INTEGRATING MARSSIM AND TRIAD TO ACHEIVE RADIOLOGICAL SITE CLEANUP AND CLOSURE

R. L. Johnson, L. A. Durham
Argonne National Laboratory
9700 South Cass Avenue, Argonne, IL 60430

J. Hummel, C. R. Rieman
U.S. Army Corps of Engineers Buffalo District
1766 Niagara Street, Buffalo, NY 14207

ABSTRACT

The U.S. Army Corps of Engineers (USACE) is conducting cleanup of radiologically contaminated properties as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP). USACE is using guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) for establishing that sites satisfy site-specific cleanup requirements. While MARSSIM's focus is on final status surveys and site closure, it also provides an overall framework for initial site characterization and remediation. More recently, the U.S. EPA has presented the Triad approach as a means for streamlining data collection at hazardous waste sites and addressing decision uncertainty. The Triad refers to the combination of the following: 1) systematic planning, 2) dynamic work plans, and 3) real-time measurement technologies. Within the radiological cleanup world, MARSSIM also recognizes and embraces the value of real-time measurement systems. The Rattlesnake Creek FUSRAP site provides an excellent example of how MARSSIM, combined with Triad concepts, can be used to accelerate the characterization, remediation, and closure process at a hazardous waste site, while addressing key site-specific issues such as subsurface contamination, and sparse historical data sets. At Rattlesnake Creek, the USACE developed site-specific Derived Concentration Guideline Level (DCGL) requirements consistent with MARSSIM in response to unexpected contamination, and an Explanation of Significant Differences was prepared for the Record of Decision to address these new concerns. Systematic planning targeted the area of concern and identified data gaps to be addressed before remediation plans were finalized. Pre-remediation sampling and analysis plans were designed to be explicitly consistent with final status survey requirements, allowing data sets to support both excavation planning needs and closure requirements in areas where contamination was not encountered above DCGL standards. Judicious use of real-time technologies such as x-ray fluorescence (XRF) and gamma walkover surveys minimized expensive of off-site alpha spectrometry analyses, while at the same time providing the ability to respond to any unexpected field conditions.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) is conducting cleanup of radiologically contaminated properties as part of the Formerly Utlilized Sites Remedial Action Program (FUSRAP). USACE is using guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) for establishing that sites satisfy site-specific cleanup requirements (EPA 2000). While MARSSIM's focus is on final status surveys and site closure, it also provides an overall framework for initial site characterization and remediation that mirrors the Comprehensive Environmental Response, Compensation, and Liability Act's (CERCLA) process.

More recently, the U.S. Environmental Protection Agency (EPA) has presented the Triad approach as a means for streamlining data collection at hazardous waste sites and addressing decision uncertainty in a cost-effective manner. The Triad refers to the combination of the following: 1) systematic project planning, 2) dynamic work strategies, and 3) real-time measurement technologies. For sites contaminated with radionuclides, MARSSIM also recognizes and embraces the value of real-time measurement systems and field-deployable analytical techniques where appropriate.

The Rattlesnake Creek FUSRAP site provides an example of how the Triad, executed within a MARSSIM closure framework, can be used to accelerate the characterization, remediation, and closure process at a hazardous waste site. In particular, a Triad approach at Rattlesnake Creek provides a cost-effective process to address key site-specific issues that include sparse historical characterization data, subsurface contamination, difficult-to-measure contaminants of concern, and accelerated schedules.

MARSSIM AND THE TRIAD

MARSSIM provides an overall framework for conducting data collection programs (also known as final status surveys) to demonstrate compliance with site closure requirements. The MARSSIM framework is intended to have inter-agency concurrence and support, to be technically defensible, to have sufficient inherent flexibility to handle site-specific requirements, and to be performance-based. MARSSIM assumes that sites have risk or dose-based standards that must be met, and that there is a site-specific dose or risk pathway model that can convert these standards into activity concentration equivalents. MARSSIM calls these Derived Concentration Guideline Levels (DCGLs). MARSSIM presumes that there will be two different types of DCGL requirements, a wide-area average requirement called the $DCGL_w$, and an elevated area (or hot spot) requirement called the $DCGL_{emc}$. The site is divided in to survey units and the DCGL requirements are applied to individual survey units.

MARSSIM manages decision uncertainty in the closure process through the use of statistically-designed sampling programs and the application of non-parametric statistical techniques. In this context, project managers and stakeholders can set performance goals for acceptable Type I and Type II (false positive and false negative) decision error rates, and then design data collection programs to ensure that these goals are achieved. For the $DCGL_w$, this means calculating the appropriate number of samples based on the desired statistical test, existing information about the distribution of contamination across a site, and desired maximum error rates. For the $DCGL_{emc}$, this means either establishing an investigation level for a particular scanning technology so that the $DCGL_{emc}$ can be detected at some prescribed certainty level, or, if a suitable scanning technology does not exist for the contaminants of concern, calculating sampling grid densities so that an elevated area with the size associated with the $DCGL_{emc}$ will be detected at some prescribed level of certainty.

For radiologically contaminated sites, there is a long history of using scanning, screening, and direct measurement technologies for characterization work. These technologies span a range of analytical quality, including on the one extreme, less definitive but quick and cost-effective mobile gross gamma surveys that can provide 100% coverage of exposed soil surfaces. In recent years, these gross gamma scan detectors have been coupled with Global Positioning Systems (GPS) and data loggers to enhance their effectiveness, and to provide a means for recording the measurements for later analysis and documentation. On the other extreme are relatively definitive *in situ* gamma spectroscopy measurement systems that can provide radionuclide-specific estimates of activity concentrations contained in soils and other materials. These types of technologies all share the common characteristic of being able to provide measurement results in "real-time".

MARSSIM recognizes and endorses the use of real- time measurement technologies as part of the closure process. In fact, MARSSIM assumes that the preferred methodology for establishing compliance with $DCGL_{emc}$ requirements is through the use of scanning technologies, if an appropriate technology exists. Likewise, there is nothing in MARSSIM that prevents the substitution of *in situ* direct measurement results for discrete sampling to establish compliance with $DCGL_w$ requirements, if one can establish that the direct measurement technique will provide data of suitable quality.

The Triad approach arose as a result of the technology advances in real-time measurement techniques developed during the last decade. Unlike the radiological world, reliable field-deployable analytical and direct measurement systems for chemical contaminants have only recently become available. For Superfund Sites being remediated under CERCLA, a first generation approach to managing decision quality assumed that decision quality was equivalent to laboratory analytical quality for environmental sample analyses. Experience since the inception of CERCLA has repeatedly demonstrated, however, that significantly greater uncertainty is injected into the decision-making process by the sparseness of data (i.e., sampling uncertainty) rather than by the quality of analytical methods (i.e., analytical uncertainty) and their associated sample results. This has led to the Triad's emphasis on a second generation approach to managing decision quality, with the use of more cost-effective and perhaps less definitive, methods to increase data density. The increase in data density will improve overall decision-making quality, while balancing analytical uncertainty with sampling uncertainty. The Triad approach makes use of systematic planning techniques to determine the most cost-effective data collection approach to satisfy decision-making needs.

The Triad approach also recognizes that many of the newer, field-deployable techniques enable the production of "real-time" data, i.e., data that are available quickly enough to have an impact on the progress of field work. The availability of real-time information can significantly improve the efficiency of characterization and remediation work by keeping efforts as focused on programmatic objectives as possible, changing the direction of work in response to unexpected field conditions as they are encountered. The Triad exploits these potential efficiencies by incorporating real-time measurement technologies within a dynamic work strategy. Dynamic work strategies can be used in characterization, remediation, and monitoring programs.

For radiologically contaminated sites, MARSSIM provides a natural framework for executing a Triad approach to characterizing, remediating, and obtaining site closure.

MARSSIM provides the overarching guidance for how the closure process should be designed. With its implicit flexibility, emphasis on performance-based approaches, and recognition of real-time techniques, MARSSIM facilitates the implementation of Triad-based decision-making. The net result is the ability to deploy streamlined, cost-effective, and technically defensible data collection programs that can be tightly integrated with the overall remediation and closure strategy.

CASE STUDY

The Rattlesnake Creek FUSRAP site provides an example of how the Triad can be implemented within a MARSSIM framework. Rattlesnake Creek is located in Tonawanda, New York, and the remedial action is being managed by the USACE Buffalo District. Rattlesnake Creek is an ephemeral stream that drains three other FUSRAP sites, the Ashland 1 and 2 sites and the Seaway site. All three sites contained surface and subsurface soils contaminated with radionuclides. The primary radionuclides of concern are uranium-238, radium-226, and thorium-230 and their respective radioactive decay products. For the Ashland sites, a site-specific cleanup guideline of 40 pCi/g thorium-230 was developed and adopted for the radionuclides in soils. The Ashland 1 and 2 sites have recently undergone remediation and closure. Remediation consisted of identifying, excavating, and shipping offsite to a permitted disposal facility those soils that exceeded the site-specific thorium-230 guideline (USACE 1998).

The remedial investigation work originally conducted for Ashland 1 and Ashland 2 did not identify Rattlesnake Creek as an area of concern. However, as remediation work at the Ashland 2 site proceeded, it became clear that contaminated soils had also been carried into the streambed and deposited as sediments within the primary stream flood plain. Additional investigative work demonstrated that contaminated sediments were more extensive than previously thought, extending for approximately one mile down the length of the streambed. The results of the sampling also confirmed that the creek contained radionuclide contamination that had originated from the Ashland and Seaway properties. However, the distribution of the radionuclides of concern in the sediments of the creek is different than the distribution of those same radionuclides in the soils at the Ashland sites as a result of the way the material was transported and differences in solubility of the radionuclides and dilution. In order to address the different distribution of radionuclides of concern in the Rattlesnake Creek sediments, USACE developed site-specific derived DCGLs for use in the field during the remediation of the Rattlesnake Creek area.

An Explanation of Significant Differences (ESD) (USACE 2003) was prepared for the Rattlesnake Creek Portion of the Ashland sites to address this additional contamination and to document the DCGLs. The DCGLs were derived by using RESidual RADioactivity computer code (RESRAD) version 6.10 (USACE 2003). The overall remediation and closure process is expected to be completed consistent with MARSSIM.

A primary issue is the limited historical data available for designing a remedial action for the site, and in particular, for estimating the volume and associated footprint of contaminated sediments that would require excavation and off site disposal. A walk down of the creek bed and associated civil survey determined that the potential depositional area that might have been impacted and exceed the DCGL standards includes 41,000 square meters of surface area. Assuming that contamination might potentially extend to a depth of two feet, the estimated volume of contaminated soil/sediments is 33,000 cubic yards. The actual contaminated volume is likely to be significantly less than this based on historical sample results, but was unknown.

A second issue that complicates the Rattlesnake Creek remedial action is the fact that the contaminated sediment layer is in many places covered by more recent sedimentation. This (and the nature of the stream bed itself) makes gamma walkover surveys relatively ineffective for determining the presence and extent of contamination along the length of the stream bed. Gamma walkover surveys were very effective at the Ashland 1 site in providing volume estimates, determining the exact location of contamination footprints, and providing data to demonstrate meeting the closure requirements (in addition to the discrete samples).

The third issue for Rattlesnake Creek is the contaminants of concern. Like Ashland 1 and 2, thorium-230 is the principal contaminate for Rattlesnake Creek, and the thorium-230 DCGL values drive the remedial efforts. However, at its DCGL levels, thorium-230 is not identifiable in the field with currently available real-time measurement technologies. Quantitative estimates of thorium-230 at DCGL levels require alpha spectroscopy, an expensive and time-consuming procedure usually conducted in a fixed laboratory setting. At Ashland 1 and Ashland 2, there was sufficient collocated radium-226 with the thorium-230 to allow the use of gamma walkover surveys to determine contamination footprints. However, the relative ratios of radionuclides are different for Rattlesnake Creek, precluding the use of gross gamma sensing techniques for determining the presence or absence of thorium-230 at its cleanup levels with radium-226 as a surrogate.

The remedial strategy developed for the Rattlesnake Creek site to address these issues includes several components:

- A Final Status Survey (FSS) plan was developed for the potentially impacted area of the creek bed, consistent with MARSSIM guidance. It lays out the data needs required to demonstrate compliance with DCGL standards for each type of survey unit, and also describes a general strategy for how these data will be collected.

- Upon completion of the FSS plan, a pre-excavation Field Sampling Plan (FSP) was developed. The purpose of the FSP is to provide data that would support better contaminated volume estimates, and provide more definitive excavation footprints. The pre-excavation FSP was written to be consistent with the FSS plan. The intent of the FSP was to ensure that data collected during pre-excavation sampling could be used for FSS purposes in the event that no contamination above DCGL levels was encountered for particular areas.

The sampling and analysis strategy for both the pre-excavation and FSS data collection emphasize real-time data collection and in-field decision-making as part of a dynamic work strategy to the extent possible. Both the FSS and pre-excavation FSP require collecting data to a depth of 3 feet at each sampling location to ensure that any potential subsurface sediment contamination would be identified. The base-line approach is to submit each six-interval for off-site alpha spectroscopy analysis, which is extremely expensive, and would not allow for information about the contamination status of areas being sampled to be available during the data collection process.

The alternative was to find a surrogate for thorium-230 that could be addressed using real-time techniques. The surrogate selected was total uranium present and the real-time technique x-ray fluorescence (XRF). A review of existing sample results revealed that almost all samples with thorium-230 results greater than the DCGL had total uranium values greater than 90 ppm. The majority (>80%) of samples that had a total uranium value greater than 300 ppm also had thorium-230 greater than DCGL requirements. Total uranium results between 90 and 300 ppm were not conclusive regarding the presence or absence of thorium above its DCGL requirements. Uranium at these levels in soil cores/samples is difficult to detect with gamma sensing equipment in the field, but is well above the detection capabilities of XRF. XRF had been used for characterizing soil uranium concentrations at a nearby Department of Energy site in Ashtabula, Ohio, with excellent agreement between XRF results and those from gamma spectroscopy analyses.

The dynamic strategy employs screening each six inch interval of soil cores with an XRF in the field for the presence of uranium. Locations that have all soil core intervals less than 90 ppm total uranium are deemed ready for more definitive FSS sampling that includes alpha spectroscopy analysis of a surface sample and a sample homogenized over the length of the core representative of the subsurface. Locations that yielded one or more core intervals greater than 300 ppm total uranium were identified as requiring remediation. Locations where the highest core interval total uranium value was between 90 and 300 ppm were deemed suspect, and a sample sent from that interval for more definitive alpha spectroscopy analysis.

Since the performance of the XRF is critical to the overall performance of the proposed strategy, a methods of applicability study was performed prior to the initiation of field work. This study made use of selected archived samples from previous characterization activities at the Rattlesnake Creek site. Archived samples were selected for XRF analysis based on their previously reported total uranium values, with samples specifically targeted that had total uranium values between 50 and 200 ppm. The purposes of the study demonstrated that practical detection capabilities were well below 90 ppm for total uranium and identified any potential interferences or complications from site soil matrices that might affect system performance. During pre-excavation sampling work, samples with total uranium results between 90 and 300 ppm were to be sent off for alpha spectroscopy analysis. The results from these samples were to be used both to verify the presence or absence of thorium-230 contamination above DCGL requirements, and to monitor the performance of the 90 and 300 ppm investigation levels as surrogates for thorium-230.

- The results from the pre-excavation sampling will be used either to define the excavation footprint (for those areas where contamination at levels of concern was encountered), or to support the FSS process (for those areas where there was no evidence of contamination at levels of concern). Post-excavation, additional FSS sampling will be conducted over the exposed dig faces to establish DCGL compliance

The overall objective of the dynamic work strategy is to expedite remediation and closure of the Rattlesnake Creek area with as little redundant data collection as possible, as cost-effectively as possible, and in a manner that provides the USACE Buffalo District with sufficient pre-excavation data to make accurate project planning decisions. The current status of the Rattlesnake Creek effort is that the ESD, the pre-excavation FSP, and the FSS plan have all been submitted to stake holders for review and comment. Pending approval, field work for the pre-excavation data collection is slated to begin as early as possible in 2004.

CONCLUSIONS

Using a Triad approach within a MARSSIM framework provides a means for expediting and making more efficient the decision-making and data collection process at radionuclide-contaminated sites. Rattlesnake Creek provides an example of how the two can be implemented in tandem to better integrate pre-remedial design, remediation support, and FSS data collection. The use a Triad approach in this particular setting is expected to cut overall analytical costs by at least a factor of three as compared to the base-line by minimizing the number of samples requiring alpha spectroscopy analysis, and allow remedial design and subsequent excavation to proceed in a more expeditious manner than would have been possible otherwise.

REFERENCES

1 EPA, 2000, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, EPA 402-R-97-016, Rev. 1, August.

2 USACE 1998, *Record of Decision for the Ashland 1 (including Seaway Area D) and Ashland 2 Sites, Tonawanda, New York*, April.

3 USACE 2003, *Explanation of Significant Differences for the Rattlesnake Creek Portion of the Ashland Sites*, Tonawanda, New York, Oct.