Conf-931095--72

WHC-SA-1949-FP

# ResonantSonic Drilling: History, Progress and Advances in Environmental Restoration Programs

Prepared for the U.S. Department of Energy
Office of Environmental Restoration
and Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Date Received: 9-28-93 VE

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Title of Journal
N/A

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|---|---|---|---|---|---|
| Classification/Unclassified Controlled Nuclear Information | [] | [X] | | | |
| Patent - General Counsel | [X] | [] | BW Volk for S.W. Berglin | Ben W. Volk | 9-28-93 |
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| Applied Technology/Export Controlled Information or International Program | [] | [X] | | | |
| WHC Program/Project | [X] | [] | J. D. Berger | J. Di Berger | 9/28/93 |
| Communications | [X] | [] | D.P. Whiting / M.C. Druby | Ben W. Volk per FAX | 9-28-93 |
| RL Program/Project | [X] | [] | DE Trader | | 9/28/93 |
| Publication Services | [X] | [] | DJ Hastings | Debra J. Hastings | 9/28/93 |
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| Project or Program | Lead Org Code | | Sponsor Agency (DOE, DOT, NRC, USGS, etc.) |
| Drilling Technology Development, Arid Integrated Demonstration | 81730 | | DOE |
| Editor | Phone | MSIN | DOE/HQ Program (DP, EH, EM, NE, etc.) |
| S. A. Williams | 6-1518 | N3-05 | EM-50 |

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# ResonantSonic Drilling: History, Progress and Advances in Environmental Restoration Programs

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Date Published
September 1993

To be presented at
Environmental Remediation '93
Augusta, Georgia
October 24-28, 1993

Prepared for the U.S. Department of Energy
Office of Environmental Restoration
and Waste Management

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Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

**RESONANT SONIC DRILLING: HISTORY, PROGRESS AND ADVANCES IN ENVIRONMENTAL RESTORATION PROGRAMS**


## ABSTRACT

ResonantSonic℠ drilling is being used in the environmental industry to drill faster, cheaper, and safer than conventional drilling methodologies. ResonantSonic is a registered service mark of the Water Development Corporation, Woodland, California. The ResonantSonic drilling method, requires no mud, air or water for rapid penetration through geologic materials ranging from rock and clay to sand and boulders. The specialized drill head imparts high frequency vibrations into a steel drill pipe creating a drilling action which allows the retrieval of continuous, undisturbed cores. An added benefit is that the method can be used for angle drilling.

The ReasonantSonic method has been used in the past for projects ranging from pile driving to horizontal drilling. Current programs are utilizing the technique as a valuable tool for obtaining in situ, pristine environmental samples. In the future, this drilling technology could be used for remote, automated sampling at hazardous waste sites.


## INTRODUCTION

The Department of Energy (DOE) Office of Technology Development (OTD) and its contractors Westinghouse Hanford Company (Westinghouse Hanford) and Pacific Northwest Laboratory (PNL) and industry partner Water Development Corporation (WDC), through a cooperative research and development agreement (CRADA), are developing improvements to the ResonantSonic drilling technology to enhance environmental cleanup efforts at DOE sites. Funding for the CRADA is being provided via the Drilling Technology Development Program which is part of the Volatile Organic Compound-Arid Integrated Demonstration (VOC-Arid ID). The VOC-Arid ID is one of several integrated demonstrations throughout the DOE complex designed to support the testing and development of emerging Environmental Restoration Technologies.

## HISTORY OF SONIC DRILLING

The resonant sonic technology was first developed in the 1950s by Albert Bodine, Jr. Mr. Bodine discovered how to design and build a machine that would generate high-frequency vibrations with very high force output that would not self-destruct while passing the vibrations on to the object being resonated. In the 1970s and 1980s, Hawker Siddeley, Ltd., in Canada, made further advances to the patented drilling head and built several rigs for field application. In the forty years since its invention, traditional sonic drilling equipment has been under-used, suffered reliability problems as a system, and had difficulty being accepted in the marketplace. WDC acquired much of the existing equipment in 1990 and is working in concert with DOE contractors and Department of Defense (DOD) facilities to enhance the reliability and acceptance of the resonant sonic drilling system and to reduce the drilling costs of environmental remediation projects.

## HOW SONIC DRILLING WORKS

The resonant sonic drilling method uses a hydraulic drill head that transmits high-frequency, sinusoidal pressure waves through a steel drill pipe to create a cutting action at the bit face. The pressure waves are created by counter-rotating, offset balance roller weights located in the sonic drill head as shown in Figure 1. The drill head is designed to operate at frequencies close to the natural frequency of the steel drill column causing the column to vibrate elastically along its longitudinal axis (See Figure 2.). In the resonant condition, the drill pipe acts like a flywheel, storing energy for its intermittent release at many times the input level. Operating frequencies exceeding 150 Hz and forces ranging up to 1112 KN (250,000 lbs-force) per cycle are reliably generated by WDC's newly designed ResonantSonic drill heads.

There are several ways to perform the sonic drilling activity. The method which yields the coolest core and a representation of near in situ quality core is the dual rod approach. By coupling the sonic drill head to the drill pipe, the cutting action developed at the bit face yields a continuous core of formation material moving into the core barrel. One drill stem affixes to the core barrel and the other drill rod encapsulates the core barrel. Both drill rods can be resonated simultaneously or independently, one rod ahead of the other rod, depending upon formation conditions. Resonant sonic drilling proceeds in five foot, ten foot, twenty foot, or longer core runs as dictated by sampling requirements. Once the desired amount of core is in the core barrel, the inner drill rod and core barrel are removed in sections from the borehole and the core is retrieved. The outer drill pipe remains in place to support the borehole while the core is removed. Because of the high forces developed by the resonant drill head and the external flush nature of the drill pipe, formation material displaced by the cutting face of the bit is forced either into the borehole wall or into the core barrel resulting in no cuttings generated in the drilling process. In order to enhance core quality, little, if any, rotation of the drill rods is used in this method.

Another method of core retrieval is to run the core barrel on a wireline system. In this method, the core barrel simply rests on the inner shoulder of the drill bit and cored material is displaced into the core barrel. A weight on top of the core barrel provides resistance as the soil enters. Because this is a less positive method of filling the core barrel, it is limited by short drilling intervals of approximately 6 inches to 3 feet. As a result, even though the wireline method is faster than the dual rod method for retrieving the core sample, the drilling time often takes longer with more wear on the system components.

It is important to note the difference between ResonantSonic drilling and rotosonic drilling which has been used at some DOE sites. The rotosonic drilling method uses a water washover technique to advance the outer drill casing which makes this procedure little different than a mud rotary coring approach. Substantial liquid and cuttings wastes are generated in the process and loose formation cores are very disturbed since the core must be vibrated out of the drill rod into plastic bags to effectuate core removal. The ResonantSonic drilling method uses no fluids or flushing medium to advance the coring process and thus operates in a totally dry environment. Furthermore, specially designed split barrel samplers, clear lexan liners, bit designs, axial loading units, and closely monitored drill head operating procedures are utilized in ResonantSonic drilling to yield near in situ quality environmental core samples in a safe, efficient manner.

The action of the ResonantSonic drill system in achieving penetration varies with the type of soil and is a result of displacement, shearing, and fracturing actions. (Barrow, 1993) The displacement drilling action is achieved by the vibration "fluidizing" the particles of soil in contact with the drill column, making them highly mobile, causing them to move out of the way and allowing the drill pipe to pass through. This action occurs primarily in granular materials that have sufficient free volume to accept the material displaced. Soils that are plastic in nature, such as clays, are penetrated by a shearing action. For this to occur, the force and related vibratory amplitude must be of sufficiently high magnitude to overcome the elastic nature of the material. Sonic drilling action by impact is associated with the penetration of rock and large boulders. In this case, the vibration of the drill bit promotes high contact forces between the bit of the drill steel and the rock surface, causing fragmentation. To provide a "fresh" rock surface to the bit, continuous rotation of the drill steel is superimposed upon the vibrational action. Each of the drilling actions, displacement, shearing, and fracturing, will result in a core of formation material moving into the resonating drill steel as penetration progresses. The cored material is then retrieved in the core barrel as discussed previously.

Laboratory grade, split-spoon samples are also retrieved with the sonic drill by removing the inner core barrel and driving a 0.61 m (2 ft) split tube sampler [12.7 cm (5 in) outside diameter by 10.2 cm (4 in) inside diameter] ahead of the drill pipe. These split spoon samplers are used for retrieving environmental samples for chemical analyses.

## BENEFITS OF SONIC DRILLING

The ResonantSonic drilling method can yield continuous, relatively undisturbed cores; requires no air, water, mud, or other circulation media for penetration; is very fast; can drill at any angle from horizontal to vertical; and, most important, generates no cuttings in the drilling process. Additionally, the method can be used to resonate a closed-bottom pipe to several hundred feet pushing all formation material aside much like a pile driver. The bottom can then be removed and a well constructed by installing a screen and seal material and back-pulling the temporary drill pipe. All this is accomplished without generating any core, formation water, or waste stream in the process.

## AREAS OF SONIC DRILLING REQUIRING IMPROVEMENT

The primary limitation of sonic drilling is the destructive effect that the vibrations have on the steel drill pipe. The weak links are the threaded connections which exist at the ends of the drill pipe and drill rod. Because the drill pipe and drill rods are currently made from flush joint material, the threads become the most susceptible part of the system. A substantial percentage of the steel is cut away to create the tool joint; thus, at each connection a weak area is created. A solution may be to use thick wall drill pipe with up to 1.27 cm (0.5 in) wall thickness; however, this can result in excessively heavy joints, especially in the larger diameter drill pipe.

Problems have also been encountered in the past with the reliability of the sonic drill head. A number of older machines still in use today are plagued with oscillator, bearing, and rotation linkage problems. The new RSD*300 Sonic Drill head series designed by WDC and in use at Hanford, is demonstrating excellent reliability, and coupled with an aggressive preventative maintenance program, should result in eliminating most down time caused by drill head malfunction.

## PAST USES OF THE SONIC METHOD

The resonant sonic method was used in the early 1970s to drive steel piling to depths up to 200 feet in the ground. The method is much quieter and faster than pile driving and results in no damage to surrounding structures.

Resonant sonic drilling has been successfully used at a number of DOD military bases over the last several years. The method has also been used for environmental drilling projects at the Hanford Site, Idaho Nuclear Engineering Laboratory, Sandia National Laboratories (SNL), and Rocky Flats Plant for various DOE contractors. At SNL in Albuquerque, WDC used its ResonantSonic drilling system to drill, core, and construct two, 160 foot wells at a 15 degree off horizontal angle under a chemical waste landfill. These projects demonstrate that the resonant sonic drilling method can be cost effective, can eliminate or greatly minimize the waste stream of drill cuttings, is safe in highly hazardous conditions, and can perform acceptably under regulatory requirements.

In 1991-1992, the sonic method was used by Harrison Western Drilling Incorporated to install 11 boreholes at the Hanford Site (Volk, 1992). This drilling program showed that the method was 2 to 3 times faster than cable tool drilling and samples were retrieved of equal or better quality than the cable tool rigs. During the 1991-1992 test, excessive downtime was encountered due to failures in the drill pipe and drill head. Enough positive data was generated to warrant further research and development by Hanford to develop the system as a viable option to the baseline cable tool technology currently in use.

## PRESENT SONIC DRILLING ACTIVITIES

As described in the introduction, a CRADA program has been established to pursue refinements to the resonant sonic drilling method and help overcome some of its current problem areas. Westinghouse Hanford, PNL, WDC, and the DOE joined forces to improve the reliability of the resonant sonic equipment, develop more reliable drill pipe, develop various bit designs, enhance angle drilling and directional drilling capabilities, and pursue automated tool handling and decontamination systems. The CRADA participants are also jointly working on a research program to develop a computerized feedback control system for the sonic drilling process. The focus of this system will be to allow operation of the sonic system at optimum frequencies without damaging the drill pipe or causing excess heating of samples.

The first field demonstration of the ResonantSonic drilling method under the CRADA program was initiated on July 19, 1993 and completed on September 6, 1993. During this 7 week period, approximately 4 1/2 weeks were spent in a drilling and sampling mode. A total of 5 boreholes were drilled, four of which were at 45 degree angles. The two deepest wells reached linear lengths of 50 meters (164 feet) and 52 meters (172 feet). A total of 186 meters (610 feet) were drilled at the Hanford Drilling Technology Test Site located north of the 200 Areas Fire Station on the Hanford Site (See Figure 3.). During this testing phase average rates for drilling and sample retrieval were 6 feet per hour.

Current testing under the CRADA program included installation of a 45 degree angle borehole below a parking lot in the 200 West area of the Hanford Site. The soil beneath the parking lot has become contaminated with carbon tetrachloride from fuel processing operations conducted over the past 40 years. As shown in Figure 4, angle drilling allowed placement of the borehole without removing overhead power lines or drilling through the parking lot cover material. The borehole was drilled to a measured depth of 51 m (168 feet) [36 m (118 feet) vertical depth] with 16.8 cm (6 5/8 in) drill pipe and will be completed with 7.62 cm (3 in) stainless steel casing. Future sampling and vapor extraction from the well will be conducted away from the parking lot thus preventing any inconveniences to users of the facility. The sonic drill rig with the RSD*300 sonic drill head is shown in an angle drilling mode in Figure 5 and the remote handling arm is shown in Figure 6. Preliminary results from this carbon test borehole test were: (a) actual drill head time to drill to 168 feet was 5.5 hours; (b) almost all core temperatures were under 90 °F; (c) the use of clear lexan liners resulted in superior core quality; (d) the use of a robotic arm to place the pipe at a 45 degree angle into and out of the mast, yielded a safe operation and demonstrated the automated possibilities of this method; (e) the amount of sampling waste remaining was less than a barrel; and (f) the well was completed as designed with no problems.

Ongoing testing under the CRADA will involve drilling with larger drill pipe [27.3 cm (10 3/4 in)] and installing deep [70 m (230 ft)] vapor extraction wells with 10.2 cm (4 in) stainless steel completions at the carbon tetrachloride site. In addition, a 750 horsepower RSD*750 ResonantSonic drill rig designed and manufactured by WDC will be mobilized to the Hanford Site in 1994 for testing large diameter drill pipe [up to 51 cm (20 in)] in various drilling and driving conditions.

## FUTURE USES OF SONIC DRILLING

A schematic of one of the potential future uses of sonic drilling is shown in Figure 7. The sonic system would be operated in a remote mode to drill long reach angle wells under waste disposal cribs and tanks. Limit switches mounted in the hydraulic circuitry of the rig would prevent excessive force from damaging the drill pipe and would optimize the penetration rate. By using remote handling capabilities and video cameras, the drilling crew would be completely separated from the hazardous materials being removed from the borehole.

Another possible future use would involve the driving of casing for groundwater well installation purpose with no waste production. By driving a blunt ended casing into the ground, the soil would be displaced and compacted into the surrounding porous soil and the drill pipe would be advanced into the ground. Upon reaching total depth, the disposable blunt end of the casing would be knocked off and the borehole could be completed as a groundwater monitoring well.

## CONCLUSIONS

The CRADA process is expected to take approximately 3 years and will culminate in the transfer of technology improvements to the environmental drilling industry. By forming these industry-government cooperative programs, it is believed that the ResonantSonic drilling technology will be greatly enhanced and the results will tremendously assist the efforts to clean up DOE facilities, military bases, and other waste sites.

## REFERENCES

1. Barrow, J. C., "The ResonantSonic℠ Drilling Method-An Innovative Technology for Environmental Restoration Programs," Submitted for Publication to Groundwater Monitoring Review, May 1993.

2. Volk, B. W., G. W. McLellan, and V. L. King, "Results of Testing the Sonic Drilling System at the Hanford Site (September 1991 to May 1992)," WHC-SD-EN-TRP-002, Westinghouse Hanford Company, Richland, Washington.

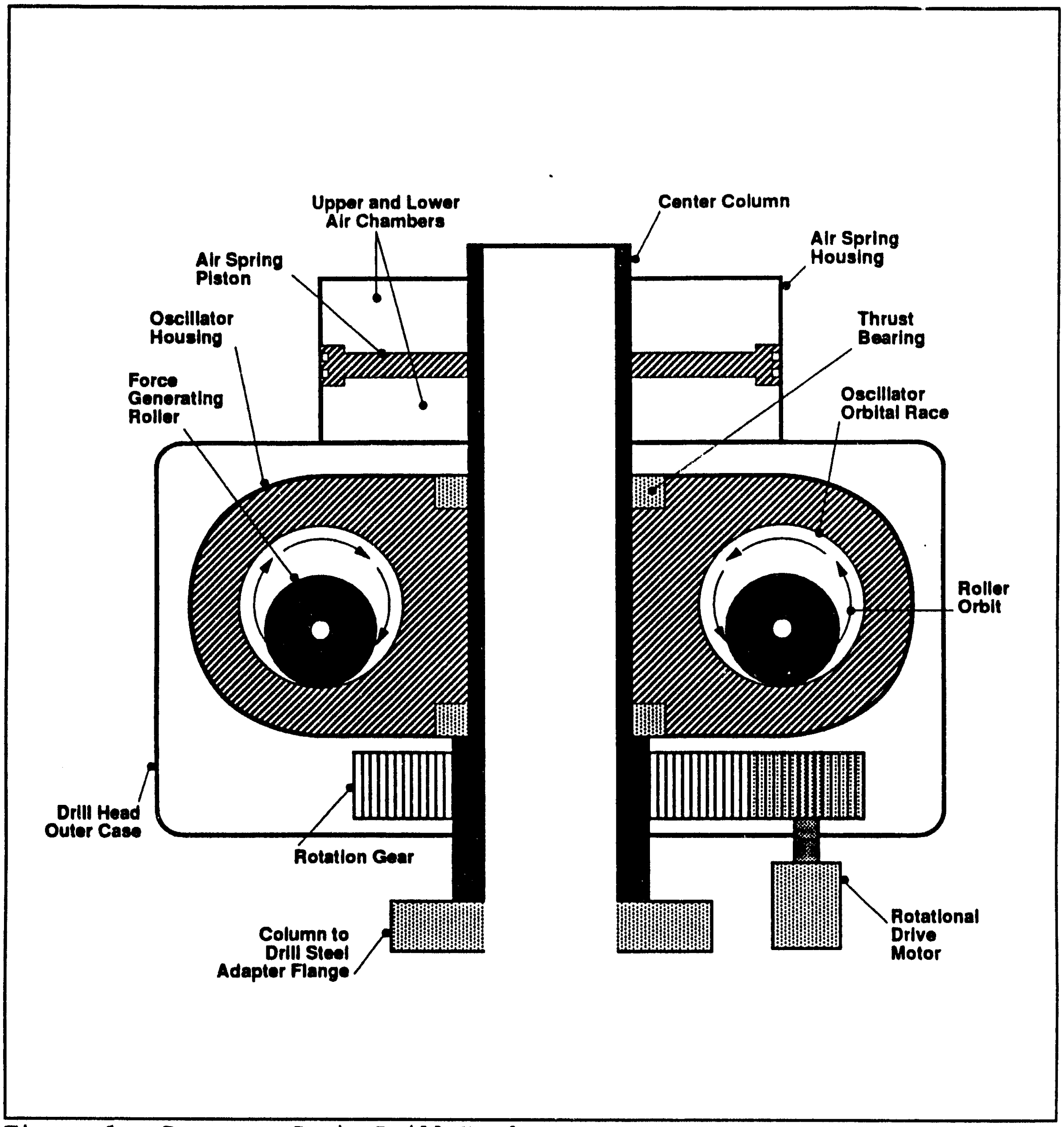


**Figure 1.** Resonant Sonic Drill Head

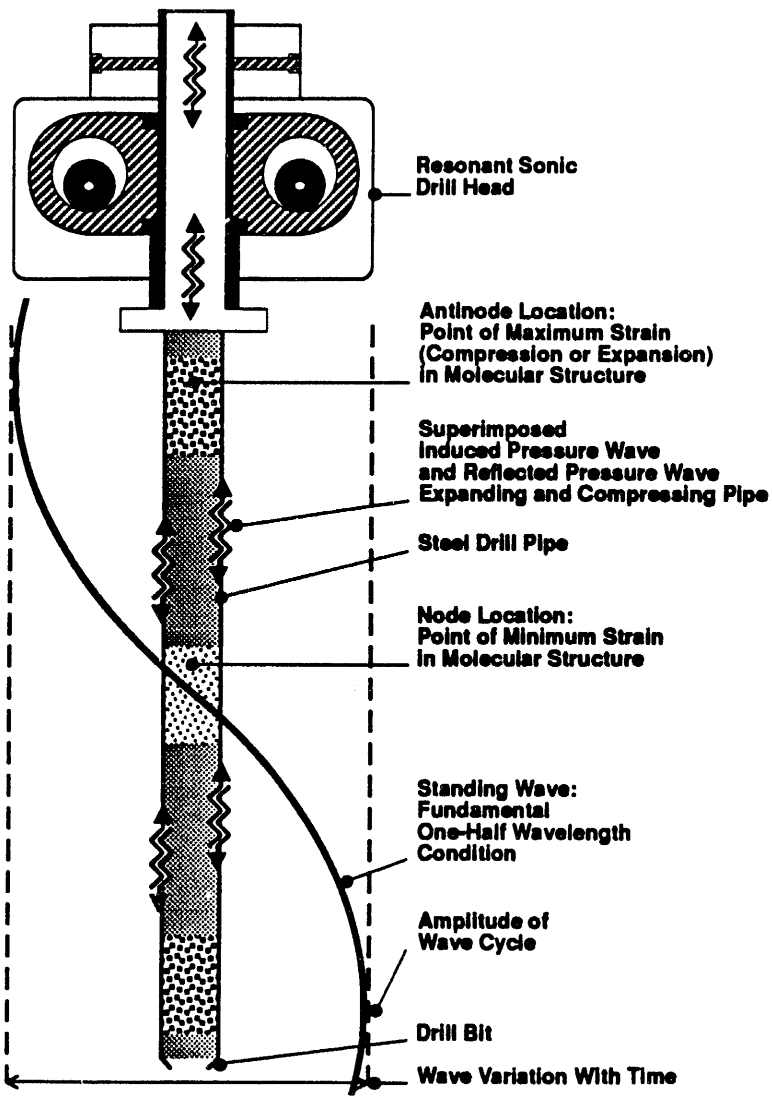


**Figure 2.** One-half Wavelength Resonant Condition With No Dampening

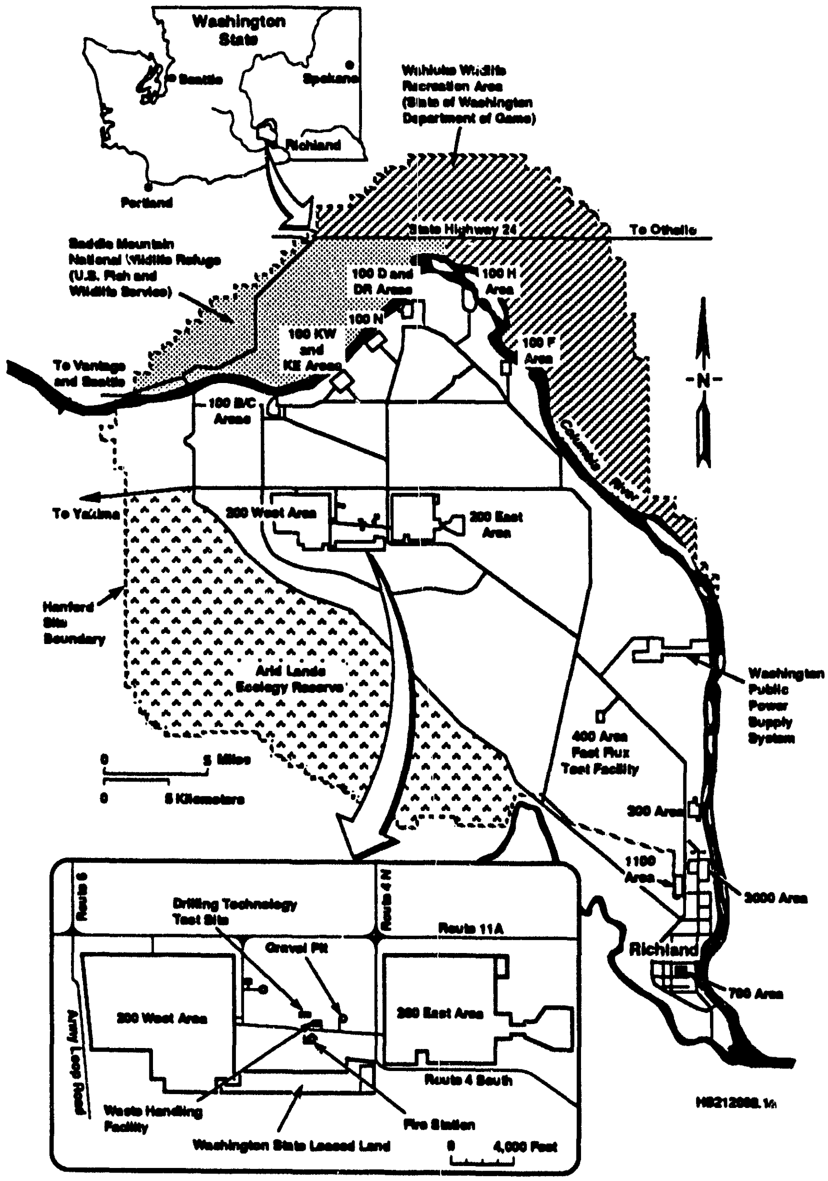


**Figure 3.** Hanford Drilling Technology Test Site

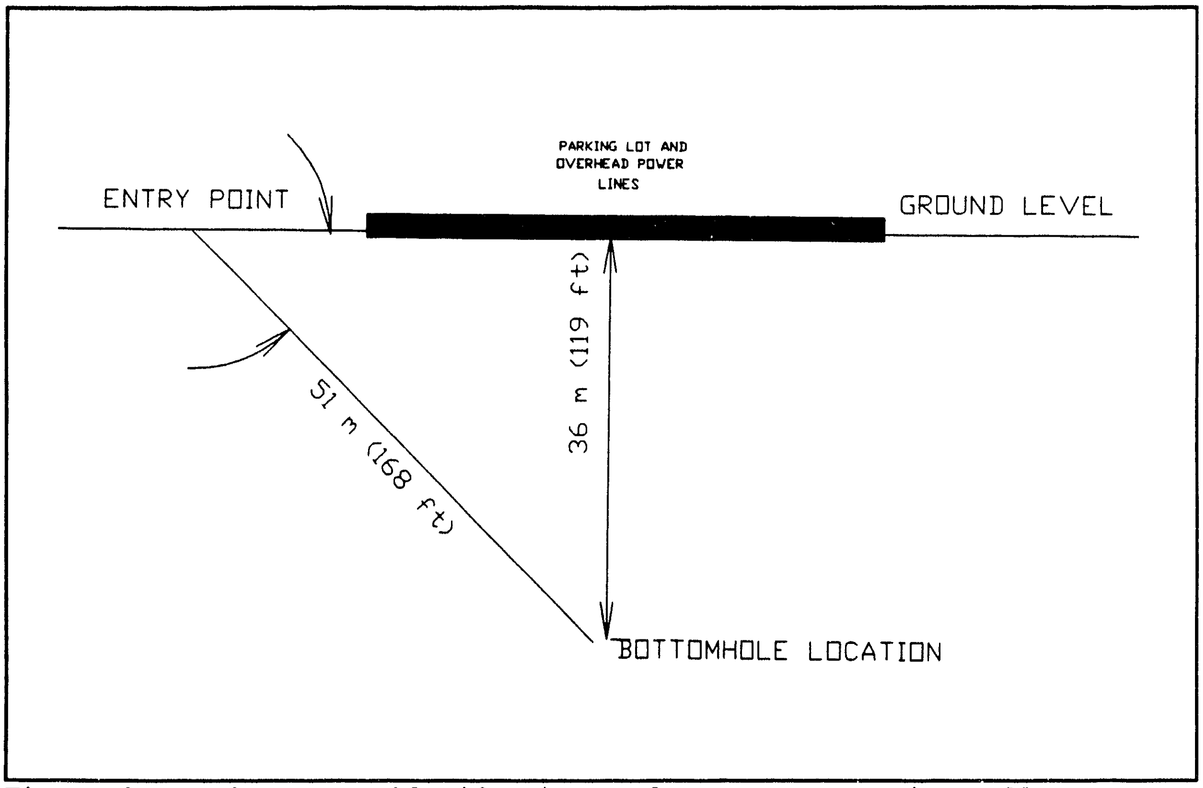


**Figure 4.** Carbon Tetrachloride Site Angle Vapor Extraction Well

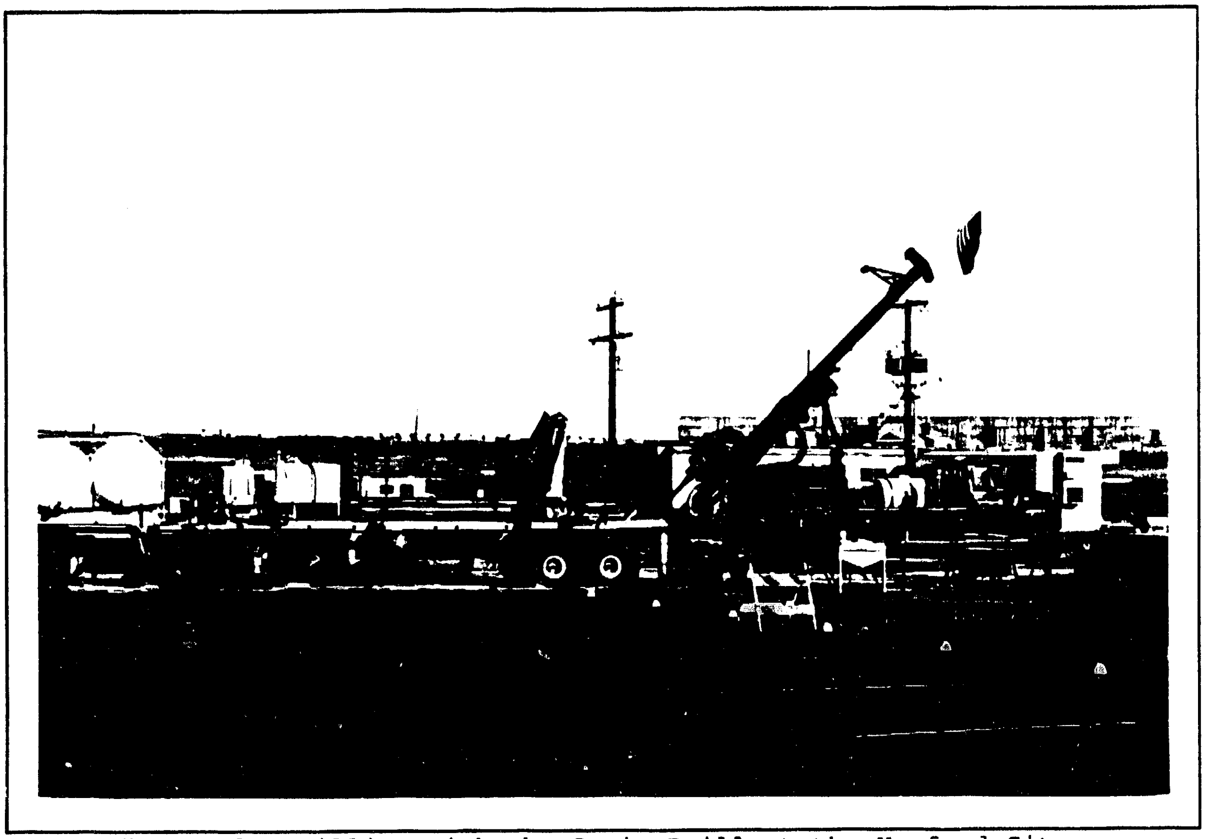

**Figure 5.** Angle Drilling with the Sonic Drill at the Hanford Site

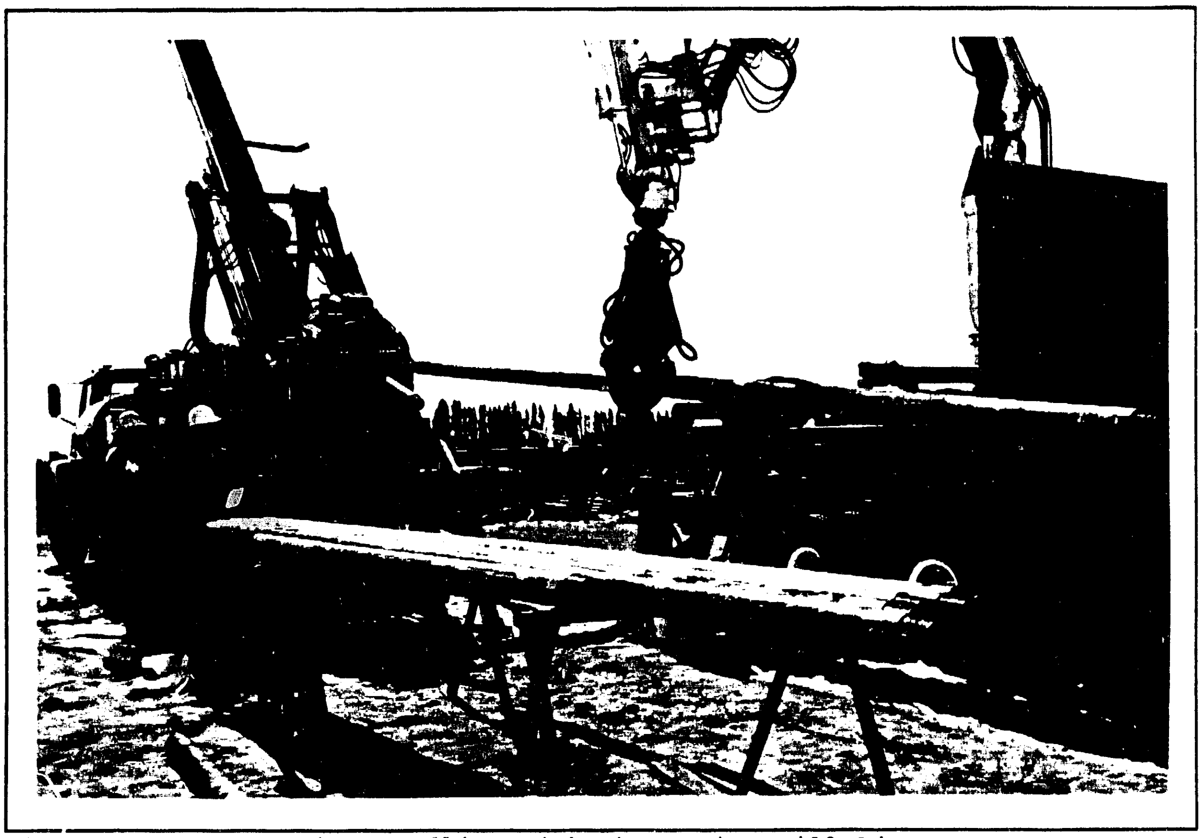

**Figure 6.** Remote Pipe Handling with the Sonic Drill Rig

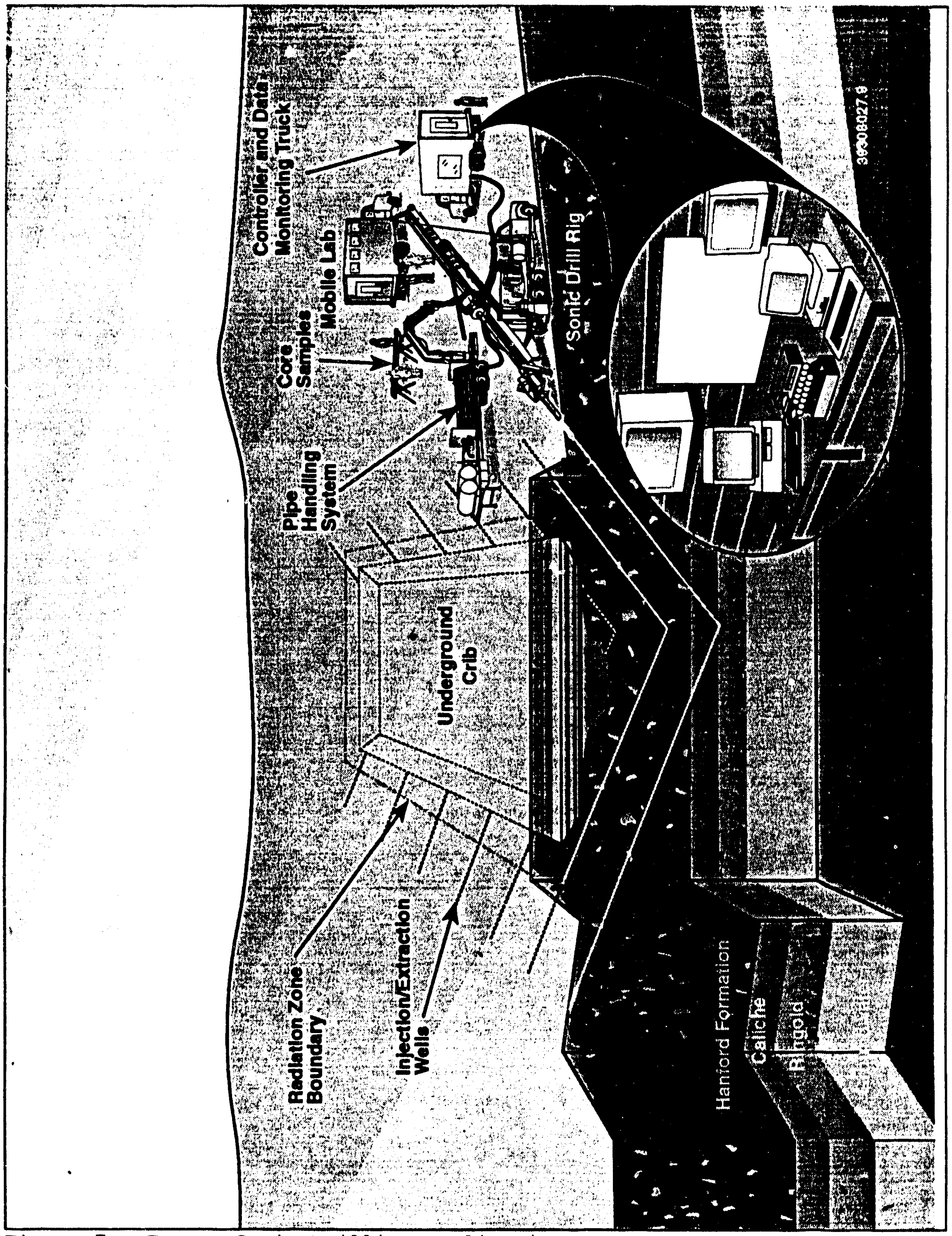


**Figure 7.** Future Sonic Drilling Application

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