

## Section 5.0 Performance Assessment

### 5.1 Performance Data

#### 5.1.1 Analytical Methods Employed

Standard analytical procedures for data collected in the laboratory are provided in Appendices D-1 through D-19. EDTA in all sampling results is reported as Na<sub>2</sub>EDTA and as EDTA. For EDTA, analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is:  $(292.24\text{g/mol EDTA})/(336.21\text{g/mol Na}_2\text{EDTA}) = 0.8692$ . On a molar basis, there is no difference: one mole of disodium EDTA is equivalent to one mole of EDTA.

### 5.2 Data Assessment

#### 5.2.1 Preliminary Site Characterization

At the beginning of the demonstration, preliminary soil characterization samples were collected from both Site C and Site 129-3 to map the extent and location of lead contamination in the soil at the proposed demonstration sites (Figures 5-1 and 5-2). Each demonstration site was divided into 36 grids. A soil sample was collected from each of the 36 grids and the samples were analyzed for pH and total lead (Tables 5-1 and 5-2). These results indicate that the soil at both sites was uniformly alkaline (pH approximately 8.2) down to the depth sampled (12 inches).

The lead concentrations in the soil at both sites varied extensively. At Site C, the lead concentration averaged 2,610 mg/kg at the 0- to 6-inch depth and ranged from 1,240 mg/kg to 8,170 mg/kg. The average lead concentration at the 6- to 12-inch depth was 2,850 mg/kg and ranged between 1,050 mg/kg to 7,150 mg/kg. The lead concentrations at Site C are consistent with those of a site with a moderate level of lead contamination. Based on the state of development of the technology at the onset of the demonstration, the soil contained lead concentrations which were reported to be just within the practical and economic limits of the technology. However, results of this demonstration showed that remediation of soil at these lead concentrations under the conditions of the site was not technologically and economically practical.

Much of the lead in the soil at Site 129-3 was present at concentrations below the regulatory residential use target of 400 mg/kg. The lead concentrations averaged 329 mg/kg at the 0- to 6-inch depth and ranged from 6 mg/kg to 1,730 mg/kg; the average lead concentration at the 6- to 12-inch depth was 249 mg/kg, with a range of 3 mg/kg to 918 mg/kg (Table 5-2). For demonstration purposes, the lower lead concentrations at this site would be similar to those which would be encountered near the end of a remediation effort. Demonstrating remediation at

<b>Grid #</b>	<b>31</b>	<b>32</b>	<b>33</b>	<b>34</b>	<b>35</b>	<b>36</b>
<b>0-6 in.</b>	1,840	1,780	2,980	4,200	3,010	1,820
<b>6-12 in.</b>	2,820	2,100	1,300	2,620	4,050	1,580
<b>Grid #</b>	<b>25</b>	<b>26</b>	<b>27</b>	<b>28</b>	<b>29</b>	<b>30</b>
<b>0-6 in.</b>	1,760	2,340	1,240	3,490	2,400	2,010
<b>6-12 in.</b>	3,550	3,630	1,500	4,800	2,550	1,200
<b>Grid #</b>	<b>19</b>	<b>20</b>	<b>21</b>	<b>22</b>	<b>23</b>	<b>24</b>
<b>0-6 in.</b>	2,030	2,870	8,170	6,340	2,360	2,730
<b>6-12 in.</b>	4,270	4,540	1,050	7,150	1,990	2,160
<b>Grid #</b>	<b>13</b>	<b>14</b>	<b>15</b>	<b>16</b>	<b>17</b>	<b>18</b>
<b>0-6 in.</b>	1,340	2,510	1,810	2,390	3,000	2,670
<b>6-12 in.</b>	2,570	4,060	2,030	3,640	2,430	2,620
<b>Grid #</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>
<b>0-6 in.</b>	1,800	2,200	2,410	1,940	1,720	2,130
<b>6-12 in.</b>	2,360	2,820	2,870	2,110	2,000	2,800
<b>Grid #</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>0-6 in.</b>	2,690	3,650	2,420	1,410	1,590	3,090
<b>6-12 in.</b>	1,100	5,320	4,670	1,680	2,000	2,710

**Figure 5-1**  
**Map of Initial Lead Contamination (mg/kg) at Site C**

<b>Grid #</b>	<b>31</b>	<b>32</b>	<b>33</b>	<b>34</b>	<b>35</b>	<b>36</b>
<b>0-6 in.</b>	353	682	130	170	490	973
<b>6-12 in.</b>	784	802	20	237	396	6
<b>Grid #</b>	<b>25</b>	<b>26</b>	<b>27</b>	<b>28</b>	<b>29</b>	<b>30</b>
<b>0-6 in.</b>	1,730	349	311	41	117	300
<b>6-12 in.</b>	249	549	45	17	133	300
<b>Grid #</b>	<b>19</b>	<b>20</b>	<b>21</b>	<b>22</b>	<b>23</b>	<b>24</b>
<b>0-6 in.</b>	1,050	221	356	232	365	117
<b>6-12 in.</b>	301	344	495	13	521	516
<b>Grid #</b>	<b>13</b>	<b>14</b>	<b>15</b>	<b>16</b>	<b>17</b>	<b>18</b>
<b>0-6 in.</b>	56	101	402	98	44	149
<b>6-12 in.</b>	41	289	377	23	218	299
<b>Grid #</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>
<b>0-6 in.</b>	705	6	169	126	41	85
<b>6-12 in.</b>	122	3	3	194	57	20
<b>Grid #</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>0-6 in.</b>	206	206	913	178	188	188
<b>6-12 in.</b>	151	196	918	321	224	133

**Figure 5-2**  
**Map of Initial Lead Contamination (mg/kg) at Site 129-3**

**Table 5-1**  
**Initial Soil pH and Total Lead at Site C**

Grid No.	pH		Pb, mg/kg	
	Depth, inches		Depth, inches	
	0-6	6-12	0-6	6-12
1	8.1	8.3	2,690	1,100
2	8.3	8.4	3,650	5,320
3	8.0	8.1	2,420	4,670
4	8.4	8.5	1,410	1,680
5	8.3	8.0	1,590	2,000
6	8.6	8.0	3,090	2,710
7	8.5	8.4	1,800	2,360
8	8.1	8.3	2,200	2,820
9	8.3	8.5	2,410	2,870
10	8.7	8.0	1,940	2,110
11	8.3	8.1	1,720	2,000
12	8.0	8.4	2,130	2,800
13	8.3	8.3	1,340	2,570
14	8.3	8.7	2,510	4,060
15	8.3	8.6	1,810	2,030
16	8.2	8.2	2,390	3,640
17	8.5	8.3	3,000	2,430
18	8.4	8.5	2,670	2,620
19	8.1	7.9	2,030	4,270
20	8.3	8.0	2,870	4,540
21	8.6	8.9	8,170	1,050
22	8.7	8.4	6,340	7,150
23	8.3	8.1	2,360	1,990
24	8.2	8.4	2,730	2,160
25	8.5	8.3	1,760	3,550
26	8.3	8.5	2,340	3,630
27	8.3	8.6	1,240	1,500
28	8.4	8.3	3,490	4,800
29	8.3	8.2	2,400	2,550
30	8.6	8.3	2,010	1,200
31	8.7	8.4	1,840	2,820
32	8.5	8.0	1,780	2,100
33	8.5	8.0	2,980	1,300
34	8.7	8.3	4,200	2,620
35	8.7	8.2	3,010	4,050
36	8.7	8.1	1,820	1,580
<b>Mean</b>	<b>8.2</b>	<b>8.1</b>	<b>2,610</b>	<b>2,850</b>
<b>Std. Dev.</b>	<b>0.3</b>	<b>0.4</b>	<b>1,340</b>	<b>1,340</b>

**Table 5-2**  
**Initial Soil pH and Total Lead at Site 129-3**

Grid No.	pH		Pb, mg/kg	
	Depth, inches		Depth, inches	
	0-6	6-12	0-6	6-12
1	8.6	8.1	206	151
2	8.3	8.2	206	196
3	8.0	8.1	913	918
4	8.4	8.6	178	321
5	8.3	8.1	188	224
6	8.1	8.0	188	133
7	8.5	8.4	705	122
8	8.1	8.3	6	3
9	8.2	8.5	169	3
10	8.8	8.1	126	194
11	8.4	8.1	41	57
12	8.1	8.2	85	20
13	8.2	8.3	56	41
14	8.2	8.9	101	289
15	8.2	8.3	402	377
16	8.2	8.2	98	23
17	8.5	8.8	44	218
18	8.4	8.5	149	299
19	8.1	8.1	1,050	301
20	8.3	8.0	221	344
21	8.6	8.9	356	495
22	8.7	8.4	232	13
23	8.6	8.1	365	521
24	8.2	8.4	117	516
25	8.5	8.3	1,730	249
26	8.2	8.5	349	549
27	8.3	8.6	311	45
28	8.4	8.3	41	17
29	8.3	8.2	117	133
30	8.6	8.1	300	300
31	8.7	8.4	353	784
32	8.6	8.0	682	802
33	8.5	8.0	130	20
34	8.7	8.3	170	237
35	8.7	8.2	490	396
36	8.8	8.1	973	6
<b>Mean</b>	<b>8.2</b>	<b>8.3</b>	<b>329</b>	<b>249</b>
<b>Std. Dev.</b>	<b>0.3</b>	<b>0.4</b>	<b>358</b>	<b>244</b>

low-end concentrations was an important aspect of the phytoextraction demonstration, since removal of lead by plants can vary with soil concentration.<sup>Ref. 24</sup>

Lead concentrations across the plots were analyzed statistically using Model 1 (Section 4.3.2.3.1) to test for a difference in site lead concentrations and for variability across grid rows and grid columns within each site. Since site differences were significant, the sites were analyzed separately for row and column variability (Appendix E, Table E-1). The lead concentrations in rows and columns for both Site C and Site 129-3 were not significantly different because the variability in the data was too great. If the variability of the grids within each row and column is large, it would give a large error term for testing for significance. A large error term makes detecting differences in row and column variability more difficult. The large standard deviations for both sites (Tables 5-1 and 5-2), which indicates a large amount of variability in lead concentrations, suggested that differences in row and column variability were not detected due to a large error term in the statistical analysis for both sites.

After selecting the demonstration sites, the soils from each area were further analyzed to determine fertilization requirements, various chemical and physical properties, and COCs (Table 5-3). The alkaline soil pH (pH >8.0) at both sites is the principle factor in the naturally low solubility and plant availability of lead. The sandy texture, low cation exchange capacity, and low organic matter of the soils make it difficult for nutrients to be retained. Most of the soil fertility parameters at Site C were low. Overall, soil fertility parameters at Site 129-3 were adequate for crop growth. Low extractable P levels at Site C indicated a potential for P deficiency in crops grown on this plot. Levels of P at Site 129-3 appeared adequate for good crop growth.

The iron levels at Site C were high which usually indicates a significant level of iron hydroxides and oxides in the soil mineralogy at the site. Although the soil class at Site C (Mollic Hapludalf) is not usually characterized by a high iron oxide content, the concentration reported here could reasonably be found in this soil. The soil survey also indicated aluminum oxides in the subsurface B horizon mineralogy, as indicated by exchangeable Al in the soil analysis. The specific mineralogy of the soil at Site 129-3 is normally characterized by a significant iron oxide content and aluminum oxides may also be present in quantities that would dominate the mineralogy.

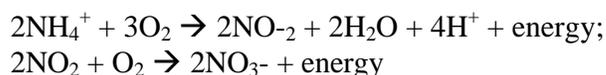
Iron and aluminum minerals play a major role in primary sorption reactions in the soil, particularly those involving multivalent cations, such as antimony and thallium, and organic compounds such as EDTA. In addition, iron will effectively compete with lead for complexation by EDTA. High concentrations of iron will result in displacement of lead from the EDTA complex in the neutral to acidic soil pH range, with subsequent re-precipitation of lead as insoluble compounds in the soil. Analysis of cation-EDTA equilibria reactions indicate that EDTA will eventually predominate as the iron (III) chelate in acidic to neutral soils, and as the calcium chelate in alkaline soils. The abundance of calcium in the soil at Site C and the neutral to slightly alkaline soil pH would support formation of both calcium and iron complexes of EDTA.

## 5.2.2 Soil Sampling 1998 - Corn Crop

### 5.2.2.1 Pre-Amendment Soil Sampling - 1998 Corn Crop

Pre-amendment plant and soil sampling for the corn crop at Sites C and 129-3 were completed the week of July 20, 1998.

Soil samples were taken from Sites C and 129-3 immediately prior to adding the soil amendments to determine if any changes had occurred from the time the soil was initially sampled to the point at which the corn was ready for soil amendment addition. During this period, the soil pH at both sites decreased from approximately 8.2 (Tables 5-1 and 5-2) to pH 7.7 (Tables 5-4 and 5-5). Such decreases commonly occur in soils after fertilization and tilling due to the nitrification process. Tilling kills soil microbes and breaks up organic matter; decomposition of the microbes provides an ammonium source in addition to the ammonium ions from the added fertilizer. Nitrification (oxidation) of the ammonium ions to nitrate then provides the protons which are responsible for the decrease in pH. The reaction is as follows:



Organic acids are produced during decomposition of organic matter, which provides a secondary source of acidity. In addition, the sandy soils at TCAAP have a fairly low buffering capacity against change in pH and this has also contributed to the decrease in pH.

At both sites, the lead concentrations obtained prior to soil amendment addition varied significantly from the initial soil characterization. At Site C, the average lead concentration across all grids at the 0- to 12-inch depth was about 46% higher than the initial characterization (compare Tables 5-1 and 5-4). Just prior to soil amendment addition, the average lead concentration for Site C was 4,000 mg/kg and 3,830 mg/kg at the 0- to 12-inch and 12- to 24-inch depths, respectively. In contrast, the average lead concentrations at the 0- to 12-inch depth at Site 129-3 were 76% lower than the levels found during the initial characterization (compare Tables 5-2 and 5-5). The differences in lead concentrations were observed at both sites even though the samples were taken in close proximity to each other in the grids at each sampling. The differences in concentration were likely due to the non-uniform distribution of lead as a result of the random placement of the contaminants over a period of many years. Tilling during plot preparation and planting might also account for some of the variability. Information in the RI/FS indicates that lead-contaminated waste was disposed of over much of the demonstration plot area. The higher lead concentrations in the 12- to 24-inch depth could indicate a downward movement of lead deposited by surface disposal and burning of such lead-contaminated waste. More likely, however, the lead in the 12- to 24-inch zone was placed there over years of disposal activities, since historical data indicates lead is at 5 and 10 ft in the general area. Further, lead-contaminated soil from other areas of TCAAP may well have been dumped into the area of the 1962 Pit as fill soil after the original soil had been excavated during equipment decontamination activities.

An average of 2 mg/kg arsenic was detected in the Site C soil (Table 5-4). Since the arsenic content in a typical non-contaminated glacial till sandy soil may be 6 mg/kg and range between

2-12 mg/kg,<sup>Ref. 24</sup> the concentrations reported may be of natural origin and not the result of disposal practices.

Although beryllium is listed as a COC for Site C, concentrations of the element in the soil were <0.15 mg/kg (Table 5-4), less than the 0.7 mg/kg figure reported in the Record of Decision (ROD). At these concentrations, the element does not appear to be cause for concern. The normal range of concentration for beryllium in uncontaminated soils is from <1 to 15 mg/kg and averages 1.6 mg/kg.<sup>Ref. 25</sup> Beryllium occurs most often in a divalent oxidic-bonded form. In the alkaline environment at TCAAP, it would likely be present as a complex carbonate anion. Beryllium is usually immobile in soil and does not leach readily. In the anion form, it is not easily taken up and concentrated in plants. However, relatively low concentrations of beryllium in a soluble form, in the range of 2-16 mg/kg ( $10^{-3}$  to  $10^{-4}$  M), are highly toxic to plants. Symptoms of toxicity include inhibited seed germination and inhibition of P absorption. When there is appreciable uptake, toxicity is manifested in mature leaves at a concentration range from 10 to 50 mg/kg.

Manganese concentrations were considerably less than the concentration of 2,500 mg/kg at Site C and 850 mg/kg at Site 129-3, as reported in the ROD (Tables 5-4 and 5-5). Concentrations were fairly uniform with soil depth across the field at both sites, averaging 297 mg/kg at Site C and 314 mg/kg at Site 129-3. It is difficult to discern if these concentrations are indigenous levels in the soil or a result of contamination. An average manganese concentration for soils that is usually cited is 600 ppm.<sup>Ref. 26</sup>

Antimony concentrations in the pre-amended soil at both sites were below the detection limit of the analytical method employed (Tables 5-4 and 5-5). Apparently, the concentrations reported in the ROD of 67 mg/kg at Site C and 22 mg/kg at Site 129-3 do not accurately reflect actual antimony concentrations across the demonstration areas. Antimony may be part of lead bullet composition and manufacture and antimony would be a likely soil contaminant at the site. However, the values reported in the ROD were based on a limited number of samples. Concentrations of antimony in the original waste may have been very low and the area of deposition limited, which may account for the present low concentrations. A typical concentration range for antimony in sandy soils is 0.05-1.33 mg/kg, with a mean of 0.19 mg/kg,<sup>Ref. 27</sup> so the low concentrations may be the natural concentrations in these soils. However, the mobility of antimony in sandy soil can be relatively high, particularly if the element is in association with Fe hydroxides,<sup>Ref. 27</sup> and the iron hydrous oxide content in these type soils may be appreciable.<sup>Ref. 28</sup> Thus, movement out of the surface soil to lower depths could account for the low antimony concentrations observed in these samples. In addition, the samples for the ROD were taken in the summer of 1990. The time differential between sampling for the ROD and subsequently occurring events such as tillage, planting, and irrigation operations, as well as adequate rainfall, may have caused the levels of antimony observed here.

**Table 5-3**  
**Characterization of Bulk Soil from Sites C and 129-3**

	Site C	Site 129-3
Texture	various	sand
pH	8.2	8.0
CEC, cmol/kg	4.9	2.4
Field capacity, %	12	10
Organic carbon, %	0.6	0.4
TKN, %	0.008	0.007
Total Pb, mg/kg	3,200	400
Exchangeable Al, mg/kg	7	5
"    Ca    "	1,447	1,120
"    Mg    "	88	116
"    K    "	51	58
Extractable P, mg/kg	16	38
"    Fe    "	21	8
"    Mn    "	16	3
Total As, mg/kg	<4.5	<4.5
"    Be    "	<0.6	<0.6
"    Mn    "	260	250
"    Sb    "	<40	<40
"    Tl    "	<50	<50
Plant-available Pb, mg/kg	12	4

**Table 5-4**  
**Soil pH, Water-Soluble Pb, and Contaminants of Concern at Site C**  
**Prior to Adding Soil Amendments to 1998 Corn**

Grid No.	pH		Water-Soluble Pb, mg/kg		Pb <sup>1</sup> , mg/kg		As <sup>1,2</sup> , mg/kg		Be <sup>1,2</sup> , mg/kg		Mn <sup>1,2</sup> , mg/kg		Sb <sup>1,2</sup> , mg/kg		Tl <sup>1,2</sup> , mg/kg	
	Depth, inches															
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
4	7.3	7.3	1.9	<0.5 <sup>3</sup>	2,110	2,510	1.5	1.5	<0.15 <sup>3</sup>	<0.15 <sup>3</sup>	324	275	<40 <sup>3</sup>	<40 <sup>3</sup>	<50 <sup>3</sup>	<50 <sup>3</sup>
8	7.4	7.6	1.1	0.7	12,700	3,310	1.8	1.0	<0.15	<0.15	205	252	<40	<40	<50	<50
12	7.9	7.9	0.7	<0.5	3,210	1,280	2.4	1.7	<0.15	<0.15	541	264	<40	<40	213	<50
16	8.0	8.0	1.4	0.8	5,470	7,120	2.1	5.4	<0.15	<0.15	261	207	<40	<40	<50	<50
20	7.4	7.5	1.7	1.6	3,390	4,060	1.8	1.4	<0.15	<0.15	220	205	<40	<40	73	<50
24	7.6	7.7	1.8	<0.5	2,330	266	2.1	1.6	<0.15	<0.15	240	222	<40	<40	<50	<50
28	8.0	7.9	<0.5 <sup>3</sup>	1.6	1,910	6,090	1.9	1.3	<0.15	<0.15	213	203	<40	<40	<50	<50
32	7.9	8.1	1.3	<0.5	2,400	6,320	1.8	1.7	<0.15	<0.15	252	898	<40	<40	<50	<50
36	8.1	7.8	0.6	1.6	2,470	3,530	2.3	1.5	<0.15	<0.15	365	198	<40	<40	<50	<50
<b>Mean</b>	<b>7.7</b>	<b>7.8</b>	<b>1.1</b>	<b>0.7</b>	<b>4,000</b>	<b>3,830</b>	<b>2.0</b>	<b>1.9</b>	<b>NA<sup>4</sup></b>	<b>NA</b>	<b>291</b>	<b>302</b>	<b>NA</b>	<b>NA</b>	<b>32</b>	<b>NA</b>
<b>Std. Dev.</b>	<b>0.3</b>	<b>0.3</b>	<b>0.6</b>	<b>0.7</b>	<b>3,440</b>	<b>2,330</b>	<b>0.3</b>	<b>1.3</b>	<b>NA</b>	<b>NA</b>	<b>108</b>	<b>225</b>	<b>NA</b>	<b>NA</b>	<b>72</b>	<b>NA</b>

- (1) Concentrations were determined by acid digestion.
- (2) Contaminant of Concern for this site.
- (3) Method Detection Limit.
- (4) NA = Not Applicable.

**Table 5-5**  
**Soil pH, Water-Soluble Pb, and Contaminants of Concern at Site 129-3**  
**Prior to Adding Soil Amendments to 1998 Corn**

Grid No.	pH		Water-Soluble Pb, mg/kg		Pb <sup>1</sup> , mg/kg		Mn <sup>1,2</sup> , mg/kg		Sb <sup>1,2</sup> , mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
4	7.0	7.3	0.6	0.5	21	191	226	254	<40 <sup>3</sup>	<40 <sup>3</sup>
8	7.4	7.8	1.0	0.4	55	2	368	1,190	<40	<40
12	7.7	7.8	0.4	<0.2 <sup>3</sup>	93	334	228	374	<40	<40
16	7.7	7.7	<0.2 <sup>3</sup>	0.4	54	10	203	197	<40	<40
20	8.0	8.0	0.3	<0.2	22	2	209	409	<40	<40
24	8.0	7.6	<0.2	<0.2	67	2	198	197	<40	<40
28	7.8	7.6	0.4	<0.2	230	35	206	288	<40	<40
32	8.0	8.0	<0.2	<0.2	28	2	188	178	<40	<40
36	8.0	8.0	0.5	<0.2	52	10	288	439	<40	<40
<b>Mean</b>	<b>7.7</b>	<b>7.7</b>	<b>0.4</b>	<b>&lt;0.1</b>	<b>69</b>	<b>65</b>	<b>235</b>	<b>392</b>	<b>&lt;40</b>	<b>&lt;40</b>
<b>Std. Dev.</b>	<b>0.3</b>	<b>0.2</b>	<b>0.4</b>	<b>0.2</b>	<b>65</b>	<b>118</b>	<b>58</b>	<b>315</b>	<b>NA<sup>4</sup></b>	<b>NA</b>

- (1) Concentrations were determined by acid digestion.
- (2) Contaminant of Concern for this site.
- (3) Method Detection Limit.
- (4) NA = Not Applicable.

Thallium occurred in soil at Site C in localized, isolated areas (Table 5-4). However, the extent of thallium contamination was not determined for every grid since only every fourth grid was sampled. Concentrations were highest in the top 12 inches of soil and, in some cases, greatly exceeded the cleanup level stipulated for Site C by the ROD. Concentrations in the 12- to 24-inch depth were less than the detection limit, which may indicate limited mobility and migration of the element in soil. The normal thallium concentration range is from 0.02 to 2.8 mg/kg in surface soils of the U.S.<sup>Ref. 29</sup> The element is highly associated with K and other basic cations and may be incorporated into soil minerals during weathering. If in a soluble form, it is readily mobilized and transported together with the alkaline metals.<sup>Ref. 30</sup> Thus, in soluble form, the element is readily leached from sandy soils, particularly in the presence of basic cations such as K and Ca. Thallium uptake by plants is greatly affected by the presence of K. Thallium can replace K in several enzyme systems with deleterious effects on plants.<sup>Refs. 31, 32</sup> Soil levels from 2.1 mg/kg to 8.5 mg/kg may adversely affect plants with severe damage occurring at the higher concentration.<sup>Ref. 32</sup> Toxicity is greatest in soils of low fertility. Thus, the conditions at Site C could be conducive to thallium toxicity in crops grown there. Since accumulation in plants seems to be a function of thallium concentration in soil, a significant accumulation in the crops grown at Site C could occur should plants remain sufficiently viable for active uptake of thallium to occur.

#### **5.2.2.2 Post-Amendment Soil Sampling - 1998 Corn Crop**

Soil amendment additions (acidifier and chelate) to corn at Site C and Site 129-3 were completed the week of July 20, 1998, after pre-amendment sampling. Soil amendment (acetic acid and EDTA) formulation, mixing, and application were done in cooperation with Lynn Sinness, Manager, ConAgra, Inc., 7632 Highway 101, Shakopee, Minnesota 55379, (612) 445-6570.

Soil amendment additions were as follows:

Acetic acid was applied to acidify the soil to a pH of 5.5 and a depth of two feet. The amount of acetic acid needed was calculated from buffer curves determined on bulk soil collected from the sites. The application rate of acetic acid at both Site C and at Site 129-3 was 4,018 pounds per plot. The acetic acid was hand-applied over a three-hour period at each site using a hose applicator connected to a 5,000-gallon tanker truck.

The EDTA was added to optimize the solubilization of lead in the first two feet of soil (root zone) with the application rate designed to provide an EDTA:lead molar ratio of 1:1, based on the lead soil concentrations found in the bulk soil samples (Table 5-3). The EDTA application rate at Site C was 6,750 pounds; the application rate at Site 129-3 was 850 pounds. The lower rate at 129-3 resulted from the lower average soil lead concentration at that site. Application was made with the equipment used for application of acetic acid. Application time was 5 hours at Site C and 3 hours at Site 129-3.

These loading rates were not considered excessive and were applied in a controlled manner. Far higher amounts of EDTA are released to the environment through essentially uncontrolled industrial processes every year. For example, one report documents the release of 60 tons of EDTA into the Ruhr River annually, while 1,080 tons or more of EDTA were released into the Rhine River over a 3-year period.<sup>Ref. 33</sup> Concentrations of EDTA in German rivers thus range up

to 60 µg/L. Concentrations in American rivers and tributaries are somewhat lower, averaging about 30 µg/L.<sup>Ref. 34</sup> Nonetheless, this represents significant input of EDTA, thus making EDTA one of the most abundant organic contaminants in natural waters of the U.S.

By July 27, 1998, the treated corn was bleached and dead. Stalks were collapsed and touching the ground at both sites. Untreated areas of the plots (a border row on each side of the plot) appeared to be in a normal growth state for corn plants and were upright and green. Appropriate care was used to obtain clean, soil-free plant samples from collapsed stalks.

To obtain post-amendment soil samples, the soil samples were taken three to four days after soil amendment application. These samples were obtained to determine the concentrations of EDTA and COCs in the soil and the effect of the application on soil pH.

After the addition of EDTA, the soil pH increased slightly at both sites (Tables 5-6 and 5-7). The initial drop in pH caused by the acetic acid was only temporary, as determined in the SFAAP greenhouse studies. The pH of the EDTA solution was approximately 7.5. The increase over indigenous soil pH may be due to solubilization, complexation, and concentration of calcium into the soil liquid phase by addition of EDTA to the soil.

Soil samples from half of the grids (every other grid) were analyzed for EDTA concentration. Concentrations were quite variable, but tended to be higher in the top 12 inches of soil (Tables 5-6 and 5-7). EDTA did not appear to move with the applied solution. Factors which may have influenced and reduced initial EDTA movement were: (1) a highly varied infiltration rate at both sites with reduced infiltration at the actual sampling point; (2) a wide range of soil types within the plot resulted in inaccurate estimation of soil field capacity, and additional solution would have been required for adequate wetting of the root zone; (3) adsorption of EDTA as a water-insoluble form on soil iron hydroxides and oxides and on the silt, clay, and organic matter fractions of the soil, as occurred in the SFAAP study. The silt and clay occurred as irregular, isolated pockets or “lenses” over the entire plot and this may have reduced EDTA mobility in some areas more than others. At Site C, particularly, the presence of a pan layer in part of the plot very close to the soil surface, within 6 inches in some areas, may have influenced depth of infiltration. As shown below in Tables 5-10 and 5-11 (see Section 5.2.3), a significant amount of EDTA was also removed from the soil by the plants.

Concentrations of water-soluble lead at Site C greatly increased after amendment application, averaging 455 mg/kg and 148 mg/kg for the 0- to 12-inch and 12- to 24-inch depths, respectively (Table 5-6). The large increase in water-soluble lead compared to the concentrations in the unamended soil provides an indication of treatment effectiveness in solubilizing lead in the soil. These concentrations were lower in the 12- to 24-inch depth, which coincided with the lower EDTA concentrations. The corresponding average concentrations of EDTA were 982 mg/kg and 323 mg/kg.

The variability in water-soluble lead concentrations among grids across the field was quite high at both depths, as indicated by the large standard deviations. The molar ratio of EDTA to water-soluble lead was approximately 1:1, which is similar to the ratio found for EDTA and lead in soil after amendment additions during the SFAAP greenhouse treatability study.<sup>Ref. 2</sup> The soils at Site C consist of an extreme range in texture (sand to clay), but encompass the soil types in the SFAAP study soils (i.e., silty clay, silt loam). Since the ratio of EDTA:Pb is fairly constant across these soil types, this finding may prove useful as a tool to predict the impact of chelate and acidifier additions on dissimilar soils. Average total lead concentrations across the field at Site C were very similar both before (Table 5-4) and after (Table 5-6) amendment addition, but levels within the same grid varied quite widely between the before and after samplings. Also, a change in total lead concentration did not always reflect a concomitant change in the concentrations of water-soluble lead.

A paired comparison t-test was used to test whether total soil lead had decreased after soil amendment addition and corn harvest for Site C (Model 2, Section 4.3.2.3.2). The same grids sampled before soil additions (Table 5-4) were used after corn harvest for the paired comparisons. Lead concentration differences before and after corn harvest were not significant at both the 0- to 12-inch depth (probability>T of 0.9320) and the 12- to 24-inch depth (probability>T of 0.3973), indicating that a decrease in lead concentration at Site C could not be detected. However, the large variability in lead concentrations observed in different samplings, as discussed in Section 5.2.2.1, precludes detecting differences in lead concentrations after one harvest.

At Site 129-3, average EDTA concentrations were 262 and 103 mg/kg for the 0- to 12-inch and 12- to 24-inch depths, respectively, and the corresponding water-soluble lead concentrations were 47 mg/kg and 20 mg/kg (Table 5-7). These concentrations represent a molar ratio of EDTA to lead of 3:1, as compared with the 1:1 ratio found at Site C. The reasons for this are unclear, but may be due to differences in the mineralogy at Site C. The presence of aluminum hydroxides at Site 129-3 would result in less adsorption of EDTA, with more in soluble form, as is observed here.

Results of a paired t-test (Model 2, Section 4.3.2.3.2) for Site 129-3 indicate that soil lead concentrations were not significantly changed by lead uptake in the corn at the 0- to 12-inch depth (probability>T of 0.3375) and the 12- to 24-inch depth (probability>T of 0.5350).

Arsenic concentrations at Site C were somewhat higher than the pre-amendment concentrations, but were within the statistical limits of the standard deviations of the pre- and post-amendment sampling (Tables 5-4 and 5-6). As with lead, there were isolated instances in localized areas where arsenic concentrations greatly exceeded the mean concentration. However, unlike lead which exists principally as the divalent cation (although a shift to the  $Pb^{4+}$  state may occur at higher pH, usually >10), arsenic may be present in several valence states, ranging from -3 to +5. This influences arsenic behavior in soil and availability to plants. The +3 and the +5 states exist under higher redox and pH conditions such as those at TCAAP. The highest oxidation state limits bioavailability. Thus, when assessing potential environmental effects, the total arsenic

**Table 5-6**

**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern at Site C After Soil Amendment Additions to 1998 Corn**

Grid No.	pH <sup>1</sup>		EDTA as Na <sub>2</sub> EDTA <sup>1</sup> , mg/kg		EDTA as EDTA <sup>1</sup> , mg/kg		Water-Soluble Pb, mg/kg		Pb <sup>2,3</sup> , mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	268	90	15,000	8,950
2	8.3	8.0	251	130	218	113	150	97	2,870	2,210
3	NS	NS	NS	NS	NS	NS	293	114	4,550	11,800
4	8.4	8.2	363	1,540	316	1,340	185	700	5,000	3,820
5	NS	NS	NS	NS	NS	NS	780	429	2,780	3,360
6	8.2	8.5	1,834	172	1,590	150	656	122	5,800	11,300
7	NS	NS	NS	NS	NS	NS	451	33	627	1,500
8	8.3	8.5	655	61	569	53	295	74	4,870	8,240
9	NS	NS	NS	NS	NS	NS	138	64	2,660	2,940
10	8.3	8.4	27	380	23	330	36	207	732	1,810
11	NS	NS	NS	NS	NS	NS	306	13	2,100	1,290
12	8.3	8.5	5,740	198	4,990	172	1,270	116	2,670	2,080
13	NS	NS	NS	NS	NS	NS	92	56	5,450	1,710
14	8.3	8.1	543	469	472	408	256	209	3,060	2,240
15	NS	NS	NS	NS	NS	NS	449	208	5,090	6,550
16	8.2	8.4	743	1,020	646	887	359	506	4,680	4,880
17	NS	NS	NS	NS	NS	NS	811	137	2,370	5,470
18	8.2	8.5	2,380	551	2,070	479	761	100	2,340	1,100
19	NS	NS	NS	NS	NS	NS	54	51	3,490	4,860
20	8.4	8.5	1,280	517	1,110	449	563	179	2,870	5,570
21	NS	NS	NS	NS	NS	NS	496	58	3,390	3,620
22	8.3	8.3	235	19	204	17	129	44	3,980	3,130
23	NS	NS	NS	NS	NS	NS	1,280	196	3,320	3,730
24	8.1	8.4	1,180	42	1,030	37	448	25	2,370	1,480
25	NS	NS	NS	NS	NS	NS	371	538	6,270	2,550
26	8.3	8.3	1,660	37	1,440	32	652	64	9,180	6,460
27	NS	NS	NS	NS	NS	NS	259	73	3,870	3,880
28	8.3	8.3	314	265	273	230	127	108	4,570	4,940
29	NS	NS	NS	NS	NS	NS	1,900	92	3,710	3,860
30	8.0	8.5	867	296	754	257	400	127	1,740	2,870
31	NS	NS	NS	NS	NS	NS	670	44	4,660	6,380
32	8.4	8.5	1,170	602	1,020	523	477	199	5,970	7,700
33	NS	NS	NS	NS	NS	NS	181	49	2,750	3,440
34	8.4	8.7	809	380	703	330	277	121	5,020	5,630
35	NS	NS	NS	NS	NS	NS	416	35	2,870	1,750
36	8.1	8.7	305	24	265	21	136	41	2,100	1,650
<b>Mean</b>	<b>8.3</b>	<b>8.4</b>	<b>1,130</b>	<b>372</b>	<b>982</b>	<b>323</b>	<b>455</b>	<b>148</b>	<b>4,020</b>	<b>4,300</b>
<b>Std. Dev.</b>	<b>0.1</b>	<b>0.2</b>	<b>1,310</b>	<b>392</b>	<b>1,140</b>	<b>341</b>	<b>388</b>	<b>156</b>	<b>2,520</b>	<b>2,730</b>

NOTE: Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-6 (Continued)**

**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern at Site C After Soil Amendment Additions to 1998 Corn**

Grid No.	As <sup>2,3</sup> , mg/kg		Be <sup>2,3</sup> , mg/kg		Mn <sup>2,3</sup> , mg/kg		Sb <sup>2,3</sup> , mg/kg		Tl <sup>2,3</sup> , mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	6.2	3.2	1.2	1.2	249	275	<40 <sup>5</sup>	<40 <sup>5</sup>	92	74
2	3.2	2.6	1.2	1.2	281	210	<40	<40	99	74
3	2.3	2.9	1.2	1.2	288	204	63	<40	<50 <sup>5</sup>	89
4	2.7	2.3	1.2	1.1	240	186	<40	<40	<50	<50 <sup>5</sup>
5	5.1	3.7	1.3	1.4	324	357	<40	20	123	106
6	3.9	3.8	1.3	1.2	283	287	<40	<40	106	94
7	2.2	1.9	1.2	1.2	231	202	<40	<40	<50	64
8	2.8	3.2	1.2	1.2	225	216	<40	<40	<50	71
9	2.4	9.9	1.1	1.1	187	209	<40	<40	63	74
10	1.9	2.0	1.1	1.1	174	194	<40	<40	56	61
11	11.8	16.3	1.5	1.6	550	826	<40	<40	241	470
12	3.7	3.3	1.2	1.3	361	278	<40	<40	115	102
13	2.4	2.6	1.1	1.2	198	251	<40	<40	<50	71
14	2.8	2.7	1.2	1.2	218	445	<40	<40	96	66
15	2.6	2.7	<0.5 <sup>5</sup>	<0.5 <sup>5</sup>	211	299	<40	<40	64	62
16	2.5	2.9	<0.5	<0.5	214	170	<40	<40	66	80
17	9.4	9.6	<0.5	<0.5	517	528	<40	<40	188	196
18	4.6	3.8	<0.5	<0.5	267	307	<40	<40	107	107
19	2.4	2.5	<0.5	<0.5	179	379	<40	<40	<50	53
20	2.2	3.3	<0.5	<0.5	182	215	<40	<40	<50	64
21	2.6	4.1	<0.5	<0.5	210	319	<40	<40	58	64
22	3.5	2.5	<0.5	<0.5	421	241	<40	<40	71	60
23	3.3	3.0	<0.5	<0.5	252	276	<40	<40	67	83
24	3.2	3.1	<0.5	<0.5	209	212	<40	<40	62	75
25	1.9	2.4	<0.5	<0.5	181	208	<40	<40	57	71
26	3.0	2.9	<0.5	<0.5	230	189	107	<40	64	61
27	2.3	2.4	<0.5	<0.5	238	513	<40	<40	51	57
28	2.6	2.2	<0.5	<0.5	337	151	<40	<40	58	<50
29	3.7	3.2	<0.5	<0.5	264	311	139	<40	64	<50
30	1.9	2.0	<0.5	<0.5	242	164	<40	<40	<50	<50
31	2.4	3.0	<0.5	<0.5	192	179	<40	<40	<50	<50
32	2.3	2.3	<0.5	<0.5	205	172	3.2	<40	<50	<50
33	2.1	1.8	<0.5	<0.5	233	196	<40	<40	<50	<50
34	2.2	2.6	<0.5	<0.5	181	206	<40	19.6	<50	<50
35	7.3	3.2	<0.5	<0.5	640	339	<40	<40	159	92
36	1.9	2.0	<0.5	<0.5	191	192	<40	<40	<50	<50
<b>Mean</b>	<b>3.4</b>	<b>3.6</b>	<b>0.5</b>	<b>0.5</b>	<b>267</b>	<b>275</b>	<b>8.6</b>	<b>1.1</b>	<b>59</b>	<b>59</b>
<b>Std. Dev.</b>	<b>2.2</b>	<b>2.8</b>	<b>0.6</b>	<b>0.6</b>	<b>108</b>	<b>132</b>	<b>30.2</b>	<b>4.6</b>	<b>59</b>	<b>85</b>

- (1) Half (18) of the grids were sampled for pH and EDTA analysis.
- (2) Concentrations were determined by acid digestion.
- (3) Contaminant of Concern for this site.
- (4) NS = Not sampled.
- (5) Method Detection Limit.

**Table 5-7**

**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern at Site 129-3 After Soil Amendment Additions to 1998 Corn**

Grid No.	pH <sup>1</sup>		EDTA as Na <sub>2</sub> EDTA <sup>1</sup> , mg/kg		EDTA as EDTA <sup>1</sup> , mg/kg		Water-Soluble Pb, mg/kg		Pb <sup>2,3</sup> , mg/kg		Mn <sup>2,3</sup> , mg/kg		Sb <sup>2,3</sup> , mg/kg	
	Depth, inches													
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	29	44	233	265	222	258	<40 <sup>5</sup>	<40 <sup>5</sup>
2	8.5	8.6	237	89	206	77	96	44	301	258	229	223	<40	<40
3	NS	NS	NS	NS	NS	NS	121	61	305	230	281	216	<40	<40
4	8.6	8.4	296	62	257	54	132	39	363	403	227	191	<40	<40
5	NS	NS	NS	NS	NS	NS	43	11	161	123	281	324	<40	<40
6	8.2	8.6	296	38	257	33	23	4	114	57	244	208	<40	<40
7	NS	NS	NS	NS	NS	NS	15	11	49	57	209	196	<40	<40
8	8.5	8.9	341	319	296	277	38	17	88	78	257	689	<40	<40
9	NS	NS	NS	NS	NS	NS	45	14	99	65	262	217	<40	<40
10	8.7	8.7	73	18	63	16	3	<1.0 <sup>5</sup>	30	23	245	274	<40	<40
11	NS	NS	NS	NS	NS	NS	3	<1.0	32	26	276	241	<40	<40
12	8.4	8.6	69	36	60	31	2	<1.0	25	17	226	204	<40	<40
13	NS	NS	NS	NS	NS	NS	3	6	29	32	224	220	<40	<40
14	8.4	8.7	346	246	301	214	30	21	89	140	236	330	<40	<40
15	NS	NS	NS	NS	NS	NS	49	25	361	140	272	285	<40	<40
16	8.5	8.3	966	69	840	60	35	2	83	36	297	307	<40	<40
17	NS	NS	NS	NS	NS	NS	6	3	36	104	286	279	<40	<40
18	8.1	8.2	451	282	392	245	47	12	105	52	278	244	<40	<40
19	NS	NS	NS	NS	NS	NS	63	54	376	447	228	225	<40	<40
20	8.6	8.6	70	31	61	27	34	14	226	143	183	277	<40	<40
21	NS	NS	NS	NS	NS	NS	38	2	74	32	230	304	<40	<40
22	8.2	8.7	16	5	14	4	2	<1.0	37	42	255	322	<40	<40
23	NS	NS	NS	NS	NS	NS	11	9	45	42	238	244	<40	<40
24	8.4	8.6	321	130	279	113	15	11	54	46	229	268	<40	<40
25	NS	NS	NS	NS	NS	NS	210	116	795	600	317	265	<40	73

**Table 5-7 (Continued)**

**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern at Site 129-3  
After Soil Amendment Additions to 1998 Corn**

Grid No.	pH <sup>1</sup>		EDTA as Na <sub>2</sub> EDTA <sup>1</sup> , mg/kg		EDTA as EDTA <sup>1</sup> , mg/kg		Water-Soluble Pb, mg/kg		Pb <sup>2,3</sup> , mg/kg		Mn <sup>2,3</sup> , mg/kg		Sb <sup>2,3</sup> , mg/kg	
	Depth, inches													
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
26	8.6	8.7	672	166	584	144	227	65	563	246	231	265	<40	<40
27	NS	NS	NS	NS	NS	NS	102	44	540	235	189	249	<40	<40
28	8.5	8.4	116	100	101	87	12	11	35	46	209	210	<40	<40
29	NS	NS	NS	NS	NS	NS	22	7	84	40	228	215	<40	<40
30	8.4	8.5	125	182	109	158	5	14	33	49	272	280	<40	<40
31	NS	NS	NS	NS	NS	NS	23	18	41	48	189	209	<40	<40
32	8.8	8.7	561	200	488	174	32	19	83	62	240	212	<40	<40
33	NS	NS	NS	NS	NS	NS	31	5	117	49	279	231	<40	<40
34	8.4	8.6	43	8	37	7	25	15	171	211	216	221	<40	<40
35	NS	NS	NS	NS	NS	NS	106	12	2,130	144	269	216	<40	<40
36	8.4	8.7	429	139	373	121	25	8	135	40	255	215	<40	<40
<b>Mean</b>	<b>8.5</b>	<b>8.6</b>	<b>302</b>	<b>118</b>	<b>262</b>	<b>103</b>	<b>47</b>	<b>20</b>	<b>223</b>	<b>128</b>	<b>245</b>	<b>259</b>	<b>&lt;40</b>	<b>&lt;40</b>
<b>Std. Dev.</b>	<b>0.2</b>	<b>0.2</b>	<b>250</b>	<b>97</b>	<b>217</b>	<b>84</b>	<b>54</b>	<b>24</b>	<b>372</b>	<b>134</b>	<b>32</b>	<b>83</b>	<b>NA<sup>6</sup></b>	<b>NA<sup>6</sup></b>

- (1) Half (18) of the grids were sampled for pH and EDTA analysis.
- (2) Concentrations were determined by acid digestion.
- (3) Contaminant of Concern for this site.
- (4) NS = Not Sampled.
- (5) Method Detection Limit.
- (6) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

content of the soil, as well as the chemical form of arsenic, should be considered. However, a determination of arsenic speciation was beyond the scope of this study and, in any event, arsenic concentrations were so low as not to generate concern. Arsenic was not a Contaminant of Concern at Site 129-3.

Antimony concentrations at both Sites C and 129-3 were below the analytical Method Detection Limit (MDL) (Tables 5-6 and 5-7). This may indicate a very limited occurrence of antimony in these areas, which may diminish the importance of antimony as a primary COCs.

Thallium was detected in two-thirds of the soil samples collected after amendment addition at Site C (Table 5-6). The distribution was fairly uniform over the entire demonstration area, both at the 0- to 12-inch depth and the 12- to 24-inch depth. In only two instances were thallium not found at the 12- to 24-inch depth, which reflects the propensity for thallium leaching in sandy soils. Thallium concentrations averaged 59 mg/kg and ranged from <50 to 241 mg/kg in the top 12 inches of soil. Concentrations in the 12- to 24-inch depth also averaged 59 mg/kg, but the range of concentrations was higher at <50 to 470 mg/kg. These concentrations are considerably higher than found in the pre-amendment sampling (Table 5-4), but this is likely a function of the greater number of samples collected during the post-amendment sampling period. Since 2.1-8.5 mg/kg of thallium in soil can adversely affect plants,<sup>Ref. 30</sup> thallium present at Site C may be a significant factor in any remediation effort at this site.

### **5.2.3 Plant Sampling - 1998 Corn Crop**

#### **5.2.3.1 Plant Growth - 1998 Corn Crop**

The marginal levels of soil phosphorus at Site C (see Section 5.2.1) resulted in the development of a P deficiency, evidenced by stunted plants with a purple coloration of stems and leaves, early in the growing corn. The high lead concentrations at the site may have additionally reduced available P to the crop. In this situation, large amounts of P would have been needed to prevent the problem. However, over-applications of P could have caused complexation of lead as insoluble Pb-phosphates which would have hindered chelate efficiency. Only a small amount of additional P fertilizer had been added at Site C. To correct the deficiency, two foliar applications of a 0.5% P solution were made to the affected plants. This treatment resulted in the disappearance of visual deficiency symptoms. The initial inadequate P nutrition nonetheless resulted in less vigorous plants. A nutritional imbalance and deficiency of iron (Fe) and nitrogen subsequently developed. The affected plants were treated with a foliar application of a 2% solution of ferrous ammonium sulfate, which appeared to correct the Fe and N deficiency. However, the plants did not achieve maximum growth and yields were reduced. Corn at Site 129-3 appeared to grow normally during the season.

#### **5.2.3.2 Pre-Amendment Plant Sampling - 1998 Corn Crop**

Lead concentrations in corn plants grown on Site C averaged 30 mg/kg before soil amendment addition (Table 5-8). Of the other COCs, only manganese accumulated in appreciable amounts in the tissue, averaging 34 mg/kg. Concentrations of arsenic, beryllium, and antimony were originally low in the soil. Consequently, little uptake of these elements occurred. Normal plant tissue concentrations are 1 to 1.7 for arsenic, <1 to 7 for beryllium, 7 to 50 for antimony, and <1 mg/kg for thallium.<sup>Ref. 32</sup> Arsenic, antimony, and thallium were present in corn tissue at concentrations below the lower limit of these ranges or at the detection limit of the analytical method; beryllium was found at slightly higher concentrations in plants from several of the grids.

Although soil concentrations of thallium were quite high, little thallium was found in the plant. Apparently, thallium was present in a form which had only limited availability to plants. The manganese concentrations observed in corn at Site C were within the commonly reported sufficiency level of 20 to 300 mg/kg for most plants, and well below the most commonly reported toxicity level of 500 mg/kg.<sup>Ref. 32</sup>

Lead concentrations in corn plants at Site 129-3 were much lower than at Site C, primarily due to the much lower lead content of the soil at this location (Table 5-9). Manganese levels in corn from Site 129-3 were comparable to levels found in plants at Site C.

Overall, there was nothing remarkable about the concentrations of COCs found in corn at both sites before soil amendment application. Arsenic and antimony (and beryllium except in a small area at Site C) were present in the tissue below toxic levels to the plant or were present in such low concentrations as to likely preclude contamination of the food chain if the plant tissues were consumed. Since thallium was found to be below the Method Detection Limit, there is uncertainty as to the potential impact of this element.

**Table 5-8**  
**Contaminants of Concern in 1998 Corn from**  
**Site C Prior to Adding Soil Amendments**

<b>Grid No.</b>	<b>Pb, mg/kg</b>	<b>As<sup>1</sup>, mg/kg</b>	<b>Be<sup>1</sup>, mg/kg</b>	<b>Mn<sup>1</sup>, mg/kg</b>	<b>Sb<sup>1</sup>, mg/kg</b>	<b>Tl<sup>1</sup>, mg/kg</b>
4	34	<0.2 <sup>2</sup>	<0.6 <sup>2</sup>	37	<40 <sup>2</sup>	<50 <sup>2</sup>
8	33	<0.2	2.2	41	<40	<50
12	14	<0.2	<0.6	25	<40	<50
16	44	<0.2	3.5	39	3	<50
20	36	<0.2	<0.6	35	<40	<50
24	30	<0.2	2.2	34	<40	<50
28	35	<0.2	<0.6	37	<40	<50
32	17	<0.2	<0.6	29	<40	<50
36	31	<0.2	<0.6	32	<40	<50
<b>Mean</b>	<b>30</b>	<b>&lt;0.2</b>	<b>0.9</b>	<b>34</b>	<b>&lt;40</b>	<b>&lt;50</b>
<b>Std. Dev.</b>	<b>10</b>	<b>NA<sup>3</sup></b>	<b>1.4</b>	<b>5</b>	<b>NA</b>	<b>NA</b>

(1) Contaminant of Concern for this site.

(2) Method Detection Limit.

(3) NA = Not Applicable.

### 5.2.3.3 Post-Amendment Plant Sampling - 1998 Corn Crop

The total yield of corn plant material at Site C (dry weight basis) was 850 pounds for the 0.2-acre area. On a per-acre basis, this was 4,250 lb/acre. The average lead concentration in plants was 6,460 mg/kg (0.65%) [see Table 5-10]. The amount of lead removed from the soil was calculated by the following:

$$4,250 \text{ lb/acre} \times 0.0065 = 27.6 \text{ lb lead/acre removed}$$

The total yield of corn plant material at Site 129-3 (dry weight basis) was 1,431 pounds for the 0.2-acre area. On a per-acre basis, this was 7,155 lb/acre. The average lead concentration in plants was 1,300 mg/kg (0.13%) [see Table 5-11]. The amount of lead removed from the soil was calculated by the following:

$$7,155 \text{ lb/acre} \times 0.0013 = 9.3 \text{ lb lead/acre removed}$$

These biomass yields were lower than those reported in the literature. The values in the literature were likely for reproductively mature plants, i.e., full-grown plants with mature ears, which would explain the discrepancy.

The EDTA content of post-amendment corn samples at Site C (Table 5-10) averaged 4.3% (43,000 mg/kg) and ranged from 2.3% (23,000 mg/kg) up to 7.2% (72,000 mg/kg). Values attained with corn in the previous greenhouse study<sup>Ref. 2</sup> were approximately 11%, but the corn plants were confined in pots and root exploration of the soil was at a maximum. However, the concentrations found in corn in the TCAAP demonstration are sufficiently high as to be considered significant as a removal mechanism of EDTA from the soil. The EDTA was present in corn tissue at an average ratio of EDTA to lead of 3.6 at Site C and 2.9 at Site 129-3.

Lead concentrations in corn at Site C averaged 6,460 mg/kg (0.65%) after amendment additions and ranged from 3,300 mg/kg (0.33%) up to 11,300 mg/kg (1.1%) [see Table 5-10]. These lead concentrations were very similar to concentrations attained in corn in the SFAAP greenhouse pot study.<sup>Ref. 2</sup> Soils in that study differed in chemical and physical properties from soils at TCAAP, but had a similar lead content as the soil at Site C. These results indicate that the technology is applicable across differing soil types if the soil types being treated are fairly homogeneous. There was considerable variation in plant tissue lead content because of the variability across the field, but generally, uptake of lead increased with increasing amounts of lead in the soil. Lead concentrations in corn across the plots were analyzed statistically using Model 1 in Section 4.3.2.3.1. Variability across rows was not significant (Appendix E, Table E-2). Variability across columns was significant at the 0.1 level of probability, indicating variable uptake of lead by corn across the field. The variable concentrations of soil lead across the plot was expected to affect the amount of uptake by the plants and this is indicated by these statistics. The comparisons of column means using the Least Significant Difference t-test is given in Appendix E, Table E-2A.

**Table 5-9**  
**Contaminants of Concern in 1998 Corn from Site 129-3**  
**Prior to Adding Soil Amendments**

<b>Grid No.</b>	<b>Pb, mg/kg</b>	<b>Mn<sup>1</sup>, mg/kg</b>	<b>Sb<sup>1</sup>, mg/kg</b>
4	<1 <sup>2</sup>	27	<40 <sup>2</sup>
8	4	29	<40
12	9	28	<40
16	8	31	<40
20	9	33	<40
24	7	34	<40
28	13	36	<40
32	7	36	<40
36	27	36	<40
<b>Mean</b>	<b>9</b>	<b>32</b>	<b>&lt;40</b>
<b>Std. Dev.</b>	<b>7</b>	<b>4</b>	<b>NA<sup>3</sup></b>

- (1) Contaminant of Concern for this site.
- (2) Method Detection Limit.
- (3) NA = Not Applicable.

**Table 5-10**  
**EDTA and Contaminants of Concern in 1998 Corn from Site C**  
**After Soil Amendment Additions**

Grid No.	EDTA as Na <sub>2</sub> EDTA <sup>1</sup> , mg/kg	EDTA as EDTA <sup>1</sup> , mg/kg	Pb <sup>2</sup> , mg/kg	As <sup>2,3</sup> , mg/kg	Be <sup>2,3</sup> , mg/kg	Mn <sup>2,3</sup> , mg/kg	Sb <sup>2,3</sup> , mg/kg	Tl <sup>2,3</sup> , mg/kg
1	NS <sup>4</sup>	NS <sup>4</sup>	4,510	0.2	2.5	802	<40 <sup>5</sup>	<50 <sup>5</sup>
2	NS	NS	7,170	0.3	3.1	589	<40	<50
3	NS	NS	7,800	0.2	<0.6 <sup>5</sup>	580	<40	<50
4	26,000	23,000	6,240	0.2	<0.6	420	<40	<50
5	NS	NS	4,940	0.2	<0.6	358	<40	<50
6	NS	NS	5,680	<0.16 <sup>5</sup>	<0.6	392	<40	<50
7	NS	NS	5,740	0.2	<0.6	851	<40	<50
8	43,000	37,000	6,330	0.2	<0.6	560	<40	<50
9	NS	NS	7,380	0.2	8.0	669	<40	<50
10	NS	NS	5,090	0.4	<0.6	530	<40	<50
11	NS	NS	4,730	<0.16	2.9	414	<40	<50
12	43,000	37,000	4,020	<0.16	<0.6	433	<40	<50
13	NS	NS	7,520	<0.16	<0.6	764	<40	<50
14	NS	NS	8,300	<0.16	<0.6	661	<40	<50
15	NS	NS	5,590	<0.16	<0.6	593	<40	<50
16	49,000	43,000	9,700	<0.16	<0.6	446	<40	<50
17	NS	NS	3,970	0.2	1.6	385	<40	<50
18	NS	NS	5,630	<0.16	<0.6	520	<40	<50
19	NS	NS	8,390	0.2	<0.6	641	<40	<50
20	75,000	65,000	9,040	0.2	<0.6	576	<40	<50
21	NS	NS	5,130	0.2	<0.6	601	<40	<50
22	NS	NS	11,300	0.2	0.7	504	<40	<50
23	NS	NS	5,090	<0.16	<0.6	407	<40	<50
24	39,000	34,000	6,290	<0.16	<0.6	431	<40	<50
25	NS	NS	6,590	<0.16	<0.6	576	<40	<50
26	NS	NS	8,970	0.3	<0.6	563	<40	<50
27	NS	NS	3,300	<0.16	<0.6	634	<40	<50
28	40,000	35,000	8,270	<0.16	<0.6	456	<40	<50
29	NS	NS	6,910	<0.16	<0.6	335	<40	<50
30	NS	NS	7,600	<0.16	<0.6	593	<40	<50
31	NS	NS	5,870	<0.16	1.0	642	<40	<50
32	83,000	72,000	5,630	0.2	<0.6	591	<40	<50
33	NS	NS	3,720	<0.16	<0.6	562	<40	<50
34	NS	NS	6,200	<0.16	<0.6	453	<40	<50
35	NS	NS	8,620	<0.16	<0.6	424	<40	<50
36	52,000	45,000	5,440	<0.16	0.9	507	<40	<50
		-						
<b>Mean</b>	<b>50,000</b>	<b>43,000</b>	<b>6,460</b>	<b>&lt;0.16</b>	<b>&lt;0.6</b>	<b>541</b>	<b>&lt;40</b>	<b>&lt;50</b>
<b>Std. Dev.</b>	<b>18,000</b>	<b>16,000</b>	<b>1,830</b>	<b>NA<sup>6</sup></b>	<b>NA<sup>6</sup></b>	<b>123</b>	<b>NA<sup>6</sup></b>	<b>NA<sup>6</sup></b>

- (1) Nine of 36 grids sampled for EDTA analysis. (4) NS = Not sampled.  
(2) Concentrations were determined by acid digestion (5) Method Detection Limit.  
(3) Contaminant of Concern for this site. (6) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-11**  
**EDTA and Contaminants of Concern in 1998 Corn from**  
**Site 129-3 After Soil Amendment Additions**

<b>Grid No.</b>	<b>EDTA as Na<sub>2</sub>EDTA<sup>1</sup>, mg/kg</b>	<b>EDTA as EDTA<sup>1</sup>, mg/kg</b>	<b>Pb<sup>2</sup>, mg/kg</b>	<b>Mn<sup>2,3</sup>, mg/kg</b>	<b>Sb<sup>2,3</sup>, mg/kg</b>
1	NS <sup>4</sup>	NS <sup>4</sup>	1,110	521	<40 <sup>5</sup>
2	NS	NS	2,090	799	<40
3	NS	NS	1,700	838	<40
4	4,000	3,000	1,440	773	<40
5	NS	NS	1,140	739	<40
6	NS	NS	106	61	<40
7	NS	NS	608	877	<40
8	5,000	4,000	1,000	971	<40
9	NS	NS	1,190	865	<40
10	NS	NS	901	771	<40
11	NS	NS	391	565	<40
12	1,000	900	9	27	6
13	NS	NS	822	783	<40
14	NS	NS	984	607	<40
15	NS	NS	2,230	531	<40
16	8,000	7,000	643	659	<40
17	NS	NS	147	642	<40
18	NS	NS	153	321	<40
19	NS	NS	3,220	449	26
20	10,000	9,000	4,380	486	16
21	NS	NS	859	520	<40
22	NS	NS	425	647	<40
23	NS	NS	465	812	<40
24	13,000	11,000	381	504	<40
25	NS	NS	3,200	396	8
26	NS	NS	2,990	546	<40
27	NS	NS	4,130	725	<40
28	13,000	11,000	1,230	504	<40
29	NS	NS	1,670	799	<40
30	NS	NS	372	516	4
31	NS	NS	1,590	614	<40
32	11,000	10,000	972	612	<40
33	NS	NS	1,270	723	<40
34	NS	NS	1,180	653	<40
35	NS	NS	1,550	763	<40
36	8,000	7,000	308	295	<40
<b>Mean</b>	<b>8,000</b>	<b>7,000</b>	<b>1,300</b>	<b>609</b>	<b>1.7</b>
<b>Std. Dev.</b>	<b>4,000</b>	<b>3,000</b>	<b>1,100</b>	<b>211</b>	<b>5.2</b>

- (1) Nine of 36 grids sampled for EDTA analysis. (4) NS = Not Sampled.  
(2) Concentrations were determined by acid digestion. (5) Method Detection Limit.  
(3) Contaminant of Concern for this site.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

Lead concentrations in corn at Site 129-3 were much lower than at Site C (Table 5-11) and reflect the much lower soil lead content at Site 129-3 (Table 5-4). Lead concentrations in the corn averaged 1,300 mg/kg (0.13%) at Site 129-3 and ranged from a low of 9 mg/kg (<0.001%) to a high of 4,380 mg/kg (0.44%).

Variability analysis for grid rows and columns using Model 1 in Section 4.3.2.3.1 indicated variable uptake of lead by the corn across the plots (Appendix E, Table E-3), as shown by significance at the 0.05 level of probability for both rows and columns. No discernible pattern is apparent for the row means (Appendix E, Table E-3A); however, the lowest means are found for columns 4, 5, and 6 (Appendix E, Table E-3B). Soil lead concentrations were also lowest for these columns, although variability analysis was not significant for columns (Section 5.2.1 and Appendix E, Table E-1). These results indicate a lower level of lead contamination in the eastern side of the plot.

Given that the objective of the demonstration at Site 129-3 was to determine the effect of low soil lead concentrations on treatment effectiveness, a level of 0.44% in the plants may be significant for removing lead from a low-level contaminated site. What is notable is that similar EDTA-to-lead ratios in tissue were observed at both sites, as discussed in the section above, indicating that a similar uptake mechanism may occur at either low or high soil lead concentrations. However, phytoremediation may be more applicable to sites with low soil lead concentrations, since remediation time would be far less than for sites with higher concentrations.

Concentrations of arsenic in plants growing on uncontaminated soils normally range from 1 to 1.7 mg/kg and may be found at levels of 20 mg/kg under contaminated conditions. As such, the low levels reported for corn after amendment addition at Site C (<0.16 to 0.4 mg/kg, Table 5-10) are likely insignificant from an environmental standpoint.

Beryllium concentrations in the corn at Site C were generally below the detection limit of 0.6 mg/kg for the analytical method employed, with the highest concentration being 8.0 mg/kg (Table 5-10). The higher values occurred at isolated areas within the plot. These values are below the reported toxicity level of 10 to 50 mg/kg manifested in mature leaves.

The average manganese concentrations in corn were 541 mg/kg for Site C and 609 at Site 129-3 (Tables 5-10 and 5-11), which were 15- to 20-fold greater than in corn sampled before amendment application (Tables 5-8 and 5-9). This indicated solubilization of manganese and subsequent uptake by the plants. However, the lower concentrations of manganese in the plants relative to lead are most likely due to EDTA specificity for lead rather than manganese. The low concentrations of manganese in the soil relative to lead may have also been a factor in the lower uptake of manganese, as the amount of metals uptake induced by EDTA application to the soil is usually a function of the metal concentration in the soil.

Antimony concentrations in corn from Site C and at Site 129-3 were below the detection limit of the analytical method employed (Tables 5-10 and 5-11).

Thallium concentrations in corn from Site C also were below Method Detection Limits. This indicates that either the chemical form of thallium in the soil was unchanged by amendment application or that the corn did not accumulate appreciable amounts of thallium.

Overall, lead and manganese were the only COCs that accumulated in significant concentrations in the corn at either site. Other COCs were, for the most part, present at very low concentrations in the soil and, consequently, little or no plant uptake occurred.

Regression analyses were conducted to discern whether the level of a measured parameter, such as soil lead concentration, could be used to predict the level of another parameter, such as uptake of lead by the crop (Appendix E, Table E-4). For Site C, only the regression of corn lead concentration on the initial total soil lead concentration was significant. The regression of corn lead concentrations on total soil lead concentrations at 0-12 inches and 12-24 inches, and concentrations averaged using the values at 0-12 inches and 12-24 inches, were not significant. The regressions of corn lead concentrations on water-soluble lead concentrations were not significant, and the regressions of water-soluble lead on total soil lead also were not significant. This is evident from the data in Table 5-6 which, for any given sample, shows wide variability between the total lead content of the soil and the water-soluble lead and no consistent ratio between the two.

Regressions for Site 129-3 were all significant. These results indicate that plant lead uptake increased with an increase in the lead concentration of the soil. As would be expected, plant lead uptake also increases with an increase in water-soluble lead in the soil. However, the R-square values for these regressions are low, which indicates that while soil lead concentrations affect plant lead uptake, the ability to predict plant lead uptake from soil lead concentrations is low.

#### **5.2.3.4 Ancillary Plant Sampling**

Browning and loss of foliage from cottonwood trees located adjacent to the demonstration plots was observed shortly after amendment addition at Site C. Inspection at Site C revealed more extensive browning and loss of leaves in trees adjacent to the downhill side (extreme northwestern corner) of the demonstration plot after amendment addition for corn. In addition, a trail of dead grass following an old, compacted gravel roadbed led away from the plot exclusion fence into a nearby field. One small cottonwood located about 90 feet from the fence, but only 20 feet from the trail, was also affected. A willow tree about the same distance from the trail as the small cottonwood was not affected, nor was a wetlands area in the vicinity.

Leaf samples were taken from affected branches from the trees adjacent to the exclusion fence, from the small tree 90 feet from the fence, and from an unaffected tree some distance from the plot on the uphill (southern) side of the demonstration plot. Samples were placed in separate plastic bags and labeled. These samples were delivered to ATK staff for further packaging and transport to an overnight delivery service and, from there, to the TVA Analytical Laboratory in Muscle Shoals, Alabama. Analysis of the leaf tissue showed a concentration of 1,300 ppm lead in the impacted trees and 10 ppm in non-impacted trees. The leaves of apparently unaffected trees immediately adjacent to the affected trees were not analyzed.

It was determined that runoff of acetic acid had occurred from a limited portion of Site C, which resulted in vegetation kill and may have enhanced lead uptake by these plants. It was also determined that only a small quantity of EDTA, if any, was in the runoff since the problem was detected immediately after acetic acid addition. Although this runoff affected adjacent vegetation and trees, roots of the impacted plants were found growing well into the plot area, which exposed the plants to lead in a plant-available form. Thus, these plants would have been impacted regardless of contact with the runoff.

To prevent dispersion of lead in wind-blown leaves outside the immediate area at both sites, and to prevent a recurrence of this event, trees within 100 feet of the plot fences were removed, regardless of whether or not they had been affected by runoff. To formulate disposal options of the cut trees, tree trunk sections were analyzed for lead content. Results showed an average lead content of 99 mg/kg in both affected and unaffected trees. The slope of the land was so slight that a runoff was not anticipated. However, this slope, in conjunction with restricted infiltration in some areas of the plot due to the varying soil texture, and the hardpan road bed which channeled the solution, did result in some runoff. Therefore, pro-active construction of dikes and berms around potential runoff areas at both Site C and at Site 129-3 was undertaken and completed to prevent future occurrences. After harvest of the corn, deeper tillage was conducted within the plot in areas of preferential flow before planting of the white mustard crop to improve infiltration of amendment solutions.

Samples of bark, trunk, and branches from cottonwood trees growing on Site A were also collected by ATK personnel and analyzed by the TVA Analytical Laboratory for total lead content. Site A (Figure 3-2) is another of the source area sites at TCAAP that has shallow soil lead contamination and is being excavated as part of the Superfund cleanup. The results were compared with lead concentrations in cottonwood trees from Site C affected by runoff during amendment application for corn. Lead concentrations in trees from Site A (average - 276 mg/kg) were two to three times higher than lead concentrations in trees from Site C (average - 99 mg/kg). The higher concentrations may have been due to the spatial variability of the soil lead within each contaminated area, natural variations within the soil body, the type of waste at each site, or the proximity of trees to the contamination source. Thus, while exposure to runoff at Site C may have resulted in elevated lead concentrations in the trees, it is also possible that random variation in lead could have accounted for a significant amount of the increase in tissue lead.

## **5.2.4 Soil Sampling - 1998 White Mustard Crop**

### **5.2.4.1 Pre-Amendment Soil Sampling - 1998 White Mustard Crop**

Prior to planting the white mustard crop (August 17, 1998), a drip delivery system was installed on Site C and on Site 129-3. The system at Site C consisted of a 90-foot-long main header across the south end of the field with 90-foot-long strips of drip tubing attached every two feet along the length of the header. These strips extended northerly across the entire field and provided the means for chelate delivery for the white mustard. The system was the same at Site 129-3, except that the header was placed on the north end of the field and drip tubing extended from it across the demonstration area in a southerly direction.

Sampling and amendment addition activities for the white mustard crop commenced on October 7, 1998. Pre-amendment plant and soil sampling for Site C was completed on October 7, 1998, and for Site 129-3 on October 8, 1998. At this time, at Site C, essentially all of the white mustard had bolted and was in full bloom. About 10%-15% of the plants had shed blooms and had initiated seed pod formation. At Site 129-3, the plants were in various stages of bloom and bolt. The full blossom stage had not been reached in about 25% of the plants. Blooming was about 75% complete in these plants. About 15% of the plants had not bolted.

The average pH at Site C changed very little for white mustard (Table 5-12) from the post-amendment soil sampling after corn harvest (Table 5-6). At Site 129-3, soil pH decreased slightly from 8.5 to 8.1 for the 0- to 12-inch depth and from 8.6 to 8.1 for the 12- to 24-inch depth. In this case, the tendency of EDTA to increase soil pH was negated to an extent by the tillage/irrigation cycle conducted before the white mustard was planted. As discussed in Section 5.2.2.1, tilling of soil tends to cause a decrease in soil pH. Thus, the increase in soil pH caused by release of ammonia during degradation of EDTA was offset somewhat by tillage. However, degradation of ferric-EDTA (and possibly other cation-EDTA complexes such as Ca- or Mg-EDTA) has been shown to be inhibited above pH 8.0, and this may have resulted in essentially no net change in pH.<sup>Ref. 35</sup> Less EDTA was added at Site 129-3 than at Site C, so the effect on pH would not be as large.

At Site C, the average EDTA concentration in the 0- to 12-inch depth decreased from 982 mg/kg after adding the soil amendments to corn (Table 5-6) to 360 mg/kg (Table 5-12) ten weeks later at pre-amendment sampling for white mustard. The decrease in EDTA most likely was due to a combination of (1) adsorption onto soil minerals, e.g., iron oxides and hydroxides; (2) some degradation of EDTA due to tillage/irrigation discussed above, and (3) downward movement of EDTA. Downward movement in the rooting zone of EDTA apparently did occur since concentrations in the 12- to 24-inch depth increased from 323 mg/kg in the post-amendment soil samples for corn (Table 5-6) to 887 mg/kg in the pre-amendment samples for white mustard (Table 5-12).

At Site C, higher concentrations of water-soluble Pb were generally found at the 12- to 24-inch level (Table 5-12); whereas, with post-amendment soil samples for corn, the higher concentrations were observed in the 0- to 12-inch level (Table 5-6). This indicated that water-soluble lead may have moved downward in the soil, similar to EDTA. Some of the reduction might be attributed to removal by the crop, although biomass production was insufficient to account for a significant portion of this lead. The inherent variability in soil lead concentration and the difficulties in sampling also made an accounting difficult.

A decrease in water-soluble Pb, particularly in the 0- to 12-inch level, may also have been due to some degradation of EDTA from the tillage/irrigation cycles, or displacement of Pb from the EDTA complex by other cations. This would release complexed lead, which then would react with soil to revert to an insoluble form. This might readily occur if EDTA was complexed with iron or other nutrient cations such as Ca, Mg, and Mn. Lauff *et al*<sup>Ref. 35</sup> found high degradation rates of ferric-EDTA (up to 24mM/day), which was an order of magnitude greater than previously reported rates of EDTA and its metal chelates. Nortemann<sup>Ref. 33</sup> reported rapid and

complete biodegradation of Ca, Mg, and Mn complexes of EDTA by a mixed microbial population. These metals are of low toxicity and are essential micronutrients which serve as a food source to microbes, which would result in an enhanced microbial population capable of degrading EDTA. The resulting degradation products would have lower affinity for lead than the parent EDTA compound, and lead released from the complex would remain bound as insoluble forms in the soil. Also, sorption could simply remove the lead-EDTA complex from solution.

The average concentration for water-soluble lead in the top 24 inches of soil at Site C after amendment additions to corn was 301 mg/kg and for pre-amendment samples for white mustard, the average concentration was 255 mg/kg (where the 24-inch average is the average of the concentrations of 0-12 inches and 12-24 inches). Therefore, *ten weeks after adding EDTA to the soil, the majority of water-soluble lead (84.7%) remained in the top two feet*, which is considered the rooting zone of the plant.

At Site 129-3, very little EDTA remained in the 0- to 12-inch or the 12- to 24-inch soil levels (6 and 16 mg/kg, respectively, Table 5-13), as compared to levels found in post-amendment soil samples for corn of 262 and 103 mg/kg (Table 5-7). Similarly, very little water-soluble lead remained in the top 24 inches (Tables 5-7 and 5-13). EDTA appears to have also moved downward at this site, as concentrations at the 12- to 24-inch level were higher than at the 0- to 12-inch depth. Apparently, a large portion of the water-soluble lead and EDTA moved downward in the top 24 inches within the ten weeks between the corn harvest and pre-amendment soil sampling for white mustard. A high concentration of EDTA in the soil solution three weeks after soil amendments were applied for corn on August 6, 1998 (Section 5.2.6, Table 5-22) may have been indicative of downward movement of EDTA. However, sorption of EDTA in the top 12 inches by iron oxides in the top 12 inches would also have reduced the concentrations of extractable EDTA.

At Site C, the average total lead concentration was 5,430 mg/kg at the 0- to 12-inch depth (Table 5-12), which was higher than the level measured in post-amendment soil samples taken for the corn crop; however, if the concentration of 50,900 mg/kg for grid 20 was discounted, then the average total lead concentration would be 2,760 mg/kg, which is very similar to the average total lead concentration of 2,730 mg/kg found in the initial soil characterization (Table 5-1). The average total lead concentration of 2,930 mg/kg for the 12- to 24-inch depth at Site C is much lower than the post-amendment concentration for corn of 4,300 mg/kg (compare Tables 5-12 and 5-6). Again, this variation in average lead concentration for both soil levels was due to the non-uniform distribution of lead across the plot.

There appeared to be some reductions in total lead concentrations at Site 129-3 (Table 5-13), compared to total lead concentrations for post-amendment samples for the corn crop (Table 5-7), but the variation at this site also was too large to distinguish whether an actual reduction occurred.

**Table 5-12**

**Soil pH, EDTA, Water-Soluble Pb, and Other Contaminants of Concern in Soil at Site C Prior to Adding Soil Amendments to 1998 White Mustard**

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb mg/kg		Pb <sup>1,2</sup> mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	8.5	8.6	4	11	3	10	70	56	2,739	4,170
3	8.6	8.6	<0.3 <sup>3</sup>	8	<0.3 <sup>3</sup>	7	4	79	131	2,710
5	8.8	8.3	3	7	3	6	5	1	661	752
8	8.5	8.1	6	98	5	85	33	66	13,500	4,020
10	9.1	8.7	<0.3	53	<0.3	46	12	23	346	222
12	8.4	8.0	<0.3	20	<0.3	17	3	6	381	348
13	7.9	8.2	297	1,660	258	1,440	137	693	2,460	1,380
15	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	NS <sup>4</sup>	13	860	263	4,463
17	8.1	7.9	2,090	3,440	1,817	2,990	592	305	4,696	2,340
20	9.0	8.8	21	165	18	143	102	28	50,900	6,040
22	NS	NS	NS	NS	NS	NS	80	939	4,590	2,080
24	9.1	7.9	43	1,540	37	1,340	33	691	8,930	3,280
25	8.6	8.2	397	2,880	345	2,500	110	1,100	3,860	1,360
27	NS	NS	NS	NS	NS	NS	96	1,730	524	4,190
29	8.3	8.1	1,280	3,180	1,113	2,760	252	464	2,000	3,740
32	NS	NS	NS	NS	NS	NS	49	77	850	9,820
34	NS	NS	NS	NS	NS	NS	88	293	762	1,320
36	8.2	8.0	3	210	3	183	4	98	162	466
					-	-				
<b>Mean</b>	<b>8.5</b>	<b>8.3</b>	<b>414</b>	<b>1,020</b>	<b>360</b>	<b>887</b>	<b>93</b>	<b>417</b>	<b>5,430</b>	<b>2,930</b>
<b>Std. Dev.</b>	<b>0.4</b>	<b>0.3</b>	<b>710</b>	<b>1,350</b>	<b>617</b>	<b>1,170</b>	<b>140</b>	<b>490</b>	<b>11,880</b>	<b>2,400</b>

(1) Concentrations were determined by acid digestion.

(4) NS = Not sampled.

(2) Contaminant of Concern for this site.

(5) NA = Not Applicable.

(3) Method Detection Limit.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-12 (Continued)**

**Soil pH, EDTA, Water-Soluble Pb, and Other Contaminants of Concern in Soil at Site C Prior to Adding Soil Amendments to 1998 White Mustard**

Grid No.	As <sup>1,2</sup> mg/kg		Be <sup>1,2</sup> mg/kg		Mn <sup>1,2</sup> mg/kg		Sb <sup>1,2</sup> mg/kg		Tl <sup>1,2</sup> mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	<5 <sup>3</sup>	<5 <sup>3</sup>	<0.4 <sup>3</sup>	<0.4 <sup>3</sup>	183	201	<40 <sup>3</sup>	<40 <sup>3</sup>	<50 <sup>3</sup>	<50 <sup>3</sup>
3	<5	<5	<0.4	<0.4	81	143	<40	<40	<50	<50
5	9	5	<0.4	<0.4	329	272	<40	<40	150	111
8	<5	<5	<0.4	<0.4	173	348	<40	<40	63	57
10	<5	<5	<0.4	<0.4	91	120	<40	<40	86	70
12	<5	<5	<0.4	<0.4	169	134	<40	<40	<50	<50
13	<5	<5	<0.4	<0.4	223	352	<40	<40	<50	<50
15	<5	<5	<0.4	<0.4	88	169	<40	<40	92	<50
17	8	12	<0.4	<0.4	976	649	<40	<40	163	263
20	<5	<5	<0.4	<0.4	166	200	<40	<40	103	62
22	<5	<5	<0.4	<0.4	147	178	<40	<40	60	<50
24	<5	<5	<0.4	<0.4	161	246	<40	<40	77	60
25	<5	<5	<0.4	<0.4	226	260	<40	<40	68	64
27	<5	<5	<0.4	<0.4	95	362	<40	<40	72	<50
29	6	18	<0.4	<0.4	405	727	<40	<40	92	286
32	<5	<5	<0.4	<0.4	125	206	<40	<40	89	65
34	<5	<5	<0.4	<0.4	227	599	<40	<40	51	<50
36	<5	<5	<0.4	<0.4	73	174	<40	<40	<50	<50
<b>Mean</b>	<b>1.3</b>	<b>1.9</b>	<b>&lt;0.4</b>	<b>&lt;0.4</b>	<b>219</b>	<b>297</b>	<b>&lt;40</b>	<b>&lt;40</b>	<b>55</b>	<b>50</b>
<b>Std. Dev.</b>	<b>4.7</b>	<b>4.9</b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>208</b>	<b>183</b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>53</b>	<b>88</b>

- (1) Concentrations were determined by acid digestion.
- (2) Contaminant of Concern for this site.
- (3) Method Detection Limit.

- (4) NS = Not sampled.
- (5) NA = Not Applicable.

Concentrations of the other COCs at either site, with the exception of thallium at Site C, were only slightly affected by treatments (Tables 5-12 and 5-13). Arsenic was found in isolated, localized areas within the plot. There did not appear to be a significant decrease in manganese concentrations from those found in post-amendment soil samples for corn. Beryllium and antimony were below the analytical Method Detection Limit. Thallium was present in several areas of Site C at concentrations which would be toxic to plants (Table 5-12). These concentrations were similar to those found in the previous soil samplings. In almost all cases, where thallium was present in the soil, plant growth was severely inhibited (Section 5.2.5.1, Table 5-16).

#### **5.2.4.2 Post-Amendment Soil Sampling - 1998 White Mustard**

Soil amendment additions (EDTA only) were made to the white mustard crop at Site C on October 9, 1998, and to white mustard at Site 129-3 on October 10, 1998. EDTA formulation, mixing, and application was done in cooperation with Lynn Sinness, Manager, ConAgra, Shakopee, Minnesota. The EDTA was applied through the drip delivery system. Application time for Site C was approximately 7 hours and for Site 129-3 about 4 hours.

The EDTA was added to optimize the solubilization of lead in the first two feet of soil (root zone). Since only half the plot area at Site C was populated with plants, the EDTA application rate there was reduced from the originally planned 6,750 pounds to 3,375 pounds of EDTA. Only the grids with growing plants received the chelate application. The reduced application was achieved by selectively blocking the sections of the drip tubing which extended across bare areas in the plot. The application rate at Site 129-3 was 850 pounds, the same amount as applied for the 1998 corn crop. The lower rate at 129-3 was selected due to the lower average soil lead concentration at that site. Adjustments were made in the sampling activities at Site C due to the reduced plant stand and, as such, a reduced number of both plant and soil samples was collected.

There was little change in soil pH at Site C after EDTA application for white mustard (Table 5-14).

EDTA concentrations in the soil at Site C were much higher in the 0- to 12-inch depth than in the 12- to 24-inch depth for most grids (Table 5-14). Also, EDTA concentrations were approximately five times higher in post-amendment soil samples for white mustard than in post-amendment soil samples for corn. Soil sampling was not done directly beneath the drip lines in order to avoid sampling in a zone of high EDTA concentration. A drip delivery system was used to apply EDTA to the soil over a 7-hour period. The slower application rate allowed the EDTA to infiltrate into the soil slowly, thus minimizing runoff, compared to the hose application method used for corn, which applied the solution rapidly so that amendments ran down the slight slope. The corn crop removed 42.5 pounds of EDTA at Site C and 11.5 pounds at Site 129-3. White mustard removed 70.6 pounds of EDTA at Site C and 39.3 pounds at Site 129-3. These amounts alone cannot account for the difference in EDTA concentrations in soil for Site C for the post-amendment soil samples for corn and white mustard. However, sampling was done seven days after application for corn, but two days afterward for white mustard. The EDTA,

**Table 5-13**

**Soil pH, EDTA, Water-Soluble Pb, and Other Contaminants of Concern in Soil at Site 129-3 Prior to Adding Soil Amendments to 1998 White Mustard**

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA mg/kg		EDTA as EDTA mg/kg		Water-Soluble Pb mg/kg		Pb <sup>1,2</sup> mg/kg		Mn <sup>1,2</sup> mg/kg		Sb <sup>1,2</sup> mg/kg	
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	8.1	8.0	<0.3 <sup>3</sup>	2	<0.3 <sup>3</sup>	2	2	2	114	130	225	178	<40 <sup>3</sup>	<40 <sup>3</sup>
3	7.8	7.7	<0.3	4	<0.3	3	<0.3 <sup>3</sup>	<0.3 <sup>3</sup>	52	63	153	161	<40	<40
5	8.3	8.1	7	3	6	3	<0.3	1	71	146	176	262	<40	<40
8	8.4	8.5	<0.3	3	<0.3	3	<0.3	<0.3	28	23	120	199	<40	<40
10	7.1	7.9	<0.3	<0.3 <sup>3</sup>	<0.3	<0.3 <sup>3</sup>	<0.3	<0.3	64	56	186	241	<40	<40
12	7.8	8.1	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	25	20	295	263	<40	<40
13	8.0	7.9	<0.3	87	<0.3	76	<0.3	<0.3	54	27	357	289	<40	<40
15	8.0	8.2	3	16	3	14	6	13	352	255	186	230	<40	<40
17	8.3	8.3	3	4	3	3	<0.3	<0.3	24	22	155	326	<40	<40
20	7.9	8.0	13	28	11	24	47	26	1,336	353	227	167	<40	<40
22	8.2	8.2	4	4	3	3	<0.3	<0.3	49	80	175	193	<40	<40
24	8.4	8.3	3	<0.3	3	<0.3	<0.3	<0.3	20	42	244	261	<40	<40
25	8.2	8.0	2	3	2	3	12	3	440	207	188	225	<40	<40
27	8.2	8.3	16	94	14	82	25	57	423	215	218	247	<40	<40
29	8.1	8.0	2	3	2	3	1	<0.3	74	112	146	345	<40	<40
32	8.2	8.4	3	4	3	3	<0.3	<0.3	31	14	262	222	<40	<40
34	8.3	7.8	19	<0.3	17	<0.3	1	<0.3	93	44	177	208	<40	<40
36	8.0	8.4	<0.3	1	<0.3	1	<0.3	<0.3	63	46	183	288	<40	<40
<b>Mean</b>	<b>8.1</b>	<b>8.1</b>	<b>7</b>	<b>18</b>	<b>6</b>	<b>16</b>	<b>5.2</b>	<b>5.6</b>	<b>184</b>	<b>96</b>	<b>204</b>	<b>239</b>	<b>&lt;40</b>	<b>&lt;40</b>
<b>Std. Dev.</b>	<b>0.3</b>	<b>0.2</b>	<b>6</b>	<b>31</b>	<b>5</b>	<b>27</b>	<b>12.2</b>	<b>14.4</b>	<b>318</b>	<b>96</b>	<b>58</b>	<b>52</b>	<b>NA<sup>4</sup></b>	<b>NA<sup>4</sup></b>

- (1) Concentrations were determined by acid digestion.
- (2) Contaminant of Concern for this site.
- (3) Method Detection Limit.
- (4) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

thus, may have moved downward to a greater extent with the corn crop. Adsorption of EDTA onto various soil fractions could not be measured, but this mechanism likely played a major role in the decrease of EDTA. The time difference between sampling events after chelate application would have allowed more adsorption to occur for the corn crop soils.

Water-soluble lead in the soil at Site C increased significantly after chelate addition to white mustard (Table 5-14). The concentrations were higher with white mustard than with the corn (Table 5-6), but, again, the soil for corn was sampled after a longer time interval.

At Site 129-3, there was a slight increase in pH associated with the application of EDTA (Table 5-15). Most grids showed very low concentrations of EDTA, apparently due to the slow rate of delivery by the drip delivery system and consequent limited lateral movement away from the drip lines. Soil sampling was not done directly beneath the drip lines in order to avoid sampling in a zone of high EDTA concentration. The average concentration for the 0- to 12-inch depth was 311 mg/kg, but the high concentrations in grids 30 and 32 skewed this value upwards. Water-soluble lead concentrations were also low, likely due to the low concentrations of EDTA in the areas sampled. In a number of the grids, concentrations of water-soluble lead were non-detectable. However, the low concentration of lead and the amount of variability confounded the interpretation of these results.

At Site C, the average total lead concentration of 2,320 mg/kg at the 0- to 12-inch depth was slightly lower than values found in the previous soil samplings for both corn and white mustard (Tables 5-1, 5-4, 5-6, and 5-12); the value of 2,320 mg/kg was within the standard deviation of the means of all previous samplings. This could mean either that a decrease in soil lead occurred due to uptake by plants, that lead moved out of the top 12 inches of soil due to EDTA complexation, or simply that the variability in soil lead concentration was too great to determine if the change was real. At the 12- to 24-inch depth, the average lead concentration was within the range of values found in previous samplings (Tables 5-4, 5-6, and 5-12).

For Site 129-3, average lead concentrations were also within ranges found in previous sampling for both 0- to 12-inch and 12- to 24-inch soil levels (Tables 5-2, 5-5, 5-7, and 5-13).

At Site C, there was very little change in the average manganese concentration as a result of chelate application (Tables 5-12 and 5-14). At Site 129-3, the average manganese concentration did not change at the 0- to 12-inch depth (Tables 5-13 and 5-15); there appeared to be an increase at the 12- to 24-inch depth, but this is probably due to variation across the demonstration plot and is within the standard deviation of the means.

Arsenic was found at detectable concentrations in soil at Site C in only three grids (Table 5-14). Antimony concentrations were all below the Method Detection Limit. Thallium was again found in significant concentrations across the field area at Site C. Although thallium concentrations in the post-amendment soil samples varied somewhat from the concentrations in samples taken before amendment application, the areas where thallium was found essentially corresponded to areas of poor plant growth.

**Table 5-14**

**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern  
in Soil at Site C After Soil Amendment Additions to 1998 White  
Mustard**

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb mg/kg		Pb <sup>1,2</sup> mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	8.0	8.2	3,650	1,620	3,170	1,410	773	488	759	3,470
2	8.4	7.9	3,500	1,050	3,040	910	1,700	434	1,440	2,280
5	8.3	7.9	11,800	2,840	10,300	2,470	918	488	1,610	1,710
6	8.6	8.5	4,360	2,080	3,790	1,810	907	941	10,300	9,490
7	8.2	8.2	6,070	431	5,280	370	633	146	702	479
8	8.1	8.6	5,380	963	4,680	840	865	430	895	3,190
12	8.4	8.1	8,900	1,450	7,740	1,260	1,320	764	1,620	2,780
13	8.0	8.3	9,240	502	8,030	440	821	205	1,720	469
14	8.3	8.5	760	1,520	660	1,320	274	463	745	5,910
15	NS <sup>3</sup>	NS <sup>3</sup>	NS <sup>3</sup>	NS <sup>3</sup>	NS <sup>3</sup>	NS <sup>3</sup>	172	1,140	2,210	10,300
18	8.4	7.9	2,770	2,090	2,410	1,820	1,200	1,000	1,800	2,300
19	8.9	8.6	4,820	811	4,190	700	1,650	419	4,440	1,310
20	9.0	8.5	1,130	1,770	980	1,540	609	969	2,860	5,400
21	NS	NS	NS	NS	NS	NS	517	2,120	659	4,210
24	8.8	8.4	3,970	1,050	3,450	910	1,370	502	1,860	3,910
25	8.8	8.4	2,740	1,470	2,380	1,280	1,240	748	4,800	4,140
26	8.8	8.1	1,000	2,510	870	2,180	444	885	5,850	9,600
27	NS	NS	NS	NS	NS	NS	346	1,290	1,110	6,790
29	8.6	8.3	7,960	8,190	6,920	7,120	671	1,130	867	2,180
30	8.6	8.0	2,390	1,220	2,080	1,060	532	254	2,900	428
35	8.4	8.0	7,210	1,530	6,270	1,330	928	432	1,140	3,280
36	8.7	8.5	12,600	1,650	11,000	1,430	672	803	691	1,330
<b>Mean</b>	<b>8.5</b>	<b>8.2</b>	<b>5,280</b>	<b>1,830</b>	<b>4,590</b>	<b>1,590</b>	<b>844</b>	<b>730</b>	<b>2,320</b>	<b>3,860</b>
<b>Std. Dev.</b>	<b>0.3</b>	<b>0.2</b>	<b>3,510</b>	<b>1,660</b>	<b>3,050</b>	<b>1,440</b>	<b>422</b>	<b>449</b>	<b>2,290</b>	<b>2,960</b>

- (1) Concentrations were determined by acid digestion.
- (2) Contaminant of Concern for this site.
- (3) Method Detection Limited.
- (4) NS = Not sampled.
- (5) NA = Not applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-14 (Continued)**  
**Soil pH, EDTA, Water-Soluble Pb, and**  
**Contaminants of Concern in Soil at Site C After Soil Amendment**  
**Additions to 1998 White Mustard**

Grid No.	As <sup>1,2</sup> mg/kg		Be <sup>1,2</sup> mg/kg		Mn <sup>1,2</sup> mg/kg		Sb <sup>1,2</sup> mg/kg		Tl <sup>1,2</sup> mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	<5 <sup>3</sup>	<5 <sup>3</sup>	11	<0.4 <sup>3</sup>	172	246	<40 <sup>3</sup>	<40 <sup>3</sup>	<50 <sup>3</sup>	<50 <sup>3</sup>
2	<5	<5	4	<0.4	232	259	<40	<40	250	265
5	5.2	6	<0.4 <sup>3</sup>	<0.4	278	407	<40	<40	305	368
6	<5	<5	<0.4	<0.4	268	482	<40	<40	293	244
7	<5	<5	26	<0.4	125	231	<40	<40	79	53
8	<5	<5	<0.4	<0.4	149	248	<40	<40	<50	<50
12	<5	<5	<0.4	<0.4	172	185	<40	<40	<50	<50
13	<5	<5	<0.4	<0.4	152	182	<40	<40	<50	<50
14	<5	<5	<0.4	<0.4	132	232	<40	<40	<50	<50
15	<5	<5	<0.4	<0.4	98.3	284	<40	<40	70	77
18	<5	<5	<0.4	<0.4	144	246	<40	<40	<50	<50
19	<5	<5	<0.4	<0.4	1,140	140	<40	<40	<50	<50
20	<5	<5	<0.4	<0.4	159	198	<40	<40	84	56
21	17.3	<5	<0.4	<0.4	166	326	<40	<40	55	58
24	<5	<5	<0.4	<0.4	246	153	<40	<40	64	53
25	<5	<5	<0.4	<0.4	155	250	<40	<40	51	62
26	<5	<5	<0.4	<0.4	187	318	<40	<40	62	54
27	<5	<5	<0.4	<0.4	164	250	<40	<40	<50	<50
29	<5	6	<0.4	<0.4	152	486	<40	<40	68	161
30	<5	<5	<0.4	<0.4	134	179	<40	<40	52	<50
35	<5	<5	<0.4	<0.4	219	327	<40	<40	89	89
36	<5	<5	<0.4	<0.4	146	241	<40	<40	75	63
<b>Mean</b>	<b>1.2</b>	<b>0.8</b>	<b>2.7</b>	<b>&lt;0.4</b>	<b>218</b>	<b>267</b>	<b>&lt;40</b>	<b>&lt;40</b>	<b>76</b>	<b>73</b>
<b>Std. Dev.</b>	<b>4.2</b>	<b>2.0</b>	<b>6.5</b>	<b>NA<sup>5</sup></b>	<b>211</b>	<b>94</b>	<b>NA<sup>5</sup></b>	<b>NA<sup>5</sup></b>	<b>93</b>	<b>100</b>

- (1) Concentrations were determined by acid digestion.
- (2) Contaminant of Concern for this site.
- (3) Method Detection Limit.
- (4) NS = Not sampled.
- (5) NA = Not Applicable.

Table 5-15

Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern in Soil at Site 129-3 After Soil Amendment Additions to 1998 White Mustard

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb, mg/kg		Pb <sup>1,2</sup> mg/kg		Mn <sup>1,2</sup> mg/kg		Sb <sup>1,2</sup> mg/kg	
	Depth, inches													
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	NS <sup>3</sup>	NS <sup>3</sup>	NS <sup>3</sup>	NS <sup>3</sup>	NS <sup>3</sup>	NS <sup>3</sup>	<0.3 <sup>4</sup>	<0.3 <sup>4</sup>	314	330	212	267	<40 <sup>4</sup>	<40 <sup>4</sup>
2	8.2	8.0	3	2	3	2	<0.3	2	266	305	192	221	<40	<40
3	NS	NS	NS	NS	NS	NS	3	<0.3	288	274	198	231	<40	<40
4	8.2	8.1	3	3	3	3	<0.3	<0.3	219	248	208	219	<40	<40
5	NS	NS	NS	NS	NS	NS	6	6	97	130	218	242	<40	<40
6	8.3	8.6	<0.3 <sup>4</sup>	<0.3 <sup>4</sup>	<0.3 <sup>4</sup>	<0.3 <sup>4</sup>	2	2	73	71	476	300	<40	<40
7	NS	NS	NS	NS	NS	NS	<0.3	<0.3	27	18	276	211	<40	<40
8	8.5	8.5	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	28	27	223	259	<40	<40
9	NS	NS	NS	NS	NS	NS	5	9	123	91	168	276	<40	<40
10	8.3	8.7	3	2	3	2	7	4	55	35	168	233	<40	<40
11	NS	NS	NS	NS	NS	NS	4	2	37	35	206	606	<40	<40
12	8.3	8.6	<0.3	<0.3	<0.3	<0.3	3	3	23	25	268	314	<40	<40
13	NS	NS	NS	NS	NS	NS	160	4	314	37	208	266	<40	<40
14	8.3	8.5	209	57	182	50	119	14	351	76	217	311	<40	<40
15	NS	NS	NS	NS	NS	NS	10	2	259	74	175	458	<40	<40
16	8.2	8.4	<0.3	3	<0.3	3	<0.3	<0.3	68	40	197	350	<40	<40
17	NS	NS	NS	NS	NS	NS	<0.3	<0.3	21	27	208	491	<40	<40
18	8.3	8.2	<0.3	5	<0.3	4	<0.3	<0.3	26	39	190	274	<40	<40
19	NS	NS	NS	NS	NS	NS	348	104	1240	669	241	196	<40	<40
20	8.3	8.5	128	78	111	68	100	19	1380	80	185	178	<40	<40
21	NS	NS	NS	NS	NS	NS	<0.3	<0.3	43	26	165	236	<40	<40
22	8.3	8.4	5	2	4	2	2	<0.3	62	60	188	231	<40	<40
23	NS	NS	NS	NS	NS	NS	8	1	24	73	188	190	<40	<40

**Table 5-15 (Continued)**

**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern in Soil at Site 129-3 After Soil Amendment Additions to 1998 White Mustard**

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb, mg/kg		Pb <sup>1,2</sup> mg/kg		Mn <sup>1,2</sup> mg/kg		Sb <sup>1,2</sup> mg/kg	
	Depth, inches													
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
24	8.4	8.7	<0.3	2	<0.3	2	<0.3	<0.3	18	142	213	302	<40	<40
25	NS	NS	NS	NS	NS	NS	15	23	499	187	209	212	<40	<40
26	8.5	8.4	2	32	2	28	4	74	234	471	226	250	<40	<40
27	NS	NS	NS	NS	NS	NS	260	116	797	374	225	238	<40	<40
28	8.4	8.5	12	4	10	3	5	3	145	64	226	266	<40	<40
29	NS	NS	NS	NS	NS	NS	<0.3	<0.3	81	9	191	196	<40	<40
30	8.3	8.3	985	3	856	3	14	<0.3	10	12	176	314	<40	<40
31	NS	NS	NS	NS	NS	NS	<0.3	<0.3	11	9	198	207	<40	<40
32	7.7	8.2	2940	187	2,560	163	34	7	12	9	130	1560	<40	<40
33	NS	NS	NS	NS	NS	NS	<0.3	1	11	8	230	321	<40	<40
34	8.3	8.3	2	2	2	2	1	1	14	9	193	232	<40	<40
35	NS	NS	NS	NS	NS	NS	1	2	11	3	187	254	<40	<40
36	8.4	8.5	3	3	3	3	1	<0.3	12	7	146	230	<40	<40
<b>Mean</b>	<b>8.3</b>	<b>8.4</b>	<b>358</b>	<b>21</b>	<b>311</b>	<b>18</b>	<b>31</b>	<b>11</b>	<b>200</b>	<b>114</b>	<b>209</b>	<b>309</b>	<b>&lt;40</b>	<b>&lt;40</b>
<b>Std. Dev.</b>	<b>0.2</b>	<b>0.2</b>	<b>713</b>	<b>47</b>	<b>620</b>	<b>41</b>	<b>77</b>	<b>28</b>	<b>321</b>	<b>152</b>	<b>54</b>	<b>231</b>	<b>NA<sup>5</sup></b>	<b>NA<sup>5</sup></b>

- (1) Concentrations were determined by acid digestion.
- (2) Contaminant of Concern for this site.
- (3) NS = Not Sampled.
- (4) Method Detection Limit.
- (5) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

## **5.2.5 Plant Sampling - 1998 White Mustard Crop**

### **5.2.5.1 Plant Growth - 1998 White Mustard Crop**

The white mustard crop was broadcast seeded on August 20, 1998. However, poor stand establishment (approximately 50% at Site C and 70% at Site 129-3) necessitated replanting after two weeks. This was done by broadcast seeding over the existing crop. A final stand establishment of about 50% at Site C and 90% at Site 129-3 was achieved. Many of the plants at Site C were stunted and coverage within individual plots varied considerably (Table 5-16). Coverage and plant size at Site 129-3 was more uniform and consistent (Table 5-17). However, examination of plants excavated from the soil at both sites revealed a very shallow and sparse root system, approximately 6 inches in spread, which penetrated the soil for only about 3 to 4 inches deep. A more typical spread would be 1 foot, with penetration down to 2 to 3 feet.

### **5.2.5.2 Pre-Amendment Plant Sampling - 1998 White Mustard Crop**

At Site C, the average lead concentration of white mustard plants before soil amendment addition was 47 mg/kg (Table 5-18). This is slightly more than the value of 30 mg/kg observed in corn before soil amendment additions (Table 5-8). Manganese was the only other COCs that accumulated to detectable levels and this was in the same range as observed with corn before soil amendment application. The low concentrations of lead and manganese in the white mustard plants indicate that the EDTA remaining in the soil from the application to the corn crop, which was measured immediately before soil amendment application to white mustard (Table 5-12), did not significantly enhance uptake of lead and manganese during the growth of the white mustard crop over that expected from a contaminated soil without soil amendments. However, no analysis was conducted for EDTA in plant tissue before soil amendments to white mustard. Possibly the effect on mustard during the growing season of residual EDTA from the previous application to corn could have caused reduced lead uptake (discussed in Section 5.2.5.3) when EDTA was applied to mustard. In addition, factors such as other contaminants in the soil, the poor agronomic conditions at the site, and excess rainfall likely contributed to diminished plant function and lead uptake was reduced as a result.

For Site 129-3 also, lead accumulated only in low concentrations in the white mustard during the growing season (Table 5-19). There was less lead accumulation in these plants than at Site C due to the lower concentration of lead in the soil at Site 129-3. Lead concentrations in white mustard were only slightly higher than concentrations seen in corn (Table 5-9) before EDTA application (18 and 9 mg/kg for white mustard and corn, respectively). Manganese accumulated in low amounts in concentrations similar to those observed in corn (Table 5-9) before chelate application. The low lead and manganese concentrations in white mustard were not unexpected, since at Site 129-3, very little EDTA and water-soluble lead remained in the soil from the previous amendment application to corn (Table 5-13).

**Table 5-16**  
**1998 White Mustard Crop Characteristics at Site C**  
**Before Soil Amendment Application**

Site	Grid No.	Percent of Grid Covered by Plants	Relative Plant Size <sup>1</sup>
C	1	100	L
	2	75	S, L
	3	20	S
	4	50	S
	5	50	S, M
	6	90	L
	7	100	L
	8	60	L
	9	0	NA
	10	10	VS
	11	30	M
	12	90	L
	13	100	M, L
	14	75	M, L
	15	0	NA
	16	0	NA
	17	10	S, M
	18	85	M, L
	19	100	M, L
	20	50	S, M
	21	0	NA
	22	0	NA
	23	5	VS
	24	90	S, M, L
	25	45	L
	26	50	M, L
	27	0	NA
	28	0	NA
	29	35	S, M
	30	100	L
	31	5	S
	32	5	S
	33	0	NA
	34	10	VS
	35	50	S, M
	36	90	L

(1) VS - Very small plants, <6 inches tall.

S - Small plants, 6-12 inches tall.

M - Medium plants, 12-24 inches tall.

L - Large plants, 24-36 inches.

NA - Not Applicable.

Note: More than one designation indicates equal distribution of plants among categories.

**Table 5-17**  
**1998 White Mustard Crop Characteristics at Site 129-3**  
**Before Soil Amendment Application**

Site	Grid No.	Percent of Grid Covered by Plants	Relative Plant Size <sup>1</sup>
129-3	1	100	M, L
	2	75	M, L
	3	70	S, M
	4	80	S, M, L
	5	100	VL
	6	100	VL
	7	50	S, M
	8	50	S, M
	9	80	S, M, L
	10	80	S, M
	11	95	VL
	12	90	VL
	13	85	S (10%), M, L
	14	95	VL
	15	95	M, VL
	16	90	M, L, VL
	17	95	VL
	18	100	VL
	19	95	M, L
	20	100	VL
	21	100	VL
	22	90	S(10%), M(30%), VL
	23	95	VL
	24	80	S(10%), VL
	25	95	VL
	26	100	VL
	27	90	S, M
	28	90	S, M, VL
	29	100	VL
	30	75	L
	31	100	VL
	32	100	VL
	33	100	VL
	34	90	M,VL
	35	100	VL
	36	70	L

(1) VS - Very small plants, <6 inches tall.

S - Small plants, 6-12 inches tall.

M - Medium plants, 12-24 inches tall.

L - Large plants, 24-36 inches.

VL - Very large plants, >36 inches tall.

Note: Unless otherwise noted, more than one designation indicates equal distribution of plants among categories. Numbers in parentheses indicate percent of plants populated by the given plant size.

**Table 5-18**  
**Contaminants of Concern in 1998 White Mustard from**  
**Site C Prior to Adding Soil Amendments**

<b>Grid No.</b>	<b>Pb, mg/kg</b>	<b>As<sup>1</sup>, mg/kg</b>	<b>Be<sup>1</sup>, mg/kg</b>	<b>Mn<sup>1</sup>, mg/kg</b>	<b>Sb<sup>1</sup>, mg/kg</b>	<b>Tl<sup>1</sup>, mg/kg</b>
1	27	<4.4 <sup>2</sup>	<0.34 <sup>2</sup>	21	<40 <sup>2</sup>	<50 <sup>2</sup>
3	62	<4.4	<0.34	18	<40	<50
5	27	<4.4	<0.34	20	<40	<50
8	20	<4.4	<0.34	65	<40	<50
10	94	<4.4	<0.34	23	<40	<50
12	21	<4.4	<0.34	36	<40	<50
13	40	<4.4	<0.34	13	<40	<50
17	21	<4.4	<0.34	24	<40	<50
20	124	<4.4	<0.34	38	<40	<50
24	95	<4.4	<0.34	44	<40	<50
25	47	<4.4	<0.34	19	<40	<50
29	20	<4.4	<0.34	19	<40	<50
36	14	<4.4	<0.34	25	<40	<50
<b>Mean</b>	<b>47</b>	<b>&lt;4.4</b>	<b>&lt;0.34</b>	<b>28</b>	<b>&lt;40</b>	<b>&lt;50</b>
<b>Std. Dev.</b>	<b>36</b>	<b>NA<sup>3</sup></b>	<b>NA</b>	<b>14</b>	<b>NA</b>	<b>NA</b>

- (1) Contaminant of Concern for this site.
- (2) Method Detection Limit.
- (3) NA = Not Applicable.

### 5.2.5.3 Post-Amendment Plant Sampling - 1998 White Mustard Crop

Post-harvest soil and plant sampling was done at Site C on October 11, 1998, and at Site 129-3 on October 12, 1998. Plant sampling at both sites was performed at or shortly after the prescribed 48-hour period determined to be optimal during the SFAAP Treatability Study conducted at TVA.<sup>Ref. 2</sup> At this time, the treated white mustard was observed to be mostly green, but wilted, although some bleaching of leaves had occurred with drooping flower heads and leaves. The plants had not dried out. Stalks were upright with leaves still attached. Plants directly adjacent to the drip delivery lines were wilted to a greater extent than plants in between the lines. The plants between the lines were wilting, but at a slower rate. As the plants were wilted, but were not desiccated and brittle, this facilitated the subsequent harvest. This operation was performed with no shattering and wind dispersal of plant tissue and the material was easily bundled for removal from the field and transport to the smelter. At a small untreated area at each site, the plants appeared to be in a normal growth state for white mustard plants, i.e., upright and green. However, the root system for the plants appeared to be diminutive and shallow. Appropriate care was used to obtain clean, soil-free plant samples from sampled stalks.

Harvesting of the crop was completed on October 13, 1998, and the crop was transported to the smelter on October 28, 1998, after appropriate samples were taken to determine final moisture content for yields. Yields of white mustard at both sites were determined by delineating several 2.8-square-foot areas within each plot, then harvesting plants within that area by cutting the stem 1 inch above the soil surface and extrapolating the plant biomass in the areas to obtain the biomass of the whole plot.

The total yield of white mustard at Site C (dry weight basis) was 377 pounds for the 0.2-acre area at 44% plant coverage. However, assuming 100% coverage, this was 4,280 lb/acre on a per-acre basis. The total yield of white mustard at Site 129-3 (dry weight basis) was 700 pounds for the 0.2-acre area at 89% plant coverage. Assuming 100% coverage, this was 3,890 lb/acre.

Lead uptake by white mustard after soil amendment application was lower than expected at both Site C and Site 129-3 (Tables 5-20 and 5-21). The average lead concentration in white mustard for Site C was 829 mg/kg and for Site 129-3, 338 mg/kg. This compares to average concentrations of 6,460 mg/kg and 1,300 mg/kg for corn (Tables 5-10 and 5-11). The average lead concentrations found for white mustard in the SFAAP greenhouse studies were 15,000 mg/kg.<sup>Ref. 2</sup> The average EDTA concentrations in white mustard at Site C and Site 129-3 of 77,200 mg/kg and 47,300 mg/kg, respectively, were higher than concentrations of 40,000 mg/kg observed in white mustard in the SFAAP greenhouse study.

Several factors may have contributed to the low uptake of lead by white mustard. The rooting system of the white mustard on the demonstration plots was shallow and limited, whereas corn roots were deep and extensive. The limited rooting pattern of the white mustard may have been due to carry-over EDTA and water-soluble lead from the amendment application to corn, or may have resulted from the poor soil conditions and excess rainfall. The greenhouse studies of white

**Table 5-19**  
**Contaminants of Concern in 1998 White Mustard from**  
**Site 129-3 Prior to Adding Soil Amendments**

<b>Grid No.</b>	<b>Pb, mg/kg</b>	<b>Mn<sup>1</sup>, mg/kg</b>	<b>Sb<sup>1</sup>, mg/kg</b>
1	7	25	<40 <sup>2</sup>
3	17	39	<40
5	7	33	<40
8	16	38	<40
10	9	38	<40
12	3	35	<40
13	10	55	<40
15	54	34	<40
17	6	40	<40
20	25	30	<40
22	13	34	<40
24	<1.5 <sup>2</sup>	27	<40
25	35	31	<40
27	61	61	<40
29	15	38	<40
32	6	41	<40
34	20	37	<40
36	10	25	<40
<b>Mean</b>	<b>18</b>	<b>37</b>	<b>&lt;40</b>
<b>Std. Dev.</b>	<b>17</b>	<b>9</b>	<b>NA<sup>3</sup></b>

- (1) Contaminant of Concern for this site.
- (2) Method Detection Limit.
- (3) NA = Not Applicable.

mustard grown in pots did not indicate the type of rooting that occurred at TCAAP. Lead may have moved downward to varying extents in the soil, after the corn crop was harvested, due to solubilization by EDTA and subsequent tillage/irrigation cycles before white mustard was planted. A large portion of the lead could have moved below the shallow rooting zone of the white mustard, but still be present in significant concentrations in the top 24 inches of soil, as shown in Tables 5-12 and 5-13.

The drip delivery system used for application of EDTA to the white mustard crop did not rapidly saturate the soil and required an extensive time for application, up to seven hours at Site C. The plant could take up lead in the vicinity of its roots as it was solubilized by EDTA, but as the soil was not quickly saturated, an aqueous medium did not exist for the constant movement of water-soluble lead to the plant roots. However, the plants were continuously exposed to EDTA by the slow application of the drip delivery system, which would allow the plants to take up large amounts of EDTA without concomitant accumulation of lead (Tables 5-20 and 5-21). Prolonged exposure of white mustard to EDTA may have killed the plants before they could take up significant amounts of lead.

#### **5.2.6 1998 Soil Solution Data for Sites C and 129-3**

Soil solution sample collection was attempted three weeks prior to amendment application in accordance with the procedures outlined in the Technology Demonstration Plan. The first sample that could be collected was on July 20, 1998, immediately following soil amendment applications to corn and ceased on October 19, 1998, two weeks after chelate application to white mustard. Lead and manganese were the only COCs present in detectable concentrations in soil solution samples collected from Site C and from Site 129-3 (Table 5-22). The sample solutions were also analyzed for EDTA to monitor movement of the chelate down through the soil (Table 5-22). Samples could not be obtained during corn growth apparently because the soil was too dry from water use by the dense rooting system of corn which prevented water from moving below the rooting zone.

Lead, EDTA, and manganese were detected in the soil solution at Site C beginning on August 1, 1998, about two weeks after amendment addition and harvest of the corn. The concentration of EDTA and lead at Site C reached a maximum of 2,170 mg/L and 900 mg/L, respectively, on October 2, 1998. However, these concentrations represented the contribution from only one lysimeter (#4) of the twelve that were installed, and these values radically skewed the averaged results (Table 5-23). When this lysimeter was collecting soil moisture, the average concentrations of lead and EDTA in the composite samples of soil solution increased. When this lysimeter did not collect solution, the average concentration of lead and EDTA in the composite sample decreased dramatically.

The lysimeter was installed correctly according to the manufacturer's instructions, and was effective in collecting the soil solution, although the amounts collected from week to week were somewhat erratic (Table 5-23). However, the lysimeter was installed in the area of the 1962 Pit, an area of the plot where extensive alteration to the native soil occurred due to dumping, burning, and soil excavation and replacement. Quite likely, the decomposing debris in the pit left channels and voids in the soil through which water from the surface could channel and collect.

**Table 5-20**  
**EDTA and Contaminants of Concern in 1998 White Mustard from Site C After Soil**  
**Amendment Additions**

Grid No.	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg	Pb, mg/kg	As <sup>1</sup> , mg/kg	Be <sup>1</sup> , mg/kg	Mn <sup>1</sup> , mg/kg	Sb <sup>1</sup> , mg/kg	Tl <sup>1</sup> , mg/kg
1	NS <sup>2</sup>	NS <sup>2</sup>	629	<4.5 <sup>3</sup>	0.4	152	<40 <sup>3</sup>	<50 <sup>3</sup>
2	80,000	69,500	627	<4.5	0.7	121	<40	<50
5	NS	NS	651	<4.5	<0.35 <sup>2</sup>	127	<40	<50
6	100,000	86,900	811	<4.5	<0.35	93	<40	<50
7	NS	NS	356	<4.5	<0.35	88	<40	<50
8	80,800	70,200	934	<4.5	<0.35	131	<40	<50
12	NS	NS	602	<4.5	<0.35	99	<40	<50
13	105,000	91,300	582	<4.5	<0.35	87	<40	<50
14	NS	NS	1,030	<4.5	<0.35	82	<40	<50
18	78,900	68,600	937	<4.5	<0.35	129	<40	<50
19	98,200	85,400	824	<4.5	<0.35	85	<40	<50
20	NS	NS	1,960	<4.5	<0.35	110	<40	<50
24	NS	NS	1,240	<4.5	<0.35	148	<40	<50
25	NS	NS	636	<4.5	<0.35	85	<40	<50
26	84,800	73,700	1,440	<4.5	<0.35	131	<40	<50
29	82,800	72,000	597	<4.5	<0.35	78	<40	<50
30	NS	NS	589	<4.5	<0.35	81	<40	<50
35	NS	NS	787	<4.5	<0.35	94	<40	<50
36	89,100	77,400	514	<4.5	<0.35	93	<40	<50
		-						
<b>Mean</b>	<b>88,800</b>	<b>77,200</b>	<b>829</b>	<b>&lt;4.5</b>	<b>&lt;0.35</b>	<b>106</b>	<b>&lt;40</b>	<b>&lt;50</b>
<b>Std. Dev.</b>	<b>9,800</b>	<b>8,500</b>	<b>379</b>	<b>NA<sup>4</sup></b>	<b>0.2</b>	<b>24</b>	<b>NA</b>	<b>NA</b>

- (1) Contaminant of Concern for this site.
- (2) NS = Not sampled.
- (3) Method Detection Limit.
- (4) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-21**  
**EDTA and Contaminants of Concern in 1998 White Mustard**  
**from Site 129-3 After Soil Amendment Additions**

<b>Grid No.</b>	<b>EDTA as Na<sub>2</sub>EDTA, mg/kg</b>	<b>EDTA as EDTA, mg/kg</b>	<b>Pb, mg/kg</b>	<b>Mn<sup>1</sup>, mg/kg</b>	<b>Sb<sup>1</sup>, mg/kg</b>
1	NS <sup>2</sup>	NS <sup>2</sup>	108	143	<40 <sup>3</sup>
2	NS	NS	76	133	<40
3	NS	NS	128	197	<40
4	40,200	34,900	95	231	<40
5	NS	NS	159	301	<40
6	NS	NS	216	481	<40
7	NS	NS	59	145	<40
8	31,500	27,400	129	201	<40
9	NS	NS	238	254	<40
10	NS	NS	105	348	<40
11	NS	NS	76	324	<40
12	57,900	50,300	47	613	<40
13	NS	NS	238	850	<40
14	NS	NS	236	220	<40
15	NS	NS	1,530	419	<40
16	67,900	59,000	101	335	<40
17	NS	NS	90	432	<40
18	NS	NS	108	478	<40
19	NS	NS	1,530	124	<40
20	36,300	31,600	719	274	<40
21	NS	NS	239	189	<40
22	NS	NS	88	261	<40
23	NS	NS	87	222	<40
24	53,700	46,700	44	368	<40
25	NS	NS	1,080	377	<40
26	NS	NS	532	347	<40
27	NS	NS	1,730	331	<40
28	73,100	63,500	261	359	<40
29	NS	NS	226	301	<40
30	NS	NS	83	275	<40
31	NS	NS	274	247	<40
32	64,700	56,200	308	309	<40
33	NS	NS	411	331	<40
34	NS	NS	439	322	<40
35	NS	NS	151	362	<40
36	64,200	55,800	232	343	<40
		-			
<b>Mean</b>	<b>54,400</b>	<b>47,300</b>	<b>338</b>	<b>318</b>	<b>&lt;40</b>
<b>Std. Dev.</b>	<b>15,000</b>	<b>13,000</b>	<b>437</b>	<b>139</b>	<b>NA<sup>4</sup></b>

(1) Contaminant of Concern for this site. (3) Method Detection Limit.  
(2) NS = Not sampled. (4) Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-22**  
**EDTA and Contaminants of Concern in Soil Solution from Lysimeters (1998)**

Date	Site	Sample Event	EDTA as Na <sub>2</sub> EDTA, mg/L	EDTA as EDTA, mg/L	Pb, mg/L	As <sup>1</sup> , mg/L	Be <sup>1</sup> , mg/L	Mn <sup>1</sup> , mg/L	Sb <sup>1</sup> , mg/L	Tl <sup>1</sup> , mg/L
07/20/98	C	Pre-Amendment Corn	<0.1 <sup>2</sup>	<0.1 <sup>2</sup>	<0.1 <sup>2</sup>	<0.3 <sup>2</sup>	<0.01 <sup>2</sup>	1	<0.6 <sup>2</sup>	<1.0 <sup>2</sup>
08/01/98	C	Post-Amendment Corn	40	35	10	<0.3	<0.01	2	<0.6	<1.0
08/06/98	C	Post-Amendment Corn	54	47	7	<0.3	<0.01	2	<0.6	<1.0
08/11/98	C	Post-Amendment Corn	40	35	10	<0.3	<0.01	2	<0.6	<1.0
08/25/98	C	Growing-Season Mustard	516	449	131	<0.3	<0.01	16	<0.6	<1.0
09/04/98	C	Growing-Season Mustard	488	424	260	<0.3	<0.01	21	<0.6	<1.0
09/11/98	C	Growing-Season Mustard	1,890	1,640	270	<0.3	<0.01	19	<0.6	<1.0
09/18/98	C	Growing-Season Mustard	73	63	17	<0.3	<0.01	1	<0.6	<1.0
09/25/98	C	Growing-Season Mustard	2,170	1,890	644	<0.3	<0.01	24	<0.6	<1.0
10/02/98	C	Growing-Season Mustard	2,500	2,170	900	<0.3	<0.01	32	<0.6	<1.0
10/19/98	C	Post-Amendment Mustard	1,946	1,690	783	<0.3	<0.01	34	<0.6	<1.0
08/06/98	129-3	Post-Amendment Corn	1,430	1,240	14	<0.3	<0.01	10	<0.6	NA
09/04/98	129-3	Growing-Season Mustard	380	330	155	NA <sup>3</sup>	NA	16	<0.6	NA
09/18/98	129-3	Growing-Season Mustard	5	4	2	NA	NA	<0.01	<0.6	NA

- (1) Contaminant of Concern for this site.
- (2) Method Detection Limit.
- (3) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

The porous cup may have been inserted into a void, and lead and EDTA-contaminated water from the treated upper soil layer may have pooled around the cup, thus accounting for the elevated concentrations of lead and EDTA in the solution. Alternately, a leakage could have occurred in the bentonite clay seal around the neck of the lysimeter at the soil surface, and leakage would have allowed channeling from the surface. Such a break would not have been obvious to an observer, since tilling operations normally covered the clay cap.

This lysimeter was located in the southeast corner of Site C, which was part of the 1962 Pit, a large area (60 ft x 20 ft x 30 ft) where equipment was decontaminated by drenching with fuel oil and burning. The equipment was removed, but a considerable amount of metal scrap, wood, and concrete debris was subsequently disposed of in the pit, and soil of diverse type was used as fill and cover. The soil of Unit 1 was shallow in this part of the field and the underlying clay of Unit 2 may have created an impermeable "bowl" which trapped a pool of contaminated water which bathed the porous cup of the lysimeter. Samples could not be obtained from lysimeters at Site 129-3 until August 6, 1998 (Table 5-24). EDTA and lead were also detected in lysimeter samples at Site 129-3 beginning on August 6, 1998.

**Table 5-23**  
**Summary of Soil Solution Collection in Lysimeters at Site C in 1998**  
**(Milliliters)**

Lys. No.	8/01	8/06	8/11	8/25	9/04	9/11	9/18	9/25	10/02	10/19
1	----	776	64	434	149	----	----	----	----	----
2	----	927	10	290	94	----	----	----	----	----
3	----	508	64	206	72	----	----	----	----	----
4	----	1017	100	120	728	531	----	528	360	500
5	----	684	96	526	230	40	----	----	----	210
6	----	1060	376	714	410	185	54	82	4	----
7	----	---	----	24	----	----	----	----	----	----
8	----	898	----	----	----	----	----	----	----	----
9	125	80	130	317	268	150	24	----	----	----
10	----	798	----	214	----	----	----	----	----	----
11	----	----	----	----	----	----	----	----	----	----
12	----	418	----	----	----	----	----	----	----	----

**Table 5-24**  
**Summary of Soil Solution Collection in Lysimeters at Site 129-3 in 1998**  
**(Milliliters)**

Lys. No.	8/01	8/06	8/11	8/25	9/04	9/11	9/18	9/25	10/02	10/19
1	----	1086	----	----	1071	----	----	----	----	----
2	----	----	----	----	----	----	----	----	----	----
3	----	----	----	----	965	----	----	----	----	----
4	----	547	----	----	606	----	----	----	----	----
5	----	213	----	----	536	----	----	----	----	----
6	----	937	----	----	1156	----	----	----	----	----
7	----	204	----	----	614	----	----	----	----	----
8	----	468	----	----	775	----	----	----	----	----
9	125	123	----	----	610	----	270	----	----	----
10	----	485	----	----	380	----	----	----	----	----
11	----	----	----	----	168	----	----	----	----	----
12	----	----	----	----	900	----	----	----	----	----

A sample collected from the lysimeter in the northwest corner of Site C (lysimeter #9) on August 25, 1998, exhibited a blue color. This blue color prompted an analysis for cobalt and copper, since these elements may form complexes which, in solution, are blue in color, e.g., sulfates, amines, etc.

Blue-colored soil solution samples showed copper concentrations ranging from 3 ppm up to 267 ppm over the 8-week period in which they were collected (Table 5-25). A soil solution sample taken immediately prior to amendment addition showed a copper concentration of <0.004 ppm. The presence of copper in the solutions likely was the result of a reaction between acetic acid and EDTA with copper particulate (copper-jacketed projectiles, copper scrap metal, wire, etc.) which have been observed in the soil. It is likely there was a localized copper source in the soil in the immediate vicinity of the lysimeter collecting the solution. This episode seemed to be an isolated event from a single source and the reduction in concentration at subsequent sampling events (Table 5-25) indicated that copper persistence in the soil solution would probably diminish with time.

**Table 5-25  
Results of Copper Analysis on Water Collected  
from Lysimeter at Site C (1998)**

Sample	Date	Copper, mg/L
1	7/20/98 <sup>1</sup>	<0.004 <sup>2</sup>
2	8/6/98	8
3	8/11/98	3
4	8/25/98	12
5	9/4/98	57
6	9/11/98	253
7	9/18/98	11
8	9/25/98	267
9	10/2/98	190
10	10/19/98	77

- (1) Pre-amendment addition sample; however, a single sample may not be indicative of true baseline copper concentrations.
- (2) Method Detection Limit.

## 5.2.7 Soil Sampling - 1999 Corn Crop

### 5.2.7.1 Pre-Amendment Soil Sampling - 1999 Corn Crop

At Site C, the EDTA in the soil was present at very low concentrations in samples taken immediately before soil amendment application for the 1999 corn crop (Table 5-26). The most recent application of EDTA before this sampling was in October 1998 for the white mustard crop (Table 5-14). At that time soil samples taken 2 to 3 days after EDTA was added to the mustard showed EDTA concentrations of 4,590 mg/kg at the 0- to 12-inch depth and 1,590 at the 12 to 24-inch depth (Table 5-14). Over the winter and during the following spring and summer growing season, EDTA concentrations decreased to those shown in Table 5-26. This could be due to degradation of EDTA, adsorption of EDTA onto organic matter and soil minerals (e.g., iron oxides and hydroxides), or movement of EDTA to soil depths below the sampling zone of 2 feet, but is likely a combination of all these factors.

Water-soluble lead concentrations, as shown in Table 5-26, were also low, compared to 1998 values following the EDTA application to the white mustard crop (Table 5-14). This would be expected from the low concentrations of EDTA. Adsorption of EDTA onto hydrous oxide fractions, or degradation of EDTA and re-precipitation of lead into less soluble forms in the soil, could account for the large decrease in soluble lead concentrations in the top 24 inches of soil.

Downward movement of lead could also have occurred. As with EDTA, this would likely have been promoted by the heterogeneous physical nature of the site.

Overall, total lead concentrations were lower at both sampling depths (Table 5-26) than observed in the 1998 growing season after amendment application to white mustard (Table 5-14). Since there was lead uptake by the corn crop in 1998, this decrease in soil lead concentration was partly attributed to phytoextraction by the crop. The mean for total lead at the 12- to 24-inch depth (1,281 mg/kg) was slightly lower than in the upper layer. However, the variability in lead

concentrations from grid to grid and at different sampling periods prevents a conclusive determination of the dynamics of lead in the soil. There was one outlier value in the data (54,300 mg/kg in grid 36) which may be artificially high due to contamination of the sample by particulate lead.

Of the other COCs in pre-amendment soil samples, manganese concentrations were similar to values found in the 1998 demonstration. Concentrations of antimony, arsenic, and beryllium were essentially below the method detection limit at both soil depths. Thallium was found at high levels only in grid 11.

At Site 129-3, inadequate plant growth throughout the plot area precluded sampling any grids except grids 1 and 2. However, total lead concentrations in these grids (Table 5-27) were similar to values obtained for soil samples taken throughout the 1998 growing season (Tables 5-5, 5-7, 5-13, 5-15). Both EDTA and water-soluble lead were found at very low concentrations. The concentrations of manganese and antimony found in 1999 in one of the two grids was similar to 1998 values.

#### **5.2.7.2 Post-Amendment Soil Sampling - 1999 Corn Crop**

For Site C, EDTA concentrations in soil (Table 5-28) tended to be quite variable and localized primarily in the top 12 inches of soil. Although a sufficient volume of EDTA solution was applied to wet the top 24 inches of soil, the concentration of EDTA this year was reduced by one-third from the concentration applied in 1998 to reflect an application based on the frequency of occurrence of a given lead concentration within the grids across the field. Adsorption of the majority of EDTA on the organic matter and hydrous oxides in the soil likely occurred in the top 12 inches at the time of application. Therefore less of the EDTA was found at the lower depth. Higher concentrations of water-soluble lead were found at the 0- to 12-inch than at 12- to 24-inch depth, corresponding to the higher concentration of EDTA in the upper layer. Total lead concentrations were highly variable, and no discernible patterns of lead distribution in the soil were observed.

None of the other COCs showed significantly altered concentrations in the soil after amendment application (Table 5-26 vs Table 5-28).

At Site 129-3, EDTA concentrations in soil at the 0- to 12-inch depth in the two grids sampled (Table 5-29) averaged about the same as the average concentration found after amendment additions for corn in the 1998 demonstration (Table 5-7). Very little EDTA was found at the 12- to 24-inch depth.

Water-soluble lead concentrations were a reflection of the amount of EDTA found in the soil. Detectable levels of water-soluble lead were found only in grid 1 at the 0- to 12-inch depth, which corresponds to a high concentration of EDTA in the soil (Table 5-29).

Total lead concentrations were quite variable (Table 5-29), but were generally somewhat lower in grid 1 than found in the 1998 demonstration. Grid 2 values varied widely from values found after amendment application to mustard (Table 5-15), most likely due to the high variability of lead in the soil.

Antimony concentrations were below detection limits; manganese concentrations were relatively unchanged from the 1998 values.

In order to determine if lateral movement of amendments occurred, samples (designated as A, B, C, and D in Table 5-30) were taken from locations in grids 4, 10, 16, and 22 at Site C that were immediately adjacent to the treated areas. There was a possibility that some lateral movement of EDTA occurred, but this was minimal, since EDTA concentrations observed in the treated areas (Table 5-28) were higher than concentrations observed in the adjacent areas. Similarly, concentrations of water-soluble lead in the treated areas were much higher than in the non-treated areas. The limited data collected for Site 129-3 from grids 3 and 7 (samples A and B in Table 5-30) adjacent to the sampled grids 1 and 2 did not indicate lateral movement of EDTA at this site.

**Table 5-26  
Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern  
at Site C in 1999 Prior to Soil Amendment Additions to Corn**

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb, mg/kg		Pb, mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
5	8.8	8.7	7.9	9.1	6.9	7.9	29.8	13.3	956	1,740
6	8.6	8.7	3.2	5.7	2.8	5.0	48.9	93.6	3,220	3,410
11	8.7	8.5	13.1	7.0	11.4	6.1	14.3	2.6	686	813
12	8.6	8.8	3.3	2.3	2.9	2.0	27.6	5.9	826	382
17	8.5	8.6	4.1	13.6	3.6	11.8	2.9	1.4	382	861
18	8.5	8.7	4.1	4.7	3.6	4.1	54.0	2.5	3,540	595
23	8.0	8.2	7.6	14.2	6.6	12.3	6.6	<0.96 <sup>2</sup>	774	1,660
24	8.5	8.5	4.6	6.1	4.0	5.3	41.4	29.5	1,500	1,110
29	8.6	8.4	5.6	7.5	4.9	6.5	31.3	24.5	755	1,340
30	8.6	8.7	<0.3 <sup>2</sup>	3.4	<0.3 <sup>2</sup>	3.0	16.4	3.8	903	315
35	8.6	8.7	2.6	4.1	2.3	3.6	20.8	40.6	3,200	1,870
36	8.4	8.7	<0.3 <sup>2</sup>	<0.3 <sup>2</sup>	<0.3 <sup>2</sup>	<0.3 <sup>2</sup>	<0.87 <sup>2</sup>	14.8	1,260	(54,300) <sup>3</sup>
<b>Mean</b>	<b>8.5</b>	<b>8.6</b>	<b>4.7</b>	<b>6.5</b>	<b>4.1</b>	<b>5.6</b>	<b>24.5</b>	<b>19.4</b>	<b>1,500</b>	<b>1,280</b>
<b>Std. Dev.</b>	<b>0.2</b>	<b>0.2</b>	<b>3.6</b>	<b>4.2</b>	<b>3.1</b>	<b>3.7</b>	<b>17.6</b>	<b>26.7</b>	<b>1,135</b>	<b>887</b>

- (1) Contaminant of Concern for this site.
- (2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL). The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied. For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.
- (3) 54,300 is an outlier, probably caused by particulate lead. This result was excluded from the statistical analysis.
- (4) Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-26 (Continued)**  
**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern at**  
**Site C in 1999 Prior to Soil Amendment Additions to Corn**

Grid No.	As <sup>1</sup> , mg/kg		Be <sup>1</sup> , mg/kg		Mn <sup>1</sup> , mg/kg		Sb <sup>1</sup> , mg/kg		Tl <sup>1</sup> , mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
5	<1.02 <sup>3</sup>	<1.14 <sup>3</sup>	<0.05 <sup>3</sup>	<0.06 <sup>3</sup>	355	652	<1.53 <sup>3</sup>	<1.71 <sup>3</sup>	<2.54 <sup>3</sup>	<2.86 <sup>3</sup>
6	<0.92	<0.76	<0.05	<0.04	171	193	<1.38	<1.15	<2.30	<1.91
11	<1.11	<1.23	0.4	0.1	539	684	<1.67	<1.85	96.9	32.8
12	<1.08	<0.97	0.1	0.3	198	276	<1.62	<1.45	<2.71	<2.42
17	<0.95	<0.94	0.3	0.3	445	736	<1.42	<1.41	<2.37	10.6
18	<0.84	<1.01	0.1	0.1	265	254	<1.26	<1.51	4.03	<2.51
23	<0.91	<0.77	0.1	3.9	235	274	<1.37	<1.15	<2.28	4.67
24	<0.80	<0.75	0.5	0.2	190	237	<1.20	<1.13	<2.01	<1.88
29	<0.95	<0.99	0.5	5.4	259	295	<1.43	<1.49	<2.38	<2.48
30	<0.95	<1.10	0.7	0.3	170	169	<1.42	<1.65	<2.37	<2.75
35	<1.01	<0.88	0.1	0.0	196	274	<1.52	<1.32	<2.53	<2.21
36	<1.07	<0.67	0.1	0.1	221	212	<1.61	852	<2.68	<1.68
<b>Mean</b>	<b>&lt;MDL<sup>3</sup></b>	<b>&lt;MDL<sup>3</sup></b>	<b>0.2</b>	<b>0.9</b>	<b>270</b>	<b>355</b>	<b>&lt;MDL<sup>3</sup></b>	<b>71.0</b>	<b>9.4</b>	<b>4.9</b>
<b>Std. Dev.</b>	<b>NA<sup>4</sup></b>	<b>NA<sup>4</sup></b>	<b>0.2</b>	<b>1.8</b>	<b>117</b>	<b>207</b>	<b>NA<sup>4</sup></b>	<b>NA<sup>4</sup></b>	<b>27.6</b>	<b>9.2</b>

- (1) Contaminant of Concern for this site.
- (2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL).  
 The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied.  
 For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.
- (3) 54,300 is an outlier, probably caused by particulate lead. This result was excluded from the statistical analysis.
- (4) Not Applicable.

**Table 5-27**  
**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of**  
**Concern at Site 129-3 in 1999 Prior to Soil Amendment Additions to Corn**

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb, mg/kg		Pb, mg/kg		Mn <sup>1</sup> , mg/kg		Sb <sup>1</sup> , mg/kg	
	Depth, inches													
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	7.8	8.1	1.9	1.6	1.7	1.4	6.0	2.8	27	117	262	315	<1.35 <sup>2</sup>	<1.44 <sup>2</sup>
2	7.5	8.1	<0.3 <sup>2</sup>	1.3	<0.3 <sup>2</sup>	1.1	<0.87 <sup>2</sup>	4.1	60	216	1,230	206	<1.18	<1.61
<b>Mean</b>	<b>7.7</b>	<b>8.1</b>	<b>1.0</b>	<b>1.4</b>	<b>0.9</b>	<b>1.2</b>	<b>3.2</b>	<b>3.4</b>	<b>44</b>	<b>167</b>	<b>746</b>	<b>261</b>	<b>&lt;MDL<sup>2</sup></b>	<b>&lt;MDL<sup>2</sup></b>
<b>Std. Dev.</b>	<b>0.3</b>	<b>0.1</b>	<b>NA<sup>3</sup></b>	<b>0.2</b>	<b>NA<sup>3</sup></b>	<b>0.2</b>	<b>NA<sup>3</sup></b>	<b>0.9</b>	<b>23</b>	<b>70</b>	<b>684</b>	<b>77</b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>

- (1) Contaminant of Concern for this site.
- (2) Method Detection Limit. Where one datum point was equal to or less than the MDL, one-half the value of the MDL was substituted for this number when calculating the mean and standard deviation.
- (3) Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-28**  
**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern at Site C in**  
**1999 after Soil Amendment Additions to Corn**

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb, mg/kg		Pb, mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
5	8.9	8.8	26	6	23	5	13	2	553	1,510
6	9.3	9.5	238	47	207	41	200	80	3,120	12,900
11	8.7	8.8	3,760	13	3,270	11	182	<1.05 <sup>2</sup>	953	2,320
12	9.3	9.4	794	158	690	137	314	162	2,100	2,840
17	8.8	8.6	6,290	15	5,470	13	192	3	551	732
18	8.7	9.1	377	135	328	117	190	121	1,310	2,030
23	8.9	8.5	2,390	21	2,080	18	138	<1.08	469	1,240
24	8.6	9.3	1,390	569	1,210	495	747	340	4,030	3,900
29	9.1	8.7	12	38	10	33	15	31	991	4,200
30	9.1	9.4	2,740	5	2,380	4	469	34	542	256
35	9.2	8.9	1,210	135	1,050	117	217	83	1,070	1,660
36	9.4	9.3	1,020	396	887	344	492	258	797	5,160
<b>Mean</b>	<b>9.0</b>	<b>9.0</b>	<b>1,660</b>	<b>179</b>	<b>1,440</b>	<b>156</b>	<b>264</b>	<b>93</b>	<b>1,370</b>	<b>3,230</b>
<b>Std. Dev.</b>	<b>0.3</b>	<b>0.3</b>	<b>943</b>	<b>199</b>	<b>820</b>	<b>173</b>	<b>212</b>	<b>111</b>	<b>1,138</b>	<b>3,378</b>

- (1) Contaminant of Concern for this Site.
- (2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL).  
 The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied.  
 For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.
- (3) Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-28 (Continued)**  
**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of Concern at**  
**Site C in 1999 after Soil Amendment Additions to Corn**

Grid No.	As <sup>1</sup> , mg/kg		Be <sup>1</sup> , mg/kg		Mn <sup>1</sup> , mg/kg		Sb <sup>1</sup> , mg/kg		Tl <sup>1</sup> , mg/kg	
	Depth, inches									
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
5	<0.95 <sup>2</sup>	<0.82 <sup>2</sup>	<0.05 <sup>2</sup>	<0.04 <sup>2</sup>	1100	305	<1.43 <sup>2</sup>	<1.23 <sup>2</sup>	<2.39 <sup>2</sup>	<2.04 <sup>2</sup>
6	<0.78	<0.96	<0.04	<0.05	258	166	<1.17	<1.27	<1.95	<2.39
11	<0.97	<1.03	<0.05	<0.05	232	766	<1.46	<1.55	<2.43	47.3
12	<0.68	<1.03	1.69	0.23	240	217	<1.02	<1.55	<1.70	<2.58
17	<0.83	<1.01	<0.04	<0.05	371	564	<1.24	<1.52	<2.07	<2.53
18	<0.99	<0.74	<0.05	<0.04	187	294	<1.49	<1.10	<2.48	<1.84
23	<0.70	<1.18	<0.04	<0.06	222	438	<1.06	<1.77	<1.76	<2.95
24	<0.79	<0.73	<0.04	2.68	190	341	<1.18	<1.10	<1.97	<1.83
29	<1.00	<0.70	<0.05	<0.04	235	313	<1.50	<1.05	<2.49	<1.75
30	<0.73	<0.66	4.06	0.39	223	200	<1.09	<1.00	<1.82	<1.66
35	<0.91	<0.98	0.09	<0.05	234	354	<1.36	<1.47	<2.27	<2.45
36	<0.88	<0.80	<0.04	3.15	147	169	<1.32	<1.21	<2.20	<2.01
<b>Mean</b>	<MDL <sup>2</sup>	<MDL <sup>2</sup>	<b>0.5</b>	<b>0.4</b>	<b>303</b>	<b>344</b>	<MDL <sup>2</sup>	<MDL <sup>2</sup>	<MDL <sup>2</sup>	<b>11.0</b>
<b>Std. Dev.</b>	<i>NA</i> <sup>3</sup>	<i>NA</i> <sup>3</sup>	<i>NA</i> <sup>3</sup>	<i>NA</i> <sup>3</sup>	<b>257</b>	<b>176</b>	<i>NA</i> <sup>3</sup>	<i>NA</i> <sup>3</sup>	<i>NA</i> <sup>3</sup>	<i>NA</i> <sup>3</sup>

- (1) Contaminant of Concern for this Site.
- (2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL).  
 The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied.  
 For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.
- (3) Not Applicable.

**Table 5-29**  
**Soil pH, EDTA, Water-Soluble Pb, and Contaminants of**  
**Concern at Site 129-3 in 1999 After Soil Amendment Additions to Corn**

Grid No.	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb, mg/kg		Pb, mg/kg		Mn <sup>1</sup> , mg/kg		Sb <sup>1</sup> , mg/kg	
	Depth, inches													
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
1	8.2	8.6	665	2.6	578	2.3	19.6	<0.96 <sup>2</sup>	63	105	212	187	<1.19 <sup>2</sup>	<1.16 <sup>2</sup>
2	8.4	8.3	6	2.8	5	2.4	<0.97 <sup>2</sup>	<0.92	556	69	234	214	<1.48	<1.22
<b>Mean</b>	<b>8.3</b>	<b>8.4</b>	<b>336</b>	<b>2.7</b>	<b>292</b>	<b>2.3</b>	<b>9.8</b>	<b>&lt;MDL<sup>2</sup></b>	<b>310</b>	<b>87</b>	<b>223</b>	<b>201</b>	<b>&lt;MDL</b>	<b>&lt;MDL</b>
<b>Std. Dev.</b>	<b>0.1</b>	<b>0.1</b>	<b>466</b>	<b>0.1</b>	<b>405</b>	<b>0.1</b>	<b>13.9</b>	<b>NA<sup>3</sup></b>	<b>349</b>	<b>25</b>	<b>16</b>	<b>19</b>	<b>NA</b>	<b>NA</b>

- (1) Contaminant of Concern for this site.
- (2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL).  
 The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied.  
 For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.
- (3) Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-30**  
**Analyses of Soil Samples Taken in 1999 from**  
**Grids Adjacent to Areas Receiving Soil Amendments**

Sample	pH		EDTA as Na <sub>2</sub> EDTA, mg/kg		EDTA as EDTA, mg/kg		Water-Soluble Pb <sup>1</sup> , mg/kg		Pb <sup>1</sup> , mg/kg	
	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
<b>Site C</b>										
A	8.7	9.0	28	44	24	38	129	74.1	4,940	14,200
B	8.8	8.7	<0.3 <sup>2</sup>	11	<0.3 <sup>2</sup>	10	40	61	1,350	1,720
C	8.7	8.6	75	33	65	29	92	147	1,340	4,390
D	8.8	8.5	14	66	12	57	116	153	3,800	8,630
<b>Mean</b>	<b>8.8</b>	<b>8.6</b>	<b>29</b>	<b>39</b>	<b>25</b>	<b>34</b>	<b>94</b>	<b>109</b>	<b>2,858</b>	<b>7,235</b>
<b>Std. Dev.</b>	<b>0.1</b>	<b>0.1</b>	<b>33</b>	<b>23</b>	<b>29</b>	<b>20</b>	<b>39</b>	<b>48</b>	<b>1,807</b>	<b>5,446</b>
<b>Site 129-3</b>										
A	8.5	8.6	<0.3	3.4	<0.3	3.0	<0.93 <sup>2</sup>	<0.96 <sup>2</sup>	127	11
B	8.2	8.4	<0.3	<0.3 <sup>2</sup>	<0.3	<0.3 <sup>2</sup>	48.9	13.4	2,280	356
<b>Mean</b>	<b>8.4</b>	<b>8.5</b>	<b>&lt;MDL<sup>2</sup></b>	<b>1.8</b>	<b>&lt;MDL<sup>2</sup></b>	<b>1.6</b>	<b>25</b>	<b>7</b>	<b>1,203</b>	<b>184</b>
<b>Std. Dev.</b>	<b>0.2</b>	<b>0.1</b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>1,522</b>	<b>244</b>

(1) Contaminant of Concern for this site.

(2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL). The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied. For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.

(3) Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

## 5.2.8 Plant Sampling - 1999 Corn Crop

### 5.2.8.1 Plant Growth

Three changes in the corn crop were implemented in the 1999 season: (1) use of a silage variety of corn planted at twice the density of the 1998 crop; (2) a higher rate of nitrogen fertilizer than used in 1998 was applied during the growing season to meet N requirements of the silage corn; and (3) additional phosphate was applied at planting.

The silage variety of corn rather than a seed variety was chosen for use in 1999 based on recommendations from plant breeders and growers in the Minnesota/North Dakota region for a deeper rooting, higher yielding strain. The additional N fertilizer was required for the additional biomass production by the silage corn variety. Additional P was band-applied along the seed row to prevent a recurrence of P deficiency in the corn that was observed in 1998. Although there is the potential for binding of some soil lead by phosphate into insoluble forms, application of additional P was deemed acceptable since not all of the soil lead will be complexed with phosphate. There are several Pb-PO<sub>4</sub> compounds which can exist in soil, depending on pH and halogen (Br-, Cl-, F-) content. The most soluble and most plant-available of these (i.e., Pb(H<sub>2</sub>PO<sub>4</sub>)<sub>2</sub>, PbHPO<sub>4</sub>, and to a much lesser extent, Pb<sub>4</sub>O(PO<sub>4</sub>)<sub>2</sub>) form soon after fertilizer addition. EDTA is a sufficiently strong chelate to break the Pb-PO<sub>4</sub> complex and form the EDTA-Pb complex that is taken up into the plant. The most recent P addition doesn't react to fully complex Pb into the most insoluble PO<sub>4</sub> complex (chloropyromorphite). Cerrusite (PbCO<sub>3</sub>) is the compound which will most strongly control lead solubility in this type soil, regardless of the amount of P added. Therefore, the supplemental P would have minimal effect on lead solubility. For Site C, cooler temperatures and continued rainfall after planting and seedling emergence resulted in stunted growth and symptoms of nitrogen deficiency (yellowing of leaves from the leaf tip in a "V" shape back toward the stalk). Extensive bird damage to the emerging seedlings necessitated several replantings over many areas of the plot, which resulted in various stages of plant development across the plot. On many areas within the plot, the plant population was very sparse or barren altogether. Coverage on individual grids ranged from 8% - 42% of the potential maximum population of 180 plants/grid (Table 4-4). In the eastern third of the plot, where sampling and amendment application activities were conducted, the maximum plant height was 6 ft, the average height was 5 ft, and the range was 3 to 6 ft (Table 4-4). Plants appeared generally healthy, except for sporadic necrotic spots on the leaves. Ear development was at the brown silk stage; kernels were at the milk stage, and very small. The average ear diameter was 1.5 inches.

The rooting depth for the Norvartis/Mycogen silage corn variety, according to plant breeders in the North Dakota/Minnesota region, was purported to be 6-8 ft in a sandy soil. However, excavated plants across the plot showed a fibrous root system of only about 8 inches across and 6 inches in length. The limited root development for plants throughout the plot shows the effect of excess rainfall, where roots stay close to the surface in the saturated zone and do not develop deeper into the soil. In addition, in the western part of the plot, a hard pan layer in the soil (visible underneath the plants) likely inhibited deeper root growth. Since the pan layer is not present in the eastern part of the plot, toxicity from one or more other contaminants in the soil could also have been a cause of root stunting in that area. Most of the debris that was deposited

at Site C (railroad ties, metal scrap, burned material, and broken concrete) is found in this eastern part of the plot, and this could be a source of some toxic components.

At Site 129-3, extensive bird damage and several replantings resulted in plants ranging in size from 2 to 7 ft (Table 4-5). The plant coverage on individual grids ranged from 2% to 42%. Fully mature plants were 7 ft tall and usually had two ears. Many of the ears showed abnormal development in that the shuck development was incomplete and bare kernels were showing for 1-3 inches from the tip of the ears. Ears were at the brown silk stage and had an average diameter in most mature plants of 2 inches. Kernels were at the milk stage. The bird damage affected the plant population to the extent that only grids 1 and 2 had a sufficient number of mature plants to justify amendment additions, in spite of several replantings. Other grids had 3 to 4 rows of mature plants, while some had almost a full complement of immature plants. None of these grids, however, had sufficiently uniform and mature growth to provide representative lead uptake. Excavated plants showed a root system of about 10 inches across and 15-18 inches in length which, as with Site C, was much less than the expected root length of 6 ft.

#### **5.2.8.2 Pre-Amendment Plant Sampling - 1999 Corn Crop**

Lead concentrations in plants at Site C before adding soil amendments (Table 5-31) were as low or lower than observed for corn before soil amendment additions in 1998 (Table 5-8). EDTA concentrations in the 1999 plants were below the method detection limit. This indicates that there was no carry-over lead or EDTA from the previous year taken up into the plant. Concentrations of the other COCs, except for manganese, were low or below detection limit (Table 5-31).

Results at Site 129-3 were similar to those found at Site C and at Site 129-3 in 1998 (Table 5-9), i.e., lead concentrations were very low, and EDTA and antimony were below detection limits (Table 5-32). Concentrations of manganese were similar to that found in corn at Site C (Table 5-31).

#### **5.2.8.3 Post-Amendment Plant Sampling - 1999 Corn Crop**

At Site C, the lead concentration in corn plants averaged 854 mg/kg, and ranged from 343 to 1,380 mg/kg (Table 5-33). These values were tenfold less than obtained in corn treated in 1998 (Table 5-10). Conditions in 1999 were not optimal for lead uptake, as the corn crop at this site exhibited several different growth stages, ranging from immature to mature plants with ears. In addition, corn plants exhibited a shallow rooting system at site C, with the majority of roots in the top 6 inches of soil. This top soil layer would be most susceptible to movement of lead down to lower layers due to EDTA applications in the previous year. The average for total lead in the top 0-12 inches was lower for measurements taken before soil amendments in 1999 (Table 5-26) than for measurements taken before and after amendment additions for white mustard at the end of the previous year (Tables 5-12 and 5-14). This suggests that the 6-inch rooting zone for corn most likely had lower lead concentrations than the previous year, so that efficient scavenging for lead by corn roots could not be achieved. However, as noted above in Section 3.2, the high degree of variability in lead concentrations from grid to grid makes a conclusive determination of soil lead dynamics difficult. EDTA concentrations in the corn averaged approximately 40% lower than found in the corn crop in 1998 (Table 5-9), but still averaged 26,200 mg/kg in 1999

(Table 5-33). This lower average concentration was probably a function of the overall poor growth of the corn and the application of less EDTA in 1999.

Arsenic, beryllium, and antimony were below concentration detection limits in plant tissue. The average manganese concentration was approximately fourfold higher than pre-amendment concentrations (Table 5-31), indicating that the soil amendments enhanced manganese uptake, similar to results in the 1998 corn crop (Table 5-9). Thallium, at low but detectable concentrations, was found in plants from 8 of the 12 grids sampled, whereas plant samples from just two grids contained detectable levels of thallium in the pre-amendment sampling. This indicated that, as with manganese, EDTA application enhanced thallium uptake.

**Table 5-31**  
**Concentrations of EDTA and Contaminants of Concern in 1999**  
**Demonstration Year Corn from Site C Prior to Adding Soil Amendments**

Grid No.	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg	Pb, <sup>1</sup> mg/kg	As <sup>1</sup> , mg/kg	Be <sup>1</sup> , mg/kg	Mn <sup>1</sup> , mg/kg	Sb <sup>1</sup> , mg/kg	Tl <sup>1</sup> , mg/kg
5	<3.7 <sup>2</sup>	<3.2 <sup>2</sup>	12.3	<0.49 <sup>2</sup>	<0.02 <sup>2</sup>	32.8	<0.74 <sup>2</sup>	<1.24 <sup>2</sup>
6	<3.7	<3.2	6.6	<0.50	<0.03	25.8	<0.75	<1.25
11	<3.7	<3.2	12.9	<0.49	<0.02	35.0	<0.74	<1.23
12	<3.7	<3.2	6.2	<0.50	0.18	30.7	<0.75	<1.24
17	<3.7	<3.2	10.1	<0.49	<0.02	25.0	<0.74	<1.24
18	<3.7	<3.2	8.9	<0.49	<0.02	32.1	<0.74	<1.24
23	<3.7	<3.2	7.8	1.59	1.83	34.9	1.88	1.71
24	<3.7	<3.2	18.3	<0.49	<0.02	30.1	<0.75	<1.24
29	<3.7	<3.2	10.6	1.51	1.44	18.7	1.94	1.59
30	<3.7	<3.2	6.3	<0.49	<0.02	28.6	<0.74	<1.23
35	<3.7	<3.2	9.7	<0.51	<0.03	29.8	<0.76	<1.27
36	<3.7	<3.2	9.4	<0.49	<0.02	23.4	<0.74	<1.23
<b>Mean</b>	<b>&lt;MDL<sup>2</sup></b>	<b>&lt;MDL<sup>2</sup></b>	<b>9.9</b>	<b>0.5</b>	<b>0.3</b>	<b>28.9</b>	<b>0.6</b>	<b>0.8</b>
<b>Std. Dev.</b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>3.4</b>	<b>0.5</b>	<b>0.6</b>	<b>4.9</b>	<b>0.6</b>	<b>0.4</b>

(1) Contaminant of Concern for this Site.

(2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL). The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied. For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.

(3) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-32**  
**Concentrations of EDTA and Contaminants of Concern**  
**in 1999 Demonstration Year Corn from**  
**Site 129-3 Prior to Adding Soil Amendments**

Grid No.	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg	Pb <sup>1</sup> , mg/kg	Mn <sup>1</sup> , mg/kg	Sb <sup>1</sup> , mg/kg
1	<3.7 <sup>2</sup>	<3.2 <sup>2</sup>	6.2	29.2	<0.65 <sup>2</sup>
2	<3.7	<3.2	5.8	53.8	<0.73
<b>Mean</b>	<MDL <sup>2</sup>	<MDL <sup>2</sup>	<b>6.0</b>	<b>41.5</b>	<MDL <sup>2</sup>
<b>Std. Dev.</b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>0.3</b>	<b>17.4</b>	<b>NA<sup>3</sup></b>

(1) Contaminant of Concern for this Site.

(2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL). The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied. For calculating the mean and deviation for a set of values, where data was standard equal to or less than the MDL, one-half the value of the MDL was used.

(3) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-33**  
**Concentrations of EDTA and Contaminants of Concern in 1999**  
**Demonstration Year Corn from Site C After Adding Soil Amendments**

Grid No.	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg	Pb <sup>1</sup> , mg/kg	As <sup>1</sup> , mg/kg	Be <sup>1</sup> , mg/kg	Mn <sup>1</sup> , mg/kg	Sb <sup>1</sup> , mg/kg	Tl <sup>1</sup> , mg/kg
5	19,900	17,300	496	<0.48 <sup>2</sup>	<0.02 <sup>2</sup>	122	<0.72 <sup>2</sup>	<1.20 <sup>2</sup>
6	25,600	22,300	714	<0.49	<0.02	113	<0.73	1.98
11	25,600	22,300	439	<0.50	<0.02	113	<0.75	<1.25
12	37,600	32,700	1,120	<0.51	<0.03	152	<0.77	2.16
17	26,400	22,900	343	<0.49	<0.02	101	<0.74	<1.23
18	39,000	33,900	1,320	<0.50	<0.02	203	<0.75	2.03
23	27,900	24,300	660	<0.50	<0.02	105	<0.75	1.3
24	42,400	36,900	1,380	<0.50	<0.02	197	<0.75	1.93
29	20,800	18,100	885	<0.48	<0.02	107	<0.72	1.64
30	27,200	23,600	875	<0.50	<0.02	139	<0.75	1.4
35	30,400	26,400	1,000	<0.48	<0.02	124	<0.72	1.98
36	39,700	34,500	1,010	<0.46	<0.02	160	<0.69	2.31
<b>Mean</b>	<b>30,200</b>	<b>26,200</b>	<b>854</b>	<b>&lt;MDL<sup>2</sup></b>	<b>&lt;MDL<sup>2</sup></b>	<b>136</b>	<b>&lt;MDL<sup>2</sup></b>	<b>1.55</b>
<b>Std. Dev.</b>	<b>7,610</b>	<b>6,610</b>	<b>334</b>	<b>NA<sup>3</sup></b>	<b>NA<sup>3</sup></b>	<b>35</b>	<b>NA<sup>3</sup></b>	<b>0.63</b>

(1) Contaminant of Concern for this site.

(2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL). The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied. For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.

(3) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

Very little lead uptake occurred in the plants from the two grids sampled at Site 129-3 (Table 5-34), most likely due to the limited root system of the plants and low lead concentrations in the root zone. Concentrations of lead in the plants were ten-fold higher in the previous year. EDTA concentrations in the corn were similar to concentrations observed in the 1998 crop (Table 5-11). EDTA again enhanced uptake of manganese by sixfold for this site. Antimony concentrations in the corn tissue were below the method detection limit.

**Table 5-34**  
**Concentration of EDTA and Contaminants of Concern in 1999**  
**Demonstration Year Corn from Site 129-3 After Adding Soil Amendments**

Grid No.	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg	Pb <sup>1</sup> , mg/kg	Mn <sup>1</sup> , mg/kg	Sb <sup>1</sup> , mg/kg
1	6,970	6,060	93.6	262	<0.74 <sup>2</sup>
2	14,100	12,300	115.0	304	<0.74
<b>Mean</b>	<b>10,500</b>	<b>9,130</b>	<b>104</b>	<b>283</b>	<b>&lt;MDL<sup>2</sup></b>
<b>Std. Dev.</b>	<b>5,040</b>	<b>4,380</b>	<b>15</b>	<b>30</b>	<b>NA<sup>3</sup></b>

- (1) Contaminant of Concern for this site.
- (2) Values preceded by a less than sign "<" indicate that the results were less than the Method Detection Limit (MDL). The MDL varied for these results because the sample weights and/or the dilution factors used in the analyses varied. For calculating the mean and standard deviation for a set of values, where data was equal to or less than the MDL, one-half the value of the MDL was used.
- (3) NA = Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

### 5.2.9 Soil Sequential Extraction Analysis

Basing EDTA applications on the total soil lead concentrations may result in excess amounts of EDTA being applied, since the metal is partitioned in soil in fractions of varying solubility and plant-availability. A sequential extraction analysis procedure uses progressively stronger extractants to differentiate and quantify that fraction of the total amount of a metal in soil that is available or potentially available to plants. The purpose for using the sequential extraction technique is to determine the percentage of total lead that is most plant-available. The molar ratio of EDTA-to-soil lead then can be equalized to match the plant-available fraction of soil lead, which will reduce the amount of chelate required to solubilize lead for plant uptake.

The results of the sequential extraction analyses are shown in Tables 5-35 through 5-38. It should be noted that the sum of the values for lead concentration in the individual fractions does not necessarily equal the value for the total lead concentration. This is because: (1) analyses for total and water-soluble lead and the sequential extraction were performed on soil from the same bulk field sample, but on two separate samples (i.e., the sequential analysis was done later on a

separate sample from the same batch of soil); and (2) the soil was not analyzed for two additional fractions, the lead that is bound to organic matter, and the “residual” fraction, or lead that is bound up in the soil mineral crystalline matrix, since lead in these two components is in a form that is not immediately plant-available. However, it should also be noted that, although lead in the Fe and Mn oxide fraction is considered a plant-available form, lead in this fraction is more tightly bound, and thus is more slowly available.

The amount of EDTA to be added could be determined from the plant-available lead concentration that is equal to or greater than the plant-available lead concentration in 75% of the grids, as determined by the frequency distribution for the grids (Figure 5-3). The bars in this figure indicate the frequency or number of grids that fall within each lead concentration range. The cumulative percentage line plot indicates the percentage of grids that have lead concentrations equal to or less than the concentration range at a given point on the line. From the cumulative percentage plot, 75% of the grids contain plant-available lead concentrations of 1000 mg/kg or less. This concentration of lead would be used to determine the molar amount of EDTA to be added.

Combining the 0- to 12-inch and the 12- to 24-inch results, the amount of plant-available lead at Site C before EDTA application was about 55% of the total lead concentration (Table 5-35). The sequential extraction method provides a better basis for calculating the amount of EDTA needed to solubilize a sufficient amount of lead for plant uptake. This practice would further reduce the amount of EDTA added to soil, thus reducing potential adverse environmental effects.

The effect of EDTA on increasing the pool of plant-available lead is clearly shown in Table 5-36, wherein the total plant-available lead pool increased at both soil depths. In the 0- to 12-inch soil layer, the water-soluble and exchangeable lead pool increased while the carbonate-bound pool showed an insignificant decrease. In the 12- to 24-inch depth, the water-soluble, exchangeable, and carbonate pools all increased, with the largest apparent increase being in the carbonate pool.

The lead concentration in the carbonate pool at the 12- to 24-inch depth was nearly threefold higher in the post-amendment samples than in pre-amendment soils. However, the percentages of lead in the plant-available pools at the 12- to 24-inch depth was the same for the pre- and post-amendment samples.

The increase in the carbonate pool at the 12- to 24-inch depth after EDTA application and the higher soil pH (9.0) were consistent with degradation of EDTA and production of CO<sub>2</sub> and ammonia. The CO<sub>2</sub> would have been converted to carbonate and the ammonia would have caused the rise in soil pH. Carbonate dissolution is dependent upon particle size and the type and percentage of the various carbonate minerals in the soil. Differential solubilization of the various carbonate minerals by acetic acid may have resulted in varying release of lead that was bound to carbonates. No conclusions could be drawn from the limited data obtained for Site 129-3 (Tables 5-37 and 5-38).

**Table 5-35**  
**Sequential Fractionation Analysis of Soil from Site C Prior to**  
**Adding Soil Amendments in 1999**

Grid No.	Depth, inches	Sequential Fraction- Pb, mg/kg					
		Total	(A) Water-soluble	(B) Exchange-able	(C) Carbonate	Fe+Mn Oxide	Total Plant-Available (A+B+C)
5	0-12	956	30	2	223	367	255
6	0-12	3,220	49	13	1,940	721	2,002
11	0-12	686	14	1	73	275	88
12	0-12	826	28	1	291	392	320
17	0-12	382	3	0	26	152	29
18	0-12	3,540	54	16	2,660	920	2,730
23	0-12	774	7	1	113	303	121
24	0-12	1,500	41	13	1,400	800	1,454
29	0-12	755	31	2	355	319	388
30	0-12	903	16	3	289	180	308
35	0-12	3,200	21	6	563	456	590
36	0-12	1,260	1	1	212	208	214
<b>Mean</b>	<b>0-12</b>	<b>1,500</b>	<b>25</b>	<b>5</b>	<b>679</b>	<b>424</b>	<b>708</b>
<b>Std. Dev</b>	<b>0-12</b>	<b>1,135</b>	<b>17</b>	<b>6</b>	<b>853</b>	<b>254</b>	<b>873</b>
5	12-24	1,740	13	2	271	538	286
6	12-24	3,410	94	16	3,080	683	3,190
11	12-24	813	3	1	103	371	107
12	12-24	382	6	1	858	349	865
17	12-24	861	1	1	105	252	107
18	12-24	595	3	5	412	224	420
23	12-24	1,660	1	2	184	565	187
24	12-24	1,110	30	6	637	273	673
29	12-24	1,340	25	5	612	595	642
30	12-24	315	4	2	1,370	394	1,376
35	12-24	1,870	41	15	1,590	623	1,646
36	12-24	1,200	15	3	293	192	1,703
<b>Mean</b>	<b>12-24</b>	<b>1,274</b>	<b>20</b>	<b>5</b>	<b>793</b>	<b>422</b>	<b>934</b>
<b>Std. Dev.</b>	<b>12-24</b>	<b>846</b>	<b>27</b>	<b>5</b>	<b>866</b>	<b>172</b>	<b>912</b>

**Table 5-36**  
**Sequential Fractionation Analysis of Soil from Site C After Adding Soil**  
**Amendments in 1999**

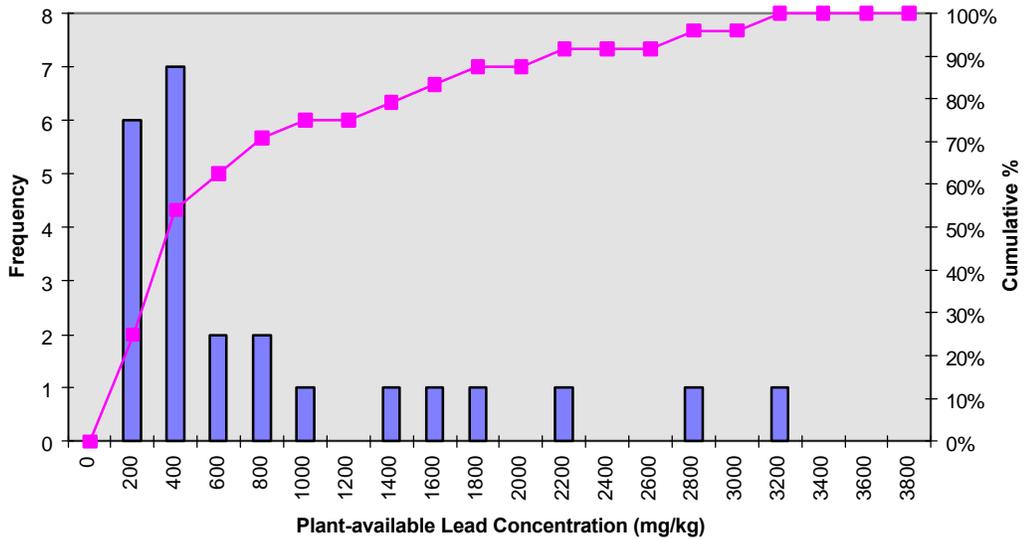
		Sequential Fraction - Pb, mg/kg					
Grid No.	Depth, inches	Total	(A) Water-soluble	(B) Exchange-able	(C) Carbonate	Fe+Mn Oxide	Total Plant-Available (A+B+C)
5	0-12	553	13	4	502	549	519
6	0-12	3,120	200	111	2,380	781	2,691
11	0-12	953	182	168	39	139	389
12	0-12	2,100	314	340	410	272	1,064
17	0-12	551	192	176	23	157	391
18	0-12	1,310	190	174	841	366	1,205
23	0-12	469	138	81	112	229	331
24	0-12	4,030	747	618	1,580	507	2,945
29	0-12	991	15	3	339	345	357
30	0-12	542	469	344	130	175	943
35	0-12	1,070	217	226	339	434	782
36	0-12	797	492	400	627	305	1,519
<b>Mean</b>	<b>0-12</b>	<b>1,374</b>	<b>264</b>	<b>220</b>	<b>610</b>	<b>355</b>	<b>1,095</b>
<b>Std. Dev.</b>	<b>0-12</b>	<b>1,138</b>	<b>212</b>	<b>179</b>	<b>705</b>	<b>189</b>	<b>891</b>
5	12-24	1,510	2	2	343	416	347
6	12-24	12,900	80	33	10,400	1,010	10,513
11	12-24	2,320	1	1	162	423	164
12	12-24	2,840	162	88	2,430	439	2,680
17	12-24	732	3	1	217	400	221
18	12-24	2,030	121	38	1,340	431	1,499
23	12-24	1,240	1	2	288	461	291
24	12-24	3,900	340	247	3,230	643	3,817
29	12-24	4,200	31	5	842	678	878
30	12-24	256	34	2	124	88	160
35	12-24	1,660	83	15	1,250	723	1,348
36	12-24	5,160	258	129	3,570	619	3,957
<b>Mean</b>	<b>12-24</b>	<b>3,229</b>	<b>93</b>	<b>47</b>	<b>2,016</b>	<b>528</b>	<b>2,156</b>
<b>Std. Dev.</b>	<b>12-24</b>	<b>3,378</b>	<b>111</b>	<b>75</b>	<b>2,905</b>	<b>228</b>	<b>2,974</b>

**Table 5-37**  
**Sequential Fractionation Analysis of Soil from Site 129-3**  
**Prior to Adding Soil Amendments in 1999**

		Sequential Fraction- Pb, mg/kg					
Grid No.	Depth, inches	Total	(A) Water-soluble	(B) Exchange-able	(C) Carbonate	Fe+Mn Oxide	Total Plant-Available (A+B+C)
1	0-12	27	6	1	18	39	25
2	0-12	60	1	1	30	39	32
<b>Mean</b>	<b>0-12</b>	<b>43.5</b>	<b>3.5</b>	<b>1</b>	<b>24</b>	<b>39</b>	<b>29</b>
<b>Std. Dev.</b>	<b>0-12</b>	<b>23</b>	<b>4</b>	<b>0</b>	<b>8</b>	<b>0</b>	<b>5</b>
1	12-24	117	3	1	57	72	61
2	12-24	216	4	1	26	54	31
<b>Mean</b>	<b>12-24</b>	<b>167</b>	<b>4</b>	<b>1</b>	<b>42</b>	<b>63</b>	<b>46</b>
<b>Std. Dev.</b>	<b>12-24</b>	<b>70</b>	<b>1</b>	<b>0</b>	<b>22</b>	<b>13</b>	<b>21</b>

**Table 5-38**  
**Sequential Fractionation Analysis of Soil from Site 129-3 After**  
**Adding Soil Amendments in 1999**

		Sequential Fraction- Pb, mg/kg					
Grid No.	Depth, inches	Total	(A) Water-soluble	(B) Exchange-able	(C) Carbonate	Fe+Mn Oxide	Total Plant-Available (A+B+C)
1	0-12	63	20	16	12	34	48
2	0-12	556	1	1	15	54	17
<b>Mean</b>	<b>0-12</b>	<b>310</b>	<b>11</b>	<b>9</b>	<b>14</b>	<b>44</b>	<b>33</b>
<b>Std. Dev.</b>	<b>0-12</b>	<b>349</b>	<b>13</b>	<b>11</b>	<b>2</b>	<b>14</b>	<b>22</b>
1	12-24	105	1	1	26	73	28
2	12-24	69	1	1	38	32	40
<b>Mean</b>	<b>12-24</b>	<b>87</b>	<b>1</b>	<b>1</b>	<b>32</b>	<b>53</b>	<b>34</b>
<b>Std. Dev.</b>	<b>12-24</b>	<b>25</b>	<b>0</b>	<b>0</b>	<b>8</b>	<b>29</b>	<b>8</b>



**Figure 5-3**  
**Plant-Available Lead at**  
**Site C Pre-Amendment**

Frequency distribution of grids for plant-available lead concentration ranges, and cumulative percentage of grids at each plant-available lead concentration range.

## 5.2.10 2000 Field Sampling Results

### 5.2.10.1 Mechanisms Controlling Lead Solubility and EDTA Degradation at Site C and Site 129-3

A discussion of the primary mechanisms involved in the overall outcome of the demonstration is essential to understanding the final results of the 2000 field activities.

#### 5.2.10.1.1 Lead Solubility

In a phytoextraction scheme, lead may undergo several reactions (or pathways) in a soil following treatment with acetic acid and EDTA. These reactions involve both the dissolution of lead from the non-water-soluble solid phases into soluble forms which are available to plants and may be subject to leaching, as well as the subsequent re-precipitation of lead into *insoluble* forms which are unavailable to plants and which are less conducive to movement.

A summary of the three general processes lead will undergo in soil during a phytoextraction scheme is presented in Figure 5-4. These reactions are:

1. Dissolution of lead solid phases and complexation by EDTA, followed by uptake into plants.
2. Inactivation of EDTA through degradation or sorption on soil components with subsequent release and re-precipitation of lead in soil.
3. Displacement of lead from the EDTA complex by competing cations and subsequent reprecipitation of lead in soil.

An understanding of the first reaction of lead in the soil must be preceded by a discussion of the basic components of the system. The water-soluble and exchangeable forms are considered to be the most readily complexed by EDTA, while the carbonate form is less so. The availability to plants follows the same order. These forms of lead in soil may be grouped as follows:

1. Water-soluble
2. Exchangeable
3. Carbonate-bound
4. Iron and manganese oxide-bound
5. Organic-bound
6. Crystalline matrix-bound

The first three forms are considered to be the most potentially available to plants in the phytoextraction process. The water-soluble and exchangeable forms are considered to be most available to plants, while the carbonate form is less so. The ease of complexation by EDTA follows the same order. Harsh dissolution processes would be required to make lead in the oxide, organic, and crystalline matrix forms available to plants. In the TCAAP soils, the amount of lead that is potentially plant available (sum of the first three forms) is 55% of the total lead concentration in soil. This was determined by the sequential extraction procedure in Section 5.2.9.

Therefore, in the first reaction (i.e., dissolution and complexation) (Fig. 5-4) reduction of soil pH to 5.5 by acetic acid helps release lead from the most soluble solid phase forms into the soil

solution as the free lead ion ( $\text{Pb}^{2+}$ ). The lead ion is then complexed by EDTA and maintained in a water-soluble form that is available to plants. The soil returns to its indigenous pH after a short time, but for a time, lead remains in a water-soluble form. Lead in this form may react with the soil to again become unavailable, it may be taken up into the plant, or it may remain in solution.

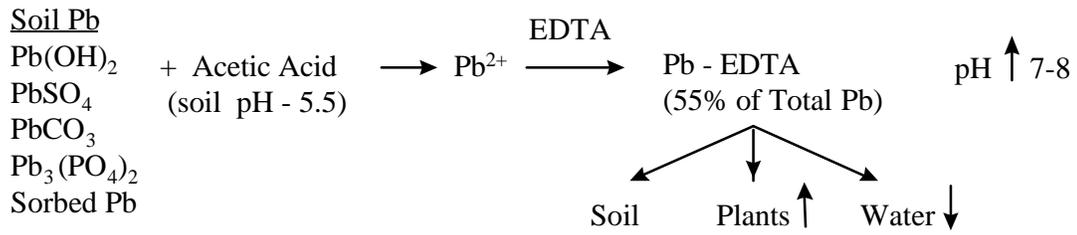
In the second reaction, several individual processes are at work simultaneously. Other cations in the soil, which are typically found at far greater concentrations in the soil than lead, compete with lead for complexation by EDTA. Also, as EDTA undergoes microbial degradation, (see Section 5.2.10.1.2, below, for a more detailed discussion of EDTA degradation in soil) lead may be released and re-precipitated in the soil as progressive degradation of EDTA produces compounds that are more selective for cations other than lead. If there is a sufficient amount of iron oxide present in the soil, EDTA may be sorbed onto these compounds, and the lead in the EDTA complex may be subject to reaction with soil. This usually involves the formation of a weak bond between EDTA and the oxide, so the oxide must be present at fairly high concentration for this reaction to be significant.

In the third reaction, other cations such as Ca, Mg, Fe, etc., compete with lead in soil micro-sites for complexation by EDTA. Lead is displaced from the complex by simple mass action (i.e., the abundance of other cations relative to lead “swamps” the system). The cation that will replace lead (1) will be determined by the system pH; (2) will follow metal-chelate selectivity coefficients (i.e., displacement series); and (3) is dependent on the cation concentration in the soil. The Ca-EDTA complex will ultimately predominate in alkaline soil, and Fe-EDTA will be the predominate form in acid to neutral soil. Once lead is displaced, the processes of ion exchange, adsorption, and precipitation on soil minerals and organic matter will eventually convert lead into insoluble forms, such as carbonates, phosphates, sulfates, and organic complexes. At higher soil pH, the solubility of lead in these complexes is low. The pH-dependent sorption of lead on hydrous oxides of aluminum, iron, and manganese will also occur, which will limit the activity of the lead ion in solution. Thus plant availability and the potential for leaching of lead is also low. This reversion process will take several decades before lead is as insoluble as it was before the phytoextraction process.<sup>Ref. 9</sup>

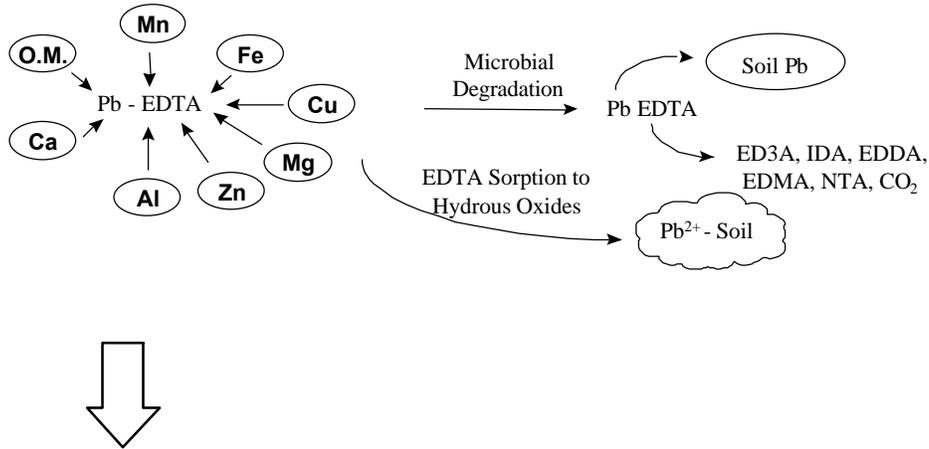
#### **5.2.10.1.2 EDTA Fate and Degradation in Soil**

The aminopolycarboxylic acid chelate EDTA is produced in large quantities for a variety of uses ranging from cleaning solutions and detergents to food preservatives to decontamination of nuclear power plant equipment. EDTA sales in Europe in 1997 were 32,550 tons.<sup>Ref. 36</sup> No instances of EDTA toxicity to mammals have been reported at the concentrations found in aquatic environments, although annual loading rates in surface waters have in the past been quite high. For example, annual amounts of EDTA released into the Ruhr River, Germany, in 1984 were about 60 tons, and over 1,080 tons were released annually into the Rhine River, Germany, from 1985 to 1987.<sup>Ref. 33</sup> EDTA is persistent in the environment, and for many years was thought to be resistant to degradation.<sup>Ref. 37,38</sup> However, biodegradation of EDTA has been investigated from the perspective of many different researchers and EDTA is now recognized to

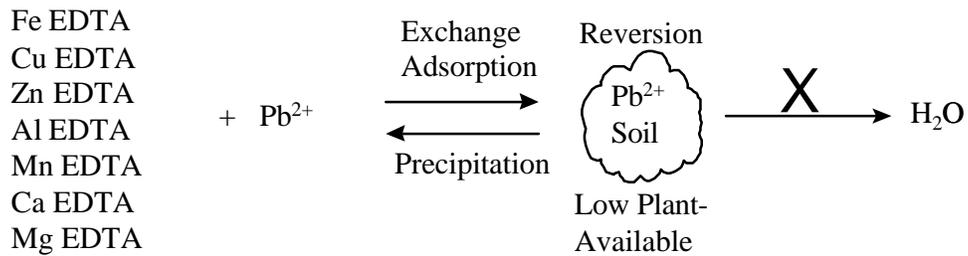
1.)



2.)



3.)



**Figure 5-4**  
**Lead Pathways in Soil**

biodegrade through several various mechanisms.<sup>Ref. 39</sup> EDTA may react in soil systems to persist or to disappear entirely depending on the unique set of conditions that occur in different soils. Overall, in a typical soil, the fate of EDTA is governed by five mechanisms:

1. Reaction and complexation with soil cations
2. Microbial degradation
3. Adsorption onto iron hydrous oxide surfaces and soil organic matter
4. Binding to clay fractions
5. Leaching

The affinity of EDTA for metal cations varies with system pH and the displacement series for EDTA and metals. The displacement series is based on formation constants of EDTA-metal complexes (i.e., bonding energies) derived either experimentally or empirically. So, the displacement series is a measure of the strength of bonding of a given cation-EDTA complex. The series may be a function of the concentration of a given cation that can potentially bond with EDTA. Thus, a primary cation with a strong binding affinity for EDTA may be replaced by a secondary cation which has less affinity for EDTA, but which is present in far greater concentration. For example the primary cation, lead, may be replaced by secondary cations such as calcium, iron, or magnesium in an EDTA complex.

Direct degradation of EDTA is obviously an important mechanism for controlling the activity of EDTA in a soil. The rate and extent of EDTA microbial degradation is highly variable.<sup>Ref. 40</sup> Factors controlling and influencing degradation include:

- Aeration
- pH
- Temperature
- Appropriate microbial population in soil
- Organic matter content and fertility level of soil
- Resistance of EDTA to degradation
- EDTA concentration
- Metals that EDTA is complexed with

Overall, annual degradation rates of EDTA may range from <5% after 10 weeks in acidic soil to 50% - 75% after one year in alkaline soil.<sup>Ref. 41</sup> EDTA will normally be degraded by the indigenous soil microbial population. Ironically, EDTA may be degraded more rapidly in cold (i.e., freezing) temperatures than during warmer periods.<sup>Ref. 41</sup> An alkaline pH is more conducive to degradation, since the primary cation complexes of EDTA at higher pH are those with the nutrient cations, which tend to sustain the microbial population. The rate will vary depending on the cation with which the EDTA is complexed. Heavy metal complexes of EDTA, such as Cu-, Ni-, or Cd- which may be toxic to soil microbes, will degrade at a slower rate than EDTA complexes of low toxicity nutrient cations, such as Ca-, Fe-, or Mg-EDTA.<sup>Ref. 42</sup> Ferric iron complexes of EDTA potentially will degrade at higher rates than EDTA complexes with other nutrient cations.<sup>Ref. 36</sup> As EDTA degrades, heavy metals such as lead may be released into solution, where adsorption reactions may render the metal insoluble. Incorporation of an

inorganic complexing agent, such as phosphate, to scavenge the released metal by precipitation may help avoid metal toxicity to the microbial population, thus hastening or at least prolonging degradation of EDTA. <sup>Ref. 42</sup>

A higher iron oxide and organic matter content will also increase EDTA retention by soil, although the bond between iron hydrous oxides and EDTA is a relatively weak one. The binding capacity is dependent instead on the oxide content of the soil, and binding and disappearance of EDTA in soils characterized by a high iron oxide content can be significant. This phenomena was recognized as early as 1955 by Wallace *et al.* <sup>Ref. 43</sup> The following year, Lunt *et al.* <sup>Ref. 44</sup> reported rapid losses of 26% and 20% EDTA from soil-applied iron-EDTA in calcareous and noncalcareous soils. EDTA disappeared at a 1:1 ratio with Fe loss in the noncalcareous soils, which suggested that the complex was adsorbed intact. Such a substitution and adsorption mechanism may thus be important in controlling the fate of potentially environmentally harmful metal complexes of EDTA, such as lead.

Although EDTA is an anion, it will rarely exist in soil solely as EDTA, and these amounts will be negligible. It will almost always be complexed with a cation. The charge on the cation-EDTA complex is cation- and pH-dependent, with the Zero Point of Charge (ZPC) for cation-EDTA complexes occurring between pH 7.0 and 9.0 depending on the associated cation. Thus, EDTA may be adsorbed onto negatively charged clay micelles as a positively charged moiety at pH values higher than the ZPC. This may reduce movement of EDTA through the soil.

Normally, heavier-textured clay soils will retain EDTA more strongly than will sandy soils. Leaching is thus quite likely in sandy soils. However, the heavier textured soil constitutes only a temporary physical barrier to vertical movement of EDTA, and eventual breakthrough of EDTA can occur.

Obviously, reactions involving metal complexation and metal-chelate interactions in soil are not straightforward, and many variables in the heterogeneous system of a soil will influence the ultimate fate of EDTA and lead in soil. These same reactions can equally be applied to interactions within groundwater systems and their aquifers, and to surface waters as well.

#### **5.2.10.2 Groundwater Sampling - 2000**

Groundwater and surface water sampling was conducted only at Site C. Figure 5-5 is an overview drawing showing the pertinent features and the groundwater and surface water sampling locations at Site C. The overall summary of results for the groundwater and surface samplings at Site C is shown in Table 5-39. Individual results for each of the samplings are shown in subsequent tables. All groundwater samples were muddy in appearance upon sampling. The pH of all water samples was about 7.5, which favors reactions of the EDTA with basic cations such as Ca and Mg. An important criteria to be remembered in considering the results of the groundwater samples is that EDTA complexes with lead on a 1:1 ratio. An EDTA to lead ratio greater than 1:1 indicates that lead has been displaced through some mechanism from the EDTA complex and is thus no longer in appreciably water-soluble form.

#### **5.2.10.2.1 April 11, 2000 - First Groundwater Sampling**

The analytical results of the April 11, 2000 samples for lead, EDTA, and pH, and the calculated molar ratios of EDTA to lead, are shown in Table 5-40.

The sampling locations for this set of groundwater samples is shown in Figure 5-5 and Figure 5-6. Lead and EDTA concentrations in groundwater samples were consistent with movement through the surface soil in the plot to the groundwater within the plot (Samples GW-5 and GW-6). This was likely due to movement of the soluble lead-EDTA complex caused in part by the physical condition of the site and the shallow and fluctuating groundwater flow through the plot. Realistically, all movement of the EDTA-lead complex did not occur down through the soil, but rather may have occurred in part due to preferential flow through channels caused by debris in the soil or through sand and around clay lenses in the soil. The influence of soil

physical properties is discussed in more detail in Section 5.2.10.3, Deep Core Soil Sampling, below. Also, as the level of groundwater fluctuated, the soil in the upper layers may have been in essence “washed” and EDTA and lead removed to lower depths.

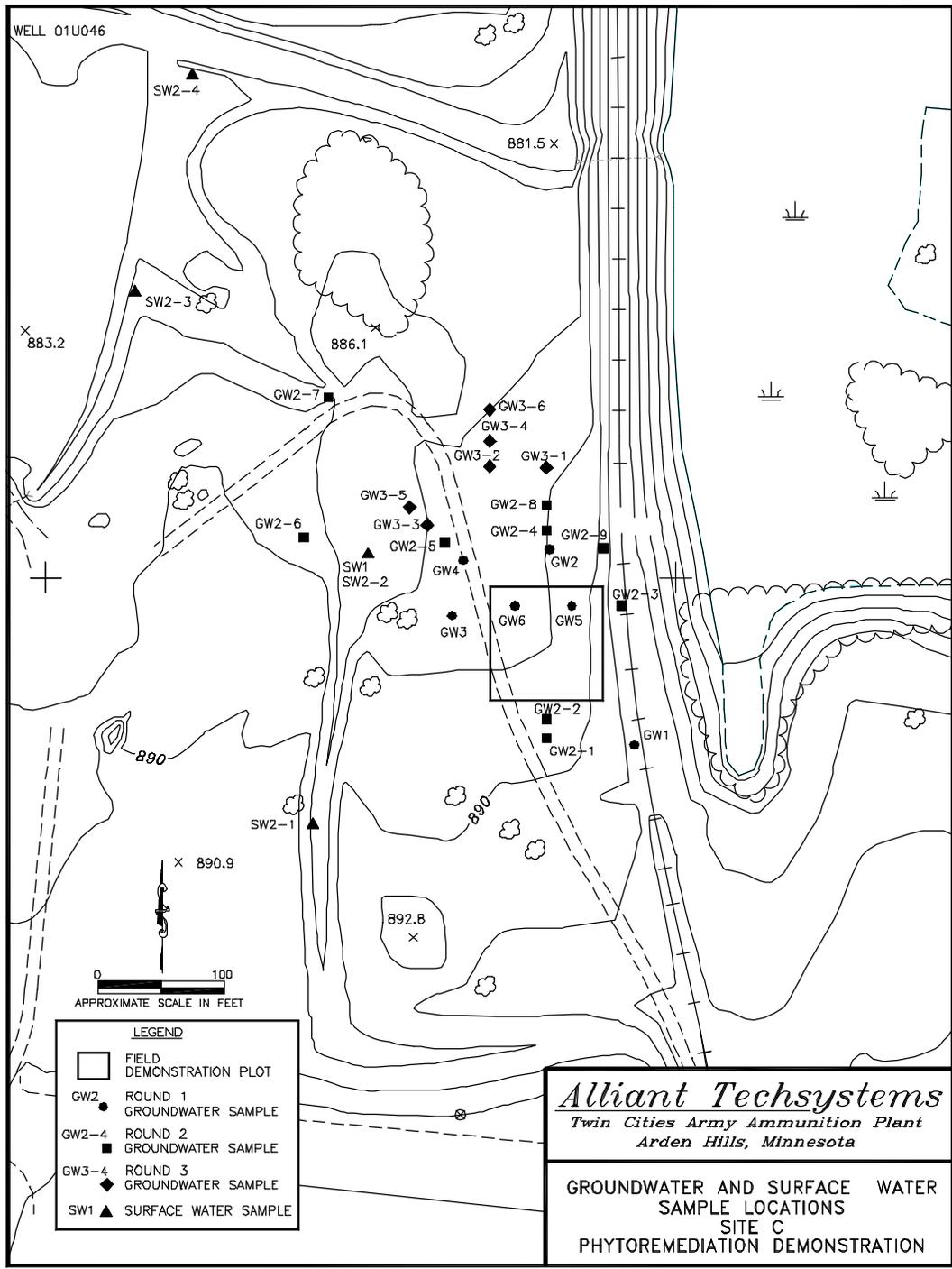
One area (GW6) showed a high concentration of lead (988 mg/L) and of EDTA (4,910 mg/L) in groundwater within the plot. This area was in the poorly drained northwestern quadrant of the plot. This area is also the lowest part of the plot. The high concentrations may have resulted from collection and stagnation of EDTA and solubilized lead from other parts of the plot.

Lead and EDTA concentrations from the other sampling point within the plot (GW5) were much lower, averaging 228 mg/L and 2,265 mg/L for lead and EDTA, respectively. This point was more upgradient of the slope within the plot.

There were four sampling locations outside the plot area, one upgradient (GW1) and three down-gradient (GW2, GW3, and GW4). Neither lead nor EDTA was found in the upgradient sample (GW1) located outside the southeastern corner of the plot according to the TVA analysis. However, a concentration of 71 mg/L was determined by the MDH laboratory. The disparity in the data between MDH and TVA warrants the need for additional measurements, such as samples and monitoring.

Lead and EDTA were present in sample GW2 at concentrations of 274 and 1,210 mg/L respectively. This sample point is located 30 feet to the north of the northeastern corner of the plot. Lead and EDTA were present in the sample from GW4 at concentrations of 573 and 2,310 mg/L, respectively. This sample point is located 30 feet to the northwest of the northwestern corner of the plot. Neither lead nor EDTA were found in down gradient sample GW3. This sample point is located 27 feet due west outside of the plot, 46 feet to the south of GW4.

Lead and EDTA moved outside of the plot boundaries in the groundwater at a slow rate. The rate of groundwater movement at Site C according to the original RI/FS is 0.017 - 55 ft per year. However, there was no indication of lead and only a trace amount (0.5 mg/L) of EDTA



**Figure 5-5**  
**Overview of Site C Showing**  
**Groundwater and Surface Water Sampling Locations**

**Table 5-39  
Overall Results and Sampling Schedule for Groundwater  
and Surface Water Samples at Site C**

Sampling Phase	Sample ID	Description	Sampling Date	Approximate Groundwater Depth (ft)	Laboratory <sup>1</sup>	Pb, mg/L	EDTA (as Na <sub>2</sub> EDTA) mg/L	EDTA (as EDTA) mg/L
GW -1	FB1	Field Blank	11-Apr-00		TVA	<0.02	<0.03	<0.03
1	RB1	Rinse Blank	11-Apr-00		TVA	<0.02	0.3	0.3
1	RB2	Rinse Blank	11-Apr-00		TVA	0.02	0.3	0.3
1	GW1	Groundwater Sample	11-Apr-00	7 - 7.5	TVA (MDH)	<0.02 (71)	0.2	0.2
1	GW2	Groundwater Sample	11-Apr-00	5 - 5.5	TVA (MDH)	274 (280)	1,390	1,210
1	GW3	Groundwater Sample	11-Apr-00	5	TVA (MDH)	<0.02 (1.1)	0.3	0.3
1	GW4	Groundwater Sample	11-Apr-00	4	TVA (MDH)	573 (580)	2,660	2,310
1	GW5	Groundwater Sample	11-Apr-00	6	TVA (MDH)	228 (270)	2,590	2,250
1	GW5 dup	Groundwater Sample	11-Apr-00	6	TVA (MDH)	227 (270)	2,620	2,280
1	GW6	Groundwater Sample	11-Apr-00	5.5	TVA (MDH)	988 (1100)	5,650	4,910
SW-1	SW1	Surface Water Sample	11-Apr-00		TVA (MDH)	<0.02 (4.2)	0.5	0.5
SW-2	PRB2-1-U	Pre-Rinse Blank	4-May-00				<0.03	<0.03
2	PRB2-1-F	Pre-Rinse Blank Filtered	4-May-00		CompuChem	0.0011		
2	FB2-1-U	Field Blank Unfiltered	4-May-00				<0.03	<0.03
2	FB2-1-F	Field Blank Filtered	4-May-00		CompuChem	0.0011		
2	RB2-1-U	Rinse Blank Unfiltered	4-May-00				<0.03	<0.03
2	RB2-1-F	Rinse Blank Filtered	4-May-00		CompuChem	0.0011		
2	SW2-1-U	Surface Water Sample - Unfiltered	4-May-00				0.1	0.1
2	SW2-1-F	Surface Water Sample - Filtered	4-May-00		CompuChem	0.0012		
2	SW2-2-U	Surface Water Sample - Unfiltered	4-May-00				0.2	0.2

**Table 5-39 (Continued)**  
**Overall Results and Sampling Schedule for Groundwater**  
**and Surface Water Samples at Site C**

Sampling Phase	Sample ID	Description	Sampling Date	Approximate Groundwater Depth (ft)	Laboratory <sup>1</sup>	Pb, mg/L	EDTA (as Na <sub>2</sub> EDTA) mg/L	EDTA (as EDTA) mg/L
2	SW2-2-F	Surface Water Sample - Filtered	4-May-00		CompuChem	0.0019		
2	SW2-3-U	Surface Water Sample - Unfiltered	4-May-00				<0.03	<0.03
2	SW2-3-F	Surface Water Sample - Filtered	4-May-00		CompuChem	0.0011		
2	SW2-4-U	Surface Water Sample - Unfiltered	4-May-00				1.2	1.1
2	SW2-4-F	Surface Water Sample - Filtered	4-May-00		CompuChem	0.0118		
2	SW2-4-UD	Surface Water Sample - Unfiltered Duplicate	4-May-00				1.2	1.0
SW-2	SW2-4-FD	Surface Water Sample - Filtered Duplicate	4-May-00		CompuChem	0.0119		
GW-2	PRB 2-1U	Pre-Rinse Blank	17-May-00				<0.03	<0.03
2	PRB 2-1F	Pre-Rinse Blank Filtered	17-May-00		CompuChem	0.0017		
2	FB2-1U	Field Blank Unfiltered	17-May-00				<0.03	<0.03
2	FB2-1F	Field Blank Filtered	17-May-00		CompuChem	0.0018		
2	RB2-1U	Rinse Blank Unfiltered	17-May-00				<0.03	<0.03
2	RB2-1F	Rinse Blank Filtered	17-May-00		CompuChem	0.0141		
2	GW2-1U	Groundwater Sample - Unfiltered	17-May-00	9.5 - 10			6.7	5.8
2	GW2-1F	Groundwater Sample - Filtered	17-May-00	9.5 - 10	CompuChem	0.228		

**Table 5-39 (Continued)**  
**Overall Results and Sampling Schedule for Groundwater**  
**and Surface Water Samples at Site C**

Sampling Phase	Sample ID	Description	Sampling Date	Approximate Groundwater Depth (ft)	Laboratory <sup>1</sup>	Pb, mg/L	EDTA (as Na <sub>2</sub> EDTA) mg/L	EDTA (as EDTA) mg/L
GW-2	GW2-2	DID NOT SAMPLE	17-May-00	DID NOT SAMPLE				
2	GW2-3	DID NOT SAMPLE	17-May-00	DID NOT SAMPLE				
2	GW2-4U	Groundwater Sample - Unfiltered	17-May-00	9 - 9.5			788	685
2	GW2-4F	Groundwater Sample - Filtered	17-May-00	9 - 9.5	CompuChem	208		
2	GW2-5U	Groundwater Sample - Unfiltered	17-May-00	5			701	609
2	GW2-5F	Groundwater Sample - Filtered	17-May-00	5	CompuChem	20		
2	GW2-6U	Groundwater Sample - Unfiltered	17-May-00	8			<0.03	<0.03
2	GW2-6F	Groundwater Sample - Filtered	17-May-00	8	CompuChem	0.17		
2	GW2-7	DRY	17-May-00	DRY				
2	GW2-8U	Groundwater Sample - Unfiltered	17-May-00	7.5			192	167
2	GW2-8F	Groundwater Sample - Filtered	17-May-00	7.5	CompuChem	54.4		
2	GW2-9	DRY	17-May-00	DRY				
GW-3	FB3-1U	Field Blank Unfiltered	30-May-00				<0.03	<0.03
3	FB3-1F	Field Blank Filtered	30-May-00		CompuChem	0.0011		
3	PRB3-1U	Pre-Rinse Blank	30-May-00				<0.03	<0.03

**Table 5-39 (Continued)**  
**Overall Results and Sampling Schedule for Groundwater**  
**and Surface Water Samples at Site C**

Sampling Phase	Sample ID	Description	Sampling Date	Approximate Groundwater Depth (ft)	Laboratory <sup>1</sup>	Pb, mg/L	EDTA (as Na <sub>2</sub> EDTA) mg/L	EDTA (as EDTA) mg/L
3	PRB3-1F	Pre-Rinse Blank Filtered	30-May-00		CompuChem	0.0011		
3	GW3-1U	Groundwater Sample - Unfiltered	30-May-00	8			0.26	0.23
3	GW3-1F	Groundwater Sample - Filtered	30-May-00	8	CompuChem	0.0015		
3	GW3-2U	Groundwater Sample - Unfiltered	30-May-00	6			850	739
3	GW3-2F	Groundwater Sample - Filtered	30-May-00	6	CompuChem	1.56		
3	GW3-3U	Groundwater Sample - Unfiltered	30-May-00	8			570	495
3	GW3-3F	Groundwater Sample - Filtered	30-May-00	8	CompuChem	10.8		
3	GW3-4U	Groundwater Sample - Unfiltered	30-May-00	8			0.38	0.33
3	GW3-4F	Groundwater Sample - Filtered	30-May-00	8	CompuChem	0.0256		
3	GW3-4U-DUP	Groundwater Sample - Unfiltered	30-May-00	8			0.37	0.32
3	GW3-4F-DUP	Groundwater Sample - Filtered	30-May-00	8	CompuChem	0.0208		
3	GW3-5U	Groundwater Sample - Unfiltered	30-May-00	3			410	356
3	GW3-5F	Groundwater Sample - Filtered	30-May-00	3	CompuChem	27.3		

**Table 5-39 (Continued)**  
**Overall Results and Sampling Schedule for Groundwater**  
**and Surface Water Samples at Site C**

Sampling Phase	Sample ID	Description	Sampling Date	Approximate Groundwater Depth (ft)	Laboratory <sup>1</sup>	Pb, mg/L	EDTA (as Na <sub>2</sub> EDTA) mg/L	EDTA (as EDTA) mg/L
GW-3	GW3-6U	Groundwater Sample - Unfiltered	30-May-00	6			7	6
3	GW3-6F	Groundwater Sample - Filtered	30-May-00	6	CompuChem	1.45		

(1) Laboratory: TVA - Tennessee Valley Authority Specialty Laboratory.  
 MDH - Minnesota Department of Health.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-40**  
**Analysis and Molar Ratios of EDTA:Pb in Groundwater and Surface Water**  
**Samples Taken at Site C on April 11, 2000 (First Phase Sampling)**

Sample	pH	EDTA as Na <sub>2</sub> EDTA mg/L	EDTA as EDTA mg/L	EDTA <sup>1</sup> $\mu$ moles/L	Pb mg/L	Pb <sup>2</sup> $\mu$ moles/L	EDTA:Pb Molar Ratio <sup>3</sup>
GW 1	7.8	0.2	0.2	0.6	<0.02	--	--
GW 2	7.0	1,390	1,210	4,130	274	1,320	3.1
GW 3	7.1	0.3	0.3	0.9	<0.02	--	--
GW 4	7.5	2,660	2,310	7,910	573	2,770	2.9
GW 5	7.2	2,590	2,250	7,700	228	1,100	7.0
GW 5 (Duplicate)	7.2	2,620	2,280	7,790	227	1,100	7.1
GW 6	7.2	5,650	4,910	16,800	988	4,770	3.5
SW 1	7.7	0.6	0.5	2	<0.02	--	--
Field Blank	8.3	<0.03	<0.03	--	<0.02	--	--
Rinse Blank	8.6	0.3	0.3	0.8	<0.02	--	--
Rinse Blank	8.6	0.3	0.3	0.8	0.02	0.1	--

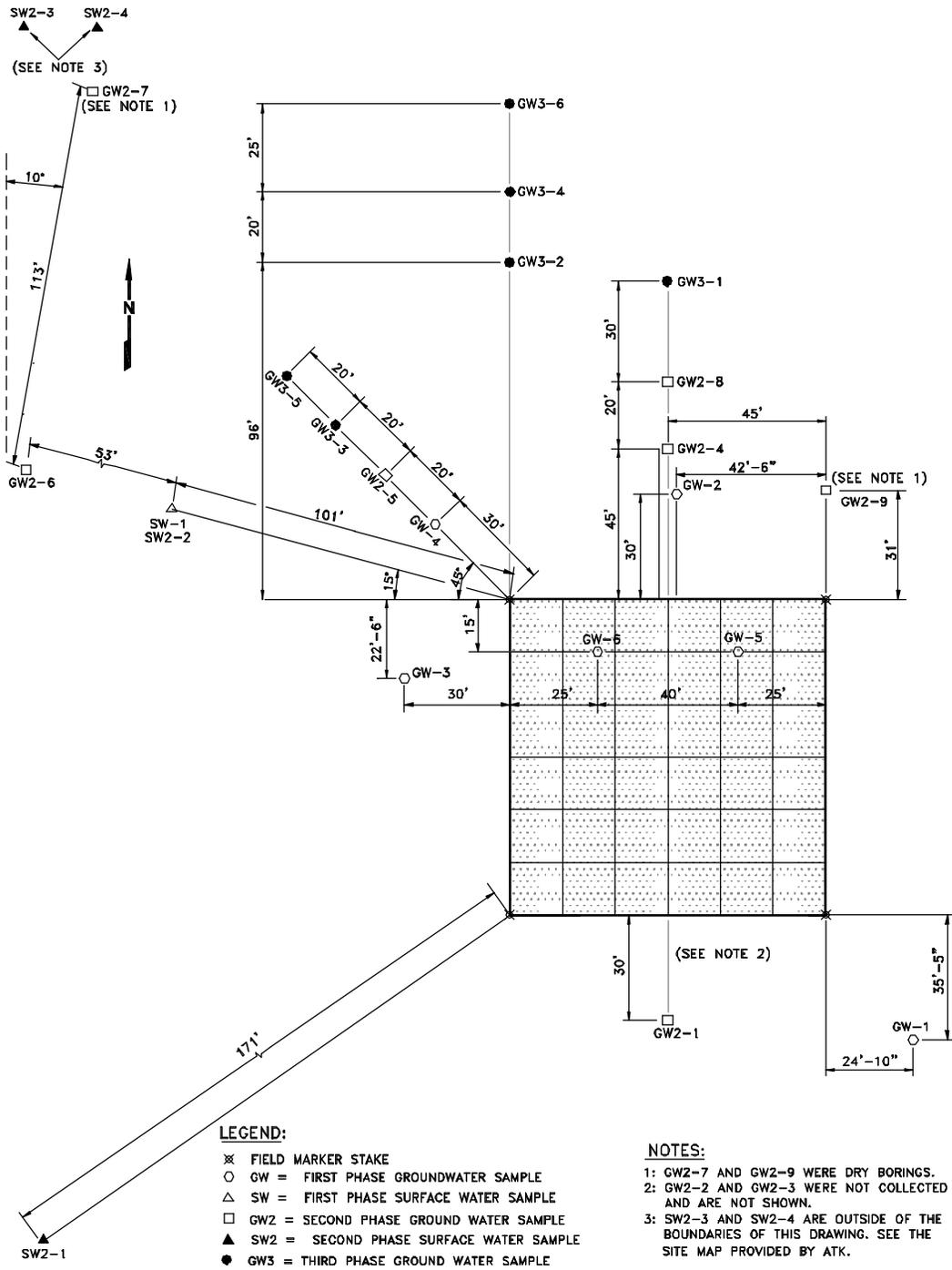
(1) Obtained by dividing mg/L of EDTA by the molecular weight of EDTA (292.24 g/mol) and multiplying by 1000.

NOTE: 1 mol EDTA = 1 mol Na<sub>2</sub>EDTA.

(2) Obtained by dividing mg/L of Pb by the molecular weight of Pb (207.2 g/mol) and multiplying by 1000.

(3) Obtained by dividing  $\mu$ moles/L of Na<sub>2</sub>EDTA by  $\mu$ moles/L of Pb.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.



**Figure 5-6**  
**Groundwater and Surface Water Sampling Locations**  
**Site C - April 2000**

contamination in a surface water sample (SW1) taken from a drainage ditch located 125 feet to the northwest of the plot. The charge mechanism for water in the ditch is unknown, i.e., whether water present in the ditch results from water flow into the ditch across the soil surface or from groundwater flow up into the ditch. However, since the groundwater flow is suspected to be from southeast to northwest, some water present in the ditch could originate from groundwater flow.

EDTA concentrations in the equipment rinse blanks were 0.3 mg/L, or half the EDTA concentration found in the surface water sample. EDTA was not found in the field blank. Lead was not detectable in the rinse blanks or in the field blank.

The change in the 1:1 molar ratio of EDTA to lead indicated that the lead had been displaced by other ions. EDTA was applied twice in 1998 at a molar ratio of 1:1 EDTA to *total lead* in the soil. EDTA was applied once in 1999 at a molar ratio of 1:1 *plant-available* lead (55% of total soil lead). The molar ratios of EDTA to lead at sample points GW2, GW4, GW5, and GW6 were considerably greater than the 1:1 ratio originally applied in 1998 and in 1999. This indicated that lead had been displaced from the EDTA complex. The lead re-precipitated in the soil.

Accordingly, the samples were analyzed for a suite of other cations which could potentially complex with EDTA (Table 5-41). These analyses are given in mg/L and in  $\mu$ moles/L so that molar quantities of each element may be directly compared with molar quantities of EDTA and lead. Of these cations, calcium (Ca) and magnesium (Mg) were present at the greatest concentration, with iron (Fe) and manganese (Mn) also being present at lower concentrations (Figure 5-7). Although EDTA has greater affinity for lead, the considerably higher concentration of Ca and Mg would, by simple mass action, result in these ions “swamping” the system and displacing the lead from the EDTA complex (refer to Section 5.2.10.1.1).

#### **5.2.10.2.2 May 17, 2000 - Second Groundwater Sampling**

When splits from the first groundwater samples collected on April 11, 2000, were analyzed by TVA and MDH, the results were consistently a little higher on the samples analyzed by MDH (Table 5-39). A review was made of sample collection practices for the two laboratories. One difference was noted. The Minnesota laboratory utilized 0.45- $\mu$  Millipore<sup>®</sup> filters while the TVA laboratory utilized 0.2- $\mu$  Millipore<sup>®</sup> filters to filter samples prior to digestion and analysis. The 0.45- $\mu$  filters utilized by MDH may have allowed silt particles and colloidal material to be collected with the water samples. Insoluble lead tends to be adsorbed on the surface of these particles which have an extremely high surface area. This insoluble lead would then be solubilized during sample digestion and would show up as higher lead concentrations in analysis.

By agreement with MPCA, for the second groundwater sampling, an outside laboratory (CompuChem) was officially responsible for lead analyses. TVA was responsible for EDTA analysis. In addition, the groundwater samples at this sampling were processed in two ways: (1) filtered in the field through a 0.45 micron filter and acidified, then shipped to CompuChem for lead analysis; (2) shipped to TVA unfiltered and unacidified for EDTA analyses. Upon receipt at TVA, the samples were filtered through a 0.45 micron Millipore<sup>®</sup> syringe filter and analyzed for EDTA. The nine groundwater sample locations for the second sampling are designated by GW2-1 through GW2-9 on Figure 5-6. However, only five water samples were

**Table 5-41**  
**Analysis for Potential Competing Cations in Groundwater and Surface Water Samples**  
**Taken at Site C on April 11, 2000 (First Phase Sampling)**

Sample	pH	EDTA as Na <sub>2</sub> EDTA	EDTA as EDTA	Pb	Ca	Fe	Mg	K	Mn	Na	Zn	Sr
<b>mg/L</b>												
GW 1	7.8	0.2	0.2	<0.02 <sup>1</sup>	78	<0.002 <sup>1</sup>	15	1	2	4	0.03	0.3
GW 2	7.0	1,390	1,210	274	328	136	62	4	23	11	24	6
GW 3	7.1	0.3	0.3	<0.02	162	1	43	3	3	12	0.04	2
GW 4	7.5	2,660	2,310	573	321	257	145	7	4	18	10	17
GW 5	7.2	2,590	2,250	228	603	321	118	91	39	21	43	3
GW 5 (Duplicate)	7.2	2,620	2,280	227	604	308	119	92	39	21	43	3
GW 6	7.2	5,650	4,910	988	761	537	141	15	79	40	28	32
SW 1	7.7	0.6	0.5	<0.02	135	0.06	67	4	0.2	38	0.5	2
FB 1 Field Blank	8.3	<0.03 <sup>1</sup>	<0.03 <sup>1</sup>	<0.02	23	<0.002	5	3	0.006	6	0.04	0.05
RB 1 Rinse Blank	8.6	0.3	0.3	<0.02	7	<0.002	1	0.5	0.007	2	0.03	0.02
RB 2 Rinse Blank	8.6	0.3	0.3	0.02	6	<0.002	1	0.8	0.009	2	0.05	0.02
MDL <sup>1</sup>	-- <sup>2</sup>	0.03	0.03	0.02	0.01	0.002	0.002	0.2	0.005	0.02	0.004	0.003
<b>mmoles/L<sup>3</sup></b>												
GW 1	--	0.7	0.6	<MDL <sup>1</sup>	1,940	<MDL <sup>1</sup>	617	36	36	177	0.5	4
GW 2	--	4,130	4,130	1,320	8,180	2,440	2,560	89	417	470	370	64
GW 3	--	0.9	0.8	<MDL <sup>1</sup>	4,040	23	1,770	73	53	526	0.7	21
GW 4	--	7,910	7,910	2,770	8,010	4,600	5,970	189	79	783	148	199
GW 5	--	7,700	7,700	1,100	15,000	5,750	4,860	2,320	703	905	650	39
GW 5 (Duplicate)	--	7,790	7,790	1,100	15,100	5,520	4,900	2,350	712	918	658	39
GW 6	--	16,800	16,800	4,770	19,000	9,620	5,800	394	1,430	1,749	422	360
SW 1	--	2	2	<MDL <sup>1</sup>	3,370	1	2,770	97	3	1,650	8	21
FB 1 Field Blank	--	<MDL <sup>1</sup>	<MDL <sup>1</sup>	<MDL <sup>1</sup>	569	<MDL <sup>1</sup>	192	67	0.1	272	0.6	0.6
RB 1 Rinse Blank	--	0.8	0.7	<MDL <sup>1</sup>	163	<MDL <sup>1</sup>	44	14	0.1	92	0.5	0.2
RB 2 Rinse Blank	--	0.8	0.7	0.1	153	<MDL <sup>1</sup>	39	21	0.2	94	0.8	0.2
MDL	--	0.09	0.08	0.1	0.3	0.04	0.08	5	0.09	0.9	0.06	0.03

(1) Method Detection Limit.

(2) -- Not Applicable.

(3) Obtained  $\mu\text{moles/L}$  by dividing  $\text{mg/L}$  by the respective molecular weight ( $\text{g/mol}$ ) of each compound or element and multiplying by 1,000.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as  $\text{mg/kg}$  or  $\text{mg/L Na}_2\text{EDTA}$ . Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is  $(292.24\text{g/mol EDTA})/(336.21\text{g/mol Na}_2\text{EDTA}) = 0.8692$ .

**Table 5-41 (Continued)**  
**Analysis for Potential Competing Cations in Groundwater and Surface Water Samples**  
**Taken at Site C on April 11, 2000 (First Phase Sampling)**

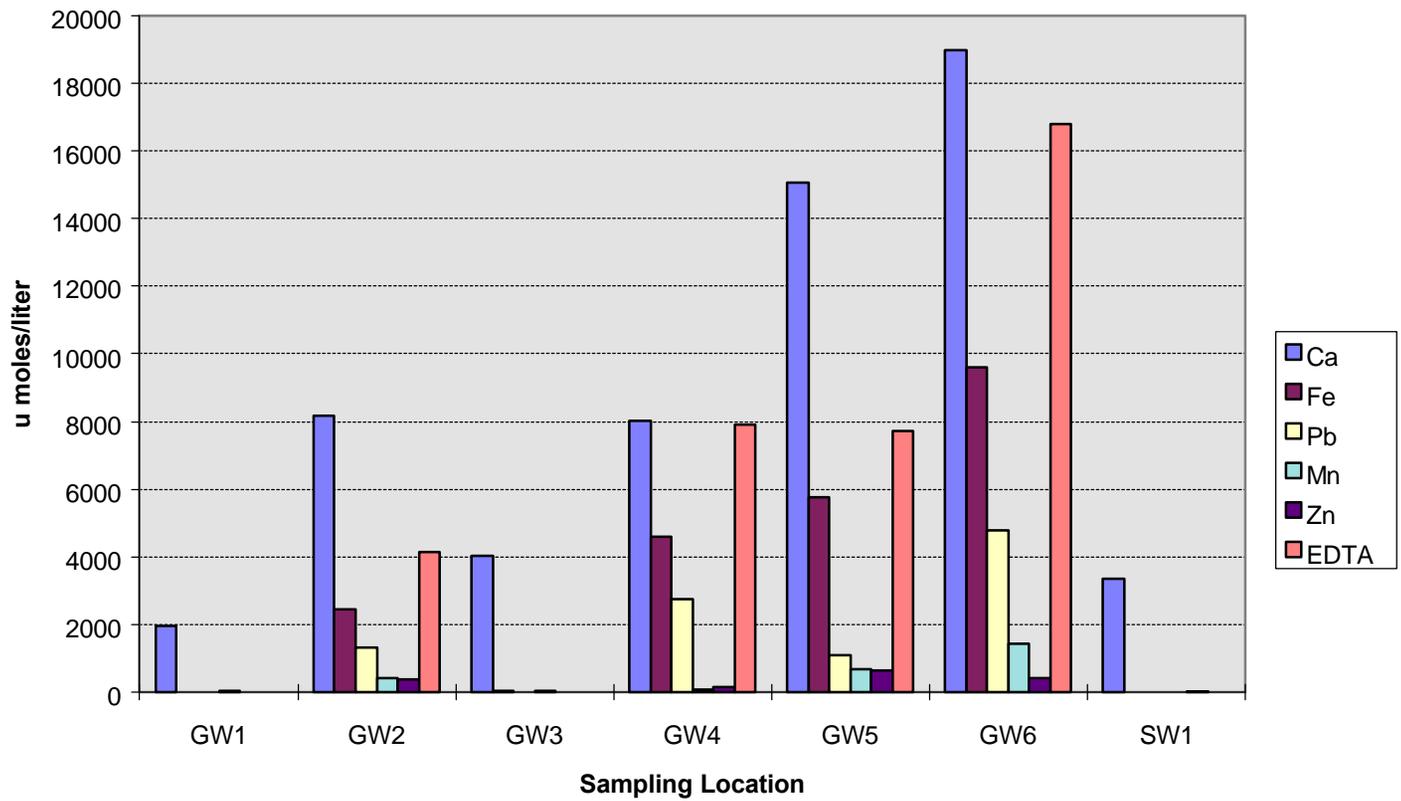
Sample	Al	As	Ba	Be	Co	Cu	Ni	Sb	Ti	Tl	V
<b>mg/L</b>											
GW 1	<0.04 <sup>1</sup>	0.4	0.1	<0.002 <sup>1</sup>	0.02	<0.004 <sup>1</sup>	<0.01 <sup>1</sup>	<0.06 <sup>1</sup>	0.007	<0.1 <sup>1</sup>	0.02
GW 2	<0.07	1	3	<0.003	0.9	0.07	2	0.3	0.02	0.4	0.2
GW 3	<0.04	0.9	0.7	<0.002	0.02	<0.004	<0.01	0.06	0.01	<0.1	0.03
GW 4	<0.04	2	22	<0.002	0.5	0.4	0.5	0.2	0.02	0.9	0.1
GW 5	<0.04	3	0.9	0.002	1	0.08	2	0.3	0.03	0.8	0.2
GW 5 (Duplicate)	<0.04	3	0.8	<0.002	1	0.9	2	0.3	0.03	0.8	0.2
GW 6	<0.04	5	4	0.003	2	<0.004	2	0.4	0.03	1	0.6
SW 1	<0.04	0.6	0.2	<0.002	0.02	0.03	0.02	0.07	0.02	<0.1	0.03
FB 1	<0.04	0.1	0.02	<0.002	0.02	0.01	<0.01	<0.06	0.02	<0.1	0.02
Field Blank											
RB 1 Rinse Blank	<0.04	<0.04 <sup>1</sup>	0.06	<0.002	0.007	<0.004	<0.01	<0.06	0.02	<0.1	0.009
RB 2 Rinse Blank	<0.04	<0.04	0.05	<0.002	0.01	0.005	<0.01	<0.06	<0.004 <sup>1</sup>	<0.1	0.01
MDL <sup>1</sup>	0.04	0.04	0.012	0.002	0.01	0.004	0.01	0.06	0.004	0.1	0.004
<b>µmoles/L<sup>3</sup></b>											
GW 1	-- <sup>2</sup>	5	0.9	-- <sup>2</sup>	0.4	-- <sup>2</sup>	-- <sup>2</sup>	-- <sup>2</sup>	0.2	-- <sup>2</sup>	0.4
GW 2	--	16	22	--	14	1	30	2	0.4	2	3
GW 3	--	12	5	--	0.4	--	--	0.5	0.2	--	0.6
GW 4	--	33	160	--	8	6	8	1	0.4	4	2
GW 5	--	44	6	0.2	21	1	30	2	0.6	4	4
GW 5 (Duplicate)	--	46	6	--	22	15	30	2	0.6	4	4
GW 6	--	61	28	0.3	26	--	35	3	0.6	7	12
SW 1	--	9	1	--	0.3	0.5	0.3	0.6	0.4	--	0.6
FB 1	--	1	0.1	--	0.3	0.2	--	--	0.4	--	0.4
Field Blank											
RB 1 Rinse Blank	--	--	0.4	--	0.1	--	--	--	0.4	--	0.2
RB 2 Rinse Blank	--	--	0.4	--	0.2	0.08	--	--	--	--	0.2
MDL	1.5	0.5	0.09	0.2	0.17	0.06	0.2	0.5	0.08	0.5	0.08

(1) Method Detection Limit.

(2) -- Not Applicable.

(3) Obtained µmoles/L by dividing mg/L by the respective molecular weight (g/mol) of each compound or element and multiplying by 1,000.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.



**Figure 5-7**  
**Major Competing Cations in Groundwater and Surface Water Samples at Site C**  
**(First Sampling)**

**Table 5-42**  
**Analysis and Molar Ratios of EDTA:Pb in Groundwater**  
**Samples Taken at Site C on May 17, 2000 (Second Phase Sampling)**

Sample	EDTA as Na <sub>2</sub> EDTA <sup>1</sup> mg/L	EDTA as EDTA <sup>1</sup> mg/L	EDTA <sup>2</sup> μmoles/L	Pb mg/L	Pb <sup>3</sup> μmoles/L	EDTA:Pb Molar Ratio <sup>4</sup>
GW2-1U <sup>5</sup>	6.7	5.8	20	--	--	--
GW2-1F <sup>6</sup>	--	--	--	0.228	1.1	18
GW2-2	no sample <sup>7</sup>	no sample <sup>7</sup>	-- <sup>8</sup>	--	--	--
GW2-3	no sample	no sample	--	--	--	--
GW2-4U	788	685	2,345	--	--	--
GW2-4F	--	--	--	208	1,004	2.3
GW2-5U	701	609	2,086	--	--	--
GW2-5F	--	--	--	20	97	21.5
GW2-6U	<0.03 <sup>9</sup>	<0.03 <sup>9</sup>	--	--	--	--
GW2-6F	--	--	--	0.17	1	--
GW2-7	dry	dry	--	--	--	--
GW2-8U	192	167	571	--	--	--
GW2-8F	--	--	--	54.4	263	2.2
GW2-9	dry	dry	--	--	--	--
Pre-rinse Blank, unfiltered	<0.03	<0.03	--	--	--	--
Pre-rinse Blank, filtered	--	--	--	0.0017	0.01	--
Field Blank, unfiltered	<0.03	<0.03	--	--	--	--
Field Blank, filtered	--	--	--	0.0018	0.01	--
Rinse Blank, unfiltered	<0.03	<0.03	--	--	--	--
Rinse Blank, filtered	--	--	--	0.0141	0.1	--

- (1) EDTA was determined on samples that were not filtered in the field..
- (2) Obtained by dividing mg/L of EDTA by the molecular weight of EDTA (292.24 g/mol) and multiplying by 1000.  
NOTE: 1 mol EDTA = 1 mol NA2EDTA.
- (3) Obtained by dividing mg/L of Pb by the molecular weight of Pb (207.2 g/mol) and multiplying by 1000.
- (4) Obtained by dividing μmoles/L of Na2EDTA by μmoles/L of Pb.
- (5) U = Unfiltered, unacidified in the field, filtered and acidified on receipt by TVA.
- (6) F = Filtered and acidified in the field.
- (7) Time constraints and bad weather prevented taking a sample at this location.
- (8) -- Not Applicable.
- (9) Method Detection Limit (MDL).

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

taken. Time constraints prevented sampling at GW2-2 and GW2-3 (the two upgradient locations), and the bore holes were dry at GW2-7 and GW2-9. Lead and EDTA concentrations in groundwater for the sampling on May 17 are shown in Table 5-42.

As with the first set of groundwater samples (Section 5.2.10.1.1), the EDTA:lead ratio was consistently greater than 1:1, which indicated that EDTA was associated with elements other than lead and that lead had been displaced from the EDTA complex. Concentrations of EDTA and lead decreased significantly with increasing down-gradient distance north and northwest from the plot.

#### **5.2.10.2.3 May 30, 2000 - Third Groundwater Sampling**

EDTA had continued to migrate with the groundwater in a northwesterly direction down-gradient of the demonstration plot to the locations where these samples were taken (Figure 5-6, Table 5-43, sample locations GW3-3 and GW3-5), but lead concentrations tended to decrease with distance from the plot. As a consequence, the EDTA to lead ratio remained high in these samples, which indicated that lead was dissociating from EDTA. Concentrations of EDTA and lead decreased as the groundwater moved northward and down-gradient away from the plot (sample locations GW3-2, GW3-4, and GW3-6). The samples were analyzed only for EDTA and lead.

#### **5.2.10.3 May 4, 2000 - Surface Water Sampling**

Four additional samples were taken from various locations in the ditch (Figure 5.5, Figure 5-6, Table 5-44) to determine if contamination of surface water had occurred. A trace amount of EDTA (0.1 ppm) was found in the upgradient sample (SW2-1) taken 171 feet from the southwest corner of the demonstration plot. A slightly higher concentration of EDTA (0.2 ppm) was found at the original sampling site (SW-1) about 100 feet to the northwest of the plot when this site was re-sampled. However, the concentration had decreased from the 0.5 ppm originally present in the water at that location. This could have been due to dilution by additional influx of water into the ditch, or to movement of EDTA away from the sample point or degradation of the small amount of EDTA. EDTA was not detected in water from the third sampling point (SW2-3) located approximately 475 feet northwest of the plot (Figure 5-5). Notably, lead was not detected in any of the surface water samples, which indicated that EDTA had not mobilized lead into the surface water.

EDTA was present in the water sample from the fourth location (SW2-4, Figure 5-6) at a concentration of 1.1 ppm. This location was 500 feet from the demonstration plot. No lead was associated with the EDTA.

As with the first phase groundwater samples, these surface water samples were analyzed for 19 other cations (Table 5-45). The only cations present in quantities sufficient to compete with lead for complexation by EDTA were Ca and Mg. Potassium and sodium were present at average concentrations of 2 and 41 ppm, respectively, but these cations are not typically complexed by EDTA. The relationship between the competing cations and EDTA for the surface water samples is shown in Figure 5-8.

The concentrations of Ca and Mg in Figure 5-8 are expressed in  $\mu\text{moles/L}$ . The corresponding average concentrations for Ca expressed in mg/L across the four locations (SW2-1, SW2-2, SW2-3, and SW2-4) are 118, 148, 86, and 117 mg/L. For Mg, the corresponding values for the four locations are 21, 58, 23, and 28 mg/L. Since lead was not present in the samples, the small quantity of EDTA present would have been complexed with Ca and Mg.

#### **5.2.10.4 April 11, 2000 - Deep Core Soil Sampling**

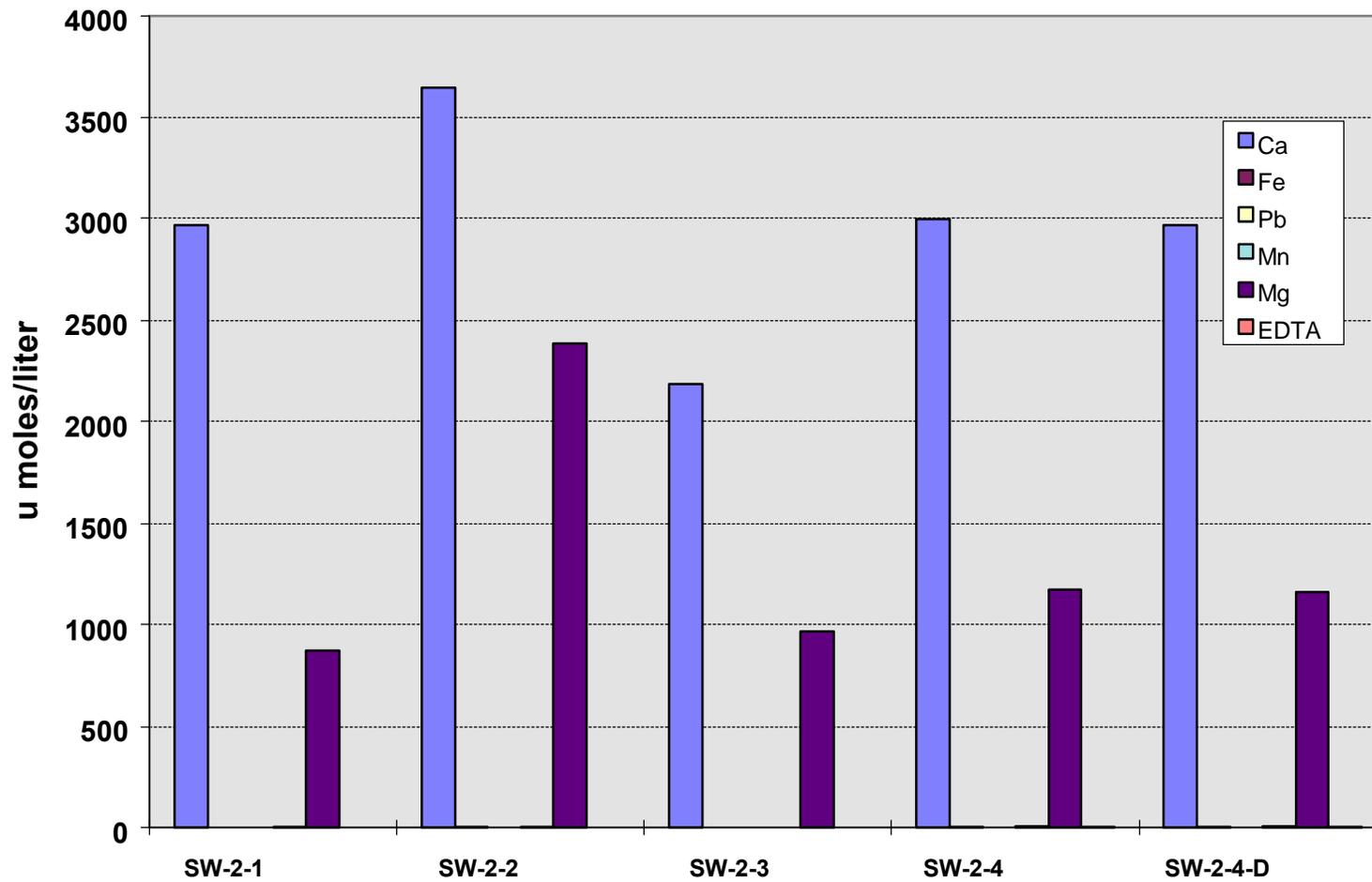
Site C, and to a lesser extent at Site 129-3, were difficult sites to work. The large amount of debris and the observed different soil types at Site C directly contributed to and greatly exacerbated these problems. Deep core soil sampling was conducted to “dissect” the site and specifically determine and describe some of the factors responsible for the adverse conditions at the site.

The sample locations for deep core samples taken at Site C are shown in Figure 5-9, and for Site 129-3 in Figure 5-10. At Site C, nine samples were taken within the plot and five were taken outside the plot. Two of the samples within the plot at Site C were in the poorly drained northwest quadrant which would tend towards high concentrations of EDTA and lead. Of the five samples taken outside the plot, three were up-gradient of the plot and two were down-gradient. At Site 129-3, the plot was divided into quadrants and a sample was taken from each quadrant within the plot. No samples were taken outside the demonstration plot at Site 129-3.

A description of the soil core samples at Site C and Site 129-3 by depth with the concentrations of EDTA and lead in the soil down to 4 feet is given in Table 5-46. The core samples represent 4 feet of soil. The 4-ft sections were cut into two 2-ft sections for shipment to the TVA Analytical Laboratory. Compression occurred during sampling so the length of each core was in many cases less than two feet. However, the amount of soil in each core is representative of two feet of field soil.

Examination of the soil cores revealed the following:

- The dominant soil type identified by the RI/FS for the area at Site C is sandy loam. However, the soil at Site C is extremely heterogeneous, which suggested dumping of soil from other areas when disposal activities occurred.
- Seven soil textures, ranging from sand to clay, were identified during the examination of the cores. The soil varied markedly in texture within each 4-foot core. Frequently, a deposit of each soil type was present in each core sample.
- Clay and sand lenses (i.e., a stratified layer) ranging in thickness from 1 inch to 5 inches, were commonly found in the samples at soil depths of 0.5 to 3.5 ft.



**Figure 5-8**  
**Major Competing Cations in Surface Water Samples at Site C**  
**(Second Sampling)**

**Table 5-43  
Analysis and Molar Ratios of EDTA:Pb in Groundwater  
Samples Taken at Site C on May 30, 2000 (Third Phase Sampling)**

Sample	EDTA as Na <sub>2</sub> EDTA <sup>1</sup> mg/L	EDTA as EDTA <sup>1</sup> mg/L	EDTA <sup>2</sup> μmoles/L	Pb mg/L	Pb <sup>3</sup> μmoles/L	EDTA:Pb Molar Ratio <sup>4</sup>
GW3-1U <sup>5</sup>	0.26	0.23	0.8	-- <sup>7</sup>	--	--
GW3-1F <sup>6</sup>	--	--		0.0015	0.01	80.0
GW3-2U	850	739	2,530	--	--	--
GW3-2F	--	--	--	1.56	8	316.0
GW3-3U	570	495	1,696	--	--	--
GW3-3F	--	--	--	10.8	52	32.6
GW3-4U	0.38	0.33	1	--	--	--
GW3-4F	--	--	--	0.0256	0.1	10.0
GW3-4U duplicate	0.37	0.32	1	--	--	--
GW3-4F duplicate	--	--	--	0.0208	0.1	10.0
GW3-5U	410	356	1,220	--	--	--
GW3-5F	--	--		27.3	132	9.2
GW3-6U	7	6	21	--	--	--
GW3-6F	--	--	--	1.45	7	3.0
Pre-rinse Blank, unfiltered	<0.03 <sup>8</sup>	<0.03 <sup>8</sup>	--	--	--	--
Pre-rinse Blank, filtered	--	--	--	0.0011	0.01	--
Field Blank, unfiltered	<0.03	<0.03	--	--	--	--
Field Blank, filtered	--	--	--	0.0011	0.01	--

- (1) EDTA was determined on samples that were not filtered in the field.  
(2) Obtained by dividing mg/L of EDTA by the molecular weight of EDTA (292.24 g/mol) and multiplying by 1000.  
NOTE: 1 mol EDTA = 1 mol Na<sub>2</sub>EDTA.  
(3) Obtained by dividing mg/L of Pb by the molecular weight of Pb (207.2 g/mol) and multiplying by 1000.  
(4) Obtained by dividing μmoles/L of Na<sub>2</sub>EDTA by μmoles/L of Pb.  
(5) U = Unfiltered, unacidified in the field, filtered and acidified on receipt by TVA.  
(6) F = Filtered and acidified in the field.  
(7) Time constraints and bad weather prevented taking a sample at this location.  
(8) -- Not Applicable.  
(9) Method Detection Limit (MDL).

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-44**  
**Analysis of Pb and EDTA in Surface Water Samples**  
**Taken from Drainage Ditch at Site C on May 4, 2000**  
**(Second Phase Sampling)**

Sample <sup>1</sup>	pH	EDTA as Na <sub>2</sub> EDTA <sup>2</sup> mg/L	EDTA as EDTA <sup>2</sup> mg/L	EDTA <sup>3</sup> μmoles/L	Pb mg/L	Pb <sup>4</sup> μmoles/L
SW-2-1U-A	7.4	0.10	0.09	0.3	<0.02 <sup>5</sup>	<0.1 <sup>5</sup>
SW-2-1U-B		0.11	0.10	0.3	<0.02	<0.1
SW-2-1F		NA <sup>6</sup>	NA <sup>6</sup>	--	<0.02	<0.1
SW-2-2U-A	7.7	0.20	0.17	0.6	<0.02	<0.1
SW-2-2U-B		0.19	0.17	0.6	<0.02	<0.1
SW-2-2F		NA	NA	--	<0.02	<0.1
SW-2-3U-A	7.6	<0.03 <sup>5</sup>	<0.03 <sup>5</sup>	<0.09 <sup>5</sup>	0.02	0.1
SW-2-3U-B		<0.03	<0.03	<0.09	<0.02	<0.1
SW-2-3F		NA	NA	--	<0.02	<0.1
SW-2-4U-A	7.3	1.21	1.05	3.6	<0.02	<0.1
SW-2-4U-B		1.21	1.05	3.6	<0.02	<0.1
SW-2-4F		NA	NA	--	<0.02	<0.1
SW-2-4U-A (dup.) <sup>7</sup>	7.3	1.20	1.04	3.6	<0.02	<0.1
SW-2-4U-B (dup.)		1.20	1.04	3.6	<0.02	<0.1
SW-2-4F (dup.)		NA	NA	--	<0.02	<0.1
Pre-Rinse Blank-U-A	5.5	<0.03	<0.03	<0.09	<0.02	<0.1
Pre-Rinse Blank-U-B		<0.03	<0.03	<0.09	<0.02	<0.1
Pre-Rinse Blank-F		NA	NA	--	<0.02	<0.1
Rinse Blank-U-A	6.0	<0.03	<0.03	<0.09	<0.02	<0.1
Rinse Blank-U-B		<0.03	<0.03	<0.09	<0.02	<0.1
Rinse Blank-F		NA	NA	--	<0.02	<0.1
Field Blank-U-A	6.2	<0.03	<0.03	<0.09	<0.02	<0.1
Field Blank-U-B		<0.03	<0.03	<0.09	<0.02	<0.1
Field Blank-F		NA	NA	--	<0.02	<0.1

- (1) "A" fractions of surface water samples were not filtered or acidified in the field. The samples were filtered through 0.45 micron Millipore® syringe filters upon arrival at the TVA Analytical Lab, then acidified after a subsample taken for EDTA analysis. "B" fractions were filtered at TVA through 0.2 Millipore® syringe filters, subsampled for EDTA analysis, and acidified. "F" fractions were filtered and acidified in the field.
- (2) EDTA was determined on samples that were not filtered in the field..
- (3) Obtained by dividing mg/L of EDTA by the molecular weight of EDTA (292.2224 g/mol) and multiplying by 1000. NOTE: 1 mol EDTA = 1 mol Na<sub>2</sub>EDTA.
- (4) Obtained by dividing mg/L of Pb by the molecular weight of Pb (207.2 g/L) and multiplying by 1000.
- (5) Method Detection Limit.
- (6) NA = Not Applicable.
- (7) Dup. = duplicate samples collected in field.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

- A major deposit (6-inch thickness) of dense, brittle, consolidated hardpan material was found at the one foot depth in samples from the western-most third of the plot. The color indicated that the pan material is likely iron-rich. The pan sloped toward the low northwestern corner of the field (site of GW-6 sample, Figure 5-6).
- Iron oxide deposition was common throughout the soil.
- Manganese concretions (nodules of manganese sulfide) were found in several samples. Such deposits are indicative of a fluctuating water table level, which results in alternating aerobic and anaerobic zones in the soil and periodic low redox status. Such concretions are caused when Mn is solubilized under low redox and then is re-precipitated as the water recedes and the soil returns to an aerobic, high redox state.
- Several samples (primarily clay) were grey in color at the 3- to 4-ft depth, which indicated poor drainage or periodic water logging.
- Some of the cores were extremely wet, particularly at the 3- to 4 ft-depth, and moisture could be freely expressed from the soil.
- A considerable amount of char as well as unburned wood and what appeared to be rail tie was found. Layers of consolidated and unconsolidated char were found at various depths, ranging from 6 inches to almost 4 feet. Other debris consisted of diverse glass, wood, sheet metal, wire, concrete, copper-clad lead bullets, and brass shell casings.
- Numerous cobbles ranging in size from small pebbles to 12-inch stones were present.

The dominant soil type at Site 129-3 is fine sand. However, the soil at this site also varied in texture from fine sand to clay. No debris was noted in the Site 129-3 soil. The soil in all cores was well drained.

Analysis of deep core samples at Site C showed total lead concentrations in the soil ranging from less than 1 ppm to greater than 44,000 ppm. Water-soluble lead concentrations ranged from less than 1 ppm up to 549 ppm. Concentrations of EDTA in the soil ranged from less than 0.3 ppm to 1,570 ppm. Concentrations of water-soluble lead and EDTA at Site 129-3 were lower due to the lower total lead content of the soil and the correspondingly lower amount of EDTA added to the soil.

The amount of EDTA remaining in the soil at Site C was less than anticipated. Apparently, the heterogeneous soil texture and the many discontinuities within the soil body may have promoted downward movement of EDTA and reduced the contact time of EDTA with the soil and thus expected reactions of EDTA in the soil did not occur. However, degradation of EDTA was not as great as anticipated. Normally the primary mechanisms are aerobic microbial degradation and photo-degradation. Possibly the general microbial population in this soil is low due to the presence of toxic contaminants in the soil.

**Table 5-45**  
**Analysis for Potential Competing Cations in Surface Water Samples**  
**Taken at Site C on May 4, 2000 (Second Phase Sampling)**

Site	pH	EDTA as	EDTA as	Pb	Ca	Fe	Mg	K	Mn	Na	Zn	Sr
		Na <sub>2</sub> EDTA	EDTA									
mg/L												
SW-2-1-U	7.38	0.10	0.09	<0.02 <sup>1</sup>	117	<0.001 <sup>1</sup>	21	1.8	0.084	10.1	0.029	0.2
SW-2-1-U	NA <sup>2</sup>	0.11	0.10	<0.02	119	<0.001	21.2	1.8	0.066	10	0.031	0.2
SW-2-1-F	1.91	NA	NA	<0.02	118	<0.001	21.2	1.7	1.2	9.25	0.009	0.21
SW-2-2-U	7.66	0.20	0.17	<0.02	146	0.061	58.3	2.7	0.111	24.5	0.111	1.75
SW-2-2-U	NA	0.19	0.17	<0.02	146	0.06	58	2.7	0.103	23.8	0.124	1.7
SW-2-2-F	2	NA	NA	<0.02	152	0.191	56.1	2.4	0.541	22.4	0.208	1.68
SW-2-3-U	7.55	<0.03 <sup>1</sup>	<0.03 <sup>1</sup>	<0.02	88	<0.001	23.8	1.1	0.005	45	0.021	0.21
SW-2-3-U	NA	<0.03	<0.03	<0.02	88	<0.001	23.5	1	0.005	43	0.024	0.21
SW-2-3-F	1.35	NA	NA	<0.02	82	0.068	21.7	0.9	0.111	40	<0.004 <sup>1</sup>	0.2
SW-2-4-U	7.33	1.21	1.05	<0.02	121	0.162	28.9	2.3	0.348	69.2	0.04	0.41
SW-2-4-U	NA	1.21	1.05	<0.02	120	0.162	28.5	2.33	0.342	66.4	0.044	0.39
SW-2-4-F	1.35	NA	NA	<0.02	111	1.16	25.9	2.2	0.351	61.1	0.02	0.38
SW-2-4-U-D	7.32	1.20	1.04	<0.02	121	0.162	28.7	2.4	0.351	68.7	0.038	0.41
SW-2-4-U-D	NA	1.20	1.04	<0.02	119	0.166	28.3	2.4	0.344	66.2	0.043	0.41
SW-2-4-F-D	1.33	--	--	<0.02	112	1.21	26.1	2.2	0.356	61.6	0.015	0.38

Note: A fractions were filtered at TVA through 0.45 μ syringe filters and acidified.  
 B fractions were filtered at TVA through 0.2 μ syringe filters and acidified.  
 F fractions were filtered and acidified in the field.

- (1) Method Detection Limit (MDL).  
 (2) NA - Not Applicable.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-45 (Continued)**  
**Analysis for Potential Competing Cations in Surface Water Samples**  
**Taken at Site C on May 4, 2000 (Second Phase Sampling)**

Site	pH	EDTA as Na <sub>2</sub> EDTA	EDTA as EDTA	Pb	Ca	Fe	Mg	K	Mn	Na	Zn	Sr
		mmoles/L <sup>3</sup>										
SW-2-1-U	--	0.30	0.26	<0.0965 <sup>1</sup>	2920	<0.018 <sup>1</sup>	864	46.0	1.53	439	0.44	2.28
SW-2-1-U	--	0.33	0.28	<0.0965	2970	<0.018	872	46.0	1.20	435	0.47	2.28
SW-2-1-F	--	NA <sup>2</sup>	NA <sup>2</sup>	<0.0965	2940	<0.018	872	43.5	21.84	402	0.14	2.40
SW-2-2-U	--	0.60	0.52	<0.0965	3640	1.09	2400	69.1	2.02	1070	1.70	20.0
SW-2-2-U	--	0.57	0.49	<0.0965	3640	1.07	2390	69.1	1.87	1030	1.90	19.4
SW-2-2-F	--	NA	NA	<0.0965	3790	3.42	2310	61.4	9.85	974	3.18	19.2
SW-2-3-U	--	<0.09 <sup>1</sup>	<0.09 <sup>1</sup>	<0.0965	2200	<0.018	979	28.1	0.09	1960	0.32	2.40
SW-2-3-U	--	<0.09	<0.09	<0.0965	2190	<0.018	967	25.6	0.09	1870	0.37	2.40
SW-2-3-F	--	NA	NA	<0.0965	2030	1.22	893	23.0	2.02	1740	<0.06 <sup>1</sup>	2.28
SW-2-4-U	--	3.6	3.1	<0.0965	3020	2.90	1190	58.8	6.33	3010	0.61	4.68
SW-2-4-U	--	3.6	3.1	<0.0965	2990	2.90	1170	59.6	6.22	2890	0.67	4.45
SW-2-4-F	--	NA	NA	<0.0965	2770	20.8	1070	56.3	6.39	2660	0.31	4.34
SW-2-4-U-D	--	3.6	3.1	<0.0965	3020	2.90	1180	61.4	6.39	2990	0.58	4.68
SW-2-4-U-D	--	3.6	3.1	<0.0965	2970	2.97	1160	61.4	6.26	2880	0.66	4.68
SW-2-4-F-D	--	NA	NA	<0.0965	2790	21.7	1070	56.3	6.48	2680	0.23	4.34

Note: A fractions were filtered at TVA through 0.45 μ syringe filters and acidified.

B fractions were filtered at TVA through 0.2 μ syringe filters and acidified.

F fractions were filtered and acidified in the field.

(1) Method Detection Limit (MDL).

(2) NA - Not Applicable.

(3) Obtained μmoles/L by dividing mg/L by the respective molecular weight (g/mol) of each compound or element and multiplying by 1,000.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-45 (Continued)**  
**Analysis for Potential Competing Cations in Surface Water Samples**  
**Taken at Site C on May 4, 2000 (Second Phase Sampling)**

Site	Al	Ba	Be	Co	Cu	Ni	Sb	Ti	Tl	V
	mg/L									
SW-2-1-U	0.05	0.054	<0.001 <sup>1</sup>	<0.005 <sup>1</sup>	<0.002 <sup>1</sup>	<0.006 <sup>1</sup>	<0.03 <sup>1</sup>	<0.002 <sup>1</sup>	<0.05 <sup>1</sup>	0.009
SW-2-1-U	0.06	0.057	<0.001	<0.005	0.003	<0.006	<0.03	0.006	<0.05	0.009
SW-2-1-F	<0.02 <sup>1</sup>	0.04	<0.001	<0.005	<0.002	<0.006	<0.03	0.005	<0.05	0.008
SW-2-2-U	0.03	0.195	<0.001	<0.005	0.016	0.006	<0.03	<0.002	<0.05	0.009
SW-2-2-U	0.05	0.199	<0.001	<0.005	0.018	0.007	<0.03	<0.002	<0.05	0.014
SW-2-2-F	0.02	0.202	<0.001	0.007	0.016	0.013	<0.03	0.013	<0.05	0.016
SW-2-3-U	0.05	0.088	<0.001	<0.005	<0.002	<0.006	<0.03	<0.002	<0.05	0.005
SW-2-3-U	0.05	0.106	<0.001	<0.005	0.003	<0.006	<0.03	0.005	<0.05	0.008
SW-2-3-F	<0.02	0.054	<0.001	<0.005	<0.002	<0.006	<0.03	0.012	<0.05	0.01
SW-2-4-U	0.04	0.191	<0.001	<0.005	0.002	<0.006	<0.03	<0.002	<0.05	0.008
SW-2-4-U	0.06	0.212	<0.001	<0.005	0.003	<0.006	<0.03	0.003	<0.05	0.009
SW-2-4-F	<0.02	0.152	<0.001	<0.005	0.003	0.008	<0.03	0.012	<0.05	0.011
SW-2-4-U-D	0.04	0.193	<0.001	<0.005	<0.002	<0.006	<0.03	<0.002	<0.05	0.008
SW-2-4-U-D	0.06	0.203	<0.001	<0.005	<0.002	<0.006	<0.03	0.005	<0.05	0.008
SW-2-4-F-D	0.03	0.155	<0.001	<0.005	0.002	0.007	<0.03	<0.002	<0.05	0.012

Note: A fractions were filtered at TVA through 0.45 μ syringe filters and acidified.  
 B fractions were filtered at TVA through 0.2 μ syringe filters and acidified.  
 F fractions were filtered and acidified in the field.

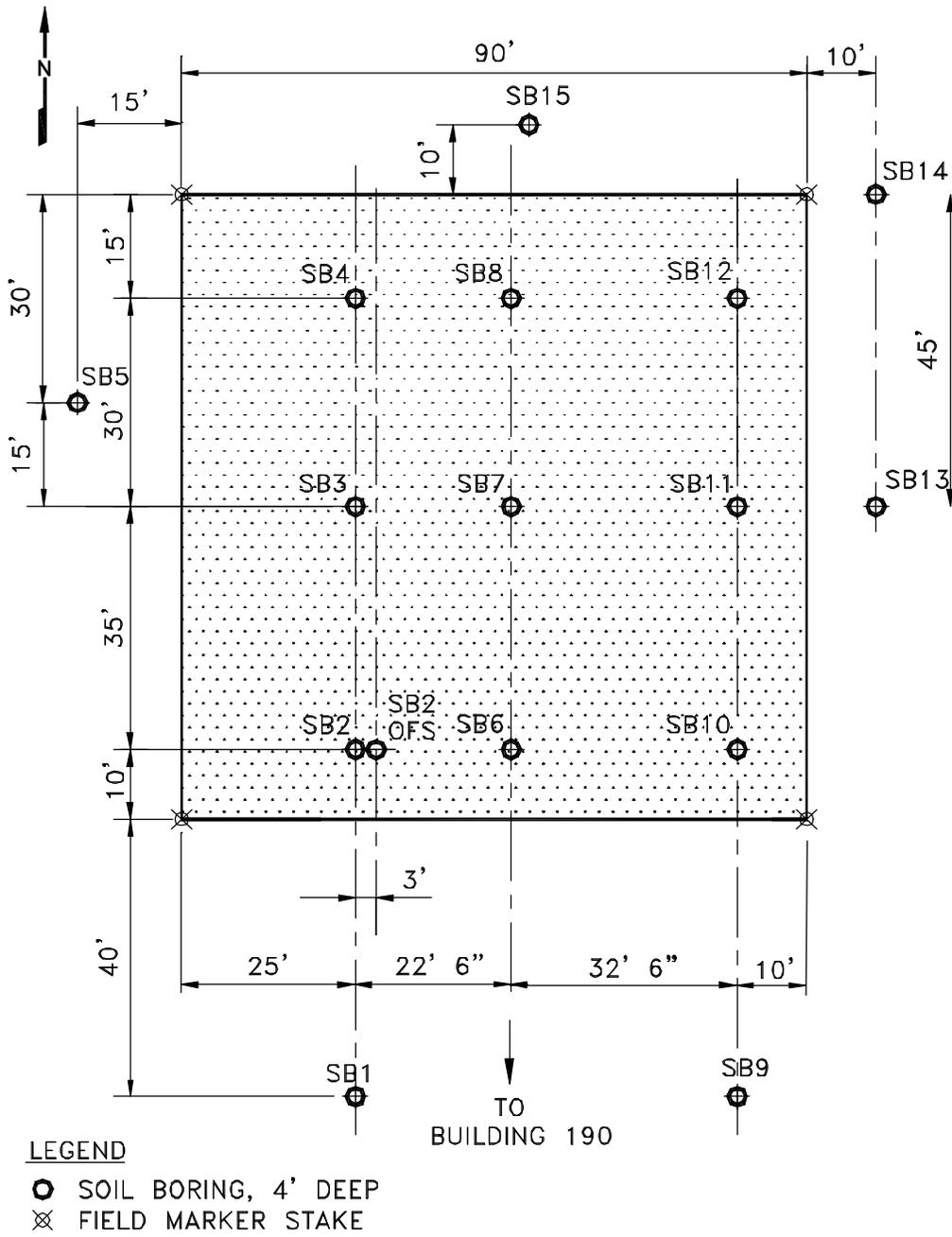
- (1) Method Detection Limit (MDL).
- (2) NA - Not Applicable.

**Table 5-45 (Continued)**  
**Analysis for Potential Competing Cations in Surface Water Samples**  
**Taken at Site C on May 4, 2000 (Second Phase Sampling)**

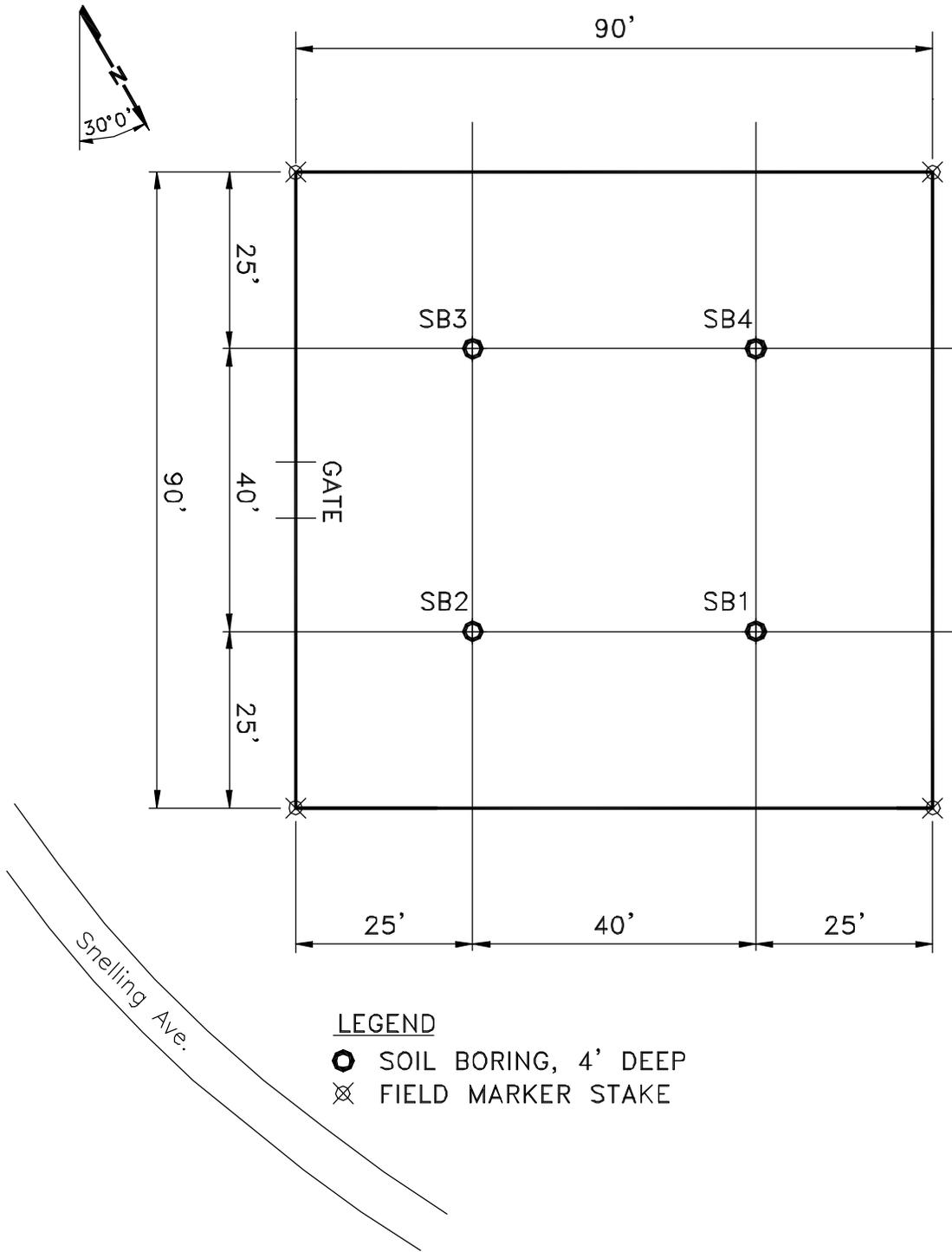
Site	Al	Ba	Be	Co	Cu	Ni	Sb	Ti	Tl	V
	mmoles/L <sup>3</sup>									
SW-2-1-U	1.85	0.393	<0.111 <sup>1</sup>	<0.119 <sup>1</sup>	<0.031 <sup>1</sup>	<0.102 <sup>1</sup>	<0.246 <sup>1</sup>	<0.042 <sup>1</sup>	<0.245 <sup>1</sup>	0.177
SW-2-1-U	2.22	0.415	<0.111	<0.119	0.0472	<0.102	<0.246	0.125	<0.245	0.177
SW-2-1-F	<0.741 <sup>1</sup>	0.291	<0.111	<0.119	<0.031	<0.102	<0.246	0.104	<0.245	0.157
SW-2-2-U	1.11	1.420	<0.111	<0.119	0.252	0.102	<0.246	<0.042	<0.245	0.177
SW-2-2-U	1.85	1.449	<0.111	<0.119	0.283	0.119	<0.246	<0.042	<0.245	0.275
SW-2-2-F	0.74	1.471	<0.111	0.119	0.252	0.221	<0.246	0.271	<0.245	0.314
SW-2-3-U	1.85	0.641	<0.111	<0.119	<0.031	<0.102	<0.246	<0.042	<0.245	0.098
SW-2-3-U	1.85	0.772	<0.111	<0.119	0.0472	<0.102	<0.246	0.104	<0.245	0.157
SW-2-3-F	<0.741	0.393	<0.111	<0.119	<0.031	<0.102	<0.246	0.251	<0.245	0.196
SW-2-4-U	1.48	1.391	<0.111	<0.119	0.03148	<0.102	<0.246	<0.042	<0.245	0.157
SW-2-4-U	2.22	1.544	<0.111	<0.119	0.04721	<0.102	<0.246	0.063	<0.245	0.177
SW-2-4-F	<0.741	1.107	<0.111	<0.119	0.04721	0.136	<0.246	0.251	<0.245	0.216
SW-2-4-U-D	1.48	1.405	<0.111	<0.119	<0.031	<0.102	<0.246	<0.042	<0.245	0.157
SW-2-4-U-D	2.22	1.478	<0.111	<0.119	<0.031	<0.102	<0.246	0.104	<0.245	0.157
SW-2-4-F-D	1.11	1.129	<0.111	<0.119	0.0315	0.119	<0.246	<0.042	<0.245	0.236

Note: A fractions were filtered at TVA through 0.45 μ syringe filters and acidified.  
 B fractions were filtered at TVA through 0.2 μ syringe filters and acidified.  
 F fractions were filtered and acidified in the field.

- (1) Method Detection Limit (MDL).
- (2) NA - Not Applicable.
- (3) Obtained μmoles/L by dividing mg/L by the respective molecular weight (g/mol) of each compound or element and multiplying by 1,000.



**Figure 5-9**  
**Location for Deep Core Soil Samples Taken at Site C**  
**April 11, 2000**



**Figure 5-10**  
**Locations for Deep Core Soil Samples Taken at Site 129-3**  
**April 11, 2000**

**Table 5-46  
Visual Characterization and Description of Soil Cores taken to Four Foot Depth at Site C and Site 129-3**

DESCRIPTION <sup>1</sup>				ANALYSIS				
Sample No.	Nominal Depth (ft)	Column Length <sup>2</sup> (in.)		Depth <sup>3</sup> (ft)	Total Pb, mg/kg	H <sub>2</sub> O-sol. Pb, mg/kg	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg
-----Site C-----								
SB-1	0-2	20.5	10'' - dark brown sandy clay, char material throughout, iron oxide accumulations; 5.5'' - a layer of consolidated, extremely dense, red pan material; 5'' - medium brown, fine sandy loam	1	32	<1	<0.3	<0.3
				2	<1	<1	<0.3	<0.3
SB-1	2-4	15.75	11'' - light brown fine loamy sand; 4'' - heavy, dark brown clay, albic mottling	3	<1	<1	<0.3	<0.3
				4	<1	<1	<0.3	<0.3
SB-2	0-2	14.0	13.5'' mixed, mottled, sandy clay throughout; pronounced char material mixed throughout; clay lenses present; Fe <sub>2</sub> O <sub>3</sub> inclusions and splotching throughout top 2.5'' darker layer	1	888	16	<0.3	<0.3
				2	7,440	116	5	4
SB-2	2-4	13.5	3'' dark brown sandy clay; 4'' char mixed with gray-brown clay; 5.5'' unburned wood	3	1,860	49	15	13
				4	325	49	340	296
SB-2 (offset) <sup>4</sup>	0-2	15.0	2'' dark brown organic layer; 2'' medium brown sand; 2.5'' clay with char; 3'' medium brown fine loamy sand; 3'' dark brown coarse sandy loam, char material	1	1,440	45	5	4
				2	3,100	66	4	3
SB-2 (offset)	2-4	12.75	1'' medium brown coarse sand 10'' char and unburned wood; a clay lens at 8''	3	1,610	31	82	71
				4	212	21	116	101

- (1) Soil is described incrementally from the top to the bottom of each column.
- (2) Length as taken from field which represents a two-foot depth increment in the soil. Compaction during sampling reduced the length of the sample to less than two feet.
- (3) Depth is in 1-foot increments. Compaction during sampling reduced the incremental length of the soil sample to less than one foot.
- (4) Sample location offset 3 feet to the east of the original designated location due to obstruction.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-46 (Continued)**  
**Visual Characterization and Description of Soil Cores taken to Four Foot Depth at Site C and Site 129-3**

DESCRIPTION <sup>1</sup>				ANALYSIS				
Sample No.	Nominal Depth (ft)	Column Length <sup>2</sup> (in.)		Depth <sup>3</sup> (ft)	Total Pb, mg/kg	H <sub>2</sub> O-sol. Pb, mg/kg	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg
-----Site C-----								
SB-3	0-2	14.0	3.5" dark brown fine loamy sand;	1	432	6	<0.3	<0.3
			3" medium brown fine loamy sand; 2" sandy clay 3" char 1" clay	2	23,200	245	7	6
SB-3	2-4	12.25	sample was very wet;	3	152	43	94	82
			2" mixture of dark brown coarse loamy sand mixed with dark clay; 9.5" coarse loamy sand mixed with medium brown smooth gravel	4	127	50	192	167
SB-4	0-2	19.0	6" dark brown sandy clay;	1	149	2	<0.3	<0.3
			12.5" light brown, fine loamy sand; numerous Fe <sub>2</sub> O <sub>3</sub> inclusions	2	44,100	12	25	22
SB-4	2-4	18.5	18" medium brown loamy sand;	3	33,700	36	80	70
			very wet in the last 6"; numerous Fe <sub>2</sub> O <sub>3</sub> inclusions and Mn concretions	4	15,200	16	220	191
SB-5	0-2	19.0	2" dark organic layer;	1	3,720	46	<0.3	<0.3
			3" medium brown sandy loam; 5.5" char/unburned wood layer; 8" medium brown fine loamy sand	2	30	8	52	45
SB-5	2-4	19.5	16" medium brown uniform coarse loamy sand;	3	<1	<1	<0.3	<0.3
			3" heavy yellow-orange clay; 1" gravel	4	<1	<1	<0.3	<0.3

- (1) Soil is described incrementally from the top to the bottom of each column.
- (2) Length as taken from field which represents a two-foot depth increment in the soil. Compaction during sampling reduced the length of the sample to less than two feet.
- (3) Depth is in 1-foot increments. Compaction during sampling reduced the incremental length of the soil sample to less than one foot.
- (4) Sample location offset 3 feet to the east of the original designated location due to obstruction.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-46 (Continued)**  
**Visual Characterization and Description of Soil Cores taken to Four Foot Depth at Site C and Site 129-3**

DESCRIPTION <sup>1</sup>				ANALYSIS				
Sample No.	Nominal Depth (ft)	Column Length <sup>2</sup> (in.)		Depth <sup>3</sup> (ft)	Total Pb, mg/kg	H <sub>2</sub> O-sol. Pb, mg/kg	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg
-----Site C-----								
SB-6	0-2	16.5	6.5" dark brown fine sandy clay;	1	13,500	42	7	6
			6" light brown fine sandy loam w/ Fe <sub>2</sub> O <sub>3</sub> inclusions; 3.5" dark brown sandy clay w/ Fe <sub>2</sub> O <sub>3</sub> inclusions and char material	2	3,440	56	66	57
SB-6	2-4	24.0	5" dark sandy clay w/ char material;	3	203	34	52	45
			19" medium brown loamy sand w/ Fe <sub>2</sub> O <sub>3</sub> inclusions and Mn concretions	4	68	27	79	69
SB-7	0-2	18.5	6" dark brown fine loamy sand;	1	4,820	53	7	6
			9.5" medium brown fine loamy sand, Mn concretions; 3" medium yellow-brown clay	2	270	13	4	3
SB-7	2-4	11.5	11.5" medium brown coarse loamy sand, Mn concretions, very wet	3	1,090	32	15	13
				4	5,850	7	7	6
SB-8	0-2	19.0	6" dark brown sandy loam, with clay lens at 5";	1	100	92	1,800	1,570
			13" light brown fine loamy sand with clay lens at 12"; Several Fe <sub>2</sub> O <sub>3</sub> inclusions and Mn concretions throughout	2	13,600	117	363	316
SB-8	2-4	15.5	15.5" medium brownish-gray coarse loamy sand w/ Fe <sub>2</sub> O <sub>3</sub> inclusions and Mn concretions throughout, numerous pebbles	3	24,200	84	377	328
				4	830	48	815	708

- (1) Soil is described incrementally from the top to the bottom of each column.
- (2) Length as taken from field which represents a two-foot depth increment in the soil. Compaction during sampling reduced the length of the sample to less than two feet.
- (3) Depth is in 1-foot increments. Compaction during sampling reduced the incremental length of the soil sample to less than one foot.
- (4) Sample location offset 3 feet to the east of the original designated location due to obstruction.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-46 (Continued)**  
**Visual Characterization and Description of Soil Cores taken to Four Foot Depth at Site C and Site 129-3**

DESCRIPTION <sup>1</sup>				ANALYSIS				
Sample No.	Nominal Depth (ft)	Column Length <sup>2</sup> (in.)		Depth <sup>3</sup> (ft)	Total Pb, mg/kg	H <sub>2</sub> O-sol. Pb, mg/kg	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg
-----Site C-----								
SB-9	0-2	19.5	19.5" full depth medium brown loamy sand, Mn concretions	1	7,000	81	<0.3	<0.3
				2	126	2	<0.3	<0.3
SB-9	2-4	20.0	4" medium brown sandy clay; 16" medium brown fine loamy sand	3	<1	<1	<0.3	<0.3
				4	<1	<1	<0.3	<0.3
SB-10	0-2	19.0	7.5" dark brown loamy sand w/ char material; 2" light brown sand; 2" char material; 8" medium brown loamy sand, Fe <sub>2</sub> O <sub>3</sub> inclusions	1	427	42	81	70
				2	10,400	73	37	32
SB-10	2-4	19.5	2" char, sandy clay; 10" light brown fine sand, Fe <sub>2</sub> O <sub>3</sub> inclusions; 6.5" mottled brown sandy loam mixed with char, several Mn concretions	3	161	56	180	156
				4	171	70	205	178
SB-11	0-2	22.0	8.5" dark brown loamy sand mixed with char, w/ Fe <sub>2</sub> O <sub>3</sub> inclusions; 7" medium brown fine loamy sand w/ Fe <sub>2</sub> O <sub>3</sub> inclusions; 7" medium brown sandy clay	1	1,980	253	500	435
				2	313	136	736	640
SB-11	2-4	14.0	2" dark brown fine loamy sand; 4" mottled clay w/ Mn concretions; 8" dark brown coarse loamy sand and gravel	3	355	178	570	495
				4	87	14	65	56
SB-12	0-2	13.5	5.5" medium brown loamy sand w/ Fe <sub>2</sub> O <sub>3</sub> inclusions; 3" brown clay mixed with char material; 6" medium brown loamy sand Fe <sub>2</sub> O <sub>3</sub> inclusions	1	525	96	293	255
				2	17,800	549	350	304

- (1) Soil is described incrementally from the top to the bottom of each column.
- (2) Length as taken from field which represents a two-foot depth increment in the soil. Compaction during sampling reduced the length of the sample to less than two feet.
- (3) Depth is in 1-foot increments. Compaction during sampling reduced the incremental length of the soil sample to less than one foot.
- (4) Sample location offset 3 feet to the east of the original designated location due to obstruction.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-46 (Continued)**  
**Visual Characterization and Description of Soil Cores taken to Four Foot Depth at Site C and Site 129-3**

Sample No.	Nominal Depth (ft)	Column Length <sup>2</sup> (in.)	DESCRIPTION <sup>1</sup>	ANALYSIS				
				Depth <sup>3</sup> (ft)	Total Pb, mg/kg	H <sub>2</sub> O-sol. Pb, mg/kg	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg
-----Site C-----								
SB-12	2-4	13.5	5" medium brown fine loamy sand;	3	729	281	1,370	1,191
			2" medium brown clay; 4" medium brown fine loamy sand; 1" dark black clay; 1" fine sand, cobbles	4	890	296	1,390	1,208
SB-13	0-2	15.5	8" dark brown loamy sand, high O.M. content;	1	2,100	25	<0.3	<0.3
			1" limestone gravel; 2" dark brown loamy sand, high O.M. content; 4.5" light brown fine sand	2	6	<1	<0.3	<0.3
SB-13	2-4	17.0	1.5" light brown fine sand;	3	<1	<1	<0.3	<0.3
			1" dark organic fine sand; 6" light brown fine sand; 9" medium brown fine sand w/ numerous cobbles	4	<1	<1	<0.3	<0.3
SB-14	0-2	11.0	4" dark brown organic loamy sand;	1	4,820	156	199	173
			8" light brown fine sand mixed with char material	2	<1	<1	<0.3	<0.3
SB-14	2-4	17.5	2" light brown fine sand;	3	<1	<1	<0.3	<0.3
			2" char material; 13" light brown fine sand	4	<1	<1	10	9
SB-15	0-2	15.0	4" dark organic loamy sand and char;	1	3,870	42	<0.3	<0.3
			11" medium brown sandy loam, clay slicks and char material throughout	2	1,160	13	5	4
SB-15	2-4	17.75	2" dark woody fragments;	3	969	3	16	14
			16" medium brown sandy clay Fe <sub>2</sub> O <sub>3</sub> inclusions, Mn concretions	4	8,880	19	73	63

- (1) Soil is described incrementally from the top to the bottom of each column.
- (2) Length as taken from field which represents a two-foot depth increment in the soil. Compaction during sampling reduced the length of the sample to less than two feet.
- (3) Depth is in 1-foot increments. Compaction during sampling reduced the incremental length of the soil sample to less than one foot.
- (4) Sample location offset 3 feet to the east of the original designated location due to obstruction.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-46 (Continued)**  
**Visual Characterization and Description of Soil Cores taken to Four Foot Depth at Site C and Site 129-3**

DESCRIPTION <sup>1</sup>				ANALYSIS				
Sample No.	Depth (ft)	Column length <sup>2</sup> (in.)		Depth <sup>3</sup> (ft)	Total Pb, mg/kg	H <sub>2</sub> O-sol. Pb, mg/kg	EDTA as Na <sub>2</sub> EDTA, mg/kg	EDTA as EDTA, mg/kg
-----Site 129-3-----								
129-3/SB-1	0-2	21.0	21" light brown fine sand	1	<1	<1	4	3
				2	<1	<1	<0.3	<0.3
129-3/SB-1	2-4	20.5	16" medium brown fine sandy loam with sandy clay lenses; 4" medium brown fine sandy loam	3	<1	<1	<0.3	<0.3
				4	<1	<1	2	2
129-3/SB-2	0-2	16.25	16.5" medium brown fine sandy loam	1	30	<1	7	6
				2	18	<1	<0.3	<0.3
129-3/SB-2	2-4	18.0	14" medium brown fine sandy loam; 4" medium brown fine sandy clay	3	14	<1	1	1
				4	6	<1	<0.3	<0.3
129-3/SB-3	0-2	19.0	7" light brown fine sand, organic material; 5" dark brown clay lense w/ woody particles; 2" light brown fine sand; 5" medium brown sandy clay	1	49	2	3	3
				2	16	<1	<0.3	<0.3
129-3/SB-3	2-4	19.0	13" medium brown fine sandy loam; 5.5" medium brown fine sandy clay	3	162	17	44	38
				4	33	2	11	10
129-3/SB-4	0-2	16.25	2" organic fine sand; 12.5" medium brown fine sand; 3" dark brown sandy clay	1	<1	<1	8	7
				2	5	<1	1	1
129-3/SB-4	2-4	21.0	10" medium brown fine loamy sand; 6" albic clay layer; 4" medium brown loam	3	<1	1	10	9
				4	<1	1	<0.3	<0.3

- (1) Soil is described incrementally from the top to the bottom of each column.
- (2) Length as taken from field which represents a two-foot depth increment in the soil. Compaction during sampling reduced the length of the sample to less than two feet.
- (3) Depth is in 1-foot increments. Compaction during sampling reduced the incremental length of the soil sample to less than one foot.
- (4) Sample location offset 3 feet to the east of the original designated location due to obstruction.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

Also, EDTA is not amenable to degradation by all microorganisms, and the particular population required for maximum removal may be lacking or low in this soil. The top two feet of this soil generally appeared to be in an aerobic state. The carbonate content in the top two feet and the higher pH was an indication that degradation had occurred in this zone. The greater than 1:1 molar ratio of EDTA to lead in all groundwater samples indicates that dissolution of the EDTA complex did likely occur, with subsequent release and re-precipitation of lead in the soil. However, the lower soil layers showed signs of waterlogging which most likely resulted in a reduced population of the appropriate aerobic microorganisms. Movement to groundwater depths obviously precluded photodegradation.

A full appreciation for the generally coarse-textured nature of the soil at Site C and the amount and variety of debris present was not gained until the deep core soil samples were taken and dissected at the end of the demonstration. At that time the true diversity of the soils, and of the waste materials and the potential effect on the outcome of the demonstration became apparent. It is likely that some leaching of EDTA (and lead) occurred from the upper layers due to these factors. Periodic water saturation of the upper soil layers due to a fluctuating water table of unknown height may have resulted in “washing” of the soil, and EDTA that was bound in the soil may have been re-solubilized and carried into the lower depths. Preferential flow and channeling caused by debris may have promoted movement in to the groundwater stream.

The data in Table 5-47 for the analysis of other cations in the soil at Site C clearly shows the potential for other cations to compete with lead for complexation by EDTA. The predominance of the basic cations Ca and Mg, as well as high concentrations of Fe, radically change the molar balance between EDTA and lead. There was an average of about 20 moles of lead in the soil over the 4-ft depth range; for Ca, Fe, and Mg, the averages were 276, 222, and 202. From these results, it is not surprising to see the increased EDTA:lead ratio in water samples due to displacement of lead in the EDTA complex by these cations.

#### **5.2.10.5 Overview of 2000 Groundwater, Surface Water, and Deep Core Soil Sampling Activities and Results at Site C**

##### **5.2.10.5.1 Sample Collection**

On April 11, 2000, the Army (AEC, TCAAP) and the MPCA collected splits of six groundwater hydro-punch samples and one drainage ditch surface water sample. On May 4, 2000, four surface water samples were collected at Site C:

- Upgradient to the previous sampled location.
- At the previous location.
- Down-gradient to the previous location.
- Exiting Site C further down-gradient to the previous location.

Additional groundwater samples were taken on May 17 and May 30, 2000, to identify the extent of the impacted area. A total of 12 groundwater samples and a combined total of 5 field and rinse blanks were collected using the hydro-punch technique.

Soil borings, to a depth of four feet, were collected on April 11, 2000 (Figures 5-9, 5-10), by TCAAP and sent to TVA for EDTA and lead analyses. Sampling locations were internal to the plot with several taken outside the plot perimeter.

#### **5.2.10.5.2 Analysis and Results**

Based on the analytical results from the four surface water samples in the drainage ditch (SW2-1, SW2-2, SW2-3, and SW2-4), and the discontinuous surface water in the drainage ditch, lead does not appear to be migrating from the phytoremediation plot due to solubilization by EDTA. Site C-1 is located just north of the drainage ditch flowing east to west. The proximity of this site to the drainage ditch, the slope toward the ditch, combined with the past burning and disposal operations at this site are strong indicators that Site C-1 is the probable cause of the lead detection at the last sampling point. It should be cautioned, however, that the detection of lead for a single sampling event is not indicative of contamination. Historical soil borings from Site C-1 do indicate the presence of lead in quantities sufficient enough to produce the levels of lead in the drainage ditch running east to west. The data also proves out that surface water contamination has not occurred and there is no immediate risk to the environment.

The analytical results indicated that the lead concentration in the groundwater was dropping rapidly moving away from the plot, basically dropping from 1100 ppm to 1 ppm in approximately 100 feet. Most likely lead levels would continue to decrease rapidly. Considering that the impacted groundwater is in Unit 1, an alluvium, extreme variations are probable within short distances in the aquifer. Based on the two periods of sampling, depths to groundwater are highly variable. During the April sampling event, groundwater was found at approximately 5 feet below the surface; during the May sampling at approximately 10 feet below the surface. The higher the groundwater the more likely the transport of EDTA due to “washing” of the soil by the fluctuating water table. This question could be answered by the placement of monitoring wells and monitoring over several seasons to understand water level changes as well as contaminant flow rates. Also, the ratios of EDTA:lead rise as distance away from the plot increases. This supports a basic conceptual model that the longer the EDTA exists in the groundwater the more likely it is for other cations to outcompete the lead in solution, leading to a general reduction of lead in solution over time and as distance from the plot increases.

EDTA and lead were found throughout the plot, with the concentration of total lead being greater than the concentration of lead which had complexed with EDTA. EDTA values were less than those of total lead within the plot and tended to be below the detection limit outside of the plot. The soil analytical results indicated that while EDTA and lead were found in the shallow soils (less than 4 feet), these levels were lower than were observed in the April round of groundwater sampling. Soil concentrations for EDTA ranged from less than 0.3 ppm to 1,570 ppm. Concentrations of EDTA in the April groundwater samples were from less than 0.03 ppm up to 4,910 ppm. Only three of the soil samples were higher than the highest values seen in the May groundwater sampling of 739 ppm. Water soluble lead concentrations in the soil ranged from less than 1 ppm to 549 ppm; lead concentrations in the April groundwater samples ranged from less than 0.02 ppm to 988 ppm. It would appear from this data that the overall concentrations of EDTA are decreasing in the soil column and that the EDTA is degrading at the site as was originally expected.

**Table 5-47  
Analysis of Other Cations in Deep Soil Cores Taken from Site C**

Soil Boring Location	Depth (ft)	pH	Pb (Total)	Pb (Water Soluble)	EDTA as Na <sub>2</sub> EDTA	EDTA as EDTA	Al	Sb	As	Ba	Be	Ca	Co	Cu	Fe
1	1	8.68	32	<1.04 <sup>1</sup>	<0.3 <sup>1</sup>	<0.3 <sup>1</sup>	7,400	<2 <sup>1</sup>	<1 <sup>1</sup>	85	0.58	14,000	6.0	19	11,300
1	2	8.68	<1 <sup>1</sup>	<1.04	<0.3	<0.3	6,350	<2	<1	71	0.54	6,260	6.6	16	12,300
1	3	8.61	<1	<1.07	<0.3	<0.3	5,140	<2	<1	38	0.50	5,590	4.4	11	9,700
1	4	8.65	<1	<1.11	<0.3	<0.3	7,170	<2	<1	47	0.54	9,390	4.5	14	9,660
2	1	8.17	888	16	<0.3	<0.3	5,310	<2	<1	183	0.51	14,800	4.9	192	11,000
2	2	9.55	7,440	116	5	4	5,780	<2	<1	2,470	0.48	11,500	5.9	665	20,200
2	3	9.04	1,860	49	15	13	6,500	<2	<1	334	0.52	16,300	4.6	238	10,900
2	4	8.03	325	49	340	296	2,940	<3	<2	77	0.63	20,400	3.2	109	12,600
2 Dup. <sup>2</sup>	1	9.33	1,440	45	5	4	4,960	<1 <sup>1</sup>	<1	131	0.25	21,700	5.4	348	13,700
2 Dup. <sup>2</sup>	2	9.46	3,100	66	4	3	5,520	<1	<0.9 <sup>1</sup>	747	0.26	12,000	5.5	289	10,100
2 Dup. <sup>2</sup>	3	8.48	1,610	31	82	71	4,800	<2	<1	471	0.24	13,500	3.7	608	8,630
2 Dup. <sup>2</sup>	4	7.97	212	21	116	101	1,760	<1	<1	31	0.11	9,770	2.5	44	5,680
3	1	9.14	432	6	<0.3	<0.3	4,700	<2	<1	134	0.19	10,000	4.4	209	14,500
3	2	9.61	23,200	245	7	6	5,390	206	<1	843	0.18	16,500	4.6	1,500	10,600
3	3	9.51	152	43	94	82	5,650	<2	<1	42	0.25	13,100	4.3	56	11,700
3	4	9.42	127	50	192	167	5,030	<2	<1	44	0.24	6,570	4.8	84	8,850
4	1	7.76	149	2	<0.3	<0.3	8,960	<1	<1	37	0.24	6,230	11.6	72	17,400
4	2	9.74	44,100	12	25	22	3,980	232	<1	386	0.13	18,000	4.2	6,750	11,400
4	3	9.75	33,700	36	80	70	4,900	349	<1	209	0.23	12,600	5.2	3,920	12,800
4	4	9.09	15,200	16	220	191	5,010	2	<1	411	0.22	18,100	5.0	1,530	12,000
5	1	8.58	3,720	46	<0.3	<0.3	5,680	<2	<1	190	0.25	15,000	4.8	460	10,600
5	2	8.49	30	8	52	45	4,220	<1	<1	38	0.22	3,370	4.5	17	9,070
5	3	8.91	<1	<1.10 <sup>1</sup>	<0.3	<0.3	3,950	<2	<1	24	0.19	4,190	4.3	14	8,670
5	4	8.94	<1	<1.07 <sup>1</sup>	<0.3	<0.3	6,110	<2	<1	33	0.32	6,230	5.7	12	12,400
6	1	9.27	13,500	42	7	6	5,300	<2	<1	172	0.47	21,400	5.2	9,080	19,300
6	2	8.92	3,440	56	66	57	7,020	<2	<1	669	0.55	9,260	6.0	745	10,300

(1) MDL - Method Detection Limit.

(2) Dup. - Duplicate Sample.

(3) Moisture (%) refers to the moisture content of the soil as received from the field. All analyses are reported on an oven dry weight basis.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-47 (Continued)  
Analysis of Other Cations in Deep Soil Cores Taken from Site C**

Soil Boring Location	Depth (ft)	pH	Pb (Total)	Pb (Water Soluble)	EDTA as Na <sub>2</sub> EDTA	EDTA as EDTA	mg/kg								
							Al	Sb	As	Ba	Be	Ca	Co	Cu	Fe
6	3	8.86	203	34	52	45	5,370	<1	<1 <sup>1</sup>	39	0.25	15,500	4.3	9	11,300
6	4	8.74	68	27	79	69	7,450	<2	<1	47	0.29	7,340	5.6	11	12,900
7	1	9.24	4,820	53	7	6	5,910	<1	<0.9	302	0.22	20,300	4.7	672	11,100
7	2	8.60	270	13	4	3	18,600	<2	<1	83	0.71	3,570	6.7	46	30,200
7	3	9.02	1,090	32	15	13	6,550	<2	<1	127	0.27	7,060	5.6	164	15,300
7	4	8.99	5,850	7	7	6	4,500	<1	<1	296	0.19	12,200	4.4	426	16,500
8	1	9.68	100	92	1,800	1,565	6,080	<2	<1	65	0.27	8,680	3.6	62	9,650
8	2	9.04	13,600	117	363	316	6,000	<1	<0.9	337	0.21	19,400	5.6	1,470	12,300
8	3	9.06	24,200	84	377	328	6,000	92	<1	229	0.20	34,800	5.3	1,100	12,800
8	4	8.95	830	48	815	708	4,190	<2	<1	66	0.20	4,920	4.0	545	8,200
9	1	8.76	7,000	81	<0.3 <sup>1</sup>	<0.3 <sup>1</sup>	8,250	<1	<0.9	316	0.20	21,200	5.6	1,070	11,000
9	2	8.78	126	2	<0.3	<0.3	6,210	<1	<1	127	0.33	6,220	7.5	22	13,300
9	3	8.25	<1 <sup>1</sup>	<1.00 <sup>1</sup>	<0.3	<0.3	3,980	<1	<1	24	0.18	2,140	4.0	9	8,620
9	4	8.35	<1	<1.02	<0.3	<0.3	5,070	<2	<1	27	0.23	2,530	4.7	11	10,100
10	1	9.53	427	42	81	70	4,820	<1	<0.9	84	0.49	4,000	5.0	117	10,300
10	2	9.71	10,400	73	37	32	5,650	<1	<1	562	0.43	15,200	5.2	742	12,000
10	3	9.55	161	56	180	156	3,960	<2	<1	57	0.43	1,580	3.5	52	9,050
10	4	9.43	171	70	205	178	4,880	<1	<1	43	0.52	5,020	3.5	46	9,230
11	1	9.69	1,980	253	500	435	7,660	<2	<1	264	0.37	25,200	4.4	268	15,700
11	2	9.10	313	136	736	640	7,180	<2	<1	76	0.31	7,290	5.6	77	12,200
11	3	8.45	355	178	570	495	6,580	<2	<1	54	0.30	8,700	7.5	115	13,300
11	4	8.51	87	14	65	56	5,040	<2	<1	37	0.22	6,430	4.9	32	11,000
12	1	7.93	525	96	293	255	8,030	<2	<1	108	0.28	7,240	6.3	4,880	15,200
12	2	9.27	17,800	549	350	304	4,970	<1	<1	426	0.15	15,700	5.1	8,860	27,300

(1) MDL - Method Detection Limit.

(2) Dup. - Duplicate Sample.

(3) Moisture (%) refers to the moisture content of the soil as received from the field. All analyses are reported on an oven dry weight basis.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-47 (Continued)  
Analysis of Other Cations in Deep Soil Cores Taken from Site C**

Soil Boring Location	Depth (ft)	pH	Pb (Total)	Pb (Water Soluble)	EDTA as Na <sub>2</sub> EDTA	EDTA as EDTA	mg/kg								
							Al	Sb	As	Ba	Be	Ca	Co	Cu	Fe
12	3	9.21	729	281	1,370	1,191	6,000	<1	<0.9	56	0.29	9,620	4.0	191	11,200
12	4	8.80	890	296	1,390	1,208	7,630	<2	<1	75	0.33	12,700	7.7	274	15,300
13	1	8.44	2,100	25	<0.3	<0.3	7,000	<2	<1	149	0.59	9,640	6.8	517	15,900
13	2	8.38	6	<1.00	<0.3	<0.3	3,170	<1	<1	19	0.15	2,100	3.6	10	7,160
13	3	8.20	<1	<0.99	<0.3	<0.3	2,780	<1	<1	13	0.13	1,620	3.1	7	6,480
13	4	8.39	<1	<1.01	<0.3	<0.3	5,780	<1	<1	37	0.28	3,980	7.5	11	12,500
14	1	9.77	4,820	156	199	173	5,370	<1	<1	319	0.22	20,400	4.5	460	10,000
14	2	8.63	<1 <sup>1</sup>	<1.01 <sup>1</sup>	<0.3 <sup>1</sup>	<0.3 <sup>1</sup>	4,270	<1 <sup>1</sup>	<1 <sup>1</sup>	21	0.18	4,150	4.1	10	8,610
14	3	8.36	<1	<1.01	<0.3	<0.3	4,530	<2	<1	26	0.21	2,020	4.5	9	9,210
14	4	8.55	<1	<1.01	10	9	4,990	<1	<1	29	0.29	4,710	5.0	11	12,400
15	1	8.52	3,870	42	<0.3	<0.3	6,250	<2	<1	227	0.25	12,100	5.6	539	11,800
15	2	8.65	1,160	13	5	4	5,600	<1	<1	184	0.23	13,800	5.3	918	14,900
15	3	8.86	969	3	16	14	6,000	<2	<1	201	0.27	21,200	6.0	1,020	14,700
15	4	8.73	8,880	19	73	63	4,050	<2	<1	506	0.09	11,300	47.1	2,010	19,300

(1) MDL - Method Detection Limit.

(2) Dup. - Duplicate Sample.

(3) Moisture (%) refers to the moisture content of the soil as received from the field. All analyses are reported on an oven dry weight basis.

**NOTE:** Analytical results are based on comparison with Na<sub>2</sub>EDTA standards and are calculated as mg/kg or mg/L Na<sub>2</sub>EDTA. Earlier reports on this project reported EDTA results calculated as Na<sub>2</sub>EDTA without note. This Results Report shows the data calculated as Na<sub>2</sub>EDTA and as EDTA. The conversion factor is (292.24g/mol EDTA)/(336.21g/mol Na<sub>2</sub>EDTA) = 0.8692.

**Table 5-47 (Continued)**  
**Analysis of Other Cations in Deep Soil Cores Taken from Site C**

Soil Boring Location	Depth (ft)	Mg	Mn	Ni	K	Na	Sr	Tl	Ti	V	Zn	Moisture (%) <sup>3</sup>
		mg/kg										
1	1	7,200	342	14.9	1,260	145	37	<3 <sup>3</sup>	463	33	32	6.34
1	2	3,980	482	16.3	771	215	31	<3	490	31	26	6.10
1	3	3,500	193	11.7	758	146	25	<3	426	22	23	8.79
1	4	5,180	200	12.3	840	156	34	<3	374	27	26	11.69
2	1	5,110	179	12.7	1,940	159	89	<3	378	26	75	12.96
2	2	5,800	241	14.1	1,240	288	1,180	<3	432	25	146	6.24
2	3	5,210	212	11.8	1,860	288	278	<3	449	24	65	16.70
2	4	3,280	620	20.1	1,790	207	65	<5	232	12	69	57.07
2 Dup. <sup>2</sup>	1	8,400	296	11.8	1,210	221	69	<2	435	26	71	4.56
2 Dup. <sup>2</sup>	2	6,530	216	12.2	981	256	461	<2	442	19	70	4.46
2 Dup. <sup>2</sup>	3	3,810	186	8.7	1,530	163	334	<3	264	18	59	26.52
2 Dup. <sup>2</sup>	4	1,810	267	8.1	395	117	31	<2	177	8	30	7.40
3	1	6,440	144	11.1	1,570	166	41	<3	358	18	88	10.55
3	2	6,900	509	11.4	1,120	293	554	<2	365	19	207	7.55
3	3	5,750	181	11.9	1,300	252	32	<3	439	26	35	10.42
3	4	3,740	209	9.3	1,340	184	23	<3	696	21	31	10.75
4	1	6,750	277	25.4	876	449	30	<2	718	33	66	3.95
4	2	6,920	251	10.3	974	225	485	<3	407	17	614	8.94
4	3	7,070	248	15.0	1,150	198	217	<3	489	24	385	13.09
4	4	7,530	263	11.1	723	296	421	<2	413	24	189	8.21
5	1	4,660	225	11.0	722	264	138	<3	366	25	90	13.05
5	2	2,300	204	9.4	502	167	28	<2	457	27	18	6.52
5	3	2,490	172	9.6	478	174	21	<3	403	24	17	11.86
5	4	3,440	156	12.7	925	291	43	<3	629	35	21	11.82
6	1	6,600	215	15.3	1,450	166	110	<3	391	25	809	8.28
6	2	5,130	217	14.6	1,350	197	397	<3	554	30	91	11.59
6	3	9,120	365	9.8	794	126	62	<2	404	24	28	6.90
6	4	4,370	164	11.8	1,150	201	102	<3	576	36	25	7.66
7	1	4,930	185	10.6	1,130	269	205	<2	549	25	116	4.65
7	2	3,530	102	15.1	2,860	71	112	10.10	442	72	45	16.94
7	3	4,400	206	12.2	1,290	170	84	<3	598	31	68	10.74
7	4	4,990	333	9.5	664	166	211	<2 <sup>1</sup>	410	21	100	7.87

(1) MDL - Method Detection Limit.

(2) Dup. - Duplicate Sample.

(3) Moisture (%) refers to the moisture content of the soil as received from the field. All analyses are reported on an oven dry weight basis.

**Table 5-47 (Continued)**  
**Analysis of Other Cations in Deep Soil Cores Taken from Site C**

Soil Boring Location	Depth (ft)	Mg	Mn	Ni	K	Na	Sr	Tl	Ti	V	Zn	Moisture (%) <sup>3</sup>
		mg/kg										
8	1	4,380	128	8.4	3,080	137	25	<3	371	27	31	6.77
8	2	8,570	313	13.4	1,210	323	304	<2	497	25	223	6.80
8	3	8,860	274	12.1	1,330	169	339	<3	448	22	171	12.24
8	4	2,590	182	8.4	1,090	102	52	<3	404	22	75	10.77
9	1	7,610	205	16.3	690	528	730	<2	401	24	170	4.66
9	2	4,410	268	11.6	699	109	54	<2	550	24	32	6.07
9	3	1,780	215	9.2	586	127	49	<2	372	19	13	3.53
9	4	2,040	158	9.9	695	132	45	<3	458	28	15	6.77
10	1	3,050	205	13.6	1,350	171	23	<2	385	23	94	4.08
10	2	6,580	197	12.6	1,420	313	391	<2	500	22	167	5.04
10	3	1,770	182	10.7	1,250	105	15	<3	353	21	29	5.42
10	4	3,140	178	8.7	1,990	97	45	<2	353	25	36	8.04
11	1	10,400	292	9.7	3,920	176	133	<3	336	38	112	8.76
11	2	4,150	404	11.8	2,490	242	22	<3	568	37	67	7.94
11	3	5,640	299	17.5	1,540	244	31	<3	693	32	79	10.16
11	4	4,100	355	11.4	732	206	29	<3	490	24	27	7.12
12	1	4,710	209	13.8	1,840	274	30	<3	675	34	666	8.21
12	2	5,050	251	28.0	1,300	340	257	12.60	366	19	908	4.28
12	3	4,340	292	9.6	2,040	128	25	<2	393	26	124	4.55
12	4	5,900	439	22.7	2,270	280	112	<3	576	33	123	24.98
13	1	5,340	447	17.2	887	161	61	<3	369	26	486	7.09
13	2	1,550	207	7.6	402	117	16	<2	303	16	13	2.87
13	3	1,300	197	7.3	356	94	13	<2	278	14	11	2.98
13	4	3,500	409	14.4	575	177	16	<2	687	31	23	3.81
14	1	6,090	178	10.7	1,580	240	192	<2	466	22	121	6.69
14	2	2,180	187	9.3	455	187	12	<2	342	19	16	2.83
14	3	1,590	267	8.6	559	122	11	<3	435	25	14	4.37
14	4	2,470	252	9.3	734	162	16	<2	513	25	19	5.17
15	1	5,230	262	12.2	786	154	179	<3	467	27	104	7.44
15	2	6,520	385	11.8	841	255	145	<2	451	27	129	6.05
15	3	9,070	363	13.8	683	304	73	<3	627	27	162	8.60
15	4	4,130	2,870	102.0	287	202	190	619	342	28	211	10.22

(1) MDL - Method Detection Limit.

(2) Dup. - Duplicate Sample.

(3) Moisture (%) refers to the moisture content of the soil as received from the field. All analyses are reported on an oven dry weight basis.

The soils at Site C were found to be much more heterogeneous than was originally anticipated. Seven soil types ranging from sand to clay were identified in the cores from the latest sampling events. This is contrary to the single soil type identified in the RI/FS. Clay and sand lenses were common throughout the soil, and a considerable amount of burned as well as unburned wood was found. Debris consisting of glass, metal, wire, concrete, bullets, and brass shell casings was found throughout the plot. Iron oxide deposition was common in the cores as were manganese sulfide concretions (usually a representation of alternating aerobic and anaerobic zones in the soil profile, likely caused by a fluctuating water table). In soils the major mechanisms determining the fate of EDTA and therefore its ability to continue to solubilize lead are:

- Adsorption to iron oxide and soil organic matter
- Binding to clay particles
- Reactions with soil cations
- Microbial degradation
- Rates of movement through soil

Most likely the extreme heterogeneous nature of these shallow soils accelerated movement of EDTA through the soil column and reduced the contact time of EDTA in the soils, which affected the rate at which the reductive fate processes were taking place. It is also possible that the microbial population in the shallow soils was (is) low, due to other toxic contaminants and debris in the soils and perhaps the slow draining of the soils, which would lead to waterlogging during significant periods of the year. In addition, of interest is the relatively high pH of the shallow soils, which averages from 8.5 to 9.5. This may be partly attributed to degradation of EDTA and release of ammonia from the amine groups and the formation of carbonate compounds from the CO<sub>2</sub> that is also released. As lead is more soluble at lower pH, the amount of soluble lead available for movement will continue to decline. A natural drop in soil pH to a level that would re-solubilize lead is highly unlikely.

In conclusion, results of the soil, groundwater, and surface water sampling suggested that, although the EDTA has lasted longer in the soil and in groundwater than originally expected, the concentrations of soluble lead within and outside the demonstration plot are falling through time and will continue to fall. These conclusions can be verified through monitoring over time of the soils, groundwaters, and surface waters.

#### **5.2.10.6 Summary and Conclusions**

This project was funded by ESTCP from January 1998 through May 2000 as reported here. A summary showing the lead concentrations in plants, crop yields, and the amount of lead removed in the plant biomass for the two year demonstration in 1998 and 1999 is shown in Table 5-48. A detailed discussion of these results is presented immediately following this table. Selection of the demonstration sites by TCAAP and ATK based on information in the RI/FS was done in October 1997. The sites chosen were a 0.2-acre area on Site C (total area - 16.4 acres) and a 0.2-acre area on Site 129-3 (total area - 1.5 acres) at TCAAP. Due to time constraints for beginning the project, soil samples for preliminary site characterization were collected under snow cover in November 1997, and a complete visual and physical assessment of the sites was not possible. For Site C, the preliminary assessment did not reveal how heterogeneous the soil

was and the nature and quantity of debris that had been dumped at the site. Site 129-3 was composed of a variety of glacial till debris which also was problematic to the demonstration.

The preliminary soil samples were analyzed to map lead concentrations within each area. Site C contained moderate to high levels of lead, whereas Site 129-3 had levels approaching or below the cleanup standard. The demonstration at Site 129-3 was intended to illustrate the effectiveness of phytoextraction methods near the conclusion of a remediation program, or for situations in which the level of contamination is low and the use of a "polishing treatment" is desirable. A high degree of spatial variability in lead concentrations, particularly at Site C, (standard deviations were equal to means) indicated the presence of particulate lead in addition to ionic lead forms.

Upon completion of preliminary analyses, the draft Technology Demonstration Plan was developed and submitted to ESTCP, AEC, TCAAP, USEPA, and MPCA. The draft Technology Demonstration Plan was thoroughly reviewed and comments were provided by each organization. The Technology Demonstration Plan was revised based on the comments, and written responses to comments were provided to the originating organization. The demonstration was conducted in accordance with the revised Technology Demonstration Plan.

The demonstration was initiated in 1998 with the planting of a grain corn crop. At Site C, large quantities of diverse scrap and debris (concrete, glass, wire, scrap metal, rail ties, burned and unburned wood, large cobbles, etc.) were unearthed during field preparation and had to be removed before the crop could be planted. In addition, an old hardpan and gravel road bed, from 6 to 12 inches beneath the soil surface, ran through the western half of the plot. Visually variously dark and light areas throughout the plot indicated burn areas and differing soil types. Apparently soil of different types was deposited at the site when scrap from other areas on the installation was brought in for disposal on the site. About one-third of the 1962 Pit (a burn and burial area for decontamination of large equipment that was backfilled with diverse soil) intruded on the southeastern quadrant of the plot. The topography of Site C was a depression consisting of a three-way concave slope east to west and south to north. Large boulders and cobbles deterred proper tillage at Site 129-3. The plot at Site 129-3 consisted of a three-way convex slope, with a north to south downhill slope.

Problems with growth and nutrition developed early on at Site C in the form of phosphorus and iron deficiencies in the plants. The deficiencies were treated by foliar applications of Fe and P which corrected visual symptoms, but the plants remained stunted and did not realize full yield potential, particularly in the western half of the plot underlain by the hardpan. The plants grew more normally in the eastern half of Site C, but the considerable debris and likely presence of other toxic soil contaminants limited full growth potential of the crop. Plant growth was much better at the more agronomically-suitable Site 129-3.



Soil amendments (acetic acid to reduce soil pH to 5.5 and EDTA equimolar to the average total soil lead content) were applied in July 1998 to solubilize soil lead in order to facilitate uptake of lead into the plants. The amendments were applied based on results obtained in previous greenhouse studies and the average total lead content of the soil. However, the amount of EDTA was reduced by one-third from the maximum effective rate demonstrated in the greenhouse studies to partially offset any environmental effects of large chelate additions. The amendments were added in an amount of solution intended to saturate only the top two feet of soil (i.e., the rooting zone). The varying infiltration rates of the soil due to diverse soil textures and the three-way slope at Site C caused some run-off of amendments (primarily acetic acid, with a small amount of EDTA) from the plot area, and nearby cottonwood trees were affected. Although these trees are considered a “nuisance” tree, they were left in place at the beginning of the project at the request of AEC to minimize the environmental impact of the demonstration. Although not recognized initially, the roots from these trees extended into and throughout the plot. The runoff was only partially responsible for the damage to the trees which would have been affected regardless.

Lead uptake by the 1998 corn crop was promising, averaging 0.65% at Site C and 0.13% at Site 129-3. The range in concentration at Site C was from 0.33% to 1.13%, and at Site 129-3, lead concentrations in the crop ranged from less than 0.001% up to 0.44%. The biomass produced was less than anticipated, and consequently the amount of lead removed from the soil was not as great as anticipated. However, the extreme variability in soil lead concentrations, quite likely due to the presence of particulate lead, precluded a direct assessment of the amount of lead removed from the soil. Modern statistical procedures (i.e., parametric statistics, geostatistics, kriging analysis) were employed to distinguish differences in before and after lead concentrations in soil, but the variability in soil lead was simply too great to detect differences.

Uptake of EDTA by the 1998 corn constituted a viable mechanism for reducing the amount of EDTA remaining in the soil. Concentrations up to 72,000 mg EDTA/kg plant tissue were measured in plants from Site C and up to 11,000 mg/kg in plants at Site 129-3. This may have indicated uptake of the intact EDTA-lead complex by the plant, and thus a significant mechanism for removal of EDTA from the soil. Also possible was passive influx of EDTA into the plant due to root damage by EDTA, ion imbalance due to excessive influx of ions complexed by EDTA, or by solubilized lead.

Lysimeters were installed in the plots to monitor potential movement of lead or EDTA below the rooting zone. Intensive tillage and irrigation was performed during the month between harvest of the corn crop and planting of a white mustard crop to stimulate degradation of EDTA. Lead and EDTA were detected in the soil solution at Site C about two weeks after amendment addition and harvest of the corn. The concentration of EDTA and lead at Site C reached a maximum the first week in October 1998. However, these concentrations represented the contribution from only one lysimeter of the twelve that were installed, and the values from this lysimeter radically skewed the averaged results. When soil solution was not collected in this lysimeter, the average concentration of lead and EDTA in the solution decreased dramatically.

The lysimeter was installed correctly according to the manufacturer's instructions, and was effective in collecting the soil solution, although the amounts collected from week to week were somewhat erratic (Table 5-23). However, the lysimeter was installed in the area of the 1962 Pit, an area of the plot where extensive alteration to the native soil occurred due to dumping, burning, and soil excavation and replacement. Quite likely, the decomposing debris in the pit left channels and voids in the soil through which water from the surface could channel and collect. The porous cup may have been inserted into a void, and lead and EDTA-contaminated water from the treated upper soil layer may have pooled around the cup, thus accounting for the elevated concentrations of lead and EDTA in the solution. Alternately, a leakage could have occurred in the bentonite clay seal around the neck of the lysimeter at the soil surface, and leakage would have allowed channeling from the surface. Such a break would not have been obvious to an observer, since tilling operations normally covered the clay cap.

A white mustard crop was planted in August 1998 as the second crop in the demonstration year. The poor conditions at Site C, possibly some carryover EDTA, and toxic contaminants in the soil, likely thallium, combined to reduce viable stands at Site C by half. The final stand at Site 129-3 was about 90%. However, plants at both sites had a shallow rooting system caused by the excess rainfall. The white mustard crop at Site C had very woody, solid stems; the plants growing at Site 129-3 had hollow stems. Typically, mustard plants exhibit woody, solid stems.

A drip delivery system was used to supply EDTA to the 1998 white mustard crop over a 7-8 hour period. However, the slow rate of EDTA delivery through the system resulted in damage to the mustard before a desired level of lead uptake was achieved. The shallow root system was inefficient in scavenging lead much below 6 inches in the soil. The average EDTA concentration in white mustard at Site C was almost 8% and at Site 129-3 was almost 5%. EDTA is toxic to plants, and the high levels in these plants may have been a combination of prolonged exposure to EDTA and damage to root membranes which allowed passive influx of EDTA into the plant, and actual plant uptake of EDTA.

Overall, at both sites, there was no change in the total lead content in the top two feet of soil after the 1998 corn crop. Water-soluble lead had greatly increased since that was the reason for adding soil amendments in the first place, but higher concentrations of water-soluble lead were found in the top foot than in the lower layer. There was no change in soil pH after the corn crop. About three times as much EDTA was present in the top foot of soil as was found in the two foot depth. EDTA complexes with lead on a one-to-one molar basis. If the EDTA:lead ratio is greater than 1:1, this means that lead has been displaced from the EDTA by another cation. The equimolar EDTA:lead ratio originally imposed in the soil when the amendments were applied had increased from 1:1, which indicated that EDTA had complexed with elements other than lead. Lead had been displaced, quite likely by the abundance of calcium and magnesium ions, which at the soil pH of 8.0-8.3 would "swamp" the system, and lead would re-precipitate into insoluble form in the soil.

Immediately prior to adding amendments to 1998 white mustard, concentrations of water-soluble lead and EDTA were significantly higher in the two-foot soil depth. This may have been a result of downward movement due to multiple irrigation events. Again the EDTA:lead ratio had

shifted from 1:1, which indicated that lead had been displaced from the EDTA complex and had likely been re-precipitated in the soil.

### **1999 Season**

A higher yielding, deeper rooting silage corn instead of grain corn was used in 1999 in an attempt to maximize lead uptake by the crop. Planting of corn was delayed by excessive rainfall until late May 1999. Heavy rainfall and cool temperatures shortly after planting caused poor stand establishment, and extensive bird damage necessitated several replantings, resulting in a plant stand of various growth stages. Due to insufficient growth of the corn that resulted in bare areas in the plots, only selected areas were designated to receive soil amendments of acetic acid and EDTA. Only these areas were used for pre-amendment plant and soil sampling. Only 12 grids at Site C and two grids at Site 129-3 received soil amendments in 1999.

Soil total lead concentrations in the 12 grids sampled before amendment application to 1999 corn were lower overall than observed in the 1998 growing season after amendment application to white mustard. Both EDTA and water-soluble lead in the soil were present at very low concentrations in samples taken immediately before soil amendment application in 1999. This may have been due to degradation of EDTA, adsorption of EDTA onto organic matter and soil minerals (e.g., iron oxides and hydroxides), with re-precipitation of lead in the soil, movement of EDTA and lead to soil depths below the sampling zone of 2 feet, or a combination of these factors.

Plant lead concentrations in 1999 plants before adding soil amendments were as low or lower than observed for corn and mustard prior to amendment additions in 1998. EDTA concentrations in the 1999 plants prior to amendment additions were below the method detection limit. This indicated that there was no carry-over lead or EDTA from the previous year taken up into the plant.

For the amendment application at Site C, a drip delivery system was used that contrasted with the 1998 system by having triple the number of delivery tubes which provided a much faster rate of amendment application. Amendments were applied by hand at Site 129-3 using a hose, since only two grids were selected for amendment application. On August 11, 1999, acetic acid and EDTA solutions were applied to the designated grids at Site C and at Site 129-3. Two to three days after amendment application, the treated areas were sampled for soil and plant lead, EDTA, and other COCs. Additionally, four locations at Site C immediately adjacent to the treated area were sampled for soil lead, EDTA, and other COCs to determine if lateral movement of amendments occurred. Attempts to collect soil solution samples before and after amendment application were unsuccessful.

The lysimeters did not collect soil solution in 1999. Random lysimeters pulled from the field did not show evidence of clogging due to algal growth or other obvious cause. A complicating factor in addition to the poor soil conditions and the variety of debris in the soil which affected performance may have been that the lysimeters were left in place in the soil during the winter of 1998, in accordance with the manufacturer's instructions (SoilMoisture Equipment Corp., P.O. Box 30025, Santa Barbara, CA 93105). However, freezing and thawing of the soil during the winter and the following spring likely led to shrinking of the soil away from the porous cup. This

would have prevented proper contact with the soil and a poor suction vacuum in the lysimeter during sampling attempts, although this was not obvious until attempts were made to collect soil solution in 1999. When contacted in regards to this problem, the manufacturer supported the position that loss of contact of the porous cup with the surrounding soil due to freezing and thawing could have been a cause for the lack of water infiltration into the lysimeters.

The concentration of EDTA applied in 1999 was reduced by one-third from the concentration applied in 1998. Although a sufficient volume of EDTA solution was applied to wet the top 24 inches of soil, EDTA was localized primarily in the top 12 inches of soil. Higher concentrations of water-soluble lead were found at the 0- to 12-inch depth, corresponding to the higher concentrations of EDTA in the upper soil layer. Total lead concentrations were highly variable, and no discernible patterns of lead distribution in the soil were observed. Soil sampling adjacent to the treated areas at Site C indicated that lateral movement of EDTA did not occur.

A sequential fractionation analysis procedure performed on pre-amendment soil samples showed that potentially plant-available lead concentrations overall were about 55% of the total lead concentrations in the soil. If the concentration of potentially plant-available lead were to be used as the criterion for calculating the amount of EDTA to be added to the soil rather than total lead concentrations, the amount of EDTA required could be reduced accordingly.

The lead concentration in corn plants at Site C averaged 854 mg/kg. These values were tenfold less than obtained in corn treated in 1998. Conditions in 1999 were not optimal for lead uptake, as the corn crop at this site exhibited several different growth stages, ranging from immature, non-tasseled plants to mature plants with ears. Root development was limited to the top 6-8 inch soil layer. EDTA concentrations in the 1999 corn averaged approximately 40% lower than found in the corn crop in 1998, but still averaged 26,200 mg/kg in 1999. Lead uptake by corn in the two grids sampled at Site 129-3 averaged 104 mg/kg.

The overall results of the phytoremediation technology during the 1998-1999 demonstration were less than hoped for with respect to crop growth, plant lead uptake, and removal of lead from the soil. In order for this technology to be effective, greater uptake of lead by plants from the soil will have to be realized. This may be difficult to achieve in the site conditions such as those at TCAAP, particularly at Site C. The poor chemical and physical condition of the soil, and the extreme heterogeneity of both the concentration and the form of lead in the soil were factors that were not known prior to undertaking the demonstration at this site.

### **2000 Season**

There were plans to demonstration phytoextraction at Site 129-3. After observation of lead and EDTA in groundwater, no phytoextraction activities were conducted in 2000. Instead, three groundwater sampling events and two surface water sampling events were carried out by TCAAP and MPCA personnel during April and May 2000. Groundwater samples were taken upgradient from the demonstration plot, from within the plot, and down-gradient of the plot. Surface water samples were taken upgradient and down-gradient of the plot from a drainage ditch near the plot. These samples were taken to determine how much of the 16-acre area of Site C proper had been impacted by demonstration activities. In addition, deep core soil samples were taken by TVA to “dissect” and more fully characterize the demonstration area.

It is important to note that the demonstration plot at Site C constituted only a 0.2 acre portion of a highly contaminated 16.5 acre area, and that the soil in the entire 16.5-acre area was scheduled to be excavated and treated in 2000 to chemically stabilize lead in the soil before disposal in a landfill.

Based on analysis of four surface water samples, lead did not appear to be migrating to surface waters from the phytoremediation plot due to solubilization by EDTA. Site C-1, an area within Site C proper, is located just north of the drainage ditch flowing east to west. The proximity of this site to the drainage ditch, the slope toward the ditch, combined with the past burning and disposal operations at this site indicate that Site C-1 may have been the probable cause of the lead detection (1 ppm) at the sampling point most distant from the plot. Historical data in the RI/FS indicated the presence of lead at Site C-1 in quantities that would produce the levels of lead in the drainage ditch running east to west. The data also proved that surface water contamination had not occurred and there was no immediate risk to the environment.

For groundwater samples, results indicated that the lead concentration in the groundwater had decreased rapidly with distance away from the plot. Lead concentrations decreased from 1,100 ppm to 1 ppm in approximately 100 feet. This rapid decline indicated that lead levels would continue to decrease. Considering that the impacted groundwater is in Unit 1, an alluvium, extreme variations would likely be observed within short distances in the aquifer. The depths to groundwater in the area were highly variable. A higher level of the water table could have resulted in "washing" of the soil and transport of EDTA. The fluctuation could have been due to demonstration irrigation activities as well as rainfall.

The ratios of EDTA:lead in the groundwater increased as the distance from the plot increased. This supported a basic conceptual model that the longer the EDTA exists in the groundwater the more likely it is for other cations to out-compete lead for complexation by EDTA, which will reduce lead in solution over time and as distance from the plot increases. Degradation of EDTA also played a role in lead re-deposition.

EDTA and lead were found throughout the plot, with the concentration of total lead being greater than the concentration of lead which had complexed with EDTA. EDTA values were less than those of total lead within the plot and tended to be below the detection limit outside of the plot. The soil analytical results indicated that while EDTA and lead were found in the shallow soils (less than 4 feet), the concentrations of these were lower than were observed in the April round of groundwater sampling. Soil concentrations for EDTA ranged from less than 0.3 to 1,570 ppm.

Concentrations of EDTA in the April groundwater samples were from less than 0.03 up to 4,910 ppm EDTA. Only three of the soil samples were higher than the highest values seen in the May groundwater sampling of 739 ppm. Water-soluble lead concentrations in the soil ranged from less than 1 to 549 ppm; lead concentrations in the April groundwater samples ranged from less than 0.02 ppm to 988 ppm. This data suggested that the overall concentrations of EDTA were decreasing in the soil and that the EDTA is degrading at the site as was originally expected.

The soils at Site C were found to be much more heterogeneous than was originally anticipated. Seven soil types, ranging from sand to clay, were identified in deep soil cores which is contrary to the single soil type identified in the RI/FS. Clay and sand lenses were common throughout the soil, and a considerable amount of burned and unburned wood was found. Debris consisting of glass, metal, wire, concrete, bullets, and brass shell casings was found throughout the plot. Iron oxide deposition was common in the cores as were manganese sulfide concretions (usually a representation of alternating aerobic and anaerobic zones in the soil profile, likely caused by a fluctuating water table).

EDTA did not degrade as rapidly as expected, based on current information in the literature. However, degradation did occur, as evidenced by the relatively high pH of the shallow soils (8.5 to 9.5) which may be attributed to degradation of EDTA and release of ammonia from the amine groups, and to the formation of carbonate compounds from the CO<sub>2</sub> that is also released. In soils the major mechanisms which determine the fate of EDTA and therefore its ability to solubilize lead are:

- Adsorption to iron oxide and soil organic matter.
- Binding to clay particles.
- Reactions with soil cations.
- Microbial degradation.
- Rates of leaching.

In addition, lead solubility in soil during a phytoextraction scheme is controlled by reactions of:

- Dissolution of inorganic lead compounds.
- Complexation of lead by EDTA.
- Displacement of lead from EDTA by competing cations and re-precipitation of lead in soil.
- Degradation of EDTA and reaction of lead in soil to form insoluble compounds.

The competing cation effect was significant in this soil. A departure from a 1:1 EDTA to lead ratio in both soil and groundwater was a result of lead displacement in EDTA by another cation(s). The data showed these cations to be calcium and magnesium. As lead was displaced, reprecipitation in the soil occurred and lead was not subject to leaching or was it otherwise bioavailable. As lead is more soluble at lower pH, the amount of soluble lead will continue to decline. Given the mineralogy of this soil a natural drop in soil pH to a level that would re-solubilize lead is highly unlikely.

Most likely the extreme heterogeneous nature of these shallow soils accelerated movement of EDTA through the soil column and reduced the contact time of EDTA in the soils, which affected the rate at which the reductive fate processes were taking place. It is also possible that the microbial population in the shallow soils was (is) low, due to other toxic contaminants and debris in the soils and perhaps the slow draining of the soils, which would lead to waterlogging during significant periods of the year.

The results of the soil, groundwater, and surface water sampling suggested that, although the EDTA persisted in the soil and in groundwater longer than originally expected, the concentrations of soluble lead within and outside the demonstration plot are decreasing with time and will continue to decrease.

### 5.3 Technology Comparison

Several procedures for remediating metals-contaminated soil sites are currently available. These include traditional and proven *ex situ* methods, as well as emerging, state-of-the-art *in situ* technologies. Conventional *ex situ* methodologies include:

- Landfilling of contaminated soil.
- Soil washing (separation) - excavation of soil followed by soil washing, return of clean soil to the site, and landfilling of soil which is still contaminated.
- Incineration - excavation and incineration, with the remaining mineral fraction returned to the original site or landfilling if decontamination is not complete.
- Solidification - excavation and *ex situ* solidification with pozzolanic agents and landfilling of the stabilized material.

These methods are effective; however, they usually involve long-term monitoring and permanent and sometimes drastic alterations to the original site.

In contrast, the following *in situ* methods, except containment and flushing, provide a clean site and normally avoid future liability and restrictions to site use:

- *In situ* soil flushing - in-place washing of soil using acid or chelate solutions followed by pumping of contaminated soil solution to the surface for treatment.
- Solidification/Stabilization - similar to *ex situ*, but involves proprietary reagent delivery and mixing systems and may be less costly for large soil volumes and depths greater than 10 feet.
- Containment - placing an impermeable cap on the contaminated site to eliminate water infiltration into the contaminated soil.
- Electrokinetics - use of low intensity direct current fields between electrodes in soil to mobilize and capture contaminants at the electrodes for removal.
- Phytoremediation - a broad term for the use of plants to remediate contaminated soil and water. (The phytoextraction technique is a category of phytoremediation methods, whereby metal-accumulating plant species are used to extract lead from the soil and are then harvested.)

If applicable to the site, phytoextraction may be among the lowest cost options, but it also requires the longest amount of time. If remediation can be accomplished on areas of moderate-level contamination within one to five years, phytoextraction may be an attractive alternative to existing methods.

From the results of this project, the scope of application for the technology appears to be very limited, the remediation time would be unrealistically long, and sites that would be suitable candidates for phytoextraction appear to be scarce. In addition, some of the operating parameters are still in need of refinement. These include growing practices, plant species selection, chelate selection, amendment application methods, and amendment application rates.