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Flow-Meter and Passive Diffusion Bag Tests and Potential Influences on the Vertical Distribution of Contaminants in Wells at Galena Airport, Galena, Alaska, August to October 2002

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Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

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Conversion Factors, Datum, and Acronyms and Abbreviations

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Volume		
gallon (gal)	3.785	liter (L)
Flow rate		
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

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

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Acronyms and Abbreviations

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
BTOC	below top of casing
*c*DCE	*cis*-1,2-dichloroethene
ft/ft	foot per foot
LNAPL	light nonaqueous-phase liquid
μg	microgram
mL	milliliter
POL	petroleum, oil, and lubricants
PDB	polyethylene diffusion bag
PVC	polyvinyl chloride
RPD	relative percentage difference
TCE	trichloroethene
USGS	U.S. Geological Survey
VOA	volatile organic analysis
VOC	volatile organic compound

Flow-Meter and Passive Diffusion Bag Tests and Potential Influences on the Vertical Distribution of Contaminants in Wells at Galena Airport, Galena, Alaska, August to October 2002

By Don A. Vroblesky[1] and J E. Peterson[2]

Abstract

Past activities at Galena Airport, a U.S. Air Force Base in Galena, Alaska, have resulted in ground-water contamination by volatile organic compounds. The primary contaminants are petroleum hydrocarbons and chlorinated aliphatic hydrocarbons. The U.S. Geological Survey and Earth Tech, in cooperation with the Air Force Center for Environmental Excellence, conducted investigations at Galena Airport from August to October 2002 using polyethylene diffusion bag samplers and borehole flow-meter testing to examine the vertical distribution of ground-water contamination in selected wells. This investigation was limited to the vicinity of building 1845 and to the area between building 1845 and the Yukon River. In addition, the U.S. Geological Survey was asked to determine whether additional wells are needed to more clearly define the nature and extent of the ground-water contamination at the Air Force Base.

Little or no vertical water movement occurred under ambient conditions in the wells tested at Galena Airport, Alaska, in August 2002. All of the ambient vertical flows detected in wells were at rates less than the quantitative limit of the borehole flow meter (0.03 gallons per minute). In wells 06-MW-07 and 10-MW-01, no vertical flow was detected. In wells where ambient flow was detected, the direction of flow was downward.

In general, concentrations of volatile organic compounds detected in the low-flow samples from wells at Galena Airport were approximately the same concentrations detected in the closest polyethylene diffusion bag sample for a wide variety of volatile organic compounds. The data indicate that the polyethylene diffusion bag sample results are consistent with the low-flow sample results.

Vertical profiling of selected wells using polyethylene diffusion bag samplers at Galena Airport showed that from September 30 to October 1, 2002, little vertical change occurred in volatile organic compound concentrations along the screen length despite the fact that little or no vertical flow was measured in most of the tested wells in August 2002. Two of the wells (10-MW-03 and 06-MW-01) had slightly greater vertical concentration variation for some constituents. In these wells, the contaminant depth probably is lithologically influenced.

The close match between concentrations measured in polyethylene diffusion bag and low-flow samples indicates that the bag samples accurately represent the distribution of volatile organic compounds in the wells. It is unclear, however, whether the distribution of volatile organic compounds in the wells, as indicated by the bag samplers, represents contaminant distributions in the aquifer or transient movement within the wells. The probable change in well hydraulics between August and late September to October indicates that the relatively uniform vertical distribution of volatile organic compounds in some of the wells may represent in-well mixing. This uncertainty could be clarified by the installation and sampling of well clusters at various times of the year. Additional insight into the vertical distribution of contamination and flow possibly could be obtained by conducting flow-meter tests and collecting polyethylene diffusion bag samples from selected wells at different times of the year.

The westernmost contaminant plume at Million Gallon Hill appears to be surrounded by sufficient monitoring wells to detect changes in the plume extent; however, the installation of additional wells at Galena Airport has the potential to provide additional information on the extent of ground-water contamination in the remaining plumes. The additional information to be gained includes better definition of the vertical and lateral extents of the plumes and better definition of the ground-water flow directions.

Introduction

Past activities at Galena Airport, a U.S. Air Force Base in Galena, Alaska, have resulted in ground-water contamination by volatile organic compounds (VOCs, fig. 1). The primary contaminants are petroleum hydrocarbons and chlorinated aliphatic hydrocarbons, such as trichloroethene (TCE) and breakdown products. Light nonaqueous-phase liquids (LNAPLs) are present in various locations in the study area.

The U.S. Geological Survey (USGS) and Earth Tech, in cooperation with the Air Force Center for Environmental Excellence (AFCEE), conducted investigations at Galena
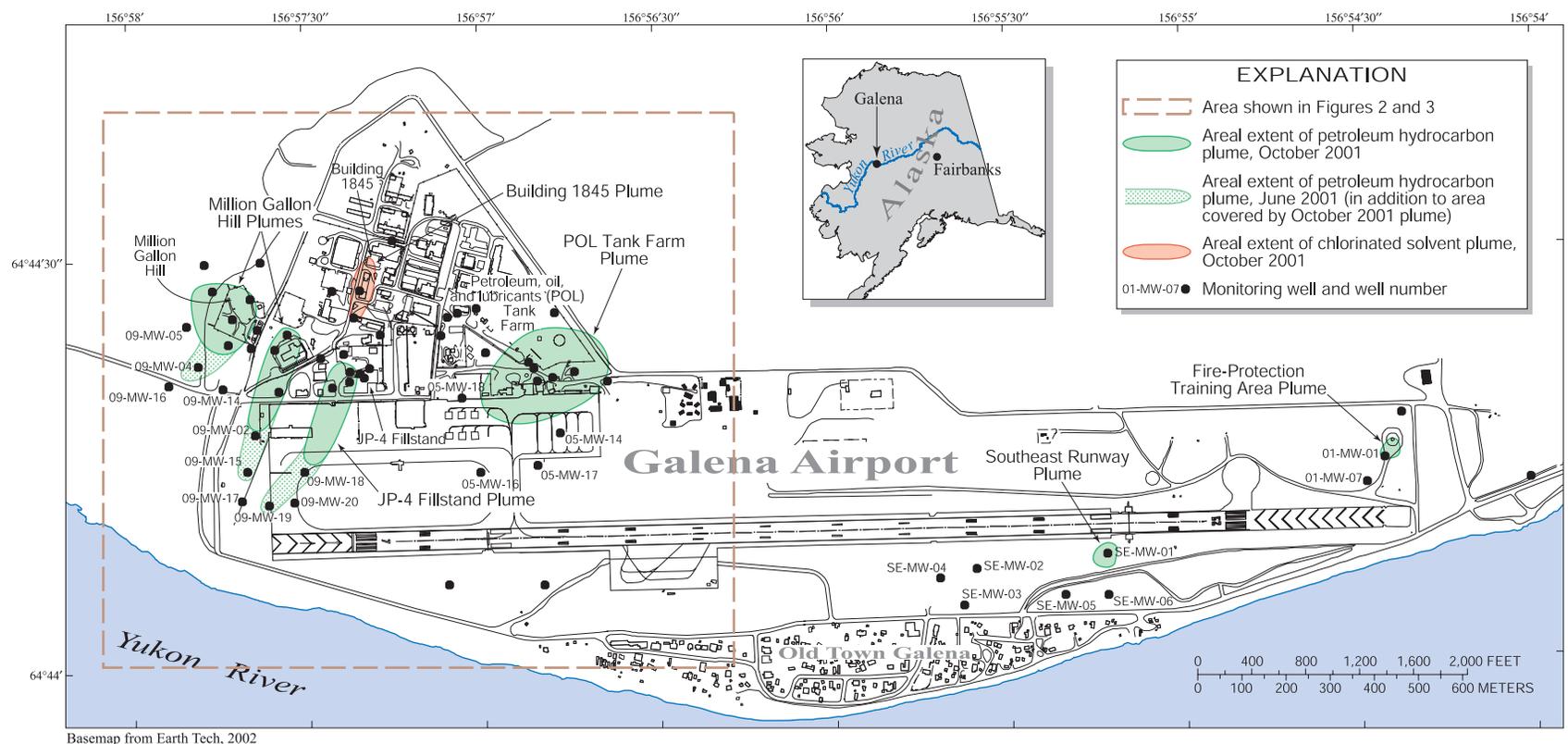
Figure 1. Locations of study area, monitoring wells, and approximate extent of ground-water contamination (U.S. Air Force, written commun., 2002) at Galena Airport, Galena, Alaska.

Airport from August to October 2002 using polyethylene diffusion bag (PDB) samplers to examine the vertical distribution of ground-water contamination in selected wells. PDB samplers have been successfully used in a variety of environments to obtain ground-water samples from wells (Vroblesky and Hyde, 1997; Parsons Engineering Science, Inc., 1999; Hare, 2000; McClellan Air Force Base Environmental Management Directorate, 2000; Vroblesky and others, 2000; Vroblesky and Petkewich, 2000; Vroblesky and Pravecek, 2002). To gain further insight into the well hydraulics, borehole flow-meter tests and geophysical logging were conducted in wells. This investigation was limited to the areas near building 1845 and between building 1845 and the Yukon River (fig. 2). In addition, the USGS was asked to determine whether additional wells are needed to more clearly define the nature and extent of ground-water contamination at the Air Force Base.

Galena Airport is in the flood plain of the Yukon River. The aquifer is composed primarily of coarse-grained sediments with some silt layers near the top of the sequence. Permafrost is present in some parts of the facility, but appears to be limited to thin isolated zones. During much of the year, ground-water flow is toward the Yukon River, which typically is frozen from November through June. During ice breakup in May to June, the Yukon River sporadically floods, causing a temporary reversal in ground-water flow (away from the river). At the time the PDB samplers were deployed in August 2002, the general trend of ground-water flow was toward the Yukon River (fig. 3).

Methods

The site investigation involved borehole flow-meter and geophysical tests, deployment and recovery of PDB samples, and the collection of low-flow samples (table 1). Chemical concentrations in ground water at wells were obtained by using PDB samplers deployed at multiple depths within wells and by low-flow sampling. VOC concentrations obtained from the PDB samples were compared to VOC concentrations obtained by low-flow sampling. Borehole flow-meter results aided in data interpretation.
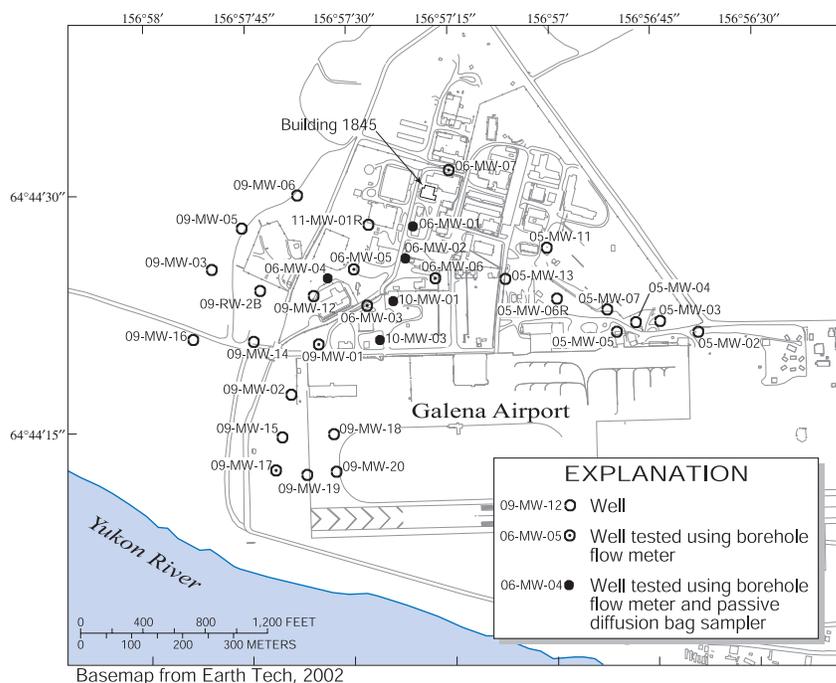
Figure 2. Locations of wells used in this investigation in the western part of Galena Airport, Alaska, August to October 2002.
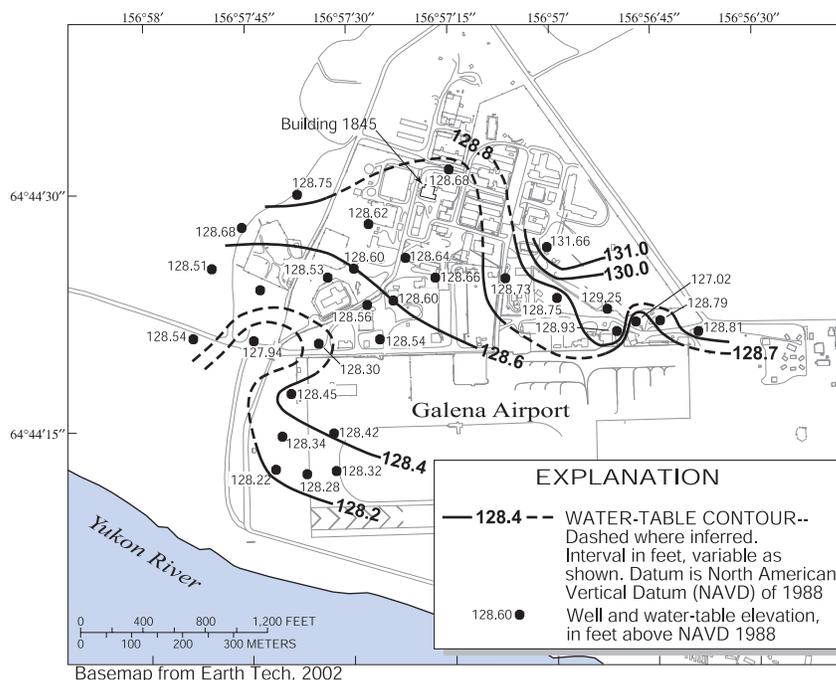
Figure 3. Water-table elevation measured on August 12, 2002, Galena Airport, Alaska (Ryan Harkness, Earth Tech, written commun., 2002).

Table 1.   Well-construction data and testing and sampling activities conducted in selected wells, Galena Airport, Alaska, August to October 2002.

[ft, feet; BTOC, below top of casing; PDB, polyethylene diffusion bag; —, data not available or not applicable; *, measured in feet below land surface]

Well name	Well depth (ft BTOC)	Top of screen (ft BTOC)	Bottom of screen (ft BTOC)	Approxi-mate screen length (ft)	Date of flow-meter test under ambient conditions	Date of flow-meter test under pumped conditions	Date of PDB-sampler deployment	Date of PDB-sampler recovery	Date of low-flow sampling
06-MW-01	53.9	13.8	53.45	40	8/12/2002	8/12–13/02	8/30/2002	9/30/2002	9/30/2002
06-MW-02	52.95	12.55	52.5	40	8/19/2002	8/19/2002	8/30/2002	9/30/2002	9/30/2002
06-MW-03	48.25	8.6	48.25	40	8/11/2002	8/11/2002	—	—	—
06-MW-04	48.7	8.6	48.25	40	8/12/2002	8/12/2002	8/30/2002	9/30/2002	9/30/2002
06-MW-06	31.5*	13*	23*	10	8/11/2002	—	—	—	—
06-MW-07	42.4	12.6	41.9	30	8/8/2002	8/9/2002	8/30/2002	10/1/2002	10/1/2002
09-MW-01	45.18	—	—	40	8/17/2002	—	—	—	—
09-MW-17	48.46	—	—	—	8/18/2002	8/18/2002	—	—	—
10-MW-01	47.85	7.5	47.4	40	8/10/2002	8/10/2002	8/30/2002	10/1/2002	10/1/2002
10-MW-03	47.85	7.83	47.4	40	8/10/2002	—	8/30/2002	9/30/2002	9/30/2002

Unless otherwise stated, all depth measurements presented in this report are in feet below the top of the polyvinyl chloride (PVC) casing (BTOC).

Borehole Flow-Meter and Geophysical Surveys

Borehole flow-meter measurements were made in the screened intervals of the wells prior to deployment of the diffusion samplers. The measurements were made with a Mount Sopris HPF-2293 heat-pulse flow meter, which is capable of quantifying vertical flow but is not capable of detecting horizontal flow. Collection of borehole flow-meter data at various depths while the well is being pumped from a constant shallow depth can indicate the horizons contributing water to the pump. The flow meter can approximately quantify the upward flow to the pump and is capable of measuring flows ranging from 0.03 to 1.5 gallons per minute (gal/min; Mount Sopris Instrument Company, Inc., 2001). When a zone shows an increase in the amount of upward flow relative to the next deeper tested zone, the data indicate that additional water is entering the well between the two depths.

There is quantitation uncertainty in the flow-meter data presented here because the wells are screened, and the flow meter cannot detect water movement through the sand pack outside of the well screen. The data are useful, however, in determining zones in which water is moving vertically in the borehole under nonpumping conditions and in determining which zones contribute water to the well under pumping conditions.

Borehole flow-meter measurements were taken at several depths, approximately 2 to 3 feet (ft) apart, within each screened interval under nonpumping (ambient) conditions. Prior to taking an initial reading at each depth, the probe was allowed to stabilize for at least 3 minutes and longer if it was suspected that water movement was related to movement of the probe. At least three readings were made at each depth to ensure stabilization of the probe and quality control and assurance of the flow-meter measurement. The flow-meter measurement was recorded when the readings had negligible or minimal variability. Each well then was pumped from a few feet below the water table. Pumping rates ranged from 0.5 to 1 gal/min.

For this investigation, the flow-meter data were divided into approximate percentages of contribution to the well during pumping. The division was done by comparing flow-meter data from a horizon with the flow-meter data from the next underlying horizon. The amount of upward-flow increase between those two horizons divided by the pumping rate in the well indicated the fractional contribution of water from the zone between the two horizons. If one or more consecutive measuring points had little or no change in flow (about 5-percent accuracy), the horizons between the measuring points were considered to make no measurable flow contribution to the pumpage. In this case, the average flow measured across the noncontributing interval was used for comparison to shallower and deeper measurements to determine approximate relative flow contributions of the bounding zones. The total amount of flow up the well typically did not total 100 percent of the pumpage because of water movement in the annular space outside the well screen and because the location of the water table necessitated that both the pump and the uppermost borehole flow-meter reading were within the screened interval rather than in the closed casing above the screen.

A suite of borehole geophysical logs was conducted in selected wells. The logs included inductive resistivity, natural gamma, fluid temperature, and fluid resistivity. In general, the logs did not provide substantial information for interpreting the vertical distribution of contamination. A correlation occurred,

however, between the lithologies noted in the geophysics and the well logs.

The inductive resistivity instrument was not calibrated in the field but was instead used to show relative differences in formation resistivity along the length of the borehole. Because the unit was not calibrated in the field, the results are reported as relative inductive resistivity (appendix).

Diffusion-Sampler Construction and Deployment

The PDB samplers (Columbia Analytical Labs, Kelso, Washington) used in this investigation were 4-milliliter (mL)-thick polyethylene bags prefilled with laboratory-grade de-ionized water, and are described in detail in Vroblesky (2001). Oasis Environmental, Inc., deployed the samplers on August 30, 2002. Deployment consisted of measuring the well depth, attaching PDB samplers to a weighted line at the appropriate intervals, and lowering the samplers into the well until the samplers were at depths adjacent to the selected horizons.

Water-Sample Collection and Diffusion-Sampler Recovery

The PDB samplers were recovered from the wells by Oasis Environmental, Inc., approximately 1 month following deployment. The recovery method consisted of raising the PDB

samplers to the top of the well and removing the uppermost sampler, while the rest of the samplers remained in the well casing. The uppermost end of the PDB sampler was cut with clean scissors, and the water was poured gently into 40-mL volatile organic analysis (VOA) vials. The samples were preserved with hydrochloric acid, placed on ice immediately, and maintained at 4 degrees Celsius ($°C$) during shipment to the laboratory. The VOA vials were sent to Columbia Analytical Laboratories for VOC analysis using U.S. Environmental Protection Agency Method 8260B (U.S. Environmental Protection Agency, 1992).

Distribution of Ground-Water Flow in Wells

Little or no vertical water movement occurred under ambient conditions in the wells tested at Galena Airport, Alaska, in August 2002 (table 2, p. 16). All of the ambient vertical flows detected in wells were at rates less than the quantitative limit of the borehole flow meter (0.03 gal/min). In wells 06-MW-06, 06-MW-07, 09-MW-17, and 10-MW-01, no vertical flow was detected. In wells where ambient flow was detected, it was in a downward direction (table 2; figs. 4A, 5A, 6A, 7A).

The vertical-flow measurements collected under pumping conditions indicated the depths of the water-yielding zones. Although most of the tested depths appeared to be capable of
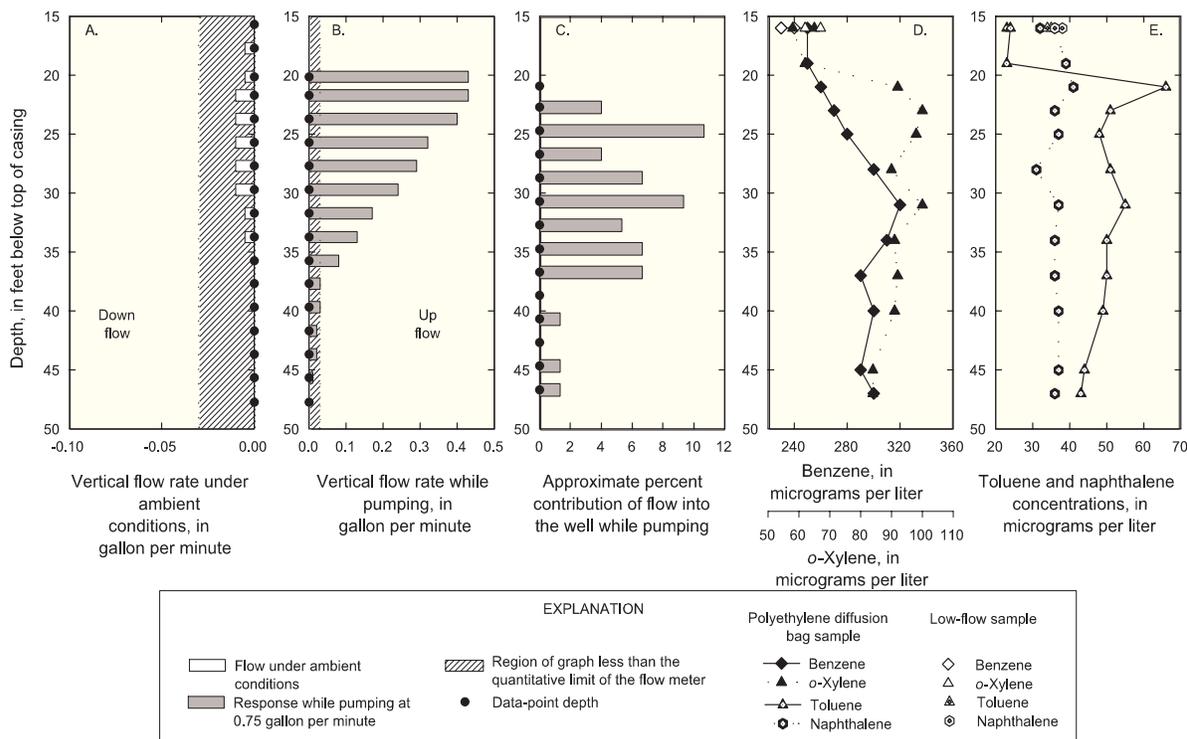
Figure 4.   Well 06-MW-04, vertical flow rate under (A) ambient and (B) pumping conditions, (C) approximate percent contribution of flow into the well while pumping, and (D, E) vertical distribution of volatile organic compounds, Galena Airport, Alaska, August to September 2002.
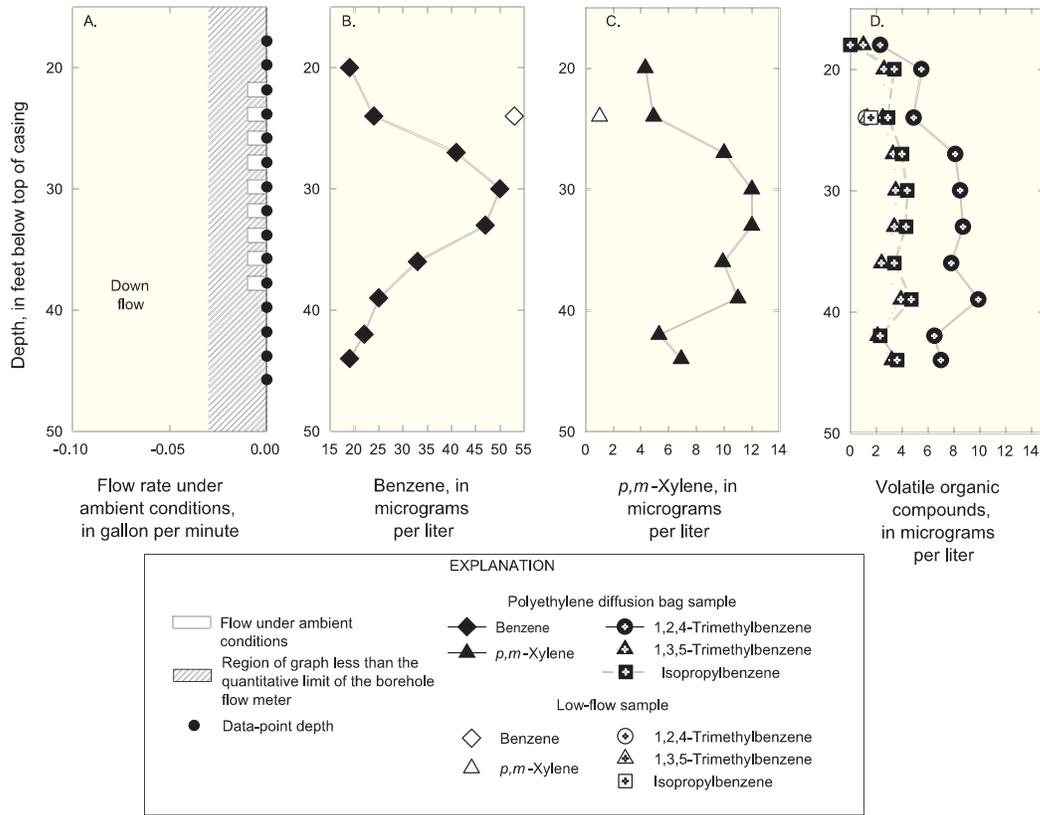
Figure 5.   Well 10-MW-03, vertical flow under (A) ambient conditions and the vertical distribution of (B) benzene, (C) *p,m*-xylene, and (D) other volatile organic compounds, Galena Airport, Alaska, August to September 2002.
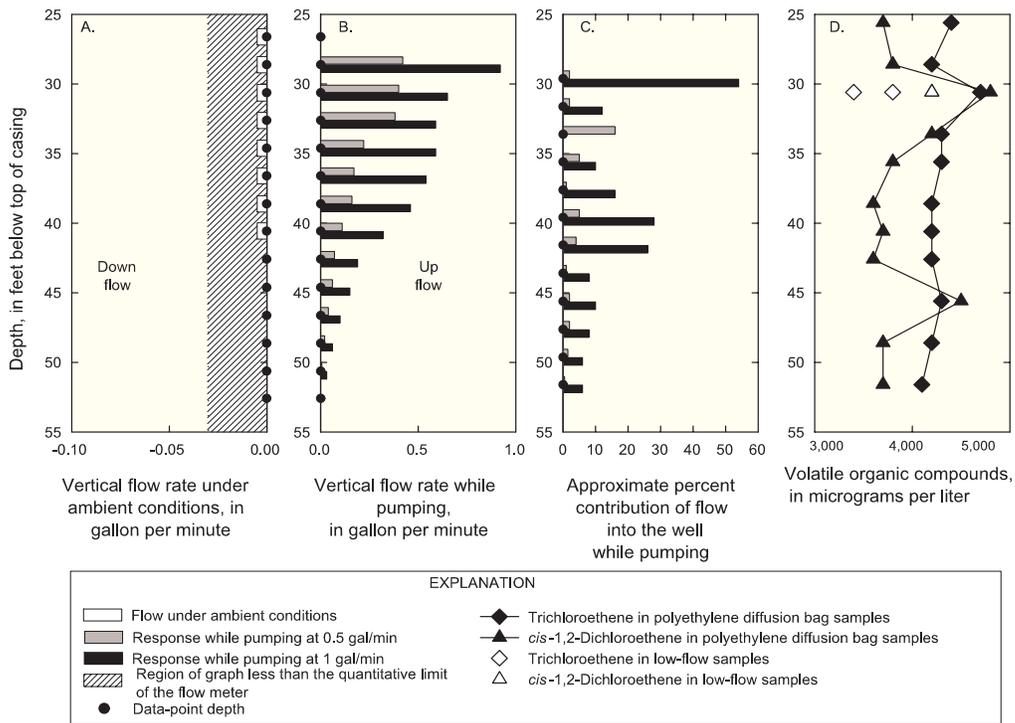
Figure 6.   Well 06-MW-01, flow rate under (A) ambient and (B) pumping conditions, (C) approximate percent contribution of flow into the well while pumping, and (D) vertical distribution of trichloroethene and *cis*-1,2-dichloroethene, Galena Airport, Alaska, August to September 2002.
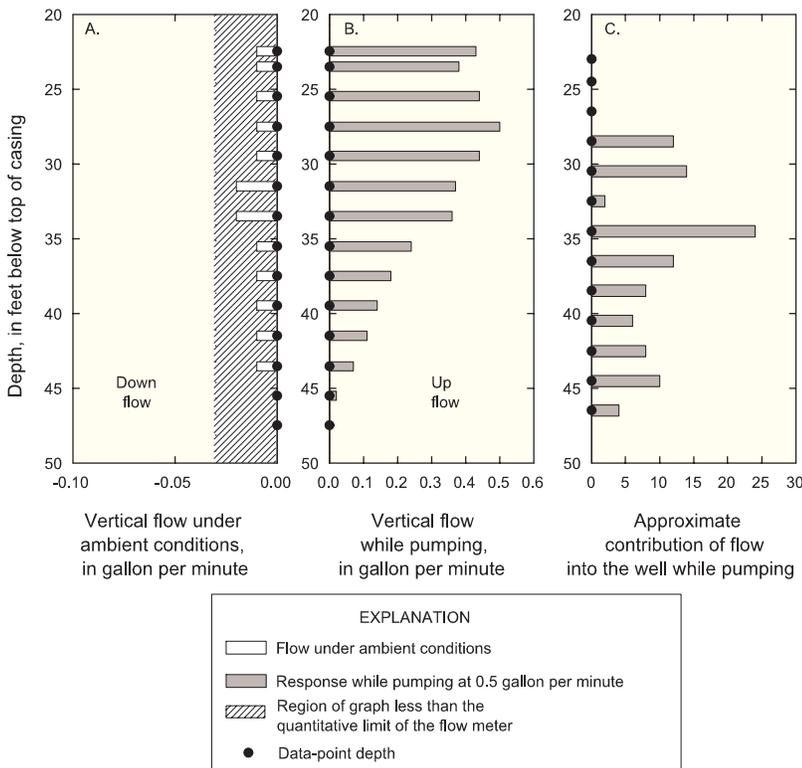
Figure 7. Well 06-MW-03, vertical flow rate under (A) ambient and (B) pumping conditions, and (C) approximate percent contribution of flow into the well while pumping, Galena Airport, Alaska, August 2002.

supplying water, the inflow typically was not evenly distributed. The greatest contrast appeared to be in well 06-MW-04, where most of the water entered the well between depths of about 25 and 37 ft (fig. 4). Relative to this zone, the amount of water entering the well at 21 ft and at five depths below about 37 ft, contributed less than about 6 percent of the pumpage. The predominant inflow zone was at a depth of about 34 ft in wells 06-MW-03 (fig. 7A, B) and 10-MW-01 (fig. 8A, B). In the remaining tested wells (06-MW-01, 06-MW-02, 06-MW-07), the maximum zone of inflow was near the top of the tested interval, which ranged from depths of about 26 to 30 ft (figs. 6A, B; 9A, B; 10A, B, respectively). Borehole-flow measurements under pumping conditions could not be obtained in well 10-MW-03 (fig. 5) because the pump did not fit inside the casing.
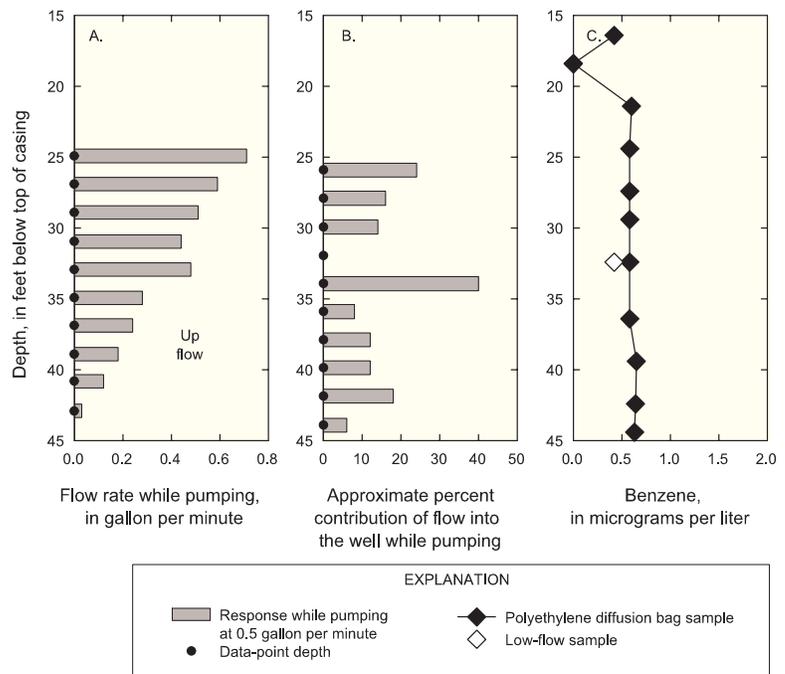
Figure 8. Well 10-MW-01, (A) vertical flow rate while pumping, (B) approximate percent contribution of flow into the well while pumping, and (C) vertical distribution of benzene, Galena Airport, Alaska, August to October 2002. No vertical flow was found under ambient conditions.
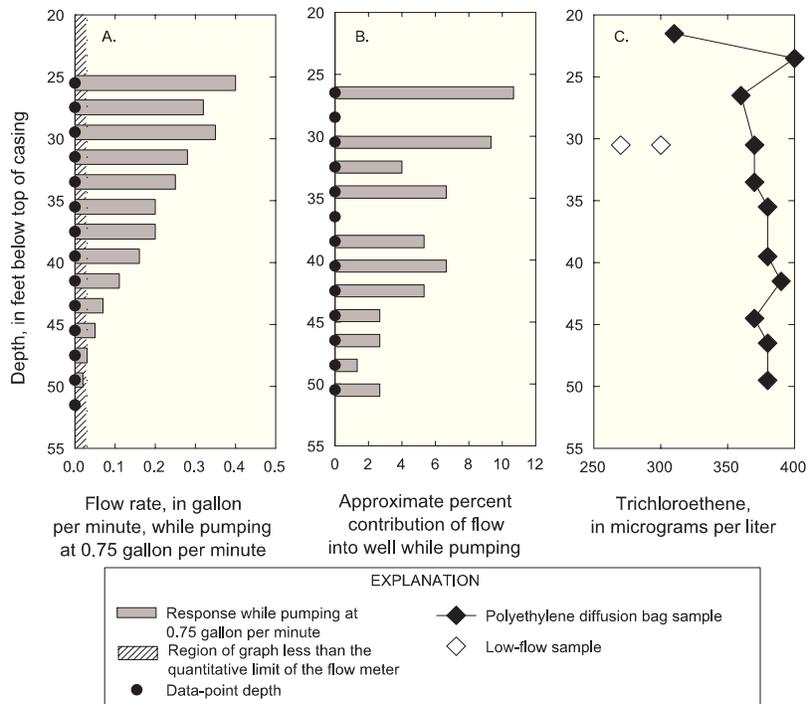
Figure 9.   Well 06-MW-02, (A) vertical flow rate under pumping conditions, (B) approximate percent contribution of flow into the well while pumping, and (C) vertical distribution of trichloroethene, Galena Airport, Alaska, August to September 2002. No vertical flow was found under ambient conditions.
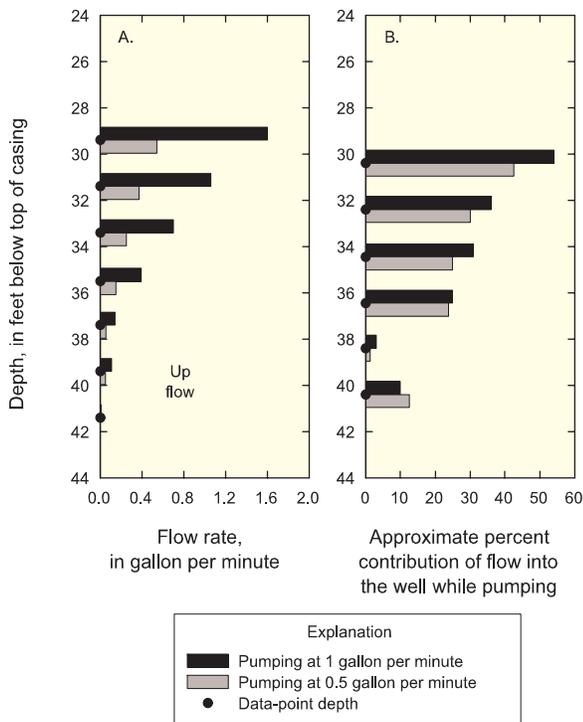
Figure 10.   Well 06-MW-07, (A) Vertical flow rate under pumping conditions, and (B) approximate percent contribution of flow into the well while pumping, Galena Airport, Alaska, August to October 2002. No vertical flow was found under ambient conditions.

Comparison of Polyethylene Diffusion Bag and Low-Flow Methods, and Vertical Distribution of Volatile Organic Compounds in Polyethylene Diffusion Bag Samples

In general, the VOC concentrations detected in the low-flow samples from wells at Galena Airport, Alaska, were approximately the same concentrations detected in the closest PDB sample for a wide variety of VOCs (table 3, p. 22; fig. 11). At concentrations less than or equal to 5 micrograms per liter (µg/L), the average difference in concentrations between PDB and low-flow sample results was only 1.2 µg/L. The average relative percentage difference (RPD) between PDB and low-flow sample results for concentrations greater than 5 µg/L was 16.5 percent. The data indicate that the PDB-sample results are consistent with the low-flow sample results.

PDB samplers were deployed at various depths in some of the wells to examine the vertical distribution of VOCs in the aquifer. Vertical variations often are observed in wells across relatively short-screened intervals (Dean and others, 1999; Pitkin and others, 1999; Vroblesky and Peters, 2000). Because there is a potential for horizontal flow to be much greater than vertical flow in short-screened wells relative to longer-screened
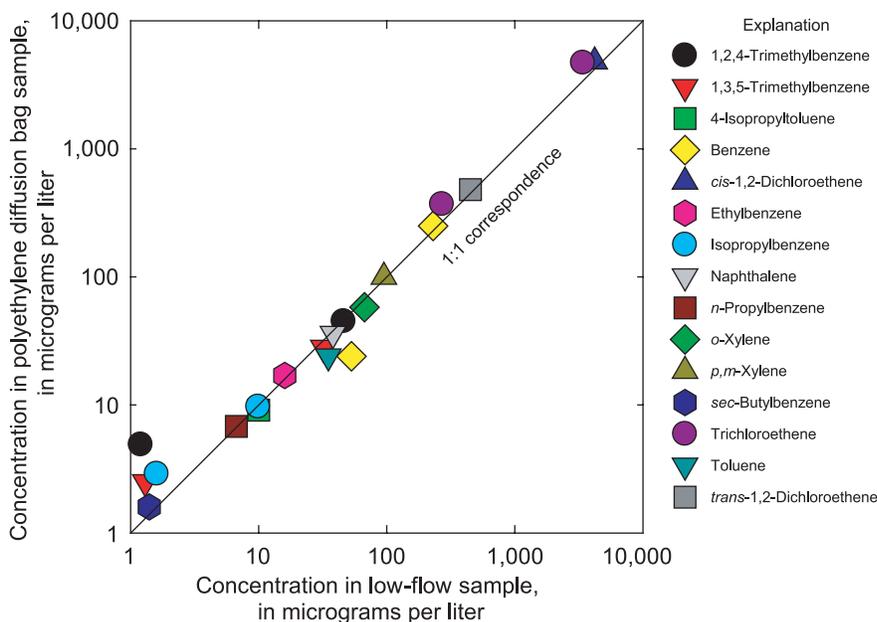
Figure 11.   Comparison of volatile organic compound concentrations in polyethylene-based diffusion bag samples and low-flow samples from wells at Galena Airport, Alaska, September 30 to October 1, 2002.

wells, VOC concentrations in relatively short-screened wells often are representative of concentrations in the adjacent aquifer. Longer screened intervals, such as greater than 10 ft, increase the potential to intercept zones of differing hydraulic head (Church and Granato, 1996). A long-screened well connecting zones of differing hydraulic head can be a conduit for vertical flow. Because such vertical flow can translocate contaminants vertically in the well, contaminant stratification in the aquifer sometimes is obscured in the well, resulting in concentrations that may vary little with depth. Thus, when approximately the same VOC concentrations are observed in PDB samples from many depths in long-screened wells, the simplest explanation usually is that some amount of vertical flow is displacing the contamination. As will be shown, vertical flow in the wells is a potential explanation for the relative uniformity of the vertical VOC distributions observed in data collected from Galena Airport, based on probable hydraulic differences between the dates of flow-meter testing and PDB-sample recovery.

Vertical profiling of selected wells with PDB samplers at Galena Airport indicated that between September 30 and October 1, 2002, in some of the wells, little vertical change occurred in VOC concentrations along the screened length despite the fact that little or no vertical flow was measured in most of the tested wells in August 2002. Well 06-MW-02 contained TCE concentrations that varied little (360 to 400 µg/L) among the 10 depths below 23 ft (fig. 9). The borehole flow meter detected what may have been slight downward flow over part of the screened interval, but the potential flow was substantially less than the quantitative limit of the flow meter (table 2). Although no vertical flow was detected in well 10-MW-01 in August 2002 (table 2), benzene

concentrations in October 2002 remained between 0.5 and 1.0 µg/L throughout most of the 40-ft well screen length (fig. 8C). These benzene concentrations are below the Regulatory Cleanup Level (Alaska Department of Environmental Conservation, 2000), and the low concentrations are subject to some degree of analytical uncertainty; however, they are shown to illustrate the uniformity of data across the screened interval.

Similarly, the presence of VOCs was detected along the entire 40-ft screen length of well 06-MW-04 (fig. 4D, E). The highest benzene and o-xylene concentrations were adjacent to the hydraulically productive zone between depths of 25 and 34 ft; however, the vertical changes were relatively small (fig. 4D). Naphthalene concentrations varied by only 10 µg/L over the 12 depths. At all depths greater than 20 ft, in well 06-MW-04, p,m-xylene concentrations ranged between 120 and 140 µg/L (table 3). The toluene concentration was highest (66 µg/L) at the 21-ft depth, adjacent to an apparently unproductive part of the aquifer. At depths ranging from 23 to 47 ft, the toluene concentrations varied only slightly (between 43 and 55 µg/L; fig. 4E; table 3).

Two of the wells (10-MW-03 and 06-MW-01) had slightly greater vertical concentration variations for some constituents (figs. 5, 6). Well 10-MW-03 contained a zone of distinctly higher benzene and p,m-xylene concentrations near the mid depth of the well screen relative to shallower or deeper depths (fig. 5B, C). The highest benzene and p,m-xylene concentrations measured in PDB samples were found at depths of 30 and 33 ft. This zone corresponds to a gravel layer at a depth approximately between 25 to 35 ft, whereas shallower and deeper horizons are predominantly sand, based on the well-installation log (Manish Joshi, Earth Tech, written commun.,

2002). Thus, the correlation between the depth and the concentrations of the benzene and *p,m*-xylene in well 10-MW-03 probably is lithologically influenced. The relation was less clear for VOCs present at concentrations less than 10 µg/L, such as 1,2,4-trimethylbenzene, 1,3,5-trimethyl-benzene, and isopropylbenzene (fig. 5D), as well as for other VOCs (table 3).

The highest TCE and *cis*-1,2-dichloroethene (*c*DCE) concentrations (4,700 and 4,800 µg/L, respectively) in PDB samples were found in well 06-MW-01 at a depth of 30.6 ft (fig. 6D). This horizon corresponds to the highest water-yielding zone in well 06-MW-01, based on flow-meter testing (fig. 6C), and to a zone of gravelly sand (Manish Joshi, Earth Tech, written commun, 2002). Thus, the zone containing the greatest water movement in this well also appears to be the primary conduit for VOC transport. Despite that relation, however, the VOC concentrations were greater than 3,500 µg/L over the entire 26-ft-long tested interval (fig. 6; table 3). The TCE and *c*DCE concentrations in the low-flow samples collected from 30.6 ft were lower than concentrations in the adjacent PDB sample. The low-flow samples probably represent a mixing effect because the low-flow *c*DCE concentrations were approximately consistent with shallower and deeper concentrations detected in PDB samples (fig. 6D). The low-flow TCE concentrations in samples from 30.6 ft were lower than any detected in the PDB samplers. A possible explanation for the difference is that the pumping may have induced flow into the well of relatively uncontaminated water that did not flow through the well screen under nonpumping conditions.

Potential Influences on the Vertical Distribution of Contaminants in Wells

A variety of potential influences at Galena Airport can contribute to the lack of more substantial variations in vertical concentration over the relatively long screen lengths in wells with little or no apparent in-well vertical flow. Perhaps the most important of these influences is the strong association between ground water and the Yukon River (Radian Corporation, 1996). During most of the year, the Yukon River is a gaining river. During ice breakup (May to June), however, the Yukon River can rise abruptly, producing a temporary ground-water potentiometric-head gradient away from the river. Ground water is affected by this event at least as far inland as the petroleum, oil, and lubricants (POL) tank farm area, approximately 1,400 ft northeast of the Yukon River, based on borehole flow-meter tests (Radian Corporation, 1996). Water-level variations of up to 14.6 ft have been measured at well 06-MW-07, attesting to the hydraulically dynamic nature of the aquifer (U.S. Air Force, Galena, Alaska, written commun. (Environmental Monitoring Report #7), 2002). In 1993, ground-water velocities of 1 to 5 feet per day (ft/d) were measured away from the river during Yukon River flood stage,

and ground-water velocities of 1 to 11 ft/d were measured toward the river in late August (Radian Corporation, 1996).

In 1999, the August ground-water levels were higher than the post-flooding levels of June and showed variable flow directions, suggesting that the August water levels represented a transitional period or a shift in ground-water flow direction from movement away from the river to movement toward the river (U.S. Air Force, Galena, Alaska, written commun. (Environmental Monitoring Report #7), 2002). Similarly, the water levels measured during the PDB-sampler deployment on August 12, 2002, indicated a generally higher water table than in August 1999 with local flows moving in various directions and a general trend in water movement toward the Yukon River (fig. 3; table 4). Thus, water levels on August 12, 2002, also may have reflected the transition period between flow regimes.

By October 1999, the gradient toward the river was re-established after the apparent August 1999 transition period. Following re-establishment of a gradient toward the river, ground-water levels declined and gradients became steeper, with the exception of rises associated with late-summer rainfall; ground-water levels continued to decline even after the Yukon River refroze (Radian Corporation, 1996).

The above discussion of water levels in relation to the Yukon River indicates that the aquifer undergoes substantial changes in water levels and directions of flow. Vertical-flow measurements in wells have not been measured during Yukon River flood stage and during a time of maximum gradient toward the river; however, it is extremely likely that these changes produce some degree of non-horizontal flow in the aquifer and in the wells. The non-horizontal flow probably has two effects. One is to cause a redistribution of ground-water contaminants vertically through the aquifer. Thus, to some extent, the vertical distribution of contaminants in the PDB samples may reflect local aquifer concentrations near the screen.

The other effect of non-horizontal flow is to distribute VOCs vertically in the wells. In a well where vertical flow occurs, the VOC concentrations measured in PDB samples and sometimes in low-flow samples mostly represent VOC concentrations in the inflowing water and may not represent VOC concentrations at the sampler deployment depth in the aquifer. Although little or no vertical flow was measured in the wells under ambient conditions, 1 month had passed between the flow-meter measurement and the PDB-sampler recovery. The flow-meter tests were conducted in August 2002. As the 1999 water-level data indicate, August can be a time of transition between directions of ground-water flow. Moreover, hydraulic gradients tend to increase after August (Radian Corporation, 1996). Consistent with historical trends, the hydraulic gradient across the site in August 2002 was relatively small (1.7×10^{-4} feet per foot [ft/ft]) between wells 06-MW-07 and 09-MW-15 compared to the average hydraulic gradient in October for 1998–2001 (8.9×10^{-4} ft/ft for the same wells [U.S. Air Force, Galena, Alaska, written commun. (Environ-mental Monitoring Report #7), 2002]). Therefore, it is probable that the well hydraulics at the time of the flow-meter tests

Table 4. Surveying and water-level measurements for selected wells at Galena Airport, Alaska, August to October 2002.

[PVC, polyvinyl chloride; ft, feet; NAVD 88, North American Vertical Datum of 1988; BTOC, below top of casing; LNAPL, light nonaqueous-phase liquid; —, data not available]

Well name	Northing[a]	Easting[a]	Elevation of the top of the PVC riser[a] (ft NAVD 88)	Depth to water[b] (ft BTOC)	Elevation of water table[b] (ft NAVD 88)	Comments[b]
01-MW-01	3,925,413.96	1,811,197.40	145.92	17.07	128.85	
01-MW-03	3,925,742.80	1,811,322.90	147.06	18	129.06	
01-MW-05	3,925,521.31	1,811,148.31	146.48	17.5	128.98	
01-MW-07	3,925,229.08	1,811,068.33	149.61	20.47	129.14	
04-MW-02	3,925,266.65	1,812,282.93	147.11	17.8	129.31	
05-MW-02	3,925,967.04	1,805,428.85	149.51	20.7	128.81	
05-MW-03	3,926,037.07	1,805,184.20	147.92	19.13	128.79	
05-MW-04	3,926,029.10	1,805,029.43	145.52	18.5	127.02	Sheen on surface
05-MW-05	3,925,969.68	1,804,904.68	146.14	17.21	—	0.5 ft thickness of LNAPL
05-MW-07	3,926,110.83	1,804,843.10	145.63	16.38	129.25	Sheen on surface
05-MW-11	3,926,508.53	1,804,454.24	149.16	17.5	131.66	
05-MW-13	3,926,307.06	1,804,190.07	147.21	18.48	128.73	
05-MW-19	3,926,478.90	1,805,031.06	147.78	19	128.78	
06-MW-02	3,926,438.79	1,803,544.63	147.79	19.15	128.64	
06-MW-03	3,926,136.62	1,803,300.95	144.50	15.94	128.56	
06-MW-04	3,926,311.95	1,803,047.68	142.62	14.09	128.53	
06-MW-05	3,926,368.74	1,803,213.78	144.92	16.32	128.60	
06-MW-06	3,926,311.17	1,803,740.46	148.81	20.15	128.66	
06-MW-07	3,927,008.05	1,803,826.47	151.58	22.9	128.68	
09-MW-01	3,925,887.33	1,802,988.51	143.25	14.95	128.30	
09-MW-02	3,925,561.20	1,802,813.92	140.48	12.03	128.45	
09-MW-03	3,926,366.05	1,802,303.33	143.83	15.32	128.51	
09-MW-05	3,926,630.71	1,802,495.76	143.04	14.36	128.68	
09-MW-06	3,926,845.24	1,802,850.79	141.07	12.32	128.75	
09-MW-14	3,925,903.67	1,802,572.90	146.29	18.35	127.94	
09-MW-15	3,925,290.25	1,802,755.02	142.55	14.21	128.34	
09-MW-16	3,925,915.43	1,802,185.20	145.38	16.84	128.54	
09-MW-17	3,925,075.02	1,802,716.06	148.62	20.4	128.22	
09-MW-18	3,925,307.45	1,803,088.26	142.04	13.62	128.42	
09-MW-19	3,925,045.05	1,802,916.04	144.53	16.25	128.28	
09-MW-20	3,925,068.29	1,803,103.82	144.07	15.75	128.32	
09-RW-2B	3,926,230.85	1,802,612.64	150.32	40.6	109.72	
10-MW-01	3,926,164.19	1,803,466.88	145.10	16.5	128.60	
10-MW-03	3,925,916.32	1,803,384.52	145.74	17.2	128.54	
11-MW-01R	3,926,655.61	1,803,308.37	145.00	16.38	128.62	

[a]Data from October 2002 survey by Louis Butera, Eagle River Engineering, Eagle River, Alaska.
[b]Data from August 12, 2002, measurements by Ryan Harkness, Earth Tech, San Antonio, Texas.

(August 8–19) differed from the well hydraulics at the time of PDB-sampler recovery (September 30–October 1). Because of the dynamic nature of the ground-water flow regime at Galena Airport, Alaska, it is not reasonable to expect that the vertical-flow measurements taken under ambient conditions in August were necessarily characteristic of the vertical flow in the wells at the time of sampler recovery in late September to October.

An additional factor influencing the vertical distribution of VOC contamination at Galena Airport is the subsurface lithology. In wells 10-MW-03 and 06-MW-01, the zones containing the greatest water movement also contained the highest benzene, TCE, and *c*DCE concentrations, which suggest that these zones are the primary conduits for VOC transport in the screened intervals.

The close match between concentrations measured in PDB and low-flow samples indicates that the PDB samples accurately represent the distribution of VOCs in the wells. It is unclear, however, whether the distribution of VOCs in the wells, as indicated by the PDB samplers, represents contaminant distributions in the aquifer or transient movement within the wells. The probable change in well hydraulics between August and late September to October indicates that the relatively uniform vertical distribution of VOCs in some of the wells may represent in-well mixing.

A variety of approaches potentially can be used to clarify understanding of the vertical distribution of ground-water contamination at the facility. One approach is to install at least one well cluster in each of the contaminant plumes of interest. The cluster wells would have screens no longer than 10 ft and be open at intervals expected to encompass the thickness of the respective plume. Sampling the wells during different periods of time can provide information on the vertical distribution of contamination within the aquifer and on the temporal changes of the ground-water flow regime.

An alternative approach to providing additional insight into the vertical nature of the contamination and information on the optimum horizon for future sampling is to conduct flow-meter tests and collect samples from multiple PDB samplers in wells at different times of the year. If multiple PDB samplers are deployed to examine seasonal differences, the optimum wells to use for such a deployment are wells 06-MW-01, 06-MW-02, 06-MW-04, and 10-MW-03. The deployment depths are listed in table 3. To optimize sampling during seasonal differences, the samplers should be retrieved at intervals that include the extremes of hydraulic conditions. Thus, the samplers would be deployed prior to ice breakup in the Yukon River and recovered sometime during the period when ground water is flowing away from the Yukon River. Samplers recovered prior to ice breakup may provide VOC information characteristic of the lowest ground-water levels in the wells.

An additional potential approach to obtaining information on the vertical distribution of contaminants is to use direct-push technology. The gravel-rich sediment at Galena Airport, however, probably will limit the depth of penetration by this technology.

Suggestions Concerning Installation of Additional Wells at Galena Airport, Alaska

The westernmost contaminant plume at Million Gallon Hill seems to be surrounded with sufficient monitoring wells to detect changes in the plume extent (fig. 1); however, the installation of additional wells has the potential to provide more detailed information on the extent of ground-water contamination in the remaining plumes. For example, the extent of ground-water contamination and direction of contaminant movement at the fire-protection training area and the southeast runway fuel spill are not known. The extent of contamination at these sites was approximately defined in 1996 by soil-gas, water samples, and sediment samples (Radian Corporation, 1996). The lateral extent of the southeast runway fuel spill in 1996 was greater than 1,000 ft, based on soil-vapor measurements. At the time of this investigation in 2002, however, the ground-water plume was defined by one well within the plume (SE-MW-01) and a series of lateral and downgradient wells outside the plume that are separated from each other by at least 300 ft (fig. 1). In a hydraulically dynamic ground-water system, such as the aquifer at Galena Airport, there is some degree of uncertainty in defining the specific ground-water pathway along which contaminations are transported. Thus, wells spaced 300 ft apart or more may not be adequate to determine flow paths. If these are issues of concern, additional wells could be used to fill in the data gaps.

Well placement would be based on probable flow directions derived from water-level measurements. Only three wells currently monitor water levels on a routine basis at the southeast runway plume (wells SE-MW-01, SE-MW-03, and SE-MW-04). The geometric arrangement of these three wells makes it difficult to determine a local direction of ground-water flow at the southeast runway spill. Three other wells in that area could be used to measure water levels routinely (wells SE-MW-02, SE-MW-05, and SE-MW-06). Mapping the water levels from these six wells would provide a better understanding of ground-water movement through the area and would optimize monitoring-well placement. In the absence of water-level data, well placement would have to be directed toward filling in some of the larger gaps between monitoring wells, such as between wells SE-MW-03 and SE-MW-05 and between wells SE-MW-05 and SE-MW-06.

Similarly, the ground-water contamination at the fire-protection training area (fig. 1) presently is defined by one upgradient well, one in-plume well, and one downgradient well. Thus, the present extent of ground-water contamination at this site is not known. The three monitoring wells are arranged approximately linearly, making it difficult to use the water levels to determine local flow direction at the fire-protection training area (fig. 1). If there is concern regarding the uncertain extent of contamination or its potential movement southward, then additional wells could be used to fill in the data gaps. If an

additional well is installed, the optimal location would be southeast of well 01-MW-01 in order to allow monitoring along the shortest potential transport pathway and to provide a water-level data point outside of the line of existing wells.

The POL tank farm plume (fig. 1) is in an area where the predominant direction of ground-water flow is approximately southwestward (U.S. Air Force, Galena, Alaska, written commun. (Environmental Monitoring Report #7), 2003). Downgradient sentinel wells for the POL tank farm plume consist of three wells to the south and one to the southeast (fig. 1). The distances between the sentinel wells range from about 300 to 600 ft. Because there is potential for a migrating ground-water contamination plume to be narrower than 300 ft, even when the source area is larger than 300 ft, it is possible that contaminants could migrate between the sentinel wells, such as between wells 05-MW-18 and 05-MW-16. Abandoned well 05-MW-15 (not shown on fig. 1) formerly filled this gap. If increased confidence in monitoring potential movement of this plume is desired, then additional wells could fill in the data gaps.

The easternmost Million Gallon Hill contaminant plume and the JP-4 fillstand plume appear to be highly dynamic in nature. The extent of contamination changed markedly between June and October 2001 (fig. 1; U.S. Air Force, Galena, Alaska, written commun. (Environmental Monitoring Report #7), 2002). In June 2001, the JP-4 fillstand plume extended at least to the farthest downgradient monitoring well (09-MW-19). Thus, the actual extent of contamination in June 2001 is unknown. These changes potentially represent seasonal influences that may recur. An additional well installed downgradient from well 09-MW-19 could be used to monitor the seasonal distribution of contaminants downgradient from the JP-4 fillstand. Furthermore, although the easternmost Million Gallon Hill plume did not intersect downgradient well 09-MW-17, the placement of well 09-MW-17 implies the assumption that the ground-water contamination followed a particular flow path defined by the line of wells, including wells 09-MW-01, 09-MW-02, 09-MW-15, and 09-MW-17 (fig. 2). Because the extent of the plume is defined by a line of wells along the presumed axis of contamination, no information is available on the lateral extent of the plume. If the assumed flowpath is incorrect, which is quite possible in this aquifer of changing flow directions, the actual contamination extent may be larger than mapped. A better understanding of the actual extent of contamination and direction of movement could be obtained by installing additional wells.

In the case of the easternmost Million Gallon Hill contaminant plume, more definition in the lateral extent of the plume and the actual axis of contamination could be obtained by installing a well approximately 150 to 200 ft west of well 09-MW-02. If VOC concentrations are higher in well 09-MW-02 than in the new well, then the plume definition as mapped probably is not substantially different from the actual plume location. On the other hand, if VOC concentrations are higher in the new well than in well 09-MW-02, then it is likely that the axis of contamination is not along a line defined by the existing monitoring wells. In addition, a well cluster approximately 150 to 200 ft west of well 09-MW-17 could provide a better understanding of the downgradient extent of contamination; however, the actual location and number of wells may depend on the data from the new well located west of well 09-MW-02. If the line of wells does not adequately track the axis of contamination from the easternmost Million Gallon Hill plume, then additional wells may be needed to define the plume.

The potential for movement of the chlorinated-solvent plume south of building 1845 toward the Yukon River appears to be adequately monitored by a series of downgradient sentinel wells; however, the lateral extent of the contamination is not well defined. If the lateral extent of contamination is important for remediation purposes, then additional wells could fill the data gap. Furthermore, because the hydraulically dynamic nature of the aquifer makes it unclear whether the distribution of VOCs in the wells, as indicated by the PDB samplers, represents contaminant distributions in the aquifer or transient movement within the wells, the vertical extent of the contamination remains unknown. If information on the vertical distribution of VOCs in the aquifer is needed, then further work is required. More definitive data could be obtained by installing a well cluster with 5- to 10-ft-long screens in the wells open at depths of about 30 to 40 ft and 65 to 75 ft through the suspected chlorinated-solvent plume between building 1845 and the Yukon River. Borehole flow-meter testing in some of the existing 40-ft-long well screens during the period of ground-water flow reversal caused by Yukon River flooding and during the late summer could provide insight into the PDB-sampler results and into the potential for in-well redistribution of contaminants. Similarly, if information on the vertical extent of ground-water contamination in the other plumes is desired, well clusters installed in those plumes probably will provide additional information.

Summary and Conclusions

Past activities at Galena Airport, a U.S. Air Force Base in Galena, Alaska, have resulted in ground-water contamination by VOCs. The primary contaminants are petroleum hydrocarbons and chlorinated aliphatic hydrocarbons. The USGS and Earth Tech, in cooperation with the AFCEE, conducted investigations at Galena Airport from August to October 2002 using PDB samplers and borehole flow-meter testing to examine the vertical distribution of ground-water contamination in selected wells. This investigation was limited to the vicinity of building 1845 and to the area between building 1845 and the Yukon River. In addition, the USGS was asked to determine whether additional wells are needed to more clearly define the nature and extent of the ground-water contamination at the Air Force Base.

Galena Airport, Alaska, is in the flood plain of the Yukon River. During much of the year, ground-water flow is toward

the Yukon River, which typically is frozen from November through June. During ice breakup in May to June, the Yukon River sporadically floods, causing a temporary reversal in ground-water flow away from the river. At the time the PDB samplers were deployed in August 2002, the ground-water movement generally was toward the Yukon River.

Little or no vertical water movement occurred under ambient conditions in the wells tested at Galena Airport, Alaska, in August 2002. All of the ambient vertical flows detected in wells were at rates less than the quantitative limit of the borehole flow meter (0.03 gal/min). In wells 06-MW-06, 06-MW-07, 09-MW-17, and 10-MW-01, no vertical flow was detected. In wells where ambient flow was detected, the direction of flow was downward.

The vertical-flow measurements collected under pumping conditions indicated the depths of the water-yielding zones. Although most of the tested depths appeared to be capable of supplying water, the inflow typically was not evenly distributed. The greatest contrast appeared to be in well 06-MW-04, where most of the water entered the well between depths of about 25 to 37 ft. The predominant inflow zone was at a depth of about 34 ft in wells 06-MW-03 and 10-MW-01. In the remaining tested wells (06-MW-01, 06-MW-02, 06-MW-07), the maximum zone of inflow was near the top of the tested interval, which ranged from depths of about 26 to 30 ft.

In general, the VOC concentrations detected in the low-flow samples from wells at Galena Airport, Alaska, were approximately the same concentrations detected in the closest PDB sample for a wide variety of VOCs. The data indicate that the PDB-sample results are consistent with the low-flow sample results.

Vertical profiling of selected wells with PDB samplers at Galena Airport indicated that from September 30 to October 1, 2002, little vertical change occurred in VOC concentrations along the screen length of some wells despite the fact that little or no vertical flow was measured in most of the tested wells in August 2002. Two of the wells (10-MW-03 and 06-MW-01) had slightly greater vertical concentration variations for some constituents. In these wells, the contaminant depth probably is lithologically influenced.

The close match between concentrations measured in PDB and low-flow samples indicates that the PDB samples accurately represent the distribution of VOCs in the wells. It is unclear, however, whether the distribution of VOCs in the wells, as indicated by the PDB samplers, represents contaminant distributions in the aquifer or transient movement within the wells. The probable change in well hydraulics between August and late September to October indicates that the relatively uniform vertical distribution of VOCs in some of the wells may represent in-well mixing.

A variety of approaches potentially can be used to clarify the vertical distribution of ground-water contamination at the Air Force Base. One approach is to install at least one well cluster in each of the contaminant plumes where vertical profiling is of interest. Sampling the wells during different

periods of time in the ground-water flow regime could provide information on the vertical distribution of contamination within the aquifer and on temporal changes of the flow regime.

An alternative approach to providing additional insight into the vertical nature of the contamination and information on the optimum horizon for future sampling is to conduct flow-meter tests and collect samples from multiple PDB samplers in wells at different times of the year. If multiple PDB samplers are deployed to examine seasonal differences, then the optimum wells for such a deployment are wells 06-MW-01, 06-MW-02, 06-MW-04, and 10-MW-03.

The westernmost contaminant plume at Million Gallon Hill seems to be surrounded with sufficient monitoring wells to detect changes in the plume extent; however, the installation of additional wells has the potential to provide more detailed information on the extent of ground-water contamination in the remaining plumes. The extent of ground-water contamination and the local directions of ground-water flow are not known with certainty at the fire-protection training area plume or the southeast runway plume. In these areas, as well as at the POL tank farm plume, the spacing of sentinel wells is great enough to allow contaminants to migrate past the wells undetected. In each of these situations, additional monitoring wells could fill in the data gaps.

The easternmost Million Gallon Hill contaminant plume and the JP-4 fillstand plume are defined primarily by a line of wells along the presumed axis of each plume. The number of lateral wells, however, is insufficient to confirm that the presumed axis of contamination is correct. If it is not correct, then the actual extent of contamination may be larger than mapped. A better understanding of the actual extent of contamination and direction of movement could be obtained by installing additional wells.

The potential for southward movement of the chlorinated-solvent plume south of building 1845 appears to be adequately monitored by a series of downgradient sentinel wells; however, the lateral extent of the contamination is not well defined. If the lateral extent of contamination is important for remediation purposes, then additional wells could fill the data gap.

References

Alaska Department of Environmental Conservation, 2000, 18 AAC 75 Oil and Other Hazardous Substances Pollution Control Regulations, no. 228, October 2000.

Church, P.E., and Granato, G.E., 1996, Effects of well design and sampling methods on bias of water-quality samples: Ground Water, v. 34, no. 2, p. 262–273.

Dean, S.M., Lendvay, J.M., Barcelona, M.J., Adriaens, Peter, and Katopodes, N.D., 1999, Installing multilevel sampling arrays to monitor ground water and contaminant discharge to a surface water body: Ground Water Monitoring and Remediation, v. 19, no. 4, p. 90–96.

Hare, P.W., 2000, Passive diffusion bag samplers for monitoring chlorinated solvents in ground water, *in* Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, Calif., May 22–25, 2000: Columbus, Ohio, Battelle Press, 7 volumes, book C2-1.

McClellan Air Force Base Environmental Management Directorate, 2000, Technology application analysis report for passive diffusion membrane samplers: Sacramento, Calif., McClellan Air Force Base Environmental Management, 282 p.

Mount Sopris Instrument Company, Inc., 2001, HFP-2293 heat pulse flow meter: Mount Sopris Instrument Company, Inc., 11 p.

Parsons Engineering Science, Inc., 1999, Technical report for the evaluation of ground water diffusion samplers: Parsons Engineering Science, Inc., report prepared for Air Force Center for Environmental Excellence Technology Division, December 1999, 35 p.

Pitkin, S.E., Cherry, J.A., Ingleton, R.A., and Broholm, Mette, 1999, Field demonstrations using the Waterloo ground water profiler: Ground Water Monitoring and Remediation, v. 19, no. 2, p. 122–132.

Radian Corporation, 1996, Remedial investigation report, Galena Airport and Campion Air Station, v. 7, final report: Radian Corporation, Report to the U.S. Air Force, March 1996, 597 p.

U.S. Environmental Protection Agency, 1992, Test methods for determining solid waste: Washington D.C., U.S. Environmental Protection Agency Office of Solid Waste, SW-846, 910 p.

Vroblesky, D.A., 2001, User's guide for polyethylene-based passive diffusion bag samplers to obtain volatile organic compound concentrations in wells, Part 1—Assembly and quality control and assurance: U.S. Geological Survey Water-Resources Investigations Report 01-4060, 18 p.

Vroblesky, D.A., Borchers, J.W., Campbell, T.R., and Kinsey, Willey, 2000, Investigation of polyethylene passive diffusion samplers for sampling volatile organic compounds in ground water at Davis Global Communication, Sacramento, California, August 1998 to February 1999: U.S. Geological Survey Open-File Report 00-307, 13 p.

Vroblesky, D.A., and Hyde, W.T., 1997, Diffusion samplers as an inexpensive approach to monitoring VOCs in ground water: Ground Water Monitoring and Remediation, v. 17, no. 3, p. 177–184.

Vroblesky, D.A., and Peters, B.C., 2000, Diffusion sampler testing at Naval Air Station North Island, San Diego County, California, November 1999 to January 2000: U.S. Geological Survey Water-Resources Investigation Report 00-4182, 27 p.

Vroblesky, D.A., and Petkewich, M.D., 2000, Field testing of passive diffusion bag samplers for volatile organic compound concentrations in ground water, Naval Industrial Reserve Ordnance Plant, Fridley, Minnesota, November 1999 and May 2000: U.S. Geological Survey Water-Resources Investigations Report 00-4246, 10 p.

Vroblesky, D.A., and Pravecek, Tasha, 2002, Evaluation of passive diffusion bag and dialysis samplers in selected wells at Hickam Air Force Base, Hawaii, July 2001: U.S. Geological Survey Water-Resources Investigations Report 02-4159, 38 p.

Table 2. Results of flow-meter testing in wells, Galena Airport, Alaska, August 2002.

[ft, feet; BTOC, below top of casing; gal/min, gallons per minute; <, less than; *, vertical flow was tentatively detected at a rate less than the lower quantitation limit of the borehole flow meter. The value indicates the estimated rate. < -0.001*, a possible indication of downward flow was observed, but at a rate less than 0.001 gallon per minute; —, data not available; negative vertical flow indicated downward water movement]

Well name	Date	Depth to water (ft BTOC)	Depth of vertical-flow measurement (ft BTOC)	Vertical flow, in gal/min					Approximate depth of inflow contribution (ft BTOC)	Approximate percentage of total flow to the well contributed from the respective horizon during pumping from 2 to 5 ft below the water table			
				Ambient conditions	Pumping at 0.4 gal/min	Pumping at 0.5 gal/min	Pumping at 0.75 gal/min	Pumping at 1 gal/min		When pumping at 0.4 gal/min	When pumping at 0.5 gal/min	When pumping at 0.75 gal/min	When pumping at 1 gal/min
06-MW-01	8/12–13/2002	22.5	24.62	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-01			26.62	-0.005*	—	—	—	—	—	—	—	—	—
06-MW-01			28.6	-0.005*	—	0.42	—	0.92	—	—	—	—	—
06-MW-01			30.6	-0.005*	—	0.4	—	0.65	29.6	—	2	—	54
06-MW-01			32.6	-0.005*	—	0.38	—	0.59	31.6	—	2	—	12
06-MW-01			34.6	-0.005*	—	0.22	—	0.59	33.6	—	16	—	
06-MW-01			36.6	-0.005*	—	0.17	—	0.54	35.6	—	5	—	10
06-MW-01			38.6	-0.005*	—	0.16	—	0.46	37.6	—	1	—	16
06-MW-01			40.6	-0.005*	—	0.11	—	0.32	39.6	—	5	—	28
06-MW-01			42.6	< -0.001	—	0.07	—	0.19	41.6	—	4	—	26
06-MW-01			44.6	< -0.001	—	0.06	—	0.15	43.6	—	1	—	8
06-MW-01			46.6	< -0.001	—	0.04	—	0.1	45.6	—	2	—	10
06-MW-01			48.6	< -0.001	—	0.02	—	0.06	47.6	—	2	—	8
06-MW-01			50.6	< -0.001	—	0.005	—	0.03	49.6	—	1.5	—	6
06-MW-01			52.6	< -0.001	—	< -0.001	—	< -0.001	51.6	—	0.5	—	6
06-MW-02	8/19/2002	19.74	21.48	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-02			23.49	< -0.001*	—	—	—	—	—	—	—	—	—
06-MW-02			25.5	< -0.001*	—	—	0.4	—	—	—	—	—	—
06-MW-02			27.48	< -0.001*	—	—	0.32	—	26.5	—	—	10.7	—
06-MW-02			29.49	< -0.001*	—	—	0.35	—	28.5	—	—	0.0	—
06-MW-02			31.49	< -0.001*	—	—	0.28	—	30.5	—	—	9.3	—
06-MW-02			33.49	< -0.001*	—	—	0.25	—	32.5	—	—	4.0	—
06-MW-02			35.5	< -0.001*	—	—	0.2	—	34.5	—	—	6.7	—
06-MW-02			37.5	< -0.001*	—	—	0.2	—	36.5	—	—	0.0	—
06-MW-02			39.49	< -0.001*	—	—	0.16	—	38.5	—	—	5.3	—
06-MW-02			41.49	< -0.001*	—	—	0.11	—	40.5	—	—	6.7	—
06-MW-02			43.49	< -0.001*	—	—	0.07	—	42.5	—	—	5.3	—

Table 2. Results of flow-meter testing in wells, Galena Airport, Alaska, August 2002.—Continued

[ft, feet; BTOC, below top of casing; gal/min, gallons per minute; < , less than; *, vertical flow was tentatively detected at a rate less than the lower quantitation limit of the borehole flow meter. The value indicates the estimated rate. < -0.001*, a possible indication of downward flow was observed, but at a rate less than 0.001 gallon per minute; —, data not available; negative vertical flow indicated downward water movement]

Well name	Date	Depth to water (ft BTOC)	Depth of vertical-flow measurement (ft BTOC)	Vertical flow, in gal/min					Approximate depth of inflow contribution (ft BTOC)	Approximate percentage of total flow to the well contributed from the respective horizon during pumping from 2 to 5 ft below the water table			
				Ambient conditions	Pumping at 0.4 gal/min	Pumping at 0.5 gal/min	Pumping at 0.75 gal/min	Pumping at 1 gal/min		When pumping at 0.4 gal/min	When pumping at 0.5 gal/min	When pumping at 0.75 gal/min	When pumping at 1 gal/min
06-MW-02	8/19/2002	19.74	45.49	< -0.001*	—	—	0.05	—	44.5	—	—	2.7	—
06-MW-02	(Continued)		47.5	< -0.001	—	—	0.03	—	46.5	—	—	2.7	—
06-MW-02			49.49	< -0.001	—	—	0.02*	—	48.5	—	—	1.3	—
06-MW-02			51.5	< -0.001	—	—	< -0.001	—	50.5	—	—	2.7	—
06-MW-03	8/11/2002	16.21	17.55	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-03			19.51	-0.01*	—	—	—	—	—	—	—	—	—
06-MW-03			22.5	-0.01*	—	0.43	—	—	—	—	—	—	—
06-MW-03			23.5	-0.01*	—	0.38	—	—	—	—	—	—	—
06-MW-03			25.5	-0.01*	—	0.44	—	—	—	—	—	—	—
06-MW-03			27.5	-0.01*	—	0.5	—	—	—	—	—	—	—
06-MW-03			29.5	-0.01*	—	0.44	—	—	28.5	—	12	—	—
06-MW-03			31.5	-0.02*	—	0.37	—	—	30.5	—	14	—	—
06-MW-03			33.5	-0.02*	—	0.36	—	—	32.5	—	2	—	—
06-MW-03			35.5	-0.01*	—	0.24	—	—	34.5	—	24	—	—
06-MW-03			37.5	-0.01*	—	0.18	—	—	36.5	—	12	—	—
06-MW-03			39.5	-0.01*	—	0.14	—	—	38.5	—	8	—	—
06-MW-03			41.5	-0.01*	—	0.11	—	—	40.5	—	6	—	—
06-MW-03			43.5	-0.01*	—	0.07	—	—	42.5	—	8	—	—
06-MW-03			45.5	< -0.001	—	0.02	—	—	44.5	—	10	—	—
06-MW-03			47.5	< -0.001	—	< -0.001	—	—	46.5	—	4	—	—
06-MW-04	8/12/2002	13.98	15.69	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-04			17.71	-0.005*	—	—	—	—	—	—	—	—	—
06-MW-04			20.1	-0.005*	—	—	0.43	—	—	—	—	—	—
06-MW-04			21.7	-0.01*	—	—	0.43	—	—	—	—	—	—
06-MW-04			23.7	-0.01*	—	—	0.4	—	22.7	—	—	4.0	—
06-MW-04			25.7	-0.01*	—	—	0.32	—	24.7	—	—	10.7	—
06-MW-04			27.7	-0.01*	—	—	0.29	—	26.7	—	—	4.0	—

Table 2. Results of flow-meter testing in wells, Galena Airport, Alaska, August 2002.—Continued

[ft, feet; BTOC, below top of casing; gal/min, gallons per minute; < , less than; *, vertical flow was tentatively detected at a rate less than the lower quantitation limit of the borehole flow meter. The value indicates the estimated rate. < -0.001*, a possible indication of downward flow was observed, but at a rate less than 0.001 gallon per minute; —, data not available; negative vertical flow indicated downward water movement]

Well name	Date	Depth to water (ft BTOC)	Depth of vertical-flow measurement (ft BTOC)	Vertical flow, in gal/min					Approximate depth of inflow contribution (ft BTOC)	Approximate percentage of total flow to the well contributed from the respective horizon during pumping from 2 to 5 ft below the water table			
				Ambient conditions	Pumping at 0.4 gal/min	Pumping at 0.5 gal/min	Pumping at 0.75 gal/min	Pumping at 1 gal/min		When pumping at 0.4 gal/min	When pumping at 0.5 gal/min	When pumping at 0.75 gal/min	When pumping at 1 gal/min
06-MW-04	8/12/2002	13.98	29.7	-0.01*	—	—	0.24	—	28.7	—	—	6.7	—
06-MW-04	(Continued)		31.7	-0.005*	—	—	0.17	—	30.7	—	—	9.3	—
06-MW-04			33.7	-0.005*	—	—	0.13	—	32.7	—	—	5.3	—
06-MW-04			35.7	< -0.001	—	—	0.08	—	34.7	—	—	6.7	—
06-MW-04			37.7	< -0.001	—	—	0.03	—	36.7	—	—	6.7	—
06-MW-04			39.7	< -0.001	—	—	0.03	—	—	—	—	—	—
06-MW-04			41.7	< -0.001	—	—	0.02*	—	40.7	—	—	1.3	—
06-MW-04			43.7	< -0.001	—	—	0.02*	—	—	—	—	—	—
06-MW-04			45.7	< -0.001	—	—	0.01*	—	44.7	—	—	1.3	—
06-MW-04			47.7	< -0.001	—	—	< -0.001	—	46.7	—	—	1.3	—
06-MW-07	8/8/2002	23.1	11.62	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			13.58	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			15.71	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			17.67	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			19.64	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			21.6	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			23.73	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			25.69	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			27.66	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-07			29.4	< -0.001	—	—	—	1.6	—	—	—	—	—
06-MW-07			31.4	< -0.001	—	—	—	1.06	30.4	42.5	—	—	54
06-MW-07			33.4	< -0.001	—	—	—	0.7	32.4	30	—	—	36
06-MW-07			35.5	< -0.001	—	—	—	0.39	34.5	25	—	—	31
06-MW-07			37.4	< -0.001	—	—	—	0.14	36.5	23.75	—	—	25
06-MW-07			39.4	< -0.001	—	—	—	0.11	38.4	1.25	—	—	3
06-MW-07			41.4	< -0.001	—	—	—	0.01*	40.4	12.5	—	—	10

Table 2. Results of flow-meter testing in wells, Galena Airport, Alaska, August 2002.—Continued

[ft, feet; BTOC, below top of casing; gal/min, gallons per minute; < , less than; *, vertical flow was tentatively detected at a rate less than the lower quantitation limit of the borehole flow meter. The value indicates the estimated rate. < -0.001*, a possible indication of downward flow was observed, but at a rate less than 0.001 gallon per minute; —, data not available; negative vertical flow indicated downward water movement]

Well name	Date	Depth to water (ft BTOC)	Depth of vertical-flow measure-ment (ft BTOC)	Vertical flow, in gal/min					Approximate depth of inflow contribution (ft BTOC)	Approximate percentage of total flow to the well contributed from the respective horizon during pumping from 2 to 5 ft below the water table			
				Ambient conditions	Pumping at 0.4 gal/min	Pumping at 0.5 gal/min	Pumping at 0.75 gal/min	Pumping at 1 gal/min		When pumping at 0.4 gal/min	When pumping at 0.5 gal/min	When pumping at 0.75 gal/min	When pumping at 1 gal/min
06-MW-06	8/11/2002	20.04	21.31	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-06			23.34	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-06			25.27	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-06			27.73	< -0.001	—	—	—	—	—	—	—	—	—
06-MW-06			29.22	< -0.001	—	—	—	—	—	—	—	—	—
09-MW-01	8/17/2002	15.35	16.41	< -0.001	—	—	—	—	—	—	—	—	—
09-MW-01			18.39	-0.01*	—	—	—	—	—	—	—	—	—
09-MW-01			20.4	-0.01*	—	—	—	—	—	—	—	—	—
09-MW-01			22.4	-0.01*	—	—	—	—	—	—	—	—	—
09-MW-01			24.42	-0.02*	—	—	—	—	—	—	—	—	—
09-MW-01			26.42	-0.02*	—	—	—	—	—	—	—	—	—
09-MW-01			28.4	-0.03	—	—	—	—	—	—	—	—	—
09-MW-01			30.42	-0.04	—	—	—	—	—	—	—	—	—
09-MW-01			32.42	-0.04	—	—	—	—	—	—	—	—	—
09-MW-01			34.43	-0.04	—	—	—	—	—	—	—	—	—
09-MW-01			36.42	-0.03	—	—	—	—	—	—	—	—	—
09-MW-01			38.4	-0.03	—	—	—	—	—	—	—	—	—
09-MW-01			40.42	-0.02*	—	—	—	—	—	—	—	—	—
09-MW-01			41.44	-0.01*	—	—	—	—	—	—	—	—	—
09-MW-01			44.42	< -0.001	—	—	—	—	—	—	—	—	—
09-MW-01			46.4	< -0.001	—	—	—	—	—	—	—	—	—
09-MW-17	8/18/2002	21.31	27.42	< -0.001	—	—	0.3	0.4	28.5	—	—	0.0	0
09-MW-17			29.55	< -0.001	—	—	0.32	0.43	30.5	—	—	5.3	0
09-MW-17			31.51	< -0.001	—	—	0.28	0.41	32.5	—	—	4.0	0
09-MW-17			33.48	< -0.001	—	—	0.25	0.42	34.5	—	—	5.3	0
09-MW-17			35.44	< -0.001	—	—	0.21	0.43	36.4	—	—	17.3	0
09-MW-17			37.4	< -0.001	—	—	0.04	0.43	38.5	—	—	0.0	48

Table 2. Results of flow-meter testing in wells, Galena Airport, Alaska, August 2002.—Continued

[ft, feet; BTOC, below top of casing; gal/min, gallons per minute; < , less than; *, vertical flow was tentatively detected at a rate less than the lower quantitation limit of the borehole flow meter. The value indicates the estimated rate. < -0.001*, a possible indication of downward flow was observed, but at a rate less than 0.001 gallon per minute; —, data not available; negative vertical flow indicated downward water movement]

Well name	Date	Depth to water (ft BTOC)	Depth of vertical-flow measure-ment (ft BTOC)	Vertical flow, in gal/min						Approximate depth of inflow contribution (ft BTOC)	Approximate percentage of total flow to the well contributed from the respective horizon during pumping from 2 to 5 ft below the water table			
				Ambient conditions	Pumping at 0.4 gal/min	Pumping at 0.5 gal/min	Pumping at 0.75 gal/min	Pumping at 1 gal/min			When pumping at 0.4 gal/min	When pumping at 0.5 gal/min	When pumping at 0.75 gal/min	When pumping at 1 gal/min
09-MW-17	8/18/2002	21.31	39.53	< -0.001	—	—	0.03	0.19		40.5	—	—	0.0	6
09-MW-17	(Continued)		41.49	< -0.001	—	—	0.08	0.16		42.5	—	—	5.3	16
09-MW-17			43.46	< -0.001	—	—	0.04	0.08		44.5	—	—	4.0	14
09-MW-17			45.58	< -0.001	—	—	0.01*	0.01*		46.5	—	—	1.3	2
09-MW-17			47.38	< -0.001	—	—	< -0.001	< -0.001		—	—	—	—	—
10-MW-01	8/10/2002	16.35	18.66	< -0.001	—	—	—	—		—	—	—	—	—
10-MW-01			20.71	< -0.001	—	—	—	—		—	—	—	—	—
10-MW-01			22.68	< -0.001	—	—	—	—		—	—	—	—	—
10-MW-01			24.9	< -0.001	—	0.71	—	—		—	—	—	—	—
10-MW-01			26.9	< -0.001	—	0.59	—	—		25.9	—	24	—	—
10-MW-01			28.9	< -0.001	—	0.51	—	—		27.9	—	16	—	—
10-MW-01			30.9	< -0.001	—	0.44	—	—		29.9	—	14	—	—
10-MW-01			32.9	< -0.001	—	0.48	—	—		—	—	—	—	—
10-MW-01			34.9	< -0.001	—	0.28	—	—		33.9	—	40	—	—
10-MW-01			36.9	< -0.001	—	0.24	—	—		35.9	—	8	—	—
10-MW-01			38.9	< -0.001	—	0.18	—	—		37.9	—	12	—	—
10-MW-01			40.8	< -0.001	—	0.12	—	—		39.9	—	12	—	—
10-MW-01			42.9	< -0.001	—	0.03	—	—		41.9	—	18	—	—
10-MW-01			44.9	< -0.001	—	< -0.001	—	—		43.9	—	6	—	—
10-MW-03	8/10/2002	16.96	17.82	< -0.001	—	—	—	—		—	—	—	—	—
10-MW-03			19.79	< -0.001	—	—	—	—		—	—	—	—	—
10-MW-03			21.84	-0.01*	—	—	—	—		—	—	—	—	—
10-MW-03			23.84	-0.01*	—	—	—	—		—	—	—	—	—
10-MW-03			25.81	-0.01*	—	—	—	—		—	—	—	—	—
10-MW-03			27.83	-0.01*	—	—	—	—		—	—	—	—	—
10-MW-03			29.84	-0.01*	—	—	—	—		—	—	—	—	—
10-MW-03			31.82	-0.01*	—	—	—	—		—	—	—	—	—

Table 2. Results of flow-meter testing in wells, Galena Airport, Alaska, August 2002.—Continued

[ft, feet; BTOC, below top of casing; gal/min, gallons per minute; <, less than; *, vertical flow was tentatively detected at a rate less than the lower quantitation limit of the borehole flow meter. The value indicates the estimated rate. < -0.001*, a possible indication of downward flow was observed, but at a rate less than 0.001 gallon per minute; —, data not available; negative vertical flow indicated downward water movement]

Well name	Date	Depth to water (ft BTOC)	Depth of vertical-flow measure-ment (ft BTOC)	Vertical flow, in gal/min					Approximate depth of inflow contribution (ft BTOC)	Approximate percentage of total flow to the well contributed from the respective horizon during pumping from 2 to 5 ft below the water table			
				Ambient conditions	Pumping at 0.4 gal/min	Pumping at 0.5 gal/min	Pumping at 0.75 gal/min	Pumping at 1 gal/min		When pumping at 0.4 gal/min	When pumping at 0.5 gal/min	When pumping at 0.75 gal/min	When pumping at 1 gal/min
10-MW-03	8/10/2002	16.96	33.83	-0.01*	—	—	—	—	—	—	—	—	—
10-MW-03	(Continued)		35.76	-0.01*	—	—	—	—	—	—	—	—	—
10-MW-03			37.78	-0.01*	—	—	—	—	—	—	—	—	—
10-MW-03			39.78	< -0.001	—	—	—	—	—	—	—	—	—
10-MW-03			41.82	< -0.001	—	—	—	—	—	—	—	—	—
10-MW-03			43.83	< -0.001	—	—	—	—	—	—	—	—	—
10-MW-03			45.76	< -0.001	—	—	—	—	—	—	—	—	—

Table 3. Volatile organic compounds in polyethylene diffusion bag samples and low-flow samples from wells at Galena Airport, Alaska, September 30 to October 1, 2002.

[PDB, passive diffusion bag sample; ft, feet; BTOC, below top of casing; μg/L, microgram per liter; LF, low-flow sample; —, data not collected or not available; < , less than; shaded cells indicate concentrations of detected compounds; two values separated by a comma indicate sample and duplicate concentrations]

Well name	PDB depth (ft BTOC)	Low-flow sampling depth (ft BTOC)	1,2,4-Trimethyl-benzene (μg/L)		1,2-Dichloroethane (μg/L)		1,3,5-Trimethylbenzene (μg/L)		4-Isopropyltoluene (μg/L)		Benzene (μg/L)	
			PDB	LF	PDB	LF	PDB	LF	PDB	LF	PDB	LF
06-MW-01	25.6	—	< 50	—	< 25	—	< 50	—	< 50	—	< 20	—
	28.6	—	< 50	—	< 25	—	< 50	—	< 50	—	< 20	—
	30.6	30.6	< 50	< 100, < 50	< 25	< 50, < 25	< 50	< 100, < 50	< 50	< 100, < 50	< 20	<40, < 20
	33.6	—	< 100	—	< 50	—	< 100	—	< 100	—	< 40	—
	35.6	—	< 100	—	< 50	—	< 100	—	< 100	—	< 40	—
	38.6	—	< 100	—	< 50	—	< 100	—	< 100	—	< 40	—
	40.6	—	< 100	—	< 50	—	< 100	—	< 100	—	< 40	—
	42.6	—	< 100	—	< 50	—	< 100	—	< 100	—	< 40	—
	45.6	—	< 50	—	< 25	—	< 50	—	< 50	—	< 20	—
	48.6	—	< 50	—	< 25	—	< 50	—	< 50	—	< 20	—
	51.6	—	< 50	—	< 25	—	< 50	—	< 50	—	< 20	—
06-MW-02	21.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
	23.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
	26.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
	30.5	30.5	< 5	< 5, < 5	< 2.5	<2.5, 2.5	< 5	< 5, < 5	< 5	< 5, < 5	< 2	< 2, < 2
	33.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
	35.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
	39.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
	41.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
	44.5	—	< 1	—	< 0.5	—	< 1	—	< 1	—	< 0.4	—
	46.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
	49.5	—	< 5	—	< 2.5	—	< 5	—	< 5	—	< 2	—
06-MW-04	16	16	54, 45	46, 45	<2.5, < 2.5	<2.5, < 0.5	30, 28	32, 30	< 5, 9.1	10, 4.7	230, 250	230, 240
	19	—	56	—	5.1	—	32	—	4.6	—	250	—
	21	—	60	—	< 0.5	—	43	—	5.3	—	260	—
	23	—	58	—	< 2.5	—	38	—	< 5	—	270	—
	25	—	59	—	< 2.5	—	39	—	< 5	—	280	—
	28	—	47	—	< 2.5	—	33	—	9.1	—	300	—
	31	—	52	—	< 2.5	—	36	—	9.6	—	320	—
	34	—	51	—	< 2.5	—	32	—	< 5	—	310	—
	37	—	49	—	< 2.5	—	34	—	9.2	—	290	—
	40	—	49	—	< 2.5	—	32	—	9.1	—	300	—
	45	—	45	—	< 2.5	—	28	—	8.8	—	290	—
	47	—	42	—	< 2.5	—	25	—	8.6	—	300	—
06-MW-07	24.7	—	< 1	—	< 0.5	—	< 1	—	< 1	—	< 0.4	—
	26.7	—	< 1	—	< 0.5	—	< 1	—	< 1	—	< 0.4	—
	28.5	—	< 1	—	< 0.5	—	< 1	—	< 1	—	< 0.4	—
	30.4	30.4	< 1	< 1	< 0.5	< 0.5	< 1	< 1	< 1	< 1	< 0.4	< 0.4
	32.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	< 0.4	—

Table 3. Volatile organic compounds in polyethylene diffusion bag samples and low-flow samples from wells at Galena Airport, Alaska, September 30 to October 1, 2002.—Continued

[PDB, passive diffusion bag sample; ft, feet; BTOC, below top of casing; µg/L, microgram per liter; LF, low-flow sample; —, data not collected or not available; < , less than; shaded cells indicate concentrations of detected compounds; two values separated by a comma indicate sample and duplicate concentrations]

Well name	PDB depth (ft BTOC)	Low-flow sampling depth (ft BTOC)	1,2,4-Trimethyl-benzene (µg/L)		1,2-Dichloroethane (µg/L)		1,3,5-Trimethylbenzene (µg/L)		4-Isopropyltoluene (µg/L)		Benzene (µg/L)	
			PDB	LF	PDB	LF	PDB	LF	PDB	LF	PDB	LF
06-MW-07	34.5	—	< 1	—	< 0.5	—	< 1	—	< 1	—	< 0.4	—
(Continued)	36.5	—	< 1	—	< 0.5	—	< 1	—	< 1	—	< 0.4	—
	40.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	< 0.4	—
10-MW-01	16.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.42	—
	18.4	—	< 1, < 1	—	<0.5, < 0.5	—	< 1, < 1	—	< 1, < 1	—	<0.4, < 0.4	—
	21.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.6	—
	24.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.58	—
	27.1	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.58	—
	29.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.58	—
	32.4	32.4	< 1	< 1, < 1	< 0.5	<0.5, < 0.5	< 1	< 1, < 1	< 1	< 1, < 1	0.58	0.42, < 0.4
	36.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.58	—
	39.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.65	—
	42.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.64	—
	44.4	—	< 1	—	< 0.5	—	< 1	—	< 1	—	0.63	—
10-MW-03	19	—	2.3	—	< 0.5	—	1	—	< 1	—	0.65	—
	21	—	5.5	—	< 0.5	—	2.6	—	< 1	—	19	—
	24	24	4.9	1.2, < 1	0.52	<0.5, < 0.5	2.5	1.3, < 1	< 1	< 1, < 1	24	53, 53
	27	—	8.1	—	< 0.5	—	3.3	—	1.9	—	41	—
	30	—	8.5	—	< 0.5	—	3.5	—	1.9	—	50	—
	33	—	8.7	—	< 0.5	—	3.4	—	1.9	—	47	—
	36	—	7.8	—	< 0.5	—	2.4	—	< 1	—	33	—
	39	—	9.9	—	< 0.5	—	3.9	—	1.9	—	25	—
	42	—	6.5	—	< 0.5	—	2.1	—	< 1	—	22	—
	44	—	7	—	< 0.5	—	3.2	—	1.9	—	19	—

Table 3.   Volatile organic compounds in polyethylene diffusion bag samples and low-flow samples from wells at Galena Airport, Alaska, September 30 to October 1, 2002.—Continued

[PDB, passive diffusion bag sample; ft, feet; BTOC, below top of casing; µg/L, microgram per liter; LF, low-flow sample; < , less than; —, data not collected or not available; shaded cells indicate concentrations of detected compounds; two values separated by a comma indicate sample and duplicate concentrations]

Well name	PDB depth (ft BTOC)	Low-flow sampling depth (ft BTOC)	Ethylbenzene (µg/L)		Isopropylbenzene (µg/L)		n-Propylbenzene (µg/L)		Naphthalene (µg/L)		o-Xylene (µg/L)	
			PDB	LF	PDB	LF	PDB	LF	PDB	LF	PDB	LF
06-MW-01	25.6	—	< 50	—	< 50	—	< 50	—	< 50	—	< 50	—
	28.6	—	< 50	—	< 50	—	< 50	—	< 50	—	< 50	—
	30.6	30.6	< 50	<100, < 50	< 50	<100, < 50	< 50	<100, < 50	< 50	<100, < 50	< 50	<100, < 50
	33.6	—	< 100	—	< 100	—	< 100	—	< 100	—	< 100	—
	35.6	—	< 100	—	< 100	—	< 100	—	< 100	—	< 100	—
	38.6	—	< 100	—	< 100	—	< 100	—	< 100	—	< 100	—
	40.6	—	< 100	—	< 100	—	< 100	—	< 100	—	< 100	—
	42.6	—	< 100	—	< 100	—	< 100	—	< 100	—	< 100	—
	45.6	—	< 50	—	< 50	—	< 50	—	< 50	—	< 50	—
	48.6	—	< 50	—	< 50	—	< 50	—	< 50	—	< 50	—
	51.6	—	< 50	—	< 50	—	< 50	—	< 50	—	< 50	—
06-MW-02	21.5	—	< 5	—	< 5	—	< 5	—	< 5	—	< 5	—
	23.5	—	< 5	—	< 5	—	< 5	—	< 5	—	< 5	—
	26.5	—	< 5	—	< 5		< 5		< 5	—	< 5	
	30.5	30.5	< 5	< 5, < 5	< 5	< 5, < 5	< 5	< 5, < 5	< 5	< 5, < 5	< 5	< 5, < 5
	33.5	—	< 5	—	< 5	—	< 5	—	< 5	—	< 5	—
	35.5	—	< 5	—	< 5	—	< 5	—	< 5	—	< 5	—
	39.5	—	< 5	—	< 5	—	< 5	—	< 5	—	< 5	—
	41.5	—	< 5	—	< 5	—	< 5	—	< 5	—	< 5	—
	44.5	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	46.5	—	< 5	—	< 5	—	< 5	—	< 5	—	< 5	—
	49.5	—	< 5	—	< 5	—	< 5	—	< 5	—	< 5	—
06-MW-04	16	16	17, 17	16, 16	< 5, 9.7	9.9, 4.6	< 5, 6.8	6.7, 4.1	32, 36	38, 36	65, 58	67, 62
	19	—	21		5.1		4.9		39		62	—
	21	—	17		4.9		4.5		41		92	—
	23	—	16		< 5		< 5		36		100	—
	25	—	17		< 5		< 5		37		98	—
	28	—	15		9.5		6.6		31		90	—
	31	—	17		9.9		7		37		100	—
	34	—	15		< 5		< 5		36		91	—
	37	—	16		9.8		6.9		36		92	—
	40	—	17		10		7		37		91	—
	45	—	16		9.8		6.7		37		84	—
	47	—	17		9.9		6.8		36		84	—
06-MW-07	24.7	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	26.7	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	28.5	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	30.4	30.4	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	32.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—

Table 3. Volatile organic compounds in polyethylene diffusion bag samples and low-flow samples from wells at Galena Airport, Alaska, September 30 to October 1, 2002.—Continued

[PDB, passive diffusion bag sample; ft, feet; BTOC, below top of casing; µg/L, microgram per liter; LF, low-flow sample; < , less than; —, data not collected or not available; shaded cells indicate concentrations of detected compounds; two values separated by a comma indicate sample and duplicate concentrations]

Well name	PDB depth (ft BTOC)	Low-flow sampling depth (ft BTOC)	Ethylbenzene (µg/L)		Isopropylbenzene (µg/L)		n-Propylbenzene (µg/L)		Naphthalene (µg/L)		o-Xylene (µg/L)	
			PDB	LF	PDB	LF	PDB	LF	PDB	LF	PDB	LF
06-MW-07	34.5	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
(Continued)	36.5	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	40.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
10-MW-01	16.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	18.4	—	< 1, < 1	—	< 1, < 1	—	< 1, < 1	—	< 1, < 1	—	< 1, < 1	—
	21.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	24.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	27.1	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	29.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	32.4	32.4	< 1	< 1, < 1	< 1	< 1, < 1	< 1	< 1, < 1	< 1	< 1, < 1	< 1	< 1, < 1
	36.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	39.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	42.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	44.4	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
10-MW-03	19	—	< 1	—	< 1	—	< 1	—	< 1	—	< 1	—
	21	—	< 1	—	3.4	—	1.8	—	< 1	—	< 1	—
	24	24	< 1	< 1, < 1	2.9	1.6, 1.6	1.7	< 1, < 1	< 1	4.8, 2.5	< 1	< 1, < 1
	27	—	< 1	—	4	—	2.3	—	5.5	—	1.4	—
	30	—	< 1	—	4.4	—	2.4	—	5.6	—	1.4	—
	33	—	< 1	—	4.3	—	2.4	—	5.5	—	< 1	—
	36	—	< 1	—	3.4	—	1.5	—	< 1	—	< 1	—
	39	—	< 1	—	4.7	—	2.6	—	5.7	—	1.4	—
	42	—	< 1	—	2.3	—	1.2	—	< 1	—	< 1	—
	44	—	< 1	—	3.6	—	1.9	—	9.3	—	1.5	—

Table 3.   Volatile organic compounds in polyethylene diffusion bag samples and low-flow samples from wells at Galena Airport, Alaska, September 30 to October 1, 2002.—Continued

[PDB, passive diffusion bag sample; ft, feet; BTOC, below top of casing; µg/L, microgram per liter; LF, low-flow sample; < , less than; —, data not collected or not available; shaded cells indicate concentrations of detected compounds; two values separated by a comma indicate sample and duplicate concentrations]

Well name	PDB depth (ft BTOC)	Low-flow sampling depth (ft BTOC)	*p,m*-Xylene (µg/L)		*sec*-Butylbenzene (µg/L)		Toluene (µg/L)		*cis*-1,2-Dichloroethene (µg/L)		Trichloroethene (µg/L)	
			PDB	LF	PDB	LF	PDB	LF	PDB	LF	PDB	LF
06-MW-01	25.6	—	< 100	—	< 50	—	< 50	—	3,700	—	4,400	—
	28.6	—	< 100	—	< 50	—	< 50	—	3,800	—	4,200	—
	30.6	30.6	< 100	<200, < 100	< 50	<100, < 50	< 50	<100, < 50	4,800	4,200; 4,200	4,700	3,400; 3,800
	33.6	—	< 200	—	< 100	—	< 100	—	4,200	—	4,300	—
	35.6	—	< 200	—	< 100	—	< 100	—	3,800	—	4,300	—
	38.6	—	< 200	—	< 100	—	< 100	—	3,600	—	4,200	—
	40.6	—	< 200	—	< 100	—	< 100	—	3,700	—	4,200	—
	42.6	—	< 200	—	< 100	—	< 100	—	3,600	—	4,200	—
	45.6	—	< 100	—	< 50	—	< 50	—	4,500	—	4,300	—
	48.6	—	< 100	—	< 50	—	< 50	—	3,700	—	4,200	—
	51.6	—	< 100	—	< 50	—	< 50	—	3,700	—	4,100	—
06-MW-02	21.5	—	< 10	—	< 5	—	< 5	—	< 5	—	310	—
	23.5	—	< 10	—	< 5	—	< 5	—	6.7	—	400	—
	26.5	—	< 10	—	< 5	—	< 5	—	< 5	—	360	—
	30.5	30.5	< 10	<10, < 10	< 5	< 5, < 5	< 5	< 5, < 5	< 5	5.7, 6.9	370	270, 300
	33.5	—	< 10	—	< 5	—	< 5	—	< 5	—	370	—
	35.5	—	< 10	—	< 5	—	< 5	—	6.1	—	380	—
	39.5	—	< 10	—	< 5	—	< 5	—	5.2	—	380	—
	41.5	—	< 10	—	< 5	—	< 5	—	5.7	—	390	—
	44.5	—	< 2	—	< 1	—	< 1	—	4.1	—	370	—
	46.5	—	< 10	—	< 5	—	< 5	—	5.3	—	380	—
	49.5	—	< 10	—	< 5	—	< 5	—	< 5	—	380	—
06-MW-04	16	16	98, 100	95, 85	< 5, < 5	6.4, 2.1	23, 24	35, 34	< 5, < 5	< 5, 1.7	< 5, < 5	< 5, 2.9
	19	—	94	—	2.2	—	23	—	< 1	—	< 1	—
	21	—	130	—	2.2	—	66	—	< 1	—	< 1	—
	23	—	120	—	< 5	—	51	—	< 5	—	< 5	—
	25	—	120	—	< 5	—	48	—	< 5	—	< 5	—
	28	—	120	—	< 5	—	51	—	< 5	—	< 5	—
	31	—	140	—	< 5	—	55	—	< 5	—	< 5	—
	34	—	120	—	< 5	—	50	—	< 5	—	< 5	—
	37	—	130	—	6.3	—	50	—	< 5	—	< 5	—
	40	—	130	—	< 5	—	49	—	< 5	—	< 5	—
	45	—	130	—	< 5	—	44	—	< 5	—	< 5	—
	47	—	140	—	< 5	—	43	—	< 5	—	< 5	—
06-MW-07	24.7	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	26.7	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	28.5	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	30.4	30.4	< 2	< 2	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	32.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—

Table 3. Volatile organic compounds in polyethylene diffusion bag samples and low-flow samples from wells at Galena Airport, Alaska, September 30 to October 1, 2002.—Continued

[PDB, passive diffusion bag sample; ft, feet; BTOC, below top of casing; µg/L, microgram per liter; LF, low-flow sample; < , less than; —, data not collected or not available; shaded cells indicate concentrations of detected compounds; two values separated by a comma indicate sample and duplicate concentrations]

Well name	PDB depth (ft BTOC)	Low-flow sampling depth (ft BTOC)	*p,m*-Xylene (µg/L)		*sec*-Butylbenzene (µg/L)		Toluene (µg/L)		*cis*-1,2-Dichloroethene (µg/L)		Trichloroethene (µg/L)	
			PDB	LF	PDB	LF	PDB	LF	PDB	LF	PDB	LF
06-MW-07	34.5	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
(Continued)	36.5	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	40.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
10-MW-01	16.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	18.4	—	< 2, < 2	—	< 1, < 1	—	< 1, < 1	—	< 1, 3.2	—	< 1, 9.9	—
	21.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	24.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	27.1	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	29.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	32.4	32.4	< 2	< 2, < 2	< 1	< 1, < 1	< 1	< 1, < 1	< 1	1.4, 2.3	< 1	2.3, 4
	36.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	39.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	42.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	44.4	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
10-MW-03	19	—	< 2	—	< 1	—	< 1	—	< 1	—	< 1	—
	21	—	4.3	—	1.4	—	< 1	—	< 1	—	< 1	—
	24	24	4.9	< 2, < 2	1.6	1.4, < 1	< 1	< 1, < 1	< 1	< 1, < 1	< 1	< 1, < 1
	27	—	10	—	1.7	—	< 1	—	< 1	—	< 1	—
	30	—	12	—	1.7	—	< 1	—	< 1	—	< 1	—
	33	—	12	—	1.7	—	< 1	—	< 1	—	< 1	—
	36	—	9.9	—	< 1	—	< 1	—	< 1	—	< 1	—
	39	—	11	—	1.8	—	< 1	—	< 1	—	< 1	—
	42	—	5.3	—	< 1	—	< 1	—	< 1	—	< 1	—
	44	—	6.9	—	1.6	—	< 1	—	< 1	—	< 1	—

Apppendix

Geophysical Logs of Wells, Galena Airport, Alaska
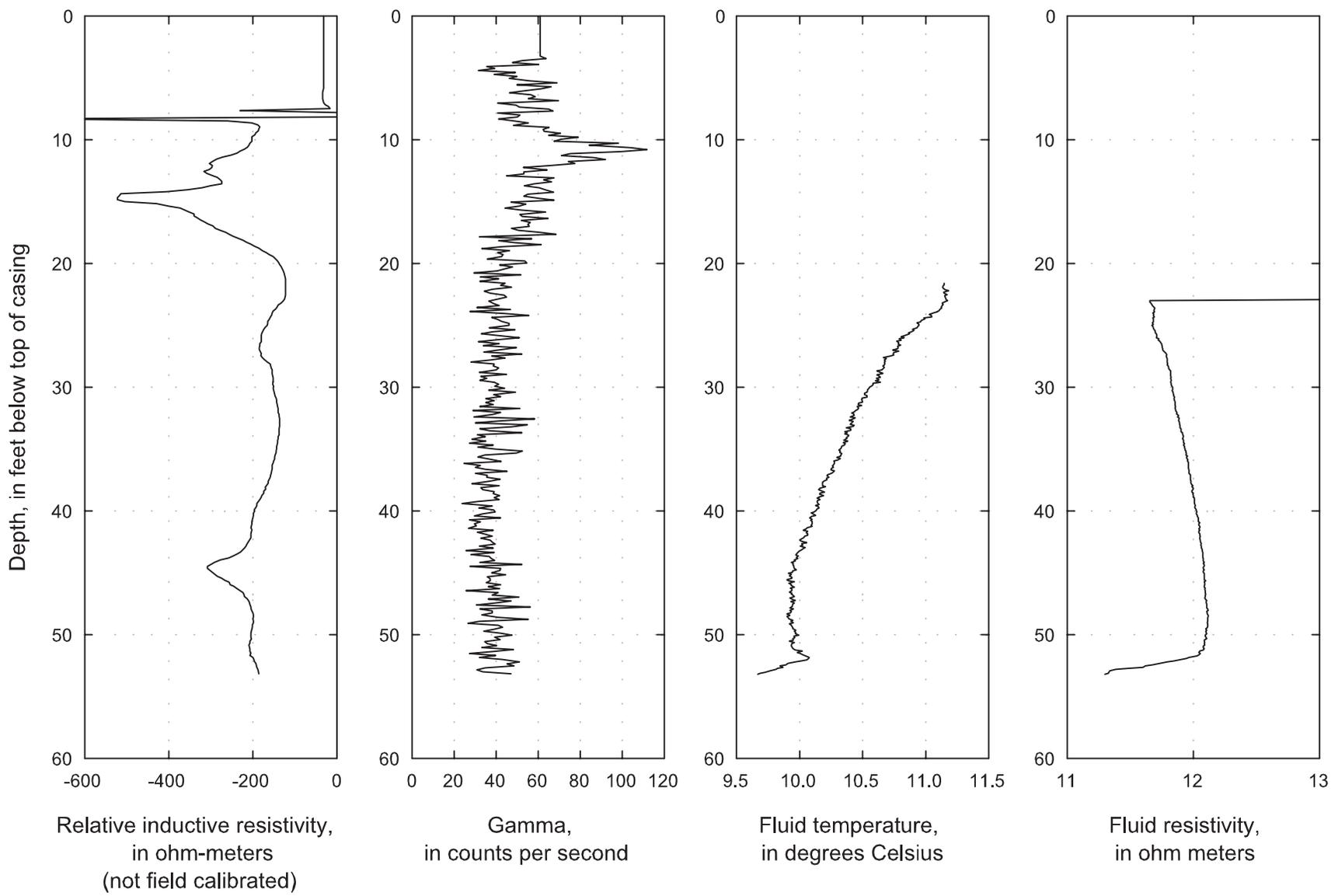
Borehole geophysical logs of well 06-MW-01, Galena Airport, August 2002.
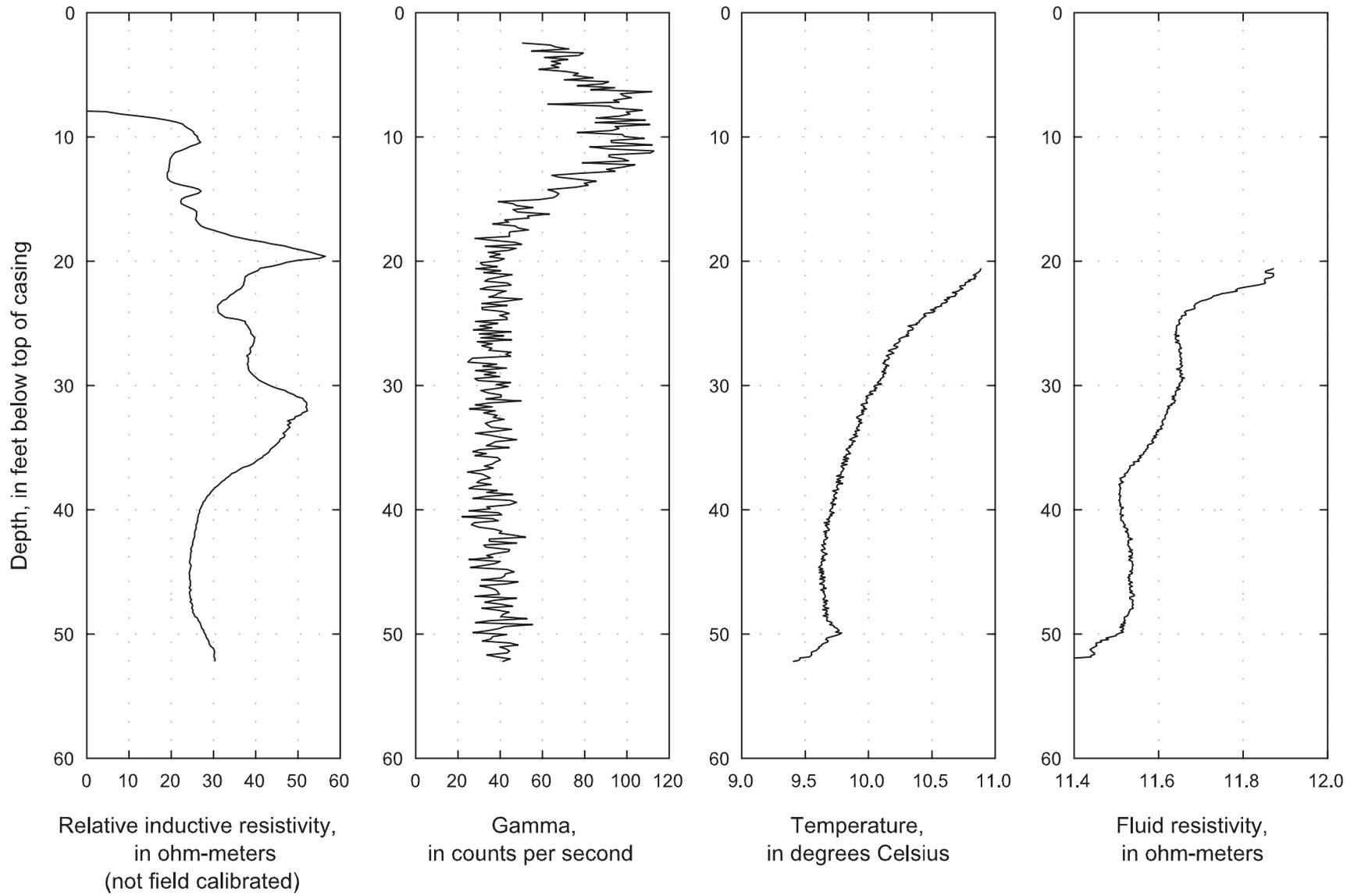
Borehole geophysical logs of well 06-MW-02, Galena Airport, August 2002.
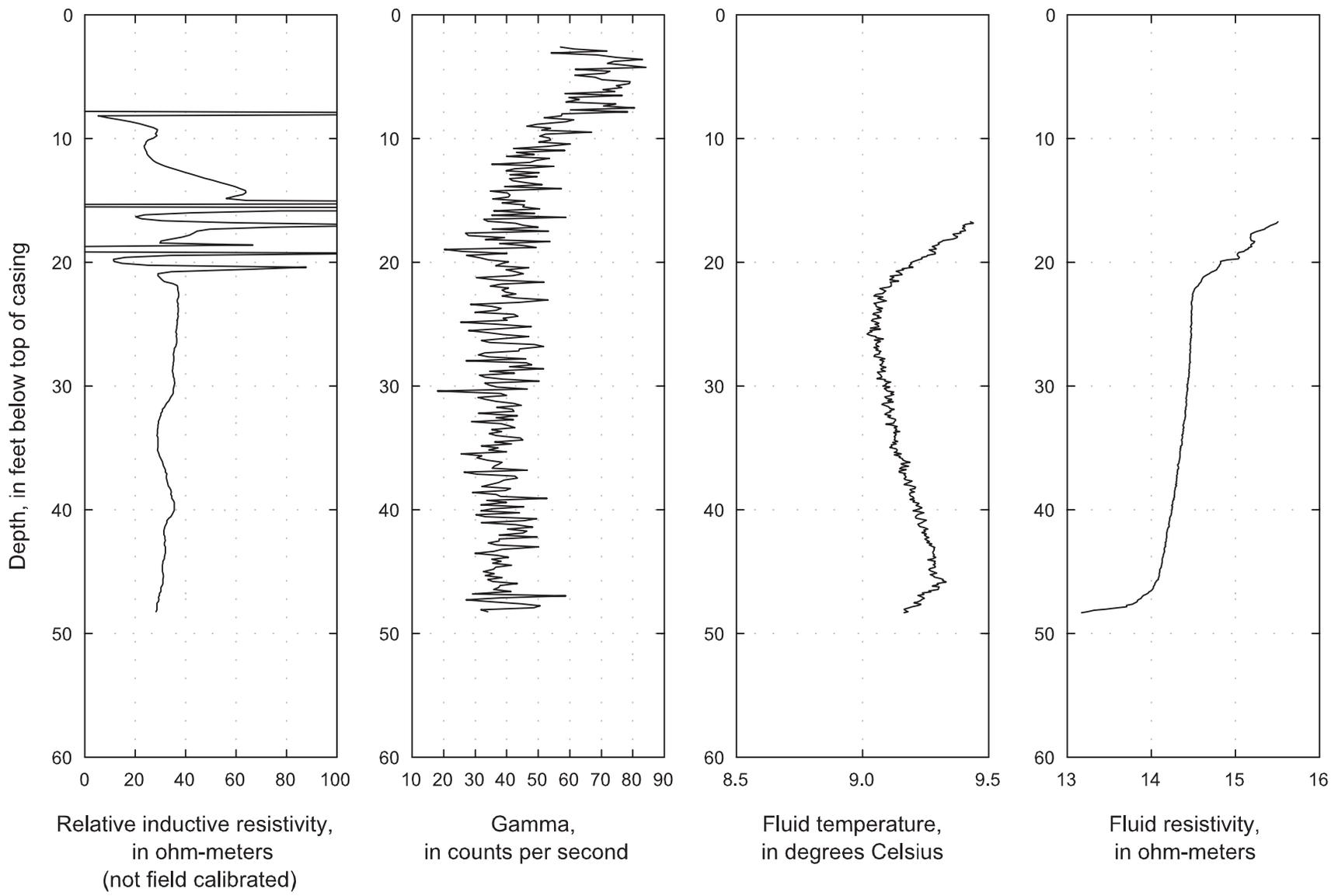
Borehole geophysical logs of well 06-MW-03, Galena Airport, August 2002.
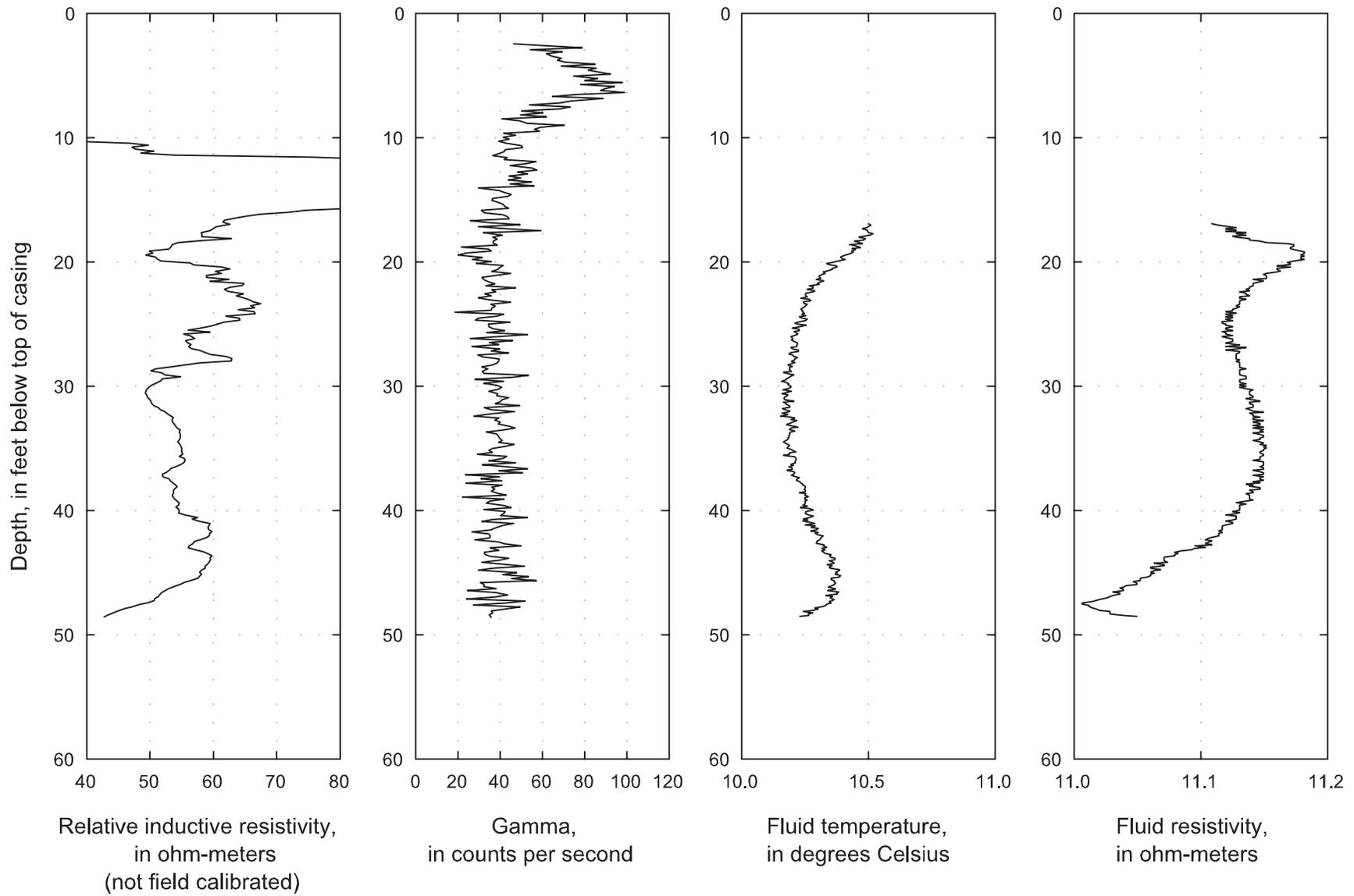
Borehole geophysical logs of well 06-MW-04, Galena Airport, August 2002.
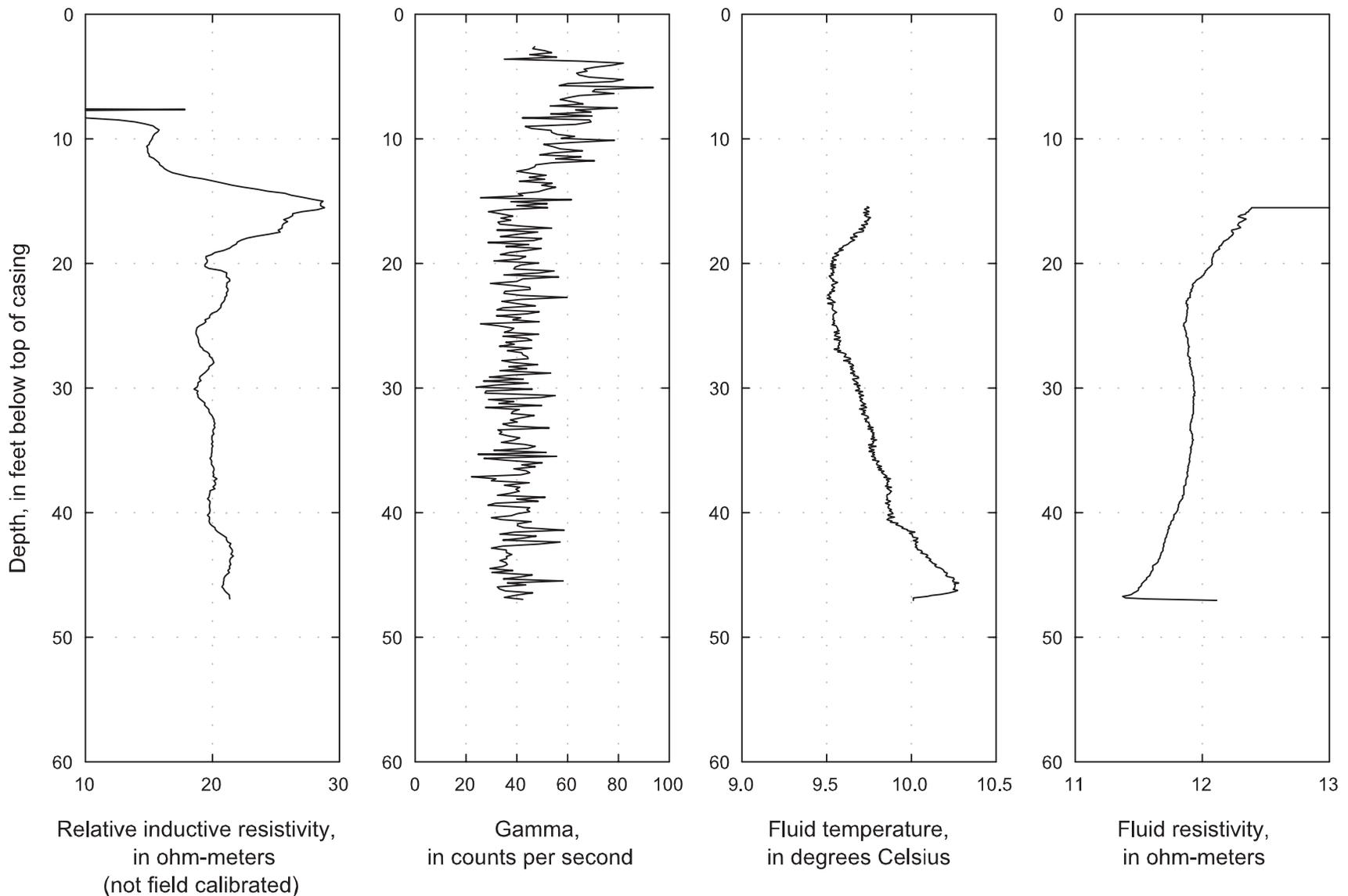
Borehole geophysical logs of well 09-MW-01, Galena Airport, August 2002.
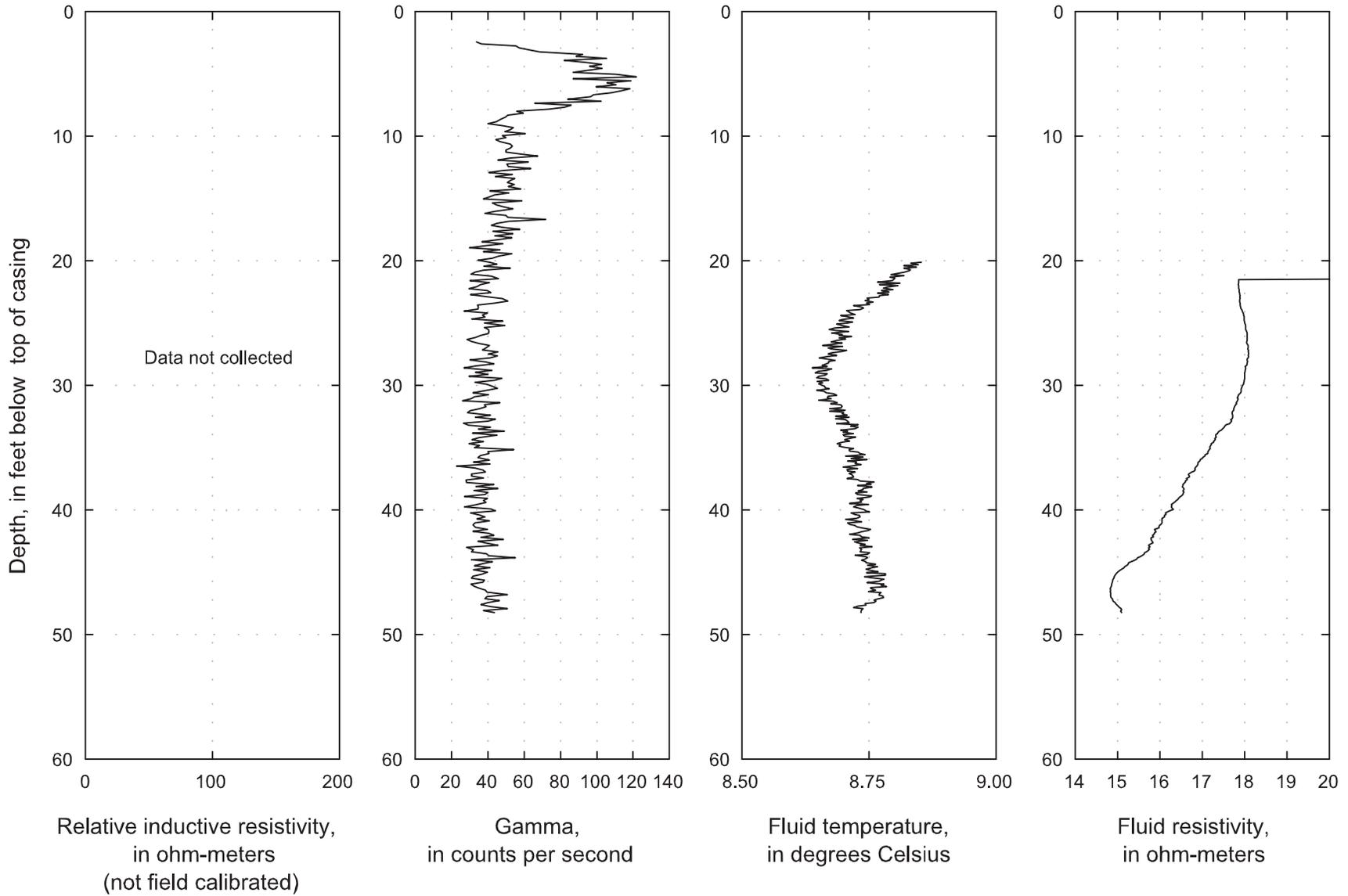
Borehole geophysical logs of well 09-MW-17, Galena Airport, August 2002.
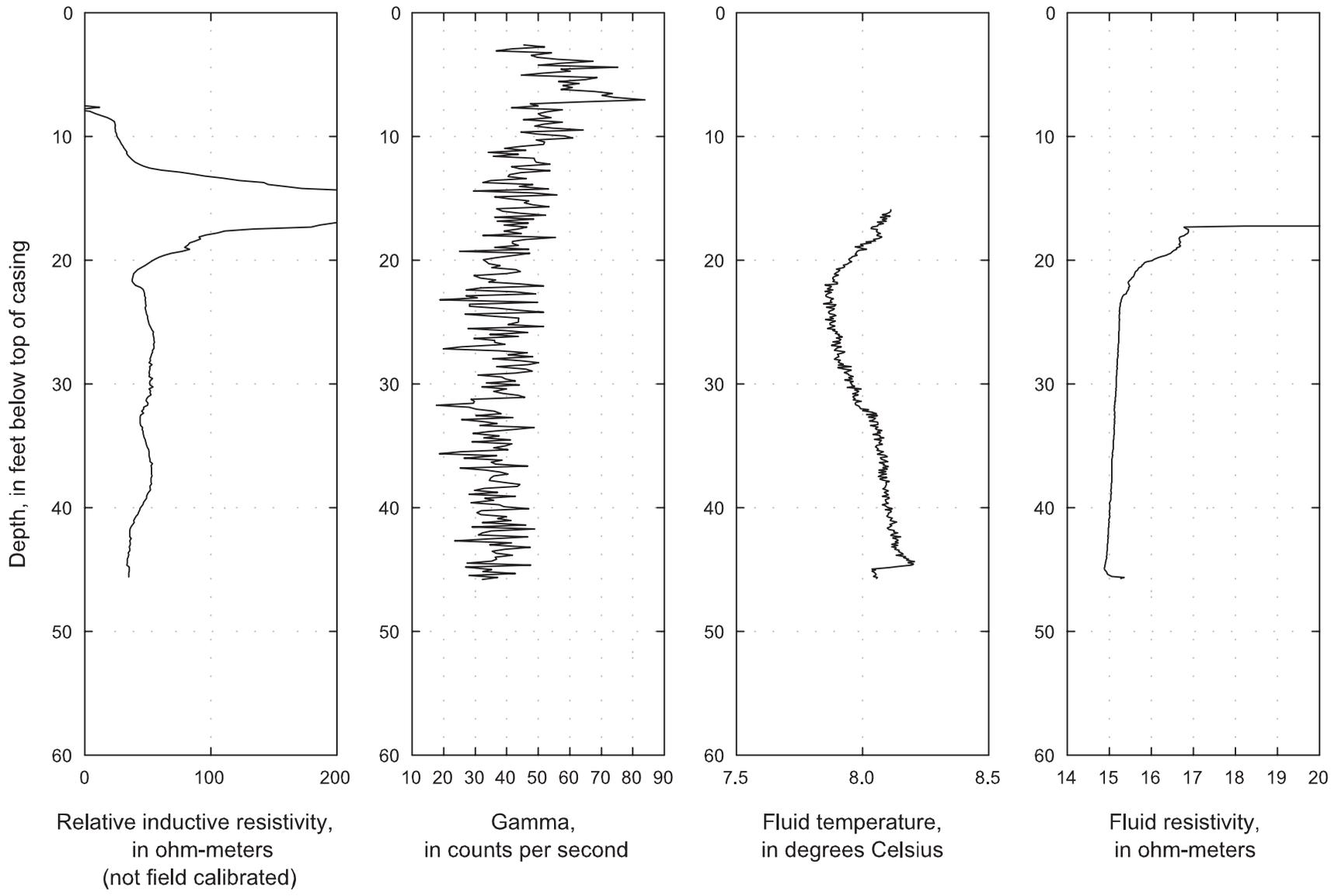
Borehole geophysical logs of well 10-MW-01, Galena Airport, August 2002.
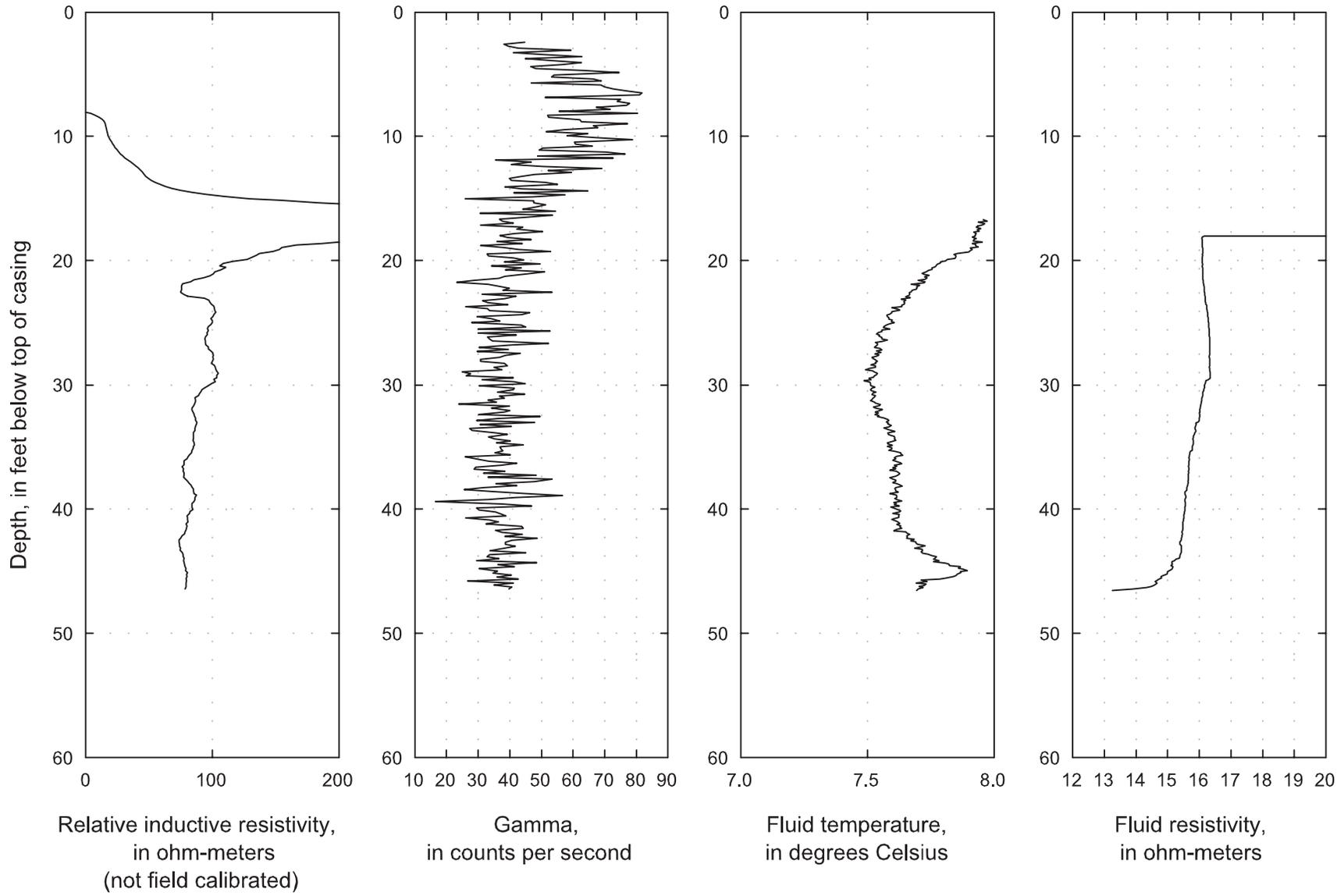
Borehole geophysical logs of well 10-MW-03, Galena Airport, August 2002.