EXECUTIVE SUMMARY

This report summarizes the findings of an evaluation of the *in situ* Steam Enhanced Recovery Process (SERP). This technology was operated by Hughes Environmental Systems, Inc. at the Rainbow Disposal site in Huntington Beach, California. The Rainbow Disposal site is an active municipal trash transfer facility that was contaminated by a spill of diesel fuel from a crushed underground pipeline. The evaluation of this technology was conducted under the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program in conjunction with a full-scale remediation using SERP at the Rainbow Disposal site.

The EPA SITE program evaluated the SERP technology to develop full-scale process performance and cost data. The critical objectives for demonstration of the SERP technology were (1) to evaluate the ability of the technology to meet the cleanup requirement set by the Regional Water Quality Control Board for the site soil, based on soil sampling results, and (2) to perform a detailed economic analysis of this full-scale application of the technology.

Conclusions from the SITE Demonstration

Based on the SITE demonstration, the following conclusions can be drawn about the *in situ* SERP technology as applied to the Rainbow Disposal site remediation:

- The demonstration test results showed that the removal of contamination by the SERP technology was less complete than originally anticipated. Forty-five percent of the post-treatment soil sample results inside the treatment area were above the cleanup criterion (1,000 mg/kg [ppm] of total petroleum hydrocarbons, or TPH). Seven percent of the soil samples had TPH levels in excess of 10,000 mg/kg.

- A geostatistical analysis of the post-treatment soil data was conducted using a computerized model to assess the spatial variability of soil contamination and to determine a weighted average concentration of the soil results. From the

geostatistical model, a post-treatment weighted average soil concentration of 2,290 mg/kg of TPH was derived, with a standard error of 784 mg/kg. Based on an approximate normal distribution for the weighted average, the 90 percent confidence interval for TPH concentration is 996 mg/kg to 3,570 mg/kg. This large interval is because of the variability of site soil sampling results due to the heterogeneity of the *in situ* soil contamination; analytical variability was within established quality control limits and contributed little to overall data variability. According to this analysis, at 90 percent confidence, the true average is probably higher than the cleanup criterion of 1,000 mg/kg.

- The geostatistical analysis results for total recoverable petroleum hydrocarbons (TRPH) yielded a weighted average post-treatment soil concentration of 1,680 mg/kg, with a standard error of 608 mg/kg. The 90 percent confidence interval for the weighted average for TRPH is 676 mg/kg to 2,680 mg/kg. No cleanup criteria were set for TRPH. The TRPH analysis provides information similar to TPH but is performed using an EPA-approved method; the TPH method is widely used but is not an EPA-approved method.

- BTEX compounds were detected at low mg/kg levels in a few pre-treatment soil samples and were found at levels below the detection limit (6 μg/kg) in all post-treatment samples. Based on these results, the SERP technology may have effected removal of BTEX compounds from the *in situ* soil, but this is inconclusive due to the lack of positive BTEX results and the heterogeneous nature of *in situ* soil contamination at the site.

- Based on the weighted averages for pre- and post-treatment soil data sets determined from geostatistical analysis, the technology may have removed 40 percent of the contamination from the site soil. Due to the high site soil contamination variability, at 90 percent confidence the actual percent removal may have been significantly higher or lower. Calculation of percent removal was a secondary objective of the technology evaluation because pre-treatment data were collected by the developer before the initiation of a SITE program demonstration test Quality Assurance Project Plan (QAPP).

- Process data collected during treatment support the finding of a low to moderate removal efficiency. Approximately 700 gallons of diesel were collected in liquid form during treatment, while approximately 15,400 gallons were oxidized in the system's vapor treatment equipment. Therefore, a combined total of approximately 16,000 gallons of diesel were removed during treatment with SERP. Compared to the estimated initial diesel spill volume of 70,000 to 135,000 gallons, this represents a reduction of approximately 12 to 24 percent. This estimated removal is within the percent removal confidence interval for the soil data.

- The technology experienced significant amounts of downtime during treatment. All major equipment systems experienced problems during treatment. An on-line factor of 50 percent was experienced at this site for the technology application over the two years of treatment. Reliability in subsequent applications of the technology is expected to be higher since this was the first full-scale application of the technology.

- Based on soil temperature profiles from several areas of the site, heating of the soil took much longer than originally anticipated and high soil temperatures were not maintained in many areas. This may have been due to the way the process was operated initially (16 hours per day, 5 days per week) and to excessive operational downtime. The heating rate improved later in the application when the process operation went to a 24-hour per day, 6-day per week cycle. These operational factors may have contributed to the SERP technology not achieving the cleanup criterion for the site. More constant process operation and monitoring should improve the performance of this technology in subsequent applications.

- The costs for use of the technology at this site were relatively low; however, site remediation did not achieve the cleanup criterion. Actual costs at the Rainbow Disposal site were estimated to be approximately $46/cubic yard. A 50 percent on-line factor was determined for this case. Under idealized conditions at this site, which assumes a 100 percent on-line factor, the technology could have cost as little as $29/cubic yard. For a site similar to the Rainbow Disposal site, under typical operating conditions (on-line factor of 75 percent), the cost for use of SERP was estimated to be $36/cubic yard. The large amount of soil treated by the technology at the Rainbow Disposal site contributed to a relatively low cost per cubic yard. The cost for use of the technology is most sensitive to the duration of remediation, and start-up and utilities costs.

The *in situ* SERP technology was evaluated based on the nine criteria used for decision-making in the Superfund Feasibility Study process. Table ES-1 presents the evaluation.

Table ES-1. EVALUATION CRITERIA RESULTS FOR *IN SITU* SERP AT THE RAINBOW DISPOSAL SITE

	CRITERIA								
	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility or Volume Through Treatment	Short-term Effectiveness	Implementability	Cost	State Acceptance	Community Acceptance
RESULTS	Reduced soil concentrations without excavation	Did not meet soil cleanup criterion, on the average, in this application	A portion of contaminants are permanently removed from the soil	Treated soil had lower concentrations overall, some areas were cleaned to well below the cleanup criterion	Soil is treated below ground so potential air emissions are minimized	Technology uses widely available construction and process equipment	Ranged from $29 to $46 per cubic yard for a large site	Minimizes excavation of and exposure to contaminated soil	Site disturbance can be minimized
	May reduce the mobility of contamination into groundwater after treatment	Less soil is excavated, thus less soil requires disposal	Removed contaminants can be incinerated or recycled	Remaining contaminants may be less mobile	Other activity can continue at surface of treatment area with minor disruption	Most regulatory permits are common and are readily acquired for fuel-related cleanups. Treatment of sites with other contaminating chemicals may require additional permitting requirements	Capital equipment, start-up, and utilities costs are high	Potential exists for off-site subsurface migration of steam and contaminants	Does not require major interruptions of existing operations
	Did not appear to cause lateral or downward migration of contaminants	Permits for drilling, operating, and air and water discharges are required	Residual contamination presents reduced risk	Lower soil concentrations are amenable to natural or enhanced biodegradation	Drilling and treatment may cause emissions, noise and dust which can be mitigated	Operational problems can occur that may delay the remediation	Remediation time is the major factor in the costs	Air emission permit may be required	May recover product for re-use or recycling
				Technology residuals are not of large volume as compared to the treated soil volume		The technology may not be able to meet stringent cleanup requirements, necessitating post-processing such as assisted biodegradation	Because the process operates in place, off-site disposal costs are minimized	Wastewater discharge permits may be required	May exceed noise limits in some areas