Sullivan County Landfill Monticello, New York; Landfill Biostabilization Study

Final Report 03-03

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Energy Research and
Development Authority

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Final Report

Prepared for the

New York State Energy Research and Development Authority

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ABSTRACT

Three contiguous areas of a new cell at the Sullivan County Landfill in Monticello, New York were monitored to evaluate the feasibility and performance of vacuum-induced, semi-aerobic (VSA) biostabilization of municipal solid waste (MSW). This procedure involves installation of 12-inch-diameter landfill conduits in horizontal trenches, spray-application of leachate during waste placement, use of spray-applied synthetic daily cover, and application of vacuum pressures within the landfill conduits to pull atmospheric air through the wetted MSW.

Details regarding successful spray application of leachate onto waste, and spray application of cementitious alternate daily cover, are provided. In-place waste densities are calculated from topographic survey volumes and scale records.

The most significant findings of this study are:

(1) Methane fluxes to the atmosphere from the effective VSA biostabilization area were reduced by an average of over 90% compared with conventional control cell flux when vacuum was applied in the landfill conduits. Conversely, these fluxes were greater than the conventional control cell under non-vacuum conditions.

(2) Influence distance of moderate vacuum corresponds with typical landfill conduit spacing.

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SUMMARY

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Methane flux to the atmosphere from locations 55 feet away from vacuum lines was reduced by an average of 90% compared with the conventional control cell; the flux directly above vacuum conduits was reduced by an average of more than 99% compared with the control cell. However, under non-vacuum conditions, the VSA stabilization area had an average flux about 30 times greater than the control cell, while the leachate recirculation area had a flux about 10 times greater than the control cell. Non-methane organic compounds (NMOC) fluxes averaged about 90% less from vacuum areas than from non-vacuum areas. These findings demonstrate that atmospheric emissions from the landfill surface are significantly reduced when vacuum gas collection is operated concurrently with biostabilization activities.

Modest vacuum of 4 to 10 inches water column applied to the HYEX™ landfill conduits produced measurable vacuum pressures in the waste up to 137 feet away. Measured vacuums were greater near the conduit, and decreased with distance. Vacuum pressures were consistently produced at a horizontal distance of 55 feet from each of the research conduits, which were buried 10 feet beneath the waste surface.

Vacuum pressures drew atmospheric air into the pore spaces of the waste mass, creating an irregular semi-aerobic pattern characterized by low methane, reduced carbon dioxide, and high balance gas (assumed to be principally atmospheric nitrogen). Typically, oxygen would initially be present, but would later be entirely consumed by microbial respiration. Cessation of vacuum conditions was followed immediately by occupation of the interstitial spaces with gas rich in methane and devoid of oxygen or balance gas. This gas was likely generated primarily by the older layer of waste beneath the upper study layer.

Waste temperatures were somewhat lower than expected in the most active semi-aerobic areas with maximums of about 145º F. Typical temperatures in the non-aerated areas were in the 100 to 120º F. range, although individual spots in the conventional control cell measured above 140º F. These relatively moderate temperatures in the semi-aerobic area indicate low potential risk for internal fire ignition.

Spray-application of leachate directly onto the MSW as it was being placed and compacted was successful. This method is inexpensive and reduced the amount of windblown paper; however, it does require a full-

time, trained operator to carefully direct the spray in order to avoid misting landfill workers or truck drivers. Leachate was applied at rates from about 20 to 40 gallons per ton of waste.

The physical density of the wetted waste was 4 to 8% greater than similarly compacted non-wetted waste. The use of Posi-Shell® spray-applied alternate daily cover increased the effective density of the landfill by 20% compared with use of soil and ash daily covers.

VSA stabilization appears to be a cost-effective, workable procedure to increase density and accelerate biostabilization of MSW while simultaneously reducing gaseous atmospheric emissions.

Section 1
INTRODUCTION

DESCRIPTION OF THE PROBLEM

Development of new landfill capacity in most of the United States is becoming increasingly difficult due to mounting public opposition and ever more stringent environmental standards. This scarcity of new landfill disposal capacity has created strong commercial interest in technologies and methods to increase the waste disposal capacity of existing landfills. At the same time, more stringent environmental standards have generated renewed interest in technologies that facilitate active management of the potential environmental impacts of landfills. Modern landfill design is evolving from the traditional "dry tomb" concept, where the intent was to "seal" the waste indefinitely, to the bioreactor landfill, where the waste is decomposed and stabilized within a shorter time frame during which the process can be actively managed.

It is generally accepted that there are three operative aspects of waste densification in a landfill. These are mechanical compaction, autogenous settlement (settlement due to gravity surcharging), and biogenous settlement or biological decay, which is the basis of a bioreactor landfill. During the last decade, the bioreactor approach has moved rapidly from vision to reality – the bioreactor or biostabilization concept has evolved from an esoteric science and a topic of Ph.D. thesis to a commercially viable and mainstream technology. New York State landfills have done pioneering work in this area, employing both aerobic and anaerobic biostabilization techniques.

The usual environment within landfilled waste is anaerobic; therefore, most of the ongoing projects that employ some form of biostabilization and leachate recirculation generally focus on the anaerobic decomposition of waste. Aerobic decay of the waste offers more rapid waste stabilization; however, there are numerous potential problems unique to aerobic landfills that have not been adequately addressed and may be inhibiting the commercial viability of this promising technology. This study investigates solutions to some of these challenges focusing primarily on two of the major problems related to aerobic biostabilization of municipal solid waste (MSW) – atmospheric emissions and uniform leachate/moisture application.

Aerobic decay of municipal solid waste results in a more rapid degradation of the organics; however, blowing air into the waste normally results in the expulsion of significantly more fugitive gases from the waste mass. This increased random emission of fugitive gas from a pressurized waste mass may result in additional atmospheric emissions and increased odor complaints. This problem is accentuated with leachate recirculation and moisture application, which accelerates the gas production and associated problems. A potential solution to this problem involves placement of conduits within the waste and subsequent application of a vacuum within these conduits to draw atmospheric air and landfill gas downward from the overlying waste as well as upward from the underlying waste into the conduits, and then transport these gases to the landfill flare where they are combusted under controlled conditions with methane-rich gas from other areas of the landfill for odor control and pollutant destruction.

Another major problem in biostabilization of municipal solid waste is achieving even distribution and equilibrium of moisture to accelerate microbial metabolism. This is particularly important prior to aeration to inhibit combustion potential. It is well established that typical U.S. waste is too dry for optimum biodegradation and, therefore, addition of moisture is necessary; the ideal liquid for this purpose is landfill leachate which is enriched in nutrients and useful biota. Various methods of leachate recirculation have been employed in the past and are currently employed at other landfills; however, uniform application of significant moisture to the waste is always challenging. A potential solution to this problem investigated during this project involves spray-application of leachate directly onto the waste as it is being rolled out and compacted. Spray-application was well controlled with leachate-wetted waste continually buried beneath new layers of incoming MSW.

GOALS AND OBJECTIVES

The major goal of this project is to evaluate the feasibility of vacuum-induced semi-aerobic biostabilization to maximize landfill capacity through optimum compaction and enhanced biostabilization. This practice results in cost-effective beneficial use of landfill leachate and an enhancement of anaerobic methane production after the initial semi-aerobic condition reverts to anaerobic conditions. There are six major objectives in support of this goal:

- Evaluation of leachate spray-application for waste moisture adjustment.
- Measurement of waste placement densities after moisture adjustment.
- Determination of the radius of influence of moderate vacuum inductions.
- Measurement of waste temperature in the semi-aerobic zone.
- Characterization of waste gas conditions in the semi-aerobic zone.
- Measurement and comparison of atmospheric emissions from biostabilization areas under vacuum conditions and conventional areas under positive-pressure conditions.

PROJECT DESIGN

The project design illustrated on the General Arrangement Plan, Appendix 1, involves a strategy to compare three contiguous areas in Cell 4 of the Sullivan County Landfill. These areas were each approximately 200 feet by 400 feet with a waste lift height of 10 feet. The HYEX™ landfill conduits necessary for creating vacuum conditions were buried beneath the first area constructed, known as Mat A. Waste placed in Mat A received spray-application of leachate during waste placement and Posi-Shell® alternate daily cover was used to avoid creation of impermeable soil barriers which might interrupt gas transmission. The second area, known as Mat B, also received leachate application; however, no subsurface conduits or aeration were involved and conventional daily covers, principally ash and soil, were used rather than the Posi-Shell cover. Mat C, the third study area, was a control area employing conventional landfill practices with no leachate addition, no aeration and no synthetic cover material. Each of these mats received an average of about 720 tons per day of solid waste for approximately one month's operating time.

Table 1-1

Mat Comparison Summary

Activity	Mat A	Mat B	Mat C
Leachate Spray Application	X	X	
Posi-Shell® Daily Cover	X		
Vacuum Aeration	X		

The operating sequence included the following elements:

- Placement of geomembrane thermocouples
- Placement of the select lift and second MSW lift above liner
- GPS baseline topographic survey
- Installation of HYEX™ conduits in second MSW lift beneath biostabilization Mat A
- Waste placement and leachate application to Mat A
- Posi-Shell® daily cover applied to Mat A
- GPS topographic survey of Mat A
- Waste placement of biostabilization Mat B
- Application of leachate during waste placement in Mat B
- Installation of well-point probes, flux boxes and random monitoring points for monitoring gas pressure, temperature and emissions from Mat A
- GPS topographic survey of Mat B
- Placement of control Mat C utilizing conventional landfill practice

- Installation of well-point probes, flux boxes and monitoring points for monitoring Mat B
- Installation of well-point probes, flux boxes and monitoring points for monitoring Mat C
- GPS topographic survey of Mat C
- Data analysis and report preparation

SAMPLING AND TESTING PROTOCOL

Four different types of sampling points were employed including valve-stem nipples, steel pipe well points, flux boxes and plunge bar probes.

A total of 24 valve-stem nipples were installed on the HYEX™ gas extraction laterals and on vacuum gas mains and the flare station. The purpose of these points was to obtain gas quality and flow data using the GEM 500 meter.

A total of 28 steel pipe well points were installed at depths of 4 and 8 feet in the MSW mats. These were fitted with Type K thermocouples for temperature measurement and valve-stem nipples for gas quality sampling.

Seven individual flux boxes, constructed from 55-gallon steel drums, were placed in the three mats for the purpose of atmospheric flux measurement. The removable gasketed top was fitted with a valve-stem nipple for extraction of samples by the GEM 500 meter and the Foxboro TVA 1000 FID.

Additionally, numerous random and fixed location plunge-bar borings were made and gas samples taken with the GEM 500 meter. Temperature measurements were made at various depths with a Reotemp compost thermometer.

Metering instruments included:

- GEM 500 landfill gas meter, which measures percent methane, percent carbon dioxide, percent oxygen and balance gas (a mathematical remainder assumed to be principally nitrogen). This meter also measures gas temperature and flow rate when connected with a thermometer and pitot tube.
- ISC HS267 meter was utilized for measurement of hydrogen sulfide.
- Type K thermocouple temperatures were measured with an Omega Multimeter thermometer.

- Magnahelic pressure gauges of various levels of precision measured vacuum and pressure conditions within the waste.
- Flux box readings were taken with a Foxboro TVA 1000 FID instrument which measured parts per million of methane.
- Non-methane organic compound (NMOC) measurements were extracted into vacuum Summa canisters and forwarded to Performance Analytical Laboratories in Simi Valley, CA for analysis.

The general protocol established in the initial Operating Plan is shown on Table 1-2. Some variations occurred in the actual field sampling schedule.

Table 1-2

GAS SAMPLING SCHEDULE

Location	Parameter	Frequency	Method*
HYEX Laterals	CH_4	Weekly	1
	CO_2	"	1
	O_2	"	1
	BAL	"	1
	H_2S	"	2
	Temperature	"	1 & 3
	Pressure	"	1 & 4
	Flow rate	"	1
Well Points	CH_4	Biweekly	1
	CO_2	"	1
	O_2	"	1
	BAL	"	1
	H_2S	"	2
	Temperature	"	1 & 3
	NMOC	Monthly	5
	Pressure	Weekly (min.)	1 & 4
Flux Boxes	CH_4	Biweekly	1
	CO_2	"	1
	O_2	"	1
	H_2S	"	2
	BAL	"	1
	Temperature	"	1 & 3
	NMOC	Monthly	5

*Method Legend

1) GEM 500 LFG Meter
2) ISC HS267 Portable H_2S Meter
3) Reotemp Compost Thermometer
4) Magnahelic Pressure Gauge
5) Summa Vacuum Canister Samples; EPA Method TO-15

PROBLEMS ENCOUNTERED

During the first two months of project operations, the availability of vacuum was intermittent and the typical vacuum available was about 4 to 8 inches water column at the HYEX intake manifold. It was originally envisioned that 15 to 20 inches water column of vacuum would be available to extract up to 300 SCFM of gas from the HYEX conduits on a steady-state basis. This problem was mitigated in August by installation of an 8-inch HDPE jumper line across the landfill to provide a more direct route to the flare. Also, the flare operations were stabilized and during the latter two months of field work, the vacuum conditions were more steady although the available vacuum still was limited to about 8 inches water column.

This problem had a positive aspect because it forced evaluation of Mat A conditions at a very moderate vacuum level. This is more affordable for landfills generally and would result in less low-methane gas delivered to the combustion system. Significant and valuable findings were developed through operation of the project at these moderate vacuums; however, future investigations could be conducted with higher vacuum and gas extraction rates to induce a greater aerobic biological activity in the waste mass. Certainly, these activities must be planned to function within the overall framework of landfill operations.

Another problem encountered involved a survey point anomaly resulting in an unreasonably large "cut" value in the final survey of Mat C. The raw value, believed to be in error, would have greatly exaggerated the density of waste by minimizing volume occupied. This value was mathematically adjusted to correspond with typical cut values determined in the previous surveys. This problem points out the need to immediately evaluate the quality of survey results because it is not possible to return later to redo surveys in an active landfill.

Finally, the project field schedule dictated that less time was available to obtain control mat data because the control mats were constructed later. Equal duration of the study periods would have been more ideal.

Section 2
CONSTRUCTION OF WASTE STABILIZATION MATS

PLACEMENT OF SELECT LIFT AND SECOND MSW LIFT

Following regulatory approval for use of Cell 4, an initial lift of select waste was placed to a depth of approximately 5 feet in a manner consistent with NYS Part 360 regulations. The entire surface area of Cell 4 was covered with the select lift which proceeded from the entry road at the northern central boundary of Cell 3 and Cell 4. Placement of the select lift took approximately 4 months to complete. Then a second lift of normal MSW approximately 10-feet-thick was placed above the select lift in order to bring the waste elevation to the height of the perimeter berms on all sides of the cell. At this time, the topography of the cell surface was approximately level and ready for construction of the biostabilization mats. Placement of the second lift of waste was in accordance with the landfill's standard approved methods, including use of ash for working face cover and processed C&D debris covering the flat upper surface.

INSTALLATION OF HYEX™ CONDUITS

HYEX landfill conduits are 12-inch ID, structurally reinforced HDPE culverts with special slotting for effective fluid exchange. These landfill conduits were placed in 100-foot lengths (one-half the width of Mat A) at six locations beneath Mat A as shown on Figure 2-1. The spacing between conduits is 55 feet horizontal separation with the conduits placed approximately 3 feet beneath the finished surface of the second waste lift. Figure 2-2 illustrates Mat A typical elevation.

The trenches were dug with a Komatsu PC-300 excavator and washed stone bottom fill was hauled in with Caterpillar Model D-350 articulated end dump trucks. The HYEX conduits were placed on the stone bedding and two interior HDPE lines were placed within the conduits for their full length. One interior line is a perforated 2-inch ID pipe and the other is a solid 3-inch ID pipe; each pipe terminates approximately 10 feet from the western end of the HYEX conduit. A third 3-inch HDPE pipe terminates approximately 10 feet inside the eastern end of the HYEX conduit. Thus it is possible to provide a vacuum at either end of the landfill conduit or to provide a vacuum evenly throughout the conduit through the perforations of the continuous 2-inch pipe. As a substitute for washed stone, these conduits were then backfilled with mixed glass bottles rejected from a recycling process. Most of these were whole beverage containers although some glass was broken or miscellaneous size jars. Since these conduits are structurally reinforced with interior columns, it is not necessary to use engineering grade structural bedding material such as washed stone for the pipe zone bedding. Also, these conduits withstand the forces of differential settlement and elevated temperatures associated with landfill placement. The eastern edge of the HYEX conduit was sealed with a plug of clay type soil to prevent weeping of leachate from the trenches created for the laterals to exit the landfill. The finished surface above the HYEX trenches (and across the entire lift) was covered with the

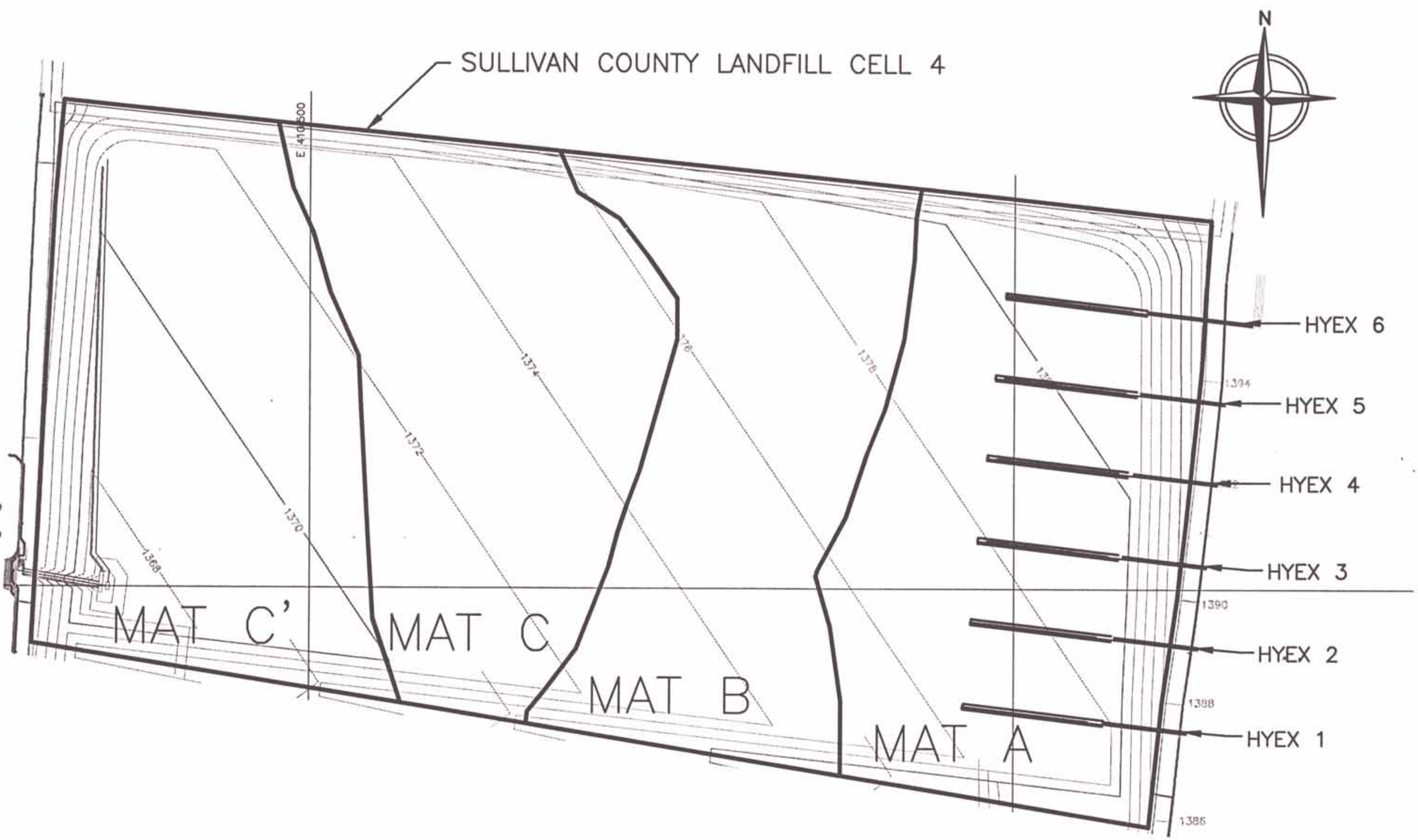


FIGURE 2-1

PROJECT GENERAL ARRANGEMENT

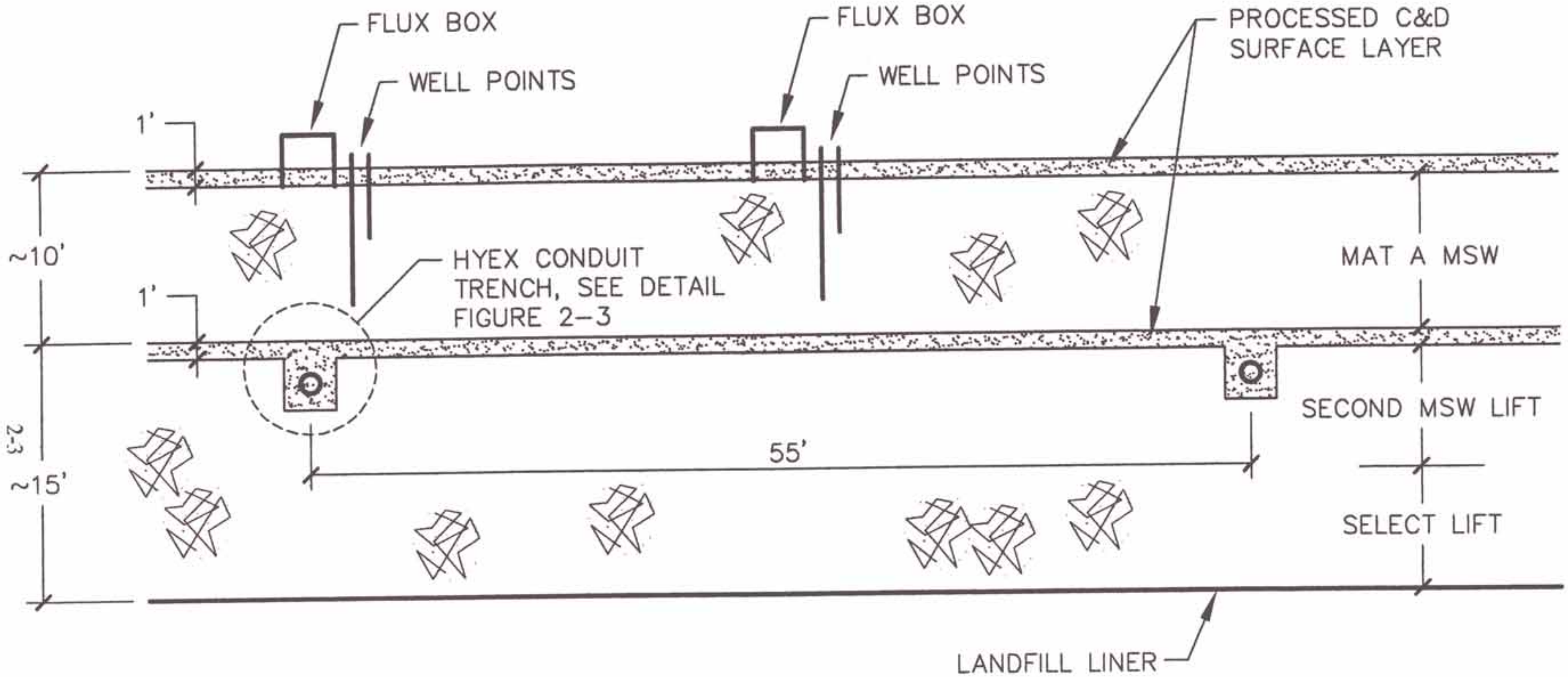


FIGURE 2-2

MAT A TYPICAL ELEVATION

SCALE: 1" = 10'

porous, recycled C&D material commonly used at the Sullivan County Landfill for driving surface daily cover. Figure 2-3 provides a detail of the conduit trench installation.

The HYEX conduits were buried only beneath Mat A since this was the only area to be placed under vacuum for the creation of semi-aerobic conditions. Once the HYEX conduits were installed, it was then possible to proceed with construction of the waste lift over the Mat A area.

MAT A

During the period of June 8th through July 5th, solid waste was placed at an average rate of 701 tons per day for 22 operating days in the area of Mat A. The daily placement tonnage ranged from 300 (Saturday) to 1350 tons per day. Intermediate soil cover was placed on the eastern and southern exterior exposed slopes.

The two significant variations in landfill procedure practiced on Mat A were spray-application of landfill leachate into the waste during placement and daily cover of the interior side slope surfaces with Posi-Shell® synthetic cover material. Posi-Shell is a spray-applied, fiber-reinforced cement mortar cover similar to stucco, which substitutes for the conventional 6-inch-thick layer of daily cover soil or ash used at Sullivan County. This material was used because it readily breaks up when a subsequent lift of waste is placed, thus avoiding creation of an impermeable barrier impeding moisture and gas movement.

The approved fill progression for Cell 4 involved filling from east to west; therefore, Mat A was envisioned as a 200-foot by 400-foot rectangle beginning at the eastern most perimeter of Cell 4 and moving approximately 200 feet in a westward direction. The actual limits of Mat A are shown on Figure 2-4 which is a topographic map of the final configuration on July 5th.

Key concerns during the construction of Mat A were whether the spray-application of leachate would create odor problems and whether the leachate application equipment and procedure would interfere with the compaction operations. Also, there was concern that application of the leachate directly onto the garbage may create slippery or muddy conditions at the truck unloading areas, thereby impeding normal operations. In all three respects, the project was a resounding success.

With respect to odors, the NYS DEC maintains an onsite monitor who was present frequently during the spray-application of leachate. This monitor indicated that odors were not a problem with this activity. Also, no offsite odor complaints were received during spray-application of leachate. During the first week, a treated leachate was used; thereafter, raw leachate was applied. Odor-control liquids were added occasionally, but were generally unnecessary.

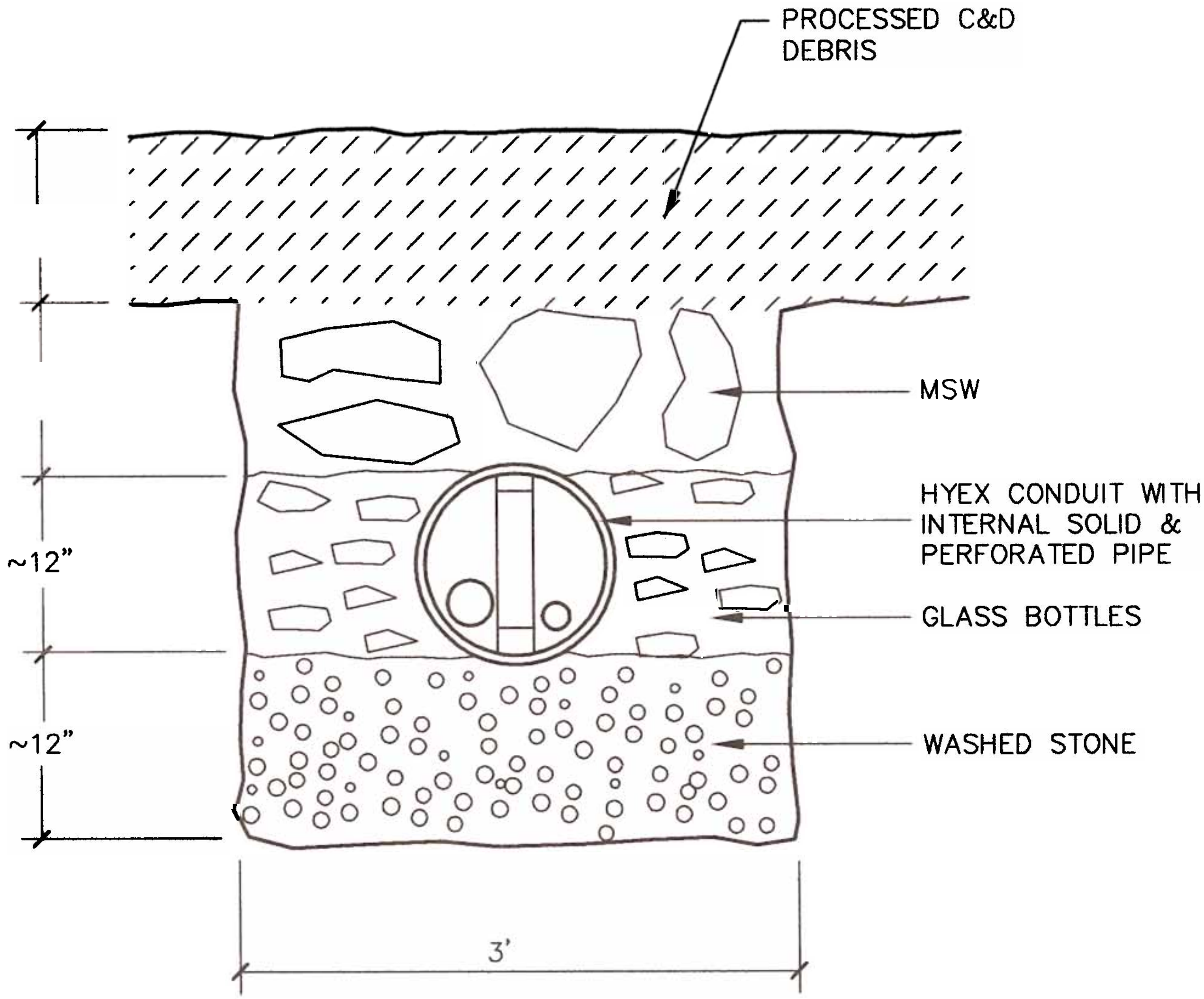


FIGURE 2–3

HYEX™ CONDUIT TRENCH DETAIL

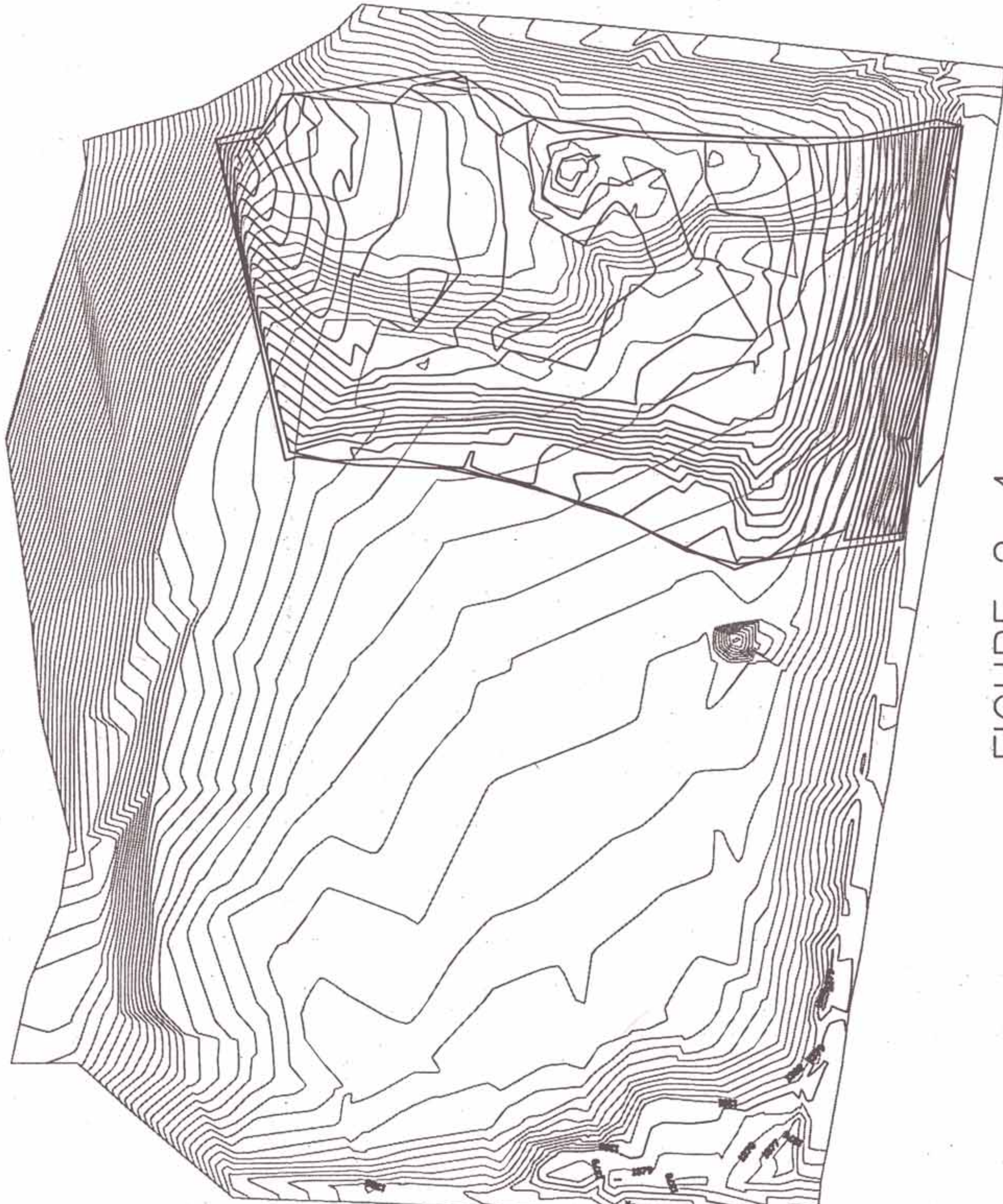


FIGURE 2-4
MAT A TOPOGRAPHY

From an operational perspective, the highly mobile PSA 3500 Applicator was able to move around the working face area in a manner which avoided conflict with the ongoing unloading and compaction activities. One additional benefit was that blowing litter was reduced by wetting the waste as it was being rolled out and compacted. This wetting prevented much of the material from becoming airborne during high wind events. The carefully directed spray-application of leachate avoided ponding of water at the toe of the slope and, therefore, muddy or sloppy conditions in the truck-unloading zone did not occur.

MAT B

Placement of waste Mat B began on July 6th and continued through July 26th for a total of 18 operating days. During that period, an average of 740.6 tons was placed each day with a range from 199 (Saturday) to 1187 tons per day.

Leachate was spray-applied to the waste in Mat B in a similar manner to that described for Mat A. The practice of leachate application was once again successful; however, there were two events on a particularly windy day, when truck drivers complained that an aerosol mist was being carried to the unloading zone. The leachate application operator was informed of this problem and adjusted his spraying pattern, and there were no further complaints for the remainder of the project. These were the only complaints of this type during the project.

Mat B was not subjected to vacuum conditions and the movement of gases was not critical in this mat; therefore, site-approved daily cover comprising principally ash from the Dutchess County Waste Energy Facility and locally available soil was placed on the sloping faces. The recycled C&D material was used on the upper driving surface for daily cover as it was on Mat A. The last waste was placed in Mat B on July 26th and a final topographic survey was taken on that day. Figure 2-5 illustrates the final topography and limit of Mat B.

MAT C

Mat C was constructed during the period between July 27th and August 21st for a total of 21 operating days. The average daily waste receipts were 718.7 tons per day with a range between 45 (Saturday) and 1204 tons per day. Mat C was constructed as an approximately 200-foot by 400-foot rectangle beginning at the easternmost perimeter of Mat B and moving approximately 200 feet in a westward direction. Mat C was the control cell and, therefore, conventional landfill placement practices were employed including the use of site-approved daily cover and placement of MSW as received with no addition of leachate or any other liquid. Figure 2-6 indicates the topographic contours achieved on August 21st. On that date, a survey was performed and Mat C was considered complete. The remainder of Cell 4 was also filled conventionally and is noted on

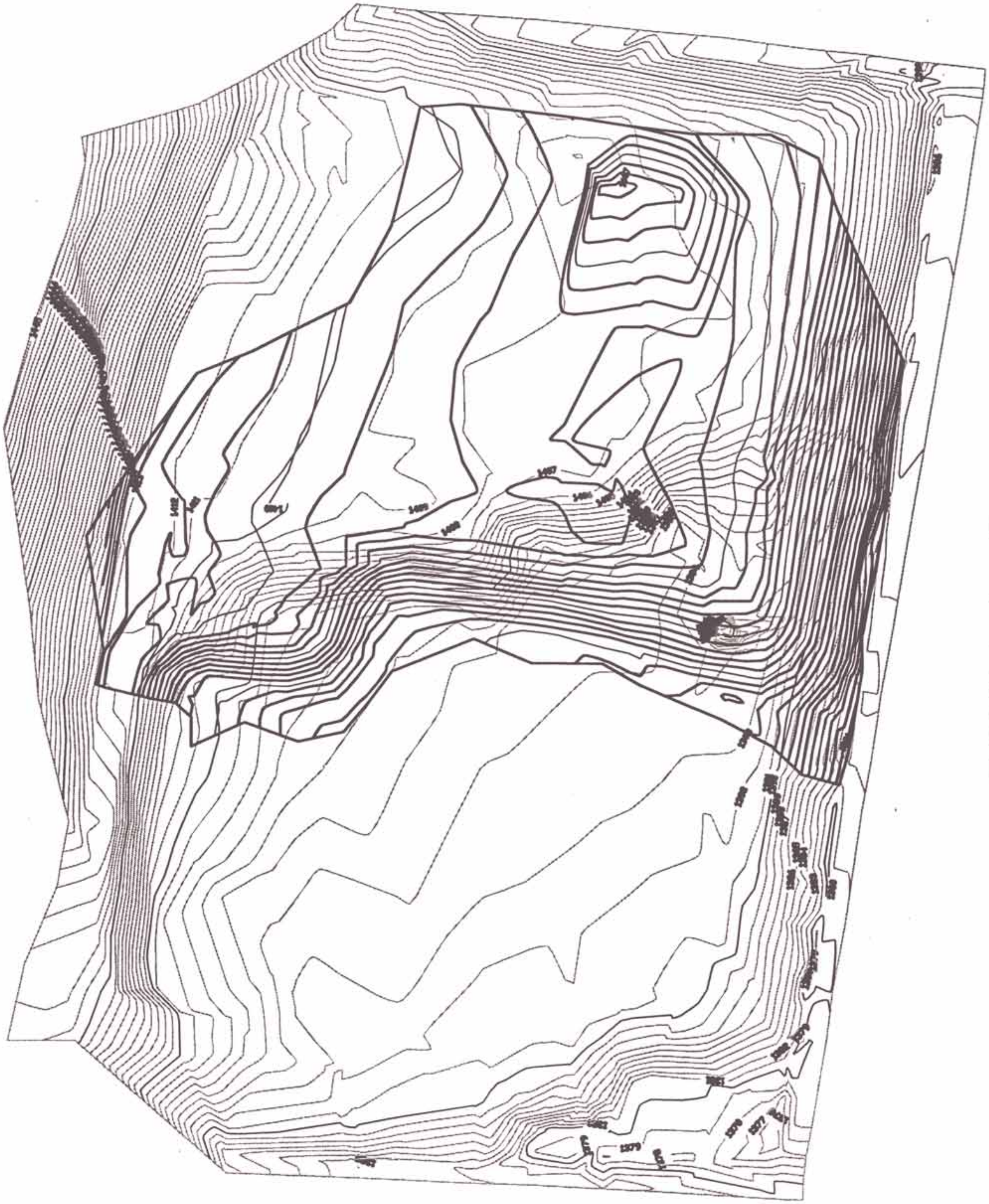


FIGURE 2–5
MAT B TOPOGRAPHY MAP

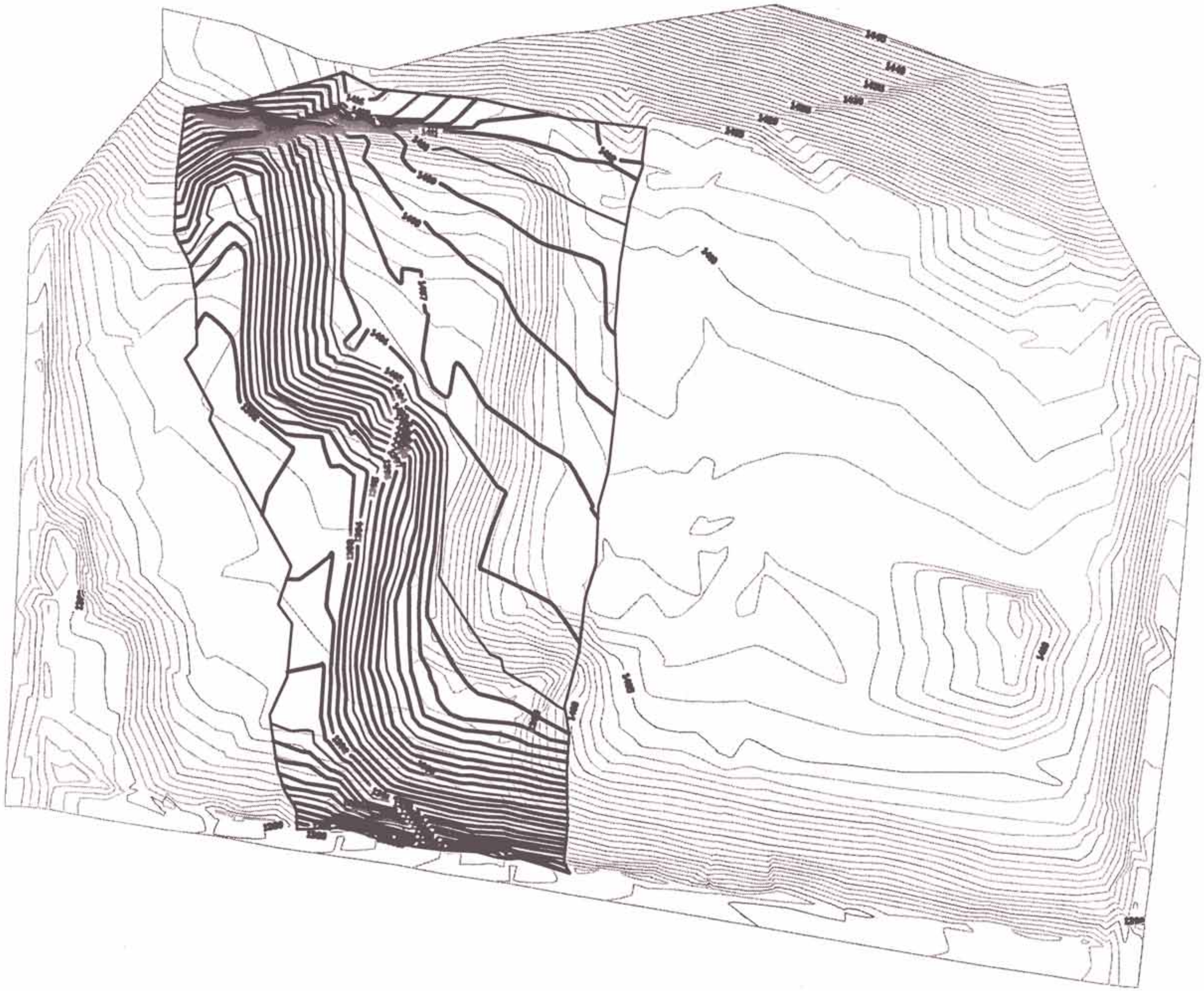


FIGURE 2-6
MAT C TOPOGRAPHY

the drawings as Mat C' ("C prime"). No measurements were performed in Mat C' other than monitoring the thermocouples placed on the landfill liner beneath this area.

LEACHATE APPLICATION SUMMARY

During the first week of the project, treated leachate was utilized for spray application to avoid any potential odor problems while fine-tuning operational methods. Since no problems were encountered with the treated leachate, raw leachate was taken directly from the leachate storage tanks during the second week and thereafter. A total of 359,300 gallons of leachate (1499 tons) was applied to Mat A and a total of 324,550 gallons (1353 tons) was applied to Mat B. The total MSW placed in Mat A was 15,426 tons and 13,331 tons in Mat B. Assuming an incoming waste moisture content of 25% by weight, then the moisture adjustment for Mat A would be an upward movement to 31.6% and Mat B, a movement to 31.9% moisture. Considering the weight of water added to the waste, the equivalent gravity surcharge depth would be less than one foot of MSW.

As previously noted, the operational feasibility of spray-application and the lack of odor complaints were very important findings of this research project because spray-application is the least expensive method of evenly distributing moisture onto solid waste in a landfill. The application rate was selected to match the leachate supply. All available leachate was consumed during the study period, and although it would have been ideal to add more moisture (up to 40-45% by weight), it was not possible. This is a typical problem at many landfills.

DENSITY MEASUREMENTS

Mechanical compaction of the waste was the same for all three mats. Equipment employed included one Caterpillar Model 816 compactor, one Caterpillar Model 836 compactor, one CMI compactor, and one Caterpillar D-8 bulldozer. A Caterpillar Model 973 loader was used to distribute cover materials which were delivered by a Caterpillar Model D-350 articulated end dump truck. When the incoming waste was split (one-half going to another area), then one compactor was at each face. The project technician utilized an Ashtech GPS survey station together with a Compaq PC and Hewlett Packard printer to produce ten individual topographic surveys during the construction of Mats A, B, and C. A base map was first produced to identify the upper surface of the second MSW lift prior to placement of the biostabilization mats. Then after each survey was taken, the new surface was transformed into the base map for the succeeding survey. By this means, the change in volume was calculated and compared with the waste tonnage and cover material volumes to calculate both the effective density and the density of solid waste only. The results of these calculations are summarized in Table 2-1.

Table 2-1
Sullivan County Biostabilization Project
Density Summary

		MSW	*Airspace*	*Interim Cover*		*Ash Daily Cover*		*C&D Daily Cover*		*Soil Daily Cover*		*Total Daily Cover*		*Placement Density*			*Leachate Applied*	
	Operating Days	Waste Placed	Volume Increase	Interm. Cover	Interm. Cover	Ash Daily Cover	Ash Daily Cover	C&D Daily Cover	C&D Daily Cover	Soil Daily Cover	Soil Daily Cover	Total Daily Cover	Total Daily Cover	Unadjusted Density	Effective Density including daily cover volume	Physical density deducting in-place cover volume	Total Leachate	Unit Leachate
		TONS	CY	truck CY	in-place CY	truck CY	in-place CY	truck CY	in-place CY	truck CY	in-place CY	truck CY	in-place CY	lb/cy	lb/cy	lb/cy	GAL	gal/ton of waste
					80%		50%		65%		80%							
MAT A	22	15,426	28,837	2,440	1,952	198	99	4,650	3,023	0	0	4,848	3,122	1,070	1,148	1,298	359,300	23
MAT B	18	13,331	27,954	NA*	89	4,963	2,482	4,725	3,071	1,140	912	10,828	6,465	954	957	1,246	324,550	24
MAT C	21	15,093	*33,837*	NA*	89	3,780	1,890	4,650	3,023	4,706	3,765	13,136	8,677	892	894	1,204	0	0

* Not available - Values for interim cover in-place cubic yards calculated based upon exposed area of southern slope

Effective density is the mass of solid waste divided by the volume occupied including the volume taken up by daily cover. This is therefore not the actual physical density but is the airspace utilization factor of primary economic interest to the landfill owner. Table 2-1 indicates that the effective density of Mat A was approximately 20% to 28% greater than Mat B or C. This is logical because Mat A utilized an alternate daily cover material which does not take up the volume consumed by soil or ash daily cover materials. Intermediate cover was deducted from the calculations because a disproportionately large quantity of soil was used to cover the long eastern slope of Mat A compared with the more typical small values from the southern slopes of Mat B and Mat C

Another important finding is provided by investigation of the waste densities calculated deducting the in-place cover volumes. This value describes the physical density of the waste itself, and indicates that a 4% to 8% improvement was obtained by wetting the waste. This effect includes not only the leachate applied to Mats A and B, but also the fact that NOAA Monticello rainfall records indicate that about 180,000, 200,000 and 95, 000 gallons of ran fell on Mats A, B, and C respectively, thus providing greater additional moisture to Mats A and B. The density, of course, will increase over time as accelerated biodegradation occurs in the wetted waste and surcharge consolidation results in higher physical densities.

Section 3
VACUUM AND PRESSURE CONDITIONS

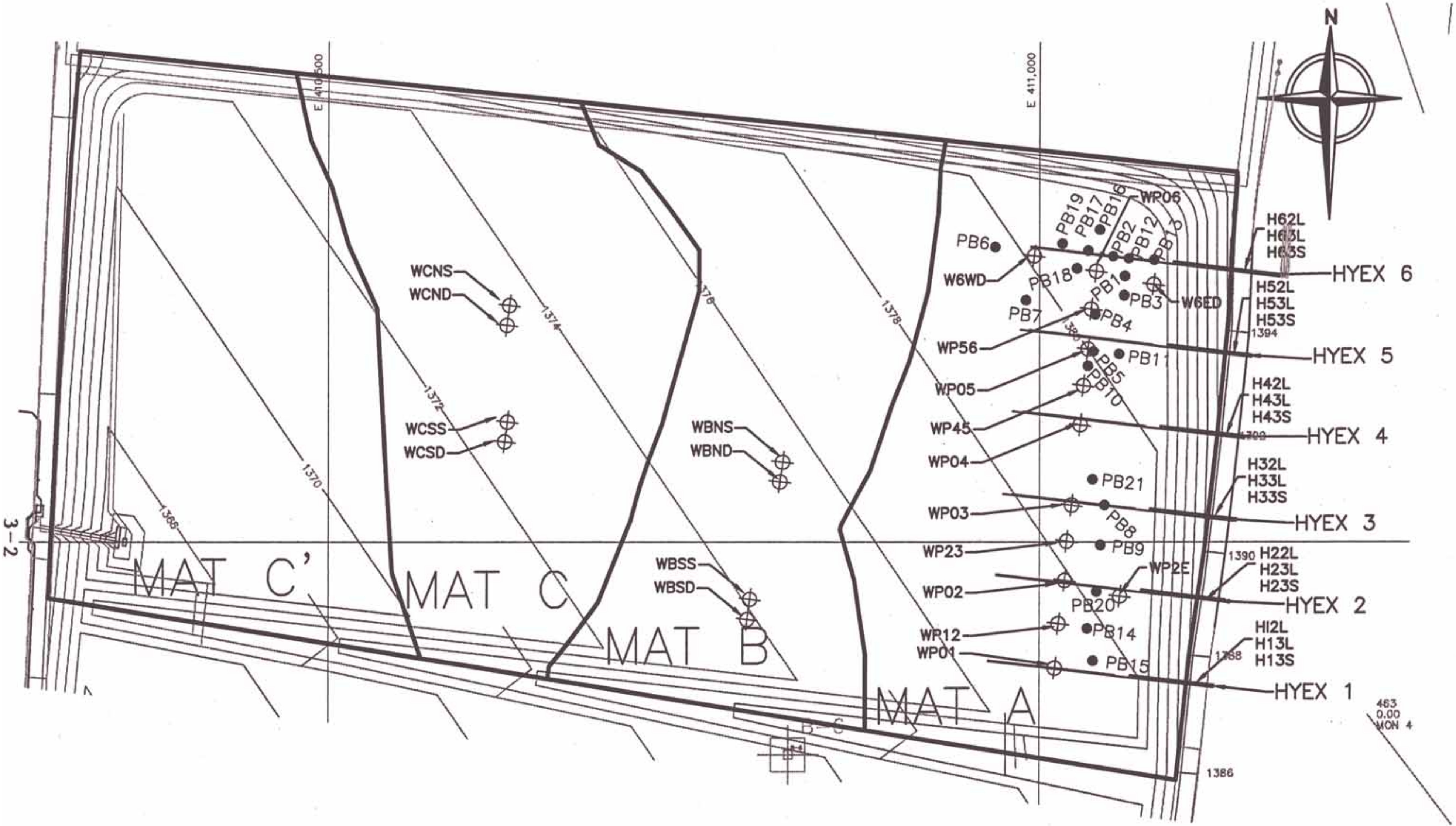
VACUUM SYSTEM DESCRIPTION

The Sullivan County Landfill is equipped with a utility flare manufactured by Landfill Gas Specialties, Inc. This flare, Model 1651, is fitted with a 10-inch flare tip and powered by a 25hp American Fan blower. This system is normally operated at vacuum pressures of about 30 to 35 inches water column at the condensate dropout tank, and this vacuum is carried through 12-inch, 10-inch and 8-inch high-density polyethylene (HDPE) manifold pipes to the individual landfill gas wells and horizontal collector laterals. The section of the system providing service to the east end of Cell 4 involves a collection line run of approximately 3280 feet and during this length, provides vacuum collection for 7 horizontal laterals servicing existing landfill Cells 2 and 3. On the east side of Cell 2, a condensate pump station allows condensate to drop from the line and be pumped to the leachate collection system. Due to a few site-specific problems which were later addressed, the first two months of the project experienced low and intermittent vacuum conditions. In mid-August, an interim 8-inch HDPE bypass line was constructed to provide a more continuous vacuum for the project. This resulted in typical available vacuums of about 4 to 10 inches water column, which were available on a relatively continuous basis during the final two months of field investigations.

MEASUREMENT METHODS AND LOCATIONS

Vacuum and pressure conditions were measured in the HYEX and flare gas-collection manifold systems with the internal pressure transducers within the GEM 500 landfill gas meter. The precision of these measurements is 0.10 inch water column; however, they are not extremely accurate in these low ranges. For the small vacuum measurements, a series of Magnahelic pressure gauges was utilized with graduations ranging from 0.10 inch water column to 0.01 inch water column. The Magnahelic gauge graduated in 0.01-inch water column divisions was particularly useful in measuring the vacuums transmitted through the waste from the HYEX pipes to adjacent well points at various distances.

The well points were constructed of 1¼” ID schedule 40, black steel pipe with ½” ID inlet holes drilled above a threaded steel well point. The top of the pipe projected about one foot above ground and was sealed with a threaded PVC cap fitted with a valve-stem nipple, which connected to either the GEM meter or Magnahelic gauge. Figure 3-1 indicates the pressure-monitoring locations. Wellpoint (WP) numbers relate to position relative to conduit numbers. The plunge bar numbers are sequential by order of installation



MONITORING LEGEND

⊕ WELL POINT PROBE

• PLUNGE BAR

NOTE: HYEX CONDUIT NOT SHOWN FOR CLARITY

FIGURE 3–1

VACUUM AND PRESSURE MEASUREMENT LOCATIONS

SIGNIFICANT FINDINGS

Valuable vacuum distribution information has been developed during the course of this research. During project planning, many reviewers speculated that the vacuum conditions would only be observable within 10 or 15 feet of the HYEX conduit locations, and that the vacuums were unlikely to be transmitted to distances useful for the desired purposes. However, observations of vacuum conditions in the waste with sensitive Magnahelic gauges provide definite confirmation that even the modest vacuums applied during this project were effective in creating measurable negative pressures at considerable distances from the center line of the active conduit. Typically, measurements showed very reliable vacuum conditions created at horizontal distances of 55 feet away from the conduits in both the shallow and deep well points. Several instances indicated vacuums measured at 110 feet distant and, in one case, as far as 137 feet. Pressure measurements of the Mat A well points took only about an hour to complete; therefore, the data may be considered "snapshots" of internal pressure conditions.

Figure 3-2 illustrates a typical condition occurring when all HYEX lines were shut off for a period of four days. No vacuum was applied anywhere within Mat A during this period and, as illustrated by the figure, all gas pressures in the well points were positive, ranging from 0.005 to 0.05 inches water column. In contrast to this, Figure 3-3 illustrates a typical condition with one HYEX line opened. In this case, HYEX line 6 had been opened for a period of 43 days, and a steady-state condition existed illustrating the transmission of a vacuum to both the shallow and deep well points over HYEX 5. The well points at 4 and 4S were not installed at the time of this measurement because the landfill required access to this area for their operations.

Figure 3-4 illustrates the effect of opening three of the adjacent HYEX lines simultaneously (4, 5 and 6). In this case, a reduction in vacuum at the deep well (WP06) near HYEX 6 is observed, which is expected due to a lower vacuum condition in the conduit. However, the gas pressures become negative in well point 3 (WP03), which is 55 feet distant from the nearest source of vacuum located in HYEX 4. Figure 3-5 illustrates the effect of closing HYEX 5 while maintaining vacuum at HYEX 4 and HYEX 6, which essentially indicates a condition of modest vacuum created by horizontally buried conduits which are 110 feet apart. This is a typical and economically feasible spacing for horizontal landfill conduits, and it is clear from the data that the vacuum condition is maintained above HYEX 5 although the line has been closed. This vacuum is transmitted from the adjacent landfill conduits HYEX 4 and HYEX 6. Also, the negative pressure measured at WP03, which is 55 feet from HYEX 4, continues in this case. Figure 3-6 illustrates the effect of once again turning on the vacuum lines at HYEX 5, which creates a slight increase in the vacuum observed at well points 5 (WP05) and WP5S. The negative pressure conditions still persist at WP03. Figure 3-7 indicates a typical pattern derived from closing the vacuum to HYEX 4, 5 and 6 and opening HYEX 3. This results in an increased vacuum at WP03, and the creation of vacuum at well point 23 (WP23).

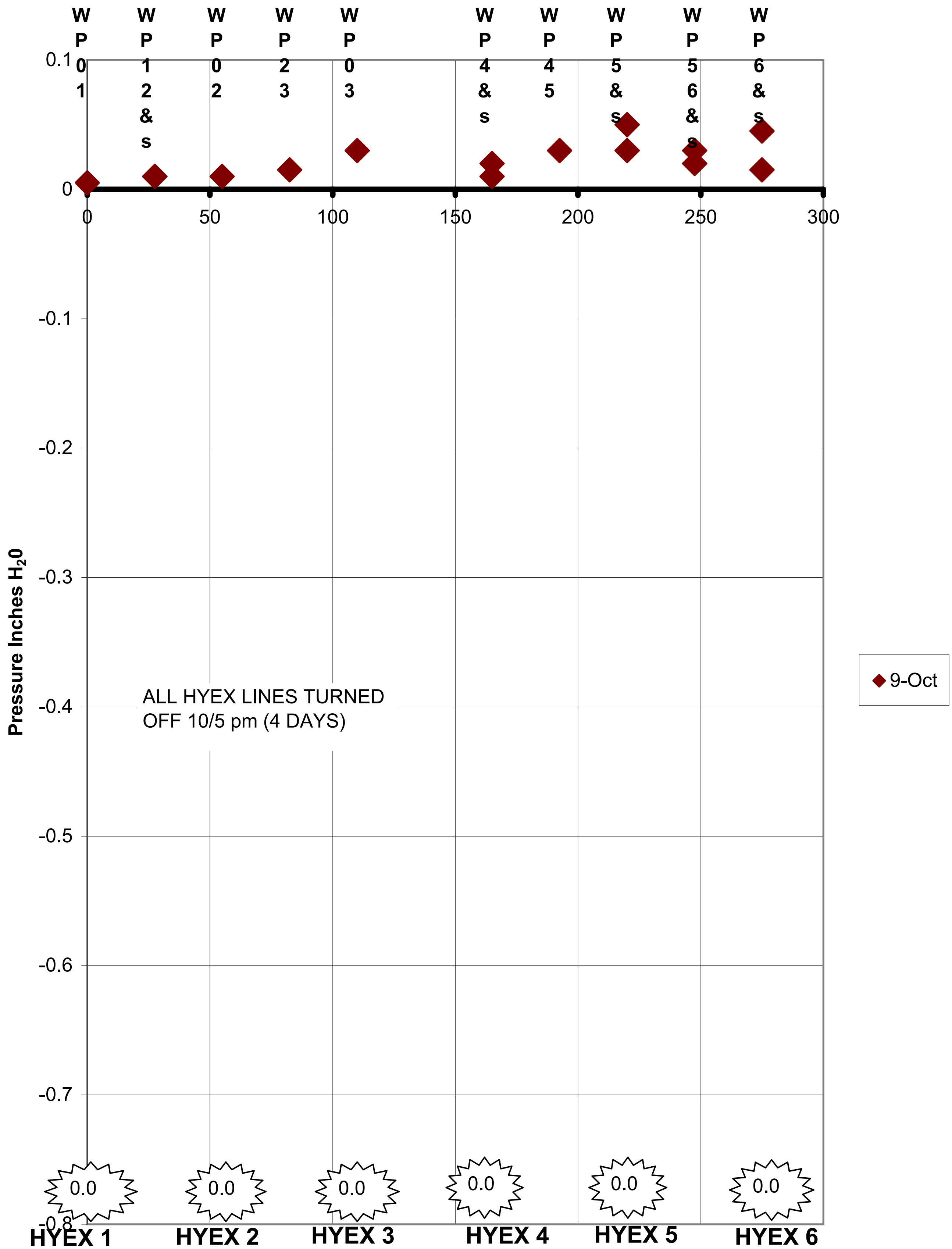


Figure 3-2
Well Point Data 10/09/01

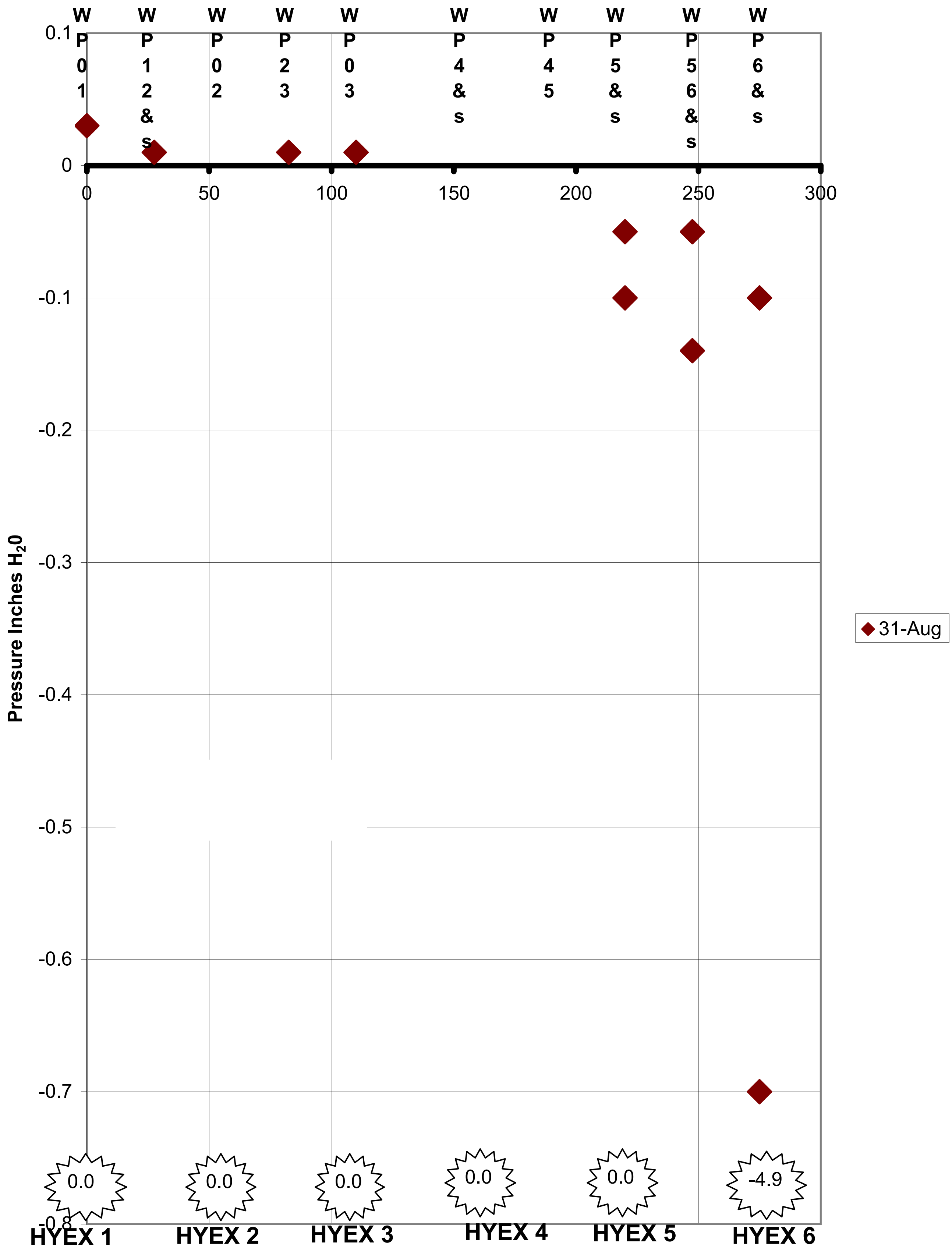


Figure 3-3
Well Point Data 8/31/01

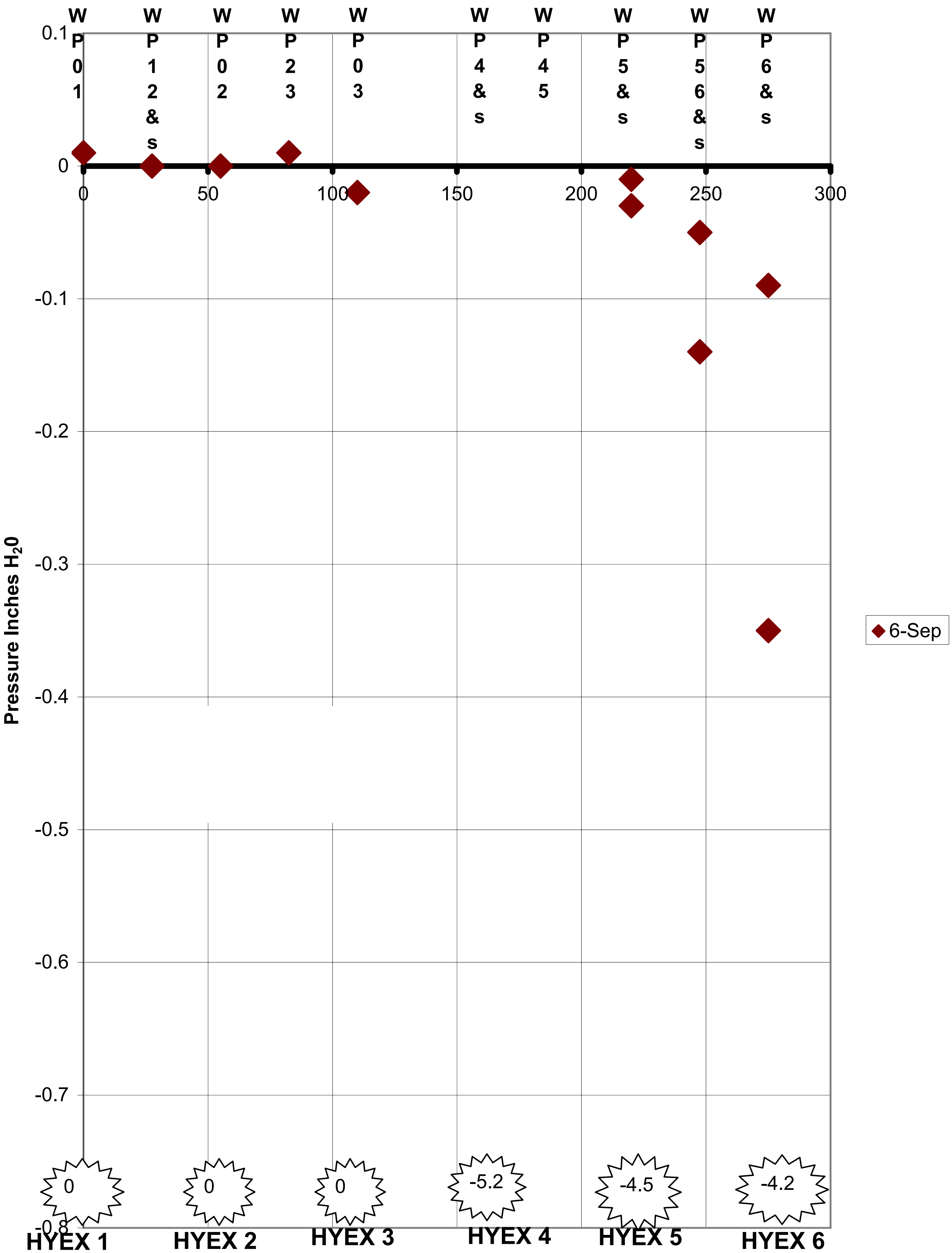


Figure 3-4
Well Point Data 9/06/01

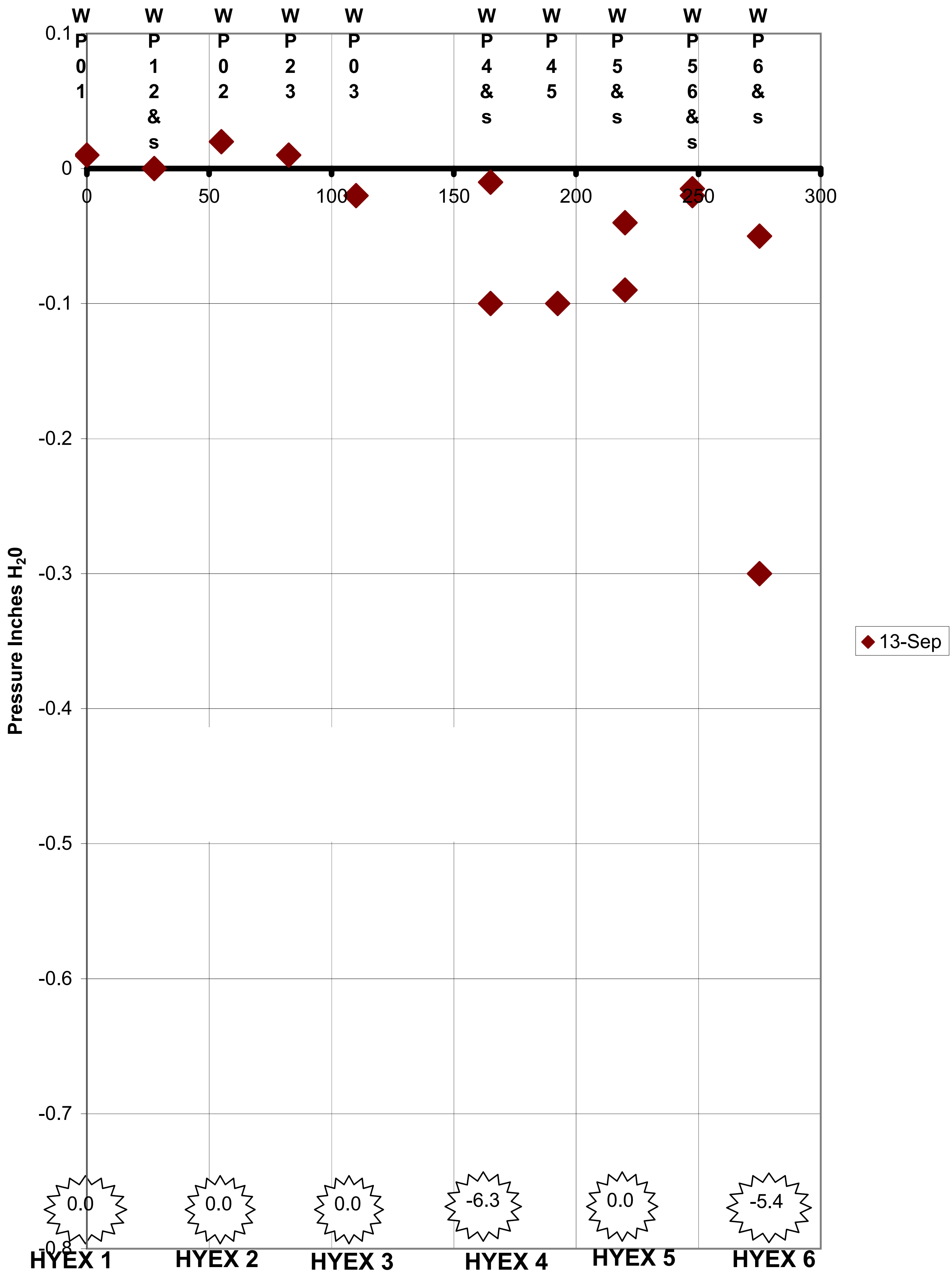


Figure 3-5
Well Point Data 9/13/01

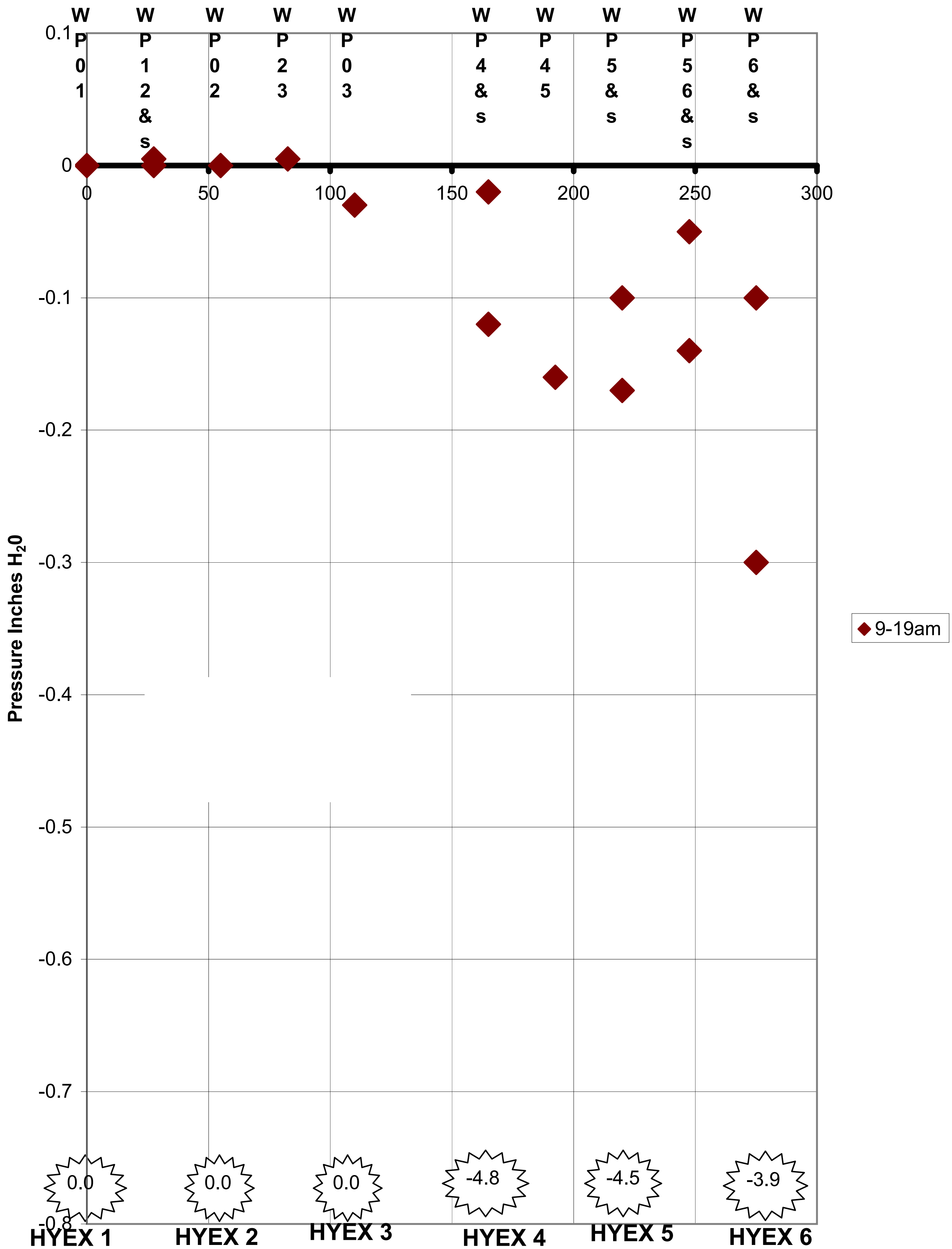


Figure 3-6
Well Point Data 9/19/01

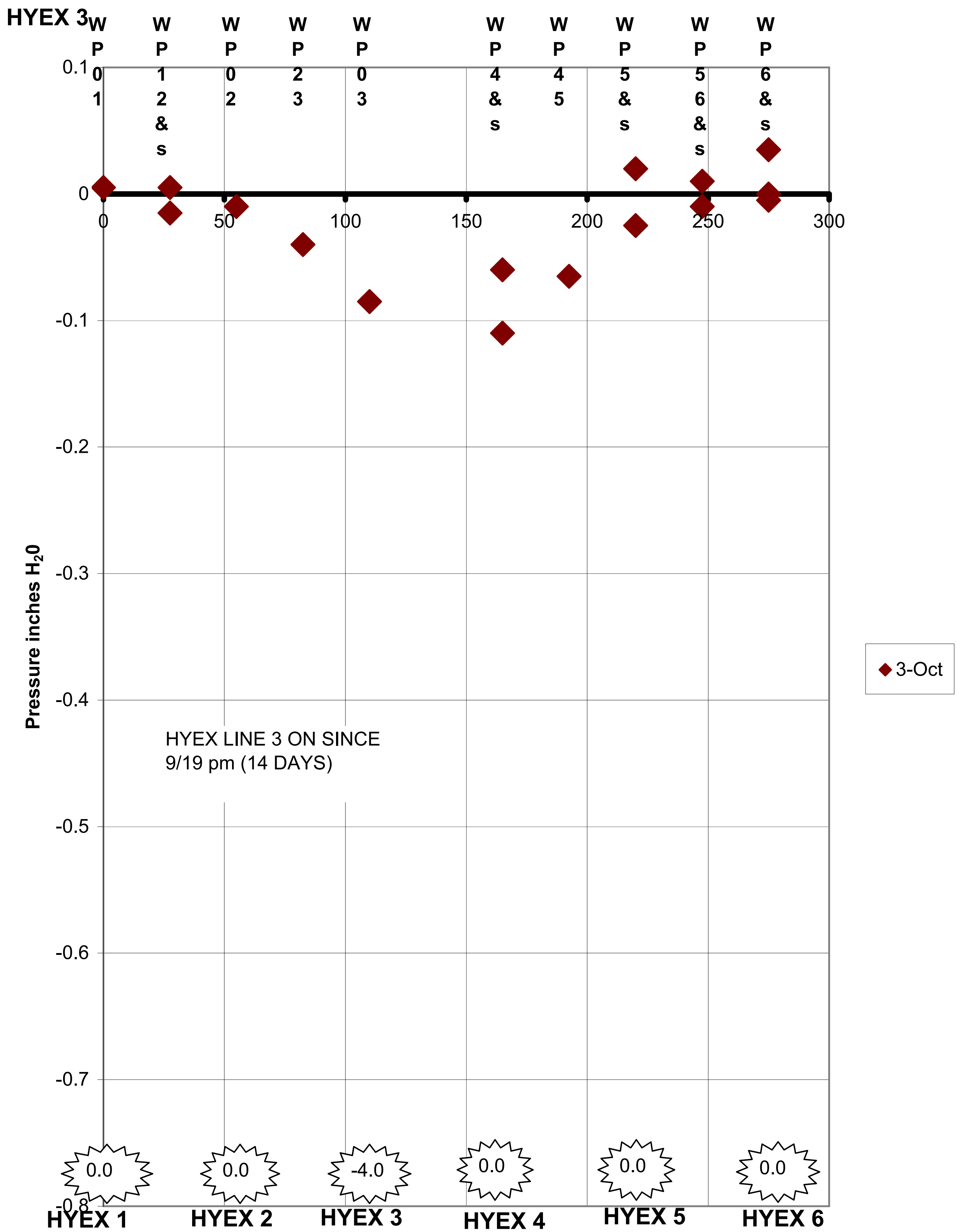


Figure 3-7
Well Point Data 10/03/01

Vacuum conditions extend as far as 137½ feet to the north with a vacuum of 0.01 inches water column at WP56 and vacuum is transmitted 82½ feet to the south (0.015 inches water column) at WP12. The data from this figure and others clearly shows vacuums can be induced over 50 feet away from the vacuum lines.

These data show a dependable and predictable pattern of vacuum in the waste mass created by inducing vacuums into the buried landfill conduits. The valve settings were changed several times during the course of the project, and pressure measurements indicated that these effects were consistently reproducible at vacuums obtainable with normal landfill flares and flow rates consistent with the objective of mixing the air-enriched gas with methane-rich gases from the landfill to provide thermal destruction of pollutants and odor-causing trace gases.

The most significant finding of this project relative to vacuum conditions is that very modest vacuums can be transmitted significant horizontal distances and that these distances are consistent with commonly feasible horizontal landfill conduit spacings. These spacings are typically 100 feet apart horizontally and 30 to 40 feet vertically.

Numerous concepts and theories have been investigated to understand these large distances of vacuum influence from the HYEX pipe. One of the concepts compares the gas flow in the waste to groundwater flow in fractured media. Similar to groundwater in fractured media, a majority of gas flow in the waste mass occurs through macropores or macrofractures or similar zones of high permeability. Gas from areas surrounding these major flow paths may enter this main flow path via a concentration gradient or a pressure gradient. The very permeable daily cover layer (processed C&D debris) above the HYEX pipes and beneath the biostabilization mats undoubtedly functioned as one of the permeable pathways, and was an important contributing factor in the vacuum distribution; use of heavy soil layers would likely reduce the vacuum transmission distance.

Section 4
GAS CONDITIONS

MEASUREMENT METHODS AND LOCATIONS

Gas quality measurements were taken at the HYEX™ landfill conduit laterals, the subsurface well points (WP), surface flux boxes (FB), and at numerous random plunge bar (PB) locations as shown on the General Arrangement Plan, Appendix 1. The primary purpose of these measurements was to determine and compare the effects of wetting of the MSW and application of vacuum conditions into the waste mass. Gases monitored included methane, carbon dioxide, oxygen, balance gas (a mathematical remainder calculation, assumed to be principally nitrogen), hydrogen sulfide, and non-methane organic compounds. The most frequent measurements were taken at the HYEX landfill conduits and the monitoring well point locations.

The majority of data was taken with a CES Landtec GEM 500 landfill gas meter which was calibrated daily. One of the main advantages of utilizing the GEM meter is the ability to economically take a large number of readings, store them in computer memory, and subsequently download the data for analysis and graphing.

Hydrogen sulfide readings were taken with an ISC Model HS267 handheld hydrogen sulfide meter with hooded power aspirator. This unit measures in parts-per-million volume and has a range from 0 to 2,000 ppm. User calibration was not possible with this meter.

The flux box measurements were taken with a Foxboro Model TVA1000 flame ionization detector measuring methane in parts per million. Use of this instrument enables numerous readings to be economically taken in order to properly describe the changing concentration of methane within the closed flux box. With this unit, it is necessary to record the readings into a field book and later transcribe them for data processing. Calibration was performed prior to each sampling day.

Non-methane organic compounds (NMOC) were evaluated by taking a Summa vacuum canister sample which was sent for analysis to Performance Analytical Laboratories in Simi Valley, CA. These samples were analyzed according to EPA Method TO-15.

BASELINE GAS QUALITY

Solid waste placement first began in Cell 4 in December 2000. Placement of the select lift moved from west to east taking about 4 months, and placement of the second MSW lift proceeded from east to west and was concluded in early June 2001. The first day of waste placement on Mat A was June 8, 2001; therefore, the age range of the waste beneath Mat A was 2 to 3 months. Waste beneath Mat B and C was 3 to 6 months old with the older waste of the select lift beneath and the newer waste of the second MSW lift above and immediately beneath the surface of the biostabilization mat. Plunge bar gas samples were taken with the GEM meter in the second waste lift beneath Mat A on June 6th and indicated a methane content ranging up to 19%. Summa canister samples taken on June 9th indicated a methane concentration of 21.5% for Mat B and 17% for Mat C. Methane concentrations for Mat A could not be analyzed at the same time because the Summa canister for Mat A was defective. Carbon dioxide concentrations were 60.2% and 71%, respectively, for Mat B and Mat C. A total of 10 individual non-methane organic compounds were found in Mat B samples and 10 NMOC compounds were found in Mat C samples. Table 4-1 summarizes GEM meter readings for the background samples beneath Mat A and Table 4-2 provides details regarding the non-methane organic compounds measured at detectable levels in Mat B and Mat C. It is important to recognize that the older waste in Cell 4 was beginning a process of anaerobic decay and methanogenesis had already commenced. Therefore, the methane concentrations in the interstitial gases of this waste mass would naturally increase over time regardless of the particular practices associated with the biostabilization project. It is likely, however, that the addition of leachate to MSW in Mats A and B increased moisture to some degree in the subsurface waste and accelerated the production of methane in that waste while simultaneously accelerating biological activity in the waste within Mats A and B.

Table 4-1

MAT A SUBSURFACE BACKGROUND GAS QUALITY – 6/06/01

		Depth	CH_4	CO_2	O_2	Bal
HYEX 6	PB6	3.5’	1.8	73.1	0	25.1
HYEX 6	PB6	2”	0.3	2.5	19.5	78
HYEX 5	PB5	3.25’	4.9	43	0.3	51.8
HYEX 5	PB5	9”	0.6	7.3	17.8	75.2
HYEX 4	PB4	3.5’	10.5	38.4	7.1	4.3
HYEX 4	PB4	4”	6	25	11	56
HYEX 3	PB3	1.5’	1.8	46.2	0.05	51.5
HYEX 3	PB3	2.75’	2.8	53	0.7	43.5
HYEX 3	PB3	3”	1.8	17.7	13.2	67.3
HYEX 2	PB2	2.5’	19.1	25.5	0.9	54.5
HYEX 2	PB2	1.75’	11.9	26.7	1.7	60.7
HYEX 2	PB2	2”	9.6	20.6	5.1	64.7
HYEX 1	PB1	1.25’	10.3	33.4	1.8	54.6
HYEX 1	PB1	3’	14.6	23.4	0.3	62.2
HYEX 1	PB1	2”	7.2	37.5	1.5	54.8
		Averages	6.9	31.6	5.4	53.6

Table 4-2

MAT B AND MAT C SUBSURFACE BACKGROUND GAS QUALITY

Compound	**Mat B (%, v/v)**	**Mat C (%, v/v)**
Carbon Monoxide	ND	ND
Methane	21.5	17.0
Carbon Dioxide	60.2	71.0
	(ppm V)	**(ppm V)**
Acetone	ND	84 M
Trichlorofluoromethane	0.50	4.9
Methylene chloride	21	3.9
Carbon Disulfide	3.4	16
Methyl tert-Butyl Ether	13	ND
2-Butanone	5.6	20
4-Methyl-2-pentanone	1.1	5.3
Toluene	5.0	9.5
Ethylbenzene	1.4	13
m,p-Xylenes	3.5	38
o-Xylene	1.1	11

M = matrix interference

Another baseline condition to be considered involves gas concentrations in Mat A measured during periods when no vacuum was applied. This condition reflects the undiluted gas quality in the waste mass, including the waste underlying the HYEX conduits. This quality would also change over time as the condition of the waste matured. Typical values obtained in the initial phase of the project are shown in Table 4-1. Later in the project, typical non-vacuum gas conditions showed increasing methane and low oxygen and balance gas.

Table 4-3 presents typical HYEX™ conduit gas concentration values reflective of operating vacuum conditions compared with closed-valve, non-vacuum conditions at the Mat A well points.

Table 4-3

BASELINE AND VACUUM GAS CONDITIONS

		Baseline Conditions (Vacuum Not Applied)			
Code	**Date**	**CH_4**	**CO_2**	**O_2**	**Bal**
WP06	Average (9/27-10/04)	37.8	39.9	0.0	22.3
WP03	Average (7/20-9/05)	55.2	44.3	0.1	0.4

Operating Gas Conditions (Vacuum Applied)

Code	Date	CH_4	CO_2	O_2	Bal
HYEX 6	Average (8/24-9/05)	11.0	21.4	4.9	62.8
HYEX 3	Average (9/27-10/04)	22.2	30.6	0.1	47.1

MAT A GAS CONDITIONS

Detailed examination of the interstitial gas conditions in Mat A, as indicated by well-point sampling, is important to the evaluation of the process dynamics of the vacuum-induced, semi-aerobic conditions. Changes in methane, oxygen, carbon dioxide and balance gas indicate not only the acceleration of biological activity but also the dilution of interstitial gas with air drawn in by vacuum influence. This is critically important to determining the sphere of influence of the landfill conduits under vacuum pressure and the effect of induced air on the microbiological environment.

Figure 4-1 displays graphed values of gas concentrations monitored at well point 1 (WP01), which is located at the center line of HYEX 1 at a depth of 8 feet beneath the surface of Mat A. Comparison of these values with the valve setting changes indicated above the graph clearly indicate the sensitivity of the gas conditions to vacuum conditions induced by negative pressure in the HYEX pipes. During the period from July 16th through September 5th, only HYEX 6 was open although certain temporary disturbances were created, such as on August 27th, when the HYEX's 1, 2 and 3 were opened to clear water from the lines. An expected drop in methane and rise in oxygen and balance gases occurred during this isolated event; however, in general, this period was characterized by high methane and CO_2 and low oxygen and balance gases. On September 5th, valves at HYEX 4 and 5 were also opened, resulting in application of vacuum closer to HYEX 1 although still 165 feet distant. A small fluctuation in methane and balance gas is observed; however, it is probably unrelated because methane continued to increase at WP02 during this period. On September 19th, the valves at HYEX 4 and 6 were closed and the valve at HYEX 3, opened, resulting in a sharp drop in methane concentration and a significant rise in oxygen and balance gas. This significant change was obviously caused by induction of vacuum at a distance of 110 feet from WP01. On September 24th, the valves at HYEX 1 were opened, resulting in a further reduction of methane and increase in balance gases to their lowest and highest values, respectively. Later changes occur when the valves at HYEX 3 are closed and HYEX 6 is opened, resulting in increasing methane and decreasing balance gas. Finally, when all valves on the project extraction lines were closed, methane and carbon dioxide continued to increase, balance gas and oxygen continued to decrease. These values fit well within the predictive model of gas performance and correlate with pressure conditions and atmospheric emissions.

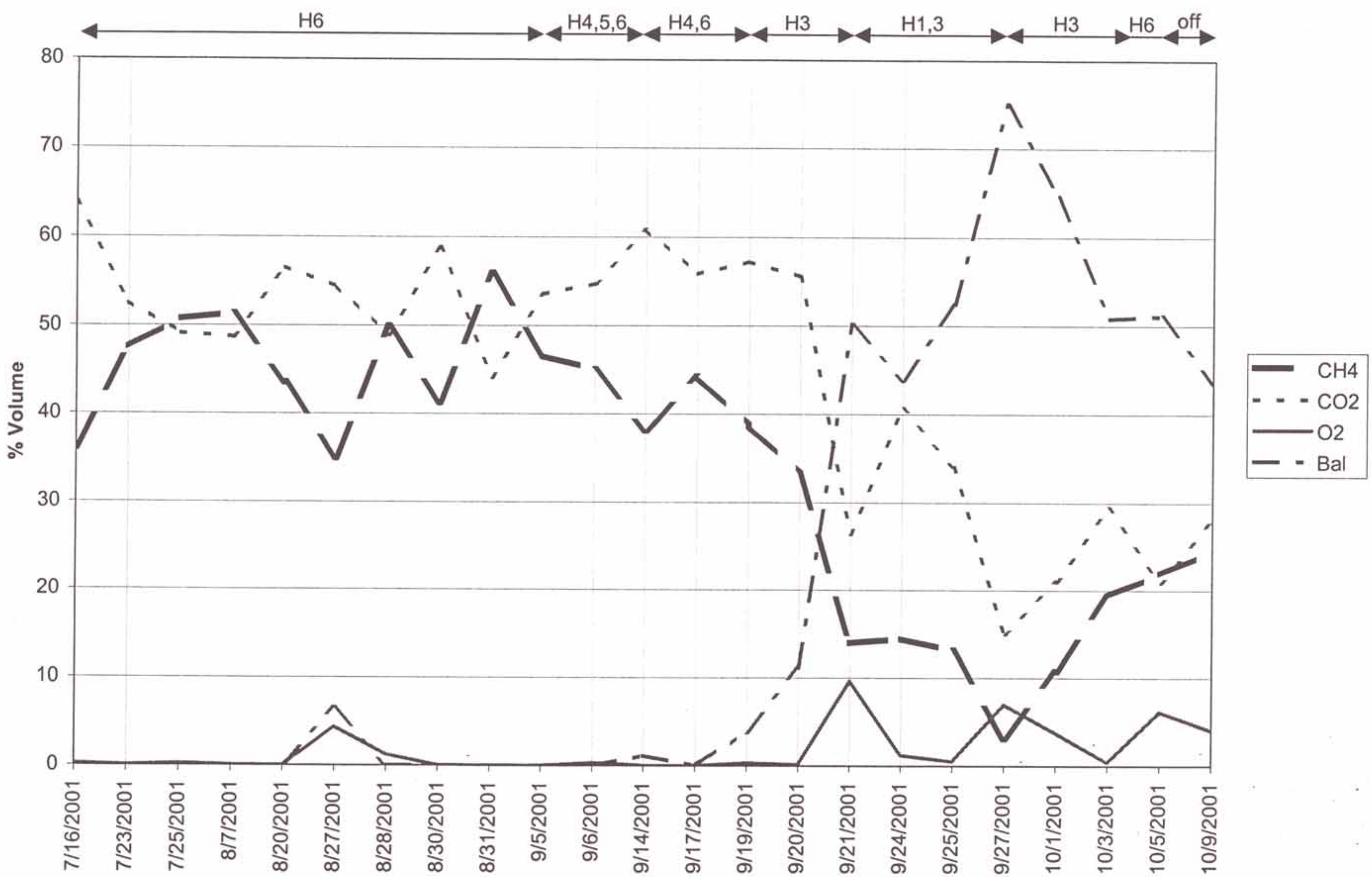


Figure 4-1
Gas Quality at WP01

Figure 4-2 illustrates a similar graph of gas conditions observed at well point 2 (WP02) placed above HYEX 2. Once again, we see relatively high methane and carbon dioxide values although it appears the waste is somewhat less mature in this area. Methane continues to increase and balance gas decreases until September 19th when the valves at HYEX 3 are opened. At this time, a very sharp decrease in methane is observed together with a sharp increase in balance gas. It is interesting to note the spike which occurs in oxygen at this time followed by a drop to zero indicating that the microbes within the waste become aerobically conditioned and consume oxygen after an initial spike. The continuing pattern fits well within expected patterns featuring increasing methane and declining balance gases as vacuums are moved away from the well point, and finally methane increasing significantly when all system valves are closed.

Figure 4-3 is a graph of well point 3 (WP03) located above HYEX 3. We see in this graph the familiar pattern of relatively high methane values ranging from 35 to 60% and low oxygen and balance gases until the valves at HYEX 4 are opened. At this time, the methane decreases dramatically and balance gas increases. This pattern is further exaggerated when the valves at HYEX 3 are opened, thus providing vacuum immediately beneath WP03. Methane drops to its lowest value and balance gas and oxygen go to their highest values. Once again, we see an initial spike in oxygen which drops and does not reappear, indicating transformation of the microbiology to adjust to the presence of oxygen within the waste mass. Once the vacuum is moved farther away from WP03 to HYEX 6, the methane begins to rise and balance gas begins to drop. Methane rises considerably when all project valves are closed and balance drops to its minimal value.

Well point 4 (WP04) was not installed until approximately September 10th due to the need for the landfill to maintain access to the area for their operations. Thus, Figure 4-4 graphs the performance of WP04 beginning on September 10th. At this time, the valves to HYEX 4 beneath WP04 were opened as were those at HYEX 5 and HYEX 6. This condition predictably resulted in low methane values and high balance gas and oxygen values. This pattern continued even when the valve at HYEX 4 was closed and HYEX 3 (a distance of 55 feet away) was opened. This is a very good indicator of the reliability of the 55-foot radius of influence from the HYEX lines. When the vacuum was weakened at HYEX 3 by opening HYEX 1 and HYEX 3 simultaneously, a small increase in methane was observed and a small decrease in balance gas was observed at WP04. When HYEX 3 was again isolated, resulting in a higher vacuum nearer to WP04, then the methane value dropped slightly and balance gas increased slightly. These patterns fit well within the theoretical model of influence from HYEX 3 to WP04. Also, the behavior at WP04 was consistent when vacuum was moved to HYEX 6 and then when all valves were closed, resulting in sharp increases of methane and a steep drop in balance gas.

Figure 4-5 illustrates gas conditions at well point 5 (WP05) above the center of HYEX 5. At this location, the monitoring point is closer to the main source of vacuum during the early part of the project located at HYEX 6. The results clearly show the effects of low available vacuum from July 23rd through about August 20th. On August 20th, the bypass jumper line was installed to improve vacuum performance at HYEX 6 and

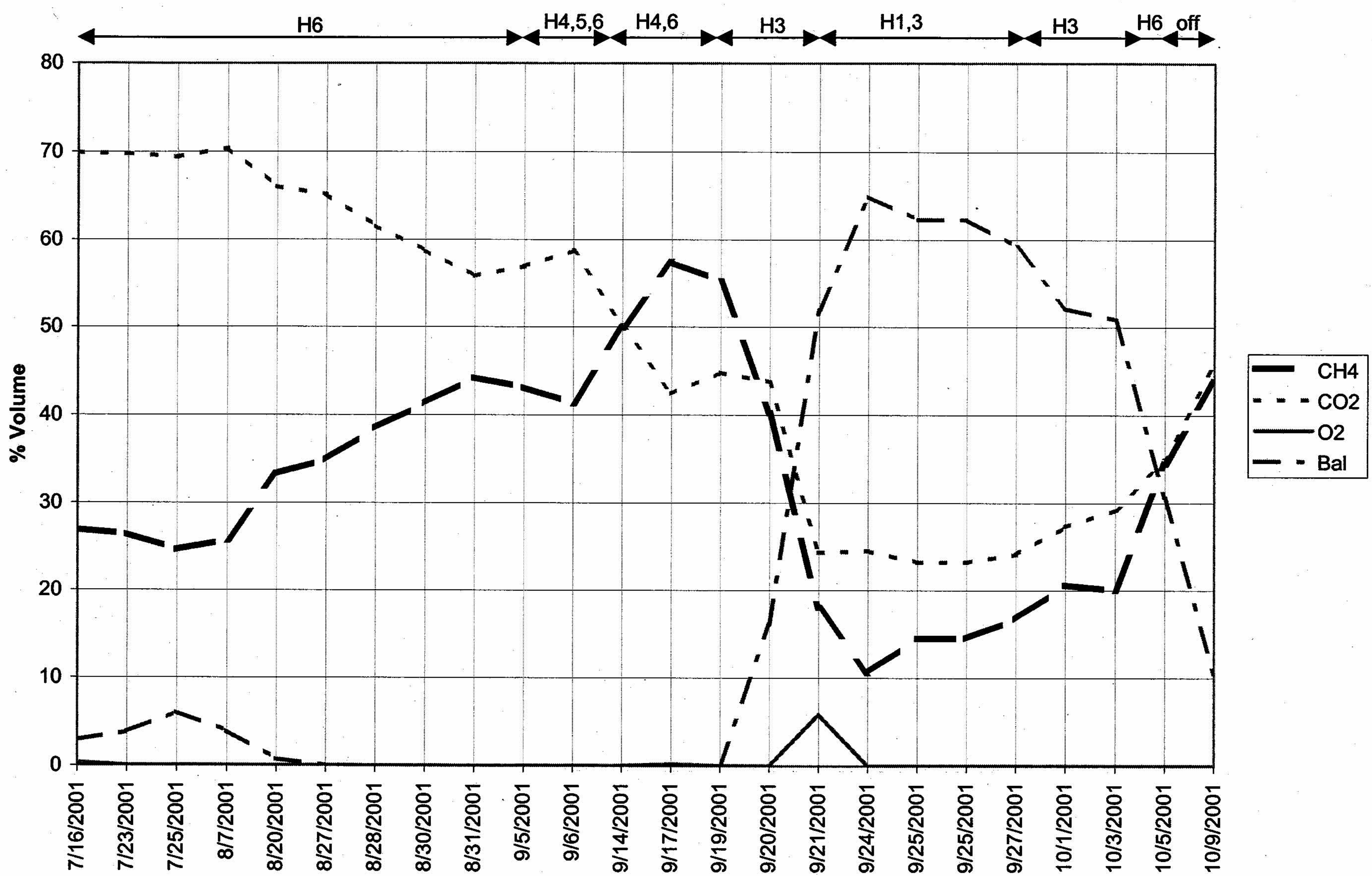


Figure 4-2
Gas Quality at WP02

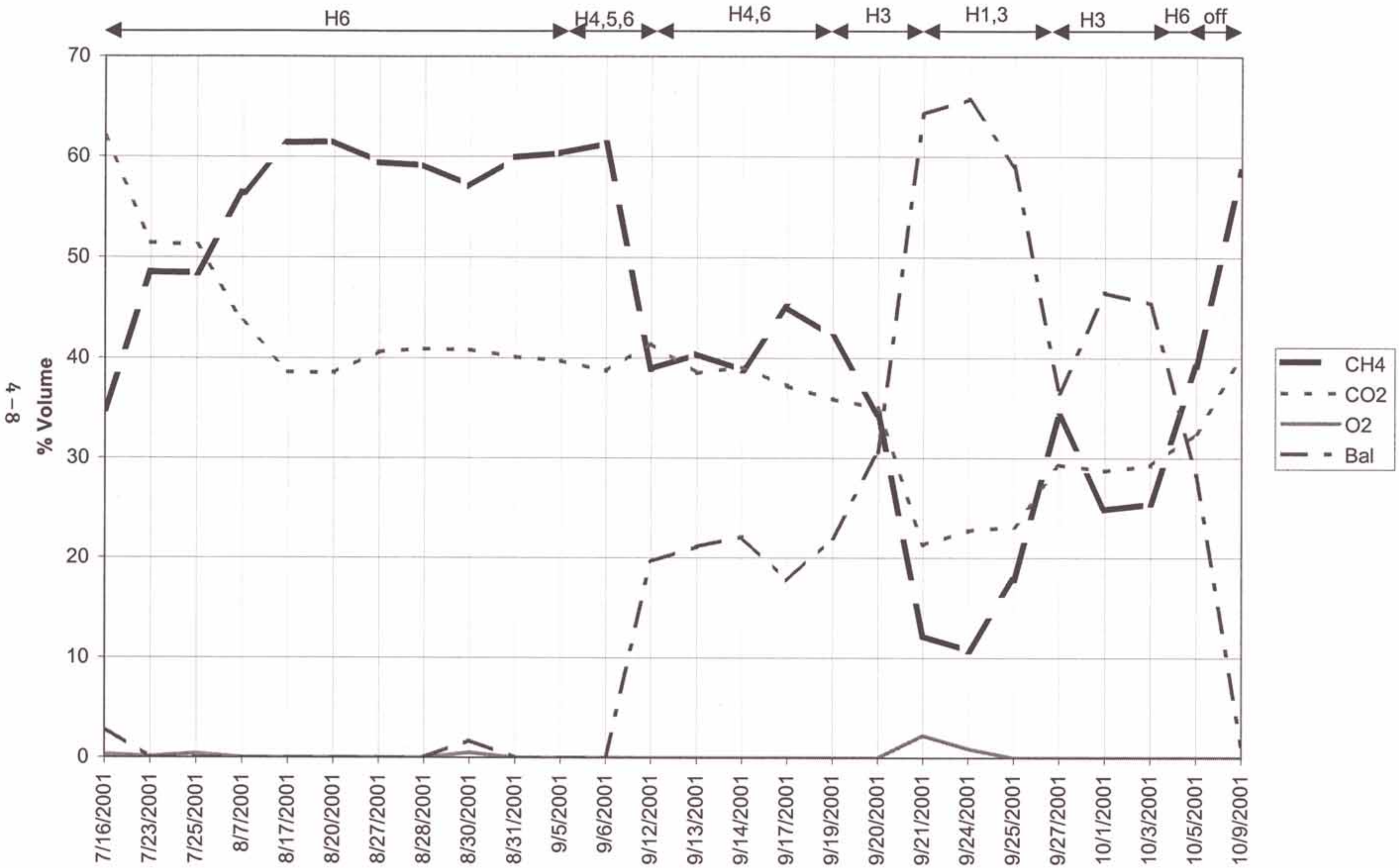


Figure 4-3
Gas Quality at WP03

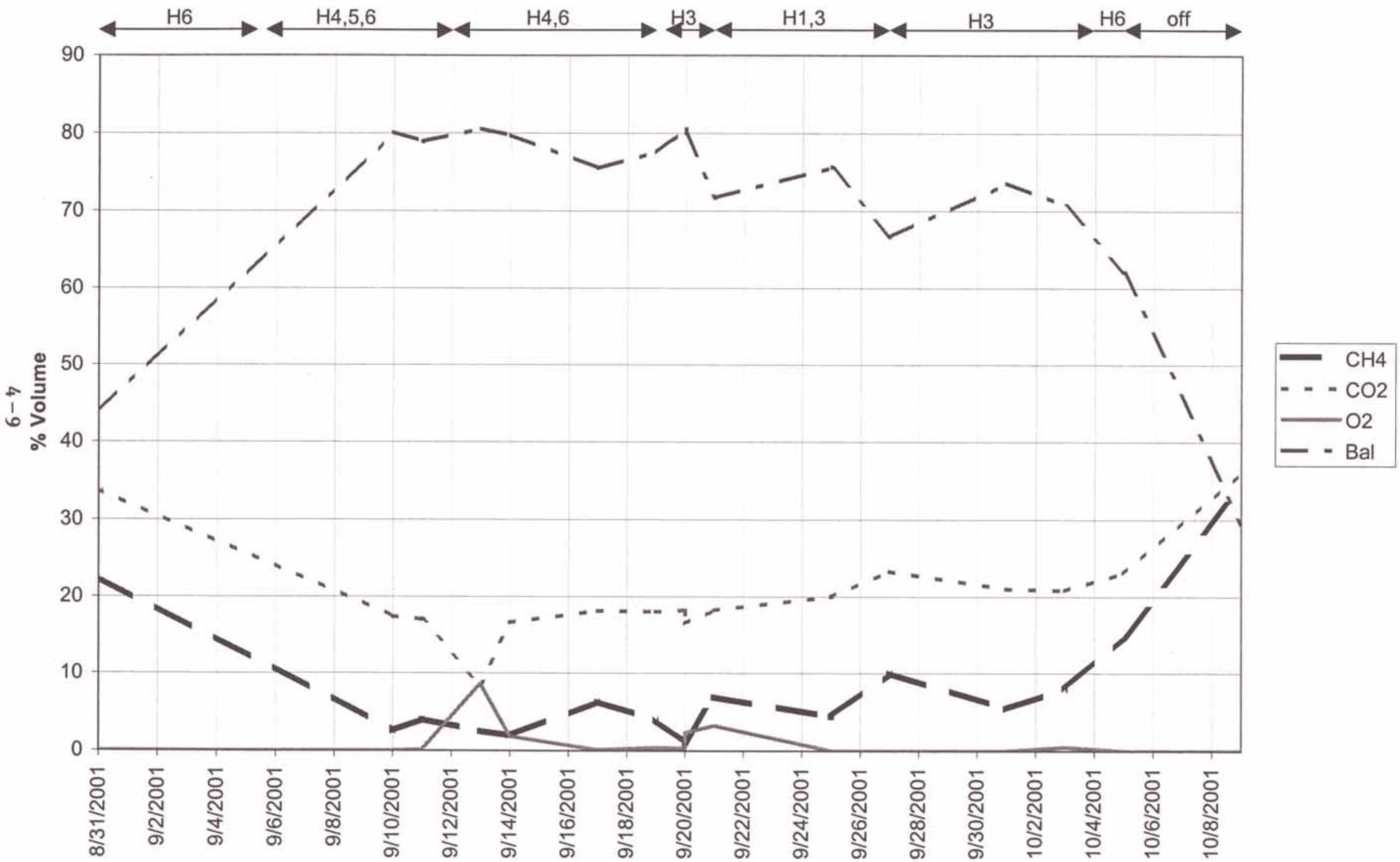


Figure 4-4
Gas Quality at WP04

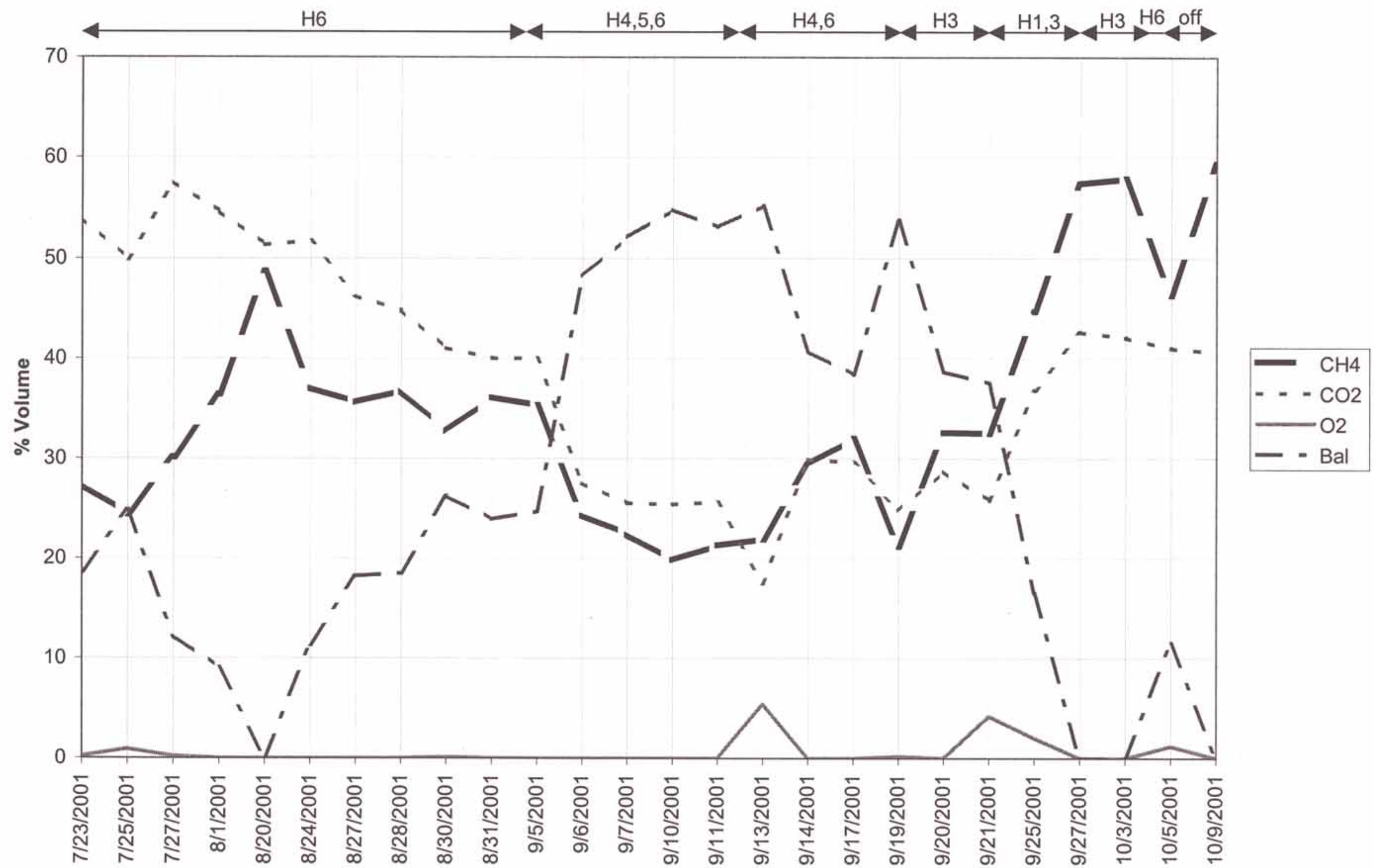


Figure 4-5
Gas Quality at WP05

we see an immediate decrease in methane concentration and an immediate increase in balance gas as would be expected. This clearly illustrates the influence from HYEX 6 located a distance of 55 feet horizontally from WP05. On September 5th, valves in HYEX 4 and 5 were also opened and a very sharp increase in balance gas was observed with a corresponding decrease in methane and carbon dioxide. When the valve beneath WP05 at HYEX 5 was closed on September 12th, an increase in methane and decrease in balance gas is observed. Movement of the vacuum to HYEX 3 begins a pattern of increasing methane concentration and sharply decreasing balance gas presence. This pattern continues as expected until the valves at HYEX 6 are opened, causing an immediate reduction in methane and increase in balance gas. When all valves are closed, the graph illustrates an increase in methane and decrease in balance gas. This performance is completely consistent with the expected pattern.

Figure 4-6 provides a clear illustration of the gas conditions above HYEX 6 which was the only conduit open during the first half of the project. The effects of declining available vacuum from July 25th through August 20th is consistent with the observed increase in methane concentration and decrease in balance gas. The installation of the bypass jumper line created an immediate drop in methane and CO_2 concentrations, and an immediate sharp increase in balance gas. Weakening the vacuum at HYEX 6 by opening HYEX 4 and HYEX 5 simultaneously produced a mild increase in methane and a small drop in balance gas. However, when the valves at HYEX 6 were closed and the valves at HYEX 3 opened on September 19th, a sharp drop in balance gas is observed together with a corresponding sharp increase in methane concentration. This pattern continues until the valves at HYEX 6 are once again opened, resulting in an immediate drop in methane from 50% to 20% and an immediate rise in balance gas from about 5% to about 45%. When all project valves were closed on October 5th, methane again rises to its previous high value and balance gas falls sharply.

The interstitial landfill gas conditions in Mat A, as illustrated by the monitoring results of the well points, show very clear and consistent influence of vacuums applied 55 feet distant horizontally. Measurable effects on gas quality were observed in one case as far as 165 feet horizontally. The primary effects of vacuum condition are a significant reduction in methane concentration with a corresponding rise in balance gas (assumed to be principally atmospheric nitrogen). Oxygen is often seen spiking during the first application of vacuum, but then typically drops off indicating consumption of oxygen by microbes. This indicates a lag time for the system to switch from primarily anaerobic to primarily aerobic conditions. This is the time for the aerobic microbes to become active and start to consume the available oxygen. Carbon dioxide generally follows the pattern of methane although not always. When vacuum conditions are moved more distant from a given monitoring point, a clear and significant rise in methane concentration is observed together with a drop in balance gas. This is consistent with cessation of air intrusion into the waste mass once the vacuum conditions are moved away from the monitoring point.

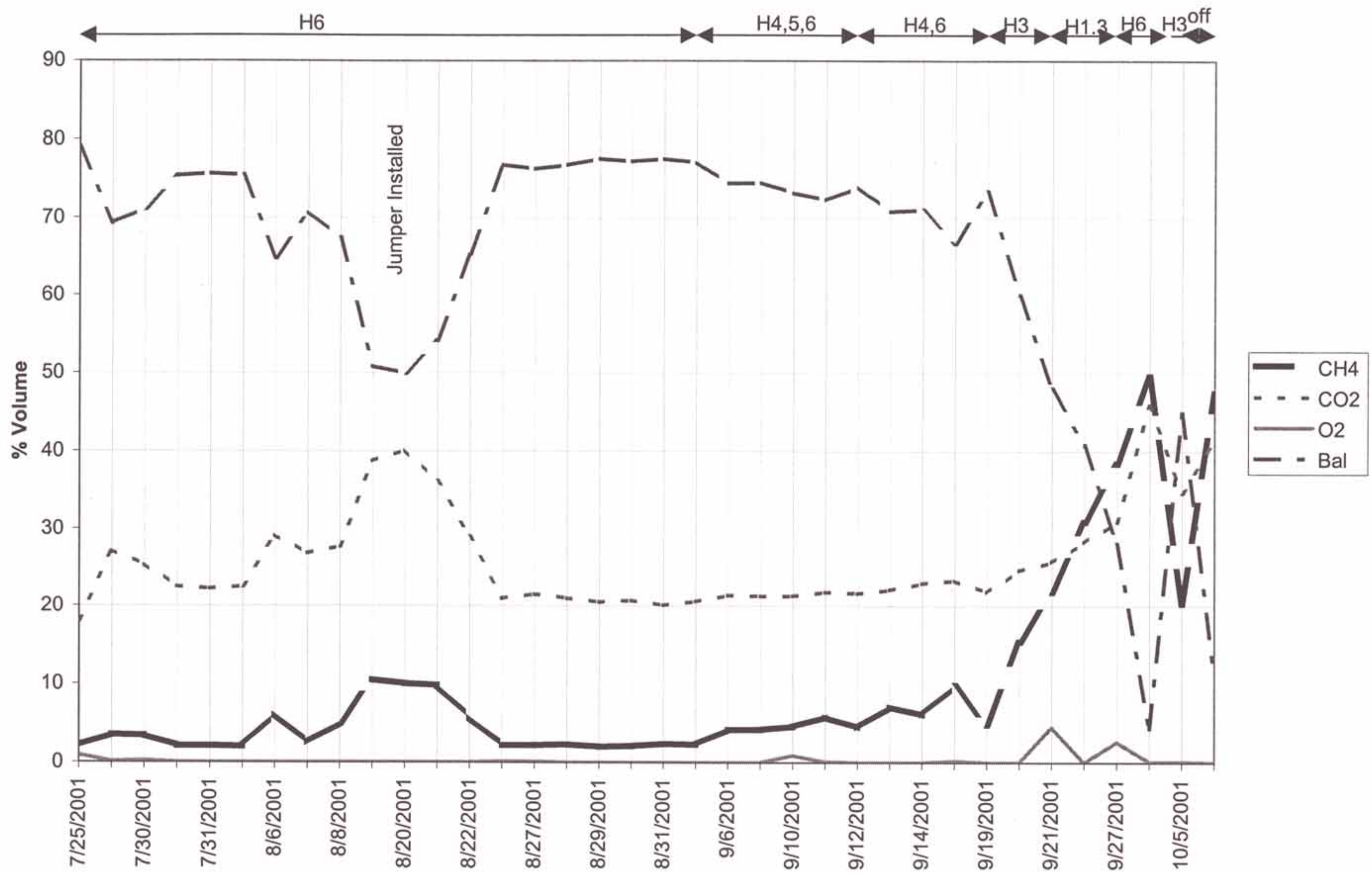


Figure 4-6
Gas Quality at W06S

Non-methane organic compounds were measured in Mat A by extracting Summa vacuum canister samples from two well points on September 21, 2001. Compounds measured at detectable levels are indicated in Table 4-4.

Table 4-4

MAT A NMOC CONCENTRATIONS

	Concentration (ppbV)	
Compound	**(WP03)**	**(W12S)**
Acetone	23,000 M	66,000
Trichlorofluoromethane	11,000	ND
Methylene chloride	1.100	860
Carbon Disulfide	3,500	3,600
1,1-Dichloroethane	ND	2,000
Methyl tert-Butyl Ether	3,600	870
2-Butanone (MEK)	33,000	41,000
Benzene	550	ND
4-Methyl-2-pentanone	590	600
Toluene	14,000	11,000
Tetrachloroethene	220	660
Ethylbenzene	1,200	3,000
m,p-Xylenes	1,700	4,500
Styrene	ND	650
o-Xylene	560	1,500

M = matrix interference

MAT B GAS CONDITIONS

Gas concentrations in Mat B were monitored by four well points in two locations as shown on the General Arrangement Plan, Appendix 1. Relatively fewer data samples were taken from Mat B and C because of the reduced variability of conditions compared with Mat A. Gas samples taken with the GEM meter indicated a maximum methane concentration of 69.4% and minimum of 18.1% while balance gas ranged from 60.8% to 0%. Factors influencing these values are the age and maturity of the waste, the wetting of the waste, and proximity of the well points to vacuum induction from Mat A. It appears possible that gas conditions were influenced at the Mat B northern sampling point by vacuums applied in HYEX 3 although negative pressures were not observed in Mat B well points.

Figure 4-7 and presents a typical graph of gas concentrations over time for one of the Mat B well points. Methane and CO_2 remain fairly high while oxygen and balance gas decline toward zero.

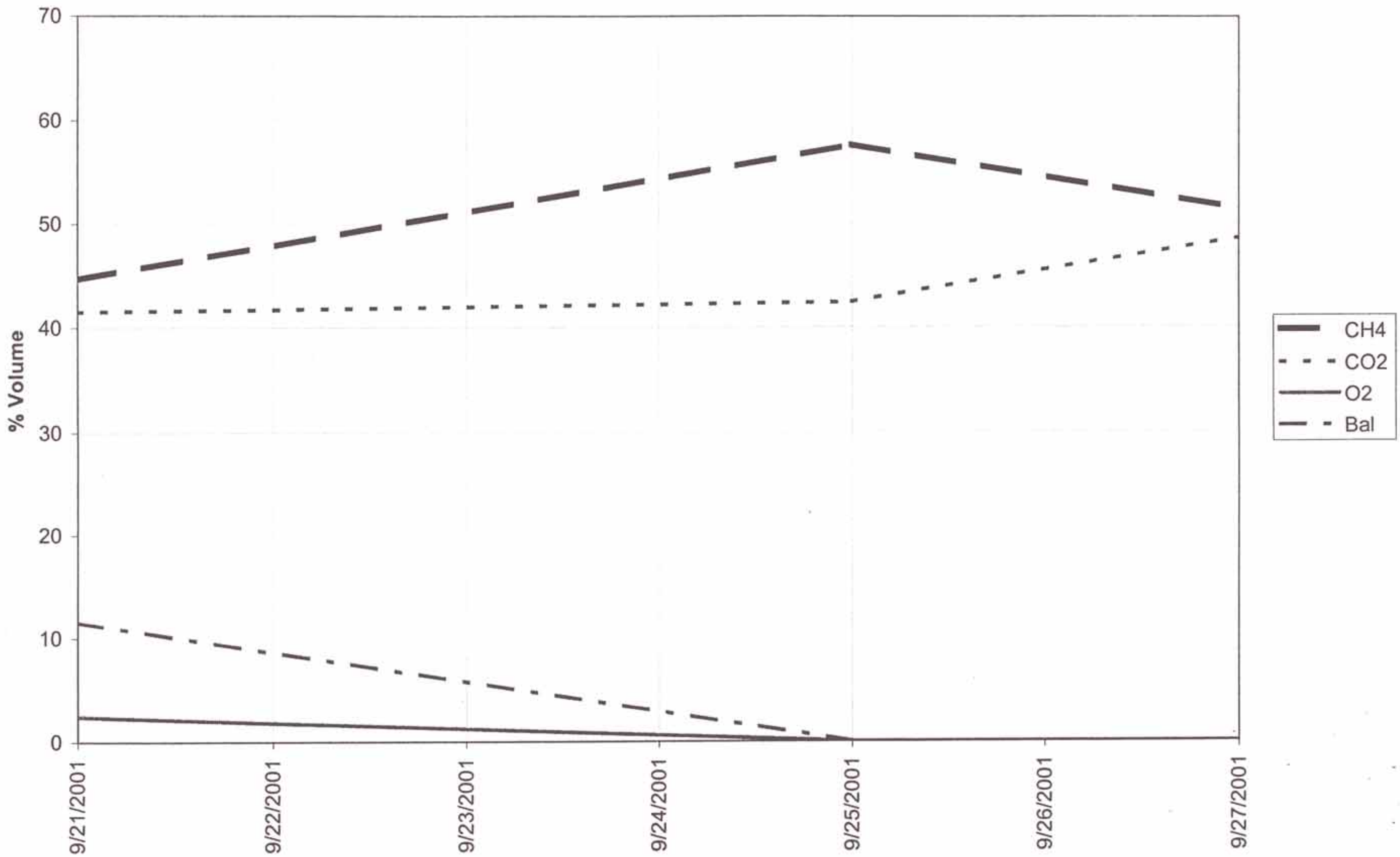


Figure 4-7
Gas Quality (Mat B Well Point - WBND)

Non-methane organic compounds measured at detectable levels in Mat B are presented in Table 4-5. This information was derived from Summa vacuum canister samples analyzed according to EPA Method TO-15.)

Table 4-5

MAT B AND MAT C NMOC CONCENTRATIONS

	Concentration (ppbV)		
Compound	(WBNS)	(WBSS)	(WCSS)
Acetone	ND	8,100	ND
Trichlorofluoromethane	10,000	6,000	25,000
Methylene chloride	2,500	1,500	4,800
Trichlorotrifluoroethane	4,700	ND	7,100
Carbon Disulfide	25 ,000	8,000	4,100
1,1-Dichloroethane	3,700	480	ND
Methyl tert-Butyl Ether	3,400	800	ND
2-Butanone (MEK)	33,000	19,000	10,000
Benzene	550	ND	1,400
Trichloroethene	ND	900	ND
4-Methyl-2-pentanone	4,200	950	ND
Toluene	140,000	20,000	18,000
Tetrachloroethene	3,200	13,000	ND
Ethylbenzene	3,400	2,800	2,300
m,p-Xylenes	9,600	7,800	6,400
Styrene	ND	550	840
o-Xylene	3,100	2,000	2,100

MAT C GAS CONDITIONS

Gas concentrations in Mat C were monitored by four well points in two locations, as shown on the General Arrangement Plan, Appendix 1. Gas samples taken with the GEM meter indicated a maximum methane concentration of 46.7% and minimum of 7.1% while balance gas ranged from 29.6% to 0%. Factors influencing these values are the age and maturity of the waste and the relatively lower moisture content of the waste. It is not likely that these values are influenced by vacuums applied in Mat A.

Figure 4-8 presents a typical graph of gas concentrations over time for one of the Mat C well points located about 50 feet from the sloping edge of the waste lift. The influx of air from this edge is apparent by the relatively low methane and continuing presence of balance gas.

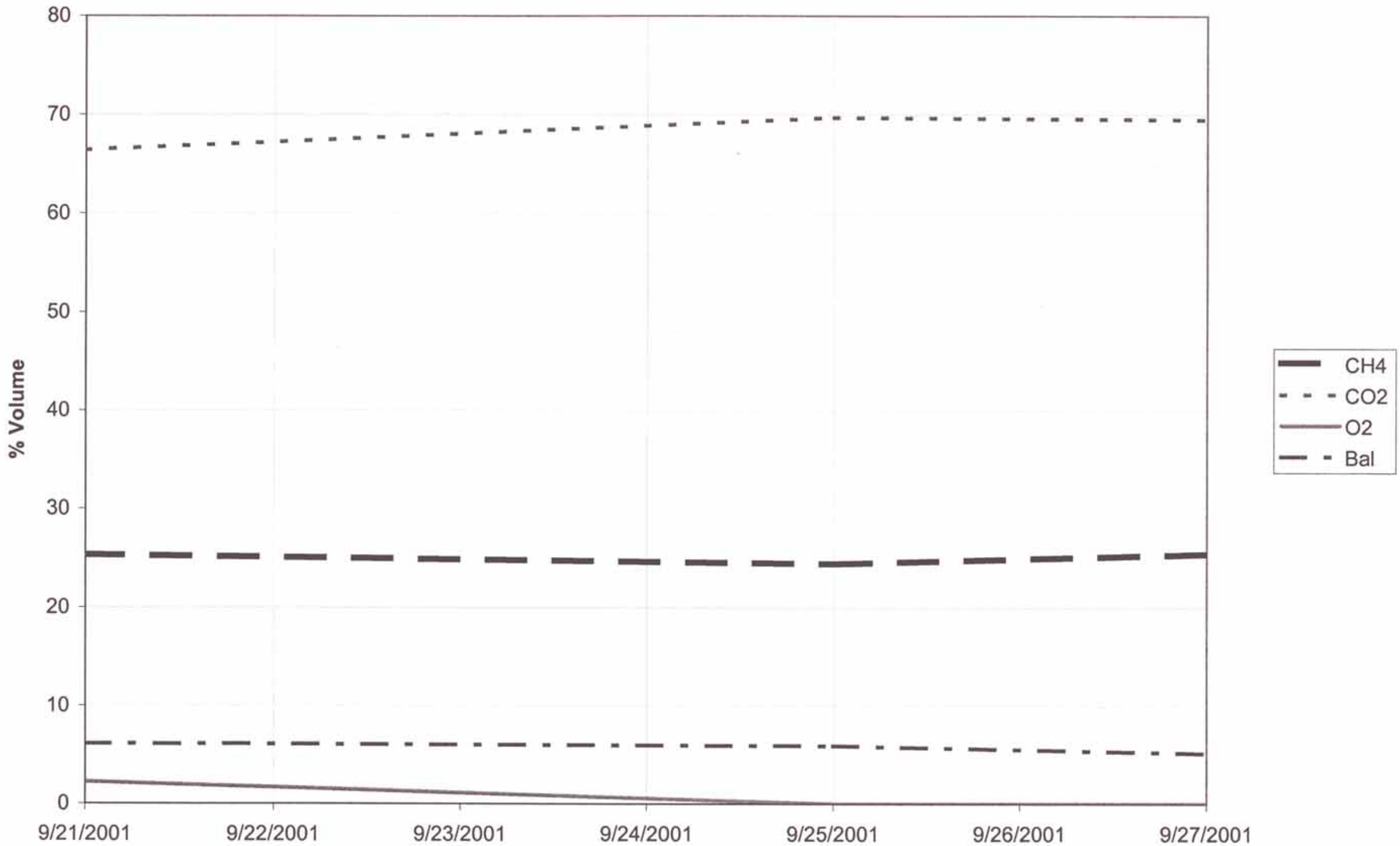


Figure 4-8
Gas Quality (Mat C Well Point - WCSD)

Non-methane organic compounds measured at detectable levels in Mat C are presented in Table 4-5. This information was derived from Summa vacuum canister samples analyzed according to EPA Method TO-15.

HYEX™ GAS CONDITIONS

Gas quality measurements in the HYEX extraction laterals were dependent upon the vacuum extraction conditions occurring at the time of measurement. In cases where no vacuum extraction had occurred for a significant time prior to sampling, methane concentrations were high, near 50% or greater, and oxygen and balance gas were zero. As vacuum was introduced into the system, then the methane concentrations would typically fall to values around 10% while balance gases may go up to 60% or more and oxygen spikes of typically 4 or 5% were sometimes evident. Carbon dioxide values varied from greater than 60% to around 20%, depending upon conditions. This is what would be expected if the gas came mostly from the under-lying mass during no-vacuum condition and was diluted with gas and air pulled in from above with the vacuum on.

The range of HYEX gas conditions can best be understood by reference to three graphs. Figure 4-9 illustrates the conditions at HYEX 2 lateral 2L which was never subjected to any open vacuum conditions. In this graph, we see ever increasing methane concentration beginning at about 11% and rising to about 44%. We also see a sharp decrease in balance gas from about 17% to 0 with oxygen remaining at zero. The pattern has a very quiet, steady appearance. The low or nonexistent oxygen and rising methane indicate a primarily anaerobic environment.

In contrast, Figure 4-10 illustrates conditions at HYEX 3 lateral 2L which initially was not subject to vacuum for several months but then on September 19th, vacuum was applied. The graph clearly illustrates a sharp drop in methane concentration to about 10% together with a rise in balance gas to over 60% and a spike in oxygen content to about 4%. When the vacuum was removed from HYEX 3, then we see a recovery of methane and corresponding decrease in balance gas with oxygen also returning to a zero value.

On the other extreme is an example illustrated by Figure 4-11 which graphs the performance of HYEX 6 lateral 2L. This location was subjected to constant vacuum application and then reduction of vacuum, both planned and unplanned, which resulted in a very busy pattern of changes with methane ranging from lows of about 8% to highs of over 60% with corresponding inverse relationships of balance gas ranging from a low of zero to a high of more than 65%. Oxygen patterns generally correlated to balance gas patterns and were typically inverse to methane. The ranges of oxygen values were zero to about 6%.

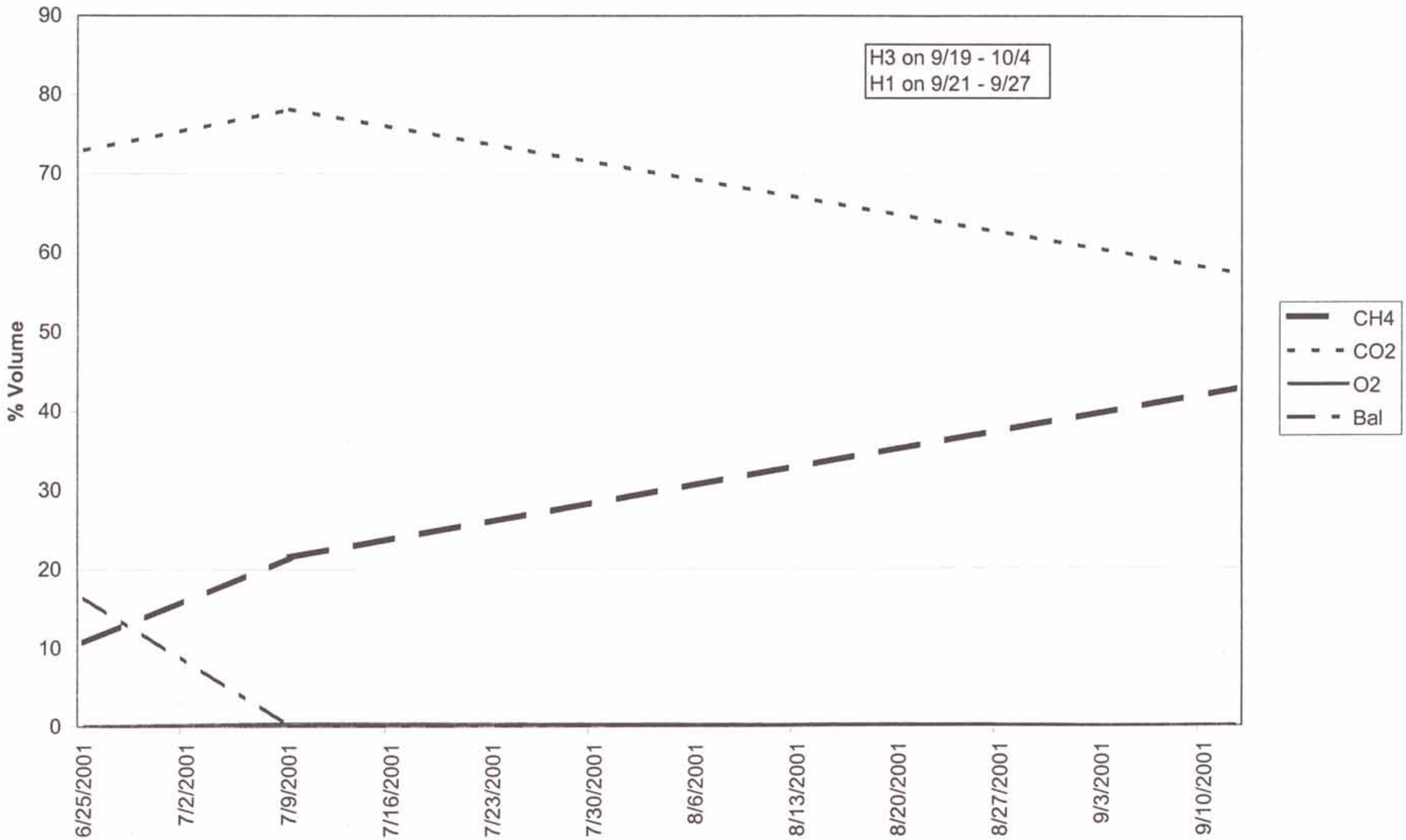


Figure 4-9
Gas Quality at H22L

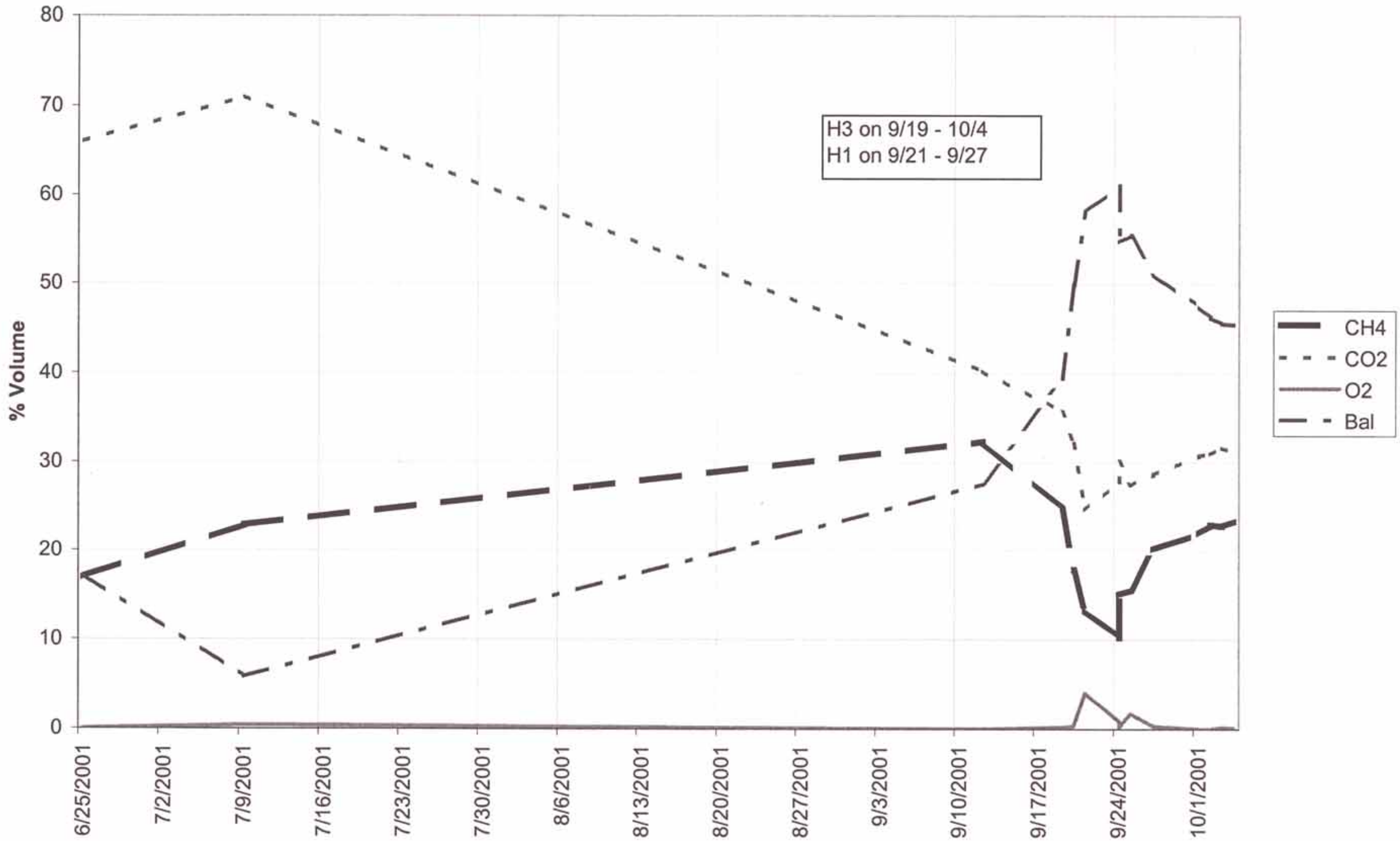


Figure 4-10
Gas Quality at H32L

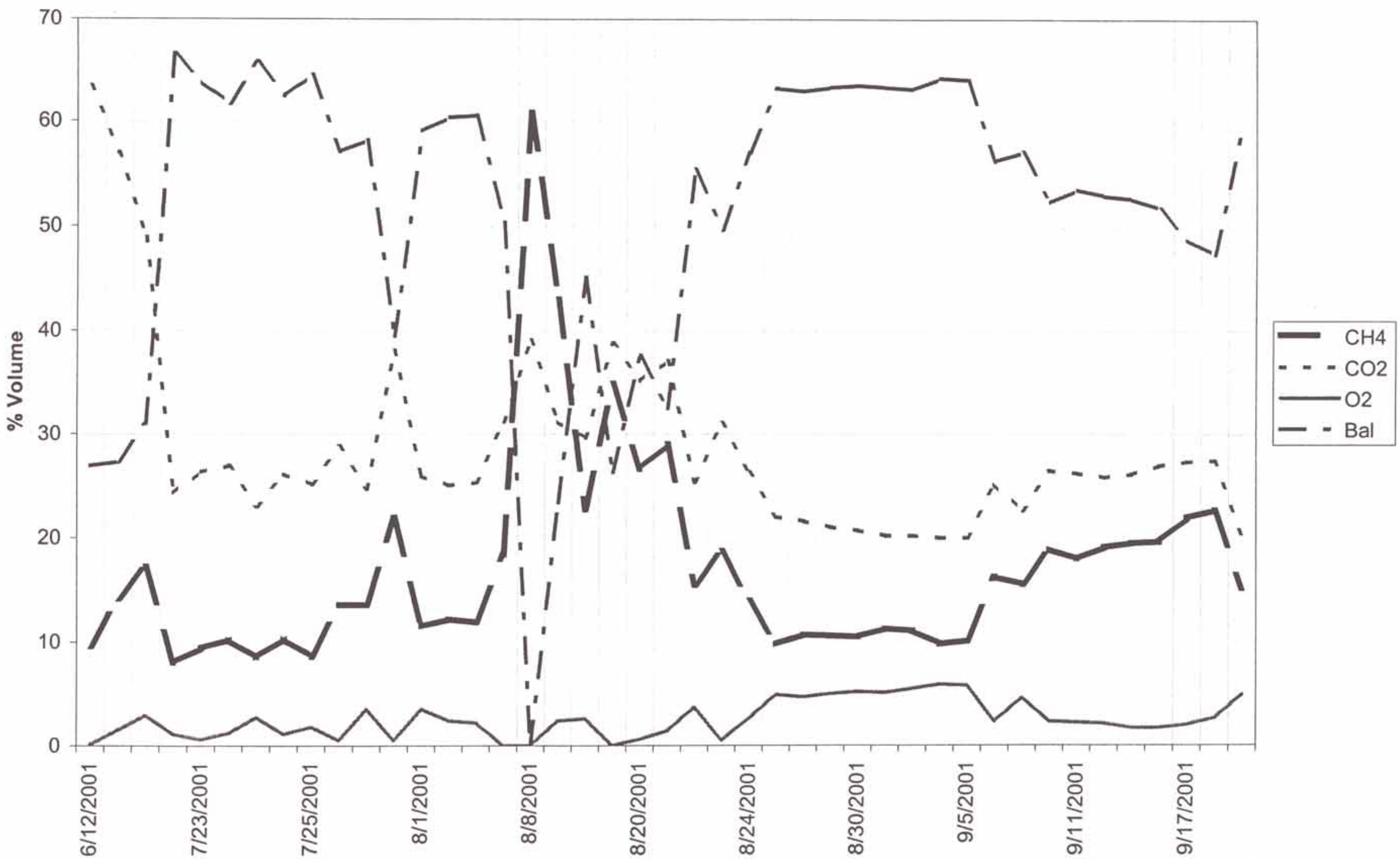


Figure 4-11
Gas Quality at H62L

The concentrations of landfill gases in the HYEX conduits varied widely depending upon the vacuum conditions. The effects of air dilution were clearly apparent and reproducible, and a reversion to typical anaerobic landfill gas occurred when vacuum conditions were removed.

Section 5
WASTE TEMPERATURE

MEASUREMENT METHODS AND LOCATIONS

Temperatures were measured at each of the HYEX™ conduits, at the well points, and at individual plunge bar locations. Gas temperatures were measured with an internal thermocouple thermometer associated with the GEM 500 meter and were cross-checked with a Reotemp bimetallic-coil compost thermometer. Temperatures in the well points were measured with a Type K thermocouple monitored by an Omega Multimeter thermometer. Waste temperatures at plunge bar locations were monitored by inserting the stem of a 36-inch bimetallic-coil Reotemp compost thermometer. The locations for the various temperature measurements are indicated on the General Arrangement Plan, Appendix 1.

PLACEMENT OF GEOMEMBRANE THERMOCOUPLES

Type K thermocouples were placed immediately above the primary geomembrane liner at eight locations as shown on the General Arrangement Plan, Appendix 1. These thermocouple units were constructed and provided by Lawrence Technological University of Southfield, MI. Professor James Hanson has placed a number of these units at various landfills throughout the Country and is conducting an ongoing study on waste temperatures. The thermocouple wires were encased in a vinyl tube which was buried approximately 6 inches deep within the stones covering the liner. The thermocouple itself was placed in direct contact with the HDPE liner at the locations shown. Standard terminal plugs were located within protected terminal boxes immediately outside the cell berm. Readings were periodically taken with an Omega Multimeter thermometer.

Unfortunately, the wires from TA-2 were broken during placement of intermediate cover, and TC2-150 was defective for an unknown reason. Nine readings were taken between July 11th and October 2nd on the five remaining thermocouples. Temperature readings from these thermocouples indicated relatively low temperatures at the liner surface ranging from 54 to 106° F. This corresponds with leachate temperatures measured in the Sullivan County system and also corresponds with findings that Dr. Hanson has measured at other landfills. These measurements clearly indicate that the methods practiced during this project did not result in elevation of liner temperatures beneath the stabilization mats.

MAT A TEMPERATURES

Waste mass temperatures in Mat A were monitored in two ways: by insertion of a Reotemp compost thermometer in plunge bar locations, and by monitoring of thermocouples located in the well points. Plunge bar temperatures in Mat A ranged from 89 to 142 degrees and the well point temperatures ranged from 94 to 135 degrees. Figures 5-1 through 5-6 illustrate the temperature patterns at various plunge bar locations.

Figure 5-1 is a graph of temperatures measured at plunge bar location 1 (PB1), 20 feet east of well point 6 (WP06), which was centered above HYEX line 6. The initial readings show a 10-degree drop in temperature consistent with the loss of vacuum which occurred during that period. The successful application of vacuum by the bypass jumper line on August 20th resulted in an increase of temperatures from about 100 degrees to the range of 135 to 140 degrees. This condition continued while vacuum was applied to HYEX 6; however, the temperature dropped when the vacuums were moved away to HYEX 3 and HYEX 1. It is apparent that the one-day application of vacuum to HYEX 6 again on October 5th did not immediately change the temperatures, and when all project valves were closed, the temperature was at its lowest point. This pattern illustrates a bioactive response to the vacuum induction of air into the waste, with temperatures moving toward the thermophilic range. It is also clear that temperature is not instantaneously responsive to changes in vacuum conditions as are the gas concentrations. In other words, gas quality is an instant indicator of the microbial environment while temperature is a lagged-response indicator.

Figure 5-2 illustrates a similar plunge bar temperature graph at a point (PB2) located 16 feet northeast of WP06, which was therefore approximately 16 feet northeast of the center line of the HYEX 6. Once again, we see an initial drop in temperatures. This is most likely associated with the drop in vacuums created by difficulties with the flare and gas collection system. Then we see rising temperatures again after the bypass line was installed on August 20th. The temperatures continue to rise to a maximum of 130 degrees during the time that vacuum was applied to HYEX 6; then temperature falls as vacuum is transitioned to HYEX 3 and 1. Once again, the lowest temperatures are measured when all valves were closed at the end of the project.

Figure 5-3 illustrates temperatures at plunge bar 3 (PB3) located 25 feet southeast of WP06, which is therefore southeast of the centerline of HYEX 6. The pattern is similar to the other two locations showing an initial decline, then an increase in temperatures after the installation of the bypass line, a rise toward aerobic thermophilic temperatures, then a fall back toward the lower temperatures when the vacuum is moved away from the area. This response is an expected behavior of waste moving from anaerobic to aerobic conditions and then reverting to anaerobic conditions.

Figure 5-4 graphs temperature behavior at plunge bar 7 (PB7) which was located 32 feet south of the extreme western end of HYEX 6. The measurements did not begin at this location until the 30th of August. Therefore, we do not see the initial patterns evident in previous graphs although we see a trend of rising temperatures influenced by the presence of vacuum conditions in HYEX 6, and then a decline in temperatures as those vacuum conditions are moved farther away. The response is not as extreme as that

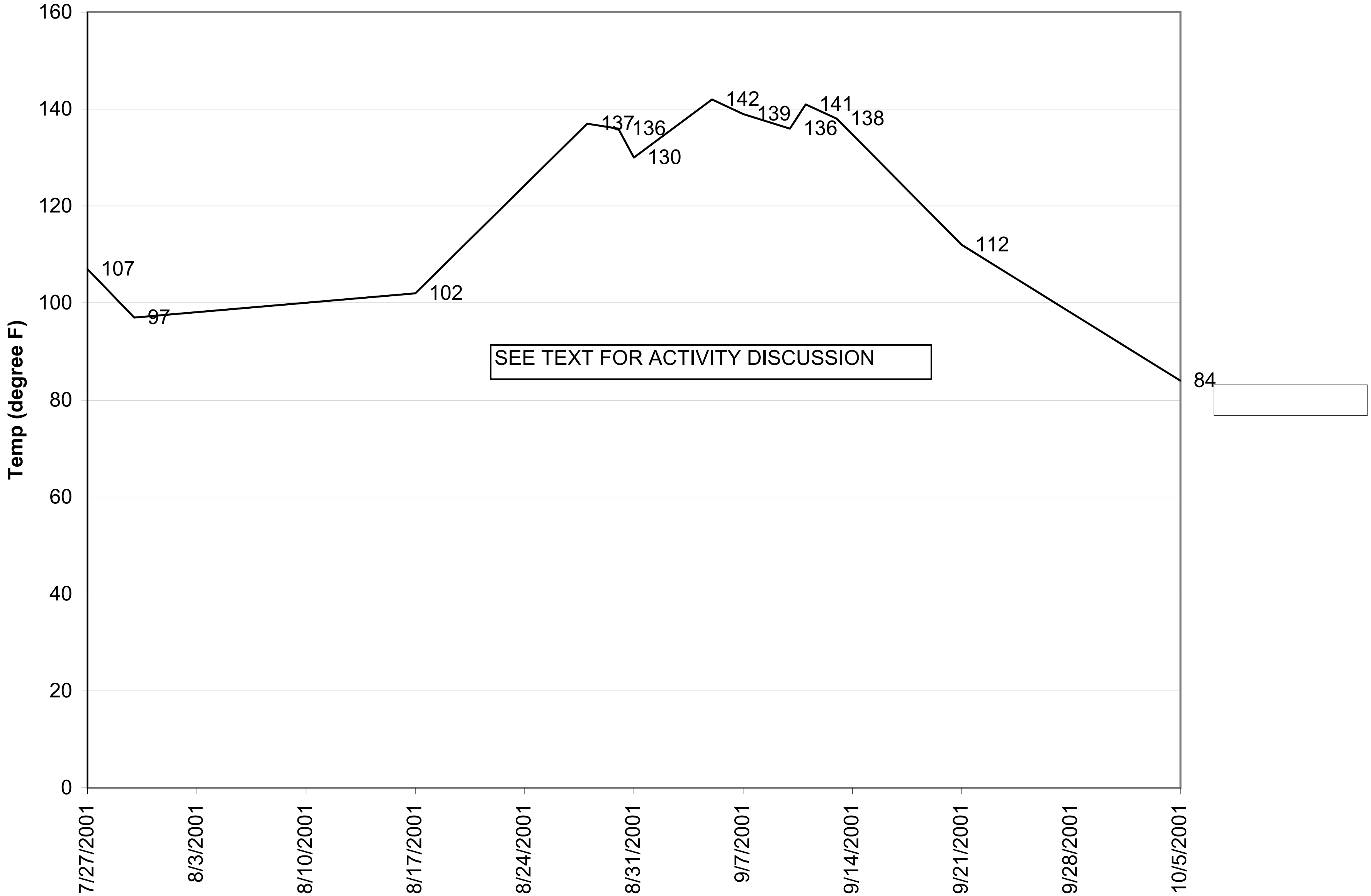


Figure 5-1
Temperature at Plunge Bar 1

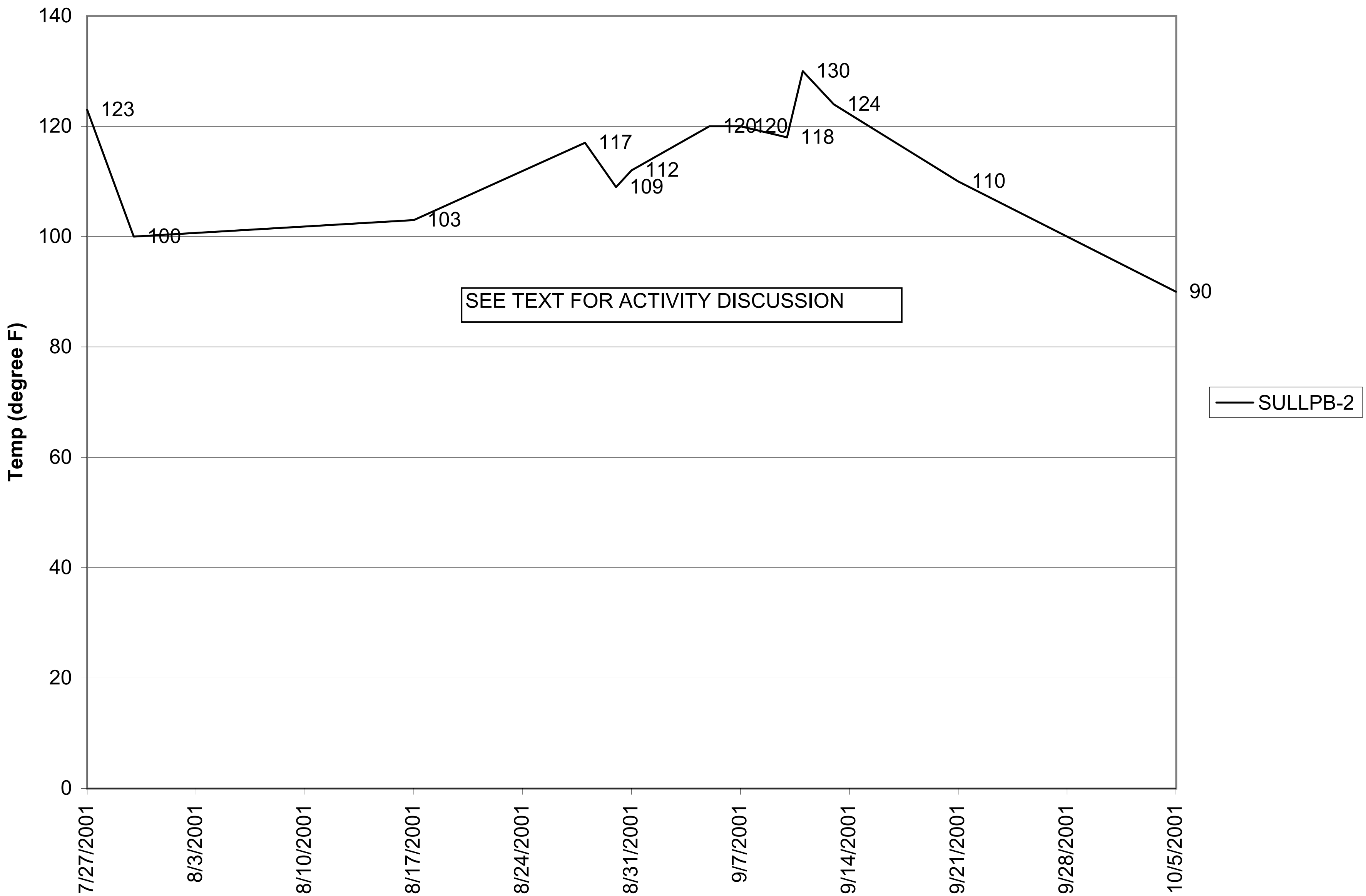


Figure 5-2
Temperature at Plunge Bar 2

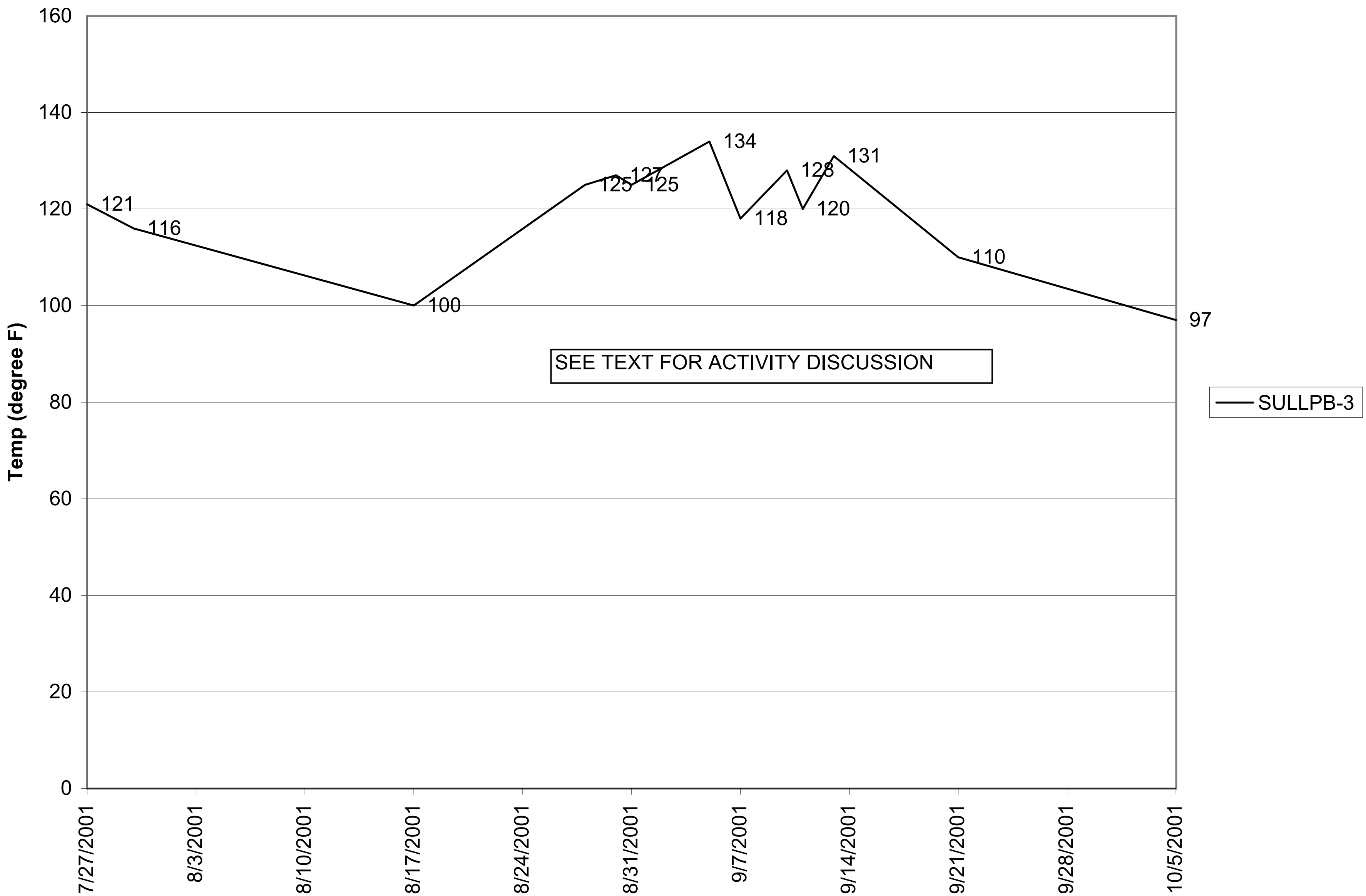


Figure 5-3
Temperature at Plunge Bar 3

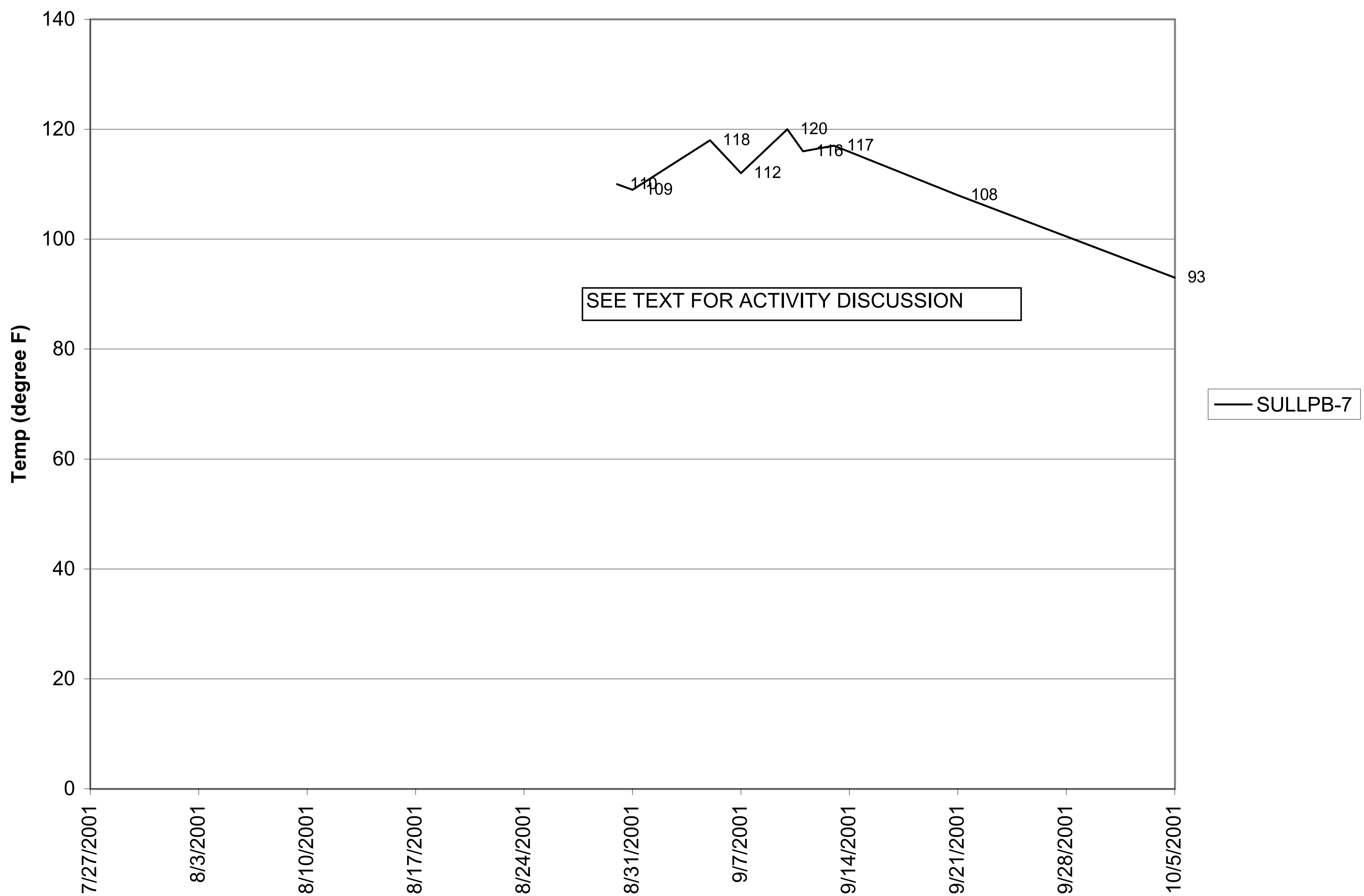


Figure 5-4
Temperature at Plunge Bar 7

found in the waste closer to HYEX 6. The lowest temperature was again measured with all system valves closed.

Figure 5-5 illustrates readings at plunge bar 5 (PB5) which was located 4 feet east of WP05, which is therefore 4 feet east of the center line of HYEX 5. In this case, we see a very minimal temperature response to the application of vacuum in HYEX 5 which occurred for only about 1 week. It is apparent that longer aeration times are required to create meaningful temperature changes in the waste mass. Also, individual areas in the waste mass may vary in temperature due to the fractured nature of the gas pathways within the heterogenous waste. This probe may have been in a cooler location and alternative probe locations may have had stronger temperature responses.

Figure 5-6 is a graph of temperatures at plunge bar 9 (PB9), measured 25 feet east of WP23 which was located between HYEX 2 and 3. In this case, we see a virtually flat line indicating essentially no temperature changes in this area, which was apparently not sufficiently affected by aeration placed in HYEX 1 and 3.

In general, information from the well point thermocouples indicated temperatures in slightly elevated ranges with a high degree of variability and relatively low conformance to predictable patterns. Table 5-1 provides the ranges and average values of temperatures measured at the Mat A well point thermocouples. None of the temperatures were high enough to create concerns for landfill fire. The temperature patterns displayed by measurements of the thermocouples within the steel well point pipes did not indicate trends that were as clear as those provided by the plunge bar samples. Perhaps the temperatures were modulated by heat transfer within the steel pipe casing or by other factors. In general, warmer average temperatures were observed nearer to HYEX 6 with W6WD showing a range of 123 to 135° F. with an average temperature of about 130° F., while well point 1 (WP01), above HYEX 1, showed a range of 106 to 110° F. with an average of 108° F. The lowest individual reading was above HYEX 2 at W02E with a range of 100 to 107 degrees and an average of 105 degrees. The well points were not fitted with thermocouples until mid-August and so the duration of monitoring was shorter.

Gas temperatures measured at the HYEX extraction laterals were subject to several variables, including bioactivity in the waste and temperature and quantity of dilution air pulled in from the atmosphere. These temperatures ranged from 92 to 130 degrees with an average value of 107 degrees.

MAT B AND C TEMPERATURES

Several of the well points, particularly those in Mat B and C, were placed late in the project and so only limited information was produced. Readings taken at well points in Mat B (over a period of 65 days) showed a range of temperatures from 101 degrees to 130 degrees with an average of 116, and the Mat C well point readings (over a period of 35 days) ranged from 98 degrees to 133 degrees with an average of 115.

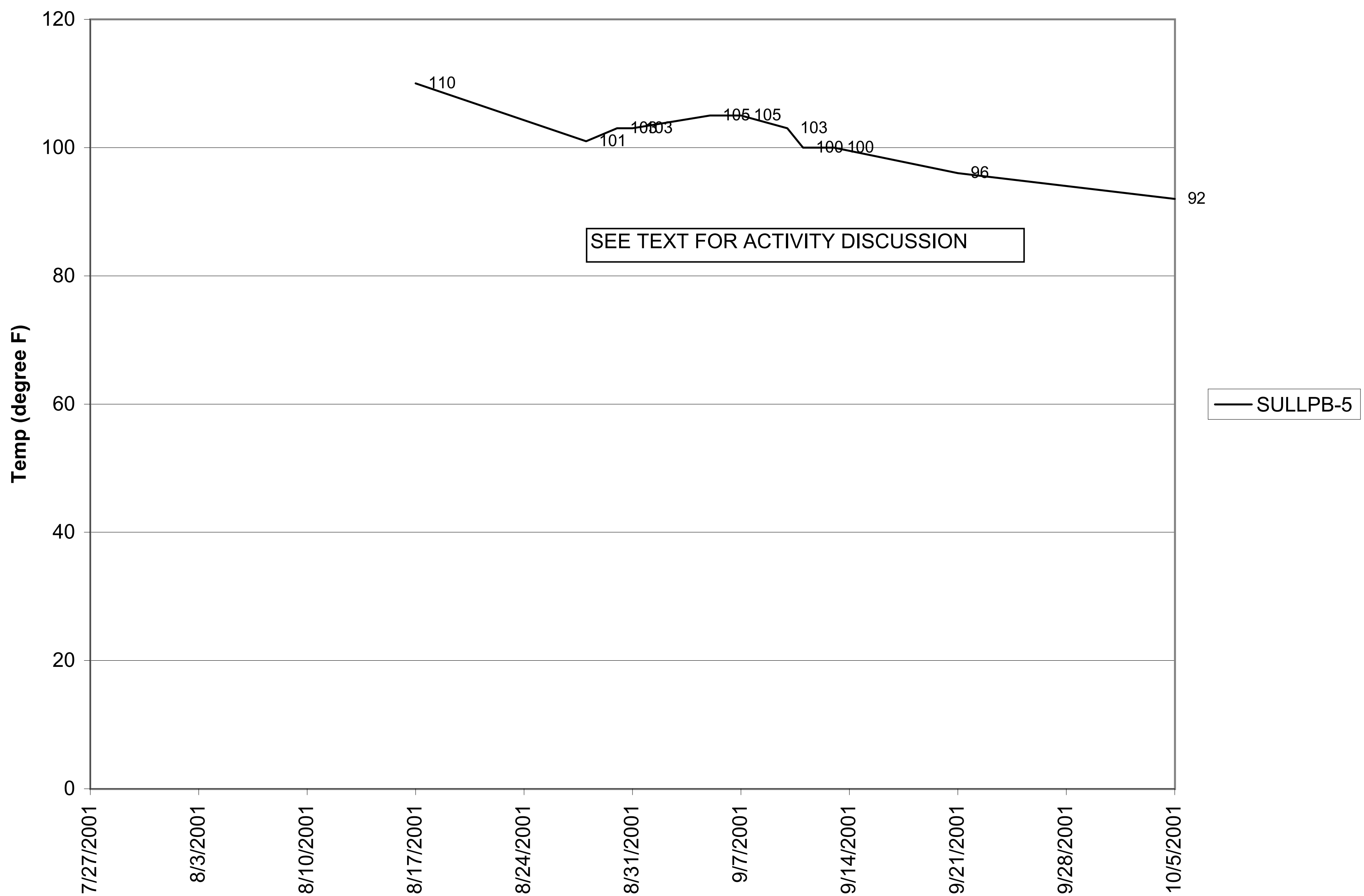


Figure 5-5
Temperature at Plunge Bar 5

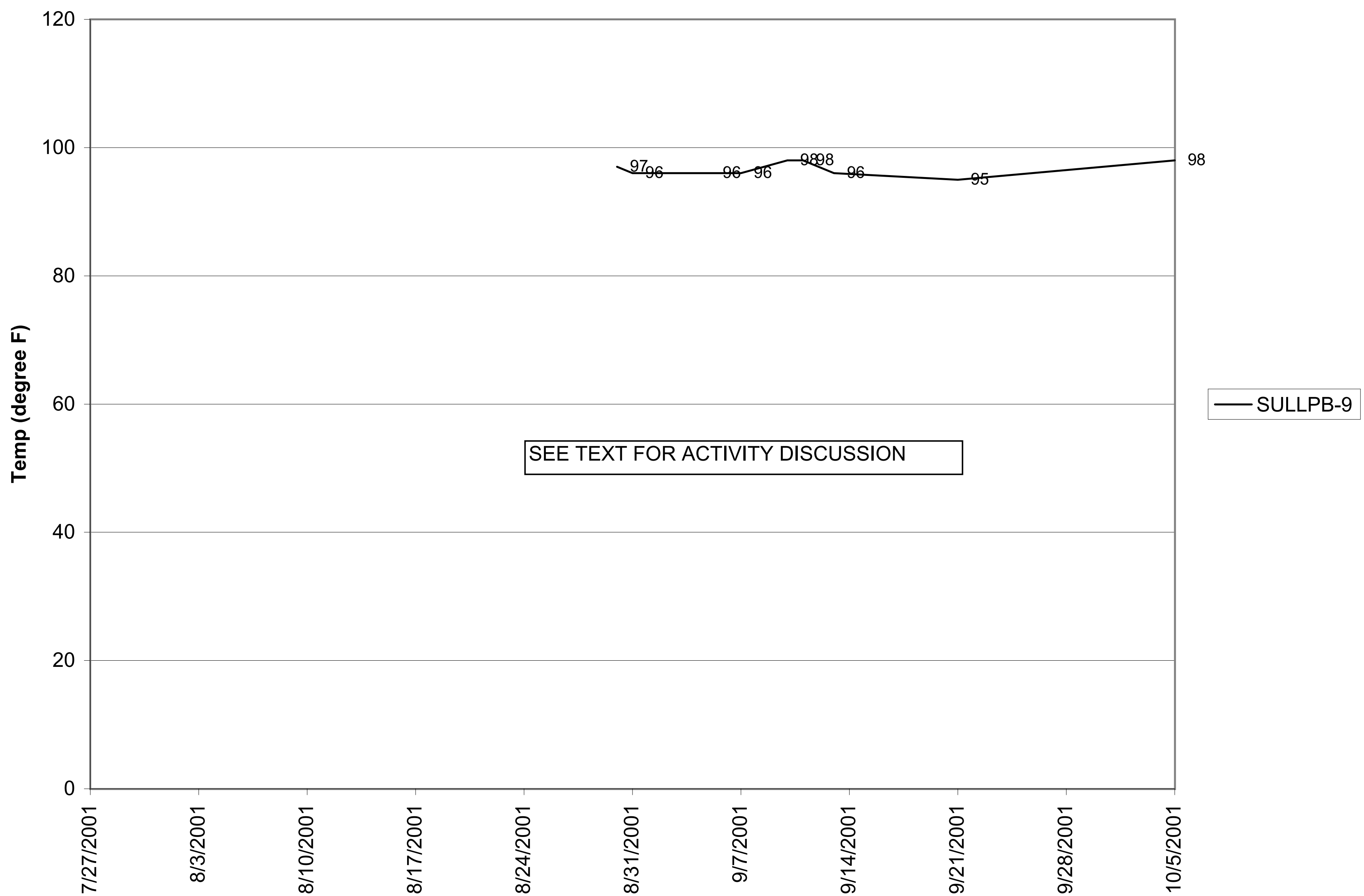


Figure 5-6
Temperature at Plunge Bar 9

Table 5-1
Sullivan County Biostabilization Project
Well Point Temperatures - Mat A

WELL POINTS	SULLWP01	SULLWP12	SULLWP02	SULLWO2E	SULLWP23	SULLWP03	SULLWP04	SULLWP04S	SULLWP45
15-Aug	107	113	111	103	113	105			
17-Aug	107	113	113	104	113	107			
20-Aug	107	114	114	105	115	107			
24-Aug									
27-Aug	107	114	115	105	115	108			
28-Aug	109	117	115	107	116	109			
30-Aug	109	115	115	106	115	107			
17-Sep	110	120	117	108	116	113	132	111	119
27-Sep			112	100	111		119	99	112
5-Oct	106	118	113	105	110	106	119	99	108

WELL POINTS	SULLWP05	SULLWP5S	SULLWP56	SULLW56S	SULLWP06	SULLW06S	SULLW6ED	SULLW6ES	SULLW6WD	SULLW6WS
15-Aug	113	108	115	106	111	106	111	110	133	118
17-Aug	113	106	115	105	117	111	115	112	135	119
20-Aug	115	108	118		116	110	120	115	133	119
24-Aug	115	107	118	107	119	110	120	116	131	118
27-Aug	117	108	120	109	119	111	120	120	131	120
28-Aug	115	107	116	106	117	111	117	118	132	120
30-Aug	115	105	117	106	116	109	120	122	130	120
17-Sep	120	113	116	105	114	106	125	121	126	116
27-Sep	111	98	113	96	114	100	127	108	123	99
5-Oct	110	96	113	94	113	100	128	105	123	101

Section 6
ATMOSPHERIC EMISSIONS

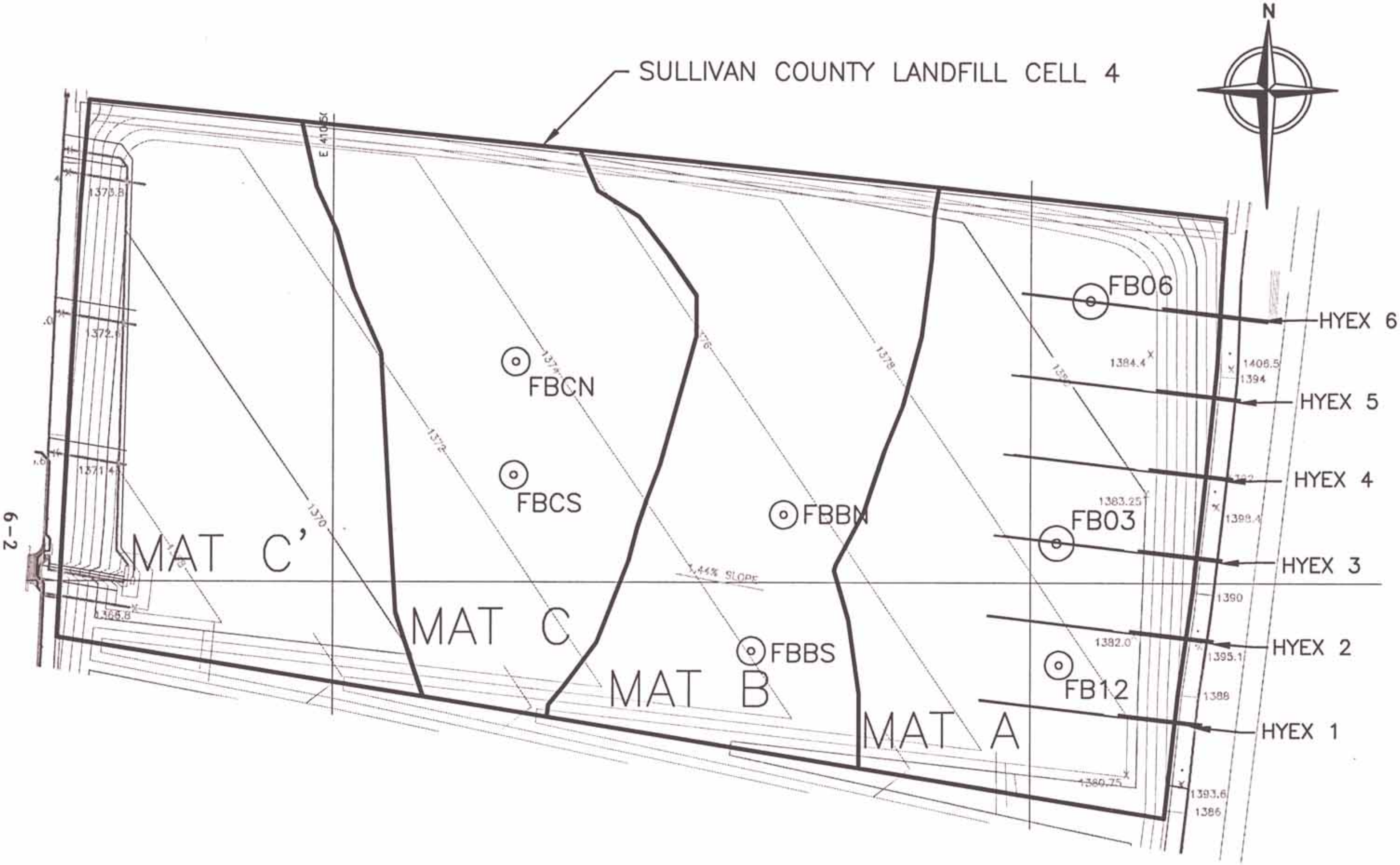
BACKGROUND

Total flux consists of two components, diffusive flux due to concentration gradients and convective flux due to pressure gradients. Flux boxes are enclosed chambers and, therefore, principally measure the effect of diffusive flux. However, the gas pressure in Mat A has been shown to correlate with the methane concentration, as illustrated by the gas concentration patterns evaluated in Section 4. Both the interstitial gas methane concentration and gas pressure are related to methane flux at the landfill surface. Also, the barometric pressure is a potential variable as well as other weather conditions, such as heavy rains which may seal the pores. Because of the great potential complexity of these variables, the scope of this work was simply to observe the major flux patterns and make simplified statistical summaries of observed values in order to generally compare the flux behavior of Mats A, B and C.

MEASUREMENT METHOD, LOCATION, AND FREQUENCY

Flux boxes constructed of cutoff 55-gallon steel drums were placed at seven different locations identified on Figure 6-1. Three of the flux boxes were located over Mat A (at the center line of HYEX 6, HYEX 3 and between HYEX 1 and 2); two flux boxes were located in Mat B and two flux boxes in Mat C. Shallow and deep well points were co-located with each flux box to measure gases at 4 and 8 feet beneath the surface. Flux boxes were fitted with removable tops which allowed evacuation of the flux box prior to beginning of measurements. The top was sealed with a rubber gasket and steel rim; samples were extracted through a Colder Products plastic sampling nipple. Flux boxes were not fitted with relief vents. Methane concentrations were measured from the flux boxes with a Foxboro TVA 1000 flame ionization detector (FID), with a precision of 0.10 ppmv; gas concentrations from the adjacent well points were measured with the GEM 500 landfill gas meter.

The flux boxes were initially opened to equilibrate with ambient air. After replacing the top, flux box samples were taken with the FID meter at five-minute intervals for a period of 30 minutes. Calculations were performed on the series of six readings, yielding a methane flux in grams per square meter per day (gm^{-2} day^{-1}). Fluxes were calculated from the product of the change in concentration over time (dc/dt) and the chamber volume/area ratio, according to the method of Rolston (1986) for static closed chambers. The FID reading is assumed to equal the methane concentration. Since a small pump was used to draw gas through the chambers for the FID determination, these fluxes should be assumed to represent maximum values. This is because, through the 30-minute sampling period, a gas flow is induced by the pumping.



MONITORING LEGEND

⊙ FLUX BOX

FIGURE 6–1

FLUX BOX LOCATIONS

On September 21st, vacuum Summa canister samples for NMOC analysis were drawn from the flux boxes after the 30-minute FID reading was taken. This was done to compare NMOC concentrations in the flux boxes of Mat A, B and C.

Flux boxes 3 and 6 were installed on August 15th and measurements were taken on nine individual days between August 17th and October 5th. Multiple readings were taken on certain days due to changing mat conditions. Flux boxes 12, BN, BS, CN and CS were installed later and readings were taken on five individual days between September 19th and October 5th.

Fluxes are presented in SI units in this report. Although all other values are in American units, SI units are more customary for landfill gas flux.

MAT A FLUXES

The methane fluxes measured from the three individual flux boxes located in Mat A varied widely depending upon the proximity and duration of vacuum conditions in the waste. The lowest value, .005 grams per square meter per day ($gm^{-2}day^{-1}$), was obtained from flux box 6 (FB06) after the HYEX line immediately beneath that flux box had been subjected to vacuum conditions for several months. On the other hand, the highest observed value of 290 $gm^{-2}day^{-1}$ was observed in flux box 12 (FB12), which was farthest from the applied vacuums and this value was measured at a time when the vacuum was most distant from that flux box. Figure 6-2 presents a graph of the flux readings from flux box 3 (FB03) together with the pressure conditions observed in the well point near FB03. A general correlation can be observed in these two parameters. Figure 6-3 is a similar graph of pressure conditions and flux box readings at FB06. This also shows a general correlation between pressure conditions and flux. Figure 6-4 graphs the readings at FB12 and, once again, a certain degree of correlation is observed between the pressure conditions and the flux box readings; however, the final reading shows a significant increase in methane flux unexplained by pressure change alone. Clearly, in this case and in certain other cases, other variables affected methane flux; however, there was no case where reducing pressure resulted in increasing flux. Table 6-1 presents a summary of fluxes observed from flux boxes located in Mat A.

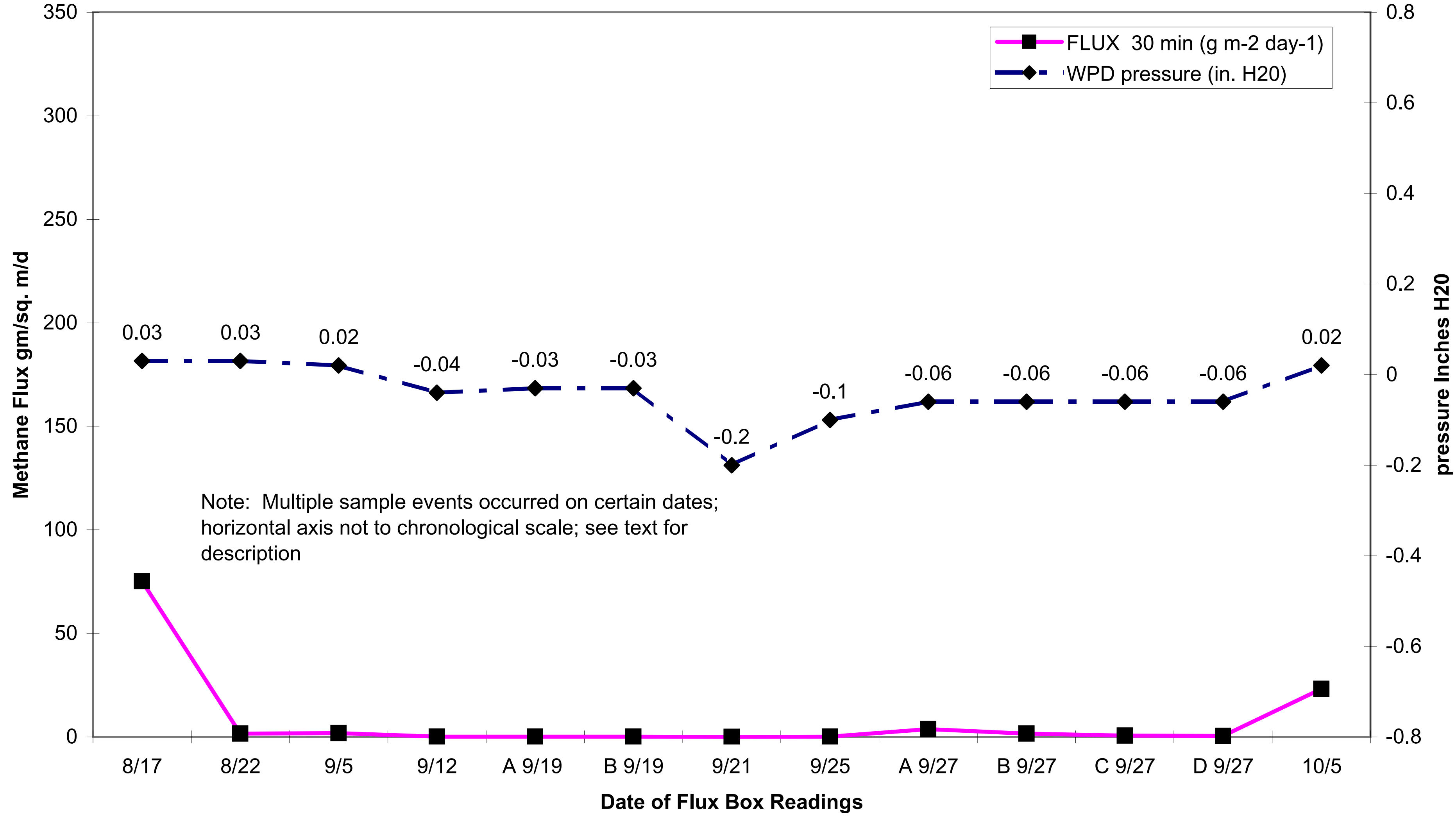


Figure 6-2
Methane Flux at FB03

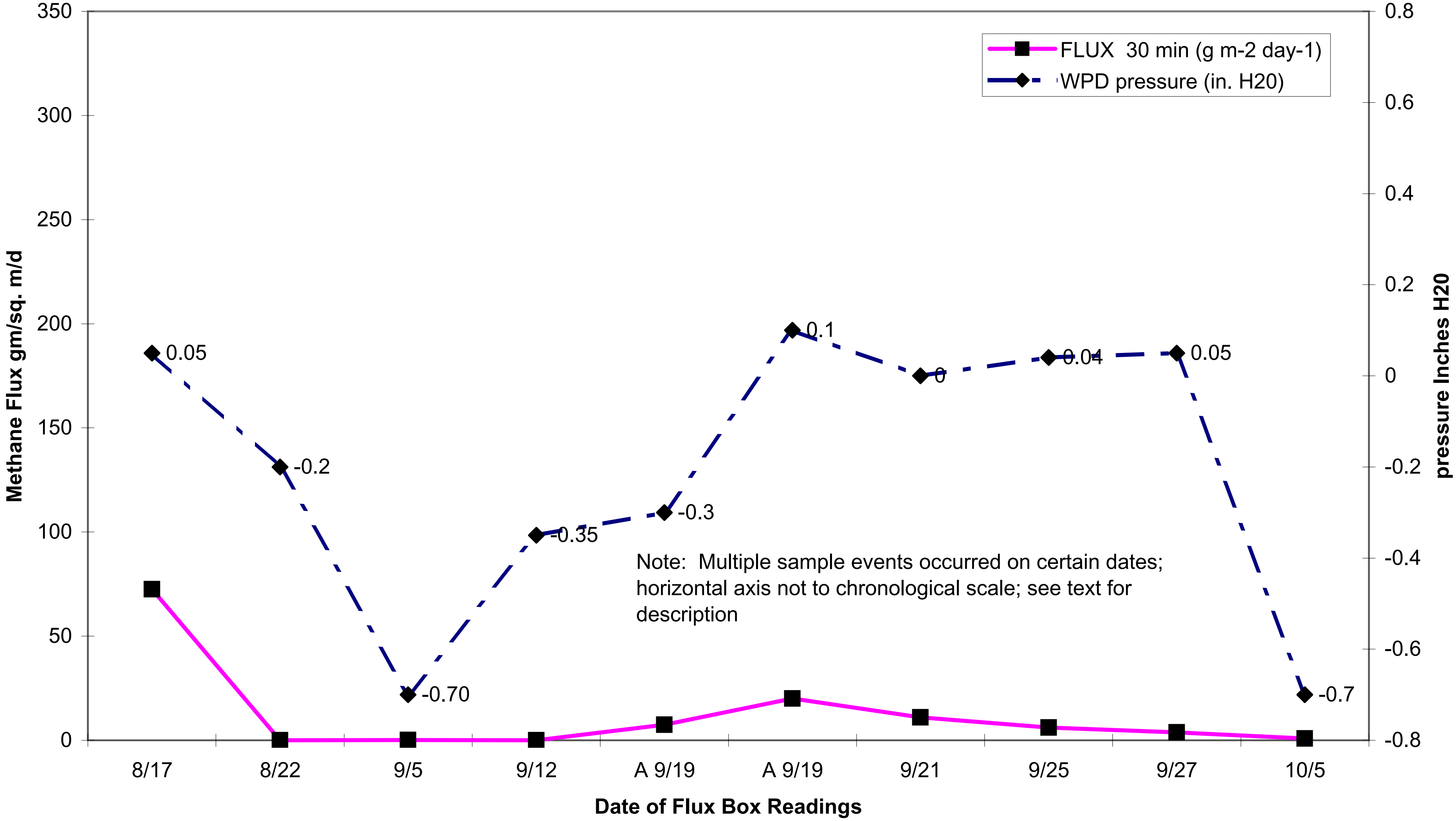


Figure 6-3
Methane Flux at FB06

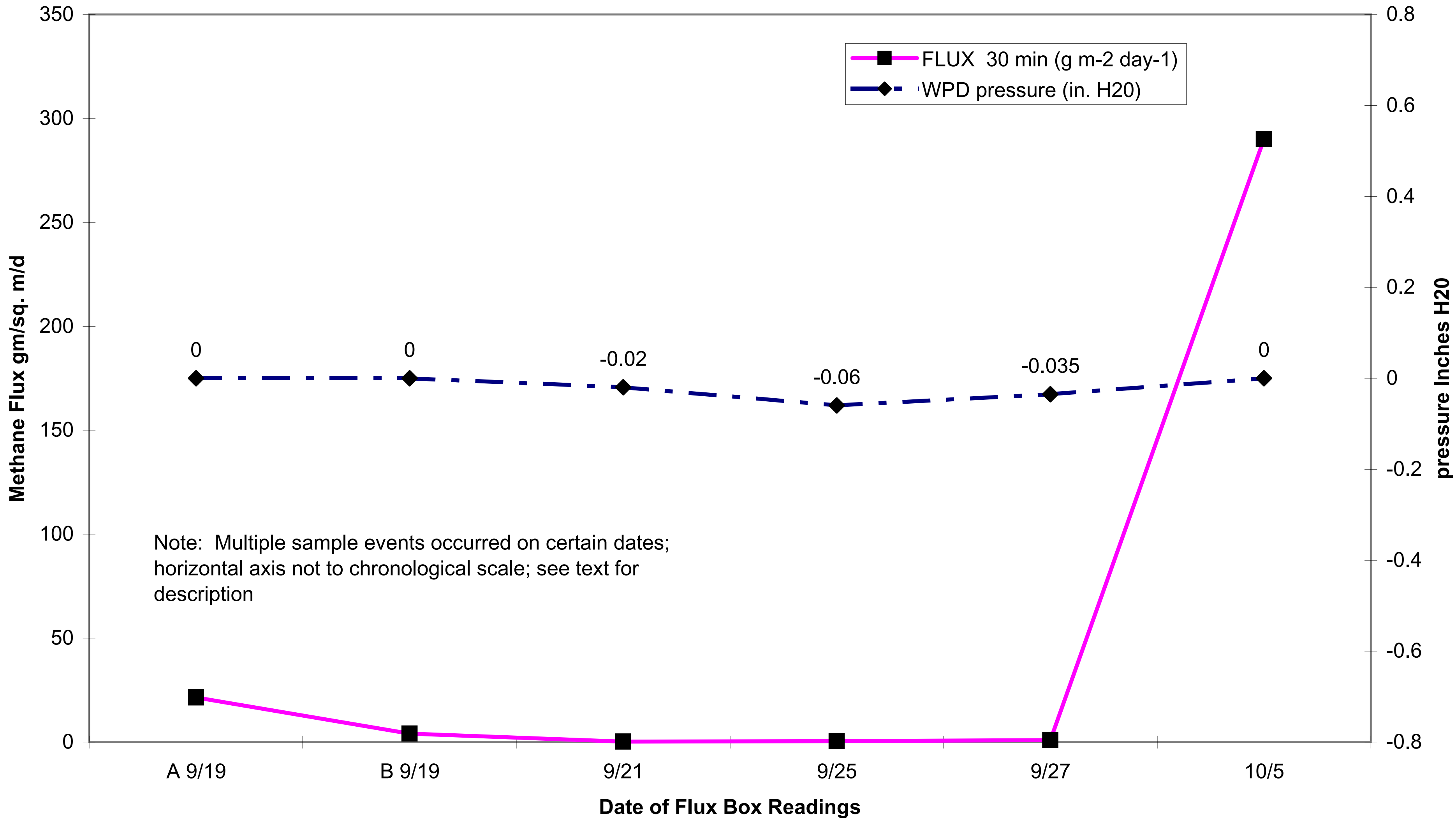


Figure 6-4
Methane Flux at FB12

Table 6-1

MAT A FLUX SUMMARY

Location	**Flux ($gm^{-2}day^{-1}$)**								
	8/17	**8/22**	**9/05**	**9/12**	**9/19**	**9/21**	**9/25**	**9/27**	**10/05**
FB 06	72.475	0.005	0.072	0.027	7.497	11.025	6.160	3.822	0.860
(B)					20.112				
FB 03	75.201	1.547	1.861	0.083	0.117	0.018	0.086	3.800	23.160
(B)					0.148			1.579	
(C)								0.628	
(D)								0.538	
FB 12					21.419	0.233	0.483	1.003	289.995
(B)					4.055				

In general, rising and falling fluxes correlate well with changes in vacuum conditions moving more distant or closer to the flux box. One interesting condition occurred during monitoring FB12 on September 19th. The initial reading was taken while the vacuum was 137 feet away, yielding a flux of 21.42 $gm^{-2}day^{-1}$. The valves were adjusted to move the vacuum condition to within 82 feet of the flux box and immediately a reduction to 4.06 $gm^{-2}day^{-1}$ was measured. Continuing this setting for about a week resulted in continuing reduction of the flux value to less than 1$gm^{-2}day^{-1}$. When the vacuum near the flux box was turned off and moved to the HYEX conduit farthest away from flux box 12, the flux jumped to a value of almost 290 grams per square meter per day.

Flux box 6 (FB06) had a baseline reading during a positive pressure condition of 72.47 grams per square meter per day, which dropped to an average of 10.27 $gm^{-2}day^{-1}$ when the vacuum was 165 feet away. When the HYEX line beneath FB06 was open for only one day; the value was 0.86 $gm^{-2}day^{-1}$. However, when the vacuum had been on at HYEX 6 beneath the flux box for more than a month, this value dropped to an average of 0.035 $gm^{-2}day^{-1}$. The value on September 5th prior to a valve change was .0716 grams per square meter per day, which is about 1,000 times less than the baseline value.

The baseline positive pressure value observed in flux box 3 (FB03) was 75.2 $gm^{-2}day^{-1}$ while an average value with vacuums 55 feet away dropped to 0.69 $gm^{-2}day^{-1}$. The flux at 55 feet from the vacuum source was about 100 times less than the baseline value. When vacuums were moved to 165 feet away, the average value rose to 12.36 $gm^{-2}day^{-1}$

Measurements at flux box 12 (FB12) indicated that when the vacuums were about 137 feet distant from the flux box at HYEX lines 4 and 6, the average flux was 155.7 $gm^{-2}day^{-1}$. However, when the vacuum was moved to within 27 feet of the flux box at HYEX 1 and 3, the average flux value dropped to 1.44 $gm^{-2}day^{-1}$, or approximately 100 times less than the baseline value.

MAT B AND C FLUXES

Variations in flux were not as great in Mat B and C because there were no vacuum lines buried beneath these mats to create the measurable pressure changes and gas quality changes observed in Mat A. Figure 6-5, which graphs the performance of FBBN, shows a wide range of values which is difficult to interpret, but perhaps relates to complex specific conditions at the flux box location. Figure 6-6 illustrates the flux and pressure pattern at flux box C-north (FBCN). This shows a very even pattern with relatively little change and a moderate flux rate averaging about 5.6 $gm^{-2}day^{-1}$.

Table 6-2 presents a summary of flux information concerning flux boxes located in Mat B and Mat C.

Table 6-2
MAT B AND C FLUX SUMMARY

Location	**Flux ($gm^{-2}day^{-1}$)**				
	9/19	**9/21**	**9/25**	**9/27**	**10/05**
FBBN	46.394	30.683	1.133	3.726	182.073
FBBS	19.910	25.769	38.273	23.968	80.345
FBCN	3.416	9.773	3.212	4.555	6.964
FBCS	2.099	0.643	6.037	5.885	0.861

The average flux at FBBN was 52.8 $gm^{-2}day^{-1}$, although the use of averages with so few data points must be considered speculative.

Flux box B-south (FBBS) had a more even flux reading with an average of 37.65 $gm^{-2}day^{-1}$ and a range of 19.1 to 80.35 $gm^{-2}day^{-1}$. Flux box C-north (FBCN) had a very small range of values with an average of 5.6 $gm^{-2}day^{-1}$. Flux box C-south (FBCS) averaged 3.1 $gm^{-2}day^{-1}$.

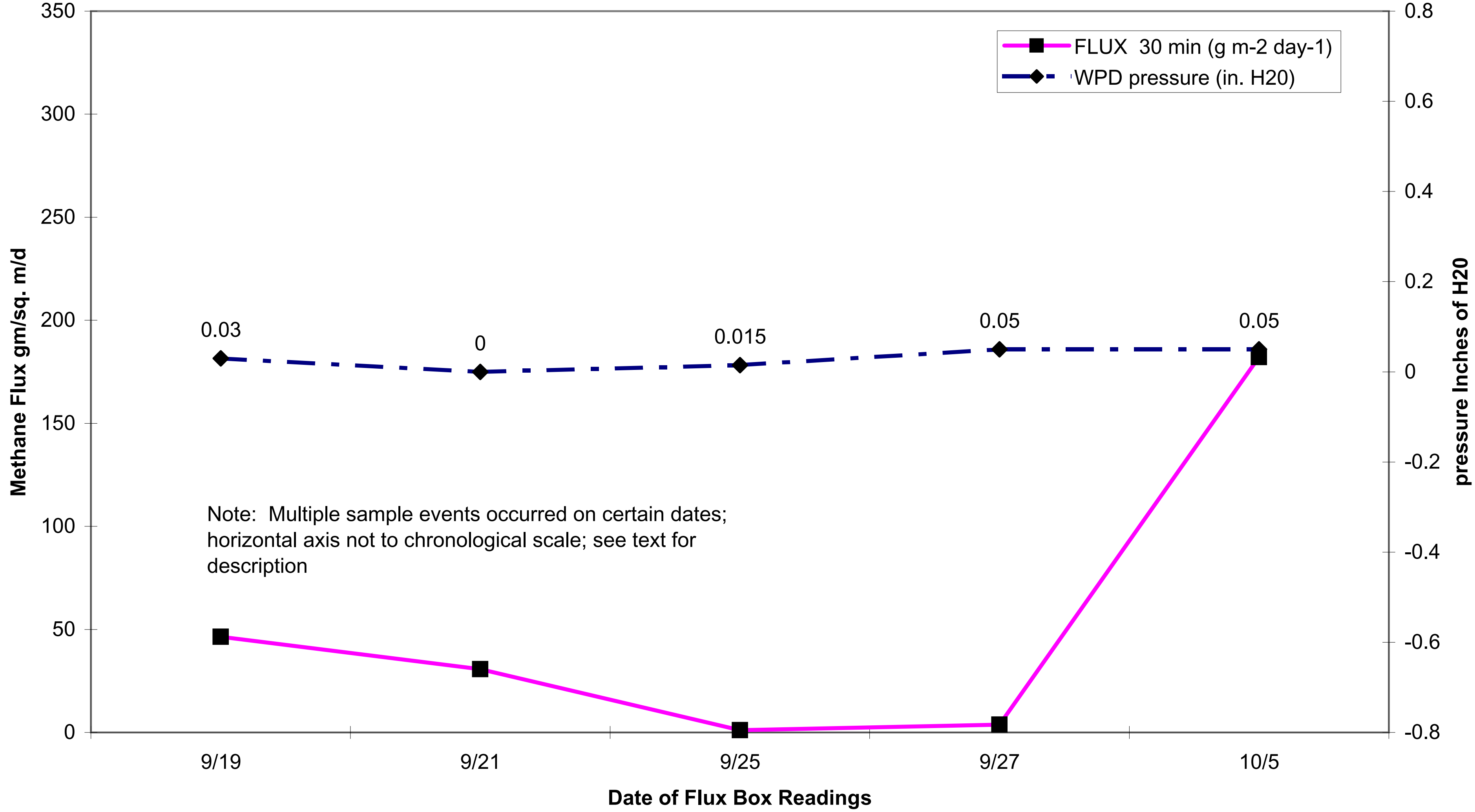


Figure 6-5
Methane Flux at FBBN

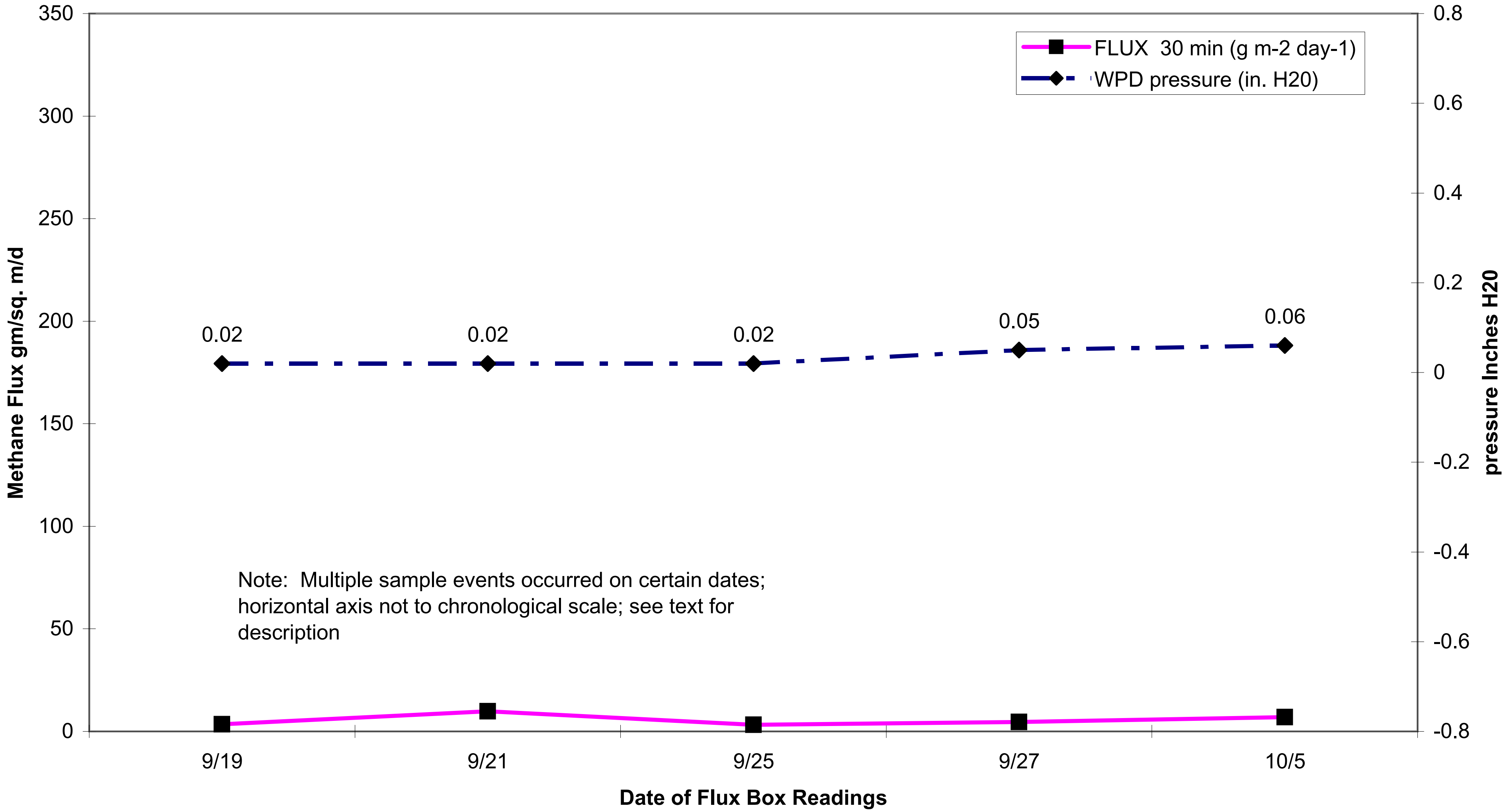


Figure 6-6
Methane Flux at FBCN

COMPARATIVE INTERPRETATION

Table 6-3 presents a comparative statistical summary of conditions observed in the flux boxes at Mat A, B and C. The methane fluxes observed in Mat C averaged 4.34 $gm^{-2}day^{-1}$. This is about ten times less than the average value of 45.23 $gm^{-2}day^{-1}$ observed in Mat B. The most likely cause for this difference is increased bioactivity in Mat B related to the leachate application. The methane fluxes during non-vacuum conditions observed in Mat A averaged 145.89 $gm^{-2}day^{-1}$, which was about 34 times the average value in Mat C. The likely explanation for this is the increased level of biodegradation occurring as a result of the facultative conditions in conjunction with the leachate application on Mat A. In contrast to the baseline condition, the typical values at FB06 for vacuums located 165 feet away dropped to 10.27 $gm^{-2}day^{-1}$, which is about 7% of the baseline value. A similar pattern is seen at FB03 with average 165-foot distance flux values of 12.36 $gm^{-2}day^{-1}$; with vacuum applied 55 feet away, the average flux dropped to 0.69 $gm^{-2}day^{-1}$. The values for short-term, nearby vacuum conditions are typically less than 1 gram per square meter per day for FB06 and FB03, while the value for prolonged vacuum conditions in the immediate vicinity of FB06 dropped the average flux rate to 0.035 $gm^{-2}day^{-1}$. Readings at FB12 indicate a 137-foot vacuum distance flux of 21.42 $gm^{-2}day^{-1}$ falling to an average value of 1.44 $gm^{-2}day^{-1}$ with vacuum at a closer distance of 82 feet. The flux climbed to 289.99 $gm^{-2}day^{-1}$ when the vacuum moved to a distance of 247 feet. Although the absolute value of averages is less meaningful with relatively few data points, the general influence pattern is clear.

Table 6-3

FLUX BOX STATISTICAL SUMMARY

Baseline Conditions

MAT A (Non-vacuum)

Location	Date	Flux ($gm^{-2}day^{-1}$)	Standard Deviation
FB06	8/17	72.47	
FB03	8/17	75.20	
FB12	10/05	289.99	
Average		145.89	124.8

MAT B (Non-vacuum)

Location	Flux ($gm^{-2}day^{-1}$)	Standard Deviation
FBBS (avg. all)	37.65	
FBBN (avg. all)	52.80	
Average	45.23	10.71

MAT C (Non-vacuum)

Location	Flux ($gm^{-2}day^{-1}$)	Standard Deviation
FBCN (avg. all)	5.58	
FBCS (avg. all)	3.11	
Average	4.34	1.75

Mat A Vacuum Conditions

Location	Date	Flux (gm^{-2}day^{-1})	Vacuum Distance (ft.)
FB06	9/19	20.11	
"	9/21	11.02	
"	9/25	6.16	
"	9/27	3.82	
	Average	10.27	165
FB03	8/22	1.56	
"	10/05	23.16	
	Average	12.36	165
FB12	9/19	4.06	
"	9/21	0.23	
"	9/25	0.48	
"	9/27	1.00	
	Average	1.44	82
FB03	9/05	1.86	
"	9/12	0.08	
"	9/19	0.12	
	Average	0.69	55
FB06	8/22	0.0050	
"	9/05	0.0716	
"	9/12	0.0273	
	Average	0.0346	0

These data suggest two general conclusions: First, that methane flux from the wetted bioactive MSW is at least an order of magnitude greater than from the control cell of non-moisture-adjusted waste and, secondly, that application of vacuums within 55 feet from the emission point reduces the flux to levels approximately one order of magnitude lower than the average flux from the non-wetted control cell. The atmospheric flux of methane in the immediate vicinity of the vacuum conduit is dropped by over two orders of magnitude.

These findings are significant when considering that the typical landfill spacing for horizontal gas collector conduits is 100 feet. With a design radius of influence of 50 feet, these data suggest that it would be possible to operate an active biostabilization cell with atmospheric emissions reduced by an order of magnitude compared with a conventional landfill cell. In contrast to this, the biostabilization cell with no vacuum control may produce atmospheric emissions significantly greater than the conventional landfill cell. These conclusions are specific to the conditions of this study and are likely to vary if, for example, higher moisture content or greater aeration are achieved; however, the general trends are likely to prevail.

Table 6-4, the total gaseous non-methane organic compounds (NMOC) as methane, provides further evidence of the contrast in vacuum cell operations. The average value of NMOCs in the 30-minute flux samples from Mat A was 9.4 ppm whereas the average value of NMOCs in Mat B and C was 111 ppm. This shows a reduction of NMOC concentrations by an order of magnitude from areas subject to internal vacuum compared with non-vacuum waste mats.

Table 6-4

FLUX BOX NMOC MEASUREMENTS - 9/21/01

Location	Total Gaseous Non-methane Organics (ppmV)
FB06	7.9
FB03	3.3
FB12	17
Average	9.4
FBBN	76
FBBS	200
FBCS	120
FBCN	48
Average	111

Rolston, D., 1986, Gas Flux, p. 1103-1118, in A. Klute, editor, Methods of Soil Analysis. Part I. Physical and Mineralogical Methods. Second Edition, Published by American Society of Agronomy/Soil Science Society of America, Madison, WI.

Section 7
CONCLUSIONS AND RECOMMENDATIONS

Methane flux rates from wetted areas under vacuum pressure averaged 90-99% less than the average flux from the control cell. Under non-vacuum conditions, the measured flux of methane from the moisture adjusted biostabilization mats was an order of magnitude greater than from the control mat, which received no leachate application. This finding is consistent with common sense and indicates the opportunity to operate a biostabilization cell with far lower atmospheric emissions, and lower odor potential than that associated with conventional landfilling. On the other hand, these findings indicate that operation of biostabilization cells without active gas collection poses the risk of increased atmospheric emissions and odor potential.

The measured flux of non-methane organic compounds (NMOC) from the Mat A area was an order of magnitude lower than that averaged in the Mat B and C areas, indicating that vacuum conditions also offer the opportunity to significantly reduce emission of these compounds to the atmosphere.

Another important product of this research was measurement of the horizontal influence distance of buried landfill conduits placed under moderate vacuum. During project planning, concerns were expressed that the vacuum would only influence the near vicinity (within 10 or 15 feet) of the buried HYEX™ pipe and would not extend throughout the waste mass. Measurement of gas conditions, temperatures and emissions, as well as actual vacuum pressure measurements, indicate that the horizontal influence is consistently beyond the 55-foot target value and in some cases extended as far as 137 feet away from the buried vacuum conduit. The results seem to suggest that the horizontal permeability within the waste mass is greater than the vertical permeability. The porous construction and demolition debris cover layer probably helped increase the lateral influence; this can be compared with groundwater flow in fractured media where the primary flow is through macropores, which in municipal solid waste can be compared with zones of higher permeability. The fact that vacuum conditions were measured at distances consistent with normally feasible pipe spacing is an important commercial finding, and provides important data for design and operation of future projects.

Interstitial gas conditions in the semi-aerobic zone were clearly influenced by the application of vacuum pressures in the buried landfill conduits. Immediate reduction in methane and increase in oxygen were observed when vacuums were applied. This clearly indicates the induction of atmospheric air into the waste mass. Typically, oxygen would spike initially and then move toward zero as the biota adjusted to consume the oxygen. During periods when the vacuum system was shut down, the gas conditions became typical of anaerobic decay with methane being in the region of 55% and carbon dioxide, around 45% with no oxygen or balance gas (assumed to be principally nitrogen) present. When vacuum conditions influenced these areas, the methane would typically drop to the neighborhood of 10% and the balance gas would rise to 50% or

60%. This indicates that a certain amount of anaerobic methane-bearing landfill gas was being extracted from beneath the HYEX conduits while a significant quantity of air was being pulled from the atmosphere into the waste mass from above the landfill surface. The extraction gas flow rate of up to 300 cubic feet per minute was mixed with about 800 to 900 cubic feet per minute of methane-rich landfill gas from other cells and was combusted without difficulty in the landfill flare.

Waste temperatures in the semi-aerobic zone did not rise into the higher thermophilic ranges typically experienced in forced-air composting, where temperatures of 160 to 180° F. are common. The maximum temperatures measured in the aerated zones of the waste mass were about 143° F. with averages in the 130° to 140° range. While this indicates a lower level of aerobic bioactivity, the positive aspect of this finding is that fears of landfill fire are mitigated by the absence of extremely high temperatures. In fact, it may be preferable for project operators to run projects at these moderate vacuums, keeping temperatures in the lower ranges, thus avoiding the danger of starting a landfill fire. Alternatively, increasing the moisture content to field capacity and increasing the airflow are likely to increase temperatures. Temperatures in the non-aerobic zones averaged around 100° to 110° generally, and temperatures in the aerated areas averaged 125° to 135° in plunge bar probes. It must be noted that the range of temperatures even in the conventional areas was 98° to 133° and so the temperature at a specific location is dependent upon the waste organic content, moisture and biological conditions at that particular location. It is important to examine the general pattern of temperatures in a specific area to interpret the influences of biostabilization practices.

Controlled spray-application of leachate during waste placement is feasible and represents a very inexpensive and efficient method to evenly distribute leachate for the purpose of waste moisture adjustment. During project planning and permitting phases, there were questions over the practicality of leachate spray-application during waste compaction. Fears of odor problems and operational conflicts were expressed at this time. The actual experience at Sullivan County, as witnessed by an onsite monitor of the New York State Department of Environmental Conservation, indicates that odors were never a problem during the carefully executed spray-application, and there were no operational difficulties such as muddy maneuvering areas or vehicle conflicts. Observers reported reductions in windblown litter during spray-application days. There were two complaints from truck drivers on a very windy day concerning drifting mist. The spray pattern was adjusted and there were no further complaints. Evaluation of landfill leachate generation records indicates that the spray-applied leachate did not recirculate through the waste and report back to leachate storage tanks. The added liquid was evidently absorbed and held by the waste.

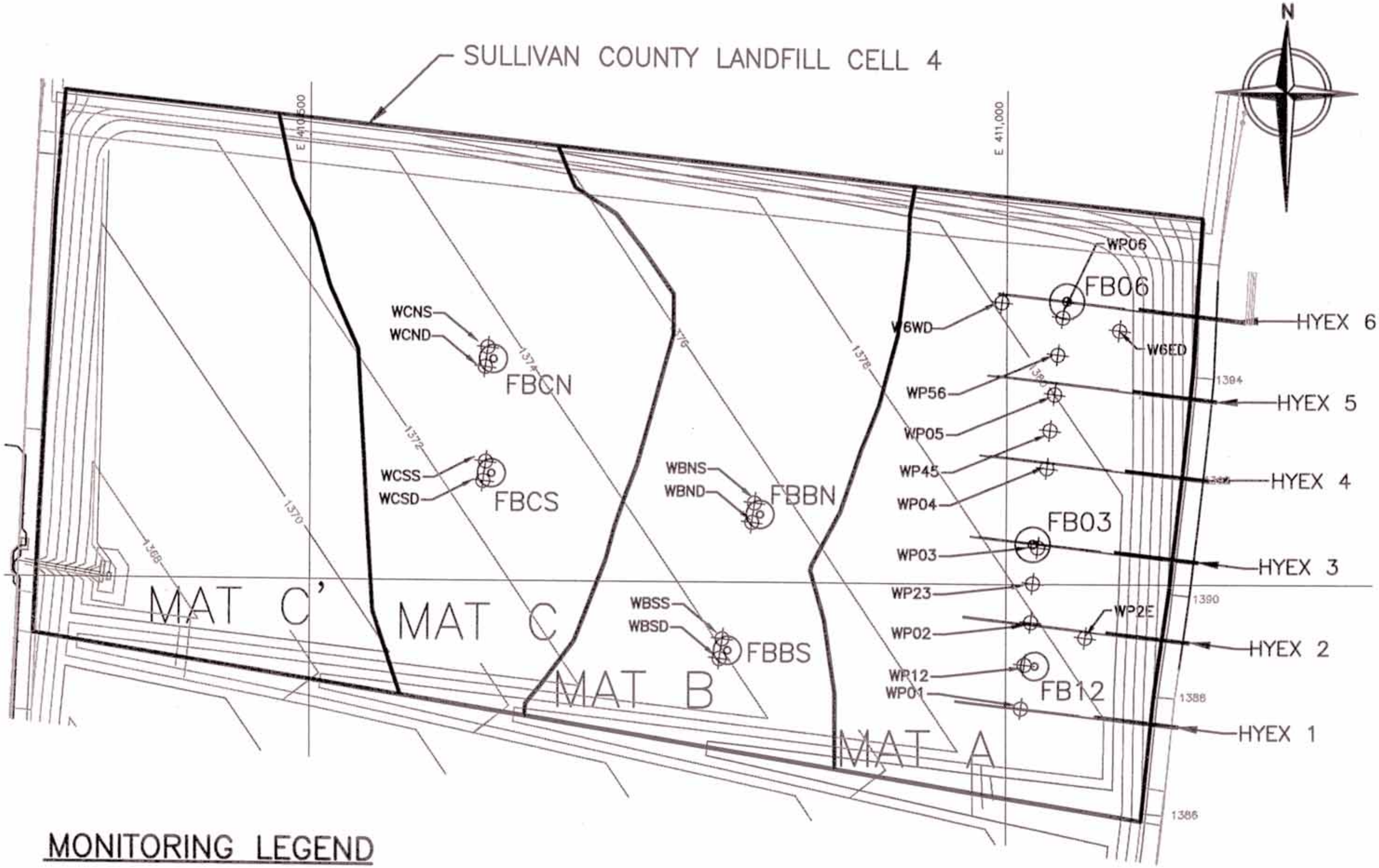
Detailed topographical measurements of landfill volumes indicated that moisture adjustment of the waste resulted in a 4% to 8% increase in initial waste placement density. Density values may be influenced by changes in waste character, addition of more liquid, and variation in compaction practice. In general, it may be concluded that spray-application of leachate has a small positive influence on initial waste placement density. The density of wetted MSW will likely continue to increase at an accelerated pace compared to conventional landfilled waste, as biological decay reduces waste mass and gravity surcharge consolidates the volume.

A significant improvement in effective density of waste was experienced through the use of Posi-Shell®, a cementitious alternate daily cover. Effective density is the mass of waste divided by the volume occupied by the waste and daily cover. This is the key economic landfill airspace utilization factor. Airspace consumption was reduced by about 20% in Mat A as compared with Mat B, which was also wetted but used soil and ash for daily cover. It is clear from these findings that the use of an alternate daily cover material, which does not consume landfill airspace, produces a significant improvement in landfill capacity.

The general recommendation formed from these conclusions is to strongly encourage the placement of horizontal landfill conduits and the use of alternate daily cover as an integral part of landfill biostabilization practice, particularly if significant moisture adjustment will be involved. Early vacuum induction offers the opportunity to create semi-aerobic zones in the active landfill areas, thus accelerating the thermophilic biostabilization process while reducing the potential for odors and atmospheric pollutant emissions. The appropriate spacing for these conduits is consistent with generally accepted practice for methane extraction and so no operating disruption is involved. Very modest vacuums are employed allowing standard landfill flaring systems to accommodate the necessary vacuum allotment and simultaneously support combustion of the induced gases when mixed with an appropriate amount of methane-rich gas from anaerobic sections of the landfill. The key advantages to this practice are density improvement and acceleration of high-rate decomposition, thus increasing the landfill's ultimate waste capacity with simultaneous reduction of atmospheric emissions from the surface of the landfill. Other benefits include beneficial use of landfill leachate and greater potential energy recovery.

APPENDIX 1

GENERAL ARRANGEMENT PLAN



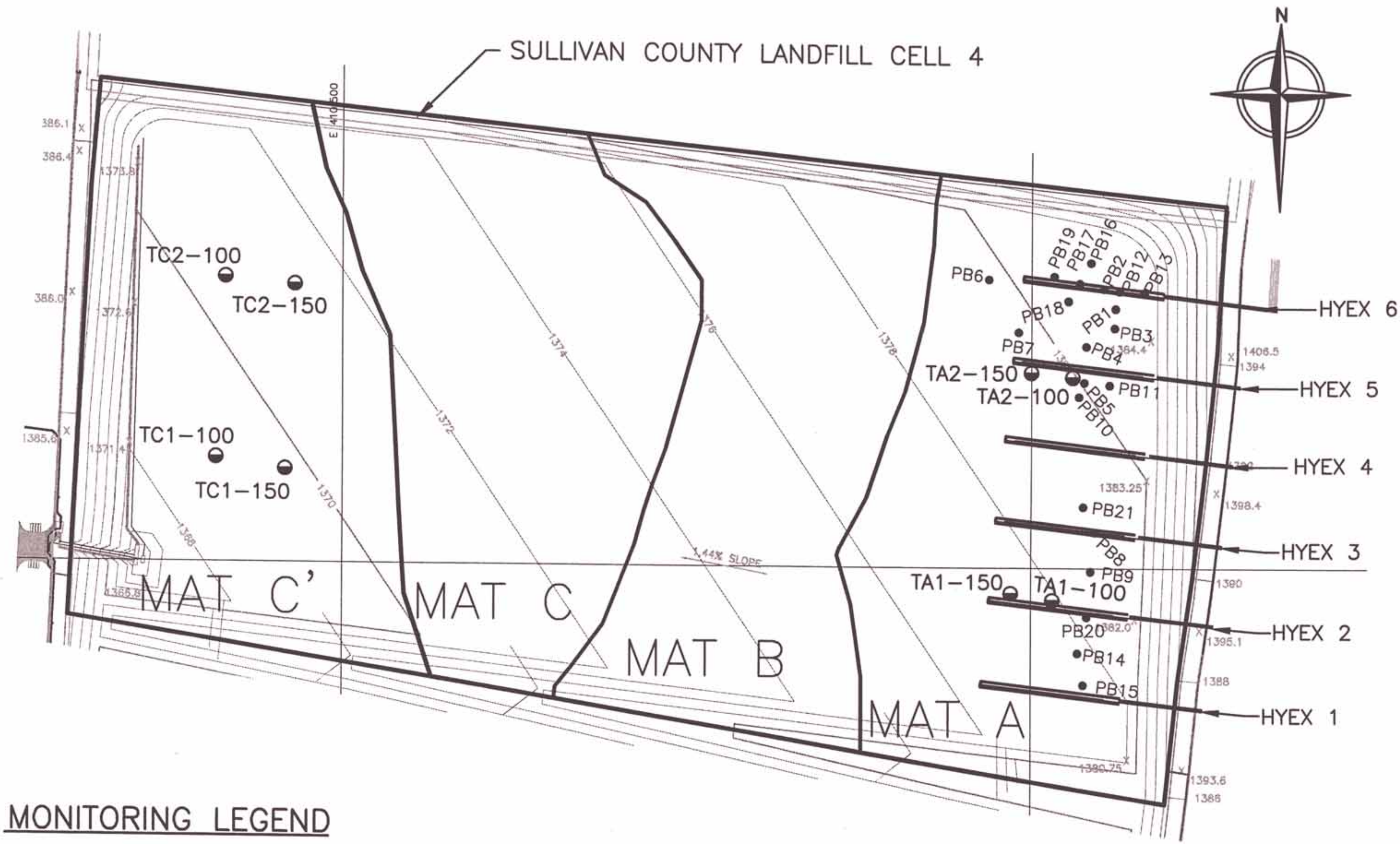
MONITORING LEGEND

⊕ WELL POINT PROBE

⊙ FLUX BOX

NOTE: HYEX CONDUIT NOT SHOWN FOR CLARITY

GENERAL ARRANGEMENT PLAN (1)



MONITORING LEGEND

- PLUNGE BAR PROBE
- LINER THERMOCOUPLE

GENERAL ARRANGEMENT PLAN (2)

APPENDIX 2

FLUX DATA

Sullivan County Biostabilization Research Project ***V/A=33***

Flux Box Data **FB06** *ID=23"* *HT=13"* *VOL=88509 cc*

Date	**8/17**	**8/22**	**9/5**	**9/12**	**A 9/19**	**A 9/19**	**9/21**	**9/25**	**9/27**	**10/5**
Outside Air Temp	86	85	60	53	70	70	73	66	55	73
Air Temp (deg C)	30	29	16	12	21	21	23	19	13	23
Baro	28.5	28.66	28.67	28.79	28.68	26.68	28.59	28.37	28.47	28.53
Precipitation 1 day before	0	0.01	0.34	0.01	0.01	0.01	1.56	0.19	0.01	0
Precipitation 2 day before	0.49	0.03	0	0.11	0.01	0.01	0.01	0.02	1.17	0.01
Ground Temp	*111	*110	*115	*107	*107	*107	*105	**80/77	*100	*100
Start Time	8:55	11:45	8:14	8:32	9:37	2:57	10:37	10:25	10:00	11:06
CH_4 (ppmv from FID) 0 min	200	16	26	16	17	42	54	17	24	21
5 min		19	32	19	147	953	342	163	91	44
10 min	2000	22	33	22	297	1296	490	296	162	56
15 min		22	38	26	453	1397	734	365	210	73
20 min	5600	24	40	29	514	1781	895	468	253	85
25 min		25	42	33	647	2011	1008	558	323	91
30 min	6900	26	46	33	753	2098	1056	609	405	108
SLOPE (ppmv min^{-1})	237.00	0.31	0.61	0.61	24.47	62.63	33.87	19.55	12.13	2.75
r^2	0.97	0.95	0.97	0.98	0.99	0.90	0.96	0.98	0.99	0.98
dc/dt (g cm^{-3} min^{-1})	1.53E-07	1.04E-11	1.51E-10	5.75E-11	1.58E-08	4.23E-08	2.32E-08	1.30E-08	8.04E-09	1.81E-09
V/A (cm^3 cm^{-2})	33	33	33	33	33	33	33	33	33	33
FLUX 30 min (g m^{-2} day^{-1})	72.475	0.005	0.072	0.027	7.497	20.112	11.025	6.160	3.822	0.860

*Temperature at Well Thermocouple

**Compost Thermometer 12"depth/6"depth

1. All FID readings performed with a Foxboro TVA-1000 FID
2. Summa Canisters were obtained from all flux boxes and their respective shallow well points on 9-21-01, and sent to lab.

Date	**8/17**	**8/22**	**9/5**	**9/12**	**9/19**	**9/19**	**9/21**	**9/25**	**9/27**	**10/5**
WPD pressure (in. H_20)	0.05	-0.2	-0.70	-0.35	-0.3	0.1	0	0.04	0.05	-0.7

Sullivan County Biostabilization Research Project *V/A=33*

Flux Box Data **FB03** *ID=23"* *HT=13"* *VOL=88509 cc*

Date	**8/17**	**8/22**	**9/5**	**9/12**	**A 9/19**	**B 9/19**	**9/21**	**9/25**	**A 9/27**	**B 9/27**	**C 9/27**	**D 9/27**	**10/5**
Outside Air Temp	86	85	60	53	70	70	73	66	55	59	59	60	73
Air Temp (deg C)	30	29	16	12	21	21	23	19	13	15	15	16	23
Baro	28.5	26.66	28.67	28.79	28.68	26.68	28.59	28.37	28.47	28.43	28.43	28.44	28.53
Precipitation 1 day before	0	0.01	0.34	0.01	0.01	0.01	1.56	0.19	0.01	0.01	0.01	0.01	0
Precipitation 2 day before	0.49	0.03	0	0.11	0.01	0.01	0.01	0.02	1.17	1.17	1.17	1.17	0.01
Ground Temp	*107	*107	*109	*105	*107	*107	*108	**82/72	*105	*105	*105	*105	*106
Start Time	9:03	11:44	8:12	8:35	9:37	3:00	11:16	10:29	10:03	2:30	3:00	3:38	11:09
CH_4 (ppmv from FID) 0 min	60	17	65	13	12	10	10	5	15	29	191	11	170
5 min		46	146	14	12	15	11	7	142	96	204	21	897
10 min	4250	80	202	16	14	19	11	9	255	135	210	32	1360
15 min		106	216	17	16	21	11	9	323	152	218	39	1619
20 min	7600	132	237	18	18	22	12	11	441	173	232	47	1952
25 min		145	249	20	20	25	12	12	543	182	240	56	2268
30 min	9900	170	268	20	23	25	12	14	662	191	250	60	2458
SLOPE (ppmv min^{-1})	328.70	5.06	6.07	0.26	0.36	0.47	0.06	0.27	20.91	4.97	1.94	1.67	72.84
r^2	0.98	0.99	0.87	0.98	0.96	0.92	0.95	0.98	1.00	0.87	0.87	0.99	0.96
dc/dt (g cm^{-3} min^{-1})	1.58E-07	3.26E-09	3.92E-09	1.74E-10	2.46E-10	3.12E-10	3.74E-11	1.80E-10	8.00E-09	3.32E-09	1.32E-09	1.13E-09	4.87E-08
V/A (cm^3 cm^{-2})	33	33	33	33	33	33	33	33	33	33	33	33	33
FLUX 30 min (g m^{-2} day^{-1})	75.201	1.547	1.861	0.083	0.117	0.148	0.018	0.086	3.800	1.579	0.628	0.538	23.160

Date	**8/17**	**8/22**	**9/5**	**9/12**	**9/19**	**9/19**	**9/21**	**9/25**	**9/27**	**9/27**	**9/27**	**9/27**	**10/5**
WPD pressure (in. H_20)	0.03	0.03	0.02	-0.04	-0.03	-0.03	-0.2	-0.1	-0.06	-0.06	-0.06	-0.06	0.02

Sullivan County Biostabilization Research Project						V/A=38
Flux Box Data	FB1-2		*ID=23"*	*HT=15*	*VOL=102126cc*	
Date	**A 9/19**	**B 9/19**	**9/21**	**9/25**	**9/27**	**10/5**
Outside Air Temp	70	70	73	66	49	71
Air Temp (deg C)	21	21	23	19	9	22
Baro	28.68	26.68	28.58	28.36	28.45	28.52
Precipitation 1 day before	0.01	0.01	1.56	0.19	0.01	0
Precipitation 2 day before	0.01	0.01	0.01	0.02	1.17	0.01
Ground Temp	*116	*116	*106	*113	*100	*102
Start Time	9:40	3:02	11:59	10:37	10:40	11:30
CH_4 (ppmv from FID) 0 min	62	140	11	3	19	586
5 min	436	588	19	12	40	4791
10 min	675	636	22	16	58	8636
15 min	950	691	26	22	73	12700
20 min	1195	663	28	28	84	16500
25 min	1528	646	30	36	93	20900
30 min	1916	614	32	45	99	24600
SLOPE (ppmv min^{-1})	59.04	11.18	0.65	1.32	2.65	800.89
r^2	0.99	0.40	0.94	0.99	0.96	1.00
dc/dt (g cm^{-3} min^{-1})	3.91E-08	7.41E-09	4.26E-10	8.83E-10	1.83E-09	5.30E-07
V/A (cm^3 cm^{-2})	38	38	38	38	38	38
FLUX 30 min (g m^{-2} day^{-1})	21.419	4.055	0.233	0.483	1.003	289.995

Date	**9/19**	**9/19**	**9/21**	**9/25**	**9/27**	**10/5**
WPD pressure (in. H_20)	0	0	-0.02	-0.06	-0.035	0

Sullivan County Biostabilization Research Project					**V/A=41**
Flux Box Data	**FBBN**	*ID=23"*	*HT=16*	*VOL=108935cc*	
Date	**9/19**	**9/21**	**9/25**	**9/27**	**10/5**
Outside Air Temp	70	73	69	61	79
Air Temp (deg C)	21	23	21	16	26
Baro	28.68	28.57	28.37	28.44	28.445
Precipitation 1 day before	0.01	1.56	0.19	0.01	0
Precipitation 2 day before	0.01	0.01	0.02	1.17	0.01
Ground Temp	**92/78	**89	**83/76	**80	**84
Start Time	10:21	1:00	11:21	11:30	14:37
CH_4 (ppmv from FID) 0 min	152	60	11	15	117
5 min	1003	359	21	56	2092
10 min	1867	667	25	154	3382
15 min	2365	1007	47	205	6669
20 min	2782	1257	56	206	9047
25 min	3306	1814	67	220	11100
30 min	3843	2572	104	325	14300
SLOPE (ppmv min^{-1})	118.53	78.83	2.89	9.36	473.07
r^2	0.98	0.96	0.94	0.92	0.99
dc/dt (g cm^{-3} min^{-1})	7.86E-08	5.20E-08	1.92E-09	6.31E-09	3.08E-07
V/A (cm^3 cm^{-2})	41	41	41	41	41
FLUX 30 min (g m^{-2} day^{-1})	46.394	30.683	1.133	3.726	182.073

Date	**9/19**	**9/21**	**9/25**	**9/27**	**10/5**
WPD pressure (in. H_20)	0.03	0	0.015	0.05	0.05

Sullivan County Biostabilization Research Project					V/A=43
Flux Box Data	**FBBS**	*ID=23"*	*HT=17*	*VOL=115744cc*	
Date	**9/19**	**9/21**	**9/25**	**9/27**	**10/5**
Outside Air Temp	70	73	69	61	65
Air Temp (deg C)	21	23	21	16	18
Baro	28.68	28.56	28.37	28.44	28.55
Precipitation 1 day before	0.01	1.56	0.19	0.01	0
Precipitation 2 day before	0.01	0.01	0.02	1.17	0.01
Ground Temp	-	**94	**84/79	**90	**89
Start Time	10:30	1:45	11:18	11:21	12:36
CH_4 (ppmv from FID) 0 min	123	175	88	183	327
5 min	385	342	450	526	1936
10 min	594	615	801	708	3474
15 min	783	1073	1117	897	4829
20 min	1062	1404	1764	1170	4880
25 min	1263	1650	2111	1452	5819
30 min	1645	1986	3002	2090	6317
SLOPE (ppmv min^{-1})	48.50	63.13	93.06	57.39	193.87
r^2	0.99	0.99	0.97	0.96	0.93
dc/dt (g cm^{-3} min^{-1})	3.22E-08	4.16E-08	6.18E-08	3.87E-08	1.30E-07
V/A (cm^3 cm^{-2})	43	43	43	43	43
FLUX 30 min (g m^{-2} day^{-1})	19.910	25.769	38.273	23.968	80.345

Date	**19-Sep**	**21-Sep**	**25-Sep**	**27-Sep**	**5-Oct**
WPD pressure (in. H_20)		0.02	0.045	0.02	0.015

Sullivan County Biostabilization Research Project					V/A=42
Flux Box Data	**FBCN**	*ID=23"*	*HT=16.5"*	*VOL=112340cc*	
Date	**9/19**	**9/21**	**9/25**	**9/27**	**10/5**
Outside Air Temp	70	73	72	58	55
Air Temp (deg C)	21	23	22	14	13
Baro	28.68	28.55	28.37	28.44	28.56
Precipitation 1 day before	0.01	1.56	0.19	0.01	0
Precipitation 2 day before	0.01	0.01	0.02	1.17	0.01
Ground Temp	**130/126	**127/134	**118/100	**120/110	**105/103
Start Time	11:26	3:26	12:18	1:54	13:48
CH_4 (ppmv from FID) 0 min	35	42	13	19	54
5 min	96	237	40	102	153
10 min	163	354	100	141	245
15 min	198	591	120	200	318
20 min	231	628	178	250	388
25 min	261	708	203	308	474
30 min	300	781	254	363	580
SLOPE (ppmv min^{-1})	8.52	24.51	8.04	11.10	16.88
r^2	0.97	0.95	0.99	1.00	1.00
dc/dt (g cm^{-3} min^{-1})	5.65E-09	1.62E-08	5.31E-09	7.53E-09	1.15E-08
V/A (cm^3 cm^{-2})	42	42	42	42	42
FLUX 30 min (g m^{-2} day^{-1})	3.416	9.773	3.212	4.555	6.964

Date	**19-Sep**	**21-Sep**	**25-Sep**	**27-Sep**	**5-Oct**
WPD pressure (in. H_20)	0.02	0.02	0.02	0.05	0.06

Sullivan County Biostabilization Research Project					V/A=41
Flux Box Data	**FBCS**	*ID=23"*	*HT=16*	*VOL=108935cc*	
Date	**9/19**	**9/21**	**9/25**	**9/27**	**10/5**
Outside Air Temp	70	73	72	59	55
Air Temp (deg C)	21	23	22	15	13
Baro	28.68	28.55	28.37	28.44	28.55
Precipitation 1 day before	0.01	1.56	0.19	0.01	0
Precipitation 2 day before	0.01	0.01	0.02	1.17	0.01
Ground Temp	**105/96	**102	**86/84	**96	**88
Start Time	11:15	2:43	12:10	1:40	13:29
CH_4 (ppmv from FID) 0 min	34	31	24	22	84
5 min	66	50	37	76	132
10 min	95	57	123	110	156
15 min	127	62	187	268	163
20 min	148	74	309	306	159
25 min	173	81	400	370	164
30 min	195	82	442	448	161
SLOPE (ppmv min^{-1})	5.36	1.65	15.48	14.72	2.14
r^2	0.99	0.95	0.97	0.98	0.62
dc/dt (g cm^{-3} min^{-1})	3.56E-09	1.09E-09	1.02E-08	9.97E-09	1.46E-09
V/A (cm^3 cm^{-2})	41	41	41	41	41
FLUX 30 min (g m^{-2} day^{-1})	2.099	0.643	6.037	5.885	0.861

Date	19-Sep	21-Sep	25-Sep	27-Sep	5-Oct
WPD pressure (in. H_20)	0.005	0.02	0.01	0.05	0.05

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SULLIVAN COUNTY LANDFILL MONTICELLO, NEW YORK;

LANDFILL BIOSTABILIZATION STUDY

FINAL REPORT 03-03

STATE OF NEW YORK
GEORGE E. PATAKI, GOVERNOR

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY
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