Evaluation of a Horizontal Well

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Air sparging reduces contaminant concentrations through a combination of two processes:

- volatile constituents are partitioned from soil or ground water into the injected air, where they may subsequently be captured by a vapor extraction system
- the injected air increases the concentration of oxygen in ground water and soil vapor, which accelerates aerobic biodegradation of contaminants.

The primary advantages offered by air sparging are:

1) surface water treatment equipment and water disposal are eliminated
2) remediation of sorbed contaminants and contaminants in the capillary fringe is accelerated
3) disturbance of surface environments is minimized (especially if horizontal wells)
4) ground water flow is not strongly disrupted

Background: Air Sparging

Air sparging is an in-situ remediation technology where air is injected into the saturated zone of an aquifer. It is an alternative to conventional ex-situ pump and treat systems for remediation of contaminated ground water.

It is necessary to understand the pattern of air flow that will occur in the subsurface in order to determine the optimal placement, number, and operating parameters of sparge wells. It is generally acknowledged that soil properties, injection pressure, and injection rate will influence the flow of air during air sparging.

Horizontal air sparging wells offer some important advantages for ground water remediation. The use of a horizontal well can provide more uniform airflow along the axis of the well (as compared to a number of aligned vertical wells) and considerably reduces the impact of well installation at the surface.

Three air sparging pilot tests on horizontal wells were conducted at a coastal test site in Southern California:

- a 50-foot long horizontal well
- a 300-foot long horizontal well
- a 400-foot long horizontal well.

Goals of this program were to evaluate:

1) the feasibility of installing both dual-ended and single-ended horizontal wells in the unconsolidated sand
2) the pattern of induced airflow in the saturated zone around horizontal sparge wells
3) the short-term efficacy of the process for remediation of dissolved phase contaminants
4) engineering design parameters necessary for future well construction.

Objectives

This paper discusses the results of the pilot test on one of the three wells, the 400-foot long well. Specific objectives for this installation and test were:

1) determine the feasibility of installing a 400-foot long well in dune sand using jet drilling techniques
2) measure the effectiveness of various well designs / air injection scenarios for delivering air over the entire 290 foot length of screen section

Local Hydrogeology

The ground surface, relatively flat at the site, is approximately 14.5 ft above msl. The water table is approximately two feet bgs and has a slight seaward gradient of 0.011 ft / ft. The subsurface consists of fine to medium grained, poorly graded sand to a depth of 21 feet. Peat and silty clay are known to be present at depth from 12 to 17 feet bgs.

Well Design

The design for the horizontal well was completed by Unocal's Environmental Technology Group. The sparging air flow was estimated by modeling site conditions using TETRAD, a three-phase flow simulator. The well was designed for a flow rate of 1000 cfm to 1300 cfm at 25 psia.

The sparge well was perforated (one 0.140 inch diameter hole every 0.4 foot) to distribute air equally along the length of the well. The sleeve was hooked up directly to the air injection hose, which was flanged to the well casing.

Drilling, Installation, and Development

When drilling in uniform sand, the three major challenges are:

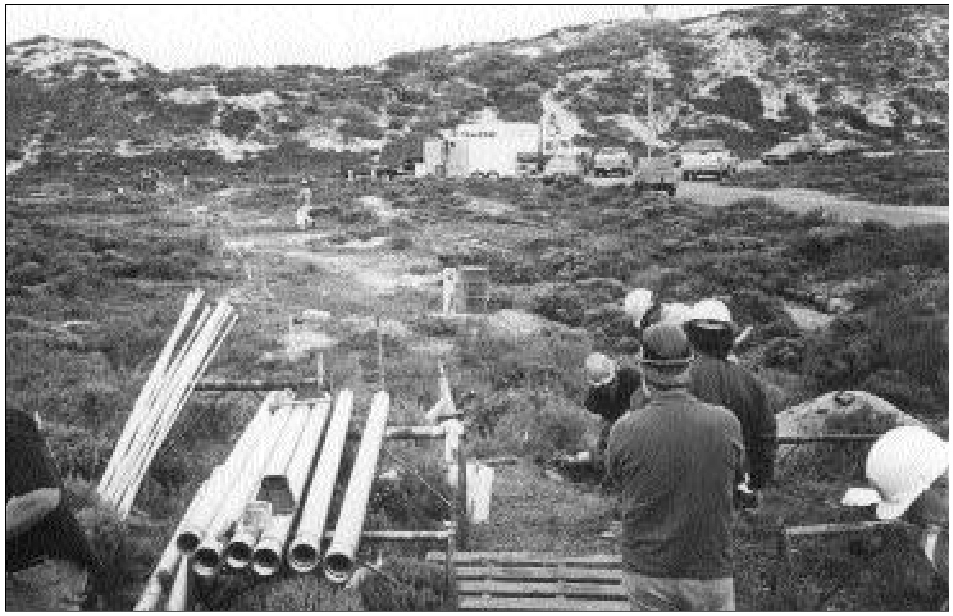
1) borehole stability

2) limiting fluid loss

A three-inch pilot borehole was drilled using a jetting tool. After the pilot hole was completed by exiting to the surface, a nine-inch reamer was attached to the drill rod and pulled back to the entrance pit. Drill rod was trailed behind the reamer to safeguard against losing the hole. The well casing and screen were pulled into the wellbore behind the final reamer pass.

The well string, consisting of the stainless steel casing and screen, inflatable packers, inflation lines, and tremie pipe, were pulled into the hole behind the reamer. The wellbore annulus was pressure grouted along the blank sections of casing from the packers to the surface.

The well was developed after installation. Approximately 450 gallons of 1500 ppmv sodium hypochlorite solution was injected to develop the well. After allowing the solution to stand for 24 hours in the well, approximately 950 gallons of fluid (one well volume) were recovered from the well.



Stainless steel pipe laid out before installation: air sparging well at test site in southern California.

Performance Testing

Monitoring data collected during the sparging test included: ground water levels, soil gas pressure, visual observations, injection pressure, temperature, and flow rate. Air injection pressure was maintained at a constant 4 psig for most tests. It was increased to 6 psig for some tests. Air injection rates ranged from 491 to 1078 scfm. A sock was installed along the length of the well screen during some of the injection tests.

During the various air injection tests performed on the well it was demonstrated that the well provided adequate air flow throughout the perforated section in all of the tests. Elevated soil gas pressure develops where injected air exits the saturated zone, and can be used as a gross estimation of airflow distribution in the wells. Soil gas pressure distribution above the well did not vary dramatically during the different injection scenarios. There appears to be a lower pressure in the center of the well, but this was probably due to factors such as residual drilling mud, sample probe depth, formation changes, or well depth.

Conclusions

- A 400-foot long horizontal sparge well was successfully installed in flowing sands and then demonstrated to be effective for air sparging.
- Horizontal wells can be effectively designed and operated to achieve uniform aeration throughout the screen interval.
- The light-weight perforated stainless steel screen worked well in this installation. Longer wells can be installed using such high tensile strength screens.

The maximum installable length for both single and double-ended wells at the site will depend on five factors:
1) minimizing fluid loss and stabilizing tunnel walls
2) clearing spoils from the borehole
3) obtaining scale-free makeup water
4) keeping drill tool jets unplugged,
5) specifying the appropriate well material.

Horizontal well head for air sparging well in southern California.