BRINE SPILLAGE IN THE OIL INDUSTRY – THE NATURAL RECOVERY OF AN AREA AFFECTED BY A SALT WATER SPILL NEAR SWAN HILLS, ALBERTA

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Abstract

Salt spills are liable to become more prevalent in the oil producing regions of Alberta as the volume of brine relative to crude oil increases with the depletion of the older oil-fields.

High concentrations of sodium chloride can cause severe damage to vegetation and produce long lasting structural damage to soils. Although current knowledge into the reclamation specifically of areas affected by oil-field salt water is not well advanced, certain treatments are commonly employed. These involve calcium saturation of the soil, leaching with freshwater, addition of manure and fertilizer and reseeding with salt tolerant plant species.

The results presented in this paper suggest that with certain organic soils, extensive treatment of spill areas may not be needed. A three year monitoring program of an area near Swan Hills, Alberta showed a gradual reduction of salts within the original spill area and a migration of salts into the surrounding drainage areas. The spill had occurred in a very wet area of treed Black Spruce/Sphagnum bog which was readily leached at the surface. In 1975, soil and water samples contained up to 22,400 ppm of chloride and 34,500 ppm of sodium. By 1977 the maximum contents of chloride and sodium recorded at the site were 4467 ppm and 2781 ppm respectively.

Extensive damage to the trees and ground vegetation was observed in 1975. Regrowth was active throughout the area in 1977 except in one small part near the original pipeline leak.

The main drainage catchment area is a small lake to the northwest of the spill. Concentrations of chloride in the lake have increased from 180 ppm in 1975 to 372 ppm in 1977.

If more conventional techniques used in the reclamation of saline soils had been employed additional damage to the area may have been produced. The extreme acidity of the soil and the saturated condition of the site would have made the establishment of non-native plant species almost impossible.

Although the treatment of most mineral soils that have been affected with brines would require a considerable reclamation effort, many organic soils may best be left to reclaim naturally.

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1. INTRODUCTION

Considerable quantities of salt water may be recovered when crude oil is pumped from producing wells. The ratio of salt water to crude oil varies widely depending upon the nature of the oil-bearing formations and the degree to which the oil-field has been exploited. Data from the early 1960s shows that the ratio of salt water to crude oil was as high as 17:1 in producing areas in Kansas and approximately 2.5:1 in Texas [(1)]. In Alberta, the production of salt water relative to crude oil has been rising steadily with time as some of the older fields are becoming depleted and salt water moves into the formations. Table 1 shows some data for between 1951 and 1974 to illustrate this trend.

Table 1. Volumes of salt water and crude oil produced annually in Alberta (1951-1974).

Year	Salt water (bbl/yr x 10^6)	Crude oil (bbl/yr x 10^6)	Ratio salt:oil
1951	1.5	43.9	0.034
1956	11.2	143.9	0.078
1969	54		
1974	188	500	0.376

Data compiled from references 2,3, and 4.

The recovered salt water and oil are transported to tanks where the oil is allowed to separate from the salt water and other residues. In the early days of the petroleum industry in the United States these brines were discharged into rivers, lakes and freshwater aquifers or even directly onto land. The damage to water supplies and farming land lead to legislation that required a safer form of disposal. Around this time much of the salt water was stored in pits where the salts could be concentrated by evaporation. Many of the pits were unlined which often resulted in subsurface percollation and seepage problems. Some improvement occurred where disposal pits were lined with materials such as concrete, gunite, asphalt, vinyl or other plastics. At present the great majority of oil-field brines are returned underground into the original producing formations through injection wells or deep disposal wells.

In Alberta, since spill reporting to the Energy Resources Conservation Board was made mandatory in 1971, data shows that the amount of salt water spilled annually has been on the increase. In 1971 a total of 4,835 barrels was spilled while by 1974 the volume had risen to 70,755 barrels [(4)]. This may be compared to spills of crude oil which between 1971 and 1975 amounted to an average of about 69,000 barrels per anum. Although a few salt water spills exceed 1,000 barrels in size, most are below 500 barrels in volume. The majority occur on land and are the result of pipeline failures or accidents at storage facilities. Spillages that occur between the producing well and the battery site can involve a mixture of crude oil and salt water.

The chemical composition of oil-field brines varies depending upon location. Several references give examples of the analysis of a great variety of brines both from the United States and Canada [(2,3, 5-10)]. Although the total salt content may be high as 650,000 ppm., the average is found to be about 40,000 to 45,000 ppm. This is more saline than seawater (normally 20,000 to 35,000 ppm) and far in excess of the concentration of salts in freshwaters (normally less tha 100 ppm). Most of the salt in oil-field brines is made up of sodium chloride although, significant amounts of calcium, magnesium and potassium may occur in association with chloride, sulfate, carbonate and bicarbonate anions. In addition the following may be found at a concentration of below 100 ppm ; Si, NH_3, Fe, Al, Br, Li, Rb, Sr, B and Ba. Other elements such as Cr, Cu, Mn, Ni, Sn, Ti, Zr, Be, Co, Ga, Ge, Pb, V, W and Zn have also been detected in the ppb. range. Table 2 shows an analysis of the major components in two Swan Hills brines from Alberta [9] which are probably similar in composition to the salt water involved in the spill that will be described later.

Salt spillages may cause severe damage to vegetation and have long lasting effects on the chemical and physical properties of soils. There are numerous reports in the literature dealing with the impact of salts from a variety of sources on plant growth. Several good reviews and books are available for those requiring a detailed treatment of the subject (e.g. references 11-13). The more direct effects of high salt concentrations on plants come under the general heading of plasmolysis. Loss of cell semipermiability results from damage to the membrane lipids and protein denaturation and aggregation. The deactivation and denaturation of enzymes leads to a complete breakdown in the biochemical functioning of the cell. Secondary affects may be related to the creation of conditions of physiological drought and ionic imbalance. A high salt concentration in the soil solution means that plants must exert more effort to obtain water. The predominance of sodium and chloride will upset the normal uptake of other essential cations and anions.

The tolerance of different plants towards salt varies between the species

Table 2. Analysis of salt water from two sources from Swan Hills, Alberta*

Source	pH	Cond. (mmhos/cm)	Total salts (ppm)	Ca	Mg	Na	K	Cl'	SO_4''	HCO_3'	CO_3''
				ppm							
AMOCO Battery No. 1.	6.8	72.7	72630	1710	212	22400	318	34612	324	276	0
AMOCO Battery NO. 8.	6.7	56.6	45940	1485	160	16000	250	24424	498	286	0

* Data adapted from Edwards and Blauel, reference 9.

involved and the stage of plant development. Many publications give listings of the relative tolerances of different species (e.g. references 11, 14 and 15). Table 3 shows the relative susceptabilities of some plants of economic importance in the Prairie regions of Canada. It is difficult to place precise limits

Table 3. Relative tolerances of different agriculturally important plants towards salts.

Very high tolerance	High tolerance	Moderate tolerance	Low Tolerance
Nuttall alkali grass	Tall wheatgrass	Smooth brome grass	Red clover
Salt grass	Slender wheatgrass	Crested wheatgrass	Alsike clover
Alkali Grass	Russian wild rye	Intermediate wheatgrass	Red top
Birdsfoot trefoil		Reed canary grass	White Dutch cl
Western wheatgrass		Meadow fescue	Timothy
Canada wild rye		Cicer milk vetch	Soybeans
		Flax	Field beans
		Oats	Peas
		Barley	Sunflower
		Rye	
		Wheat	
		Rapeseed	
		Corn	
		Sugar beets	
		Alfalfa	

upon salt effects in soil from the results of soil analysis. Table 4 shows, by way as a rough guide, the commonly accepted limits for salt damage to plants.

Table 4. The relationship between soil electrical conductivity and plant growth

Conductivity * (mmhos/cm @ 25° C)	Effect
0–2	Salinity effects mostly negligible
2–4	Growth of very salt sensitive plants may be restricted
4–8	Growth of many plants is restricted
8–16	Only salt tolerant plants grow well. Other plants may fail to germinate or show greatly reduced growth.
16+	Only a very few salt tolerant plants grow well. Few seeds germinate.

* measured in a saturated soil extract

The ability to withstand the effect of saline spills may involve avoidance or tolerance mechanisms. Avoidance of high salt concentrations is involved in the exclusion, excretion or dilution of ions. Tolerance is concerned in the accumulation of salts in vacuoles, the ability to replace K by Na within the cell and a genetically based resilience to withstand ionic imbalances, cellular dehydration and nutrient deficiencies. For example, the death of Black Spruce was thought to occur when about 7,000 ppm of chloride were accumulated in the needles while death did not occur with Birch until the leaf concentration was 30,000 ppm [9]. However, chloride was taken up more readily by Birch, which was considered to be a tolerant species while Black Spruce seemed to rely more on avoidance mechanisms.

Outward symptoms of salt damage vary from mild chlorosis of the tissues to browning and blackening and eventual death. Certain plants exhibit very distinctive colorations such as the magenta color found on salt damaged Spruce needles.

Many discussions of soil salinity problems can be found in the literature. The majority are concerned with various aspects of naturally saline soils where the problems have been created by the presence of soluble salts such as sodium sulfate, carbonate and bicarbonate which have been derived from saline parent materials. Reports of the addition of salty materials to soils are limited to the reclamation of coastal soils (especially in the Netherlands), the environmental effects of salting roads with NaCl and $CaCl_2$, the addition of heavy applications of fertilizer tc soils and a small number related to oil-field brines. Much of this research covers fairly common ground since it is primarily the sodium ion which is responsible for the deterioration in the properties of the soil.

In well drained mineral soils the colloidal particles are aggregated together and help to maintain a good pore structure. If high concentrations of sodium are added to the soil many of the cations held on the exchange sites on clays and organic matter are replaced. Sodium is ineffective in holding colloidal particles together so that when the ionic concentration of the soil solution is reduced by the residual salt leaching away, the colloidal particles become dispersed. The soil pores become blocked by clay particles and aeration and water movement are greatly reduced. The process is not irreversible and some improvement may occur if the soil can be saturated with calcium ions.

In organic soils the long term effects of salt are generally not as severe as with mineral soils. Most damage occurs due tc the death of surface vegetation and plant roots in response to the high osmotic potential. Edwards and Blauel [9] suggest immediate flushing of such soils with freshwater or water saturated with gypsum or lime.

As with the effect of salt on plants, it is difficult to set definite limits on likely salt damage to soils. In terms of analytical parameters salt damage can probably be expected when the S.A.R. value* exceeds about 10 to 15 and when the exchangeable sodium percentage or E.S.P. exceeds about 5% (i.e. Na exceeds 5% of the total exchangeable cations).

Discussions on the possible reclamation of soils damaged by oil-field brines rely heavily upon information obtained from similar research on naturally saline or alkaline soils (e.g. references 9, 10, 16-19). Comparitively few reports have evaluated the usefulness of different methods in the field. Clark and Thimm [16] have studied two spill sites on mineral soils. Different reclamation methods involved treatment with gypsum (up to 2.6 tons/ac), the addition of fertilizers and leaching. Particularly good results were obtained when addition of calcium nitrate was combined with heavy irrigation. Plice [19] found that the application of up to 6 tons of sodium chloride per acre created bad soil structure and resulted in leaching of silicates and about 67% of the soil organic matter from the soil surface. The recommended reclamation was the addition of 4-6 tons of gypsum per acre and possibly the application of manure. Clearly much more research is needed in this area if we are to evaluate salt

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* The sodium absorption ratio (S.A.R.) $= Na/\sqrt{\frac{1}{2}(Ca + Mg)}$, where the cations are expressed in millequivalents per litre in the saturation extract.

damaged soils and successfully propose adequate reclamation methods.

The study reported in this paper deals with the unaided recovery of a salt spill in the Swan Hills area of Alberta.

2. METHODOLOGY

The area is located about 4 miles west of the town of Swan Hills at the legal location 7-20-66-10 W5M.

The first signs of damage in the area was the appearance of reddened needles on some Spruce trees nearby the road to the west of the spill site. At first it was thought that the source of the damage might be an old oil spill nearby known as the Pan Am A-3 spill (see in the Figures).

The area was visited first in June of 1975 and samples of soil, water and plant tissues were taken for analysis. From the analysis it was possible to show that a spill of salt water was involved and to indicate the extent of the area affected. At this time it was thought unwise to take any further steps to reclaim the area since the soil was highly acidic and the whole region was very wet and poorly accessible. Consequently the spill was monitored over the next two years to make sure that the environmental condition of the site did not deteriorate further.

Soil, water and plant analyses were carried out by aproved standard methods. Soil pH was determined in a 2.5:1 water/soil paste. Electrical conductivity was determined in a saturated soil extract. Chloride and sodium were measured after the extraction of soil with water at a ratio of between 2.5 and 5 parts water to one of soil. Sodium was determined by atomic absorptior spectroscopy and chloride either by titration against silver nitrate or using a specific ion electrode.

3. RESULTS AND DISCUSSION

In 1975 extensive damage to the vegetation had occurred. The area primarily affected by the salt (outlined in the figures) was a very wet region of partially treed bog dominated by Black Spruce and Sphagnum Moss. Many of the trees within the central and eastern parts of the spill had been killed. These were mainly dwarf Black Spruce, Tamarak and Willows. The ground vegetation of Sphagnum, sedges and grasses had also been damaged. Large brown patches of dead plants could be seen over this area. Around the perimeter of the boggy area and more to the west the damage to the vegetation was not as serious. Many of the White and Black Spruce trees had magenta colored needles and were showing signs of die back of the branches.

The location of samples taken in 1975 is shown in Figure 1. The results of analysis are compiled in Table 5. Soil samples were taken to a depth of 54" in places but only the analysis for the 0-6" (0-15 cm) depth is given in the table.

All the soils were very acidic and had pH values ranging from 4.03 to 5.45. The generally acidic nature of the area was also reflected in the pH of the water samples that were taken. Analysis for chloride and sodium indicated firstly that the oil spill was in no way responsible for the damage that was observed. High amounts of soluble salts could be detected throughout the wet boggy area and in places in the surrounding drier treed area. Contamination by sodium and chloride extended from the pipeline to slightly beyond the roadway in the west. The most heavily contaminated area was around the pipeline and immediately west and south. At this time much of this area was very soft and

Table 5. Analysis of soil and water samples from a salt spill at Swan Hills, Alberta - June, 1975.

Sample	pH	Cond. (mmhos/cm)	Chloride (ppm)	Sodium (ppm)	SO_4-S (ppm)
Water samples:					
1	6.36	5.32	1200	1260	4.0
2	4.73	4.41	1060	1010	0.3
3	4.50	0.55	110	60	0.2
4	5.14	0.53	100	110	0.3
5	5.05	0.58	110	50	0.2
6	5.56	0.52	100	100	0.1
7	6.24	0.21	30	25	0.3
8	5.03	0.91	180	170	0.8
9	5.54	0.52	100	165	0.3
10	5.12	4.86	1050	1020	0.1
Soil samples (0-15 cm):					
A	4.50	0.15	10	100	30
B	4.75	0.09	40	130	40
C	4.53	0.26	10	70	80
D	4.65	5.47	2500	5800	35
E	5.12	5.47	3100	5000	40
F	4.82	10.64	22400	34500	30
G	5.15	1.73	4750	12000	45
H	4.80	0.79	950	3800	80
I	4.38	0.84	900	2100	40
J	5.45	0.79	1950	2600	55
K	4.78	1.06	2100	2400	150
L	4.64	1.00	3950	3200	50
M	4.56	1.40	2200	3000	115
N	4.40	1.25	2850	3150	60
O	4.40	1.08	2250	8600	95
P	4.03	0.67	650	330	15
Q	4.54	1.08	1500	1650	50
R	4.50	0.78	2050	3200	25
S	4.40	0.40	2350	2200	20
T	4.17	0.65	880	860	100
U	4.56	0.85	1600	3150	75
V	5.02	3.19	7000	6300	215
W	4.33	0.50	900	825	125
X	4.52	7.60	21550	24000	60
Y	5.27	0.88	1550	1650	65
Z	5.19	8.51	19050	30000	165

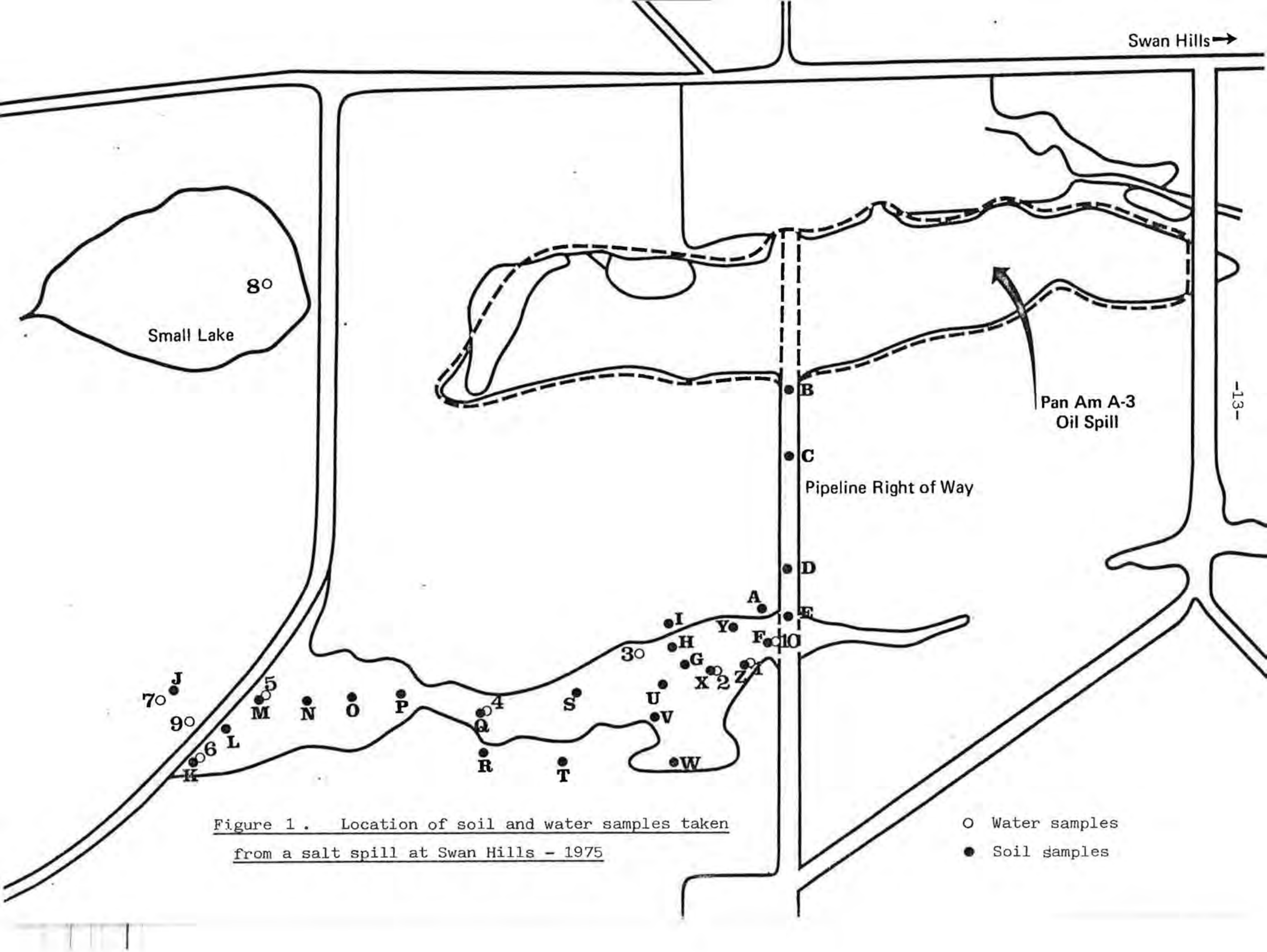

Figure 1. Location of soil and water samples taken from a salt spill at Swan Hills - 1975

and had lost its physical structure due to the destruction of the ground vegetation. The worst areas were so difficult to approach that they could not be sampled. A map of the chloride contents throughout the site can be found in Figure 2. Drainage of the site seemed to occur slowly in an east to west direction. Analysis of the water in the small lake about 3/4 mile away showed that some runoff containing sodium and chloride had already collected there. At this time the concentration of sodium and chloride was 180 ppm and 170 ppm respectively.

The electrical conductivity of soil and water samples that were taken in 1976 was considerably reduced over the previous year (see Table 6). Signs of vegetative regrowth could be seen all over the site. A relatively small area around the pipeline and to the south and west was still almost completely bare of vegetation. In other areas new Black Spruce and Tamarak seedlings had appeared and some new growth had been started on many of the damaged moss hummocks. A few of the dwarf Black Spruce and Tamarak which appeared dead the previous year had produced new shoots on some of the branches. In the far west end of the spill towards the road signs of salt damage were almost absent.

The location of soil and water samples taken in 1976 is shown in Figure 3. It was still not possible to reach the worst affected part on foot. Analysis showed that the concentrations of sodium and chloride had declined since 1975 (see Table 6). The maximum concentrations recorded were 9324 ppm for chloride and 5600 ppm for sodium as compared to 22,400 ppm for chloride and 34,500 ppm for sodium in 1975. Analysis of water from the culverts and ditches along the roadway showed that the salt was migrating generally towards the small lake and to a certain extent southwards. The concentration of chloride in the lake was slightly higher than the previous year although sodium was slightly less. Other water samples taken from around the Pan Am A-3 oil spill did

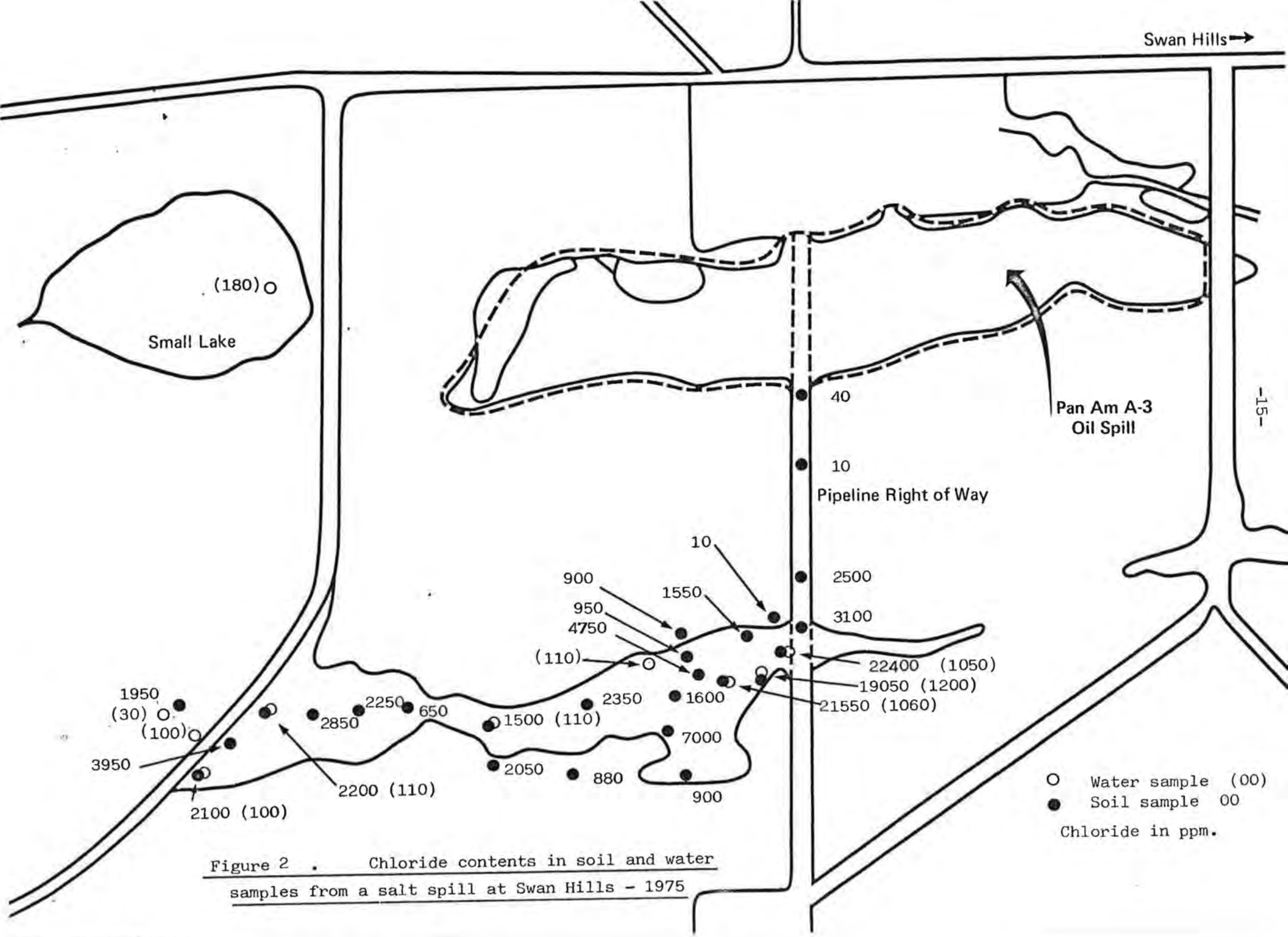

Figure 2 . Chloride contents in soil and water samples from a salt spill at Swan Hills - 1975

Table 6. Analysis of soil and water samples from a salt spill at Swan Hills, Alberta - August, 1976.

Sample	pH	Cond. (mmhos/cm)	Chloride (ppm)	Sodium (ppm)
Water samples:				
1	6.1	0.45	160	84.0
2	6.6	0.31	96.2	50.0
3	6.8	0.42	122	70.0
4	6.8	0.28	86.7	108
5	4.7	1.58	600	336
6	5.4	0.30	98.2	50.0
7	6.3	1.00	338	200
8	4.8	0.80	283	140
9	5.8	0.02	2.0	2.5
10	6.1	0.03	2.0	2.8
11	5.8	0.04	3.2	8.6
12	5.4	0.27	106	70.0
13	4.3	0.39	138	96.0
14	4.8	0.51	194	104
15	4.9	0.59	212	120
16	4.4	0.20	66.4	9.5
Soil samples (0-15 cm):				
A	5.7	0.36	950	1040
B	4.0	2.64	9324	5600
C	4.5	1.82	6672	4400
D	4.0	0.23	594	1200
E	5.1	1.68	6256	5200

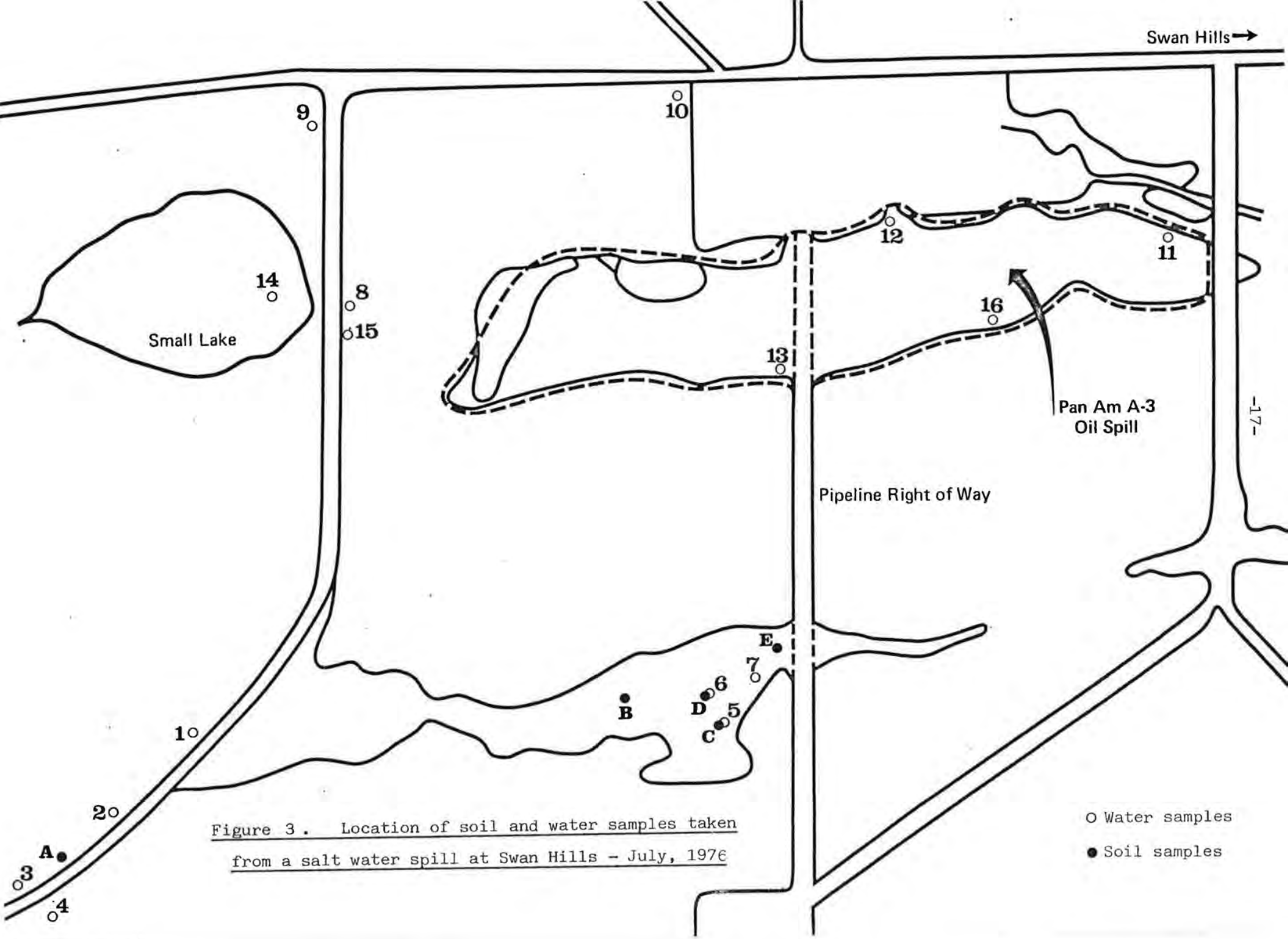

Figure 3. Location of soil and water samples taken from a salt water spill at Swan Hills - July, 1976

contain above normal levels of sodium and chloride but the contamination here was unlikely to be directly related to the main spill. Possibly some brine is leached from the battery site which tends to drain into the oil spill near where sample # 12 was taken from. Figure 4 shows the levels of chloride in the spill area in 1976.

Another visit to the area was made recently in July, 1977. Figure 5 shows the location of soil and water samples that were taken at this time. Improvement in the recovery of the vegetation over the previous two years was quite dramatic. Even the barren areas were showing good signs of growth and had regained enough structure from the new growth that they could be walked on with little danger. The more severely affected parts near the pipeline were being invaded by Slough Grass (Beckmannia syzigachne), Common Cattail (Typha latifolia), Marsh Ragwort (Senecio palustris), Fireweed (Epilobium angustifolium) and a variety of sedges and rushes. Moss hummocks that were brown the year before now showed a healthy growth of green tissues this year. Considerably more small trees of Black and White Spruce, Tamarak and Willow were present in the spill area in 1977.

Sample analysis (Table 7) showed that within the original spill area the concentration of soluble salts at the surface had been reduced to moderately low levels except in the vicinity of soil sample A and water sample # 5. The concentration of chloride had risen to 372 ppm in the small lake while a small reduction in sodium to 65.5 ppm had occurred.

Concentrations of salt around the oil spill had increased over last year. This might have resulted from additional leaching from the battery site or possibly reflect the drying trend that has been evident in the oil spill site over the last two years.

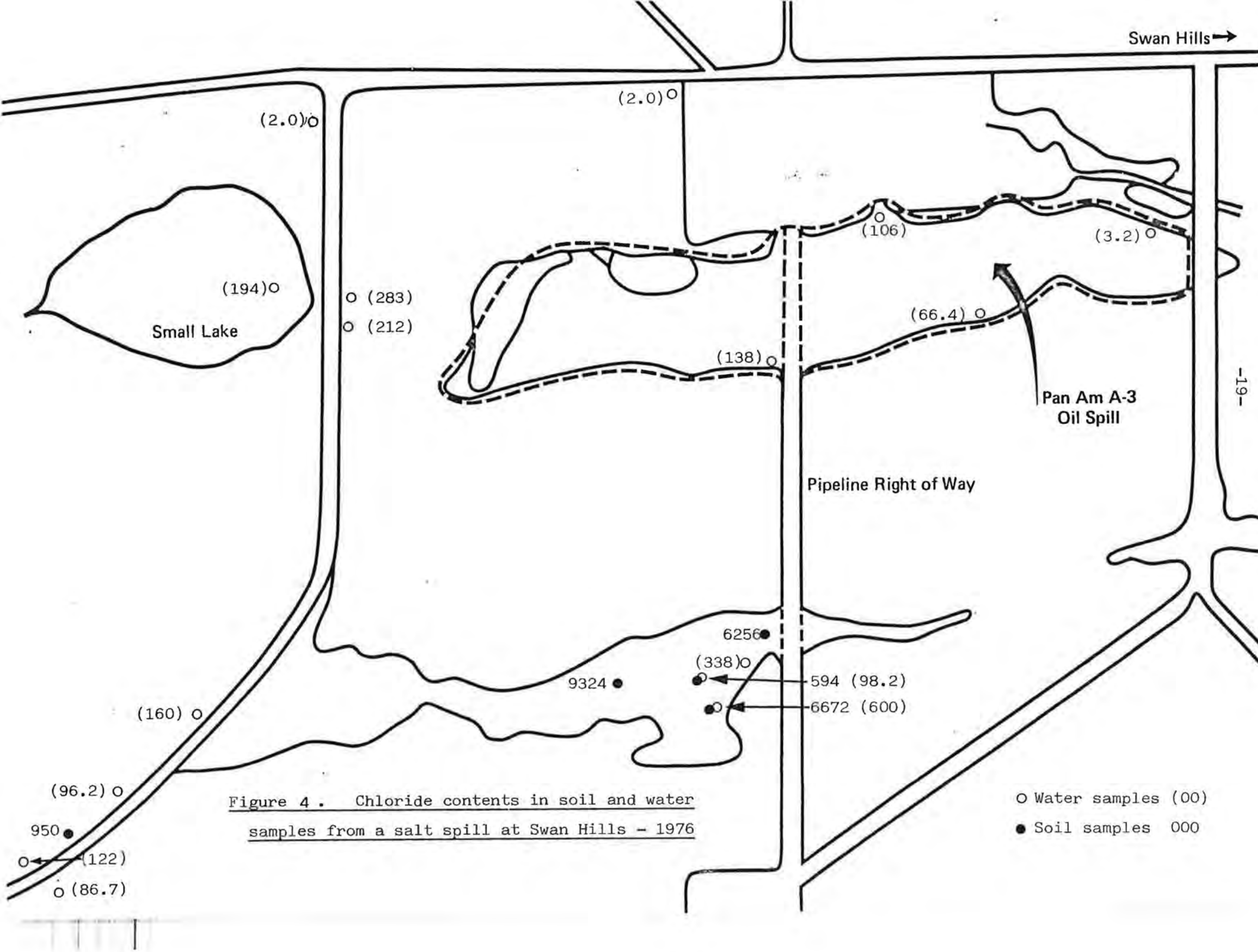

Figure 4. Chloride contents in soil and water samples from a salt spill at Swan Hills - 1976

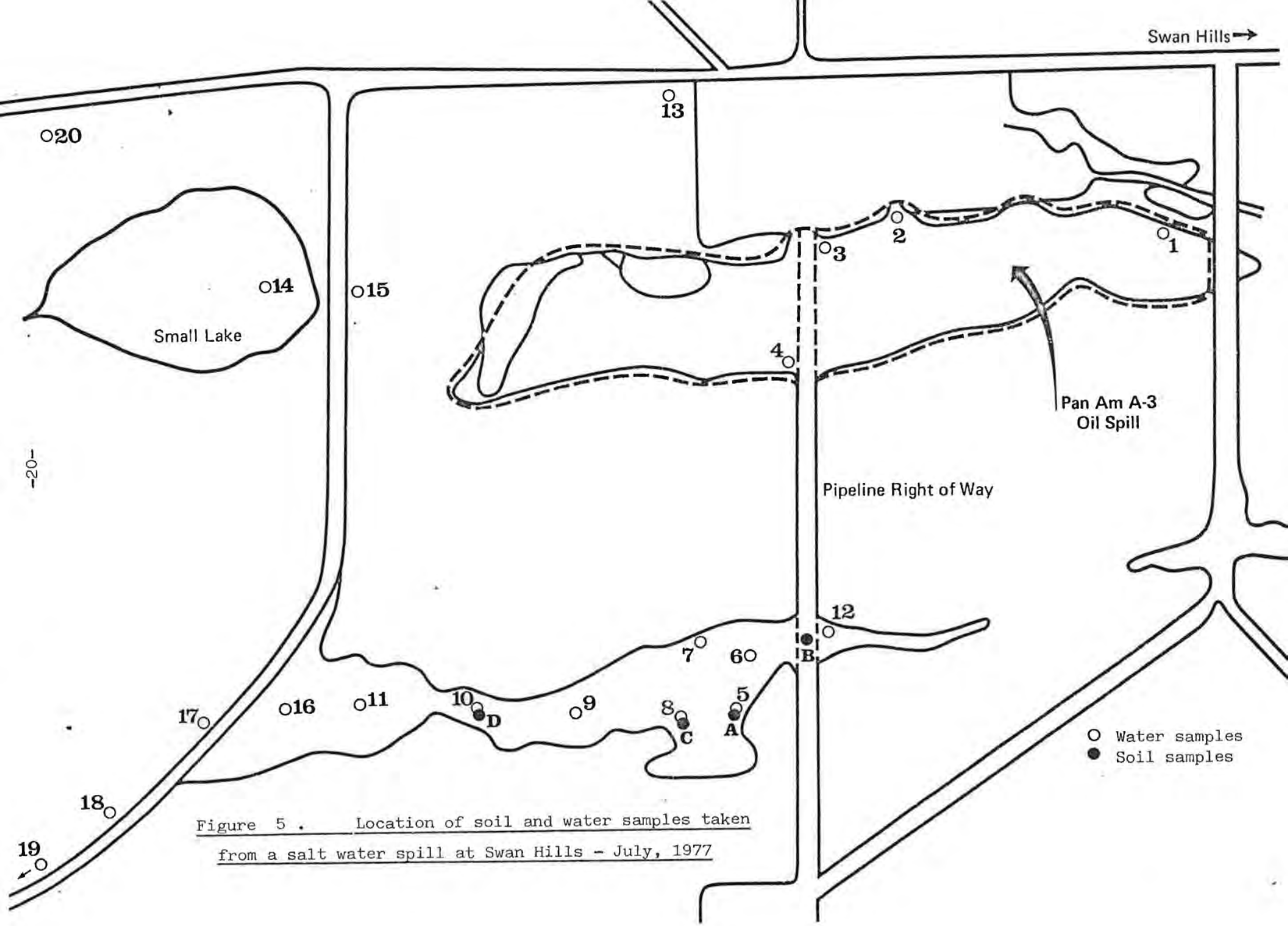

Figure 5 . Location of soil and water samples taken from a salt water spill at Swan Hills - July, 1977

Table 7. Analysis of soil and water samples from a salt spill at Swan Hills, Alberta - July, 1977.

Sample	pH	Cond. (mmhos/cm)	Chloride (ppm)	Sodium (ppm)
Water samples:				
1	6.15	0.028	28.4	1.9
2	5.55	0.37	479	68.3
3	4.55	0.53	851	73.8
4	4.95	0.10	135	3.8
5	6.20	1.45	2390	211
6	5.70	0.15	213	31.8
7	5.20	0.08	92.2	15.8
8	5.10	0.22	131	15.8
9	5.10	0.13	174	6.5
10	4.25	0.13	160	28.0
11	4.50	0.17	125	35.5
12	4.70	0.16	3.5	1.3
13	5.35	0.16	3.5	1.6
14	4.90	0.28	372	65.5
15	5.20	0.32	425	71.5
16	5.20	0.16	167	26.5
17	5.35	0.12	103	24.8
18	5.95	0.11	103	21.8
19	6.50	0.046	3.5	1.9
20	6.70	0.046	3.5	1.6
Soil samples (0-15 cm)				
A	5.25	1.16	4467	2781
B	4.85	1.04	1282	1225
C	4.90	0.39	401	800
D	4.20	0.18	801	644

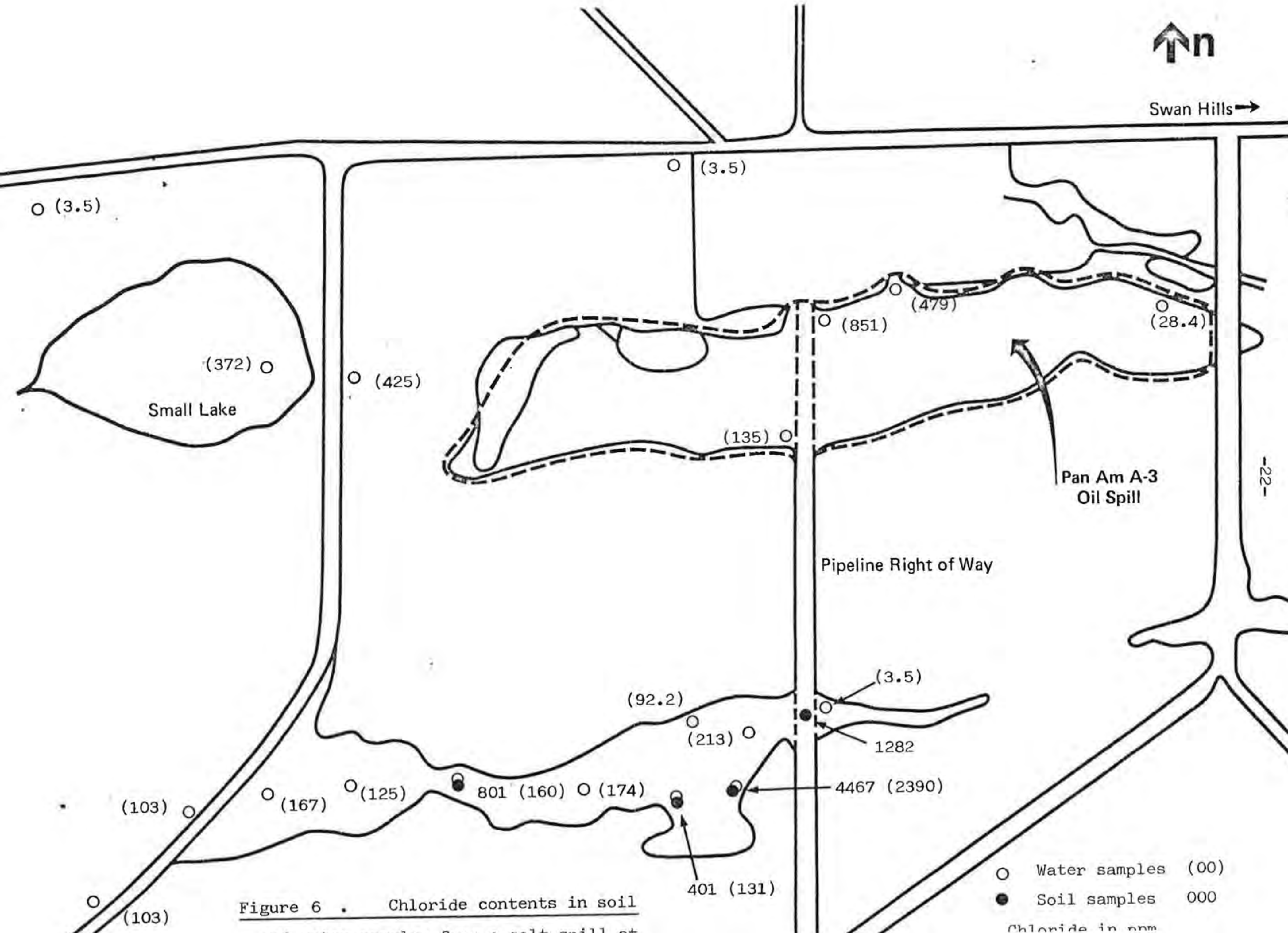

Figure 6 . Chloride contents in soil and water samples from a salt spill at

Analysis of plant samples taken from newly revegetated areas of the salt spilled revealed a wide variation in contents of water soluble sodium and chloride (see Table 8). Some plants accumulated both sodium and chloride in approximately equimolar concentrations while others only accumulated the chloride anion. The Marsh Ragwort (Senecio palustris) grew well in very salty areas and accumulated 61,144 ppm of chloride and 41,563 ppm of sodium in the sample that was analyzed. The Common Cattail (Typha latifolia) accumulated chloride (29,746 ppm chloride) but contained less water soluble sodium (5813 ppm). Slough Grass (Beckmannia syzigachne) flourished on the hitherto barren areas and contained high concentrations of both sodium and chloride. More salt accumulated in the aboveground tissues than in the roots. One sample of Fireweed (Epilobium angustifolium) growing on the salt spill contained 7294 ppm chloride but only 161 ppm of sodium. Another sample taken from an uncontaminated roadside area contained 1683 ppm of chloride and a similarly low amount of sodium (90 ppm).

Some samples of Black Spruce (Picea mariana) taken in 1975 showed that magenta colored needles contained 1800 ppm of chloride while apparently healthy needles contained 200 ppm of chloride. A similar pattern was shown in samples of White Spruce (Picea glauca). In addition, White Spruce seemed to be able to exclude sodium to a certain extent since the concentrations in salt spill samples and those from a control area were both quite low.

Accumulation of sodium with the exclusion of chloride did not seem to occur. One sample of Sphagnum Moss from the spill site did contain more sodium than chloride but the tissues had been washed proir to grinding to remove any entrapped water. It was likely that some cell-bound chloride was lost in this process.

Table 8. Water soluble sodium and chloride in various plant species

Plant type	Location	Chloride (ppm)	Sodium (ppm)
Slough grass (*Beckmannia syzigachne*)	Salt spill		
Tops		8313	6531
Roots		3325	3416
Marsh Ragwort (*Senecio palustris*)	Salt spill	61144	41563
Common Cattail (*Typha latifolia*)	Salt spill	29746	5813
Tamarak (*Larix laricina*) - needles	Salt spill	2944	134
Unidentified *Agrostis sp.*	Salt spill	7010	2594
Carex aquatilis	Salt spill	3806	254
Sphagnum sp. (washed)	Salt spill	341	1775
Fireweed (*Epilobium angustifolium*)	Salt spill	7294	161
	Control	1683	90
Black Spruce (*Picea mariana*)	Salt spill	1800	
	Control	200	
White Spruce (*Picea glauca*)	Salt spill	1022	116
	Control	80	78
Salix sp.	Salt spill	2164	70

4. CONCLUSIONS

The precise time of the salt spill studied here is not known but it probably happened about 2-3 years prior to the first visit to the site in 1975. Considerable damage to the vegetation occurred as a direct result of the high salt concentration. Natural leaching from rainfall (about 20-25 inches per anum) has reduced the concentration of salt at the soil surface to levels that have allowed most of the affected area to revegetate again. Concentrations of soluble sodium and chloride can be expected to be above normal for many years yet. However, the area can be considered to have almost completely recovered from the contamination without suffering any serious after effects. Had more drastic reclamation measures been undertaken, considerably more damage to the area may have been produced.

Increases in chloride and to a lesser extent sodium have been noted in drainage waters up to about one mile from the spill. The levels attained do not represent a serious threat to water quality in the area.

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The studies carried out in 1975 and 1976 formed two consultants reports. We greatly appreciate the cooperation of Federated Pipe Lines Ltd. and Home Oil Company Ltd. in allowing us to present this paper.

PROCEEDINGS

OF

THE SECOND ANNUAL GENERAL MEETING

OF THE

CANADIAN LAND RECLAMATION ASSOCIATION

August 17, 18, 19 & 20 — 1977 Edmonton, Alberta

(Sponsored by the Faculty of Extension, University of Alberta)

P R O G R A M

Canadian Land Reclamation Association

Second Annual General Meeting

August 17, 18, 19, 20, 1977

Edmonton, Alberta

Wednesday, August 17 (Optional Field Trips)

Field Trip No. 1 (Athabasca Tar Sands)

Leader: Philip Lulman (Syncrude Canada Ltd.)

Fee: $100.00 (covers bus and air transportation, lunch, and field trip information pamphlets)

Schedule: 7:30 am.- delegates board bus at Parking Lot T, located immediately south of the Lister Hall Student Residence complex. Air transportation from Edmonton Industrial Airport to Fort McMurray and return. Guided bus tour of surface mining and reclamation operations on Syncrude Canada Ltd. and Great Canadian Oil Sands Ltd. leases.
6:30 p.m.- delegates arrive back at Parking Lot T, University of Alberta campus.

Field Trip No. 2 (Aspen Parkland; Forestburg Coal Mine Reclamation)

Leader: George Robbins (Luscar Ltd.)

Fee: $25.00 (covers bus transportation, lunch, and field trip information pamphlets)

Schedule: 8:00 a.m. - delegates board bus at Parking Lot T, located immediately south of the Lister Hall student residence complex. Guided bus tour southeast of Edmonton, stopping at various points of interest (oil spill reclamation field plots; Black Nugget Park [abandoned minesite]; trench plots on Dodds-Roundhill Coal Field; solonetzic soil deep ploughing site) on the way to the Luscar Ltd. Coal Mine at Forestburg.
6:30 p.m. - delegates arrive back at Parking Lot T, University of Alberta campus.

Thursday, August 18

Events:	Opening of Formal Meeting; Presentation of Papers
Location:	Multi-Media Room, located on second floor of Education Building, University of Alberta.
8:00 a.m.	Authors of papers being presented on August 18 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching)
9:00 a.m.	Meeting Opened by Dr. Jack Winch (President of the C.L.R.A.; Head of the Department of Crop Science, University of Guelph). Comments by Dr. Winch.
9:15 a.m.	Welcome to delegates on behalf of the Government of Alberta by the Hon. Mr. Dallas Schmidt, (Associate Minister Responsible for Lands, Alberta Department of Energy and Natural Resources)
9:25 a.m.	Commencement of Paper Presentations. Morning session chaired by Mr. Henry Thiessen (Chairman of the Land Surface Conservation and Reclamation Council and Assistant Deputy Minister, Alberta Department of Environment).
9:30 a.m.	Paper 1. Combined Overburden Revegetation and Wastewater Disposal in the Southern Alberta Foothills by H.F. Thimm, G.J. Clark and G. Baker (presented by Harald Thimm of Chemex Reclamation and Sump Disposal Services Ltd., Calgary, Alberta).
10:00 a.m.	Paper 2. Brine Spillage in the Oil Industry; The Natural Recovery of an Area Affected by a Salt Water Spill near Swan Hills, Alberta by M.J. Rowell and J.M. Crepin (presented by Michael Rowell of Norwest Soils Research Ltd., Edmonton, Alberta)
10:30 a.m.	Coffee Recess
11:00 a.m.	Paper 3. The Interaction of Groundwater and Surface Materials in Mine Reclamation by Philip L. Hall of Groundwater Consultants Group Ltd., Edmonton, Alberta.
11:30 a.m.	Paper 4. Subsurface Water Chemistry in Mined Land Reclamation; Key to Development of a Productive Post-Mining Landscape by S.R. Moran and J.A. Cherry (presented by Stephen Moran of the Research Council of Alberta, Edmonton, Alberta).
12:00 noon	Lunch Recess

1:25 p.m. Continuation of Paper Presentations. Afternoon session chaired by Mr. Philip Lulman (member of C.L.R.A. executive; reclamation research ecologist with Syncrude Canada Ltd.).

1:30 p.m. Paper 5. Coal Mine Spoils and Their Revegetation Patterns in Central Alberta by A.E.A. Schumacher, R. Hermesh and A.L. Bedwany (presented by Alex Schumacher of Montreal Engineering Company Ltd., Calgary, Alberta).

2:00 p.m. Paper 6. Surface Reclamation Situations and Practices on Coal Exploration and Surface Mine Sites at Sparwood, B.C. by R.J. Berdusco and A.W. Milligan (presented by Roger Berdusco of Kaiser Resources Ltd., Sparwood, B.C.).

2:30 p.m. Paper 7. Agronomic Properties and Reclamation Possibilities for Surface Materials on Syncrude Lease #17 by H.M. Etter and G.L. Lesko (presented by Harold Etter of Thurber Consultants Ltd., Victoria, B.C.).

3:00 p.m. Paper 8. The Use of Peat, Fertilizers and Mine Overburden to Stabilize Steep Tailings Sand Slopes by Michael J. Rowell of Norwest Soils Research Ltd., Edmonton, Alberta.

3:30 p.m. Coffee Recess

4:00 p.m. Paper 9. Oil Sands Tailings; Integrated Planning to Provide Long-Term Stabilization by David W. Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta.

4:30 p.m. Paper 10. Bioengineering. The Use of Plant Biomass to Stabilize and Reclaim Highly Disturbed Sites by H. Schiechtel and K. (Nick) Horstmann (presented by Margit Kuttler).

5:00 p.m. End of August 18 Sessions.

Friday, August 19

Events: Presentation of Papers; C.L.R.A. Annual General Business Meeting; C.L.R.A. Annual Dinner.

Locations: Paper presentations and C.L.R.A. Annual General Business Meeting in Multi-Media Room, located on second floor of Education Building, University of Alberta.
- Annual Dinner held in Banquet Room located on second floor of Lister Hall.

8:00 a.m. Authors of Papers being presented on August 19 meet with paper presentation chairmen and audio-visual co-ordinator (Douglas Patching).

8:30 a.m. Showing of Film Rye on the Rocks. This film depicts reclamation situations at Copper Cliff, Ontario and is being shown for the purpose of introducing delegates to the site of the 1978 C.L.R.A. meeting (Sudbury, Ontario).

8:55 a.m. Continuation of Paper Presentations. Morning session chaired by Dr. J.V. Thirgood (Vice-President of C.L.R.A.; member of Forestry Faculty, University of British Columbia).

9:00 a.m. Paper 11. Reclamation of Coal Refuse Material on an Abandoned Mine Site at Staunton, Illinois by M.L. Wilkey and S.D. Zellmer (presented by Michael Wilkey of the Argonne National Laboratory, Argonne, Illinois).

9:30 a.m. Paper 12. A Case Study of Materials and Techniques Used in the Rehabilitation of a Pit and a Quarry in Southern Ontario by Sherry E. Yundt of the Ontario Ministry of Natural Resources, Toronto, Ontario).

10:00 a.m. Coffee Recess.

10:30 a.m. Paper 13. Amelioration and Revegetation of Smelter-Contaminated Soils in the Coeur D'Alene Mining District of Northern Idaho by D.B. Carter, H. Loewenstein and F.H. Pitkin (presented by Daniel Carter of Technicolor Graphic Services Inc., Sioux Falls, South Dakota).

11:00 a.m. Paper 14. The Influence of Uranium Mine Tailings on Tree Growth at Elliot Lake, Ontario by David R. Murray of the Elliot Lake Laboratory, Elliot Lake, Ontario.

11:30 a.m. Paper 15. Weathering Coal Mine Waste. Assessing Potential Side Effects at Luscar, Alberta by D.W. Devenny and D.E. Ryder (presented by David Devenny of E.B.A. Engineering Consultants Ltd., Edmonton, Alberta).

12:00 noon Lunch Recess.

1:25 p.m. Continuation of Paper Presentations. Afternoon session chaired by Dr. John Railton, (Manager, Environmental Planning, Calgary Power Ltd., Calgary, Alberta).

1:30 p.m. Paper 16. The Distribution of Nutrients and Organic Matter in Native Mountain Grasslands and Reclaimed Coalmined Areas in Southeastern B.C. by Paul F. Ziemkiewicz of the Faculty of Forestry, University of B.C., Vancouver, British Columbia.

2:00 p.m. Paper 17. Systems Inventory of Surficial Disturbance, Peace River Coal Block, B.C. by D.M. (Murray) Galbraith of the British Columbia Ministry of Mines and Petroleum Resources, Victoria, British Columbia.

2:30 p.m. Paper 18. The Selection and Utilization of Native Grasses for Reclamation in the Rocky Mountains of Alberta by D. Walker, R.S. Sadasivaiah and J. Weijer (presented by David Walker of the Department of Genetics, University of Alberta, Edmonton, Alberta).

3:00 p.m. Coffee Recess; Distribution of Proceedings.

3:30 p.m. Commencement of 1977 General Business Meeting of the Canadian Land Reclamation Association. Meeting chaired by Dr. J.V. Winch, C.L.R.A. President.

7:30 p.m. Commencement of C.L.R.A. Annual Dinner in Banquet Room, second floor of Lister Hall.

Guest Speaker: William T. Plass, Principal Plant Ecologist, U.S.D.A. Forest Service, Northeastern Forest Experiment Station, Princeton, West Virginia.

Topic of Speech: Challenges in Co-operative Reclamation Research.

Note: Following the Annual Dinner and Mr. Plass's speech, delegates may retire to the adjacent Gold Room. A bartender will be on service until midnight.