100	5.51	32.2	1.0	33.4	14.8	.4	25.4	50.0	.0	31	10	1.4	2.1
8709302230	5.41	31.8	.8	33.9	14.8	.4	25.4	54.1	.0	40	10	1.0	2.1
8710011030	5.28	33.1	1.0	34.9	14.8	.5	25.4	60.4	.0	66	10	1.0	2.2
8710020000	5.39	33.1	.8	37.4	15.6	.5	28.2	66.6	.0	50	10	1.1	2.2
8710030000	5.03	32.6	.8	36.4	15.6	.5	25.4	72.9	.0	57	10	1.2	2.3
8710040000	5.45	33.9	.8	38.4	16.5	.6	25.4	68.7	.0	27	10	1.1	2.3
8710050000	5.32	32.2	.8	36.9	18.9	.4	25.4	68.7	.0	55	10	.8	2.3
8710060000	5.32	33.5	.8	37.9	15.6	.4	28.2	70.8	.0	70	10	.9	2.4
8710070000	5.41	32.6	1.0	38.4	14.8	.4	28.2	79.1	.0	40	10	.9	2.3

Date/Time	pH	Na	K	Ca	Mg	NO_3	Cl	SO_4	ALKX	LAL	NLAL	TOC	SiO_2
8710080000	5.32	33.1	1.0	37.9	15.6	.6	36.7	99.9	.0	55	10	.9	2.3
8710100000	5.35	31.3	.8	35.4	14.0	.9	33.9	64.5	.0	52	10	.8	2.3
8710110000	5.27	31.3	.8	34.4	14.0	.9	28.2	62.5	.0	55	10	.1	2.3
8710180000	5.48	33.5	.8	33.4	14.8	.9	28.2	60.4	.0	25	10	.7	2.2
8710250000	5.57	33.5	.8	33.9	14.8	.6	25.4	60.4	.0	18	10	.7	2.4
8710310000	5.72	33.5	1.0	40.9	14.8	2.1	28.2	58.3	.0	17	10	.6	2.1
8711070000	5.67	33.5	1.0	40.4	14.8	2.1	28.2	58.3	.0	10	10	.8	2.4

SOG3 RUNOFF 1987

Date/Time	pH	Na	K	Ca	Mg	NO_3	Cl	SO_4	ALKX	LAL	NLAL	TOC	SiO_2
8611130000	5.74	41.3	1.0	24.5	14.0	.1	56.4	20.8	.0	6	10	.6	1.4
8611190000	5.82	41.8	1.0	22.0	13.2	.1	53.6	20.8	5.3	0	10	1.9	-99
8611220000	5.85	41.3	.8	25.0	13.2	.1	50.8	22.9	5.3	0	10	.6	1.8
8611280000	5.88	44.4	1.5	31.4	14.0	.1	45.1	22.9	15.3	0	10	.8	-99
8704280000	5.45	42.6	1.8	22.0	14.0	5.0	48.0	29.1	1.6	28	11	.9	.8
8704290000	5.32	44.4	2.0	20.5	14.0	.0	48.0	27.1	.0	45	11	.7	.7
8705220000	5.71	32.2	1.5	15.5	9.9	.1	31.0	20.8	15.3	2	10	.8	1.2
8705230000	5.59	26.5	1.3	13.0	8.2	-99	25.4	16.7	8.7	12	10	.2	.9
8705310000	5.74	26.1	.5	11.5	7.4	.1	22.6	16.7	7.6	0	10	.7	1.1
8706060000	5.70	26.5	1.0	12.5	6.6	.1	22.6	18.7	.0	0	10	.9	1.1
8706080000	5.65	28.3	1.3	13.0	6.6	.1	25.4	16.7	.0	0	10	1.0	1.2
8706140000	5.84	105.3	2.0	26.4	28.0	.1	112.8	41.6	9.8	0	10	.7	1.3
8706210000	5.84	30.0	.8	14.0	8.2	.1	25.4	27.1	5.3	0	10	.8	1.3
8706280000	5.76	33.1	1.0	13.5	8.2	.1	25.4	25.0	2.9	0	10	.8	1.5
8707050000	5.98	34.4	.8	17.5	9.0	.1	28.2	25.0	5.3	0	10	1.1	1.4
8707120000	5.88	80.9	1.5	16.5	9.0	.1	25.4	22.9	12.0	0	10	1.0	1.4
8707190000	5.76	37.8	.8	15.5	9.0	.2	28.2	22.9	.0	0	10	.9	1.3
8707190930	5.73	36.5	.5	15.0	9.0	.1	31.0	20.8	7.6	0	10	1.2	1.3
8707260000	5.87	43.1	1.0	18.0	9.9	.1	33.9	72.9	4.1	1	10	1.6	1.3
8708020000	6.07	43.9	1.0	18.0	7.4	.5	39.5	27.1	4.1	0	10	.8	1.1
8708090000	5.80	45.2	.8	16.5	8.2	.4	39.5	27.1	.0	0	10	.7	1.0
8708160000	5.83	44.4	.5	17.5	9.9	.6	39.5	22.9	7.6	0	10	.8	.9
8708230000	5.88	39.6	1.3	15.5	9.0	.2	36.7	20.8	5.3	0	10	.9	1.2
8708300000	5.98	39.6	1.3	18.5	9.9	.2	31.0	31.2	9.8	0	10	.8	1.5
8709060000	5.97	39.1	1.0	17.0	8.2	.1	31.0	37.5	2.9	0	10	.8	1.7
8709130000	6.08	32.6	1.0	19.5	9.0	.2	22.6	18.7	5.3	0	10	.6	1.8
8709200000	5.94	30.0	.5	15.0	8.2	.1	22.6	20.8	8.7	0	10	.6	1.5
8709270000	6.10	33.5	1.3	18.0	8.2	.1	22.6	20.8	6.4	0	10	.8	1.8
8710040000	5.99	34.8	.5	18.0	8.2	.3	25.4	25.0	8.7	0	10	.7	2.0
8710110000	5.89	31.8	.8	18.0	8.2	.4	28.2	25.0	2.9	0	10	.7	1.8
8710180000	5.00	62.6	6.1	42.4	15.6	2.3	107.2	45.8	.0	82	19	2.0	2.0
8710250000	6.02	34.8	.8	19.0	9.0	.2	25.4	31.2	12.0	0	10	.6	2.0
8710310000	6.00	34.4	.8	24.0	9.9	1.4	28.2	29.1	13.1	0	10	.5	1.7

SOG4 RUNOFF 1987

Date/Time	pH	Na	K	Ca	Mg	NO_3	Cl	SO_4	ALKX	LAL	NLAL	TOC	SiO_2
8705210000	5.47	43.9	5.4	24.5	11.5	3.6	42.3	31.2	15.3	23	17	5.2	1.6
8705220000	5.41	30.0	2.6	20.0	9.0	2.6	28.2	25.0	0.0	25	10	2.7	1.3
8705230000	5.28	22.6	1.5	16.5	7.4	1.8	19.7	22.9	6.4	28	17	1.1	1.0
8705240000	5.29	25.7	2.3	18.0	7.4	2.0	22.6	22.9	.0	33	22	1.0	1.1
8705290000	5.59	19.6	.5	15.0	5.8	1.4	16.9	18.7	8.7	8	14	1.0	1.0
8705300000	5.50	20.0	.5	14.5	5.8	1.6	16.9	20.8	7.6	6	14	.9	1.0
8706010000	5.01	17.8	.5	12.5	4.9	1.4	14.1	14.6	5.3	6	14	1.2	.8
8706020000	5.75	21.3	.5	19.5	7.4	1.1	16.9	27.1	6.4	2	14	1.1	1.2
8706030000	5.25	20.4	1.5	16.5	6.6	1.6	14.1	20.8	1.6	33	21	2.5	1.4
8706040000	5.31	33.1	2.6	22.5	8.2	.1	25.4	29.1	1.6	36	35	3.7	2.4
8706050000	5.45	24.4	.8	20.5	7.4	.5	19.7	22.9	.0	3	17	1.9	1.6
8706060000	5.34	18.3	1.3	12.5	5.8	1.3	16.9	14.6	.0	3	17	1.7	.7
8706070000	5.56	20.9	.8	18.5	6.6	.2	16.9	18.7	1.6	1	17	1.0	1.2
8706080000	5.54	27.4	.8	23.0	7.4	.1	22.6	25.0	.0	4	21	1.4	1.8
8706130000	5.41	31.3	1.3	21.5	8.2	.4	22.6	29.1	9.8	31	40	2.4	2.3
8706140000	5.47	30.9	1.0	23.0	8.2	.3	25.4	31.2	5.3	23	19	1.6	2.2
8706150000	5.52	34.8	1.0	26.9	9.0	.3	28.2	37.5	2.9	21	13	1.4	2.8
8706171340	5.41	32.2	1.3	21.0	8.2	.1	19.7	33.3	1.6	31	31	2.5	2.3
8706171500	5.14	32.6	1.3	21.5	8.2	3.8	19.7	39.6	.0	46	27	2.5	2.3
8706171600	4.54	33.1	1.3	25.0	9.9	20.0	19.7	64.5	0.0	-11	22	2.7	2.2
8706171700	4.19	36.5	1.3	56.9	20.6	63.9	25.4	135.3	0.0	361	17	-99.	1.9
8706171800	4.33	39.1	2.0	76.8	32.1	96.7	25.4	183.2	0.0	520	20	-99.	1.7
8706171900	4.17	37.8	2.6	74.8	32.9	93.5	28.2	185.3	0.0	648	22	-99.	1.6
8706172000	4.07	37.8	1.5	53.9	21.4	61.8	19.7	149.9	0.0	268	27	2.5	2.0
8706180830	4.40	41.3	2.0	63.4	25.5	42.1	19.7	137.4	0.0	320	33	2.4	2.1
8706190000	5.40	36.1	.8	35.4	14.0	.3	31.0	58.3	2.9	57	16	1.3	2.2
8706200000	5.35	38.3	1.5	32.9	12.3	.3	33.9	52.0	.0	42	13	1.6	2.2
8706210000	5.34	36.5	.5	30.9	12.3	.1	31.0	50.0	.0	45	13	1.2	2.1
8706220000	5.30	40.9	1.0	33.9	12.3	.1	33.9	56.2	.0	40	13	1.6	2.2
8706230000	5.33	41.3	.8	33.9	12.3	.1	31.0	56.2	.0	33	11	1.6	2.2
8706240000	5.33	33.5	.8	29.4	11.5	.4	25.4	50.0	.0	50	11	1.7	1.7
8706250000	5.22	40.0	1.3	32.9	13.2	.1	22.6	62.5	.0	68	11	2.3	2.3
8706260000	5.28	38.3	1.5	32.4	11.5	.2	31.0	54.1	.0	29	10	1.8	2.1
8706270000	5.44	32.6	1.0	26.9	9.9	.2	25.4	41.6	2.9	38	10	1.5	2.1
8706280000	5.41	36.5	1.3	28.9	11.5	.2	31.0	45.8	.0	38	10	1.6	2.3
8706290000	5.59	36.5	.8	29.9	12.3	.2	25.4	50.0	.0	42	10	1.5	2.4
8706300000	5.38	39.1	1.0	29.9	10.7	.1	31.0	47.9	.0	32	10	1.4	2.3
8707050000	5.56	36.5	.8	31.9	10.7	.9	31.0	37.5	.0	29	10	1.8	2.2
8707120000	5.78	32.2	.5	27.9	11.5	.2	28.2	31.2	12.0	31	11	1.4	2.1
8707190000	5.47	37.8	1.0	30.4	11.5	.1	31.0	39.6	.0	36	11	2.6	2.5
8707191300	5.65	37.8	1.8	31.4	11.5	.1	39.5	29.1	10.9	29	10	2.4	2.6

Date/Time	pH	Na	K	Ca	Mg	NO_3	Cl	SO_4	ALKX	LAL	NLAL	TOC	SiO_2
8707191700	5.08	38.3	1.3	31.9	10.7	2.1	33.9	50.0	.0	49	11	3.7	2.5
8707192100	4.63	51.8	1.3	90.3	31.3	52.1	45.1	135.3	.0	309	18	3.0	2.3
8707200100	5.07	32.6	.8	48.4	19.7	3.5	33.9	72.9	.0	91	28	2.1	2.1
8707200800	5.19	31.8	.8	36.4	14.8	.3	31.0	47.9	2.9	70	18	1.7	2.2
8707211700	5.37	34.8	1.3	32.4	10.7	.1	33.9	45.8	.0	38	11	2.1	2.4
8707260000	5.98	43.9	1.3	16.0	9.9	.1	36.7	31.2	2.9	0	10	1.4	1.3
8708020000	5.46	47.0	5.1	38.4	13.2	.1	50.8	50.0	.0	42	16	5.2	2.8
8708181700	4.48	60.0	4.6	88.3	28.8	80.7	33.9	120.8	0.0	287	10	3.9	1.6
8708181900	4.17	83.5	11.8	100.8	37.0	87.8	129.8	191.5	0.0	-99.	18	3.9	2.3
8708190700	4.41	105.3	17.9	120.3	43.6	84.6	160.8	206.1	0.0	497	33	4.5	2.4
8708190900	4.28	98.7	15.9	111.3	41.1	81.8	146.7	202.0	0.0	522	28	4.4	2.4
8708191200	4.05	95.3	15.6	109.8	38.7	98.2	129.8	218.6	0.0	562	28	4.6	2.3
8708191430	4.09	93.5	15.3	105.8	39.5	97.1	124.1	239.4	0.0	572	33	4.0	2.2
8708192010	4.20	96.1	15.1	114.8	41.1	88.2	126.9	229.0	0.0	622	33	4.8	2.3
8708201030	4.41	97.9	13.3	111.3	40.3	65.0	124.1	210.3	0.0	552	28	3.9	2.5
8708210000	4.67	69.2	7.9	69.9	25.5	18.6	87.5	135.3	.0	311	27	2.6	2.4
8708220000	5.27	29.1	1.5	29.9	11.5	1.4	28.2	47.9	.0	63	15	1.9	1.6
8708230000	5.29	32.6	.5	30.4	10.7	1.0	33.9	43.7	.0	55	15	1.6	2.3
8708240000	4.87	64.4	5.1	57.9	21.4	1.5	70.5	104.1	.0	196	21	2.6	2.6
8708250000	4.96	59.2	3.3	54.9	20.6	.3	62.1	95.8	.0	157	15	2.4	2.6
8708260000	5.26	43.5	1.3	41.9	14.0	.2	45.1	58.3	.0	74	11	1.3	2.6
8708270000	5.21	44.8	1.0	38.4	14.0	.2	45.1	60.4	.0	60	10	1.5	2.8
8708280000	5.26	33.1	1.0	40.9	15.6	1.4	31.0	68.7	.0	66	15	2.0	1.8
8708290000	5.47	36.5	.8	32.4	10.7	.6	31.0	50.0	.0	35	15	1.8	2.3
8708300000	5.48	37.8	.8	29.9	10.7	.6	33.9	39.6	.0	37	11	1.4	2.4
8708310000	5.49	27.0	.5	24.0	9.0	.9	22.6	37.5	1.6	42	20	1.7	1.6
8709060000	5.63	43.1	1.8	30.9	10.7	1.1	36.7	41.6	.0	22	15	1.6	2.8
8709130000	5.85	30.9	.5	27.9	9.9	.6	25.4	35.4	1.6	17	11	1.1	2.5
8709200000	5.72	26.1	.5	21.0	8.2	.8	22.6	25.0	7.6	19	13	1.2	1.8
8709260000	5.44	30.5	1.8	25.0	8.2	.6	22.6	31.2	2.9	46	44	2.6	1.9
8709270000	5.82	32.6	1.0	25.4	9.0	.4	25.4	29.1	4.1	19	14	2.6	2.6
8709301715	5.33	32.2	1.5	26.9	9.0	.3	22.6	29.1	4.1	50	41	2.5	2.4
8709301945	4.60	33.9	2.3	31.9	11.5	20.0	25.4	60.4	0.0	128	21	2.7	2.4
8709302145	4.20	36.1	3.3	42.9	14.8	46.4	25.4	99.9	0.0	180	18	2.9	2.3
8710011100	4.51	38.7	3.6	50.4	17.3	37.1	28.2	91.6	0.0	205	24	3.3	2.4
8710020000	5.01	39.6	2.3	51.4	16.5	20.7	28.2	77.0	.0	116	24	2.6	2.5
8710030000	5.76	32.2	1.0	28.9	9.9	.8	25.4	77.0	6.4	18	10	1.3	2.8
8710040000	5.69	32.6	1.0	28.9	9.0	.8	25.4	41.6	5.3	26	13	1.1	2.6
8710050000	5.23	39.6	2.0	41.9	14.0	6.9	28.2	66.6	.0	83	24	2.5	2.8
8710060000	5.60	29.1	1.0	25.0	8.2	.5	22.6	37.5	5.3	19	13	1.2	2.3
8710070000	5.27	38.3	2.6	40.9	14.0	5.1	31.0	64.5	.0	74	18	2.4	2.7
8710080000	5.60	32.6	1.0	30.9	9.9	1.8	25.4	41.6	.0	24	11	1.2	2.9
8710100000	5.24	31.8	1.3	31.4	10.7	1.4	28.2	70.8	.0	56	24	2.2	2.1
8710110000	5.56	30.9	.8	28.4	9.0	.9	28.2	37.5	2.9	21	11	3.0	2.6
8710180000	5.91	35.2	1.0	19.0	9.0	.5	28.2	25.0	9.8	0	10	.6	1.7
8710250000	5.18	45.2	2.6	38.4	13.2	1.2	56.4	43.7	.0	78	23	1.7	2.7
8710310000	5.23	37.8	1.8	40.4	11.5	4.8	39.5	52.0	.0	55	28	1.5	2.2

APPENDIX 9. SOGNDAL PRECIPITATION DATA.

Units: µeq/l.

DATE ON	DATE OFF	MM	PH	NA	K	CA	MG	NH4	NO3	CL	SO4
861117	861124	.5	5.80	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.
861124	861130	37.6	5.13	37.4	6.1	2.5	8.4	2.9	2.9	44.6	4.4
861201	861208	106.4	5.52	41.3	9.0	4.5	6.4	8.6	.7	36.9	6.2
861208	861215	17.5	4.50	41.3	13.1	14.0	7.0	21.4	37.1	43.1	41.8
861215	861222	1.6	6.55	282.8	122.9	21.9	20.7	171.4	59.3	293.3	46.8
861222	861229	10.8	4.81	30.4	12.0	6.0	3.5	8.6	14.3	29.3	14.4
861229	870105	19.4	5.38	56.6	13.6	4.5	7.2	11.4	5.0	60.3	13.1
870105	870111	11.5	4.70	16.5	1.5	6.5	2.0	4.3	16.4	19.2	14.4
870119	870125	20.4	5.02	66.1	4.1	9.5	13.0	7.1	7.9	73.6	18.7
870126	870201	18.5	5.03	82.6	7.9	7.5	15.1	128.5	5.7	87.7	19.4
870202	870208	10.2	4.92	93.1	7.9	9.0	16.5	20.0	10.7	102.7	31.2
870209	870215	6.7	6.20	186.2	89.5	24.0	17.3	114.2	15.0	143.0	33.5
870216	870222	9.9	5.30	60.9	10.5	6.5	11.0	15.7	7.9	73.3	22.5
870223	870301	29.0	6.23	61.8	20.2	6.5	5.1	22.8	3.6	72.2	10.6
870302	870308	2.0	4.85	27.8	6.6	8.0	3.9	17.1	19.3	27.4	22.5
870309	870315	4.1	4.83	40.9	12.0	5.5	3.0	25.7	22.1	44.6	21.2
870323	870329	16.6	4.45	17.4	5.6	4.5	2.3	11.4	26.4	9.6	27.5
870330	870405	7.3	5.89	167.0	60.1	15.5	10.0	115.7	30.7	174.9	33.7
870406	870412	1.6	5.96	87.9	30.2	8.0	4.8	42.8	14.3	89.7	13.1
870413	870419	21.7	4.35	87.0	9.2	8.5	19.1	30.0	28.6	100.4	60.0
870420	870426	12.4	4.04	16.5	5.4	5.0	2.5	61.4	50.7	21.4	94.9
870427	870503	4.8	5.77	34.8	15.1	36.4	16.3	128.5	133.5	38.1	190.5
870504	870510	17.2	4.97	16.5	3.6	3.0	3.5	2.9	1.4	16.4	12.5
870511	870517	1.9	4.42	6.1	3.8	6.5	4.6	12.1	.7	10.2	60.0
870518	870524	1.1	4.72	28.7	-99.	5.5	4.6	35.7	.7	-99.	30.6
870525	870531	8.6	4.99	11.3	.3	3.0	2.0	2.9	.7	11.8	13.1
870601	870607	19.7	4.50	1.7	.5	1.5	1.0	2.9	.7	2.3	34.4
870608	870614	10.5	4.66	7.0	.3	1.5	1.8	2.9	.7	7.3	22.3
870615	870621	1.9	4.17	27.8	6.6	9.0	4.9	2.9	.7	26.2	89.9
870622	870628	12.7	4.51	1.7	.3	2.0	.8	2.9	.7	.6	40.0
870629	870630	3.8	4.43	10.4	.3	3.0	2.6	2.9	.7	10.4	49.3
870701	870705	15.3	4.60	20.0	3.3	2.0	2.3	2.9	.7	19.2	28.7
870706	870712	46.8	5.61	15.7	7.7	3.0	2.3	61.4	10.7	13.0	31.2
870713	870719	0.0	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.
870720	870726	0.0	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.
870727	870802	11.5	4.92	7.8	5.4	5.0	3.0	2.9	.7	6.5	15.0
870803	870809	10.5	4.86	8.7	3.6	2.5	1.3	2.9	3.6	6.5	9.4

DATE ON	DATE OFF	MM	PH	NA	K	CA	MG	NH4	NO3	CL	SO4
870810	870816	7.0	4.67	13.1	2.6	3.0	.5	2.9	.7	12.1	15.0
870817	870823	15.9	4.52	3.5	1.3	2.0	1.0	4.3	9.3	6.2	21.9
870824	870830	29.0	4.30	3.5	1.5	3.0	1.2	2.9	.1	5.4	43.7
870831	870906	2.2	4.57	44.4	9.7	8.0	9.0	17.1	19.3	42.6	35.0
870907	870913	59.6	4.86	7.0	.5	1.0	1.2	4.3	4.3	8.2	7.5
870914	870920	47.5	4.89	19.1	1.5	1.5	3.9	4.3	4.3	22.3	11.2
870921	870927	22.0	4.45	7.8	2.0	4.0	1.5	4.3	10.7	8.7	25.6
870928	871004	0.0	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.
871005	871011	18.5	4.64	18.3	5.9	4.0	3.1	10.0	12.1	12.4	28.1
871012	871018	27.1	5.18	59.2	33.0	7.0	7.4	10.0	11.4	65.7	7.7
871019	871025	0.0	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.
871026	871101	11.5	5.76	19.1	5.9	108.8	13.2	17.1	41.4	19.7	81.2
871102	871108	5.3	4.17	21.8	1.5	11.0	6.9	35.7	40.7	35.0	76.2
871109	871115	6.1	4.58	3.0	3.3	15.5	3.8	8.6	31.4	5.9	23.1
871116	871122	9.9	4.67	13.9	1.5	3.5	3.3	2.9	5.7	20.3	11.9
871123	871129	0.0	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.	-99.
871130	871206	4.0	4.48	45.2	10.2	11.0	9.4	35.0	29.3	46.3	40.0
871207	871213	11.1	4.14	65.3	12.0	7.5	14.3	15.7	22.8	78.4	71.8
871214	871220	52.5	4.74	20.9	3.3	3.0	4.4	2.9	7.9	22.0	10.0
871221	871227	29.3	5.10	105.3	9.7	8.5	23.7	10.0	.7	120.5	18.1
871228	880102	22.3	5.17	29.1	7.2	4.5	5.6	5.0	3.6	30.7	7.5

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