IN-SITU AIR SPARGING

Presentation Objectives

- Discuss important processes affecting success
- Describe in-situ air sparging technologies, applicability
- Identify data needs for technology selection/design
- Recommend pilot testing approaches
- Provide design guidance
- Discuss operational strategies
- Identify closure strategies and tools to determine progress toward close-out
- Identify IAS frontiers

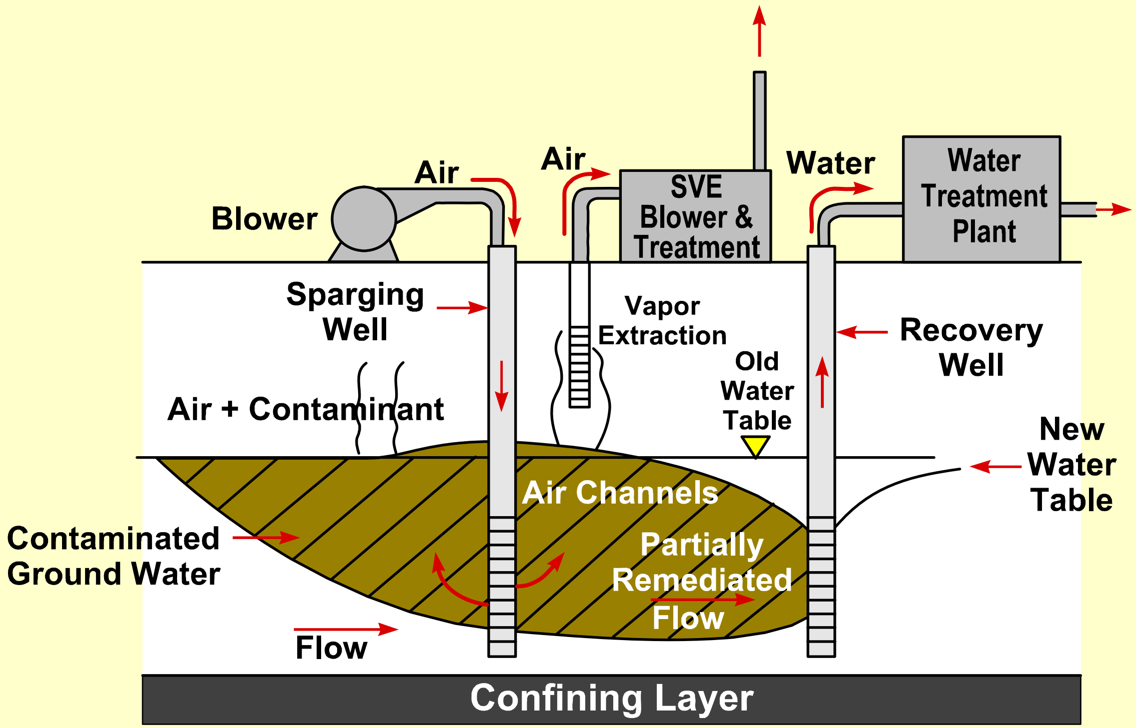
Air Sparging Technology Description

- Concept description
  - Inject air into aquifer
  - Volatilize contaminants into air
  - Oxygenate water - promote bioremediation of light hydrocarbon contaminants
- Basic components
  - Subsurface
    - Vertical injection wells
    - Horizontal wells
    - Gravel-filled trenches
  - Air delivery system

Air Sparging Technology Description

- Other components
  - Soil vapor extraction system
  - Rarely, collection/containment wells
  - Treatment system (vapor and liquid)
  - Monitoring

Schematic of Air Sparging



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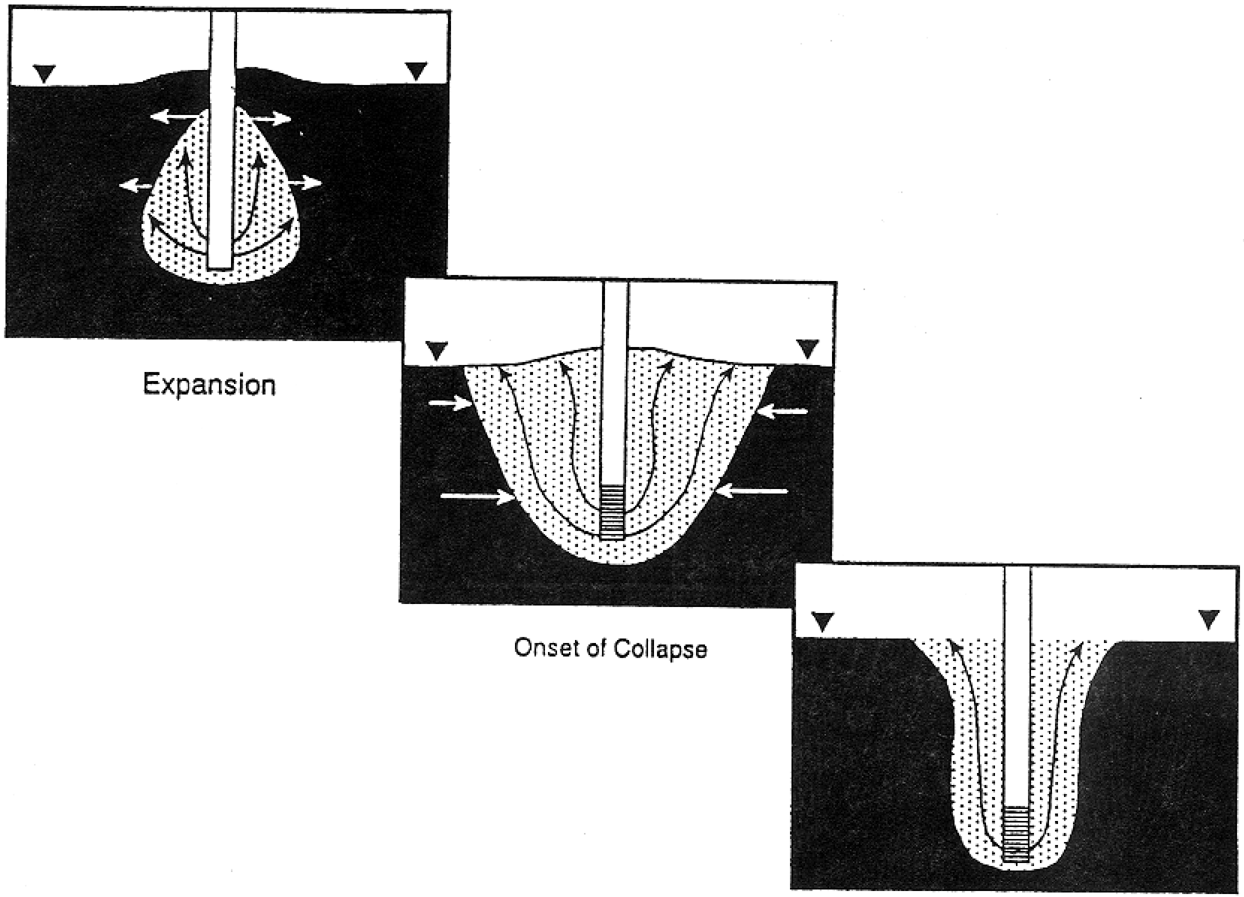
Important Processes Governing Air Movement During Air Injection

- Air must displace water from pores
- Air will displace water from largest pores first, need higher pressure to displace water in smaller pores due to higher capillary forces to be overcome
- Most pores will not be aerated: variation in saturation
- Air will move in channels that represent easiest paths
- Depend on diffusion between contamination and channel
- Initiation of air injection
  - Need higher pressure to move water
  - Upwelling of water table occurs
  - Once air discharges to water table, paths equilibrate and pressure typically drops, water table back to static

Important Processes Governing Air Movement, Continued

- Cessation of sparging
  - Channels collapse
  - Air trapped in pores, slowly dissolve
  - Water table falls, then recovers
- Channels may be widely separated, shunted past contaminants, or migrate far from injection
- Pulsing
  - Re-inflate channels periodically
  - May deflect particles, change channel location
  - Allow delivery of dissolved oxygen with minimum effort
- Reduced transmissivity due to air

Air Injection Behavior



Applicability

Air Sparging

- Contaminants
  - Chlorinated volatiles, volatile hydrocarbons
  - Low solubility/high vapor pressure compounds
  - Biodegradable contaminants
- Homogenous, permeable soils
  - Subtle differences in soil pore size affects where air can displace water at a given pressure
  - If shallow water table, can overcome heterogeneous geological strata by installing sparging trench
- Unconfined aquifer (limited application to confined aquifers)

Limitations

- Not appropriate for thick product layers
- Limitations
  - Preferred pathways
  - Low permeability zones
  - Dispersal of plume

Air Spargine Enhancements, Variations

- Injection of other gases
  - Ozone – oxygen source, oxidizer, limited lifespan
  - Pure oxygen
  - Methane, propane as co-metabolites
- Biosparging
- Ground water recirculation wells
  - Closed system, various configuration, treatment in "well"
  - More in later lecture

Design Data Needs
In-Situ Air Sparging

- Water table depth, fluctuations, gradient
- Stratigraphy
- Distribution and nature of contaminants
  - Solubility / vapor pressure
  - Location relative to flow
  - Biodegradability
- Soil permeability and air entry pressures
- Ground water geochemistry
- SVE properties, bacteriological nature
- Cleanup levels

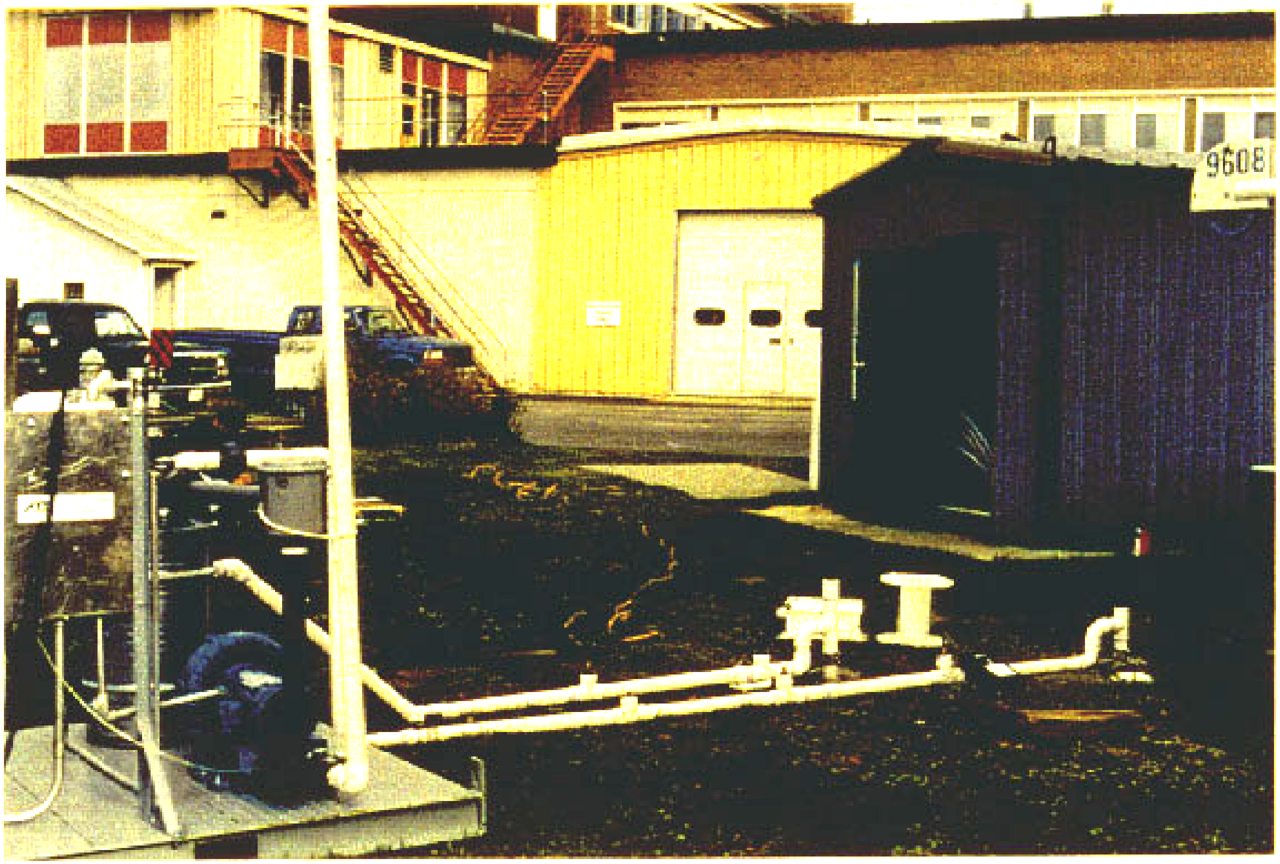
Pilot Testing

- SVE pilot
- Primary objective - determine air distribution
  - Neutron probe data, time-domain reflectometry
  - Dissolved oxygen increase
  - Change in SVE performance
  - Groundwater response to air injection
  - Tracer gases
  - Geophysics - electrical resistivity tomography

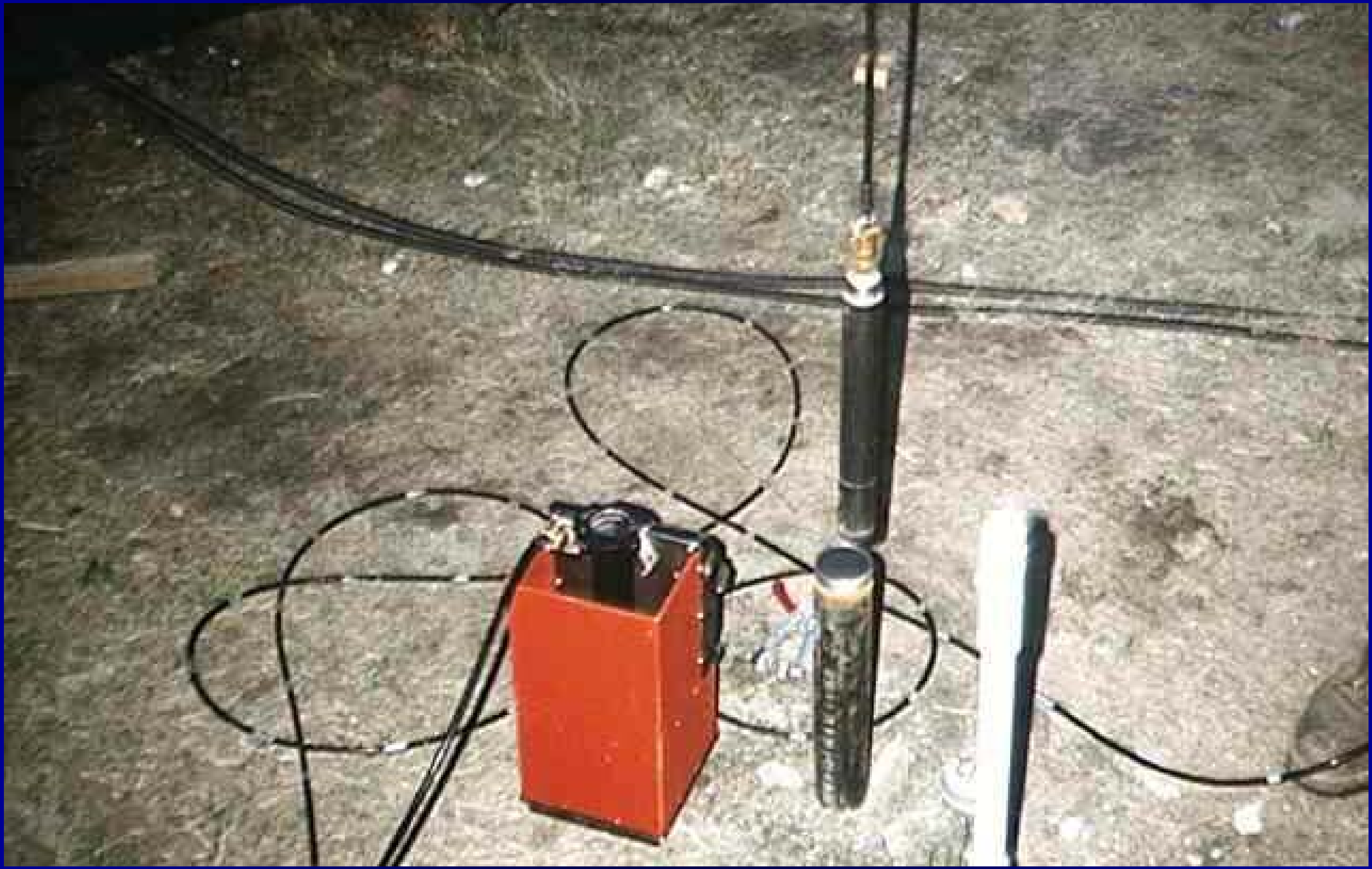
Pilot Testing, Continued

- Air injection pressures and rates
  - Compare pressure at which air begins to enter well to air entry pressure of predominant soil type
  - Air entry pressure of predominant soil type can be measured or estimated based on gradation
  - If pressure when flow begins is substantially less than air entry pressure, preferred flow, poor air contact

AOC-9 layout, looking North-northeast, with blue Ice Well building in gackground



Neutron Probe



Design Issues

Well Spacing
Screen Placement

- Well placement
  - Cover **<u>3-D</u>** extent with adequate air distribution to achieve removal. Do NOT just draw circles on site map
  - Channels likely less laterally extensive at depth
  - Criteria:
    - Achieve minimum air saturation/channel spacing (10-20% air saturation)
    - Models: generally inadequate information at scale of interest determining air distribution

Well Spacing, Continued

- Well placement, continue
  - Strategy
    - Can orient line of wells across plume
    - Distribute wells through plume
    - Address source
  - Can use vertical or horizontal wells

US Air Force Design Paradigm

- Determine feasibility
- Well spacing 5 meters
- Well depth 5 meters below water table
- Inject at 0.5 cubic meters/minute
- Site considerations

Component Design

- Well design
  - Drill method: do not use drilling mud if possible
  - Careful logs of materials encountered, take samples
  - Diameter: typical 5 cm diameter, larger at high flows
  - Materials: typically steel, some PVC, plastic is dangerous under high pressure
  - Screen: continuous wrap, size slot based on formation, short screen length (most air goes out the top)
  - Filter pack: design as for water wells
  - Grout seal very important
  - Development important, pulsing will draw in fines
  - Horizontal wells: most appropriate with thin saturated zone

Component Design, Continued

- Trench – Alternative to Wells
  - Applicable if shallow water table, plume containment is goal
  - Avoids heterogeneity issues
  - Consider ground water flux
    - Inject adequate air to strip contaminants or transfer oxygen
    - Geochemical changes, mineral precipitation
    - Trench may be preferred path
  - Backfill sized for formation

Component Design, Continued

- Piping:
  - Can use flexible tubing
  - Air under pressure - materials need to handle pressures
  - Calculate balanced flow for individual piping legs
  - Spreadsheets useful to design
- Blowers/compressors
  - Type: typically rotary vane or air compressor,
  - Identify necessary pressure to inject air, predict flow
  - Match blower performance curve to system conditions, including the losses in piping

Component Design, Continued

- Monitoring systems
  - Parameters: pressure/air flow, ground water and soil gas concentrations
  - Permanent probes, small diameter, SHORT SCREEN
    - Multiple depths - use to confirm design
    - Choose representative locations based on geology, contaminants
  - Flow control valves, pressure gauge at each well
  - Flow measurement device for each wellhead
    - Pitot tubes, orifice plate, rotometers, anemometer
  - Temperature, vacuum/pressure measurement before/after blower

Other Components, Continued

- Control system
  - Typically unattended operation
  - Typically modest level of automation
  - Automatic pulsing
  - Auto-dial for shut-down condition
  - Thermal cut-off on blower motor, high pressure
  - Pressure relief valves

Start-Up/O&M

- Objective: operate equipment, gather baseline data, adjust operating parameters to achieve desired air injection
- Perform equipment checks
- Initial/baseline monitoring of GW, soil gas concentrations
- Start up: open bleed valve, start blower, gradually close bleed valve to get air to flow to formation
- Note pressure at which air begins to flow into each well - indication of preferred flow
- Balance air flow to multiple wells by adjusting valves

Start-up Of IAS Systems, Data Collection

- Verify vacuum/pressure distribution
- Monitor water table rise around representative wells, moisture content
- Monitor contaminant and DO concentrations in subsurface
- Monitor equipment performance (current draw, temperature)

IAS System O&M Monitoring

- Verify vacuum / pressure distribution
- Monitor water table rise around representative wells, moisture content (e.g., using neutron logs)
- Monitor contaminant and DO concentrations in subsurface
- Monitor equipment performance (pressures, temperature)
- Subsurface monitoring
  - Verify vacuum / pressure distribution
  - Periodic soil gas, ground water sampling
  - Concentrations in “blowing” wells are unrepresentative
  - Water level monitoring
  - Air quality in nearby buildings

IAS System Operations and Maintenance

- Periodic system checks and routine maintenance
  - Check, lubricate blower
  - Check/clean particulate filter
  - Verify flow rates (total, individual wells)
  - Balance multi-well system
  - If simple offgas treatment (for SVE), O&M not costly

IAS System Operations and Maintenance, Continued

- Pulsing
  - Take advantage of air channel expansion
  - Reduce costs for power
  - Base pulse time on time for water table rise and decay after start-up
- Safety
  - Vapor migration to buildings, utilities
  - Blowers (rotating equipment, hot piping)
  - Piping failure
  - Liquids (fuels, etc.) Ejected from monitoring points

IAS System Optimization

- Periodic analysis of monitoring data critical
  – Verify adequacy of air flow, distribution
  – Evaluate ground water concentrations
  – Recommend changes in operation
- Tracer testing
- System rebound - analysis of data clarifies progress toward cleanup
- Rebound is very common at sites with poor monitoring system design
- Subsurface performance evaluation checklist

IAS Site Shutdown & Closure

- Closure goals
  - Meet absolute concentration in ground water
  - Minimum rebound

Air Sparging Case Study
Hastings, Nebraska USA

- Building 124, Former Ammunition Loading Plant, 1942-1958
- Trichloroethylene up to 16,000 ug/L
- Hydrogeology:
  - Water table at 33 m
  - Silt over sand/gravel
  - 1-m thick clay aquitard at 38 m
  - Deeper sand/gravel aquifer with few silt/clay layers below, also contaminated

Air Sparging Case Study
Hastings, Nebraska USA, Continued

- Applied technology (large pilot study)
  - Air sparging with co-metabolic biosparging and SVE
  - Both horizontal and vertical wells used in shallow aquifer
    - Vertical wells in source area
    - Horizontal wells
      - Downgradient to contain plume
      - Installed 15 cm diameter well with petroleum industry and utility burial rigs
  - 8.5 cu m/min rotary lobe blowers for air injection at 310 kilopascals
  - 17 cu m/min from 2 regenerative SVE blowers up to 40 kilopascals vacuum
  - Vapor-phase carbon off-gas treatment
  - Methane, nitrous oxide, tetraethyl phosphate injection

Air Sparging Case Study Hastings, Nebraska USA, Continued

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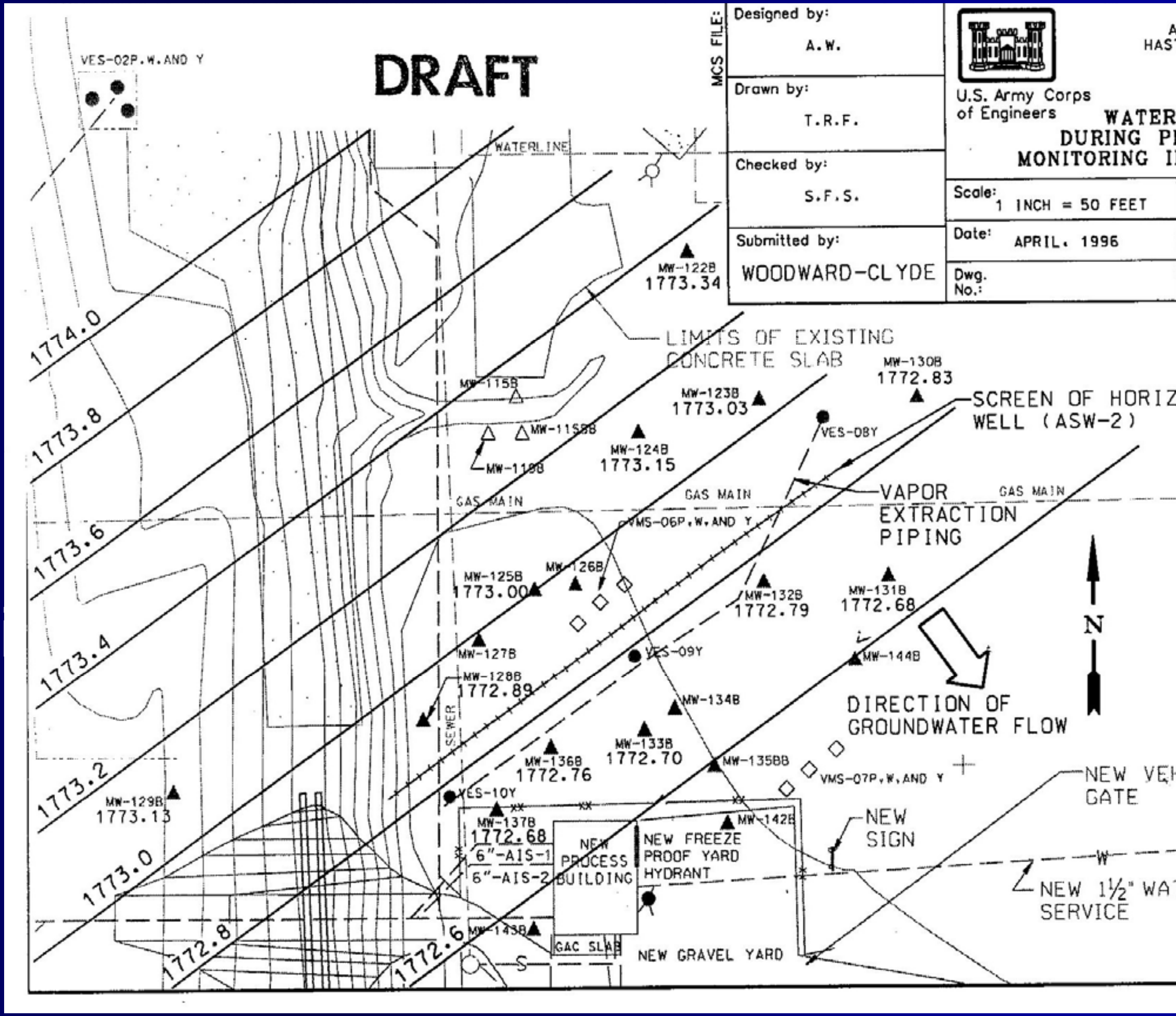

Air Sparging Case Study Hastings, Nebraska USA, Continued

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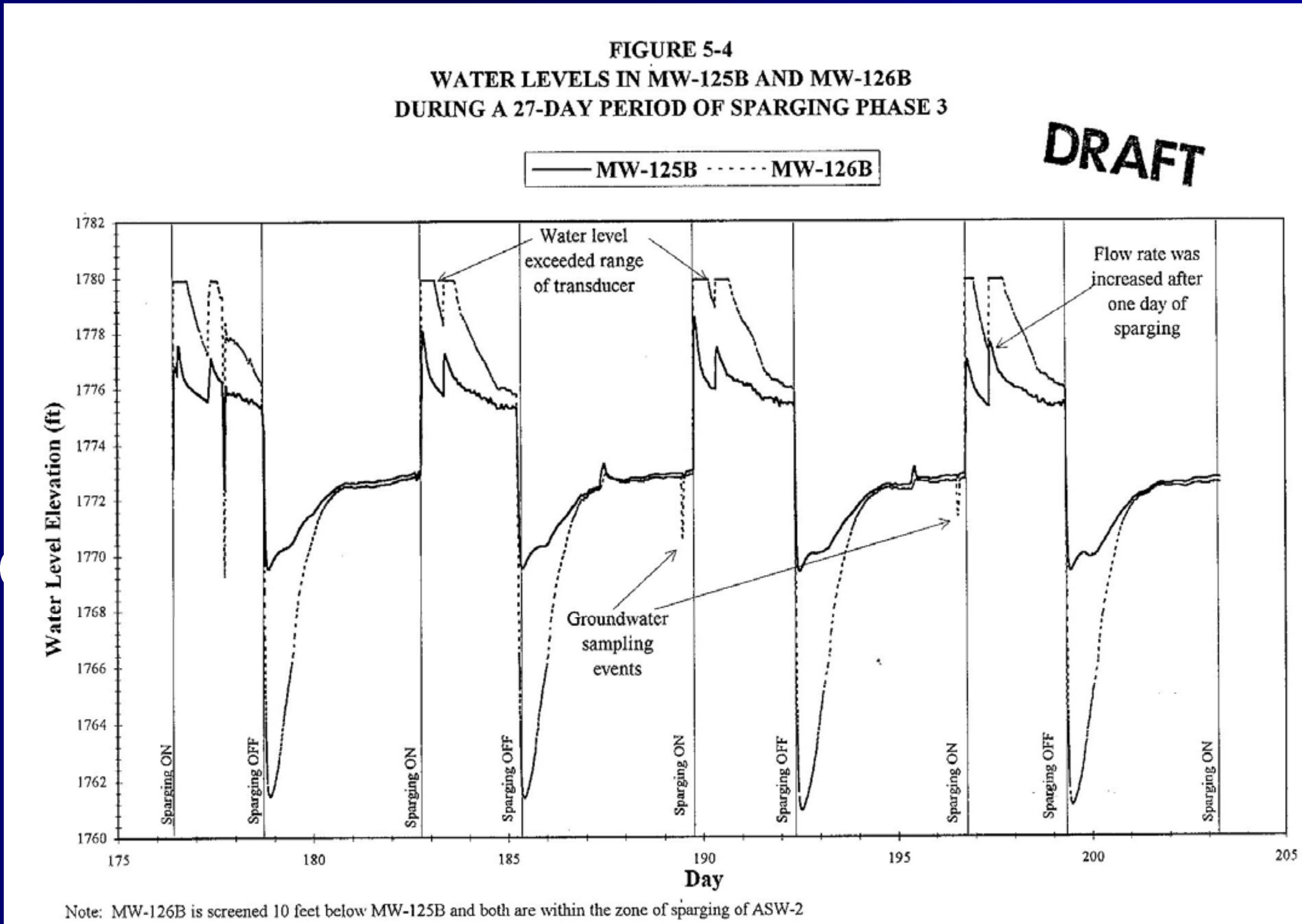

Air Sparging Case Study Hastings, Nebraska USA, Continued

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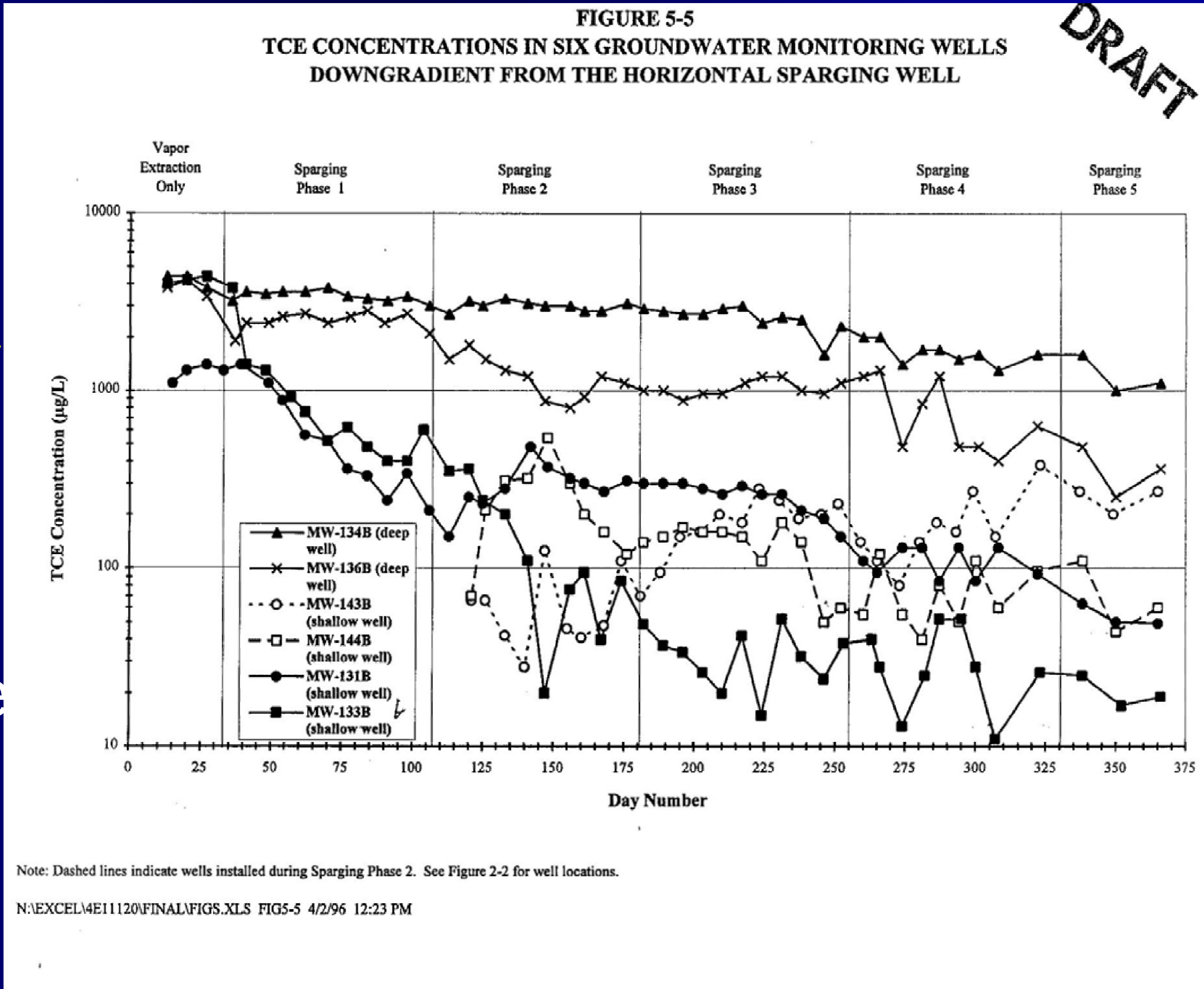

Air Sparging Case Study Hastings, Nebraska USA, Continued

- Results
  - Operated for approximately a year
  - Concentrations were reduced
  - Good air distribution with horizontal well
  - Phosphate injection discontinued
  - Injected air reduced aquifer transmissivity
  - Evidence of plume displacement, underflow
  - Difficulty in sparging down to underlying clay

Air Sparging References

- EM 1110-1-4005 In-Situ Air Sparging
  http://140.194.76.129/publications/eng-manuals/em1110-1-4005/toc.htm
- Battelle Air Sparging Paradigm
  - http://www.estcp.org/documents/techdocs/Air_Sparging.pdf
- EPA/600/R-96/041 Diagnostic Evaluation of In-Situ SVE-Based System Performance
- Remediation System Evaluation Checklists
  http://www.environmental.usace.army.mil/rse.htm

Presentation Summary

- Applicability: VOCs, aerobically degradable organics
- Pilot tests: determine air distribution, injection pressures and flow rates
- Design:
  - Do NOT use radius of influence
  - Consider three dimensional air distribution
- Operation:
  - Collect subsurface, above-ground equipment data
  - Check/maintain equipment
- Closure
  - Evaluate concentrations remaining
  - Rebound tests
- Enhancements: other gases, biosparging