Landfill Gas - Basics

Training: Day 4

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ISWA-SWIS Winter School

Topics Presentation

1. LFG Basics
2. Landfill Modeling
3. LFG Migration Monitoring & Control
4. LFG Collection System Design and Construction
5. Blower / Flare Stations

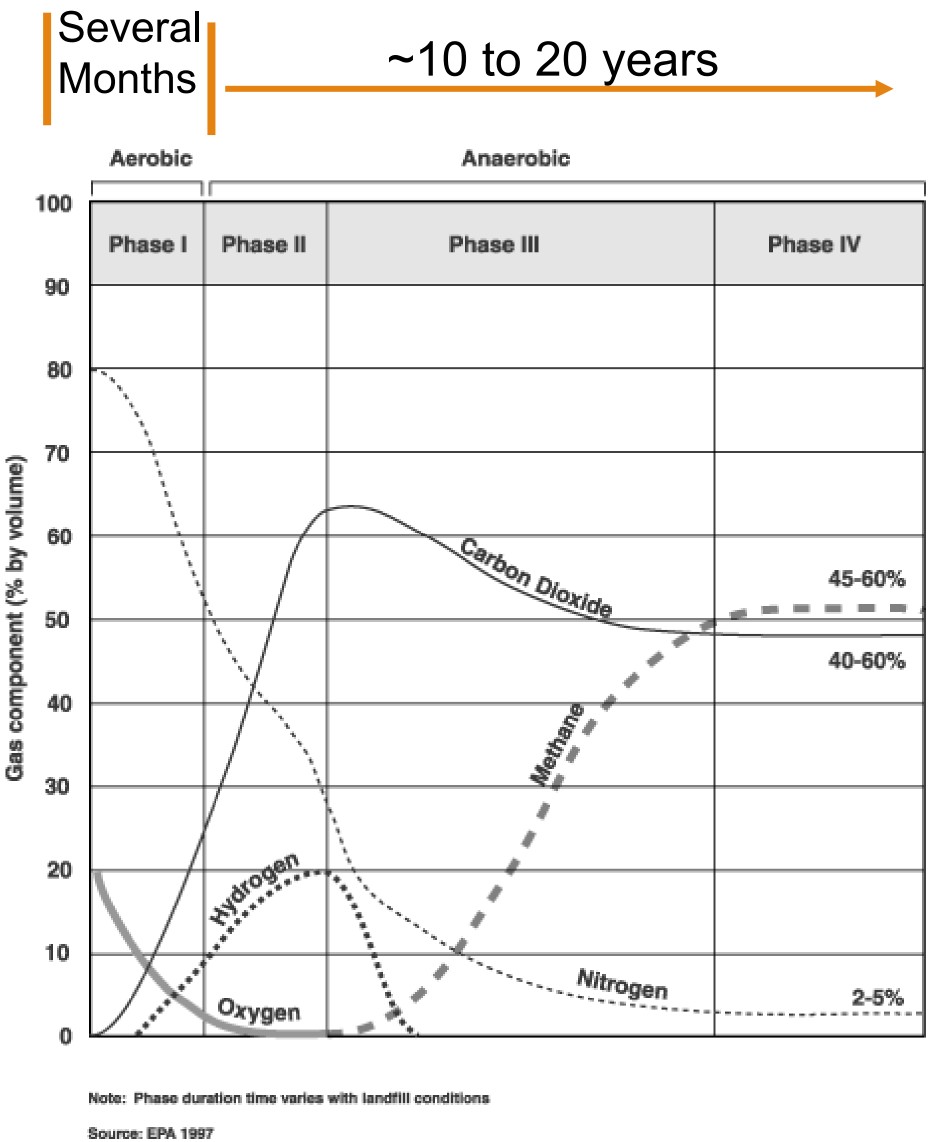
Topic 1

1. **LFG Basics**
2. Landfill Modeling
3. LFG Migration Monitoring & Control
4. LFG Collection System Design and Construction
5. Blower / Flare Stations

Landfill Gas Basics

- What is Landfill Gas:
  - Landfill gas is generally produced via the decomposition of organic materials in landfills
    - Starting - Aerobic (with oxygen) microorganisms consume oxygen and break down organic waste
    - Followed by - Anaerobically (without oxygen) microorganisms break down organic waste

Landfill Gas Generation



Phase 1:

- Aerobic bacteria consume oxygen and break down waste
- Occurs first few months – but can occur anytime if oxygen is present
- Higher temperatures
- Primary Components:
  - Nitrogen
  - Carbon dioxide
  - Low methane

Phases 2-4:

- Composition and production rates of LFG remain relatively constant
- LFG produced at a stable rate, typically for about 10 to 20 years
- Primary components :
  - Methane 40% to 60%
  - Carbon Dioxide 40% to 60%
  - Trace amounts: Nitrogen, oxygen, and various other gases

Landfill Gas Generation

Amount of LFG production is governed by amount of waste (more waste, typ. more LFG).

Rate of LFG production is governed by:

- age of waste
  - Older waste may produce LFG as a slower rate (most of the biological decomposition has already occurred)
- moisture content
  - Moisture is needed for biological decomposition of waste
  - Very low moisture content may prevent decomposition of waste and thus limit gas production
  - The optimum moisture content to maximize gas production is in the 50 to 60 percent range
- Waste composition
  - Inert material (e.g., soil) produce less LFG than municipal solid waste

Landfill Practices Affect LFG Generation

- Waste characteristics (e.g., amount of C&D)
- Cover material practices
- Final cover (e.g., geomembrane/soil) cover
- Leachate management

Topic 2

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LFG Modeling

- LFG emissions are site specific
- Need waste history/projections as an input
  - preferably broken down into types of waste
  - total amount of waste
- Also requires important parameters for the LFG generation equation used:
  - how fast organics are converted into LFG; and
  - The amount of landfill gas that can be generated per unit of waste
- Output includes gas curves, wide range of LFG outputs
- Various models are available
  - EPA LandGEM
  - Proprietary models

LandGEM Model

- Spreadsheet model, easy to use
- EPA sanctioned, other models available
- Estimates ***generation***, not emissions/recovery

LFG Modeling

EPA's LandGEM: First Order Decay Rate Model:

$$Q_{CH_4} = \sum_{i=1}^{n} kL_0 M_i e^{-kt_i}$$

Q_{CH4} = methane recovery (ft^3/year)

M_i = annual waste disposal in year i (ton)

- Possible removal of non-degradable waste

k = decay rate constant (1/year) - how fast organics are converted into LFG

- Clean air act (CAA) – Conventional Landfill – 0.05
- CAA – Arid Area – 0.02
- Depends on the moisture content of waste (among others), higher k values mean the faster the generation rate increases than decreases over time (greater slope on the curve)

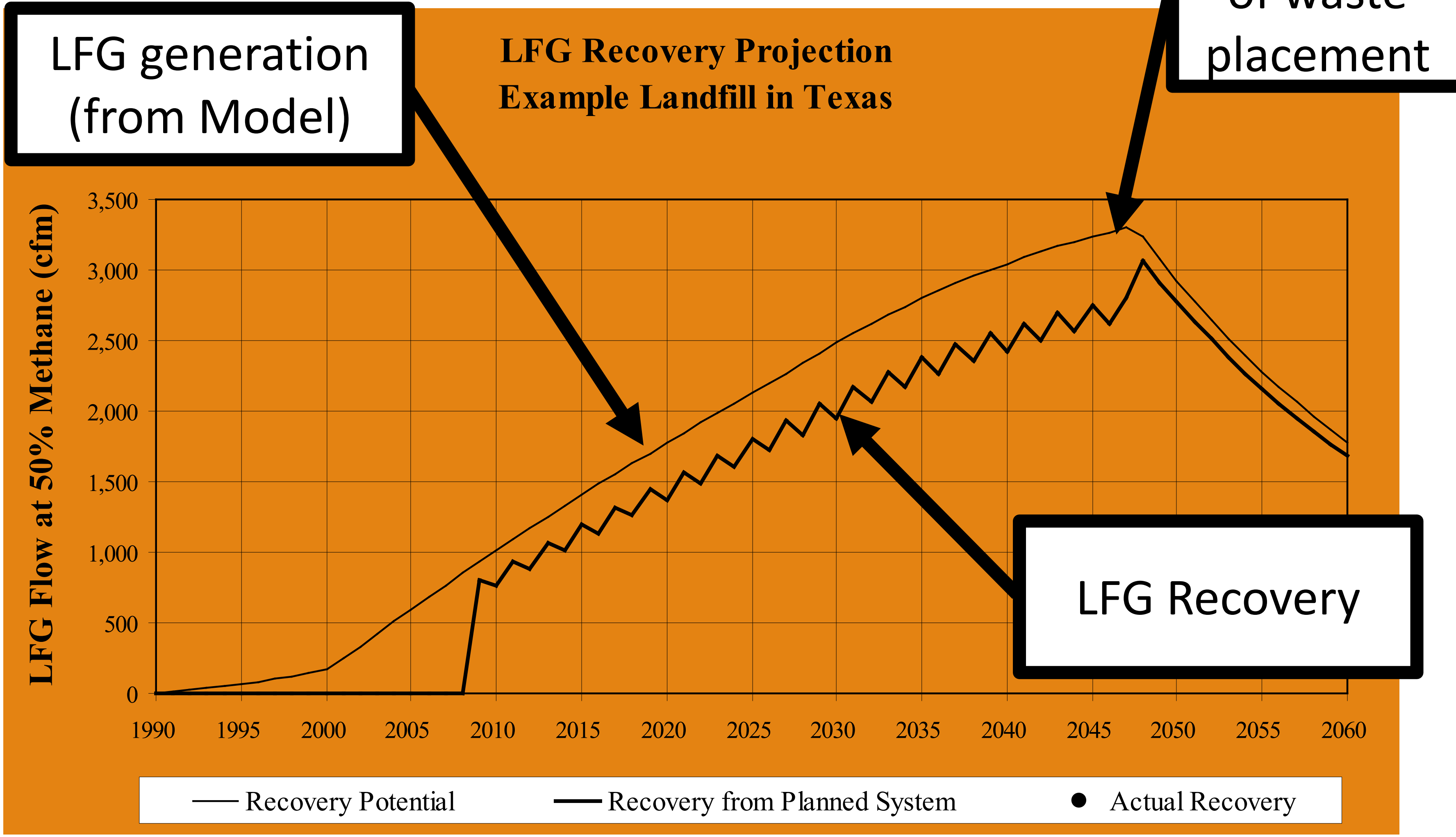
Lo = ultimate methane recovery (ft3/ton) - the amount of landfill gas that can be generated per unit of waste

- CAA – Conventional Landfill – 170
- CAA – Arid Area – 170
- Depends on the type and composition of waste placed in the landfill (higher organic, higher value and more LFG produced)

t = time elapsed (years)

System Coverage (%, potential versus planned recovery)

Potential LFG Recovery



Topic 3

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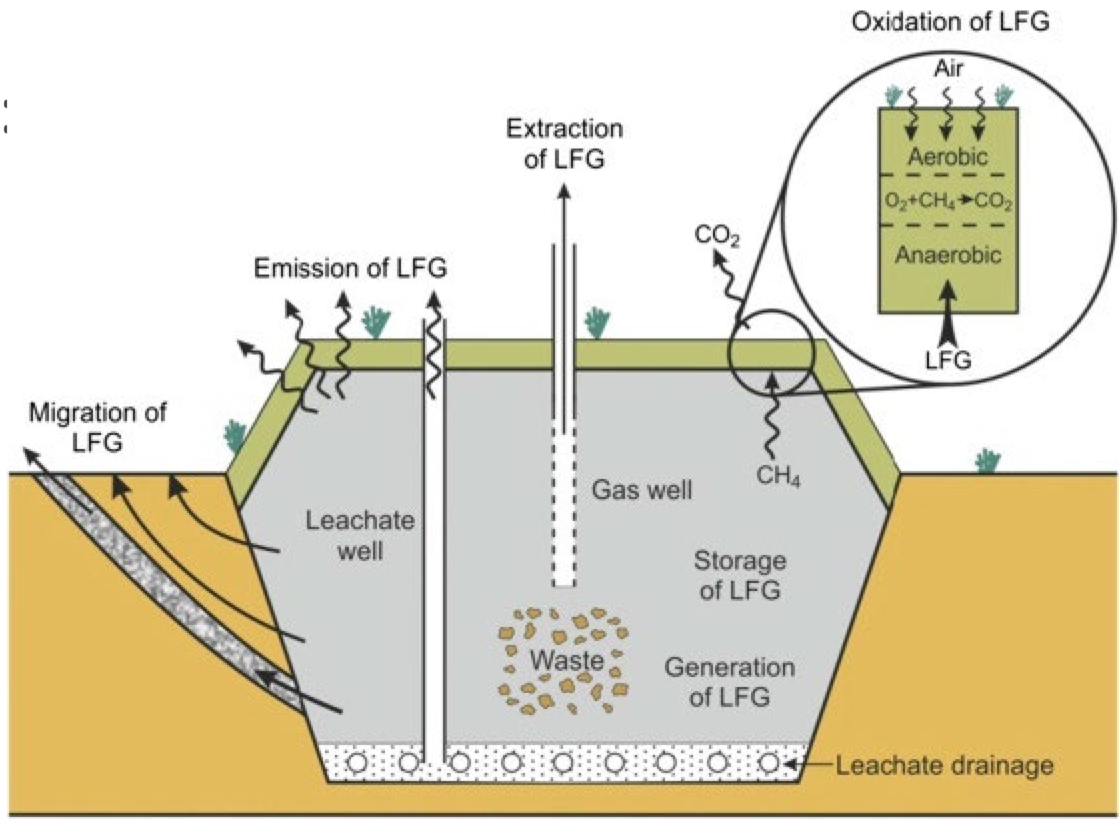
Landfill Gas Concerns

- Explosive (high concentrations of methane)
- LFG migration
- Odorous
- Vegetation stresses
- Potential groundwater impacts
- Can contain harmful substances (e.g., H_2S)
- Global warming potential
- Also a potential energy source!

LFG Migration

- LFG Moves underground:
  - Follows the path of least resistance
  - e.g., utility trenches, gravel/sand layers
- Can leave the site
- Can collect under structures
- Can cause explosions (although uncommon)
- Important to monitor for methane in structures and limits of the property limits of the landfill

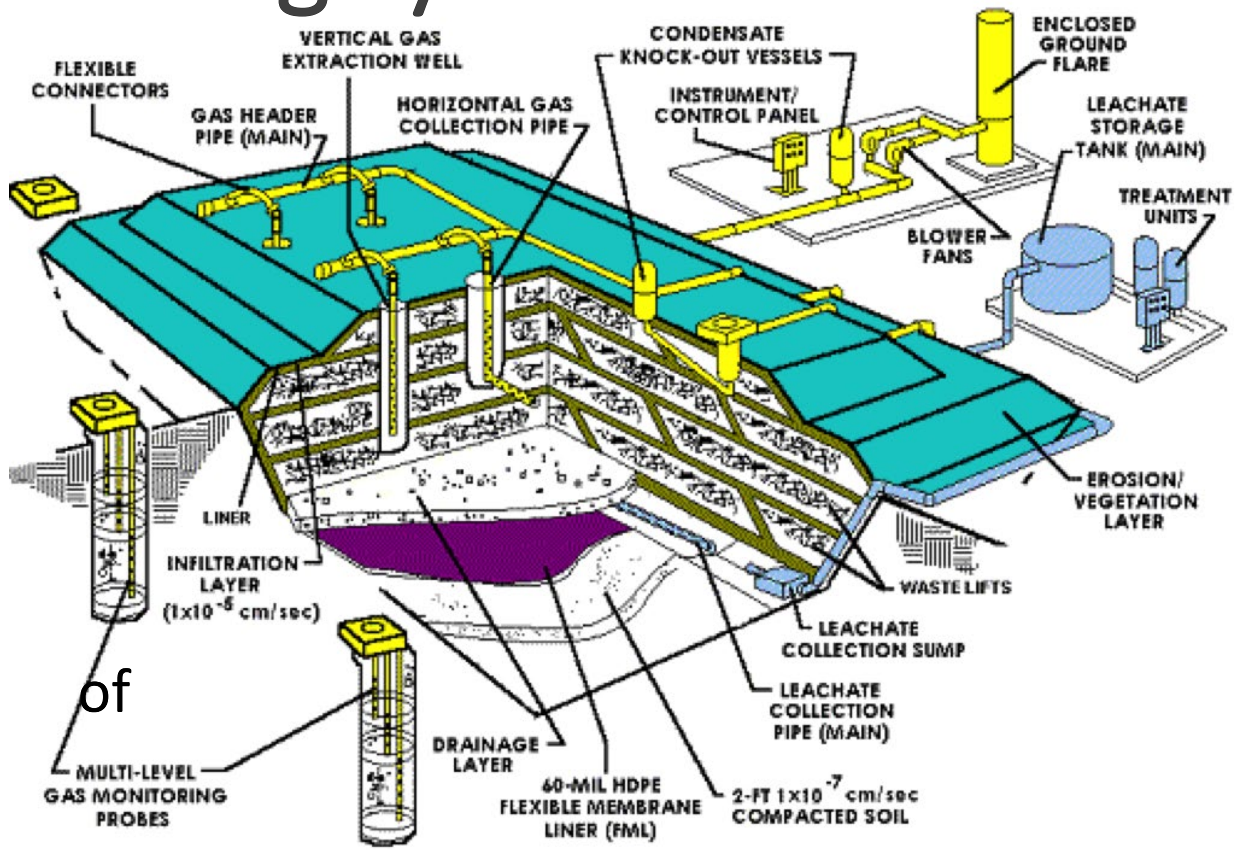


Factors Affecting LFG Movement

- Liner system (soil vs synthetic)
- Final cover system
- Site geology and soils:
  - Depth to groundwater
- Depth, age, and type of wastes in fill
- Characteristics of soil used for cover
- LFG control system
- Amount of soil cover
- Conduits (channels/pipelines)

Migration Monitoring Systems and Locations

- **Off-Site:**
  - Property boundary
  - Permanent gas monitoring probe construction
  - Probe spacing
    - Maximum spacing of 150–300 m (500–1000 ft)
    - closely spaced, every 30–60 m (100–200 ft),
  - Trenches and conduits

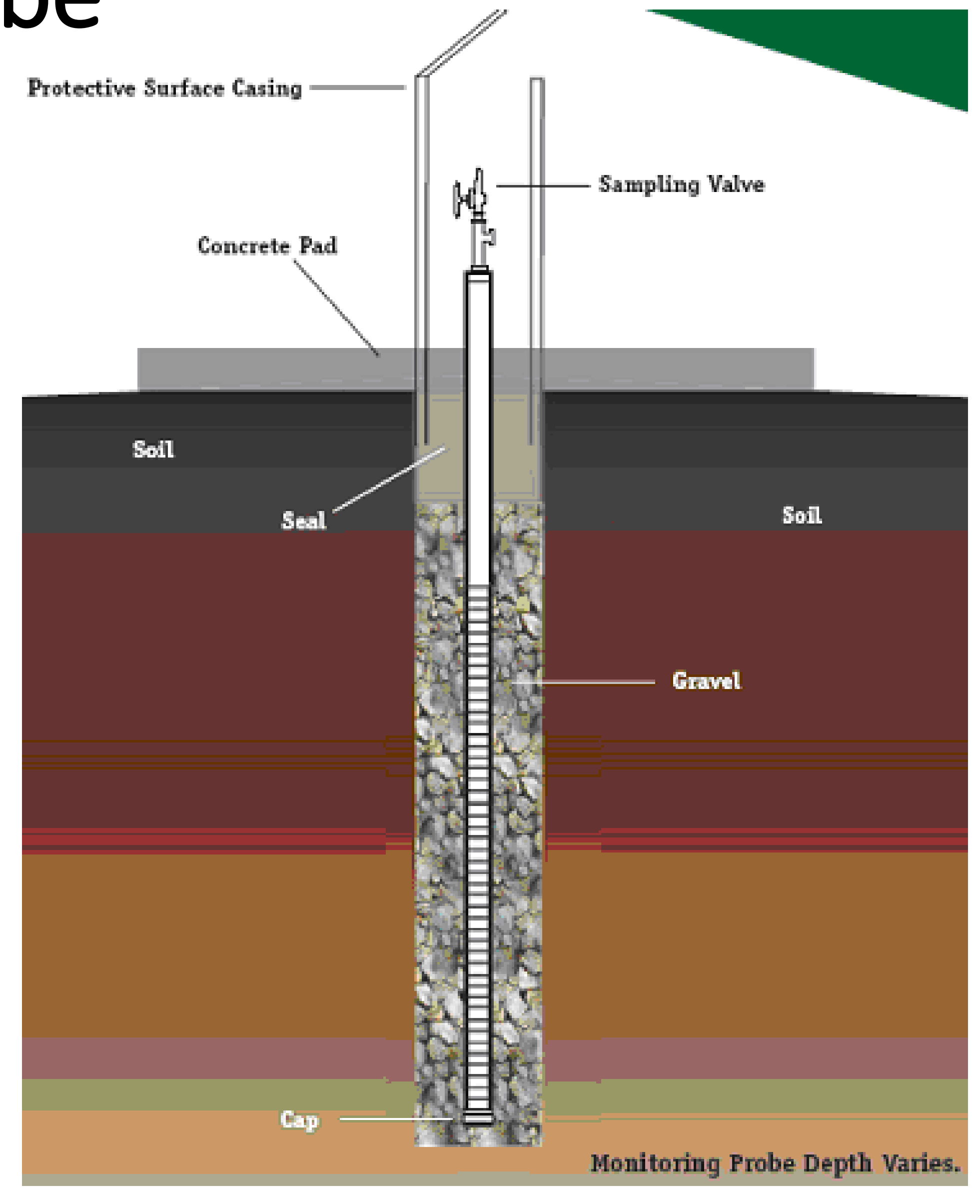


On-Site Structures:

- Continuous Monitoring

Gas Monitoring Probe

- Typically placed into the ground to at least the same depth of the waste
- A 1.9 to 5.1 cm (0.75 to 2 inch) diameter perforated PVC pipe
- Space between the borehole wall and pipe is filled with sand or gravel
- Sand/Gravel layer should generally begin at least 1.5 m (5 feet) below the ground
- A bentonite seal is placed above the filter pack



Gas Monitoring Probe

LFG Migration Control

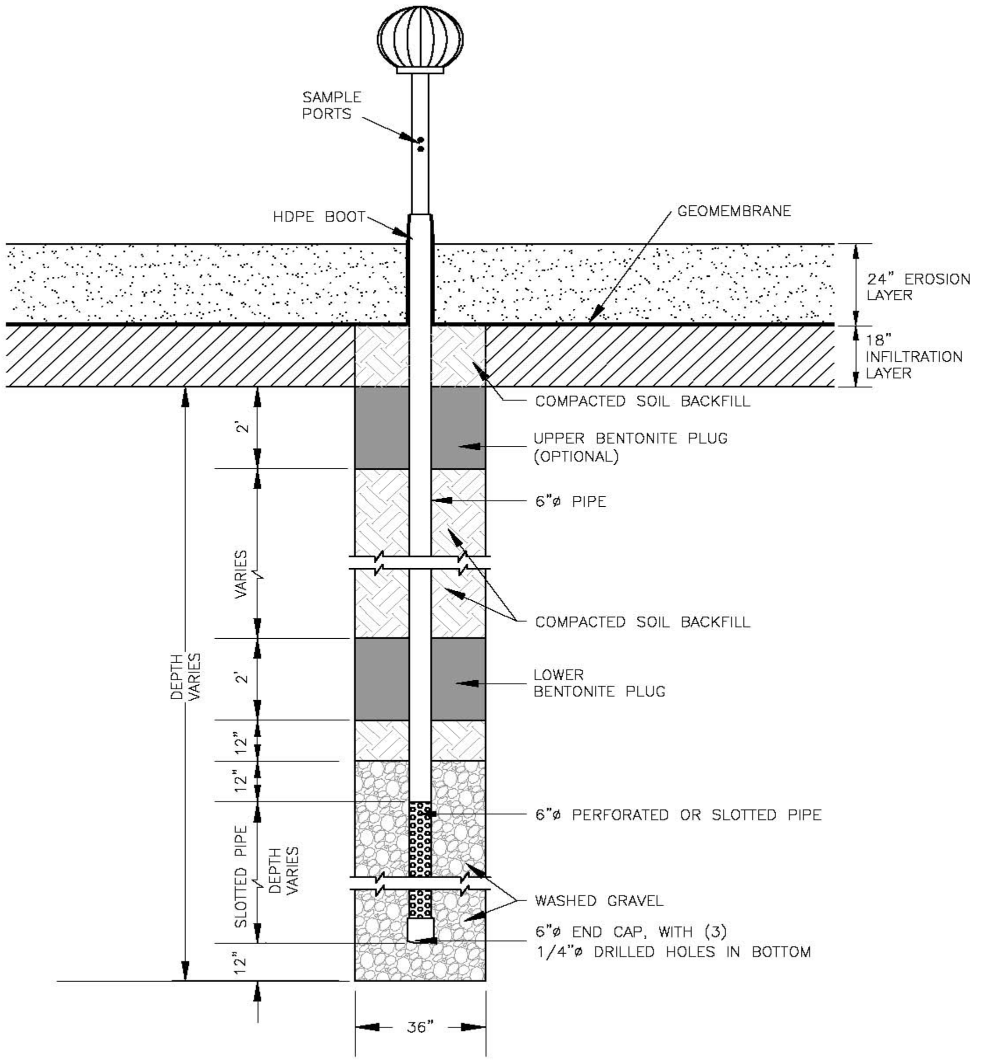
Passive Systems:

- Trench Vents
- Well Vent
- Low Permeability Barriers
  (e.g., slurry wall)

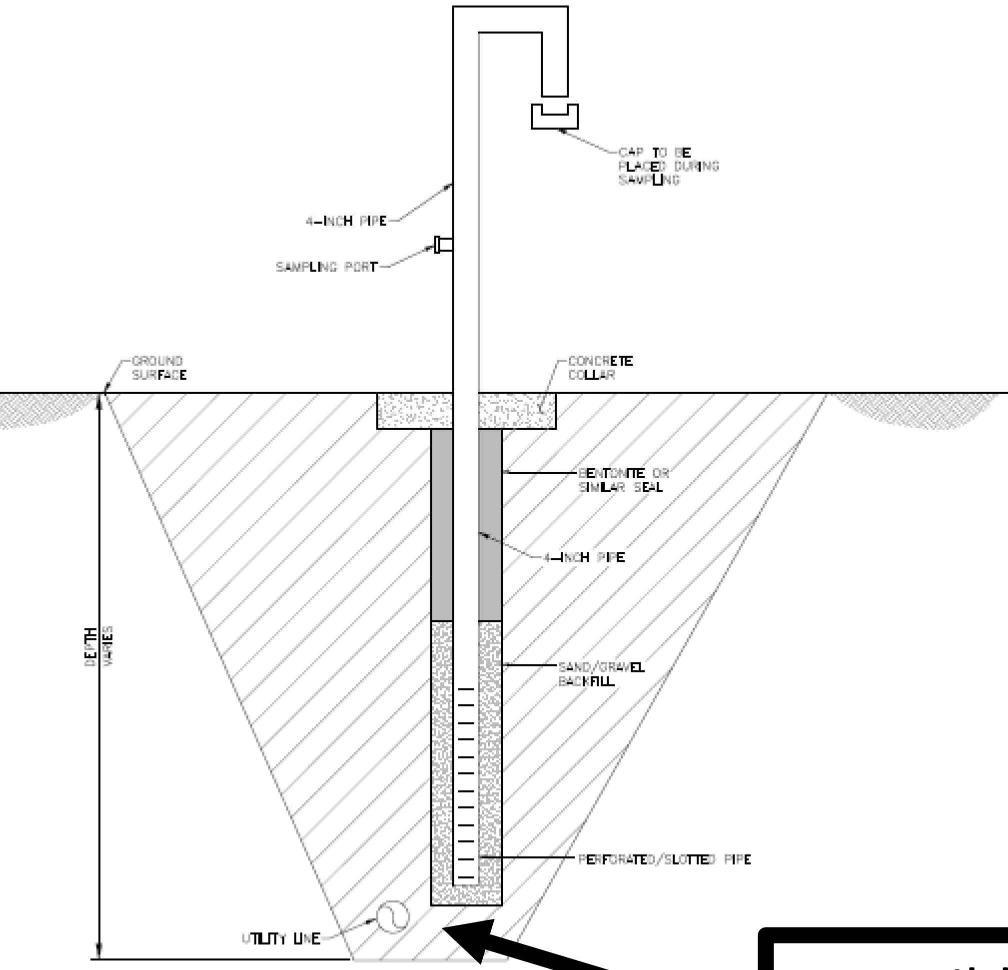
Active Systems:

- LFG Collection Systems

Typical Passive Well Vent



Trench Vent



Possible sand layer

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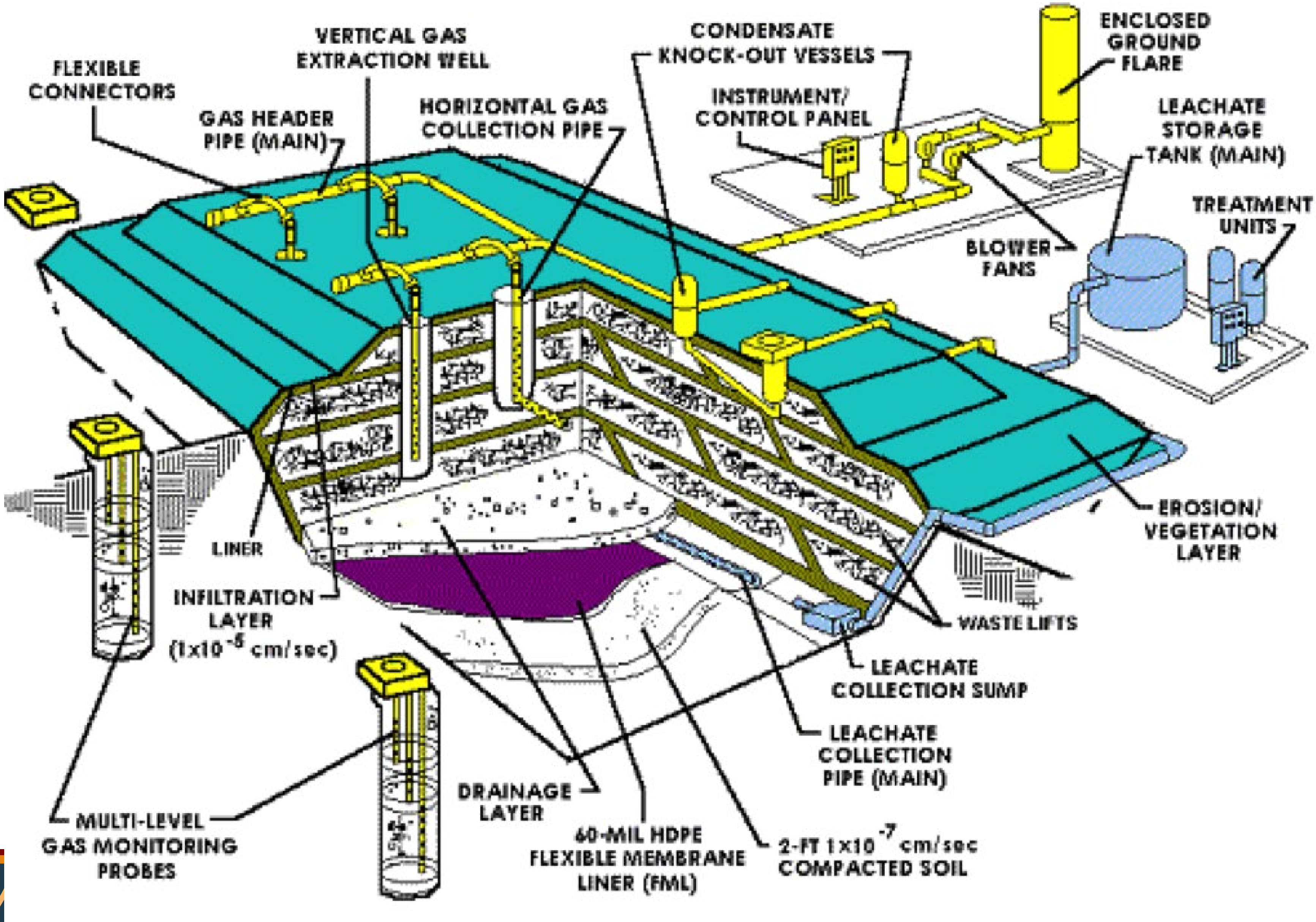
Why Collect LFG?

- Odor Control
- LFG Migration Control
- Reduction in Surface Emissions
- Protection of Final Cover
- Minimize Vegetation Stress
- Beneficial-use Projects
    - Provide revenue for landfills

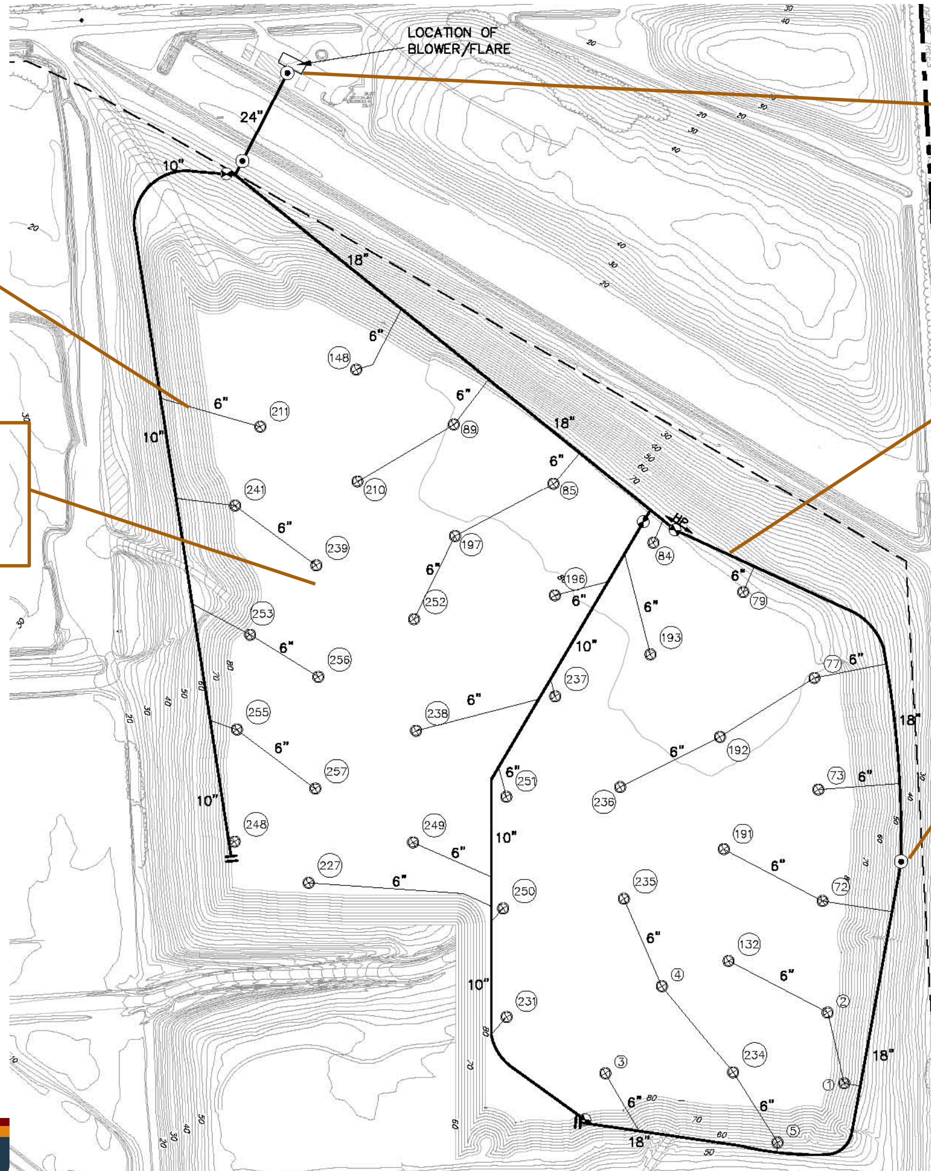
Components of LFG Collection System Design

1. Estimating Flow Rates (LFG Recovery Modeling)
2. LFG Extraction Well Options (vertical wells versus horizontal collectors)
3. Wellfield Layout
4. LFG Collection Pipe Layout and Sizing
5. Condensate Management
6. Blower/Flare

LFG Collection System Design



LFG Collection System



Blower/Flare

Lateral Pipe

Header Pipe

Vertical Extraction Well

Condensate Sump (low point)

LFG Extraction Well Options

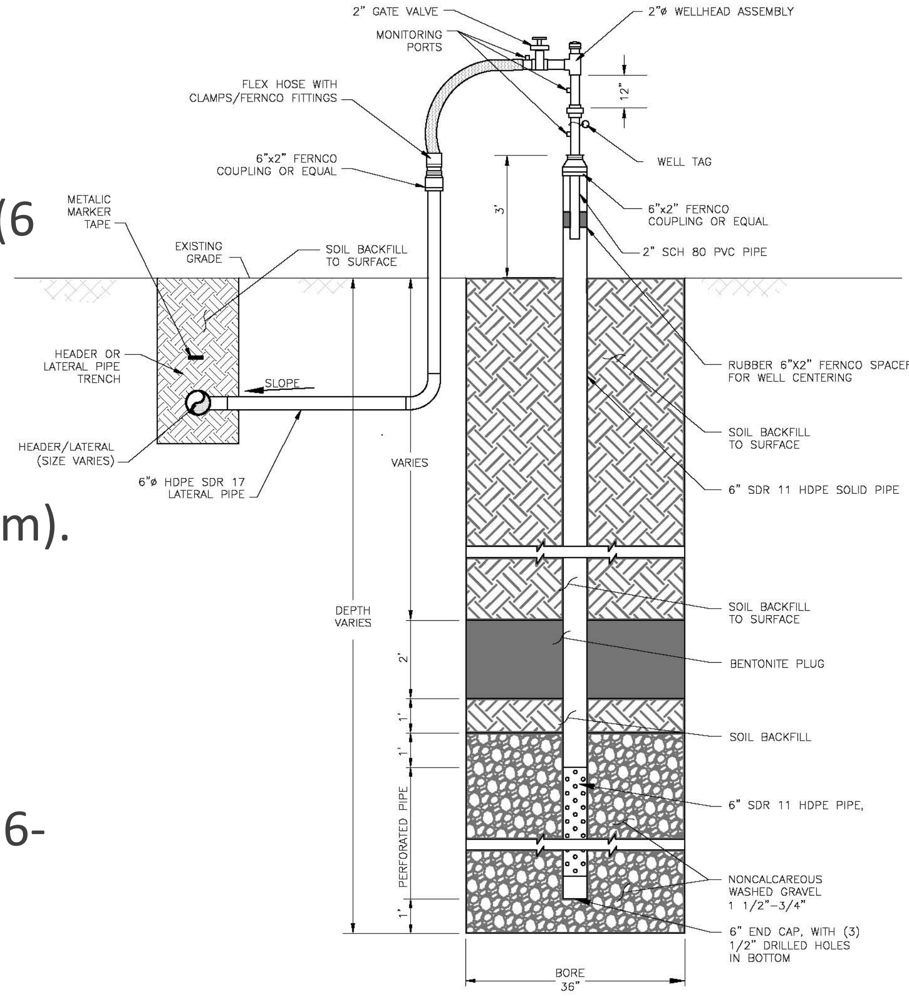
Vertical Extraction Wells Versus Horizontal Collectors:

Intermediate Grades: Can use either vertical wells or horizontal collectors while refuse is being placed.
Horizontal collectors may cause less interference with refuse placement.

Final Grades: Vertical extraction wells are the predominant choice for gas extraction.

Vertical Extraction Wells: Typical Design Parameters

- Pipe is usually perforated (can also be slotted).
- Typically perforated in bottom 2/3 of well. Perforations normally start 20 to 40 ft BGS (6 to 12 m).
- Solid pipe depth depends on cover soil and helps solid air intrusion
- Typical spacing: 100 ft to 400 ft (30 to 120 m).
- Drilled to within 75% of waste depth or 15 feet of liner protective cover.
- Bentonite seal prevents air infiltration (typically 2). Borehole diameter: typically 36-inch (0.9 meters)
- Casing: PVC, HDPE or steel/CPVC (infrequently)



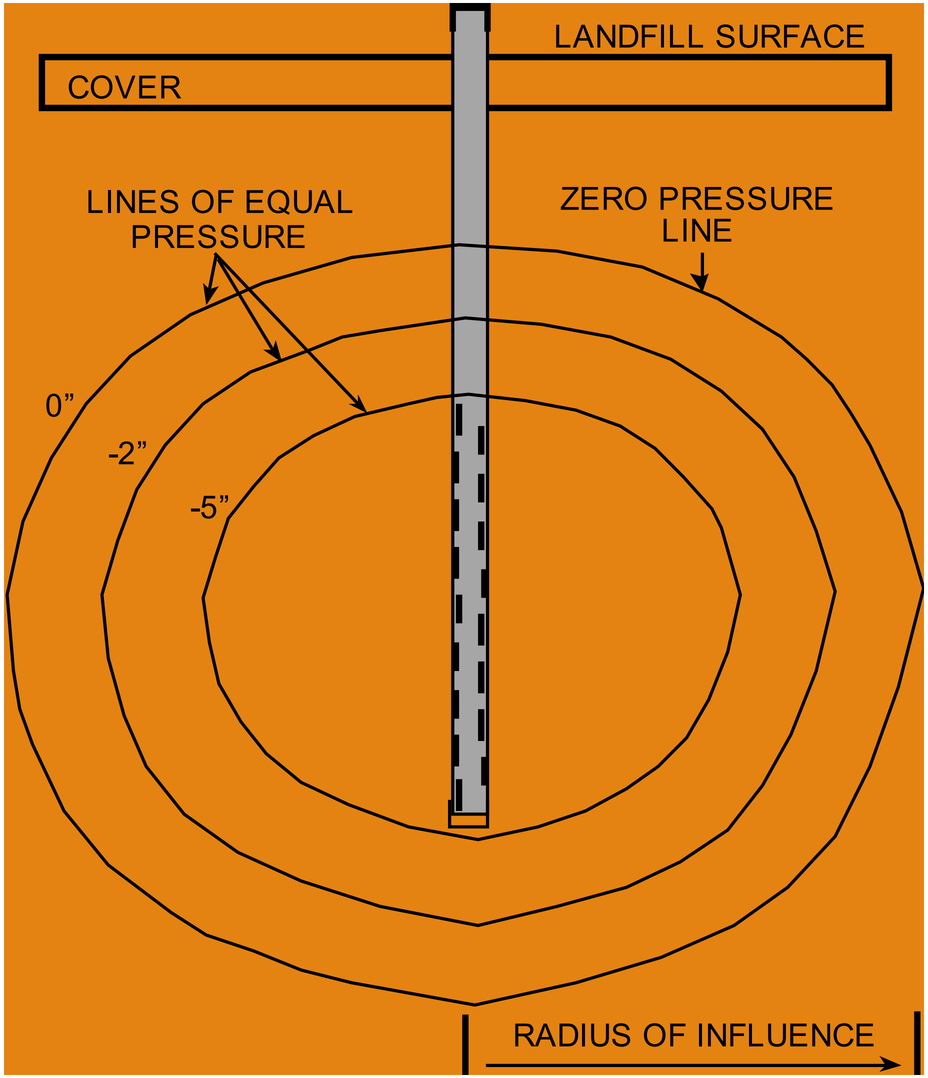
VERTICAL LFG EXTRACTION WELL

Typical Vertical Extraction Wellhead

Wellhead incorporates:

- Flow control valve
- Pressure monitoring ports
- Wellhead Flow Element (Orifice Plate)
- Thermometer (optional)

Theoretical Radius-of-Influence



Empirical equations exist for calculating ROI.

Rule-of-thumb: 2.5 times well depth.

Influence is assumed to be greater horizontally than vertically.

Increases in the vacuum at the wellhead will extend the zone of capture and increase LFG flow at that well.

Drilling Vertical Extraction Well

Extraction Well Completion

Horizontal Collectors: General Design Parameters

Installed as refuse is being placed.

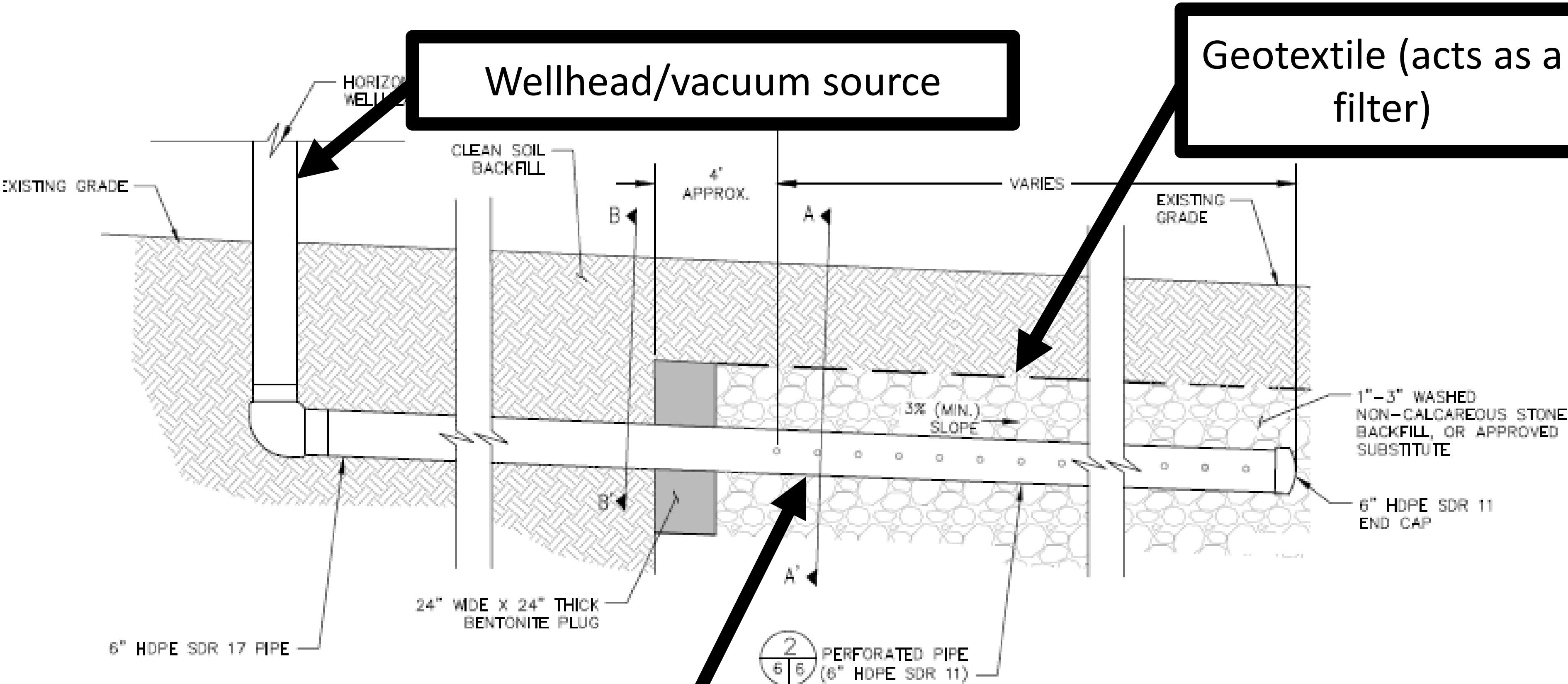
Typically spaced 100 to 200 ft horizontally and 30 to 60 ft vertically.

Standard design length is less than 1,000 feet.

Pipe is typically perforated or slotted HDPE/PVC
The pipe is placed in a trench filled with porous material (e.g., crushed stone, tire chips, crushed glass).

Trench covered or wrapped with geotextile filter fabric.

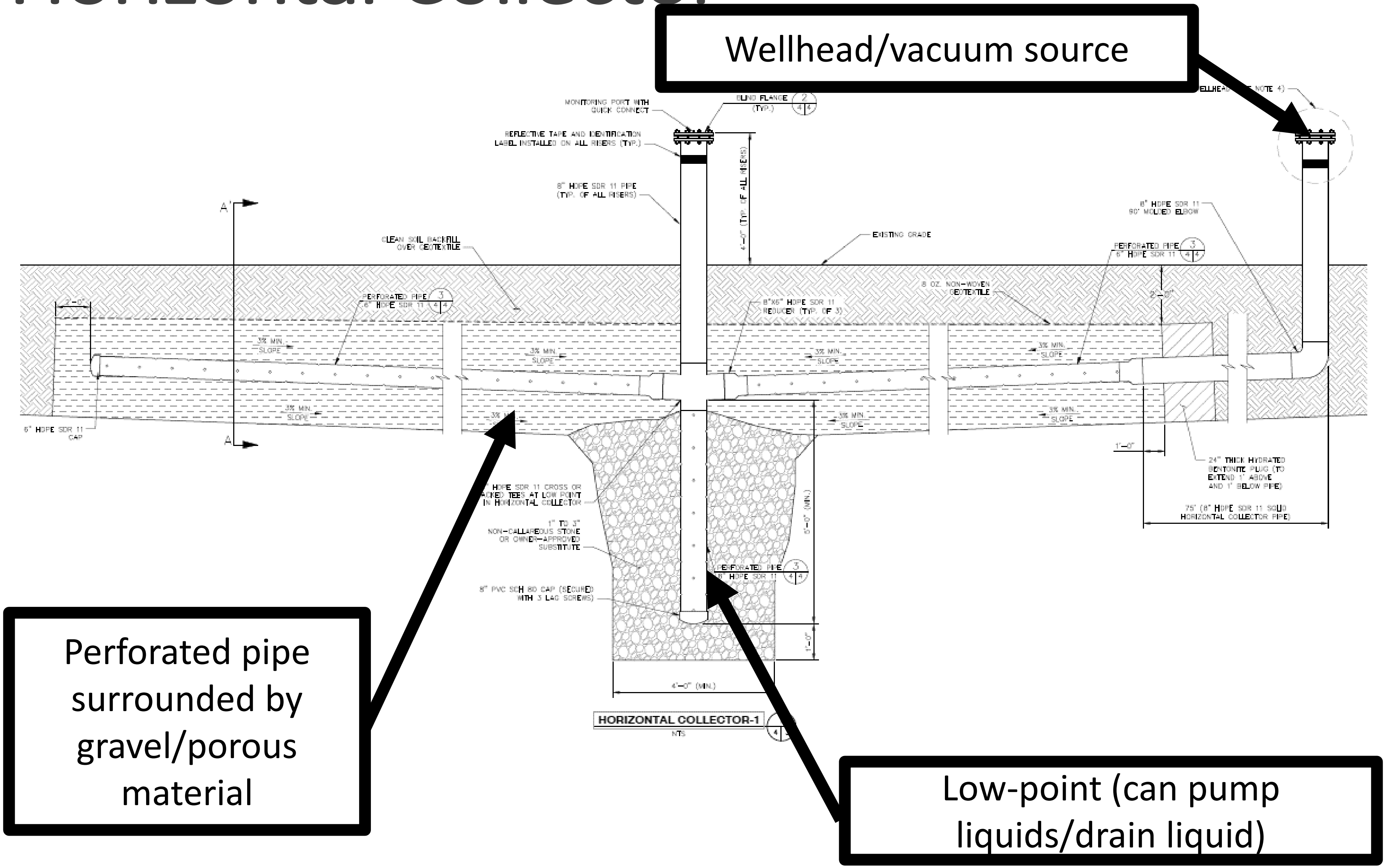
Horizontal Collector



Perforated pipe surrounded by gravel/porous material

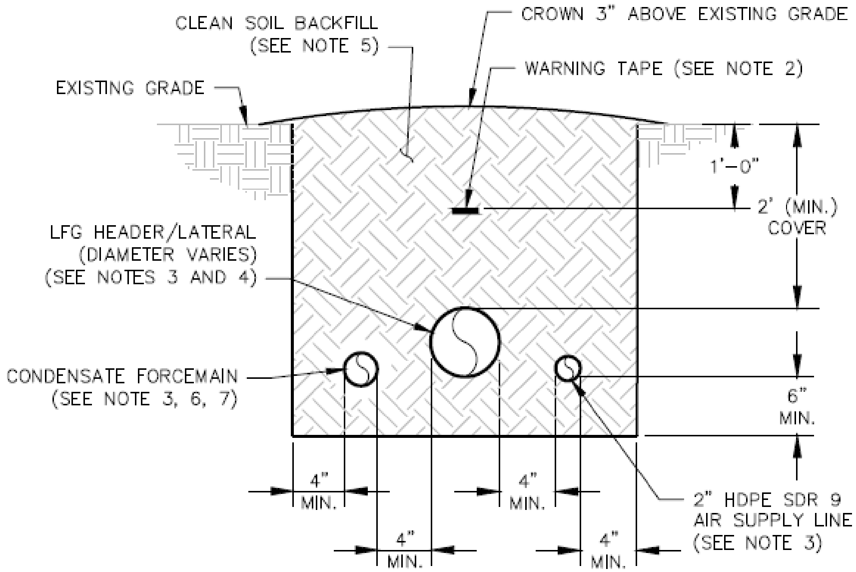
- Depth to trench 20+ feet (6+ m) to avoid pulling in oxygen (fire potential)

Horizontal Collector



Horizontal Collector

Below-Grade Piping



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Above-Grade Piping

LFG Condensate

LFG condensate volume depends on LFG temperature and flow.

As LFG cools in the LFG collection pipes, the moisture condenses out and drains to low points in the piping.

Condensate can restrict flow and vacuum, completely plug a line, and freeze in the collection piping.

Condensate Management

Condensate must be properly disposed:

- Can contaminate surface water and groundwater
- It contains trace quantities of VOCs

Condensate is collected in condensate sumps, leachate collection sumps, knock-out vessels, and storage tanks.

Management options similar to leachate:

- Onsite storage for offsite transport
- Commingle with leachate for treatment/disposal
- Discharge to sanitary sewer or forcemain
- Evaporation basins

Condensate Sumps

- Installed at header low points to collect & convey condensate out of header
- Slow down LFG & change direction to knock-out liquids

Condensate Management Practices

- Used as infrastructure for dual extraction wells
- SDR 9 airline piping
  - PE4710 Pressure rating: 250 psi
- SDR 11 force main piping
  - PE4710 pressure rating: 200 psi
- Dual contained FM piping outside of landfill
- Cleanouts & valves critical
- Use sweeping fittings to prevent clogging of CFM piping

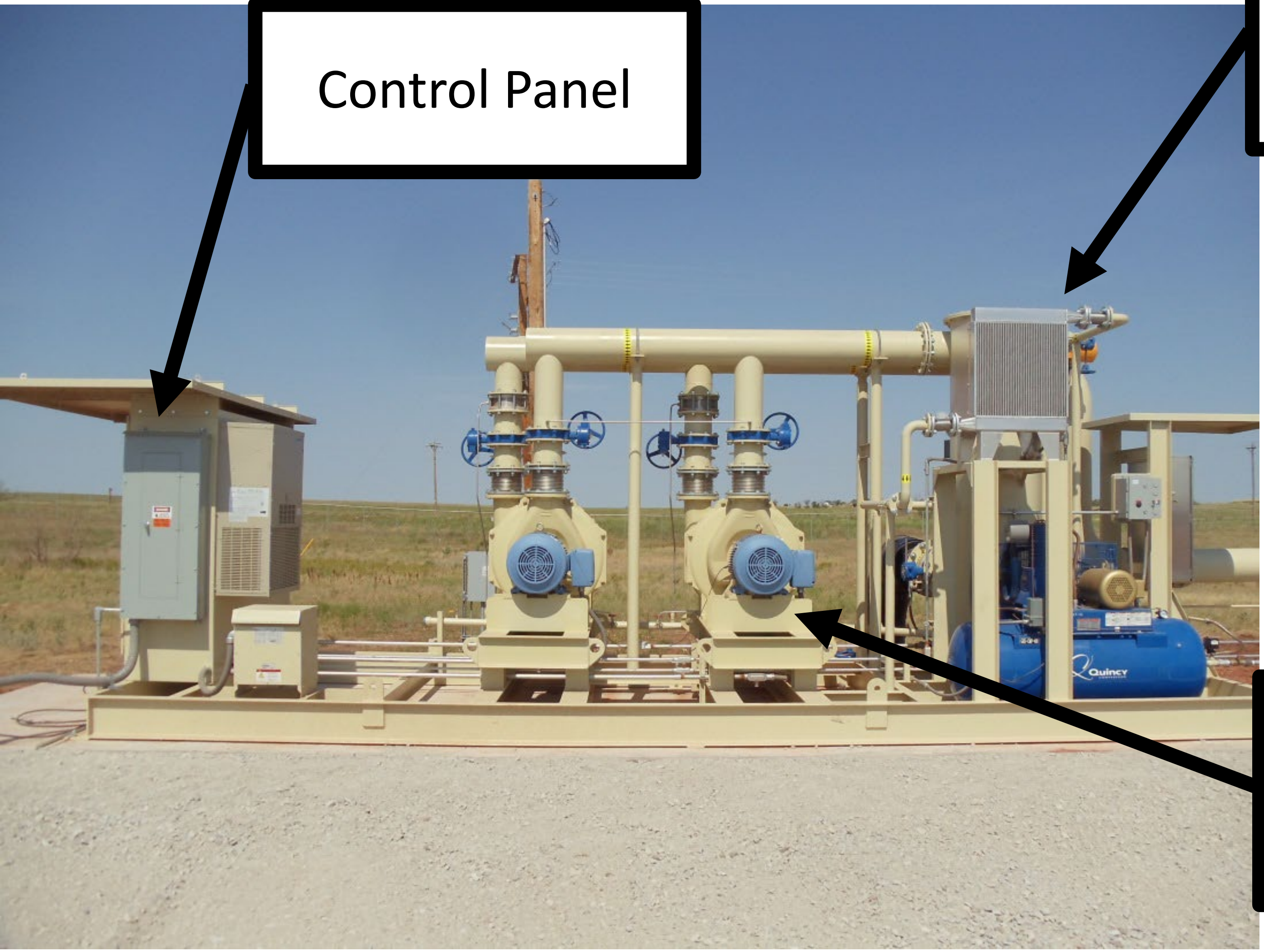
Blower and Flare Skids

Enclosed Flare

Blower Skid

Knockout Pot (removes moisture for LFG

Control Panel



Blowers (applies vacuum to collection system)

Candlestick Flares

Advantages of Candlestick Flares:

- Lower capital cost than enclosed flare
- Simpler to design
- Higher turndown ratio (10:1)
- Low maintenance cost

Disadvantages of Candlestick Flares:

- Visible flame
- Wind turbulence can cause a flame-out
- Slightly higher emissions than enclosed flares

Enclosed Flares

Advantages of Enclosed Flares:

- Lower emissions than candlestick flares
- No visible flame

Disadvantages of Enclosed Flares:

- Higher cost than candlestick flares
- More complicated to design
- Lower turndown ratio (5:1)
- Higher potential maintenance costs

QUESTIONS?

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