2015 International Petroleum Environmental Conference

HORIZONTAL DIRECTIONAL DRILLING AND WELL INSTALLATION AT SMALL SITES

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History of Horizontal Environmental Wells

- **Horizontal/Directional Oil Wells in the 1930s – Present**
- **Directional "River Crossings" in the 1970s**
- **Environmental Applications for the Department of Energy in 1988**
- **Utilized for Most Remediation Applications by 2015**

Environmental Applications

- Sampling under obstructions
- Extraction techniques
  - Groundwater
  - Free phase product – NAPL and DNAPL
  - Vapors
  - Dual phase
- Injection techniques
  - ISCO
  - Nutrient injection
  - Air sparge
  - Bio sparge
  - Barriers – PRBs/HRx
- Thermal treatment
  - Hot air/steam injection
  - Electrical resistance heating
- Dewatering
- Slope stability
- Mine tailings
- Ground water production

Applications/Advantages of Horizontal Wells

Three Major Advantages

- **Geometry**
- **Access areas unreachable to vertical wells**
- **Minimal site impact**

Directional Control

- The bit is navigated along a prescribed path
- The well need not be horizontal
- Bore path is design is based on
  - Allowable bending radius of drill pipe and well materials
  - Geology
  - Treatment objective
  - Surface constraints

Directional Control/Steering

- The drill string is steered by pushing the drill pipe against an asymmetric bit with a hydraulic jet; “duck bill” or bent sub
- The force against the bit or sub forces the drill pipe in direction of the bit orientation
- When the entire assembly is rotated, the drill string goes straight
- A sensor behind the bit sends the direction/orientation of the bit to the surface

Directional Control/Steering

Locating Technologies

- **Several Options Available**
  - **Walkover/Radio Beacon**
  - **Wireline**
    - **Oil Field Technology**
    - **Short Steering Tool (SST)**
  - **Gyroscopic**
- **Selection based on bore path, interference risk, depth and cost**
- **All methods have ± 0.5 – 2% depth accuracy**

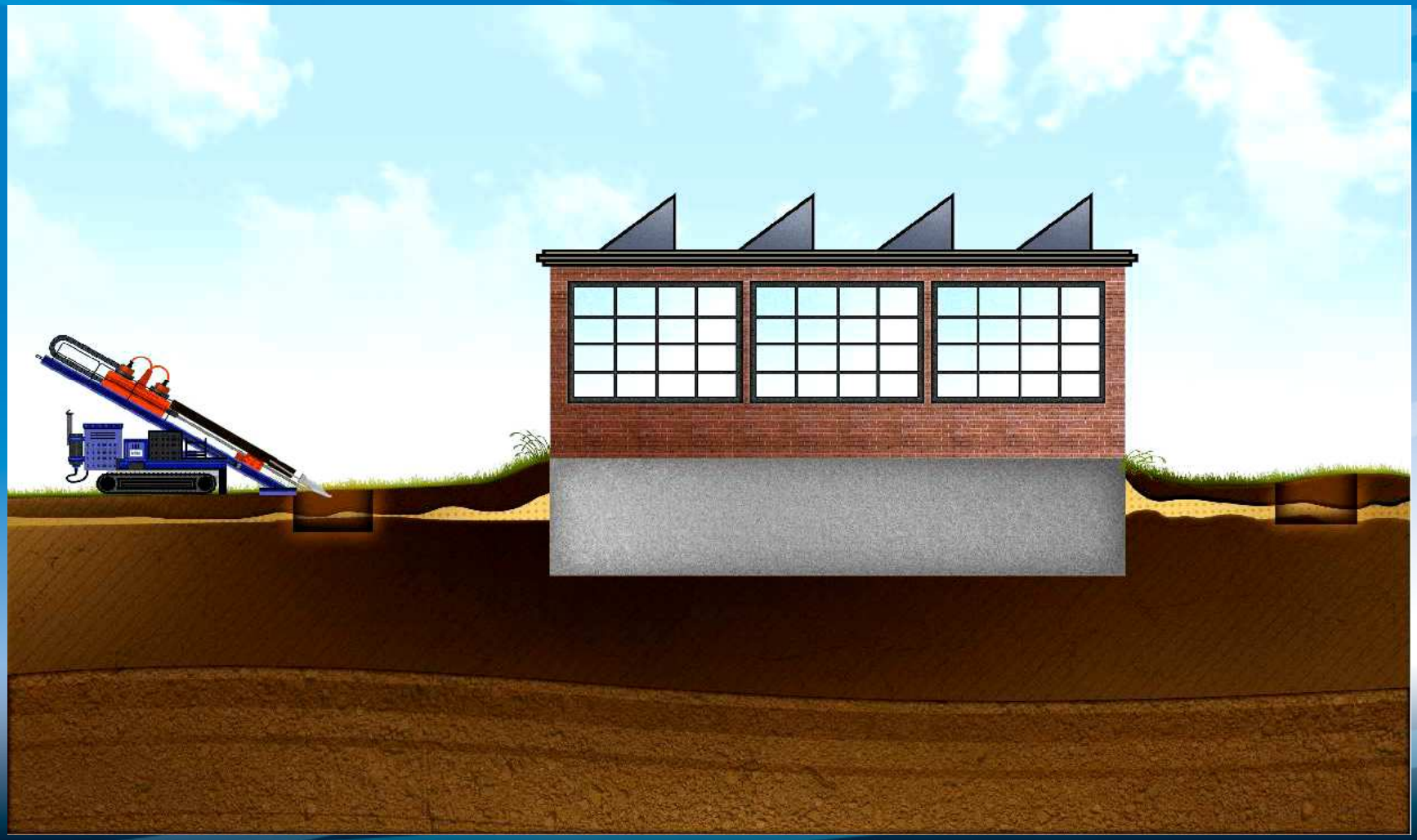
Drilling Fluids are Required

- **Maintain hole stability**
- **Remove cuttings**
- **Limit drilling fluid loss to the formation**
- **Cool bit and steering tools**
- **Two types commonly utilized**
  - **Bentonite**
  - **Biodegradable polymer**

Well Materials (Screen & Casing)

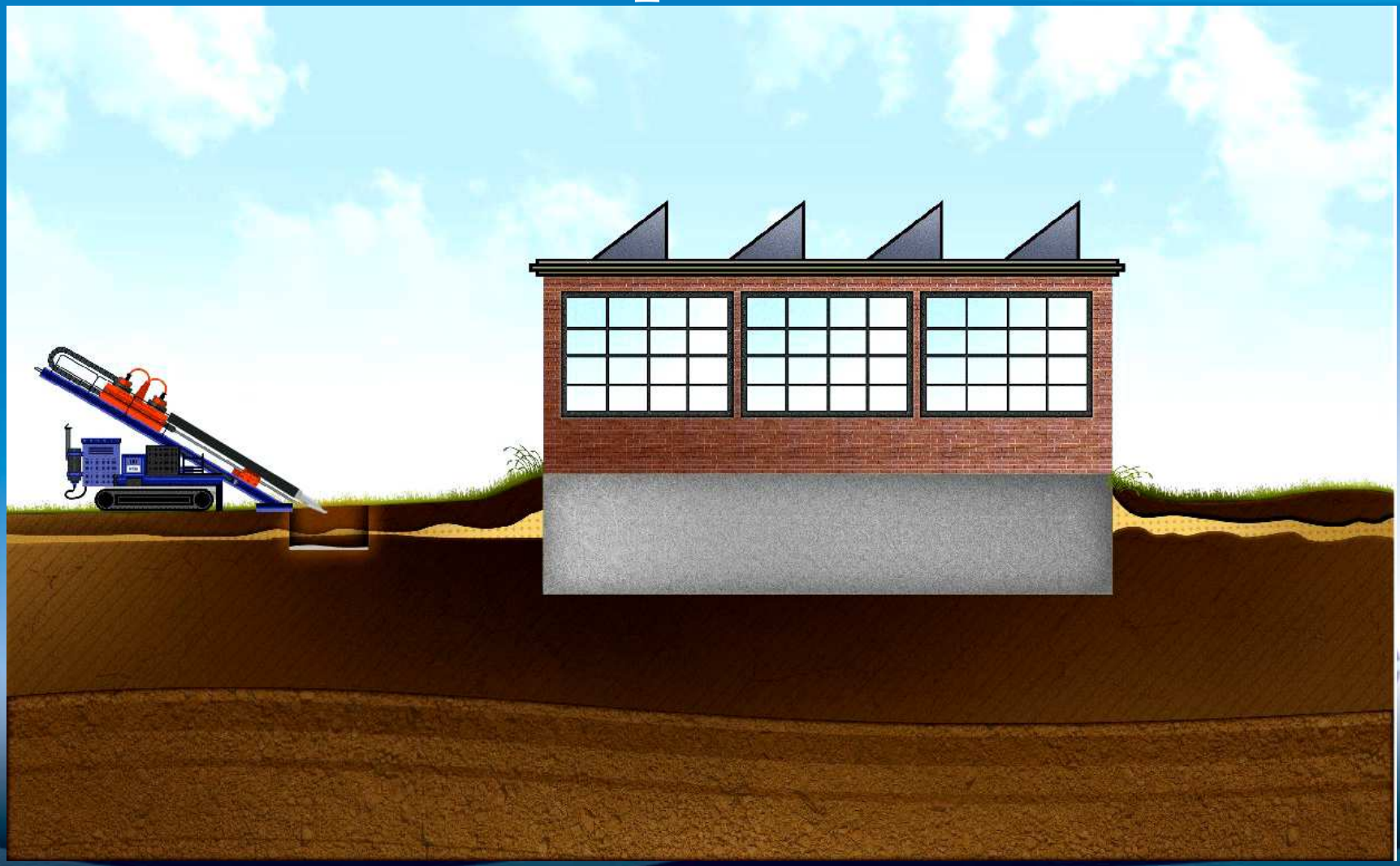
- **Similar materials to vertical well installations**
  - **PVC**
  - **Carbon steel**
  - **Stainless steel (304 and 316L)**
  - **HDPE**
  - **Fiberglass**

Continuous Well Installation



Continuous Well Installation

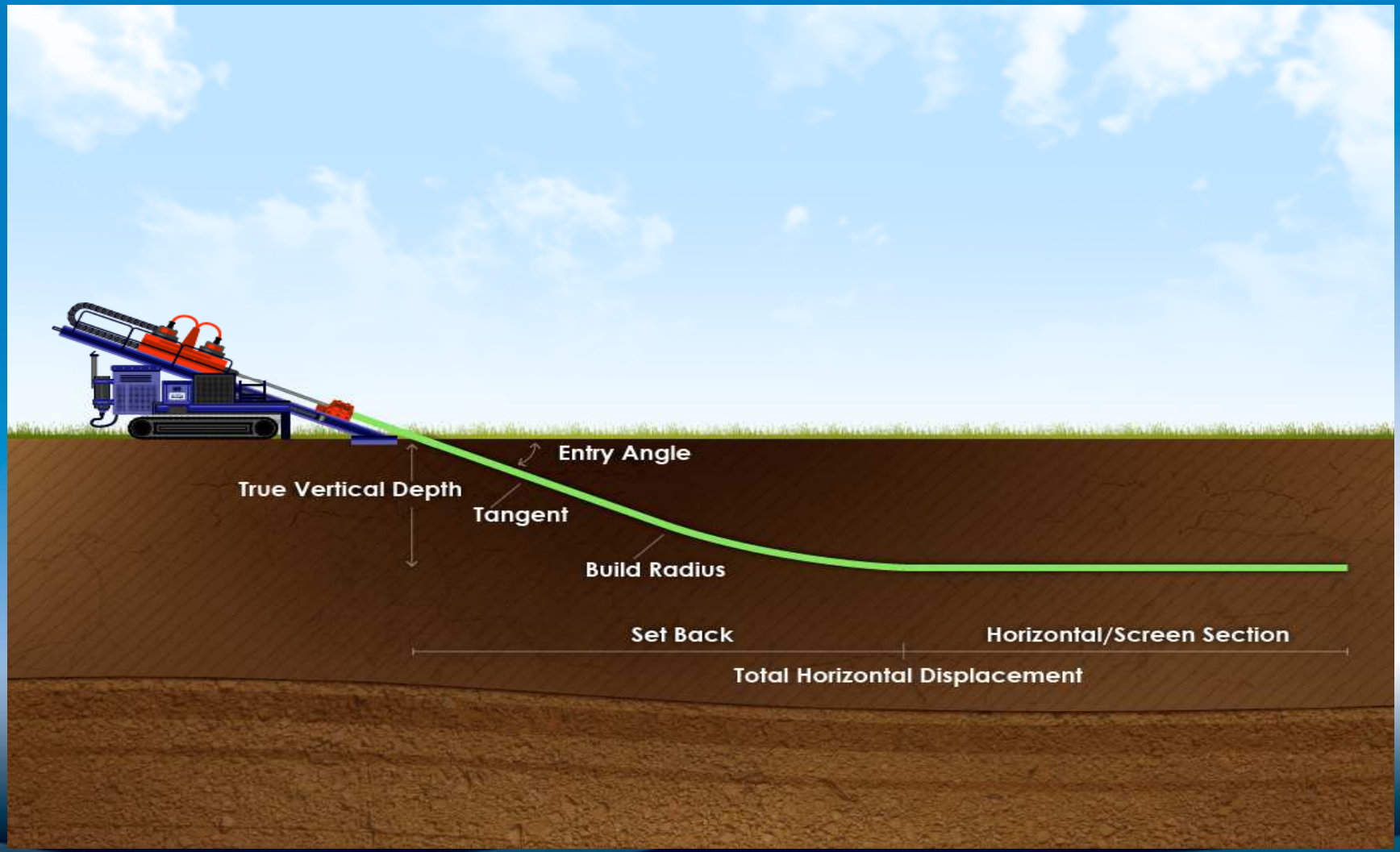
Blind Well Open Hole



Borepath/Well Geometry

- **Terminology**
  - **Entry angle**
  - **Tangent**
  - **Radius of curvature (build radius)**
  - **Horizontal section**
  - **True vertical depth**
  - **Measured depth/pipe length**
  - **Set back – determined by combination of the above**

Borepath/Well Geometry



Drilling Equipment

- **Drill rig**
- **Fluid cleaning/recycling system**
- **Pipe trailer**
- **Support vehicles**
  - **Water truck**
  - **Crew truck**

Small Rig Set Up Area

- **7,000 lb. capacity rig**
- **30’ x 50’ area**
- **Continuous well requires area at exit point**

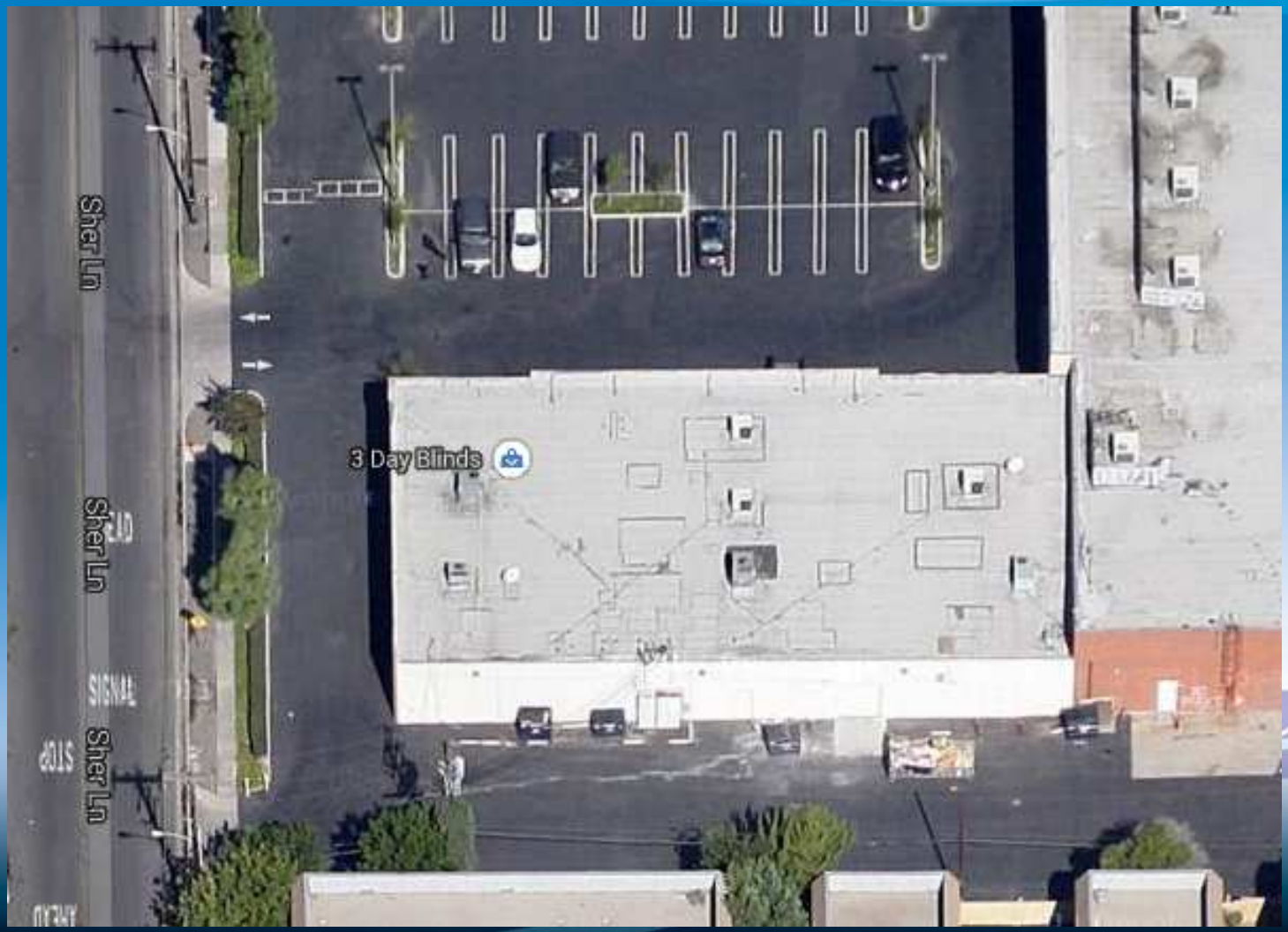
Sparge/SVE

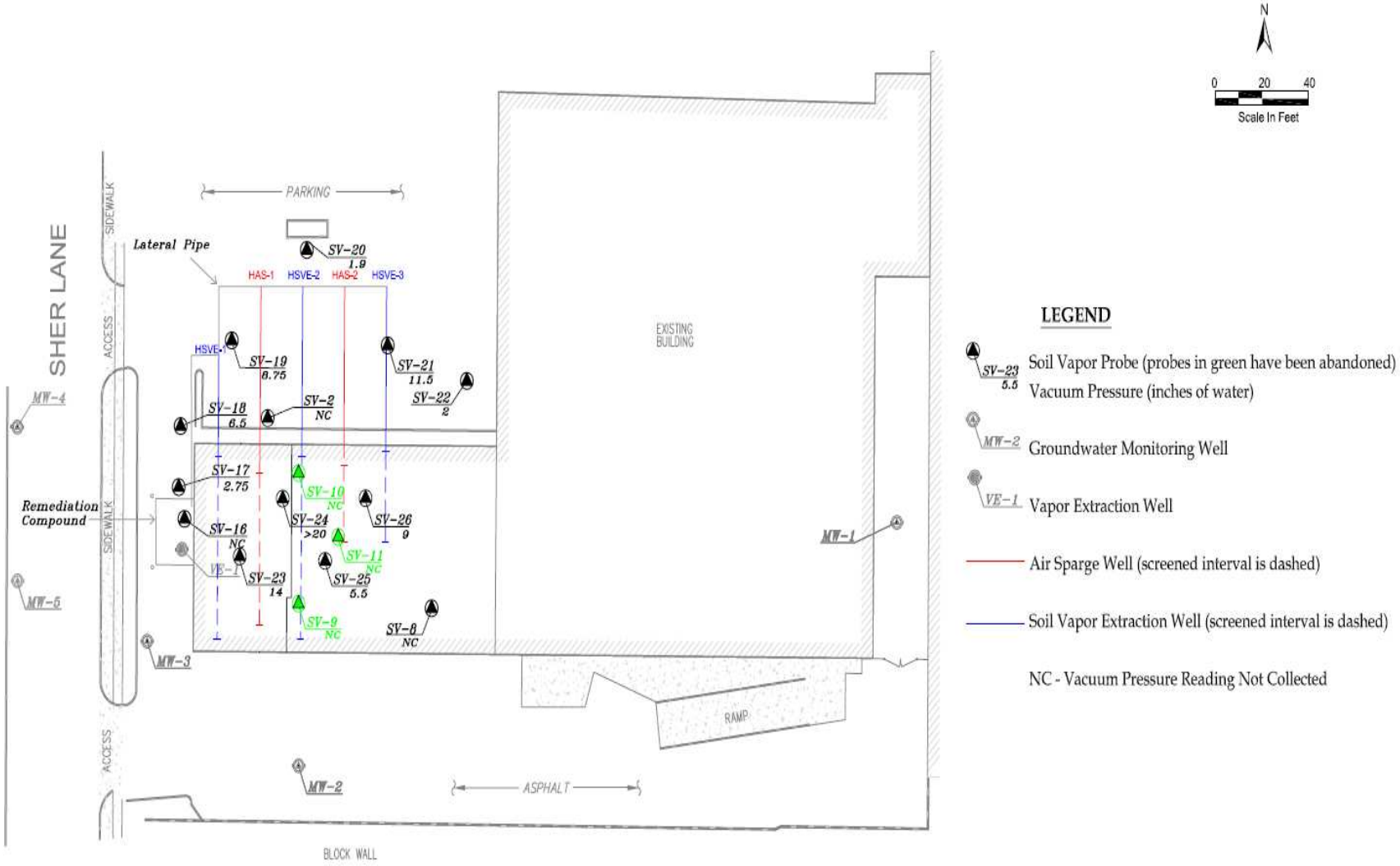
- Former dry cleaning facility, Los Angeles Basin
- Active retail site
- Contaminant mass in soil and groundwater under building
- Remedy could not impact ongoing operations
- Original plan included 20 vertical wells – businesses closed for 60 days for construction
- Horizontal wells to the rescue

Sparge/SVE

- **Original design called for continuous wells**
  - **Three SVE**
  - **Two sparge**
- **Site constraints altered design**
- **Blind well technology was utilized**
  - **Three SVE wells: 99' long, 4' deep, 2" sch. 80 PVC**
  - **Two sparge wells: 99' long, 11' deep, 2" sch. 80 PVC**

SVE




N
0
20
40
Scale In Feet
SHER LANE
SIDEWALK
ACCESS
PARKING
Lateral Pipe
SV-20
1.9
HAS-1
HSVE-2
HAS-2
HSVE-3
HSVE-1
SV-19
6.75
SV-21
11.5
SV-22
2
SV-18
6.5
SV-2
NC
SV-17
2.75
SV-10
NC
SV-24
>20
SV-26
9
SV-16
NC
SV-11
NC
SV-23
14
SV-25
5.5
SV-9
NC
SV-8
NC
Remediation
Compound
VE-1
MW-4
MW-5
MW-3
MW-2
MW-1
EXISTING
BUILDING
RAMP
ASPHALT
BLOCK WALL
LEGEND
SV-23
5.5
Soil Vapor Probe (probes in green have been abandoned)
Vacuum Pressure (inches of water)
MW-2
Groundwater Monitoring Well
VE-1
Vapor Extraction Well
Air Sparge Well (screened interval is dashed)
Soil Vapor Extraction Well (screened interval is dashed)
NC - Vacuum Pressure Reading Not Collected

Sparge/SVE

- All wells installed in three days with no impact to ongoing operations
- Soil vapor probe observed negative pressure 68' from the horizontal well screen
- Concentration of PCE was reduced by 99% in three months
  - Data provided by Rincon Consultants, Inc.
    - Mr. Torin Snyder
    - 760.918.9444
    - tsnyder@rinconconsultants.com

Western US Site

- **Challenging site conditions**
  - **Highly urbanized/residential area**
  - **Very small site**
  - **No room for set back**
  - **Cobbles from surface to 12’ bgs**
  - **Sparge and SVE well pair**

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Western US Site

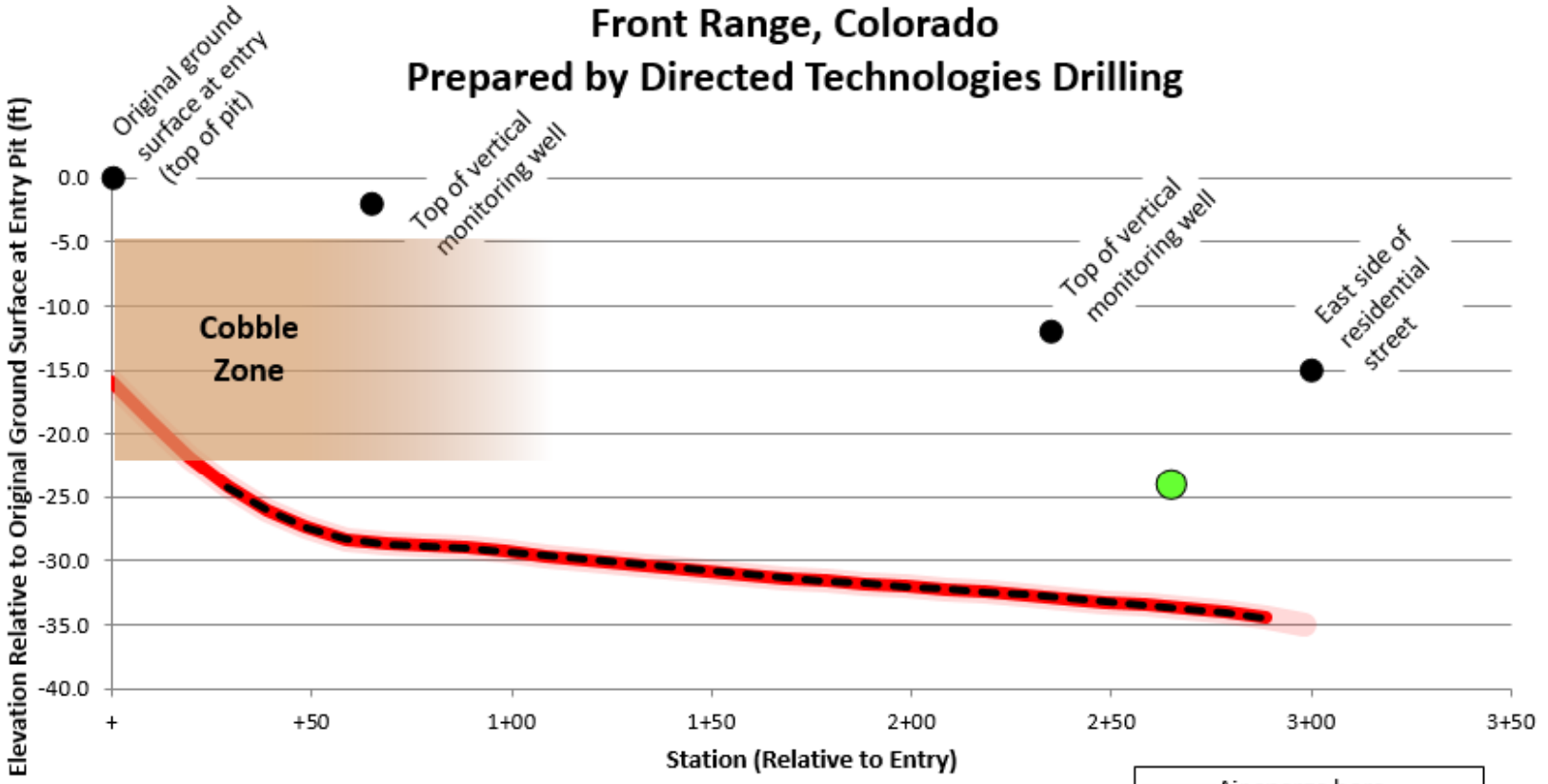
- **Solution**
  - **Place rig in tank pit excavation**
    - **Borehole starts below cobble zone**
    - **Significant decrease in set back distance**


THIS SIDE IN
THIS SIDE IN
THIS SIDE IN


2045


2045

UST Remediation Site
3-inch Diameter HDPE Sparge Well
For Undisclosed Client
Front Range, Colorado
Prepared by Directed Technologies Drilling



Bore Notes:
Borehole drilled length - 300 ft
Borehole horizontal length - 298 ft
Well overall length - 290 ft
Well screen length - 260 ft

Western US Site

- Creative Thinking Overcame Site Challenges
- Total of 255’ of drilling
- Seven rig days
- Cost for drilling and well installation
  - $85,000
  - $153/ft.
  - Costs do not include excavation, shoring and waste containment and disposal

In Summary

- **The technology is innovative - not experimental**
- **Horizontal wells are a proven, cost effective installation method**
- **Thousands of wells have been successfully completed in the US**
- **Horizontal wells can be used with all remediation technologies**
- **The technology is innovative – not experimental**