APPENDIX E

MIRAMAR LANDFILL STEAM INJECTION PILOT STUDY

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STI Engineering conducted a 10-month steam injection pilot study at the Miramar Landfill for the City of San Diego. The study began on May 16, 2005, and ended on March 17, 2006. The area studied was a 1-acre lined portion of the landfill that had no LFG collection system. Leachate collected from the leachate collection and recovery system (LCRS) was used as the water supply for the boiler. The pilot study's main objectives were to:

- Determine the migration patterns of the steam through the waste prism.
- Determine how fast the steam heats up the waste instead of cooling the waste as in water injection.
- Determine if leachate and condensate can be used as a water supply.
- Determine if the increase in LFG production can be controlled using LFG collectors.
- Determine the rate of settlement and airspace recovery in relation to the amount of steam injected over time.

OPERATIONS

STI Engineering began operations by injecting steam using a 360,000 British thermal unit (btu) boiler that was capable of delivering over 4,000 gallons of steam per 24-hour period. This size boiler was utilized because of the 20% void space calculated in the test area. Due to the minimal leachate (1,500 gallons) produced by the landfill, STI Engineering had to change the test parameters because 3,400 gallons were planned to be used per day for the study. Although there was a limited water supply, STI increased the boiler to a 600,000 btu to increase the steam influence within the test site. Attempts to utilize recycled water to offset the 1,900 gallons a day needed were rejected by the RWQCB.

Problems were encountered using the leachate as feed boiler water. High concentrations of solid particles and dissolved solid matter in the leachate clogged the machinery. This caused significant cost increases to run the study and increased

downtime to repair the machinery. The clogging issues were overcome by installing filters in the system.

STI ENGINEERING STUDY FINDINGS

STI Engineering considers the pilot study to be successful because, in their evaluation, it proved the process worked on a small area with some results, but the expense and operations for installation on large site makes it unattractive for further consideration. The findings were:

- The refuse in the cell was dry and prevented the entire void space to be filled with steam. The lack of water prevented a prolonged injection surge to overcome the dryness and reach the full 100-foot radius of the study cell.
- As the ambient temperature cooled, the leachate water temperature dropped causing the usage of propane to increase by 5% to heat the water. The use of solar panels would be ideal to use because it would drop the fuel costs by as much as 50%.
- There was an average of 3 inches of settlement per month at some of the survey points. The 2-foot settlement goal was met by the end of the 10-month study period.
- The average methane concentration was 54% at the start of the study throughout the landfill. Within a couple of months, the concentrations moved up to 66% in the study area. During the summer months, the landfill outside the test area dropped to about a 45% concentration, while the test area remained at 66%.
- All of the steam injected was converted to an average 62% methane gas and 38% carbon dioxide gas and extracted.

According to STI there were no environmental impacts or adverse impacts to the landfill using steam injection technology. The target cost to use steam injection was $4,500 per acre. The study did not meet this goal but did say this cost is achievable by using solar or geothermal pre-heating of the water and pre-ordering propane gas. Extra water needed was not accounted for in the pricing of the steam injection.

CITY OF SAN DIEGO STUDY FINDINGS

The City ESD found that the steam injection pilot study had limited success. Field issues encountered were primarily a lack of sufficient liquids (leachate and landfill gas condensate) and an attempt to try to use reclaimed water was not feasible due to regulatory issues with the water board.

The leachate clogged STI's boiler and piping and it was difficult to achieve continuous steaming for all of the injection probes. The blended product seems to have mitigated the particulate issues encountered with the leachate only option. However, due to the arid climate and minimal rainfall to date throughout the trial period, the amount of leachate generated combined with the gas condensate was not sufficient to allow for continuous operation of the steam generator. Nevertheless, optimum temperatures for anaerobic biodegradation have been achieved within the test area and have been sustained as long as a steam source was available.

Although the test results indicate an increase in temperature at various depths, there was no appreciable, observable evidence of landfill settlement throughout the test area. In addition, the arid environment and limited leachate generation within the entire lined section of the landfill would require that a dependable external water source be made available for a continuous operation.

The cost of the project exceeded initial estimates and the above ground piping with its insulation kept falling off and required extensive maintenance. It was determined that the water requirements and the need to obtain several regulatory permits ((CIWMB, local enforcement agency (LEA), RWQCB)) for external water resources, and the lack of significant evidence of subsidence makes this technology impractical for the West Miramar Landfill.