Section 9.0
Lessons Learned

Procedures and methodology that could be modified to improve the technology application are as follows:

1. Do not rely on past historical documentation for site characterization.

2. Thoroughly investigate the site history, soil hydraulics, and groundwater data before beginning. Site history would reveal if alteration of normal soil characteristics had occurred due to activities such as excavation, dumping and burial of debris, burning of wastes, and introduction of varying soil types as fill material. An accurate assessment of soil hydraulic conductivity would allow a valid mass water balance that would take into account varying soil texture, infiltration rates, and amounts of precipitation. Existing groundwater data will provide information about the concentration of contaminants in the groundwater prior to phytoextraction.

3. Realize that an area having a shorter growing season may preclude the use of multiple crops in a season.

4. Establish a strong and empathetic working relationship with the appropriate regulatory authorities from the outset. Freely provide information and accede to requests for additional information.

5. Do not try to implement *in situ* phytoextraction as a sole remediation technology on areas of heterogeneous waste, debris, and unknown contaminants. Instead, limit implementation of *in situ* to sites where lead is known to be in ionic form and sites which are homogeneous.

6. If a site is non-homogeneous and particulate lead will be a problem, use screening and separation techniques to make the soil at the site as uniform as possible and to remove particulate lead.

7. Install a leachate containment and collection system if soil properties are conducive to leaching.

8. Determine plant available forms of lead and use as the basis for the amount of EDTA that will be applied.

9. Consider sacrificing maximum lead uptake and extending the remediation period by using minimal quantities of EDTA. The nature of the chelate, the effect of carry-over EDTA on subsequent crops, and the toxicity thresholds for plants have not been established, and the mechanism for plant damage has not been determined. Root damage may occur directly from exposure to the chelate, and the electrolyte balance within the plant may be upset by increased ion uptake due to the chelate. These problems will have to be addressed and

resolved before the true potential of the technology is realized. This can only be done by further bench-scale laboratory and greenhouse research. Quite possibly, some of the second-generation chelates recently approved for use in land systems may overcome these problems. Although these chelates have weaker affinity for metals (and other nutrient cations), their half-life in soil is much less. Possibly, these chelates can be safely added in multiple increments that do not harm plants and thus may prove useful in establishing a "chronic" exposure to a given element rather than the "acute" dose with EDTA. The reduced affinity for other ions may also prevent overload of the ion uptake mechanism. However, only additional research can address these questions.

10. Investigate the use of second generation chelates. According to representatives of BASF Corporation (BASF Corporation, 3000 Continental Drive - North, Mount Olive, New Jersey 07828-1234) second generation derivatives of EDTA have several properties which may make such chelates desirable for use in phytoextraction schemes. Depending upon specific circumstances, these chelates 1) may degrade more quickly and easily than EDTA; 2) have less affinity for lead, which greatly decreases the potential for lead leaching; 3) may be less toxic to plants; and 4) are comparable in unit cost.

11. If EDTA is used, consider soil amendments that will adsorb and limit potential migration of EDTA. Such amendments are iron-enriched municipal biosolids or poultry litter. The addition of organic matter will also stimulate microbial population growth and encourage more rapid degradation of EDTA.

12. Consider addition of innocuous basic cation sources, such as calcium sulfate, calcium nitrate, magnesium sulfate, etc., to complex with EDTA and displace and re-precipitate lead in soil to limit potential lead leaching through soil.

13. Develop an analytical method to measure residual EDTA absorbed on soil. This would be EDTA sorbed onto soil in non water-soluble form which is not detectable by current analytical methods, and which affect subsequent crop plantings.

14. Conduct agronomic operations with mechanized agricultural equipment to save on labor costs.

15. Plan on using proven high-yielding, prolific rooting crop varieties, such as silage corn, and maximize vegetative production by high rate use of fertilizers, particularly nitrogen.

16. Employ deep-tilling practices to return lead that has moved out of the root zone to the plant rooting zone.

17. Instigate pest repellent measures (e.g., for birds) before the problem becomes too serious to correct.

18. Carefully consider the time frame for remediation. Indications are that the time required for remediation of appreciable amounts of lead from soil using phytoextraction will be unrealistically long.