Evaluating and Rehabilitating an Aging Landfill Gas System: I-95 Landfill Case Study

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ABSTRACT

Landfill gas (LFG) management systems age like any other engineered mechanical system. However, the unique nature of landfill decomposition and the demands of safety, environmental compliance, and energy recovery create a dynamic environment under which the system has to perform. These conditions place long term stresses on system components and increasingly challenge the ability of operators to effectively and efficiently manage the collection and control of LFG in a cost effective manner. We will present a case study of the I-95 Landfill, located in northern Virginia, where due to an aging system, operation and maintenance had become onerous and expensive. As a result, Fairfax County moved forward with a plan to evaluate, redesign, and rebuild the system with the intention to simplify operation and optimize performance while reducing lifecycle operation and maintenance costs. This paper presents the site history, our approach and findings from a system evaluation, and the design recommendations. Construction and our lessons learned are also discussed.

INTRODUCTION

LFG collection systems evolve and age through the lifecycle of a landfill. Systems expand in scale and complexity to complement the build-up of the waste mass and subsequent increase in LFG generation. Following closure, LFG generation decreases but often the infrastructure remains the same while experiencing the stresses imposed by an aging landfill. This process is no more evident than at the I-95 Landfill, in Lorton, Virginia which reigned from 1973 until 1995 as the regional waste disposal site for Fairfax County, Northern Virginia's District of Columbia suburb. Faced with unsustainable and increasing LFG collection system operation and maintenance costs, the Fairfax County Solid Waste Management Program teamed with SCS Engineers in 2014 and 2015 to evaluate and rehabilitate this aging system. The infrastructure and operational performance were evaluated, and a new piping system was designed and constructed to simplify operation, improve performance and reduce life cycle operation and maintenance costs.

I-95 LANDFILL BACKGROUND

The I-95 Landfill, and in particular the LFG collection system, has an interesting and probably not unusual history for a site where the design, construction, disposal and closure life spanned before, during and after the promulgation of RCRA Subtitle D and NSPS Subpart WWW (and companion Emissions Guideline Subpart Cc to which this facility is subject). The following development history helped to explain the aging process and informed the rehabilitation design decisions.

A site layout is shown in Figure 1. The I-95 Landfill occupies an area of approximately 308 acres, of which 261 are devoted to the closed Municipal Solid Waste Unit (MSW Unit) and 96 acres to the Area Three Lined ash monofill (ATLL Unit). The ATLL Unit overlays a portion of the MSW Unit and is currently operating. The MSW Unit, germane to this LFG rehabilitation project, is an unlined waste disposal unit which accepted MSW from 1973 until the end of 1995. Termination of MSW disposal ended well before the design capacity was reached, causing the top of the landfill to retain relatively mild slopes. Capping was completed in accordance with RCRA Subtitle D and Virginia Solid Waste Management Regulations standards in four phases between 1994 and 2007. The first two phases included approximately 105 side-slope acres, capped with flexible membrane liner, and the remainder capped with low permeability soil.

Unlike many modern landfills, the design and evolution of the LFG collection system was not laid out in a comprehensive and contiguous design plan, but rather designed and constructed based on the priorities of the day. That's not to say no design was prepared, but that designs were developed to align with the characteristics consistent with specific periods of the landfill's active and regulatory life.

Initial development of the LFG collection system began in the mid-1980's as a migration control measure to protect the nearby Youth Authority Prison and landfill scale house. Followed by expansion for energy recovery in the early 1990's; integration into side-slope closure capping in the early to mid-1990's; and continued expansion and rehabilitation through 2014 to comply with the Emissions Guidelines. The resultant collection system was essentially stitched together from smaller, project and priority specific collection systems, each conforming to the topography of the day. See Figure 1 for a drawing of the existing wellfield.

APPROACH

Our general approach to this wellfield evaluation was as follows:

- Develop a LFG recovery curve to understand the handling capacity of the collection system
- Review recent LFG collection system data to understand the overall performance of the system
- Review recent wellfield data to understand the performance of individual headers/laterals and collection devices

FINDINGS

LFG Recovery Curve

A LFG recovery curve is presented in Figure 2. As illustrated, the LFG recovery rate peaked at approximately 7,000 standard cubic feet per minute (scfm) in Year 1991, the year after waste filling peaked. As filling decreased and the MSW unit was closed, LFG recovery rates have been declining each year. At the end of the year 2014, the recovery rate was approximately 1,900 scfm, approximately 3.7 times less than the peak rate. This decrease in LFG quantities could have major impacts on the LFG collection system operation. As an example, some wellheads which once flowed 100 scfm now flow less than 30 scfm. At this lower flow rate, a different wellhead was required to provide proper tuning capability.

Overall Performance

Analogous to a doctor's visit where vital signs (e.g., the heart rate) are measured to gauge a person's health, measurements are taken at various points of the LFG collection system to gauge its health. One key parameter is vacuum. Figure 3 illustrates vacuum readings at one location near the system's vacuum source. It shows wide fluctuations, ranging from 10 inches of water column (in.-wc) to 65 in.-wc. Unlike a person's heart rate, the vacuum at a point in the wellfield should be near constant, i.e., flat-lined, during normal operation. Wide fluctuations as observed suggest an unhealthy collection system.

It was identified that the root cause of this problem was the vacuum source. The landfill gas energy (LFGE) developer at the site was in sole control of the vacuum applied to the wellfield and as its demand varied, so did the vacuum on the wellfield. The variance in the demand was driven by three partially independent end uses. Further complicating matters, there were challenges in timely communication and response between the developer and County, who is responsible for the wellfield operation.

LFG Header System

Figure 4 shows the locations of problem headers. These headers were either sagging and filled with water, pinched, and/or broken and detached from the rest of the system. These conditions were contributing to vacuum and flow fluctuations in the system and in some portions a complete loss of vacuum. In a majority of areas, the headers were buried deeply (sometime over 40 feet) in the landfill.

LFG Collection Devices

The following conditions were evaluated for each LFG well:

- Watered-in: wells with perforations buried with liquid
- Silted-in: wells with perforations buried with silt
- Damaged
- Poor gas quality
- Poor gas flow
- Turned off or isolated for one year or more
- Less than 15-feet of solid pipe: an indication of a potential source of oxygen infiltration
- Greater than 30-feet of solid pipe: an indication poor LFG influence near the surface

These conditions are color-coded in Figure 5; refer to Figure 6 for the color-code legend. We find these figures to be useful visualization tools that helped with the evaluation.

Approximately 90 percent of the wells were producing less than 30 scfm each, and most of these wells had deteriorating 2-inch gate valve wellheads. At this flow range, wells are essentially either full open or full closed; i.e., there is little-to-no ability to tune low-flow wells using 2-inch gate valves.

Furthermore, the majority of wells had no built-in flow measurement devices. Adjustments were being made on vacuum and LFG quality measurements.

RECOMMENDATIONS

The recommendations provided below were centered around simplifying operations and maintenance and optimizing performance while reducing long-term lifecycle operation and maintenance costs.

Overall Performance

As the County is responsible for wellfield operations and maintenance, it was recommended that the County take full control of LFG withdrawal from the wellfield to help stabilize the overall system vacuum fluctuations and/or LFG flow rate. The concept is that the County applies the system vacuum at a single point in the collection system and routes all collected LFG through this point for delivery to a flare or the LFGE developer utilization projects.

Refer to Figure 7 for a schematic representation of this concept. The blowers modulate to maintain either a constant wellfield system vacuum or flow rate. They push the LFG out to a flare with a continuous LFG pilot and to the LFGE plants. A series of valves modulate to maintain a blower discharge pressure setpoint. As the demand from the LFGE plants decreases, the extra LFG will be combusted by the flare. As the demand from the LFGE plants increases, the flow of LFG to the flare will decrease. If the LFGE plant pulls too hard, a valve on their LFG line will close and the LFG will be combusted by the flare.

LFG Header System

It was recommended that a majority of the LFG header system be redesigned and reconstructed. The major design considerations included the following:

- Abandon poor functioning sections of header pipe
- Incorporate a looped header design
- As LFG flows are on the decline, size headers to handle the present maximum flow rates
- Realigning headers, sub-headers and laterals down slope/across contours, to direct condensate drainage to three existing leachate pump stations; design of specific, terminal endpoints for condensate and de-watering flow creates opportunities to monitor and record flow
- Reduction in the number of condensate traps
- Locate the header system piping close to the landfill surface to simplify access for troubleshooting and to make adjustments to compensate for settlement; in membrane capped locations, the new headers were to be installed below grade, but above the membrane for easy access. installed below grade, but above the membrane for easy access.
- Separation of well de-watering flow from the collection system piping and creating independent force-main and gravity drain system
- Valves at major header, sub-header and lateral intersections create additional operational flexibility and provide shut-off locations to allow targeting of troubleshooting activities without sacrificing large regions of the wellfield

These design considerations resulted in the design illustrated in Figure 8. The design eliminates most of the existing LFG header pipe and laterals, aside from the north-east section of the landfill.

LFG Collection Devices

It was recommended that 66 out of 335 existing LFG wells be decommissioned. These wells had been either closed off for long periods (mostly one year or more), were silted-in, or had poor gas quality. In areas that lacked coverage, 18 new wells were recommended. Refer to Figure 8 for the recommended design layout.

One-inch gate valve type wellheads were recommended to replace low flowing (less than 30 scfm) wellheads, and 2-inch fine-adjustment valve type wellheads were recommended for wells with more than 30 scfm. These wellheads were selected to appropriately match their design ranges with anticipated flow rates, while also giving consideration to the investment costs.

Lastly, with regard to wellheads, it was recommended for each to have built-in flow measuring devices. In our opinion, wellhead flow is an important parameter that should be measured (in addition to vacuum and LFG quality) to provide a full understanding of the well's performance. As a fairly common example, a well could show ideal vacuum and LFG quality, while flow rate is zero. In such a case, if flow rate is not measured, the operator would have no reason to question the well's performance and could easily be misled.

CONSTRUCTION/POST-CONSTRUCTION FINDINGS

Construction Highlights/Lessons Learned

Implementation of the physical rehabilitation plan began in November 2014 with the boring and development of 18 new wells. Trenching and laying of the new header system piping began in earnest in April 2015. Construction was phased by region, and that region was activated before moving on to the next. The general process was to install header, lateral, condensate and de-watering system piping in a region, replace well heads, then disconnect the wells in that region from the older header system and re-connect to the new header system. Valves were strategically placed at intersections between the primary header, and sub-header/lateral branch to allow that part of the system to be shut off from the vacuum source without impacting the rest of the collection system during local transition. Regions were generally assigned based on the location of the leachate pump station to which condensate would drain by gravity. This construction phasing process evolved region by region from April until the bulk of the system was installed and fully connected by the end of December. Approximately nine miles of pipe ranging in diameters from 4 to 24 inches were installed in 11 months.

As with all construction projects, there were hard lessons learned and several off-design construction additions that added value. Below are highlights:

- The topographic drawing which was relied upon for the header system design was several years old. Settlement and grade repairs subsequent to this altered the underlying site grades and required the construction team to improvise. As a result, significant off-site soils were brought in to establish adequate grades, and pipe locations were altered to align with the new grades. More recent topographic surveying may have limited this issue.
- Depth to the synthetic cap membrane on side slopes was often unknown, requiring test pitting to ensure that adequate depth was available to bury large diameter header pipe without penetrating cap membrane. Again, in some cases, additional soils were brought in to increase the depth, but may have also triggered additional grading to establish adequate slopes for condensate drainage. Strategic, pre-construction test pitting may have limited this issue. However, as this type of issue is inevitable with older landfills, it may be more efficient and cost effective to accommodate some additional field engineering during the construction phase to address these issues as they arise.
- Local construction companies involved in land development and looking for a home for surplus soils were able to provide that plus grading capabilities at no cost to the County.
- Design locations for a 100-foot segment of large diameter header and future (24-inch) discharge line conflicted with the synthetic cap system anchor trench on paper. As-builts were not available to accurately locate these limits. Trenching activity cut through this complicated anchor trench requiring hiring of a liner installer to repair and restore the system to existing conditions. Pre-design test pitting would have provided better information to prepare a suitable pipe location, or if the location was unmovable, would have allowed the County to be better prepared for the inevitable repairs.
- The trench for the above piping was used to install two additional leachate force mains pipes, allowing the County to double the discharge flow rate of two leachate pump stations.
- County survey crews provided surveying of the pipe network as the project progressed. Hollow marker pipe was placed on the top of the buried header pipe to allow survey crews access for accurate surveying at their availability. Occasionally, marker piping was knocked down by equipment or inadvertently removed before surveying was completed. Nevertheless, an accurate as-built of new conditions will simplify future troubleshooting.

Post-Construction Operational Observations

The rehabilitated LFG collection system was predominantly in service by the end of December 2015, but improvements to performance were being realized as early as August, and an increase in methane content to the LFGE developer as early as November. However, the recommended modifications to the blower/flare station that will allow the County to take full control of the applied wellfield system vacuum and LFG flow rate remain the be done.

One of the most important improvements has been the shift to expect satisfactory gas quality and expect well balancing to be simpler. Previously, tuning actions were expected to far exceed the typical cycle (observe, adjust, re-check) necessary to monitor and demonstrate compliance because of inconsistent vacuum and wellfield parameters. Eliminating choke points in the header system due to water and settlement, and minimizing air infiltration appears to have stabilized the vacuum. With these changes, maintaining compliance is expected to be simpler because the new well-heads dial in on parameter targets more certainly; see Figure 9 for data from an example well. Once de-watering activity returns, we expect most wells to maintain compliance more regularly and without excessive tuning.

Some highlighted improvements are as follows:

- Gas quality to the energy developer improved post-construction to greater than 54 percent methane (by volume) and less than 1 percent oxygen. See Figure 10.

- Some poor performing wells showed more stable (less erratic) performance after header and well-head replacement.
- Fewer wells to monitor going forward. Decommissioning eliminated more than:
    - 20 vertical extraction wells that required extra attention due to low LFG flow and high rate of oxygen infiltration.
    - 30 horizontal collectors which were originally installed, more than 20 years ago, to capture migration contained under the synthetic cap system.

CONCLUSION

As LFG management systems age, we have found that operations and maintenance costs can increase to a point where they are unsustainable and capital investment in major infrastructure improvements may be the preferred economic option. At the I-95 Landfill, this point occurred at a system age of approximately 20 years. Our approach began with a comprehensive system evaluation, that lead to redesign and construction. With the exception of improvements to the blower flare station, most of the recommendations have been completed, and we have already begun to see favorable results. Because of this, the County now feels comfortable taking direct control over the routine operations, maintenance, monitoring, tuning, record keeping and reporting associated with LFG management systems and did so in February 2016. The rehabilitation has shown to be the right choice for us to date.

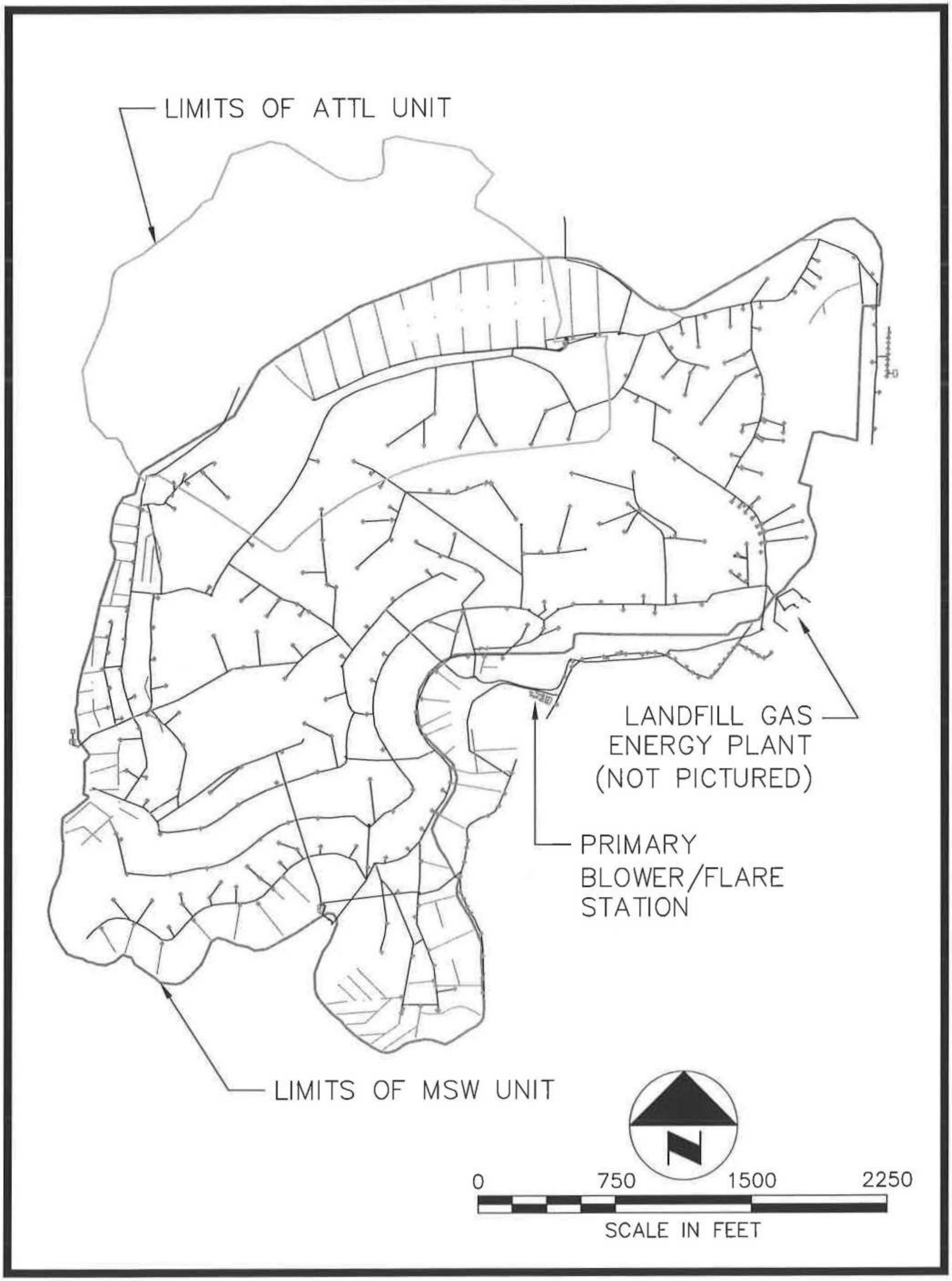

FIGURE 1: EXISTING SITE LAYOUT

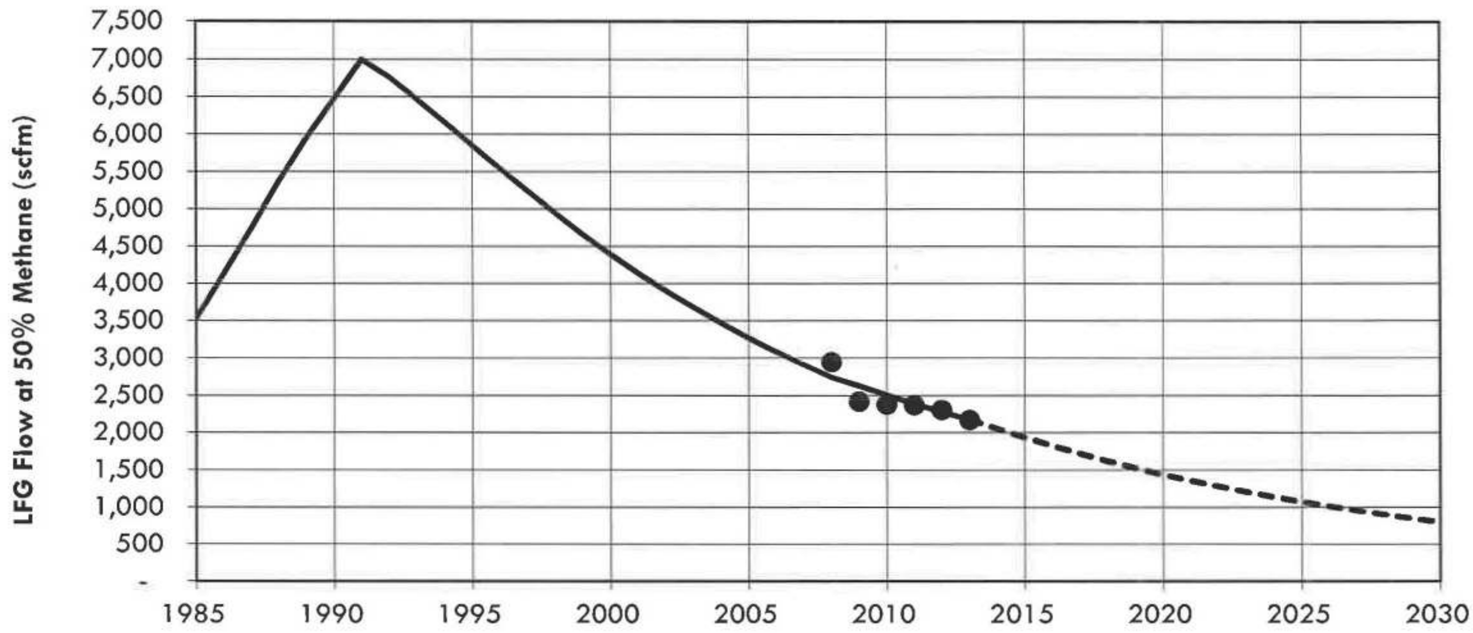

FIGURE 2: LANDFILL GAS RECOVERY CURVE

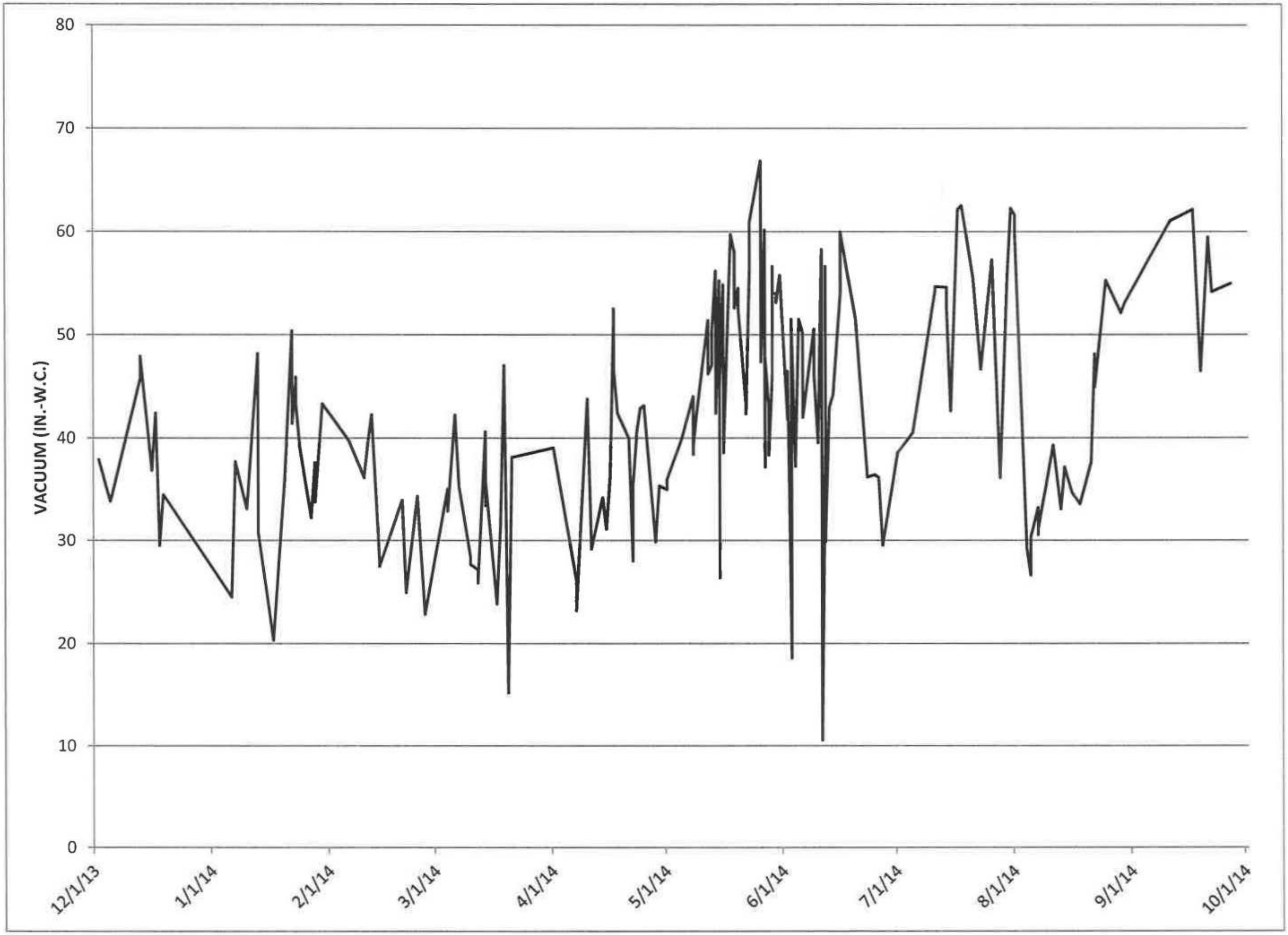

FIGURE 3: WELLFIELD VACUUM - PRE-CONSTRUCTION

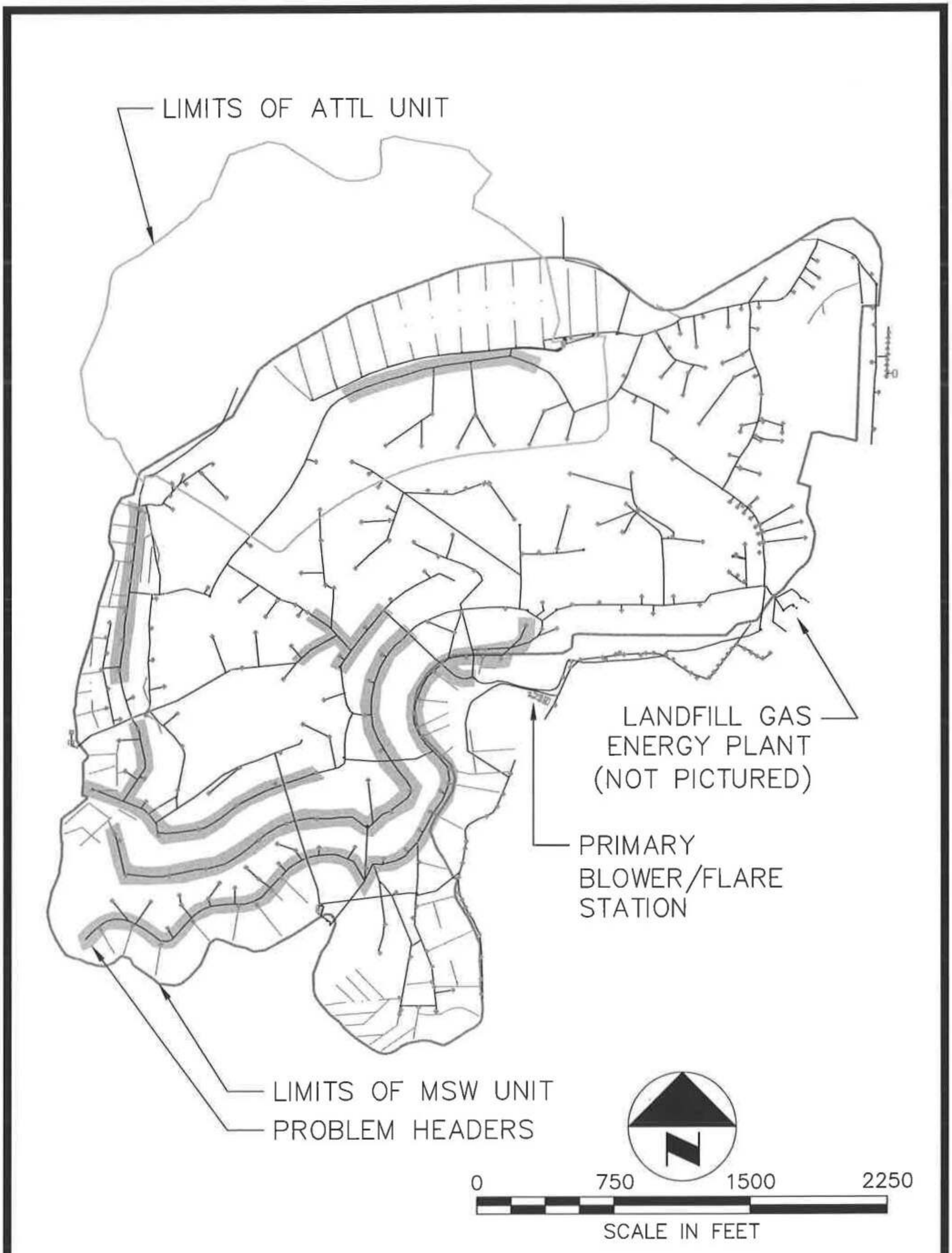

FIGURE 4: PROBLEM AREAS OF EXISTING HEADER SYSTEM

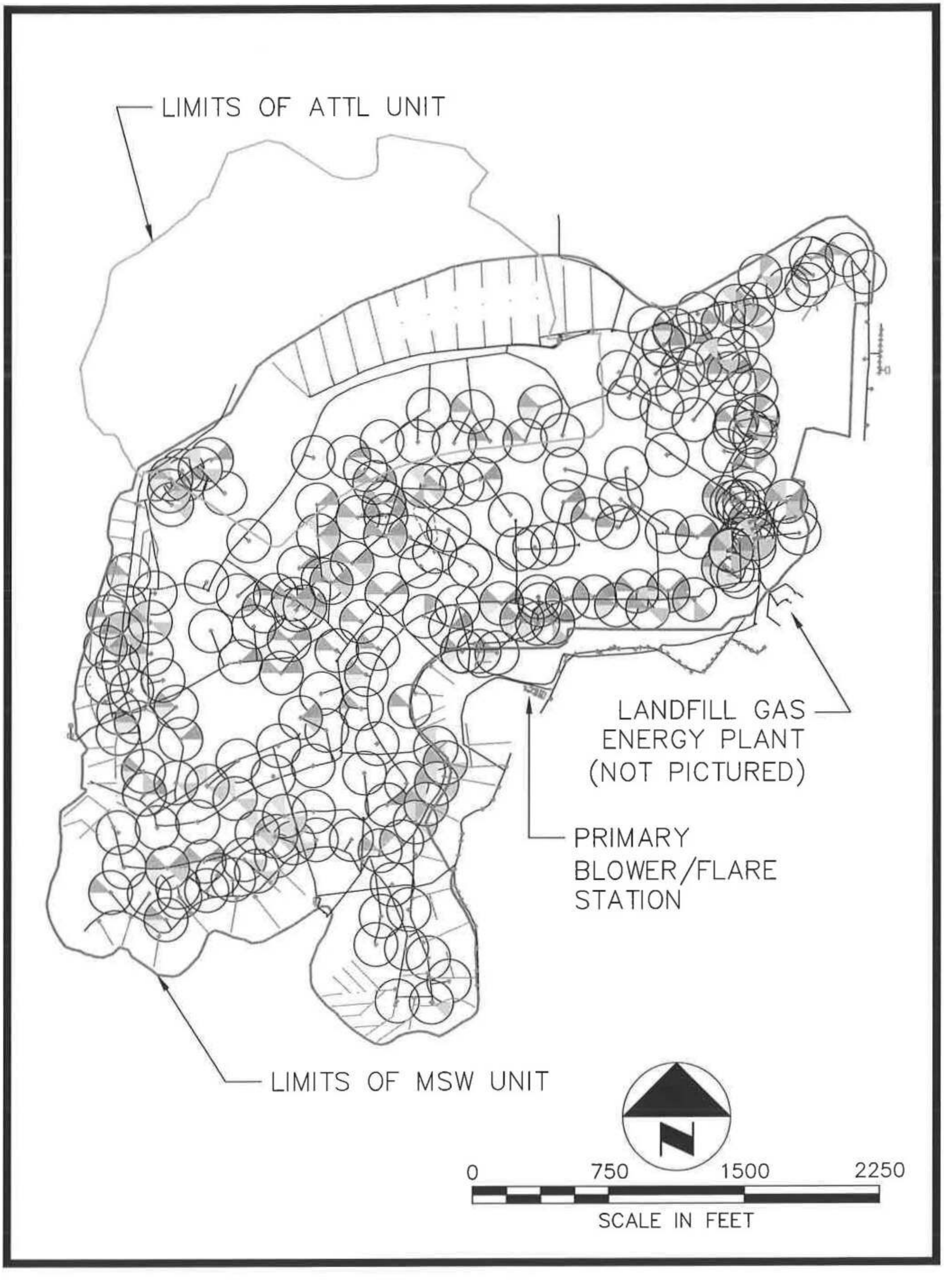

FIGURE 5: LFG COLLECTION DEVICE EVALUATION

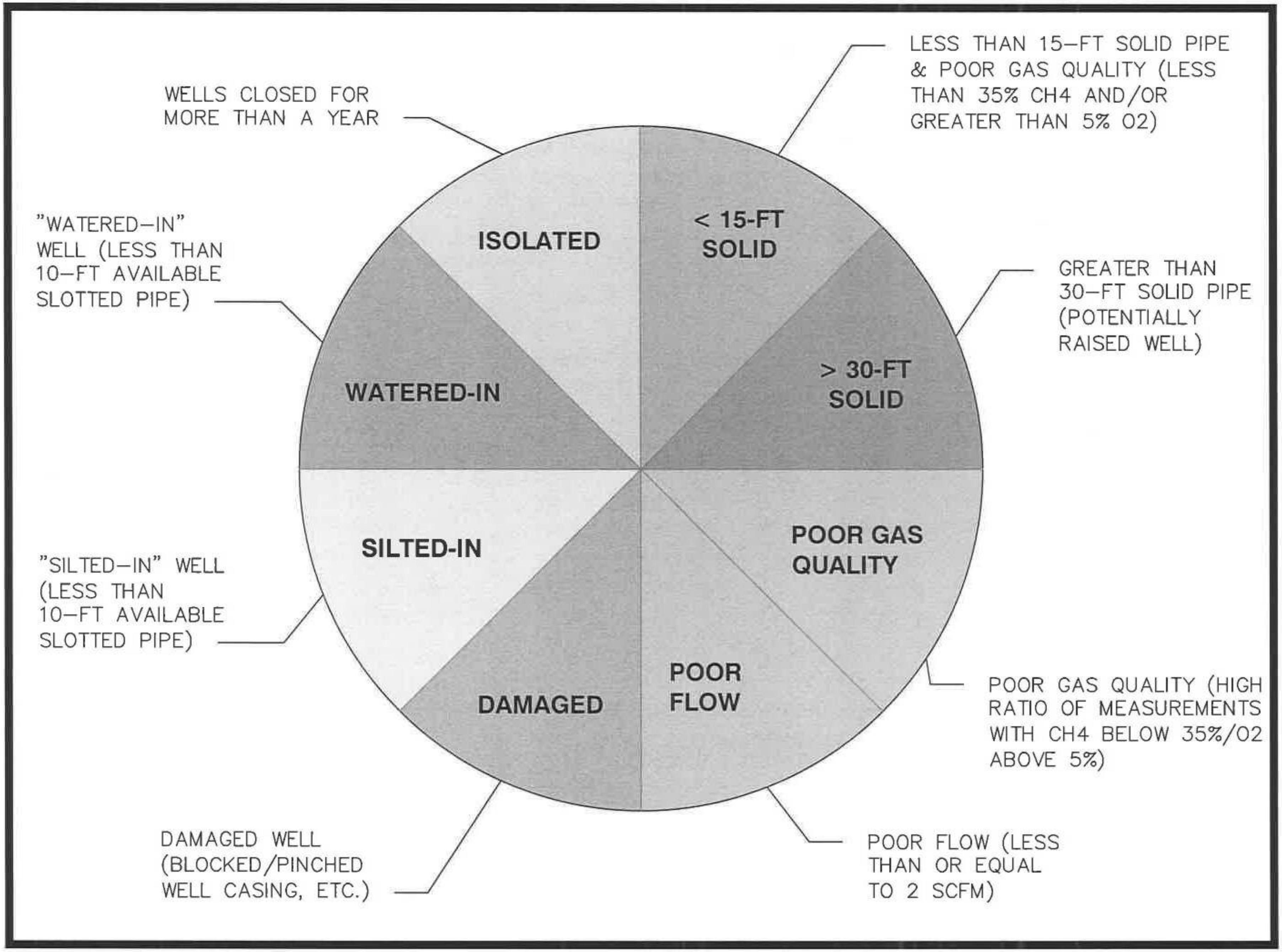

FIGURE 6: LFG COLLECTION DEVICE EVALUATION CRITERIA KEY

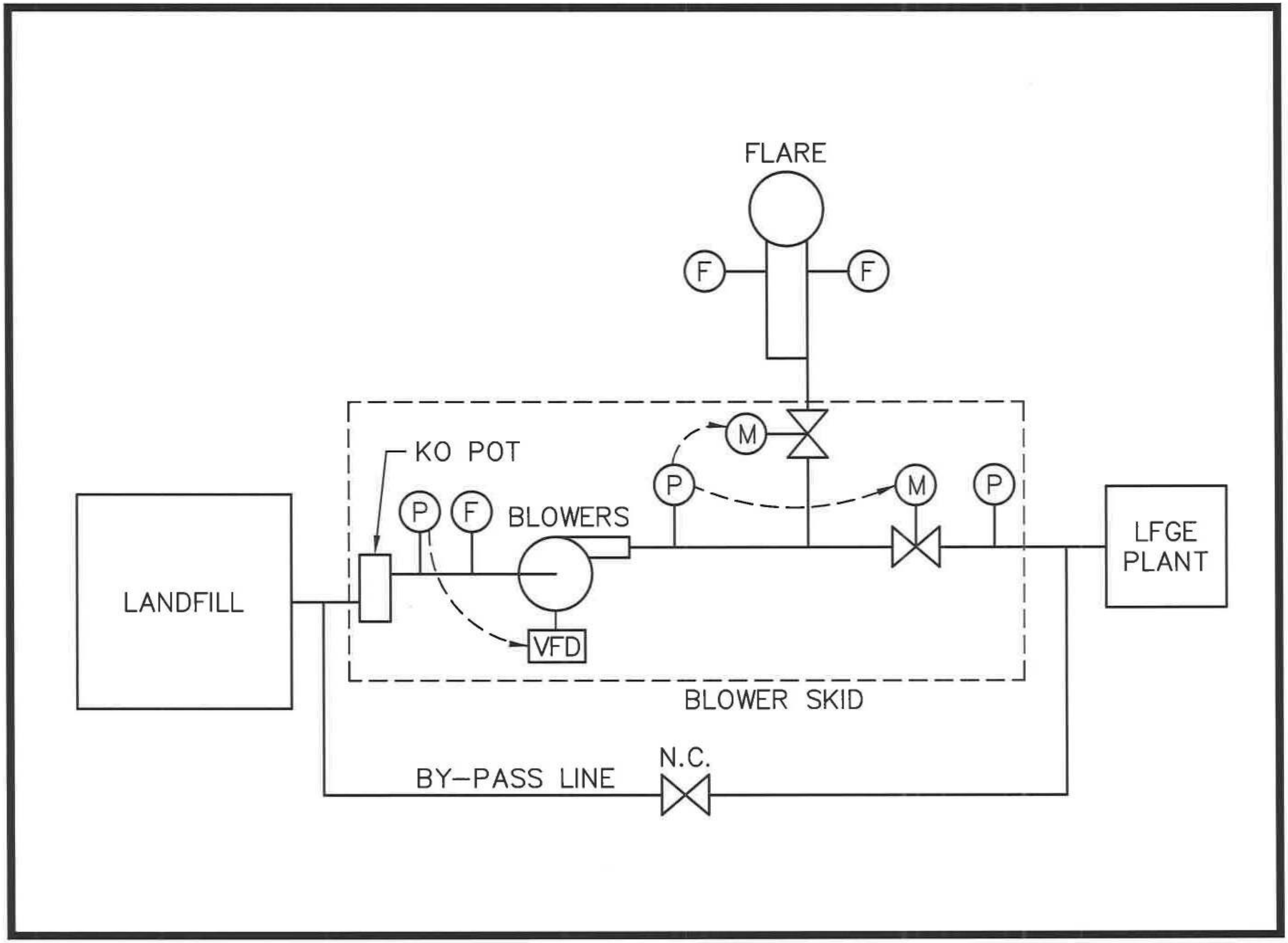

FIGURE 7: BLOWER / FLARE STATION CONCEPT

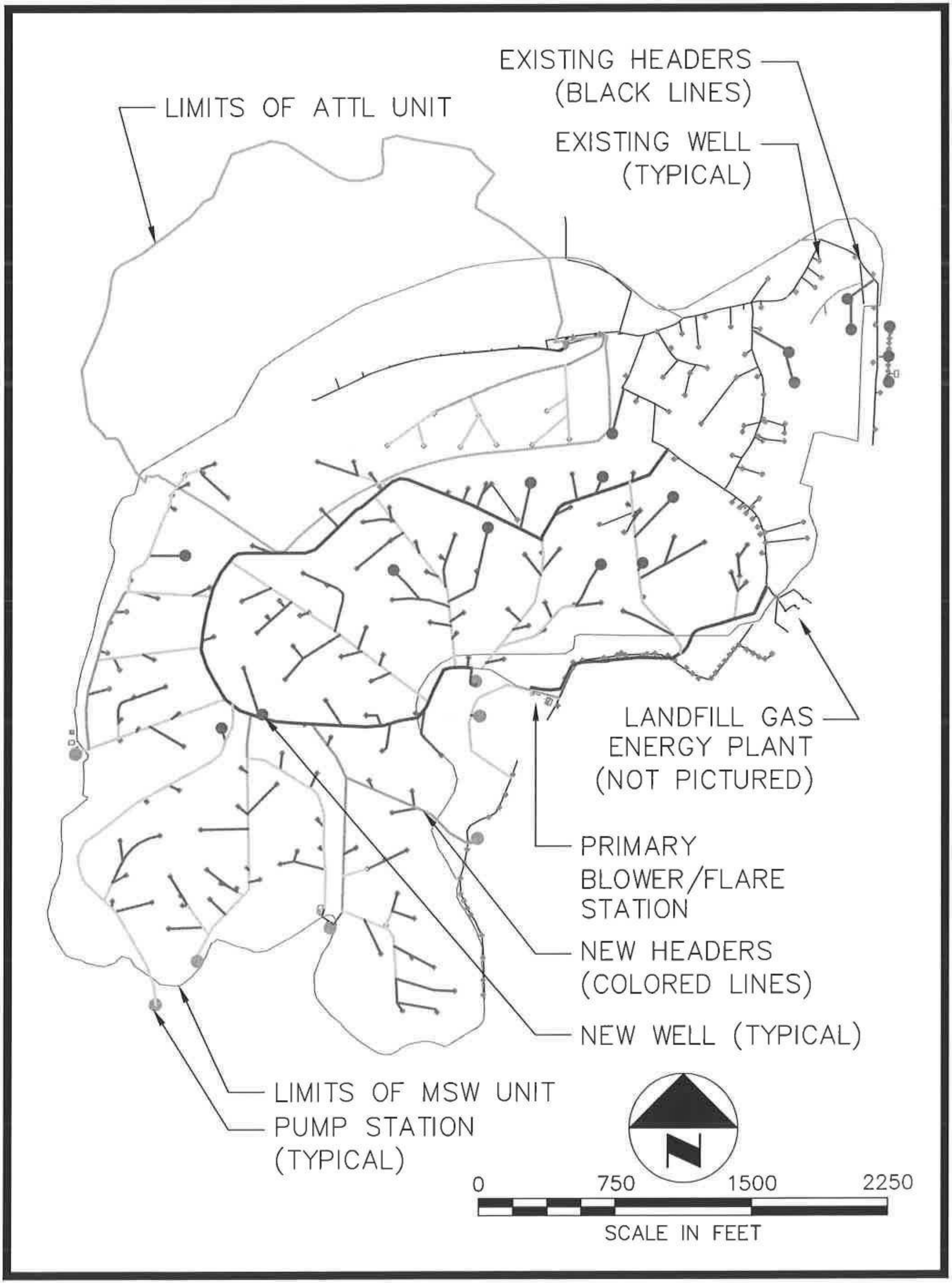

FIGURE 8: NEW WELLFIELD CONCEPT

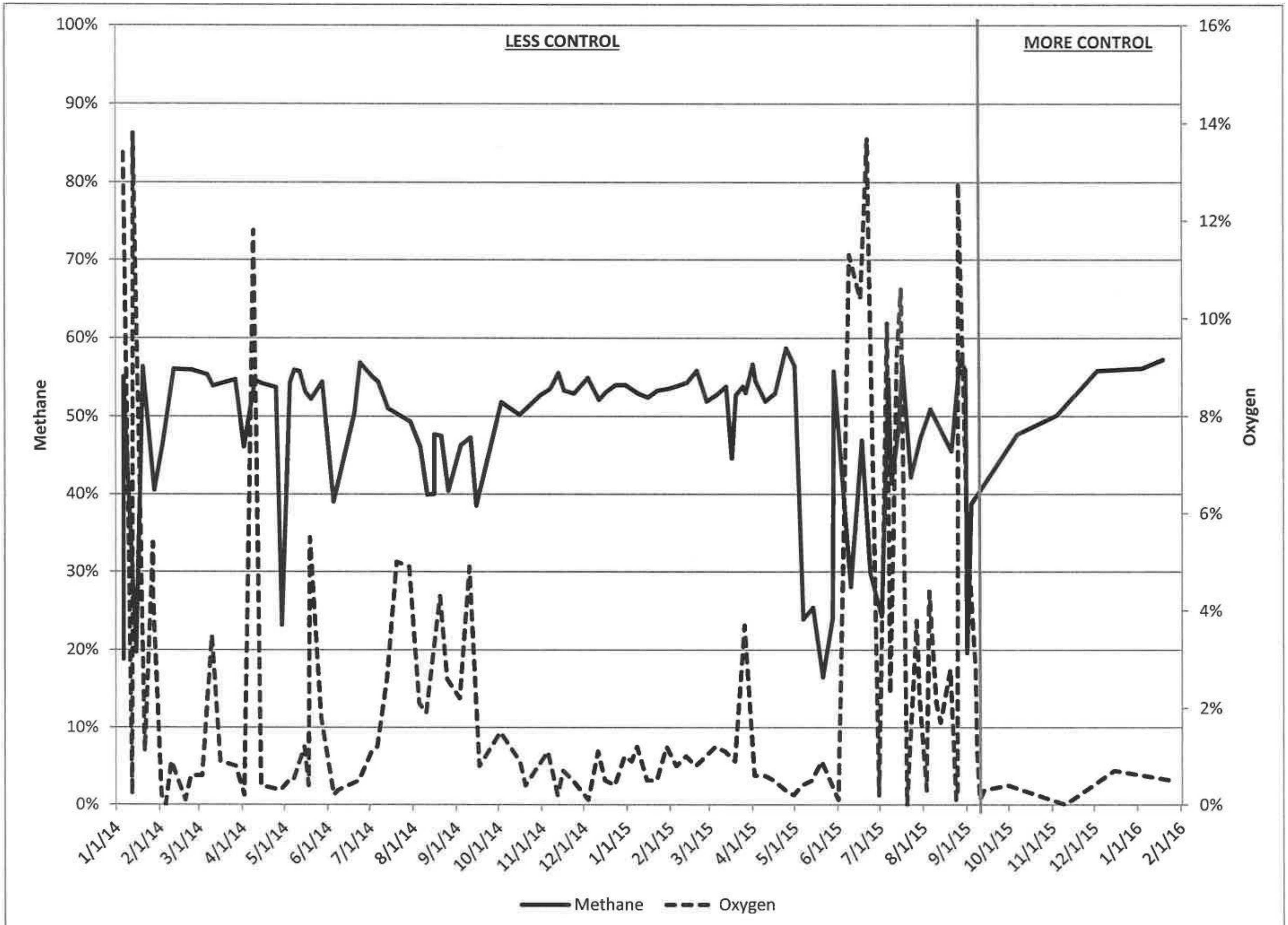

FIGURE 9: EXAMPLE WELL DATA

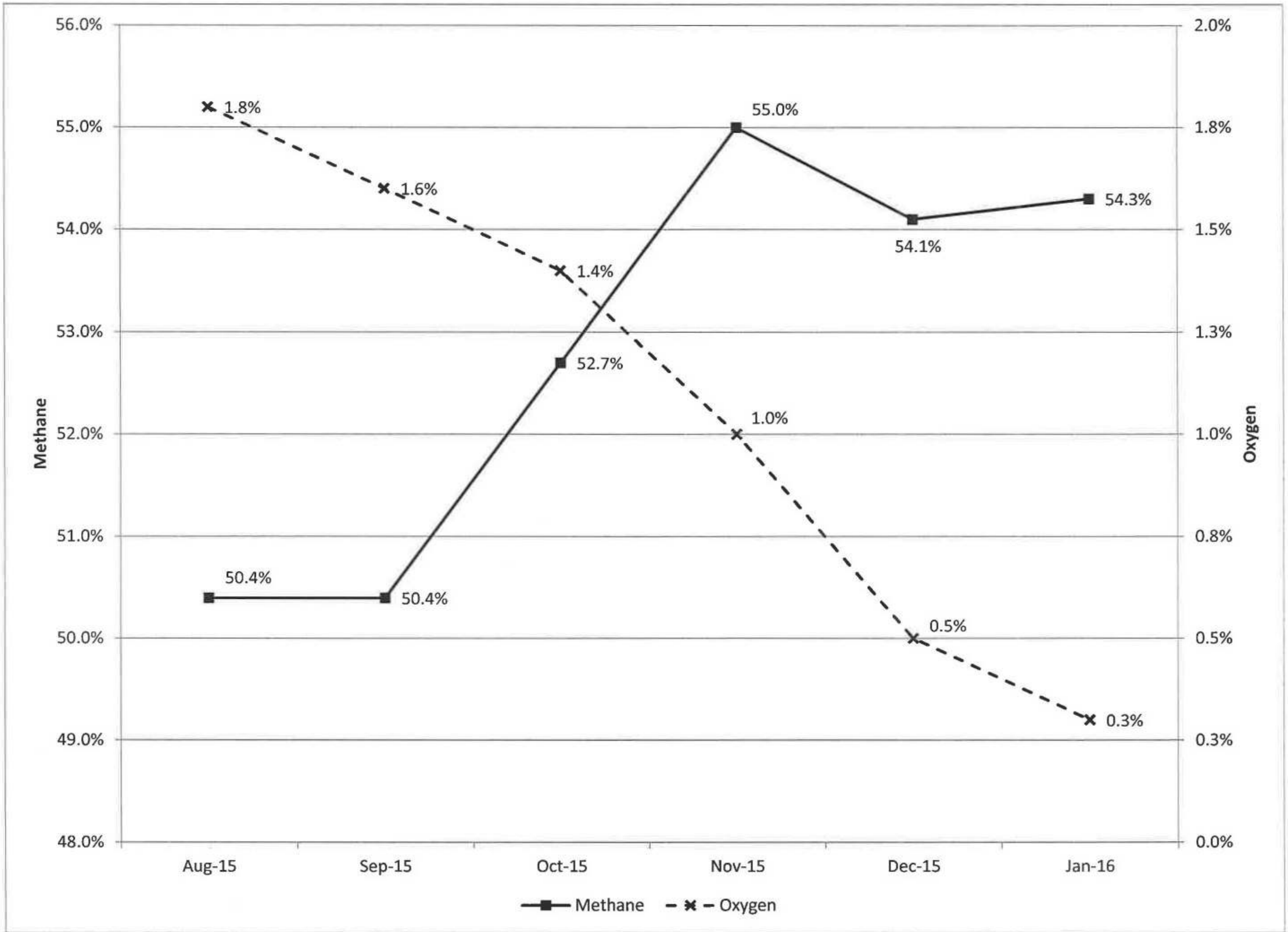

FIGURE 10: IMPROVED GAS QUALITY