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QuickSite^{SM}, The Argonne Expedited Site Characterization Methodology

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ABSTRACT: Expedited site characterization (ESC), developed by Argonne National Laboratory, is an interactive, integrated process emphasizing the use of existing data of sufficient quality, multiple complementary characterization methods, and on-site decision making to optimize site investigations. The Argonne ESC is the basis for the provisional ESC standard of the ASTM (American Society for Testing and Materials). QuickSite^{SM} is the implementation package developed by Argonne to facilitate ESC of sites contaminated with hazardous wastes. At various sites, Argonne has successfully implemented QuickSite^{SM} and demonstrated the technical superiority of the ESC process over traditional methodologies guided by statistics and random-sampling approaches. For example, in a QuickSite^{SM} characterization of a perched aquifer at the Pantex Plant in Texas, past data and geochemical analyses of existing wells were used to develop a model for recharge and contaminant movement. With the model as a guide, closure was achieved with minimal field work.

INTRODUCTION

Argonne National Laboratory has developed a package of implementation tools to facilitate ESC of sites contaminated with hazardous wastes. The expertise (intellectual property, methods, software, etc.) gained by Argonne during the development and practice of ESC since 1989 (Burton et al. 1993; Burton 1994) has been consolidated into the QuickSite^{SM} package being commercialized by Argonne. ("SM" signifies a service mark.) The commercialization will permit corporations with environmental problems and organizations within the environmental industry to gain access to Argonne's intellectual property without the time and expense of developing equivalent expertise and implementation tools. The ESC methodology is an interactive, integrated process emphasizing the use of existing data of sufficient quality, multiple complementary characterization methods, and on-site decision making to optimize site investigations. Throughout this paper, the terms "QuickSite^{SM}" and "Argonne ESC" are used interchangeably.

On March 7, 1996, President Clinton signed into law the National Technology Transfer and Advancement Act of 1995 (PL 104-113). Section 12 of this Act requires federal agencies to adopt and use, to the extent practicable, technical standards developed by voluntary, private-sector, industry-led, consensus-standard bodies and to work closely with those organizations to ensure that the standards are consistent with agency needs. Federal agencies must report to the Office of Management and Budget their reasons if they do not use such standards. As a result, the U.S. Department of Energy funded the development of a provisional ASTM standard for ESC (ASTM 1997), with the Argonne ESC as the basis.

The QuickSite^{SM} process ensures cost minimization and rapid closure for site characterizations, leading to correct remedial action decisions. For sites of the U.S. Departments of Agriculture (USDA), Interior (DOI), Energy (DOE), and Defense (DOD), Argonne has successfully demonstrated the technical superiority of the QuickSite^{SM} process over traditional methodologies guided by statistics and random-sampling approaches. At former facilities of the USDA, QuickSite^{SM} reduced site characterization costs by 80-90% and time by 70-80%, compared to traditional methods (Burton 1994). DOE estimated that QuickSite^{SM} saved $4 million and four years in a remedial site investigation at the Pantex Plant in Texas (Ferguson 1995).

Argonne's ESC is a flexible process that is neither site nor contaminant dependent. ESC can be tailored to fit the unique characteristics distinguishing one site from the next, in contrast to the traditional approach of making all sites conform to the same rigid, inflexible investigation regimen. QuickSite^{SM} has

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been applied successfully to remedial site investigations of landfills with multiple contaminants in the southwestern United States for the DOI, former grain storage facilities in the Midwest for the USDA, a weapons production facility in Texas for DOE, and closing and active military bases in several locations for DOD. The process can be applied both at sites that have seen little investigation and at sites subjected to many previous site characterizations without closure. In the latter case (e.g., at many DOE and DOD sites), QuickSite^{SM} offers a rapid solution, frequently with little additional field work.

QUICKSITE^{SM} FUNDAMENTALS

The QuickSite^{SM} approach to ESC emphasizes good scientific investigation principles and expert judgment. Key features are as follows: (1) The technical team leader has broad expertise in geosciences, and the multidisciplinary, geoscience-based team has strong field experience. (2) The team leader and team remain constant throughout the work and participate in all phases of the program, including all field activities. (3) The process uses multiple, complementary technical methodologies and emphasizes nonintrusive and minimally intrusive investigation methods. (4) High-quality data are required throughout the program for accurate decision making; screening techniques of lower quality are not used. (5) A dynamic work plan allows adjustments to the program in response to on-site data analysis and decision making.

Processes and costs of ESC and conventional site characterization methods have been compared in detail (ASTM 1997). The example below of the application of QuickSite^{SM} at the DOE Pantex Plant demonstrates the use of the approach within a large facility with a prior history of environmental investigations.

QUICKSITE^{SM} AT THE PANTEX PLANT

In 1993, DOE selected the Pantex Plant for the first application of the Argonne ESC to a DOE environmental problem. This project was to serve as a model for future implementation of the QuickSite^{SM} process at DOE sites by private and government contractors.

Site Setting and History: Pantex is located at an elevation of 1,148 m (3,500 ft) above sea level in the Southern High Plains region of west Texas in Carson County, approximately 27 km (17 mi) northeast of Amarillo (Figure 1). The regional climate is semiarid, with annual precipitation of about 51 cm (20 in.). Dry air, high temperatures, and moderate winds produce an evaporation rate as high as 178 cm/yr (70 in./yr) over exposed water areas. The area's principal topographic features are numerous shallow depressions called playas.

The Pantex Plant encompasses approximately 6,475 ha (16,000 acres). The plant has been operated as a weapons facility since 1942 and is now used primarily for the disassembly of nuclear weapons. The specific task set for the QuickSite^{SM} work at Pantex was characterization of a perched aquifer within Zone 12, in the southeastern portion of the facility (Figure 1). The objective was to determine the nature and extent of groundwater contamination beneath Zone 12 and to characterize the source and migration rate of the hazardous constituents. Numerous solvents, metals, pesticides, polychlorinated biphenyls, petroleum hydrocarbons, acids, inorganic compounds, and high explosives are used in operations in and near Zone 12, and discharges of these chemicals have occurred. In the past, surface drainage ditches in and around Zone 12 carried untreated process water to the nearby playas.

At Pantex, groundwater occurs directly above bedrock and in a shallower perched zone. Although both water zones occur in the unconsolidated Tertiary Ogallala Formation, the convention at the Pantex site is to refer to the shallow perched zone as the "perched aquifer" and the deeper zone as the "Ogallala aquifer." The aquifers are unconfined. The saturated thickness of the main Ogallala aquifer is 65.6-131.2 m (200-400 ft) in the vicinity of the Pantex Plant and exceeds 98.4 m (300 ft) to the northeast, where the aquifer is a primary source of

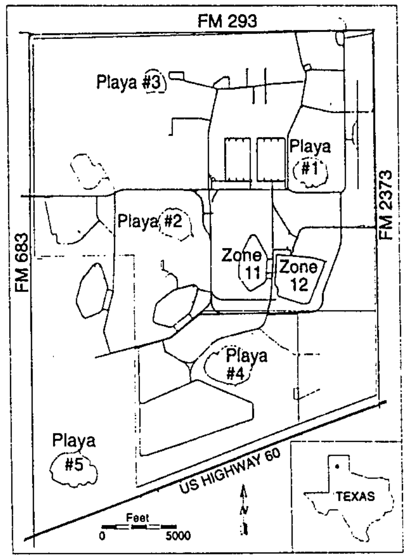

Figure 1. Location and plan of the Pantex Plant.

water for the city of Amarillo. The municipal well field is located within 1.6 km (1 mi) of the northeast corner of the Pantex Plant.

The upper part of the Ogallala Formation contains an apparently persistent zone of low-permeability, fine-grained material called the fine-grained zone (FGZ). This unit serves to perch water above the main Ogallala aquifer in the vicinity of the Pantex Plant and more specifically in the area of Zone 12. Although water from the perched aquifer is not used, this groundwater zone is significant because it contains both organic and inorganic contaminants that could migrate downward into the Ogallala aquifer.

THE QUICKSITE^{SM} PROCESS AT PANTEX

Existing Data: Argonne's first task in the QuickSite^{SM} process is assimilation, quality evaluation, and integration of all technically acceptable existing site data. Before Argonne's QuickSite^{SM} investigation for Pantex began, the large volume of data generated by previous investigations had not been evaluated or integrated to formulate hydrogeologic models consistent with all data for the site. After preliminary examination of the results of previous investigations, Argonne concluded that the existing database was mostly usable, with some modification and reinterpretation. Gaps and data of questionable quality were identified, but minimal field work was needed to fill the gaps. Therefore, no major field data acquisition activity was required for Argonne's Phase I study.

Results of Previous Studies: A significant amount of background information on contamination of the perched groundwater in the vicinity of Zone 12 was accumulated in conjunction with ongoing and previous studies. Included were data from 25 monitoring wells installed in various Zone 12 studies and from other monitoring and domestic wells in the area. The conclusions from prior studies were as follows: (1) Recharge and hence contaminant transport were thought to occur mainly through the floors of the playa lakes. (2) The direction of groundwater flow in the perched aquifer was believed to be controlled by focused recharge through the playas (i.e., groundwater flowed radially from the playa centers). (3) Groundwater in the perched aquifer was thought to leak through the FGZ into the underlying Ogallala Aquifer. (4) The continuity of the perched aquifer was unclear; possibilities included segmentation of the perched aquifer and hydraulic isolation of the segments. (5) The ionic and isotopic concentrations in the perched and Ogallala aquifers were not considered particularly useful for determining the continuity of the perched aquifer or evaluating potential hydraulic connections between the two aquifers.

Evaluation of Existing Data: The QuickSite^{SM} review of the contaminant and geochemical data from Pantex indicated that these data were largely inconsistent with prior conclusions. For example, the concentration of the high explosive HMX in the perched aquifer, based on the June 1993 sampling results, is shown in Figure 2. The pattern of higher concentrations directly under the Zone 12 area was observed for all contaminants. In addition, concentrations failed to decrease with distance from Playa 1 (the playa lake nearest Zone 12, considered to be the principal source of recharge for the perched aquifer in this area). Argonne's review of contaminant sources and waste disposal practices revealed that the explosives wastes (e.g., HMX) were placed mainly in ditches in the eastern part of Zone 12. The HMX distribution suggested that recharge in the Zone 12 area occurs largely between the playas, by downward infiltration. Thus, Argonne found the existing contaminant distribution to be inconsistent with the previous model of playa recharge for the perched aquifer beneath Zone 12.

Argonne's detailed geologic analysis, based on existing well logs, suggested that a gravel-filled channel crosses Zone 12 and opens to the southeast. Data from previous studies were insufficient to evaluate the effectiveness of the FGZ as a barrier to vertical water movement or to determine whether the absence of water at the perched level resulted from

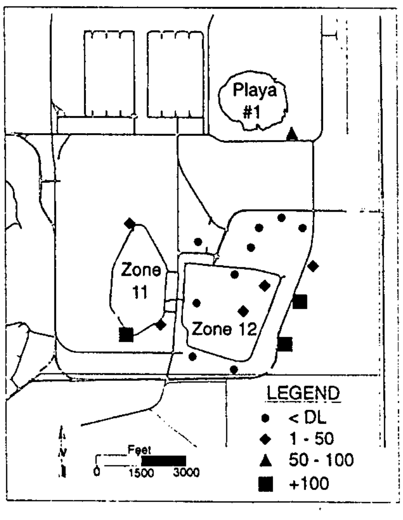

Figure 2. Concentrations of HMX (µg/L) in the perched aquifer in June 1993. (DL denotes detection limit.)

the absence of the FGZ or from lateral lithologic changes within the FGZ. Alternatively, Argonne believed that the water might be absent because the top of the FGZ occurs locally above the top of the perched water.

Argonne's review of 27 km (17 mi) of existing seismic reflection data for Zone 12 and adjacent areas uncovered several problems and inconsistencies in data acquisition, processing, and interpretation. Little information of geologic significance could be extracted from the survey. However, Argonne's work with a short section of one of the lines demonstrated that reprocessing of the original data could enhance the geophysical expression of the Zone 12 perched aquifer, possibly providing independent data to support a technically sound model for that aquifer. Hence, Argonne was able to identify specific areas for data collection and evaluation that would minimize field work and costs and would maximize the use of existing wells and data to answer questions about the groundwater.

PHASE I QUICKSITE^{SM} PROCESS AT PANTEX

The Phase I goal was to develop a working model for answering technical questions about the perched aquifer by using available data and existing monitoring wells, without an extensive field program. The basic QuickSite^{SM} multidisciplinary approach was followed, however. The program emphasized integration of all data (geologic, geophysical, and geochemical) within a dynamic work plan to begin answering questions and to constrain the system.

Phase I Geophysics Results: Reprocessed seismic lines showed strong, continuous reflections at arrival times approximately corresponding to the depth to the top of the perched aquifer, consistent with the seismic response predicted for this unconsolidated geologic section, where acoustic impedance is controlled largely by pore fluids. The perched-water reflection was seen on all seismic lines reprocessed by Argonne. However, in some segments the reflection was partially or completely attenuated, indicating that the perched water was too thin to be resolved in the seismic data or was absent. Integration of these data with the geologic constraints indicated locations for field testing to determine the extent of the perched aquifer.

Phase I Hydrogeology and Geochemistry Results: Geochemical and water level data collected by Argonne from existing wells suggested that the perched aquifer at Pantex might be present as at least two geochemically distinct and hydraulically separate aquifers. The perched aquifer under Playa 1 and north of Zone 12 appeared to be hydraulically separate from that under Zone 12. This conclusion was based on the presence of a dry hole at the location of well PTX06-1009 and differences in the stable oxygen, hydrogen, and carbon isotope compositions of groundwater samples. The location of well PTX06-1009 and the distribution of oxygen isotope compositions in the perched aquifer are shown in Figure 3. The isotopically heavier samples were all located near Playa 1 and between Playa 1 and Zone 12. The apparent boundary between the two isotopically distinct perched aquifers coincided with the absence of the perched aquifer at well PTX06-1009.

The geochemical data indicate that recharge and hence contaminant transport to the perched aquifer in the vicinity of Zone 12 occur by downward percolation between playas. Recharge to the perched aquifer under Playa 1 occurs mainly from infiltration of slightly evaporated water through the playa. Differences in the isotopic geochemistry also indicate that groundwater recharged through the playa does not flow under Zone 12. These data entirely contradict previous models identifying the playas as the main source of water for the perched aquifer beneath Zone 12.

PHASE II QUICKSITE^{SM} PROCESS AT PANTEX

On the basis of the model developed by evaluating existing data and the multidisciplinary Phase I program, Argonne carried out a Phase II field program of soil boring, coring, and HydroPunch

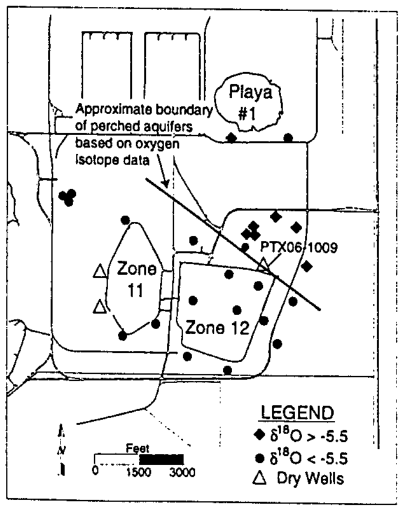

Figure 3. Grouping of oxygen isotope compositions ($\partial^{18}O$, per mil) in perched-aquifer water samples.

sampling at locations delineated by the Phase I data integration. Argonne's geologic hypothesis was that the thickness and extent of the perched aquifer were controlled largely by significant relief on the upper surface of the perching layer (the FGZ) and by the distribution of gravels above the FGZ, suggesting the presence of a paleodrainage channel crossing beneath Zone 12 and emptying to the southeast. In Phase I, seismic reprocessing showed that perched water is present beneath the Zone 12 vicinity, except for an area immediately south of Zone 12 and at two other locations to the west and northwest. The interpreted absence of the perched aquifer to the south of Zone 12 was consistent with the postulated location of the southern boundary of the channel.

The four soil borings drilled and cored to the FGZ in Phase II were placed to test this hypothesis and to define the extent of contamination to the southeast of Zone 12. Soil boring 1 was near the southern edge of the postulated channel, hole 2 was close to the center of the channel, and hole 3 was south of the channel. Drill site 4 was at the eastern boundary of the plant, on the southeast extension of the postulated channel. The locations of Phase II drill sites and geologic cross section A-A′ are shown in Figure 4. The conventional Phase II approach planned prior to Argonne's involvement called for the installation of 13 perched-aquifer monitoring wells in a ring around Zone 12. However, all of Argonne's subsurface data were obtained from lithologic cores, geophysical logs, and groundwater samples without installing wells.

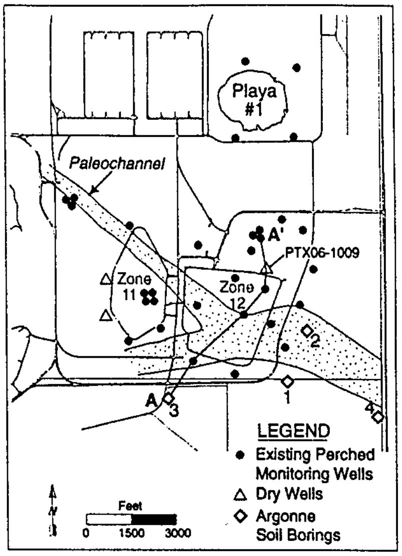

Figure 4. Locations of Argonne drill sites, cross section A-A′, and the postulated paleochannel.

Phase II Results: Argonne's drilling showed that the FGZ is a dry, fine-grained sandstone with a variable clay content. Palygorskite is the most abundant clay mineral, followed by illite-smectite, a swelling clay. Palygorskite is known to form in arid environments characterized by high evaporation rates, such as floodplains, mud flats, playa lakes, and soil horizons developing under arid conditions. The unsorted character of the core samples in thin sections and the presence of abundant palygorskite with calcite cement suggest that the FGZ formed at a paleoland surface under desert conditions. Depressions in the land surface deepened by erosion and subsidence could have localized the paleochannel that crosses beneath Zone 12. The relief on the top of the FGZ is at least 19.7 m (60 ft) in this area.

The dips in the top of the FGZ are the primary control on distribution of the perched aquifer and on the thickness of the water present (Figure 5). The thickest saturated zones occur where the top of the FGZ is lowest. The ridge on the top of the FGZ northeast of the main channel is structurally high enough to be above the perched water table at well PTX06-1009, which is dry. The existence of this ridge trending northwest to southeast was also suggested by hydrologic and geochemical differences between the segments of the perched aquifer to the north and south of the ridge. The constraint on the south side of the main channel is provided by the high on the FGZ at Argonne's drill site 3. Argonne postulated that the channel system continues off the plant site to the southeast.

Boreholes in the Argonne Phase II ESC field program were placed to test the hypothesis that the principal contaminants (largely high explosives) originated from plant activities on the eastern flank of Zone 12, migrated vertically to the perched aquifer in the interplaya area, and then followed a southeasterly course dictated by the local hydraulic gradient, the configuration of the FGZ perching layer, and the distribution of hydraulically conductive gravels within paleochannels trending southeastward. Results of Argonne's HydroPunch sampling of the perched aquifer confirmed that high-explosives contamination extends to the eastern boundary of the Pantex Plant at drill site 4. At the request of the DOE, this site was converted to a monitoring well because of its critical location at the plant boundary downgradient from Zone 12.

DISCUSSION

The QuickSite[SM] process at Pantex relied heavily on preexisting data and existing monitoring wells. This

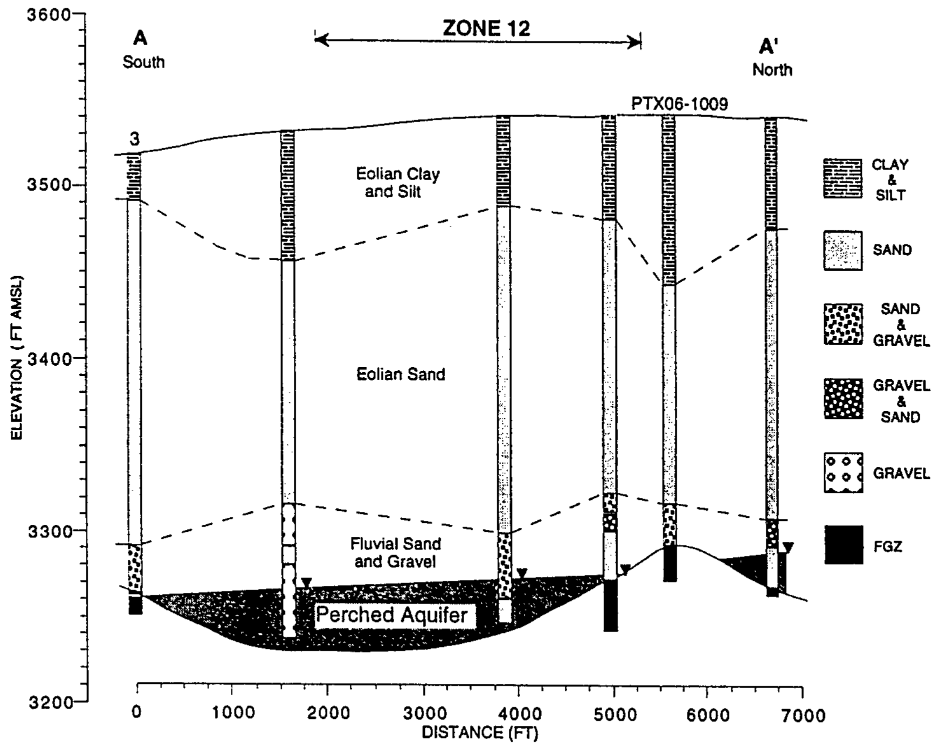

Figure 5. Geologic cross section A-A′ showing the perched aquifer underlying Zone 12.

approach of maximizing the use of existing resources is a cornerstone of the Argonne ESC process. The multidisciplinary scientific team integrated data from many sources and site studies to develop a technically defensible model of the perched aquifer in the vicinity of Zone 12. This model was used to guide and focus characterization of the aquifer in Phase II. The minimization of Argonne's Phase I and Phase II field activities reduced DOE's projected schedules and budget for the Zone 12 field investigation significantly from the previous plan (Starke 1996). Additional savings were realized by canceling planned monitoring well installations, along with quarterly sampling and analysis. Reducing costs (time and money) while generating technically defensible data is the main goal of QuickSite^{SM}.

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