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IMPACTS OF OIL FIELD WASTES ON SOIL AND GROUND WATER IN RICHLAND COUNTY, MONTANA
PART IV

RECLAMATION OF SOILS DAMAGED BY OIL FIELD WASTES RICHLAND COUNTY, MONTANA
PART IV

by

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RECLAMATION OF SOILS DAMAGED BY OIL FIELD WASTES
RICHLAND COUNTY, MONTANA
PART IV

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INTRODUCTION

In the Williston Basin oil field of eastern Montana, salinization of ground water and soil resources is a potential environmental impact of oil drilling and production. Often, the impacts are associated with the disposal of drilling muds saturated with sodium chloride. Improper disposal of these muds, particularly on-site burial in areas of high water tables and irrigated crop production, has led to salinization on a variety of sites investigated by Montana Salinity Control Association (MSCA) over the past several years. This report outlines results of these investigations and reclamation activities on these sites, located in eastern Richland County, Montana.

MILO HUNTER SITE:

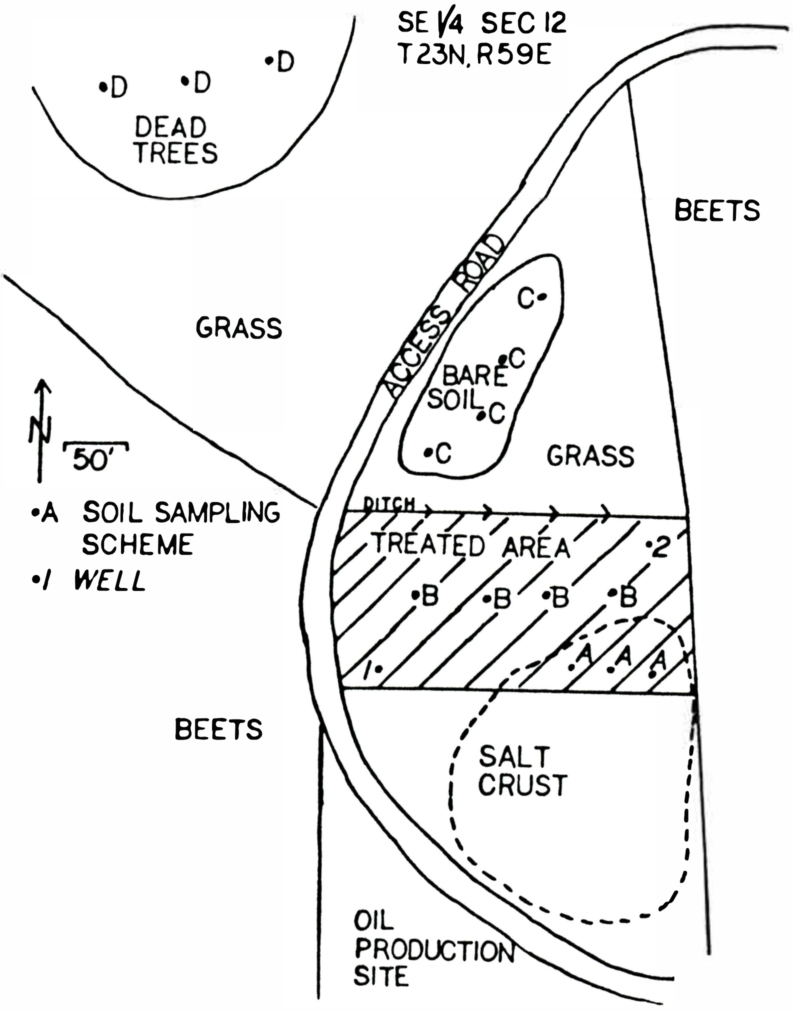
The Hunter site is located in section 33, T.25N., R.59E. This is a dryland site that was used as a central disposal facility for drilling muds, which were simply buried in several trenches. Recontouring and seeding was recommended in areas where the muds were not buried at a sufficient depth. The trenches were recontoured in spring 1988 to provide adequate soil cover. Due to the drought of 1988, the site was not seeded until spring of 1989. The seed mix included Russian wildrye, crested wheatgrass, and yellow sweet clover. This seeding was evaluated over the summer of 1989. Although a 2 year period is needed before dryland grass seedings can be fully evaluated, the number of new grass plants populating the site should eventually provide sufficient vegetal cover.

RICHARD PROPP SITE:

The Propp site, located in Sec. 12, T.23N., R.59E., is an irrigated site on the lowest terrace of the Yellowstone River valley. A drilling mud reserve pit has salinized about 2 acres of land. 9.3 tons of sulfuric acid (H_2SO_4) was applied to 1 acre in September, 1988. The status report describing the sulfuric acid application is included in Appendix A. A map of the site is shown in Figure 1. The intent of the sulfuric acid treatment was to release calcium from calcium carbonate ($CaCO_3$) naturally present in the soil. This is followed by intensive irrigation treatments to leach soluble salt from the soil. As the salt is leached, the released calcium exchanges with sodium present on the cation exchange sites on the soil clays. This prevents the soil from developing a sodic condition subsequent to salt removal. Sodic soils exhibit physical problems that inhibit growth of roots and movement of water and gases.

The treated area was resampled in June and October, 1989 to assess the effectiveness of the treatment in lowering exchangeable sodium as salts were leached away. Resampling was performed along the A and B transects. Transect A is located in the most salinized part of the treated area (southeast corner), and transect B represents average conditions across the area. The results of the soils analysis are provided in Table 1.

Figure 1. Map of the Propp site.



In the June sampling, a surface crusting was evident in the top inch of soil. This condition is rare in salt affected soils, but is a common problem with sodic soils. The crust appeared to interfere with emergence of beet seedlings, and therefore was sampled separately. Although exchangeable sodium and the sodium absorption ratio are higher for the crust than the 0-6 inch sample along the A transect, this is not evident for the B transect samples. The crusting is probably associated a high clay content (40%), and low organic matter (measured at about 2 percent before and after treatment).

Table 1. Results of soils analyses from a pretreatment and two post treatment sampling events at the Propp site. Transect locations are shown in Figure 1.

TRANSECT AND DEPTH (INCHES)	TIME OF SAMPLING	pH	EC mmhos/cm	CATION EXCHG CAP	EXCHG SODIUM	SODIUM	CALCIUM	MAGNESIUM	SODIUM ABSORPTION RATIO
				-----meq/100g-------		-----------meq/l-----------			
A 0-6	PRETRT	7.0	18.0	18.2	23.0	388.7	188.0	121.7	31.2
	JUNE 89	7.7	19.6		11.1	181.3	60.0	103.3	19.8
	CRUST	7.4	18.2		19.1	383.0	90.5	417.5	24.2
	OCT 89	6.2	31.3		17.4	277.5	115.3	158.6	23.7
A 6-18	PRETRT	7.5	19.2	19.3	14.3	195.2	87.0	50.8	23.5
	JUNE 89	7.4	19.1		11.0	180.4	68.5	50.0	23.5
	OCT 89	7.2	17.1		16.8	153.5	71.4	49.6	19.7
B 0-6	PRETRT	7.9	16.3	20.1	6.1	98.7	59.5	35.8	14.3
	JUNE 89	7.6	13.7		5.9	73.9	41.5	47.5	11.1
	CRUST	7.7	19.0		5.5	84.3	51.5	95.8	9.9
	OCT 89	7.3	20.0		10.9	124.6	61.8	85.7	14.5
B 6-18	PRETRT	7.8	16.4	18.7	7.7	104.8	56.5	35.0	15.5
	JUNE 89	7.4	14.6		6.9	86.1	44.0	38.3	13.5
	OCT 89	7.5	17.9		12.2	124.8	62.0	53.9	16.4

Generally, the soils data show that little change has taken place in the salt load of the soil over the past year. An increase in exchangeable sodium was measured this fall at the end of the irrigation season. The conclusion from the data is that this season's irrigation did not successfully remove (leach) a sufficient quantity of salt from the soil profile for the treatment to be effective. There are three possible reasons for this; all were probably a factor to some extent. First, the quantity of irrigation water applied may have been insufficient. MSCA did not have the opportunity to determine the timing or amount of irrigation water applications. After the H_2SO_4 application, the treatment area was joined with the adjacent crop field and managed for sugar beet production. Much more water is needed to leach salt than to grow beets and these two objectives may have been incompatible. A more effective option would have been to dike off the treatment area and pond water over it on a weekly basis.

The second reason that salt was not removed is that a larger quantity of salt is present than can be leached during one irrigation season. Drilling muds often have saturated extract salt concentrations in the 100,000-200,000 mg/l range. Release of so much salt from drilling muds of low hydraulic conductivity may take several decades regardless of the amount of water applied. As salt is leached from the native soil surrounding the muds, it could be replenished by the large source of salts in the mud through diffusion and mass flow.

The third reason for high salt contents remaining in the soil is an elevated water table during the irrigation season. When the site was selected, the depth to ground water was estimated at five feet by the landowner. In order to obtain ground water quality samples, two thirteen foot wells were installed in June, 1989 (locations shown in Figure 1). In mid July, the water table depths were 2.7 and 2.4 feet below surface (wells 1 and 2, respectively), which was higher than expected. Irrigation water applied with the water table at this depth would not leach any salt from the soil profile, as downward water movement would stop at the water table. Evaporation and capillary movement could easily move salt back up to the soil surface from a depth of 2.7 feet. The wells were measured again in mid October at 4.8 and 4.7 feet. Apparently the water table fluctuates significantly over the growing season, rising as irrigation water is applied across the Yellowstone valley, and declining as irrigation is discontinued in the fall. This limits the leaching effectiveness of irrigation treatments applied during the growing season. The landowner appears to have little control over the water table level, as the site is located on the lowest terrace of the valley.

When the wells were drilled, logs of soils and moisture conditions were recorded, and are presented in Table 2. Fine textured clay loams, 5 to 10 feet thick, overlie fine sands. Water samples were collected from the two wells in mid July and analysis results are presented in Table 3. Results for well 1 are probably typical of ground water quality on this low terrace of the Yellowstone River valley. The Total Dissolved Solids (TDS) level, 1460 mg/l, is only slightly influenced by chloride salts associated with the drilling muds. Although not good for drinking, this water would be suited for most agricultural uses. Well 2, however, although less than 100 yards away, shows a 10 fold increase in sodium and chloride, and an increase in TDS to 10,700 mg/l. This water is highly salinized by buried drilling muds, and is not suited for irrigation or livestock use.

Table 2. Logs of monitoring wells drilled at the Propp site.

WELL NO	DEPTH INTERVAL (FEET)	SOIL TEXTURE	MOISTURE CONDITIONS
1	0 TO 5	CLAY LOAM	VERY MOIST
	5 TO 9	VERY FINE SANDY LOAM	SATURATED
	9 TO 13	VERY FINE LOAMY SAND	SATURATED
2	0 TO 4	CLAY LOAM	VERY MOIST
	4 TO 10	DENSE CLAY	WET
	10 TO 13	VERY FINE SAND	SATURATED

Table 3. Results of water quality analyses conducted on samples collected from monitoring wells at the Propp site.

CONSTITUENT	CONCENTRATION (mg/l)	
	WELL 1	WELL 2
SODIUM	242	2280
CALCIUM	154	679
MAGNESIUM	102	493
SULFATE	519	588
CHLORIDE	42	5030
TOTAL DISS SOLIDS	1460	10700
SPEC CONDUCTANCE	2080	15800
pH	7.7	6.9
NITRATE & NITRITE N	0.11	0.06
METALS:		
ARSENIC	LT 0.005	LT 0.005
BARIUM	0.1	0.4
CADMIUM	LT 0.001	0.001
IRON	2.31	30.94
LEAD	LT 0.01	LT 0.01
NICKEL	LT 0.03	LT 0.03
SELENIUM	LT 0.005	LT 0.005

LT = Less Than (below detection limit)

JAMES WATTS SITE

The Watts site, located in sections 21 and 22, T.24N., R.59E., is essentially a slough that was salinized by subsurface pollution from an upslope oil well. The well is now used for injection of salt water. The affected area, about five acres in size, used to produce over two tons of hay per acre, and is now void of vegetation. Two soil samples were collected along different transects at 0 to 10 inches, and a shallow well was drilled for ground water quality assessment. Results of the soil and water analysis are given in table 4.

Both soils and water analysis results indicate that chloride salts have caused the site to lose its productivity. Soil conductivities near 30 mmhos/cm will not allow establishment of salt tolerant grasses. The information implicates the upslope oil well as the likely source of salinization. The oil company that operates the well has paid for the initial investigative work, and has agreed to a full investigation to pinpoint the source of salt at company expense. Although the well is currently used for salt water injection, recent pressure tests have not indicated any leakage from injection. Therefore, the likely source of salt is the drilling mud reserve pit that was installed when the well was drilled. These pits are usually trenched before backfilling, and the unlined trenches may contribute significant quantities of salt to the ground water. This is particularly true if the water table is at a lesser depth than the trench, as appears to be the case at this site.

Table 4. Results of soil and water analysis from the Watts site.

	SOILS ANALYSIS			WATER ANALYSIS	
CONSTITUENT	UNITS	0 TO 10 INCHES SAMPLE 1	 SAMPLE 2	UNITS	RESULT
pH	STD	6.9	7	STD	7.5
CONDUCTANCE	MMHOS/CM	26.8	30.7	UMHOS/CM	9460
SATURATION	% VOL	37	45		
CALCIUM	MEQ/L	121	128	MG/L	755
MAGNESIUM	MEQ/L	213	218	MG/L	310
SODIUM	MEQ/L	69.5	90.7	MG/L	885
SAR		5.4	6.9		6.8
CHLORIDE	PPM	5300	6200	MG/L	3040
SULFATE	PPM	948	1770	MG/L	274
TDS				MG/L	6990
NO3 & NO2 N				MG/L	4.6
METALS:					
ARSENIC				MG/L	LT 0.005
BARIUM				MG/L	0.5
CADMIUM				MG/L	LT 0.001
IRON				MG/L	0.06
LEAD				MG/L	LT 0.01
NICKEL				MG/L	LT 0.03
SELENIUM				MG/L	LT 0.005

LT = LESS THAN (BELOW DETECTION LIMIT)

CONCLUSIONS

The information presented indicates that drilling muds should be disposed off-site if a shallow water table and/or irrigated cropland is present. Release of the salts contained in the muds will occur most rapidly under saturated conditions. Where the water table is above the depth of burial, salts have the greatest chance of being released into surrounding soils. When salty water is subject to upward movement by evaporation and capillarity, salts will become concentrated in surface soils. Although these salts can be leached downward with irrigation water, this water may only be available when irrigation on adjacent lands brings the water table to its highest level. This is when the irrigation treatments would be least effective. Also, leaching treatments may adversely affect ground water quality. The best solution to this problem is not to bury drilling muds on sites where complications can arise from a high water table. Where such impacts have occurred, excavation and removal of the drilling muds may be necessary as an initial corrective measure.

The sulfuric acid application is a method that has been proven successful in the reclamation of saline-sodic soils. However, the effectiveness of irrigation treatments that follow the treatment are critical. Where there is lack of control over factors that can cause upward movement of shallow ground water, this method should not be used. In order to determine the suitability of a site for this treatment, there should be a monitoring period prior to treatment application. Given its cost, the method should only be used when the following conditions exist: 1. clay rich soils (at least 20 to 25 percent, depending on mineralogy) 2. $CaCO_3$ present in soil 3. availability of irrigation water 4. water table remains 6 feet below surface during growing season. If the soil is very saline, leaching treatments can be initiated before the acid is applied, to ensure that downward movement of salt can be maintained. Given these constraints, proper siting of disposal sites, as well as improved methods for solidifying or recycling these muds, should be viewed as the best way to minimize adverse environmental impacts from reserve pit drilling muds.

APPENDIX A

STATUS REPORT

Soil reclamation projects have continued on two sites in Richland County this past field season. Objectives for this season were to complete topsoiling, resurfacing, and seeding over the disposal trenches at the Milo Hunter site, and to select an additional site on irrigated land for reclamation through chemical amendments and irrigation. The topsoiling and resurfacing at the Hunter site was completed on April 19. However seeding was delayed until this fall or early spring 1989 due to the drought.

SELECTION AND DESCRIPTION OF PROPP SITE

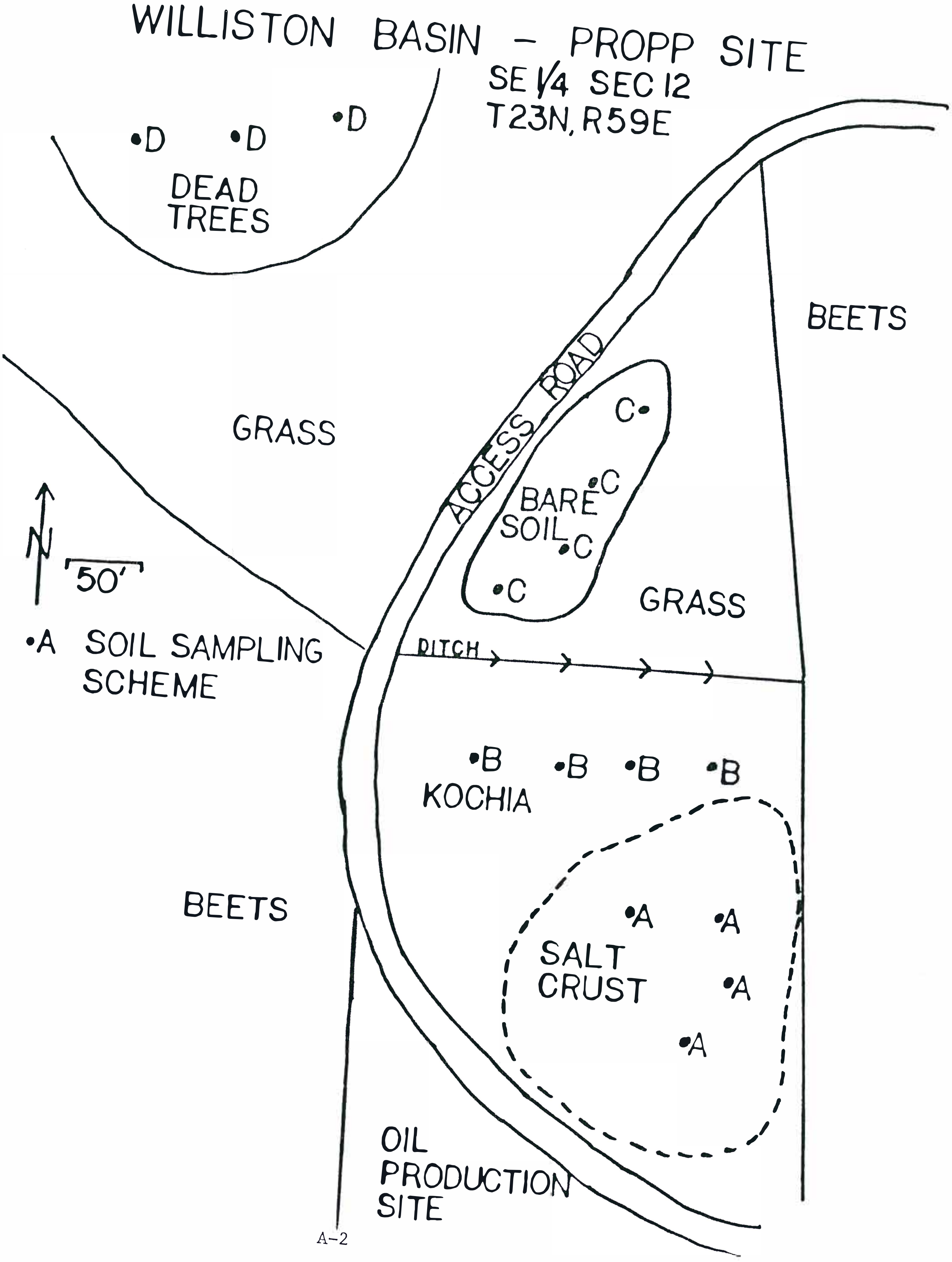
On April 21, an irrigated site in the SE1/4 of Sec. 12, T. 23 N., R. 59 E., owned by Richard Propp, was selected as the second site for investigation. Due to budgetary and logistical limitations, the feasibility of a reclamation research project involving replicated plot treatments was suspect. Therefore the site was investigated with the objective of applying a single treatment to the area for effective reclamation. Given this objective the site could still serve as a public demonstration of reclamation on soils impacted by drilling fluid brine.

An enclosed map (Fig. 1) shows the layout of the Propp site. The oil production site (oil well and storage tanks) is rather large, covering 2 or 3 acres. The drilling fluid reserve pit is just north of the well site. Depth to ground water is estimated at about 5 feet. About 1.7 acres cannot be farmed due to saline conditions over and north of the reserve pit. These are noted on the map as salt encrusted and kochia infested areas. Further to the north, there was concern about an area of bare soil where some "topsoil" had been dumped and an area where 20 to 30 trees had dies. These areas are also shown on the map and were included in the soil sampling scheme.

SITE INVESTIGATION

Prior to collection of soil samples, a conductivity survey of the site was performed with an EM-38 on June 15 (50 by 50 ft. grid). The purpose of the survey was to map the variation in salinity across the site and determine an optimal soil sampling scheme. The EM-38 is used to monitor salinity to a 1 meter depth. The results of the survey are shown on Figure 2. As a reference, readings over 125 mmhos/m indicate salinity levels which would affect production of most crops. Survey results show extreme salinity over the reserve pit (salt encrusted area) and lower but still elevated readings in the area infested with Kochia. This confirmed that the two areas should be sampled separately. Accordingly, the site was sampled as shown on the map (Fig. 1) on June 16. (Readings taken in the tree kill area were about 130 mmhos/m).

FIGURE 1. General map of Propp site with soil sampling scheme



Soils were sampled in 3 depth intervals (0-6, 6-18, and 18-33 inches). Sub-samples from each sampling point were combined by depth for each transect (A, B, C, & D) to give a total of 12 samples. Soils were analyzed at MSU's soil analytical lab for pH, EC, Sodium Absorption Ratio (SAR), percent saturation, Cation Exchange Capacity (CEC), chloride, sulfate, nitrate, percent organic matter, and texture. Results of the analyses are shown in Table 1.

DISCUSSION OF SOIL SAMPLE RESULTS

The results show decreasing salinity from transect A to D, yet significant salinity hazards at depth along all four transects. Salinity hazards (EC) and SAR data along transects A and B are very high. Soils are fine textured clay loams, silty clay loams, and silty clays. As NaCl dominated salts are leached from such fine textured soils, there is a potential for sodic conditions to result. Therefore a relatively soluble source of calcium should be made available to enhance removal of sodium during leaching. Relatively high saturation percentages further suggest the need for soluble calcium addition prior to irrigation.

Along transect C, no amendment appears to be necessary since the surface EC is fairly low. Seeding this area to salt tolerant vegetation should provide cover. Along transect D, comparison of chloride versus sulfate data show that naturally occurring sulfate salts are probably responsible for the death of elm trees in the area. During sampling of transect D, saturated conditions were noted at 33 inches. Establishment of other tree species such as cottonwood or Russian olive is recommended.

Additional analyses were requested on the A and B transect samples for exchangeable sodium and calcium carbonate equivalent. This is necessary to calculate exchangeable sodium percentage (ESP = exchangeable Na/CEC), and determine the amount of calcium present in the soil as CaCO3, which is unavailable for exchange as is (CaCO3 data are discussed under amendment selection). Results of these additional analyses are given in Table 2.

ESP data show that soils over the reserve pit (transect A) have cation exchanges nearly saturated with sodium (74 to 100%). In order to avoid sodic soil conditions, ESP levels must be reduced to 15. Due to the high quantity of amendment which would be required to achieve this, and potential negative effects of leachate water on adjacent fields, this area was not considered for treatment. Soils along the B transect, however, have lower ESP levels (30 to 87%) and lower salt concentrations (not extractable Na and Cl data in Table 1). This area would have a lower amendment rate and reduced risk to adjacent fields from leachate water, and was therefore targeted for reclamation treatment.

FIGURE 2. Results of EM 38 conductivity survey

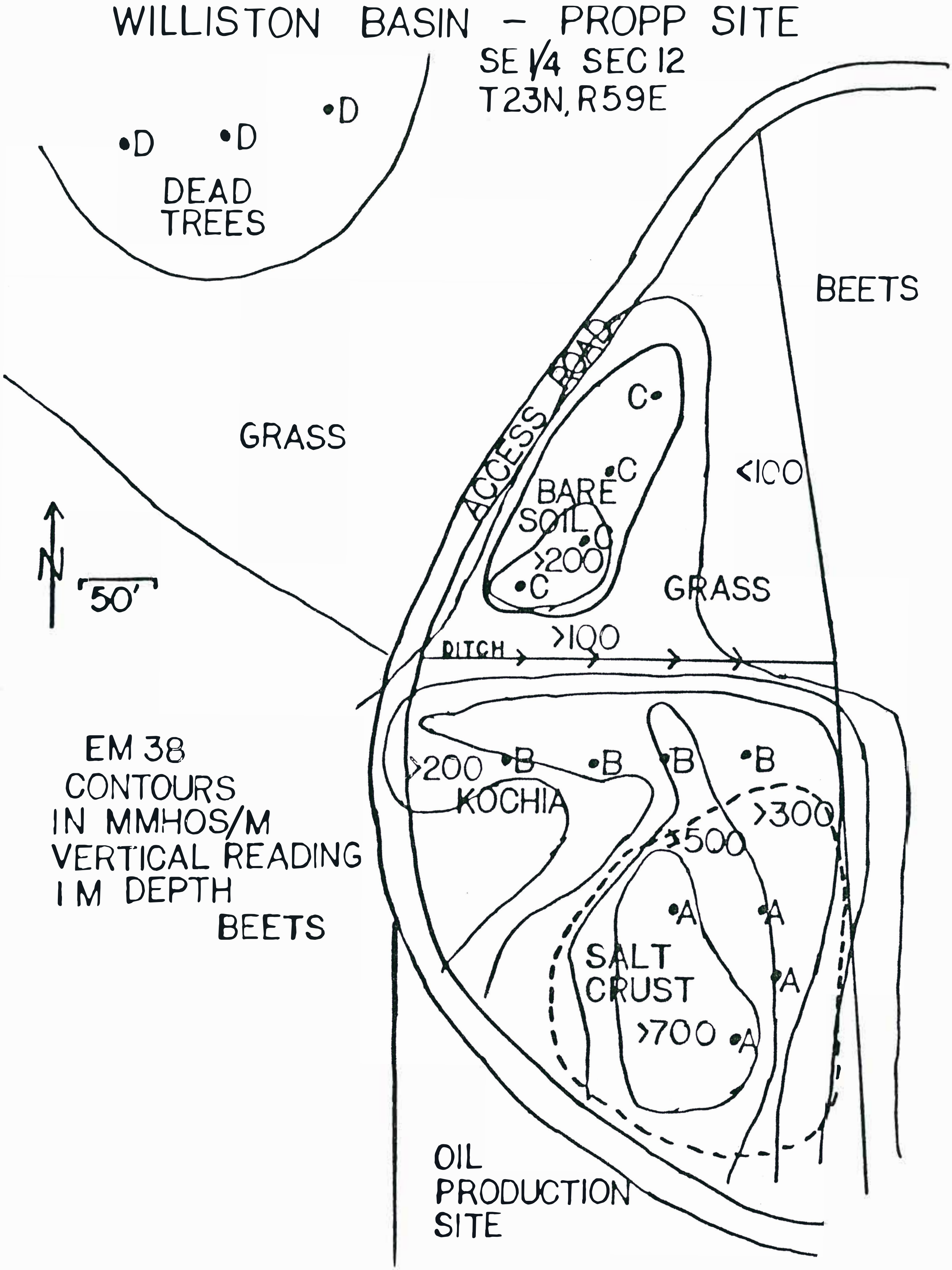


TABLE I – SOIL ANALYSIS RESULTS

Sample		pH	EC mmhos/cm	% Saturation	Sat. Paste Ext. (mg/l) Ca	Mg	Na	SAR	CEC meq/100g	Cl mg/l	SO_4 mg/l	NO_3 ug/g	% OM	Texture % S/Si/C
A	0-6	7.0	18.0	62.9	3760	1460	8940	31.2	18.2	22,840	1958	20.0	2.23	18/40/42
	6-18	7.5	19.2	71.1	1740	610	4490	23.5	19.3	10,070	2252	7.5	2.03	16/44/40
	18-33	7.3	18.7	76.6	2000	760	6100	29.3	18.5	13,630	1981	2.9	1.96	20/42/38
B	0-6	7.9	16.3	61.3	1190	430	2270	14.3	20.1	5,960	1282	8.0	1.96	18/42/40
	6-18	7.8	16.4	63.7	1130	420	2410	15.5	18.7	4,830	2306	5.4	2.11	18/44/38
	18-33	7.9	19.2	68.1	1390	640	4820	26.8	19.1	9580	2930	0.6	1.81	22/40/38
C	0-6	8.0	3.8	61.4	162	44	660	11.8	19.6	672	759	8.4	2.11	16/46/38
	6-18	7.4	11.1	64.3	727	230	1580	13.0	21.2	2838	2308	5.7	2.60	16/46/38
	18-33	7.4	13.2	67.8	853	470	1710	11.6	21.7	3050	3056	4.0	2.51	8/48/44
D	0-6	7.9	1.1	67.9	131	33	46	0.9	25.9	73	79	15.2	5.26	14/48/38
	6-18	7.7	8.9	58.7	483	330	1460	12.5	18.7	221	4680	3.2	2.00	16/56/28
	18-33	7.6	11.6	76.0	436	570	2120	15.7	20.6	263	7220	6.3	1.67	8/54/38

TABLE 2 - RESULTS OF ADDITIONAL ANALYSIS

		Exch Na meq/100 g	ESP	% Lime
A	0-6	23.0	100	6.7
	6-18	14.3	74	7.0
	18-33	21.6	100	7.0
B	0-6	6.1	30.3	6.2
	6-18	7.7	41.2	6.0
	18-33	16.6	87	7.7

To calculate the rate of chemical amendment needed, regardless of the amendment chosen, the amount of exchangeable Na which must be replaced to reduce the ESP to 15 is calculated first. Fifteen percent of the CEC is subtracted from the amount of exchangeable Na present in the sample. Units are meq/100g.

Transect B 0-6": 6.1 - (20.1 x .15) = 3.1
6-18": 7.7 - (18.7 x .15) = 4.9
18-33":16.6 - (19.1 x .15) = 13.7

Obviously, most of the sodium replacement would be below the 18 inch depth if the entire profile is to be addressed. It would be impractical and expensive to move such a large quantity of amendment below 18 inches through irrigation. Also the most adverse impacts of sodic conditions are expressed near the soil surface (crusting, poor seedling emergence, poor infiltration). However, movement of some amendment below the 18 inch depth would be desirable. This would help obtain proper internal drainage, aeration, and root penetration. To balance these considerations, an arbitrary decision was made to replace 4.9 meq Na/100g between 6 and 24 inches rather than 6 to 18 inches.

SELECTION OF THE SOIL AMENDMENT

Several types of amendments may be considered for reclamation of saline-sodic soils. Calcium based amendments include calcium chloride and gypsum. $CaCl_2$ would be a good choice due to its high solubility, yet high cost is a drawback ($300/T). Although gypsum has a low solubility, phosphogypsum (a by-product of phosphorus fertilizer manufacture) has higher solubility than mine gypsum (10 times as soluble), and is inexpensive ($60/T).

Sulfuric acid is another amendment which has been used to reclaim saline sodic soils. It is a fairly common practice in the southwest U.S. to use H_2SO_4 for preparing native saline sodic soils for agricultural production. This amendment will not work without the presence of sufficient $CaCO_3$ in the soil. The following reaction occurs:

$$H_2SO_4 + CaCO_3 \qquad CaSO_4 + H_2O + CO_2$$

The sulfuric acid amendment in effect releases calcium already present in the soil, but unavailable (insoluble) in the form of lime. Once the $CaCO_3$ is converted to $CaSO_4$, the calcium is more soluble and available to exchange with sodium. Soil analyses (B transect) show that the calcium carbonate equivalent varies from 6.0 to 7.7 percent. Using atomic weights of these elements (Ca=40, C=12, 0=16), $CaCO_3$ is 40% Ca (40/(40+12+(3 x16))). If the soil is 6.0% $CaCO_3$, then it is also 2.4% (6.0 x .40) Ca. This is the same as 24,000 ppm or 2400 mg/100 g. (.024 x 10^6 g/10^6g = 24,000 g/10^6 g = 2.4 g/100 g = 2400 mg/100 g). Milligrams are converted to millequivalents as follows: 2400 mg/100 g x 2 meq/40 mg = 120 meq Ca/100 g (multiply by valence over atomic weight).

Therefore at least 120 meq/100 g of calcium are available for release from lime, and sulfuric acid is a reasonable amendment (cost of $120/T).

Rates of amendments are calculated based on the amount of sodium to be replaced in the soil. This is equal to the amount of calcium which must be added and made available in the soil system. The following calculation shows the amount of calcium which must be added per each meq/100 g of sodium replaced per acre foot of soil. One acre foot of soil weighs approximately 4,000,000 lb.

1 meq Ca/100 g x 40 mg/2 meq = 20 mg Ca/100 g = .02 g/100 g = 200 ppm
200 ppm Ca = 200 lb/10^6lb x 4 x 10^6/ac ft. = 800 lb Ca/ac ft.

The total amount of calcium to be added is calculated from the total amount of sodium to be replaced (see previous calculation).

0-6" 3.1 meq/100 g x 0.5 ft. x 800 lb/meq/100 g/ac ft. = 1240 lb/ac
6-24" 4.9 meq/100 g x 1.5 ft. x 800 lb/meq/100 g/ac ft. = <u>5880</u> lb/ac
TOTAL = 7120 lb/ac

Therefore 7120 lb of calcium must be added to or released in the soil. The following calculations compare quantities of each amendment actually required and projected costs. Percent calcium for each amendment is on an atomic weight basis.

Phosphogypsum: $CaSO_4$-$2H_2O$ is 23.2 percent Ca. An impurity factor of 1.22 is included plus a factor of 1.25 for lack of quantitative displacement (due to low solubility).

7120 lb/ac 0.232 x 1.22 x 1.25 = 46,801.8 lb/ac = 23.4 T/ac
Projected cost: 23.4 T/ac x $60/T = $1,404/ac + freight

Calcium chloride: $CaCl_2$ is 36.0 percent Ca, with an impurity factor of 1.05.

7120 lb/ac/0.36 x 1.05 = 20,766.7 lb/ac = 10.4 T/ac
Projected cost: 10.4 T/ac x $300/T = $3,115/ac + freight

Sulfuric acid: assuming 1 mole of Ca would be released per mole of H_2SO_4 added, the release efficiency on an atomic weight basis would be 40/98, or 40.8 percent. The impurity factor is 1.07

7120 lb/ac/0.408 x 1.07 = 18,672.5 lb/ac = 9.3 T/ac
Projected cost: 9.3 T/ac x $120/T = $1,116/ac + freight

Therefore sulfuric acid appears to be the most economical amendment, as well as the most efficient (D. Dollhopf - pers. comm.). Another advantage is that sulfuric acid is available in state, whereas phosphogypsum would have to be shipped in from Idaho. Calcium chloride would be nearly cost prohibitive. Therefore H_2SO_4 was selected as the best amendment.

APPLICATION OF THE AMENDMENT

The area selected for treatment covered 1.0 ac (150 x 300 ft. - see figure 3). An obvious problem for application of this highly corrosive acid was safety and handling of the material. After consultation with reclamation specialists and Mr. Propp about equipment needs and availability, the following system was devised to apply the acid (see Figure 4). A 300 gallon steel fuel tank was mounted in a pickup bed trailer. A plastic valve was attached to the bottom outlet of the tank. From the valve, a 1 inch hose (about 18 in. long) was run to the bottom of the vertically dropped tailgate. The hose was T joined to 2 sections of 2 inch plastic pipe about 5 feet long, which were wired and bolted along the bottom of the tailgate. The pipe was plugged at the ends, and 1/8 in. holes were drilled every 6 inches along the bottom. The system was tested for leaks with water prior to actual use with the acid.

The acid was applied on Sept. 13; 9.35 tons were ordered, and 9.32 tons were delivered. The delivery truck and driver remained on site during application so that proper storage and transfer equipment and a person experienced with handling the acid were present. During application, rubber boots and gloves, acid resistant coveralls, and plastic face shields were worn for protection. A 240 gallon tank of water was also at the site as a safety precaution. The acid tank was not filled more than halfway due to the high density (15.3 lb/gal) of the H_2SO_4. The application took about 8 hours. On Sept. 14, the site was ripped with tool bars and irrigated with approximately 0.5 acre foot of water. Mr. Propp reported excellent infiltration of the irrigation water. Over an inch of precipitation was received the following weekend.

Mr. Propp plans to seed the area to beets next year. This is not on MSCA's recommendation, but it is not a poor choice since beets are salt tolerant. MSCA will attempt to obtain pH and EC data prior to seeding to determine if crop production is feasible. Later in the spring, additional samples will be collected to fully describe the treatment's effect on the soil chemistry at the site. Results will be included in a final report on the project in June, 1989.

REFERENCES

Richards, L.A., 1969. Diagnosis and Improvement of Saline and Alkaline Soils. Agr. Handbook No. 60 USDA, Washington, D.C. 160 p.

Smith, S.C., 1988. Reclamation of Abandoned Bentonite Mine Spoils with Phosphogypsum and Magnesium Chloride Amendments. M.S. Thesis. MT. State University, Bozeman, MT, 106 p.

FIGURE 3. Area selected for treatment

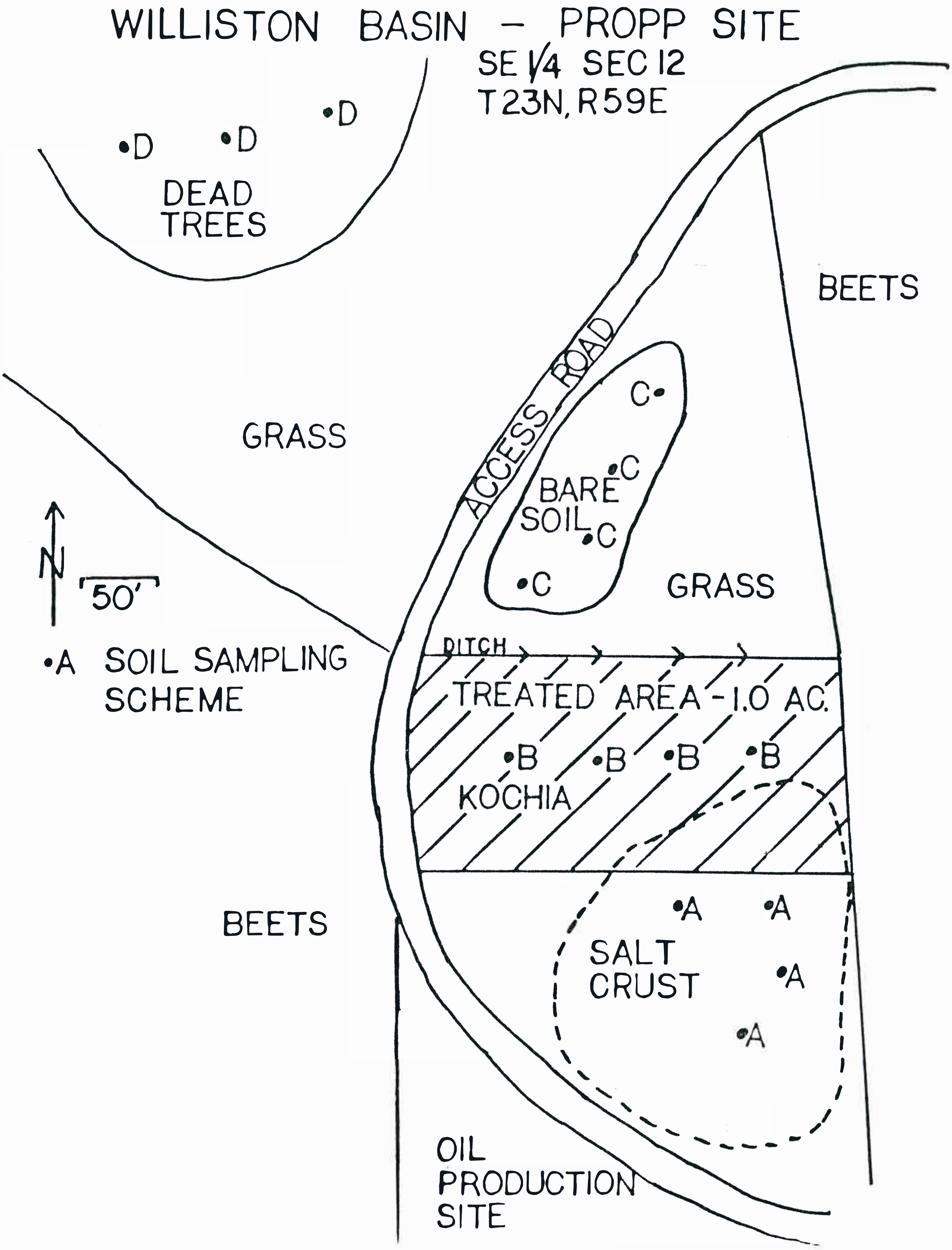


FIGURE 4. Design of system used to apply H_2SO_4