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7. Abstract

A feasibility test of the ODEX air rotary method was conducted with the installation of three RCRA compliant groundwater monitoring wells in 1992. This transmittal contains the results and conclusions of this testing.

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1.0 SUMMARY

This report presents the results and conclusions derived from the demonstration of the ODEX (a trademark of Atlas Copco Company) air-rotary drilling method on the Hanford Site as outlined in the ODEX Test Plan (WHC 1992b). The test plan scope specified that a minimum of three Resource Conservation and Recovery Act (RCRA) groundwater monitoring wells would be drilled to provide data for this evaluation. The objectives were to demonstrate improved economic performance for the installation of RCRA compliant monitoring wells, and obtain quality site specific characterization data.

Although initial drilling met with minor technical problems, drilling productivity increased as the problems were resolved and additional operation experience was gained. In conclusion, the three well demonstration shows that the ODEX method is a technically favorable method of well installation, both from a RCRA compliance standpoint and from an economic point. At this time it is the position of Kaiser Engineers Hanford (KEH), Westinghouse Hanford Company (WHC) Projects, and WHC Geosciences that the use of the ODEX method in nonhazardous to low-hazard sites will result in an approximate 40% cost savings per well.

2.0 INTRODUCTION

2.1 BACKGROUND

Due to the inherent ability of the cable-tool drilling method to prevent the spread of contamination while drilling, this method has been used for installing groundwater monitoring wells at the Hanford Site. Drilling progress for the cable-tool method is relatively slow and consequently expensive. Since the implementation of the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) (Ecology 1990), the U.S. Department of Energy-Richland Field Office (DOE-RL) has been actively seeking alternative drilling methods for installing groundwater monitoring wells that would reduce cost, maintain construction compliance, and meet milestones required under the Tri-Party Agreement. The ODEX drilling method was selected as a possible alternative.

Additional equipment needed to support the operation is primarily "off-the-shelf" technology (i.e., materials are readily available from drilling equipment or industrial supply vendors). The only additional support apparatus that has a specific application to hazardous/radiological site drilling is the drill cutting containment system (DCCS). This system was field tested at the Hanford Site in conjunction with the dual wall percussion hammer (DWPH or Becker Test) system (WHC 1990). The units' design was adapted from a similar DOE project at Oak Ridge, Tennessee, which utilized air bailing as a hole cleaning technique.

2.2 PURPOSE

The primary purpose of the demonstration was to evaluate the suitability of the ODEX air-rotary drilling method and to show the viability of using this method for installing RCRA compliant groundwater monitoring wells at the Hanford Site (WHC 1992b). Additionally, the intent was to illustrate efficiency, establish cost savings to RCRA drilling through utilization of a proven drilling technology, and to verify containment and control of drilling effluents and the minimization of drilling derived waste. This report summarizes the results of the ODEX demonstration program.

2.3 SCOPE

The test plan (WHC 1992b) specified drilling a minimum of three RCRA program groundwater monitoring wells to meet RCRA standards and internal data quality objectives. The demonstration project received adequate funding to construct three wells. Safety, contractual, and program constraints required that wells were located in uncontaminated areas; therefore, locations were selected where the stratigraphy was well known from adjacent wells, and there was no indication of radioactive or chemical contamination. These wells also support completion of Tri-Party Agreement Milestone M-24-00.

2.4 WELL LOCATIONS

Well locations were selected to test the ODEX method in several representative stratigraphic sections. As a result, two wells were drilled and completed near the north perimeter road at the Low-Level Burial Grounds in the 200 West Area and the final well was drilled and completed south of the Grout Pit east of the 200 East Area. The well identification numbers are 299-W6-11, 299-W6-12, and 299-E25-44 and their locations are shown in Figure 2-1.

The 200 West Area wells were installed as part of the Low-Level Waste Management Area 5 (LLWMA-5) monitoring network. They were drilled and completed in excess of 260 ft. This area was selected because of continuing drilling and completion problems associated with lithologies present at this location.

The Grout Pit well was installed as part of the Grout Treatment Facility (GTF) monitoring network. It was drilled and completed at a depth in excess of 280 ft. The drilling at this location was expected to demonstrate the optimum penetration rates the system could deliver because of the lithologies present.

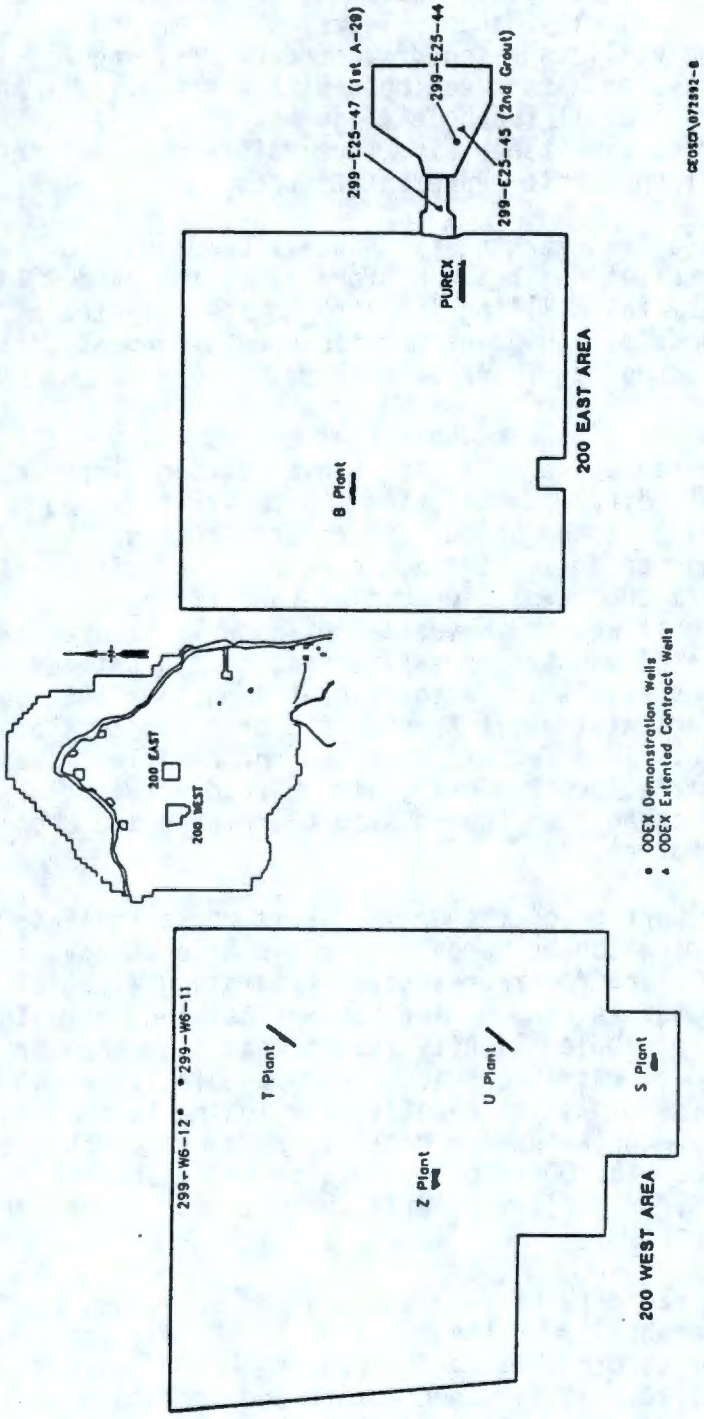


Figure 2-1. Location of ODEX Method Demonstration Wells.

2.5 ODEX DESCRIPTION AND OPERATION

The ODEX method of drilling was developed for advancing a well casing through all types of earth materials including the unconsolidated and semi-consolidated sand, gravel, clay, and boulders, which are common at the Hanford Site. The ODEX method utilizes a top-drive rotary drilling rig in combination with a down-hole percussion hammer equipped with a special bit and eccentric swing-out underreamer to drill the hole (Figure 2-2). This method drills and advances a casing string simultaneously, thus maintaining the integrity of the well bore and controlling sample representativeness.

Although TUBEX (a trademark of the Sandvik Company) equipment was employed for the demonstration at the Hanford Site, the name ODEX is used since it is accepted by the drilling industry to identify the method. TUBEX is one of several brands of equipment manufactured by competitors. Commercial application of ODEX technology spans over 20 yr.

The method utilizes compressed air that powers a down-hole percussion hammer and provides circulation media to remove cuttings from the drill bit face. The air flow is "direct circulation" where air flows down the center of the drill pipe or string to the hammer and returns through the annular space between the casing and the drill string. Airstream velocity in the annular space is in excess of 3,000 ft/min, providing the lifting capacity necessary for removal of drill cuttings as they are continuously cleared away from the bit face. This action eliminates excessive heating and extends bit life. The high annular velocities result in insignificant lag times between the displacement of cuttings at the bit face by the drilling action and their arrival at the surface. This feature provides for excellent sample correlation to the drilled depth. Using air instead of water-based drilling fluids also minimizes changes to the in situ hydrologic and chemical properties of the formation.

The underreamer portion of the drill bit is retractable so the bit assembly and drill string can be removed from the hole at any time while leaving the casing in place for representative sampling with split spoons, measuring formation water levels, or for geophysical logging. The underreamer is sized to drill the borehole slightly larger than the temporary casing size, allowing the casing to be easily extracted upon completion of the hole. This bit and underreamer system has the benefit of allowing telescoped casing for added depth capability, contamination control, or meeting other special requirements as needed. The ODEX tools are also sized so that conventional mud-rotary, air-rotary, or cable-tool drilling methods can be used below the final ODEX casing point.

The drill depth capacity of the ODEX system is limited by the hoisting and casing handling capability of the rig, casing tensile strength, and the amount of air required to circulate and clean the hole. Air is supplied by up to two high-pressure (220 psi) air compressors and is passed through an air filtration system before introduction into the borehole (Figure 2-3). The filtration system is capable of removing oil, water droplets, and other possible contaminant particulate down to 0.01 μ in size and is rated at 99.99% efficiency by the manufacturer. The lubrication in use for the down-hole hammer is a U.S. Environmental Protection Agency (EPA) approved nonhydrocarbon based oil.

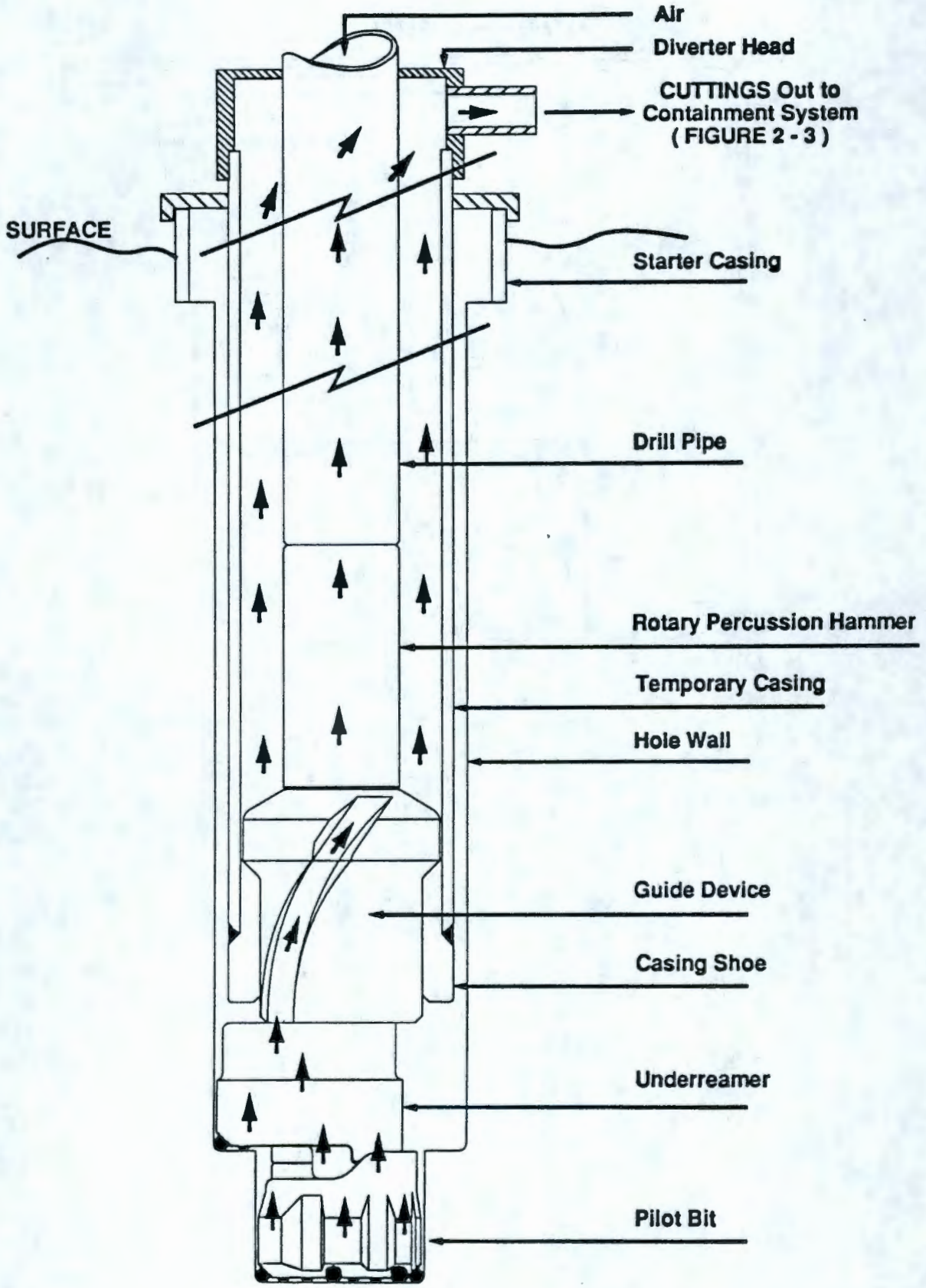


Figure 2-2. Down-Hole Components of ODEX Drill System.

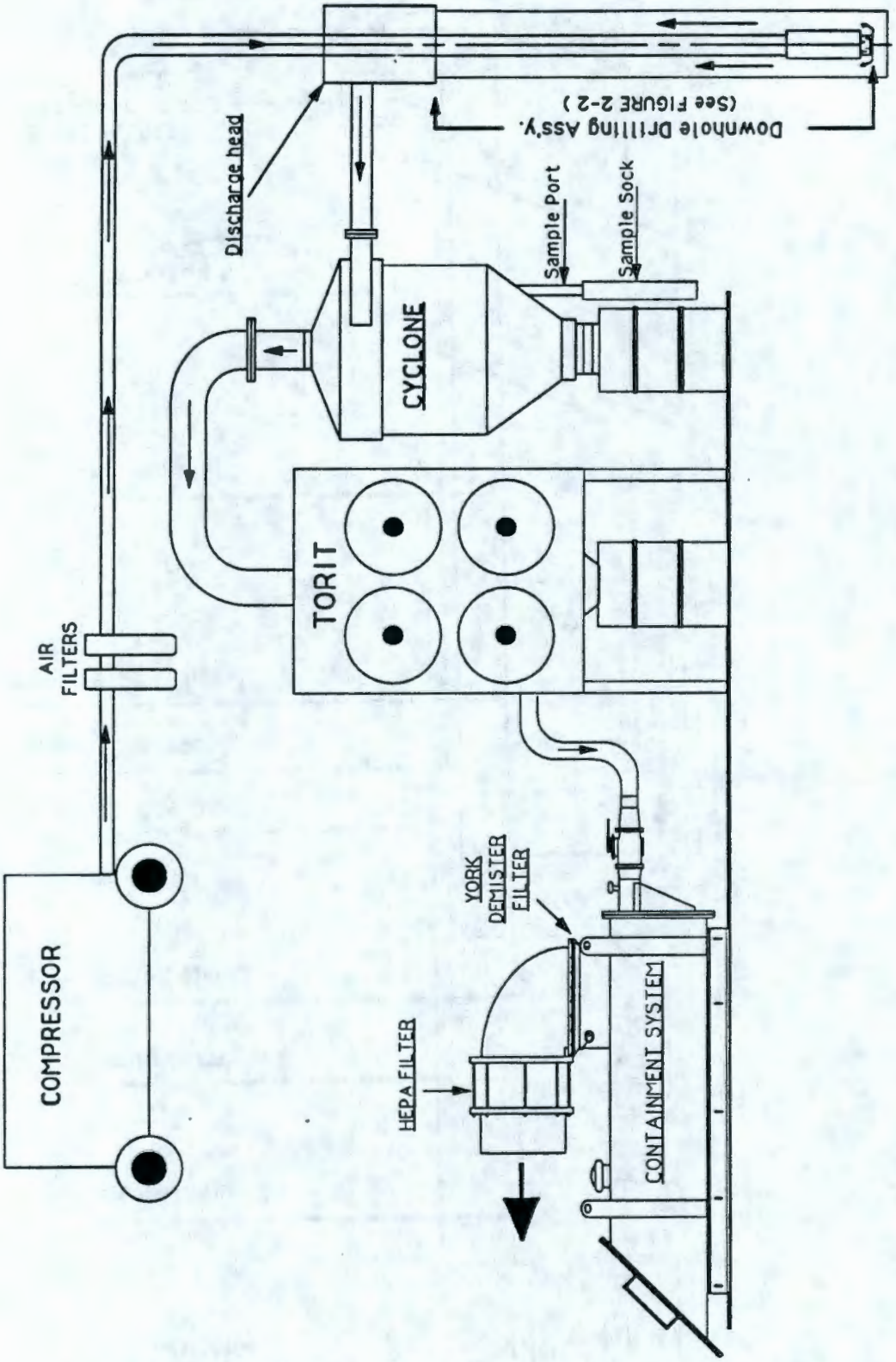


Figure 2-3. Surface Equipment for ODEX Drill System.

Cuttings and any potential contaminants from the drilling process are controlled at the surface by a diverter or discharge head that routes the cuttings through flexible hosing to a cyclone separator and then to a dust control system. Coarse fragments drop out of the airstream by centrifugal action in the cyclone and are captured in drums or, ideally, in tote bins. The finer, dust size portion of the cuttings is carried in the airstream to a cartridge dust collection system that further reduces the exhaust stream load. Finally, the airstream passes through a high-efficiency particulate air (HEPA) filter followed by atmospheric discharge. Figure 2-3 depicts the current configuration of the ODEX method circulating system.

3.0 RESULTS

3.1 CONTROL OF EFFLUENTS

Drill cuttings, finer effluents, and formation water in the circulating airstream represent the greatest potential source of contamination to personnel and drilling equipment. Prior to and during the demonstration, particular attention was given to integrity of the numerous couplings, connections, and sealing components.

The "lessons learned" during the preceding "Becker Test" (i.e., surface seal failures and quantities of dust at start-up) were applied to the ODEX demonstration (WHC 1990), and efforts were made early in the project to maintain satisfactory seals on all components of the containment system. Fewer problems were encountered with the diverter head hookup than were experienced during the Becker drilling test because the ODEX method does not require the extra connection necessary for dual wall pipe seals. Dust control problems were reduced at the start of drilling due to placement of a conductor pipe (starter pipe) with a backhoe. Use of the conductor pipe also provided a means for controlling drill cuttings at start-up.

Successful containment and dust control were achieved through engineering a completely contained cuttings return system that included redesigning and adjusting the various hose and drum connections. During start-up for the first two wells of the demonstration, the WHC Vents and Balance Group conducted detailed operating procedure challenge tests on the containment system. The results of these challenges indicated that the system was functioning as designed. Subsequent drilling has indicated that other areas required improvement. Those areas are discussed in the following sections.

3.1.1 Containment of Fine Particulates

As the demonstration progressed, an unanticipated problem arose that reduced productivity during drilling of the first two holes. This problem was associated with the DCCS and was resolved by modifying the dust control system by adding a negative pressure, pre-filter apparatus to eliminate excessive fines from reaching the DCCS containment box.

The volume of compressed air required to provide adequate hole cleaning, combined with fines produced while drilling, exceeded the designed volume ranges of the DCCS and continual plugging occurred. Two types of filters that have specific limitations, are used in the DCCS; 1) a HEPA filter that is not designed to function when the airstream is wet or moist, and 2) a demister filter that is designed to remove moisture but is not designed to remove dust. These two features limit the DCCS's ability to function as a dust control device. Attempts to solve the volume problem with higher capacity filters and an internal baffle to provide greater particulate drop-out to reduce plugging and resulting downtime, proved to be inadequate.

The problem was solved by the addition of a Torit (a trademark of Donaldson Company, Incorporated, Torit/Day Division) cartridge dust collection system. The Torit utilizes fan induced air flow to pull fines from the cyclone, passing the airstream though filter cartridges, and eventually passing the discharge to the containment box. With the Torit dust collection system in place, plugging of the DCCS filters has been minimal. The Torit system has several advantages over other filtering systems (in this case the DCCS), or other commercially available systems. A partial listing of the observed advantages are as follows:

- Designed to accommodate HEPA filtration on the output side - thus removing the necessity of the DCCS or other separate HEPA type filtration systems
- Filters are easily replaced - very little downtime for filter changes as opposed to several hours for a complete change of filters for the DCCS
- Filters for the Torit are cleanable and reusable - HEPA and demister filters for the DCCS are not
- Maintains significant negative pressures from the well head to the filter box - thus greatly reducing contamination potential from any breaches in the effluent containment system

3.1.2 Containment of Coarse Cuttings

In general, the hoses, cyclones, drums, and containment box provided satisfactory containment of the drill cuttings produced by the ODEX drilling process. Minor leaks were experienced early in the drilling demonstration, but these leaks were easily remedied and do not represent an obstacle to the proposed use of the system.

Engineering solutions were undertaken to solve minor operational problems. The following is a brief listing of some of these problems and the engineering solutions that improved cuttings containment:

- Poor cutting recovery and drop-out of the sample - replacement of the original cyclone with a larger model
- Excessive dust leaks around the casing - redesign of the rotating diverter head

- Excessive back pressure and filter loading on DCCS - addition of the negative pressure Torit dust filtration system
- As operations continued dust leaks developed at stress points in the system - redesign of the hose connections and methodology improvements in system handling
- Cuttings and formation water containment and handling problems (poor efficiencies due to excessive time spent changing the drums used to move cuttings away from the cyclone) - solved with procurement of a cuttings (tote) bin to handle larger quantities of cuttings and water, and thus reduce the amount of time that drilling is stopped to remove filled drums

3.1.3 Containment of Formation Water

During the demonstration, no water handling problems were encountered while drilling shallow monitoring wells because no formation water enters the well bore while the air is circulating. Water is generated only when circulation is stopped, the formation yields water to the annular space, water rises to static levels, and is subsequently brought to surface when air circulation is resumed. The volume of water generated is simply the volume of the annular space. This volume varies from .8 to 1.0 gal/ft, depending on the casing diameter. Therefore, unloading a hole with 20 ft of water in the casing yields approximately 20 gal of water. Handling and containment of these volumes did not prove to be a problem. Subsequent deep well drilling has revealed a handling problem with water generated while unloading quantities contained in the pipe when the water column height was in excess of 35 ft. The addition of a large containment bin to the system (Section 3.1) is expected to solve this problem.

To date, no formation pressures have been encountered that have overcome the circulating air pressures and produced any water while drilling. After review of the confined aquifer conditions known to be present on the Hanford Site it is not expected that any subsequent drilling will encounter formation pressures that are significant enough to overcome circulating pressures.

3.2 DRILLING

This section summarizes the results of drilling performance with the ODEX drilling method. Particular emphasis is given to representative sample recovery and drilling rates.

3.2.1 ODEX Performance

The first two wells drilled had greater than anticipated downtime, but the problems encountered were resolved with effective engineering remedies. As the demonstration progressed, the efficiency of drilling was significantly improved. This improvement is shown on the drilling and completion time charts for the three demonstration wells (Figures 3-1, 3-2, and 3-3). At the conclusion of the demonstration, the average daily drilling rate for the ODEX was 11.3 ft/d. When re-engineering and waiting on equipment delays are removed, the average is 36 ft/d. The range of daily performance on the three well series varied from 25 to 120 ft/d. The average for the final well (299-E25-44) was 72.5 ft/d. The best daily performance during drilling of the three demonstration wells was in excess of 120 ft in one 10-h work day (Figure 3-3).

Since the conclusion of the ODEX demonstration program, the first two contract extension wells were drilled at an average rate in excess of 85 ft/d. Expected improvements in the process and operation should result in consistent daily average rates of 80 to 100 ft/d with reduced moving and downtime.

The overall ability of the ODEX system to conform to expected performance and quality criteria, (i.e., Environmental Investigation Instructions (EII), Washington Administrative Code (WAC) Regulations, and the WHC Generic Well Specification [1992a]), was also closely monitored by WHC Quality Assurance. Each well was visited several times during drilling or well construction which resulted in three satisfactory surveillances. No findings were reported for any of the wells.

3.2.2 Drilling Problems

During and following the demonstration, several drilling problems relating to bit attachment occurred. On the first well, the bit unscrewed from the drill string because of a sheared keeper pin. The pin supplied with the bit was incorrect and Sandvik tools accepted responsibility for this component failure. A bit was dropped in another well during the extended contract drilling. This bit became separated from the drill string because of pin failure also. The pin showed excessive wear and fatigue failure. The wear and fatigue is interpreted to have occurred because the pin had not been replaced after drilling the previous hole and, therefore, had too many operational hours. The solution was to change maintenance procedures; the pins are now replaced after drilling each hole.

Another problem that was encountered on the second well was damage to the driveshoe device on the casing. The shoe was damaged from excessive wear caused by poor hole cleaning. Annular velocities were too low to adequately lift the cuttings to surface causing accumulation around the hammer, shoe, and bit. The accumulation of cuttings wore down the driveshoe face and allowed the guide device on the drill string to become lodged in the driveshoe. Poor hole cleaning was caused by excessive back-pressures from the dust containment system and air volume loss to the formation. Proper sizing of the drill pipe increased annular velocities, and the addition of the Torit filter box effectively decreased system backpressures. The combination of these two solutions has proven to be adequate in solving the problem.

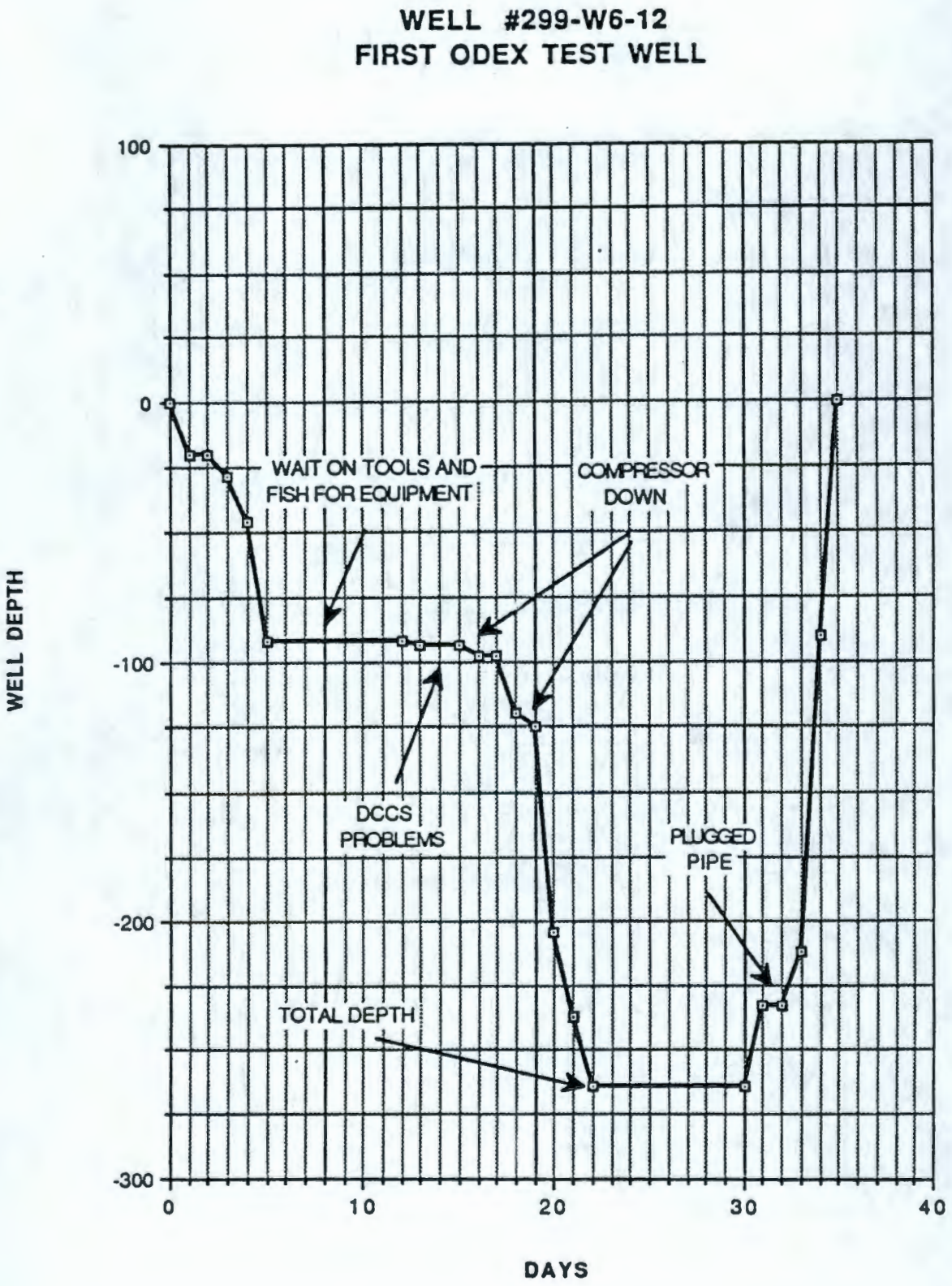


Figure 3-1. Drilling and Completion Chart, Well 299-W6-12.

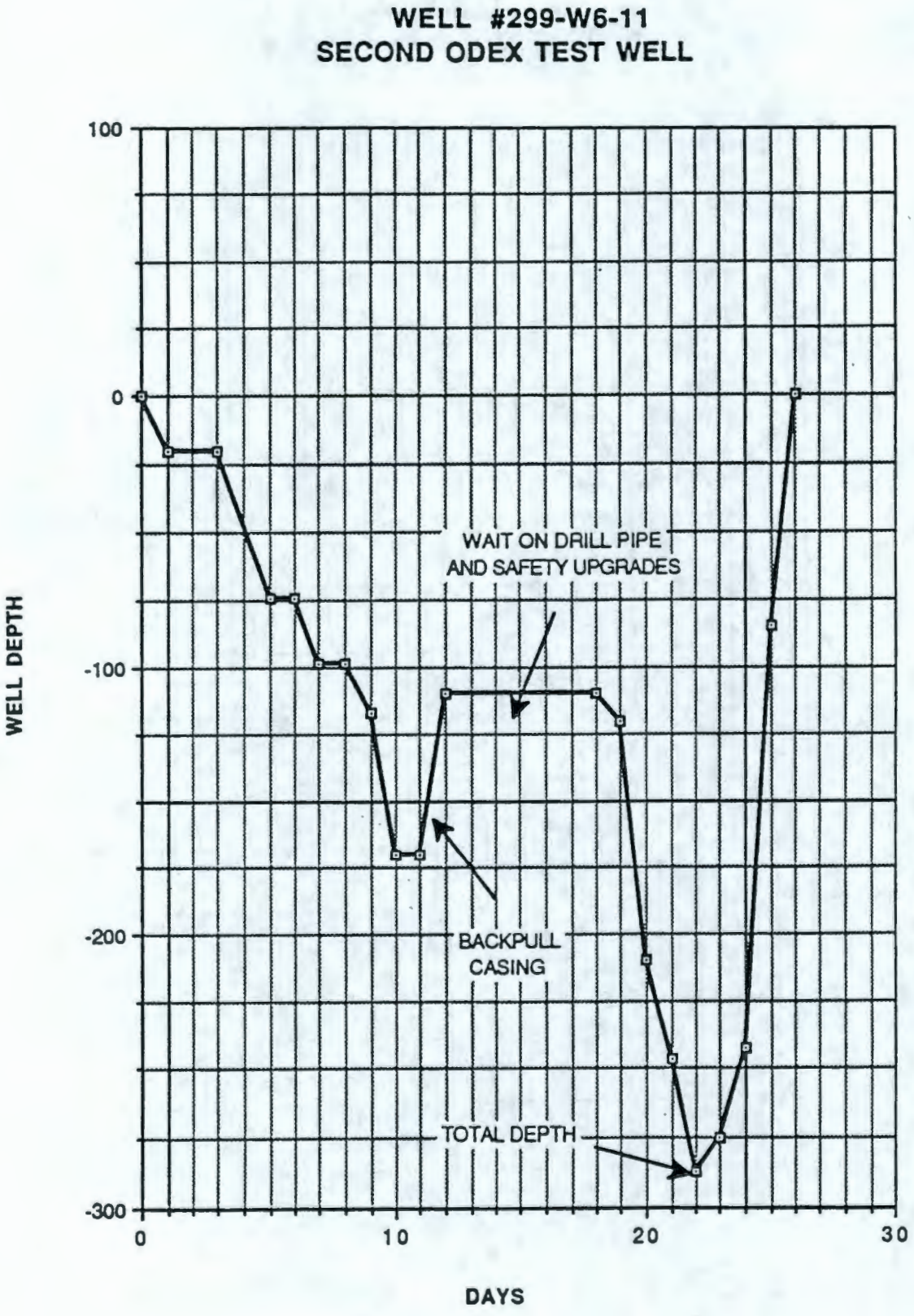


Figure 3-2. Drilling and Completion Chart, Well 299-W6-11.

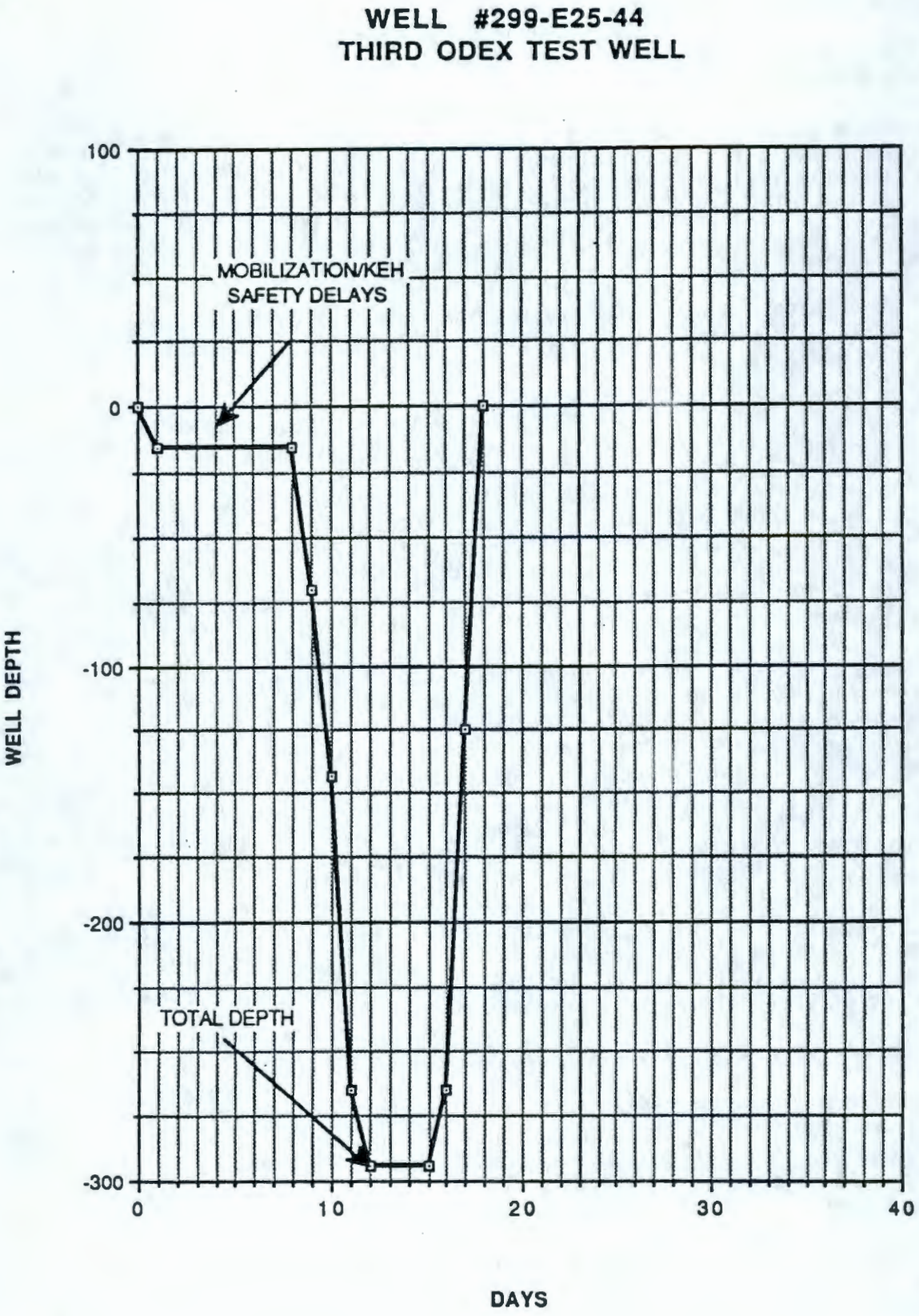


Figure 3-3. Drilling and Completion Chart, Well 299-E25-44.

3.2.3 Sampling and Geophysical Logging

Sampling requirements for the three demonstration wells are outlined in the applicable project work plans, WHC (1988), and EPA (1986). Particular attention was given to the drilling method's ability to provide representative samples for geologic interpretation. Split spoon samples were obtained at various intervals for interpretation and comparison with logs from adjacent ODEX and cable-tool drilled wells. In several cases (wells in the 200 West Area and the GTF), the accuracy of interpretations was verified by comparing drill cuttings with split spoon samples recovered from the same interval on subsequent wells.

Geophysical logging was performed per the well construction specification to verify lithologic contacts and to facilitate drilling technique comparisons.

3.2.3.1 Cutting Samples. Cutting samples are collected in compliance with WHC (1988) Well Construction Specifications, and other various requirements (EPA 1986 and WHC 1992a). Samples are captured from the airstream at the sampling port located on the lower side of the cyclone (Figure 2-3). Material captured at the port falls into the sample sock, thereby providing a continuous collection of representative material circulated from the bottom of the hole. The sample socks used are 3 and 1/2-in. glove box port bags. These socks are 50 in. long and will hold sample material representing 20 to 40 ft of drill advance depending on sedimentary facies being drilled.

Continuous sampling enables accurate interpretation of lithology because of the reliable correlation of depth with changes in sample texture, and the instantaneous arrival of samples at the surface. Distinct changes in lithology were observed in the sample sock and were discernable to within 1 ft of the contact, as determined by the drilling penetration recorder. Depth correlation to the sampling interval is confirmed by measuring casing lengths and determining the depth to the bottom of the bit. Numerous measurements confirmed that the hole was not being overdrilled ahead of the drill bit face, which would have allowed an unsupported cavity to form.

A comparison of the interpretations of cuttings with the descriptions from split spoon sampling, geophysical logging, and geologic logs from adjacent holes indicates the ODEX method is able to collect samples that will accurately portray different lithologies of at least 1 ft thick.

Samples retrieved by split spoon sampler on the second Low-Level Burial Ground well in 200 West Area (299-W6-11) confirmed an interpretation of a cemented, semi-confining zone for the aquifer that was discovered while drilling the 299-W6-12 well. The presence of the cemented zone was previously unknown because the drilling method commonly used in the area is cable-tool drilling. At this depth, hard tool drilling is required to penetrate the Ringold Formation, and this masked the presence of the cemented zone.

After the contract extension, split spoon sampling at the second GTF monitoring well confirmed the presence of alternating thin beds of fine grain sands and silts with minor caliche at a depth of over 225 ft. This zone was correctly identified and interpreted from cuttings captured in the sampling sock during drilling of well 299-E25-44.

3.2.3.2 Split Spoon Sampling. Split spoon samples were used to compare with drill cuttings and to evaluate the ability of the ODEX system to use this sampling method. The ODEX method uses a pneumatic down-hole hammer to drive the split spoon. Actual sampling time is approximately 2 min per sample. However, due to setup and trip in/out times for the sampler, the time required by the Odex method to collect split spoon samples is comparable to that of cable-tool drilling (approximately 2 h per sample). Since both methods use the same sampling tool, the quality of the samples should be identical.

Split spoon sampling for chemical analysis has been conducted on wells drilled during the contract extension. No results from this sampling are available at this time. Evaluation of these samples is ongoing.

3.2.3.3 Evaluation of Sample and Groundwater Contamination. Soil sample contamination is not expected because the compressed air used to bail the hole is filtered to prevent contaminants from entering the borehole. Also, due to these air filters, there is no expectation that the quality of groundwater will be adversely effected by the drilling airstream. An evaluation of the potential for sample contamination from the airstream was performed during the drilling demonstration to verify the effectiveness of the input air filtration system (Section 3.1). This test demonstrated that the filters were not allowing detectable amounts of contaminants to enter the well bore. Further evaluation of this aspect of the ODEX program is ongoing and will be tracked as groundwater from the demonstration wells is sampled and analyzed.

Formation vapor collection has been conducted with the SEAMIST (a downhole collection system developed by Science and Engineering Associates, Inc. Santa Fe, New Mexico) at two wells on the extended contract. Results of chromatographic analysis of the formation gas samples and samples of the circulating air did not reveal any detectable contaminants attributable to the drilling method.

3.2.3.4 Geophysical Logging. Geophysical logging was performed for both casing intervals at the 200 West Area wells, at the end of drilling activities for the GTF well, and during drilling on the contract extension. In contrast to the Becker Test, the geophysical logging was not complicated or as highly attenuated from the multiple casing strings. The geophysical logs obtained from these wells are comparable to those obtained with cable-tool drilling. Geophysical logging also confirmed lithologic contacts described through continuous sampling of the borehole cuttings.

3.3 WELL COMPLETION

Each of the three demonstration wells were drilled to depths in excess of 260 ft using three temporary casing strings. The 12-in. outside diameter starter casing was set using a backhoe and the telescoped 10- and 8-in. outside diameter casings were installed during drilling to predetermined depths. These intervals were specified per the Data Sheets and subsequently refined by the wellsite geologist in accordance with the Well Construction Specification (WHC 1992a). Well completion activities were performed on all of the demonstration wells to WAC and WHC-S-014 specification standards and the results of the individual phases are outlined in the following sections.

3.3.1 Installation of Screen and Riser

All three wells were completed with 4-in inside diameter Schedule 5 Type 304 stainless steel permanent casing with 0.010-in. continuous wire wrap well screens. The permanent well materials were lowered to the bottom of the well inside the 8-in. inside diameter temporary casing. No installation problems were encountered on any of the three demonstration wells. Figures 3-1, 3-2, and 3-3 depict the time needed to complete each of these wells.

3.3.2 Installation of Annular Fill

The ODEX system requires the use of a special casing shoe that creates a reduced annular space around the permanent casing. Since the sand pack and bentonite seal material are allowed to free fall through the annular space between temporary and permanent casings, well completion difficulties due to the smaller than usual annular space were encountered. Problems were associated with the narrower annular space between the 8-in. casing shoe and the permanent casing. Some completion material bridging did occur, but these events were infrequent and have been eliminated by adding the materials more slowly to the annular space. The frequency of the bridging events decreased with each completion, and there were no bridging occurrences on the final well of the demonstration program (GTF 299-E25-44 well) or in any of the wells drilled on the extended contract.

It is expected that there is no difference in the quality of the installed sand pack and annular fill material between either an ODEX or a cable-tool drilled well.

3.3.3 Casing Removal

Casing extraction is one of the advantages of using the ODEX method over other drilling technologies. The ODEX drilling process improves casing removal efficiency and reduces the risk of either separating or lodging the casing - a major problem in past drilling operations. Casing extraction problems were not experienced on any of the ODEX drilled wells. The average completion time for the three ODEX wells was 4 d.

3.3.4 Well Development

As of this date, all three demonstration program wells have been developed. Low purge water volumes were an expected advantage of the air drilling method because of the effective removal of fine cuttings from the well bore. Achievement of the required 5 NTU turbidity levels produced 2,050 gal from well 299-W6-11, 1,315 gal from well 299-W6-12, and 885 gal from well 299-E25-44. Further analysis of well development data is ongoing.

3.4 WASTE MINIMIZATION

Minimization of wastes generated from drilling, completion, or development activities is especially desirable because of the escalating costs

associated with storage, handling, and characterization of drilling waste prior to final disposition.

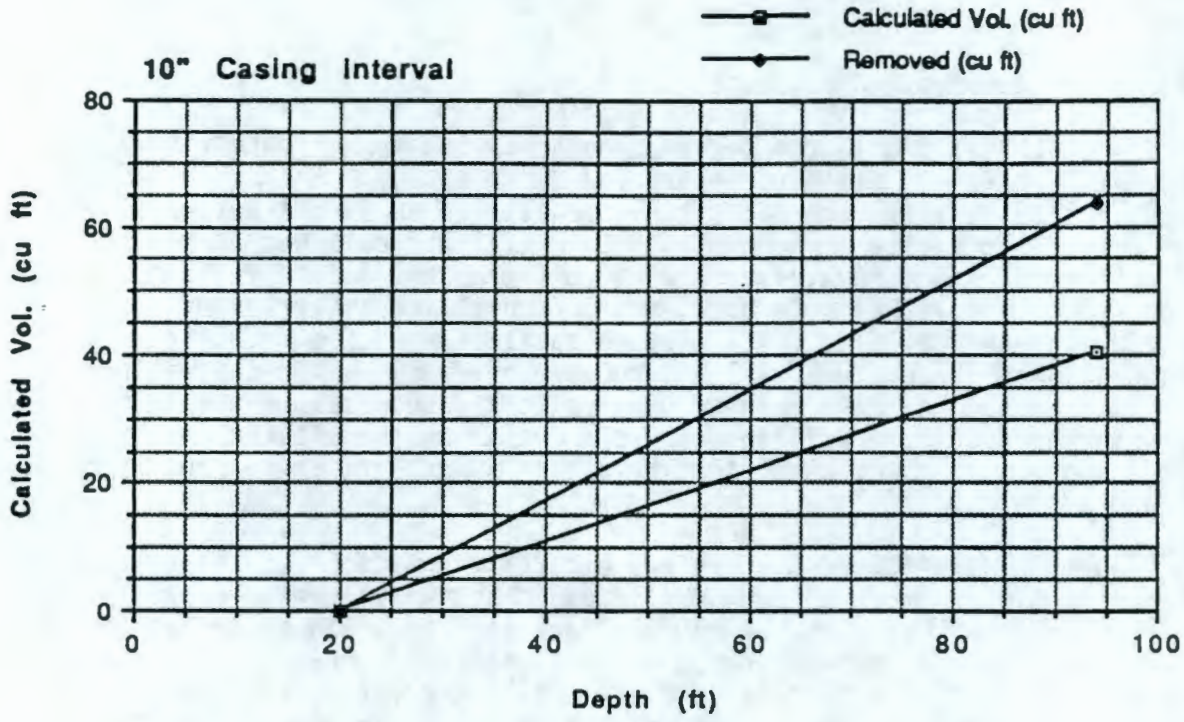
3.4.1 Drill Cuttings and Effluent

The ODEX drilling in the vadose zone generated approximately 8 ft^3 of cuttings per 10 ft of hole with either the 8- or 10-in. temporary casing. Cuttings collected above the water table are stored on 10 mil poly on the ground near the rig site as per WHC (1988). Effluent cuttings from the capillary fringe and saturated zone were collected and sealed in 55-gal drums as required by WHC (1988). To date, the ODEX drilling is averaging three drums of waste per well. Since almost no water is produced from the well bore during drilling, these drums will not require overpacking for the winter. They will also not need any special pumping to remove excess water from the drums prior to dumping. Drilling of deeper wells on the extended contract has produced amounts of purge water that have been pumped off as per the purge water procedure.

Figures 3-4, 3-5, and 3-6 are graphic representations of the calculated or expected volumes produced from drilling and actual volumes removed from the borehole. When the expected volumes are increased by a 35% swell factor (a normal expansion used in engineering estimations to account for the change in volume when excavating materials) and the drilling problems encountered in specific areas are factored in, the calculated and measured volumes compare very favorably. Comparison of the volume charts for 299-W6-12, 299-W6-11, and 299-E25-44 with their respective drilling down time graphs (Figures 3-1, 3-2, and 3-3), reflects the problems encountered, including:

- Long circulating times for some zones, due to poor hole cleaning, caused over excavation (8-in. casing intervals on 299-W6-12 and 299-W6-11)
- Circulating in the same zone to facilitate fishing for the dropped bit at 299-W6-12 (over excavation at 95 ft - 10-in. casing downsize point)
- Redrilling the 8 in. of 299-W6-11 after extracting the casing (8-in. chart for 299-W6-11)

Problems encountered on these two holes led to changing drill pipe sizes for more efficient cuttings removal. Improvements in the circulating system are demonstrated on the graph for 299-E25-44. Both the 10- and 8-in. casing volumes have values well within acceptable ranges. Spot checks of volumes removed during drilling of later wells and review of completion material volumes indicate the borings, in most cases, have a high degree of hole uniformity. The favorable comparison indicates that the drilled holes are very uniform in shape and total production of cuttings is being minimized. Uniformity of a borehole is attractive from both casing extraction and data quality standpoints.



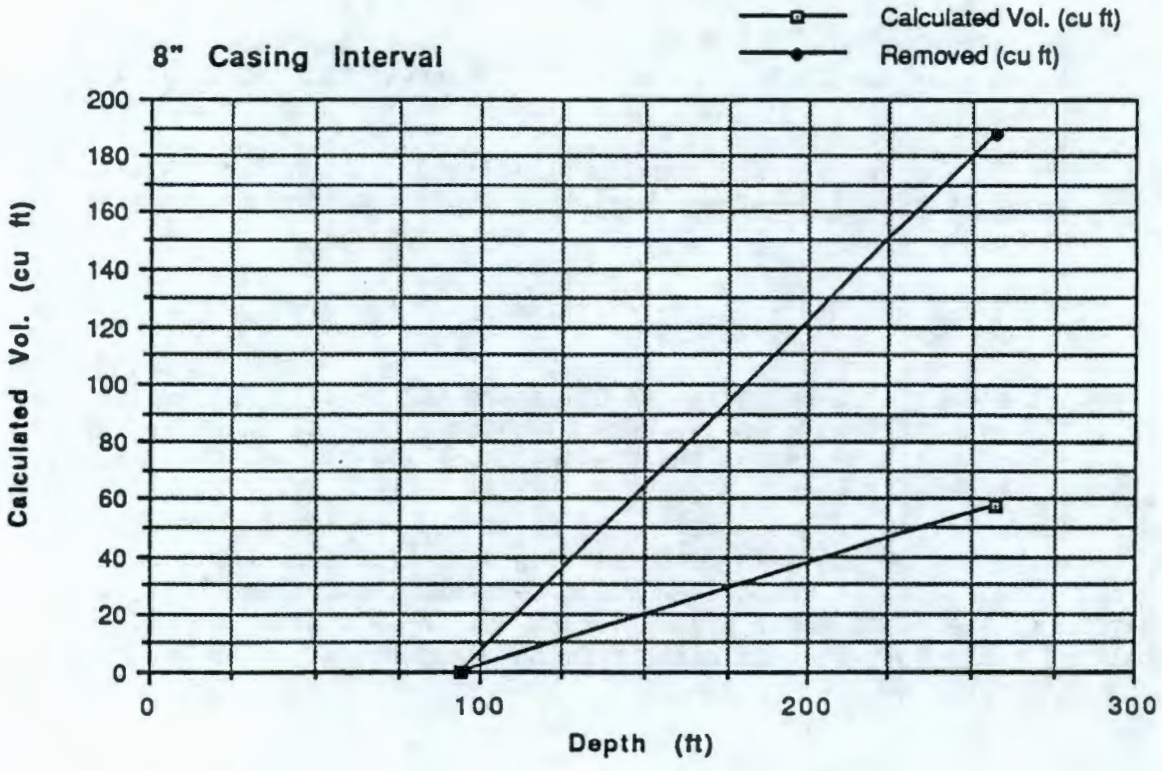
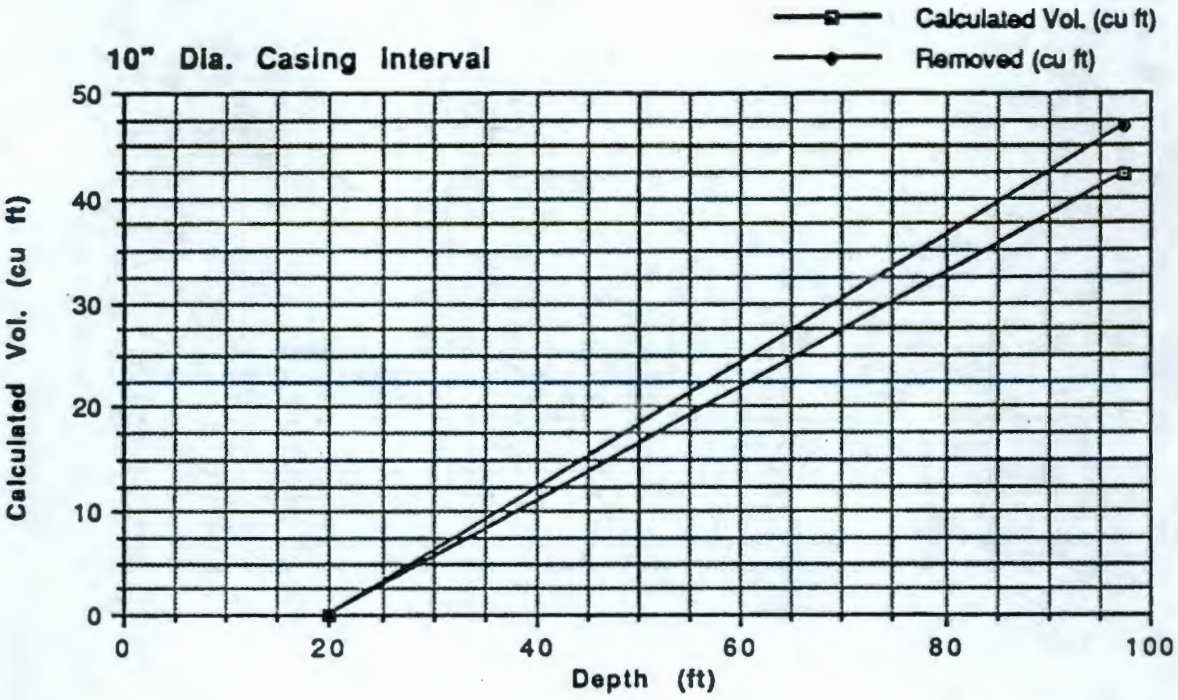


Figure 3-4. Volumetric Graph for Well 299-W6-12.



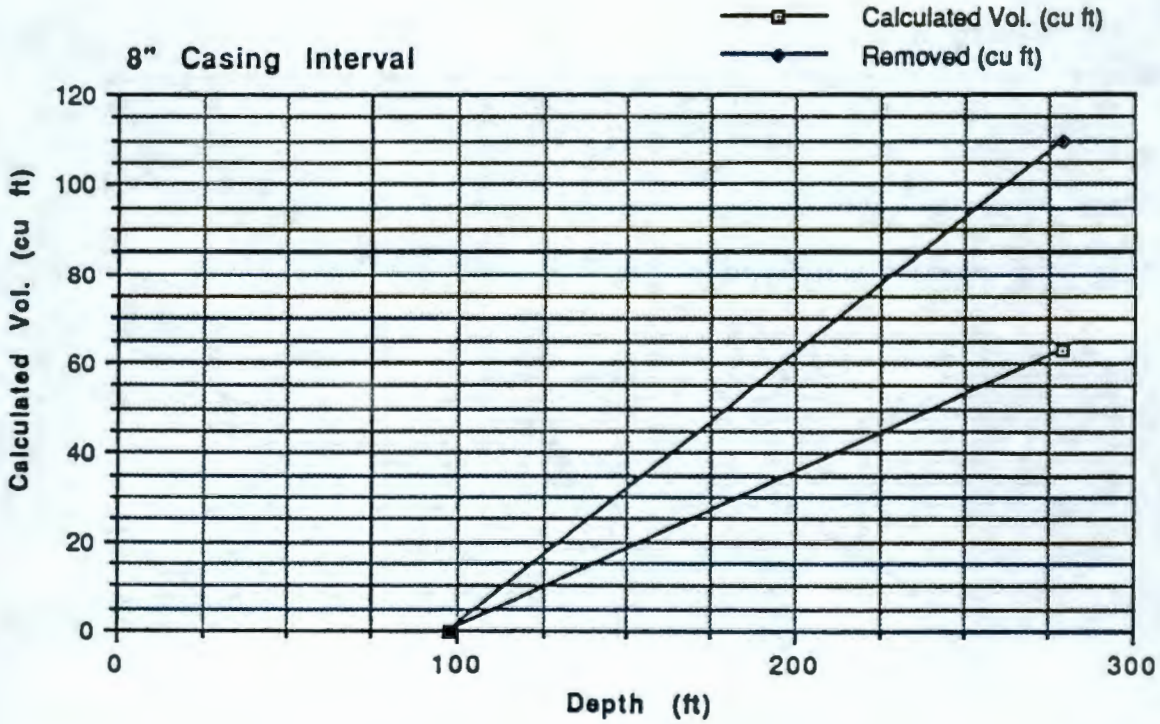
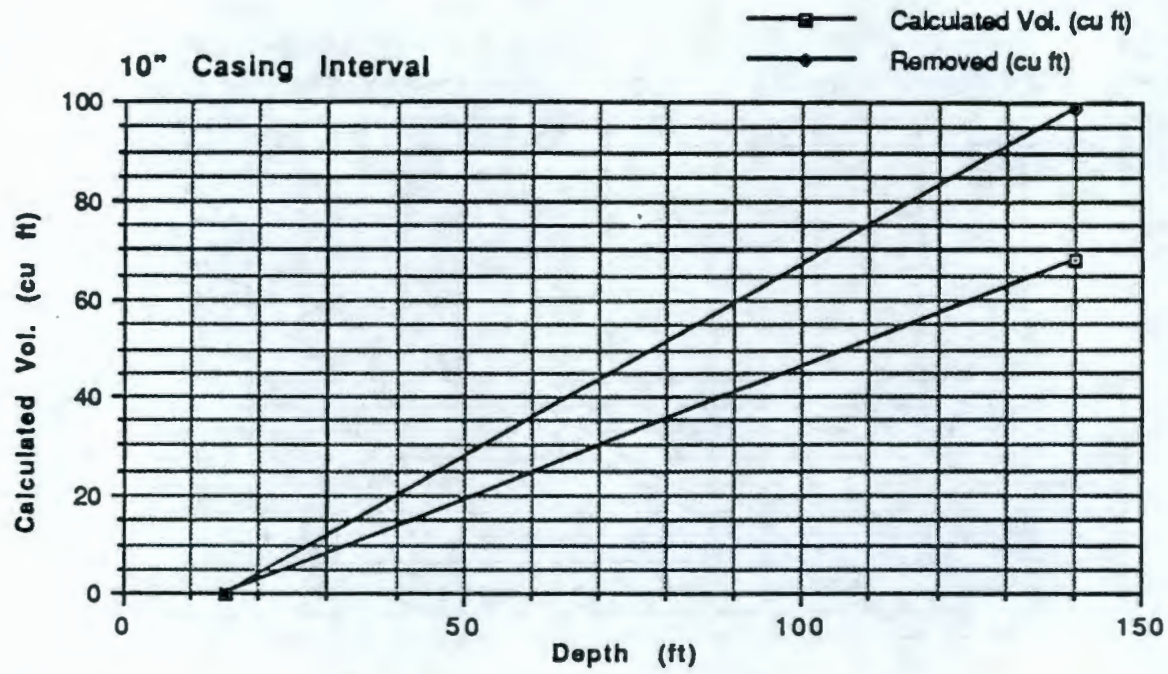


Figure 3-5. Volumetric Graph for Well 299-W6-11.



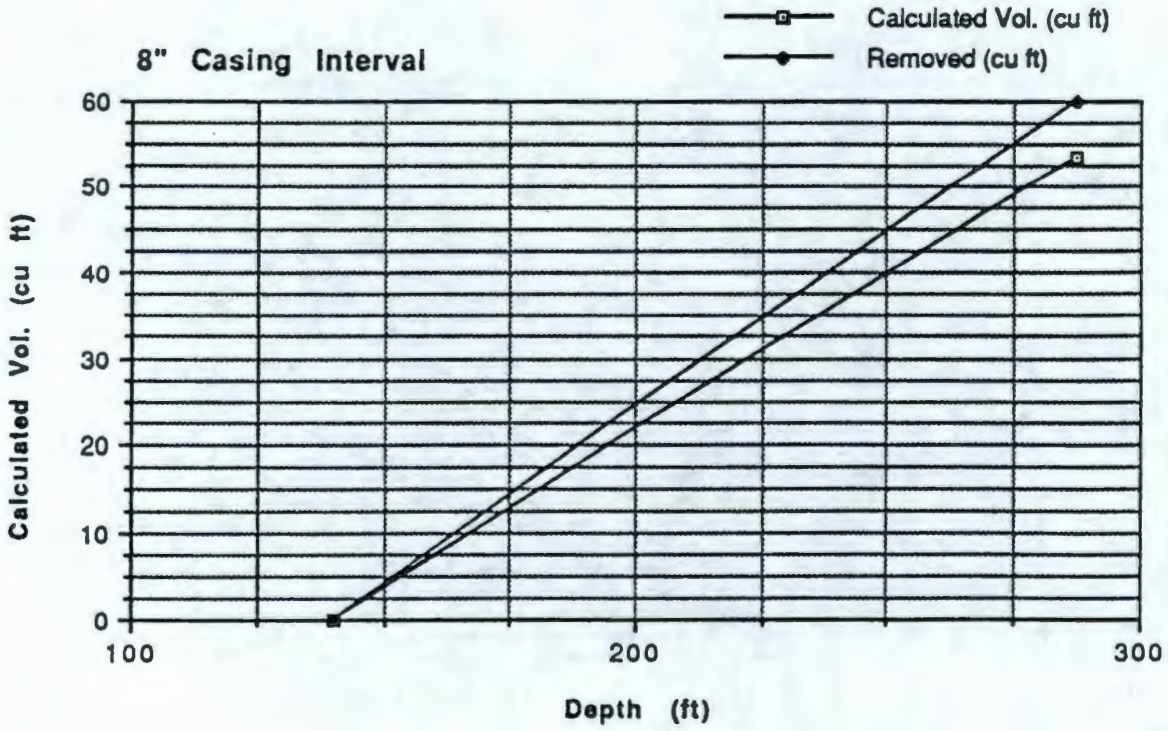


Figure 3-6. Volumetric Graph for Well 299-E25-44.

3.4.2 Spills Documented During Operations

The top-drive rotary drill rig incorporates several hydraulic motors and control circuits. All of the associated lines and connections increase the risk for release of hydraulic fluid to the environment should any components fail. Three separate releases did occur during drilling at the 200 West Area wells. All releases were attributable to faulty hydraulic hose connections and were remedied by replacing the faulty component.

None of the releases caused contamination of the well being drilled at the time of the release. The majority of hydraulic fluid spilled was contained on plastic sheeting under the drill rig and immediately captured with adsorbent pads. Soil that was contaminated with the remainder of the hydraulic fluid was placed into drums and removed as per KEH spill procedure requirements. KEH Occurrence Reporting determined that the amounts spilled during each of the failures was under reportable quantities.

3.5 SCHEDULE

The test plan originally allowed 20 to 25 days for drilling and completing the first well, 20 days for the second well, and 15 days for the third well. Due to unanticipated equipment incompatibilities, engineering problems, and drilling tool supplier delays, the first two wells failed to meet these projected times, taking 40 and 38 days, respectively. The third well was drilled and completed in the expected time of 15 days.

The integration and modifications of the equipment, along with changes in operating philosophies and procedures, and the gain of operational experience have resulted in an efficient and productive working unit. As mobilization and demobilization efficiencies are increased, and the remaining engineering problems are remedied, it is expected that the ODEX system will produce a monitoring well that is drilled in 5 days and completed in 4 days, for a total time of 9 working days per well.

4.0 COMPARISON WITH THE CABLE-TOOL DRILLING METHOD

The following sections present the results of a comparison of production statistics from the three ODEX demonstration holes and 47 cable-tool drilled wells that were drilled by the Construction Forces (CF) for the RCRA Program at the Hanford Site during 1991. This comparison indicates improvement in all categories as justified by data and results reported previously.

4.1 DRILLING PERFORMANCE

4.1.1 Daily Drilling Rate

In a direct comparison of drilling penetration rates (feet per day) as documented in the field activity reports, the drilling penetration rate with the ODEX method was significantly faster than the average cable-tool drilling rate. Figure 4-1 tracks the improvement of daily footage produced by the ODEX drill during the three well demonstration series and the first two extended contract wells. The average daily production from the 1991 RCRA CF wells is included for reference. Comparison of these production records and the drilling and completion graphs (Figures 3-1, 3-2, and 3-3), to the graph of the 1991 RCRA CF average drilling productivity (Figure 4-2) supports the following conclusions:

- As process modifications and engineering changes were implemented, the ODEX method showed a sustained improvement in productivity from less than 30 ft/day initially, to over 70 ft/day on the final demonstration well. Productivity was over 75 ft/day on the subsequent wells of the extended contract.

- The slowest production from the ODEX method was on average three times better than the 1991 cable-tool average (9.5 ft/day) and the last well's average was 7.5 times better than the 1991 cable-tool average.

- The total number of drilling days spent on the third ODEX demonstration well (5 days) is 1/6 the amount of drilling days of the 1991 cable-tool average when adjusted for comparable depths.

- The amount of time required to complete an ODEX well (4 days) is approximately 1/2 of the 1991 cable-tool average (7.5 days).

4.1.2 Hole Straightness

In several areas of the Hanford Site, cable-tool drilling has experienced severe deviation problems that resulted in costly time delays and well construction difficulties. Hole straightness is not expected to be a problem for the ODEX method due to the configuration of the down-hole tools.

The location of the hammer near the drilling face and the two concentric strings of pipe (drill pipe and temporary casing) increase the stiffness of the down-hole assembly. This stiffness is referred to as the bend moment of the system. High bend moments increase the tendency of the hole to remain straight when encountering opposing forces in the well bore. The flexible cable of a cable-tool rig has a very low bend moment and adds no stiffness to the temporary casing.

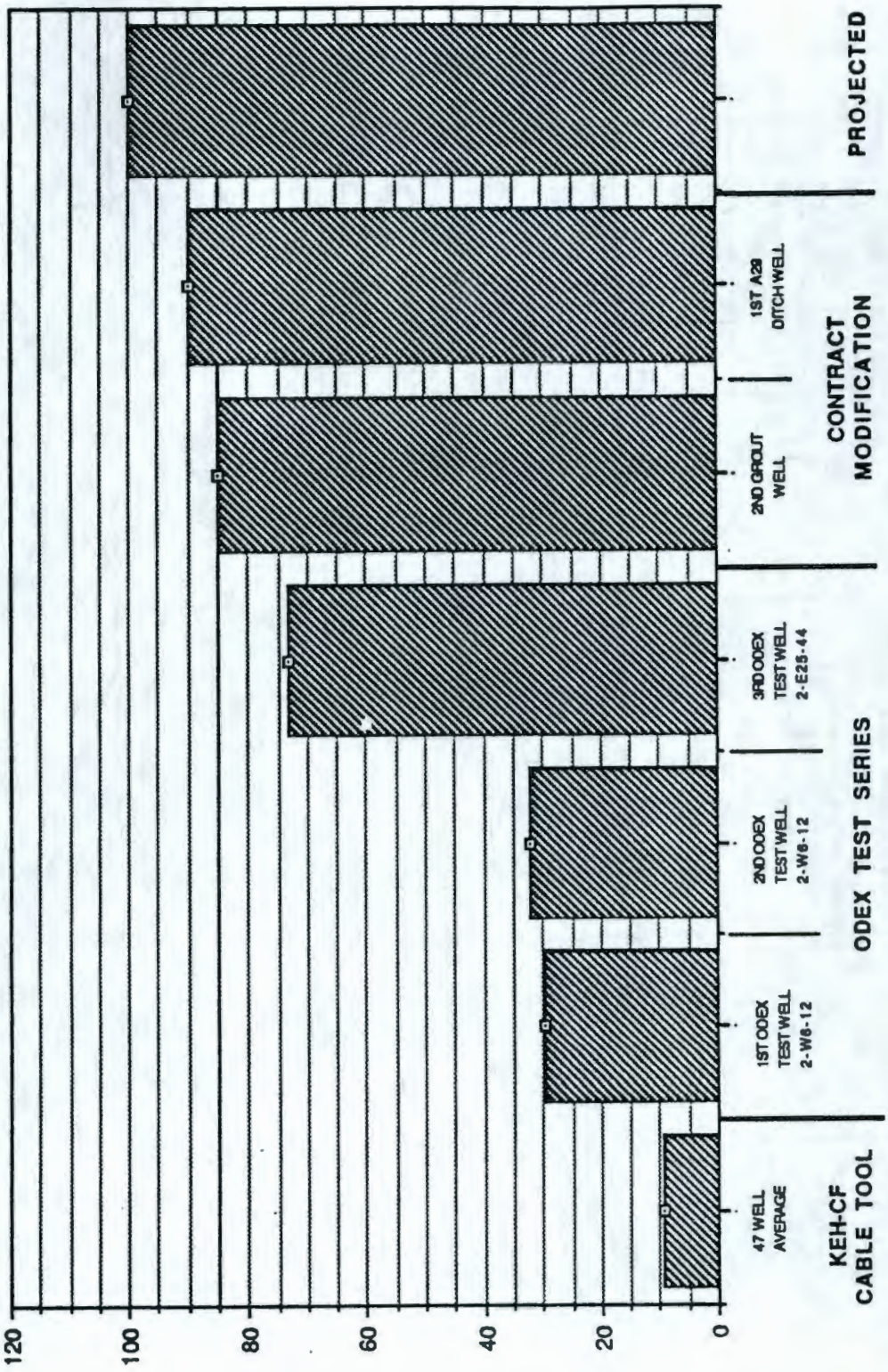


Figure 4-1. Average Daily Drilling Rates (ft).

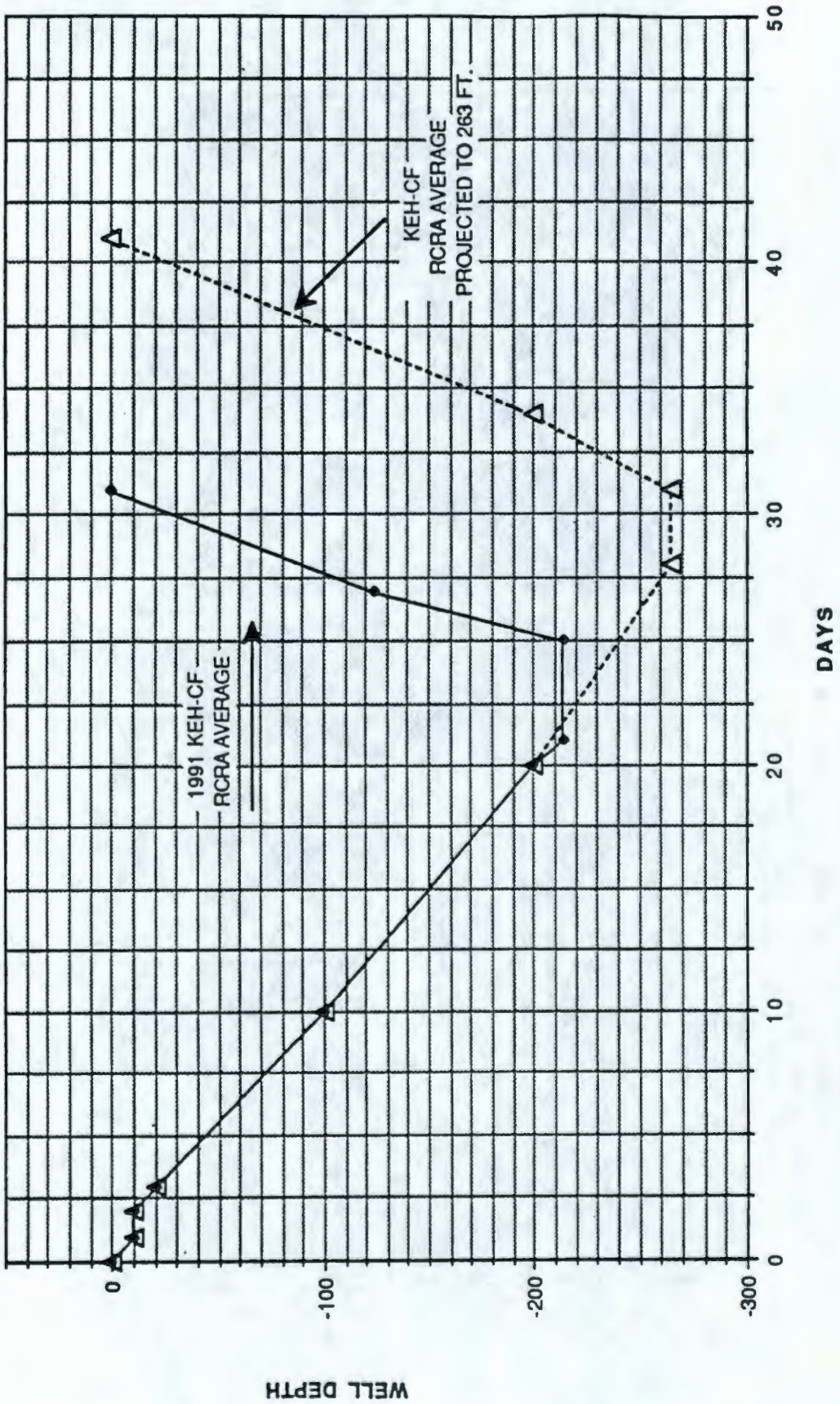


Figure 4-2. 1991 RCRA Construction Forces Average Drilling and Completion Chart.

Pendulum effects, or the tendency of the drill string to hang in a vertical position, also contribute to hole straightness. Stiffness and weight are important factors and reduce the potential for the drill string to deviate from plumb. Deviations cause problems during installation of the permanent casing or pump column. The heavier and stiffer the pendulum, the more effective it is. ODEX appears to have a clear advantage over cable-tool in minimizing deviation.

Casing removal from ODEX drilled wells has been notably trouble free. In the demonstration holes completed and developed to date, field crews report that pump installation has been extremely easy without the detectable sidewall friction that would indicate hole deviation.

4.1.3 Effect of Lithology

As stated earlier, hole locations were selected to test the ODEX drilling response in different lithologies. Effects on drilling from changes in rock type penetrated by the ODEX method were negligible. Only slight reductions in penetration rate, as expected when encountering harder formations, boulders, or some open-framework gravels, were observed. Daily rates in excess of 70 ft/day are still achievable even in harder lithologies.

The effect of formation changes on cable-tool drilling is more severe. Cable-tool drilling in soft or unconsolidated formations is accomplished with a drive barrel. When a hard or consolidated formation is encountered, a hard-tool bit is used to break the formation. Water is added to the hole to produce a slurry, and a bailer is used to remove cuttings from the hole. When hard-tooling is required to advance the hole, not only is the drilling progress drastically reduced, but sample quality is greatly degraded. The addition of water during hard-tool drilling may also mask the subsurface hydrologic conditions and increase the volume of investigation derived waste to be handled.

4.1.4 Personnel Requirements

Compared to the average cable-tool drilling operation, additional manpower is required to optimize the production of an ODEX drilling operation. The additional drilling and support personnel required for an efficient ODEX operation include a second driller's helper and part-time well-site support for the geologist. These drilling personnel are needed due to increased penetration rates, resulting increases in pipe handling, and the large amount of equipment on location. Increased drill rates, drilling equipment inspection requirements (fulfilled by the wellsite geologist), and the number of samples taken per hour have required periodic extra support for the site geologist. In comparison by drilling method, there are three personnel assigned to an average cable-tool drill site and four full-time personnel assigned to a comparable ODEX drill site with occasional support for the geologist to complete sample labeling and other documentation activities.

Improvements in crew efficiency and training are expected to reduce the need for the part-time well-site geologist so that one geologist should be able to support the ODEX drilling operation.

4.1.5 Recognition of the Water Table

Identification of saturated zones (the water table or perched zones) with the cable-tool rig does not occur until moist cuttings are lifted from the well with the drive barrel or the well is bailed and the level of the fluid in the hole is monitored with a steel tape or E-tape to determine a rise in fluid level. As a result, penetration through a thin perched water zone or failure to recognize confining conditions while cable-tool drilling is possible. This would result in the loss of hydrogeologic characterization data and a potential for allowing the downward flow of contaminated water. This problem is minimal or nonexistent when the ODEX method is employed. With the ODEX method, the uphole movement of cuttings in the airstream and the transparent sample catching sock allow for almost-immediate recognition of saturated zones. The ability to rapidly recognize a saturated zone allows the well-site geologist and the driller to take appropriate action before the saturated zone has been drilled through.

4.1.6 Isolation of Perched Water

The key to isolating perched water is in early recognition that a perched zone has been encountered. Because sampling equipment on the ODEX rig allows little lag time between removal of the sample from down-hole and capture in the transparent cuttings sock, it is unlikely that a perched interval would be missed. As stated in the previous section, it is possible that a thin, saturated perched zone and confining layer may be penetrated and never recognized when cable-tool drilling with a hard-tool bit.

Once a perched aquifer is recognized, both drilling methods have identical corrective actions. In both cases, the drill casing in use is terminated in the underlying confining layer and drilling continues with the next smaller casing diameter telescoped into the hole from the surface. This action is intended to isolate the aquifer and prevent migration of the water downward.

4.1.7 Effluent Control

The ODEX equipped drill rig has hoses and fittings connecting the drill hole casing to the cuttings containment equipment. Before the use of negative pressure Torit dust control equipment, failure of any of the hoses or fittings while drilling could have caused the release of drill hole cuttings to the surrounding environment. The inclusion of the Torit dust control equipment places the cuttings exhaust stream from the drill hole casing to the Torit under negative operating pressure. This effectively eliminates any chance of an outward leak. Operating experience gained during the demonstration indicates that proper utilization of the equipment, and effective preventive maintenance combine to reduce the risk to acceptable levels. Current improvements in the ODEX cuttings containment equipment also ensures that there will be no spilling of cuttings or fluids bailed from the well as could happen when emptying a cable-tool rig bailer into an open topped barrel.

When drilling at locations where there is a risk of encountering organic vapors (e.g., carbon tetrachloride), the ODEX rig has less risk of exposure for personnel than a cable-tool rig. All gases released from the formation

are diluted in the circulating airstream, travel in an enclosed negative pressure system, and are discharged many feet away from the drill rig. In addition, activated carbon canisters could be added to the cuttings containment system to capture any carbon tetrachloride vapors emitted from the well.

4.2 SAMPLING

Collection of drill cuttings or intact samples is often required during the drilling of a groundwater monitoring well. Drill cuttings are generally used for the physical description of the formation penetrated and occasionally for physical testing. Since the cuttings are removed and carried in the airstream with the ODEX, the potential for contaminating the cuttings samples with compressor oil in the airstream exists. Potential for minute quantities of lubricating oils to become entrained in the groundwater also exists. Potential contamination is reduced due to installation of a 0.01 μ size air filter on the air inlet line. Proper sizing and maintenance of the air filters according to manufacturer's recommendations will ensure that the bailing air remains free of potential contaminants. Samples of the bailing air have been taken for analysis and the results will be reported. Results from chemical split spoon samples will also be tracked with respect to possible downhole or formation water contamination.

Intact samples are required from drill holes for physical testing or chemical analysis. Both cable-tool and ODEX methods use nearly identical split spoon tools to acquire intact samples. During cable-tool drilling, the drive barrel or hard tool is detached and the drilling jars are used to pound the sampler into the drilling face. The ODEX rig uses a down-hole hammer to advance the split spoon into the formation. The cable-tool derived sample is usually over-compacted during collection and must be corrected for before hydraulic property tests are performed. Since the ODEX driller can control the amount of advance, over-compaction of the sample can be minimized.

4.3 WELL COMPLETION

Both ODEX and cable-tool drilling methods allow for the installation of well screen, casing, sand pack, and annular seal in compliance with the Well Specification (WHC 1992a), applicable EII (WHC 1988), and appropriate regulations. Because the ODEX has a tendency to drill a truer (straighter) borehole, and the bit and underreamer drill a slightly larger hole than the temporary casing, there is less formation friction on the casing surface during the well completion process. Reduction in friction results in expedient extraction of temporary casing from the hole, and it is anticipated that fewer instances of parted or stuck casing will occur. Well completion durations for the three ODEX demonstration wells averaged slightly less than 4 days per well while the average for 1991 RCRA CF wells was 7 days per well. Completion times tracked as drilling continues support this average.

4.4 WELL DEVELOPMENT AND GROUNDWATER SAMPLING

Cable-tool and ODEX methods have equivalent capabilities for obtaining either representative groundwater samples or water-level measurements from the borehole prior to completion of the well. In both cases, drilling tools are removed from inside the temporary casing and groundwater is sampled with a bailer or other device, or the water level is measured with a steel tape or E-tape.

Development of the three wells of the demonstration (299-W6-11, 299-W6-12, and 299-E25-44) required extraction of 2,050 gal, 1,315 gal, and 885 gal of development water respectively to attain required clarity standards. This compares very favorably with the 1991 RCRA CF cable-tool average of 3,100 gal per developed well. Reductions of development water were anticipated since the ODEX drill utilizes a continuous cuttings removal process. Cuttings are immediately removed from the hole in the airstream instead of remaining in the hole until they are bailed-out or smeared into the borehole wall. Based on three demonstration wells, the duration of development work and the amount of development water produced is less than those for the development of cable-tool drilled wells. Volumes of development water produced and associated time demands for personnel is approximately half that for cable-tool drilled wells. This initial trend is expected to continue for all the ODEX drilled wells and should result in substantial cost savings to current or future drilling programs.

4.5 WASTE MINIMIZATION

Demonstration wells each produced approximately three 55-gal barrels of cuttings and formation water during drilling below the water table. By comparison, the 47 wells of the 1991 RCRA CF program generated an average of 17 55-gal barrels for each well drilled. At a handling and disposal cost in excess of $700/barrel based on actual RCRA drilling program costs. This cost savings becomes quite substantial when drilling additional wells with the ODEX method instead of with cable tool.

4.6 COST

Because drilling accounts for the single-most expensive segment of groundwater monitoring well installation for the RCRA program, it is logical that, if the ODEX drilling system drills faster and has fewer total drilling and completion days per well, significant cost savings are possible. When considering minimization of waste handling costs, the expectation of fewer drilling and completion problems, and lower drilling costs, total cost savings become even more substantial.

The three ODEX method demonstration wells were completed at an average depth of 279 ft for a total, fully burdened cost of $222,300, or $74,100 per well (approximately $270/ft). When these costs are compared to the 1991 RCRA CF average for cable-tool wells drilled to an average depth of 214 ft, the ODEX method demonstrates an approximate 40% cost savings.

5.0 CONCLUSIONS

The ODEX demonstration has confirmed that this method of drilling has a viable application on the Hanford Site. Based on experience gained to date, it can be concluded that:

- RCRA compliant wells can be installed by the ODEX method
- Safety and ALARA concerns for the workers on location are minimized
- To date, there are no identified technical problems associated with the method that would interfere with its continued use
- Significant economic savings over the cable-tool method are possible.

The consensus of opinion among KEH, WHC Projects, and WHC Geosciences is that the ODEX method is an economic and appropriate drilling method for use on selective areas of the Hanford Site.

6.0 RECOMMENDATIONS

Continuing development efforts and acquisition of additional components will optimize productivity and further enhance the flexibility of the existing equipment configuration. Based on favorable quality and economic considerations, and the ability to support RCRA Tri-Party Agreement milestones and other schedule requirements, it is recommended that the scope of ODEX drilling at the Hanford Site be extended to include locations other than those characterized as nonhazardous/nonradioactive. The ODEX method of drilling should be employed at drill sites where data quality objectives and applicable safety concerns can be achieved by the proper utilization of this method.

In order to support these recommendations and corroborate the observations, measurements, and conclusions made during the three well demonstration of the ODEX system, WHC Projects and Geosciences will continue to monitor the application of the ODEX system. Specific attention will be given to, and an information report prepared, discussing the volumes of development water produced and results of chemical analyses that will be done when the wells are sampled.

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