BIOVENTING

Presentation Objectives

- Describe various configurations of in-situ bioremediation technologies
- Describe applicability of bioremediation technologies
- Identify data needs for technology selection/design
- Recommend pilot testing approaches
- Provide design considerations
- Discuss operational strategies
- Compare closure strategies

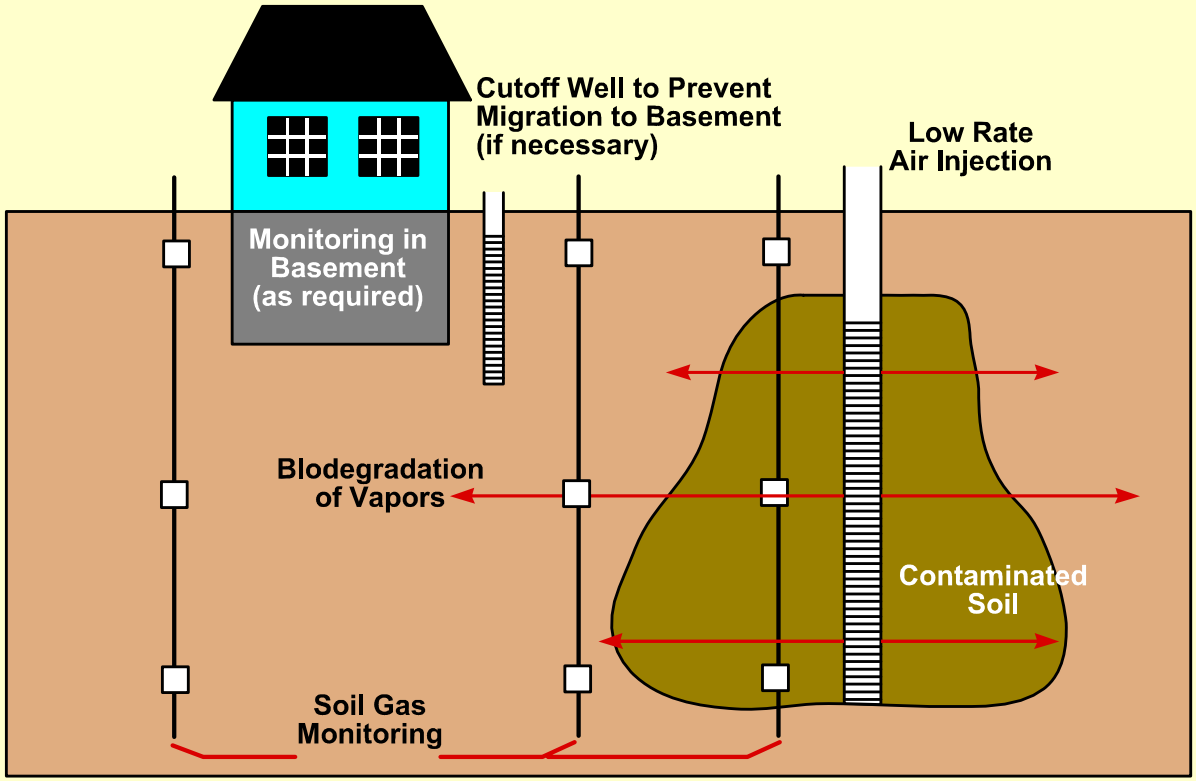
Bioventing

- Operating principles
  - Air injected at low rates (can be extraction in some cases)
  - Increase oxygen content - oxygen limited conditions
  - Minimize mobilization of vapors
  - Enhance existing natural bioremediation
  - May be able to use passive air injection
- May prevent intrusion of hydrocarbons vapors
- Passive bioventing
  - Use of barometric changes to inject air
  - Need barrier to vapor exchange to surface

Other Bioventing Configurations

- Can inject other gases to promote degradation of chlorinated solvents
  - Cometabolic bioventing
  - Methane, propane injection (at <LEL)
  - Create enzymes to destroy TCE
- Creating reducing conditions to treat metals, others?
  - Inject N_2, carbon source, induce anaerobic conditions

Bioventing (Injection)



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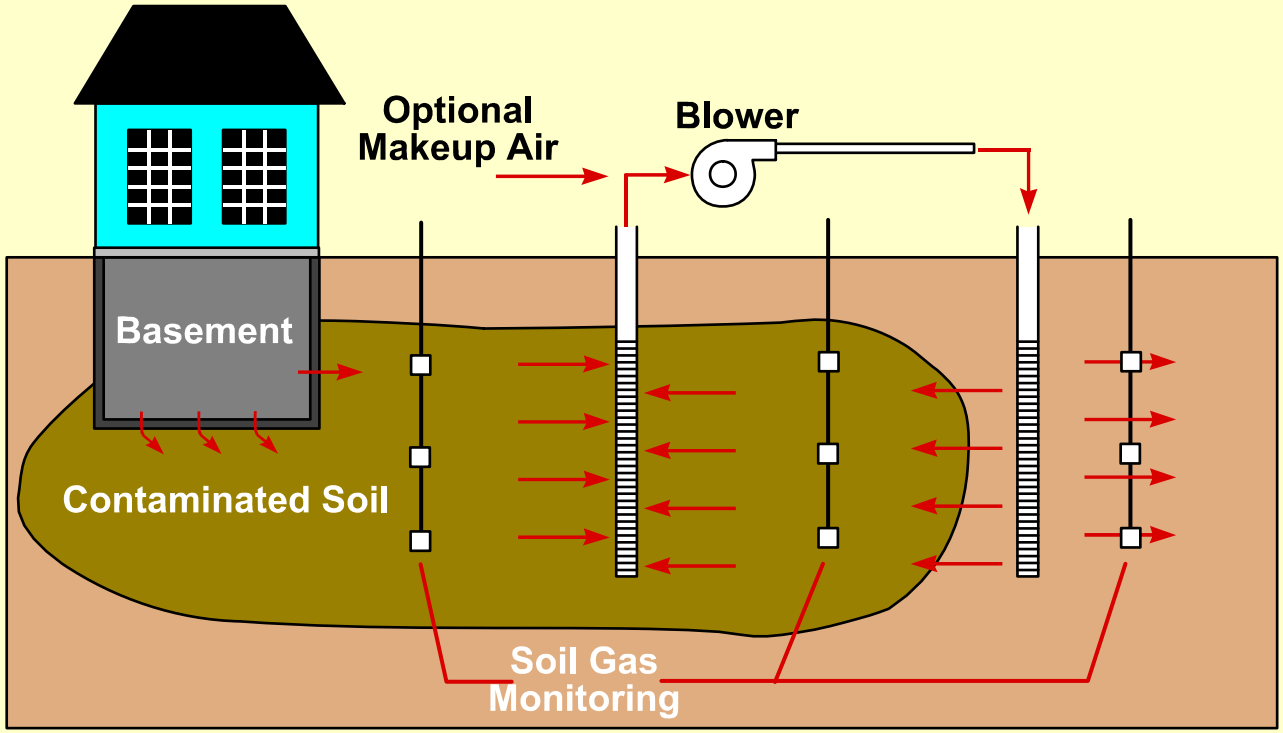
Bioventing (Extraction)



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Bioventing Applicability

- By nature, an aerobic process
  - Aerobically degradable hydrocarbons
  - Co-metabolic degradable chlorinated organics
- Require adequate air permeability
  - Similar site applicability as SVE
- Often effective for light hydrocarbons, but very slow for heavier hydrocarbons
  - May achieve limits for benzene, etc., But not for total petroleum hydrocarbons
  - Does remove more mobile contaminants

Bioventing Limitations

- Moisture/nutrient control
  - May be needed in dry areas
  - Some researchers claim nutrients not needed
  - Other studies suggest nutrients may help
  - Nutrient, moisture addition by liquid, vapor

BV Data Needs
BV Design Consideration

- Needs type, quantity, and 3-D distribution of contaminants and free products for locations of injection, extraction, and monitoring wells
- Determine biodegradation vs. abiotic processes (e.g., dilution / dispersion / volatilization)
  - Mass balance of O_2, CO_2, and contaminants if extractive BV
  - Compound Specific Isotope Analysis (CSIA) – stable isotope ratios change and serve as unique "signatures" (www.epa.gov/ada/pubs/reports/600r08148/600r08148.pdf)

BV Data Needs

- Soil gas oxygen, carbon dioxide content
- Stratigraphy
- Moisture content
- Nutrient availability
- Site features (utilities and basements)
- Air permeability
- Water table fluctuations, floating product
- Enumeration studies

Bioventing Pilot Studies

- Air permeability testing, step testing
- Respiration tests
  - Verify oxygen depletion
  - Aerate portion of contaminated site
  - Can use aeration part of test to determine air permeability
  - Use of helium - determine diffusive losses
  - Aerate background site – assess natural oxygen demand

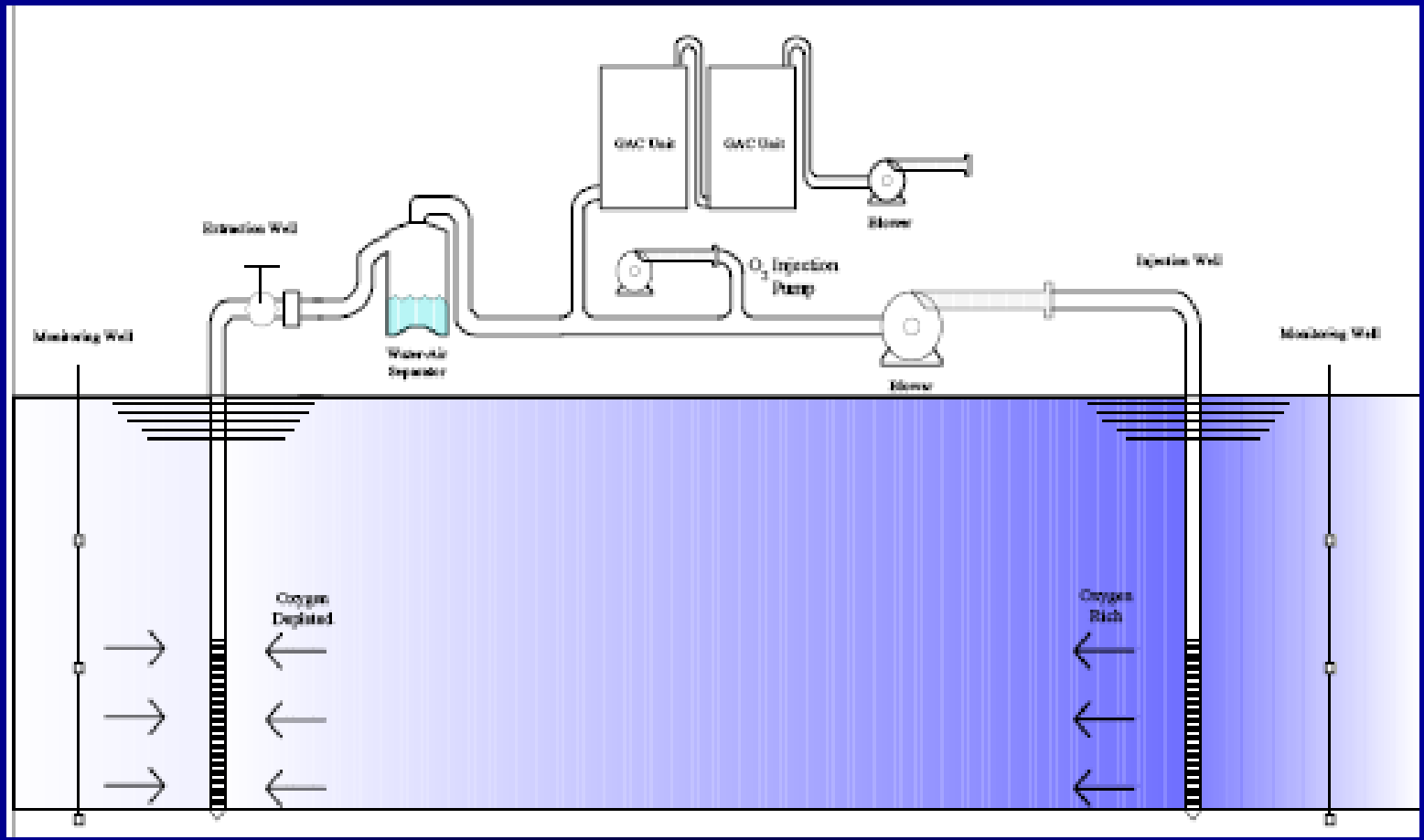
Bioventing Pilot Studies

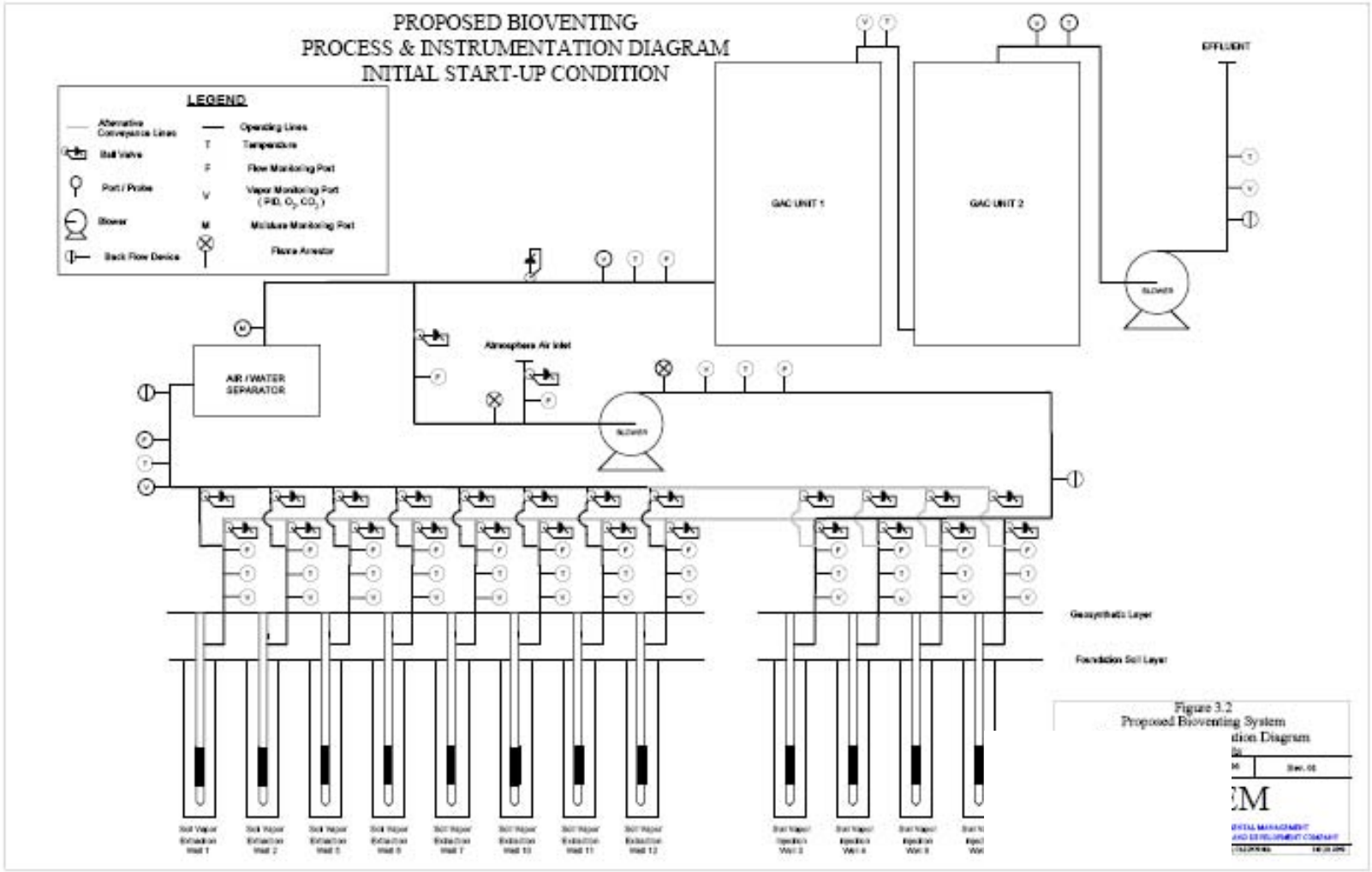
- Respiration tests, continued
  - Sample soil gas in multi-depth probes over time
    - Monitor carbon dioxide, oxygen levels, he
    - Look at oxygen uptake, use stoichiometry to estimate mass destroyed
    - Estimate respiration rate
    - Subtract background rate, diffusive losses

Bioventing Design

- Well spacing and screen placement
  - Air delivery obviously critical
  - Space wells, choose air injection to achieve one air exchange throughout treatment volume in 2 to 4 days
  - Consider contaminant distribution in choosing screened interval
- Well design: similar to SVE wells, injection rates low
- Monitoring system: multi-depth probes, in areas near and far from injection points
  - Assess vapor intrusion at occupied buildings

Bioventing Piping





Air-Based Remediation Technologies

BV Piping Design

- Piping:
  - Similar considerations as for SVE piping
  - Consider pressure drop along piping
  - Address potential for condensation

Blower Design

- Types: typically regenerative, positive displacement (rotary lobe)
- Identify necessary flow, predict wellhead pressure/vacuum
- Match blower performance curve to system conditions, including the losses in piping
- Minimize energy use, maximize speed, need flexibility - variable speed drive motors

Monitoring System Design

- Permanent probes, small diameter, good seal
  - Multiple depths - use to confirm design
  - Choose representative locations based on geology, contaminants
- Flow control valves, sample port
- Flow measurement device for each wellhead
  - Pitot tubes, orifice plate, rotometers, anemometer
- Temperature, vacuum/pressure measurement before/after blower

Other Components

- Condensate handling
  - Insulate, heat tracing
  - If extracting, address as would for SVE
- Particulate filters
  - Dust at intake
  - Filters: ~10 um paper cartridge, others
  - Measure pressure drop across filter

BV Off-gas Treatment

- Offgas Treatment (if operating in extraction mode)
  - Carbon Adsorption, Resin Adsorption
  - Thermal Destruction
  - Catalytic Oxidation
- Considerations similar to SVE

Control System

- Control system
  - Well suited to unattended operation
  - Typically modest level of automation
  - Auto-dial for shut-down condition
  - Thermal cut-off on blower motor, high condensate tank level, high vacuum/low pressure
  - Pressure relief valves, bleed valve

Off-site Considerations

- Noise < 120 dB
- VOC vapor migration (in injection mode)
  - Utility corridors
  - Basements
  - Vapor discharge to atmosphere
    - Ambient air sampling may rarely be needed

Bioventing Construction and Operations

- Bioventing remediation in months to years
- Construction:
  - Weeks to months
  - Installation of wells, piping
  - Above-ground equipment
    - Often leased
    - Concrete pad, temporary building
- Safety
  - If extraction, similar to SVE
  - Rotating machinery
  - Unexpected vapor migration

Bioventing Start-up And Operations

- Start up
  - Similar to SVE
  - Baseline oxygen uptake in new wells
- Operations
  - Balance air flow to wells
    - Match oxygen demand in area
  - Maintain blower
  - SVE - to - bioventing conversion
- Optimization

BV System O&M Monitoring

- Monitoring – contaminant concentrations in vapor, O_2, CO_2 levels
  - Portable meters typically used
- Periodic respiration tests
- Monitor flow rates, pressures at each well
- Possibly sample soil periodically to assess progress

Bioventing Operations and Closure

- Duration - Longer than SVE, Still Few Years
- Monitoring - Contaminant Concentrations in Vapor, O_2, CO_2 Levels, Air Injection Rates
- Periodic Respiration Tests
- Subsurface Performance Evaluation Checklist
- Verification Sampling and Closure Criteria
  - Based on Respiration Rates: If No O Demand, Done All You Can Do
  - Soil Sampling

References

- Soil Vapor Extraction and Bioventing EM
- EPA/AF Principles & Practices Manual available
  http://www.afcee.af.mil/shared/media/document/AFD-070926-074.pdf
- Air Force Bioventing Design Tool
  http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/bioventing/resources/index.asp

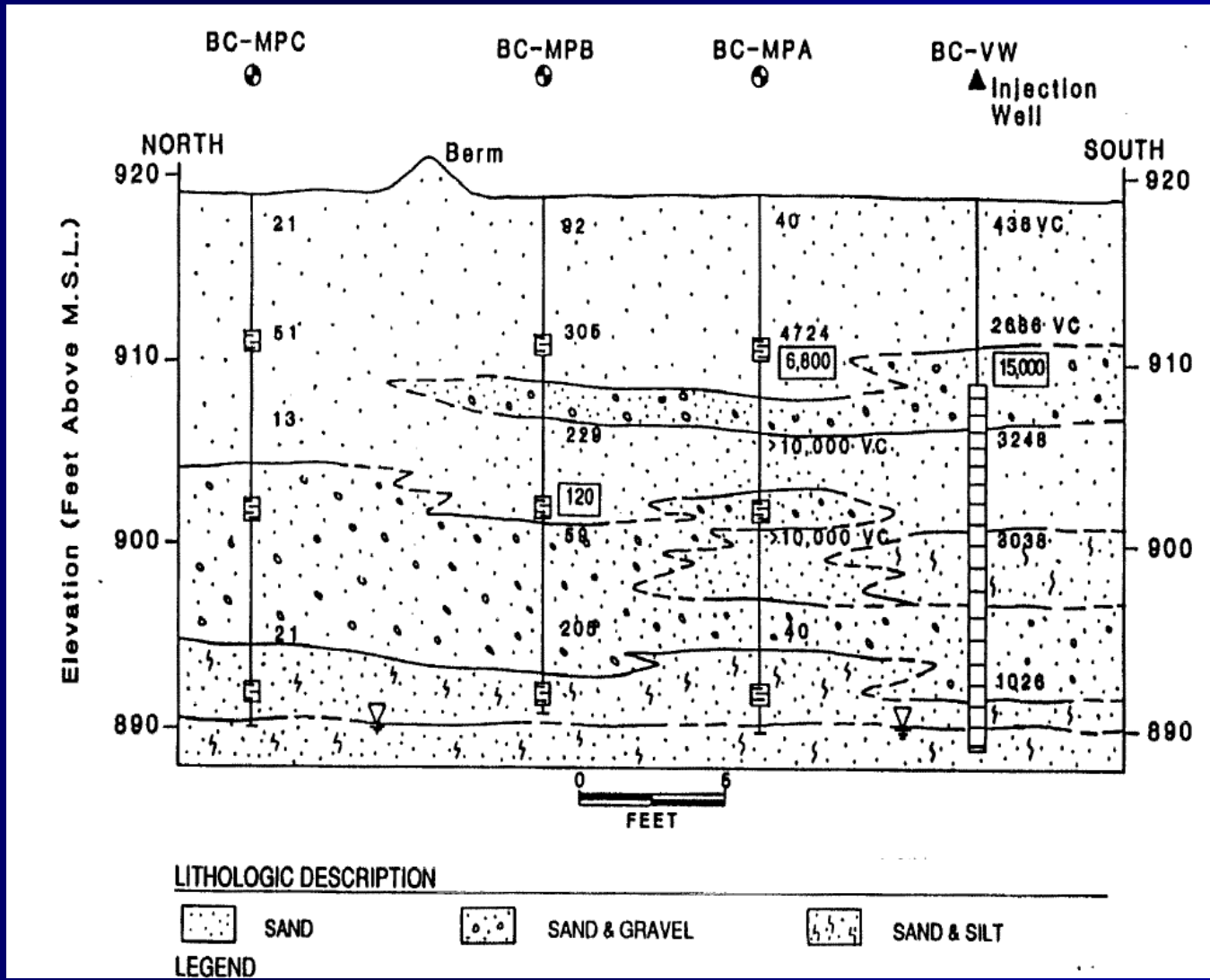
Bioventing Case Study
Battle Creek, Michigan USA

- Fire-training area
- Contaminants
  - 280,000 L of fuels, solvents
  - Benzene, related contaminants to 15,000 mg/kg total petroleum hydrocarbons
- Hydrogeology
  - Sand and gravel

Bioventing Case Study, Continued

- Technology Implemented
  - Air injection, small 1 HP regenerative blower
  - Large area of influence per well (>15 m)
  - Monitored soil gas concentrations
  - Final soil sampling

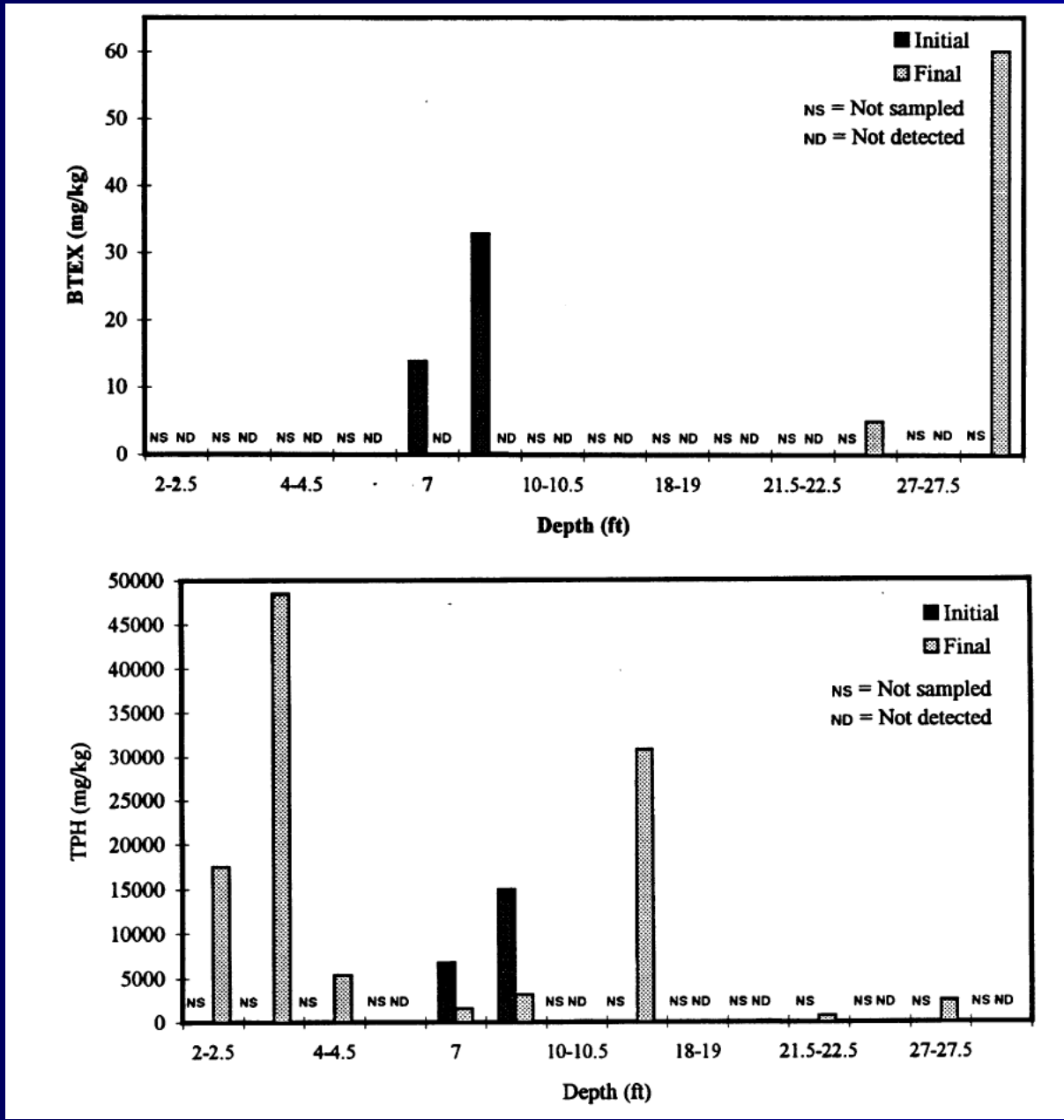
Site Conditions



Air-Based Remediation Technologies

Results

- Benzene, other constituents largely removed
- Less effective for other hydrocarbons



Presentation Summary

- Bioventing for aerobic degradation of organics
  - Look for oxygen limiting conditions
  - Do respiration testing
  - Design aeration system
  - Assess performance by periodic respiration tests
- Variations tailored to biodegradation of chlorinated organics
- Passive bioventing is potentially sustainable option