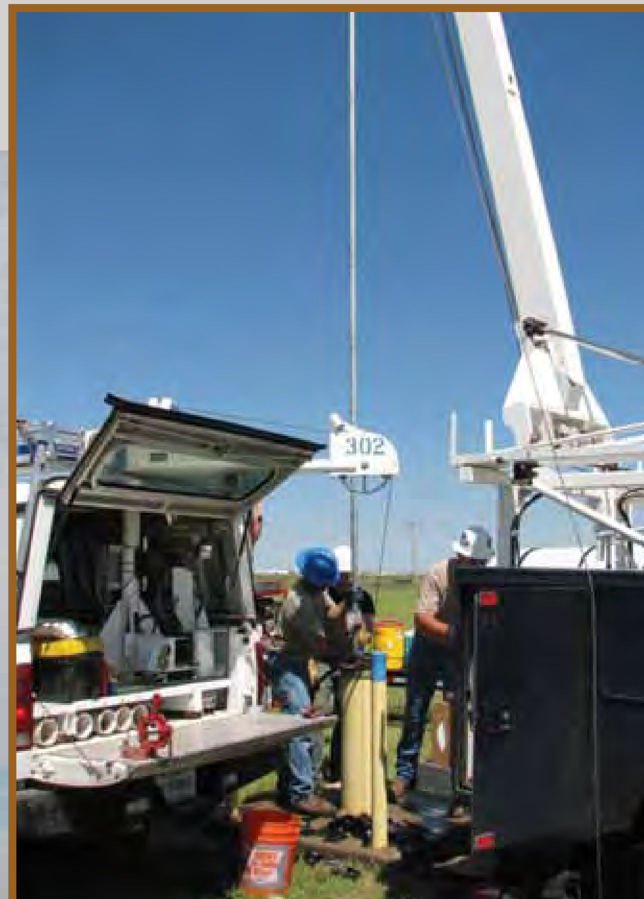
In cooperation with the U.S. Department of Energy/National Nuclear Security Administration and Babcock & Wilcox Technical Services Pantex, LLC

Analysis of Vertical Flow During Ambient and Pumped Conditions in Four Monitoring Wells at the Pantex Plant, Carson County, Texas, July–September 2008



Open-File Report 2009–1017

U.S. Department of the Interior
U.S. Geological Survey

Front cover:

Left, U.S. Geological Survey and Pantex personnel and equipment setup for pumping flowmeter measurements at monitoring well site.

Right, Pantex-owned pump hoist equipment raising pipe-deployed submersible pump in monitoring well with electromagnetic flowmeter being supported in well by U.S. Geological Survey borehole geophysical unit.

Back cover: Measuring water level in monitoring well PTX06-1056 during pumping flowmeter measurements.

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U.S. Geological Survey

U.S. Department of the Interior
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Conversion Factors and Datums

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Transmissivity[1]	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

[1] Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness ($[(ft^3/d)/ft^2]/ft$). In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Analysis of Vertical Flow During Ambient and Pumped Conditions in Four Monitoring Wells at the Pantex Plant, Carson County, Texas, July–September 2008

By Gregory P. Stanton, Jonathan V. Thomas, and Jeffery Stovall[1]

Abstract

The Pantex Plant is a U.S. Department of Energy/National Nuclear Security Administration (USDOE/NNSA)-owned, contractor-operated facility managed by Babcock & Wilcox Technical Services Pantex, LLC (B&W Pantex) in Carson County, Texas, approximately 17 miles northeast of Amarillo. The U.S. Geological Survey, in cooperation with B&W Pantex through the USDOE/NNSA, made a series of flowmeter measurements and collected other borehole geophysical logs during July–September 2008 to analyze vertical flow in screened intervals of four selected monitoring wells (PTX01–1012, PTX06–1044, PTX06–1056, and PTX06–1068) at the Pantex Plant. Hydraulic properties (transmissivity values) of the section of High Plains (Ogallala) aquifer penetrated by the wells also were computed. Geophysical data were collected under ambient and pumped flow conditions in the four monitoring wells. Unusually large drawdowns occurred at two monitoring wells (PTX06–1044 and PTX06–1056) while the wells were pumped at relatively low rates. A decision was made to redevelop those wells, and logs were run again after redevelopment in the two monitoring wells.

Logs collected in monitoring well PTX01–1012 during ambient conditions indicate a dynamic environment that probably was affected by pumping of nearby irrigation or public-supply wells. During pumping, downward vertical flow of 0.2 to 2.1 gallons per minute that occurred during ambient conditions was either reversed or reduced. During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed. Estimated total transmissivity for four production zones identified from Flow–B numerical model results taken together was calculated to be about 3,100 feet squared per day.

Logs collected in monitoring well PTX06–1044 during ambient conditions before redevelopment indicate a static environment with no flow. During pumping there was upward vertical flow at rates ranging from 0.1 to about 1.5 gallons per minute. During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed. Estimated total transmissivity before redevelopment for five production zones identified from Flow–B numerical model results, and transmissivity values for each zone, are considered to be in error because of the lack of communication between the well and the aquifer before redevelopment. After redevelopment, logs for well PTX06–1044 during ambient conditions indicate a near-static environment with minimal downward flow. During pumping there was upward vertical flow at rates ranging from 0.5 to about 4.8 gallons per minute. During pumping, a gradual trend of more positive flowmeter values with distance up the well was observed. Estimated total transmissivity after redevelopment for the same five identified production zones taken together was calculated to be about 520 feet squared per day.

Logs collected in monitoring well PTX06–1056 during ambient conditions before redevelopment indicate a static environment with no flow. During pumping there was upward vertical flow at rates ranging from 0.3 to about 1.5 gallons per minute. During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed. Estimated total transmissivity before redevelopment for four production zones identified from Flow–B numerical model results taken together was calculated to be about 450 feet squared per day. After redevelopment, logs collected in monitoring well PTX06–1056 during ambient conditions indicate a near-static environment with no flow except for a very small amount of downward flow near the bottom of the well. During pumping there was upward vertical flow at rates ranging from 0.7 to about 2.9 gallons per minute. Estimated total transmissivity after redevelopment for five production zones identified from Flow–B numerical model results taken together was calculated to be about 330 feet squared per day.

Logs collected in monitoring well PTX06–1068 during ambient conditions indicate a static environment with no flow. During pumping there was upward vertical flow at rates ranging from 0.4 to 4.8 gallons per minute. During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed. Estimated total transmissivity for four production zones identified from

[1] Babcock & Wilcox Technical Services Pantex, Amarillo, Texas.

Flow–B numerical model results taken together was calculated to be about 200 feet squared per day.

Introduction

The Pantex Plant is a U.S. Department of Energy/National Nuclear Security Administration (USDOE/NNSA)-owned, contractor-operated facility managed by Babcock & Wilcox Technical Services Pantex, LLC (B&W Pantex) in Carson County, Tex., approximately 17 miles northeast of Amarillo. The Pantex Plant was originally constructed by the U.S. Department of Army for production of conventional ordnance during World War II. The Pantex Plant was deactivated after the war and the property reverted to the War Assets Administration. Texas Technological College (now Texas Tech University [TTU], Lubbock) purchased the installation in 1949. The Army Ordnance Corps reclaimed the site in 1951 for use by the Atomic Energy Commission as a nuclear weapons facility. Today (2009) the mission of the Pantex Plant is to assemble nuclear weapons for the Nation's stockpile; disassemble nuclear weapons being retired from the stockpile; evaluate, repair, and retrofit nuclear weapons in the stockpile; sanitize components from dismantled nuclear weapons; provide interim storage for plutonium pits from dismantled nuclear weapons; and develop, fabricate, and test chemical explosives and explosive components for nuclear weapons to support USDOE/NNSA initiatives (U.S. Department of Energy, 2009). The U.S. Geological Survey (USGS), in cooperation with B&W Pantex through the USDOE/NNSA, made a series of flowmeter measurements and collected other borehole geophysical logs during July–September 2008 to analyze vertical flow in screened intervals of four selected monitoring wells at the Pantex Plant. Hydraulic properties (transmissivity values) of the section of High Plains (Ogallala) aquifer penetrated by the wells also were computed.

Purpose and Scope

The purpose of this report is to analyze vertical flow during ambient and pumped conditions in four monitoring wells at the Pantex Plant in Carson County, Tex., and to document the methods of collection of electromagnetic (EM) flowmeter data and fluid-resistivity, temperature, and natural gamma logs at the Pantex Plant during July–September 2008. The USDOE/NNSA contractor, B&W Pantex, identified the four wells open to the Ogallala aquifer for the analysis. The wells are constructed of 4-inch-diameter stainless steel casing and range in total depth below land-surface datum (LSD) from 475 to 900 feet. Data were collected at various depths below LSD to assess the distribution of flow in screened intervals and compute transmissivity values for the adjacent section of Ogallala aquifer. Transmissivity values were computed using a numerical flow model developed for analysis of flowmeter data.

Description of Study Site

The Pantex Plant main area of operations is bounded on the north by Farm to Market Road (FM) 293, on the east by FM 2373, and on the west by FM 683 (fig. 1). Recently, USDOE/NNSA purchased 1,526 acres of land east of FM 2373 to provide access for ground-water monitoring and positive control over future land and ground-water use (B&W Pantex, writtten commun., 2008). The Pantex Plant site now consists of a total of 17,559 acres, of which 5,856 acres owned by TTU constitutes a safety and security buffer. TTU leases the safety and security buffer property back to USDOE/NNSA; Texas Tech Research Farm manages the buffer zone as rangeland and farmland.

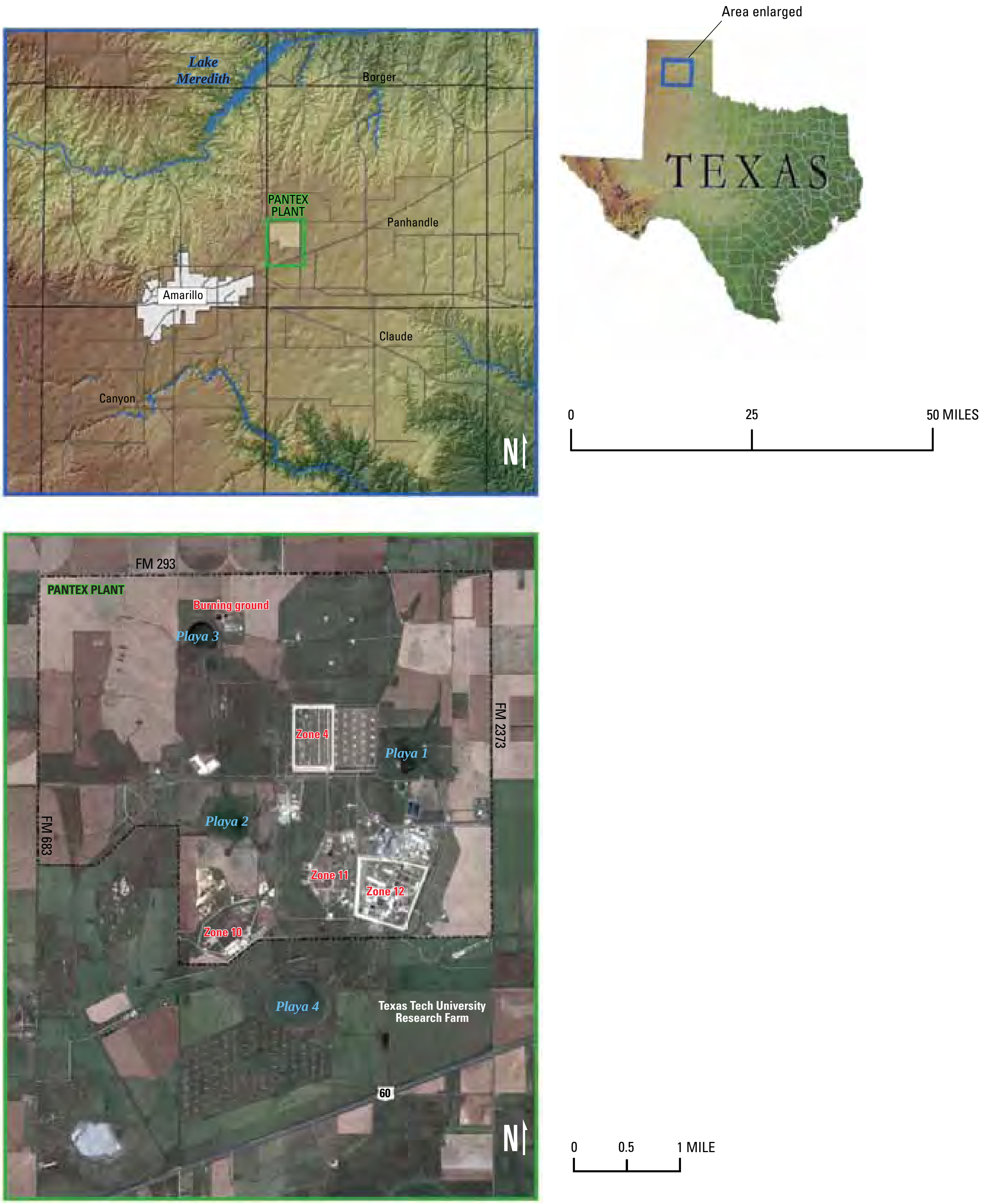
Hydrogeology

The primary subsurface geologic units at the Pantex Plant are the Triassic-age Dockum Group (sand to clay), the Tertiary-age Ogallala Formation (sand to silty sand), and the Quaternary-age Blackwater Draw Formation (clayey silts) (Holliday, 1989). The uppermost of two water-yielding units (aquifers) in the Ogallala Formation at the study site is perched at depths of approximately 200 to 300 feet below LSD. This unit is underlain by a zone of relatively low permeability, informally referred to as the fine-grained zone, which consists of silts and clays that retard the downward migration of perched water. The perched aquifer flows radially and away from beneath a playa lake designated Playa 1 (fig. 2) and ranges in thickness from less than 1 foot near its lateral extent to more than 50 feet near Playa 1.

The second water-yielding unit in the Ogallala Formation, below the fine-grained zone, is the Ogallala aquifer. The Ogallala aquifer is the primary source of drinking and irrigation water for most of the High Plains region in Texas. The Ogallala aquifer generally occurs at depths of approximately 350 to 900 feet below LSD at the study site. Because of regional water-level declines, the upper 150 feet of the aquifer is mostly unsaturated. The water level is about 500 feet below LSD and the saturated part of the aquifer is about 1 to 100 feet thick in the southern part of the Pantex Plant site and about 250 to 400 feet thick in the northern part. The primary flow direction in the Ogallala aquifer at the site is north to northeast.

Acknowledgments

The authors thank Tony Biggs, B&W Pantex, for providing technical information on the wells; and Scott McLaughlin and Ken Nicholson, B&W Pantex, for their many hours setting and operating the pump for the pumping flowmeter measurements.



Base from Babcock & Wilcox Technical Services Pantex, LLC

Figure 1. Location of the Pantex Plant, Carson County, Texas.

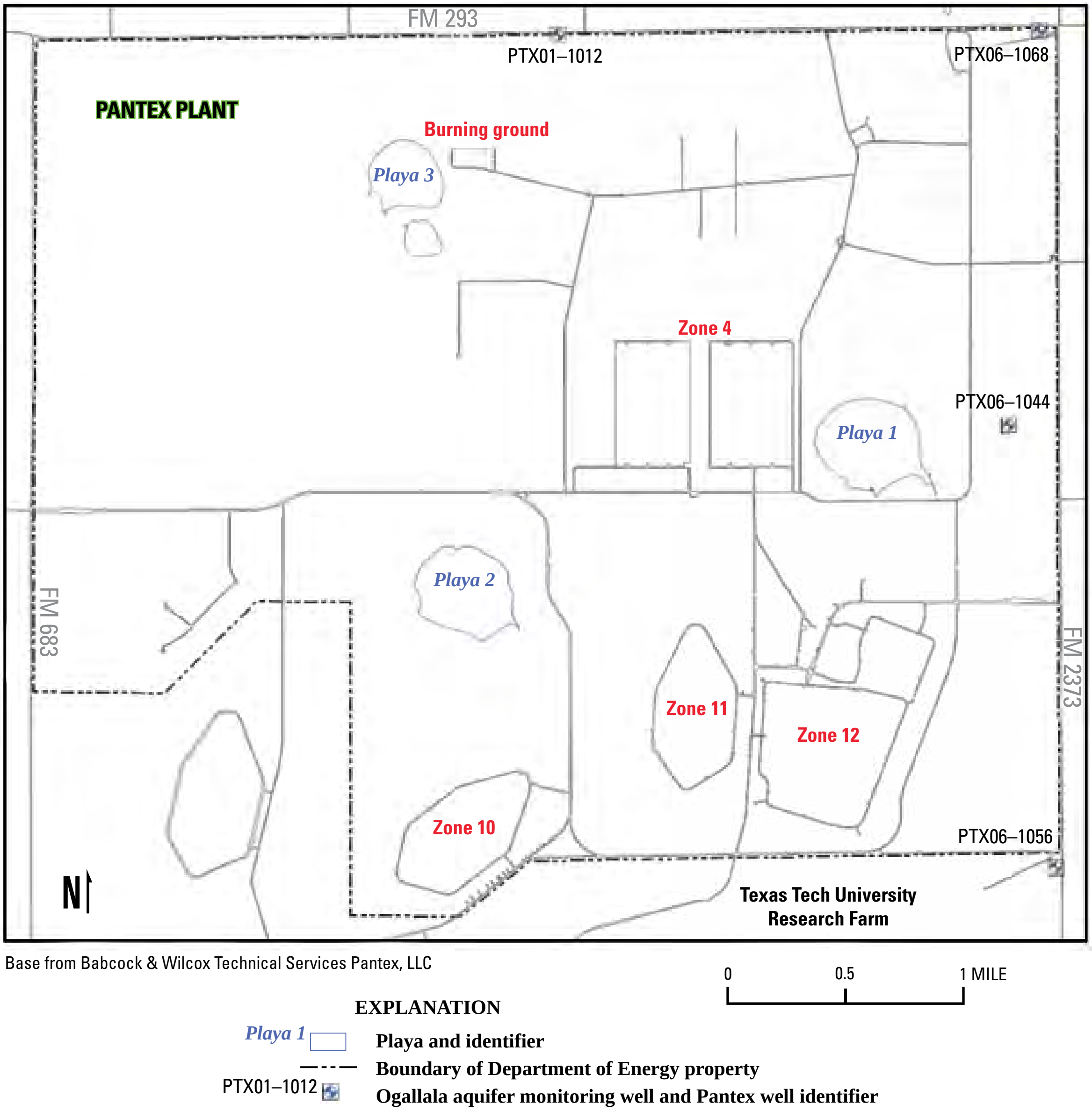


Figure 2. Ogallala aquifer monitoring wells logged with flowmeter at the Pantex Plant, Carson County, Texas.

Methods of Borehole Geophysical Data Collection

The USGS collected borehole geophysical data consisting of vertical flow rates, fluid resistivity/temperature, and natural gamma radiation in the four monitoring wells (PTX01–1012, PTX06–1044, PTX06–1056, and PTX06–1068) (fig. 2; table 1). These data were analyzed to determine the direction and magnitude of vertical flow in the screened intervals and distribution of transmissivity in the adjacent section of the aquifer.

Pertinent information for monitoring wells (well identifier, location, altitude of LSD, total depth, depth to water, total screen length, and number of screened intervals) (table 1) was provided by B&W Pantex. In addition to the logs collected for this study, the Pantex monitoring wells were logged by a contractor at the time of drilling (B&W Pantex, writtten commun., 2008). Among the logs collected at that time were 16- and 64- inch normal resistivity, single-point resistance, spontaneous potential, and natural gamma in wells PTX01–1012, PTX06–1056, and PTX06–1068 and natural gamma and neutron in well PTX06–1044. Selected previously collected logs (normal resistivity and neutron) were digitized for use in this study because only photocopies of the logs were available.

All geophysical probes used in the data collection for this study interfaced to a Century System VI log-acquisition system in the USGS Texas Water Science Center logging unit by way of ¼-inch-diameter four-conductor wireline. The log-acquisition system was interfaced to a personal computer and data storage by way of an Ethernet connection.

Vertical flow rates were measured under ambient and pumped flow conditions in the four monitoring wells. Unusually large drawdowns occurred at two monitoring wells (PTX06–1044 and PTX06–1056) while the wells were pumped at relatively low rates (about 1.5 gallons per minute [gal/min]), which might adversely affect the accuracy of the calculated transmissivity values. Accordingly, a decision was made to redevelop those wells using common methods such as scrubbing the screened interval with tubing-conveyed brushes to loosen fine-grained material in the filter pack and then surging the well to remove the loosened material. Logs were run again after redevelopment during ambient and pumped flow conditions in the two monitoring wells.

B&W Pantex furnished a 3-inch-diameter submersible pump capable of reaching the existing depths to water, which allowed for drawdown at a pumping rate of at least 5 gal/min. The submersible pump was deployed using a Smeal 5T pump hoist rig and 1.5-inch-diameter steel pipe. The pump and hoist rig was operated by B&W Pantex personnel.

Electromagnetic Flowmeter

The EM flowmeter measures the rate and direction of vertical flow in a borehole using the principle of Faraday's Law of Induction. The EM flowmeter probe consists of an electromagnet and two electrodes 180 degrees apart and 90 degrees to the magnetic field inside a hollow cylinder or tube. The voltage induced by a conductor moving at right angles through the magnetic field is directly proportional to the velocity of the conductor (water) through the field (Century Geophysical Corporation, 2006).

Generally, when using the tool to measure low-velocity vertical flow in small-diameter wellbores, rubber diverters are installed around the sensor to direct the water flow through the open tube in the sensor. The diameter of the tube and voltage response is calibrated, and the volume of flow is instantaneously recorded. The direction of vertical water flow is determined by the polarity of the response with upward flow being positive and downward flow being negative.

The flowmeter is placed in the wellbore with a rubber diverter installed to direct the flow through the sensor (fig. 3). Relatively high hydraulic head in a transmissive zone of the aquifer will push the flow from that high-head zone into the wellbore, through the tool in the direction of a transmissive zone of relatively low hydraulic head, to the low-head zone and out of the wellbore.

Downward flow was calibrated at a rate of 1 gal/min and upward flow was calibrated at a pumped rate in the well, which was between 1.5 and 5 gal/min depending on the well and development status. Flowmeter log data were collected in stationary and trolling conditions for both ambient and pumped conditions. When possible, flowmeter data were collected at the same depths during both ambient and pumped flow conditions.

Fluid Resistivity/Temperature Logs

Fluid resistivity logs provide a record of the capacity of the borehole fluid to conduct electrical current (Keys, 1997). Changes in fluid resistivity are measured by ring electrodes inside a housing that allows borehole fluid to flow through it. The best fluid resistivity logging results are achieved when logging downward into boreholes containing ambient fluid that has had sufficient time to stabilize. Ideally, fluid resistivity logs are the first logs run to record ambient conditions before other probes have passed through the borehole and vertically mixed the borehole fluid. Curve deflections on the fluid resistivity log can indicate horizontal or vertical flow, stratification of borehole fluid, or screen openings in cased wells. Fluid resistivity values also can be used in calculations with other logs.

Table 1. Pertinent information for Ogallala aquifer monitoring wells logged at the Pantex Plant, Carson County, Texas, July–September 2008.

USGS site identifier	Pantex well identifier	Location (latitude and longitude in degrees, minutes, seconds)	Altitude of land-surface datum (feet above NAVD 88)	Total depth (feet below land-surface datum)	Static depth to water (feet below land-surface datum)	Total screen length (feet)	Number of screened intervals
352111101352301	PTX01–1012	N35 21 11.4 W101 35 22.6	3,572	900	500	380	3
351944101324201	PTX06–1044	N35 19 44 W101 32 42	3,555	613	475	180	2
351806101322901	PTX06–1056	N35 18 06 W101 32 29	3,489	475	393	120	1
352111101323401	PTX06–1068	N35 21 11 W101 32 34	3,519	804	508	325	2

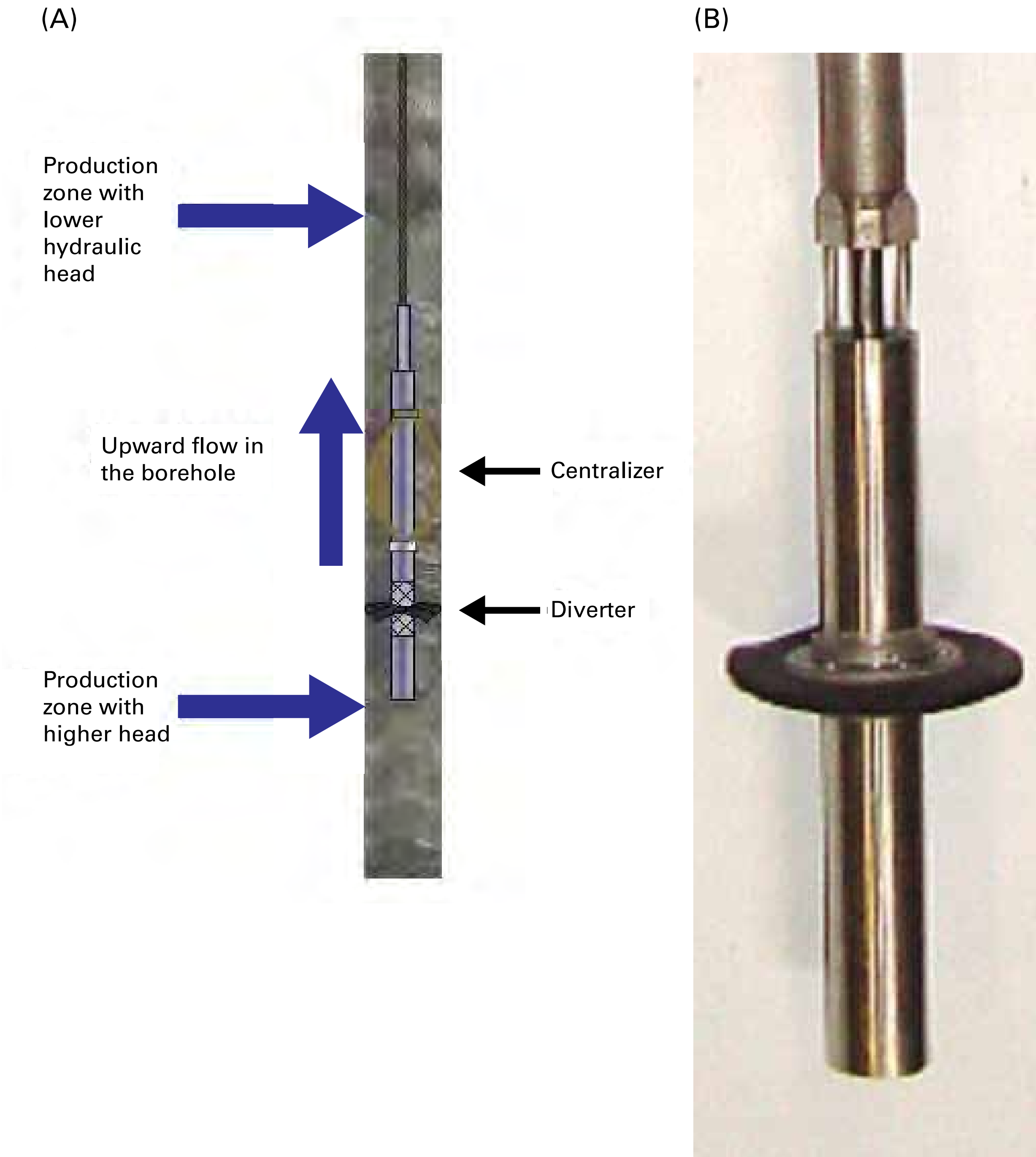


Figure 3. (A) Diagram of flowmeter in borehole showing zones of differing hydraulic head and direction of flow in the borehole, and (B) photograph of Century Model 9721 electromagnetic flowmeter with rubber diverter installed.

The fluid resistivity logs collected in this study were converted to fluid conductivity for comparison to specific conductance values of ground water in the area. The fluid conductivity values contained in the logs for this study are the values recorded in the ambient borehole temperature and are not corrected to a standard temperature.

A Century model 8144c multiparameter probe was used to log fluid resistivity and temperature. Calibration of the fluid resistivity logging probes was done with solutions of known conductivity/resistivity in a two-point calibration.

Natural Gamma Logs

Natural gamma logs provide a record of gamma radiation detected at depth in a borehole. Natural gamma radiation can be useful in determining lithologies and contact depths of the strata penetrated by the borehole. Fine-grained sediments that contain abundant clay tend to be more radioactive than quartz-grain sandstones or carbonates (Keys, 1997). The natural gamma log was run in conjunction with the fluid resistivity log and was recorded simultaneously in natural gamma counts per second.

A natural gamma sensor with a sodium iodide detector built into the Century 8144c multiparameter probe was used. The natural gamma probe is calibrated at the factory and does not require calibration in the field. Natural gamma count rates, which commonly will increase in the proximity of clay and shale, could be slightly increased adjacent to any bentonite seals in the wells.

Analysis of Vertical Flow

Flowmeter and fluid resistivity/temperature data were analyzed by (1) plotting the logs with existing pertinent information such as other geophysical logs and casing and well-construction records provided by B&W Pantex, (2) evaluating the flowmeter data to identify potential zones of fluid movement to or from the wellbore and the magnitude and direction of vertical flow, (3) evaluating the flowmeter data with the USGS Flow–B numerical model (Paillet, 2000) to compute total transmissivity and distribution of transmissivity and head (as depth to water) in the screened intervals, and (4) plotting the transmissivity and head values on the logs.

The Flow–B numerical model of Paillet (2000) is a computer program developed for analysis of flowmeter data. The model gives estimates of transmissivities and hydraulic heads of two or more water-producing (flow) zones intersecting a single interval of open borehole under typical field conditions. Zone transmissivity and hydraulic head are obtained by running the model in a series of iterations in which transmissivity and head values are adjusted by trial-and-error to develop a best-fit match between simulated and measured borehole flows. The output data from the numerical model are in appendix 1.

Monitoring Well PTX01–1012

Monitoring well PTX01–1012 was constructed by Stewart Brothers Drilling Company near the northern Pantex Plant property boundary (fig. 2) on April 28, 2000. The well was drilled 7.9 inches in diameter to a total depth of 903 feet below LSD and constructed of schedule 10, 4-inch-diameter stainless steel casing and screened to 900 feet below LSD. The well has slotted screen openings of 0.010 inch in the following intervals: 460–640 feet, 660–720 feet, and 755–895 feet below LSD. Well records indicate that 8-16 sieve-size silica sand filter pack material is in the annular space of the screened intervals, and bentonite seal is in the annular space above each screened interval. Static water level (depth to water) was about 500 feet below LSD on the day of logging.

Data Collected

The USGS collected EM flowmeter, fluid resistivity, temperature, and natural gamma measurements on August 13, 2008. Flowmeter measurements were collected in trolling and stationary modes during ambient and pumped conditions. Thirty-six stationary measurements were collected during ambient conditions, and 32 stationary measurements were collected during pumped conditions. The well was logged during pumped conditions on the same day the well was logged during ambient conditions. The pump was set at about 520 feet below LSD and discharged about 5.5 gal/min at the surface, which created a constant drawdown of about 2 feet.

Flow During Ambient and Pumped Conditions

Logs collected in monitoring well PTX01–1012 during ambient conditions (fig. 4) indicate a dynamic environment that probably was affected by pumping of nearby irrigation or public-supply wells. Downward flow ranging from 0.2 to 2.1 gal/min indicates a lower hydraulic head in the interval below 750 feet below LSD. The highest rate of ambient flow was measured at the stations in the casing between screened intervals (645–655 and 725–750 feet below LSD) that contained a bentonite seal in the annular space. The screened intervals below 650 feet below LSD are losing flow from the wellbore to the aquifer. In contrast, the screened interval above 650 feet below LSD appears to be gaining downward flow from the aquifer into the wellbore. This lower hydraulic head observed below 650 below LSD during ambient conditions probably is caused by nearby pumping.

During pumping, downward vertical flow during ambient conditions was either reversed or reduced. At depths from 700 to 850 feet below LSD, vertical flow that was downward during ambient conditions was reduced, and at depths from 575 to

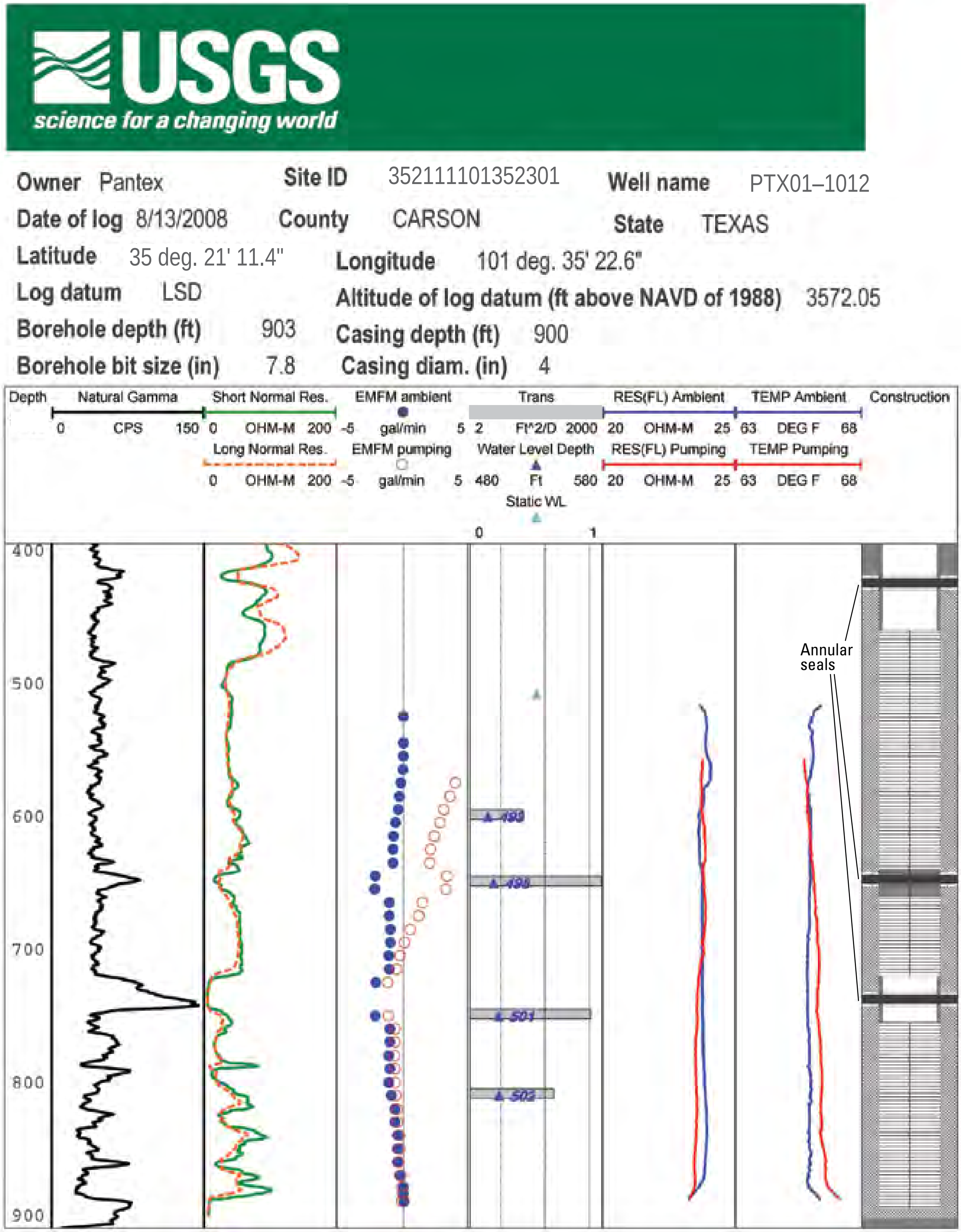


Figure 4. Borehole geophysical logs plotted with calculated transmissivity and well construction in screened intervals of monitoring well PTX01–1012 at the Pantex Plant, Carson County, Texas. [LSD, land-surface datum; ft, feet; in, inches; diam., diameter; CPS, counts per second; Res., resistivity; OHM-M, ohm-meters; EMFM, electromagnetic flowmeter; gal/min, gallons per minute; Trans, transmissivity; Ft^2/D, feet squared per day; WL, depth to water from LSD; RES(FL), fluid resistivity; TEMP, temperature; DEG F, degrees Fahrenheit]

695 feet below LSD, downward ambient flow was reversed to upward as a result of the pumping.

Ambient and pumped flowmeter values were entered into the Flow–B numerical model, as well as other data such as static water level, drawdown, and well diameter. The flowmeter values were plotted in Flow–B (appendix 1.1) and visually evaluated for fluctuations in the data that might indicate individual flow (production) zones. In well PTX01–1012, the flow zones were defined as originating below the following depths below LSD: 600, 650, 750, and 810 feet. Measurements at depths 650 and 750 feet below LSD correspond to cased intervals (hereinafter referred to as blanks) between the sealed screened intervals and show greater differences between ambient and pumped flowmeter values. Greater differences between ambient and pumped flowmeter values in the blanks probably are a result of a better seal of the flow diverter on the flowmeter to the smooth surface of the casing in the blank section and the bentonite seal in the annular space more efficiently funneling flow through the flowmeter sensor. The static depth to water for each of the production zones was computed:

Zone 600–650 feet below LSD, 493 feet.

Zone 650–750 feet below LSD, 498 feet.

Zone 750–810 feet below LSD, 501 feet.

Zone 810–900 feet below LSD, 502 feet.

These calculated depths indicate hydraulic head was several feet lower in the lower two zones than the static head for the entire water column (500 feet below LSD), probably caused by nearby irrigation or public-supply well pumping at times during the flowmeter measurements.

During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed from about 715 to 575 feet below LSD, with fluctuations at the blanks between sealed screened intervals (fig. 4; appendix 1.1).

Estimated total transmissivity was calculated to be about 3,100 feet squared per day (ft^2/d) and is distributed among the production zones as indicated:

Zone 600–650 feet below LSD about 1 percent of the estimated transmissivity (31 ft^2/d).

Zone 650–750 feet below LSD about 60 percent of the estimated transmissivity (1,860 ft^2/d).

Zone 750–810 feet below LSD about 34 percent of the estimated transmissivity (1,054 ft^2/d).

Zone 810–900 feet below LSD about 5 percent of the estimated transmissivity (155 ft^2/d).

The zone of highest transmissivity (650–750 feet below LSD) corresponds with a sand unit at about 650–715 below LSD with reduced gamma counts per second and increased resistivity, which indicate decreased clay content and greater sand content.

Monitoring Well PTX06–1044

Monitoring well PTX06–1044 was constructed by the Water Development Corporation near the eastern Pantex Plant property boundary (fig. 2) during August 13–27, 1999. The well was drilled 7.9 inches in diameter to a total depth of 622 feet below LSD and constructed of schedule 10, 4-inch-diameter stainless steel casing and screened to 613 feet below LSD. The well has slotted screen openings of 0.020 inch in the following intervals: 393–493 and 533–613 feet below LSD. Well records indicate that 8-16 sieve-size silica sand filter pack material is in the annular space at 373–622 feet below LSD. Static water level was about 475 to 479 feet below LSD on the days of logging.

Data Collected

The USGS collected EM flowmeter, fluid resistivity, temperature, and natural gamma measurements on July 25, August 11, and September 24, 2008. Ambient logs were collected July 25, 2008, and pumping logs were collected August 11, 2008, because muddy conditions delayed access to the well. Ambient measurements were rechecked on August 11, 2008, to confirm ambient conditions had not changed. Flowmeter measurements were collected in trolling and stationary modes during ambient and pumped conditions. Fourteen stationary measurements were collected during ambient conditions on July 25, 2008, and 11 stationary measurements were collected while pumping 1.5 gal/min on August 11, 2008.

The pump was set at about 511 feet below LSD. The unusually low well yield of 1.5 gal/min resulted in 30 feet of drawdown. To improve well yield and reduce drawdown, the well screens were cleaned, and the well was redeveloped by B&W Pantex and subsequently logged again by the USGS with an EM flowmeter on September 24, 2008. After redevelopment, the pump was set at about 500 feet below LSD. Thirteen stationary measurements were collected during ambient conditions, and 11 stationary measurements were collected while pumping 5 gal/min. The drawdown observed while pumping 5 gal/min after redevelopment was about 17 feet, considerably less than the 30 feet of drawdown before redevelopment while pumping 1.5 gal/min.

Flow During Ambient and Pumped Flow Conditions Before Redevelopment

Logs collected in monitoring well PTX06–1044 July 25, 2008, during ambient conditions (fig. 5) before redevelopment indicate a static environment with no flow. This lack of flow during ambient conditions indicates generally uniform hydraulic heads throughout the screened intervals; however in this case, results obtained after redevelopment indicate that screened intervals were not allowing adequate flow to enter the wellbore during ambient conditions before redevelopment.

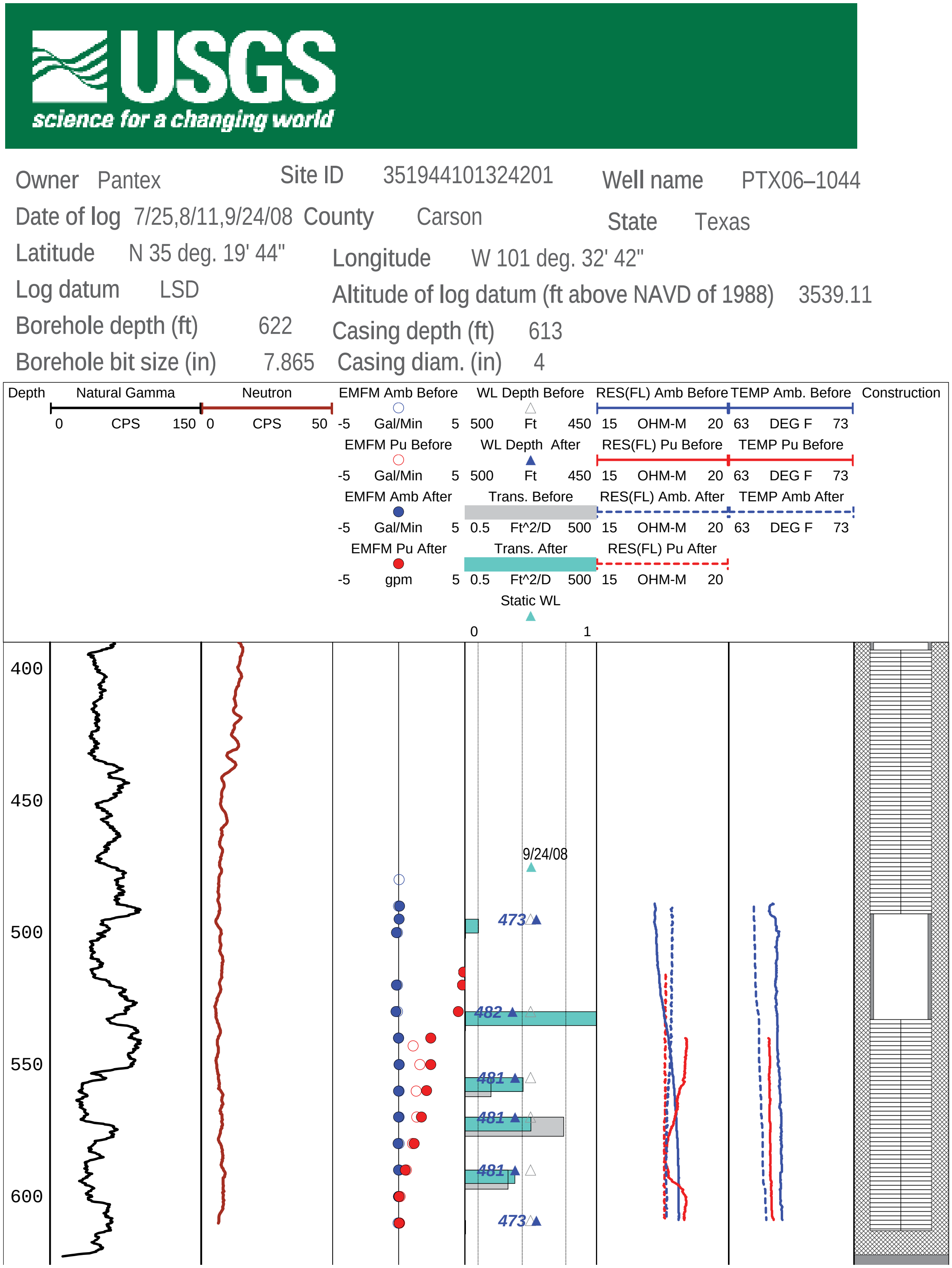


Figure 5. Borehole geophysical logs plotted with calculated transmissivity and well construction in screened intervals of monitoring well PTX06–1044 at the Pantex Plant, Carson County, Texas. [LSD, land-surface datum; ft, feet; in, inches; diam., diameter; CPS, counts per second; EMFM, electromagnetic flowmeter; Amb, ambient; Before, before redevelopment; Gal/min (gpm), gallons per minute; Pu, pumping; After, after redevelopment; WL, depth to water from LSD; Trans, transmissivity; Ft^2/D, feet squared per day; RES(FL), fluid resistivity; OHM-M, ohm-meters; TEMP, temperature; DEG F, degrees Fahrenheit]

During pumping there was upward vertical flow at rates ranging from 0.1 to about 1.5 gal/min. Upward vertical flow occurred at 590 to 542 below LSD, with most of the flow entering the well at depths below 570 feet below LSD.

Ambient and pumped flowmeter values were entered into the Flow–B numerical model, as well as other data such as static water level, drawdown, and well diameter. The flowmeter values were plotted in Flow–B (appendix 1.2) and visually evaluated for fluctuations in the data that might indicate individual flow zones. To discretize the numerical model with consistent flow zones, the flowmeter logs collected after redevelopment were ultimately used for the selection of flow zones, which facilitated a detailed analysis of the flow distribution. The flow zones were defined as originating below the following depths below LSD: 495, 530, 555, 570, and 590 feet. The depth to static water level for each zone was about 475 feet below LSD, about the same as depth to the static water level for the entire water column (475–479 feet below LSD).

During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed from about 590 to 542 feet below LSD (fig. 5; appendix 1.2).

Estimated total transmissivity before redevelopment was calculated to be about 95 ft^2/d and is distributed among the production zones as indicated:

Zone 495–530 feet below LSD none of the estimated transmissivity.

Zone 530–555 feet below LSD about 0.5 percent of the estimated transmissivity (less than 1 ft^2/d).

Zone 555–570 feet below LSD about 2 percent of the estimated transmissivity (2 ft^2/d).

Zone 570–590 feet below LSD about 92.5 percent of the estimated transmissivity (88 ft^2/d).

Zone 590–609 feet below LSD about 5 percent of the estimated transmissivity (5 ft^2/d).

The zone of highest transmissivity (570–590 feet below LSD) corresponds with a sand unit 577–603 feet below LSD. However, these transmissivity values are considered to be in error because of the lack of communication between the well and the aquifer before redevelopment. The hydraulic properties listed here are for documentation of results only.

Flow During Ambient and Pumped Flow Conditions After Redevelopment

Logs collected in monitoring well PTX06–1044 during ambient conditions after redevelopment September 24, 2008 (fig. 5; appendix 1.3), indicate a near-static environment with minimal downward flow (-0.17 gal/min) from about 495 to 530 feet below LSD. This very low downward flow during ambient conditions indicates lower hydraulic head (compared to static water level) at the bottom of the zone (530 feet below LSD). No flow is apparent elsewhere in the well, indicating essentially uniform hydraulic head throughout the screened intervals; however, the lower hydraulic head at 530 feet below LSD must be maintained to the bottommost zone of production to prevent upward flow from occurring.

During pumping there was upward vertical flow at rates ranging from 0.5 to about 4.8 gal/min. Upward vertical flow occurred at 590 to 514 feet below LSD, with most of the flow entering the well at depths between 529 and 539 feet below LSD.

Ambient and pumped flowmeter values were entered into the Flow–B numerical model (appendix 1.3), as well as other data such as static water level, drawdown, and well diameter, as before redevelopment. The flow zones defined were the same as those defined before redevelopment, originating below the following depths below LSD: 495, 530, 555, 570, and 590 feet. The static depth to water for each of the production zones was computed:

Zone 495–530 feet below LSD, 473 feet.

Zone 530–555 feet below LSD, 482 feet.

Zone 555–570 feet below LSD, 481 feet.

Zone 570–590 feet below LSD, 481 feet.

Zone 590–609 feet below LSD, 481 feet.

These calculated depths indicate hydraulic head was 8 to 9 feet lower in the zones of production from 530 to 609 feet below LSD than the hydraulic head for the entire water column, probably caused by nearby wells pumping at times during the flowmeter measurements.

During pumping, a gradual trend of more positive flowmeter values (upward flow of 0.5 to 2.4 gal/min) with distance up the well was observed from about 590 to 540 feet below LSD. A large increase in upward flow occurred between 540 and 530 feet below LSD indicating the most productive zone between those depths (fig. 5; appendix 1.3).

Estimated total transmissivity after redevelopment was calculated to be about 520 ft^2/d and is distributed among the production zones as indicated:

Zone 495–530 feet below LSD less than 1 percent of the estimated transmissivity (1 ft^2/d).

Zone 530–555 feet below LSD about 93.5 percent of the estimated transmissivity (486 ft^2/d).

Zone 555–570 feet below LSD about 2 percent of the estimated transmissivity (10 ft^2/d).

Zone 570–590 feet below LSD about 3 percent of the estimated transmissivity (16 ft^2/d).

Zone 590–609 feet below LSD about 1 percent of the estimated transmissivity (7 ft^2/d).

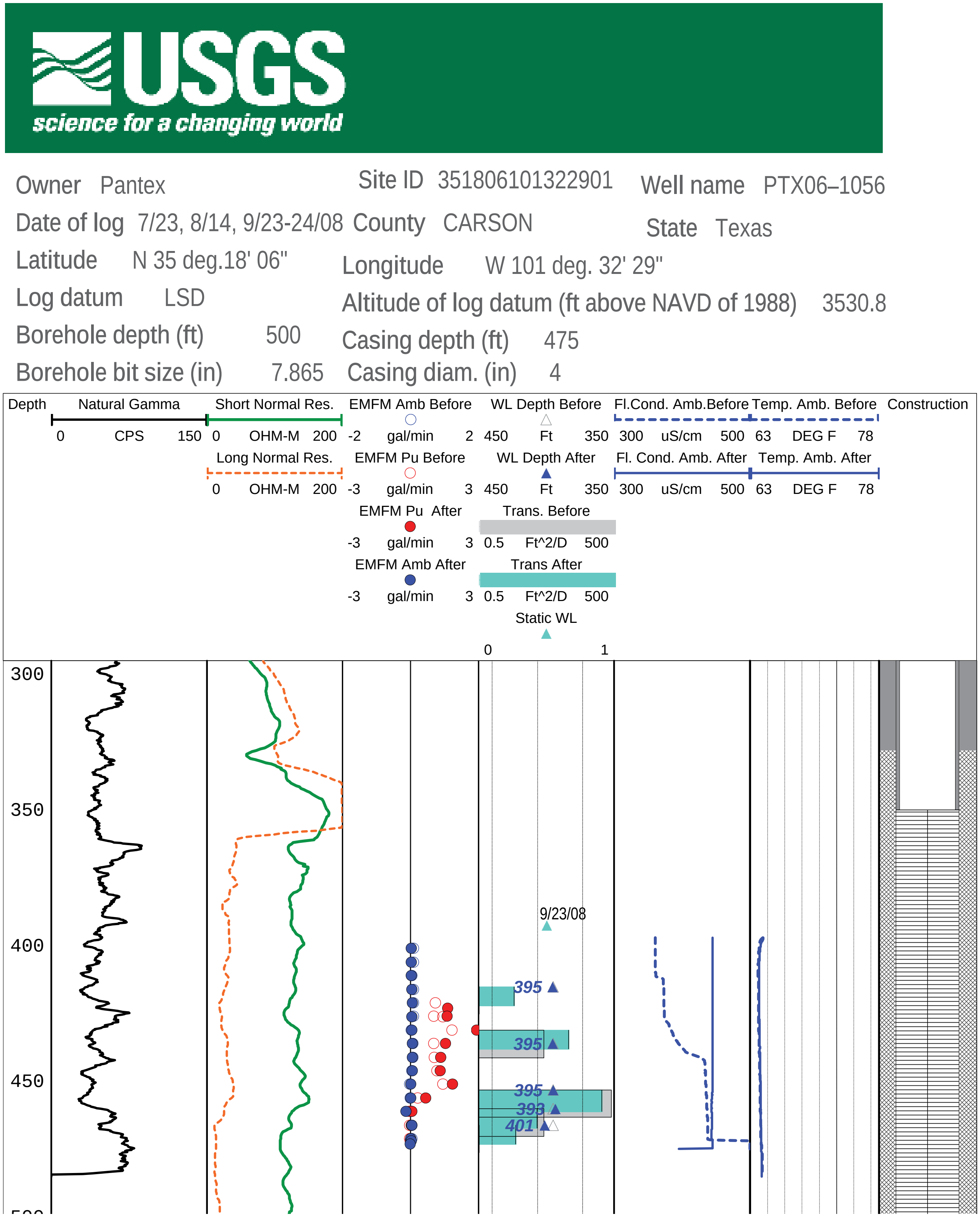


Figure 6. Borehole geophysical logs plotted with calculated transmissivity and well construction in screened interval of monitoring well PTX06–1056 at the Pantex Plant, Carson County, Texas. [LSD, land-surface datum; ft, feet; in, inches; diam., diameter; CPS, counts per second; Res., resistivity; OHM-M, ohm-meters; EMFM, electromagnetic flowmeter; Amb, ambient; Before, before redevelopment; gal/min, gallons per minute; Pu, pumping; After, after redevelopment; WL, depth to water from LSD; Trans, transmissivity; Ft^2/D, feet squared per day; Fl. Cond., fluid conductivity at well; uS/cm, microsiemens per centimeter; Temp, temperature; DEG F, degrees Fahrenheit]

The zone of highest transmissivity (530–555 feet below LSD) corresponds with a thin sand unit with somewhat higher natural gamma counts, which indicates moderate clay content, less sand content, and likely lower permeability than other units. The noted increase in flow entering the well at depths between 529 and 539 feet below LSD (fig. 5) could be attributed to the blank section of casing improving the seal of the flowmeter diverter thus forcing more fluid to enter the sensor in that range. If this is the case, the large computed percentage of flow in the zone 530–555 feet below LSD likely is more indicative of the transmissivity of the entire lower screened section below 530 feet below LSD.

Monitoring Well PTX06–1056

Monitoring well PTX06–1056 was constructed by Stewart Brothers Drilling Company near the southeastern corner of the Pantex Plant property boundary (fig. 2) on May 15, 2000. The well was drilled 7.9 inches in diameter to a total depth of 500 feet below LSD and constructed of schedule 10, 4-inch-diameter stainless steel casing and screened to 475 feet below LSD. The well has slotted screen openings of 0.020 inch in the interval 350–470 feet below LSD. Well records indicate that 8-16 sieve-size silica sand filter pack material is in the annular space at 328–622 feet below LSD. Static water level was about 392 to 393 feet below LSD on the days of logging.

Data Collected

The USGS collected EM flowmeter, fluid resistivity, temperature, and natural gamma measurements on July 23, August 14, and September 23–24, 2008. Ambient logs were collected July 23, 2008, and pumping logs were collected August 14, 2008, because muddy conditions delayed access to the well. Ambient measurements were rechecked on August 14, 2008, to confirm ambient conditions had not changed. Flowmeter measurements were collected in trolling and stationary modes during ambient and pumped conditions. Sixteen stationary measurements were collected during ambient conditions on July 23, 2008, and 11 stationary measurements were collected while pumping 1.5 gal/min on August 14, 2008 (fig. 6; appendix 1.4;).

The pump was set at about 403 feet below LSD. The unusually low well yield of 1.5 gal/min resulted in a constant drawdown of about 7.6 feet. To improve well yield and reduce drawdown, the well screen was cleaned, and the well was redeveloped by B&W Pantex and subsequently logged again by the USGS with an EM flowmeter on September 23, 2008. After redevelopment, the pump was set at about 412 feet below LSD. Sixteen stationary measurements were collected during ambient conditions, and 12 stationary measurements were collected while pumping 3 gal/min (fig. 6; appendix 1.5). The drawdown observed while pumping 3 gal/min after redevelopment was about 13.5 feet, substantially larger than the 7.6 feet of drawdown before redevelopment while pumping 1.5 gal/min.

Flow During Ambient and Pumped Flow Conditions Before Redevelopment

Logs collected in monitoring well PTX06–1056 during ambient conditions before redevelopment July 23, 2008 (fig. 6), indicate a static environment with no flow. The lack of flow during ambient conditions generally indicates uniform hydraulic heads throughout the screened interval.

During pumping there was upward vertical flow at rates ranging from 0.3 to about 1.5 gal/min. Upward vertical flow occurred at 423 to 456 below LSD, with most of the flow entering the well at depths below 450 feet below LSD.

Ambient and pumped flowmeter values were entered into the Flow–B numerical model, as well as other data such as static water level, drawdown, and well diameter. The flowmeter values were plotted in Flow–B (appendix 1.4) and were visually evaluated for fluctuations that might indicate individual flow zones. To discretize the numerical model with consistent flow zones, the flowmeter logs collected after redevelopment were ultimately used for the selection of flow zones, which facilitated a detailed analysis of the flow distribution. The flow zones were defined as originating below the following depths below LSD: 415, 431, 453, and 460 feet. The static depths to water for the production zones were the same as the static depth to water for the entire water column (about 392 feet below LSD).

During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed from about 455 to 432 feet below LSD. The upward flow results from an apparent increase in flow below 450 feet below LSD and remains relatively constant through the uppermost measurement at 423 feet below LSD (fig. 6; appendix 1.4). Increased upward flows are observed at 431 and 451 feet below LSD, depths in the well that could correspond to decreased inside diameter at the threaded connections of screen sections, which likely improve the diverter seal on the flowmeter sensor to the casing.

Estimated total transmissivity before redevelopment was calculated to be about 450 ft^2/d and is distributed among the production zones as indicated:

Zone 415–431 feet below LSD none of the estimated transmissivity.

Zone 431–453 feet below LSD about 2.5 percent of the estimated transmissivity (13 ft^2/d).

Zone 453–460 feet below LSD about 95 percent of the estimated transmissivity (427 ft^2/d).

Zone 460–466 feet below LSD about 2.5 percent of the estimated transmissivity (13 ft^2/d).

The zone of highest transmissivity (453–460 feet below LSD) corresponds with a sand unit 443–460 feet below LSD with

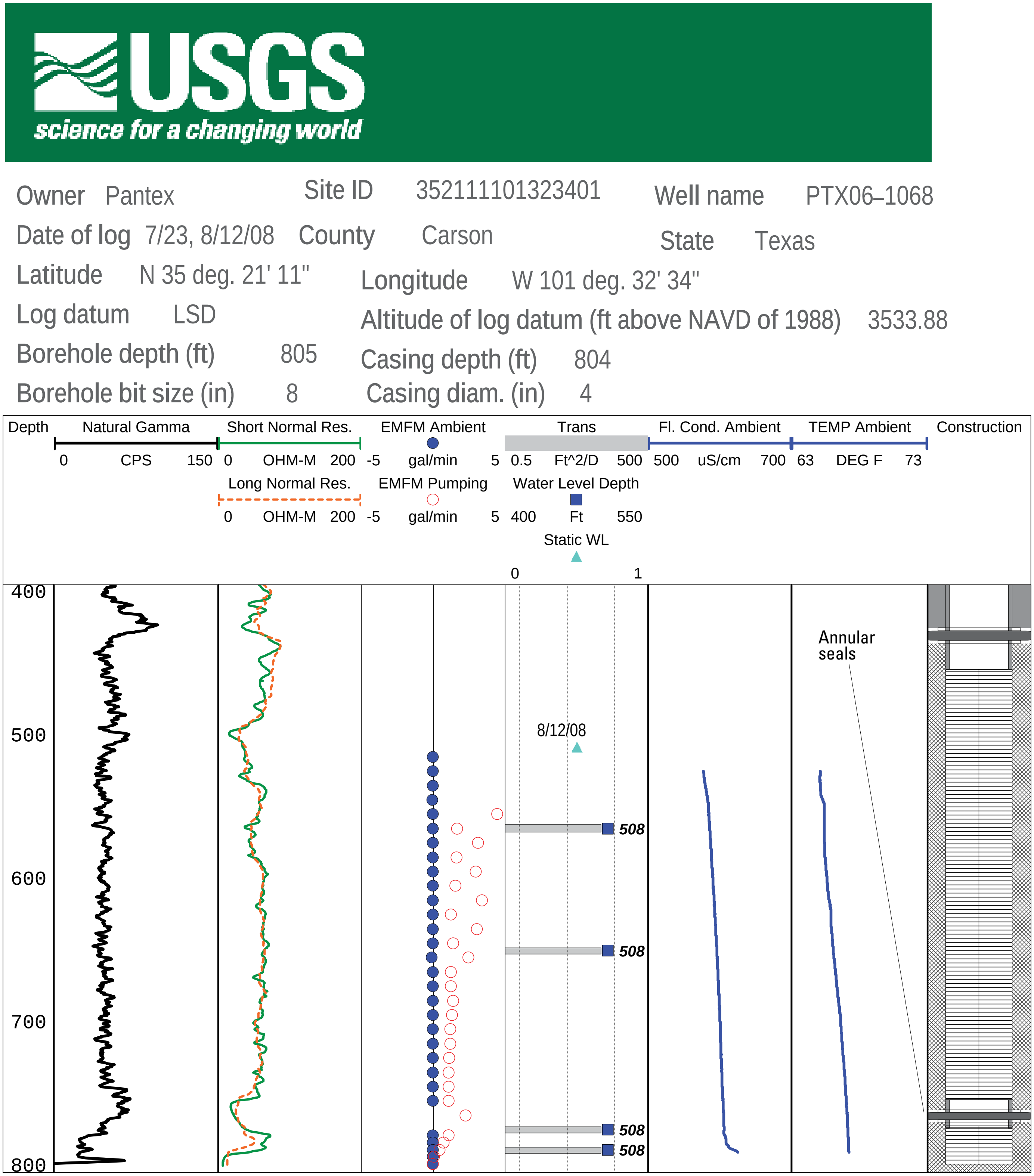


Figure 7. Borehole geophysical logs plotted with calculated transmissivity and well construction in screened interval of monitoring well PTX06–1068 at the Pantex Plant, Carson County, Texas. [LDS, land-surface datum; ft, feet; in, inches; diam., diameter; CPS, counts per second; Res., resistivity; OHM-M, ohm-meters; EMFM, electromagnetic flowmeter; gal/min, gallons per minute; Trans, transmissivity; Ft^2/D, feet squared per day; WL, depth to water from LSD; Fl. Cond., fluid conductivity at well temperature; uS/cm, microsiemens per centimeter; TEMP, temperature; DEG F, degrees Fahrenheit]

somewhat decreased natural gamma counts (fig. 6), which indicates less clay content and more sand content.

Flow During Ambient and Pumped Flow Conditions After Redevelopment

Logs collected in monitoring well PTX06–1056 during ambient conditions after redevelopment September 23, 2008 (fig. 6; appendix 1.5), indicate a near-static environment with no flow from about 401 to 456 feet below LSD. This lack of flow during ambient conditions indicates generally uniform hydraulic heads throughout the section of screened interval above 456 feet below LSD. A very small amount of downward flow occurred during ambient conditions at 461 feet below LSD, which indicates lower hydraulic head at the bottom of the zone (466 feet below LSD).

During pumping there was upward vertical flow at rates ranging from 0.7 to about 2.9 gal/min. Upward vertical flow occurred at 456 to 423 below LSD, with most of the flow entering the well at depths between 456 and 451 feet below LSD.

Ambient and pumped flowmeter values were entered into the Flow–B numerical model (appendix 1.5), as well as other data such as static water level, drawdown, and well diameter, as before redevelopment. The flow zones were defined as originating below the following depths below LSD: 415, 431, 453, 460, and 466 feet. The static depth to water for each of the production zones was computed:

Zone 415–431 feet below LSD, 395 feet.

Zone 431–453 feet below LSD, 395 feet.

Zone 453–460 feet below LSD, 395 feet.

Zone 460–466 feet below LSD, 393 feet.

Zone 466–475 feet below LSD, 401 feet.

These calculated depths indicate a 2- to 3-foot decrease in hydraulic head in the zones 415–460 feet below LSD and about an 8-foot decrease in hydraulic head in the zone 466–475 feet below LSD relative to the hydraulic head for the entire water column (392–393 feet below LSD). Similar to the other wells, the head decreases likely are caused by nearby irrigation or supply wells pumping during the flowmeter measurements.

During pumping, a sharp increase in positive flowmeter values (upward flow) ranging from 0.7 to 1.85 gal/min occurred from about 456 to 451 feet below LSD and indicates a zone of dominant inflow. This upward flow continues up the well, decreases in magnitude somewhat from 446 to 436 feet below LSD, then increases again between 436 and 431 feet below LSD indicating another productive zone between those depths (fig. 6; appendix 1.5).

Estimated total transmissivity after redevelopment was calculated to be about 330 ft^2/d—slightly lower than before redevelopment (450 ft^2/d)—and is distributed among the production zones as indicated:

Zone 415–431 feet below LSD about 1 percent of the estimated transmissivity (3 ft^2/d).

Zone 431–453 feet below LSD about 15 percent of the estimated transmissivity (50 ft^2/d).

Zone 453–460 feet below LSD about 80 percent of the estimated transmissivity (264 ft^2/d).

Zone 460–466 feet below LSD about 3 percent of the estimated transmissivity (10 ft^2/d).

Zone 466–475 feet below LSD about 1 percent of the estimated transmissivity (3 ft^2/d).

The zone of highest transmissivity (453–460 feet below LSD) corresponds with a sand unit 443–460 feet below LSD with somewhat decreased natural gamma counts (fig. 6), which indicates less clay content and more sand content. Redevelopment resulted in the percentage of total transmissivity accounted for by this zone to decrease from 95 to 85 percent. The percentage of transmissivity of the zone accounting for the second-highest percentage of transmissivity (431–453 feet below LSD) increased from about 2.5 percent of the total transmissivity (about 13 ft^2/d) before redevelopment to about 15 percent of the total transmissivity (about 50 ft^2/d) after redevelopment. This redistribution of transmissivity is related not only to the redevelopment but also to the amount of stress on the well. Drawdown in this well increased from 7.6 feet while pumping at 1.5 gal/min before redevelopment to 13.5 feet while pumping at 3 gal/min. The larger pumping stress caused a redistribution of flow that resulted in more drawdown, which caused the model to calculate a lower total transmissivity.

Monitoring Well PTX06–1068

Monitoring well PTX06–1068 was constructed by Layne Christensen near the northeastern corner of the Pantex property boundary (fig. 2) during May 1–5, 2001. The well was drilled 8 inches in diameter to a total depth of 805 feet below LSD and constructed of schedule 10, 4-inch diameter stainless steel casing and screened to 804 feet below LSD. The well has slotted screen openings of 0.010 inch in the following intervals: 454–754 and 774–799 feet below LSD. Well records indicate that 10-20 sieve-size silica sand filter pack material is in the annular space of the screened intervals, and bentonite seal is in the annular space above each screened interval. Static water level was about 508 feet below LSD on the days of logging.

Data Collected

The USGS collected EM flowmeter, fluid resistivity, temperature, and natural gamma measurements on July 23 and August 12, 2008. Flowmeter measurements were collected in trolling and stationary modes during ambient and pumped conditions. Thirty stationary measurements were collected during ambient conditions, and 27 stationary measurements were collected during pumped conditions. The well was logged during pumped conditions on August 12, 2008, because muddy conditions delayed access to the well. The pump was set at about 531 feet below LSD and discharged about 4.5 gal/min at the surface, which created a constant drawdown of about 10 feet.

Flow During Ambient and Pumped Conditions

Logs collected in monitoring well PTX06–1068 on July 23, 2008, during ambient conditions indicate a static environment with no flow (fig. 7; appendix 1.6). The lack of flow during ambient conditions indicates generally uniform hydraulic heads throughout the screened interval with no influence from nearby pumping wells.

During pumping there was upward vertical flow at rates ranging from 0.4 to 4.8 gal/min. Ambient and pumped flowmeter values were entered into the Flow–B numerical model, as well as other data such as static water level, drawdown, and well diameter. The flowmeter values were plotted in Flow–B (appendix 1.6) and were visually evaluated for fluctuations in the data that might indicate individual flow zones. In this well, the flow zones were defined as originating below the following depths below LSD: 565, 650, 775, and 789 feet. Measurements at depths of 775 and 789 feet below LSD correspond to measurements collected at blank intervals at the threaded parts of screened intervals and show the greatest relative difference between ambient and pumped flowmeter values. This is probably a result of a better seal of the flow diverter on the flowmeter to the smooth surface of the casing blank section and more efficient funneling of flow through the flowmeter sensor. The static depths to water for the production zones were the same as static depth to water for the entire water column (about 508 feet below LSD).

During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed from about 789 to 765 feet below LSD, with the highest values at the blanks between sealed screened intervals (fig. 7; appendix 1.6). Flowmeter values between 555 and 655 feet below LSD appear to alternate between relatively high and low flow values with highest values every 20 feet. This likely is an artifact of well construction. The screen sections have a threaded connection every 20 feet, and there is a better seal with the diverter in the threaded (smaller diameter) part of the screen sections. The higher flowmeter values were used in the numerical model.

Estimated total transmissivity was calculated to be about 200 ft^2/d and is evenly distributed among the production zones as indicated:

Zone 565–650 feet below LSD about 25 percent of the estimated transmissivity (50 ft^2/d).

Zone 650–775 feet below LSD about 25 percent of the estimated transmissivity (50 ft^2/d).

Zone 775–789 feet below LSD about 25 percent of the estimated transmissivity (50 ft^2/d).

Zone 789–804 feet below LSD about 25 percent of the estimated transmissivity (50 ft^2/d).

Summary

The Pantex Plant is a U.S. Department of Energy/National Nuclear Security Administration (USDOE/NNSA)-owned, contractor-operated facility managed by Babcock & Wilcox Technical Services Pantex, LLC (B&W Pantex) in Carson County, Tex., approximately 17 miles northeast of Amarillo. The U.S. Geological Survey (USGS), in cooperation with B&W Pantex through the USDOE/NNSA, made a series of flowmeter measurements and collected other borehole geophysical logs during July–September 2008 to analyze vertical flow in screened intervals of four selected monitoring wells at the Pantex Plant. Hydraulic properties (transmissivity values) of the section of High Plains (Ogallala) aquifer penetrated by the wells also were computed.

The USGS collected borehole geophysical data consisting of vertical flow rates, fluid resistivity/temperature, and natural gamma radiation in the four monitoring wells (PTX01–1012, PTX06–1044, PTX06–1056, and PTX06–1068). Vertical flow rates were measured under ambient and pumped flow conditions in the four monitoring wells. Unusually large drawdowns occurred at two monitoring wells (PTX06–1044 and PTX06–1056) while the wells were pumped at relatively low rates (about 1.5 gal/min), which might adversely affect the accuracy of the calculated transmissivity values. Accordingly, a decision was made to redevelop those wells. Logs were run again after redevelopment during ambient and pumped flow conditions in the two monitoring wells.

Flowmeter and fluid resistivity/temperature data were analyzed by (1) plotting the logs with existing pertinent information such as other geophysical logs and casing and well-construction records provided by B&W Pantex, (2) evaluating the flowmeter data to identify potential zones of fluid movement to or from the wellbore and the magnitude and direction of vertical flow, (3) evaluating the flowmeter data with the USGS Flow–B numerical model to compute total transmissivity and distribution of transmissivity and head (as depth to water) in the screened intervals, and (4) plotting the transmissivity and head values on the logs.

Logs collected in monitoring well PTX01–1012 during ambient conditions indicate a dynamic environment that probably was affected by pumping of nearby irrigation or public-supply wells. Downward flow ranged from 0.2 to 2.1 gal/min. During pumping, downward vertical flow that occurred during ambient conditions was either reversed or reduced. The flow (production) zones in the well were defined from Flow–B numerical model results as originating below the following depths below LSD: 600, 650, 750, and 810 feet. During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed from about 715 to 575 feet below LSD. Estimated total transmissivity for the four identified production zones taken together was calculated to be about 3,100 ft^2/d. The zone of highest transmissivity (1,860 ft^2/d) corresponds with a sand unit at about 650–715 below LSD.

Logs collected in monitoring well PTX06–1044 during ambient conditions before redevelopment indicate a static environment with no flow. During pumping there was upward vertical flow at rates ranging from 0.1 to about 1.5 gal/min. The flow zones in the well were defined from Flow–B numerical model results as originating below the following depths below LSD: 495, 530, 555, 570, and 590 feet. During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed from about 590 to 542 feet below LSD. Estimated total transmissivity before redevelopment for the five identified production zones taken together was calculated to be about 95 ft^2/d; but this and associated transmissivity values for the individual zones are considered to be in error because of the lack of communication between the well and the aquifer before redevelopment.

Logs collected in monitoring well PTX06–1044 during ambient conditions after redevelopment indicate a near-static environment with minimal downward flow (-0.17 gal/min). During pumping there was upward vertical flow at rates ranging from 0.5 to about 4.8 gal/min. The flow zones defined from Flow–B numerical model results were the same as those defined before redevelopment. During pumping, a gradual trend of more positive flowmeter values (upward flow of 0.5 to 2.4 gal/min) with distance up the well was observed from about 590 to 540 feet below LSD. A large increase in upward flow occurred between 540 and 530 feet below LSD indicating the most productive zone between those depths. Estimated total transmissivity after redevelopment for the five identified production zones taken together was calculated to be about 520 ft^2/d. The zone of highest transmissivity (486 ft^2/d) corresponds with a thin sand unit.

Logs collected in monitoring well PTX06–1056 during ambient conditions before redevelopment indicate a static environment with no flow. During pumping there was upward vertical flow at rates ranging from 0.3 to about 1.5 gal/min. The flow zones in the well were defined from Flow–B numerical model results as originating below the following depths below LSD: 415, 431, 453, and 460 feet. During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed from about 455 to 432 feet below LSD. Estimated total transmissivity before redevelopment for the four identified production zones taken together was calculated to be about 450 ft^2/d. The zone of highest transmissivity (427 ft^2/d) corresponds with a sand unit 443–460 feet below LSD.

Logs collected in monitoring well PTX06–1056 during ambient conditions after redevelopment indicate a near-static environment with no flow from about 401 to 456 feet below LSD. A very small amount of downward flow occurred during ambient conditions at 461 feet below LSD. During pumping there was upward vertical flow at rates ranging from 0.7 to about 2.9 gal/min. The flow zones in the well were defined from Flow–B numerical model results as originating below the following depths below LSD: 415, 431, 453, 460, and 466 feet. During pumping, a sharp increase in positive flowmeter values (upward flow) ranging from 0.7 to 1.85 gal/min occurred from about 456 to 451 feet below LSD and indicates a zone of dominant inflow. Estimated total transmissivity after redevelopment for the five identified production zones taken together was calculated to be about 330 ft^2/d. The zone of highest transmissivity (264 ft^2/d) corresponds with a sand unit 443–460 feet below LSD.

Logs collected in monitoring well PTX06–1068 during ambient conditions indicate a static environment with no flow. During pumping there was upward vertical flow at rates ranging from 0.4 to 4.8 gal/min. The flow zones in the well were defined from Flow–B numerical model results as originating below the following depths below LSD: 565, 650, 775, and 789 feet. During pumping, a gradual trend of more positive flowmeter values (upward flow) with distance up the well was observed from about 789 to 765 feet below LSD. Estimated total transmissivity for the four identified production zones taken together was calculated to be about 200 ft^2/d and is evenly distributed among the selected zones.

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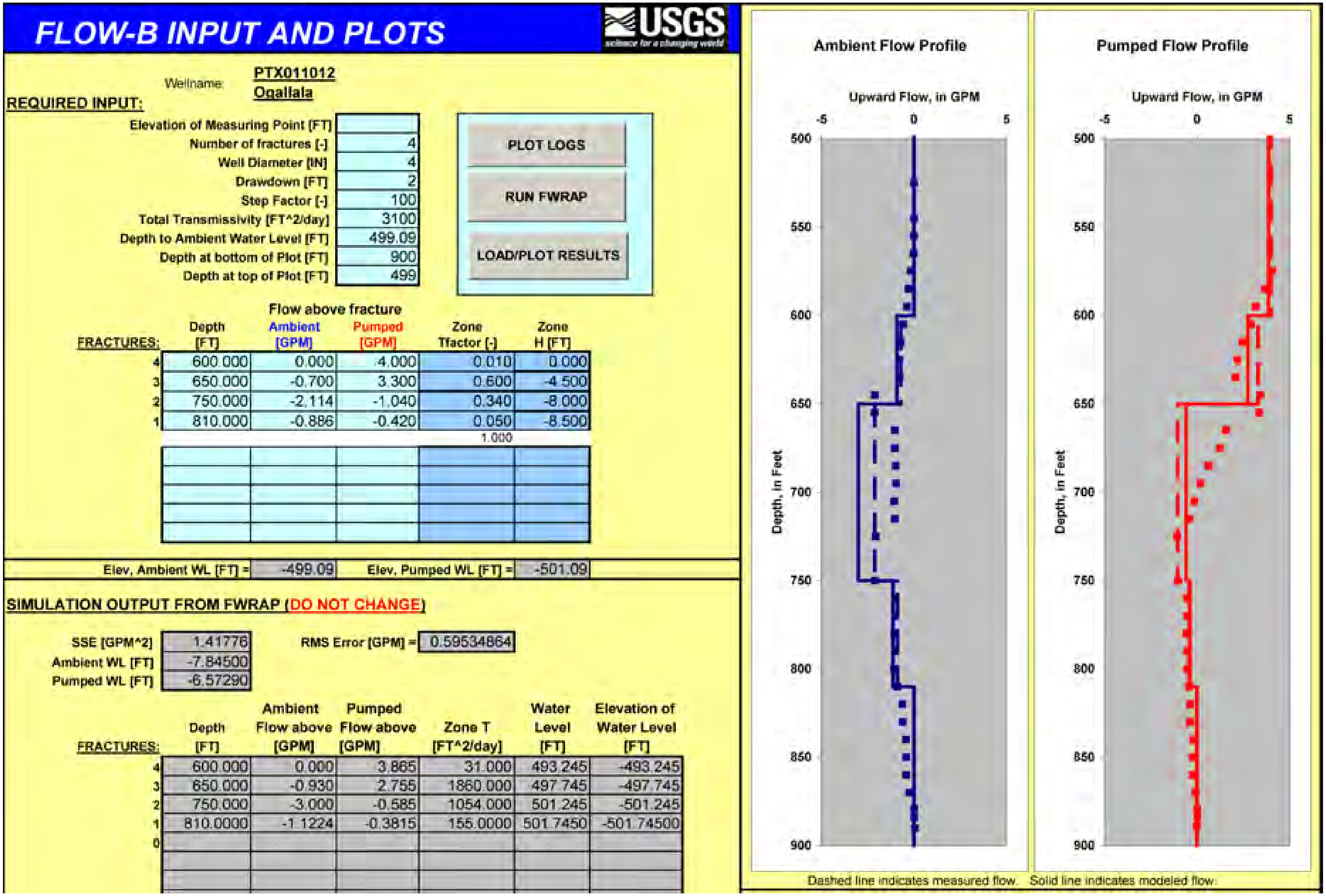
Appendix 1—Flowmeter Analyses of Monitoring Wells With Flow–B Numerical Model Input and Results



FLOW-B INPUT AND PLOTS

Wellname: PTX011012
Ogallala

REQUIRED INPUT:

Elevation of Measuring Point [FT]	
Number of fractures [-]	4
Well Diameter [IN]	4
Drawdown [FT]	2
Step Factor [-]	100
Total Transmissivity [FT^2/day]	3100
Depth to Ambient Water Level [FT]	499.09
Depth at bottom of Plot [FT]	900
Depth at top of Plot [FT]	499

PLOT LOGS

RUN FWRAP

LOAD/PLOT RESULTS

FRACTURES:	Depth [FT]	Flow above fracture Ambient [GPM]	Flow above fracture Pumped [GPM]	Zone Tfactor [-]	Zone H [FT]
4	600.000	0.000	4.000	0.010	0.000
3	650.000	-0.700	3.300	0.600	-4.500
2	750.000	-2.114	-1.040	0.340	-8.000
1	810.000	-0.886	-0.420	0.050	-8.500
				1.000	

Elev, Ambient WL [FT] = -499.09 Elev, Pumped WL [FT] = -501.09

SIMULATION OUTPUT FROM FWRAP (DO NOT CHANGE)

SSE [GPM^2]	1.41776
Ambient WL [FT]	-7.84500
Pumped WL [FT]	-6.57290

RMS Error [GPM] = 0.59534864

FRACTURES:	Depth [FT]	Ambient Flow above [GPM]	Pumped Flow above [GPM]	Zone T [FT^2/day]	Water Level [FT]	Elevation of Water Level [FT]
4	600.000	0.000	3.865	31.000	493.245	-493.245
3	650.000	-0.930	2.755	1860.000	497.745	-497.745
2	750.000	-3.000	-0.585	1054.000	501.245	-501.245
1	810.0000	-1.1224	-0.3815	155.0000	501.7450	-501.74500
0						

1.1. Monitoring Well PTX01–1012

FLOW-B INPUT AND PLOTS

USGS science for a changing world

Wellname: PTX061044 Ogallala

REQUIRED INPUT:

Elevation of Measuring Point [FT]	
Number of fractures [-]	6
Well Diameter [IN]	4
Drawdown [FT]	30
Step Factor [-]	90
Total Transmissivity [FT^2/day]	95
Depth to Ambient Water Level [FT]	475
Depth at bottom of Plot [FT]	620
Depth at top of Plot [FT]	450

PLOT LOGS

RUN FWR/

LOAD/PLOT RESULTS

FRACTURES:	Depth [FT]	Flow above fracture Ambient [GPM]	Flow above fracture Pumped [GPM]	Zone Tfactor [-]	Zone H [FT]
6	495.000	0.021	1.600	0.000	0.000
5	530.000	-0.080	1.600	0.005	0.000
4	555.000	0.021	1.600	0.020	0.000
3	570.000	0.036	1.370	0.925	0.000
2	590.000	0.022	0.600	0.050	0.000
1	609.000	-0.020	0.060	0.000	0.000

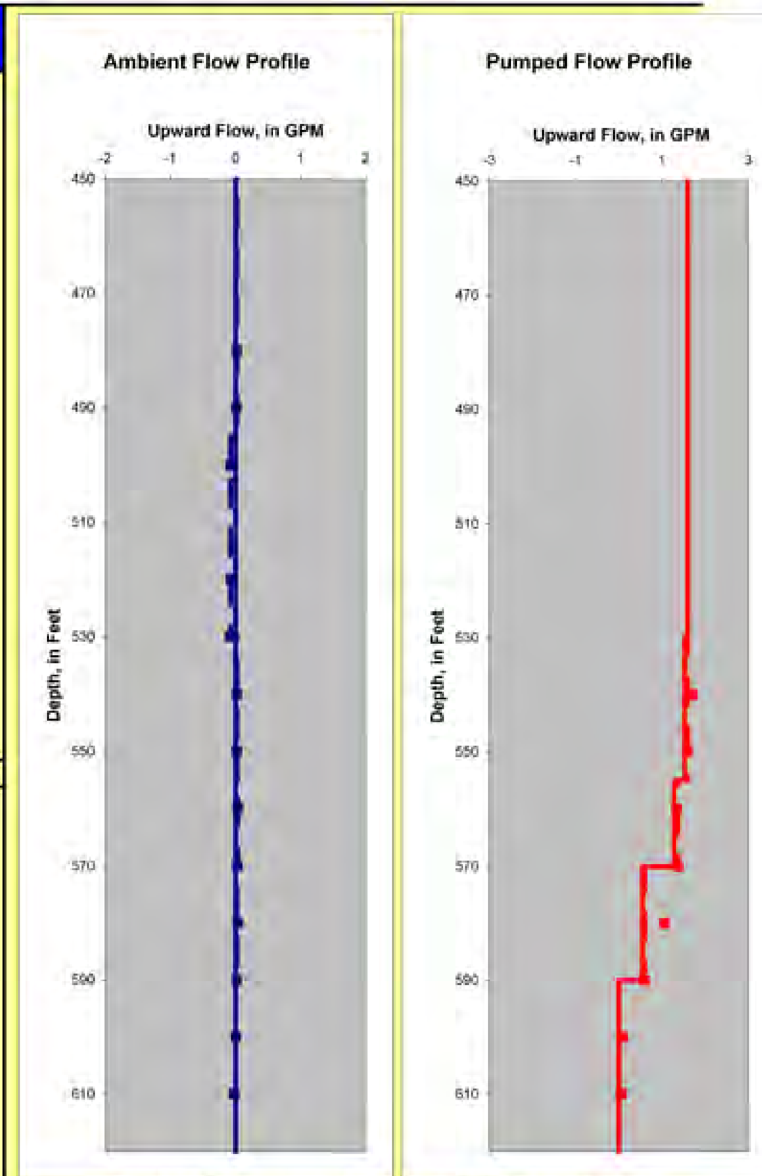
Elev, Ambient WL [FT] = -475.00 Elev, Pumped WL [FT] = -505.00

SIMULATION OUTPUT FROM FWRAP (DO NOT CHANGE)

SSE [GPM^2]	0.02971
Ambient WL [FT]	-30.00000
Pumped WL [FT]	0.00000

RMS Error [GPM] = 0.07036726

FRACTURES:	Depth [FT]	Ambient Flow above [GPM]	Pumped Flow above [GPM]	Zone T [FT^2/day]	Water Level [FT]	Elevation of Water Level [FT]
6	495.000	0.000	1.597	0.000	475.000	-475.000
5	530.000	0.000	1.597	0.475	475.000	-475.000
4	555.000	0.000	1.526	1.900	475.000	-475.000
3	570.0000	0.0000	1.2788	87.8750	475.0000	-475.00000
2	590.0000	0.0000	0.5471	4.7500	475.0000	-475.00000
1	609.0000	0.0000	0.0000	0.0000	475.0000	-475.00000
0						



Dashed line indicates measured flow. Solid line indicates modeled flow.

1.2. Monitoring Well PTX06–1044 Before Redevelopment

FLOW-B INPUT AND PLOTS

USGS science for a changing world

Wellname: PTX061044 Post Redevelopment Ogallala

REQUIRED INPUT:

Elevation of Measuring Point [FT]	
Number of fractures [-]	6
Well Diameter [IN]	4
Drawdown [FT]	17.2
Step Factor [-]	90
Total Transmissivity [FT^2/day]	520
Depth to Ambient Water Level [FT]	482
Depth at bottom of Plot [FT]	620
Depth at top of Plot [FT]	470

PLOT LOGS

RUN FWR/

LOAD/PLOT RESULTS

FRACTURES:	Depth [FT]	Flow above fracture Ambient [GPM]	Flow above fracture Pumped [GPM]	Zone Tfactor [-]	Zone H [FT]
6	495.000	0.019	5.000	0.002	0.000
5	530.000	-0.172	4.800	0.935	-9.000
4	555.000	0.040	2.400	0.020	-8.000
3	570.000	0.036	1.700	0.030	-8.000
2	590.000	0.022	0.600	0.013	-8.000
1	609.000	0.000	0.020	0.000	0.000

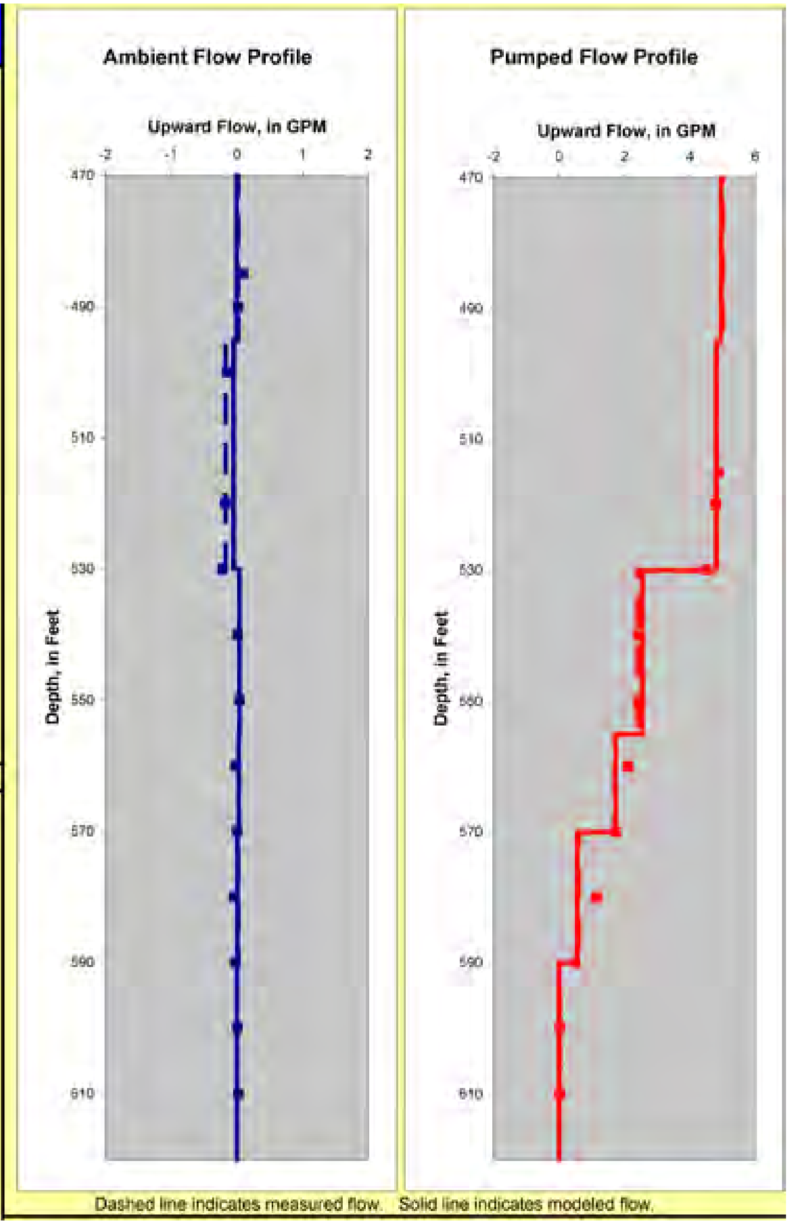
Elev. Ambient WL [FT] = -482.00 Elev. Pumped WL [FT] = -499.20

SIMULATION OUTPUT FROM FWRAP (DO NOT CHANGE)

SSE [GPM^2]	0.04151
Ambient WL [FT]	-26.11900
Pumped WL [FT]	-8.30373

RMS Error [GPM] = 0.08317363

FRACTURES:	Depth [FT]	Ambient Flow above [GPM]	Pumped Flow above [GPM]	Zone T [FT^2/day]	Water Level [FT]	Elevation of Water Level [FT]
6	495.000	0.000	4.952	1.040	473.081	-473.081
5	530.000	-0.049	4.798	486.200	482.081	-482.081
4	555.000	0.043	2.542	10.400	481.081	-481.081
3	570.0000	0.0289	1.7254	15.6000	481.0810	-481.08099
2	590.0000	0.0092	0.5511	6.7600	481.0810	-481.08099
1	609.0000	0.0000	0.0000	0.0000	473.0810	-473.08099
0						



1.3. Monitoring Well PTX06–1044 After Redevelopment

FLOW-B INPUT AND PLOTS

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Wellname: PTX061056 Ogallala

REQUIRED INPUT:

Elevation of Measuring Point [FT]	
Number of fractures [-]	5
Well Diameter [IN]	4
Drawdown [FT]	7.58
Step Factor [-]	100
Total Transmissivity [FT^2/day]	450
Depth to Ambient Water Level [FT]	392.5
Depth at bottom of Plot [FT]	480
Depth at top of Plot [FT]	410

PLOT LOGS

RUN FWRAP

LOAD/PLOT RESULTS

FRACTURES:	Depth [FT]	Flow above fracture Ambient [GPM]	Flow above fracture Pumped [GPM]	Zone Tfactor [-]	Zone H [FT]
5	415.000	0.000	1.500	0.000	0.000
4	431.000	0.000	1.500	0.030	0.000
3	453.000	0.000	1.300	0.950	0.000
2	460.000	0.000	0.300	0.030	0.000
1	466.000	0.000	0.000	0.000	0.000

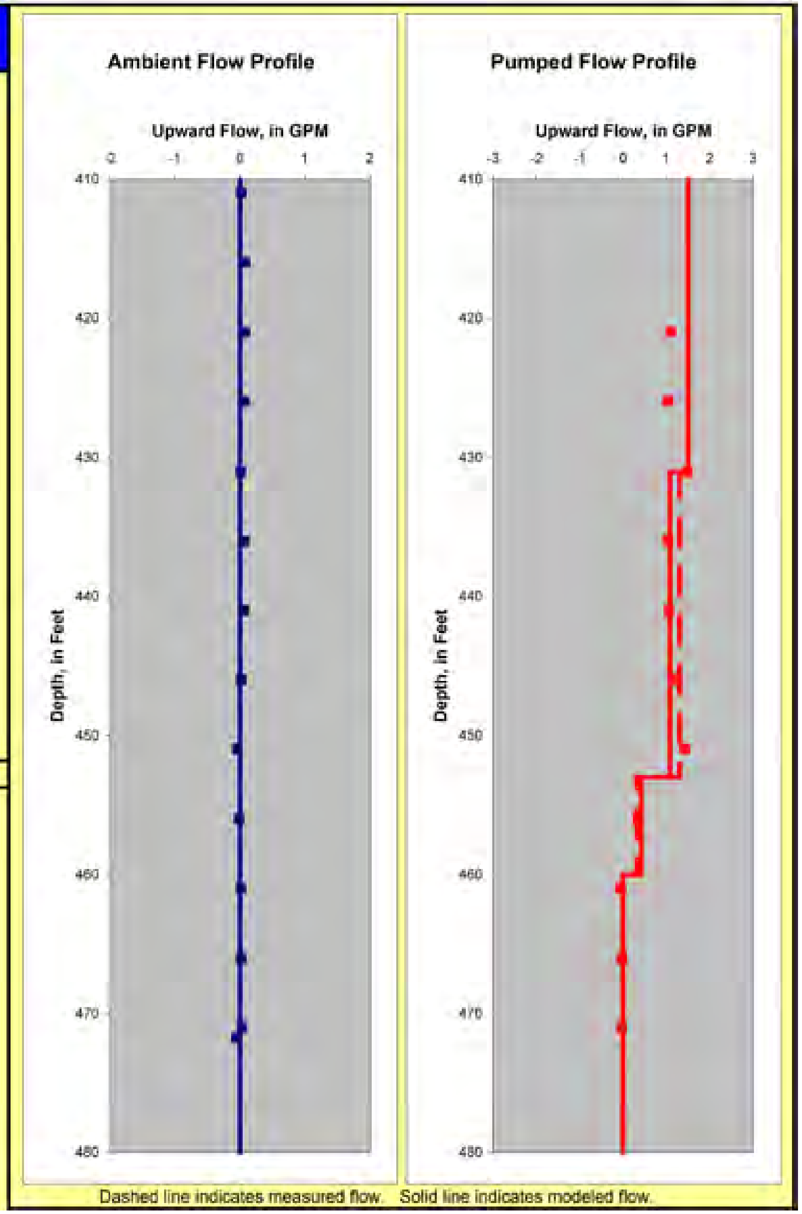
Elev, Ambient WL [FT] = -392.50 Elev, Pumped WL [FT] = -400.08

SIMULATION OUTPUT FROM FWRAP (DO NOT CHANGE)

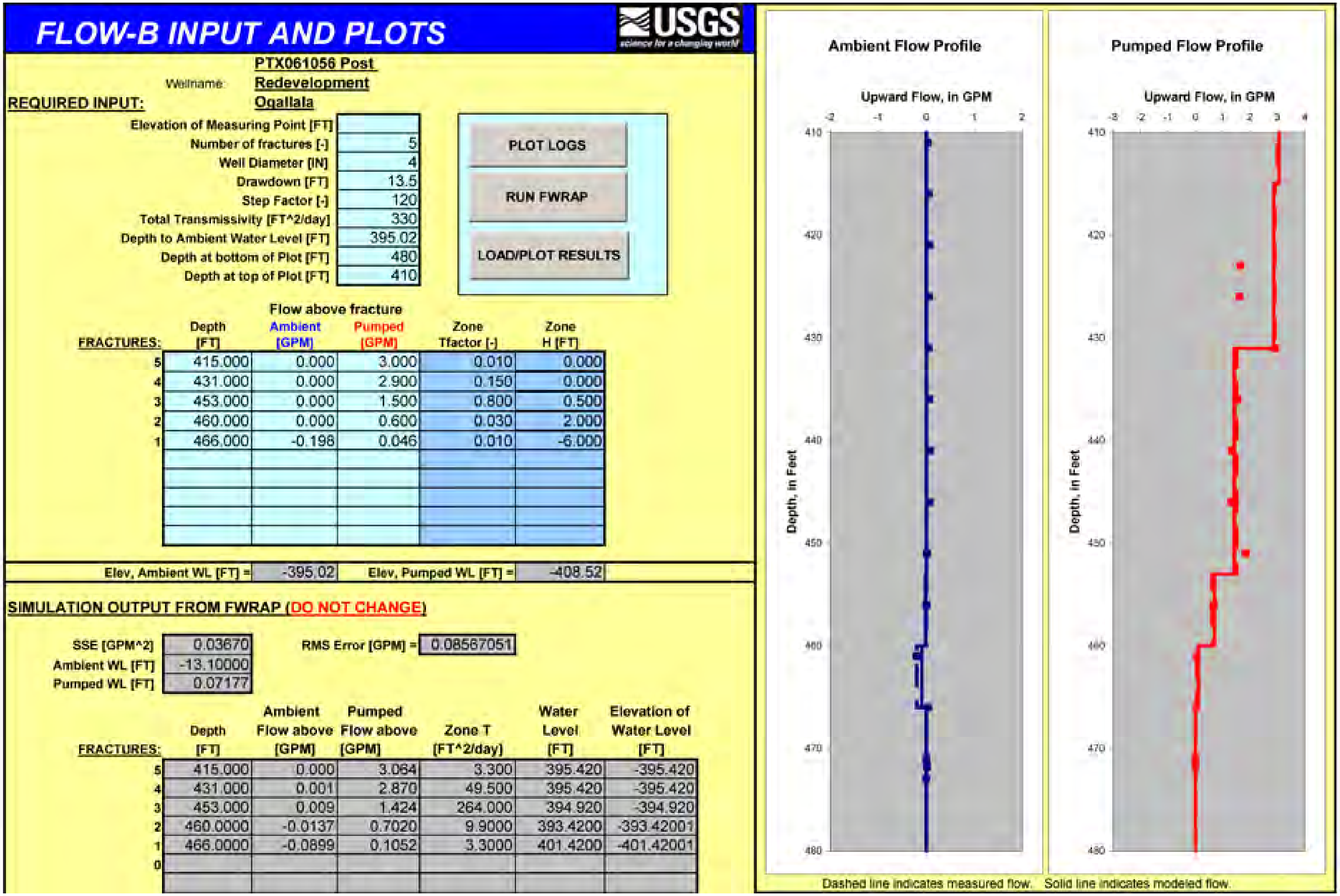
SSE [GPM^2]	0.05982
Ambient WL [FT]	-7.58000
Pumped WL [FT]	0.00000

RMS Error [GPM] = 0.10938085

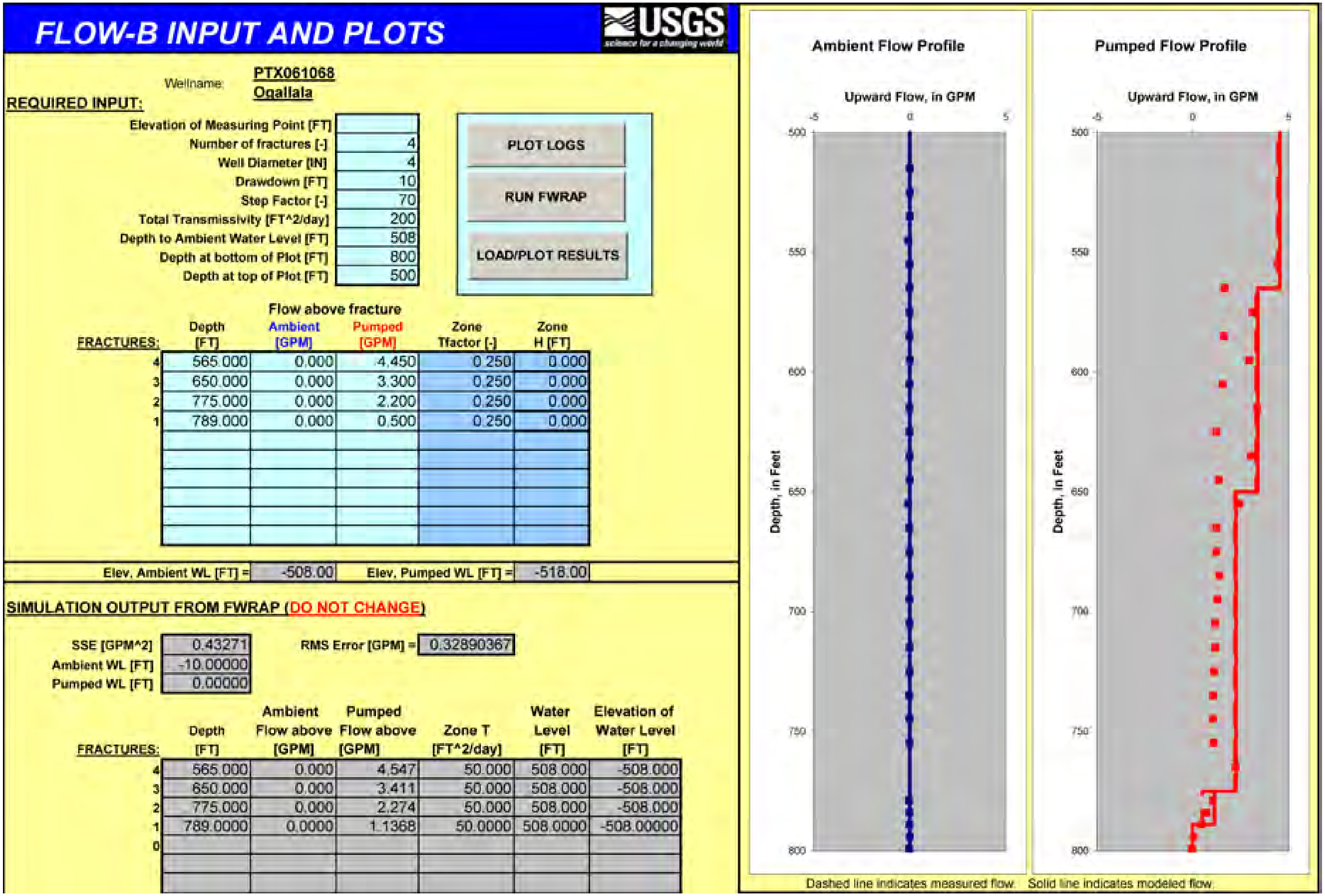
FRACTURES:	Depth [FT]	Ambient Flow above [GPM]	Pumped Flow above [GPM]	Zone T [FT^2/day]	Water Level [FT]	Elevation of Water Level [FT]
5	415.000	0.000	1.506	0.000	392.500	-392.500
4	431.000	0.000	1.506	13.500	392.500	-392.500
3	453.000	0.000	1.087	427.500	392.500	-392.500
2	460.0000	0.0000	0.4195	13.5000	392.5000	-392.50000
1	466.0000	0.0000	0.0000	0.0000	392.5000	-392.50000
0						



1.4. Monitoring Well PTX06–1056 Before Redevelopment



1.5. Monitoring Well PTX06–1056 After Redevelopment



1.6. Monitoring Well PTX06–1068

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Information regarding water resources in Texas is available at
http://tx.usgs.gov/

Stanton, Thomas, and Stovall—Analysis of Vertical Flow During Ambient and Pumped Conditions in Four Monitoring Wells at the Pantex Plant, Texas—OFR 2009–1017

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