Response to U. S. Environmental Protection Agency and Kentucky Department for Environmental Protection Comments Submitted November 16, 2012, and November 9, 2012, on the *60% Remedial Design Report In Situ Source Treatment Using Deep Soil Mixing for Southwest Groundwater Plume Volatile Organic Source at the C-747-C Oil Landfarm (Solid Waste Management Unit 1) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-1276&D1, Dated August 2012

General Comments

United States Environmental Protection Agency

Comment 1: Although the stated purpose of the 60% Remedial Design Report (RDR) is to present the 60% conceptual design for the remedial action to be implemented at the Southwest Groundwater Plume source area, the information provided represents a 30% remedial design submittal. The report does not provide sufficient detail of the design or rationale for the design criteria. For example, operational criteria such as the target temperature (a critical operational parameter for thermal remediations) are based just on experience at other sites, and no information on the characteristics of the sites and the performance of the technology at those sites has been provided. For other operational criteria, such as the ZVI dosing criteria, no information is provided on how the criteria were developed to demonstrate that the doses specified are adequate or sufficient. Nowhere in the document is it established that the operating parameters presented will achieve the soil cleanup criteria for the site. The lack of delineation of the extent of contamination directly impacts many RD components (e.g., number of injection points, size of the treatment areas, radius of influence (ROI), number of performance monitoring wells, duration of treatment). Additional information inputs will require significant changes to the RD prior to implementation, which directly contradicts the purpose of the phased approach for RD. The 90% RDR should present a RD adequately supported by design information which meets the level of detail specified for a pre-final 90% RD submittal as described in the RD/RA Handbook (EPA/540/R-95/059).

Response 1: Unlike some more conventional remedial technologies that were available at the time that the RD/RA 1995 Handbook (EPA/540/R-95/059) was prepared, the proposed remedial technology (LDA with steam and ZVI injection) is an innovative technology provided by a limited number of remediation vendors that is not constructed on-site as a longer-term in-place system (such as the case of a conventional mid-1990s era pump and treat system, which would warrant a significant level of process design, pipe sizing, etc.) Accordingly, the Remedial Design Report (RDR) is intended to provide information regarding the area and depth to be treated, approach, and desired outcome, with a high-level of flexibility to facilitate implementation by LDA contractors with equipment suitable for project performance. The intent is for the remedial design to be largely performance-based, facilitating the bidding of the project implementation by more than one company and also enabling the bidding contractors that own existing equipment to have the flexibility to use their existing equipment to meet project objectives. This specific approach and the design format have been successfully used at other sites including Launch Complex 15, Ordnance Support Facility 1381; and Security Police Confidence Course (Facility 18003) located at Cape Canaveral Air Force Station; and Offutt Air Force Base, Nebraska. To assist with many of EPA's questions regarding implementation of the technology, electronic copies of Corrective Measures Implementation reports for Ordnance Support Facility 1381, the Security Police Confidence Course, and the Offutt Air Force Base are attached to the RDR back cover (CD).

Operating parameters are based upon field implementations of the technology at other sites (examples attached). Many of the design criteria for this unique technology are based upon the implementation success learned at other sites; accordingly, the shroud temperature, mixing rates, steam temperature, ZVI dosing criteria, etc., are based upon the successful implementation at other sites. The text (Section 4) in the 90% RDR has been revised to include specific language to provide the required soil cleanup criteria for the site.

With regard to the delineation, EPA was made aware that the Remedial Design Support Investigation (RDSI) was ongoing immediately prior to the submittal of the 60% RDR; accordingly, this information could not be fully incorporated into the 60% RDR. The 90% RDR includes a discussion and presentation of the RDSI data and the development of the treatment area footprint and implementation approach based upon the RDSI data. Section 1.3 and 1.4 were extensively modified to include discussions on the utilization of the RDSI data, including modeling with Environmental Visualization Software and contouring with Golden Software's Surfer kriging algorithm to develop the treatment area.

Comment 2: In order to determine the operational parameters needed to successfully treat the soil contamination at SWMU 1, EPA recommends that a performance optimization study be completed as part of implementation of the technology, with extensive data collection to demonstrate that the technology will achieve the established cleanup criteria and the operational criteria that must be achieved to meet the soil cleanup level. The study should be located in the highly contaminated soils, and monitoring should include the collection of continuous soil cores to determine the residual contamination levels, the temperature distribution within the soils, and the distribution of zero-valent iron (ZVI) achieved with a given set of operating conditions. The results from the study can then be used to determine the operational parameters needed to successfully treat the soil contamination, given the contaminant concentrations present and the soil characteristics. Specific comments are included to support this recommendation to perform an optimization study which in turn will support the full scale design.

Response 2: The performance of an optimization study in the area of highest contaminant levels is not warranted. This technology already has been successfully demonstrated at sites with concentrations significantly higher than those identified at SWMU 1. Three separate attachments for this comment response summary are provided on CD contained in the RDR. These attachments present the results of implementation at project sites with higher contaminant concentrations than at SWMU 1. Two of the sites are at Cape Canaveral and the third is at an Air Force Missile Base in Nebraska. Additionally, the implementation approach presented in the 90% RDR includes real-time monitoring and adjustments that will be made during implementation to ensure that objectives are being achieved (consistent with the example corrective measures implementation (CMI) reports attached).

Conducting an optimization study will provide only refined information for supporting a full-scale design and operation. Major implementation issues are not expected to occur at the SWMU 1 area during the full-scale operation that have not occurred at other completed sites, as referenced in the previous paragraph. An optimization study in the highest contamination area would require a reduced number of soil mixing columns; yet all the same equipment would be required for the optimization study and further the cost reductions would not be proportional to the reduced areas. The equipment sizing, modifications and setup of the mixing equipment and treatment equipment will be the same for the reduced duration test as it would be for the full-scale operation. Additionally, schedule modifications would be required to implement an optimization study into the project prior to going to a full-scale operation; therefore, the project would incur an overall increase in cost and schedule for a minimal increase in technical information.

Comment 3: Note 3 of Table 1, provides the decision criteria that was utilized to define the treatment area states the following: “If soil boring averaged concentrations of TCE and TCE degradation products in soil of the UCRS exceed cleanup levels for a given soil boring, then the sample location will be included in the treatment area. If the soil boring-averaged soil concentrations do not exceed cleanup levels, then the area need not be included in the treatment area." Yet, this decision criterion was not utilized in Figure 3. Specifically, the soil boring averaged soil concentrations at soil boring locations 001-314, 001-304, 001-315, 001-308, and 001-303 exceed cleanup levels but are not located within the approximate treatment area shown on Figure 3. As a result, the treatment area presented in Figure 3 is incorrect which directly impacts the RD. Also, Section 1.3 indicates that some of the boring locations shown on Figure 3 were adjusted in the field and the actual sampling locations are not shown on the figure. Ensure that the treatment area is sufficiently defined prior to developing the 90% RD.

Response 3: At the time of development for the 60% remedial design package, samples and data still were being collected in the field at SWMU 1 as part of the RDSI. The time available with the data had not allowed the source area to be remapped. Figure 3 contained the tabulation of new data, but not a revised source area. The revised source has been mapped utilizing the Surfer program and is now shown in Figure 3 of the 90% Remedial Design Document. The revised source area surface expression is now 13,423 ft^2. All RDSI soil borings that exceed the established cleanup levels l (i.e., within the revised source area).

Figure 3 has been revised to include the new treatment area, the expected TCE contaminant levels within the area, and the results of the RDSI borings used to generate the source surface expression.

Comment 4: As shown in Figure 3, 12 of the RDSI borings have TCE concentrations at the bottom of the boring (60 ft bgs or greater) that exceed the soil cleanup criteria. In particular, 4 of the borings (001-309, 001-310, 001-311, and 001-315) have extremely high concentrations at 60 to 65 feet bgs ranging from 1,300 ug/kg to 2,500 ug/kg. Implementation of the treatment technology should extend to the top of HU5 in the area of these 4 borings to ensure the full extent of soils/sediments are treated where TCE concentrations are very high at the base of the UCRS – top of the RGA.

Response 4: The proposed LDA with steam and ZVI technology configuration with an 8-ft diameter mixing blade can achieve an anticipated maximum design soil mix depth of 60 ft below ground surface (bgs), which is based upon the physical limitations of the Kelly-bar length, soil conditions, and equipment torque. In order to provide additional treatment depth, the 90% RDR has been revised to reflect that in the contoured area with average concentrations exceeding 1,000 micrograms per kilogram, the upper 2 ft of surface soils will be excavated prior to LDA activities, enabling the physical LDA mixing to a depth of 62 ft below the original land surface elevation. Additionally, a discussion and figure have been added to Section 4 concerning the treatment to a depth of HU-4/HU-5 interface. Two ft of surface soil will be removed from the soil mixing treatment area for the following reasons:

- Removal of the soil protects the surface treatment equipment from non-VOC contaminants such as PCBs that are known to be present in the surface soils,

- Allows soil mixing at depths greater than 60 ft in subsurface. Figure 4 shows that with a treatment to a total depth of 62 ft (2 ft of surface soil removed plus the 60 ft treatment depth), treatment to the HU-4/HU-5 interface is feasible with the 8 ft auger system.

Comment 5: Specific details associated with the components and parameters that will be utilized in the RD are not provided and/or referenced. For example:

a. Section 1.4, Sequencing with Other Remedies, indicates that the source area surface soil will be removed and stockpiled on the west side of SWMU 1; however, the stockpile location is not shown on any figures within the 60% RDR.

Response a: The location of the soil stockpile has been added to Figure 7.

b. Section 4.2, Critical Parameters, states "Soil properties dictate the rate at which the LDA can penetrate the subsurface, appropriate angle of repose for the mixing blade, and considerations regarding the auger blade terminus." However, the soil properties specific to SWMU 1 are not discussed. In addition, the rate at which the LDA will penetrate the subsurface, the appropriate angle of repose for the mixing blade and the considerations that apply to the auger blade terminus are not provided for the RD.

Response b: The specific penetration rate of the LDA, angle of repose for the mixing blade, and auger blade terminus are considerations for the equipment vendor based upon the Standard Penetration Test (SPT) data provided as Appendix C in the 90% RDR and which would be included in vendor bidding information. It is not the intent of the RDR to detail this information specifically, it is intended that the LDA vendors be made aware of subsurface conditions and that they select, based upon application experience, the appropriate penetration rate, angle of repose, and blade terminus to achieve project objectives. The 90% RDR does specifically mention the likelihood that "rock teeth" should be considered based upon the SPT-identified hard layer present at approximately 22 to 23 ft bgs and 55 to 59 ft bgs.

c. Section 4.2 states that the vapor extraction equipment will be capable of extracting vapors at a flow rate that is twice the maximum flow rate of the hot/air steam injection; however, the extraction flow rate is not specified nor is the vapor extraction equipment that will be utilized.

Response c: The intent of the language in Section 4.2 was to provide the LDA equipment vendor with operational flexibility to utilize preexisting equipment to achieve performance objectives and ensure adequate capture of the vapors, rather than having to build a customized LDA system for the application at SWMU 1. The 60% RDR included a range of hot air/steam injection flow rates in Section 4.4.1.2 and the range of extraction flow rates were described in Section 4.4.1.3. The 90% RDR has been updated (see Section 4) to include a general range of anticipated flows and an anticipated vapor extraction blower specification, or equivalent, to meet the objective in Section 4.2.

d. Section 4.3, Design Requirements, provides a list of the general input requirements for the *in situ* LDA soil mixing with hot air/steam and ZVI injection remediation design, but does not provide any specific information related to the listed requirements.

Response d: The intent of the language in Section 4.3 was to provide the LDA equipment vendor with flexibility to achieve performance objectives. Section 4.3 has been expanded in the 90% RDR to include additional information relating to each of the listed requirements.

e. Section 4.4.1.3, Off-gas extraction and vapor conditioning system, indicates that, "The contaminants will be collected within a shroud of sufficient diameter to provide capture of VOCs." However, the diameter of the shroud is not specified. In addition, the 60% RDR does not specify how a sufficient diameter will be determined.

Response e: The intent of the language in Section 4.4.1.3 was to provide the LDA equipment vendor with operational flexibility to utilize preexisting equipment to achieve performance objectives and ensure adequate capture of the vapors, rather than having to build a customized LDA system for the application at SWMU 1. The vapor shroud used by FECC (for example) is 12-ft diameter and steel construction and has been documented via previous applications (CMI reports attached) to achieve project vapor capture objectives. Section 4.4.1.3 of the 90% RDR will include text that provides the minimum shroud diameter based upon operational performance at other sites with concentrations significantly higher than those measured at SWMU 1.

f. While Section 6.2, Sampling and Monitoring Post Remedial Action, includes post-remedial evaluation of soil homogeneity and ZVI distribution, the text does not discuss how rebound will be assessed following ZVI injection. At a minimum, three years of monitoring is needed to assess and address rebound.

Response f: Section 6.2 of the RD report provides general components for postremedial monitoring, but also commits to the development of Postremedial Sampling and Analysis section in the Remedial Action Work Plan, with specifics on soil boring approach, locations, sampling, and contaminant analysis.

g. Section 6.2 does not identify the monitoring wells that will be used to monitor the groundwater remedy (e.g., to evaluate whether injections push contamination outside the treatment zones). Sufficient wells are needed to monitor distribution and potential migration of substrates and contamination within and beyond the treatment areas. Note that when injections are done, radial flow should be assumed, so the full boundary of treatment areas should be monitored.

Response g: Section 6.2 of the RD report provides some general components for postremedial monitoring but also commits to the development of Postremedial Sampling and Analysis section in the Remedial Action Work Plan, with specifics on boring approach, locations, sampling, and contaminant analysis.

The comment suggests that radial flow occurs from the soil mixing borehole during steam and ZVI injections. In a closed borehole where the formation is receiving, the full pressure of the injection radial flow would be an appropriate assumption. In the case of soil mixing, flow radially from the borehole into the formation will be limited. The reason for this is that flow will take the path of least resistance, which will be up the borehole. As the large diameter augers are mixing the soil, the primary porosity and permeability of the soil are being increased dramatically due to the blades making openings in the soil. The steam and ZVI injection take place as the auger blades are moving through the soil. In addition to the open environment, the vacuum extraction is removing air, volatilized contaminant, and, to some degree, water from the mixing borehole, which is increasing the pressure gradient toward the surface. In view of this injection and flow mechanism, it is reasonable to assume that some limited flow from the borehole will occur especially in the direction of adjacent boreholes, which will exhibit increased porosity and permeability from the mixing process. Section 6.2 has been modified to indicate that postremedial monitoring will include soil sampling from borehole locations to check for the movement of contaminants into non-soil-mixed areas.

Provide specific details associated with components and parameters that will be utilized.

Response 5: As described above in responses a through g, additional details have been provided in the 90% RDR, while attempting to balance the EPA's request for detail with a level of flexibility that enables LDA vendors to focus on achieving performance objectives.

Specific Comments

United States Environmental Protection Agency

Comment 1, Section 1.2, Treatment Site Location, Page 4: The locations of the other potential Southwest Plume source areas, relative to SWMU 1, are not provided in the report. Revise Figure 2 to show all the potential Southwest Plume source areas.

Response 1: Figure 2 has been revised to show SWMUs 211-A and 211-B, which were identified as sources to the Southwest Plume and subject to signed record of decision.

Comment 2, Section 1.4, Sequencing with other Remedies, Page 19: This section discusses only the sequencing of the LDA remediation with the remedy for PCBs in the surface soil; however, based on the first paragraph of Section 1.3, there are other remedies (enhanced bioremediation and long term monitoring) planned for this area. Also, Section 4.2, last paragraph, states that there are other contaminants of concern (polynuclear aromatic hydrocarbons, dioxins, radionuclides, and heavy metals) in the treatment zone. The sequencing of the remediation for these contaminants should be included in Section 1.4.

Response 2: The comment incorrectly indicates that other remedies (enhanced bioremediation and long-term monitoring) are planned for this area (SWMU 1—Oil Landfarm). Soil mixing with large diameter augers with steam and ZVI is the only remedial action documented for SWMU 1 in the *Record of Decision for Solid Waste Management Units 1, 211-A, 211-B, and Part of 102 Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0365&D2/R1.

Section 1.4 (now Section 1.5) has been modified to discuss the coordination required with other contaminants present in the surface soil and in the subsurface soil of the Soils Operable Unit to prevent impacts to the soil mixing process or initiating an uncontrolled migration of contaminants. Consistent with the 60% RD, the top 2 ft of soils will be excavated. The soils will be stockpiled and respread following completion of the mixing operations. Because the soils will have been disturbed, the area mixed will be recharacterized as part of the Soils Operable Unit at the appropriate time in the future. Section 4.2 verbiage was modified to remove any reference to contaminants that might be present in the soils and refers the reader to Section 1.5 for those details.

Comment 3, Section 3, Treatment System Objectives, Page 19: The text states "For the SWMU 1 site, information required to optimize soil mixing effectiveness and attain remediation goals will be obtained during the RDSI;" yet, the 60% RDR does not discuss the optimization of soil mixing effectiveness despite including the preliminary data from the RDSI. Discuss the optimization of the soil mixing effectiveness to attain the remediation goals.

Response 3: The 90% RDR includes an LDA treatment layout that is specifically tailored to the results of the RDSI, as detailed in the revised text included in Section 4.2 and on Figure 5. The optimization of the mixing process during implementation is discussed in Section 4.2.

Comment 4, Section 4.1, Technical Justification for Selection of Remedial Technology, Page 24: The text states "Unique to the in situ LDA soil mixing with hot air/steam and ZVI injection technology, the mixing process and treatment application is adapted real-time based upon the monitoring of off-gas VOC concentrations. Accordingly, the selected RA has flexibility and can be actively adapted during individual borehole mixing to spend additional time, providing enhanced treatment to specific depth intervals and/or boreholes with higher levels of VOCs, as appropriate;" however, the decision criteria associated with this flexibility is not specified. Provide the decision criteria that will be used with the treatment technology to alter operating parameters in real time.

Response 4: Section 4.2 and Section 4.4.2.1 and 4.4.2.2, provide the decision criteria. The 90% RDR text was modified to reflect that the decision criteria are described in the referenced sections, with some expanded language.

Comment 5, Section 4.2, Critical Parameters, Page 24: The discussion entitled Soil and Groundwater Temperature indicates that a target soil and groundwater temperature of 170 degrees Fahrenheit (^{o}F) has been used "at other sites" to achieve volatilization of TCE and daughter products; however, the other sites are not identified. This temperature is above the co-boiling point of TCE and water, which is 163^{o}F, but below the boiling point of TCE alone, which is 189°F. Temperatures above the boiling point of TCE will greatly enhance the removal rate of the TCE, reducing both the time needed for remediation and the residual contaminant concentrations.

Also, the text subsection states that adding a correction factor of 10°F to the shroud gas temperature was used "at other sites" to represent the downhole temperature; however, the other sites are not identified. Specify the other sites where a temperature of 170°F and a correction factor of 10°F were used, and clarify how these sites and proposed temperatures are applicable to PGDP.

Response 5: See response to Comment 1. Implementation reports for the referenced sites are attached and provide the requested information that has been found to be operationally successful. Unlike conventional thermal remediation projects, which are 100% reliant on achievement of the boiling point of the contaminant to volatilize the constituents, the LDA technology achieves volatilization/remediation through a combination of (i) heating of the soil, (ii) enhanced aggressive stripping within the soil column associated with the injected steam (essentially heated air stripping of the soil column) and associated mixing, (iii) real-time monitoring to focus additional heating/enhanced steam stripping based upon off-gas data, and (iv) follow-up polishing via the ZVI application. Specifically, the Corrective Measures Implementation report for Ordnance Support Facility 1381 describes previously conducted subsurface thermocouple evaluations which support the above-described correction factor.

Comment 6, Section 4.2, Critical Parameters, Page 24: The second paragraph of this section states, "A downhole thermocouple will be used to monitor subsurface temperatures, which will be retrieved on a daily basis." It is not clear what this means. Ideally, downhole temperatures should be measured continuously in several locations throughout the soil column being treated to ensure that all of the soils are heated to the target treatment temperature.

Response 6: The downhole thermocouple is attached to the LDA auger blade and the data associated with the thermocouple is physically retrieved from the thermocouple and reviewed each day. Continuous real-time direct readings from a downhole thermocouple present a technical challenge, which we understand has not been overcome with currently available technology. While the continuous measurement in several locations is consistent with a typical thermal remediation project, this is not practical when using the LDA technology that requires drill steel and augers to rotate in the subsurface. As described in the RDR, the continuous monitoring of shroud temperature and PID/FID vapor response is used to ensure that objectives are achieved and to optimize treatment during project implementation. The RDR proposed approach is consistent with the approach used and documented in the corrective measure implementation (CMI) example documents attached.

Comment 7: Section 4.2, Critical Parameters, Page 24: Percentage of Auger Boring Overlap: This section presents two different sets of criteria for determining the amount of overlap to be used for LDA borings, and it is not clear which set of criteria will be used to determine the overlap in the field. Also it is not clear what is the basis for this criteria, and it has not been demonstrated that this criteria will achieve the soil cleanup goals for this site.

In the second set of criteria for determining the overlap, the use of PID/FID results should be tied to a temperature criteria. PID/FID readings will be strongly dependent on the soil temperatures as well as the contaminant concentrations.

Response 7: In consideration of the confusion with the different sets of auger boring overlap criteria [and disagreement with regard to the approach for measuring the secondary criteria(temperature vs PID/FID readings)], the 90% RDR has been modified to base the auger boring overlap entirely on the distribution of soil impacts based upon the RDSI results. The proposed auger boring overlaps are conservative since the technology has been successfully demonstrated at lower overlap spacing at sites with higher concentrations than those measured at SWMU 1 (CMI reports attached). Additionally, since the increased number of LDA passes and ZVI addition provides a mechanism for optimized treatment and polishing, the single set of overlap criteria is more than adequate.

Comment 8, Section 4.2, Critical Parameters, Page 24: The first bullet in the discussion entitled Percentage of Auger Boring Overlap states "The 17.5% overlap will be applied to the group of LDA borings (minimum four locations) adjoining a "high" TCE RDSI concentration." However, the text does not specify why a minimum of four locations will be utilized in the area of the treatment zone with TCE concentrations exceeding 10,000 µg/kg. Clarify why a minimum of four locations will be utilized in an area with TCE concentrations exceeding 10,000 µg/kg.

Response 8: See response to Comment 7. The auger boring overlap approach has been revised in the 90% RDR to be based entirely on the RDSI data to minimize confusion and make the conservative implementation approach as straightforward as possible.

Comment 9, Section 4.2, Critical Parameters, Pages 24-26: While the percentage of LDA boring overlap is discussed in the Percentage of Auger Boring Overlap subsection of Section 4.2, the radius of influence (ROI) is not. The ROI is a key operational parameter which will directly impact the overlap spacing. Discuss the ROI that will be utilized in the RD and how it was determined.

Response 9: The LDA auger blade diameter (8 ft) is considered a conservative minimum radius of influence that was utilized in the RD. Implementation of the technology at other sites (CMI reports attached) has documented a ROI that extends a short distance beyond the edge of the auger blade (which is why a 12 ft diameter shroud is utilized for vapor extraction).

Comment 10, Section 4.2, Critical Parameters, Page 26: Soil Properties/Mixing Rate: This section should discuss what the soil properties are that dictate design parameters, and what the penetration rate, angle of repose for the mixing blades, and auger terminus is expected to be based on these soil properties at this site.

Response 10: The specific penetration rate of the LDA, angle of repose for the mixing blade, and auger blade terminus are considerations for the equipment vendor based upon the SPT data provided as a CD attachment in the 90% RDR and which would be included in vendor bidding information. This information is also dependent on the specific torque of the equipment the vendor proposes to utilize to achieve project objectives. It is not the intent of the RDR to specifically detail this information, it is intended that the LDA vendors be made aware of subsurface conditions and that they select, based upon application experience, the appropriate penetration rate, angle of repose, and blade terminus to achieve project objectives. The 90% RDR does specifically mention the likelihood that "rock teeth" should be considered based upon the SPT-identified hard layers present. A copy of available geotechnical data for soils will be included in the 90% RDR in Appendix C.

Comment 11, Section 4.2, Critical Parameters, Page 26: The discussion entitled Concentration of VOCs in Extracted Vapor states "If the PID/FID data monitoring equipment becomes saturated due to the presence of high VOC concentrations and/or dense nonaqueous-phase liquids (DNAPLs) present in the subsurface, adjustments will be made in the field to compensate by adjusting the ascent/descent rate of the soil mixing, recalibration of the PID/FID equipment to a higher calibration standard to facilitate measurement, and/or introduction of additional bleed air to the system to provide for the adequate real-time monitoring of VOCs;" however, the decision criteria that will be utilized for these adjustments is not provided and/or referenced. Provide decision criteria for all in-field adjustments.

Response 11: The 90% RDR, Section 4.2 was revised to include decision criteria; however, based upon the results of the RDSI, it is unlikely that saturation of the monitoring equipment will be an issue.

Comment 12, Section 4.2, Critical Parameters, Page 26: Concentration of VOCs in Extracted Vapor: What is the maximum concentration of contaminants that can be treated by the above ground vapor treatment system? What is the PID/FID and GC sampling frequency?

Response 12: The vapor-phase granular activated carbon vessels (in series) are capable of providing treatment of approximately 1,800 pounds of VOCs (18 times more than the VOC mass calculated using the RDSI data and an EVS model described in the 90% RDR). There is no specific maximum vapor concentration that is problematic for this treatment system. However, once vapor-phase carbon has been saturated, the removal efficiency is depleted. Continuous monitoring of the air effluent from the vapor-phase carbon exhaust stack will be conducted to provide assurance that air emissions control measures are adequate throughout the operation. Further discussion regarding the air emissions thresholds and risks are described in Section 4.4. The treatment mass is based upon a typical 5:1 mass carbon to mass/VOCs removal rate and three 3,000-lb vessels in series. Section 4.4 also contains discussions concerning the vapor phase sampling frequency, processing, and control.

Comment 13, Section 4.2, Critical Parameters, Page 27: The discussion entitled ZVI Dosing Concentration provides PID/FID response criteria that will be used to determine the amount of ZVI delivered to an LDA boring location; however, information to substantiate the use of the PID/FID response criteria is not provided and/or referenced. Provide information to substantiate the use of the PID/FID response criteria for the determination of the amount of ZVI to be delivered to an LDA boring location.

Response 13: Corrective measures implementation reports, which demonstrate the successful application of the referenced criteria, are attached.

Comment 14, Section 4.2, Critical Parameters, Page 27: ZVI Dosing Concentration: What is the rationale for the planned ZVI dosing concentrations given in this section? It would appear that the statement, "higher weight ZVI slurry delivered to the perimeter ring of mixing locations" contradicts the dosing criteria given in the following three bullets, as it would not be expected that the highest concentrations would be in the perimeter ring of mixing locations (Figure 4 shows that the perimeter ring is just outside of the area determined to contain soil concentrations greater than the cleanup criteria, where PID/FID readings during treatment may be expected to be less than in soils that are more heavily contaminated).

Response 14: The higher weight ZVI slurry at the perimeter was intended to serve as a best management practice, similar to early deployments of the technology. The increased ZVI dosing around the perimeter ring of mixing locations has been eliminated in the 90% RDR, which is consistent with more recent LDA soil mixing project implementations.

Comment 15, Section 4.2, Critical Parameters, Page 27: ZVI Dosing Concentration: What is meant by, "after subtracting the methane value"? Why is it tied here to the PID/FID criteria while not included in other criteria that are based on PID or FID readings?

Response 15: The “after subtracting the methane value” is included simply because a PID does not measure methane, but an FID does. Accordingly, the text is making it clear that any considered FID response should be the methane-corrected value. The language pertaining to the “subtraction of the FID methane value, if present” was added in the 90% RDR to other areas of the document where criteria are based on PID/FID readings. The intent of the language is to avoid inadvertently implementing a stronger ZVI dose based upon a naturally occurring methane response.

Comment 16, Section 4.2, Critical Parameters, Page 27: Contaminants of Concern: This paragraph states that other contaminants that are not VOCs and cannot be treated by this technology, have been identified within the SWMU 1 boundaries. Are any of these contaminants located within the target treatment area? Treatment sequencing details for these contaminants are not included in Section 1.4 (see comment 2).

Response 16: Please refer to the response to EPA Specific Comment #2 for a discussion of the modifications made to Section 1.5 and 4.2 concerning the measures for coordinating the soil mixing with the Soils Operable Unit scope.

Comment 17, Section 4.3, Design Requirements, Page 27: This section states what is needed for a design, but does not include a design based on these requirements.

Response 17*:* The 90% RDR, Sections 3 and 4, as revised, specifically addresses the bulleted elements identified.

Comment 18, Section 4.3, Design Requirements, Page 27: The ninth bullet of this section states that the design requires an absence of low-volatility co-contaminants. However, the last paragraph of Section 4.2 states that of contaminants of concern in SWMU 1 include PAHs, radionuclides and heavy metals, which are commonly of low volatility. How will this affect the remediation?

Response 18: The 90% RDR details how the low-volatility co-contaminants will be excavated prior to LDA implementation. Specific verbiage has been added to Section 1.5 concerning the presence of contaminants and what is necessary to prevent impacts to the treatment equipment and process. Specific actions that will be utilized to reduce or minimize impacts of co-contaminants include the removal of the top 2 ft of soil in the mixing area.

Comment 19, Section 4.4, Process Description, Page 28: The second paragraph of this section states that steam ‘and/or’ hot air will be injected during the remediation. Other sections of the document indicate that both will be injected. Please clarify.

Response 19: The referenced text has been revised in the 90% RDR to reflect steam and hot air will be injected.

Comment 20, Section 4.4.1.2, Hot air/steam generation and delivery system, Page 29: What is the temperature of the hot air that is to be injected? Will the injection temperature be monitored?

Response 20: Section 4.4.1.2 of the 90% RDR has been revised to indicate that the temperature of the hot air/steam will be a minimum of 385ºF and will be monitored during injection.

Comment 21, Section 4.4.1.2, Hot air/steam generation and delivery system, Page 29: The first paragraph of this section states that the maximum operating pressure for the hot air injection system will be 150 pounds per square inch gauge (psig). The second paragraph of this section states that the minimum steam temperature will be 385^{o}F, and the injection rate will be 8,000 to 14,000 pounds per hour at a maximum operating pressure of 135 psig. These operating pressures for injection of air and steam at a maximum depth of 60 feet bgs seem excessive. For a steam injection extraction (SEE) system, where steam is injected in some wells to flow laterally through the subsurface to extraction wells, the maximum steam injection pressure is generally less than 0.5 psi per foot of overburden pressure, in order to avoid fracturing the soil and short circuiting the steam to the ground surface. Based on that, it seems that the very high pressures used here for injecting steam and air would short circuit the steam and air to the soil surface not far from the injection point, rather than distributing it throughout the soil column.

This is one of the reasons EPA believes it is important to demonstrate through a performance optimization study that the soil throughout the column is being heated. This could be done by obtaining continuous soil cores soon after a column of soil has been treated and checking the temperature of the soil.

Response 21: The operating parameters described above have been demonstrated at other sites (implementation reports attached). LDA is not a Steam Enhanced Extraction (SEE) system with an objective of lateral flow intended not to exceed the overburden pressure, and with injection applications, lasting for months. The LDA technology is a highly aggressive technology, which results in a hot air/steam front that travels up the LDA auger borehole (with minimal lateral spreading/treatment). Comparing SEE to LDA is not appropriate. Based upon the existing record of successful applications of the LDA technology, a performance optimization study is not warranted.

Comment 22, Figure 5, Process Flow Diagram, Page 30: The addition of guar gum should occur after pretreatment of the source water occurs and the water is sent to the steam generator. Figure 5 currently implies that source water treated with guar gum could be sent to the steam generator. Revise Figure 5 to address this error.

Response 22: Figure 5 has been modified in the 90% RDR to correct this error.

Comment 23, Section 4.4.1.3, Off-gas extraction and vapor conditioning system, Page 31: The first paragraph of this section states that "The shroud will provide the ability to capture off-gases beyond the diameter of the drilling blades." What will be the size of the shroud? What is its expected radius of influence? What monitoring will be conducted to ensure that the design capture radius is being achieved in the field?

Response 23: The 90% RDR includes text that indicates that the shroud will be a minimum of 12 ft in diameter. The shroud provides a vacuum ROI of 12 ft. The shroud vacuum is continuously monitored during implementation to ensure that the vapors traveling up the LDA borehole are captured.

Comment 24: Section 4.4.1.4, Vapor Treatment System (Vapor-Phase Carbon Adsorption), Page 31: The text states that "GAC vessel change out, if required, will occur when GAC breakthrough is documented, as indicated by a spike in the measured air exhaust concentration/PID or FID response, compared to previous measurements." However, it is not clear what is meant by "a spike in the measured air exhaust concentration/PID or FID response." Clarify what is meant by "a spike in the measured air exhaust concentration/PID or FID response."

Response 24: The 90% RDR text has been revised to provide clarification with regard to what air exhaust change following the initial GAC vessel in series represents a "spike in concentration." The "spike" will be specifically described as an increase in initial GAC vessel exhaust concentrations to a level that is within 50% of influent concentrations, suggesting that breakthrough has occurred in the initial GAC vessel. Please note that the second vessel still provides treatment.

Comment 25, Section 4.4.1.6, Real-time data collection and monitoring system, Page 32: Please specify how each of these parameters listed will be monitored and recorded.

Response 25: The specific frequencies of data collection, monitoring, and associated documentation for each parameter have been added to the 90% RDR. Section 6.1 provides a specific discussion for each parameter.

Comment 26, Section 4.4.2, Implementation Sequence, Page 33: This section states that ZVI slurry in the perimeter ring will provide treatment to ground water that is displaced outward during implementation. How will ground water be monitored to ensure that the ZVI slurry is providing adequate treatment and contaminants are not being displaced outward at concentrations exceeding the cleanup criteria?

Response 26: The ZVI slurry perimeter ring represents a conservative implementation approach that has been implemented (corrective measures implementation reports attached) in fully saturated aquifers to mitigate potential contaminant displacement during implementation. In consideration of the hydrogoelogic characteristics of the UCRS and hydrogeologic unit HU4, minimal groundwater displacement would be anticipated. Since the perimeter ZVI slurry approach has been used as a best management practice at other LDA sites, this approach was considered favorable for SWMU 1. Because of the site conditions present with little quantities of groundwater in the UCRS, monitoring is not warranted to ensure that the ZVI slurry is providing adequate treatment, and those contaminants are not being displaced outward at concentrations exceeding the cleanup criteria.

Comment 27: Section 4.4.2.1, Description of soil mixing and hot air/steam delivery procedure, Page 33: The second paragraph of this section states that "if warranted based on field conditions, a drilling mud may be utilized as a cutting fluid to assist in auger advancement in the formation." What field conditions would warrant the use of drilling mud? What effect will the use of drilling mud have on the thermal treatment process? On the ZVI injection process?

Response 27: The language regarding the use of drilling mud allowance has been included to provide flexibility to the LDA contractor. The field conditions that could warrant the drilling mud would be a very dense layer or soils with a high friction coefficient where the injection of a drilling mud assists with achievement of LDA penetration. The drilling mud has no negative effect on thermal treatment processes, and, as previously indicated by EPA, the rate of steam injection is substantial. The drilling mud also has no impact on the ZVI injection process since the mixing blade provides the mechanism for distribution within the soil column.

Comment 28, Section 4.4.2.1, Description of soil mixing and hot air/steam delivery procedure, Page 33: What is the basis for setting 100 ppm as the low VOC concentration target threshold? Why are the completion criteria being based on FID measurements rather than PID or GC measurements? What is the basis for setting a maximum treatment time of 240 minutes?

Response 28: The basis for the referenced procedures/time frames is based upon previous successful LDA implementations (implementation reports attached). The completion criteria in the 90% RDR will be modified to reflect that it is based on FID/PID or GC measurements. The maximum treatment time of 240 minutes represents a realistic endpoint that facilitates effective project implementation costing.

Comment 29, Section 4.4.2.1, Description of soil mixing and hot air/steam delivery procedure, Page 34: The fifth paragraph of this section states that, "to obtain completion criteria of an FID concentration less than 80% of the highest peak FID value obtained during the first pass". What is this criteria based on? It seems that if the FID reading is high during the first pass, then a reading during subsequent passes as high as or even close to 80% of the peak would be an indication that significant contaminant mass is still being recovered, and it is likely beneficial to continue the steam/hot air treatment until there are further reductions in the amount of contaminant mass being released from the soils. Although ZVI injection will be used as a secondary or 'polishing' treatment technology, it is recognized that steam/hot air injection is the more effective treatment, and it should be continued to be employed while it is still being effective at recovering a large amount of contaminant mass.

Response 29: The criteria is based upon the successful application of the LDA technology using similar criteria at other sites with higher concentrations than those present at SWMU 1 (implementation reports attached). In the 90% RDR, the FID reading has been reduced from 80% to 50% of the peak FID reading to provide for an increase in the required mixing.

Comment 30, Section 4.4.2.1, Description of soil mixing and hot air/steam delivery procedure, Page 33: The sixth paragraph of this section provides two alternatives for determining what the Low VOC concentration target threshold should be for this site. It is not recommended that field-screening PID readings from soil cores that are at ambient temperatures be the basis for determining the target threshold at treatment temperatures.

Response 30: As requested, the reference to field-screening PID readings from soil cores that are at ambient temperature has been deleted from the 90% RDR.

Comment 31, Section 4.4.2.1, Description of soil mixing and hot air/steam delivery procedure, Pages 33-34: Section 4.4.2.1 provides three categories for the cell treatment protocol; however, the basis for this decision criterion is not provided and/or referenced. Provide the basis for the decision criterion.

Response 31: The basis for the cell treatment decision criterion is based upon a set of protocols that has been successfully implemented at other project sites (implementation reports attached).

This comment did not result in a change to the document.

Comment 32, Section 4.4.2.2, Description of ZVI Dosing, Page 34: What is the rationale for the criteria for determining the weight percent of ZVI that will be applied in a given cell? How has it been established that this procedure for injecting the ZVI will distribute the slurry throughout the soil column?

Response 32: The rationale is based upon the successful application of the technology at other sites. The distribution of the ZVI slurry throughout the soil column also has been successfully demonstrated (implementation reports attached). Section 4.4.2.2 has been modified to indicate the source of the dosing process.

Comment 33, Section 5.1 and 5.2, Page 35: These sections contain only lists of the Construction Equipment and Soil Mixing Equipment. Where are the specifications for the Construction Equipment and Soil Mixing Equipment provided?

Response 33: Detailed specifications for the construction equipment and soil mixing equipment beyond those provided are not warranted. The objective is to provide LDA contractors with a general listing of required equipment to meet project objectives. The 90% RDR includes additional information regarding equipment; however, it is not intended or desired for the document to include rigid specifications.

Comment 34, Section 6.1, Sampling and Monitoring During Soil Mixing, Page 33: How will all of these parameters be monitored during the remediation? Will monitoring to ensure that contaminants are not being pushed out of the treatment area be performed?

Response 34: Section 6.1 of the RDR has been expanded to document the frequencies of individual parameter monitoring and recording of the collected information. Monitoring outside the treatment area will not be performed, except during the postremedial investigation following treatment. See comment response to EPA General Comment 5.g, for further information.

Comment 35, Section 6.2, Sampling and Monitoring Postremedial Action, Page 37: Section 6.2 does not commit to monitoring for at least one 5-year assessment period following ZVI treatment to account for rebound, dissipation of injectants, and stabilization of groundwater conditions. As a result, sufficient data to evaluate the performance of the groundwater remedies will not be available for the Five Year Review Report. Ensure sufficient monitoring is conducted for at least one 5-year assessment period following ZVI treatment to account for rebound, dissipation of injectants, and stabilization of groundwater conditions.

Response 35: Section 6.2 of the RD report provides some general components for postremedial monitoring, but also commits to the development of Postremedial Sampling and Analysis section in the Remedial Action Work Plan, with specifics on boring approach, locations, sampling, and contaminant analysis. The Postremedial Sampling and Analysis Section, along with other sections, will provide the necessary information to support the completion of the Five-Year Reviews, as committed to in the signed ROD and required by CERCLA, but which are not considered a component of the selected remedy.

Commonwealth of Kentucky

Comment 1, Treatment System Objectives, Section 1.4, Page 19: The stockpiling of surface soil prior to the initiation of remedial activities is mentioned here. It seems unavoidable that excavation and subsequent re-depositing of soil in the area to be treated will have a negative effect upon characterization efforts as documented in the Soils Operable Unit RI Report for SWMU 1. The proposed action will likely have the effect of rendering current characterization data and associated risk calculations null and void. DOE should strongly consider disposing of these soils rather than simply placing them back on the ground so that they will need to be re-characterized to support future action under the Soils OU.

Response 1: Please also refer to the comment response to USEPA Specific Comment 2 and the revised text of Section 1.5 (previously Section 1.4) of the RD. DOE recognizes that moving the soils will necessitate a recharacterization of the mixed area as part of the Soils OU at the appropriate time in the future.

Comment 2, Critical Parameters, Section 4.2, Page 24: The discussion of a downhole thermocouple to monitor subsurface temperatures seems to suggest that only one thermocouple will be in use, although measurements and monitoring will presumably be needed at multiple depths. Please provide further information on how such measurements will be taken, whether multiple thermocouples will be needed, and at which depths measurements will be taken.

Response 2: Language was added to the 90% RDR text to clarify that there will be a thermocouple on the topside of the auger blade and two thermocouples on the vapor shroud in the off-gas stream. The text will indicate that the thermocouple data will be collected on a continuous basis during LDA operations. However, the data from the downhole thermocouple will not be available on a real-time basis, but rather will be evaluated on a daily basis. This is due to technology limitations preventing the direct reading of real-time data from the thermocouple located upon the auger.

Comment 3, Percentage of Auger Boring Overlap, Section 4.2, Page 24: The reference to experience with this remedial alternative at other sites and the adding of 10 degrees Fahrenheit to the shroud gas temperature needs to be referenced.

Response 3: Corrective measures implementation reports documenting this approach are attached.

Comment 4, Figure 4, Page 25: Figure 4 depicts various conceptual options for overlapping large diameter augers (LDAs). Kentucky believes that the 17.5% overlap option provides the best approach to the placement of LDAs regardless of the field PID readings obtained. Please consider using the 17.5% overlap approach for the 90% Remedial Design Report.

Response 4: The 17.5% overlap is considered a conservative overlap and was, therefore, reserved for the area with highest VOC concentrations in soil. It should be noted that the radius of influence of the injected steam extends beyond the auger blade; accordingly, even with 0% overlap, effective treatment has been documented in post-LDA confirmatory sampling at Cape Canaveral Air Force Station. The additional costs for applying a 17.5% overlap at all LDA locations is not warranted based upon the concentrations of VOCs present and the documented effectiveness of LDA at sites with reduced overlap.

Comment 5, Critical Parameters, Section 4.2, Page 26: The use of PID measurements to guide the direction of remedial efforts at depth may be somewhat compromised by there being no seal between the ground surface and the shroud intended to contain vapors generated by the soil mixing process. Fluctuations in the volume of air and steam injected into the system as well as the introduction of outside air cannot help but influence PID concentrations obtained in the field. A more conservative approach to implementing the soil mixing would be to maintain the 17.5% overlap as discussed above.

Response *5:* The weight of the 12-ft diameter (min) steel shroud provides an adequate surface seal to contain vapors and mitigate short-circuiting of ambient air into the shroud. Additionally, the measurement of shroud vacuum to confirm the seal at ground surface provides a mechanism for testing the shroud and, if necessary, adjusting the shroud to provide the required vacuum. While some variability, would be expected in PID/FID response due to the various variables present, it has been demonstrated to be an effective tool for providing real-time, measurable results. As described in the Response to Comment 4, there is no need to provide an overly conservative additional overlap simply to account for potential PID/FID variability.

Comment 6, Figure 5, Page 30: The Process Flow Diagram depicted in Figure 5 shows the treatment and disposal of air stripper effluent as well as COC monitoring of steam, air, and organic vapors emitted from the blowers following the filtering of this flow through carbon bed filters. Please provide additional detail regarding how treated vapors will be monitored prior to release to the atmosphere. The Kentucky Division of Air Quality (DAQ) is likely to require an air monitoring and system as robust as that used to monitor gaseous discharges associated with the C-400 Remedial Action. This system requires the use of a photoacoustic analyzer at the stack. DOE should be aware that DAQ may also require air modeling to determine acceptable air concentration thresholds levels at the point of discharge.

Response 6: The vapor-phase polishing system will consist of three vessels in series that will remove VOCs from the effluent air. The units will contain granular activated carbon to remove extracted VOCs (primarily TCE) from the air. Off-gas from the vapor-phase polishing system will be discharged to the atmosphere through a 20-ft tall by 8-inch diameter stack. Off-gas emissions will be monitored by a photoacoustic analyzer. The analyzer will communicate with a control system to notify operations personnel in the event of an exceedance of discharge criteria. The set point at the stack that will cause the vapor extraction and treatment system to shut down is 20 ppmv of any VOC of concern. This is based on the air dispersion modeling results included in the 90% design report. The air dispersion modeling results indicate that a stack concentration of 20 ppmv results in property boundary concentrations that are significantly lower than the off-site limits; thus, the system will be shut down before emissions reach the quantities that will exceed acceptable risk levels.

Comment 7, ZVI Dosing Concentration, Section 4.2, Page 27: The decision process for determining ZVI slurry mixtures is not clear. Additional discussion of the perimeter ring of mixing locations is needed.

Response 7: The decision process for ZVI loading was based upon successful applications at CCAFS and former Offutt AFB. Following initial testing of LDA equipment in an area of elevated TCE concentrations to confirm equipment operations, the LDA will complete the perimeter ring of mixing location. By performing LDA mixing at the perimeter locations, any fluids potentially displaced during the performance of LDA remediation within the treatment zone have a high potential for contacting the ZVI material within the perimeter ring, providing for flux control during implementation (serves as a best management practice). The 90% RDR has been revised to reflect the perimeter ring implementation sequence.