APPENDIX E

COLLECTION SYSTEM DESIGN PLANS

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All owners and operators of affected landfills are required to submit to the Administrator a collection and control system design plan prepared by a professional engineer. This appendix provides a summary of the design plan requirements for all collection systems: active collection systems that meet the requirements of §60.759 as well as alternate collection systems. It also provides guidance on what to look for in such plans and case study examples.

Design Plan Requirements

Under §60.752(b)(2), landfill owners/operators subject to control requirements (i.e., those with a calculated NMOC emission rate $\geq$50 Mg/yr) are given the option to:

(a) submit a collection and control system plan conforming to the specifications provided in §60.759, or

(b) submit a collection and control plan for an alternative design.

The design plan provisions of the rule were intended to provide flexibility and allow innovation. It is clear that some landfill owners/operators will choose to submit a plan for a collection system that does not conform to the specifications in §60.759. Because of the many site-specific factors involved with landfill gas collection system design, alternative systems may be more appropriate for a given landfill. A wide variety of system designs are possible, such as vertical wells, combination horizontal and vertical collection systems, horizontal trenches, and passive systems. All plans will need to be reviewed by the implementing agency on a case-by-case basis to ensure that they meet the requirements of §60.752(b)(2)(ii).

For active collection systems, the plan must demonstrate that the collection system will:

(1) be designed to handle, over the intended use period of the gas control or treatment system equipment, the maximum expected gas flow rate from the entire landfill area that warrants control;

(2) collect gas from each area, cell, or group of cells in the landfill in which the initial solid waste has been placed for a period of 5 years or more if active or 2 years or more if closed or at final grade;

(3) collect gas at a sufficient extraction rate (a rate sufficient to maintain a negative pressure at all well heads in the collection system without causing air infiltration, including any well heads connected to the system as a result of expansion or excess surface emissions, for the life of the blower); and

(4) be designed to minimize off-site migration of subsurface gas.

For passive collection systems, the plan must demonstrate that the collection system will:

(1) be designed to handle, over the intended use period of the gas control or treatment system equipment, the maximum expected gas flow rate from the entire landfill area that warrants control;

(2) collect gas from each area, cell, or group of cells in the landfill in which the initial solid waste has been placed for a period of 5 years or more if active or 2 years or more if closed or at final grade;

(3) be designed to minimize off-site migration of subsurface gas; and

(4) include landfill liners on the bottom and all sides in all areas in which gas is to be collected. The liners must be installed as required by the RCRA solid waste rules under 40 CFR 258.40.

Specifications for Active Collection Systems

Owners or operators seeking to comply with the specifications for active collection systems in §60.759 must meet the following:

(1) Demonstrate that the siting of active collection wells, horizontal collectors, surface collectors, or other extraction devices is of sufficient density throughout all gas producing areas.

(2) Devices located within the interior and along the perimeter must be certified by a professional engineer to achieve uniform control of surface gas emissions.

(3) Design plans must address the 13 issues listed in Table E-1.

(4) Collection system siting should be of sufficient density to address landfill gas migration issues, and augmentation of the system through the use of active or passive systems at the perimeter or exterior.

(5) The system should control all gas producing areas except those that are excluded because either (1) they are segregated and shown to contain asbestos or nondegradable material, (documentation must include nature, location, amount of asbestos or nondegradeable material deposited, and date of deposition) or (2) they are nonproductive areas and can be shown to contribute less than 1 percent of the total amount of NMOC emissions from the landfill (amount, location, and age of the material must be documented).

(6) To qualify for exclusion based on nonproductivity, emissions must be calculated for each section proposed for exclusion, and the sum of all such sections must be compared with the NMOC emission estimate for the entire landfill. Emissions from each section must be calculated according to the following equation, from §60.759(a)(3)(ii) of the NSPS:

$$Q_i = 2\ k\ L_o\ M_i\ (e^{-kt_i})\ (C_{NMOC})\ (3.6 \times 10^{-9})$$

where,

Q_i	=	NMOC emission rate from the i^{th} section, Mg/yr
k	=	methane generation rate constant, $year^{-1}$
L_o	=	methane generation potential, m^3/Mg solid waste
M_i	=	mass of the degradable solid waste in the i^{th} section, Mg
t_i	=	age of the solid waste in the i^{th} section, years
C_{NMOC}	=	concentration of NMOCs, ppmv
3.6×10^{-9}	=	conversion factor

The values for k and C_{NMOC} determined in field testing must be used, if field testing has been performed in determining the NMOC emission rate or the radii of influence. The radii of influence is the distance from the well center to a point in the landfill where the pressure gradient applied by the blower or compressor approaches zero. If field testing has not been performed, default values for k, L_o and C_{NMOC} of 0.05/year (0.02/year in arid areas), 170 m^3/Mg, and 4,000 ppmv, respectively, must be used as provided for Tier 1 calculations from § 60.754(a)(1). For landfills located in

TABLE E-1. LIST OF DESIGN PLAN REQUIREMENTS

	Issue Description
1.	Depth(s) of refuse
2.	Refuse gas generation rates and flow characteristics
3.	Cover properties
4.	Gas system expandability
5.	Leachate and condensate management
6.	Accessibility
7.	Compatibility with filling operations
8.	Integration with closure end use
9.	Air intrusion control
10.	Corrosion resistance
11.	Fill settlement
12.	Resistance to the refuse decomposition heat
13.	Topographical map of the surface area and proposed surface monitoring route [required in § 60.753(d)]

geographical areas with a 30-year annual average precipitation of less than 25 inches, as measured at the nearest representative official meteorological site, a k value of 0.02 per year should be used as provided in the Tier 1 calculations in §60.754(a)(1). Note: The mass of nondegradable solid waste contained within the given section may be subtracted from the total mass of the section when estimating emissions provided the nature, location, age, and amount of the nondegradable material is documented as indicated in paragraph (5) above.

(7) The gas extraction components must be constructed of polyvinyl chloride (PVC), high density polyethylene (HDPE) pipe, fiberglass, stainless steel, or other nonporous corrosion-resistant material.

(8) The extraction components must be of suitable dimensions to: convey projected amounts of gases; withstand installation, static, and settlement forces; and withstand planned overburden or traffic loads.

(9) The collection system must be capable of any expansion needed to comply with emission and migration standards.

(10) Collection devices such as wells and horizontal collectors must be perforated to allow gas entry without head loss sufficient to impair performance across the intended extent of control. Perforations must be situated to prevent excessive air infiltration.

(11) Vertical wells cannot endanger underlying liners and must address the occurrence of water within the landfill.

(12) Holes and trenches must be of sufficient cross-section for proper construction and completion. For example: the design should call for the centering of pipes and allow for the placement of gravel backfill.

(13) Collection devices must be constructed of PVC, HDPE pipe, fiberglass, stainless steel, or other nonporous corrosion-resistant material and must not allow for air intrusion into the cover, refuse into the collection system, or landfill gas into the atmosphere.

(14) Any gravel used around the pipe perforations should be large enough to prevent penetration or blockage of the perforations.

(15) The connections for collection devices may be above or below ground, but must include: a positive closing throttle valve, necessary seals and couplings, access couplings, and at least one sampling port.

(16) The system must convey the landfill gas to a control system through the collection header pipe(s). The gas mover equipment must be of a size capable of handing the maximum gas generation flow rate expected over the intended use period of the equipment.

(17) For existing systems the maximum flow rate must be determined by existing flow data, or by using the following equation. New systems must also use the equation.

Two equations are provided for determining the maximum flow rate: one equation for sites with an unknown year-to-year solid waste acceptance rate, and one equation for sites with a known year-to-year solid waste acceptance rate. A combination of the equations can be used if the acceptance rate is known for only part of the life of the landfill.

For sites with unknown year-to-year solid waste acceptance rate:

$$Q_m = 2L_o R (e^{-kc} - e^{-kt})$$

where,

Q_m	=	maximum expected gas generation flow rate, m^3/yr
L_o	=	methane generation potential, m^3/Mg solid waste
R	=	average annual acceptance rate, Mg/yr
k	=	methane generation rate constant, $year^{-1}$
t	=	age of the landfill at equipment installation plus the time the owner or operator intends to use the gas mover equipment or active life of the landfill, whichever is less. If the equipment is installed after closure, t is the age of the landfill at installation, years
c	=	time since closure, years (for an active landfill c = O and $e^{-kc} = 1$)

For sites with known year-to-year solid waste acceptance rate:

$$Q_M = \sum_{i=1}^{n} 2 k L_o M_i (e^{-kt_i})$$

where,

Q_M	=	maximum expected gas generation flow rate, m^3/yr
k	=	methane generation rate constant, $year^{-1}$
L_o	=	methane generation potential, m^3/Mg solid waste
M_i	=	mass of solid waste in the i^{th} section, Mg
t_i	=	age of the i^{th} section, years

Review of Plans

In reviewing design plans for active collection systems designed to meet §60.759, it is important to ensure that adherence to each of the requirements in the section entitled "Specifications for Active Collection Systems" is adequately demonstrated. In reviewing alternate plans (for active or passive systems), it is important to ensure that the requirements listed in the "Design Plan Requirements" section are followed. It is also important to recognize that the rule includes operational standards along with monitoring and reporting requirements to ensure that landfill gas is extracted from the landfill at a sufficient rate. Section 60.753 requires operation of collection systems so that the methane concentration is less than 500 ppmv at all points around the perimeter of the collection area and along a pattern that traverses the landfill at 30-meter intervals. The design plan must include a topographical map with the proposed monitoring route. This operational standard ensures that LFG is extracted at a sufficient rate and off-site migration is minimized. Any undetected flaws in the plan will most likely have to be corrected after the system is operating to meet the operational standards.

At the same time, sufficient discretion needs to be exercised to avoid the installation of inadequate collection systems. Failure to recognize an inadequate collection system design could lead to excessive periods of noncompliance or required replacement of the collection system. Such an occurrence would be detrimental to the environment and create an unnecessary financial burden on the landfill owner or operator.

For this reason, an appropriate burden must be placed on the landfill owner/operator to demonstrate that the operational standards will be achievable with the proposed design. Such demonstrations should be supported by performance data at that landfill or a similar landfill when practical. At a minimum, the landfill owner/operator should be required to provide a written rational and appropriate engineering calculations for the design of systems which do not adhere to the requirements in §60.759.

Possible Design for an Active Vertical Collection System (AVCS)

This section presents the design for an AVCS that the EPA believes would satisfy all the requirements in §60.759. It should be noted that final approval of such a design plan is left to a State's discretion, and adherence to the specifications presented do not guarantee design plan approval by a State. Furthermore, other designs may satisfy the criteria in §60.759.

Well Siting: Site active vertical collection wells such that the radius of influence (ROI) from a collection well includes all gas-producing areas of the landfill that contain solid waste. The ROI is the radial distance that a well can effectively extract LFG through compacted refuse without causing air infiltration. A well extracts LFG from compacted refuse by creating a negative pressure drop in the surrounding refuse. The negative pressure drop is produced by maintaining a negative gauge pressure within a well using blowers or air compressors. The pressure drop at a location in the landfill decreases as the distance from the collection well increases. The ROI for a collection well is defined as the shortest distance radially out from a collection well to where the pressure drop gradient applied by the blower or compressor approaches zero.

The interior ROI and perimeter ROI used to determine well placement will be determined using one of the following:

- Use a single ROI of 30 meters for siting both perimeter and interior wells; or
- Establish a site-specific ROI by following the procedure in EPA Method 2E. (Method 2E data may already be available if LFG flow rate was tested to perform Tier 3 NMOC emission rate calculations.)

The ROI will be used to site wells along the perimeter of all gas-producing areas of the landfill, at a maximum of one ROI from the perimeter boundary. After siting the perimeter wells, the interior wells will be sited. Both perimeter and interior wells will be spaced no more than two times the ROI apart. (Well spacing greater than this value will create gaps between the ROI of adjacent wells. The wells would be unable to collect LFG from these gaps.) Wells will be staggered such that all gas-producing areas of the landfill containing solid waste that has been in the landfill for at least 5 years (for active sites) or 2 years (for sites at closure or final grade) are covered by the ROI.

Wells do not need to be placed in segmented areas documented as containing (1) asbestos or nondegradeable material or (2) older, nonproductive areas (provided that they contribute less than 1 percent of the total NMOC emissions). The documentation will provide the nature, location, amount of asbestos or nondegradable material deposited in the area, and date of deposition. This documentation will be provided to the Administrator upon request. The amount, location, and age of the material in nonproductive areas will also be documented and provided to the Administrator upon request. A separate NMOC emission estimate will be made for each section proposed for exclusion, and the sum of all such sections compared to the NMOC emission estimate for the entire landfill. Emissions from each section will be computed using the equation presented in item (6) under "Specifications for Active Collection Systems" in this appendix. [This equation is from §60.759(a)(3)(2) of the rule.]

Well pipe construction: Table E-2 summarizes example well pipe construction. The landfill gas extraction well will be constructed of either: PVC, HDPE pipe, fiberglass, stainless steel, or other noncorrosive, nonporous material. Pipe material should be non-corrosive to minimize maintenance and failures, thereby maximizing the overall effectiveness of the gas collection system. Materials such as black-iron or galvanized pipe are not recommended because the collection system must remain operational for at least 15 years. These materials would most likely corrode within that period and sacrifice the effectiveness of the gas collection system. Pipe material should also be non-porous so LFG is collected without air infiltration. Porous well pipes could allow ambient air to be drawn from the landfill surface into the upper section of the pipe.

The well will be at least 0.075 meters in diameter and of suitable wall-thickness. The length of the pipe will be at least 75 percent of the depth of the solid waste or the depth to the water table, whichever is less. Installing a well pipe equal to 75 percent of the refuse depth prevents collection wells from being extended through landfill liners. Collection wells are

TABLE E-2. EXAMPLE WELL PIPE SPECIFICATIONS

Parameter	Specification
Material of construction	Schedule 40 or 80 PVC, HDPE, fiberglass, or stainless steel pipe.
Diameter of pipe	At least 0.075 m (3 in.).
Length of pipe	Pipe length will be 75 percent of the refuse depth or the distance from the landfill surface to the top of the water table, whichever is less.
Perforations along pipe length	Perforations will have a diameter of 0.012 m (1/2 in.). Four perforations will be located in a horizontal row around the pipe at intervals of 90°. Well pipes will have perforations along the lower two-thirds of the well pipe. The top 20 feet of a well pipe will not be perforated. The horizontal spacing between each row of holes will be 0.1 to 0.2 m (4 to 8 in.) apart.
Placement of pipe in well hole	The center line (longitudinal axis) of the well pipe will be located on the center line of the well hole.

extended only to the top of a water table because pipe extensions below the water level would be unable to collect LFG.

Perforations or holes are drilled into the well pipe at designated locations. The perforations allow LFG to be drawn into the pipe over a range of landfill depths. Four perforations with a diameter of 0.012 m (0.5 in.) will be located in a horizontal row around the pipe at intervals of 90º. The horizontal spacing between each row of holes will be 0.1 to 0.2 m (4 to 8 in.). Each well pipe will include perforations along the lower two-thirds of the pipe. However, no perforations must be present in the top 20 feet of a well pipe. In addition, the centerline of the pipe will be located on the centerline of the well hole in order to maintain an equal pressure drop throughout the cross sectional area of the well.

Well hole specifications: Table E-3 summarizes example will hole specifications. A well drilling rig will be used to dig a hole at least 0.60 meters in diameter in the landfill to a depth of at least 75 percent of the landfill depth or the depth to the water table. (This corresponds to the depth of the wells.)

The extraction well will be placed in the center of the hole and the hole will be backfilled with materials selected to accomplish two objectives:

(1) Allow unrestricted passage of LFG from the landfill through the perforations in a well pipe; and

(2) Create a sealed barrier near the top of the collection well to prevent air infiltration into the well.

Gravel with a diameter range of 2 to 7.5 cm (1 to 3 in) is used to fill the bottom of the well hole where well pipe perforations exist as shown in Figure E-1. Gravel is added to the well hole to a level 0.3 m (1 ft) above the uppermost perforation on the well pipe. This gravel layer acts as a filter to prevent refuse from clogging well pipe perforations. On top of the gravel are three more layers of material. First a layer of backfill consisting of at least 1.2 m (47 in.) is placed over the gravel. Next is a layer of bentonite clay with a depth of at least 1.0 m (39 in.). Bentonite clay acts as a seal or cap for the well hole to prevent air infiltration. Finally, a layer of

TABLE E-3. EXAMPLE WELL HOLE SPECIFICATIONS

Parameter	Specification
Diameter of well hole	At least 0.6 m (2 ft) in diameter.
Depth of well hole	A depth equal to 75 percent of the refuse depth or the distance from the landfill surface to the top of the water table, whichever is less. (Same as depth of well pipe.)
Fill material: Surrounding pipe perforations	Fill with gravel sized 2 to 7.5 cm (1 to 3 in) in diameter to a level of 0.3 m (1 ft) above the uppermost perforation.
Fill material: Above pipe perforations	Sequence of adding fill material over the crushed stone: (1) At least 1.2 m (47 in.) of backfill, (2) At least 1.0 m (39 in.) of bentonite, and (3) For the remainder, cover material or material of permeability equal to the existing cover material.

cover material or other material of equal permeability to the cover material can be used to fill the remaining space.

Well head fittings: The wellhead may be connected to the collection header pipes below or above the landfill surface. The wellhead assembly will include a ball or butterfly valve, flanges, gaskets, connectors, access couplings and at least one sampling port. The cap and header pipe will be constructed of PVC, HDPE, fiberglass, stainless steel, or other nonporous material of suitable wall thickness. A schematic of the gas extraction well and wellhead assembly is also illustrated in Figure E-1.

Conveyance system: The gas conveyance system transports LFG from the collection wells to the gas control system. The conveyance system must consist of gas movers and piping for the gas collection header. Gas movers can be either a fan, blower, or compressor. Piping for conveying collected LFG may run above or below the landfill surface. The gas mover equipment will be sized to handle the maximum gas generation flow rate expected over the intended use period of the gas moving equipment based on flow data (if existing) or the following equation:

$$\text{Peak Flow } [m^3/yr] = 2L_o\, R\, (e^{-k}c - e^{-kt})$$

where,

L_o = methane generation potential, m^3/Mg solid waste

R = average annual acceptance rate, Mg/yr

k = methane generation rate constant, year^{-1}

t = age of the landfill at equipment installation plus the time the owner or operator intends to use the gas mover equipment or expected active life of the landfill, whichever is less. If the equipment is installed after closure, t is the age of the landfills at installation, yrs c = time since closure, yrs (for active landfill c = O and $e^{-kc} = 1$)

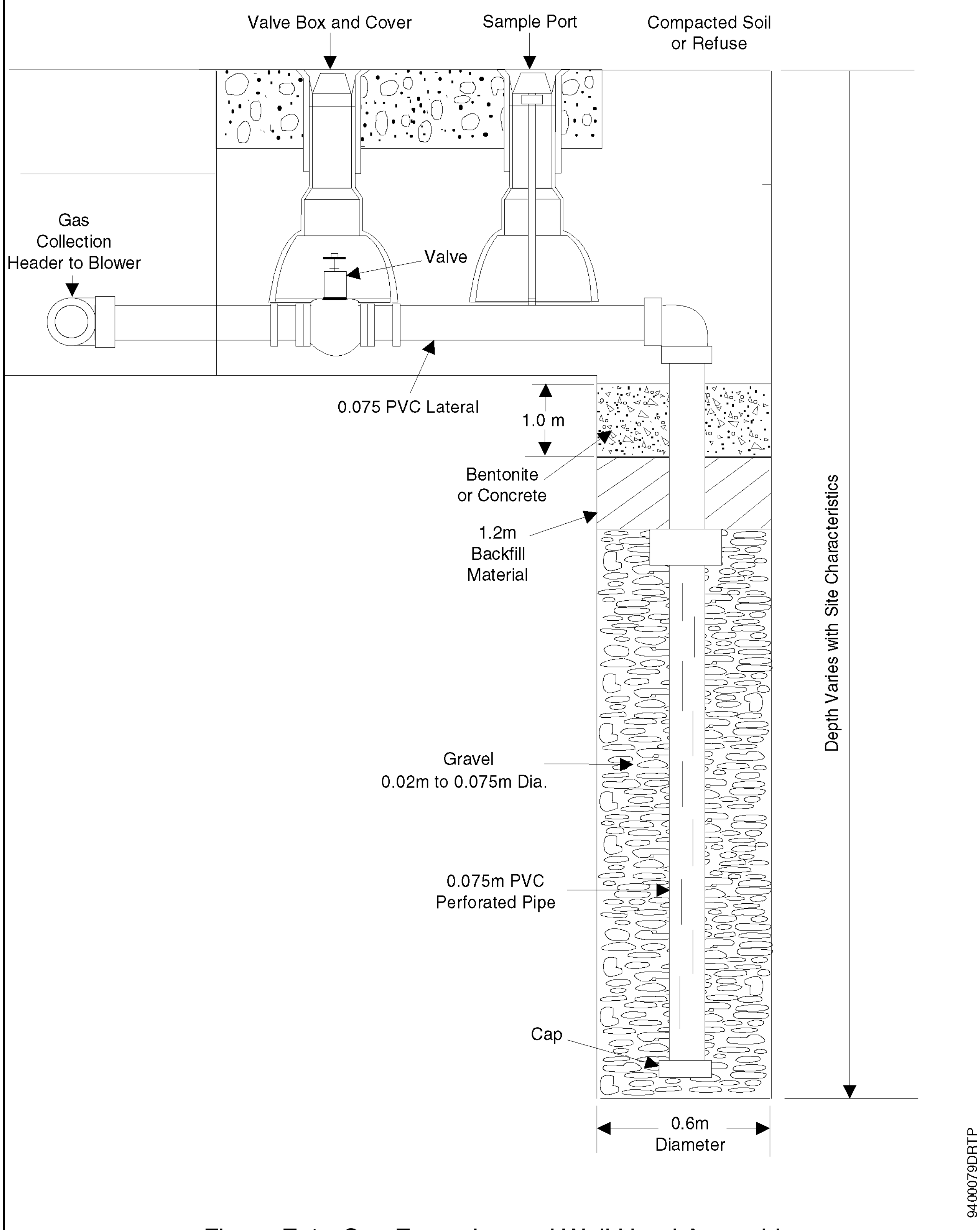

Figure E-1. Gas Extraction and Well Head Assembly

An average value will be used for L_o. If k has been determined, the value of k determined from the test will be used; if k has not been determined, an average value will be used. The average values specified in Compilation of Air Pollutant Emission Factors (AP-42) (currently 125 m^3/Mg for L_o and 0.04 $year^{-1}$ for k) may be used.

Case Studies

While the EPA believes that the AVCS presented above would qualify for approval, it does not represent the range of approvable systems. The EPA anticipates that variations on some of the design specifications would also be approvable. This section of the appendix illustrates some of those variations in the form of case studies.

Based on case studies provided by the Solid Waste Association of North America (SWANA), three types of collection designs other than that presented for an AVCS can be anticipated. These include:

(1) alternative vertical well specifications and/or construction;
(2) horizontal collection systems; and
(3) combinations of vertical and horizontal collectors.

Case studies illustrating each of these are provided in this section. Alternative specifications and/or construction for vertical well collection systems are presented in Case Studies A through E. Case Study F presents an alternative to the nitrogen monitoring procedures for determining air infiltration presented in Method 2E. Case Studies G and H present alternatives to standard vertical collection systems. All of these case studies were provided by SWANA. The purpose of these case studies is to illustrate the kind of demonstrations that should be provided by owners or operators submitting collection plans. Additionally, these demonstrations might be used in combination with other supporting information to demonstrate the adequacy of these designs for other landfills. The case studies provided in this appendix are as follows:

A. Gas wells with depths less than 75 percent of refuse depth.

B. Perforations for wells less than 90 feet deep

C. Alternate gas well perforations

D. Pile-driven vertical gas well installation

E. Compacted low permeability

F. Monitoring vacuum levels as an indicator of air infiltration in arid regions

G. Horizontal collector design

H. Design for LF with horizontal collectors and vertical wells

As included in most of these case studies, a key to demonstrating effectiveness of system designs is showing it can meet the operational standards (i.e., methane concentration less than 500 ppmv around the perimeter of the collection area and along a pattern that traverses the landfill at 30-meter intervals).

In some cases, the design already exists at that particular landfill and actual data on performance of the design can be provided. In other cases, it may be necessary to demonstrate the effectiveness of a design based on data collected at another landfill (such as the case studies included in this appendix). In these cases, it is important for the owner/operator to demonstrate similarities between the landfill where supporting data were collected and the landfill where the design is being proposed.

Case Study A: Gas Wells With Depths Less Than 75 Percent of Refuse Depth

AVCS Specification: The pipe the lesser of 75 percent of the depth of refuse or the depth to the water table in length.

Alternative Design: Gas wells with depths less than 75 percent of refuse depth

Location: Palos Verdes Landfill, City of Rolling Hills Estates, CA.
Operated by Los Angeles County Sanitation Districts (Districts)

The Districts operate an extensive gas collection system at the Palos Verdes Landfill (PVLF) which collects approximately 8000 cfm of landfill gas. Parcel 6 of the main site which extends along the northeast boundary was filled starting in the early 1970's and completed in October, 1980. The depth of refuse as measured from the top deck of Parcel 6 is approximately 185 feet.

The top deck at the eastern end of Parcel 6 covers an area of approximately 390,000 ft^2. Landfill gas is collected and emissions controlled in this area by fifteen vertical gas collection wells (approx. 26,000 ft^2/well), shown in Figure 1. All but two of the wells, listed in Table 1, are 60 feet in depth which is approximately 32 percent of the refuse depth. As shown in Table 2, integrated surface gas emissions, measured along the five routes covering this area, from July 1993 through July 1994 have averaged between 2 and 3 ppm total organic compounds as methane. These background level concentrations are well below the SCAQMD's stringent 50 ppm average surface gas limit and indicate that the area has excellent gas control.

Clearly, the 75 percent of refuse depth specification should be relaxed to allow for well installations such as those at PVLF where 32 percent depth of refuse wells have proven effective in controlling surface gas emissions.

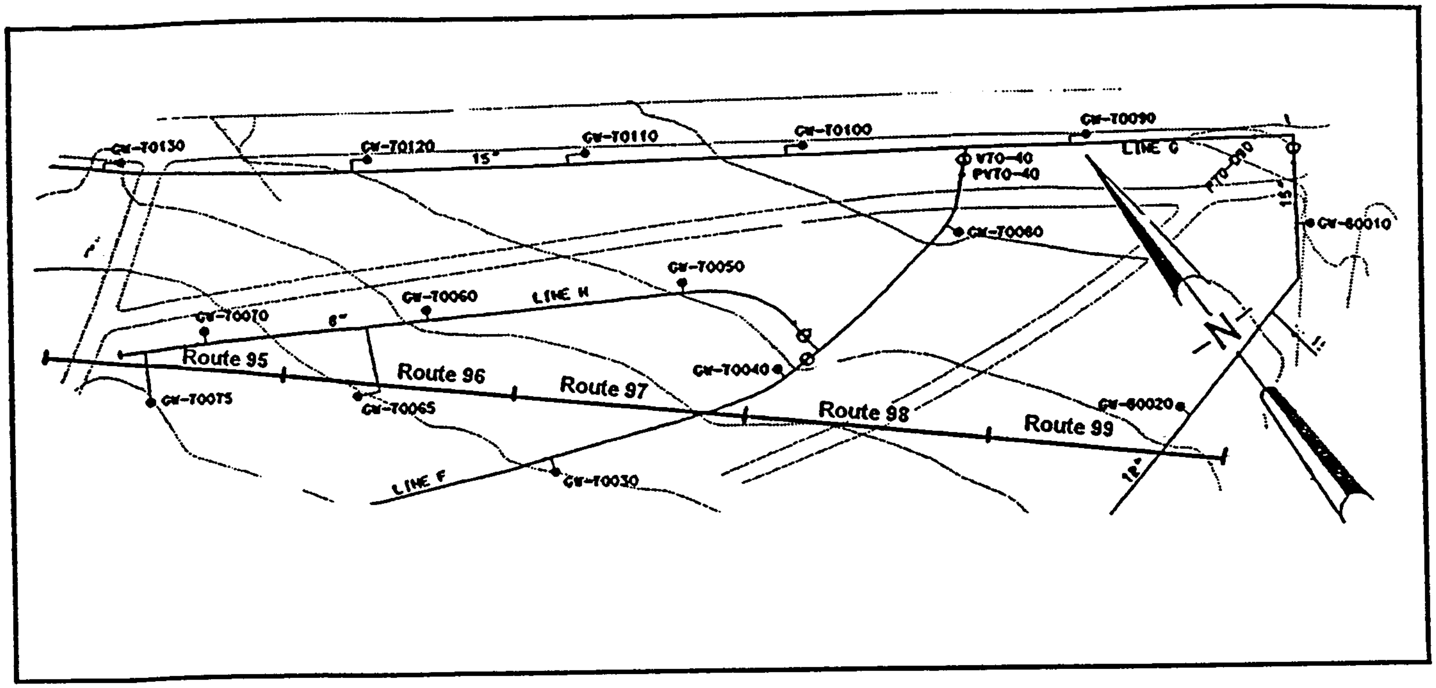

Figure 1. PVLF - Parcel Six Top Deck Gas Wells

Table 1
Parcel 6 - Top Deck Gas Wells

Well Number	**Well Depth (ft)**	**Refuse Depth (ft)**	**Well Depth as Percent of Refuse Depth**
70030	60	185	32%
70040	60	185	32%
70050	60	185	32%
70060	60	185	32%
70065	135	185	73%
70070	60	185	32%
70075	78	185	42%
70080	60	185	32%
70090	60	185	32%
70100	60	185	32%
70110	60	185	32%
70120	60	185	32%
70130	60	185	32%
80010	60	185	32%
80020	60	185	32%

Table 2
Parcel 6 - Top Deck Surface Gas Results

Surface Gas Route No.	7/93 - 7/94 Avg. TOC (ppm)
95	3
96	3
97	2
98	2
99	2

Case Study B: Perforations For Wells Less Than 90 Feet Deep

AVCS Specification: The bottom two-thirds of the pipe should be perforated

Alternative Design: At least the bottom two-thirds of the pipe should be perforated if the well is at least 90 feet deep. For wells less than 90 feet deep, the well perforations should be at least 5 feet in length or 30 percent of the well depth.

Location: Spadra Landfill, Pomona, CA
Operated by Los Angeles County Sanitation Districts (Districts)

Table 1 demonstrates that for this particular well installation, the Districts used an alternative to the AVCS design of perforating the bottom 66 percent of the gas extraction wells. SCAQMD requires surface gas route monitoring for methane at Spadra Landfill. As shown in Table 2, the areas around these gas extraction wells were reading at 4-5 ppm of methane. That is far below the SCAQMD's 50 ppm regulatory limit, and reflects that these wells are having good collection, even though they are designed differently than the proposed AVCS design. In addition, for 1993, the average methane collection percentage in the gas at Spadra Landfill was approximately 36 percent, but in the five wells in question, 47 percent of the collected gas was methane.[1] (Figure 1 is a map of the area of discussion at the Spadra Landfill.) Most of the other wells on site meet the AVCS specification of at least 66 percent of the pipe being perforated. This shows that these wells are performing better than the majority of the wells on site. Most of the other wells on site meet the AVCS specification of at least 66 percent of the pipe being perforated.

1 This calculation was based on the monthly readings at each wellhead.

Table 1
Spadra Landfill Case Study Well Specifications

Well No.	Well Depth	Slotted Length	Corresponding Surface Gas Route
03-040	60'	30'	32, 33
03-050	60'	30'	33
15-010	60'	30'	115, 118
15-020	60'	30'	118, 117
15-030	60'	30'	117, 116

Table 2

Cooresponding Surface Gas Monitoring Results

Surface Gas Route	Avg CH_4 Reading Over Past Year (ppm)
32	3.5
33	4
115	5
116	4
117	4
118	4

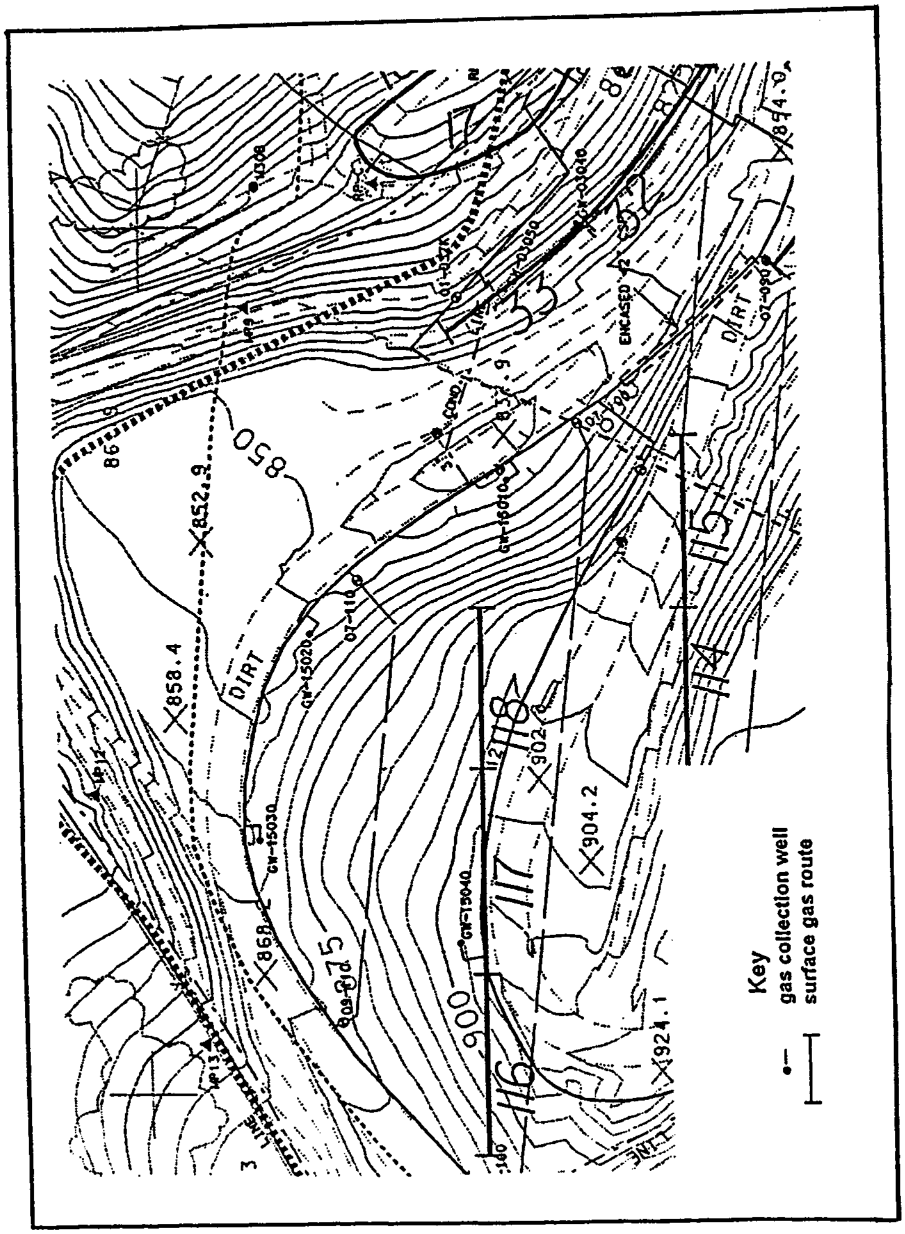

Figure 1. Partial Map of Gas Collection System and Surface Gas Routes at Spadra Landfill

There are often situations in which perforating the bottom two-thirds of the pipe is not advisable. For example, a well that is only 30 feet deep would be required by the AVCS design to have its lower 20 feet slotted or perforated. In an arid region like Southern California, it is not advisable to be applying a vacuum that is only 10 feet below the surface. Significant air infiltration could result. However, for a sufficiently deep well, perforating the bottom 66 percent of the well casing would not pose a threat. Accordingly, the bottom two-thirds specification for perforations should be specified only for wells that are at least 90 feet deep. For wells less than 90 feet deep, a minimum of 5 feet should always be perforated or 30 percent of the well depth. This additional alternative design is based on successful field designs implemented in the past.

Case Study C: Alternate Gas Well Perforations

AVCS Specification: ...with a minimum of four .012 m (1/2 inch) diameter holes, or other perforations spaced 90 degrees apart every 0.1 to 0.2 m (4 to 8 inch).

Alternative Design: The use of either slots or circular perforations with a minimum open area/ft. of pipe of 1-2 $inch^2$/ft.

Locations: Palos Verdes Landfill, Rolling Hills Estates, CA.
Spadra Landfill, Pomona, CA.
Operated by Los Angeles County Sanitation Districts

Lopez Canyon Landfill, Lakeview Terrace, CA.
Sheldon-Arleta Landfill, Sun Valley, CA.
Operated by City of Los Angeles

Table 1 presents specifications for a variety of slots and perforations used at landfills in Southern California as well as the AVCS specifications. The data contained in Table 1 suggest that the slots used by all the landfills are more than adequate to collect landfill gas in terms of percent open area of the pipe. The slots used include both vertical and horizontal slots, as shown in Figure 1. All the landfills in this case study have integrated surface gas measurements of less than 50 ppm. Therefore, all sites are in compliance with the SCAQMD's stringent site-average limit of 50 ppm methane. The specifications listed in Table 1 reflect a range of open areas used between 3.1 to 16 $inch^2$/ft. The AVCS requirements result in an open area of either 1.2 to 2.4 $inch^2$/ft. Accordingly, a reasonable minimum open area/ft. of pipe would be 1 to 2 $inch^2$/ft.

Table 1

Comparison Between Industry Examples and EPA New Source Performance Standards

Source of Specification	A Diameter	B Width	C Length	D Distance Between Centers	Orientation of Slots	Openings Per Row	Staggered? Offset in Row	Open Area/ft (sq.in)
Palos Verdes LF	3" to 4"	1/4"	2"	6"	Vertical	8	Y	8.0
Spadra LF	4" to 6"	1/8"	1"	3/8"	Horizontal	4	N	16.0
Lopez Canyon LF	4"	1/4"	2"	6"	Vertical	8	Y	8.0
Sheldon-Arleta LF	6"	1/4"	12"	18"	Vertical	4	N	8.0
EPA required	none	0.5" circle	0.5" circle	4.5"	N/A	4	N	2.4
EPA required	none	0.5" circle	0.5" circle	8.5"	N/A	4	N	1.2

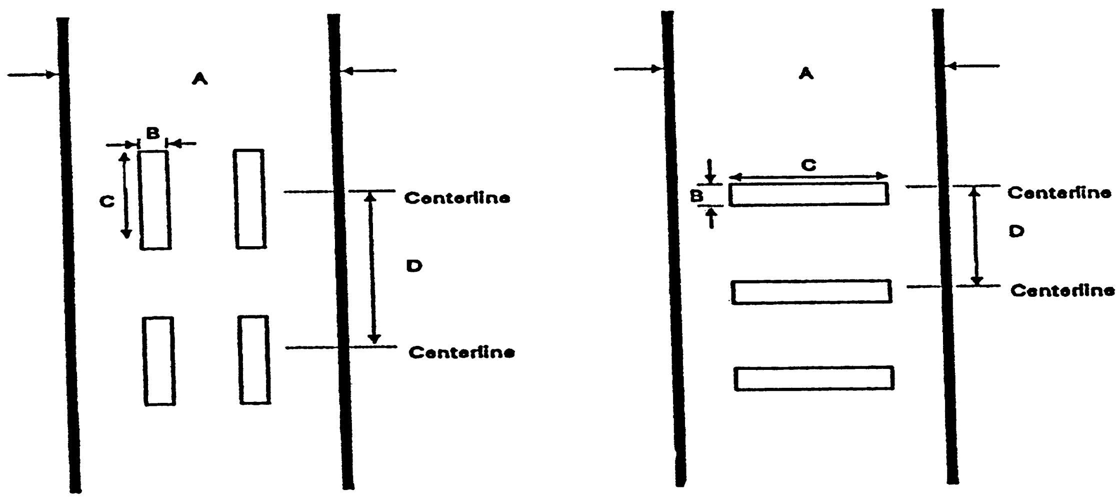

Figure 1. Key to Slot Specifications

Case Study D: Pile Driven Vertical Gas Well Installation

AVCS Specification: A well drilling rig will be used to dig a 0.60 m (24 inch) diameter hole in the landfill

Alternative Design: Pile driven vertical gas well installation

Location: Calabasas Landfill, Agoura, CA.
Operated by Los Angeles County Sanitation Districts (Districts)

The Districts operate an extensive gas collection system at the Calabasas Landfill (CALF) which collects approximately 6000 cfm of landfill gas. In 1989 and again in 1991, a series of vertical gas collection wells were installed along one of the site's benches, shown in Figure 1. Two pile driving installation methodologies were employed. For the 1989 wells, a 20 inch diameter hollow steel casing with an expendable, slip fit steel point was driven to the designed depth. A permanent well casing with slotted sections was centered within the pile casing, backfilled and the pile casing was then removed. For the 1991 wells, a steel casing with a conical steel point, and slotted section was driven to the design depth. It was left in place and served as the gas well casing. Both of these pile driven gas well installation techniques offered advantages over conventional drilling methodologies most important of which being the elimination of drill spoils.

The pile driven wells have performed well in collecting landfill gas and controlling surface gas emissions. Table 1 lists well performance data, including gas flow, percent methane, and percent oxygen, measured in July 1994. Table 2, lists the integrated surface gas monitoring routes which cover the pile driven gas well area and the one year average of surface gas concentrations. The one year average surface gas concentrations are well below the SCAQMD's stringent 50 ppm average surface gas limit and indicate that the area has excellent gas control.

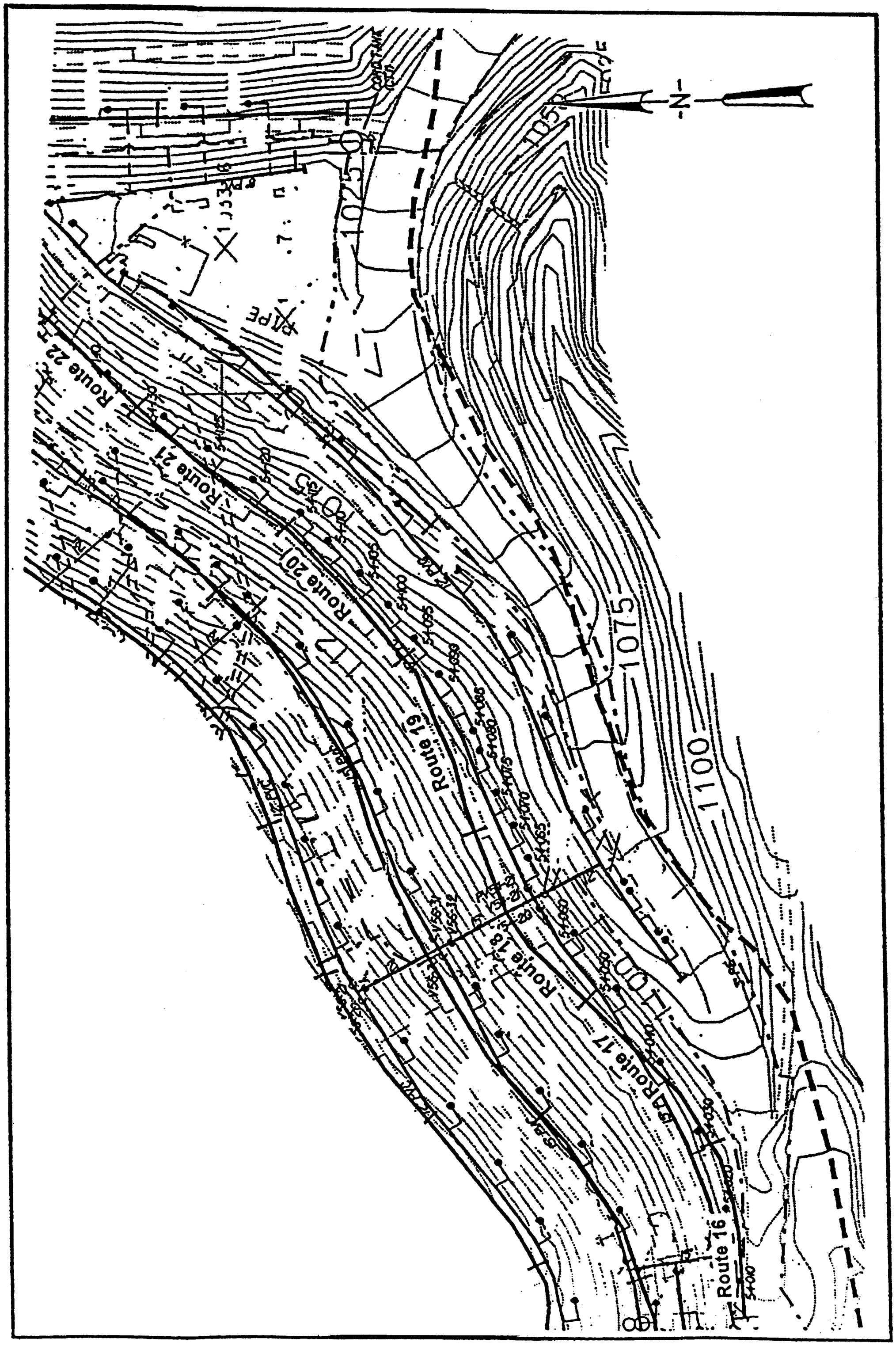

Figure 1. CALF - Pile Driven Gas Wells (54-000 Series)

Table 1

Calabasas Landfill - Pile Driven Gas Wells (54-000 Series)

Well No.	Install Date	Install Method	Depth (ft)	Well Data - July 1994 CH$_4$ (%)	Well Data - July 1994 0$_2$ (%)	Well Data - July 1994 Flow (cfm)
54020	11/9/89	pile driven	36.5	52	0	10
54030	11/9/89	pile driven	36	52	1	10
54040	11/9/89	pile driven	35.5	44	7	10
54050	11/9/89	pile driven	35.5	56	0	10
54060	11/9/89	pile driven	36.5	57	0	10
54065	10/25/91	pile driven	100	55	0	10
54070	11/9/89	pile driven	36	12	15	10
54075	11/9/89	pile driven	100	48	3	39
54080	11/9/89	pile driven	36	46	3	10
54085	10/29/91	pile driven	96	56	0	10
54090	11/9/89	pile driven	36.5	50	2	10
54095	10/29/91	pile driven	100	58	0	50
54100	11/9/89	pile driven	36.5	55	1	10
54105	10/29/91	pile driven	100	57	0	31
54110	11/9/89	pile driven	36.5	55	0	10
54115	11/1/91	pile driven	100	55	0	10
54120	11/13/89	pile driven	36.5	54	0	10
54125	11/1/91	pile driven	100	11	16	10
54130	11/13/89	pile driven	36	55	0	29
54140	11/13/89	pile driven	61	50	0	10

Table 2

Integrated Surface Gas Routes Controlled by 54-Series Gas Wells

Surface Gas Rt. No.	June 93 - June 94 Average TOC* (ppm)
16	12
17	15
18	17
19	9
20	12
21	17
22	12

* TOC = total organic compounds as methane.

Clearly, pile driven vertical gas well installations offer a viable alternative to conventional drilling methodologies as evidenced by the CALF wells. This alternative to drilling is not be excluded by regulation.

Case Study E: Compacted Low Permeability

AVCS Specification: ... the hole will be backfilled with gravel to a level at least 0.3 m (1 ft.) above the perforated section. A layer of backfill material at least 1.2 m (4 ft.) thick will be added on top of the gravel. A layer of bentonite at least 0.9 m (3 ft.) thick will be added on top of the backfill material, and the remainder of the hole will be backfilled with cover material or material equal to the permeability to the existing cover material.

Alternative Design 1. From the fill surface, a 19 ft. layer of compacted low permeability cover soil backfill which extends down to the gravel.

Alternative Design 2. From the fill surface, the uppermost 10 ft. is a layer of compacted low permeability cover soil backfill that is underlain by a 4 inch thick lean concrete layer. The concrete layer is in turn underlain by backfill down to the gravel.

Location: Puente Hills Landfill, Whittier, CA
Operated by Los Angeles County Sanitation Districts (Districts)

The Districts operate an extensive gas collection system at Puente Hills Landfill (PHLF) which collects approximately 26,000 scfm of landfill gas. Three foot bentonite seals for gas wells had been consistently used by the Districts for ten years. However, high swelling materials including bentonites shrink on dehydration and allow short circuiting under applied well vacuums. Well seal air short circuiting had been identified as a significant problem at Districts operated landfills.

Two alternative designs utilizing compacted soil were developed which significantly reduced air short circuiting. Both well alternatives were implemented in 30 inch diameter bore wells.

Alternative Design 1

Alternative Design 1 substitutes compacted low permeability cover soil for the bentonite seal. It stemmed from a study of well seal designs performed by the Districts.[1] The seals in the study each commenced with backfilling the hole with gravel to a level 1 ft. above the perforated section. Four different designs were developed for the remainder of the fill:

- Bentonite: One foot cap of backfill, underlain by 5 ft. of bentonite-cement grout. The bentonite-cement grout is underlain by 10 ft. of backfill, which is in turn underlain by 3 ft. of hydrated bentonite pellets extending down to the gravel. Backfill for all seal designs was cover soil backfill (low permeability marine siltstone).
- Soil backfill: Nineteen feet of backfill extending down to the gravel.
- Compacted soil: Nineteen feet of compacted backfill extending down to the gravel. Backfill placed in 3 ft. lifts. Each lift wetted with 5 gallons of water. (See Table 5).
- Sand-cement grout: One foot cap of backfill, underlain by 17 ft. of a sand-cement grout, which is in turn underlain by 1 ft. of backfill extending down to the gravel.

Twenty-eight wells scheduled for construction in early 1991 were selected for the study. The twenty-eight wells were divided into seven groups of four wells each. Wells in each group were selected in order to be as close to one another as possible. The four seal designs were then randomly assigned among the four wells in each group.

Five months after construction, the wells were monitored in a series of ten daily monitoring to determine short term seal effectiveness. Intermediate term seal effectiveness was

1 Cutts, S. P., Huitric, R. L., and Ackman, P. W., "Alternative Landfill Gas Well Seal Designs", SWANA 16th Annual Landfill Gas Symposium Proceedings, 1993.

observed by repeating the daily monitoring nine months later. Subsequent routine monthly monitoring data were analyzed to provide long term results.

Well seal effectiveness was ascertained in terms of three performance parameters: methane flow, air fraction, and aerobic gas production. Aerobic gas production was quantified in terms of a composting ratio[1]. The composting ratio measures apparent aerobic decomposition gases relative to anaerobic gases. Higher methane flow, lower air fraction, and lower composting ratio are desirable traits.

Average performance parameter values for the four different seal designs are presented in Tables 1 through 4.

Results from the controlled short term and intermediate term monitoring programs, as well as the long term routine monitoring data, consistently show a much higher average methane collection rate for wells with compacted soil seals, nearly twice that of wells with any of the other seal designs. Wells with compacted soil seals also have a lower average air fraction than other wells. Associated with the lower air fraction is a lower level of aerobic activity. The differences in the performance parameters between the compacted seal and other seals are almost always significant for all the monitoring programs.

The investigation of alternative seal designs shows significantly better performance for wells with compacted soil seals than for wells with a bentonite seal design: higher methane flow, lower air fraction, and lower composting ratio. Compacted soil seals have since been implemented in all subsequent gas well designs at the Districts.

Table 1
Bentonite

Parameter	Controlled Monitoring Programs		Routine Monitoring Data: Long Term		
	Short Term	Intermediate Term	7/92 to 12/92	1/93 to 12/93	1/94 to 7/94
CH_4 Flow (cfm)	12.1	15.2	12.8	17.5	12.3
Air Fraction (%)	32.5	39.2	30.2	21.4	30.8
Composting Ratio X 100	6.29	11.3	11.0	5.35	5.36

Table 2
Soil Backfill

Parameter	Controlled Monitoring Programs		Routine Monitoring Data: Long Term		
	Short Term	Intermediate Term	7/92 to 12/92	1/93 to 12/93	1/94 to 7/94
CH_4 Flow (cfm)	11.8	12.2	10.3	11.5	12.3
Air Fraction (%)	40.2	34.9	35.7	22.5	30.0
Composting Ratio X 100	5.76	7.60	12.7	5.21	7.51

Table 3
Compacted Soil

Parameter	Controlled Monitoring Programs		Routine Monitoring Data: Long Term		
	Short Term	Intermediate Term	7/92 to 12/92	1/93 to 12/93	1/94 to 7/94
CH_4 Flow (cfm)	23.7	17.3	22.8	21.9	18.9
Air Fraction (%)	24.3	26.8	25.5	16.1	20.2
Composting Ratio X 100	2.05	4.99	5.43	4.38	4.43

Table 4
Sand-Cement Grout

Parameter	Controlled Monitoring Programs		Routine Monitoring Data: Long Term		
	Short Term	Intermediate Term	7/92 to 12/92	1/93 to 12/93	1/94 to 7/94
CH_4 Flow (cfm)	10.4	8.04	7.24	9.20	6.10
Air Fraction (%)	29.0	34.4	32.3	29.4	44.9
Composting Ratio X 100	2.20	8.30	11.3	10.6	18.8

Alternative Design 2

Alternative Design 2 differs from Design 1 in that a shorter depth of compacted soil is used (10 ft compared to 19 ft) and a 4 inch layer of lean concrete underlies the compacted soil. A slightly different compaction method was used at the Puente Hills Landfill in 1992/3. Table 5 summarizes the two compaction methods.

To evaluate the performance of Alternative Design 2, fifteen wells were randomly selected from the 1992/3 installation. Eighteen months of routine monthly monitoring data through July 1994 were analyzed to determine average values of the methane collection rate, air fraction, and composting ratio. These data are presented in Table 6.

The average methane flow, air fraction, and composting ratio for these wells constructed with Alternative Design 2 are comparable to the respective parameter values in Table 3 for the compacted soil seal wells constructed according to Alternative Design 1.

Table 5
Compaction Specifications for Well Seals

Parameter	Wells Installed in 1991	Wells Installed in 1992/3
Soil Lift Size	3'	1'
Wetting of Soil	Each lift wetted with 5 gallons of water	Soiled mixed with water prior to backfilling to bring to optimum moisture content. Thoroughly mixed to a uniform moisture content.
Compaction Procedure	Compaction with 28" circular steel disk w/6" annular opening. Disk welded to 6" diameter pipe. Disk/pipe assembly (weight > 500 lb) lowered into well bore hole, raised 1', and dropped to compact soil. This procedure repeated five time for each lift	Compaction with hand-held pneumatic tamper (Ingersoll-Rand Model 241A2M). Weight = 26.9 lb, length = 52.8", barrel bore = 1 5/16", avg. piston stroke = 4", blows per minute = 1590. Compaction to 90% of optimum density.

Table 6
Average Data for Wells with 1992/3 Compaction Method

CH_4 Flow (cfm)	Air Fraction (%)	Composting Ratio X 100
19.9	21.5	5.85

Case Study F: Monitoring Vacuum Levels As An Indicator Of Air Infiltration In Arid Regions

Test Method Specification:	Test for infiltration of air into the landfill by measuring the gauge pressures of the shallow pressure probes and using Method 3C to determine the LFG N_2 concentration ... reduce the blower vacuum so that the N_2 concentration is less than 1 percent. (Section: Method 2E: Section 3.7.2)
Alternative Design:	Determine appropriate vacuum levels from landfill gas composition rather than nitrogen content
Locations:	Palos Verdes Landfill, Rolling Hills Estates, CA. Scholl Canyon Landfill, Glendale, CA. Spadra Landfill, Pomona, CA. Calabasas Landfill, Agoura, CA. Puente Hills Landfill, Whittier, CA. Mission Canyon Landfill, Los Angeles, CA. Operated by Los Angeles County Sanitation Districts (Districts)

The rationale for the proposed rules in the Federal Register (56 FR 24491, May 30, 1991) states:

> "Excessive air infiltration poses a safety hazard, because too much air may lead to an explosion or landfill fire. Nitrogen concentration is used as a surrogate measure for air infiltration. Based on these safety concerns, EPA has determined that N_2 concentration should be maintained under 1 percent by volume."

All the landfills in the case study generally operate at nitrogen concentrations greater than 20 percent in the header lines. Table 1 presents the average of the monthly gas analyses for the

1993 year. The nitrogen percentage ranges from 24 to 60 percent. Being in an arid region, these landfills probably draw in more air than the majority of landfills in the nation. That fact alone does not mean that the landfills are being dangerously operated or that the header lines face danger of explosion.

The Permanent Gas Sample[1] results from Table 1 were used to produce the two attached graphs. Figure 1[2] shows the percent volume of methane relative to the percent volume of additional inerts. The "additional inerts" is the quantity of inert gas that is present but not accounted for by the presence of air. For example, if a mixture was 50 percent air, there would be a corresponding percent nitrogen present; any nitrogen present above that percent would be additional inert gas in the sample. The volume percent of air is approximated by the oxygen content found in the sample. Figure 1 includes a curve that represents the flammability limits of a mixture of methane, nitrogen and air. Considering a mixture with nitrogen is the most conservative approach because the other inert gas found in landfill gas, carbon dioxide, limits the flammability of methane even more. The area bounded by the y-axis on the left and the curve on the right is a region wherein the gas mixture is flammable. Outside of this curve, the gas mixture is not flammable. The gas characteristics from all six of the landfills in the case study fall outside of this curve, and therefore are not flammable gas mixtures despite their volume percentages of nitrogen being well above 1 percent.

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1 Permanent gas samples are samples of gas collected at each landfill on a monthly basis and then analyzed in a laboratory by a gas chromatograph.

2 This graph was adapted from Figure 28 of the Michael G. Zabetakis article "Flammability Characteristics of Combustible Gases and Vapors", published in 1965 as Bulletin 627 of the U.S. Bureau of Mines.

Table 1
Gas Composition Data for Case Study Landfills

Landfill	Average 1993 Permanent Gas Monthly Samples				* Calculation of Corresponding	
	Oxygen %	Carbon Dioxide %	Nitrogen %	Methane %	Air %	Additional Inerts %
Puente Hills (PH)	4.3	31.4	23.7	38.5	20.5	39.1
Palos Verdes (PV)	10.8	17.2	50.0	20.2	51.5	27.0
Spadra (SP)	4.7	32.6	24.4	36.2	22.4	39.5
Calabasas (CA)	5.6	30.5	29.8	31.6	26.6	39.5
Mission Canyon (MC)	7.9	16.6	60.4	13.4	37.7	47.6
Scholl Canyon (SC)	6.0	29.0	30.9	32.0	28.6	37.6

* Air percent is determined from oxygen percent in sample. Additional inerts are the sum of nitrogen and carbon dioxide present that would be additional to percents present due to air percent.

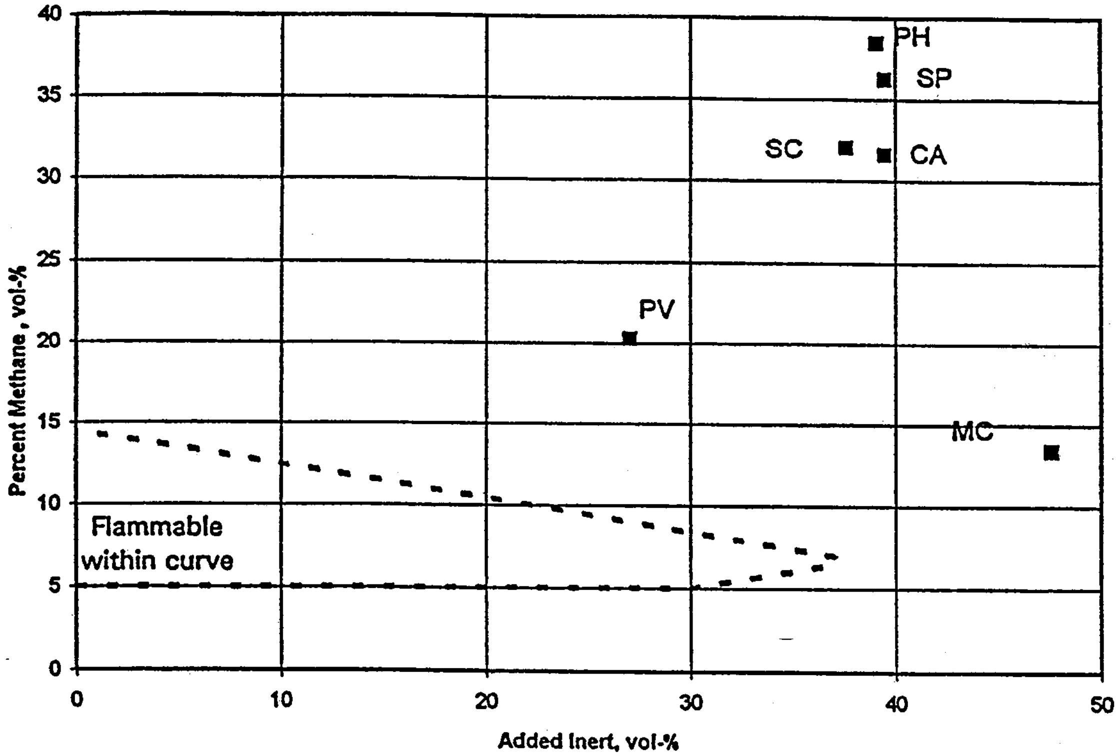

Figure 1. Limits of Flammability of Methane-Nitrogen-Air Mixture

Figure 2[3] presents the range of flammability of gases according to their volume percent of methane and oxygen. Once again, the data from the case study landfills fall well outside the specified flammable area. If a considerable amount of oxygen was added to the landfill gas, the composition would start to approach the flammable region. However, the landfills are operating safely at the current specifications. For the landfills in the case study, at least, the proposed nitrogen percent limit would make it impossible to operate what is currently safely operated landfills.

3 This graph was adapted from Figure 22 of the H. F. Coward and G. W. Jones article "Limits of Flammability of Gases and Vapors", published in 1952 as Bulletin 503 of the U. S. Bureau of Mines.

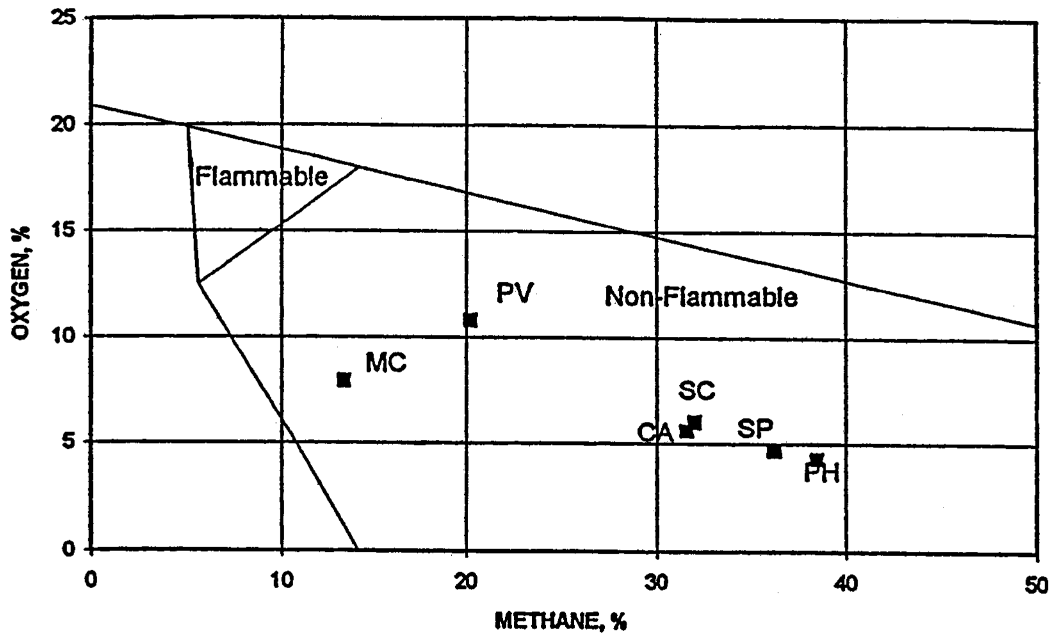

Figure 2. Relation Between Gas Composition and Flammability

Case Study G: Horizontal Collector Design

Specification: Horizontal Collector (only) System

Location: Scholl Canyon Landfill, Glendale CA.
Operated by Los Angeles County Sanitation District (Districts)

Introduction

In 1988, a group of horizontal landfill gas collectors was installed on the top deck area of Scholl Canyon Landfill (SCLF). Twelve collectors were installed in an area that had no existing gas collection system (either vertical wells or horizontal collectors) in place. These twelve collectors, shown in Figure 1, are the subject of this case study. Eight of the twelve collectors (main collectors) span the width of the landfill from its southern to its northern border. The remaining four collectors (auxiliary collectors) follow roughly the daylight line along the site's southeast boundary. All twelve collectors are connected to the same 18-inch diameter gas header which is located on a fire road which runs along the southern boundary. The following discussion provides design details, operational information and performance data for the subject collectors.

Horizontal Collector Design

Main Collectors

The main top deck horizontal collectors span the width of the landfill from the southern border where they connect to the header to the northern border. In general, they consist of a trench, casing, backfill material, and header connection. The main collectors (listed in Table 1) range in length from 1300 to 1800-feet with a horizontal spacing of 250-feet. They are constructed in 2-foot 3-inch wide by 5-foot 9-inch deep trenches that span the top deck but are

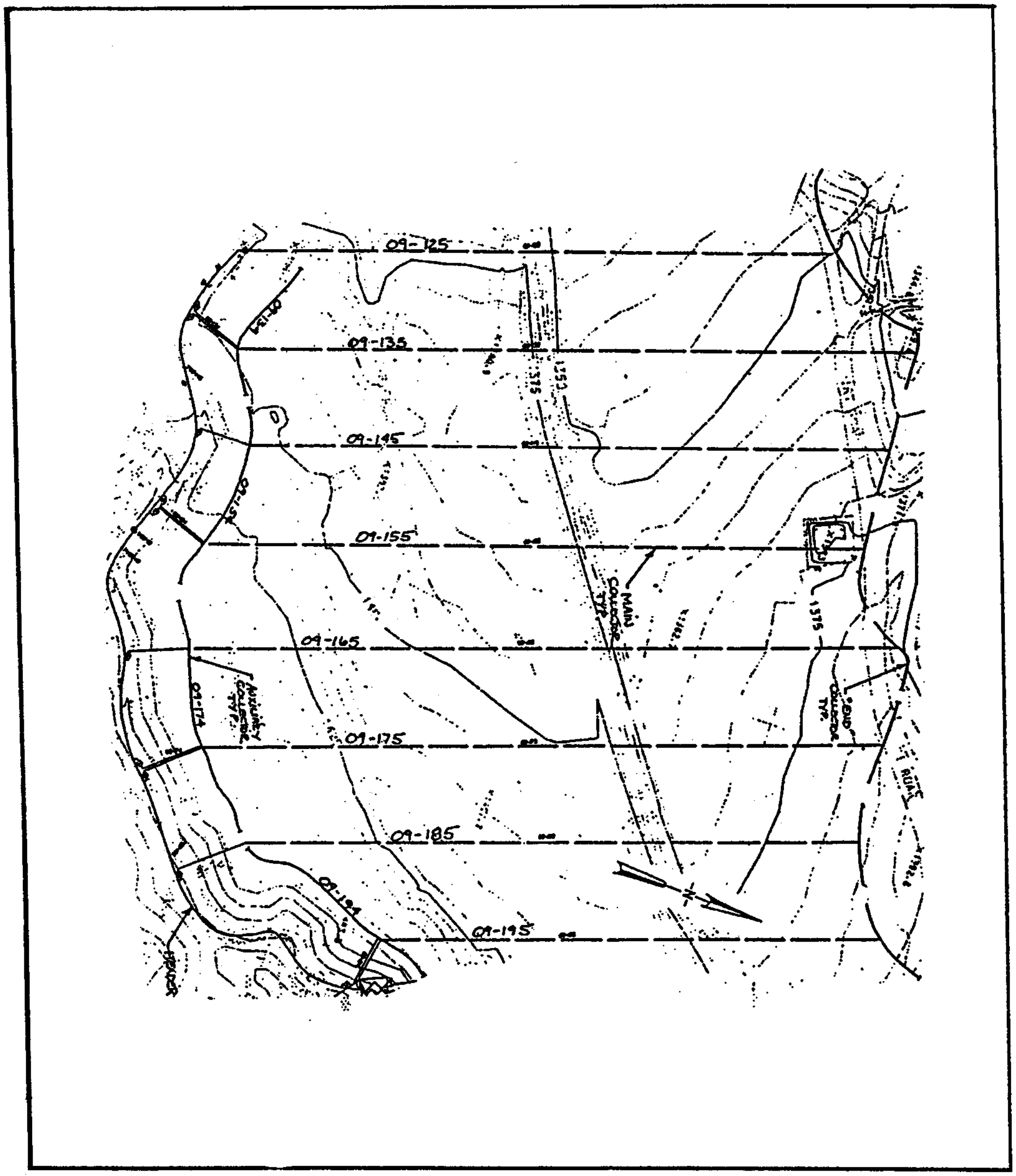

Figure 1. Scholl Canyon Landfill - Horizontal Collectors

Scholl Canyon Landfill

Table 1
Main Horizontal Collectors

Collector Number	Casing Diameter (inch)	Length (feet)	Spacing (feet)	End Collector *	
				Casing Dia. (in.)	Length (ft)
09-125	15 and 18	1320	250	8 and 12	450
09-135	15 and 18	1700	250	8 and 12	225
09-145	15 and 18	1600	250	8 and 12	225
09-155	15 and 18	1650	250	8 and 12	275
09-165	15 and 18	1780	250	8 and 12	200
09-175	15 and 18	1710	250	8 and 12	250
09-185	15 and 18	1540	250	8 and 12	225
09-195	15 and 18	1260	250	8 and 12	250

* inset 75-feet from northwest boundary daylight line

inset approximately 75-feet from the northern boundary daylight line and 30-feet from the southern boundary daylight line. These collectors have casings comprised of 10-foot sections of alternating 15-inch and 18-inch diameter corrugated steel pipe (CSP). The alternating sections of CSP have a 2-foot overlapping connection, as shown in Figure 2. The annular space created at each overlap connection allows the landfill gas to enter the casing when vacuum is applied to the collector. The casing is horizontally centered within the trench supported by a 6-inch bed of uncrushed, 0.5 to 1.5-inch diameter, rock. The trench is backfilled with additional uncrushed rock to within 2-feet of the trench top. A polypropylene filter fabric covers the gravel and extends 2-feet vertically up the trench walls. The filter fabric is covered with on-site soil filling the trench to the top as shown in Figure 3.

The main horizontal collectors have a unique termination at their northwest end where they connect to the midpoint of smaller diameter horizontal collectors (end collectors) which run roughly perpendicular to the main trench. These "end" collectors which are constructed like the main collectors except with alternating sections of 8 and 12-inch diameter CSP casing. They range in length from 250 to 500-feet, follow along the site's northern boundary (inset approximately 30-feet from the refuse line), and are spaced 30-feet apart end to end. The casing opening at both ends of these collectors is covered with 2 layers of polypropylene filter fabric. The end collectors obtain their vacuum from the main collector and have no separate vacuum control valve of their own.

The main horizontal collectors are connected at their southern end to an 18-inch diameter gas header. The header runs along a fire road which follows the southern boundary but at a higher elevation than the site's top deck. Consequently, connections from the main collectors are routed up the side slope from the top deck to the header as shown in Figure 4. As previously mentioned, the main collector trenches end approximately 30-feet in from the southern boundary daylight line. Extending from the trench end is a section of 12-inch diameter CSP which is connected within the trench to the collector casing. This 12-inch diameter section of CSP protrudes approximately 5-feet beyond the trench end where it connects, using a neoprene gasket CSP expansion joint, to another section of CSP. This CSP section connects to a 40 degree elbow

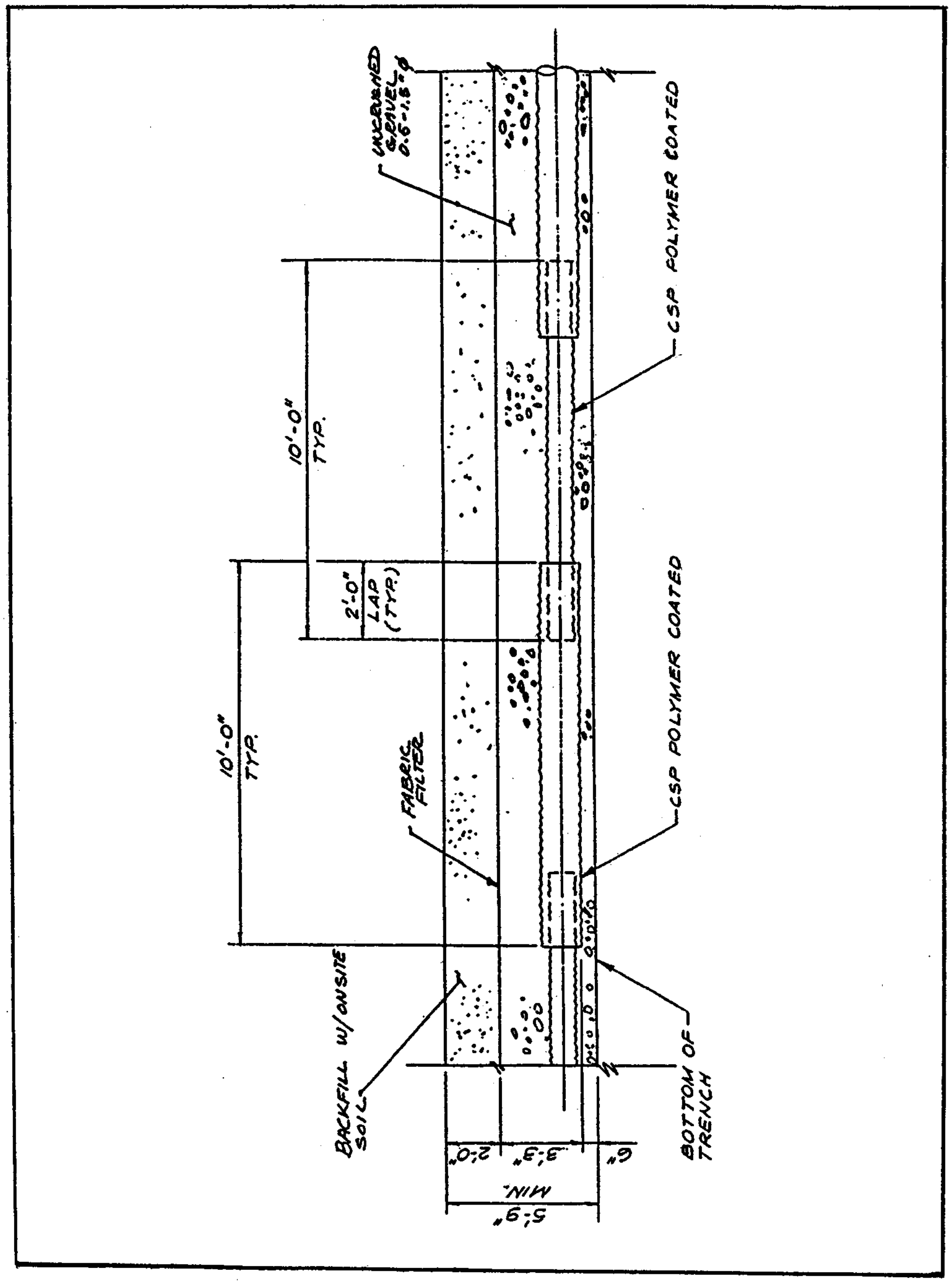

Figure 2. Horizontal Collector - Casing Sections

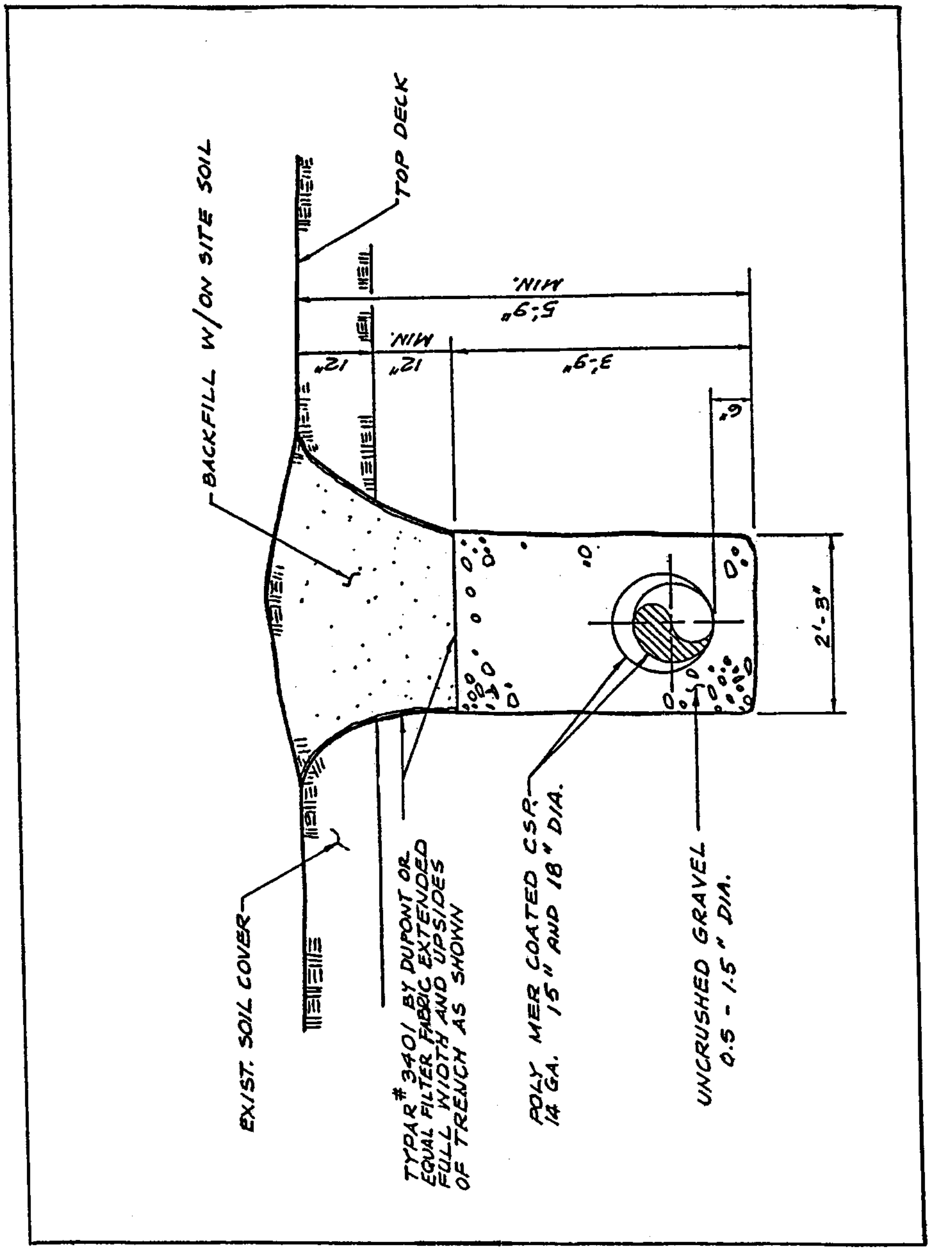

Figure 3. Horizontal Collector - Trench with Casing and Backfill

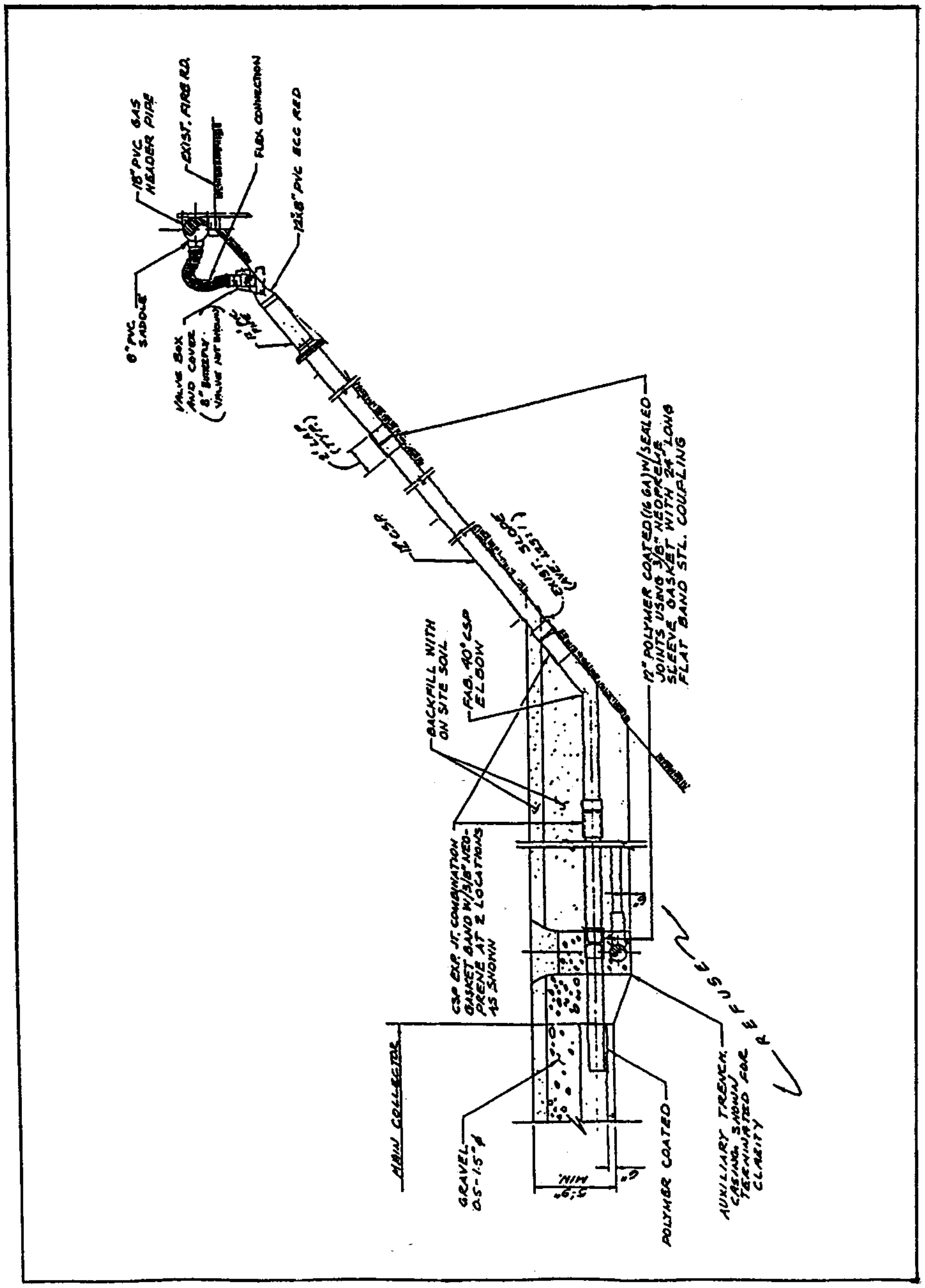

Figure 4. Main Collector to Header Connection

which re-directs the CSP up the side slope toward the gas header. As the CSP extends up the slope it breaks through the top deck and continues above ground. The CSP then connects to a 24-inch long flat band coupling that joins it to another section of CSP that has a steel flange end. The steel flange is mated to a PVC flange and a 12-inch to 8-inch diameter PVC reducer. An 8-inch diameter PVC pipe connects the reducer to an 8-inch butterfly valve (used to regulate the collector vacuum), to an 8-inch diameter by 5-foot long flex connection. The flex connection attaches to the 18-inch diameter header through an 8-inch PVC saddle.

Auxiliary Collectors

The four auxiliary collectors are located along the site's southern boundary, inset approximately 30-feet from the daylight line, as shown in Figure 1. They range in length from 400-feet to 600-feet, see Table 2, and are spaced apart at 60-foot intervals end to end. They are constructed like the main collectors described above but with alternating sections of 8 and 12-inch diameter CSP casing. The casing opening at both ends of the auxiliary collectors is covered with 2 layers of polypropylene filter fabric. At the point where main and auxiliary collectors cross, the auxiliary collector is routed under the main collector as shown in Figure 5. An 8-inch CSP tee, installed in the collector casing, is used as the collector to header connection point. From the tee, the header connection is the same as the main collector header connection except that 8-inch CSP and 4-inch PVC pipe (or 12-inch CSP and 8-inch PVC) is used as shown in Figure 6. The auxiliary collectors are connected to the header through 4-inch butterfly valves which allows independent vacuum adjustments.

Operational and Performance Characteristics

Operation

The primary objective in the operation of the SCLF horizontal collectors described above is to control surface gas emissions from the site. To meet this objective, surface gas monitoring results and collector operational data (e.g. flow rate, percent methane, percent oxygen, gas temp,

Table 2
Auxiliary Horizontal Collectors

Collector Number	Casing Diameter (inch)	Length (feet)	Spacing (feet)
09-134	8 and 12	400	60
09-154	8 and 12	500	60
09-174	8 and 12	600	60
09-194	8 and 12	600	60

* inset 30-feet from northwest boundary daylight line

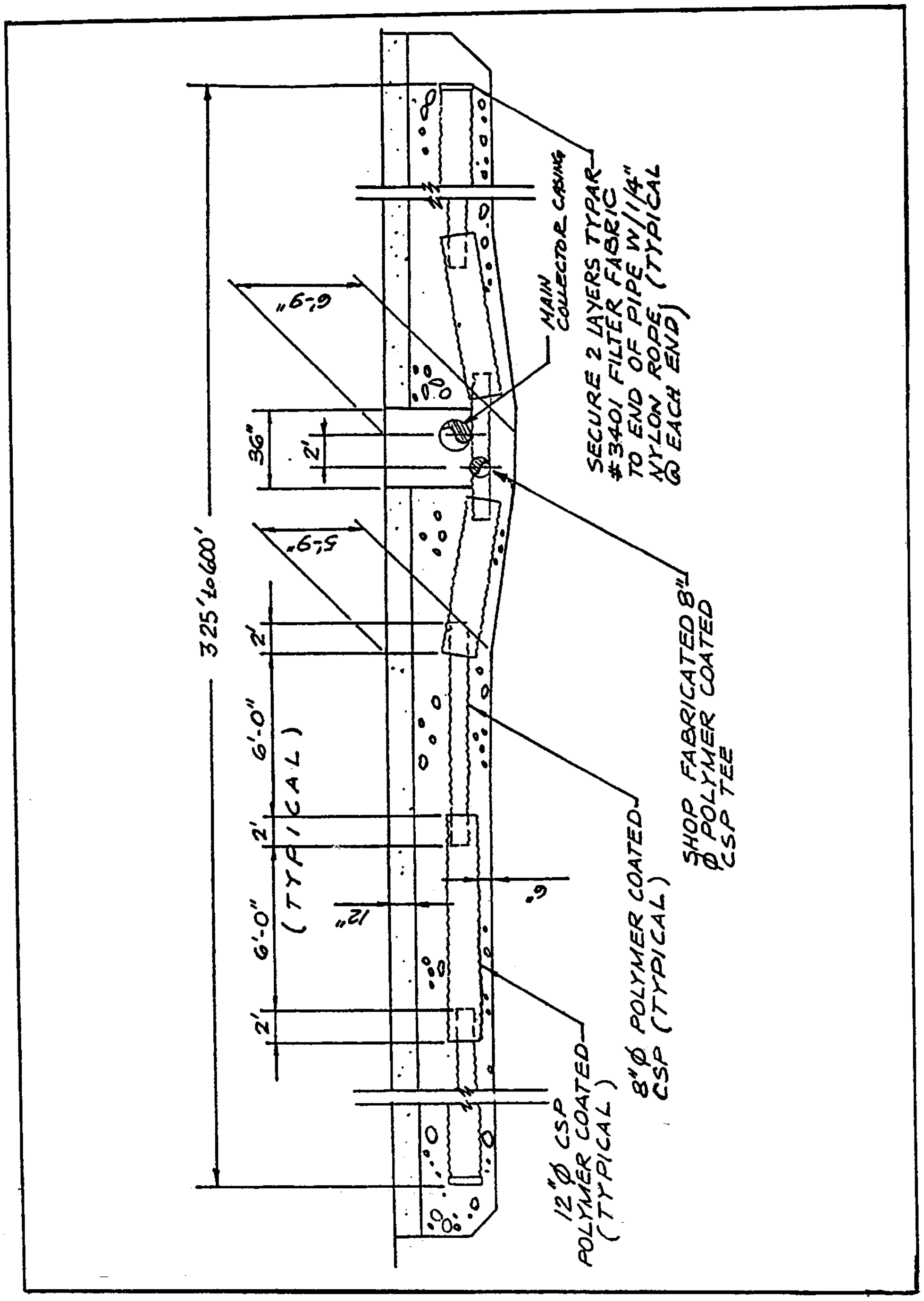

Figure 5. Auxiliary Collector - Casing Sections

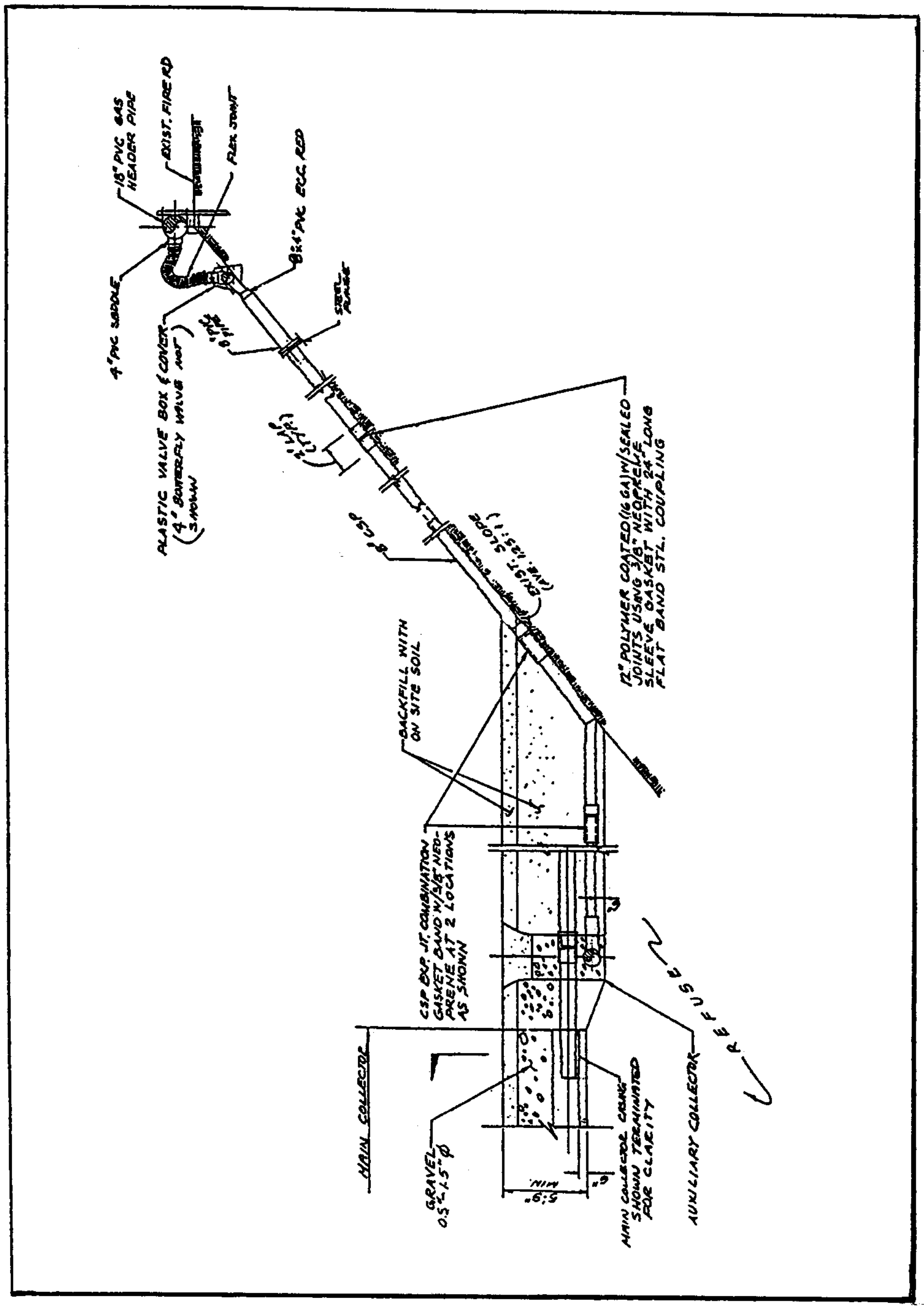

Figure 6. Auxiliary Collector to Header Connection

vacuum pressure, etc.) are obtained and reviewed on an ongoing basis. Slight variations in the operational data are corrected as necessary with minor adjustments to the collector vacuum. Any significant increase in surface gas emissions would warrant immediate and perhaps more drastic collector adjustment.

The 1993 average operational data for the horizontal collectors described herein are contained in Tables 3 and 4. Valve position corresponds to control valve opening where zero degrees is "fully closed" and 90 degrees is "fully open." Surface gas monitoring results are presented below.

Performance

In the Los Angeles area, the South Coast Air Quality Management District (SCAQMD) adopted in 1985 a rigorous landfill gas control rule, Rule 1150.1, "Control of Gaseous Emissions from Active Landfills". The rule, with its January 1989 compliance deadline, required the installation of gas collection systems at active sites and the implementation of a field monitoring program. It established a 50 ppm total organic compounds as methane (TOC as methane) limit for average gas emissions measures over the surface of the landfill (integrated surface gas monitoring). Sites complying with Rule 1150.1 are considered as having good gas control with those maintaining emission levels far below the 50 ppm limit having excellent control.

SCLF is located within SCAQMD jurisdiction and it complies with the requirements of Rule 1150.1. In the area controlled by the horizontal collectors described herein the average surface gas emissions since 1989 have stayed at background levels below 5 ppm TOC as methane.

Scholl Canyon Landfill

Table 3
Main Horizontal Gas Collectors
Average Operational Characteristics - 1993

Collector Number	Valve Position (degrees)	Percent of Time at Position	Average Percent CH_4	Average Percent O_2	Average Flow (cfm)	Average Vacuum (in. H_20)	Average Temp. (deg. F)
09-125	15	100	44.9	1.2	292	0.71	88.9
09-135	15	100	44.4	0.8	215	0.53	88.9
09-145	15	36	34.9	2.8	191	0.6	87
	30	57	30.5	4.5	302	0.8	87.2
	45	7	31	7	711	0.1	71
09-155	15	73	26.6	5	183	0.5	82.4
	30	27	16.6	11.9	194	0.56	64.9
09-165	30	21.4	45.8	0.63	191	0.52	76.5
	45	78.6	37.9	0.64	305	0.77	83.8
09-175	30	100	39.4	1.1	222	0.55	75.7
09-185	0	100	9.9	14.4	0	-0.01	80.2
09-195	15	100	42.9	1.3	257	0.48	75.2

Table 4
Auxiliary Horizontal Collectors
Average Operational Characteristics

Collector Number	Valve Position (degrees)	Percent of Time at Position	Average Percent CH_4	Average Percent O_2	Average Flow (cfm)	Average Vacuum (in. H_20)	Average Temp. (deg. F)
09-134	15	100	44.7	1.7	35	0.46	90.6
09-154	30	12.5	19.6	11.6	71	0.84	78.8
	45	87.5	23	7.8	62	0.65	75.7
09-174	15	14.3	37.5	2	64.5	0.6	73.7
	30	7.1	39	1	51	1	60
	45	78.6	39.1	0.61	65.8	0.6	79
09-194	15	100	35.8	1.8	77	0.55	76.2

Case Study H: Design For LF With Horizontal Collectors and Vertical Wells

Specification: Front Face Horizontal Collectors and Vertical Gas Wells

Location: Scholl Canyon Landfill, Glendale CA.
Operated by Los Angeles County Sanitation Districts (Districts)

Introduction

In 1988, a number of horizontal collectors and vertical gas collection wells were installed on the top deck area and front face respectively of Scholl Canyon landfill (SCLF). They were installed to collect landfill gas and control surface emissions in accordance with local regulations. A group of horizontal collectors were installed in a east-west orientation with connection (at their western end) to a front face gas header. The header which runs along a front face bench was also connected to a series of vertical gas collection wells. These wells were installed, evenly spaced, along the top of the slope leading from the header bench to the next lower bench. Six of the horizontal collectors and eight of the vertical wells, described above are shown in Figure 1. This group of wells and collectors are the subject of this case study. The following discussion provides design details, operational information, and performance data for the subject wells and collectors.

Collector/Well Design

Horizontal Collectors

The horizontal collectors (listed in Table 1) are connected at one end to the front face header, described above, and extend easterly toward the center of the landfill. The collectors range in length from 880 to 1020-feet, have a 2 percent slope downward toward the front face, and are spaced at 200-foot intervals. They are the first and only horizontal collectors installed at SCLF and consequently have no collectors below them. In general, they consist of a horizontal

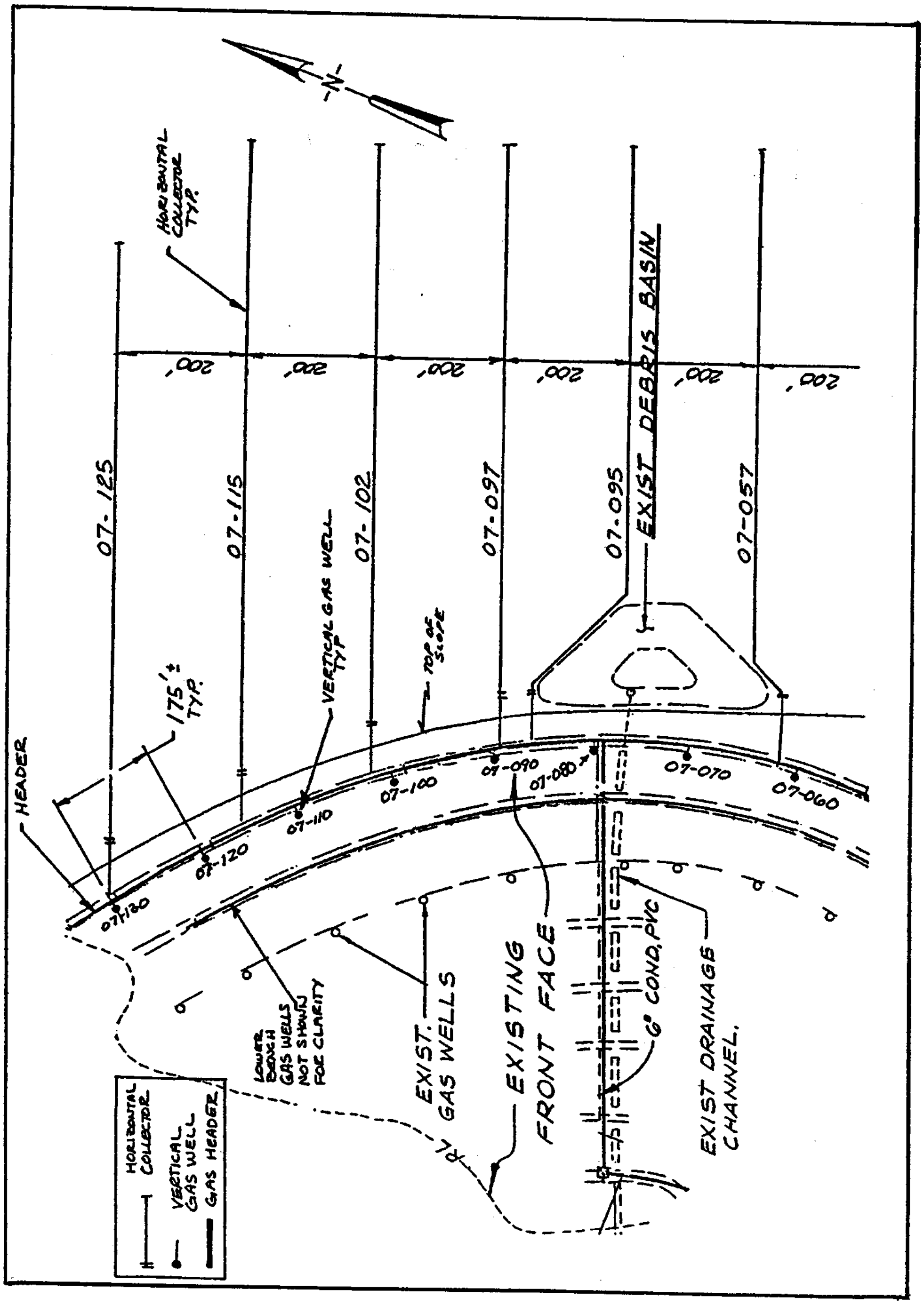

Figure 1. Scholl Canyon Landfill - Front Face Horizontal Collectors and Vertical Gas Wells

School Canyon Landfill

Table 1
Horizontal Collectors

Collector Number	Casing Diameter (inch)	Length (feet)	Spacing (feet)
07-057	12 and 15	880	200
07-095	12 and 15	910	200
07-097	12 and 15	880	200
07-102	12 and 15	930	200
07-115	12 and 15	1020	200
07-125	12 and 15	950	200

trench, casing, backfill material, and a header connection. They are constructed in a 2-foot 3-inch wide by 5-foot 9-inch deep trench that runs the length of the collector inset a minimum of 30-feet from the front face to prevent air intrusion. These collectors have casings comprised of 10-foot sections of alternating 12 and 15-inch diameter corrugated steel pipe (CSP). The alternating sections of CSP have a 2-foot overlapping connection, as shown in Figure 2. The annular space created at each overlap connection allows the landfill gas to enter the casing when vacuum is applied to the collector. The casing is horizontally centered within the trench supported by a 6-inch bed of uncrushed, 0.5 to 1.5-inch diameter, rock. The trench is backfilled with additional uncrushed rock to within 2-feet of the trench top. A polypropylene filter fabric covers the gravel and extends 2-feet vertically up the trench walls. The filter fabric is covered with on-site soil filling the trench to the top as shown in Figure 3.

The casing opening at the eastern, unconnected, end of the horizontal collectors is covered with 2 layers of polypropylene filter fabric, as shown in Figure 4. The western end of the collectors is connected to an 18-inch diameter gas header which runs along a front face bench which is at a lower elevation than the collectors. Consequently, connections from the collectors are routed down the slope from the top deck to the header bench as shown in Figure 5. The 12-inch diameter collector casing extends past the end of the trench and is coupled, using a 36-inch long flat band coupling, to another 12-inch diameter section of CSP which terminates in a steel flange. The steel flange is mated to a PVC flange and 12-inch by 8-inch diameter reducer.

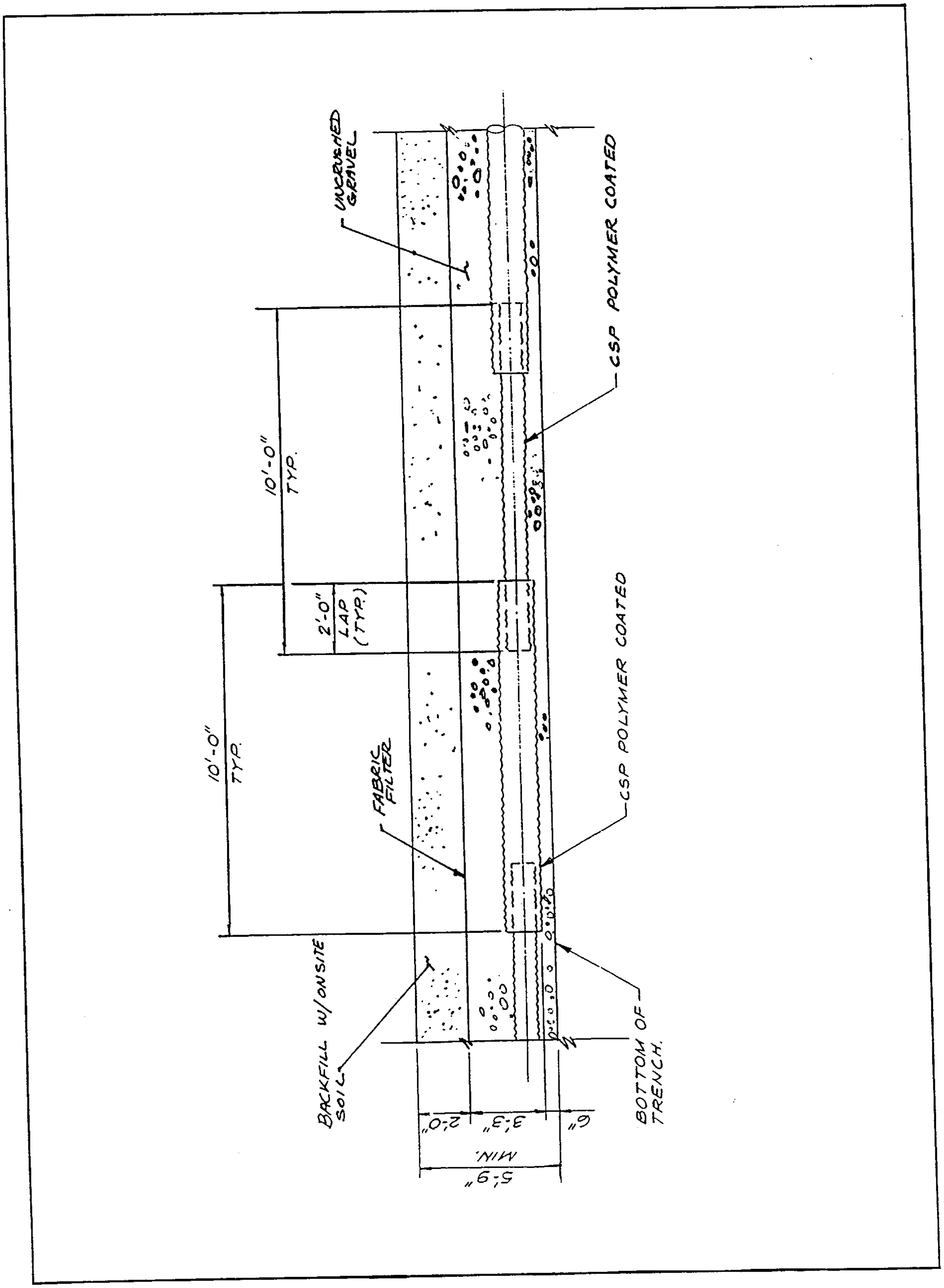

Figure 2. Horizontal Collector - Casing Sections

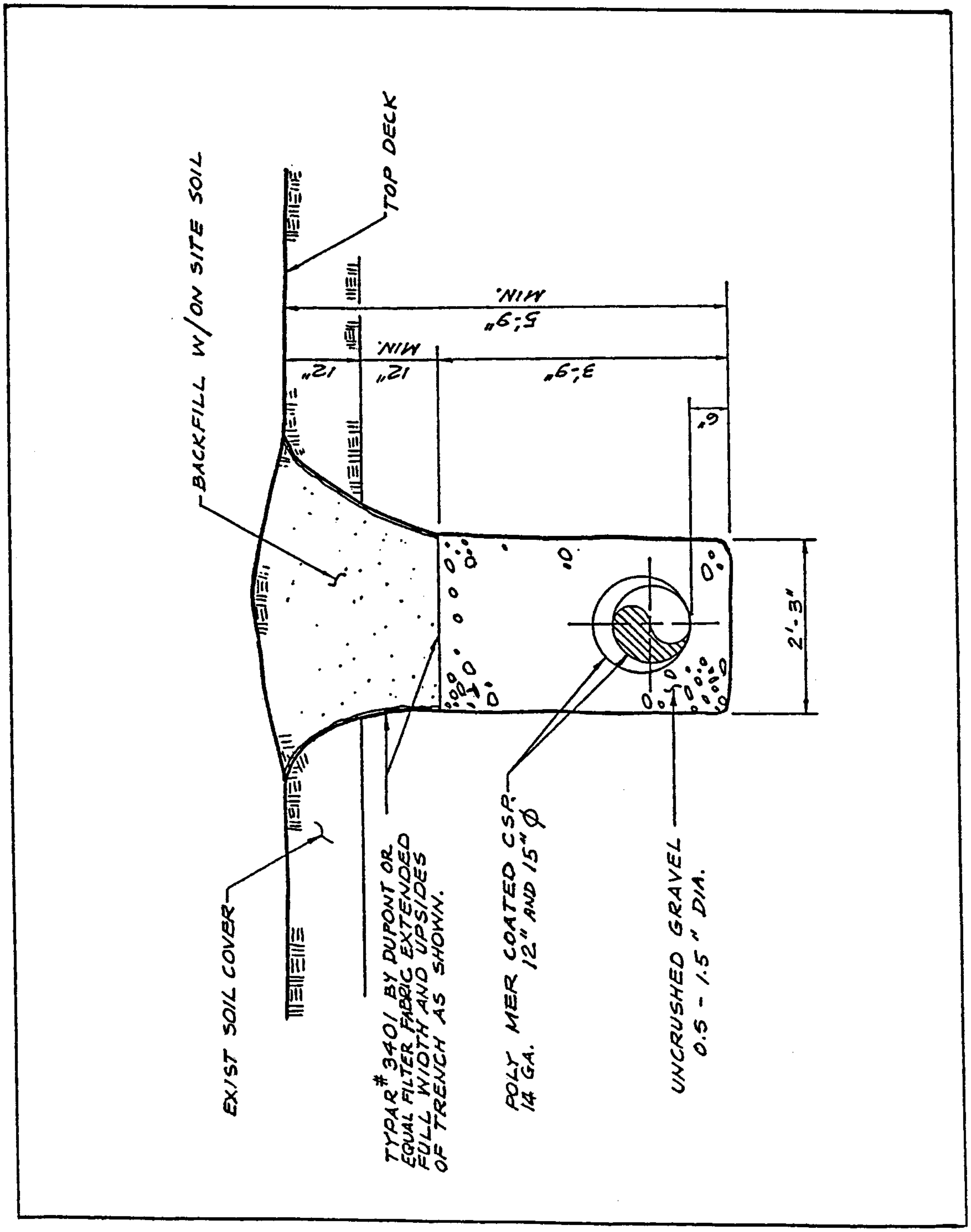

Figure 3. Horizontal Collector - Trench with Casing and Backfill

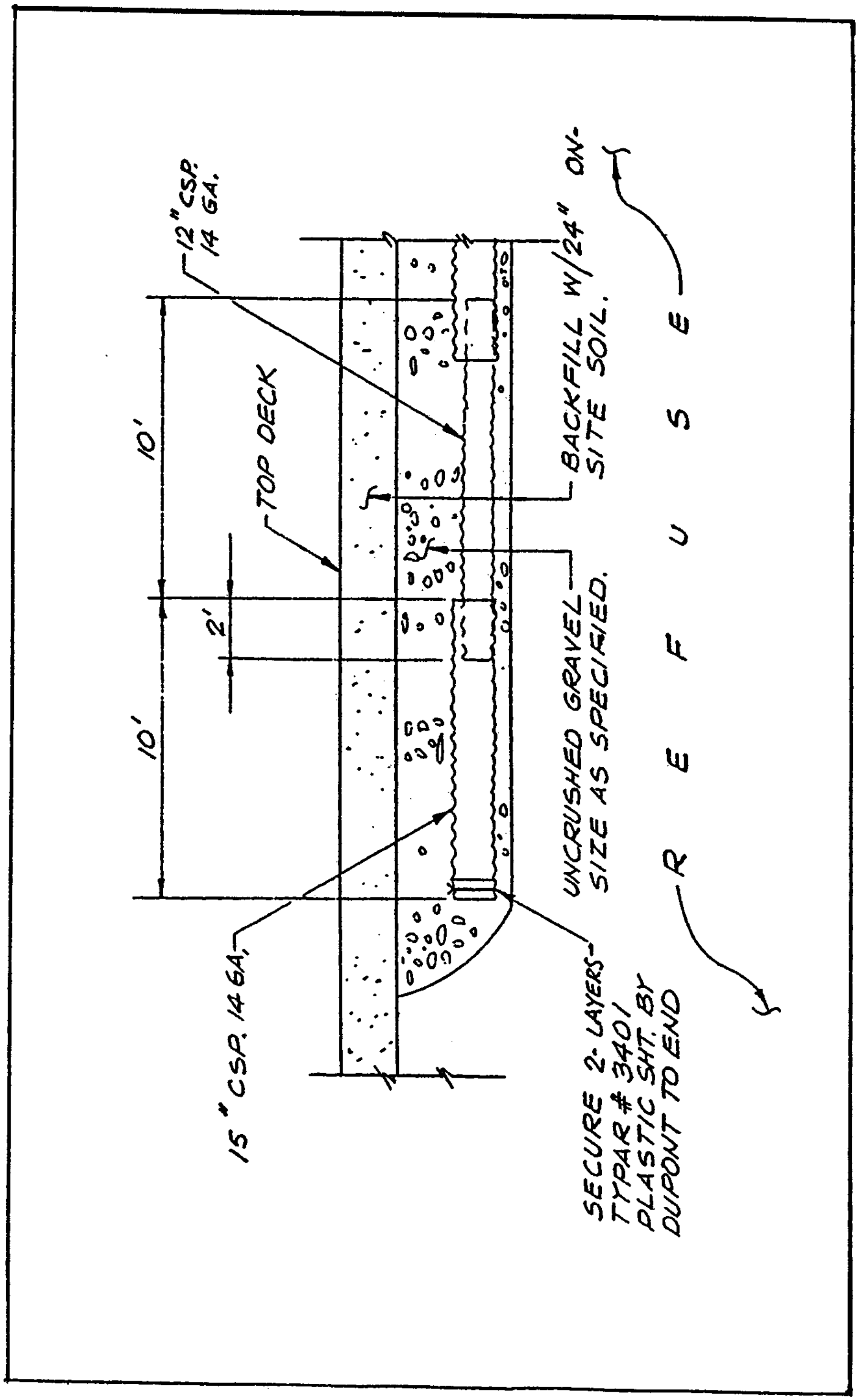

Figure 4. Horizontal Collector Termination

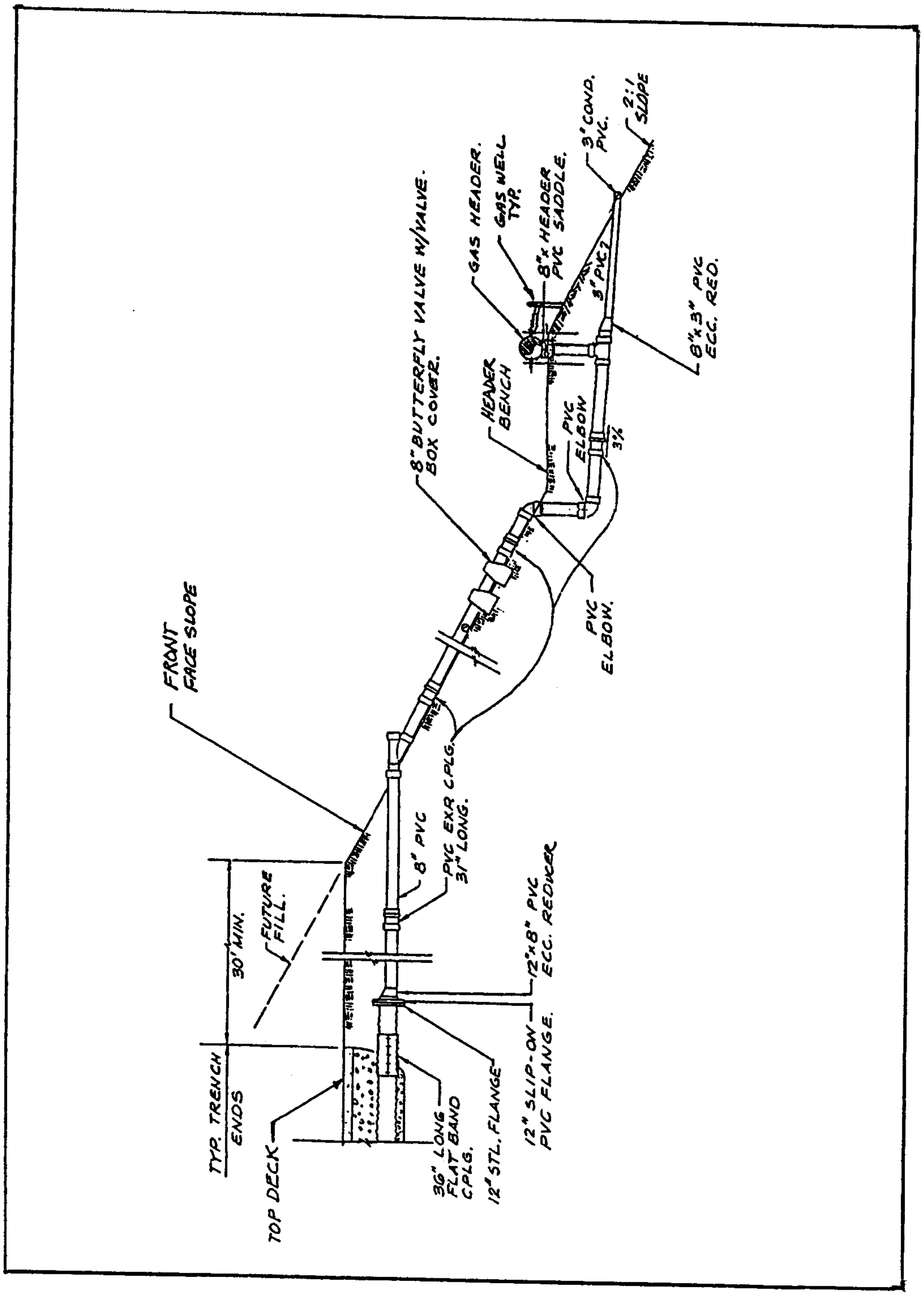

Figure 5. Horizontal Collector to Header Connection

The reducer connects to a section of 8-inch diameter PVC pipe, a 31-inch long expansion coupling, followed by another section of 8-inch diameter PVC pipe which protrudes through the front face terminating in a branch angle tee. From this point, the collector to trench connection is routed above ground as it extends down the front face slope to the toe of the header bench. The above ground section, starting at the branch angle tee, consists of three in-line sections of 8-inch diameter PVC pipe connected by two 31-inch long expansion couplings. An 8-inch butterfly valve, used to adjust the collector vacuum, is in-line between the two expansion couplings. At the toe of the slope, the 8-inch diameter PVC pipe is routed under the header bench. This buried section of pipe is sloped at 3 percent downward toward the face to facilitate the draining of condensate from the line. The buried section of pipe which transverses the bench has a 31-inch long PVC expansion coupling at its mid-point and terminates into a 8-inch PVC tee. A 3-inch diameter PVC pipe is connected to the side of the tee through a 3-inch by 8-inch reducer. It extends horizontally out through the face to the surface where it connects to the condensate collection system. An 8-inch diameter PVC pipe extends vertically from the top of the tee through the surface of the bench where it connects to a 31-inch long PVC expansion coupling. From the expansion coupling the pipe is attached to an 8-inch PVC saddle connected to the header.

Vertical Gas Wells

The vertical gas wells (listed in Table 2) are located along the front face bench on which the collector header is located. They are installed approximately 4-feet out from the header on the slope which extends down to the lower bench. The wells which are all 60-feet in length are horizontally spaced at approx. 150-foot intervals (see Figure 1). They are constructed as shown in Figure 6 with alternating sections of 4 and 6-inch diameter perforated PVC pipe in the bottom 40 feet and a 4-inch diameter PVC pipe riser. The riser connects to a 4-inch by 3-inch reducing tee which connects to a section of 3-inch PVC pipe. The pipe is connected to a 3-inch wafer type butterfly valve which is used to adjust well vacuum. A section of PVC pipe connects the valve to 3-inch diameter flex connection which is attached to the header with a 3-inch PVC saddle.

Table 2
Vertical Gas Wells

Well Number	Casing Diameter (inch)*	Length (feet)	Spacing (feet)
07-060	4 and 6	60	175
07-070	4 and 6	60	175
07-080	4 and 6	60	175
07-090	4 and 6	60	175
07-100	4 and 6	60	175
07-120	4 and 6	60	175
07-130	4 and 6	60	175

* 4 and 6-inch dia. perforated sections, 4-inch dia. solid riser

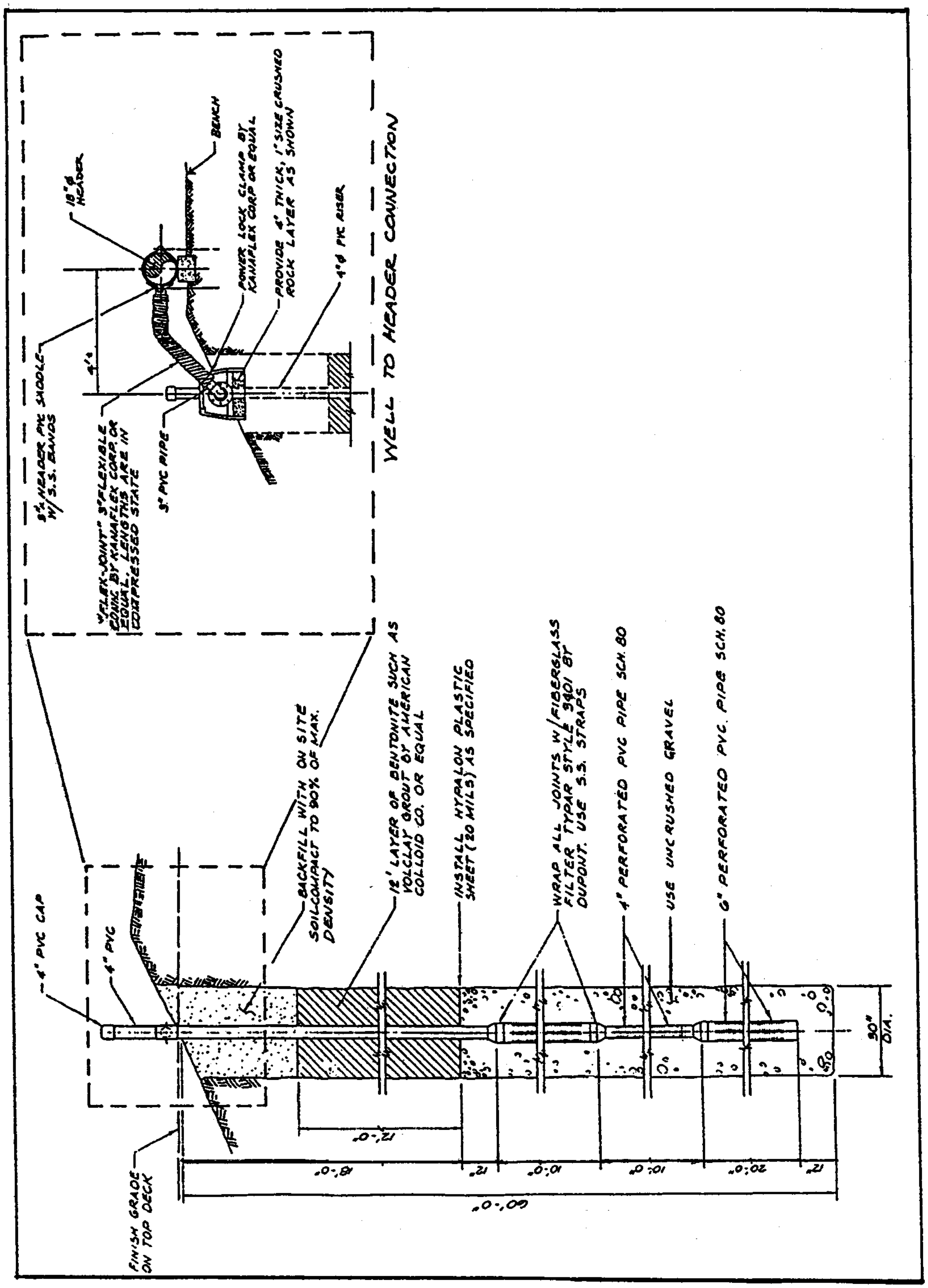

Figure 6. Vertical Gas Collection Well

Operational and Performance Characteristics

Operation

The primary objective in the operation of the SCLF horizontal collectors and vertical gas wells is to control surface gas emissions from the site. To meet this objective, surface gas monitoring results and collector/well operational data (e.g. flow rate, percent methane, percent oxygen, gas temperature, vacuum pressure, etc.) are obtained and reviewed on an ongoing basis. Slight variations in the operational data are corrected as necessary with minor adjustments to the collector/well vacuum. Any significant increase in surface gas emissions would warrant immediate and perhaps more drastic collector/well adjustments.

The 1993 average operational data for the horizontal collectors and vertical gas wells described herein are contained in Tables 3 and 4. Valve position corresponds to valve opening where zero degrees is closed and 90 degrees is wide open. Surface gas monitoring results are presented below.

Performance

In the Los Angeles area, the South Coast Air Quality Management District (SCAQMD) adopted in 1985 a rigorous landfill gas control rule, Rule 1150.1, "Control of Gaseous Emissions from Active Landfills". The rule, with its January 1989 compliance deadline, required the installation of gas collection systems at active sites and the implementation of a field monitoring program. It established a 50 ppm total organic compounds as methane (TOC as methane) limit for average gas emissions measured over the surface of the landfill (integrated surface gas monitoring). Sites complying with Rule 1150.1 are considered as having good gas control with those maintaining emission levels far below the 50 ppm limit having excellent control.

SCLF is located within SCAQMD jurisdiction and it complies with the requirements of Rule 1150.1. In the area along the header bench where the vertical gas wells are located surface

Scholl Canyon Landfill

Table 3
Horizontal Collectors
Average Operational Characteristics - 1993

Collector Number	Valve Position (degrees)	Percent of Time at Position	Average Percent CH_4	Average Percent O_2	Average Flow (cfm)	Average Vacuum (in H_20)	Average Temp. (deg. F)
07-125	15	100	50	0	118	0.6	94
07-115	15	100	50	1	159	0.7	93
07-102	15	100	35	5	117	3.2	95
07-097	15	100	49	1	152	0.6	98
07-095	15	100	45	1	131	0.6	103
07-057	15	56	44	1	115	0.9	90
	0	44	51	1	0	0.1	79

Table 4
Vertical Gas Wells
Average Operational Characteristics - 1993

Gas Well Number	Valve Position (degrees)	Percent of 1993 at that Position	Average Percent CH_4	Average Percent O_2	Average Flow (cfm)	Average Vacuum in. H_20	Average Temp. (deg. F)
07-060	30	27	54	1	37	5.0	95
	15	73	53	1	22	4.0	102
07-070	30	27	40	1	26	8.0	84
	15	73	24	1	11	4.0	94
07-080	15	100	41	2	32	9.0	97
07-090	45	92	54	0	36	2.0	102
	15	8	50	0	33	2.2	99
07-100	30	100	50	1	22	1.0	104
07-110	15	100	28	6	14	0.0	105
07-020	15	100	46	1	21	0.0	115
07-130	15	100	33	4	21	0.0	119

gas emissions since 1990 have stayed at background levels below 5 ppm TOC as methane. In the top deck area covered by the horizontal collectors surface gas emissions have also stayed at background levels below 4 ppm TOC as methane.