Evaluation of Aquifer Interconnection from Aquifer Characteristics Computed by Using Specific Capacity Data within the Vicinity of the Tremont Barrel Fill Site, Clark County, Ohio

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Open-File Report 2015–1026

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

U.S. Department of the Interior
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U.S. Geological Survey, Reston, Virginia: 2015

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Suggested citation:
Gahala, A.M., 2015, Evaluation of aquifer interconnection from aquifer characteristics computed by using specific capacity data within the vicinity of the Tremont Barrel Fill site, Clark County, Ohio: U.S. Geological Survey Open-File Report 2015-1026, 27 p., http://dx.doi.org/10.3133/ofr20151026.

ISSN 2331-1258 (online)

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Abstract

The Tremont Barrel Fill site is immediately north of the Tremont City Landfill near Tremont City, Clark County, Ohio. The site was an unlined pit used as a repository for disposing industrial liquid wastes and sludge from 1976 through 1979. Previous investigations led the U.S. Environmental Protection Agency (USEPA) to conclude that the site poses a contamination risk to nearby residents relying on private supply wells opened to the underlying deep sand and gravel and limestone aquifers. The USEPA also concluded there is a potential risk to the residents of the nearby Tremont City; the city obtains its municipal water supply from the Mad River Valley aquifer, which is recharged by the adjacent limestone aquifer. The U.S. Geological Survey (USGS) assessed the degree of hydraulic interconnection, and thus possible contaminant pathway(s), between the two aquifers (the sand and gravel and the limestone) underlying the Barrel Fill site, with consideration for the impact of an identified interconnection between the limestone and the Mad River Valley aquifer used for municipal supply.

Aquifer interconnection between the sand and gravel aquifer overlying the limestone aquifer is assessed by analysis of specific capacity data from well-construction logs for derivation of estimates of transmissivity (T) and horizontal hydraulic conductivity (K_h). Data of this nature is limited in the control or knowledge about how well these data were collected and reported; therefore, the T and K_h are estimations. Similar values of T and K_h are used to infer the degree of aquifer interconnection based on the USEPA Hazard Ranking System, which states that aquifers are considered interconnected when the hydraulic conductivities are within two orders of magnitude.

The results of the hydraulic analysis from 127 wells open to either the sand and gravel or the limestone aquifer indicate that the transmissivity of these aquifers is within one order of magnitude and horizontal hydraulic conductivity is within two orders of magnitude. As such, on the basis of the applied ranking system the two aquifers can be considered hydraulically interconnected.

Introduction

The Tremont Barrel Fill (Operable Unit) site is about 1.5 miles from Tremont City, Clark County, Ohio (fig. 1). Within the 8.5-acre Barrel Fill site, approximately 51,500 drums and 300,000 gallons of uncontained industrial liquid wastes and sludge were disposed of in unlined waste cells from 1976 through 1979 (Haley and Aldrich, 2006). On the basis of prior investigations, the U.S. Environmental Protection Agency (USEPA) concluded that there is a potential future risk to human health and the environment, if contaminants move to underlying regional water-supply aquifers (U.S. Environmental Protection Agency, 2011). The U.S. Geological Survey (USGS) in cooperation with the USEPA estimated the degree of interconnection between the sand and gravel aquifer and the underlying limestone aquifer beneath the site.

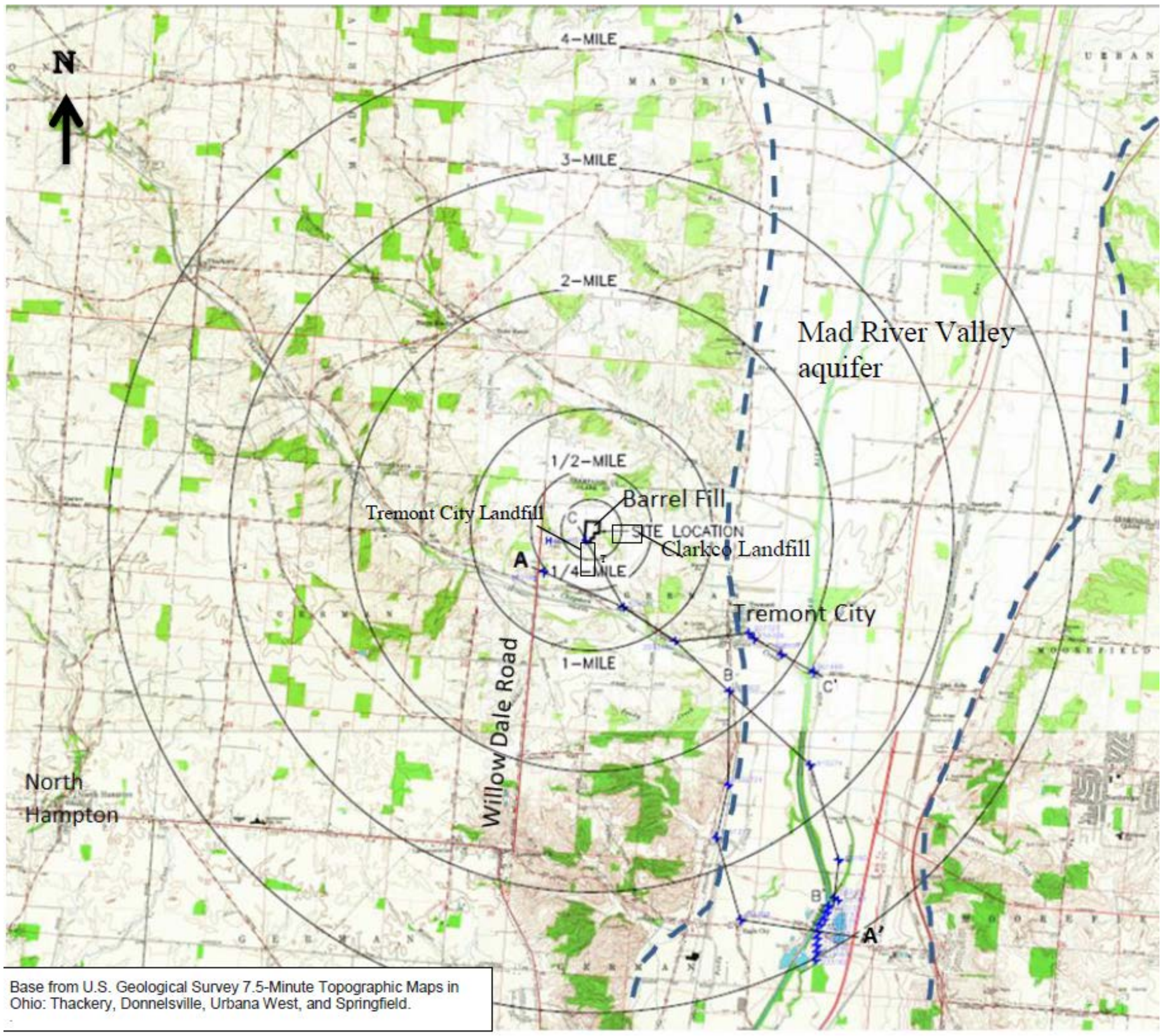

Figure 1. Map of the Barrel Fill site and distance to Tremont City and Mad River Valley aquifer (modified from Weston Solutions, Inc., 2013) [Cross-section B-B' through C-C' are not shown in this report]. Hatched lines indicate the approximate lateral extent of Mad River Valley aquifer (Sheets and Yost, 1994, fig. 1).

The USEPA Hazardous Ranking System (HRS) can be used to classify two adjoining aquifers as interconnected if the values of transmissivity (T) and horizontal hydraulic conductivity (K_h) of both aquifers are within two orders of magnitude and there are no continuous intervening materials of significantly lower K_h (for example, more than two orders of magnitude lower) (U.S. Environmental Protection Agency, 2011). This classification is supported by the hydrologic principle that similar hydraulic conductivity will result in preferential flow of water in geologic material of higher hydraulic conductivity and limited flow in geologic materials of lower hydraulic conductivity (Focazio and others, 2002).

Prior hydrogeologic investigations beneath and near the Barrel Fill site (Eagon and Associates, 1994; Voight and others, 2002; Haley and Aldrich, 2006) focused primarily on the unconsolidated deposits and provided no information on the limestone aquifer.

Therefore, the only data available to assess the potential for hydraulic interconnection between the sand and gravel aquifer and the limestone aquifer are from logs of residential wells drilled within a 2-mile radius from the Barrel fill site. Assessing the hydraulic interconnection between these aquifers is required to determine potential groundwater and contaminant flow pathways between the aquifers and potentially to the Mad River Valley aquifer.

A hydraulic interconnection between the sand and gravel and limestone aquifers has already been considered for the area from a previous investigation by Dumouchelle (2001), who published a map of the groundwater potentiometric surface of the limestone aquifer in Clark County using a combination of wells opened to the sand and gravel aquifer and the underlying limestone aquifer. Water elevations that are relatively similar between two aquifers are an indication that the aquifers are interconnected. Dumouchelle explained that if hydraulic connection between these aquifers was minimal, then water levels in glacial sediments should differ notably from water levels in bedrock. The study examined wells screened in the bedrock and wells screened in the sand and gravel. Areas of the study relevant to the present investigation of the Barrel Fill site included southwest of the site near the town of North Hampton, and northwest of the site near the landfill along Willow Dale Road (fig. 1). The water levels from each area were within 5 feet (ft) of each other, which was in the margin of error of the estimated land-surface altitude (+/-5 ft). Therefore, Dumouchelle concluded that the two aquifers were interconnected, and the water levels from wells completed in both aquifers were used to create the potentiometric-surface map and to interpret groundwater flow directions.

Purpose and Scope

This report assessed the vertical hydraulic interconnection between two aquifers underlying the Barrel Fill site near Tremont City, Ohio by evaluating the values of T and K_h derived from well-construction and testing data of 127 nearby residential wells tapping into the aquifers. The estimated hydraulic values from each aquifer are compared to determine the degree of aquifer connectivity, as based on the USEPA Hazard Ranking System (1992).

Geology

The geologic units of interest to this investigation consist of (1) the basal fractured limestone/dolomite of the Niagara Formation of Silurian age (Norris and others, 1952; Vormelker and others, 1995), (2) the directly overlying deep alluvial outwash deposits of Wisconsinan sand and gravel, and (3) the younger but related end moraine deposits (Norris and others, 1952) of till with thin interbedded sands (Haley and Aldrich, 2006) in upland areas near the Barrel Fill site. Regionally, the limestone deposits are about 170 ft thick, and the bedrock surface is hummocky, weathered, and fractured. The sand and gravel deposits filling in the undulating bedrock surfaces range in thickness from less than 5 ft to as much as 80 ft. The till deposits with thin sand beds are about 100–200 ft thick in the vicinity of the Barrel Fill site. East of the site, the limestone formation was deeply incised during an Illinoisian interglacial period (fig. 2). The resulting Mad River Valley, which is greater than 200 ft deep in places, is filled predominately with sand and gravel deposited by the Wisconsinan glacial meltwater (Norris and others, 1952).

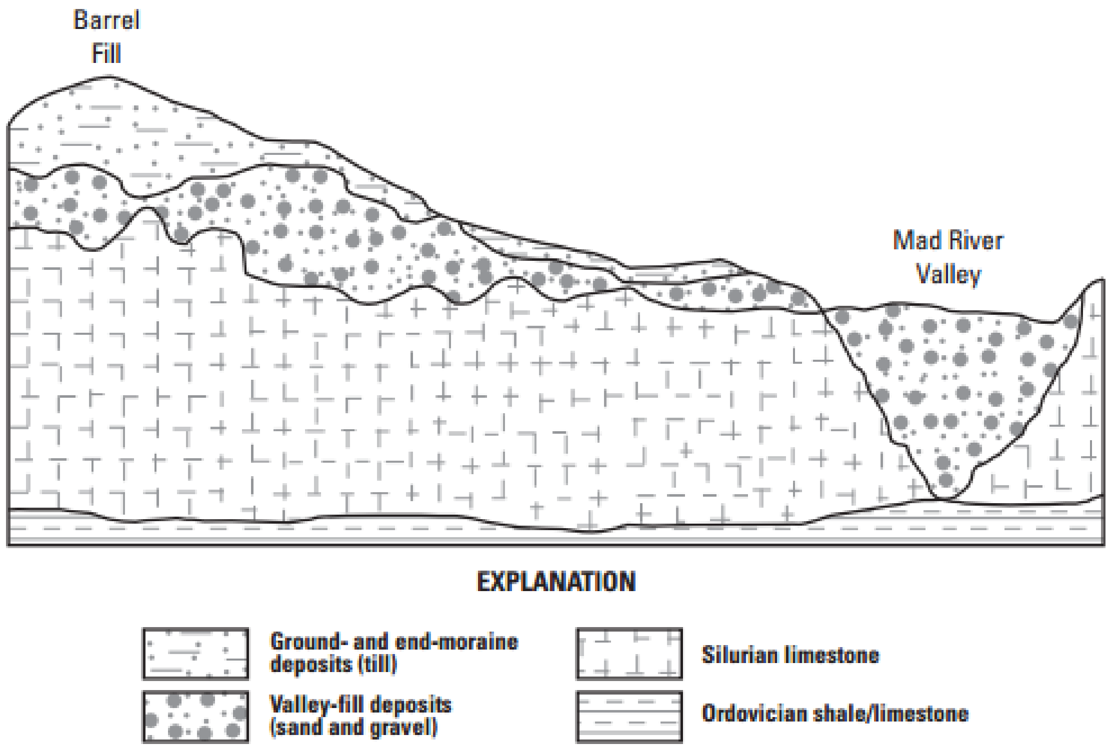

Figure 2. General schematic of geologic sections depicting the Silurian-age limestone/dolomite deposits incised by the Mad River Valley and infilled with sand and gravels (valley-fill deposits) (modified from Sheets and Yost, 1994, fig. 2).

Hydrology

Groundwater flow direction in the sand and gravel aquifer is generally from west to east beneath the Barrel Fill site and proposed Clarkco Landfill and from southwest to northeast beneath the Tremont City Landfill, toward the Mad River Valley aquifer (Eagon and Associates, 1994; Haley and Aldrich, 2006). The Mad River Valley aquifer is about 4 miles (mi) east of the Barrel Fill site and is a major groundwater source for Tremont City (fig. 1). The Mad River Valley aquifer receives a majority of its groundwater as lateral and upward flow from the adjacent limestone aquifer (fig. 2) (Sheets and Yost, 1994). Figure 3 is a cross section (A-A') transecting from about 0.25 mile south of the Barrel Fill site towards the southeast (Weston Solutions, 2013). Groundwater flows from the Barrel Fill site east towards the Mad River Valley aquifer.

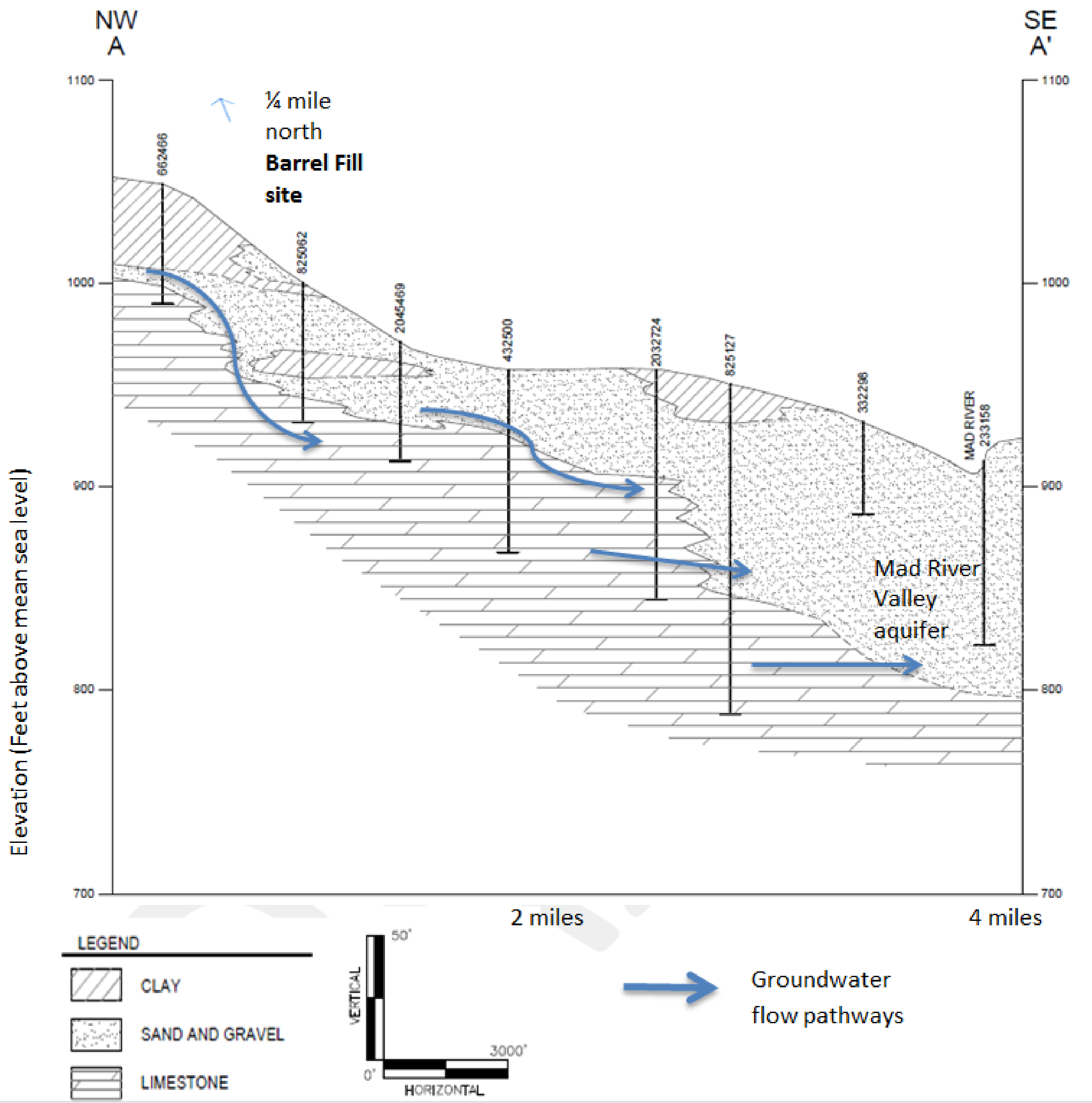

Figure 3. Cross section from Barrel Fill site to Mad River (A-A') with generalized groundwater flow pathways. Groundwater flows through the sand and gravel and the limestone and discharges into the Mad River Valley aquifer. Well numerical identifiers are well log ID from the Ohio DNR ERiN database. Well log formation descriptions are provided in Appendix 4 (modified from Weston Solutions, 2013, Cross-section A-A').

The deep sand and gravel aquifer has an estimated K_h of 42.5 feet per day (ft/d), as estimated from aquifer tests of within wells at the Barrel Fill site (Eagon & Associates, 1994). The K_h of the limestone aquifer is 39.7 to 93.5 ft/d, as estimated during studies focused outside of the vicinity of the Barrel Fill site in surrounding counties (Norris and others, 1952; Sheets and Yost, 1994; Vormelker and others, 1995) and from textbook tables (Freeze and Cherry, 1979).

Methods

Aquifer interconnection is the hydraulic communication between two adjoining aquifers. For this study, the USGS assessed the degree of aquifer interconnection between the sand and gravel and the limestone aquifers by using the USEPA Hazard Ranking System (HRS). Under the HRS, aquifers can be considered interconnected if the representative values of K_h of the adjacent aquifers are within two orders of magnitude.

For this study, the USGS used data that were collected during well-efficiency tests (also referred to as specific-capacity tests) performed by individual drillers following well installation for residential supply wells within 2 miles of the Barrel Fill site. Data from slug tests and constant-discharge tests of monitoring wells within the Barrel Fill site, completed by Haley and Aldrich and by Eagon and Associates, were compared with the T and K_h estimated from the specific capacity method. These pumping rate and water-level drawdown data from these tests were used to derive estimates of the T and K_h of the two aquifers. The T and K_h are measurements of the rate of groundwater flow through a unit width aquifer under a unit hydraulic gradient (Fetter, 1994). Transmissivity has been shown to be a vertical average of hydraulic conductivities (Senior and Goode, 1999).

Well-construction logs provide data that essentially represent a simple aquifer test performed by the well driller. The data collected were the pumping rate (in gallons per minute) and resulting drawdown from static level during pumping (in feet). The pumping rate was divided by the drawdown to obtain the specific capacity, which is a measurement of well yield (Fetter, 1994). Specific capacity data are frequently used to estimate T when other types of aquifer tests are not available (Razack and Huntley, 1991; Huntley and others, 1992; Fetter, 1994). Specific capacity is the yield, or discharge (Q), of a direct measurement of the capacity of the well and it is dependent upon the hydraulic properties of the aquifer to which the well is open (Risser, 2010), but it also reflects the characteristics of the well. Wells screened within a formation (or aquifer) that have a greater K_h generally will have a greater specific capacity. The specific capacity of a well is greatest when the well is initially drilled and installed. Over time, the specific capacity decreases as a result of siltation, biofouling, and water-level fluctuation (Brown and others, 1999). Therefore, the specific capacity data is from when these wells were first installed and are considered to most accurately represent aquifer T and K_h. However, several data limitations exist and should be understood when using this type of data to estimate T and K_h. First, these tests were not completed by the USGS and were completed by over 50 different well drillers over many years. Variations in the accuracy of the tests, water level measurements, and pumping rates can result. Furthermore, there is no control on the quality assurance. For example, it is not known whether the driller developed the well before conducting the well-efficiency test, or if the driller continued to develop the well concurrently while performing the well-efficiency test. This may have some effect on the calculated hydraulic conductivities.

Well-construction logs were obtained from the Ohio Department of Natural Resources Division of Soil and Water Website Application, ERiN (2014). The application generates a report of all the wells located within an area of interest. A 2-mile buffer zone was selected from the center of the Barrel Fill site. The application identified over 220 residential wells within the buffer zone. Only wells with pumping data and drawdown information were selected for this study. A total of 127 residential wells located within a 2-mile radius of the Barrel Fill site (fig. 4) were analyzed for this analysis of aquifer hydraulic interconnection. Figure 5 is a general distribution of wells open to the limestone and sand and gravel aquifers. All necessary construction and hydraulic property data for these wells are provided in the Appendix.

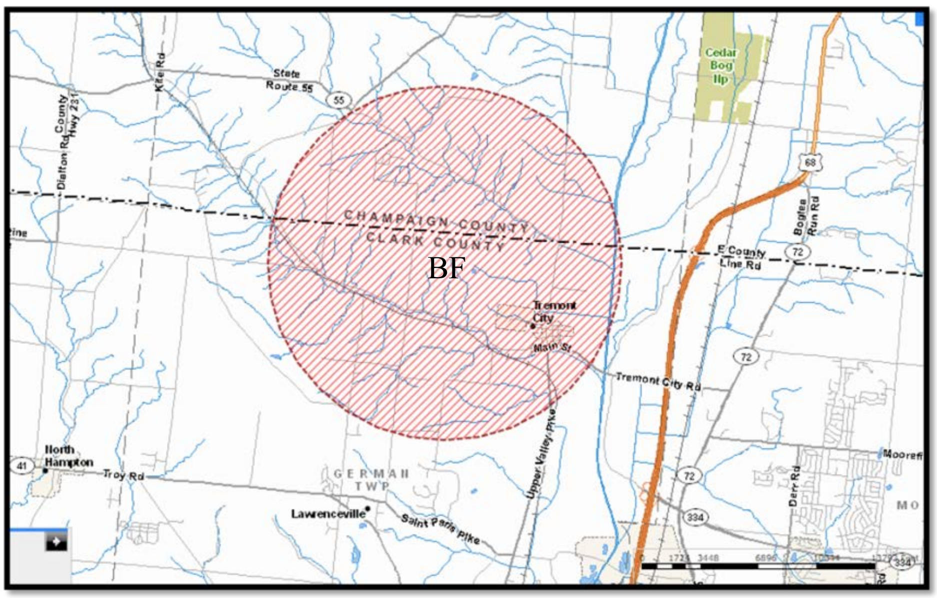

Figure 4. Map for inventory of Ohio DNR Water Records with 2-mile buffer zone (red-shaded circle) from the center of the Barrel Fill site.

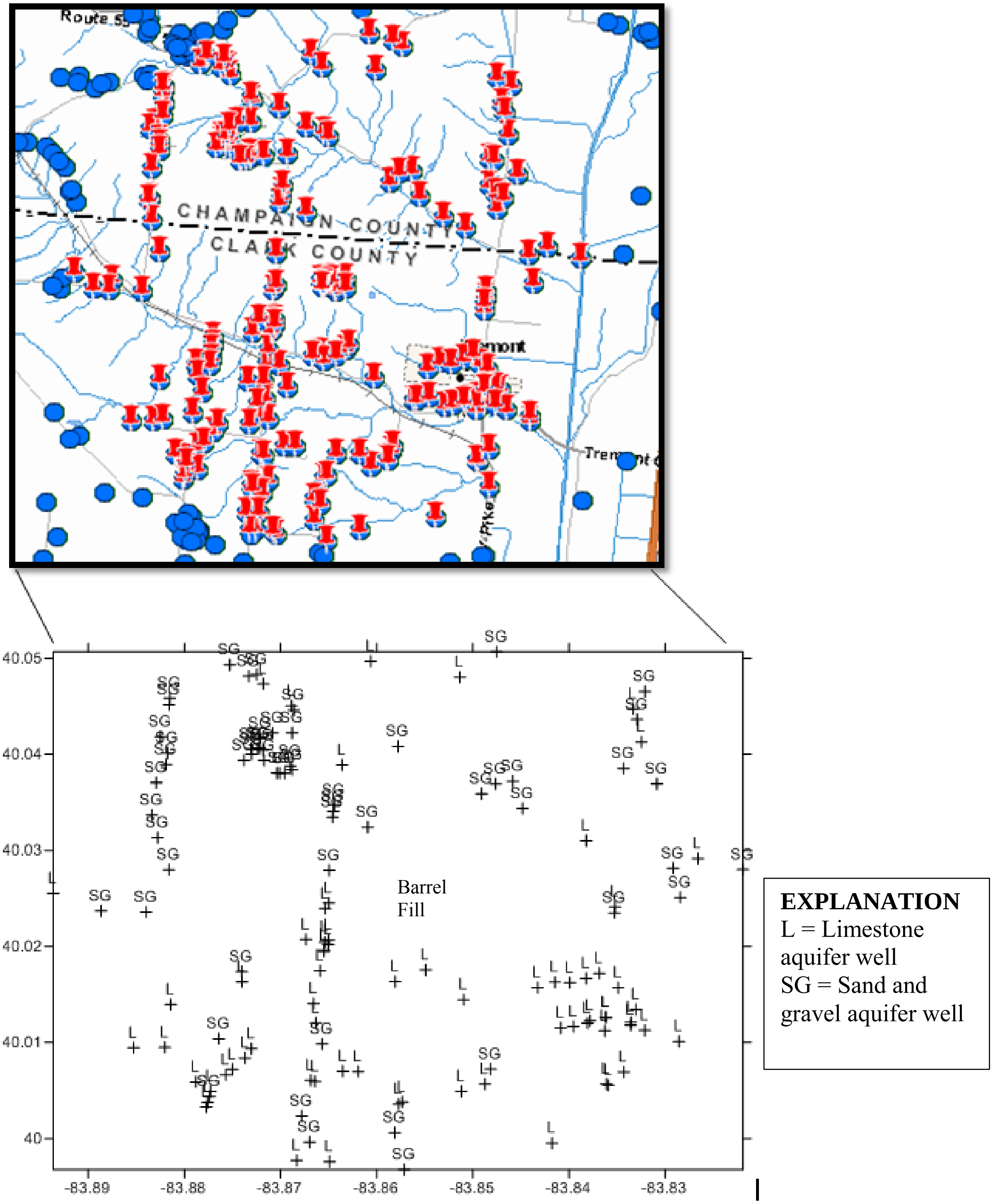

Figure 5. General distribution of 127 residential wells used for the estimation of transmissivity and hydraulic conductivity of sand and gravel and limestone aquifers near the Barrel Fill site of Tremont City, Ohio.

From specific capacity data, T was calculated for the wells open to the sand and gravel aquifer by using the empirical relation developed by Razack and Huntley (1991):

$$T = 33.6 * \left(\frac{Q}{s}\right)^{0.67} \quad (1)$$

where T = transmissivity (ft^2/d [feet squared per day]),
Q = pumping rate (ft^3/d [cubic feet per day]), and
s = drawdown (ft [feet]).

The specific capacity withdrawal data are reported on the logs in gallons per minute (gal/min) and converted to cubic feet per day (ft^3/d or Q) for this analysis.

The empirical relation developed by Razack and Huntley (1991) to compute estimates of T from specific capacity test data is one of the only methods developed that accounts for turbulent well loss. The Razack and Huntley relation is a log-log transformed best-fit regression line equation for a large heterogeneous alluvial aquifer to predict transmissivity based on specific capacity data at a 90-percent prediction interval. The prediction interval spanned more than one order of magnitude, which is within the two orders of magnitude used in the aquifer interconnection evaluation but which otherwise yields generalized estimates of T. Calculated T values are compared to T values obtained from aquifer tests at the Barrel Fill site for the sand and gravel aquifer (Eagon and Associates, 1994; Haley and Aldrich, 2006).

Transmissivity was calculated from specific capacity data obtained from the wells open to the shallow limestone aquifer by using the empirical relation for a fracture-rock system developed by Huntley and others (1992):

$$T = 0.29 * \left(\frac{Q}{s}\right)^{1.18} \quad (2)$$

where T = transmissivity (ft^2/d),
Q = pumping rate (ft^3/d), and
s = drawdown (ft).

The empirical relationship developed for fractured rock is a log-log transformed best-fit regression line for a fracture-rock system. The 90-percent prediction interval is a 1.1 log cycle, indicating that predicted transmissivities based on specific capacity have a large range of more than one order of magnitude, which is within the two orders of magnitude used in the aquifer interconnection evaluation, but otherwise yields generalized estimates of T. There are no local transmissivity values for the limestone aquifer to compare with this method.

Horizontal hydraulic conductivity is calculated from the equation K_h=T/b. This equation is often applied when the saturated thickness (b) of an aquifer is known and when T is calculated from traditional aquifer tests. In this case, the rate of pumping or discharge (Q) used when performing a well-efficiency test is often very low and is applied for only for 2 to 3 hours, as opposed to an aquifer test that withdraws large quantities of groundwater for at least 8 to 24 hours. The difference in the rate of pumping will affect the radius and depth of impact within the aquifer. Therefore, the thickness (b) of the saturated aquifer affected by the much smaller pumping rate from the well-efficiency tests is substantially reduced and is presumed to be within the limit of the well screen or open hole (Heath, 1983).

Well logs from the sand and gravel aquifer noted more wells with screens than did the well logs from the limestone aquifers. The difference between the two sets of data implicitly skews the sand and gravel aquifer to have a higher K_h. Because the sand and gravel well logs had limited information on screen length and formation thickness, and the limestone well logs (generally) had sand and gravel formation thickness, the thickness (b) of the sand and gravel aquifer was estimated from the well logs from the limestone wells. Also, because the limestone wells were not collocated with the sand and gravel wells; the geometric mean of the sand and gravel formation thickness (10 ft) was used as b for each of the sand and gravel wells. The open-hole information from the limestone well logs was used to estimate the thickness (b) for each of the limestone wells.

Computed Aquifer Characteristics

There are 57 wells open to the sand and gravel aquifer within a 2-mi radius of the Barrel Fill site. The geometric mean, arithmetic mean, maximum value, and minimum value for specific capacity, T, and K_h are presented in table 1 for the sand and gravel aquifer. The table also includes the values of T and K_h from reported sand and gravel aquifer (constant discharge or slug) tests.

Table 1. Statistical data presented for specific capacity, transmissivity, and horizontal hydraulic conductivity data from wells open to the sand and gravel aquifer. Shaded columns are data from Barrel Fill site-specific aquifer (constant-discharge or slug)tests. Unshaded columns reflect data from within the 2-mile radius of the site.

Summary statistic	Specific capacity, in cubic feet per day	Transmissivity (T), in feet squared per day	Barrel Fill site aquifer test[1] transmissivity (T), in feet squared per day	Horizontal hydraulic conductivity, (where b=10 feet), in feet per day	Barrel Fill site horizontal hydraulic conductivity[1] (aquifer/slug data), in feet per day
Sand and Gravel					
Geometric mean	373	1,776	5,294	178	43
Arithmetic mean	506	2,038	6,244	204	126
Maximum	1,925	5,332	10,374	533	368
Minimum	64	546	615	55	0.26

[1]Table 5-4, Eagon and Associates, 1994

There are 70 wells open to the limestone aquifer within 2 mi of the Barrel Fill site. Table 2 presents the statistical data for the specific capacity, T, and K_h. The estimated values of K_h (shaded) also are compared to those of other studies referenced in Vormelker and others (1995).

Table 2. Statistical data for specific capacity, transmissivity, and hydraulic conductivity from wells open to the limestone aquifer. Shaded columns represent data from areas outside the vicinity of the Barrel Fill site.

Summary statistic	Specific capacity, in cubic feet per day	Transmissivity, in feet squared per day	Hydraulic conductivity (using open hole for b), in feet per day	Other studies' hydraulic conductivity estimates (generally outside of 2-mile vicinity), in feet per day
		Limestone		
Geometric mean	115	78	4	40–94[1]
Arithmetic mean	171	136	13	
Maximum	770	739	263	
Minimum	18	9	0.16	

[1]Vormelker and others, 1995

Evaluation of Aquifer Interconnection

As estimated, the geometric mean values of transmissivity (T) and horizontal hydraulic conductivity (K_h) of the sand and gravel and limestone aquifers fall within the standard of two orders of magnitude or less and are considered to be interconnected according to a classification method in the USEPA Hazard Ranking System (1992). The arithmetic mean, maximum, and minimum values for T and K_h also fall within two orders of magnitude.

The specific capacity values of the two aquifers are within the same order of magnitude, with the geometric mean of specific capacity generally highest in the sand and gravel aquifer. The maximum specific capacity of the sand and gravel aquifer is one order of magnitude greater than the maximum specific capacity of the limestone aquifer. The minimums for each aquifer are within the same order of magnitude. There were no specific capacity data collected for monitoring wells located in the Barrel Fill site.

The empirical relation method estimated the T of the sand and gravel aquifer to be two orders of magnitude greater than that of the limestone aquifer. Transmissivity was underestimated when compared to Barrel Fill aquifer test results from monitoring wells and pumping wells within the Barrel Fill site, indicating that the sand and gravel aquifer might have a higher K_h than that estimated from specific capacity data. The range of T values is within one order of magnitude of the limestone aquifer.

The K_h of the sand and gravel aquifer is also one order of magnitude greater than that of the limestone aquifer. Values of K_h estimated from other studies outside the Barrel Fill site and Clark County have shown K_h to be within the same range of that estimated from the aquifer tests at the Barrel Fill site (Norris and others, 1952; Sheets and Yost, 1994; Vormelker and others, 1995). The K_h of the sand and gravel aquifer is within two orders of magnitude of the limestone aquifer for the entire 2-mi radius of the Barrel Fill site and within one order of magnitude at the site.

Summary

This study estimated the T and K_h from specific capacity data of residential wells open to the sand and gravel aquifer or limestone aquifer and located within 2-miles from the Barrel Fill site. The values for T and K_h are within two and one order of magnitude for the sand and gravel aquifer and the limestone aquifer. Although the specific capacity data and the equations applied to obtain T and K_h have inherent data-limitations and potential errors, the results of this study are supported by previous studies. Aquifer interconnection is further supported by a USGS study that published a potentiometric surface map for the same area based upon similar water levels within the two aquifers (Dumouchelle, 2001). Additionally, aquifer tests and slug test data from the sand and gravel aquifer at the Barrel Fill site have K_h values within the same order of magnitude as the limestone aquifer as estimated from studies outside the vicinity of the Barrel Fill site.

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Appendix 1

Data for Sand and Gravel Aquifer

Table 1. Well-log data and calculated values for specific capacity, transmissivity, and horizontal hydraulic conductivity from the 57 wells screened in the sand and gravel aquifer within a 2-mile radius of the Barrel Fill site. [DNR, Department of Natural Resources; SG, sand and gravel aquifer]

Ohio DNR Well log number	Aquifer	Total depth, in ft	Test rate, in gallons per minute	Drawdown, in ft	Specific capacity, in cubic feet per day	Transmissivity , in square feet per day	Unit thickness , in feet	Horizontal hydraulic conductivity, in feet per day (transmissivity/unit thickness)
334320	SG	125	10	10	193	1140	10	114
141260	SG	104	10	5	385	1814	10	181
127772	SG	133	8	2	770	2886	10	289
141297	SG	140	7	10	135	898	10	90
229926	SG	50	10	15	128	869	10	87
244579	SG	76	10	20	96	717	10	72
110822	SG	87	10	2	963	3351	10	335
127796	SG	97	10	2	963	3351	10	335
410413	SG	110	15	10	289	1496	10	150
431196	SG	102	14	5	539	2272	10	227
425216	SG	121	25	10	481	2106	10	211
361623	SG	80	11	3	706	2723	10	272
468560	SG	138	15	15	193	1140	10	114
468555	SG	145	15	15	193	1140	10	114
468559	SG	154	15	10	289	1496	10	150
110801	SG	90	8	5	308	1562	10	156
447356	SG	104	10	6	321	1605	10	161
447382	SG	32	15	6	481	2106	10	211
244583	SG	31	15	5	578	2380	10	238
454682	SG	48	20	12	321	1605	10	161
447397	SG	51	10	8	241	1324	10	132
377196	SG	82	8	8	193	1140	10	114
207723	SG	62	8	8	193	1140	10	114
357056	SG	120	15	10	289	1496	10	150
39680	SG	40	5	0.5	1925	5332	10	533
44487	SG	82	7	3	449	2011	10	201
41627	SG	49	5	5	193	1140	10	114
93614	SG	41	8	5	308	1562	10	156
93634	SG	77	8	6	257	1382	10	138
87795	SG	43	7	8	168	1042	10	104
890722	SG	31	10	15	128	869	10	87
898169	SG	96	30	10	577.5	2380	10	238
860024	SG	101	25	4	1203	3892	10	389
906448	SG	132	25	6	802	2966	10	297
915265	SG	169	30	8	722	2764	10	276
933648	SG	115	20	20	193	1140	10	114
918733	SG	53	2	2	193	1140	10	114
930832	SG	73	30	4	1444	4397	10	440
930854	SG	99	20	6	642	2554	10	255
933538	SG	125	30	10	578	2380	10	238
946254	SG	64	25	30	160	1009	10	101
957968	SG	126	25	30	160	1009	10	101
969149	SG	136	20	10	385	1814	10	181
983493	SG	86	20	8	481	2106	10	211
981184	SG	82	20	20	193	1140	10	114
2002650	SG	65	25	5	963	3351	10	335
2002039	SG	87	10	4	481	2106	10	211
141266	SG	68	10	3	642	2554	10	255
502702	SG	40	9	8	217	1234	10	123

Well log number	Aquifer	Total depth, in ft	Test rate, in gallons per minute	Drawdown, in ft	Specific capacity, in cubic feet per day	Transmissivity , in square feet per day	Unit thickness , in feet	Horizontal hydraulic conductivity , in feet per day (transmissivity/unit thickness)
94851	SG	71	8	4	385	1814	10	181
425217	SG	85	25	10	481	2106	10	211
1003788	SG	135	25	3	1604	4719	10	472
2010624	SG	126	5	15	64	546	10	55
2015040	SG	32	30	3	1925	5332	10	533
1006643	SG	94	10	15	128	869	10	87
2033752	SG	52	30	6	963	3351	10	335
2032033	SG	38	30	10	578	2380	10	238

Appendix 2

Data for Limestone Aquifer

Table 2. Well-log data and results for specific capacity, transmissivity, and horizontal hydraulic conductivity for 70 residential wells screened in the limestone aquifer. [DNR, Department of Natural Resources; L, limestone aquifer]

Ohio DNR Well log number	Aquifer	Total depth, in feet	Test Rate, in gallons per minute	Drawdown, in feet	Specific capacity, in cubic feet per day	Transmissivity , in feet squared per day	Open-hole thickness of wells in limestone (well depth-casing depth)	Horizontal hydraulic conductivity, in feet per day (ft/d)
319217	L	48	10	15	128	89	14	4
172451	L	192	14	7	385	326	17	16
110809	L	143	14	63	43	24	14	1
135523	L	83	7	14	96	64	12	3
377173	L	76	8	10	154	111	1	6
501713	L	110	15	10	289	232	15	12
540212	L	100	10	45	43	24	36	1
540211	L	100	10	45	43	24	36	1
561261	L	86	15	10	289	232	41	12
536061	L	125	20	40	96	64	11	3
329191	L	247	30	50	116	79	107	4
303661	L	146	10	50	39	22	7	1
303662	L	140	10	50	39	22	8	1
480986	L	61	13	25	100	67	21	3
198268	L	73	10	10	193	144	52	7
198262	L	73	10	10	193	144	52	7
349235	L	50	5	28	34	19	32	1
432500	L	90	20	25	154	111	60	6
141257	L	34	12	6	385	326	15	16
141287	L	72	14	5	539	485	59	24
183409	L	83	10	15	128	89	41	4
141296	L	45	10	10	193	144	16	7
207727	L	41	10	5	385	326	7	16
93624	L	48	8	6	257	202	18	10
39679	L	68	20	7	550	497	27	25
39681	L	51	17	4.5	727	691	21	35
895302	L	202	10	106	18	9	55	0.44
918705	L	162	15	20	144	102	52	5

Ohio DNR Well log number	Aquifer	Total depth, in feet	Test Rate, in gallons per minute	Drawdown, in feet	Specific capacity, in cubic feet per day	Transmissivity , in feet squared per day	Open-hole thickness of wells in limestone (well depth-casing depth)	Horizontal hydraulic conductivity, in feet per day (ft/d)
915226	L	140	20	50	77	49	45	2
890688	L	156	10	20	96	64	16	3
908615	L	135	20	25	154	111	27	6
908584	L	240	30	10	578	526	30	26
915241	L	179	200	100	385	326	41	16
908658	L	60	35	10	674	631	15	32
933642	L	147	20	25	154	111	20	6
930800	L	188	20	25	154	111	15	6
933684	L	163	22	50	85	55	31	3
933565	L	80	25	20	241	187	11	9
946216	L	180	20	70	55	33	28	2
946196	L	65	20	25	154	111	14	6
958031	L	197	20	50	77	49	18	2
946269	L	195	20	70	55	33	32	2
87836	L	99	6	10	116	79	4	4
246584	L	97	8	10	154	111	46	6
946190	L	117	12	30	77	49	47	2
958028	L	137	20	50	77	49	29	2
957969	L	100	15	40	72	45	22	2
966850	L	220	15	30	96	64	15	3
988163	L	158	35	60	112	76	10	4
990768	L	205	30	40	144	102	42	5
989810	L	32	10	6	321	263	1	13
994460	L	58	12	25	92	61	31	3
501712	L	55	20	5	770	739	17	37
44453	L	106	8	18	86	55	3	3
444071	L	175	16	90	34	19	9	1
371299	L	168	10	43	45	26	8	1
2005507	L	139	15	60	48	28	21	1
1003783	L	62	15	20	144	102	14	5
2011555	L	185	12	100	23	12	26	1

Ohio DNR Well log number	Aquifer	Total depth, in feet	Test Rate, in gallons per minute	Drawdown, in feet	Specific capacity, in cubic feet per day	Transmissivity , in feet squared per day	Open-hole thickness of wells in limestone (well depth-casing depth)	Horizontal hydraulic conductivity, in feet per day (ft/d)
2011557	L	200	60	120	96	64	82	3
2012278	L	196	15	100	29	15	29	1
2009615	L	100	10	8	241	187	5	9
2007823	L	98	15	55	53	31	26	2
1005708	L	182	10	30	64	39	80	2
2006806	L	156	15	57	51	30	22	1
2019568	L	180	15	60	48	28	11	1
2022885	L	180	20	40	96	64	10	3
2014777	L	192	12	30	77	49	25	2
2015420	L	195	15	80	36	20	35	1
2016117	L	202	15	45	64	39	32	2

Appendix 3

Barrel Fill Site Hydraulic Conductivity Data

[SG, sand and gravel aquifer; NA, not available]

Barrel Fill site monitoring well name	Aquifer	Transmissivity , in square feet per day	Horizontal hydraulic conductivity , in feet per day	Data source
HMW-101	SG	NA	8.8	Barrel Fill site remedial investigation (Haley and Aldrich, 2006, table 13)
HMW-501	SG	NA	93.5	Remedial Investigation (Haley and Aldrich, 2006, table 13)
HMW-202	SG	NA	31.2	Remedial Investigation (Haley and Aldrich, 2006, table 13)
HMW-401	SG	NA	28.1	Remedial Investigation (Haley and Aldrich, 2006, table 13)
HMW-402	SG	NA	53.9	Remedial Investigation (Haley and Aldrich, 2006, table 13)
HBF-20D	SG	NA	48.2	Remedial Investigation (Haley and Aldrich, 2006, table 13)
HPZ-3	SG	NA	108	Remedial Investigation (Haley and Aldrich, 2006, table 13)
HBF-19D	SG	NA	7.09	Remedial Investigation (Haley and Aldrich, 2006, table 13)
HMW302	SG	NA	0.26	Remedial Investigation (Haley and Aldrich, 2006, table 13)
PW-1	SG	8823	368	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
PW-2	SG	615	24.6	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
PW-3	SG	5788	203	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
PW-3	SG	10374	346	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
91-2D	SG	NA	0.56	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
91-5D	SG	NA	0.40	Table 5-4, Final hydrological report (Eagon& Associates,1994, table 5–4)
91-8D	SG	NA	215	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
C92-5DD	SG	6617	221	Table 5-4, Final hydrological report (Eagon & Associates,1994, table 5–4)
C92-5DD	SG	5588	186	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
C92-5DD	SG	6042	201	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
C91-5D	SG	5989	200	Table 5-4, Final hydrological report (Eagon & Associates,1994, table 5–4)
C91-5D	SG	6564	219	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)
C92-22DD	SG	6042	201	Table 5-4, Final hydrological report (Eagon & Associates ,1994, table 5–4)

Appendix 4

Well-log Formation Description from Cross-Section A—A’

Ohio DNR Well Log ID	Formation Description	Depth (in feet)	
		From	To
662466			
	Gravel & Clay	0	25
	Hardpan	25	30
	Clay	30	55
	Gravel & Clay	55	60
	Limestone	60	66
825062			
	Brown Clay	0	7
	Gravel	7	34
	Gray Clay	34	49
	Sand & Gravel	49	58
	Limestone	59	70
2045469			
	Brown Clayey Clay	0	3
	Brown Gravelly Clay & Gravel	3	18
	White-Gray Crumbly Sand & Gravel	18	40
	White Limey Limestone	40	60
432500			
	Gravel	0	30
	Limestone	30	90
825127			
	Brown Clay	0	20
	Sand & Gravel	20	80
	Gray Gravel & Clay	80	103
	Limestone	103	160
232298			
	Clay	0	6
	Gravel	6	24
	Sand	24	36
	Sand & Gravel	36	42
233158			
	Top Soil	0	2
	Gravel & Clay	2	3
	Gravel/Sand/Clay	3	14
	Coarse Sand & Gravel	14	22
	Gravel & Boulders	22	30
	Coarse Sand & Gravel	30	92
	Coarse Sand	92	94
	Fine Sand & Gravel	94	96
915274			
	Brown Clay	0	6
	Gravel & Sand	6	46

*Additional well logs can be found at the Ohio DNR website:
(http://soilandwater.ohiodnr.gov/search-file-well-logs)

ISSN 2331-1258 (online)
http://dx.doi.org/10.3133/ofr20151026