# HYPERSPECTRAL REMOTE SENSING OF SRS CAPPING SYSTEMS

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Abstract: Aerial remote sensing was conducted over the SRS Mixed Waste Management Facility and the Low Level Radioactive Waste Disposal Facility using the AVIRIS hyperspectral sensor system deployed by NASA. This sensor system provides data across a wide portion of the spectrum with very narrow band widths. Data were processed using a variety of traditional and innovative techniques to analyze the spectral signatures derived from the vegetative cover at these two facilities. Limited ground truth data were available for correlation with the remote sensing data, but substantial differences were evident across the caps. Numerous algorithms derived from the agricultural sciences proved useful in analyzing the data, as did several more novel approaches. Qualitatively, the analyses correlated with spatial differences in grass species composition, apparent vegetation density and other cap management attributes. Spectra derived from copper stressed bahia grass were also useful in analyzing the hyperspectral data, suggesting a more generic spectral response to stressors. Statistically significant correlations were obtained between certain spectral groupings and subsidence measurements on the two caps. These results indicate a significant potential for using aerial remote sensing data for monitoring the quality of the vegetative layer and possibly other parameters related to capping system functional performance.

Placement of low permeability closure caps is a common practice for the isolation of hazardous wastes in the US and throughout the world. Over the last decade, design and construction technology for cap systems has evolved, but the fundamental objective of isolating the hazardous materials from water fluxes remains the same. However, design criteria for many of the capping systems focuses on time horizons spanning a few decades, while in most cases the materials must be protected for centuries. There is a high likelihood that most existing caps will persist beyond their projected design life, but monitoring system performance becomes increasingly important as system components age and environmental influences challenge the integrity of the structure.

Traditional monitoring approaches involve a combination of perimeter monitoring wells to detect contaminant migration and periodic visual inspections to detect erosion, significant subsidence and the condition of the protective vegetative layer. More recently, installed subsidence monitors have been utilized for more

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rigorous examination of subsidence, while installed leachate collection systems and moisture detectors are used to assess moisture distributions through the system. Generally, such systems either have a coarse level of resolution for detecting anomalous system behavior, or detect problems only after a leak of potentially hazardous material has occurred.

In 1999, the Savannah River Site (SRS) was a test site for the NASA AVIRIS hyperspectral remote sensing system. The objective of the project was to determine whether hyperspectral imagery (HSI) had utility for detecting anomalies in two SRS capping systems that featured differing construction and maintenance histories. The cap at the Mixed Waste Management Facility (MWMF) was constructed in 1990 using a 2-3 ft thick clay cap overlain by native soil and planted in bahia grass. Subsequently, some areas have been overseeded with centipede grass. The Low Level Radioactive Waste Disposal Facility (LLRWDF) was partially capped in 1998 as part of an ongoing stabilization program. Prior to cap installation, part of the LLRWDF underwent 'dynamic compaction' to reduce void space. Rather than a thick clay liner, a geosynthetic liner was installed at the LLRWDF, as were gas vents. The LLWRDF system was completed with a surface of native soil and planted in bahia grass. Generally, the two systems have undergone similar maintenance with fertilization and mowing as necessary, and periodic burning to mineralize dead grass accumulations. Portions of both systems have installed subsidence monitors that are periodically resurveyed and visual inspections also occur.

The AVIRIS sensor was flown at an altitude of 3400 m with a nominal ground spatial resolution (pixel size) of 3.4 m. The sensor acquired data from 400-2500 nm with a nominal spectral resolution of 10 nm. Initial processing of the data included spatial and spectral corrections to the digital data. Further processing occurred using a wide variety of conventional and novel techniques, including a variety of techniques developed in the agricultural sciences.

The central hypothesis underpinning this work is that vegetation acts as an integrative sensor for conditions in the surface soil. Of particular interest in this case are differences in soil moisture across the cap surface which might be indicative of subsidence related pooling or channeling of water. An uneven distribution of water across the cap surface could be manifested through changes in vegetation condition, vegetation density, or plant species composition, any of which could produce changes in spectral signatures.

The results of the analyses indicated clearly detectable differences in spectral signatures across the two capping systems. Spectral data analyses and derived indices included Derivative Analysis, Yellowness Index, Physiological Reflectance Index, Normalized Difference Water Index, Normalized Difference Vegetation Index, Red Edge Position, and comparison with spectra derived from bahia grass that was experimentally stressed with copper. Ground level data that were available for comparison were limited to information from the subsidence monitors. All analytical approaches revealed differences in spectral signatures, and at a qualitative level, much of the information obtained appeared to be similar relative to the location of spectral anomalies.

All data were compared to the subsidence measurements with several showing statistically significant relationships: copper stress spectra, Normalized Difference Water Index, Derivative Analysis and the Normalized Difference Vegetation Index. Two notable features of these results are that the ‘stress’ signatures derived from the vegetation appear to be somewhat generic. Secondarily, the range of subsidence values that produced significant results was less than three inches, far less that would be cause for maintenance action, but a potential early indicator of need for closer observation. Discussions with facility O&M personnel indicate that some spectral signatures appear to also be related to differences in vegetation quality and composition.

Current studies are focused on obtaining additional HSI data using another, commercially available sensor. For this study substantial ground truth data on the caps will be collected to directly measure such factors as soil moisture and temperature, soil ‘quality’, and vegetation quality and composition. All data will be collected in a manner that will allow direct spatial correlation with the remote sensing data. Additionally, design, construction and maintenance data are being obtained. The objective is to derive direct correlations between the spectral signatures and quantitative phenomena on the ground.

It is anticipated that this technology can provide a cost effective, sensitive monitoring system for O&M personnel to allow early intervention in cap maintenance before problems such as subsidence or erosion progress to a point where major repair work is necessary. Additionally, early detection of anomalies in the surface system are expected to preclude significant moisture intrusion into the contained waste layer and potential future releases. Validation of this technology, and the continued development of more capable and cheaper sensor systems may also provide a component of the long term monitoring strategy for closure cap systems.