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Evaluation of Groundwater Characterization and Modeling at the Pantex Plant

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prepared for

STAND

Serious Texans Against Nuclear Dumping

by

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Executive Summary

This is an evaluation of the U.S. Department of Energy's (DOE) efforts to characterize and model groundwater contamination at the Pantex plant. This evaluation was performed on behalf of Serious Texans Against Nuclear Dumping (STAND).

The major findings of this evaluation are:

- Contaminants from Pantex have entered the perched aquifer and the Ogallala Aquifer. Contaminants in the perched aquifer have migrated onto private property adjacent to Pantex.
- DOE has not determined the full extent of contamination in either aquifer.
- The investigation of the Ogallala Aquifer at Pantex is inadequate. Site specific data concerning important hydraulic and geochemical properties are insufficient or nonexistent.
- DOE's efforts to estimate background concentrations for the Ogallala Aquifer at Pantex are questionable. DOE has not shown that the background samples it has used are representative of background concentrations at Pantex. DOE is reassessing its evaluation of background concentrations.
- The groundwater modeling performed to date is inadequate. The models used cannot simulate significant physical processes. Necessary data have not been collected. The models are based on questionable assumptions, and do not account for all major contaminants.
- DOE is using contaminant concentrations greater than the Maximum Contaminant Limit (MCLs[1]) to establish the limits of contamination emanating from Pantex. MCLs are the regulatory standard established to protect human health.
- On numerous occasions between 1992 and 1999 DOE failed to notify the public or regulatory agencies that it had found concentrations of contaminants in the Ogallala Aquifer above MCLs.
- DOE has not investigated the hydraulic relationship between the Ogallala Aquifer and the underlying Dockum Group. DOE has not investigated the possibility that contaminants from Pantex may enter the Dockum Group.
- DOE has not investigated the possibility that groundwater in the vicinity of Pantex Lake may be affected by wastes it has discharged to the lake.

DOE acknowledges the existence of data gaps in its characterization of groundwater contamination, and inadequacies in its groundwater modeling. It plans to fill some of the data gaps and to improve the modeling.

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Introduction

This evaluation was performed on behalf of Serious Texans Against Nuclear Dumping (STAND), a non-profit organization of concerned citizens. The purpose of this evaluation is to:

- Determine whether the U.S. Department of Energy (DOE) has adequately characterized groundwater contamination at and around Pantex.
- Determine whether the computerized groundwater models used by DOE can adequately simulate the fate and transport of groundwater contaminants, and predict the effects of remedial actions.

This evaluation is based on reviews of documents, and discussions with DOE and DOE contractor personnel[2]. The documents are listed in the reference section.

The Pantex plant is 17 miles northeast of Amarillo, Texas. It occupies 15,940 acres (figure 1)[3]. During World War II the U.S. Army produced conventional shells and bombs at the plant. Since the early 1950s Pantex has been operated by the DOE and its predecessor agencies as a facility to assemble and disassemble nuclear weapons, and to fabricate and test chemical explosives.[4] The plant contains buildings and industrial structures, a wastewater treatment plant[5], landfills, waste disposal pits, borrow pits, and agricultural lands[6]. There are five playas on the plant-site. DOE also controls Pantex Lake, a playa about 2.5 miles northeast of the plant[7] (figure 2).

Stratigraphy and Groundwater Occurrence

Pantex is underlain by four to six feet of soils. The soils are developed in the Blackwater Draw Formation, a 50 to 80 feet thick sequence of wind-deposited clays, silts, and sands. It does not contain groundwater. The Blackwater Draw is underlain by the Ogallala Formation, a sequence of clays, silts, sands, and gravels. The thickness of the Ogallala ranges from 325 to 725 feet. There are two water bearing zones in the Ogallala; a perched aquifer, and the main Ogallala Aquifer[8]. The Ogallala is underlain by the Dockum Group, a sequence of shale, siltstone, and sandstone (figure 3).The Ogallala Aquifer is also known as the High Plains Aquifer[9].

The perched aquifer is found at depths ranging from 260 to 290 feet below land surface. It exists because downward flowing water is impeded by a low permeability ‘fine grained zone’[10]. The average saturated thickness of water in the perched aquifer is about 14 feet and the maximum thickness is about 75 feet[11].

The perched aquifer does not exist beneath all of Pantex. It is absent near the Burning Grounds and in isolated areas along the eastern boundary of the plant[12]. On the other hand, the full extent of the perched aquifer in the vicinity of Pantex has not been completely determined. Its extent to the north

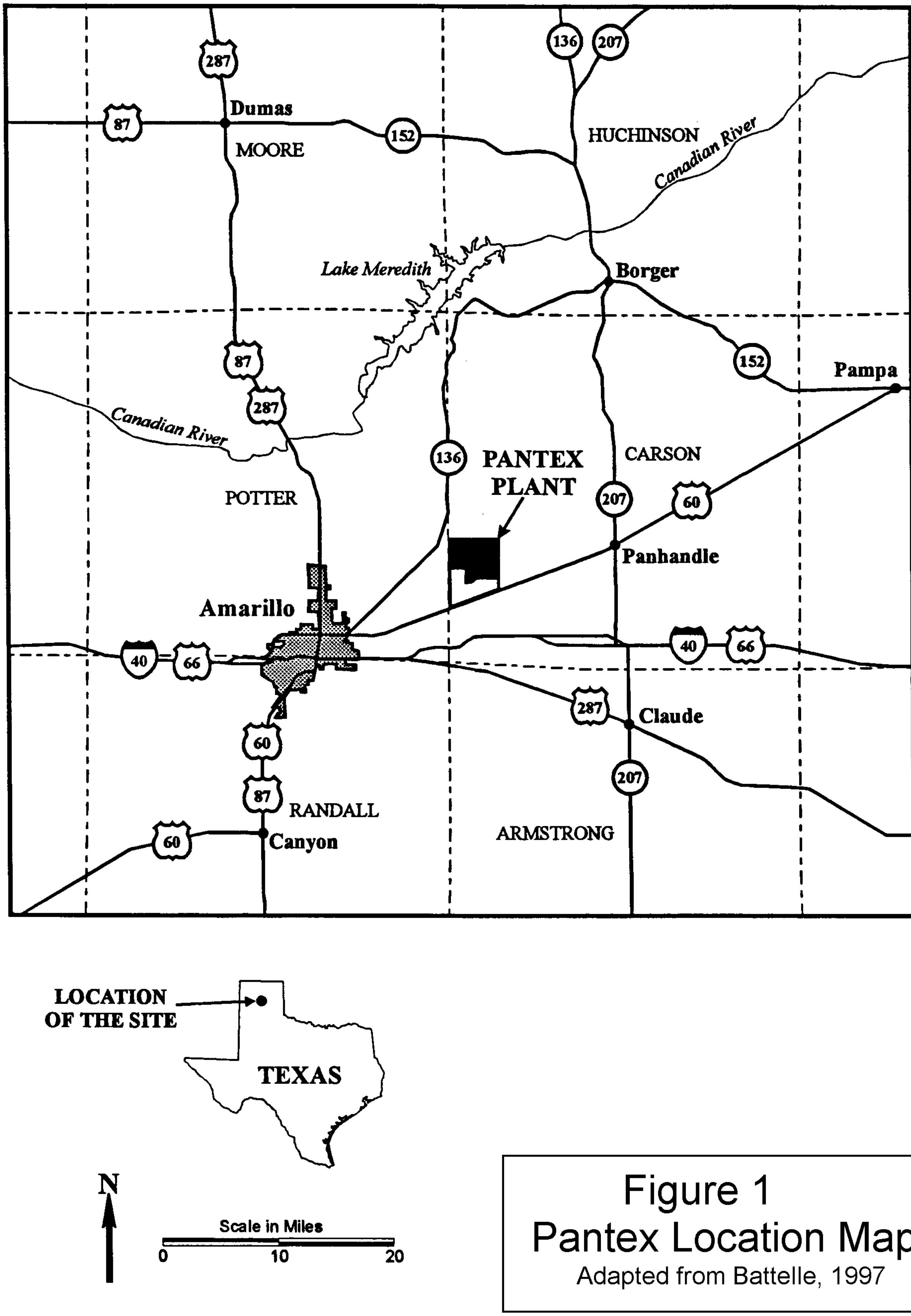

Figure 1
Pantex Location Map
Adapted from Battelle, 1997

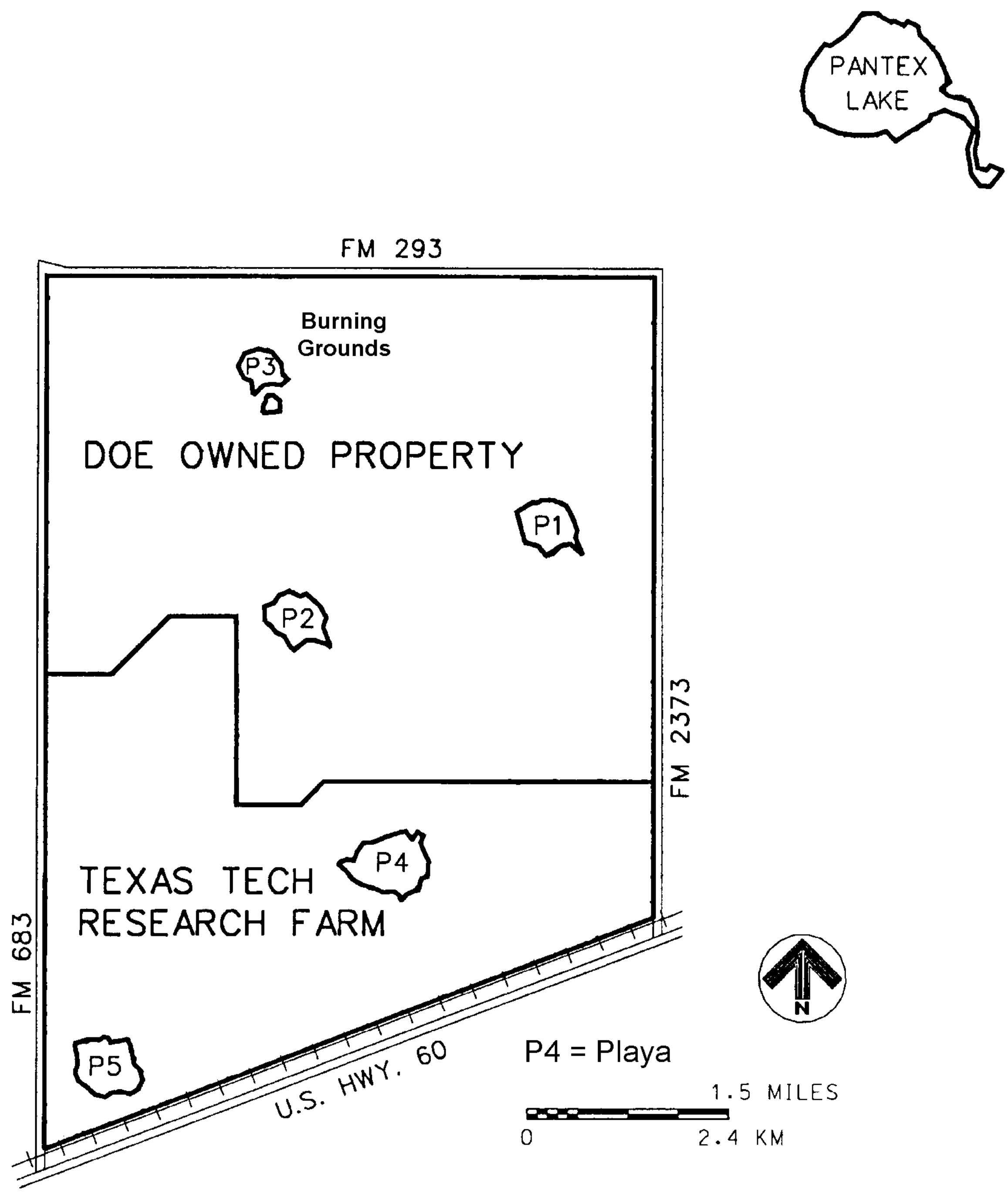

Figure 2
Pantex Site Map
Adapted from DOE, 1998b

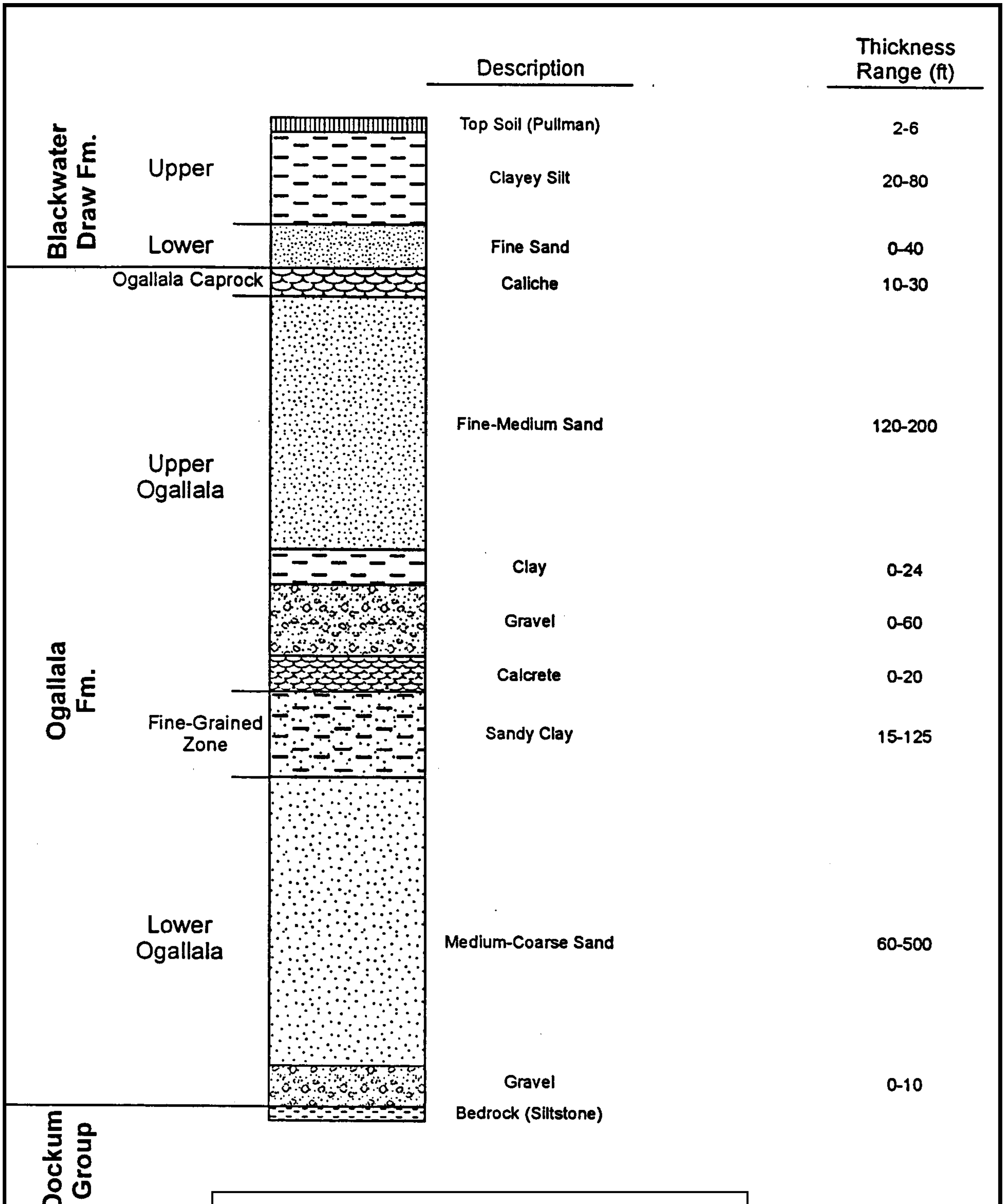

Figure 3
Geologic Column at Pantex
Adapted from Battelle, 1997

and northeast of the plant is unknown[13], and large portions of the plantsite contain no perched aquifer monitor wells (e.g., northwest corner, area west of Playa 2)[14].

Flow directions in the perched aquifer are variable. Near the western plant boundary groundwater flows southeasterly, onto the plant. In the eastern portion of the plant, groundwater flows radially (in all directions) from beneath Playa 1, with a significant amount flowing off-site to the east and southeast[15]. Recharge is believed to occur primarily through playas and ditches that discharge to the playas[16]. DOE estimates of groundwater flow rates in the perched aquifer range from 60 to 2700 feet per year[17]. Water may leave the perched aquifer by being pumped from wells or by flowing downward, toward the Ogallala Aquifer. Downward flow may occur through high permeability zones in the fine grained zone, or along the margins of the aquifer. The perched aquifer is used as a source of domestic and agricultural water[18].

. . .the full extent of the perched aquifer in the vicinity of Pantex has not been completely determined. Its extent to the north and northeast of the plant is unknown, and large portions of the plantsite contain no perched aquifer monitor wells.

The Ogallala Aquifer is separated from the perched aquifer by the fine grained zone and unsaturated sediments. The thickness of the fine grained zone ranges from about ten to 120 feet. The average thickness is about 50 feet[19]. The distance between the bottom of the fine grained zone and the water table of the Ogallala Aquifer varies greatly across Pantex. In the southern portion of the plant, the water table of the Ogallala intersects and rises above the base of the fine grained zone. However, the average distance between the bottom of the fine grained zone and the water table of the Ogallala Aquifer is about 120 feet[20]. The depth of the water table ranges from 350 to 425 feet below land surface[21]. Groundwater in the Ogallala flows to the northeast (figure 4). DOE estimates of flow rates range from 20 to 3900 feet per year[22]. Most of the water in the Ogallala beneath the plant flows in laterally from the southeast. Additional sources of recharge are leakage from the overlying perched aquifer and, where the perched aquifer is absent, directly from playas[23]. The amount of leakage from the perched aquifer depends on the properties of the underlying fine grained zone. Leakage is likely to be greatest in areas where the fine grained zone is relatively thin, or where it is composed of more permeable materials.

The Ogallala Aquifer is the primary source of groundwater in the Southern High Plains[24]. The City of Amarillo operates a public supply well field in the Ogallala north and northeast of Pantex. The nearest city well is about 2500 feet from the plant[25] (figure 4). Landowners near the plant use Ogallala water for domestic and agricultural purposes, and the plant obtains its water from five on-site Ogallala wells[26].

DOE has installed 19 Ogallala monitor wells on Pantex property, and one immediately to the east of Pantex[27]. However, large areas on Pantex contain no Ogallala wells. These include the northwest portion of the plant, the areas around playas 2 and 4, and the area between the Burning Grounds and the supply wells in the northeast corner of the plant[28].

The Ogallala is underlain by the Dockum Group. This unit is less than 100 feet thick at Pantex[29]. South of Pantex, water from the Dockum Group is used for domestic and agricultural purposes[30].

The lateral extent and hydraulic properties of the Dockum Group at Pantex are unknown. The direction of any groundwater flow between the Ogallala Aquifer and the Dockum Group is also unknown[31].

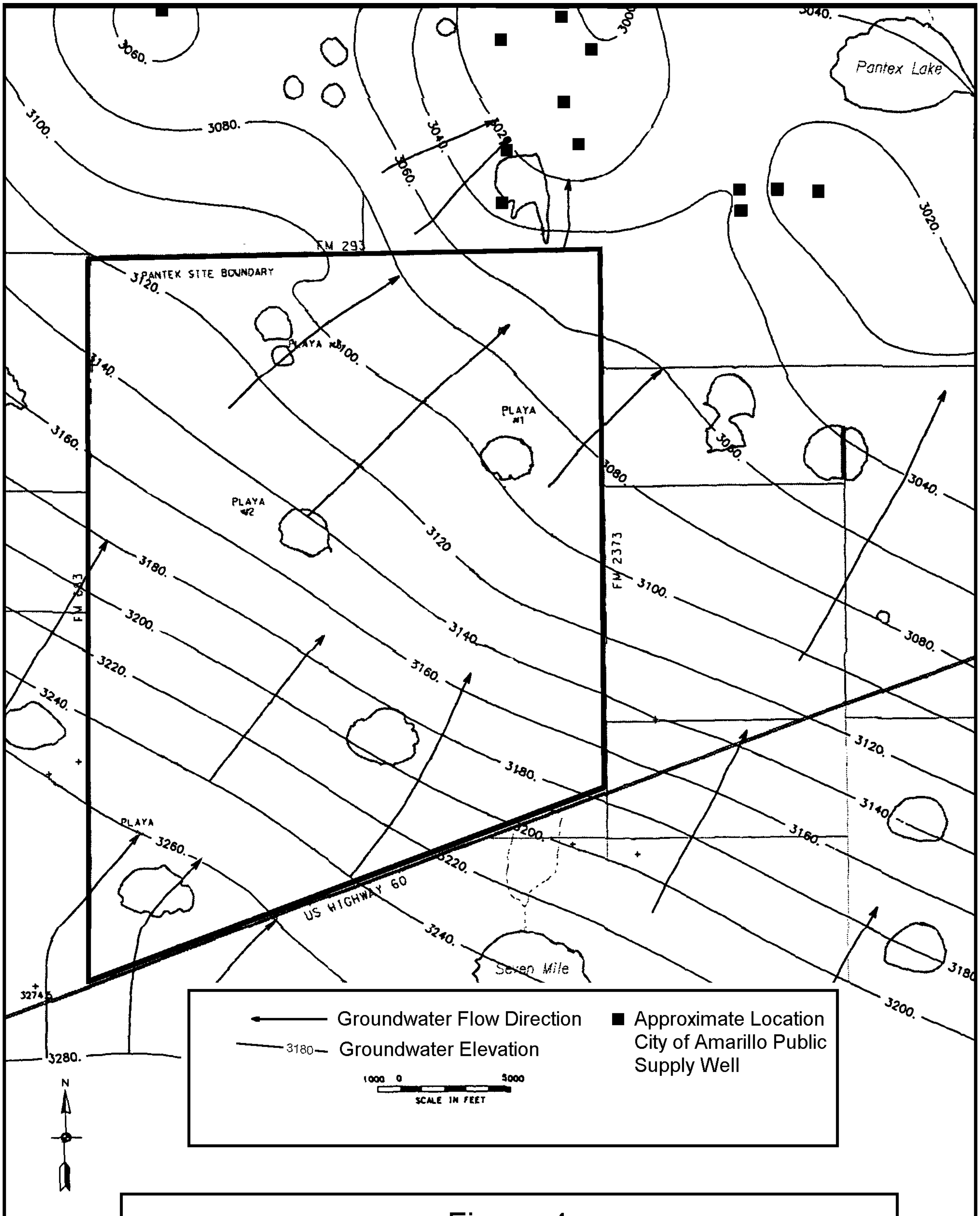

Figure 4
Groundwater Flow Directions in the Ogallala Aquifer
Adapted from Battelle, 1997

Hazardous Materials and Groundwater Contamination[32]

The following hazardous materials have been used in industrial processes at Pantex, or have been found on plant property (*e.g.*, landfills and spill sites) in concentrations that exceed risk reduction standards[33] or background concentrations.

- **Radionuclides[34]:**

  Uranium, plutonium, thorium, tritium.

- **Explosives[35]:**

  DNT, HMX, PETN, RDX, TNT.

- **Metals[36]:**

  Antimony, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, strontium, thallium, vanadium.

- **Chlorinated solvents[37]:**

  Carbon tetrachloride, chloroform, methylene chloride, perchlorethylene (PCE), trichloroethylene (TCE).

- **Fuel components and other organic chemicals[38]:**

  Acenapthylene, acetone, benzene, benzoic acid, benzo(g,h,i)perylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, bis-(2-ethylhexyl)phthalate, carbazole, chrysene, dibenz(a,h)anthracene, ethyl acetate, indeno(1,2,3-c,d)pyrene, n-nitrosodi-n-propylamine, methyl ethyl ketone (MEK), pentachlorophenol, pheneanthrene, polychlorinated biphenols (PCBs), toluene, 1,2-diphenylhydrazine, 1,3,5-trinitrobenzene, 2-methylnaphthalene.

- **Pesticides[39]:**

  Aldrin, alpha BHC, beta BHC, chlordane, DDE, DDT, dicamba, dieldrin, dinoseb, endosulfan II, endrin, heptachlor, heptachlor epoxide, lindane, toxaphene, 2,4,5-T, 2,4,5-TP.

- **Dioxins/furans[40]:**

  Heptachlorinated dibenzo-p-dioxins, octachlorodibenzo-p-dioxin, pentachlorinated dibenzofurans.

- **Miscellaneous[41]:**

  Asbestos, fluoride.

In the past, industrial wastes were discharged to all the playas at Pantex[42]. Explosives, pesticides, metals, PCBs, and volatile organic compounds were discharged to playas via unlined ditches[43]. From 1942 to 1970 Pantex Lake received wastes from the Old Sewage Treatment Plant (OSTP). The OSTP treated sewage and industrial wastes[44]. Only Playa 1 continues to receive waste waters, and the wastes are treated before being discharged to the playa[45]. All the playas receive stormwater runoff [46].

Pantex contains many sites that may have released hazardous materials to the environment[47]. These include sludge beds, unlined burn pits, subsurface leaching beds, pesticide rinse areas, leaking underground storage tanks, unlined landfills, waste drum storage areas, solvent leak sites, acid spill sites, a transformer leak site, and a scrap/salvage yard[48]. Because hazardous materials have been used at Pantex for more than 50 years, it is probably not possible to identify all areas where they have been handled, stored, spilled, buried, burned, or dumped; with or without the authorization of plant officials[49].

The perched aquifer beneath the Pantex site is contaminated with a variety of hazardous substances including: 2,4-DNT, HMX, RDX, TNT, benzene, 1,2-DCA, TCE, PCE, and chromium[50]. RDX is the most widespread groundwater contaminant[51] (figure 5). Pantex is the source of most, if not all of these contaminants. Contaminated groundwater in the perched aquifer has migrated from Pantex onto private property adjacent to the plant[52]. The extent of groundwater contamination in the perched aquifer has not been completely determined[53].

In 1996 DOE began cleaning up the perched aquifer in the eastern portion of the plant[54]. Extraction wells pump contaminated water to a treatment system that removes organics, explosives, and chromium. The treated water is injected back into the perched aquifer. DOE estimates that cleanup of the southeast contaminant plume will be completed in 35 to 55 years[55]. However, this estimate does not appear to include the time required to clean up chromium, a major contaminant in the perched aquifer[56].

Many contaminants have been found in the Ogallala Aquifer at Pantex, and contaminant concentrations have exceeded MCLs on numerous occasions between 1992 and 2000 (see Appendix I). However, until 2000, DOE failed to notify the public or regulatory agencies that it had found concentrations of contaminants above MCLs. These contaminants include bis(2-ethylhexyl)phthalate[57], DBCP[58], TCE[59], cadmium[60], chromium[61], lead[62], nickel[63], and thallium[64].

The Ogallala Aquifer at the Burning Grounds (figure 2) is contaminated with cadmium, TCE, and toluene[65]. Toluene has also been found in wells north of the Burning Grounds, along the plant boundary[66]. Groundwater at the Burning Grounds flows toward the City of Amarillo's well field (see figure 4). The nearest city well is approximately 2500 feet north of the plant[67]. The migration rates for TCE and toluene are estimated to be approximately 200 feet per year, and 150 feet per year, respectively[68] (see Appendix II).

The extent of contamination in the Ogallala Aquifer is unknown. As mentioned above, large areas on Pantex contain no Ogallala wells.

However, until 2000, DOE failed to notify the public or regulatory agencies that it had found . . . contaminants above MCLs. These contaminants include bis(2-ethylhexyl)phthalate[57], DBCP[58], TCE[59], cadmium[60], chromium[61], lead[62], nickel[63], and thallium[64].

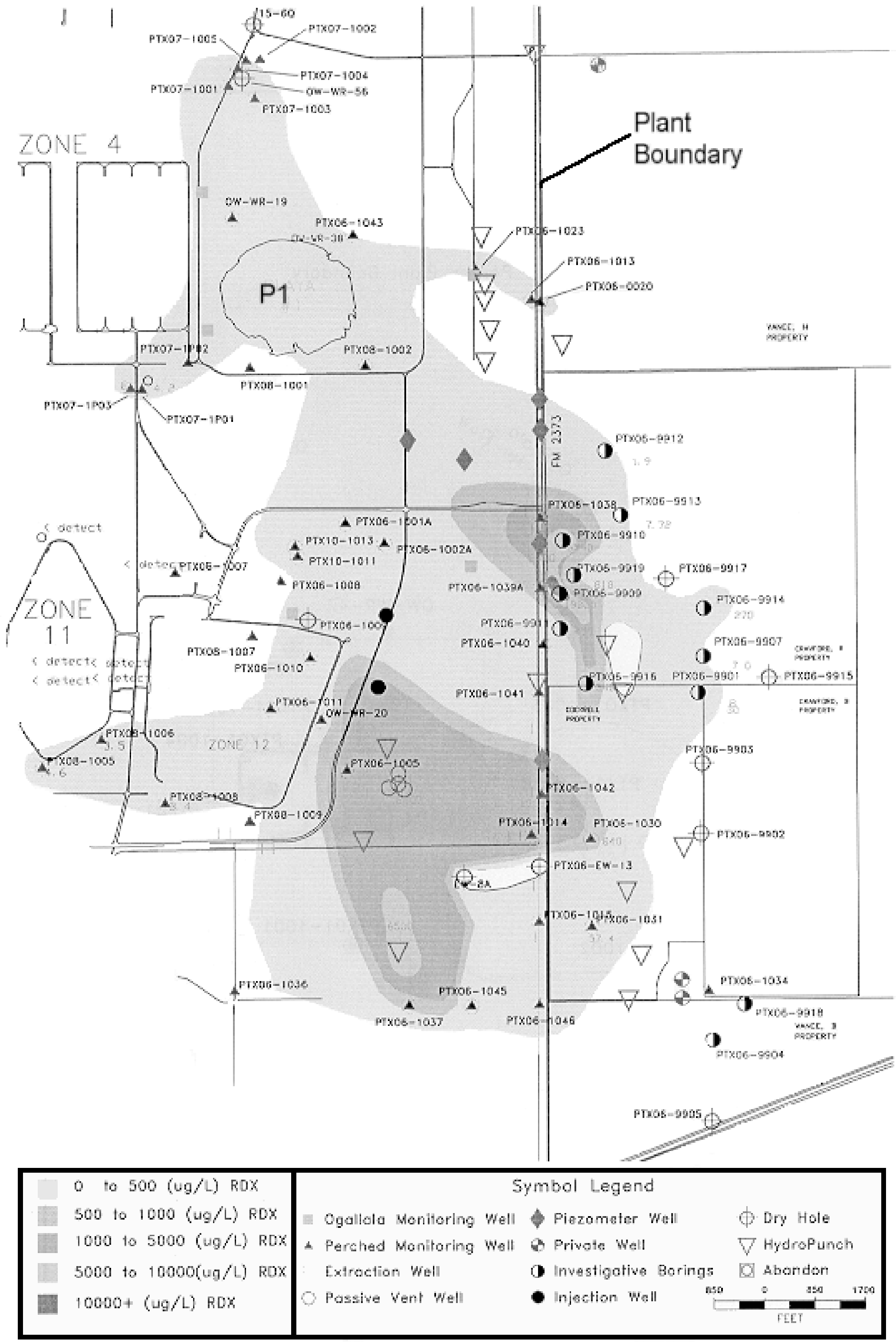

Figure 5
RDX Contamination of the Perched Aquifer
Adapted from DOE, 2000h

There are no Ogallala monitor wells between the Burning Grounds and the City of Amarillo wells[69]. DOE has not investigated the possibility that contaminants from Pantex could enter the underlying Dockum Group.

At this time, there is no reason to believe that contaminants in the Ogallala cannot flow into the Dockum.

Background and the Extent of Contamination and Cleanup

The methods DOE has used to estimate background concentrations for the Ogallala Aquifer and to estimate the extent of contamination in both aquifers are described in *Final Risk Reduction Guidance to the Pantex Plant RFI*[70].

DOE intends to use background concentrations and practical quantitation limits (PQLs)[71] to determine the extent of contamination and " … *as the basis on which the extent of acceptable residual contamination is determined."*[72]. If the PQL is greater than the background concentration, DOE will cleanup to the PQL rather than the background concentration[73]. Thus, the extent of DOE's cleanup depends on their estimates of background concentrations and on the ability of their laboratories to measure the presence of contaminants.

The methods and samples used in the *Final Risk Reduction Guidance* to estimate background concentrations in the Ogallala Aquifer have led to questionable results. For example, DOE estimated the Pantex background concentration of nitrate (as nitrogen) to be 16.2 mg/L[74]. This is the highest concentration found in over 100 Ogallala wells. It was found in a well just northwest of Amarillo, approximately 15 miles from Pantex[75].

In contrast, the highest nitrate-nitrogen concentration found within two miles of Pantex was 7.8 mg/L[76]. Based on this information, it is reasonable to conclude that the background concentration of nitrate-nitrogen at Pantex is something less than 8 mg/L, not 16.2 mg/L.

DOE plans to change the wells it uses to estimate background concentrations. It has proposed using samples from wells in the vicinity of Pantex, and discontinuing the use of wells many miles away. However, some of the proposed background wells are on Pantex property, and others are north of Pantex, in the path of contaminants that may be emanating from the Burning Grounds[77].

These wells may be affected, now or in the future, by contaminants from Pantex.

There are also problems associated with the techniques DOE is using to collect background samples for metals.

DOE is collecting unfiltered samples from private Ogallala Aquifer wells near Pantex[78]. These samples are preserved with acid. Unfiltered water samples may contain fine sediments that dissolve and release metals when acid is added.

Thus, estimates of metal concentrations that are based on unfiltered samples may be too high. The use of unfiltered samples is appropriate when the purpose of sampling is to determine what people may be ingesting with their water.

But, when the purpose is to determine the concentrations of metals being transported by groundwater, filtered samples are more appropriate.

Estimates of background concentrations based on the new set of background wells have not been published.

Groundwater Modeling

Contaminant fate and transport models may be used to predict contaminant flow rates, and to design and predict the effects of groundwater cleanup systems. The evaluation of DOE's modeling consisted primarily of reviewing documents describing modeling performed to date. Model input and output files were requested from DOE, but have not been provided[79].

In 1997 Battelle modeled groundwater flow and contaminant transport in the perched and Ogallala aquifers[80]. In 2000 IT Corporation and Battelle modeled the effects of various pump and treat systems on contaminants in the perched aquifer[81]. The later models were based on the model developed by Battelle in 1997.

The modeling performed thus far is inadequate in several respects.

First, the models used[82] are incapable of simulating flow and transport through unsaturated material. The unsaturated zones at Pantex are probably major contaminant pathways, both from ground surface to the perched aquifer, and from the perched aquifer to the Ogallala Aquifer.

Second, the hydraulic and geochemical properties of the Ogallala Aquifer at Pantex have not been adequately characterized. Only one measurement of hydraulic conductivity has been performed - a single slug test conducted in 1994[83]. No measurements of effective porosity have been performed, and only one measurement of organic carbon content has been performed[84]. In addition, little or no site specific information on dispersivities or partition coefficients have been collected for either aquifer at Pantex[85]. Reliable estimates of these properties are required in order to produce dependable simulations of contaminant migration rates and the effects of proposed remedial actions.

Third, the models are based on questionable assumptions.

- The models assume that contaminant sources are no longer contributing contaminants to the perched aquifer[86]. There is no reason to believe this is correct.

- The models assume there is no flow between Ogallala and the underlying Dockum Group[87]. There is no information to show this is correct.

- The models assume the vertical hydraulic conductivity of the fine grained zone beneath the perched aquifer is uniformly low throughout Pantex[88]. This may not be correct. Estimates of vertical hydraulic conductivity are based on laboratory tests of core samples[89]. However, laboratory tests may not identify field scale features (offset beds, fractures, stream channels) that can significantly increase the hydraulic conductivity of the fine grained zone. These localized areas of high conductivity may allow significant amounts of water to flow from the perched aquifer to the Ogallala.

Finally, the modeling of remedial designs for the perched aquifer neglects chromium contamination[90]. Chromium is one of the most widespread contaminants in the perched aquifer[91]. Because of its geochemical properties it may be more difficult to remove than other contaminants (e.g., RDX, TCE)[92].

Thus, estimates of cleanup times that neglect chromium may be unrealistically optimistic.

DOE recognizes some of the shortcomings of its modeling efforts[93]. It has formed the *Innovative Technology Remediation Demonstration Pantex Southeast Groundwater Project* (ITRD). One of the goals of the ITRD is to develop improved groundwater models for Pantex[94].

Miscellaneous Issues and Data Gaps

Pantex Lake

Wastewater from the OSTP was discharged to Pantex Lake until 1970[95]. DOE has not investigated the possibility that the wastes may have contaminated groundwater near the lake.

COPCs

DOE does not consider several contaminants to be contaminants of potential concern (COPCs)[96], even though they have been found in Ogallala Aquifer wells at Pantex in concentrations greater than MCLs or background. These include cadmium, lead, bis(2-ethylhexyl)phthalate, DBCP, and toluene (see Appendix I).

PQLs vs. MCLs

Some of DOE's PQLs are higher than MCLs. For example, the PQL for thallium is 3 mg/L while the MCL is 2 mg/L; the PQL for vinyl chloride is 10 mg/L while the MCL is 2 mg/L; and the PQL for bis(2-ethylhexyl)phthalate is 10 mg/L while the MCL is 6 mg/L[97]. Thus, areas that contain contaminant concentrations higher than MCLs may not be cleaned up, even if they are affected by contaminants emanating from Pantex.

RDX Degradation Products

DOE does not appear to be analyzing water samples for 1,1-dimethylhydrazine and 1,2-dimethylhydrazine. These degradation products of RDX[98] are believed to be human carcinogens[99]. In addition, DOE's preliminary remediation goal (PRG) for RDX is 0.0077 mg/L[100]. However, the EPA health advisory guideline for lifetime exposure to RDX is 0.002 mg/L[101]. DOE should consider reducing the PRG to the health advisory guideline.

Conclusions and Recommendations

Although DOE has been investigating environmental conditions at Pantex since the early 1980s[102], significant issues remain unresolved. Serious investigation of the Ogallala Aquifer appears to be just beginning, even though DOE has found high concentrations of contaminants in the Ogallala since the early 1990s.

Little is known about the distribution of contaminants within the Ogallala, or about the hydraulic and geochemical properties that control their distribution. More is known about the perched aquifer, but significant data gaps remain.

DOE acknowledges the existence of data gaps and other problems in its characterization and modeling of groundwater contamination at Pantex[103]. It is developing plans to correct some of these problems.

The following recommendations address the major data gaps and issues identified in this report.

1. ***More monitor wells are needed in the Ogallala Aquifer.*** Wells should be installed in the large areas on Pantex that contain no Ogallala wells. Wells should also be installed north of Pantex, in the potential flow paths of contaminants originating in the Burning Grounds. One purpose of these wells would be to detect contaminants before they reached private wells or the City of Amarillo's wells.

2. ***More monitor wells are needed to determine the extent of the perched aquifer, and to determine the extent of contaminants in the perched aquifer.*** Wells should be installed in the large areas on Pantex that contain no perched wells, and to the north and east of the plant.

3. ***DOE should develop reliable estimates of the properties that control groundwater flow and contaminant transport in all the hydraulic units at Pantex*** (i.e., the aquifers and unsaturated zones). These properties include hydraulic conductivity, dispersivity, porosity, bulk density, organic carbon content, and partition coefficients.

4. ***DOE should redo its evaluation of background water quality for the Ogallala Aquifer***[104]. Background should be determined primarily, if not entirely, from samples collected from Ogallala wells immediately (within a few hundred feet) up gradient of the plant. Because hazardous materials may have been used or disposed anywhere on the plant, no background wells should be located on property controlled by DOE or its predecessor agencies. No background samples should be collected from wells down gradient of Pantex, as they may be in the flow paths of contaminants emanating from the plant.

5. ***DOE should continue to develop a revised groundwater model for Pantex.***

6. ***The hydraulic relationship between the Ogallala Aquifer and the Dockum Group should be determined.***

7. ***Groundwater near Pantex Lake should be investigated to determine whether it has been contaminated by the wastes that DOE discharged to the lake.***

8. ***All contaminants found in Ogallala wells at Pantex in concentrations above background or MCLs should be considered COPCs.*** All PQLs should be less than MCLs. DOE should monitor groundwater for the toxic decomposition products of RDX.

Notes

[1] MCL = Maximum Contaminant Limit, the regulatory standard established to protect human health.

[2] DOE, 2001a.

[3] Battelle, 1997, page 5.

[4] DOE, 1998a, page 2-1.

[5] The treatment plant receives both sewage and industrial effluent. DOE, 2000i, page 2-8.

[6] DOE, 2000h, pages 2-11 and 4-2.

[7] Battelle, 1997, page 8.

[8] Battelle, 1997, pages 10 & 11.

[9] DOE 1998a, page 4-1.

[10] DOE, 2000f, page 1.

[11] Battelle, 1997, page 40.

[12] Stoller, 2001, figure 2-15. Note: it is sometimes difficult to determine the presence of the perched aquifer. The dry zone shown just north of Zone 12 may have been identified based on a well that was screened above the water table. The dry zone shown in Zone 11 may have been identified based on wells that were screened in the fine grained zone. See Battelle, 1997, page 40.

[13] Stoller, 2001, figure 2-15.

[14] Stoller, 2001, figure 1-19.

[15] Battelle, 1997, page 41, Figure 4-10.

[16] DOE, 2000h, page C-1.

[17] DOE, 2000h, page 4-4.

[18] Argonne and Battelle, 1995, page 5-25.

[19] DOE, 2000h, page 4-4.

[20] DOE, 2000h, pages 4-4 and 4-5.

[21] DOE, 2000h, page 2-5.

[22] DOE, 2000h, page 4-5.

[23] DOE, 2000h, page C-3.

[24] DOE, 2000f, page 2.

[25] Battelle, 1999a, page 2-6.

[26] DOE, 2000h, pages 2-10 and 2-11.

[27] Stoller, 2001, page 2-59, table 2-3, figure 2-18, and Appendix B. Total does not include the five water supply wells on Pantex or the dry well PTX06-1054.

[28] Stoller, 2001, figure 1-19.

[29] Battelle, 1997, page 13.

[30] Battelle, 1997, page 13.

[31] DOE, 2000h, page C-9.

[32] The definition of contamination used in this evaluation is: 1) for man made chemicals (e.g., RDX, TCE), water is considered contaminated if they are present; 2) for naturally occurring chemicals (e.g., cadmium, chromium), water is considered contaminated if they are present above background concentrations. A DOE definition of the extent of contamination is given in the *Final Risk Reduction Rule Guidance to the Pantex Plant RFI* (Battelle, 1999a, page 2-1): "*It is proposed that RRS 1 or PQLs be used to determine the extent of contamination at the SWMUs under investigation at the Pantex Plant.*" RRS 1 = background. PQLs = laboratory practical quantitation limits.

[33] Risk reduction standards (RRS) are a set of regulations promulgated by the State of Texas to protect health and the environment.

[34] DOE, 1998b, Appendix B.

[35] DOE, 1998b, Appendix B. Stoller, 2001, page 1-39. DNT = dinitrotoluene, HMX = cyclotetramethylene tetranitramine; PETN = pentaerythrite tetranitrate; RDX = royal demolition explosive, cyclotrimethylene trinitramine; TNT = Trinitrotoluene. These explosives are also known by other synonyms.

[36] DOE, 1998a, page 16-10. DOE, 1998b, Appendix B. Stoller, 2001, pages 1-26, 1-43, and 1-69. DOE Public Meeting, 3/5/2001, statement by Boyd Deaver regarding use of thallium at Pantex.

[37] DOE, 2000d, page 6. DOE 2000f, page 1. Stoller, 2001, pages 1-54 and 1-83.

[38] DOE, 2000d, page 6. DOE 2000f, page 1. Stoller, 2001, pages 1-26, 1-35, 1-43, 1-44, 1-54, 1-56, 1-70, 1-75, and 1-83.

[39] Stoller, 2001, pages 1-35, 1-43, 1-44, 1-75, 1-76, and 1-77.

[40] Stoller, 2001, page 1-35.

[41] DOE, 1998a, page 16-10.

[42] Battelle, 1997, page 8. The wastes discharged to playa 5 came from the Amarillo Air Base and were used as a source of irrigation water.

[43] DOE, 1999a, page 6. Stoller, 2001, pages 1-49.

[44] DOE, 1998a, page 5-5.

[45] DOE, 2000h, pages 4-6 and 4-8.

[46] Battelle, 1997, page 8.

[47] Pantex contains 143 RCRA solid waste management units (SWMUs). Stoller, 2001, page 1-14.

[48] EPA, 2000; page 2. Mason & Hanger Corporation, 1993, pages 38 - 40.

[49] An example of groundwater contamination occurring where DOE did not expect it is the area southeast of Playa 1, between monitor well PTX08-1002 and the plant boundary. In response to a TNRCC comment concerning lack of groundwater information in this area, DOE stated “ *It is unlikely that groundwater contamination exists in the perched aquifer in this area due to a lack of potential historic or present sources or releases (i.e., Plant production facilities and buildings, drainage ditches, etc.)”*. The groundwater in this area was subsequently found to be highly contaminated with RDX (>2000 µg/L). Stoller, 2001, page 1-145 and figure 4-1.

[50] IT, 2000, page 3-1; and DOE 2000f, page 1. 2,4-DNT = 2,4-dinitrotoluene.

[51] Stoller, 2001, page 4-3.

[52] Battelle, 1997, page 131; and DOE, 2000i, figures 6.4 and 6.5.

[53] Stoller, 2001, pages 4-4, 4-10, 4-12, and 4-15. In addition, the distribution of contaminants in the portions of the plant that contain no perched aquifer monitor wells (e.g., northwest corner, area west of Playa 2) is unknown.

[54] DOE, 2000h, page 2-12.

[55] DOE, 2000h, page 2-15.

[56] IT, 2000, pages 4-57 – 4-64, and Appendix B.

[57] On 3/20/96 15.00 mg/L bis-(2-ethylhexyl)phthalate was found in well OW-WR-40. The MCL for bis-(2-ethylhexyl)phthalate is 6 mg/L. The DOE claims an MCL for this compound did not exist prior to 10/96 (Mason & Hanger, 2000a, Attachment 3 and Attachment 4, comment 1). This is incorrect. The MCL for this compound was established no later than 1993 (40 CFR Ch. 1 §141.61, 7-1-93 Edition). Synonyms for this compound (Chemical Abstracts Number 117-81-7) include di-2-ethylhexylphthalate, di-sec-octyl phthalate, and DOP.

[58] On 10/7/98 3.1 mg/L and 3.2 mg/L DBCP were found in wells OW-WR-39 and OW-WR-40, respectively. The MCL for DBCP is 0.2 mg/L (Mason & Hanger, 2000a, Attachment 3). Synonyms for this compound (Chemical Abstracts Number 96-12-8) include dibromochloropropane, 2,3,-dibromo-3-chloropropane, and 3-chloro-1,2-dibromopropane.

[59] On 5/13/99 8.00 mg/L TCE (trichloroethylene) was found in well PTX01-1003. The MCL for TCE is 5 mg/L (Mason & Hanger, 2000a, Attachment 3).

[60] On 8/18/99 7.1 mg/L and 7.5 mg/L cadmium were found in wells OW-WR-46 and OW-WR-47 respectively. The MCL for cadmium is 5 mg/L. DOE appears to claim that its contractor did not tell them of these detections (Mason & Hanger, 2000a, Attachment 3 and Attachment 4 notes 56 and 64).

[61] On 8/18/99 2830 mg/L and 3020 mg/L chromium were found in well OW-WR-48 (Note: these results represent either two samples from one well, or two analyses of the same sample). The MCL for chromium is 100 mg/L. DOE appears to claim that its contractor did not tell them of these detections. It is possible that these high concentrations of chromium are due to corrosion of stainless steel well screen or sampling equipment. DOE is investigating this issue (Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 68).

[62] Lead has been found in concentrations above Risk Reduction Standard 2 (residential, 15 mg/L) in wells OW-WR-39 (20 mg/L on 9/9/92 and 7/12/93), 15-20 (30 mg/L on 4/20/92), and 15-26 (17 mg/L on 5/13/98). DOE claims it did not know what the regulatory standard for lead was (Mason & Hanger, 2000a, Attachment 3 and Attachment 4 notes 25, 26, 45, and 47).

[63] On 8/18/99 214 mg/L nickel was found in well OW-WR-48. The MCL for nickel is 100 mg/L. DOE appears to claim that its contractor did not tell them of this detection. In addition, it is possible that the nickel is a result of corrosion of stainless steel well screen or sampling equipment. DOE is investigating this issue (Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 75).

[64] On 11/15/95 and 5/8/97 2.5 mg/L and 4 mg/L thallium respectively were found in well PTX01-1003. On 1/14/96 and 5/7/97 2.3 mg/L and 4 mg/L thallium respectively were found in well OW-WR-46. The MCL for thallium is 2 mg/L. DOE appears to claim that its contractor did not tell them of these detections (Mason & Hanger, 2000a, Attachment 3 and Attachment 4 notes 54, 55, 62, and 63).

[65] DOE, 2000a, page 17, and DOE, 2000c, pages 19 and 29. High concentrations of chromium (> 500 ppb; DOE 2000b, page 22) have also been found at the Burning Grounds. However, the source of the

chromium may be the well screen or other equipment used to sample the well (DOE 2000b and DOE 2000c).

[66] DOE *Environmental Monitoring Quarterly Report* for the third quarter of 2000. On 9/5/2000 toluene (123 µg/L - 150 µg/L) was found in three of nine analyses of samples from PTX01-1012. On 9/13/2000 toluene (27 µg/L - 71 µg/L) was found in six of six analyses of samples from PTX01-1013.

[67] Battelle, 1999a, page 2-6.

[68] See Appendix 1.

[69] DOE plans to install additional Ogallala Monitor wells on Pantex and between the Burning Grounds and the City of Amarillo wells. DOE 2001a.

[70] Battelle 1999a.

[71] According to Battelle 1999a, page 2-2, "The PQL represents a practical and routinely achievable detection limit with a relatively good certainty that any reported value is reliable (APHA et al., 1995)."

[72] Battelle 1999a, page ii.

[73] Battelle 1999a, page 2-1

[74] Battelle, 1999a, page 3-44.

[75] Battelle, 1999a, figure 3-5, and pages F-5 – F-7, well 49-309.

[76] Battelle, 1999a, figure 3-5, and page F-5, analyses from ten wells. The MCL for nitrate-nitrogen is 10 mg/L, EPA 1998a.

[77] DOE Public Meeting, 3/5/2001.

[78] DOE Public Meeting, 3/5/2001. Note: some samples from private wells may have been collected from faucets. These may be affected by metals or other substances leached from tanks, pipes, or other hardware. Groundwater samples should be collected directly from the well, or as close to the well as is practical. Samples from faucets are appropriate when their purpose is to determine the quality of water that people are drinking.

[79] Model input and output files may be provided in the future. DOE 2001a.

[80] Battelle, 1997.

[81] IT, 2000.

[82] All simulations used the model MODFLOW; US Geological Survey, 1988.

[83] DOE 2000h, page C-11.

[84] Battelle, 1997, pages 66 and 68.

[85] Battelle, 1997, pages 134 and 137.

[86] Battelle, 1997, page 235; and IT, 2000, page 4-57 and Appendix B.

[87] Battelle, 1997, page 60, and IT, 2000, page 4-4.

[88] 10^{-7}cm/s, Battelle, 1997, pages 83 and 85. The fine grained zone is not a single continuous layer. It consists of several interbedded clay lenses: Battelle 1997, page 46.

[89] Battelle, 1997, page 64.

[90] IT, 2000.

[91] IT, 2000, Figure 3-3.

[92] Estimates of chromium, RDX (cyclotrimethylene trinitramine), and TCE partition coefficients (14 – 1200 [K_d], 63 [K_{oc}], and 295 [K_{oc}], respectively) are contained in: *Figure 1: 30 TAC § 350.53(e) – COC Chemical/Physical Parameter Values*. For estimates of RDX and TCE retardation factors (1.21 and 2.99, respectively) see IT 2000, *Appendix B*. A different estimate of the TCE retardation factor (1.65) is given in Appendix 1 of this report. It should be noted that the mobility of metals such as chromium may be increased by complexation. The effect of complexation on the mobility of chromium at Pantex is unknown.

[93] DOE 2000f, pages 2 – 6; and DOE 2000h, page 4-8.

[94] ITRD July 11, 2000 meeting minutes.

[95] Battelle, 1997, page 8.

[96] Stoller, 2001, pages 3-7 through 3-19.

[97] Battelle 1999a, pages vi and ix; and EPA 1998a.

[98] Battelle, 1997, page 132. 1,1-dimethylhydrazine or 1,2-dimethylhydrazine do not appear in the list of analytes given in DOE, 1999b or DOE, 2000i. Nor were analyses for these compounds found in *Environmental Monitoring Quarterly Reports* for the first, second, or third quarters of 2000. Monitoring reports available at: http://www.pantex.com/environment/epd/index.htm.

[99] ATSDR, 1997, page 3.

[100] Battelle, 1999a, page 3-44.

[101] ATSDR, 1996, page 3.

[102] Stoller, 2001, page 14.

[103] Stoller, 2001, chapter 6.

[104] Background may be defined as follows: the quality of water that would exist if it had not been affected by activities at Pantex. This is not the same as native water quality, which is the quality that would exist if it were unaffected by any human activity.

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Appendix I

Table 1
Contaminants[1] Found in the Ogallala Aquifer at Pantex

Well ID	Contaminant	Concentration[2] (µg/L)	Date	Background / MCL[3] (µg/L)
15-17 (Pantex Supply Well)[4]	bis-(2-ethylhexyl)phthalate	0.88[5]	4/29/97	NA/6
15-20 (Pantex Supply Well)	Lead	**30**[6]	4/20/92	14/15
15-26 (Pantex Supply Well)	Lead	**17**[7]	5/13/98	14/15
15-32 (Pantex Supply Well)	4-amino-2,6-dinitrotoluene	3.1[8]	5/14/98	NA/1387
	TNT	3.1[9]	5/14/98	NA/18
OW-WR-39	Lead	**20**[10]	9/9/92	14/15
	Lead	**20**[11]	7/12/93	14/15
	tetrahydrofuran	20.0[12]	11/2/93	NA/2410
	DBCP	**3.1**[13]	10/7/98	NA/0.2
	naphthalene	3.5[14]	10/7/98	NA/730
OW-WR-40	bis-(2-ethylhexyl)phthalate	**15**[15]	3/20/96	NA/6
	chloroform	2.0[16]	8/21/96	NA/100
	DBCP	**3.2**[17]	10/7/98	NA/0.2
	naphthalene	3.9[18]	10/7/98	NA/730
	1,2,3-trichlorobenzene	1.2[19]	10/7/98	NA/2670
OW-WR-46	thallium	**2.3**[20]	1/14/96	NA/2
	thallium	**4**[21]	5/7/97	NA/2
	1,2,4-trichlorobenzene	1.6[22]	10/1/98	NA/70
	cadmium	**7.1**[23]	8/18/99	3/5
OW-WR-47	cadmium	**7.5**[24]	8/18/99	3/5
	cadmium	**6**[25]	4/17/00	3/5
	toluene	1.02[26]	4/17/00	NA/1000
PTX-BEG2	tetrahydrofuran	10.0[27]	11/9/93	NA/2410
PTX01-1003	thallium	**2.5**[28]	11/15/95	NA/2
	thallium	**4**[29]	5/8/97	NA/2
	TCE	**8.0**[30]	5/13/99	NA/5.0
	TCE	3.8[31]	8/19/99	NA/5.0
	TCE	4.4[32]	10/04/99	NA/5.0
	TCE	**5.3**[33]	2/8/00	NA/5.0
	TCE	4.0[34]	3/2/00	NA/5.0
	TCE	3.0[35]	3/13/00	NA/5.0
	TCE	1.0[36]	3/15/00	NA/5.0
	toluene	1.0[37]	3/15/00	NA/1000
	TCE	4.7[38]	4/18/00	NA/5.0
	TCE	1.2[39]	4/18/00	NA/5.0
	toluene	18.9[40]	4/18/00	NA/2000

Table 1 (continued)
Contaminants Found in the Ogallala Aquifer at Pantex

Well ID	Contaminant	Concentration[41] (µg/L)	Date	Background / MCL[42] (µg/L)
PTX01-1003 (continued)	carbon tetrachloride	0.15[43]	4/18/00	NA/5
	carbon tetrachloride	0.17[44]	4/18/00	NA/5
	1,1,1-trichloroethane	0.62[45]	4/18/00	NA/200
PTX01-1005	beryllium	**5.8**[46]	1999(?)	4.6[47]/4.0
PTX01-1012	acetone	49.7[48]	9/5/00	NA/3700
	toluene	134[49]	9/5/00	NA/1000
PTX01-1013	methyl ethyl ketone	11.4[50]	9/13/00	NA/22,000
	methyl isobutyl ketone	3.6[51]	9/13/00	NA/2900
	toluene	53.2[52]	9/13/00	NA/1000
PTX06-1016	bis-(2-ethylhexyl)phthalate	2.2[53]	11/5/98	NA/6
	2-nitrotoluene	0.24[54]	5/19/99	NA/370
PTX06-1032	2-nitroaniline	20.3[55]	2/16/98	NA/2340
PTX06-1033	RDX	0.35[56]	5/11/99	NA/7.7
PTX08-1011A	RDX	0.3[57]	6/2/99	NA/7.7

[1] Definition of contaminant used in this table: 1) for man made chemicals and substances for which no background concentrations have been established (e.g., RDX, TCE), water is considered contaminated if they are present; 2) for inorganics (e.g., cadmium, chromium), water is considered contaminated if they are present above background concentrations. Background estimates for inorganic contaminants are given in Battelle, 1999a, Table 3-4. DOE has not estimated background concentrations for organic contaminants or for the metal thallium. DOE is currently reevaluating the estimates of background concentrations.

[2] Bold indicates contaminant concentration exceeds MCL or the Texas Risk Reduction Standard 2 residential value.

[3] Value given is the MCL or, for contaminants without an MCL, the Texas Risk Reduction Standard 2 residential value. Except as noted, Risk Reduction Standard 2 residential values from Battelle 1999, table 3-10.

[4] Stoller, 2001, page 2-55.

[5] Mason & Hanger, 2000a, Attachment 3.

[6] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 45.

[7] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 47.

[8] Mason & Hanger, 2000a, Attachment 3.

[9] Mason & Hanger, 2000a, Attachment 3.

[10] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 25.

[11] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 26.

[12] Mason & Hanger, 2000a, Attachment 3. Risk Reduction Standard 2 residential value from Attachment 3.

[13] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 5.

[14] Mason & Hanger, 2000a, Attachment 3.

[15] Mason & Hanger, 2000a, Attachment 3 and Attachment 4, comment 1. The MCL for bis-(2-ethylhexyl)phthalate is 6 µg/L. The DOE claims an MCL for this compound did not exist prior to 10/96. This is incorrect. The MCL for this compound was established no later than 1993 (40 CFR Ch. 1 §141.61, 7-1-93 Edition). Synonyms for this compound (Chemical Abstracts Number 117-81-7) include di-2-ethylhexylphthalate, di-sec-octyl phthalate, and DOP.

[16] Mason & Hanger, 2000a, Attachment 3.

[17] Mason & Hanger, 2000a, Attachment 3 and Attachment 4, comment 2. Synonyms for this compound (Chemical Abstracts Number 96-12-8) include dibromochloropropane, 2,3,-dibromo-3-chloropropane, and 3-chloro-1,2-dibromopropane.

[18] Mason & Hanger, 2000a, Attachment 3.

[19] Mason & Hanger, 2000a, Attachment 3. Risk Reduction Standard 2 residential value from Attachment 3.

[20] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 62.
[21] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 63.
[22] Mason & Hanger, 2000a, Attachment 3.
[23] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 56.
[24] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 64.
[25] DOE, 2000c, page 17.
[26] DOE, 2000c, page 30. Average of two samples. One of the samples below detection limit (µg/L).
[27] Mason & Hanger, 2000a, Attachment 3. Risk Reduction Standard 2 residential value from Attachment 3.
[28] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 54.
[29] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 55.
[30] Mason & Hanger, 2000a, Attachment 3 and Attachment 4 note 4.
[31] Mason & Hanger, 2000a, Attachment 3.
[32] Mason & Hanger, 2000a, Attachment 3.
[33] DOE, 2000b, page 25.
[34] DOE, 2000b, page 25.
[35] DOE, 2000b, page 25.
[36] DOE, 2000b, page 25.
[37] DOE, 2000b, page 25.
[38] DOE, 2000c, page 29. Average of four samples collected 1.5 feet below top of saturation.
[39] DOE, 2000c, page 29, sample collected at 'normal depth'.
[40] DOE, 2000c, page 29. Average of four samples collected 1.5 feet below top of saturation.
[41] Bold indicates contaminant concentration exceeds MCL or the Texas Risk Reduction Standard 2 residential value.
[42] Value given is the MCL or, for contaminants without an MCL, the Texas Risk Reduction Standard 2 residential value. Except as noted, Risk Reduction Standard 2 residential values from Battelle 1999, table 3-10.
[43] DOE, 2000c, page 29, sample collected 1.5 feet below top of saturation. Estimated value, detection limit = 5.0 µg/L.
[44] DOE, 2000c, page 29, sample collected at 'normal depth'.. Estimated value, detection limit = 1.0 µg/L.
[45] DOE, 2000c, page 29. Average of two samples collected 1.5 feet below top of saturation. Estimated value, detection limit = 5.0 µg/L.
[46] Stoller, 2001, page 1-129.
[47] Beryllium background from Stoller, 2001, table 3-6.
[48] DOE *Environmental Monitoring Quarterly Report* for the third quarter of 2000. According to DOE contractor personnel (DOE 2001a), nine samples were collected using two different methods; purge of three bore volumes before sampling (six samples), and low-flow sampling (three samples). Value in table is the average of three samples collected using the low-flow method. Highest acetone concentration in samples collected using the three bore volume purge method = 2.7 µg/L.
[49] DOE *Environmental Monitoring Quarterly Report* for the third quarter of 2000. According to DOE contractor personnel (DOE 2001a), nine samples were collected using two different methods; purge of three bore volumes before sampling (six samples), and low-flow sampling (three samples). Value in table is the average of three samples collected using the low-flow method. Toluene was not detected in any of the other samples.
[50] DOE *Environmental Monitoring Quarterly Report* for the third quarter of 2000. Average of three samples.
[51] DOE *Environmental Monitoring Quarterly Report* for the third quarter of 2000. Average of three samples.
[52] DOE *Environmental Monitoring Quarterly Report* for the third quarter of 2000. Average of six samples.
[53] Mason & Hanger, 2000a, Attachment 3.
[54] Mason & Hanger, 2000a, Attachment 3.
[55] Mason & Hanger, 2000a, Attachment 3. Risk Reduction Standard 2 residential value from Attachment 3.
[56] Mason & Hanger, 2000a, Attachment 3.
[57] Mason & Hanger, 2000a, Attachment 3.

Appendix II
Estimating the Migration Rates of TCE and Toluene in the Ogallala Aquifer Near Pantex

Table 1
Parameter Values Used to Calculate Migration Rates

Parameter	Value	Source of Data
Groundwater flow rate (V_{GW})	318 ft/yr	Battelle 1997, Table 4-5, corrected [1].
Porosity (n)	0.2	Battelle 1997, Table 4-5
Bulk density (ρ_B)	1.8 gm/cm^3	DOE 2000h, page C-12
TCE partition coefficient (normalized for organic carbon) (K_{OC})	120 L/Kg	EPA, 1998b, Table B.2.1.
Toluene partition coefficient (normalized for organic carbon) (K_{OC})	190 L/Kg	EPA, 1998b, Table B.2.1.
Organic carbon content (f_{OC})	0.0006	DOE 2000h, page C-12.
TCE partition coefficient (K_d) = K_{OC} f_{OC}	120 L/Kg 0.0006 = 0.072 L/Kg	Calculated from values given above.
Toluene partition coefficient (K_d) = K_{OC} f_{OC}	190 L/Kg 0.0006 = 0.114 L/Kg	Calculated from values given above.

The retardation coefficient for TCE (R_{TCE}) is calculated as follows[2]:

$$R_{TCE} = 1 + (\rho_B\ K_d)/n = 1 + (1.8\ \text{gm/cm}^3\ 0.072\ \text{L/Kg})/0.2 = 1.65$$

And, the migration rate for TCE (V_{TCE}) is[3]:

$$V_{TCE} = V_{GW}/R_{TCE} = (318\ \text{ft/yr})/1.65 = 193\ \text{ft/yr}.$$

The retardation coefficient for toluene (R_{tol}) is calculated as follows[4]:

$$R_{tol} = 1 + (\rho_B\ K_d)/n = 1 + (1.8\ \text{gm/cm}^3\ 0.114\ \text{L/Kg})/0.2 = 2.03$$

And, the migration rate for toluene (V_{tol}) is[5]:

$$V_{tol} = V_{GW}/R_{TCE} = (318\ \text{ft/yr})/2.03 = 157\ \text{ft/yr}.$$

It is important to note that these migration rate estimates are based on the assumed parameter values in the table. Different sets of assumptions can result in estimates that are significantly lower or higher. Unfortunately, DOE has not conducted a thorough investigation of these parameters for the Ogallala Aquifer at Pantex[6]. Thus, estimates of contaminant migration rates must be considered to be preliminary until sufficient site specific information is collected. In addition, the calculations above are only estimates of migration rates. They do not account for processes that tend to reduce contaminant concentrations as they migrate (e.g., dispersion, biodegradation).

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[1] Mean of values presented in Table 4-5, Battelle 1997, Ogallala Aquifer, for hydraulic conductivity = 22.5 ft/day and effective porosity = 0.2. The values in Table 4-5 were calculated incorrectly. Corrected values are used here.
[2] EPA, 1998b, page B2-20.
[3] EPA, 1998b, page B2-20.
[4] EPA, 1998b, page B2-20.
[5] EPA, 1998b, page B2-20.
[6] As of June 2000, DOE had performed one test in the Ogallala Aquifer to measure hydraulic conductivity (DOE 2000h, page C-11), one measurement of organic carbon content (DOE 2000h, page C-12), one measurement of bulk density (DOE 2000h, page C-12) and no measurements of porosity (DOE 2000h, page C-12). Available reports contain no indication that DOE has attempted to measure Ogallala Aquifer partition coefficients for any contaminants.