Chapter 5
Full-Scale Experiences with Bioreactor Landfills - Case Studies

Introduction

From the technical literature, telephone inquiry of state regulators, and contact with the solid waste community, a number of full-scale landfill bioreactors have been identified. These facilities evolved from demonstration projects completed in the late 1970's and early 80's described in Chapter 4 which provided essential information for the planning, design, and operation of new generation facilities. A description of many of these sites is provided below. A summary of leachate management data is provided in Table 5-1.

Southwest Landfill, Alachua County, Florida

The active Alachua County Southwest Landfill is a 10.9-ha (27-acre) composite-lined (0.15-cm (60-mil) HDPE over 30 cm (1 ft) of clay) facility located in north central Florida. Waste was first accepted in the spring of 1988 and the facility continues to receive approximately 900 metric tons (10,000 tons) of MSW per month. Maximum landfill depth will be approximately 20 m (65 ft). The landfill is permitted to recirculate up to 230 m^3/d (60,000 gpd). Leachate drains by gravity through a leachate collection system to a sump and is pumped to four 340-m^3 (90,000-gal) storage tanks. Excess leachate is treated using a high lime precipitation process and transported by truck to a local wastewater treatment facility.

Leachate recirculation began in September 1990 through the use of infiltration ponds (see Figure 5-1). A section of the landfill was purposely not exposed to leachate recirculation to provide a comparison to the test area. Over 30 million liters (8 million gal) of leachate were recycled to the landfill through the pond system from 1990 through 1992. Infiltration rates averaged between 5.3 and 7.7 l/m^2/day (0.13 to 0.19 gal/ft^2/day) (Miller, et al, 1993).

An alternative leachate recirculation system was constructed in early 1993, providing direct injection of leachate into the landfill lifts as they were constructed (see Figure 5-2). Horizontal pipes have been placed in 2.4-m (8-ft) wide and 120 to 210-m (400 to 700-ft) long trenches filled with tire chips. The first trench is 6 m (20 ft) above the liner with subsequent trenches added at vertical intervals of 6 m (20 ft) and horizontal intervals of 15 m (50 ft) for a total of 17 laterals. Each lateral has been valved separately to allow rotation of leachate introduction. Leachate was first introduced to the injection system in February, 1993. Just over 7.6 million liters (2 million gal) were pumped to the first two laterals over a period of six weeks (310 to 620 l/day per m of trench (25 to 50 gpd/ft)) at

Table 5-1. Full-Scale Leachate Recirculating Landfill Water Balance Data*

Site	Leachate Production, m^3/ha/d (gal/acre/d)	Leachate Recirculation, m^3/ha/d (gal/acre/d)	External Storage, m^3/ha (gal/acre)	Off Site Treatment, m^3/ha/d (gal/acre/d)	Design Area, ha (acres)	Active Area, ha (acres)
Alachua County	7.8 (837)	4.3 (4602)	124 (13300)	4.3 (460)	11 (27)	11 (27)
Worcester County	2.6 (275)	2.1 (230)	220 (23500)	0.64 (68)	6.9 (17)	6.9 (17)
Winfield County	19 (2000)	14 (1500)	67 (7100)	0.55 (59)	2.8 (7)	2.8 (7)
Pecan Row	2.7 (290)	1.1 (120)	690 (73600)	0	16 (40)	4.5 (11)
Lower Mt. Washington Valley	15 (1600)	9.5 (1000)	12 (1250)	4.2 (450)	3.2 (8)	0.45 (1.1)
CRSWMA	17 (1800)	12 (1200)	1600 (171000)	0	8.9 (22)	5.7 (14)
Lemons	2.2 (240)†	5 (540)	110 (11600)	NA	30 (75)	NA
Mill Seat						
Test Cell 2	2.8 (300)†	6.8 (720)	35 (3700)	NA	2.8 (6.9)	NA
Test Cell 3	2.8 (300)†	5.2 (560)	41 (4300)	NA	2.2 (5.4)	NA

*Based on current operational area

† Estimated Using the Hydrologic Evaluation of Landfill Performance Model, excludes recirculated flow

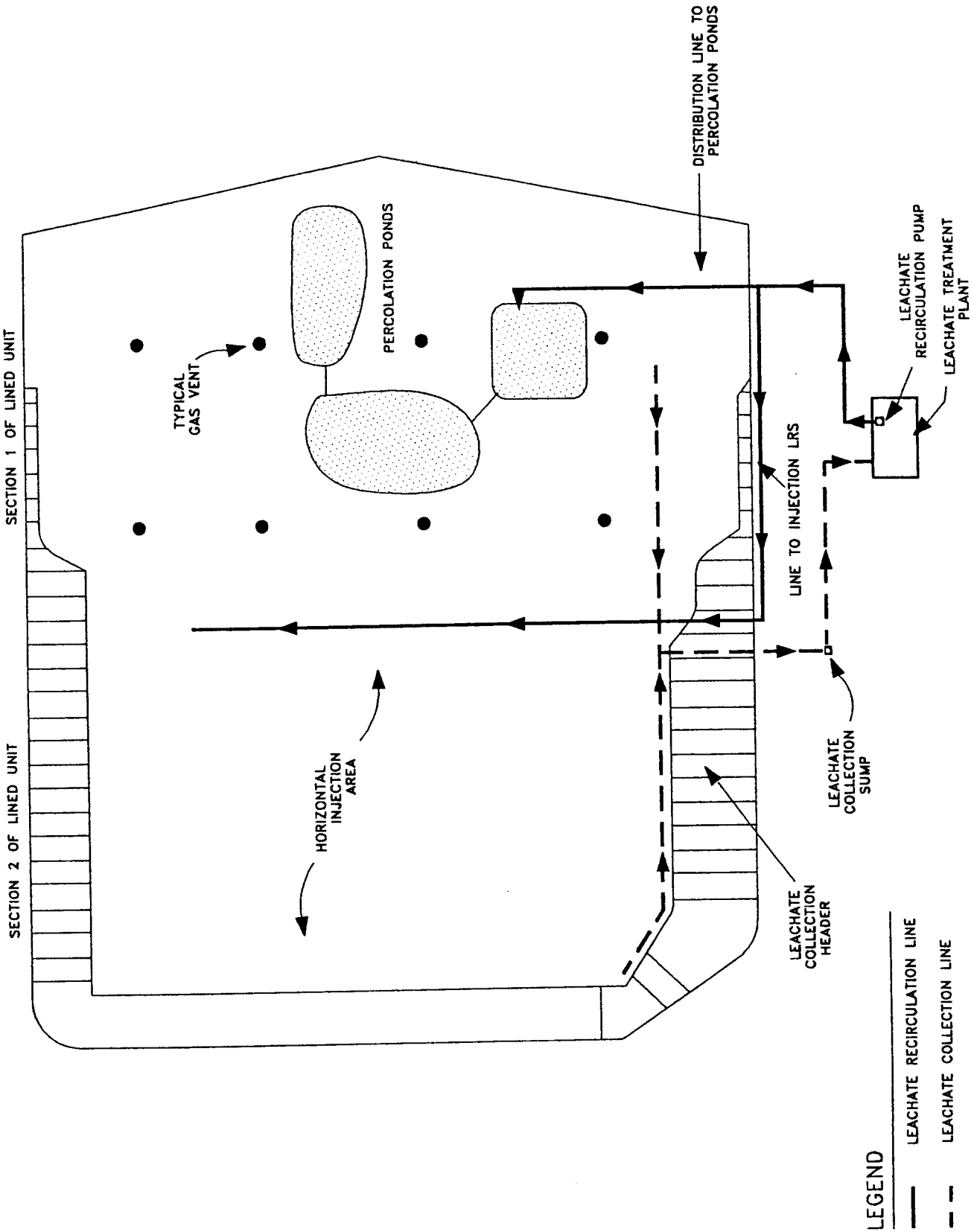


Figure 5-1. Leachate recirculation system, Alachua County, FL Southwest Landfill.

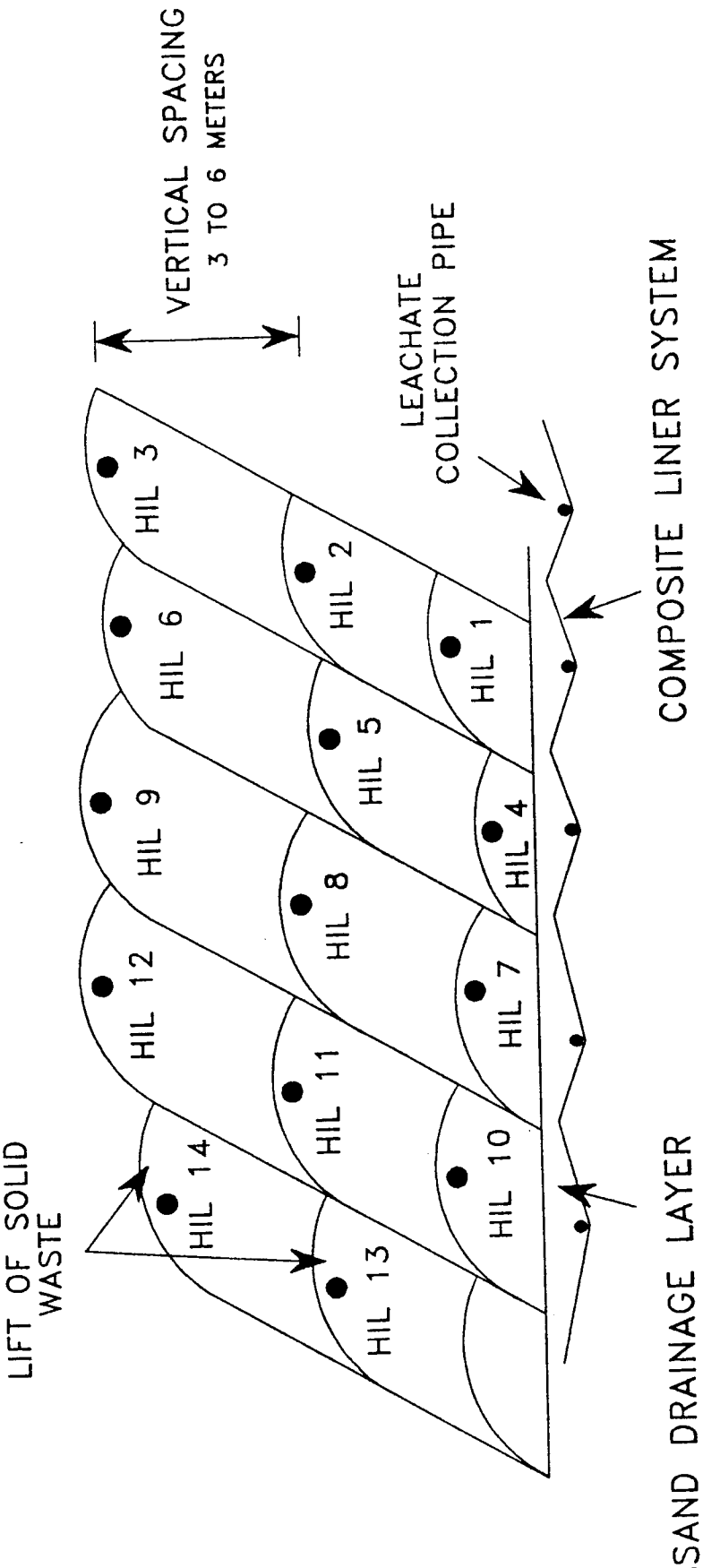


Figure 5-2. Horizontal injection system (HIL), Alachua County, FL Southwest Landfill.

a rate of 230 to 380 lpm (60 to 100 gpm) without experiencing pump discharge pressure exceeding 55 kPa (8 psi). Unlike the ponds, a direct impact on leachate quality and quantity was observed following continuous pumping to the trenches at the initial high rates. From March through September 1993, 760 to 3000 m^3/month (200,000 to 780,000 gal/month) were introduced to individual laterals, and no impact on leachate quality was noted. Recirculation laterals were connected to the landfill gas recovery system in early 1994 to permit extraction of gas during the active landfill phase.

Central Facility Landfill, Worcester County, Maryland

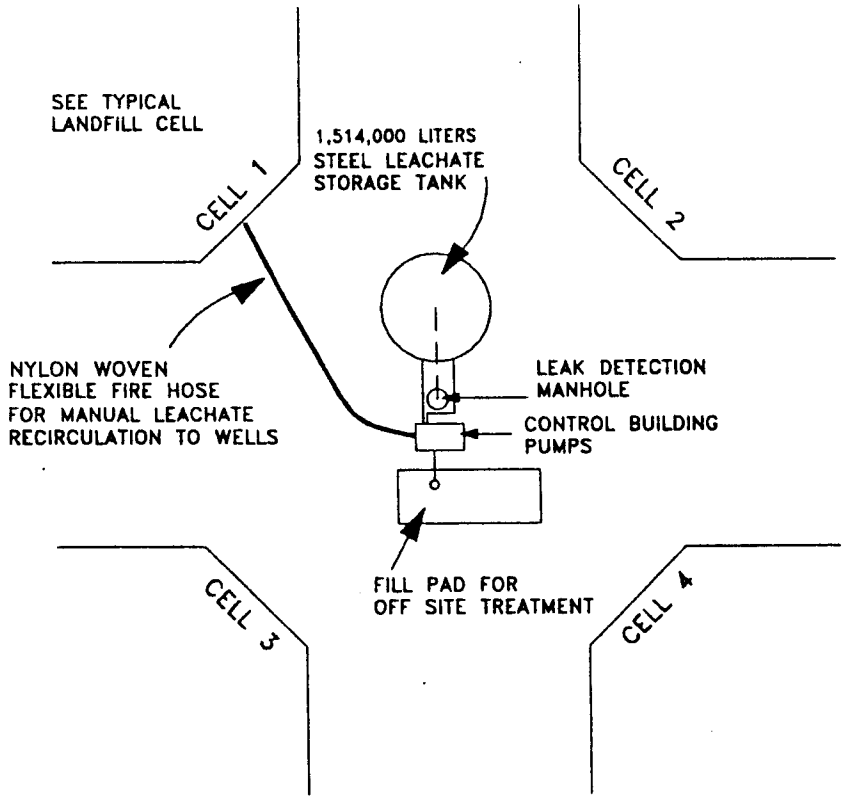
The Central Facility Landfill, located in Worcester County, Maryland, was constructed in the late 1980s and began operation in 1990. Initially, the first of four 6.9-ha (17-acre) cells was constructed (see Figure 5-3). Maximum fill height will be 27 m (90 ft). Waste receipt averages 180 TPD (200 tpd). The cell is lined with a 0.15-cm (60-mil) HDPE geomembrane installed on top of natural clay soil. Leachate drains through pea gravel to 15-cm (6-inch) perforated polyvinyl chloride (PVC) pipes which carry the leachate to sumps located at the four corners of the cell. Leachate is pumped to a 1500-m^3 (400,000 gal) steel storage tank.

Leachate recirculation is accomplished using vertical discharge wells constructed using 1.2-m (four-ft) diameter perforated concrete manhole sections. The first 2.4-m (eight-ft) section rests on a concrete base and is filled with concrete to prevent shortcircuiting of leachate. Subsequent sections are added at each waste lift, then filled with gravel. A 5-cm (two-in) PVC standpipe is installed within each well to vent gas and permit monitoring of water depth. A schematic of the vertical well used at the Central Facility Landfill is provided in Figure 5-4. Each well serves a 0.8-ha (two-acre) area. Leachate is pumped to the fill using flexible fire hose which can be dragged to the wells. Surface ponds are also permitted by the state to reintroduce leachate. Usually these ponds are constructed around the wells and isolated by berms. Estimated construction costs for recirculation facilities were $26,000 (1989 dollars).

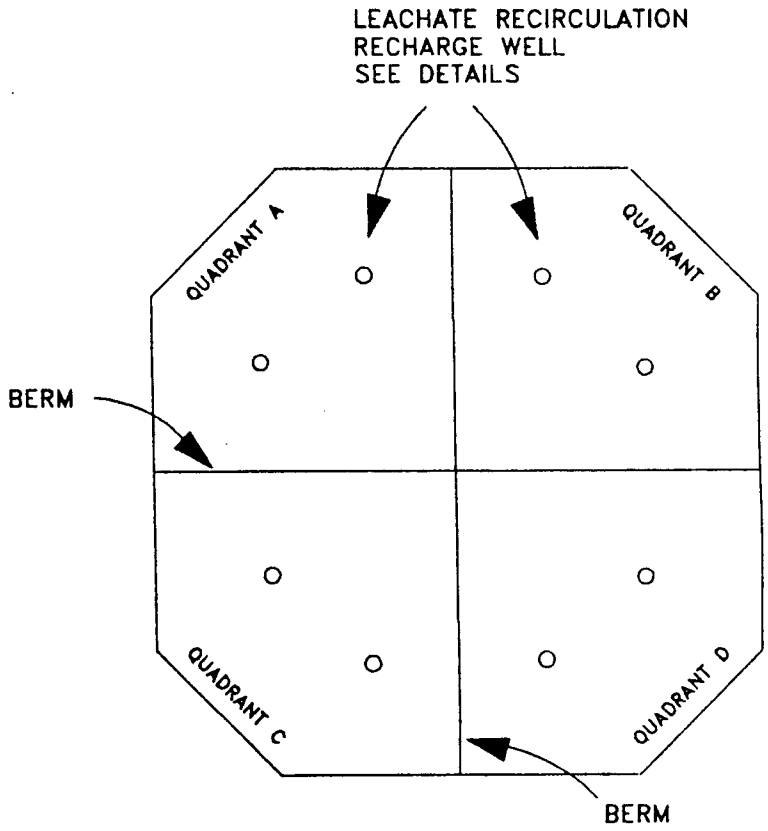
Excess leachate is transported by truck to a local wastewater treatment facility. While minimal off-site treatment has been required, the landfill operators expressed the opinion that the wells have limited impact area and recommended modifications which would move leachate laterally away from the wells.

Winfield Landfill, Columbia County, Florida

The Winfield Landfill located in Columbia County, Florida, opened in September of 1992. The double-liner system provided is composed of a 46-cm (18-in) drainage layer, 0.15-cm (60-mil) HDPE geomembrane, and leachate detection system installed over an 46-cm (18-in) clay soil liner, hydraulic conductivity 10^{-8} cm/sec. The cell is located above natural clay soils. The cell slopes to the southwest to convey leachate to a single corner sump. The present cell area (Spring 1995) is 2.8 ha (seven acres) with plans for an ultimate footprint of 8.9 ha (22 acres) in four expansion steps. Total depth is planned for 16 m (54 ft) providing 30 to 40 years of disposal capacity. Waste receipt averages approximately 49 TPD (120 tpd).



LEACHATE COLLECTION SITE (NTS)



TYPICAL LANDFILL CELL (NTS)

6.9 HECTARES

Figure 5-3. Leachate recirculation system,Worcester County, Maryland Landfill.

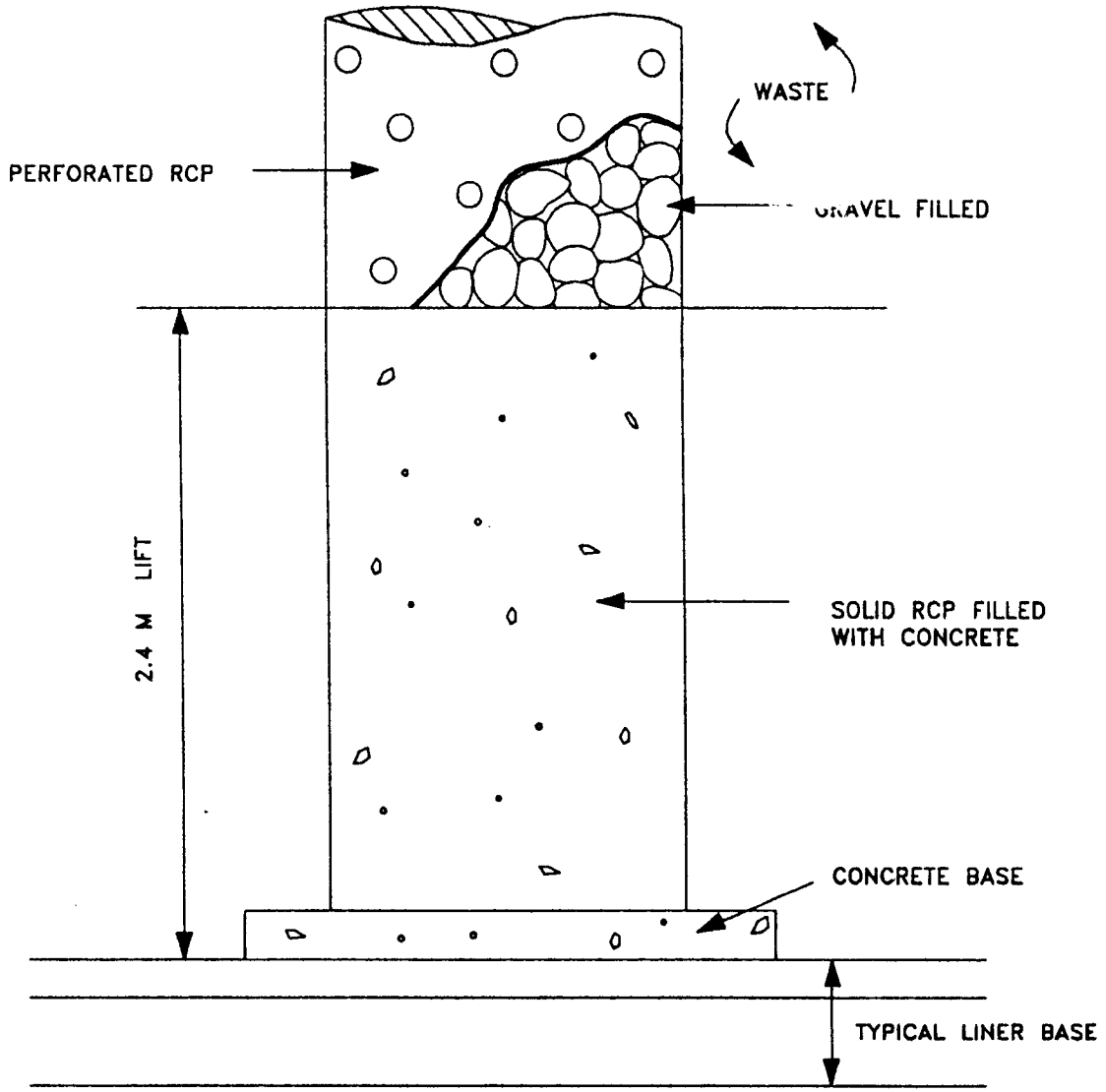


Figure 5-4 Vertical leachate recharge well, Worcester County, Maryland Landfill.

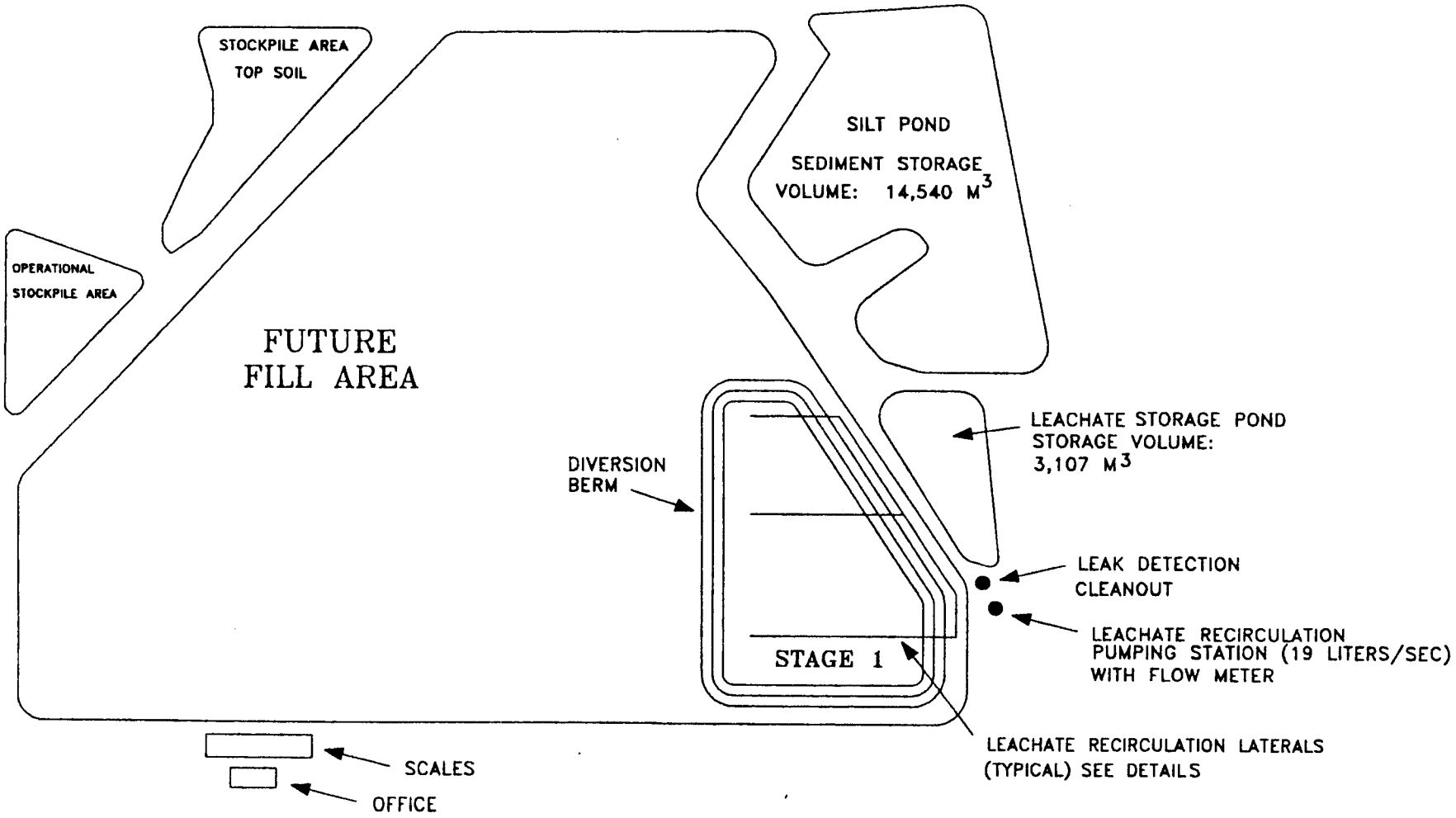


Figure 5-5 Pecan Row Landfill (Valdosta, GA).

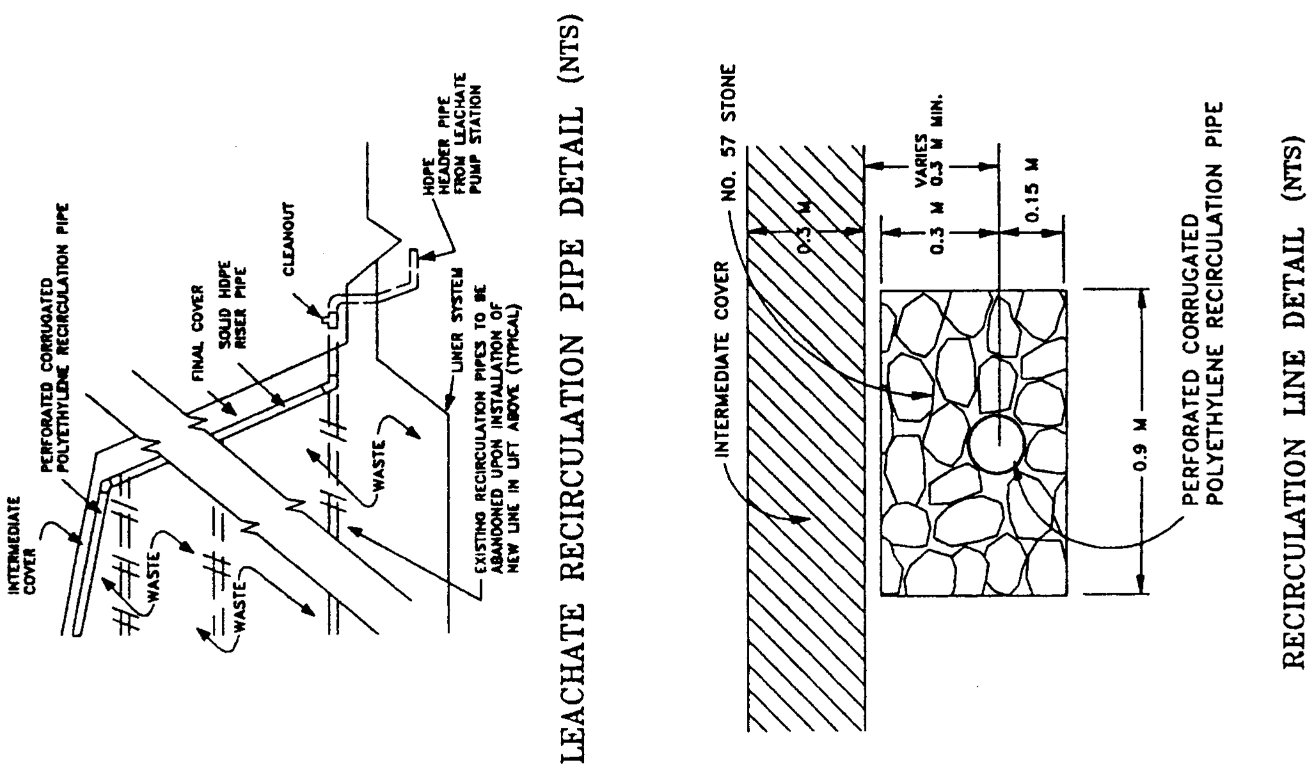


Figure 5-6. Pecan Row Landfill (Valdosta, GA) recirculation line detail.

It was observed that once the waste has been thoroughly wetted, an immediate impact on pond level can be seen following each subsequent pumping. Difficulty was encountered in recirculating during early operational phases when insufficient waste was available to absorb the moisture. Also, recirculation near the waste surface or slope led to leachate outbreaks.

Lower Mount Washington Valley Secure Landfill, Conway, New Hampshire

The Lower Mount Washington Valley Secure Landfill, located in Conway, New Hampshire is composed of eight hydraulically separated double-lined landfill cells (0.3 to 0.4 ha (0.75 to 1.0 acres)). Cell construction was completed in late 1991, with operations commencing in January of 1992. Waste receipt averages between 9,100 and 13,600 metric tons/year (10,000 and 15,000 tons/year). Leachate is stored in a 38-m^3 (10,000-gal) leachate collection tank.

Leachate recirculation began in May of 1992 at the first of eight cells, four months after start up. The primary mode of leachate recirculation was manual prewetting of waste using a fire hose to improve compaction and efficiently wet the waste. In addition, recirculation has been accomplished using a fabricated PVC pipe manifold placed in a shallow excavation of the daily cover.

In order to minimize lateral movement of leachate, horizontal trenches were installed on waste slopes for leachate recirculation into these areas. The trenches were 1.4 to 1.8 m (four to six ft) deep, 0.9 to 1.2 m (three to four ft) wide, and 2.4 to 4.6 m (eight to 15 ft) long. However, shortcircuiting resulted due to the proximity of the sand drainage layer and this practiced was discontinued. High leachate generation rates were experienced during the spring of 1993, which were attributed to saturation of the fill while recirculating during the previous fall and winter, followed by freezing and then the spring thaw. Consequently, leachate recirculation was temporarily discontinued in November of 1993. To date, leachate recirculation has not resulted in excessive head on the liner. Efforts have been made to minimize precipitation infiltration through the use of alternative daily cover and to maximize use of waste moisture holding capacity. Gas measurements suggested that leachate recirculation stimulated biodegradation of waste.

Coastal Regional Solid Waste Management Authority Landfill, Craven County, North Carolina

The Coastal Regional Solid Waste Management Authority Landfill serves three counties along the eastern coast of North Carolina. Waste receipt averages around 320 TPD (350 tpd). The 8.9-ha (22-acre) landfill is divided into three hydraulically separated cells of approximately equal surface area. Final height is expected to be around 15 m (50 ft). A composite liner composed of 0.6 m (2 ft) of drainage sand, a fabric filter, and a 0.15-cm (60-mil) HDPE liner overlying 0.6 m (2 ft) of low permeability clay was provided. A drainage system was installed beneath the liner system to protect the liner during periods of high groundwater level. Weekly cover consists of local sandy soils. The active face is covered daily with reusable tarp. Leachate from each cell drains by gravity to manholes which are connected to a common sump. Leachate is pumped from the sump to one of two 4.5-million liter (1.2-MG) lined lagoons (4.6 m (fifteen ft) maximum depth). Each lagoon is equipped with two floating mechanical aerators to provide oxygen for biological treatment of leachate.

Leachate is pumped back to the first lift of waste (depth approximately 4.6 m (15 ft)) through 500 ft of flexible hose feeding a movable vertical injection system. A steel manifold distributes leachate through twelve flexible lines to shallow black iron probes inserted into the landfill surface. Flow to each line is controlled by individual ball valves. Initially, the 1.9-cm (3/4-in) diameter probes were 1.5 m (five ft) in length with 0.32-cm (1/8-in) diameter holes drilled within 0.76 m (2.5 ft) of the bottom of the pipes. Probes are installed by driving solid pipes of similar diameter into the ground to form a hole and then inserting the probes. Early use of these probes resulted in leachate breakout at the slopes. Longer probes (three m (ten ft)) were fabricated to minimize breakout. The diameter was increased to 3.2 m (1.25 in) with 0.64-cm (1/4-in) diameter holes. Breakouts continue to occur occasionally. Leachate recirculation pump flow rates vary between 200 and 300 lpm (55 and 80 gpm) to an area approximately 30 m by 30 m (100 ft by 100 ft). Once leachate is observed at the surface near the probes, the system is moved. Generally, the system stays in any one location for two to eight days. Pressure at the recirculation manifold is monitored and remains around 310 kPa (45 psi).

Once the entire first lift is completed, horizontal trenches will be constructed in a pattern radiating out from a central distribution box fed by the leachate recirculation pump. The horizontal system will be used until the second lift is completed at which time a new distribution system will be installed and the first system will be abandoned. This procedure will continue until the fourth and final lift is completed and the landfill is closed.

Lemons Landfill, Stoddard County, Missouri

The Lemons Landfill, owned and operated by the Lemons Landfill Corporation, is located on a 66-ha (162-acre) site in Stoddard County, Missouri. Fill area at build-out will be 30 ha (75 acres). Maximum depth will be 26 m (85 ft). Waste is received at a rate of approximately 270 TPD (300 tpd). The landfill was constructed in 1993 and began operating in October of that year.

A composite liner was provided, composed of a 0.15-cm (60-mil) PVC geomembrane on top of 0.6 m (2 ft) of compacted bentonite/soil, overlain with 30 cm (12 in) of pea gravel and perforated PVC piping for conveyance of leachate. Leachate is collected in two ponds which provide total storage of 3,280 m^3 (867,800 gal). Figure 5-7 provides a schematic of the leachate management system.

Leachate recirculation will be accomplished using vertical wells located at 61-m (200-ft) spacing within the fill area (see Figure 5-8). Recirculation will be delayed until the area is filled and temporarily capped with 0.6 m (two ft) of clay. Recirculation is expected to commence approximately one year following initial waste receipt. The leachate recirculation well is constructed from a 1.2-m (48-in) diameter precast perforated concrete pipe filled with five to ten-cm (two to four-in) diameter stone. Within the structure are 30-cm (12-in) bentonite caps separating the well into three sections. PVC pipes (10-cm (four-in) diameter) are inserted into the wells reaching each of the three sections. The well structure rests on a 1.8-m (six-ft) square concrete pedestal underlain with a three-m (ten-ft) square, handtamped clay pad. Leachate distribution is supplemented by recharge laterals (7.5-cm (3-in) diameter PVC slotted pipe placed in 30-cm by 46-cm (12-in by 18-in) trenches) radiating out from each well at two depths.

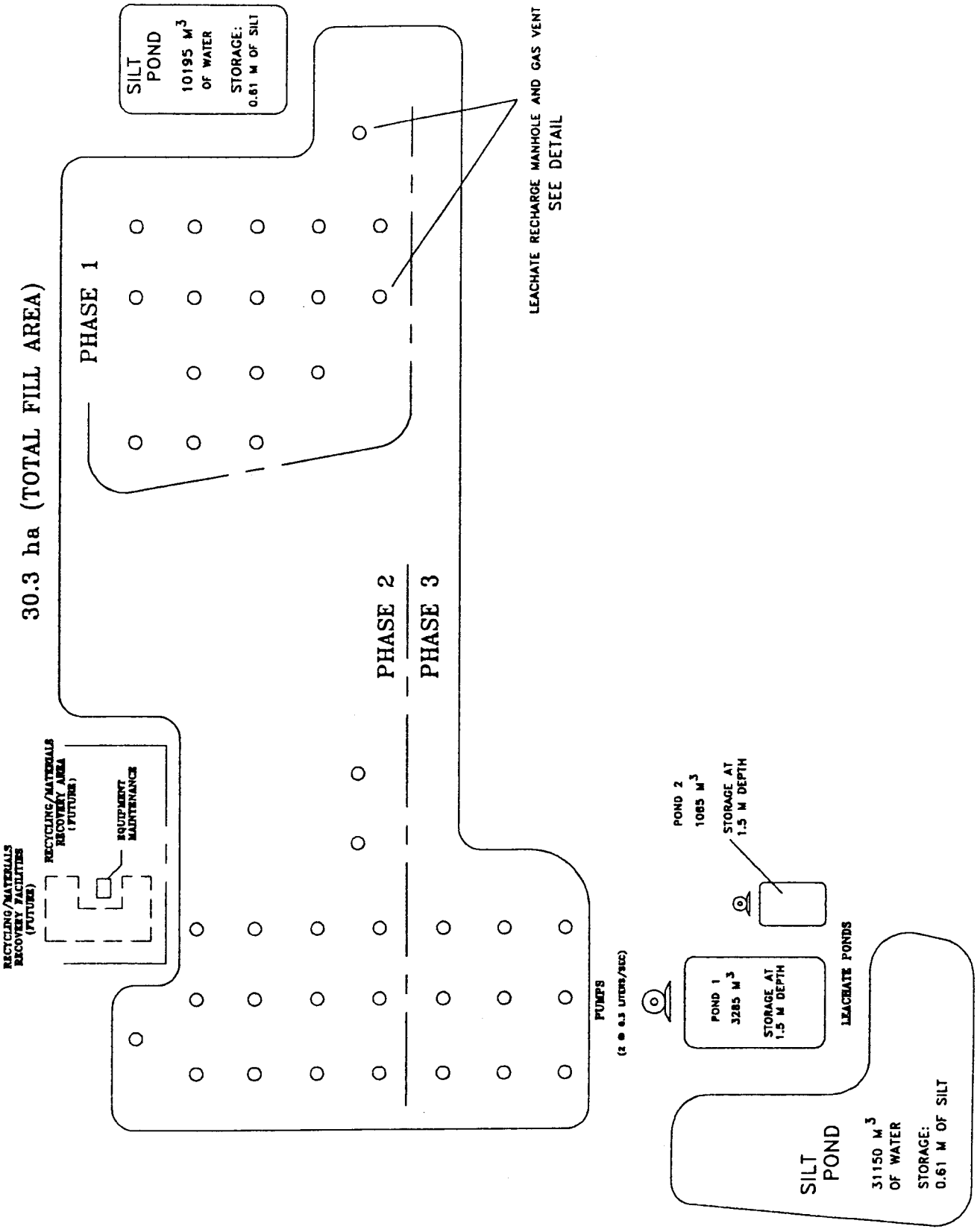
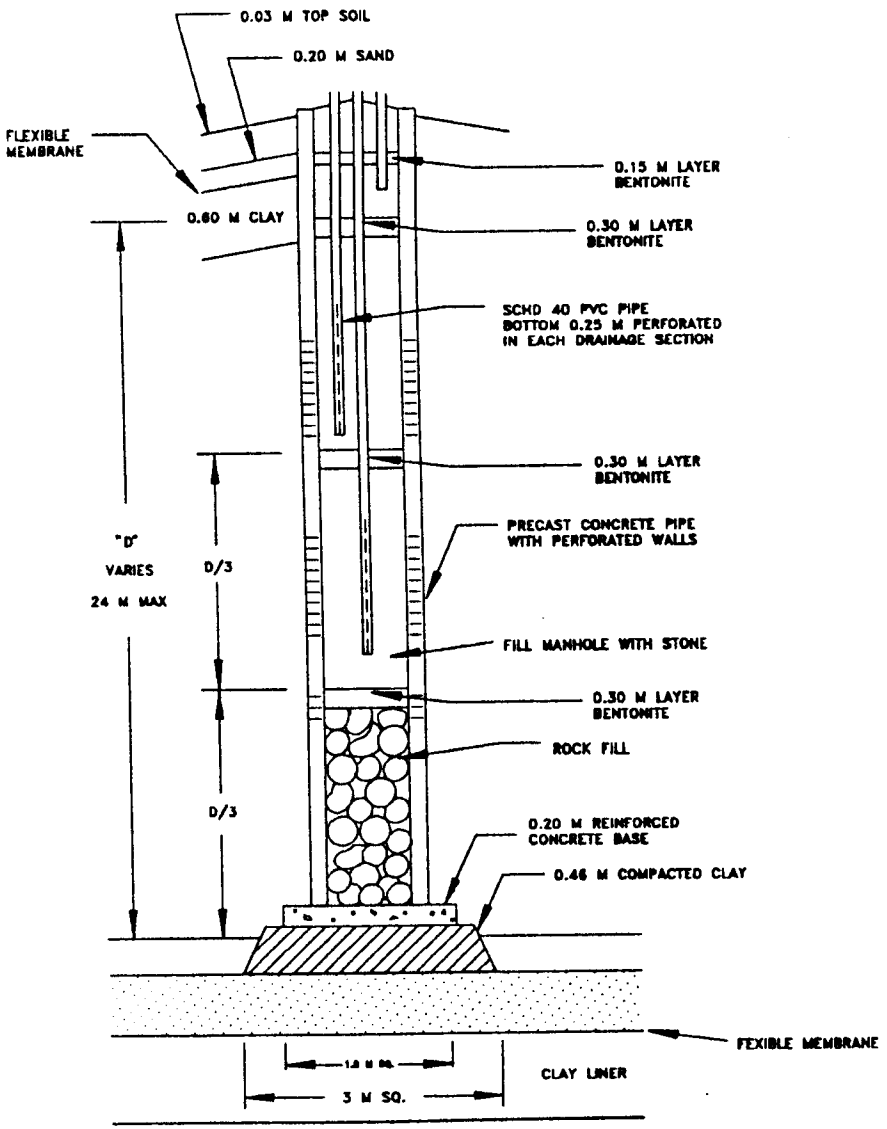
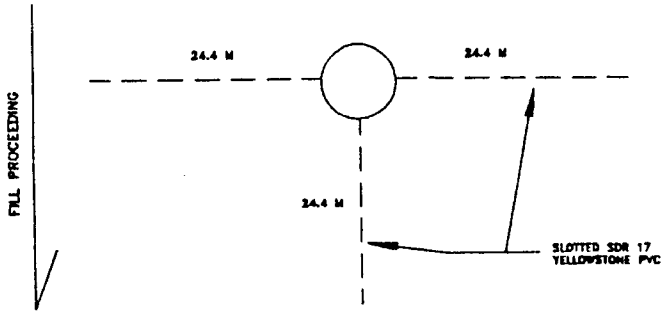


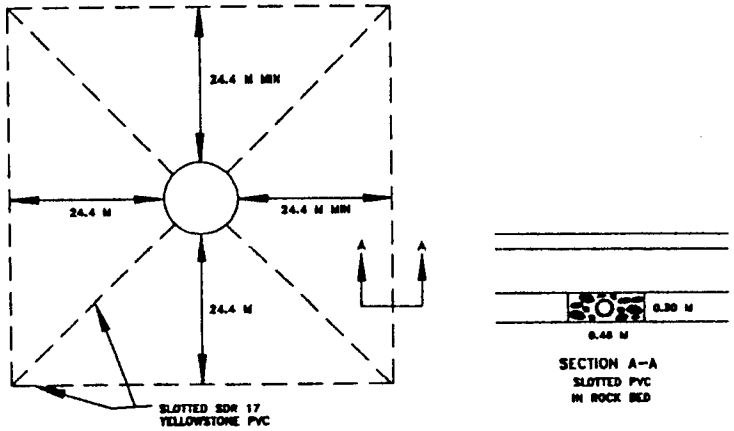
Figure 5-7. Lemon Landfill (Dexter, MO).



LEACHATE RECHARGE
MANHOLE AND GAS VENT



INTERMEDIATE RECHARGE LATERALS
(NTS)



TOP LAYER OF RECHARGE LATERALS

Figure 5-8. Lemon Landfill (Dexter, MO) leachate recirculation details.

Once leachate recirculation commences it will be collected in the first of two available storage ponds. Recirculation will continue until leachate strength is significantly reduced. At this point, leachate will be diverted to the second pond and subsequently used to irrigate completed areas of the fill (capped with 0.6 cm (two ft) of clay, 0.075-cm (30-mil) PVC geomembrane, and 0.3 m (one ft) of topsoil and seeded).

Mill Seat Landfill, Monroe County, New York

The Mill Seat Landfill, located in western New York near Rochester is hosting a bioreactor research project involving the design, construction, and monitoring of leachate recirculation in three hydraulically separated double composite-lined cells. One cell (three ha (7.4 acres)) serves as a control (gas collection only) while two test cells (2.8 ha (6.9 acres) and 2.2 ha (5.4 acres) respectively) use two different recirculation techniques. Leachate pH control will be instituted if necessary. The test cells will provide an opportunity to evaluate effects of leachate recirculation on the rate of waste stabilization, the quality of the leachate produced, and the volume of methane emitted. The three test cells comprise Stage I of the landfill which will ultimately have a 38-ha (95-acre) foot print and a total waste depth of up to 34 m (110 ft).

Leachate recirculation is accomplished using two different horizontal introduction systems The systems are shown schematically at multiple elevations in Figures 5-9 through 5-11. The first system, installed in Test Cell 2, uses three pressurized loops constructed from ten-cm (four-in) diameter perforated HDPE pipe laid in trenches filled with crushed cullet, tire chips, or other permeable material. The loops have been provided at three elevations within the cell. Collected leachate will be directed to tanks providing a total of 110 m^3 (30,000 gal) of storage from which it will be pumped back to the pressurized loop system.

The second recirculation technique used in Test Cell 3, provides 1.3-m (4-ft) wide by three-m (10-ft) deep horizontal trenches filled with permeable wastes and installed at two elevations. Prefabricated infiltrators placed within the trenches will enhance leachate distribution. As waste is placed on top of the trenches, chimneys will be constructed to allow continued feeding of leachate to the trenches (see Figure 5-12). Leachate will be introduced to the vertical chimney/wells via a tanker truck and pump. Leachate from Test Cell 3 is directed to tanks providing 76 m^3 (20,000 gal) storage. Prewetting of waste on occasion using water distribution trucks will also be practiced.

Recirculation rates are expected to be between 20 and 110 m^3/d (5,000 and 30,000 gpd). The relative moisture content of the waste will be monitored using gypsum blocks located in situ at depths of 11, 20, and 30 m (35, 65, and 95 ft) above the landfill liner. However, due to premature wetting of the blocks during waste filling, this system has not yielded any data. Gas recovery will be accomplished from both the pressurized loop system and the chimneys. In addition, vertical gas wells will be installed at closure. Gas will be either flared or used to generate electricity.

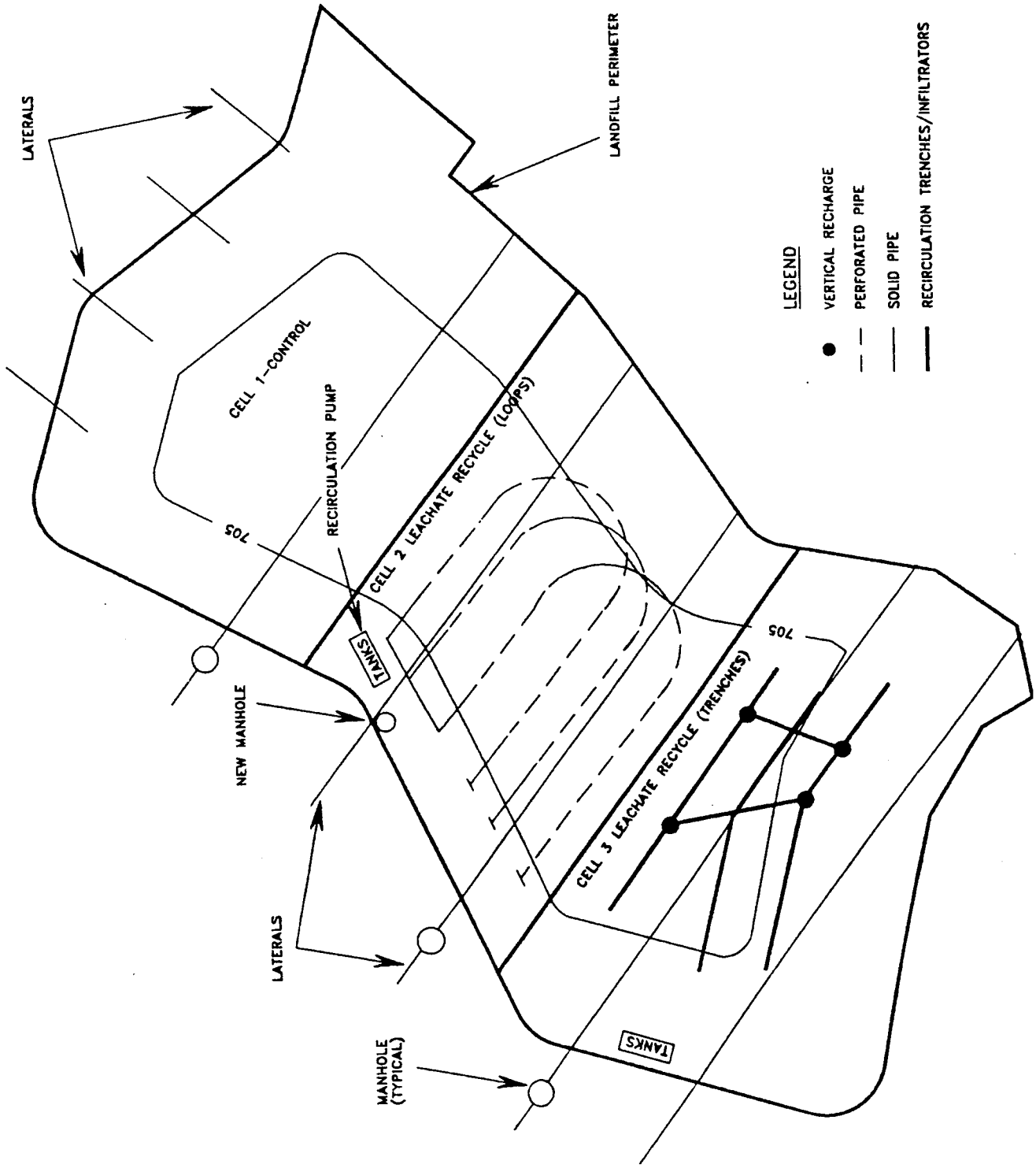


Figure 5-9. Mills Seat Landfill (Rochester, NY) recirculation layout (elevation 215 m).

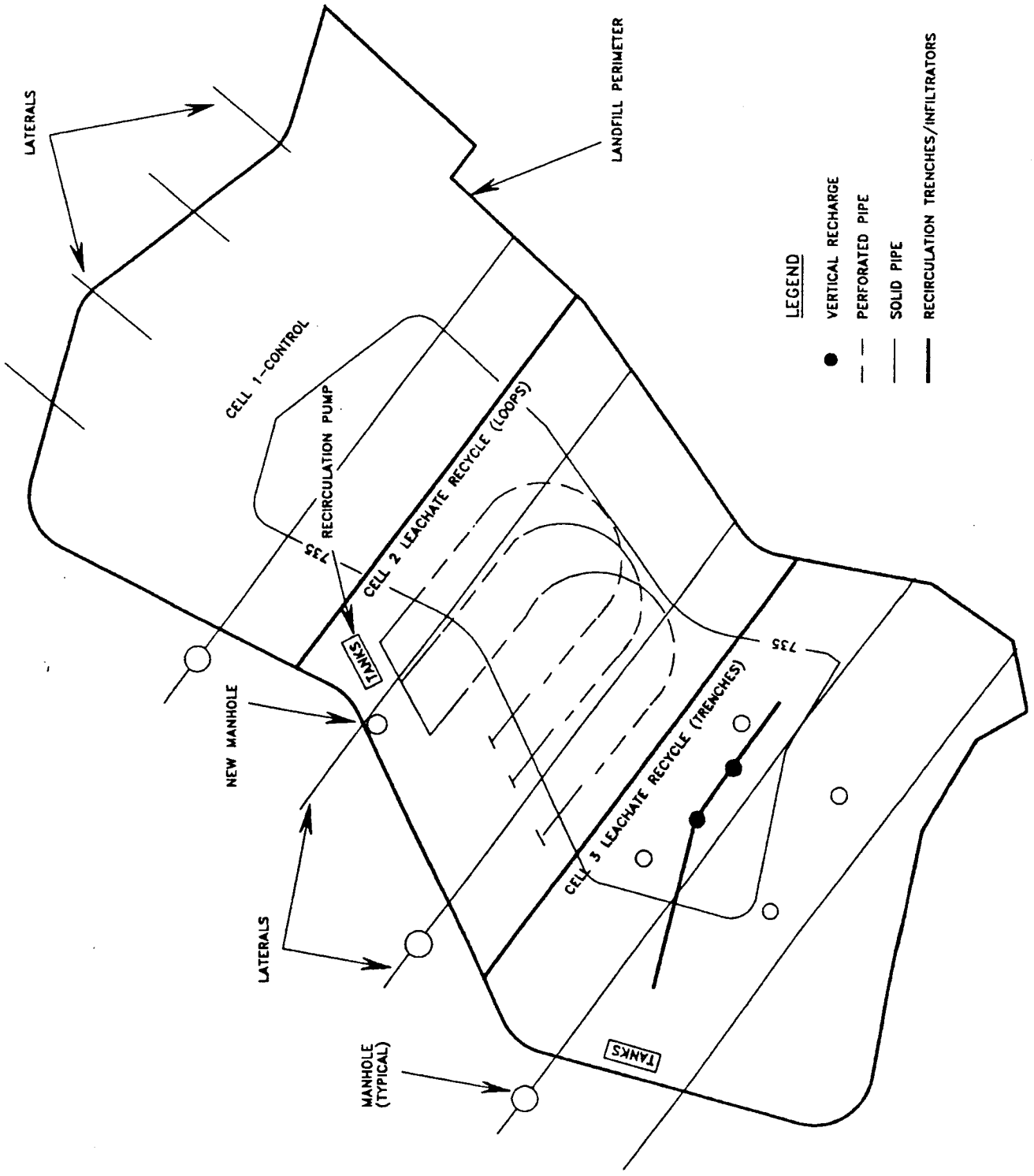


Figure 5-10. Mills Seat Landfill (Rochester, NY) recirculation layout (elevation 224 m).

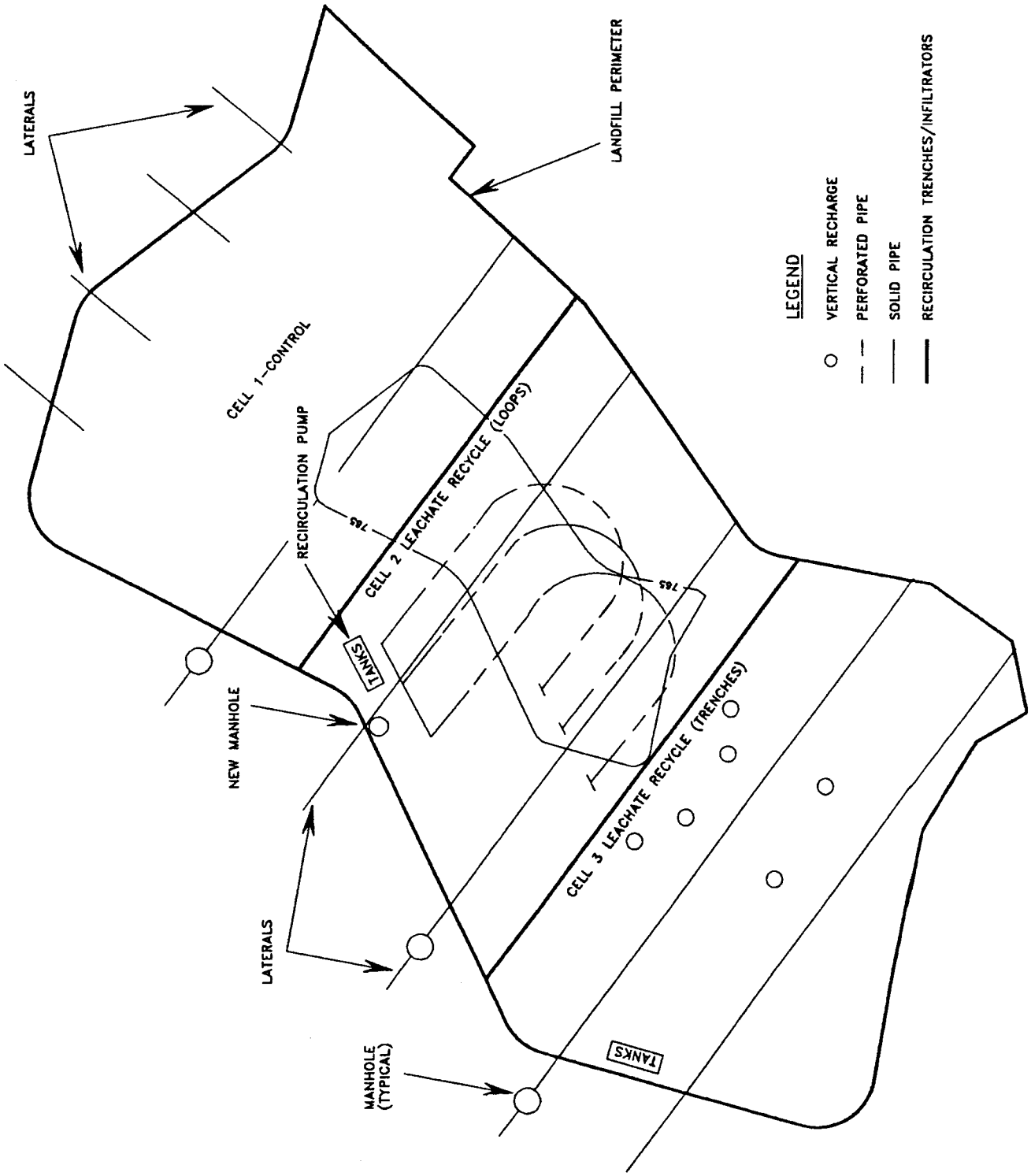


Figure 5-11. Mills Seat Landfill (Rochester, NY) recirculation layout (elevation 233 m).

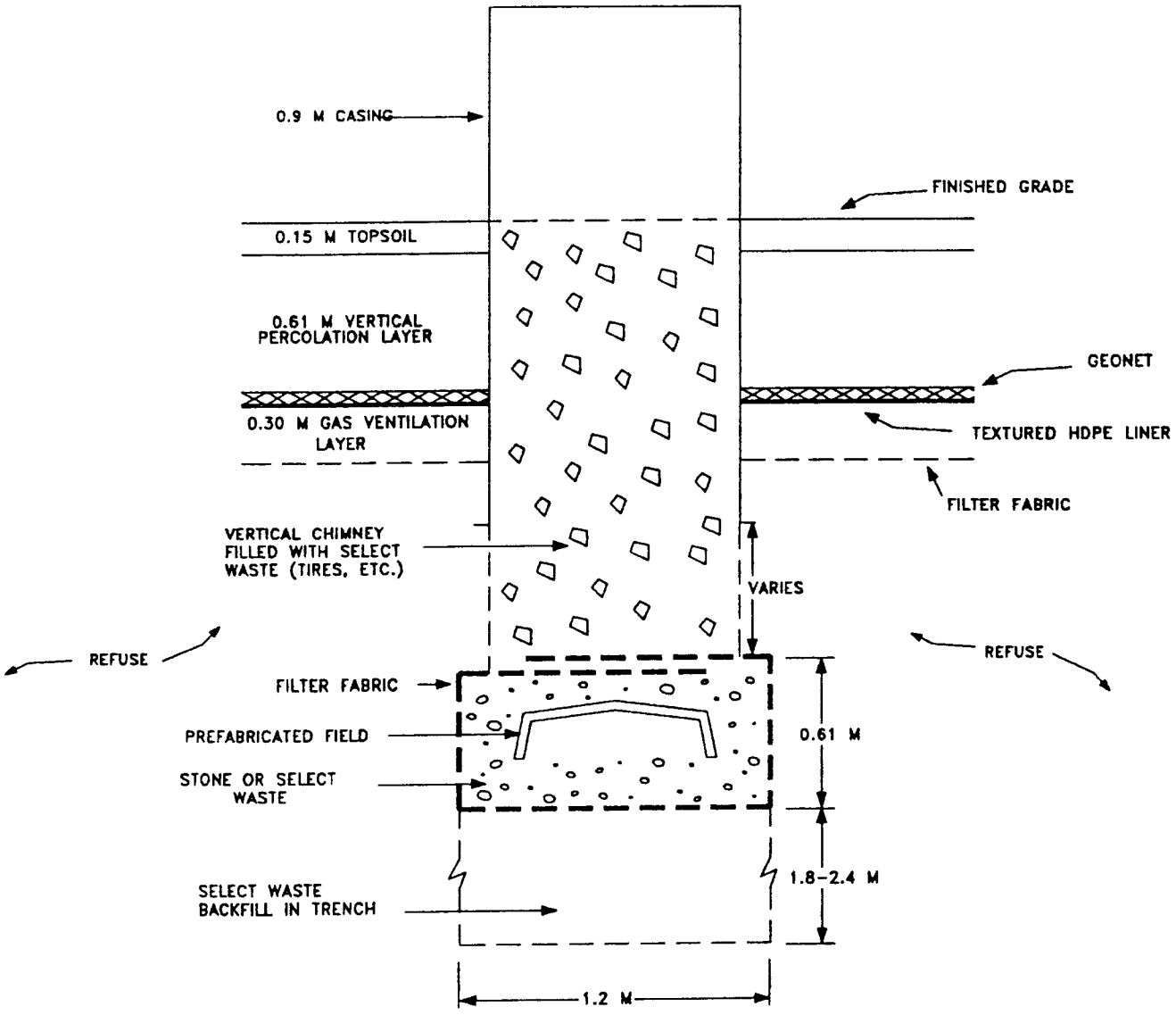


Figure 5-11. Mills Seat Landfill (Rochester, NY) prefabricated horizontal infiltration field with chimney

Yolo County Landfill, California

A demonstration initiative in Yolo County, California, funded by local and state governments was designed and constructed in 1993. Two, hydraulically separated 30 m by 30 m (100 ft by 100 ft) cells have been constructed to investigate impacts of leachate recirculation (see Figure 5-13). Leachate is introduced through a leach field at the top of one of the 12-m (40-ft) deep cells. The second cell will serve as a control. The control cell has a single composite liner, while the recirculation cell was constructed with a double composite liner. The bottom composite layer consists of 0.6 m (2 ft) of compacted clay, a 0.15-cm (60-milk) geomembrane, a drainage net, and geotextile. The top liner is composed of 30 cm (one ft) of compacted clay, a 0.15-cm (60-mil) geomembrane, drainage net, and geotextile. Independent leachate collection and removal systems have been provided.

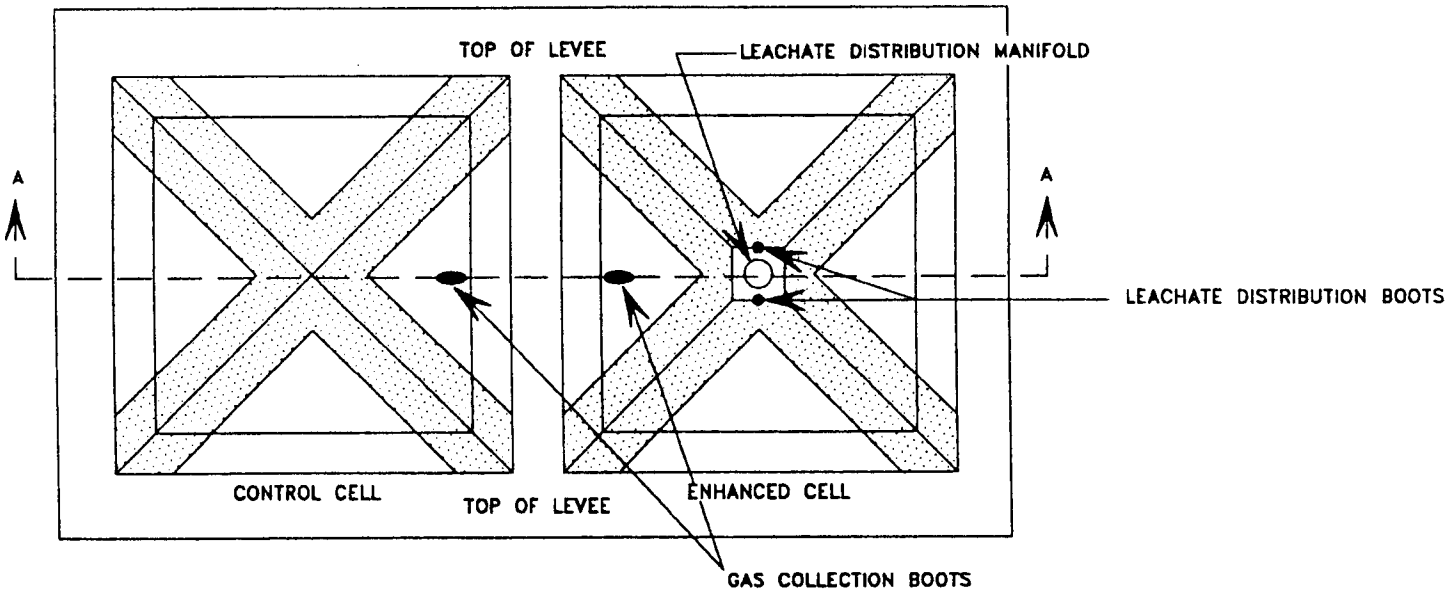
Leachate is pumped to a distribution manifold located at the top of the test cell. (See Figure 5-14.) From the manifold, leachate is introduced at 25 locations across the surface through leachate injection pipes imbedded in a 1.5-m (five-ft) deep tire chip-filled injection pit. Warming of recirculated leachate and pH buffering are being considered as additional enhancement efforts. Within the fill, pressure transducers to monitor hydraulic head, temperature probes, and survey monuments to monitor settlement have been provided.

Additional Full-Scale Efforts

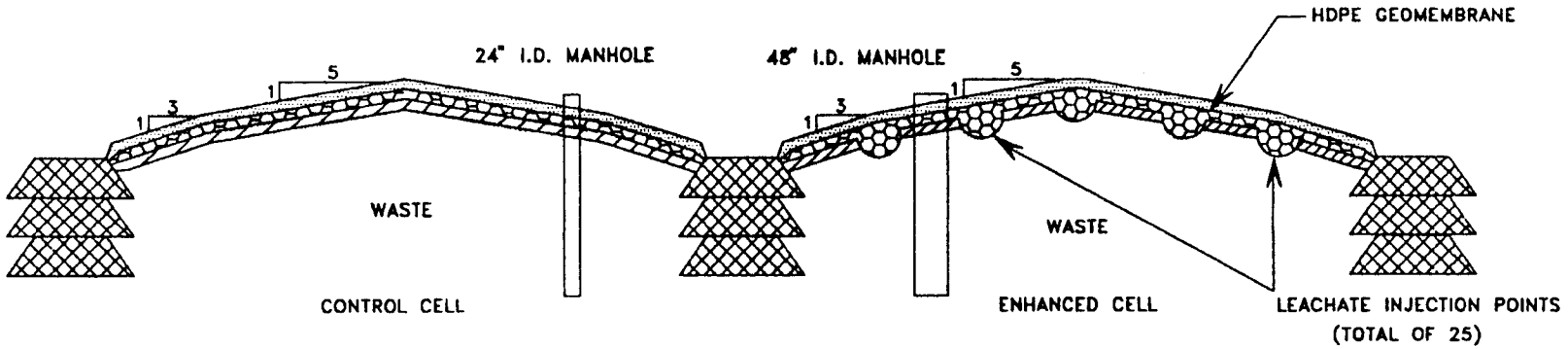
Leachate has been recirculated at the Fresh Kills Landfill on Staten Island, New York since 1986. The landfill is not lined (although it is underlain by a thick layer of low permeability natural clays) and has no leachate collection system, therefore recirculation was discontinued in late 1993. Seeps at the toe of the landfill required the installation of French drains constructed of crushed stone surrounding perforated pipe all wrapped in filter fabric. Collected leachate was pumped to the top of the landfill to a seep field dug into the waste and constructed in a similar fashion to the drain system. Each seep field served a 15 by 15-m (50 by 50-ft) area and was valved so that recirculation could be rotated from one area to another. An estimated 530 m^3/d (140,000 gpd) were recirculated to an area of 20 to 34 ha (50 to 60 acres) averaging 24 m^3/ha/d (2500 gal/acre/d). No clogging of the crushed stone was observed after operating for 5 years.

Recirculation is also practiced at the Gallatin National Balefill in Fairview, Illinois, where leachate is sprayed daily onto exposed waste surfaces using a water truck. In addition, perforated piping is installed at several elevations to provide a distribution network which will double as a horizontal gas extraction well. The Kootenai County Fighting Creek Landfill in Idaho uses two systems for reapplying leachate. One system pumps leachate from the two aerated lagoons (total storage 4,400 m^3 (1,150,000 gal)) and spray irrigates areas of the landfill which have been temporarily covered and seeded to maximize evapotranspiration opportunity during summer months. Year round, leachate is pumped from collection headworks to a subsurface system composed of horizontal perforated pipes installed at 30 m (100 ft) spacing under the final cover and vertical wells spaced at 91 m (300 ft).

Several full-scale bioreactor test programs are currently taking place in Sweden including a two-step degradation study conducted at Lulea, and an integrated landfill gas project involving landfills in



CEC CONTROL AND ENHANCED CELL COVER PLAN



CEC CONTROL AND ENHANCED CELL COVER CROSS SECTION A-A

LEGEND
ALTERNATE DAILY COVER (ADC)
SHREDDED SCRAP TIRES
SOIL COVER
COMPACTED CLAY LEVEE

Figure 5-13. Yolo County Landfill (CA) test cells.

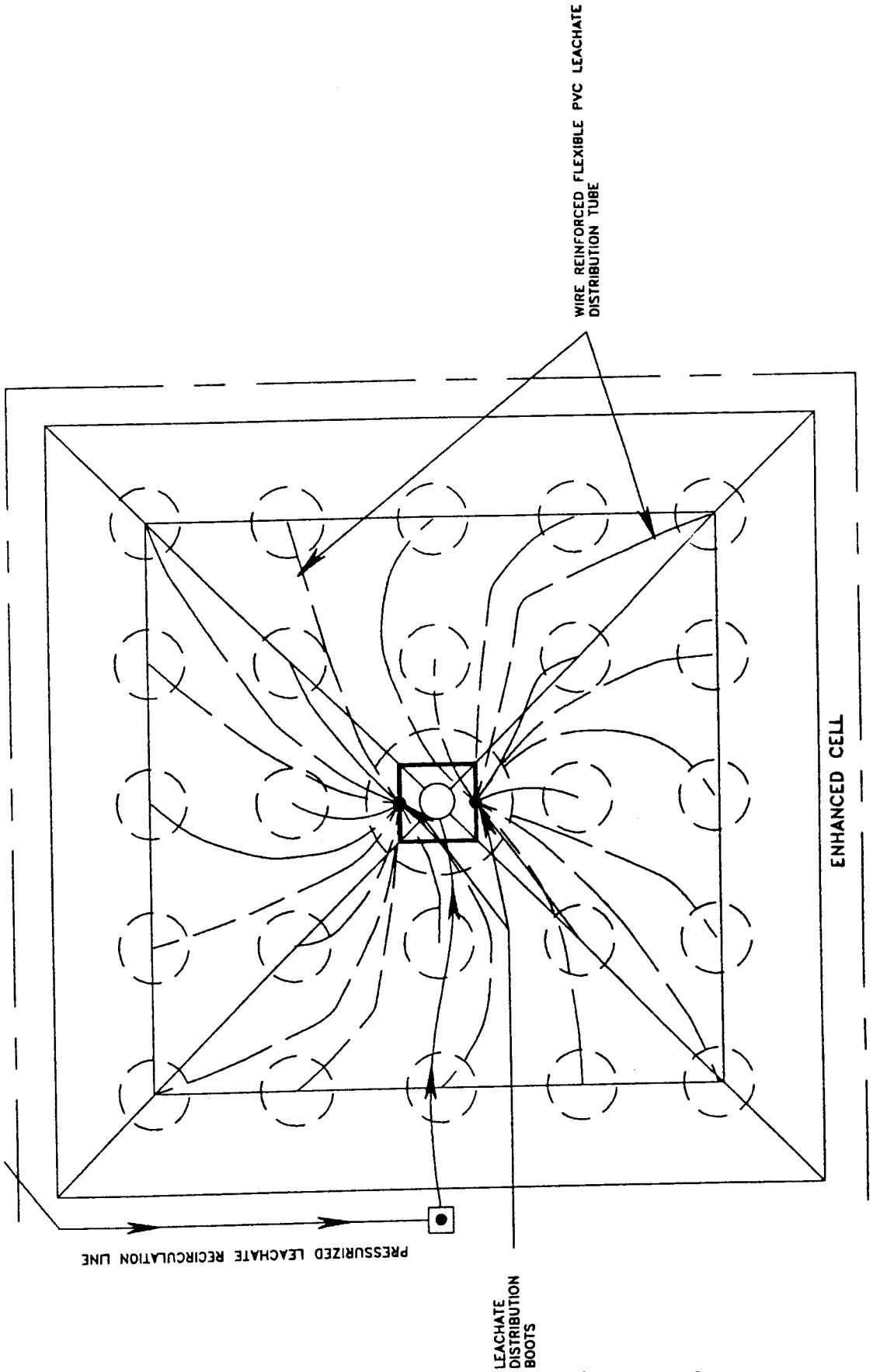


Figure 5-14. Yolo County Landfill (CA) leachate distribution system layout.

Helsingborg, Stockholm and Malmo, (Lagerkvist, 1991a, Lagerkvist, 1991b)

Two cells containing 450 m^3 (16,00 ft^3) of waste each were recently constructed in Viborg, Denmark to evaluate biogas production potential and enhancement methods. One cell contains only household waste, the second household waste and yard waste with leachate recirculation provided in both (Willumsen, 1991). Leachate recirculation is also being investigated in southern Italy where experiments are being conducted with distillation of leachate, recirculation of the distillate, and biological treatment of the condensate (Cossu and Urbini, 1989). In Canada, previous concepts of dry storage are changing and leachate injection is being promoted (Fergusen, 1989). The Rosedale Landfill in New Zealand has been recirculating leachate since the mid 1980's and leachate recirculation is planned at the Greenmount Landfill, the largest landfill in New Zealand. In San Pedro Sula, Honduras, a 250 TPD (275 tpd) landfill has been constructed to recirculate leachate using a low technology methodology (Gonzales, 1994). Leachate will be introduced to the top surface of the fill and will be intercepted as it runs down the mound slope by pipes which convey leachate to high permeability intermediate cover provided at the top of waste lifts.