Raffinate Program

License SUB-1010 Amendment No. 8

1977 Completion Report-160-acre Test Plot

Introduction

The November 1977 report submitted to the NRC contained observations, operations, physical inventory, sampling methods and preliminary results of the 1977 raffinate fertilizer test program conducted at the Kerr-McGee Sequoyah Facility. The license amendment (source Material License SUB-1010-Amendment No.8) application submitted April 15, 1977 and November 1977 report should be available for reference during review of the following completion report.

Final test plot configuration and sampling locations for water, soil and vegetation are provided in Figure 1 (Test plot plan).

Results

I. Vegetation

Samples of terminal leaves of all plants were collected prior to raffinate treatments (June 2 and 3) and at the end of the season on September 29, 1977. These data are reported in Tables 1 and 2.

Nitrogen concentrations of leaves of all species were considerably higher in September than in June indicating a soil nitrogen deficiency for optimum plant growth prior to the raffinate treatment. Generally, leaf nitrogen is higher in June than September whenever adequate nitrogen is present. The leaf nitrogen concentrations are within ranges generally reported for the various species sampled.

Concentrations of phosphorus and potassium were generally lower than expected and in some cases below established critical concentrations, indicating soil deficiency of these elements. Little change occurred between the two sampling dates.

Concentrations of calcium were high at both sampling dates and were higher in September than June. Higher than normal calcium concentrations may have resulted from low potassium and magnesium levels. Magnesium levels were abnormally low in the plants but very low soil magnesium levels were also found. Calcium and magnesium levels were unaffected by treatments.

Zinc and copper concentrations fell within the normally reported ranges and were not affected by treatments. Iron and manganese concentrations were abnormally high at both sampling dates and high soil concentrations were also found. Boron, molybdenum and lead levels were near normal and unaffected by summer treatments.[1]

Grass tetany, a dietary disease of cows, caused by low magnesium concentrations would likely be a problem if cattle grazed these areas especially on cool season forages. However, comparison between element concentrations of plant leaf samples in June and September of a single year do not give conclusive data as to treatment effects. Some differences in nutrient concentrations, especially for the perennial trees and shrubs, exists due to seasonal variations. This initial examination of the elemental concentrations suggests that treatments affected only the nitrogen content of the plants.

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[1] Analysis of Zinc, Iron, Copper and Boron were conducted by OSU Laboratories using DPTA extraction to measure <u>available</u> quantities. Kerr-McGee Technical Center analyzed <u>total</u> trace elements using acid extraction.

Table 1 - Chemical Composition of Vegetation from Raffinate Disposal Area. Sequoyah Facility, 1977 - Vegetation Pre-treatment - Samples collected on June 2 and 3, 1977. [OSU Analysis][1]

Sample No.	Species	Location: Province	Location: Flora Site	% N	% P	% K	% Ca	% Mg	PPM: Zn	PPM: Fe	PPM: Cu	PPM: B
K-1	Bluestems	3	4	1.13	0.055	1.10	0.403	31.5	318.5	13.4	17.85	0.074
K-3	Post Oaks	3	-	1.78	0.029	0.81	0.609	49.0	119.0	18.2	29.59	0.049
K-6	Eastern Red Cedar	3	-	1.21	0.053	0.85	1.085	21.0	217.0	2.8	25.32	0.091
K-8	Serecia Lespedeza	3	5	2.11	0.085	0.95	0.707	21.0	259.0	8.4	27.46	0.063
K-10	Plantains	4	-	1.32	0.096	0.25	0.767	77.0	409.5	7.7	27.99	0.137
K-13	American Elm	3	-	1.64	0.068	1.08	0.798	14.0	175.0	4.9	33.20	0.084
K-15	Fescue	1	1	1.62	0.100	1.48	0.294	28.0	238.0	18.9	17.31	0.063
K-17	Bermudagrass	4a	-	2.18	0.111	1.44	1.953	84.0	525.0	14.7	65.90	0.315
K-18	Bromes & Fescue	3	-	1.16	0.066	1.17	0.371	28.0	483.0	20.3	23.19	0.035
K-20	Walnut	3	-	1.22	0.100	1.26	1.456	21.0	147.0	5.6	32.0	0.224
K-21	Briars	3	3	2.22	0.153	1.22	0.668	21.0	168.0	4.9	17.1	0.154
K-22	Ironweed	4	-	2.98	0.189	1.38	1.400	35.0	147.0	12.6	31.7	0.301
K-27	Bermudagrass	5	7	1.48	T	1.16	0.392	28.0	763.0	16.8	15.6	0.056
K-29	Persimmon	3	5	1.85	0.105	1.31	0.658	14.0	119.0	1.4	17.2	0.189
K-30	Honey Locust	3	-	3.27	0.100	1.17	0.602	14.0	112.0	11.2	14.4	0.056
K-31	Blackberry	3	3	1.62	0.074	1.14	0.693	17.5	178.50	4.9	27.6	0.298
K-32	Weed Composite	3	-	1.55	0.203	1.43	1.428	49.0	266.0	7.0	38.0	0.224
K-33	Fescue	1	-	1.62	0.129	1.43	0.357	14.0	133.0	7.0	14.9	0.091

[1] DTPA Extractable Iron, Zinc, Manganese and Copper.

Table 1 - (Concluded) [K-M Technical Center Total Analysis]

Sample No.	Species	Location: Province	Location: Flora Site	Ra-226 pCi/gm	Th-230 Th-232 pCi/gm	PPM: U	PPM: Mo	PPM: Ni	PPM: Pb
K-1	Bluestems	3	4	.038	(.3)	.5	.5	8.0	1.7
K-3	Post Oaks	3	-	.032	.003[1] .001 (.1)[2]	.2	.1	2.8	2.4
K-6	Eastern Red Cedar	3	-	.066	.004 .006 (.2)	.2	.1	4.7	1.3
K-8	Serecia Lespedeza	3	5	.034	(.4)	.3	.2	8.1	.8
K-1[illegible]	American Elm	3	-	.037	(.3)	.5	.2	6.2	.9
K-17	Bermudagrass	4a	-	.026	(.3)	.2	.5	3.8	.9
K-18	Cheat & Other Bromes	3	-	.058	(.3)	.3	.6	6.1	1.5
K-20	Walnut	3	-	.163	(.4)	.2	.2	4.2	.9
K-21	Briars	3	3	.105	(2)	.1	.2	4.7	1.1
K-22	Ironweed	4	-	.064	(.2)	.2	.2	2.6	2.[illegible]
K-29	Persimmon	3	5	.041	.006 .001	.8	.2	3.7	1.9
K-30	Honey Locust	3	-	.059	(.3)	.2	.3	3.4	1.0
K-31	Blackberry	3	3	.043	(.2)	.2	.4	1.0	1.0
K-32	Weed Composite	3	-	.014	(.3)	.1	.2	2.0	1.9

[1] Separate Th-230 and Th-232 analyzed by α-Pulse height analysis.

[2] () Combined Th-230 and Th-232 analyzed by Liquid Scintillation counting.

Table 2 - Chemical Composition of Vegetation from Raffinate Disposal Area. Sequoyah Facility, 1977 - Vegetation Post-treatment samples - Collected on September 29, 1977. [OSU Analyses] [1]

Sample No.	Species	Location		Concentration									
				Percent					Parts/Million				
		Province	Flora Site	N	P	K	Ca	Mg	B	Zn	Fe	Cu	Mn
P1	Bermudagrass	4	2	2.75	.132	2.10	0.679	0.147	5.82	32.20	196.00	7.70	229.6
P2	Bermudagrass	4a		2.46	.129	1.14	0.658	0.126	2.10	30.80	322.00	7.70	214.2
P3	Bermudagrass	5	7	2.75	.122	1.04	0.560	0.105	2.10	44.10	238.00	8.40	294.0
P4	Persimmon	3	5	1.60	.072	2.60	1.519	0.434	37.49	23.80	105.00	N.0	1659.7
P5	Winged Elm	3	3	1.62	.079	0.55	2.030	0.210	48.66	14.70	119.00	N.0	830.2
P6	American Elm	3	-	1.43	.081	0.73	1.764	0.217	44.94	18.90	140.00	N.0	441.0
P7	Blackberry Bramble	3	3	3.54	.150	1.81	0.630	0.140	17.00	23.10	94.50	4.20	425.6
P8	Post Oak	3	-	2.09	.123	1.22	0.567	0.147	15.14	21.00	59.5	7.00	35.0
P9	Walnut	3	-	4.22	.194	1.70	0.980	0.140	31.90	18.20	42.0	6.30	23.3
P10	Pecan	3	-	3.31	.120	1.14	2.268	0.147	63.56	53.90	119.0	34.9	332.5
P11	Black Locust	3	-	1.30	.081	0.55	1.050	0.147	43.07	17.50	136.5	2.80	1273.3
P12	Hickory	3	-	1.94	.135	1.28	1.981	0.847	72.87	65.80	91.0	8.40	1183.0
P13	Eastern Red Cedar	3	-	1.87	.095	0.53	1.638	0.210	24.45	14.70	147.0	3.50	451.5

[1] DTPA Extractable Iron, Zinc, Manganese and Copper.

Table 2 - (Concluded) [K-M Technical Center Total Analyses]

Sample No.	Species	Location: Province	Location: Flora Site	Ra-226 pCi/gm	Combined[2] Th-230 Th-232 pCi/gm	Parts/Million: U	Parts/Million: Mo	Parts/Million: Ni	Parts/Million: Pb
P1	Bermudagrass	4	2	.011	.3	.27	4.7	18	3.9
P2	Bermudagrass	4a	-	.009	.4	.51	2.2	21	4.5
P3	Bermudagrass	5	7	.029	.2	.28	3.1	35	4.3
P4	Persimmon	3	5	.002	.5	.21	.3	15	5.5
P5	Winged Elm	3	3	.001	.4	.24	.3	11	7.9
P6	American Elm	3	-	.001	.7	.33	.1	9.4	7.5
P7	Blackberry Bramble	3	3	.030	.6	.17	.7	14	2.7
P8	Post Oak	3	-	.010	.3	.13	.3	15	2.3
P9	Walnut	3	-	.133	3.0	.60	.1	12	1.8
P10	Pecan	3	-	.017	.4	.40	14.0	90	5.9
P11	Black Locust	3	-	.006	.4	.21	.4	15	7.6
P12	Hickory	3	-	.007	.3	.23	.2	20	3.9
P13	Eastern Red Cedar	3	-	.017	.3	.13	1.2	16	4.7

[2] Combined Th-230 and Th-232 analyzed by Liquid Scintillation counting.

II. Soil

Soil samples from major soil units in Provinces 1, 3, 4, 4a and 5 were collected to a depth of 42 inches prior to raffinate treatments and at the end of the growing season. Preinventory soil cores (0-60") were also collected and analyzed by soil type and horizon to provide information on selected constituents through the natural divisions of the soil profiles. Preinventory core sampling (0-60") locations are provided in Figure 2 and where two or more of the same sample number are indicated in Figure 2, samples were composited into one representative sample. One surface sample composite (0-6") was also obtained by collecting 50 samples at random throughout provinces. These data are reported in Table 3 and 4.

Soils in each province were acid at both sampling dates in spite of Ag-lime applications to all areas (See Table 2, November 30, 1977 Report). In many instances, the subsoils were extremely acid. Subsoils in province 5 were an exception and became calcareous at 36 inches. Surface soils (0-6") were generally more acid in September than in June. Not all the Ag-lime had reacted with the soil but indications are that the high nitrogen treatments are leaving some residual acidity.

Nitrate nitrogen levels were low at all soil depths on June 2 and 3 but in September, surface nitrates were very high in the upper 24 inches. Considerable quantities of unused applied nitrogen were present at the end of the growing season. In most cases, significant quantities of nitrogen had not leached below the 24 inch depth. Accumulated surface nitrates probably resulted from the very dry summer which hindered uptake by plants.

With few exceptions, soil phosphorus levels were well below quantities needed for optimum plant growth and subsoil levels were extremely deficient. The addition of phosphate fertilizers prior to raffinate treatments did result in some increased soil test phosphorus readings in the 0-6 inch samples during September 1977.

Soil potassium levels were lower in September than in June and in general were too low for optimum yields. Raffinate treatments during the season had no effect on available concentrations of the micronutrients including zinc and copper.

SOIL MAP LEGEND - (Figure 2)

Map Symbol	Mapping Unit	Color Code
HeF	Hector, Linker-Enders complex, 5-40% slopes	Lt. Green
LoD3	Linker & Stigler Soils, 2-8% slope, severely eroded	Helitrope
Ma	Mason Silt Loam	Dk. Blue
PcB	Pickwick Loam, 1-3% slopes	Brown
PcC	Pickwick Loam, 3-5% slopes	Orange
PcC2	Pickwick Loam, 2-5% slopes eroded	Yellow
Ru	Rosebloom and Ennis Soils, broken	Lt. Blue
SnC	Spiro Silt Loam, 2-5% slopes	Purple
VaB	Vian Silt Loam, 1-3% slopes	Red
VaC	Vian Silt Loam, 3-5% slopes	Carmine

Drainage

Dirt Road

Water Ponds

Soil Profile Sample Locations (1)

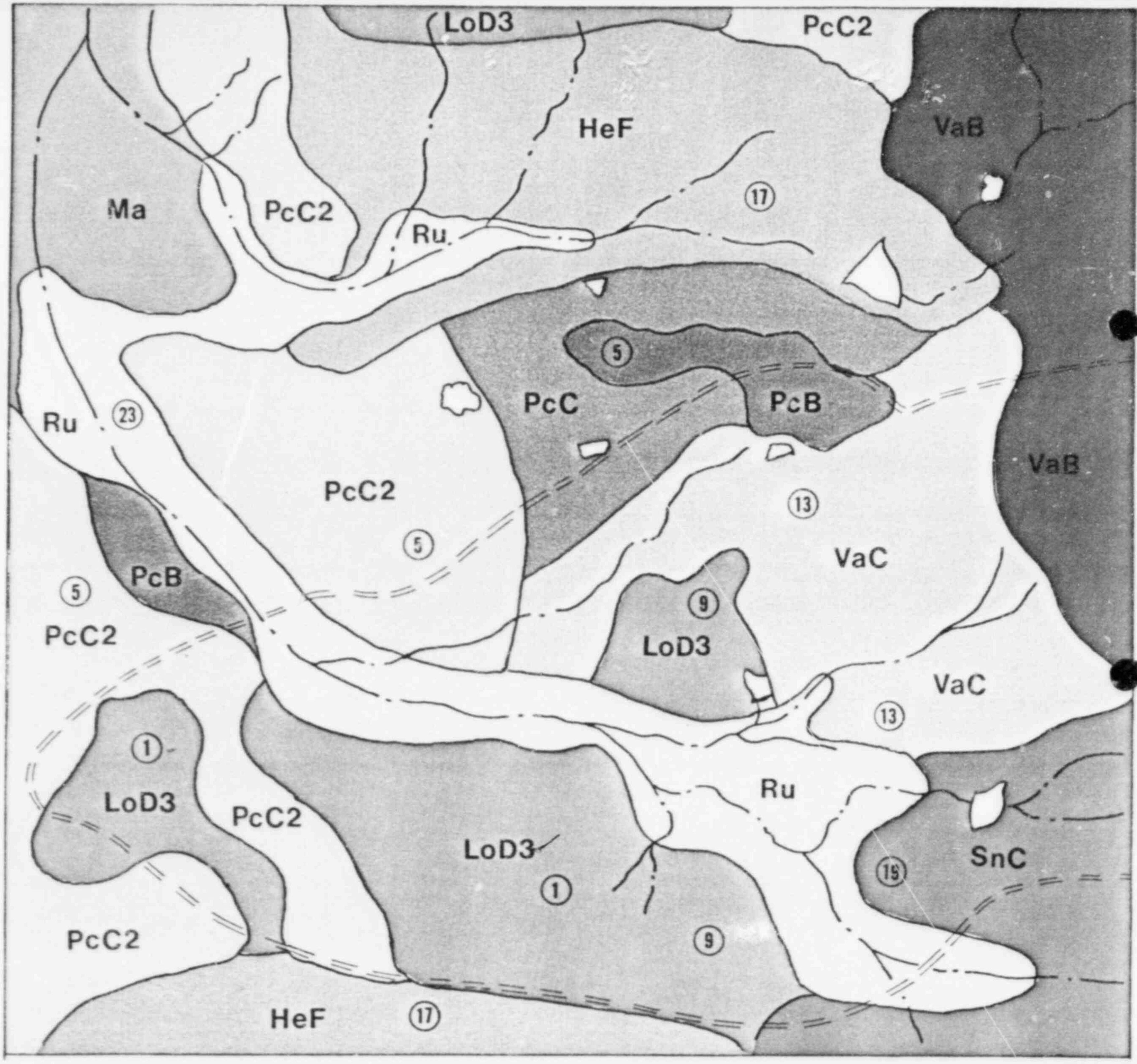

Figure 2. Final Soils Map with Core Sampling Locations.

Table 3 - Chemical Analyses of pre-season soil samples from raffinate disposal areas. Sequoyah Facility, 1977. Samples collected on June 2 & 3, 1977 (available nutrients). [OSU Analyses]

Sample No.	Mapping Unit	Soil Depth (inches)	Province	Soil Reaction pH	Soil Reaction B.I.	NO_3-N	Pounds per acre P	Pounds per acre K	Pounds per acre Ca	Mg	Fe	Parts per million Zn	Parts per million Mn	B	Cu	% O.M.
K-101	Comp.	0-6	1	6.1	7.0	28	16	492	2230	110	64.2	2.01	38.8	0.81	0.81	1.9
K-102	VaC	0-6	1	5.9	6.9	30	18	504	2180	90	53.1	1.69	29.4	1.46	0.82	1.7
K-103		6-12	1	4.7	6.9	8	5	150	1390	110	51.4	0.52	51.2	0.74	0.31	1.1
K-104		12-18	1	4.6	6.7	5	4	78	1640	380	26.8	0.16	32.1	0.41	0.13	0.9
K-105		18-24	1	4.7	6.7	3	63	119	2430	630	22.1	0.74	10.5	0.49	0.40	0.8
K-106		24-30	1	5.2	6.7	1	22	210	3690	920	11.9	0.98	8.7	0.47	0.21	0.6
K-107		30-36	1	5.8	7.0	0	4	156	3210	1205	8.7	0.22	13.1	0.27	0.18	0.5
K-108		36-42	1	6.2	7.1	0	3	181	3000	1291	9.4	0.32	7.9	0.21	0.19	0.3
K-109	Comp.	0-6	3	5.9	6.8	0	5	196	2480	230	¢8.2	1.94	57.21	0.50	0.54	2.5
K-110	LoD_3	0-6	3	5.9	6.8	5	8	203	1930	210	66.4	1.64	45.88	0.57	0.61	2.3
K-111		6-12	3	5.3	7.1	0	4	89	1550	220	21.4	0.53	32.44	0.37	0.47	1.3
K-112		12-18	3	5.2	7.0	3	3	73	1690	440	14.5	0.39	21.82	0.36	0.43	1.0
K-113		18-24	3	4.7	6.7	20	6	84	920	466	17.9	0.32	10.47	0.21	0.33	0.4
K-114		24-30	3	5.0	6.7	6	3	96	630	460	15.1	0.19	4.84	0.23	0.19	0.3
K-115		30-36	3	5.3	6.5	0	3	91	610	430	12.9	0.14	1.92	0.36	0.36	0.3
K-116		36-42	3	5.2	6.2	0	2	162	870	710	7.5	0.24	2.46	0.31	0.41	0.3
K-117	Comp.	0-6	4	5.6	..9	14	15	217	940	134	11.4	2.51	62.30	0.39	0.47	2.6
K-118	PcC	0-6	4	5.7	6.9	10	13	187	1115	163	52.7	1.10	49.13	0.22	0.42	2.3
K-119		6-12	4	5.3	7.0	7	16	110	810	197	19.4	0.22	39.42	0.21	0.29	1.1
K-120		12-18	4	4.4	6.7	13	5	144	840	241	27.4	0.14	7.66	0.24	0.21	0.9
K-121		18-24	4	4.5	6.8	6	7	172	1120	396	16.2	0.24	3.86	0.12	0.12	0.6
K-122		24-30	4	4.9	6.6	5	3	145	915	378	16.4	0.16	5.29	0.27	0.11	0.3
K-123		30-36	4	5.1	6.4	5	2	161	1890	1119	15.1	0.26	5.49	0.26	0.17	0.4
K-124		36-42	4	5.5	6.9	3	2	249	3840	1731	10.4	0.22	5.05	0.13	0.36	0.4
K-125	Comp.	0-6	4a	6.1	6.9	15	9	181	2810	100	72.7	1.48	53.59	0.54	0.46	2.9
K-126	SnC	0-6	4a	6.2	6.9	10	8	164	3150	90	98.3	1.52	99.56	0.56	0.27	2.8
K-127		6-12	4a	5.4	7.1	3	4	219	2450	130	34.2	0.13	18.92	0.14	0.21	1.9
K-128		12-18	4a	5.1	6.9	0	5	62	194h	180	41.0	0.11	10.52	0.15	0.17	0.7
K-129		18-24	4a	5.8	7.2	0.	5	181	930	130	42.3	0.13	11.52		0.15	0.7
K-130		24-30	4a	5.0	6.9	2	4	60	2640	920	19.1	0.21	3.61		0.15	0.7
K-131		30-36	4a	6.5	–	1	5	183	3850	790	11.4	0.22	9.33		0.18	0.8
K-132		36-42	4a	7.0	–	0	5	194	4670	1020	9.4	0.11	13.90		0.12	0.8
K-133	Comp.	0-6	5	5.3	6.9	40	12	80	1480	110	52.4	0.72	45.52		0.49	1.5
K-134	PcC_2	0-6	5	5.0	6.9	28	23	97	1120	90	59.6	0.89	60.31		0.52	1.3
K-135		6-12	5	4.7	6.8	5	24	73	2200	400	62.1	0.63	94.21		0.86	0.9
K-136		12-18	5	5.1	6.4	0	6	141	2900	590	90.4	0.30	21.62		3.04	0.6
K-137		18-24	5	5.3	6.7	2	3	139	2850	660	75.0	0.28	17.33		1.52	0.6
K-138		24-30	5	6.4	7.2	1	7	142	4260	940	32.0	0.11	18.80		1.12	0.5
K-139		30-36	5	7.4	–	1	6	193	4350	1050	11.2	0.14	6.35		0.87	0.3
K-140		36-42	5	8.2	–	6	10	201	6420	1830	9.8	0.46	2.38		0.56	0.2

Table 3 - (Continued) [K-M Technical Center Analysis Total Nutrients]

Soil Name/Location Depth in./Horizon	Ra-226 pCi/gm	Th-230* Th-232 pCi/gm	Parts Per Million U*	 Mo	 Ni
Linker/ 1					
0-4 / A1	.535			.2	8.3
4-12/ A2	.649			.2	6.7
12-20/ B2t	.501			.4	5.1
20-28/ B2&R	.574			.4	12
Pickwick/ 5					
0-14/ Ap	.572			.2	10
14-22/ A2	.408			.3	11
22-34/ B2t	.599			.4	14
34-60/ B3t	.481			<.1	12
Stigler/ 9					
0-9 / Ap	.465			<.1	11
9-16/ A2	.542			<.1	11
16-40/ B21t	.728			.4	20
40-60/ B22t	.687			.5	21
Vian/ 13					
0-9 / A1	.392			.2	10
9-14/ A2	.667			.2	12
14-29/ B21t	.764			<.1	9.4
29-60/ B22t	.638			<.1	9.0
Hector/ 17					
0-5 / A1	.507			.4	11
5-15/ A2&R	.505			.4	20
Spiro/ 19					
0-12/ Ap	.455			.2	10
12-18/ A2	.455			<.1	14
18-32/ B21t	.631			.2	12
32-60/ B22t	.577			.3	10
Ennis/ 23					
0-10/ Ap	.559			<.1	9.4
10-18/ A2	.439			<.1	8.1
18-36/ B21t	.581			<.1	12
36-60/ B22t	.528			<.1	10

*Composite soil samples only.

Table 3 - (Concluded) [K-M Technical Center Analysis Total Nutrients]

	Ra-226 pCi/gm	Th-230* Th-232 pCi/gm	Parts Per Million U*	 Mo	 Ni
Composite Samples by Province: (0-6")					
#1	.503	.259 .429	1.4	.4	9.1
#2	.405	.297 .575	.76	.4	10
#3	.307	.266 .457	1.04	< .1	10
#4	.472	.301 .431	1.04	< .1	9.3
#4a	.467	.461 .467	.98	< .1	12
#5	.277	.336 .277	.62	< .1	6.1

*Composite soil samples only. Separate Th-230 and Th-232 analyzed by α pulse height analysis.

Table 4 - Chemical Analyses of post season soil samples from raffinate disposal areas. Sequoyah Facility, 1977. Samples collected on September 28, 1977 (available nutrients). [OSU Analyses]

Sample No.	Mapping Unit	Soil Depth (inches)	Province	Soil Reaction pH	Soil Reaction B.I.	NO_3-N	P	K	Ca	Mg	Fe	Zn	Mn	B	Cu	% O.M.
						Element Concentrations: Pounds per acre						Parts per million				
S-79	Comp.	0-6	1	5.2	7.1	360	80	191	2430	140	118.4	2.02	33.28	0.67	0.85	2.2
S-80	VaC	0-6	1	5.1	6.9	294	10	151	1480	80	86.4	0.72	28.64	1.50	0.84	1.5
S-81		6-12	1	4.8	6.9	406	6	116	1450	150	52.8	0.52	46.88	0.55	0.28	1.2
S-82		12-18	1	4.7	6.8	252	4	64	1340	230	20.8	0.16	12.68	0.41	0.12	0.8
S-83		18-24	1	4.8	6.7	421	85	109	2160	510	16.8	0.98	7.78	0.42	0.30	0.6
S-84		24-30	1	5.1	6.7	244	38	162	3000	1000	12.8	0.74	5.46	0.57	0.22	0.7
S-85		30-36	1	5.9	7.0	29	2	174	2890	1210	10.4	0.16	9.32	0.23	0.14	0.4
S-86		36-42	1	6.4	7.1	28	2	181	2930	1230	10.2	0.18	7.96	0.18	0.20	0.4
S-87	Comp.	0-6	3	5.4	6.9	153	7	168	1180	170	59.2	1.70	53.12	0.50	0.44	2.3
S-88	LoD_3	0-6	3	5.6	6.8	19	5	137	880	140	62.4	1.60	54.88	0.57	0.72	2.3
S-89		6-12	3	5.4	7.1	43	4	78	1050	240	22.4	0.30	34.24	0.39	0.40	1.0
S-90		12-18	3	5.2	7.0	101	3	89	1350	430	14.6	0.28	19.28	0.38	0.34	0.7
S-91		18-24	3	4.9	6.8	45	4	91	1000	450	16.8	0.20	9.74	0.19	0.32	0.3
S-92		24-30	3	5.1	6.7	3	3	88	760	450	14.2	0.18	4.48	0.21	0.22	0.3
S-93		30-36	3	5.2	6.5	1	3	87	610	420	12.8	0.16	1.72	0.35	0.30	0.3
S-94		36-42	3	5.2	6.2	4	2	134	950	680	10.6	0.24	2.64	0.35	0.40	0.4
S-95	Comp.	0-6	4	4.9	6.6	208	15	327	1330	120	21.6	1.44	57.92	0.24	0.46	2.4
S-96	PcC	0-6	4	5.1	6.8	175	25	217	880	70	72.0	0.90	34.24	0.22	0.42	2.0
S-97		6-12	4	4.5	6.7	275	6	183	810	180	28.8	0.22	24.96	0.20	0.18	0.8
S-98		12-18	4	4.5	6.7	200	5	154	870	330	17.4	0.14	7.66	0.22	0.12	0.8
S-99		18-24	4	4.9	6.7	61	3	161	1020	440	12.6	0.16	3.68	0.10	0.12	0.5
S-100		24-30	4	5.3	6.5	15	3	142	990	490	14.6	0.16	5.92	0.25	0.12	0.3
S-101		30-36	4	5.5	6.4	14	2	175	1760	960	13.6	0.22	5.94	0.26	0.10	0.5
S-102		36-42	4	6.1	6.7	6	2	259	3230	1800	14.0	0.22	5.50	0.14	0.34	0.4
S-103	Comp.	0-6	4a	5.1	6.9	340	35	188	2090	110	88.0	1.28	51.68	0.54	0.40	3.0
S-104	SnC	0-6	4a	5.3	6.8	177	25	314	2250	90	158.4	1.38	94.56	0.53	0.46	3.0
S-105		6-12	4a	5.5	7.1	355	5	218	2350	130	46.4	0.34	17.88	0.14	0.22	1.9
S-106		12-18	4a	5.2	6.8	392	4	49	1830	160	40.0	0.14	5.66	0.15	0.08	1.4
S-107		18-24	4a	4.5	6.8	187	5	36	1030	170	24.0	0.12	4.56	0.12	0.06	0.6
S-108		24-30	4a	5.6	6.9	82	9	58	890	140	18.2	0.14	2.40	0.06	0.15	0.8
S-109		30-36	4a	6.4	6.9	33	2	172	2640	620	12.2	0.18	7.22	0.07	0.12	0.8
S-110		36-42	4a	6.7	-	13	2	200	3440	790	8.4	0.22	11.84	0.08	0.18	0.8
S-111	Comp.	0-6	5	5.1	7.0	346	22	157	1290	100	70.4	0.88	43.52	0.21	0.38	1.3
S-112	PcC_2	0-6	5	4.8	6.9	293	30	172	910	110	65.6	1.24	60.56	0.36	0.50	1.2
S-113		6-12	5	4.6	6.8	399	5	78	2260	370	60.8	0.70	96.32	0.63	0.96	0.8
S-114		12-18	5	5.1	6.5	131	2	132	2810	580	8810	0.30	14.00	0.21	2.02	0.7
S-115		18-24	5	5.3	6.7	15	5	131	2740	660	72.0	0.20	10.54	0.44	1.04	0.7
S-116		24-30	5	6.3	7.2	6	6	161	3780	890	24.0	0.16	11.80	0.46	1.00	0.5
S-117		30-36	5	7.3	-	16	7	183	3980	1010	12.0	0.16	5.36	0.30	0.62	0.1
S-118		36-42	5	8.2	-	6	12	189	4430	1030	9.8	0.32	3.68	2.94	0.62	0.3

Table 4 - (Continued) [K-d Technical Center Analyses-total nutrients]

Sampling No.	Mapping Unit	Soil Depth (inches)	Province	Ra-226 pCi/gm	Th-230/ Th-232 pCi/gm (1)	Parts Per Million U	Mo	Ni (2)
S-79	Comp.	0-6	1	0.467	.28/.55	1.9	1.0	38
S-80	VaC	0-6	1	0.508			1.5	26
S-81		6-12	1	0.559			0.9	32
S-82		12-18	1	0.752			1.2	49
S-83		18-24	1	0.513			0.9	51
S-84		24-30	1	0.601			1.5	87
S-85		30-36	1	0.549			1.1	85
S-86		36-42	1	0.692			0.9	82
S-87	Comp.	0-6	3	0.393	.27/.59	1.8	1.0	39
S-88	LoD_3	0-6	3	0.564			1.0	32
S-89		6-12	3	0.572			1.0	35
S-90		12-18	3	0.570			0.9	22
S-91		18-24	3	0.595			0.6	47
S-92		24-30	3	0.565			0.7	19
S-93		30-36	3	0.536			0.6	40
S-94		36-42	3	0.504			0.5	52
S-95	Comp.	0-6	4	0.576	.23/.45	1.9	0.7	33
S-96	PcC	0-6	4	0.562			0.6	24
S-97		6-12	4	0.564			0.5	25
S-98		12-18	4	0.741			0.4	26
S-99		18-24	4	0.455			1.2	32
S-100		24-30	4	0.605			1.2	25
S-101		30-36	4	0.642			0.6	32
S-102		36-42	4	0.581			0.5	52
S-103	Comp.	0-6	4a	0.531	.23/.44	1.7	0.4	20
S-104	SnC	0-6	4a	0.518			0.5	12
S-105		6-12	4a	0.478			0.4	9.0
S-106		12-18	4a	0.516			0.6	9.5
S-107		18-24	4a	0.517			0.3	18
S-108		24-30	4a	0.464			0.4	17
S-109		30-36	4a	0.792			1.3	42
S-110		36-42	4a	0.939			1.6	80
S-111	Comp.	0-6	5	0.362	.25/.53	1.3	0.6	17
S-112	PcC_2	0-6	5	0.404			0.6	16
S-113		6-12	5	0.460			0.7	16
S-114		12-18	5	0.480			0.6	35
S-115		18-24	5	0.625			0.7	29
S-116		24-30	5	0.525			0.5	41
S-117		30-36	5	0.604			0.5	47
S-118		36-42	5	0.529			0.5	35

(1) Separate Th-230 and Th-232 analyzed by α pulse height analysis.

(2) Nickel samples were contaminated by milling soils in stainless steel prior to analyses. (See Section VI Special Considerations).

III. Yields and Quality of Forage

Bermudagrass out-competed all other vegetation in open areas of 4a, 4, and 5 upon treatment with raffinate during the season. A dense cover with good growth was noted by mid-season and improved until frost. Samples collected on August 5 showed extremely high nitrogen and protein contents (Table 5). This indicates an extremely high quality hay was produced. Yield measurements were determined on September 29, 1977 for total season production (Table 6). Excluding the abnormally high yield measured on 4a which appears too high, dry matter yields up to seven tons per acre were produced. Seven tons per acre of dry matter is extremely good production. Such excellent growth precludes plant toxic levels of any ions present in the soil. The chemical analyses verifies this same conclusion. Also, no concentrations of the elements measured were high enough to be toxic to livestock.

It is also noted that Province 5 (1500 #N/Ac.) yielded no better than Provinces 4 and 4a (1000 #N/Ac.). Abnormal growth appearances were observed on Province 5 during the latter part of the growing season. It is concluded that nitrogen applications in Province 5 were above those needed for optimum production.

It was also noted that more nitrogen was often accounted for than applied (Table 7). This can be explained by: Bermudagrass yield measurements were taken from center plot areas where growth was uniform and stands were thick whereas all provinces contained some areas of trees, brush, and less densely covered spots. The soil samples were collected from representative sites in each province. No doubt, there was a "priming" effect of available nitrogen caused by accelerated decomposition of plant residues and other soil organic compounds. The "priming" effect can be substantial on newly fertilized areas.

Early applications of raffinate may have been erratically applied and placement very non-uniform which no doubt attributed to some very large experimental errors.

Nitrogen penetrated to the 18-24 inch depth but tapered off rapidly below that depth.

Table 5 - Bermudagrass grown on raffinated treated plots. Sequoyah Facility, 1977. Samples taken August 5, 1977.

Province	% N	Crude Protein %	Digestible Protein
4a	3.98	23.6	
4	4.02	25.1	19.8
5	4.99	31.2	25.5

Table 6 - Total yield of bermudagrass grown on raffinate treated provinces. Sequoyah Facility - 1977. Sampled September 29, 1977.

Province	Yield/A (Tons)	Yield of Nitrogen lbs/A
4a	11.75	935.30
4	7.63	613.45
5	6.14	612.77

Table 7 - Nitrogen balance estimated for open area provinces. Sequoyah Facility, 1977.

Province	Estimated N in Forage lbs/A	Nitrogen in Soil lbs/A	Total N Accounted For lbs/A	Total N Applied lbs/Ac.
5	613	423	1036	1561
4	613	683	1296	1028
4a	935	1208	2143*	1181

*no doubt there is experimental error - perhaps due to application misques.

IV. Water

Groundwater

Results of groundwater well sampling conducted from June 24, 1977 through February 14, 1978 are presented in Table 8. Sampling and analyses were conducted during each month to provide indication of any possible buildup of contaminants in groundwater. After December 2, 1977, samples were analyzed only for selected parameters (NO_3-N; NH_4-N and pH).

Soil Moisture Cup (Soil Water); Tensiometer Reading

Due to extremely dry conditions during the early part of the 1977 growing season, limited quantities of soil water were obtained from sorption cups. To obtain enough sample for analyses, sorption cups were pumped from 7/5/77 to 8/26/77 at locations indicated (Figure 1). Results are presented in Table 9.

Tensiometer readings showed that soil moisture was low during most of the growing season (Table 10). Subsoil moisture was higher earlier in the season than the surface moisture. By October 5, surface moisture was adequate with rather dry subsoil. This indicates a general trend of downward moisture flow and plant extraction which is characteristic of normal soil conditions. No upward flow of moisture was evident.

Surface Water

The results of surface runoff water sampling conducted at the dam site and two locations along the watercourse are provided in Table 11. The date when timber clearing was completed in Area 1 and 2 is also provided. Elevated NO_3-N and NH_4-N values in surface runoff waters at the dam site after this

date appeared related to timber clearing and application of treated raffinate for seedbed preparation and to windrows. Raffinate treatments to windrows were terminated 8/23/77, but corresponding reduction in NO_3-N levels in surface runoff did not occur until the November 1, 1977 sampling period.

The #3 sampling station is located adjacent to the road which crosses the small watercourse traversing the test area. Results from the 6/13 and 6/24 sampling periods indicated elevated NO_3-N and NH_4-N in water samples. As little flow was present in the watercourse during this period, these results are not indicative of surface runoff water condition during this period but reflect near stagnant pool condition.

Ponds

Analytical results from three pond sampling locations are presented in Table 12. Pond #3 was used as a control as no raffinate treatment or surface runoff from the treated area occurred at this location. These ponds were previously used for stock watering and although water levels were reduced due to dry conditions, ponds continued to hold water throughout the 1977 growing season.

V. Summary

Results of soil, vegetation, and water analyses indicate the general areas of deposition of raffinate components applied to the treatment area. However, comparison of element concentrations in a single growing season does not provide conclusive data as to treatment effects. Biological functioning of an ecosystem consists of inputs from various sources, outputs to various sinks, and a variable degree of internal recycling. As illustrated on Table 7

(Nitrogen balance), large amounts of nitrogen applied in raffinates were incorporated into developing plant biomass and the soil matrix. In soil, nitrogen was present to the 18-24 inch depth but levels were reduced below that depth. Results of groundwater well sampling also suggest that deep seepage of materials had not occurred. Evaluation of results of surface runoff waters, sorption cup, and pond sampling was complicated by impact of timber clearing activities, insufficient soil moisture, and limited samples available for analysis. However, elevated nitrate levels witnessed in surface runoff waters at the dam site after timber clearing in adjacent areas were not witnessed in ponds located in undisturbed pastured areas. In these undisturbed areas, vegetation cover undoubtedly precluded excess surface runoff and element losses to ponds.

The high production rate of bermudagrass on the treatment area provides a mechanism for elemental uptake and establishment of storage capacity in developing biomass. Elements essential to plant growth will be stored in organic matter and as long as biomass continues to develop, uptake and storage of materials will continue. However, the capacity of this system to store elements is finite. As storage capacity (forage development) approaches a steady state condition, it would be expected that differences between input and output of elements from the system would more nearly approach zero. This condition could eventually result in element concentrations applied with raffinate being available to various "sinks" (i.e. hydrologic environment, soil matrix).

The 1977 program confirmed many of the expected results of raffinate treatment to the 160-acre test plot (See License Amendment Application, Part VI submitted April 15, 1977). Growth rates of seven tons per acre of bermudagrass were

attained. Accumulation of forage biomass and transition of plant community structure in open areas was achieved more rapidly than expected with thick, almost monotypic stands of bermudagrass resulting from treatments to these areas. Response of native trees of Oklahoma to raffinate treatments was less pronounced due largely to inaccessibility of sprayer application equipment in timbered areas and slower growth rates of trees.

VI. Special Considerations

In our application of April 15 as modified by a revision dated April 28, control parameters were suggested for radionuclide levels in soils. The results of the 6-inch composites before and after application are presented on Table 13. It is noted that except for the Radium 226 concentrations in Province 4, the uranium concentration in all provinces subsequent to application increased more than our control limit. This increase is difficult to understand in view of the quantity of uranium contained in the treated raffinate. Uranium quantities added (November Report, Table II) calculates to an increase of approximately .017 ppm in the top 6 inches of soil, significantly less than the analysis shows. Extensive discussions were held with the Technical Division on this data, and the only explanation is the uncertainty of the fluorometric method employed for these measurements. This pairing of samples will be redone simultaneously to eliminate any difference of precision due to the time separation between samples*. In 1978, additional pre and post treatment soil samples will be taken in order to better understand this discrepancy.

Levels of Nickel reported from pre and post inventory suggested possibility of contamination of samples during preparation or handling. Because much

*This re-analysis of soil samples (0-6") was completed April 14, 1978 and is reported in Table 13.

higher values were reported throughout the soil profile during post-inventory, a check of sample preparation methods revealed both soil and vegetation samples were ground in a stainless steel mill prior to being submitted for analysis. The Technical Division rechecked selected soil samples for chrome from the pre and post application sampling periods. This resample indicated abnormally high values for chrome which verified that samples had been contaminated by stainless steel during preparation. During 1978, additional pre and post treatment soil and vegetation samples will be collected and prepared for nickel analysis to ensure no contamination of sample will result.

Table 8. Analytical Results of Groundwater Well Samples. (June 1977-February 1978)

FTP Well # and Date	Total Ra-226 pCi/l	Th-230 Th-232 pCi/l	U µgms/l	Cu mgs/l	Mo mgs/l	Ni mgs/l	NO_3-N mgs/l	NH_4-N mgs/l	pH
-1-									
6/24	.321	.024 .005	24	.005	<.001	.004	.1	<.2	7.1
7/6					L O S T				
8/10	.044	.029 .007	2	.010	.008	.006	15.0	<.2	6.9
8/26	.73	.012 .008	2	.004	.003	<.001	2.1	<.2	7.7
9/13	.06	.023 .053	6	.026	.004	.010	.2	.5	7.3
10/5	.16	.018 .009	2	.051	.016	.007	.2	<.2	6.5
11/3	.08	.011 .011	2	.010	<.001	<.001	.4	<.2	7.0
12/2	.280	.025 .004	7	.002	<.001	<.001	.3	<.2	7.4
1/4/78	.234	.026 .006	3	.002	.002	.007	.2	<.2	7.3
2/14							2.0	.4	7.3
-2-									
6/24	1.077	.050 .005	19	.081	.005	.035	1.0	<.2	7.2
7/6	.367	.048 .011	25	.009	<.001	.012		L O S T	
8/10	.182	.007 .003	8	.002	.004	.006	1.7	<.2	7.6
8/26	.42	.003 .003	10	.003	<.001	<.001	.4	<.2	7.9
9/13	.12	.023 .009	17	.006	.002	.009	.6	<.2	7.8
10/5	.88	.021 .005	13	.003	.003	.005	.7	<.2	6.8

Table 8. (Continued)

FTP Well # and Date	Total Ra-226 pCi/l	Th-230 Th-232 pCi/l	U µgms/l	Cu mgs/l	Mo mgs/l	Ni mgs/l	NO_3-N mgs/l	NH_4-N mgs/l	pH
-2-									
11/3	.06	.024 .008	8	.002	<.001	<.001	.5	<.2	7.1
12/2	.36	.010 <.003	7	<.001	.005	<.001	.5	<.2	7.1
1/4/78	.47	.036 .007	14	.001	.002	.005	.4	<.2	7.4
2/14							.4	.5	7.4
-3-									
6/24	1.252	.070 .020	21	.010	.001	.016	10.2	<.2	7.1
7/6	.514	.009 .034	18	.018	<.001	.039	LOST		
8/10	.090	.042 .042	3	.008	<.001	.091	.2	<.2	7.5
8/26	.10	.182 .010	4	.006	<.001	<.001	1.0	<.2	8.0
9/13	.19	.227 .015	15	.003	<.001	.007	1.9	<.2	7.7
10/5	.19	.028 .019	2	.002	.002	.002	.7	<.2	6.4
11/3	.32	.009 .009	4	.003	<.001	<.001	2.0	<.2	6.7
12/2	.20	.028 .004	6	.001	<.001	<.001	2.2	<.2	7.2
1/4/78	.14	.039 .004	7	.001	.002	.005	7.8*	<.2	7.2
2/14							7.8	<.2	7.0

*Sample recheck 2/27/78 yielded 6.5 mg/l NO_3-N.

Table 8. (Continued)

FTP Well # and Date	Total Ra-226 pCi/l	Th-230 Th-232 pCi/l	U µgms/l	Cu mgs/l	Mo mgs/l	Ni mgs/l	NO_3-N mgs/l	NH_4-N mgs/l	pH
-4-									
6/24	2.611	.018 .005	69	.047	<.001	.005	.2	<.2	7.0
7/6					L O S T				
8/10	.067	.019 .008	10	.010	<.001	.027	<.2	<.2	7.5
8/26	.53	.023 .023	10	.007	<.001	.097	<.2	<.2	8.0
9/13	.12	.027 .004	18	.002	<.001	<.001	<.2	<.2	7.3
10/5	.12	.043 .054	10	.029	.011	.009	<.2	<.2	6.7
11/3	.33	.009 .013	11	.002	.002	.002	<.2	<.2	7.0
12/2	.09	.011 .006	14	.003	.007	.001	.1	<.2	7.1
1/1/78							.1	<.2	7.1
2/14							.2	<.2	7.3

Table 8. (Conclusion)

FTP Well # and Date	Total Ra-226 pCi/l	Th-230 Th-232 pCi/l	U µgms/l	Cu mgs/l	Mo mgs/l	Ni mgs/l	NO_3-N mgs/l	NH_4-N mgs/l	pH
-5-									
6/24	4.503	.052 .006	5	.011	.011	.20	.1	<.2	7.8
7/6	LOST								
8/10	.398	.004 .004	3	.010	.010	.024	.3	<.2	7.8
8/26	.21	.013 .025	4	.005	<.001	.10	<.2	<.2	8.0
9/13	.14	.018 .004	6	<.001	<.001	<.001	<.2	<.2	7.8
10/5	.16	.019 .012	5	.004	.004	<.001	<.2	<.2	6.9
11/3	.22	.043 .017	3	<.001	<.001	.032	<.2	<.2	7.1
12/2	.10	.010 <.005	4	<.001	.005	<.001	.1	<.2	7.4
1/4	.13	.017 .010	4	<.001	.006	.004	.1	<.2	7.3
2/14							.1	<.2	7.3

Table 9. Analytical Results of Soil Moisture Cup Samples Collected from 7/5/77 to 8/26/77.

Sample Location Depth	Ra-226 (pCi/l)	Th-230 (pCi/l)	U (ugm/l)	Cu (mg/l)	Mo (mg/l)	Ni (mg/l)	Total N (mg/l)	pH
19/M[1]			13				<.4	7.6
41/D	.058		23	.008	.003	<.001	64.	7.7
51/S	1.129		65	.026	.017	.008	300.	6.9
51/M			91				27.	7.4
51/D	.234		54	.017	.009	.002	7.	7.5

[1] 19-number indicates grid location given on Figure 1.

S = 8" depth

M = 30" depth

D = ≤72" depth

Table 10 - Tensiometer Readings, Raffinate Disposal Study, 1977.

Tensiometer No.	Depth	DATES									
		7/19	7/26	8/2	8/23	8/30	9/6	9/13	9/20	9/28	10/5
19	8"	0	11	18	0	10	9	8	10	14	9
	30"	35	51	15	15	15	26	32	18	25	27
28	8	0	0	6	0	11	11	8	10	8	9
	30	61	0	66	0	48	62	60	63	E	23
46	8	0	0	24	0	22	29	E	24	35	16
	30	36	2	23	0	46	33	6	43	43	33
41	8	0	0	13	0	15	25	14	18	33	33
	30	24	0	18	0	19	28	24	7	E	0
51	8	0	10	18	21	11	13	10	13	13	17
	30	23	15	14	13	18	14	5	8	5	18
62	30	39	21	38	0	42	46	40	34	15	10

E = Empty

Table 11. Analytical Results of Rainwater Runoff at Two Watercourse Sampling Locations and the Dam Site (See Figure 1).

Location/Date Sampled	Ra-226 (pCi/l)	Th-230 (pCi/l)	U (ugms/l)	Cu (mg/l)	Mo (mg/l)	Ni (mg/l)	NO3-N (mg/l)	NH4-N (mg/l)	pH
Dam Site (#1)									
6/27	.364		3		.02		1.5	<.2	
6/29*							<.2	<.2	
6/30*							1.0	<.2	
7/22	-------------Timber Clearing Completed-----------------------------								
7/27	.466	.028	<2		.005		1.8/8.4[1]	-/1.5	6.6
8/23	1.001	.022	15				29/23.5	15/8.0	
8/23*-9/1*	(Measured Daily Liquid Recycled to Area 5)						20-31**	5-19**	6.4-8.6**
11/1		<.006	<2				6.8	<.2	6.4
11/14							1.9	.2	
12/2							2.0	<.2	
Location #2									
6/3	.184	.017	6		<.001		.2/.63	<.2/0.00	
6/23	.376	.021				.3	.3	-	
10/11	.376	.021	<2	.002	.002	<.001	.3	.3	7.0
Location #3									
6/13	.338	.014	3		.08	-	25/29.3	9/4.6	
6/24							16	-	

(1) 1.8/8.4 Represents KM Tech Center Results/ OSU Laboratory Results

*Resample for selected parameters only (NO_3-N; NH_4-N; pH)

**Represents range from 8/23-9/1.

Table 12. Analytical Results from Three Pond Sampling Locations (See Figure 1).

Pond # and Date	Ra-226 (pCi/l)	Th-230 (pCi/l)	U (μgms/l)	Cu (mg/l)	Mo (mg/l)	Ni (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	pH
-1-									
6/3	1.417	.75	< 2	---Insufficient Sample---			.6/1.10[1]	<.2/.33	
10/11	1.002	.047	< 2	<.001	<.001		.5	.2	7.2
-2-									
7/27	.043	.014	< 2		.001		5.5/.96	<.2/.16	6.5
8/30							<1.0	.5	
10/11	.249	.032	< 2	.004	.002	.001	.2	<.2	8.0
-3-									
8/30							<1.0	<.2	
10/11	.052	.026	5	.067	.036	.005	< .2	<.2	7.1

[1] .6/1.10 Represents results from KM Technical Center/OSU Laboratory

Table 13. Soil Samples (0-6") Composites by Province - Pre and Post Application

Province	Ra-226 pCi/gm		Th-230[1] Th-232 pCi/gm		U ppm		U ppm Resampled[2]	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	.503	.467	.259 .429	.28 .55	1.4	1.9	2.3	2.2
3	.307	.393	.256 .457	.27 .59	1.04	1.8	1.8	1.8
4	.472	.576	.301 .431	.23 .45	1.04	1.9	1.6	2.0
4a	.467	.531	.461 .467	.23 .44	.98	1.7	1.7	1.7
5	.277	.362	.336 .227	.25 .53	.62	1.3	1.3	1.4

[1]Separate Th-230 and Th-232 analyzed by α pulse height analysis.

[2]Resampling of soil composites conducted simultaneously April 14, 1978 to eliminate any differences of precision due to time separation between sampling dates.

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