Methodologies to Rehabilitate Methane Recovery Wells that Outweigh the Cost of Well Replacement

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Abstract/Introduction

The primary purposes of landfill gas (LFG) extraction wells are to capture landfill gas to mitigate the potential for subsurface migration and surface emissions. Additionally, LFG extraction wells generate revenue capacity for power plant and landfill gas-to-energy facilities. Once installed, enhancement options for improved efficiency and consistency are limited. Rehabilitation options for LFG extraction wells with operation challenges are even scarcer. Factors contributing to the limited options for enhancement and rehabilitation of methane recovery wells consist of, but are not limited to: regulatory constraints, lack of innovative technology, capital cost and facility design and logistics.

Current viable options and methodologies for rehabilitation of LFG extraction wells include: pump installations for watered-in (flooded) wells, solution/pressure-fracturing in wells that have been silted in or clogged, and replacement with a new well(s). Furthermore, the continual placement of waste requires a vertical extension of the well riser. In these situations, efficiency of the Gas Control and Collection System (GCCS) is degraded. Eventually these wells will require total replacement.

Post-perforation of LFG extraction wells provides an additional method to enhance rehabilitation of the extraction well without replacement. This technology assists in extending the life, functionality and/or production of LFG extraction wells while being a progressive step in maintaining compliance, decreasing operational costs, and increasing the capture of landfill gas over time. Post-perforation is a multi-functional approach to well rehabilitation that can be safely implemented on wells that are not maintaining standards of environmental compliance, flooded due to elevated entrained liquids, clogged, and wells that require an increase in landfill gas capture due to vertical accumulation of waste.

Background

The first legislation to enact air and subsequential LFG compliance monitoring was achieved under the Clean Air Act (CAA) of 1970. A primary goal of the CAA (amendments enacted by Congress in 1990) is to "encourage or otherwise promote reasonable Federal, State, and local governmental actions…for pollution prevention" (EPA 2008)[1]. Results of the CAA included two regulatory programs now integral to the solid waste industry: the New Source Performance Standards (NSPS) and National Emissions Standards for Hazardous Air Pollutants (NESHAP). This new regulatory framework set up standards to which all emissions must be monitored.

The New Source Performance Standards (NSPS) have impacted the way in which the solid waste industry operates, specifically over the last 14 years (EPA 1996)[2]. The NSPS are intended to promote effective mechanisms for the collection of landfill gas. By mandating new compliance standards that include regular and frequent monitoring, capture of landfill gas, and timely installation of landfill gas collection devices, the amount of LFG emitted into the atmosphere as greenhouse gas since NSPS's inception has continually declined.

Hazardous air pollutants were also outlined in the CAA Amendments of 1990 but not promulgated, in the form of National Emissions Standards for Hazardous Air Pollutants (NESHAP), until 2003 (Sullivan, 2007)[3]. This standard increased reporting requirements from an annual to semi-annual events and attempted to bring a proactive approach for self and site regulation to the industry.

Greenhouse gas regulations as they pertain to LFG are becoming stricter as the industry continues to grow, technologies to mitigate greenhouse gases increase, and the public's perception and continued awareness of global climate conditions amplify. For example, current reporting of gaseous compounds which potentially contribute to climate change is mandatory as of December 29, 2009, for all municipal solid waste facilities (MSWF) with the potential to emit greater than or equal to 25,000 metric tons of carbon dioxide equivalents per year (EPA[4]). The increasing regulatory trend creates an opportunity for owners of solid waste facilities to use these new and exacting regulations to their advantage as a new revenue stream. By installing

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[1] United States, Environmental Protection Agency. Title I Air Pollution Prevention and Control, 1990 <http://epa.gov/oar/caa/title1.html>.

[2] United States Environmental Protection Agency 40 CFR Parts 51, 52, and 60, Standards of Performance for New Stationary Sources and Guidelines for Control of Existing Sources: Municipal Solid Waste Landfills <http://www.law.cornell.edu/uscode/html/uscode42/usc_sec_42_00007411----000-.html>.

[3] Patrick Sullivan, "Update on Major Air Quality Regulations Affecting Landfills" SWANA Landfill Gas Symposium, 2007.

[4] http://www.epa.gov/climatechange/emissions/ghgrulemaking.html

and maintaining LFG extraction wells and LFG-to-energy infrastructure, solid waste facilities can start to let the landfill work for them. The generation, capture, and conversion of LFG to energy have the potential to generate income once lost in the form of emissions.

Currently Available Technologies for Rehabilitating Vertical LFG Extraction Wells

Well integrity is essential to ensure efficient capture of LFG. Even while utilizing gas capture efficiency techniques; if the screen interval is clogged, flooded and/or silted in, there is an increased likelihood of the Gas Control and Collection System (GCCS) operating at less than designed performance. This is an inevitable situation that has few remedies and ultimately will end with the same fate: a replacement well for the dysfunctional, inoperable well. Few options currently exist for attempting to rehabilitate a LFG extraction well: pump installation, solution/pressure-fracturing of the well, and ultimately, well replacement.

When wells become flooded a pump can be installed to de-water the wells, however, this is a solution that increases the operational and maintenance cost of the GCCS. The installation of a pump is a continuous operational and maintenance process for upkeep, functional efficiency, and in northern climates, operational difficulties of the pump due to freezing conditions require constant attention until the well is ultimately replaced.

When wells become silted in or clogged, solution/pressure-fracturing is an experimental option that can be applied to wells in an attempt to break up the accumulated silt and/or debris to reopen the screened interval. However, because solution/pressure-fracturing is applied only to the silt and/or debris directly on the screen, the well will most likely accumulate more silt and/or debris around the screened interval because process does not affect the environment and associated conditions surrounding the well screen. This is a temporary, localized solution to a larger problem. A common practice in the water well industry, solution/pressure-fracturing is beginning to make an entrance into the solid waste industry.

Ultimately, after one or more of the above rehabilitation techniques has been applied, the well will need to be replaced. At some point it no longer becomes cost effective to continuously attempt to rehabilitate the same well and replacement is the only solution, both physically and economically.

Post-Perforation – The New Technology to Efficiently and Effectively Rehabilitate Wells

Post-perforation is a new technology that has recently been developed after observation of the installation, unsuccessful rehabilitation, and well replacement cycle coupled with knowledge of drilling and engineering techniques, the idea to post-perforate LFG extraction wells from inside the well was a realistic solution to an industry age-old problem to provide the potential of extending the operational life of a vertical extraction well. After several years of research, design and development, the post-perforation theory has proven successful at several locations throughout the Gulf Coast Region. A patent for this technology was recently awarded under the Federal Green Technology program as a successful, innovative technology that will help to lower greenhouse gases and overall emissions from MSWFs while increasing capture and flow of LFG, which is essentially recycled and converted into usable, green energy that is put back into the grid.

Post-perforation is a new approach to rehabilitate wells once thought to be only fixed by replacement. Post-perforation greatly extends the life of LFG extraction wells and increases capture and flow of LFG almost instantaneously.

Post-perforation is achieved by sending a tool into the inner diameter of the LFG extraction well casing down the well to a desired depth. Once at that depth, the tool creates new apertures in the well, essentially creating a new screened interval. The benefit of this technology is that the new screened interval can be created at any depth within the well (i.e. the original screened interval or above). Post-perforation with a tool specifically designed for extraction wells is highly successful because this tool can be effectively navigated through slight bends and deflections in the well casing/riser and other well deviations previously rendered unfixable except by replacement. Post-perforation has proven success in HDPE and PVC wells for 6-inch and 8-inch diameter casings.

NSPS facilities are required to operate LFG extraction wells and associated systems to maintain a minimum, regulatory stated, extraction wellhead operating pressure, wellhead oxygen concentration, and wellhead temperature. Post-perforation enhances the ability of a LFG extraction well operating outside of these NSPS parameters, specifically for pressure and oxygen concentration, immense potential for the well to return within compliance and operational specifications, sometimes within minutes. By generating new apertures, LFG flow is increased while the extraction capacity of the vertical well is increased.

The generation of apertures in the well casing for flooded wells releases liquid that has built up inside the casing to allow LFG to flow into the well through the liquid via newly generated apertures. Additionally, when extraction wells are vertically extended, post-perforation makes it possible to capture LFG in higher elevations of the waste cell via new pathways where a screen or perforated zone was not originally present.

Post-perforation is also safe and successful in volatile and explosive well environments by operating with non-sparking methods to perforate the well casing. This attribute of the technology to be successful in volatile and explosive environments creates new possibilities to rehabilitate and gain LFG from wells once thought to have too dangerous of an environment to work within limiting enhancement opportunities.

By generating and/or increasing LFG-to-energy opportunities, the landfill can generate new revenue streams from those previously thought an economic drain. Landfill gas has the potential to be a large portion of the biomass energy generated nationwide and contribute to the larger energy grid with minimum integration costs, especially because capture requirements already exist. The cost of electricity generated from landfill gas is generally competitive with other renewable resources (Wiltsee, 2009)[5]. Because LFG has to be captured and regulated anyways, it makes sense that it would be collected, converted and sold to make up for the maintenance and regulation costs. Post-perforation increases the amount of LFG accessible and increases the volume and flow to the LFG-to-energy facilities, ultimately contributing to the bottom line.

[5]George Wiltsee, "Contracting with a Utility for sale of Renewable Energy and Green Attributes" SWANA Landfill Gas Symposium, 2009.

Case Study 1

Post-perforation was applied to several LFG extraction wells at Site 1 in the Metro Houston Area. The five (5) wells, on average, were post-perforated approximately 16.4 feet in length. Generally, the wells were perforated from a depth of approximately 20 feet below ground surface (ft bgs) to a depth of approximately 36.5 ft bgs. All LFG extraction wells were post-perforated in the same day. Results of readings from each of the LFG extraction wells from a time period of three consecutive months prior to post-perforation were compared with results for three consecutive months after post-perforation. Below is a summary of the results for one well, pre- vs. post-perforation.

Table 1: Results for Well 1 at Site 1 Pre- vs. Post-Perforation:

Reading Event	Methane (CH4) (%)	Oxygen (O2) (%)	Measured Flow (SCFM)
Pre-Perforation			
Event 1	58	0	1
Event 2	55	1	3
Event 3	58	0	1
Post-Perforation			
Event 1	28.8	0.4	28
Event 2	39	0.3	21
Event 3	58.1	0	10

Well 1 was post-perforated from 20 ft bgs to a depth of 43 ft bgs (23 total feet perforated). The results from Well 1 show an increase in measured flow from 7 to 28 times the volume the pre-perforated readings were achieving.

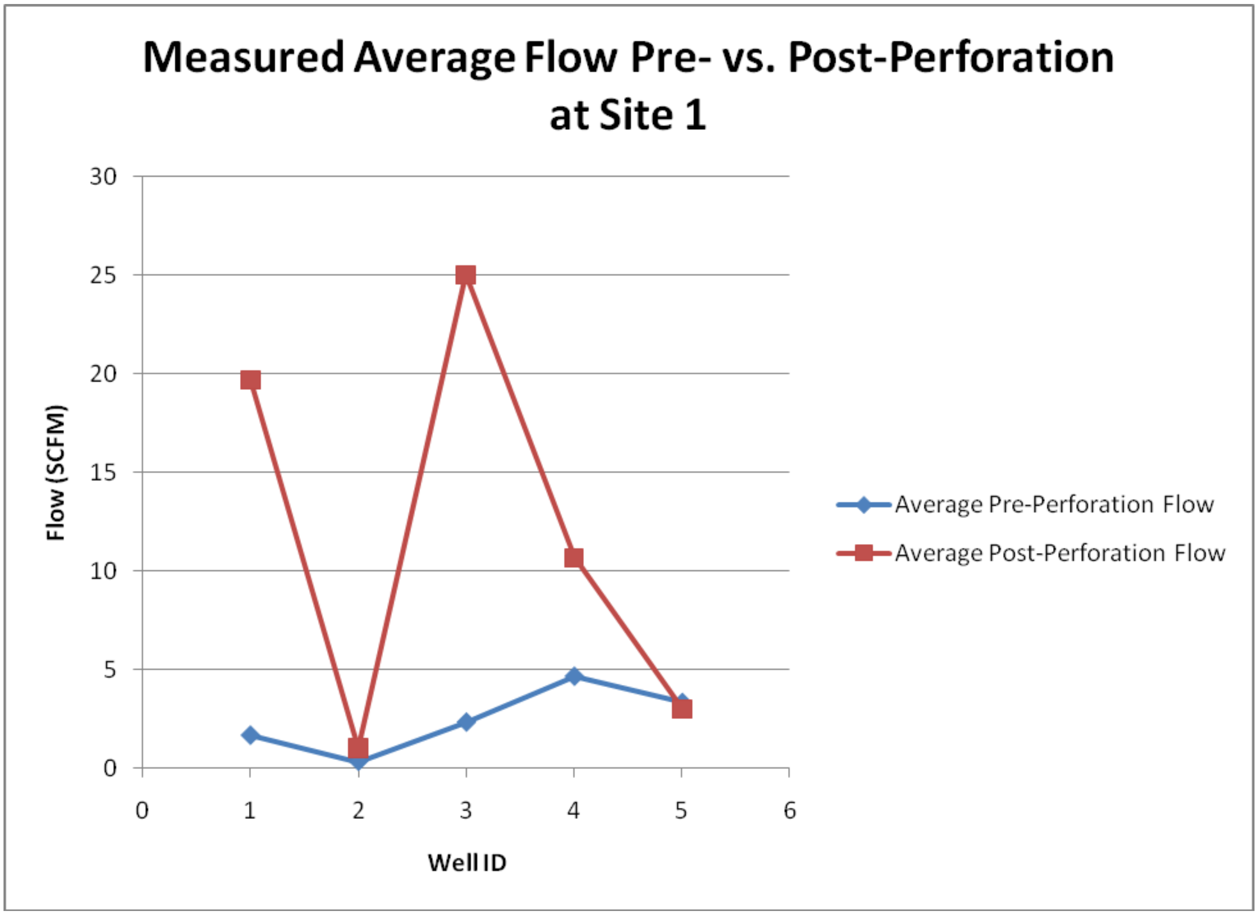
Table 2 (below) is a summary of the average measured flow for all five wells post-perforated at Site 1 for the time period of three consecutive months prior to perforation and three consecutive months post-perforation.

Table 2: Results for Average Measured Flow of All Wells at Site 1 Pre- vs. Post-Perforation

Well ID	Measured Flow Pre-Perforation (SCFM)	Measured Flow Post-Perforation (SCFM)
Well 1	1.67	19.67
Well 2	0.33	1.00
Well 3	2.33	25
Well 4	4.67	10.67
Well 5	3.33	3.0

Figure 1 (below) depicts the average measured flow of all wells at Site 1 for a time period of three consecutive months of readings pre- versus three consecutive months of readings post-perforation (numerical values are presented in Table 2 above).

Figure 1: Average Measured Flow Pre- vs. Post-Perforation for all LFG Extraction Wells Perforated at Site 1:



It is apparent in Figure 1 above that post-perforation of each well at Site 1 successfully increased the volume of flow in four of the five wells post-perforated.

Case Study 2

Post-perforation was applied to several LFG extraction wells at a Site 2 in the Metro Houston Area. The LFG extraction wells (12), on average, were post-perforated approximately 8 feet in length. Generally, the LFG extraction wells were perforated from a depth of approximately 23 ft bgs to a depth of approximately 31 ft bgs. Wells were post-perforated on two days: February 17 and March 22, 2010. Results of readings for four consecutive months prior to perforation were compared with readings of each LFG extraction well perforated for four consecutive months post-perforation. Below is a summary of the results from Well 1, pre- vs. post-perforation:

Table 3: Results for Well 1 at Site 2 Pre- vs. Post-Perforation

Reading Event	Methane (CH4) (%)	Oxygen (O2) (%)	Measured Flow (SCFM)
Pre-Perforation			
Event 1	50.3	0.6	No Data
Event 2	52.5	0	0
Event 3	51.5	0.4	1
Event 4	47	4.2	No Data
Post-Perforation			
Event 1	54.9	1.2	19
Event 2	59.8	0	0
Event 3	60.7	0	53
Event 4	57.1	0	42

Well 1 was post-perforated from 21 ft bgs to a depth of 31 ft bgs (11 total feet perforated). The results from Well 1 show an increase of measured flow from 1 to 53 times the volume the pre-perforated results were achieving.

Table 4 (below) is a summary of the average measured flow for a time period of four consecutive months of readings pre-perforation compared to four consecutive months of readings post-perforation for all of the LFG extraction wells at Site 2 both pre- and post-perforation.

Table 4: Measured Flow Results for All LFG Extraction Wells at Site 2 Pre- vs. Post-perforation

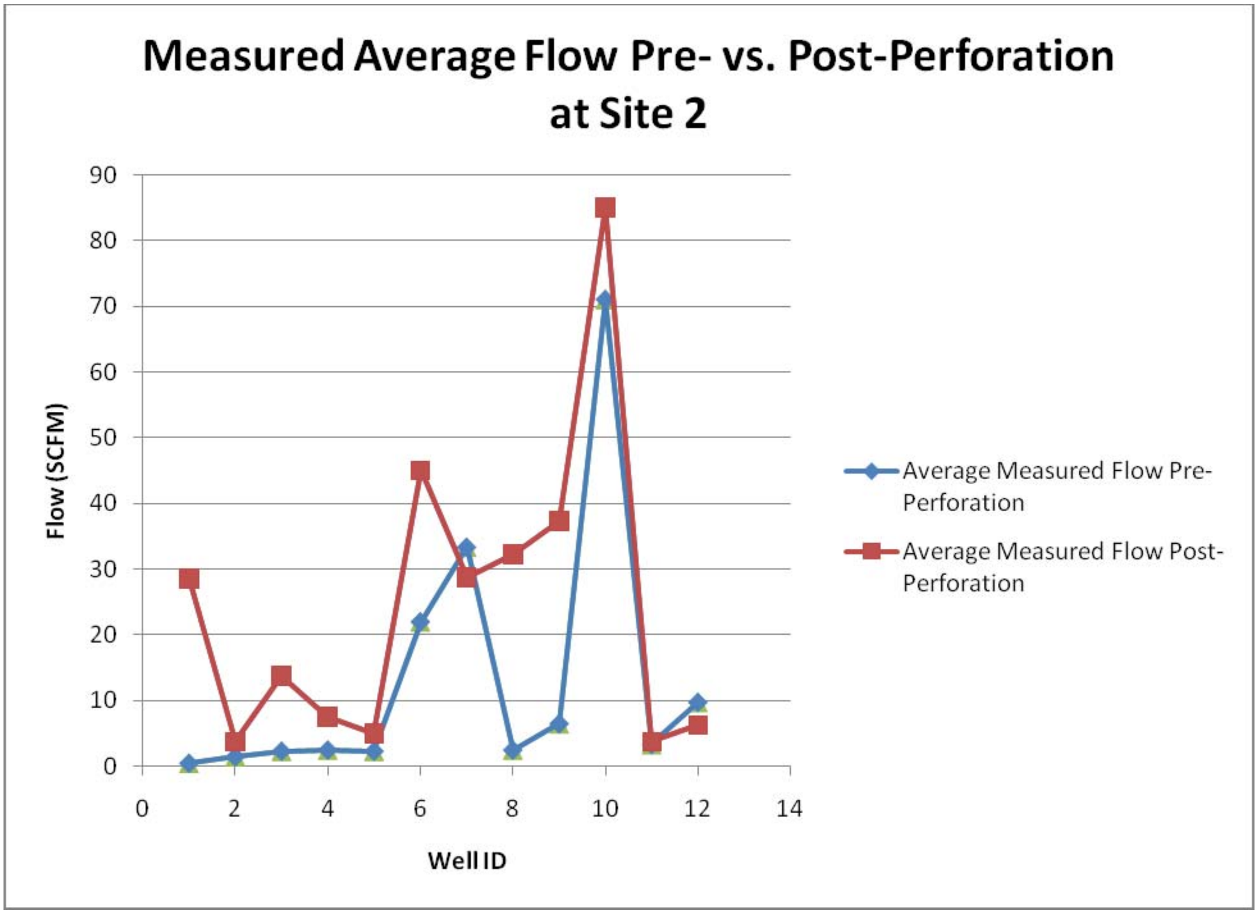
Well ID	Measured Flow (Pre-Perforation) (SCFM)	Measured Flow (Post-Perforation) (SCFM)	Difference in Pre- versus Post-Perforation (SCFM)
Well 1	0.5	28.5	28.0
Well 2	1.5	3.75	2.25
Well 3	2.33	13.75	11.42
Well 4	2.50	7.5	5.0
Well 5	2.33	5	2.67
Well 6	22	45	23
Well 7	33.3	28.75	-4.55
Well 8	2.5	32.25	29.75
Well 9	6.5	37.25	30.75
Well 10	71	85	14
Well 11	3.33	3.75	0.42
Well 12	9.75	6.25	-3.5

Measured flow increased for ten of the twelve wells post-perforated during this Case Study. Six of the twelve wells showed an increase in measured flow from one to three times the pre-perforation readings. Four of the twelve wells showed an increase in measured flow from five to fifty-six times the pre-perforation readings. Two wells showed a decrease in measured flow from pre- to post-perforation readings, Well 7 (33.3 scfm to 28.75 scfm) and Well 12 (9.75 scfm to 6.25 scfm).

Figure 2 (below) depicts the average measured flow for a time period of four consecutive months of readings pre-perforation to four consecutive months of readings post-perforation of all

LFG extraction wells at Site 2 that were perforated (numerical values are presented in Table 4 above).

Figure 2: Average Flow Pre- vs. Post-Perforation for all LFG Extraction Wells Perforated at Site 2:



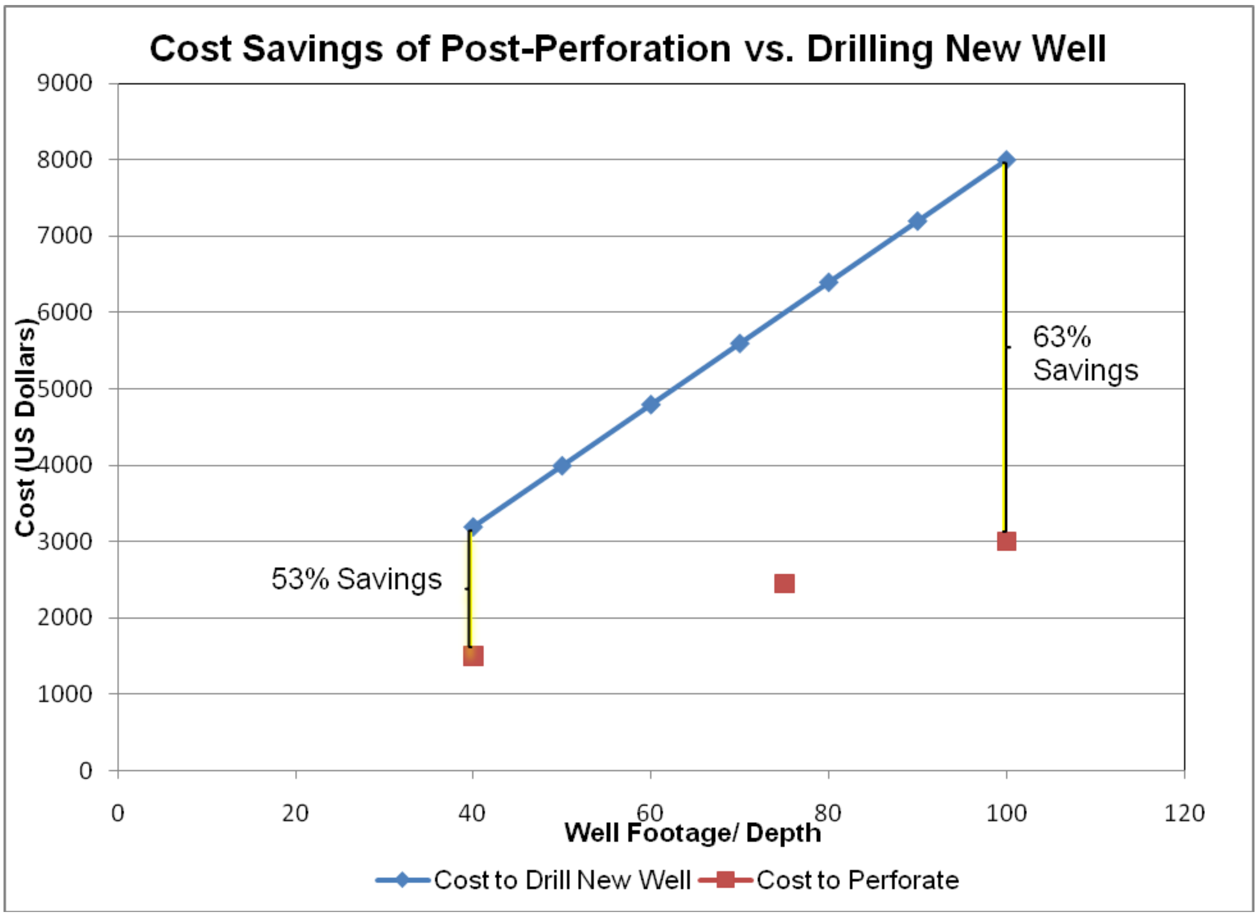
Even though success of LFG extraction well post-perforation is dependent on several outside factors and site-specific conditions (i.e. well casing integrity, entrained fluids, and operational integrity of the GCCS), success is the outcome of the large majority of LFG extraction wells post-perforated.

It is apparent in Figure 2 above that post-perforation at Site 2 successfully increased the volume of measured flow in ten of the twelve wells post-perforated.

Cost Benefit of Applying Post-Perforation vs. Drilling New/Replacement Wells

The installation of new or replacement methane extraction wells has been a necessary expense unavoidable in the past. The effective implementation of the post–perforation tool has the potential of reducing the amount of replacement wells installed on an annual basis. By rehabilitation and extending the life of a current well via post-perforation, owners and operators will notice a sharp reduction of the cost and maintenance of methane extraction wells. As an illustration, in the example below a typical cost of installing a new or replacement well forty (40) feet in length (minimum industry standard) is approximately three thousand dollars. The cost to post-perforate an inoperable or extended well the same length is approximately one thousand five hundred dollars, an approximate fifty percent savings over well replacement. Figure 3 below illustrates the cost difference between the installations of a new well versus the cost of post-perforation of the same well to be replaced.

Figure 3: Cost Difference between Drilling a New/Replacement Well and Post-Perforation



In closing, post-perforation is an exciting new technology that has demonstrated the potential capacity to increase the volume of landfill gas extracted from wells and extend the operational life of LFG extraction wells at a minimal cost. The post-perforation tool will provide methods to ensure a GCCS has the ability to operate at designed specifications, meet environmental compliance standards, and increase flow from extraction wells to the GCCS while maintaining costs savings over well replacement with minimum maintenance and operation costs during the life of the extraction well.