CLEANUP OF LEAD CONTAMINATED SOIL FROM BATTERY REPROCESSING SITES

by

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ABSTRACT

The hazards of lead in the environment have been a matter of increasing concern over the past several years. The most common sources of lead contaminated soils are those related to abandoned lead battery reclamation sites. There are over 200 such sites in the United States and several real and potential sites in Minnesota. Under present regulations such contaminated soil must be removed and placed in an approved and licensed landfill. The purpose of this study was to demonstrate that by applying conventional mineral dressing techniques it is possible to detoxify a significant percentage of the soil and thereby reduce the cost of landfill disposition.

Prior test work at the Natural Resources Research Institute's Coleraine Minerals Research Laboratory (CRL) on a sample from a battery reprocessing site in Wisconsin demonstrated that partial detoxification of the soil was practical. The object of this study was to apply similar techniques to material from a Minnesota site. The Shafer Metal site on north Plymouth avenue in Minneapolis was selected for this study after consultation with personnel from the Minnesota Pollution Control Agency and the Minnesota Department of Transportation who own the property.

The lead contamination at the Shafer Metal battery reprocessing site occurs in three principal modes: lead metal fragments, surficial coatings of precipitated lead sulphate and lead dioxide, and lead incorporated into fused plastic material. The lead metal consists primarily of fragments of battery plates and connectors. The precipitated lead compounds occur as coatings on the rock and sand particles in the soil. The fused plastic material could have resulted from melting and casting of the lead, or operation of an incinerator.

After preliminary sampling to confirm the distribution of lead contaminated soil at the site, three bulk samples of about 800 pounds each were collected for testing. These three samples were subjected to a series conventional mineral processing techniques involving attrition scrubbing, screening, and gravity separation. The tests demonstrated that over 60% of the material can be separated as a clean rock and sand product that can be disposed of on site. About 5% to 10% of the material can be recovered as a lead-rich product that would be acceptable feedstock to a lead smelter. About 25% of the weight would contain so much lead that it would have to be treated as hazardous material. Some 5% to 10% of the material would be rejected as a coarse trash product eligible for disposal in conventional landfills.

The EPA Synthetic Precipitation Leach Test for Soils (Method 1312) was run on the rock and clean sand portion which represents over 60% of the material. The tests demonstrated that this material had been effectively detoxified and could be disposed of on site.

Based on these test data a treatment flow sheet to detoxify the material represented by the bulk samples taken at the Shafer Metal site was developed. The flow sheet includes the following process steps: I) Coarse screening to remove tramp trash; 2) attrition scrubbing to remove the lead compounds from the coarser rock and sand particles; and 3) gravity concentration to separate a high lead product, a clean rock and sand reject, and a lead-bearing fused plastic product. A minus 165 mesh fines fraction is also produced containing the natural fines from the soil and the lead released by the attrition scrubbing.

The recommended treatment flow sheet is based on using conventional mineral processing equipment. The equipment could be sized small enough to be truck mounted, or set up as semi-portable units for on-site treatment. Engineering such a portable treatment

plant was included in the extended project, but is beyond the scope of this abbreviated study. Whether treatment of the Shafer Metal site is practical depends upon the cost of building and operating such a treatment plant on site as opposed to direct disposal.

It is recommended that this study be extended to include the design and engineering of a portable or semi-mobile treatment plant and that further continuous pilot plant operations be supported to confirm some of the coarse gravity separation steps. There are other similar sites in Minnesota that are contaminated by lead that would be amenable to similar treatment. Costing out the plant required and demonstration of the viability of the treatment flow sheet would make it possible to offer alternatives to the expensive disposal of such hazardous material in a licensed disposal site.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

The hazards of lead in the environment have been a matter of increasing concern over the past several years. The problem is nationwide and ranges from contaminated soils around older private houses painted with lead-based paint to emissions from commercial lead smelters. The cleanup of lead contaminated soils of all types is a major challenge facing the U.S. and the world. This project was prepared based on the assumption that the technology developed for beneficiating minerals could be applied to the detoxification of soils contaminated by heavy metals, specifically in this case lead.

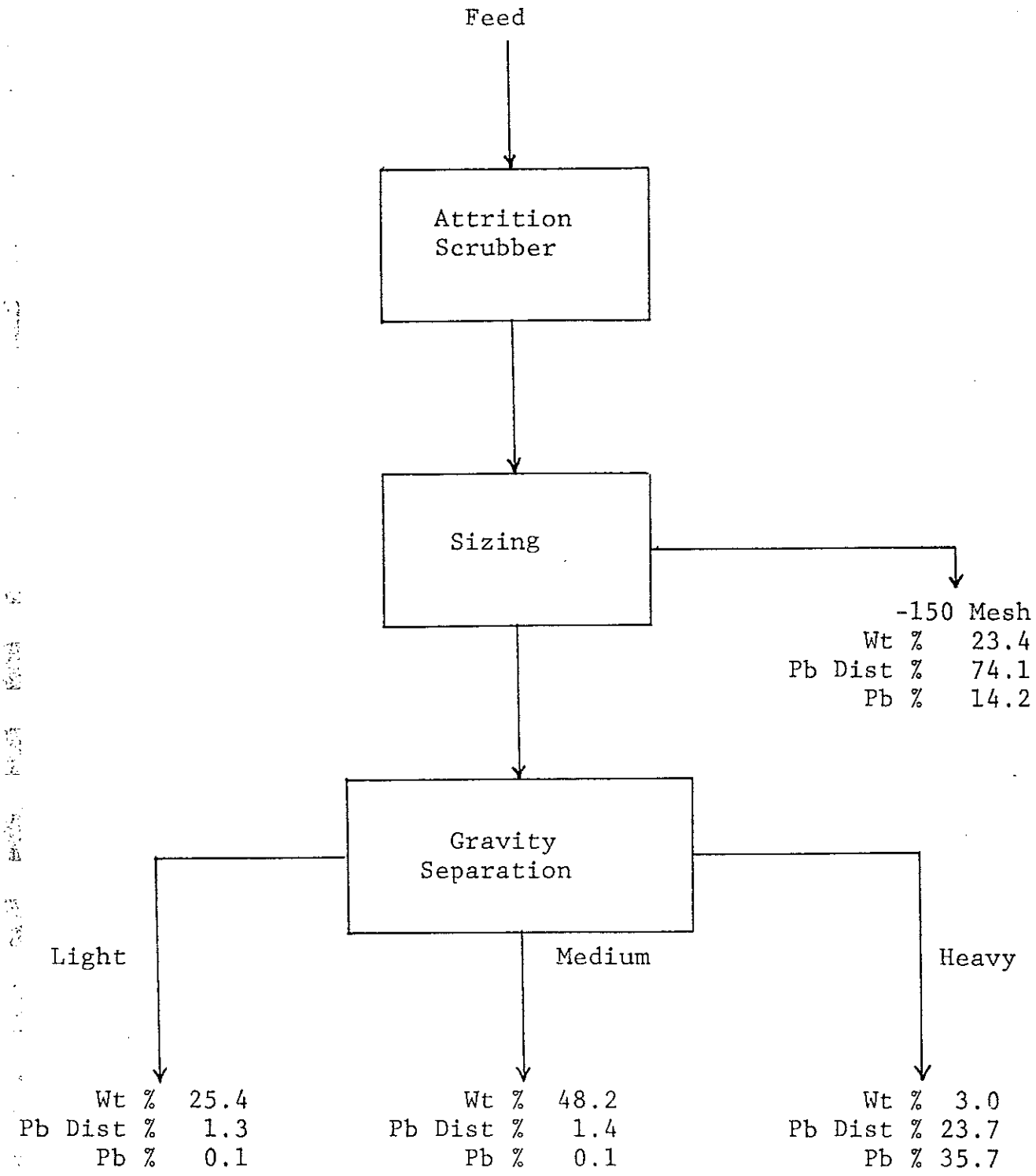
One of the environmental problems for Minnesota is the contamination of the soil under lead battery reprocessing sites. Reclamation of lead from batteries was carried out at several locations, commonly in connection with automobile junk yards. Much of this was done in the era before the environmental dangers were fully assessed and proper processing procedures enforced. The soils in these sites were commonly contaminated by lead metal from battery posts and plates that were broken up and mixed with the soil during the operation. In addition significant amounts of lead sulfate and lead dioxide precipitates are present as surficial coatings on the coarser soil particles. The Shafer Metal site also has what may be a unique occurrence of lead, that is lead incorporated into fused plastic material. Many of these battery reclamation sites have now been abandoned and the companies have moved, or gone out of existence leaving the contaminated material behind and also the burden of cleanup. Unless reprocessing can be effective the current option is to remove the soil and store it as a toxic waste. This represents a very high cost solution as it becomes more and more difficult to find disposal sites that are willing to accept toxic wastes.

The alternative is to develop methods to detoxify the soil or at least a large portion of the soil so that the volume of toxic material that has to be stored can be significantly reduced or in some cases perhaps eliminated totally. The Coleraine Minerals Research Laboratory of NRRI became interested in the problem in 1988 and conducted some preliminary laboratory test work on lead contaminated soil from the Lee Farm site in Wisconsin. That test work indicated that it was possible to detoxify a major portion of the coarser sand and gravel size material by means of attrition scrubbing, screening, and gravity separation. The schematic flowsheet for the laboratory work conducted on samples from the Lee Farm site with the test results are shown on Figure 1. While these results were encouraging they were only obtained with small bench scale laboratory equipment, not continuous pilot or commercial processing equipment.

The grant request submitted to the Greater Minnesota Corporation proposed applying this basic technology at the pilot scale to obtain design information for a small portable treatment facility. As part of the proposal a commitment was made to work on a contaminated site in Minnesota. This report covers the work funded by the Greater Minnesota Corporation in 1989.

ACKNOWLEDGEMENTS

The NRRI wishes to acknowledge the financial support provided by the Greater Minnesota Corporation to this project. We wish also to thank the Minnesota Pollution Control Agency who provided information and advice regarding selection of the Shafer Metal site, and the Minnesota Department of Transportation for permission to carry out the sampling.



FLOW SHEET FOR LABORATORY WORK ON LEE FARM SITE

Figure 1

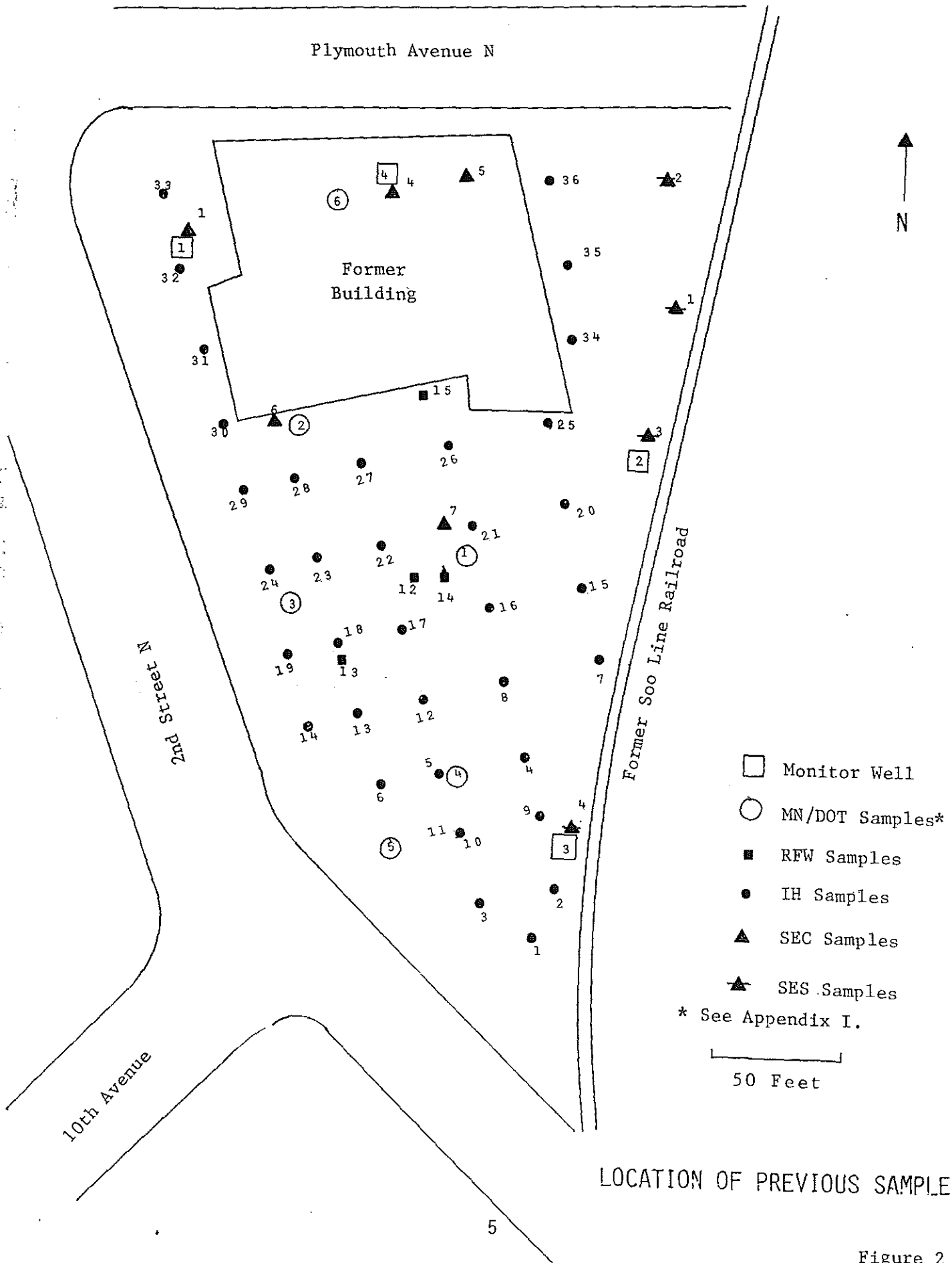
SAMPLE SITE SELECTION AND DESCRIPTION

A series of meetings were held with the site response Division of the Minnesota Pollution Control Agency, (MPCA) to identify sites that would be suitable for study. Based on these discussions agreement was reached with the MPCA to work on the Shafer Metal site in northeast Minneapolis. The site is owned by the Minnesota Department of Transportation (MNDOT) who are interested in cleaning up the area so that it could be used as a building site. Without cleanup the area would have to be covered over with sand and blacktopped to be used only as a parking area. The area would clearly have a higher value if commercial buildings could be erected.

A battery reclamation operation was operated at this location for several years. There were no detailed records available to show the nature of or the location of the original buildings. However, a sketch map was available that showed outlines of building foundations and the adjacent concrete slab.

The plant site had been extensively sampled previously and as part of the pollution control scheme four ground water monitoring wells had been installed. The location of the wells and the location of the previous sample points are shown on Figure 2. The detailed sampling data from the site are presented in Appendix I.

It is apparent from the sample logs that portions of the area are heavily contaminated with lead, up to 6.37%. The data also show that the depth of the lead contamination is only one or two feet in most cases. One unknown factor is the extent of contamination beneath the concrete slab and the buildings. The information presented was sufficient to demonstrate major lead contamination in the area and the decision was made to proceed with the sampling program and to obtain bulk samples for the treatment.



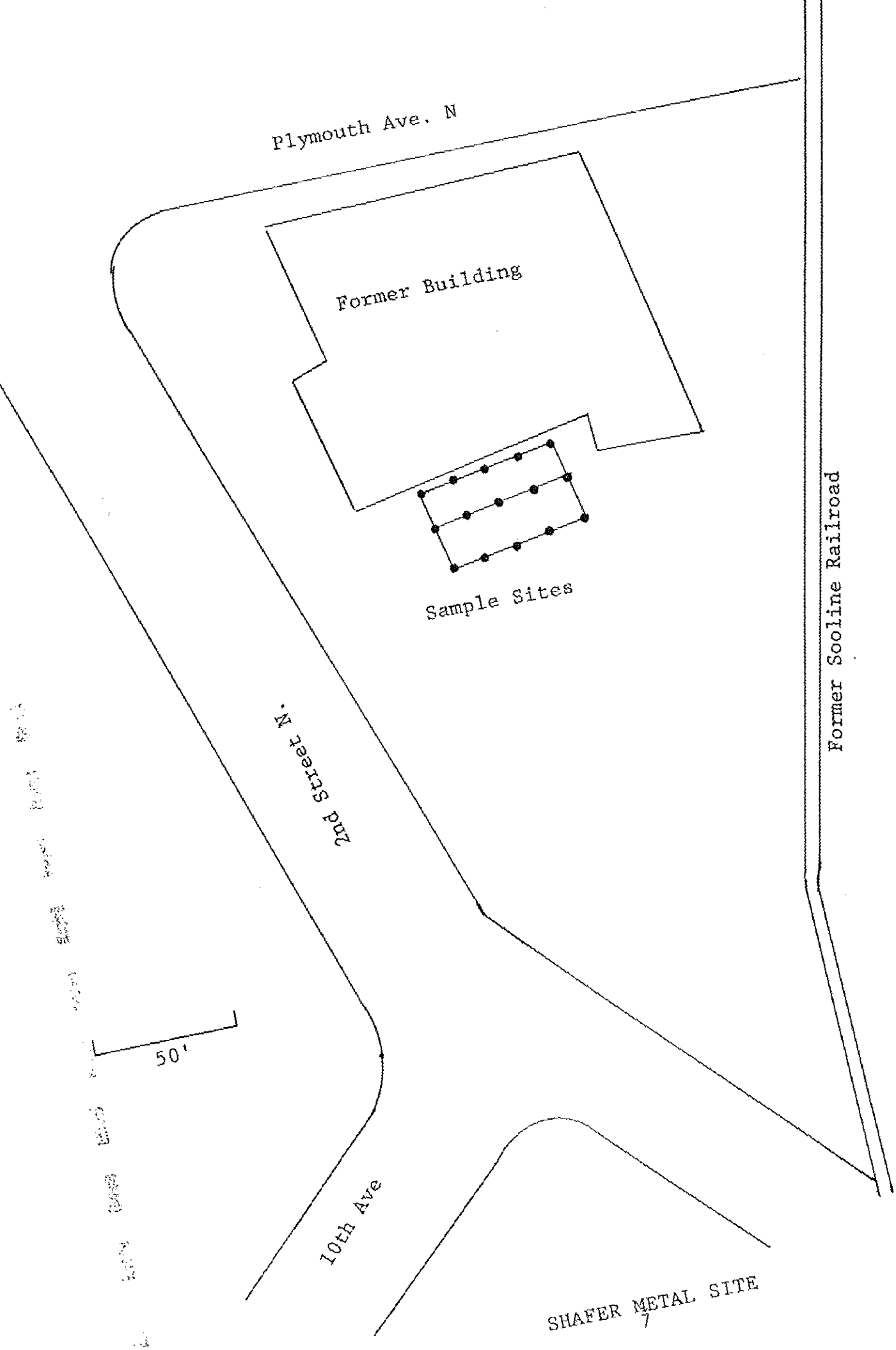
LOCATION OF PREVIOUS SAMPLES

Figure 2

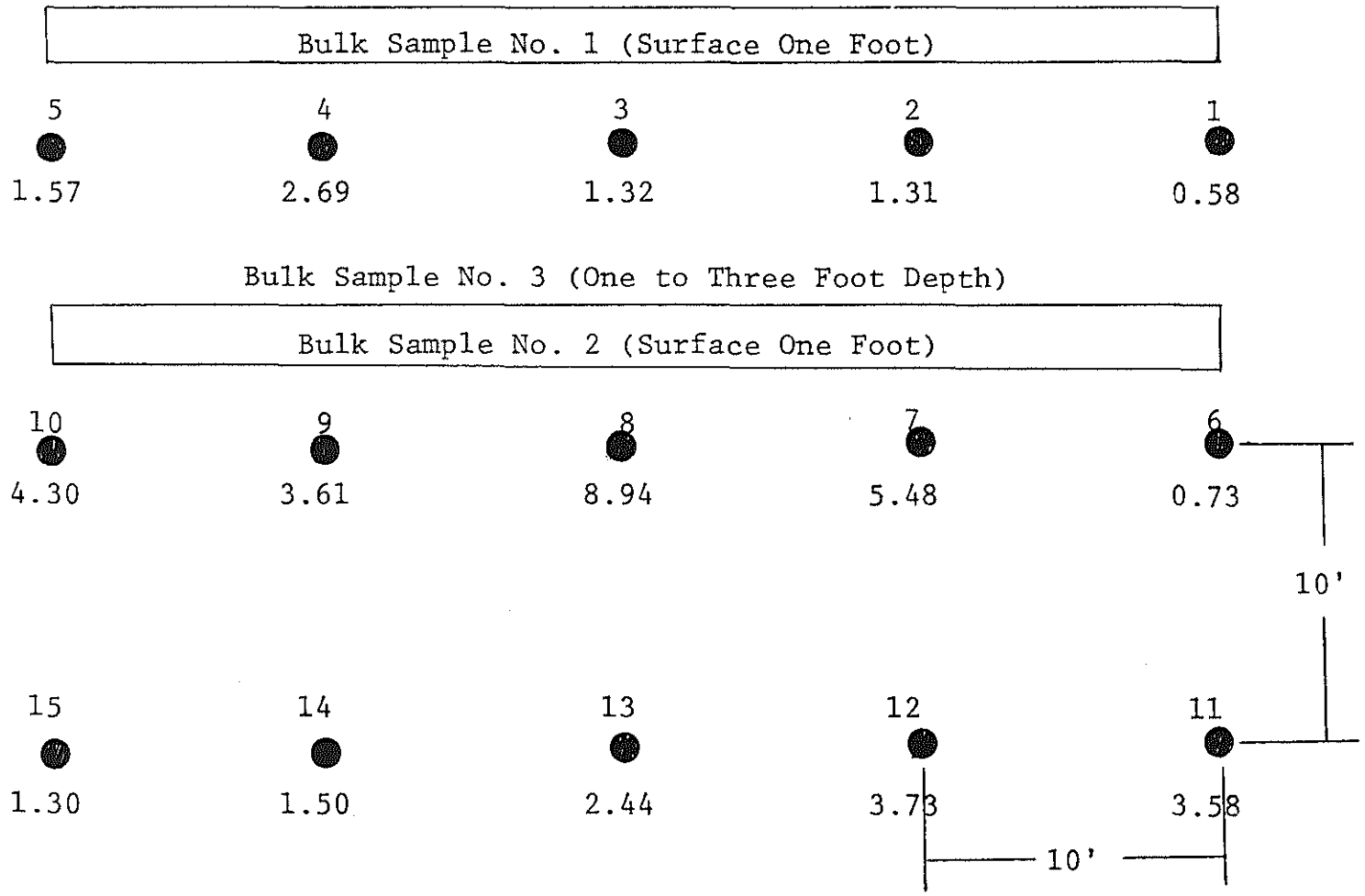
PRELIMINARY SAMPLING

Inspection of the available analyses, Appendix I, indicated that the area just south of the concrete slab shown on the sketch map, Figure 2, appeared to contain the highest lead values. However, because of expense and effort involved in collecting the larger bulk samples for testing, it was deemed essential that the site be re-sampled to be certain we had a location that contained areas of heavy contamination. Based on the available sample analyses a 10-foot by 10-foot sampling grid covering a 20 foot by 40 foot area was laid out to include the area that showed the higher lead values south of the concrete pad (Fig. 3).

The top one foot of soil was sampled at 15 locations shown on Figure 4. Auger sampling was found to be impractical because of the coarse rock fill incorporated in the soil so a one-foot deep hole was excavated by pick and shovel and then the side of the hole channel sampled. The total lead and sulfate analysis for each of the 15 samples are given in Table I. Generally the sulfate analysis track with the lead analysis which indicates that lead sulfate is a major contaminate. However, there is more sulfate present than can be accounted for by lead sulphate and it is assumed that the excess has precipitated as calcium or magnesium sulphate. The high percentage of lead present as lead sulphate is a result of precipitation from the sulfuric acid as the batteries were broken. This secondary precipitate is the component that potentially can be "scrubbed" off soil in processing so the residual soil can be land filled. Each of the sample locations carried a substantial lead and sulfate content. The location of the 3 bulk samples was based on the analytical results from these small samples.


Plymouth Ave. N
Former Building
Sample Sites
Former Sooline Railroad
2nd Street N.
50'
N
10th Ave
SHAFER METAL SITE

Figur



CLOSE UP OF HAND SAMPLE SITE SHOWING RELATIVE HOLE LOCATION
AND TOTAL LEAD CONTENT (PERCENT)

Figure 4

TABLE I

LEAD AND SULFATE CONTENT OF THE SAMPLE SITES

Site	Percent Lead	Percent Sulfate
1	0.58	0.54
2	1.31	1.04
3	1.32	1.06
4	2.69	1.53
5	1.57	1.38
6	0.73	1.04
7	5.48	3.82
8	8.94	3.62
9	3.61	1.58
10	4.30	1.63
11	3.58	1.51
12	3.73	2.34
13	2.44	1.55
14	1.50	0.97
15	1.30	0.92

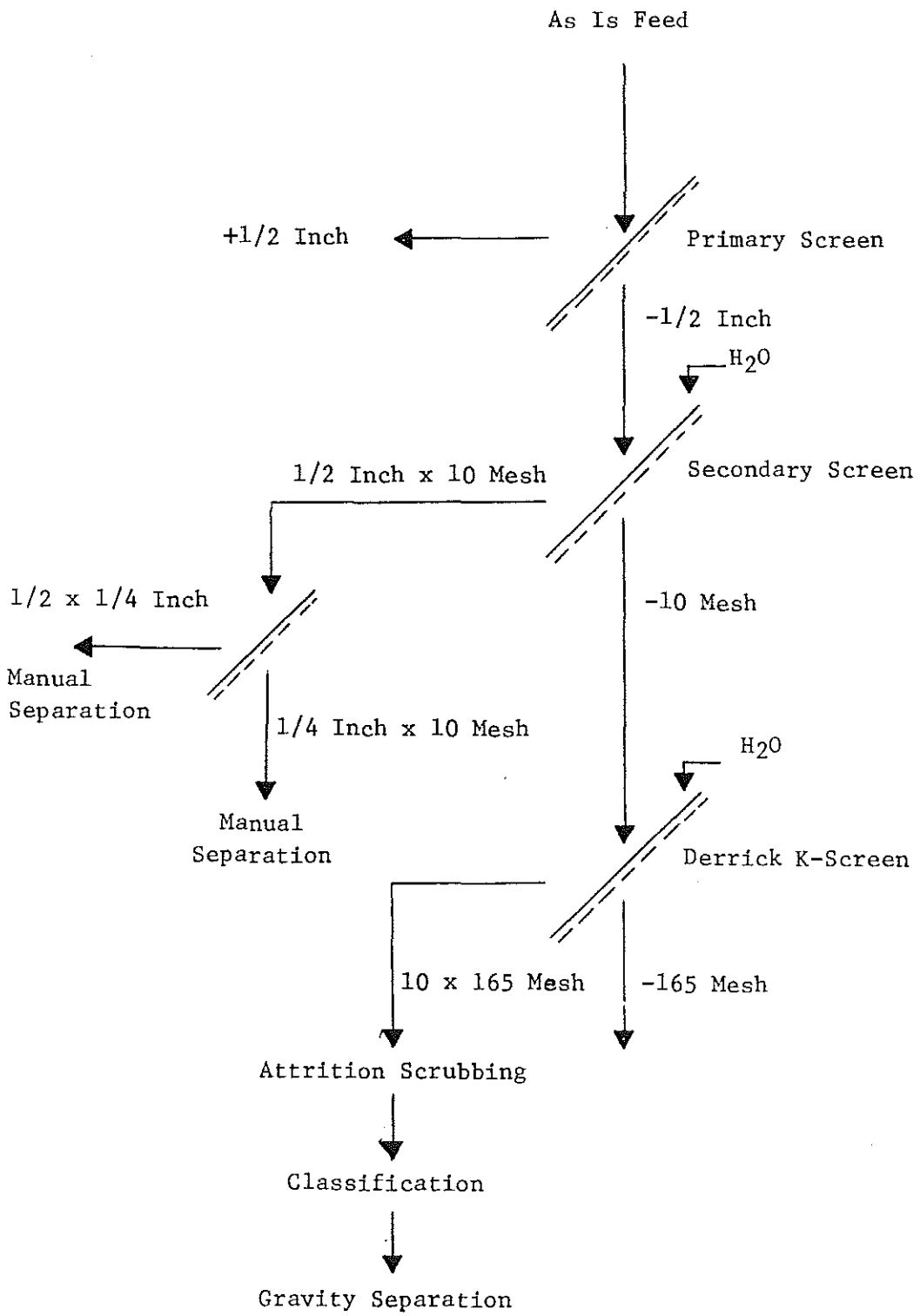
BULK SAMPLE COLLECTION

Bulk sample number 1 consisted of the top one foot of soil obtained by trenching with a backhoe along the north side of sample holes number 1, 2, 3, 4, and 5, (Fig. 4). Two drums of the material extracted from the trench were taken for Bulk Sample 1. Bulk sample number 2 was taken in the same manner to represent the top one foot of soil taken along the north side of the sample holes 6, 7, 8, 9, and 10. Two drums of material were saved as bulk sample 2. After carefully widening and cleaning the trench made for Sample 2, the third sample was taken by trenching from the one foot depth to three feet deep. One drum of material was saved for bulk sample 3 representing the two feet of soil beneath bulk sample 2. In each case described above the actual sample material was taken by incremental sampling by shovel along the length of the longpile extracted by the backhoe. Upon completion the trenches were backfilled and leveled with the backhoe.

TEST FLOW SHEET - BULK SAMPLES

The three bulk samples collected at the Shafer Metal site were processed following the flowsheet shown as Figure 5. Each bulk sample was screened on a commercial vibrating screen with a 1/2-inch square mesh deck. The plus 1/2-inch oversize was saved for subsequent visual examination and hand picking of coarse free lead. The minus 1/2-inch material was re-screened wet on a commercial vibrating screen unit with a 10-mesh deck. The plus 10-mesh oversize material was dried and rescreened on a 1/4-inch square mesh deck to produce a 1/2- by 1/4-inch product and a 1/4-inch by 10-mesh product. These two sized products were saved separately for subsequent analyses, visual sorting, and gravity concentration tests. The minus 10-mesh material was wet screened on a 165-mesh Derrick "K" screen to produce a 10 by 165-mesh product and a minus 165-mesh product. These

products were also saved for chemical analyses, further sizing tests, and gravity separation tests.



SCHEMATIC FLOW SHEET OF THE PROCESSING OF
SOIL SAMPLES FROM SHAFER METAL SITE

Figure 5

DISCUSSION OF TEST RESULTS

The screen analyses of three bulk samples are presented in Table II. The lead content of each size fraction and the distribution of the lead among the various size fractions are also shown. The lead content of the plus 1/2-inch size fraction is based on hand picking the free lead and assumes it contains 90% lead. The analyses for the smaller size fractions are based on chemical analyses. These analyses show that the total lead content of the bulk samples roughly tracks the results obtained from the preliminary sampling grid. The average analyses of samples No. 1 to 5 was 1.49% lead, the corresponding analyses of the bulk sample No. 1 was 1.73% lead. The average analyses of samples No. 6 to No. 10 was 4.61% lead, the corresponding bulk sample No. 2 contained 3.70% Pb. There were no cross-checks on bulk sample No. 3 taken at a greater depth. Beneficiation test work conducted on the specific size fraction designated in the test flowsheet, Figure 5, are discussed below.

PRIMARY SCREEN OVERSIZE (+1/2 INCH)

The plus 1/2-inch fraction from each sample was hand sorted to remove the obvious pieces of lead metal. The weight percent of metal recovered is shown in Table III. The lead metal recovered consisted largely of battery posts, heavy connectors and plate fragments. The admixed material was largely coarse fill rock and some plastic. A crude separation could be effected on this type of material using an air knife apparatus. The lead in this fraction represents nearly 50% of the lead in the total sample so use of an air knife and hand sorting would probably be practical.

TABLE II

SCREEN ANALYSIS AND LEAD DISTRIBUTION OF BULK SAMPLES

	Sample 1			Sample 2			Sample 3		
	Weight %	Pb %	Pb Dist. %	Weight %	Pb %	Pb Dist. %	Weight %	Pb %	Pb Dist. %
+1/2 inch	35.8	2.7	55.7	43.2	4.86	56.7	9.6	0.7	17.9
1/2 x 1/4 inch	10.3	0.25	1.5	13.1	0.59	2.1	0.6	3.72	5.9
1/4" x 10 mesh	15.9	1.37	12.6	15.2	3.18	13.0	0.5	1.47	2.0
10 x 165 mesh	29.0	0.63	10.5	21.9	2.12	12.5	74.2	0.10	19.8
-165 mesh	9.0	3.79	19.7	6.6	8.79	15.7	15.1	1.35	54.4
		1.73			3.70			0.37	

Note: Pb percent in +1/2-inch fraction is only hand-sorted lead metal at a lead content of 90%.

TABLE III

WEIGHT PERCENT OF PLUS 1/2-INCH FRACTION THAT WAS LEAD METAL

Sample	lb of Metal	Weight Percent Lead Metal
1	10.1	3.0
2	20.2	5.4
3	0.2	0.7

SECONDARY SCREEN OVERSIZE (1/2 INCH BY 10 MESH)

The secondary screen oversize, minus 1/2 inch by 10 mesh was rescreened on 1/4-inch to produce two separate size fractions. In commercial practice multideck screens would be used to minimize the number of screening units required. Visual examination of these two size fractions disclosed the presence of three major components, coarse rock, melted and fused black plastic, and free lead fragments. Analyses of the fused plastic showed that it contained significant amounts of lead. Grab samples showed that this material from Sample No. 1 contained 0.30% lead and Sample No. 2 contained 1.75% lead. Because of the plastic content the specific gravity of this material ranged from 2.2 to 2.4. This low specific gravity indicates that it should be possible to separate the plastic, (2.2 to 2.4 sp gr) from the rock fragments (2.65 sp gr) and the lead (7.5 sp gr) by gravity means, heavy media or jigs. To test the feasibility of separating the plastic material by gravity means a heavy-liquid separation was attempted on this material. However, the heavy liquid reacted with the plastic in the melted pieces thereby invalidating the tests. Since jig tests could not be run on the small sample size available hand sorting was used.

The 1/2-inch by 1/4-inch and the 1/4-inch by 10 mesh fractions of bulk samples No. 1 and No. 2 were sorted into rock, metal, and fused plastic. The weight percentages and available lead analyses are given in Table IV.

The analyses of the rock portions of the 1/2-inch by 1/4-inch showed 0.062% and 0.077% lead for bulk samples No. 1 and 2 respectively. The very low lead content indicates that the rock portion of each sample would be expected to pass the EP leach test and would be discarded as waste.

TABLE IV

DISTRIBUTION OF LEAD IN THE HAND-SORTED 1/2 BY 1/4-INCH FRACTIONS AND 1/4-INCH BY 10-MESH FRACTIONS

		Wt. %	% Pb
Sample 1	Rock	60.8	0.062
(1/2x1/4")	Melted	37.2	0.305
	Metal	2.0	100
Sample 2	Rock	80.3	0.077
(1/2x1/4")	Melted	17.5	1.74
	Metal	2.2	100
Sample 1	Rock	69.8	
(1/4"x10M)	Melted	27.3	
	Metal	2.9	
Sample 2	Rock	70.5	
(1/4"x10M)	Melted	26.8	
	Metal	2.7	

SECONDARY SCREEN UNDERSIZE (MINUS 10 MESH)

Treatment of the secondary screen undersize involves a combination of attrition scrubbing, fine screening, and gravity separation. The minus 10 mesh material was rescreened at 165 mesh on a Derrick "K" screen. To provide some guidance to subsequent treatment, portions of the 10 by 165-mesh fraction of each sample were subjected to screen analyses and the screen fractions analyzed for lead (Table V). Likewise portions of the minus 165-mesh fraction from each sample were also screened and the minus 325-mesh portion was sized (Warman cyclosizer) down to 12 microns. Each fraction was analyzed for lead, Table VI. Examining the lead by size fraction data in Tables IV, V, VI indicates that the lead is distributed uniformly throughout the 10 by 165 mesh and the minus 165 mesh portions of each sample and thus, no portion of the samples can be detoxified by sizing alone. The high lead analysis in each of the 49 micron fraction (Table VI) is due to the gravity effect in the cyclosizer which classifies based on size and specific gravity. The data, Tables II, V, and VI, indicate that the lead content of Sample 2 is uniformly higher than Sample 1. Also, these two surface samples contained more lead than the sample taken below the one-foot depth.

ATTRITION SCRUBBING (10 BY 165 MESH)

Although there is no low-lead size fraction in the minus 10-mesh material that can be rejected by classification or fine screening, visual examination did show that there were discrete lead, plastic, and sand particles that could be concentrated by gravity separation. Before the gravity separation tests, the 10 by 165 mesh feed was combined with water and tumbled in a drum to simulate attrition scrubbing. The purpose of the attrition scrubbing was to remove any lead compounds that were present as a surficial precipitate layer on the sand

TABLE V

SCREEN ANALYSIS AND LEAD BY SIZE FRACTIONS IN THE 10 BY 165 MESH PORTION OF EACH SAMPLE

Size Mesh	Sample 1 Wt. %	Sample 1 % Pb	Sample 2 Wt. %	Sample 2 % Pb	Sample 3 Wt. %	Sample 3 % Pb
10	0.9	0.19	0.4	0.44	0.3	0.12
20	20.4	0.66	25.9	1.88	10.4	0.41
28	14.9	0.66	14.7	1.99	13.5	0.16
35	18.4	0.56	16.3	1.67	19.4	0.07
48	16.0	0.59	14.5	1.69	17.1	0.06
65	11.1	0.74	9.0	2.34	13.9	0.07
100	7.8	0.73	8.4	2.06	12.1	0.06
150	4.9	1.22	4.6	2.56	7.7	0.14
200	2.1	1.74	2.4	3.33	2.5	0.24
270					0.6	0.43
}	0.5	1.94	0.8	4.49		
325					0.3	0.55

TABLE VI

SCREEN ANALYSIS AND LEAD BY SIZE FRACTION FOR MINUS 165 MESH PORTION OF EACH SAMPLE

	Sample 1		Sample 2		Sample 3	
Size	Wt. %	% Pb	Wt. %	% Pb	Wt. %	% Pb
65 M	2.7	1.35	4.7	9.52	6.5	1.13
100 M	0.4		0.3		0.8	0.58
	}	0.83	}	6.24		
150 M	0.3		0.4		0.6	0.50
200 M	5.9	0.53	8.2	3.20	9.6	0.30
270 M	6.9	0.73	8.9	3.82	8.8	0.25
325 M	2.4	0.83	2.0	6.28	1.4	0.29
48 μ	0.9	17.60	2.0	27.48	1.4	4.27
37 μ	4.0	3.73	5.8	7.77	5.4	0.79
26 μ	9.5	2.88	9.8	8.42	9.3	0.53
17 μ	10.0	3.09	9.7	8.98	8.4	0.59
12 μ	7.2	3.44	6.8	9.61	5.6	0.62
-12 μ	49.8	3.88	41.4	9.82	42.2	0.72

TABLE VII

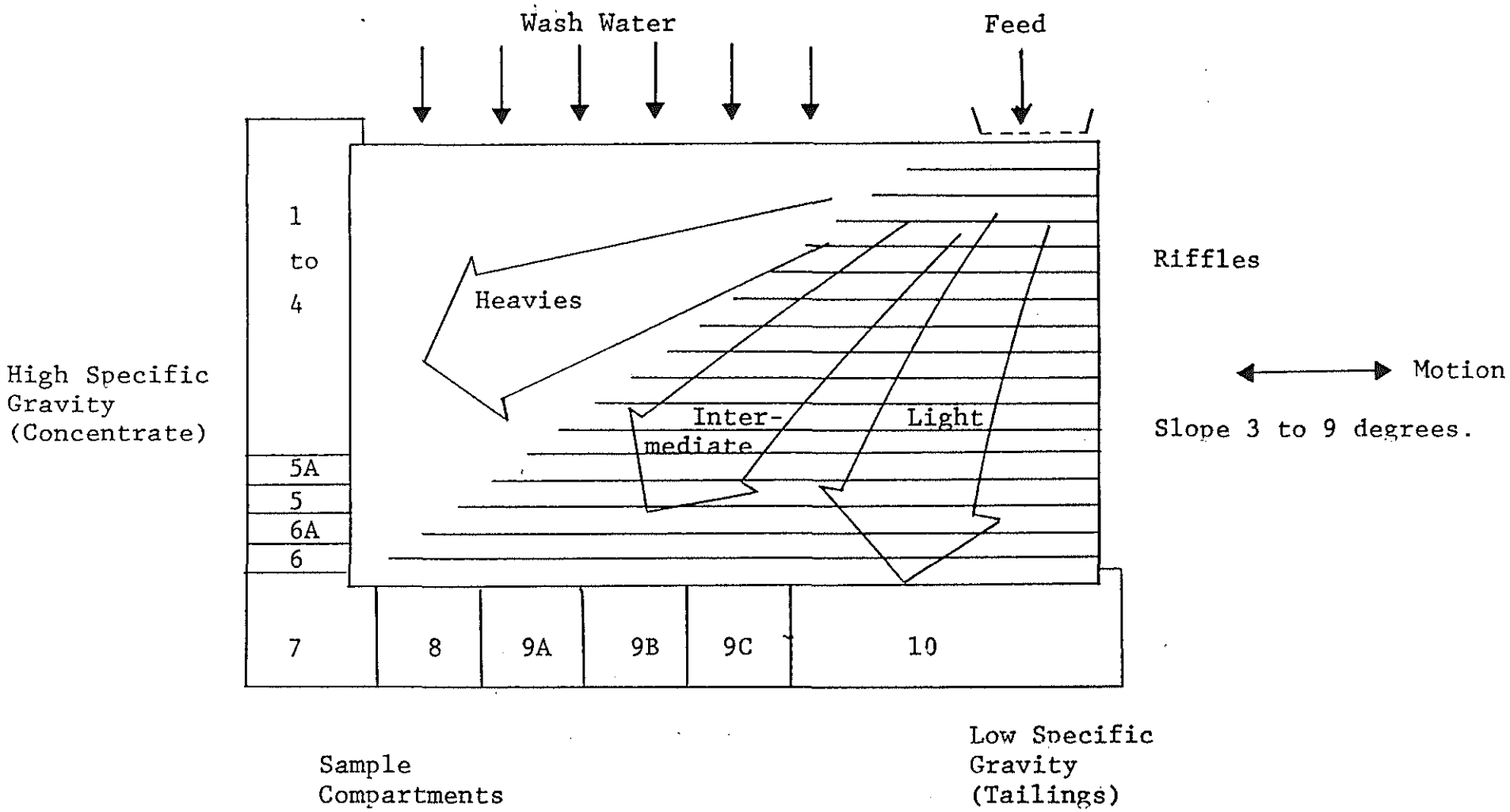
RESULTS OF ATTRITION SCRUBBING OF 10 X 165-MESH FRACTIONS PRIOR TO TABLE TESTS

Test No.	Sample No.	Wt.% Minus 325 Mesh	% Pb	% SO_4	Scrubbing Time Min.
5	1	2.1	5.86	1.18	5
6	2	5.2	10.91	2.68	5
7	2	5.9	10.83	2.71	20
8	2	4.0	11.43	2.73	20
10	1	2.2	5.67	1.15	20
11	1	2.0	6.04	1.20	20

grains so they could be rejected by classification. The classification step was simulated by wet screening on 325 mesh. The minus 325-mesh fractions were analyzed for lead. The tests show that the scrubbing step makes it possible to remove a significant amount of the lead from this size fraction as a minus 325 mesh slime. The attrition scrubbing tests on bulk Sample No. 1 showed that the scrubbing removed an average of 2.1% of the weight and 19.5% of the lead, Table VII. The removal was even greater for bulk sample No. 2 with an average of 5.03% weight and 26.2% lead rejection, Table VII. The greater weight rejection from sample No. 2 largely reflects its higher lead content, 2.12% compared with 0.63% in sample No. 1. Assuming all the sulfate in the minus 325-mesh fraction is present as lead sulfate, then the material scrubbed from bulk sample No. 1 averaged 43.4% lead sulfate while the material from bulk sample No. 2 averaged 52.9% lead sulfate. The test results in Table VII indicate that the scrubbing is a relatively fast operation in that there was essentially no difference between scrubbing for 5 minutes or for 20 minutes.

TABLE TEST DATA (10 X 65 MESH)

Gravity separation tests were run with a Wilfley table on the 10 by 165 mesh size fraction from all three bulk samples. A schematic drawing of the Wilfley table showing the feed and product discharge points is presented in Figure 6. The table consists of a slightly inclined deck on to which feed is introduced at the feed box and wash water is distributed along the balance of the feed side. The table is vibrated longitudinally, by a mechanism using a slow forward stroke and a rapid return, which causes the particles to fan out across the deck. The heaviest particles will migrate to the concentrate end while the lightest particles will remain in suspension and flow across the table to the tailings side. A series of riffles across the deck assist in the separation by allowing the heavier particles to



SCHEMATIC OF WILFLEY TABLE SHOWING SAMPLE COMPARTMENTS

Figure 6

separate out between the riffles while washing the lighter particles over the riffles to the tailings. The various products are collected at several points along the discharge sides of the table as shown in Figure 6. The samples are weighed and analyzed to provide the basic data to predict performance of a commercial machine. The separation depends on the particles specific gravity and shape. The table works best on particles between 10 and 270 mesh.

The results obtained on the three bulk samples are presented in Table VIIIa, b, c. Table tests 1 and 2 were used to establish the operating conditions and the results are not included in the data. The test data obtained on bulk sample No. 2 is discussed first because it was tested in greater detail.

Bulk Sample No. 2. A series of 8 table tests were run on bulk sample No. 2. The initial test, table test No. 4, was run with the slope at 5°. The product distribution and Pb analyses are given in Table VIIIb. The heavy mineral compartments, No. 1-6, represented 4.5% of the weight and contained 11.61% lead. The intermediate compartments, No. 7-9, represented 79.4% of the weight and contained 1.21% lead. The low gravity tailings, compartment No. 10, represented 16.1% of the weight and contained 5.21% lead.

Because the bulk of the lower grade lead products were in the intermediate gravity product, 79.4% that material was recombined and retabled with the table at a steeper slope, table test No. 5. The bulk of the material reported at an intermediate gravity, compartment, No. 9, and represented 52.4% of the weight, and contained only 0.39% lead. In this two-stage separation 41.6% of the weight could be recovered containing 0.39% lead.

The next test, table test No. 6, run with a 3° slope produced a combined intermediate product, compartments No. 6-6A, representing 47.7% of the weight and containing 0.32%

TABLE VIIIa

RESULTS OF TABLE TESTS
BULK SAMPLE No. 1

Table Test 10 Slope 5°				Table Test 11 Slope 3°			
Compartment	Wt. %	% Pb	Pb Dist. %	Compartment	Wt. %	% Pb	Pb Dist. %
1 to 6A	0.2	48.11	5.5	1 to 5	0.8	38.16	23.6
6	2.3	26.34	39.6	6A	2.1	16.04	26.0
7	60.8	1.43	49.6	6	9.5	3.75	27.5
8	24.1	0.21	2.9	7	56.5	0.24	10.5
9A	6.2	0.14	0.5	8	18.6	0.13	1.9
9B-C	0.1	0.81	0.1	9A	4.8	0.16	0.6
10	6.4	1.87	6.8	9B-C	0.3	0.38	0.1
				10	7.3	1.73	9.8

TABLE VIIIb

RESULTS OF TABLE TESTS
BULK SAMPLE NO. 2

Table Test 4
Slope 5°

Compartment	Wt. %	% Pb	Pb Dist. %
1 to 5	0.2	4.86	0.4
6A	3.5	12.74	19.2
6	0.8	8.34	2.9
7	16.9	2.25	16.4
8	14.5	0.54	3.3
9	48.0	1.05	21.7
10	16.1	5.21	36.1

Table Test 5
Feed - Compartment 7, 8, & 9 From Test 4
Slope 8°

Compartment	Wt. %	% Pb	Pb Dist. %
1 to 6	4.1	1.27	5.6
7	14.1	1.67	25.5
8	11.1	0.73	8.8
9	52.4	0.39	22.2
10	18.3	1.91	37.9

Table Test 6
Slope 3°

Compartment	Wt. %	% Pb	Pb Dist. %
1 to 4	5.5	11.48	34.5
5A	4.3	1.99	4.7
5	15.0	0.67	5.5
6A	33.4	0.30	5.5
6	13.8	0.35	2.6
7	8.8	0.68	3.3
8	1.0	1.93	1.0
9	1.0	4.59	2.5
10	17.2	4.30	40.4

Test Table 7
Slope 5°

Compartment	Wt. %	% Pb	Pb Dist. %
1 to 5A	0.6	32.72	9.3
5	1.7	20.21	16.2
6A	8.9	4.76	20.0
6	15.4	1.68	12.2
7	48.3	0.44	10.0
8	4.1	0.45	0.9
9	0.5	2.35	0.6
10	20.5	3.19	30.8

Table Test 8
Slope 9°

Compartment	Wt. %	% Pb	Pb Dist. %
1 to 7	6.7	12.21	37.6
8	25.1	1.20	13.9
9A	37.6	0.34	5.9
9B	2.9	1.16	1.6
9C	1.2	3.51	1.9
9	0.2	3.79	0.4
10	26.3	3.20	38.7

Table Test 9
Feed - Compartments 8 & 9A From Test 8
Slope 5°

Compartment	Wt. %	% Pb	Pb Dist. %
1 to 6A	0.1	9.65	1.5
6	2.0	5.38	16.4
7	78.0	0.46	54.6
8	11.2	0.63	10.7
9	0.1	0.87	0.1
10	8.6	1.28	16.7

TABLE VIIIc

RESULTS OF TABLE TESTS
BULK SAMPLE NO. 3

Table Test 3
Slope 5°

Compartment	Wt. %	% Pb	Pb Dist. %
1 to 5	0.5	7.04	35.6
6	0.6	1.10	8.3
7	10.6	0.13	17.3
8	12.8	0.003	0.1
9	71.1	0.018	16.1
10	4.4	0.41	22.6

TABLE IX

SCREEN ANALYSIS OF COMPARTMENT 7, TABLE TEST 7

Size Mesh	Wt. %	% Pb
20	11.8	0.57
28	14.4	0.51
35	23.4	0.33
48	22.0	0.25
65	16.1	0.37
100	7.8	0.52
-100	4.5	0.76

TABLE X

TOTAL CARBON ANALYSIS

Sample	% Total Carbon	% Pb
Minus 165 mesh sample 1	8.1	3.79
Minus 165 mesh sample 2	11.1	8.97
Compartment 9	6.2	1.05
Compartment 10	19.5	5.21
1/2 x 1/4 inch	26.9	1.19

lead. This was attained by only one stage of tabling, a significant improvement over table tests No. 4 and 5.

The next test, table test No. 7, was run at a 5 degree slope and produced a combined intermediate product, compartments No. 7-8, representing 52.4% of the weight and containing 0.44% lead.

Because the table separates on shape as well as gravity it was thought that perhaps screening the 0.44% lead product might produce a lead rich fraction which could be discarded. However, as shown in Table IX, the lead is uniformly distributed throughout the size fractions and rejection of a low lead size fraction is not possible.

Table tests No. 8 and 9 were another double table test aimed at producing the lowest possible lead product. In test 9 the material from compartments 8 and 9A of test 8 were retabled. This double tabling resulted in essentially the same results as obtained in test 7, i.e., a product containing about 50% of the weight with a lead content of 0.46%.

The data from these tests indicate that gravity separation could be used to separate about 50% of the 10 by 165-mesh size fraction as an intermediate product analyzing less than 0.5% lead and containing less than 15% of the total lead in this size fraction.

The light fraction or tailings, that is, material collected in compartment No. 10, always contained more lead than the intermediate gravity products. Microscopic examination of this material showed the presence of the fused plastic material equivalent to that observed in the coarser fractions as discussed previously. To estimate the amount of fused plastic material in the light fractions, samples from compartments 9 and 10 from Table test No. 4 were analyzed for total carbon along with the minus 165-mesh fractions from Bulk Samples No. 1 and 2. Analyses of fused material from the 1/2- by 1/4-inch fraction from Bulk Sample No. 2 are also included in the table. The high total carbon analysis, Table X, indicate that the

melted pieces represent fused plastic material. The amount of melted material can be estimated from the total carbon analysis. Assuming it is 26.9% C, as observed in Bulk Sample No. 2, compartment 10 from Table test No. 4 contained about 72.5% fused plastic material and compartment No. 9 contained about 23.0%.

Some of the fused pieces contain sufficient iron so that the pieces can be picked up with a hand magnet. The magnetic pieces also contained 2.38% lead. However, the proportion of magnetic material does not seem sufficient to support a magnetic cleaning step in the process.

The presence of this fused plastic material complicates the recovery and clean-up process. The samples from the Lee Farm site tested earlier had no such material so gravity separation to produce a two product split was easier to apply. The presence of this material in the Shafer material forces the use of a two-stage gravity separation step in order to obtain reasonably clean end products.

Bulk Sample No. 1. The table test results obtained on bulk sample No. 1, Table VIIIa, are somewhat better than obtained on bulk sample No. 2 in that it was possible to reject a greater weight of material containing less than 0.5% lead. This in part reflects the lower total lead content in the 10 by 165-mesh size fraction, i.e. 1.37% lead in sample No. 1 and 3.70% lead in sample No. 2. In table test No. 10, run at a slope of 5°, 30.4% of the weight was recovered as an intermediate product containing 0.20% lead.

Table test No. 11 was run with a flatter, 3° slope, and different distribution of wash water that produced superior results. The intermediate product weight recovery in compartments No. 7-9C was 80.2% and still contained only 0.21% lead.

Bulk Sample No. 3. The table test on bulk sample No. 3 produced the best results in terms of segregating the greatest weight of combined intermediate and tailings product with the lowest lead analyses. The data, Table VIIIc, show that the combined products, compartments No. 7-10, represented 98.9% of the feed weight and contained only 0.05% lead. That is over 85% of the lead was removed from this fraction in a one-stage table operation. Bulk sample No. 3 contained only 0.37% lead and was taken at a depth of 1 to 3 feet so it did not contain the coarser size fractions found in the other two surface samples. Also it contained only small amounts of the fused plastic material so the light tailings fraction was not a significant problem.

FINES (MINUS 165 MESH)

The minus 165 mesh material was not processed except for lead analysis by size fraction, Table VI, and for carbon analysis, Table X, as discussed in previous sections. Based on the total carbon analysis it appears that the minus 165 mesh portion of bulk sample No. 1 is about 30% fused plastic material. The fines from bulk sample No. 2 is about 41% fused plastic material. The fused plastic material in the fines may respond to froth flotation and that process could be used to remove it from the minus 165 mesh size fraction. However, the specific reagent combinations required have to be identified by bench-scale testing which is beyond the scope of the current project and require additional funding.

ENVIRONMENTAL LEACH TESTS

The object of the scrubbing-sizing-and concentration test program was to both extract a high lead product for possible commercial utilization and also to leave a residual product that was clean enough to be considered non-hazardous and which would also pass standard

environmental leach tests. To provide material for the leach test a gravity concentrate was synthesized. The simulated gravity concentrate was made assuming 50% came from Sample 1 and 50% from Sample 2. Using the weight distributions for the minus 1/2 inch fractions in Table II, the weight recoveries for the rock portion in Table IV for the 1/2- by 1/4-inch fraction, a 70% weight recovery for the rock portion in the 1/4-inch by 10-mesh fraction, and weight recoveries from table test 7 and 11, Tables VIII a and b, the simulation gravity concentrate was made up as shown in Table XI. This represents 60.9% of weight in the minus 1/2-inch fractions assuming 1/2 Sample 1 and 1/2 Sample 2. Because of the project termination and limited materials available for testing only the "EPA Method 1312 - Synthetic Precipitation Leach Test for Soil" was run on the sample. The Method 1312 uses a leach solution made up with sulfuric and nitric acid in the ratio of 60:40 in water at a pH of 5.0.

The leach test was negative. The leachate contained 0.066 ppm, well below the 5.0 ppm standard and it appears that the rock-sand products can be classified as non-hazardous and be disposed of on-site.

Table XI

MAKEUP OF SIMULATED GRAVITY CONCENTRATE

	Wt. grams
Sample 1	
1/2 by 1/4 inch	7.8
1/4 by 10 mesh	13.6
10 by 165 mesh*	28.6
Sample 2	
1/2 by 1/4 inch	15.8
1/4 by 10 mesh	16.0
10 by 165 mesh**	18.2

* Made from compartment 7, 8, 9A-C, Table Test 11.

** Made from compartment 7 and 8, Table Test 7.

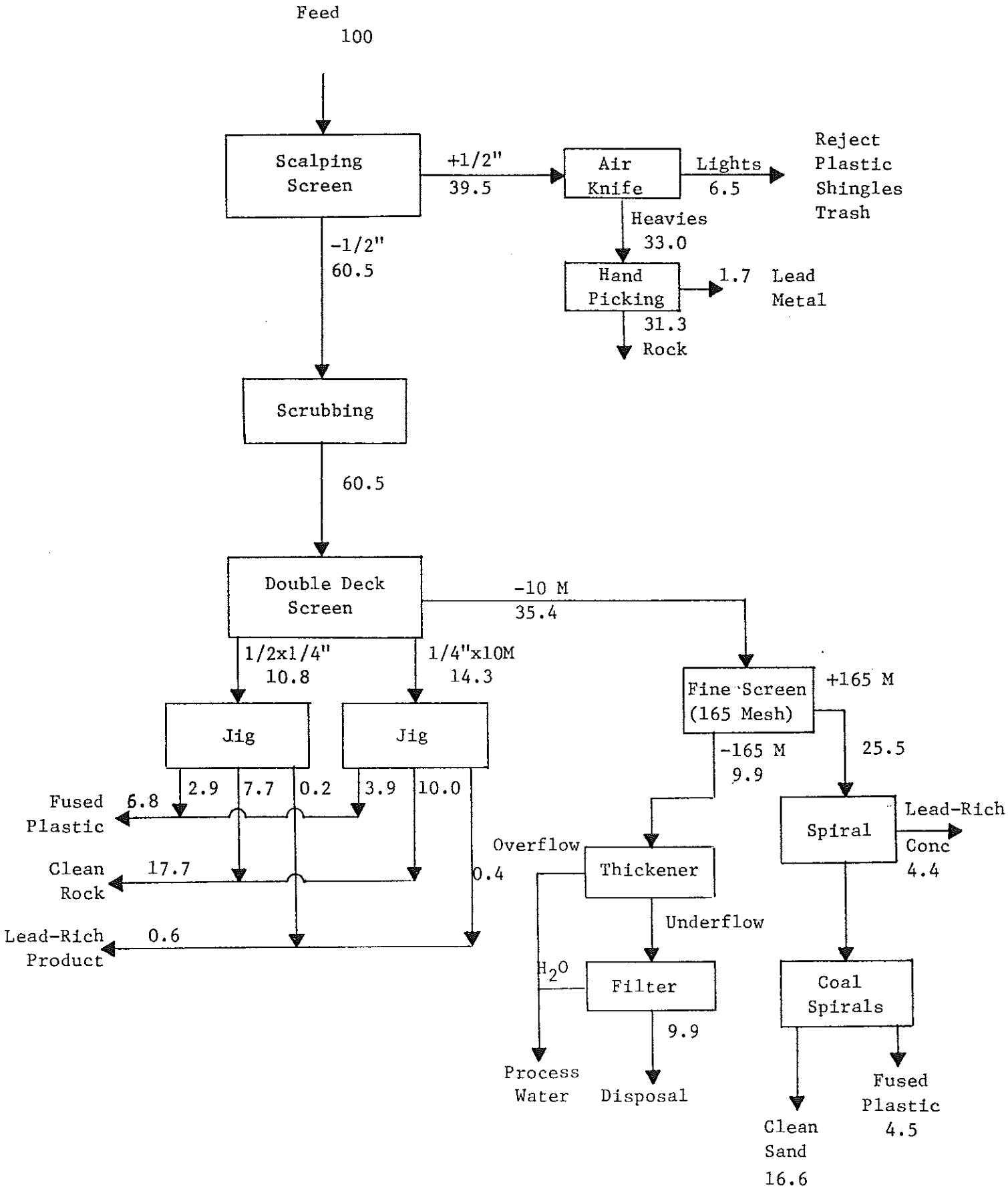
RECOMMENDED PROCESSING FLOW SHEET

The recommended treatment flow sheet to detoxify the materials taken at the Shafer Metal site is presented as Figure 7. It involves a preliminary scalping screen, 1/2-inch opening, to remove miscellaneous contaminants, plastic, shingles, cans, etc. from the process stream. The screen oversize can be upgraded with an air knife, or in a small operation, hand picked to recover a clean lead product and reject the trash. The scalping screen undersize, minus 1/2 inch, will be subjected to high energy scrubbing and then wet screened on a double deck screen to produce a 1/2-inch by 1/4-inch, 1/4-inch by 10 mesh, and minus 10-mesh product. The two coarse products would go to a jig for gravity separation. The jigs will produce three products, clean rock, fused plastic, and a lead-rich concentrate. The minus 10-mesh screen product will be re-screened at 165 mesh. The 10-mesh by 165-mesh product will go to two stage gravity separation in spirals to produce a three product split, clean sand, a lead concentrate, and a fused plastic reject.
Spirals are specified for the flow sheet because they are used for gravity separation in most commercial installations rather than tables because they require less space and have lower operating costs. Tables are used for test purposes because they require smaller feed samples and the test data can be used to predict spiral performance. The minus 165-mesh material will be thickened and filtered for disposal. The water in the thickener overflow and from the filter will be used as make-up process water.

The product weight splits are also shown on Figure 7 and are based on the assumption that the feed was a 1:1 blend of Bulk Samples No. 1 and 2. The major product weight splits are listed below:

	Wt.%
Reject, Coarse Plastic/Trash	6.5
Reject, Coarse Rock, +1/2 Inch	31.3
Reject, Jig Rock	17.7
Reject, Spiral Clean Sand	16.6
Total Reject	72.1
Lead-Rich Coarse, +1/2 Inch	1.7
Lead-Rich Jig Concentrate	0.6
Lead-Rich Spiral Concentrate	4.4
Total Lead-Rich Material	6.7
Fused Plastic Jig Product	6.8
Fused Plastic Spiral Product	4.5
Total Fused Plastic	11.3
Filter Cake (Possible Retreat)	9.9

Based on these estimates 65.6% of the material would theoretically be eligible for on-site disposal. The lead-rich fraction (7.1%) would be acceptable as feed stock to a lead smelter. This leaves the coarse trash (6.5%), the fused plastic (11.3), and the filter cake (9.9%) that would probably have to be classified as hazardous waste.



RECOMMENDED FLOWSHEET TO DETOXIFY THE SHAFER METAL SITE

Figure 7

CONCLUSIONS AND RECOMMENDATIONS

The lead contamination at the Shafer Metal battery reprocessing site occurs in three principal modes: lead metal fragments, surficial coatings of precipitated lead sulphate and lead dioxide, and lead incorporated into fused plastic material. The lead metal consists primarily of fragments of battery plates and connectors. The precipitated lead compounds occur as coatings on the rock and sand particles in the soil. The fused plastic material could have resulted from melting and casting of the lead, or operation of an incinerator.

The test results show that it is possible to detoxify a large portion of the lead contaminated soil from the Shafer Metal battery reprocessing site using conventional mineral processing techniques. A process flowsheet has been developed for the bulk of the material as represented by Bulk Samples No. 1 and No. 2. The flowsheet includes the following processing steps: 1) sizing to remove coarse trash; 2) attrition scrubbing to remove the lead sulphate from the coarser rock and sand particles; and, 3) gravity concentration to separate a high lead product, a clean rock or sand reject, and a lead-bearing fused plastic product. A minus 165 mesh fines fraction is also produced containing of the natural fines and carrying the lead released by the attrition scrubbing.

Based on the test work a clean rock and sand fraction can be produced representing about 60% of the material that will pass the synthetic precipitation leach test for soils. This material can be disposed of on-site. About 5% to 10% of the weight can be recovered as a lead-rich concentrate that would be marketable to a lead smelting operation. The fused plastic portion which contains about 4% lead and represents 10% to 15% of the material would have to be treated as hazardous waste. The minus 165-mesh fines, about 10% of the weight, has not been tested and at this time also has to be treated as a hazardous material.

The coarse trash, 5% to 10% of the material, would probably be acceptable for landfill disposal.

The material in Bulk Sample No. 3 which is predominantly sand-size can be thoroughly cleaned by scrubbing and fine gravity separation. It will produce a small amount of high lead concentrate and a clean reject material that is expected to pass environmental leach tests. However, about 15% of this material is fines which at this time will have to be treated as a hazardous material.

The recommended treatment flowsheet is based on using conventional mineral processing equipment. The equipment could be sized small enough to be truck mounted, or set up as semi-portable units for on-site treatment. Engineering such a portable treatment plant was included in the extended project, but is beyond the scope of this abbreviated study. Whether treatment of the Shafer Metal site is practical depends upon the cost of building and operating such a treatment plant on site as opposed to direct disposal.

It is recommended that this study be extended to include the design and engineering of a portable or semi-mobile treatment plant and that further continuous pilot plant operations be supported to confirm some of the coarse gravity separation steps. There are other similar sites in Minnesota that are contaminated by lead that would be amenable to similar treatment. Costing out the plant required and demonstration of the viability of the treatment flowsheet would make it possible to offer alternatives to the expensive disposal of such hazardous material in a licensed disposal site.

APPENDIX I

ANALYSIS OF PREVIOUS SAMPLES - MPCA INTERNAL REPORT

Analysis of Previous Samples - MPCA Internal Report

Site/Depth+	TOTAL LEAD 5/84 IHL	TOTAL LEAD 8/84 Serco	TOTAL LEAD 3/85 RFW	TOTAL LEAD 8/85 TCT	TOTAL LEAD 10/86 MDH	TOTAL LEAD 10/87 TCT	Pb EP TOX. (EP Toxicity stds: Pb 5 mg/l) 3/85 RFW	Pb EP TOX. 10/86 MDH	As EP TOX. (As 5 mg/l) 10/86 MDH	Cd EP TOX. (Cd 1 mg/l) 10/86 MDH	pH 5/84 IHL	pH 8/84 Serco	pH 10/86 MDH	sulfate 5/84 IHL	sulfate 8/84 Serco	sulfate 3/85 RFW	sulfate 10/86 MDH	sulfate 10/87 TCT
RFW12 (s)			63700				3.74									6.3		
RFW13 (s)			732				14.00 *									0.5		
RFW14 (s)			1060				0.54									0.4		
RFW15 (s)			38900				132 *									6.1		
SES1 0-1'				4860														
2-3.5'				3120														
4.5-6'				25														
SES2 0-1'				19400														
2-3.5'				2180														
9.5-11'				23														
SES3 0-1.5'				1890														
2-3.5'				2620														
9-11'				13														
SES4 0-2'				2800														
9.5-11'				18														
MnDOT1 2-3'					79			0.00	0.00	0.00			7.2				170	
MnDOT2 10-11'					7.9			0.00	0.00	0.00			7.6				6300	
15-16'					6.4			0.00	0.00	0.00			8.1				300	
19-20'					5.8			0.00	0.00	0.00			8.5				87	
MnDOT3 2-3'					6			0.00	0.00	0.00			5.3				430	
MnDOT4 2-3'					290			0.00	0.00	0.00			8.0				54	
MnDOT5 (s)					15000			26.00 *	0.00	0.16			7.8				220	
(s)-2'					16000			20.00 *	0.00	0.21			7.8				380	
MnDOT6 10-11'					6			0.00	0.00	0.00			4.5				5800	
15-16'					6.4			0.00	0.00	0.00			3.3				5800	
19-20'					8.8			0.00	0.00	0.21			7.2				7700	
MONITORING WELLS (1-3 installed by SEC;4-6 by MnDOT)																		
MW1 water	1	1	0.15		1.6	0					6.6	6.6	7.3	320	72	171	230	109
MW2 water	3	0.9	0.39		180	0					6.6	6.3	7.2	2240	123	3014	2700	3340
MW3 water	1	0	1.39		8.3	0					6.4	6.1	7.1	22	22	854	1400	345
MW4 water					25	0							7.7				420	455
MW5 water					3.9	dry							7.7				27	dry
MW6 water					190	0							7.0				990	1270
	<.....unfiltered.....>					filtered												

* result exceeding EP toxicity standard above
+(s)=surface sample; ' indicates depth in feet; other entries in parenthesies are depth codes from report; actual depths not indicated
IH or IHL = Industrial Health Laboratory (Jackson, TN), consultant to Union Scrap
SEC = Subterranean Exploration Co., subcontractor to IHL
Serco = Serco Laboratories, subcontractor to IHL
SES = Soil Exploration Services (consultant to Soo Line RR)
RFW = Roy F. Weston (EPA contractor)
MnDOT = Minnesota Dept. of Transportation
MDH = Minnesota Dept. of Health (provider of lab services to MnDOT)
TCT = Twin City Testing (consultant to Soo Line RR and MnDOT)

Site/Depth+	<.....TOTAL LEAD.....> 9/82 IHL	12/83 IHL	5/84 IHL	3/85 RFW	10/86 MDH	Pb std. 5 mg/l <.....Pb EP TOXICITY.....> 11/82 IHL	12/83 IHL	5/84 IHL	3/85 RFW	10/86 MDH	As std. 5 mg/l <..As EP TOXICITY..> 12/83 IHL	5/84 IHL	10/86 MDH	Cd std. 1 mg/l <..Cd EP TOXICITY..> 12/83 IHL	5/84 IHL	10/86 MDH	<.....pH.....> 12/83 IHL	5/84 IHL	10/86 MDH
(B)			14					0.30				0.00			0.00			6.7	
(C)			17					0.40				0.00			0.00			6.1	
IH33	107	98				1.67	0.34				0.00			0.00			6.5		
IH34	223	298				3.59	4.25				3.50			0.59			5.4		
IH35	339	568				1.27	2.27				1.29			0.43			4.9		
IH36	39	45				0.04	0.05				0.00			0.00			5.3		
SEC1 (1)			350					2.00				0.03			0.00			6.0	
(2)			42					2.00				0.02			0.00			6.1	
(3)			21					1.40				0.00			0.01			5.9	
(4)			10					0.60				0.00			0.00			6.3	
(5)			8					0.80				0.80			0.10			6.7	
(6)			10					0.50				0.00			0.00			6.0	
(7)			4					0.30				0.02			0.01			5.8	
(8)			6					0.00				0.00			0.00			6.0	
(9)			3					0.00				0.00			0.01			6.0	
SEC4 (1)			42					2.50				0.01			0.09			6.0	
(2)			20					2.00				0.06			0.10			5.8	
(3)			475					6.50 *				0.09			1.33 *			6.1	
(4)			10					0.90				0.00			0.80			5.9	
(5)			17.5					4.80				0.03			0.76			6.1	
(6)			11					0.60				0.90			1.45 *			6.9	
(7)			5					2.10				0.97			1.23 *			6.1	
(8)			7.1					0.30				0.09			0.09			7.1	
(9)			5.3					0.20				0.00			0.00			6.8	
SEC5 (1)			40					0.40				0.00			0.01			6.2	
(2)			2					0.50				0.00			0.00			6.0	
(3)			12.5					1.90				0.09			0.31			6.0	
(4)			2.5					0.50				0.02			0.11			5.2	
(5)			9					0.90				0.00			0.00			6.0	
(6)			15					1.30				0.00			0.00			6.0	
(7)			5					0.80				0.00			0.00			5.9	
(8)			8					1.00				0.01			0.10			6.0	
(9)																			
SEC6 (1)			652					1.60				0.00			1.23 *			6.0	
(2)			15.4					0.90				0.00			0.90			5.9	
(3)			17					0.10				0.00			0.00			6.7	
(4)			50					0.90				0.01			0.65			6.8	
(5)			1.3					0.10				0.00			0.00			6.2	
(6)			0.7					0.00				0.00			0.00			6.1	
(7)			0.2					0.00				0.00			0.00			6.0	
(8)			0.3					0.00				0.00			0.00			5.9	
(9)			0.4					0.00				0.00			0.00			6.8	
SEC7 (1)			250					1.10				0.30			0.24			6.9	
(2)			41.5					0.50				0.00			0.11			6.5	
(3)			60					1.30				0.00			0.05			6.5	
(4)			10					0.90				0.00			0.10			7.1	
(5)			0.5					0.10				0.00			0.00			6.7	
(6)			6.3					0.30				0.00			0.00			6.5	
(7)			4					0.00				0.00			0.00			6.3	
(8)			8					0.10				0.00			0.00			6.1	
(9)			9					0.00				0.00			0.00			6.2	

Site/Depth+	TOTAL LEAD 9/82 IHL	TOTAL LEAD 12/83 IHL	TOTAL LEAD 5/84 IHL	TOTAL LEAD 3/85 RFW	TOTAL LEAD 10/86 MDH	Pb EP TOXICITY (Pb std. 5 mg/l) 11/82 IHL	Pb EP TOXICITY 12/83 IHL	Pb EP TOXICITY 5/84 IHL	Pb EP TOXICITY 3/85 RFW	Pb EP TOXICITY 10/86 MDH	As EP TOXICITY (As std. 5 mg/l) 12/83 IHL	As EP TOXICITY 5/84 IHL	As EP TOXICITY 10/86 MDH	Cd EP TOXICITY (Cd std. 1 mg/l) 12/83 IHL	Cd EP TOXICITY 5/84 IHL	Cd EP TOXICITY 10/86 MDH	pH 12/83 IHL	pH 5/84 IHL	pH 10/86 MDH
BORINGS & SURFACE SAMPLES																			
IH 1	535	598				1.31	1.78				0.02			0.00			6.3		
IH 2	9	17				0.00	0.02				0.00			0.00			6.1		
IH 3 (s)	582	763				0.04	0.04				0.00			0.00			6.2		
(A)			40.4					0.30				0.00			0.00			6.5	
(B)			170					1.90				0.40			2.33 *			6.4	
(C)			160					1.70				1.40			1.33 *			6.1	
IH 4	312	298				2.30	0.98				0.02			0.01			5.9		
IH 5 (s)	605	674				0.04	0.05				0.00			0.00			6.4		
(A)			590					2.30				2.40			1.55 *			5.6	
(B)			610					1.90				1.70			0.52			6.7	
(C)			660					1.70				0.90			0.10			5.8	
IH 6	95	102				0.50	0.49				0.00			0.00			6.4		
IH 7	14	123				2.60	2.06				1.34			0.78			7.1		
IH 8	53	167				0.30	0.34				0.02			0.10			6.0		
IH 9	96	87				0.04	0.04				0.00			0.00			6.1		
IH10 (s)	838	1098				0.27	0.25				0.01			0.26			6.3		
(A)			413					1.00				1.00			0.00			6.4	
(B)			9					0.90				0.70			0.10			6.3	
(C)			47					0.10				0.00			0.00			6.1	
IH11	324	489				1.60	1.90				0.30			0.33			7.1		
IH12	228	456				3.51	4.21				1.45			0.74			6.0		
IH13	259	323				0.70	0.89				0.78			0.02			6.1		
IH14	424	348				2.91	0.90				0.23			0.00			6.3		
IH15	13	267				0.00	1.29				0.76			0.00			5.1		
IH16	30	39				0.04	0.04				0.00			0.00			5.3		
IH17	10	9				0.10	0.00				0.00			0.00			6.1		
IH18	281	65				0.16	0.12				0.20			0.00			6.4		
IH19	411	567				0.04	0.04				0.45			0.20			6.1		
IH20	68	567				0.76	3.45				2.34			0.76			5.4		
IH21 (s)	751	1198				1.93	2.12				0.98			0.45			6.3		
(A)			229					2.30				0.00			0.00			6.0	
(B)			18					0.90				0.00			0.45			5.9	
(C)			250					1.50				0.00			0.00			6.3	
IH22	58	47				1.45	1.33				0.45			0.04			6.7		
IH23	237	256				4.01	0.90				0.34			0.00			6.0		
IH24	9	9				0.01	0.09				0.04			0.00			6.1		
IH25 (s)	988	1987				1.56	3.34				2.73			0.76			5.9		
(A)			9					0.10				0.00			0.78			6.4	
(B)			10.3					0.80				0.00			0.37			6.1	
(C)			22					0.00				0.00			0.01			6.0	
IH26	333	345				1.50	1.50				0.98			0.54			6.3		
IH27	347	367				2.53	2.85				2.47			0.89			6.5		
IH28 (s)	956	900				0.51	0.50				0.08			0.00			6.1		
(A)			218					0.40				0.00			0.00			6.6	
(B)			363					1.90				0.00			0.00			6.5	
(C)			2.4					0.10				0.00			0.00			7.3	
IH29	54	54				0.48	0.69				0.00			0.00			6.2		
IH30	65	69				1.49	1.56				1.23			0.22			5.7		
IH31	411	34				0.36	0.30				0.34			0.20			6.1		
IH32 (s)	615	115				0.45	0.25				0.00			0.00			6.1		
(A)			38					1.40				0.00			0.00			6.5	