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ENTERED

U.S. Geological Survey
New Mexico Water Science Center
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PROPOSAL: AQUIFER PROPERTIES, WATER-QUALITY, AND DIRECTIONS OF GROUNDWATER FLOW UNDER SELECTED PUMPING SCENARIOS NEAR THE RIDGECREST WELL FIELD, ALBUQUERQUE, NEW MEXICO

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SUMMARY

Between 1950 and 1999, an underground pipe used to offload aviation fuel at the Kirtland Air Force Base Bulk Fuels Facility leaked fuel into the subsurface. The fuel has formed a plume of light nonaqueous phase liquid on the water table that is elongated to the north-northeast and extends toward public-supply wells in the Albuquerque Bernalillo County Water Utility Authority's Ridgecrest well field. Further movement of the fuel plume towards the Ridgecrest well field could affect the quality of the water extracted from Ridgecrest wells.

The objective of this study is to provide hydrologic characterization and analysis to the Water Authority that will assist them in determining preferred options for managing groundwater resources that may potentially be affected by the Kirtland Bulk Fuels Facility plume. Tasks to fulfill this objective will include installing observation wells, sampling the observation wells, conducting an aquifer test, modeling pumping scenarios, writing and publishing a report to document the modeling scenarios, refining the USGS Middle Rio Grande basin Groundwater Flow Model, and writing and publishing a report documenting the USGS model refinements and results of model simulations.

BACKGROUND

Between 1950 and 1999, an underground pipe used to offload aviation fuel at the Kirtland Air Force Base (KAFB) Bulk Fuels Facility (BFF) leaked an estimated two to eight million gallons of fuel into the subsurface (U.S. Air Force, 2011). Since moving down through the unsaturated zone to the water table, the fuel has formed a plume of light nonaqueous phase liquid on the water table. The plume, elongated to the north-northeast from near the BFF, extends toward public-supply wells in the Albuquerque Bernalillo County Water Utility Authority's (Water Authority) Ridgecrest well field. Ridgecrest wells #3 and #5 are potentially the closest to the leading edge of the KAFB BFF fuel plume.

Organic compounds detected in groundwater from fuel plume monitoring wells include gasoline range organics (GRO), diesel range organics (DRO), benzene, toluene, ethyl benzene and xylenes (BTEX), and ethylene dibromide (EDB) (U.S. Air Force, 2011a, 2011b). Further movement of the fuel plume towards the Ridgecrest well field could affect the quality of the water extracted from Ridgecrest wells.

The U.S. Air Force (USAF) (Kirtland Air Force Base [KAFB] and the Air Force Civil Engineer Center [AFCEC]) have been conducting aquifer characterization and monitoring studies to determine the extent, transport, and fate of the fuel plume. However, both the Water Authority and USAF have determined that the U.S. Geological Survey's (USGS) hydrologic capabilities and long-term experience in the Albuquerque area could benefit the overall study effort with respect to improved characterization of the hydrogeology of the area of interest and analysis of the potential effects of changes in aquifer stresses on hydraulic gradients and directions of groundwater flow.

OBJECTIVES AND SCOPE

The objective of this study is to provide hydrologic characterization and analysis to the Water Authority that will assist them in determining preferred options for managing groundwater resources that may potentially be affected by the Kirtland Bulk Fuels Facility plume. The tasks that the USGS will complete to meet this objective are discussed in the Approach section of this proposal. Although the groundwater flow model that will be used in this study includes the entire middle Rio Grande Basin, the focus of this study will be the area affected or potentially affected by the BFF. Some new data associated with well drilling and aquifer testing will be collected for this study, but the study will largely use existing data.

RELEVANCE AND BENEFITS

This study will benefit the Water Authority and the U.S. Air Force by providing information about potential effects of the BFF on groundwater resources and will help water managers minimize the negative effects on groundwater quality. The data collected during the study will improve the understanding of aquifer characteristics in an area heavily utilized for drinking-water supplies. The USGS will benefit from this study because of the planned updates to the USGS Middle Rio Grande basin groundwater flow model (McAda and Barroll, 2002, Bexfield and others, 2011) and the addition of lithologic and geophysical borehole logs, groundwater-level, groundwater-quality, and aquifer hydraulic data to the long-term USGS National Water Information system (NWIS) database.

APPROACH

The objectives of this study will be satisfied through the following tasks:

Task 1 – Install First Set of Observation Wells

A nest of 3 observation wells will be drilled near the Water Authority's Ridgecrest #5 public-supply well. The purpose of this observation well nest is to provide hydrogeologic data in a location near the Ridgecrest #5 supply well that could be affected by the KAFB BFF fuel plume. The well nest will be drilled in a location that is, to the best of our knowledge, located in the path or future path of the KAFB BFF fuel plume. The screen of the shallow well will be set so that it straddles the water table, about 500-600 feet below land surface; the screen of the deep well will be placed in a sandy zone at about 1,500 to 1,600 feet below land surface; and screen of the intermediate-depth well will be set in sandy zone about half way between the shallow and deep wells. A suite of geophysical borehole logs will be run prior to installation of wells in the borehole. A drilling plan is attached that describes the proposed drilling operation in more detail (Attachment A).

This observation well nest will be incorporated into the USGS observation-well network that is used to monitor regional water levels and is operated under a separate agreement with the Water Authority.

Task 2 – Sample observation wells

After the 3 observation wells have been installed and developed, we will collect samples for water-quality analysis. If desired, we will provide sample splits (a sample taken from a single source that is divided into subsamples) to KAFB, the New Mexico Environment Department, and (or) the U.S. Environmental Protection Agency.

Groundwater samples will be collected from the three newly-installed observation wells, from Ridgecrest well #3, and Ridgecrest well #5. Field water-quality parameters of pH, specific conductance, temperature, and dissolved oxygen will be monitored during sampling. Samples will be collected from the observation wells using a submersible pump. Samples will be collected from Ridgecrest wells #3 and #5 from an existing tap at each well.

To avoid carryover or cross contamination between the wells being sampled, sampling equipment will be cleaned prior to sampling each well with a Liquinox/tap-water solution, rinsed with deionized water, and finally rinsed with high-purity methanol. Quality assurance and quality control measures will include the collection of one equipment blank and an associated source solution blank, one field blank and an associated source solution blank, and one sample for replicate analysis.

Water samples will be collected using and standard procedures outlined in the USGS National Field Manuel for the Collection of Water-Quality Data (https://water.usgs.gov/owq/FieldManual). Samples will be processed and preserved as specified for each analysis and will be shipped overnight to the USGS National Water-Quality Laboratory (NWQL), the USGS Reston Stable Isotope Laboratory (RSIL), the USGS Reston CFC Laboratory, or the Lamont-Doherty Earth Observatory laboratory. Results of most analyses should be available within about a month but the tritium/helium results could take 6 months or more.

Groundwater samples from the three observation wells and from the Ridgecrest #3 and #5 wells will be analyzed for constituents shown in the following table.

List of Water Analyses

Analytical Schedule or Analyte	Number of Environmental Samples	Number of Replicates	Number of Source Solution and equipment Blanks
Major Ions (NWQL SH2750)	5	1	4
Metals (NWQL SH2710)	5	1	4
Nutrients (NWQL SH2755)	5	1	4
Volatile organic compounds (NWQL 2020)	5	1	4
UV absorbing organics (NWQL LC2614/2615)	5	1	4
Dissolved organic carbon (NWQL LC2613)	5	1	4
Tritium (Lamont LC2112)	5	1	4
Deuterium/O-18 (RSIL 1142)	5	0	0
Carbon 14 plus 13C/12C (NWQL SH2255)	5	0	0
Tritium/helium (Lamont 1033)	5	0	0
Chlorofluorocarbons (Reston CFC lab)	5	0	0
Dissolved Gases (Reston CFC lab)	5	0	0
Low-level chlorinated VOCs (Reston CFC lab)	5	0	0
Helium prescreen (Reston CFC lab)	5	0	0

Task 3 – Install Second Set of Observation Wells

If determined to be necessary, a second nest of 3 observation wells will be installed, probably near Ridgecrest well #3, during federal Fiscal Year 2014. The placement, timing, and funding for these wells will be contingent on need and will be determined at a future date and in consultation with the cooperator.

Task 4 – Conduct Aquifer Test

After the observation wells near the Ridgecrest #5 supply well have been installed, the USGS will conduct an aquifer test and analyze the results. The aquifer-test data will provide important information about vertical and horizontal hydraulic properties of the aquifer near the Ridgecrest well field. The aquifer test will be done in three phases: 1) a 4-week non-pumping phase, a 2-week pumping phase, and a 4-week recovery phase. The lengths of these phases, as stated in the previous sentence, are approximate. Hydrologic analyses will be done prior to the aquifer test to refine the required lengths of the phases.

Water levels in the three observation wells will be monitored before, during, and after the pumping phase of the aquifer test using submersible pressure transducers. If feasible, a pressure transducer will also be used to monitor water levels in the Ridgecrest #5 well – the transducer would be placed inside of 1-inch threaded PVC casing (open at the bottom) installed inside the supply well's main casing. If another observation well is available, and is in a location that is orthogonal to a line drawn between the supply well and observation wells, that well also will be equipped with a submersible transducer during the aquifer test.

Water levels in the supply and observation wells will be recorded at hourly intervals for the 4-week periods prior to and after the pumping phase of the aquifer test. During the 2-week pumping phase of the aquifer test, water levels in the supply and observation wells will be monitored at time intervals ranging from one second at the beginning of pumping to 15 minutes at the end of pumping. Water-level monitoring prior to the aquifer test will be used to observe water-level trends; water-level monitoring during the recovery phase of the aquifer test will be used to analyze water-level recovery and to observe water-level trends after the aquifer test.

The Ridgecrest #5 supply well will have to be off during the 4 weeks prior to the pumping phase of the aquifer test and off for 4 weeks during the recovery phase of the aquifer test. The volume of water pumped from the Ridgecrest #5supply well during the pumping phase of the aquifer test will be monitored and recorded using the existing flow meter in the supply well's well house.

Data from the aquifer test will be analyzed using methods that will provide estimates of horizontal and vertical hydraulic conductivity, aquifer specific storage, and horizontal and vertical anisotropy (http://pubs.usgs.gov/of/2002/ofr02197). A description of the aquifer test and analysis will be written according to USGS policy and submitted to the USGS Regional Groundwater Specialist for approval. Once the aquifer test is approved it will be electronically archived at the USGS New Mexico Water Science Center office (NMWSC) in Albuquerque and will be available on request.

Task 5 – Modeling of Pumping Scenarios

The existing USGS Middle Rio Grande groundwater flow model, developed by McAda and Barroll (2002) and refined as described by Bexfield and others (2011), will be used to simulate how changes in supply-well pumping affect the movement of groundwater in the vicinity of the Ridgecrest well field. The model, as refined by Bexfield and others (2011), will be used to perform groundwater flow simulations for this project. With the exception of pumping, the model will be used, without modifications to the existing model cell size, properties, and boundary conditions, to simulate present and future well-pumping scenarios. Groundwater movement will be tracked in the model by using the MODPATH particle-tracking software. MODPATH enables the user to track "particles" of groundwater as they move in response to model stresses such as pumping. MODPATH cannot simulate the movement of the chemical constituents making up the KAFB BFF fuel plume because MODPATH does not account for dispersion, retardation, or natural attenuation of the chemical constituents.

Task 6 – Write and Publish Report

The results of model simulations of pumping scenarios and particle tracking will be documented in a USGS Scientific Investigations Report. The report will briefly describe the past development of the groundwater flow model, describe the pumping scenarios, and present the results of particle tracking.

Task 7 – Refine USGS Groundwater Flow Model

The existing groundwater flow model, as described by Bexfield and others (2011), will be refined using data obtained from observation-well drilling and aquifer testing during this project, and other aquifer property and hydraulic information that is available. Model refinements could include making the grid-cell size smaller and improving estimates of hydraulic conductivity, porosity, vertical distribution of supply-well water intake, and horizontal and vertical anisotropy. The refined area of the model will be calibrated to observed groundwater levels and, if the data are available, to observations of groundwater flow into the Ridgecrest well. Model calibration will be done primarily using parameter-estimation techniques.

Model refinements will allow the model to more closely simulate observed hydrologic conditions in the aquifer in the area of the Kirtland Bulk Fuel plume and Ridgecrest well field. The refined model will be used to simulate selected supply-well pumping scenarios and other scenarios as may be identified by the USGS and cooperator. Simulated movement of groundwater will be mapped using the MODPATH particle-tracking program.

Task 8 – Write and Publish Report

The results of model refinement and simulations of supply-well pumping scenarios will be documented in a USGS Scientific Investigations Report.

QUALITY-ASSURANCE PLAN

All data collection will be conducted according to the quality-assurance plans on file at the USGS NMWSC in Albuquerque. Deviations from established quality-assurance procedures will be documented in writing. The refined and calibrated model will be archived electronically at the USGS NMWSC in Albuquerque and will be available on request. Geophysical borehole logs and results of the aquifer test will be electronically archived at the USGS NMWSC in Albuquerque.

Daily field notes will be recorded for all field activities in accordance with USGS procedures. Water-level measurements and water-quality data will be reviewed and entered into the USGS National Water Information System (NWIS) and will be available online through the USGS NWIS Web pages.

Progress reports will be prepared quarterly and distributed to the Water Authority to document project activities.

PRODUCTS

Products of this study will include:

1. Installation of three observation wells;
2. Geohydrologic data obtained during observation-well drilling;
3. Water-level data from observation and supply wells;
4. Aquifer-test data and analysis;
5. A report documenting simulations of supply-well pumping scenarios;

6. A refined groundwater flow model of the Kirtland Bulk Fuel plume and Ridgecrest well field area;
7. A report documenting the refined model and the results of additional supply-well pumping scenarios.

SAFETY PLAN

USGS safety procedures will be followed at all times. The USGS Project Chief or Field Operations Chief will brief all project personnel on field safety issues prior to performing field work. All USGS project personnel will read and become familiar with the Job Hazard Analysis developed for this project.

ARCHIVAL PLAN

Groundwater-level and water-quality data will be archived electronically in the USGS NWIS database. Original field sheets and notes will be kept on file at the USGS NMWSC for 3-5 years and then will be sent to the National Records Center for preservation. The results of the aquifer test will be saved in an electronic archive maintained at the USGS NMWSC. Borehole and flow-meter logs will be electronically archived in the USGS NMWSC Geophysical Borehole Log Archive.

REFERENCES

Bexfield, L.M., Heywood, C.E., Kauffman, L.J., Rattray, G.W., and Vogler, E.T., 2011, Hydrogeologic setting and groundwater flow simulation of the Middle Rio Grande Basin regional study area, New Mexico, *section 2 of* Eberts, S.M., ed., Hydrologic settings and groundwater-flow simulations for regional investigations of the transport of anthropogenic and natural contaminants to public-supply wells— Investigations begun in 2004: U.S. Geological Survey Professional Paper 1737–B, p. 2–1 to 2–61.

McAda, D.P., and Barroll, Peggy, 2002, Simulation of ground-water flow in the middle Rio Grande basin between Cochiti and San Acacia, New Mexico: U.S. Geological Survey Water-Resources Investigations Report 02-4200, 81 p.

U.S. Air Force, 2011a, Kirtland Bulk Fuels Facility cleanup questions and answers as of May 3, 2011: U.S. Air Force web document accessed January 28, 2013 at: *http://www.kirtland.af.mil/environment.asp* .

U.S. Air Force, 2011b, Kirtland Air Force Base, NM Bulk Fuels Facility Spill Assessment Report: United States Air Force Report to Congressional Committees, House Report 111-201, page 115.

Personnel

The following table lists personnel, their grades, and the number of hour they will be spending on the tasks described in the proposal.

PERSONNEL

Position	Grade	Time Spent on Project Activities					
		Federal Fiscal Year			Water Authority Fiscal Year		
		FY13	FY14	FY15	FY13	FY14	FY15
Project Chief, Hydrologist	GS-13	584	1,356	664	456	1,175	973
Senior Hydrologic Technician	GS-11	296	72	0	296	72	0
Hydrologic Technician	GS-8	100	16	0	100	16	0
Student	GS-5	0	102	0	0	102	0
Student	GS-5	156	56	0	156	56	0

BUDGET

Estimated costs for performing the tasks described in this proposal are given in the table below. The burden (overhead) amounts shown for Federal fiscal years 2014 and 2015 are estimates and could be higher or lower, depending on Federal and State fiscal health in those years. Adjustments to the burden amounts will be made as the burden rates become known.

BUDGET

Task	Sub Task	Federal Fiscal Year			Water Authority Fiscal Year		
		FY2013	FY2014	FY2015	FY2013	FY2014	FY2015
		Net Cost	Net Cost	Net Cost	Net Cost	Net Cost	Net Cost
Project administration	NMWSC labor	9,360	12,480	9,360	6,240	12,480	12,480
	TASK TOTAL	**9,360**	**12,480**	**9,360**	**6,240**	**12,480**	**12,480**
Observation well installation	NMWSC labor	17,520			17,520		
	Communication, Rental services	5,755			5,755		
	Vehicles	225			225		
	Drill crew labor and travel	162,875			162,875		
	Drilling supplies	28,219			28,219		
	Geophysical logging	10,000			10,000		
	TASK TOTAL	**224,594**			**224,594**		
Sampling	NMWSC labor	3,008			3,008		
	Laboratory analyses	22,299				22,299	
	Sampling supplies	1,000				1,000	
	Sampling equipment	1,900			1,900		
	Shipping	200				200	
	TASK TOTAL	**28,407**			**4,908**	**23,499**	
Aquifer test and analysis	Labor		12,328			12,328	
	Equipment	19,052			19,052		
	TASK TOTAL	**19,052**	**12,328**		**19,052**	**12,328**	
Model pumping scenarios	Labor	13,000			13,000		
	Supplies	2,000			2,000		
	TASK TOTAL	**15,000**			**15,000**		

BUDGET—continued							
Task	Sub Task	Federal Fiscal Year	Water Authority Fiscal Year				
		FY2013	FY2014	FY2015	FY2013	FY2014	FY2015
		Net Cost	Net Cost	Net Cost	Net Cost	Net Cost	Net Cost
Report model results	Labor	15,600	2,600		10,400	7,800	
	SPN - editing & report layout	4,000	3,500			7,500	
	Printing		1,000			1,000	
	TASK TOTAL	**19,600**	**7,100**		**10,400**	**16,300**	
Refine model	Labor		67,860			50,895	16,965
	TASK TOTAL		**67,860**			**50,895**	**16,965**
Report refined model results	Labor			33,800			33,800
	SPN - editing & report layout			12,000			12,000
	Printing			5,000			5,000
	TASK TOTAL			**50,800**			**50,800**
	Total Net Cost	**316,013**	**99,768**	**60,160**	**280,194**	**115,502**	**80,245**
	Burden	**83,838**	**96,684**	**49,598**	**73,835**	**86,594**	**69,691**
	GROSS COST	**399,851**	**196,452**	**109,758**	**354,029**	**202,096**	**149,936**

Funding

The amount in the shaded cell in the funding table below ($343,029) is the amount of new funding to be contributed by the Water Authority for the work to be done through June 30, 2013 (the end of the Water Authority Fiscal Year). At this time there is $11,000 in the existing agreement between the Water Authority and the USGS that is not already allocated to on-going studies and that can be utilized for work described in this proposal (existing agreement ends on June 30,2013). The availability of USGS matching funds to offset some of cost to the Water Authority will be reevaluated prior to the beginning of new Water Authority fiscal year in July, 2013. If USGS matching funds are available the funding table below will be updated.

FUNDING						
	Federal Fiscal Year			Water Authority Fiscal Year		
Agency	**FY2013**	**FY2014**	**FY2015**	**FY2013**	**FY2014**	**FY2015**
Water Authority, existing funding agreement	5,500			5,500		
USGS, existing funding agreement (including 17.7% Bureau Science Support	5,500			5,500		
USGS (NMWSC+17.7% Bureau Science Support)	0*	0*	0*	0	0*	0*
Water Utility Authority	388,851	196,452	109,758	343,029	202,096	149,936
Totals	**399,851**	**196,452**	**109,758**	**354,029**	**202,096**	**149,936**

*The existing USGS-Water Authority program will be reevaluated prior to the beginning of the Water Authority's 2014 fiscal year to see what funds may be available to match with Water Utility Authority Funds in the fourth quarter of Federal Fiscal year 2013 and Water Authority and Federal Fiscal years 2014 and 2015.

WORKPLAN

The anticipated schedule of work is shown in the table below. If there are delays in funding or changes in task priorities, the workplan schedule will be adjusted.

WORKPLAN

TASK	SUB TASK	2013 J	F	M	A	M	J	J	A	S	O	N	D	2014 J	F	M	A	M	J	J	A	S	O	N	D	2015 J	F	M	A	M	J	J	A	S
Project administration	NMWSC labor	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Observation well installation	NMWSC labor		X	X	X																													
	Drill crew labor and travel			X	X																													
	Geophysical logging				X																													
Sampling	NMWSC labor					X																												
	Laboratory analyses					X	X	X	X	X	X	X	X																					
Aquifer test & analysis	NMWSC labor											X	X	X																				
Model pumping scenarios	NMWSC labor			X	X	X	X																											
Report model results	NMWSC labor					X	X	X	X	X	X	X																						
Refine model	NMWSC labor										X	X	X	X	X	X	X	X	X	X	X	X												
Report refined model results	NMWSC labor																						X	X	X	X	X	X	X	X				

Attachment A

DRILLING PLAN FOR INSTALLATION OF THREE NESTED OBSERVATION WELLS NEAR THE RIDGECREST #5 PUBLIC SUPPLY WELL, ALBUQUERQUE, NM

GENERAL DESCRIPTION OF OBSERVATION WELLS

Three nested observation wells will be installed in a single borehole near the Albuquerque Bernalillo County Water Use Authority (Water Authority) Ridgecrest #5 public-supply well. The observation wells will be used to monitor groundwater levels, obtain groundwater samples for water-quality analyses, and determine hydraulic properties of the aquifer near the Ridgecrest well. We expect that it will take about 3-4 weeks to setup, drill, and install and develop the wells.

LOCATION AND DEPTH OF OBSERVATION WELLS

The observation well nest will be located near the Ridgecrest well #5 in a position between the Ridgecrest well and the Kirtland Bulk Fuel plume that extends north-northeast from Kirtland Air Force Base (KAFB). The distance between the Ridgecrest well and the observation well nest will be guided by requirements for an aquifer test, availability of places to drill, and the presence of other observation wells in the area.

The total depth of the borehole will be about 10 feet deeper than the bottom depth of the Ridgecrest #5 well screen, or about 1,460 feet below land surface (fbls).

The observation well screens will be placed at shallow, intermediate, and deep depth intervals. The shallow well screen will be 50 feet long and will be placed across the water table, from about 35 feet above the water table to about 15 feet below the water table. The deep well screen will be 10 feet long and will be placed in a productive aquifer interval near the bottom depth of the selected Ridgecrest well's intake screen. The middle well screen will be 10 feet long and will be placed in a productive zone between the shallow and deep wells.

DRILLING

Borehole diameters will vary from about 11 ½ inches in diameter at the surface to 6 ¾ inches in diameter below the bottom of the intermediate-depth well (roughly below about 1,000 fbls). The borehole will be drilled using mud-rotary to about 1,460 fbls. Drilling fluids will consist of bentonite mud with a polymer additive. The polymer additive serves to decrease the loss of drilling fluids from the borehole into the surrounding aquifer. The drilling crew will make every reasonable effort to ensure that the viscosity and gel strength of the drilling mud will provide optimal sample returns. However, the selection of drill mud and viscosity is based primarily on maintaining the integrity of the borehole so that drilling, logging, and well installation is not compromised. Drill cuttings will be collected at 10-foot intervals during drilling operations.

About 24 hours prior to reaching the planned depth, the USGS will notify the borehole geophysical logger team in of the need for their services. Geophysical logs to be obtained from the borehole will include: resistivity/conductivity, natural gamma, neutron, sonic, and caliper.

Upon evaluation of the geophysical and driller logs, screened intervals for each well will be determined by the USGS project chief in consultation with a representative of the Water Authority. Once the observation well screened intervals have been chosen, installation of the wells will begin.

WELL INSTALLATION

The deep well will be installed first, then the intermediate-depth well, followed by the shallow well. The deep and intermediate-depth wells will each consist of a bottom-capped 10-foot section of stainless steel casing to serve as a sump, a 10-foot stainless steel screen with 0.010-inch wide slots, then polyvinyl chloride (PVC) casing to the surface. The shallow well will consist of a bottom-capped 10-foot section of PVC casing, a 50-foot PVC screen with 0.010-inch wide slots, then PVC casing to the surface. Stainless steel casing and screen will be grade 316 or better, flush threaded, and will have an outside diameter of 2.5 inches. PVC casing and screen will be schedule 80, flush-threaded, with an outside diameter of 2.5 inches. O-rings will be placed at each casing joint to ensure a tight seal. At the surface, the three PVC well casings will be contained within an outer steel casing set in cement. The well installation can be finished at 2-3 feet above land surface or flush-to-land surface, depending esthetic and security needs at the location chosen for the wells. Flush-to-land surface installations are less desirable than wells finished above land surface because of the possibility of rain and runoff carrying contaminants into the wells.

Borehole fill material will be placed in the borehole using a 2-inch tremie pipe. Medium-grained silica sand (0.01-0.02 inch) will be placed in the borehole adjacent to the sump and screened interval of the deep well to a depth of 20 to 30 feet above the top of the screen. Bentonite pellets will be placed on top of the silica sand for a thickness of no less than 10 feet. Benseal (a bentonite-mud mixture) will be pumped into the borehole to fill the section from the top of the bentonite pellets to about 15 feet below the bottom of the screened interval of the middle well. Native aquifer material will be placed on top of the Benseal, not to exceed 10 feet (generally 5 feet). The middle well will be installed to the desired screened interval, then silica sand will be placed to a depth of 20 to 30 feet above the top of the screen followed by no less than 10 feet of bentonite pellets, which in turn will be followed by Benseal to a depth of about 15 feet below the bottom of the screen for the shallow well. A 5 to10 foot-thick interval of native aquifer material will be placed on top of the Benseal. The shallow well will be installed so the top of the screen is about 35 feet above the water table, as determined from the borehole geophysical logs and water-level measurements in nearby wells. Silica sand will be placed in the borehole along the screen and sump interval to a depth of 20 to 30 feet above the top of the screen and no less than 10 feet of bentonite pellets will be placed above the silica sand. From the top of the bentonite pellets to land surface, a mixture of cement and bentonite will be placed in the borehole, providing a water-tight seal. Once all wells are installed, development of the wells will begin.

The wells will be developed to the point where the discharge from each well is clear in appearance. The two deep wells will be developed by an airlift, and the water table well will be developed using a bailer (Driscoll, 1986). Once development is complete for all wells, wellhead protection, consisting of a 12 to 16-inch diameter steel casing with a locking lid will be installed.

All land-surface disturbances caused by the drilling effort at the drill site will be returned, as close as possible, to the original conditions prior to the start of drilling.

RESPONSIBILITIES OF PARTIES

USGS responsibilities will include:

- Collaborating with the Water Authority to determine the location and vertical depth of each observation well;
- Purchasing all the needed well-completion equipment and materials, which will include surface casing, well casing and screens, silica sand, cement, Benseal, and bentonite pellets and chips;
- Designing, drilling, completing, and developing observation wells;
- Obtaining the necessary borehole geophysical logs;
- Returning the drill site as nearly as possible to "as found" conditions;
- Renting a security fence for each site; and
- Obtaining clearance at the drill site for underground utilities.

Water Authority responsibilities will include:

- Collaborating with the USGS to determining the location and vertical depth of each observation well;
- Obtaining all permits/permissions/clearances/ necessary to access the drilling location, including road barricade permits and associated traffic control plans, and archeological and plat surveys, if needed;
- Providing for lithologic descriptions of the drill cuttings;
- Renting and providing dumpsters for containing drilling fluid and cuttings (drilling wastes) and providing for the final disposition of the drilling wastes, including hazardous-waste characterization, if necessary;
- Obtaining overnight security for the site during drilling operations; and
- Purchasing dedicated submersible Bennett pumps equipped with Teflon discharge tubing for each observation well.

DATA DISPOSITION

The location of the observation-well nest, well-construction details, completion information, and water-level measurements, and other hydrologic data obtained from the wells will be entered into the USGS NWIS database for documentation and retrieval purposes and for availability to the public. Geophysical logs will be archived electronically in the USGS NMWSC log archive.

REFERENCE

Driscoll, Fletcher G., 1986, Groundwater and wells (2nd ed.): St. Paul, MN, Johnson Division, 1089 p.