IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA
SOUTHERN DIVISION
Case No. 7:23-CV-897

IN RE: **CAMP LEJEUNE WATER LITIGATION** **This Document Relates To:** **ALL CASES**	**UNITED STATES' OPPOSITION TO PLG'S MOTION TO EXCLUDE CERTAIN OPINIONS OF REMY J.-C. HENNET, PH.D.**

INTRODUCTION

The Court should deny PLG's motion to exclude four opinions offered by the United States' expert geochemist and geohydrologist Dr. Remy Hennet. Contrary to PLG's arguments, Dr. Hennet's opinions are the result of reliably applying foundational scientific principles and methodologies to sufficient facts and data. In fact, Dr. Hennet employed some of the same principles and methodologies as PLG's experts.

Each of PLG's arguments to exclude Dr. Hennet's opinions are fundamentally flawed. First, PLG claims that Dr. Hennet has no method for selecting representative flow paths to estimate the range of times it likely would have taken PCE to travel from the aquifer below ABC One-Hour Cleaners to one of the Tarawa Terrace supply wells. This ignores that: (1) Dr. Hennet, like PLG's expert Dr. Konikow, used flow paths to calculate the time for PCE to travel from ABC One-Hour Cleaners to well TT-26 through the Agency for Toxic Substances and Disease Registry (ATSDR's) conceptual model of the aquifer at Tarawa Terrace and (2) Dr. Hennet selected flow paths representative of the plume predicted by the ATSDR's numerical water model that PLG's experts assert was reliable. Because Dr. Hennet's "methods are very similar to those of the other engineers, his methods likely have acceptance within a relevant scientific community[,]" and PLG's argument fails. *Browder v. State Farm Fire and Casualty Company*, No. 1:20-cv-26, 2021 WL 2517681, at *6 (W.D.N.C Jun. 18, 2021).

Second, PLG claims that Dr. Hennet has no scientific basis for his opinion that Hadnot Point water supply well HP-634 was uncontaminated with TCE. This raises factual disputes rather than challenges Dr. Hennet's methodologies. Because "'questions regarding the factual underpinnings of [an expert witness's] opinion affect the weight and credibility' of the witness' assessment, 'not its admissibility[,]'" PLG's argument fails. *See Bresler v. Wilmington Trust Co.*, 855 F.3d 178, 195 (4th Cir. 2017) (quoting *Structural Polymer Grp. v. Zoltek Corp.*, 543 F.3d 987, 997 (8th Cir. 2008)).

Third, PLG claims that Dr. Hennet's opinion on volatilization of the contaminants of concern ("COCs") from filling a water buffalo through a manhole is overly speculative. This ignores that Dr. Hennet arrived at his opinion by applying the same method he used to estimate the losses from filling a water buffalo through a filler pipe, which is the same method used by PLG's expert to estimate the losses from filling through a manhole. Again, because Dr. Hennet's "methods are very similar to those of the other engineers, his methods likely have acceptance within a relevant scientific community[,]" and PLG's argument fails. *Browder*, 2021 WL 2517681 at *6.

Fourth, PLG claims that Dr. Hennet did not explain how his experience led him to conclude that some portion of COCs were lost to sorption during water treatment. This ignores the fact that the primary basis for this opinion was a chemical phenomenon that is: (1) recognized by PLG's own experts; and (2) described in a textbook that Dr. Hennet cited. Dr. Hennet explained that he relied on his extensive education and experience studying the fate of organic chemicals, like the COCs, in the environment only to *qualitatively* discuss the magnitude of those losses, just as PLG's expert did. Yet again, because Dr. Hennet's "methods are very similar to those of the other engineers, his methods likely have acceptance within a relevant scientific community[,]" and PLG's argument fails. *Id*.

FACTS

The United States disclosed a Phase I expert report from Dr. Remy Hennet, a Doctor of Philosophy in geochemistry with over 30 years of experience studying the fate of organic chemicals in the environment, including the COCs at issue in this case. D.E. 374-3 at 80. Dr. Hennet's report included: (1) an overview of geology, hydrogeology, and geochemistry applicable to the groundwater supply at Camp Lejeune; (2) a primer on the COCs and their sources; and (3) a summary of the limited historical contaminant concentration data at Camp Lejeune. *Id.* at 4-5. The report also contained Dr. Hennet's opinions on: (1) the extent of groundwater contamination by the COCs at Camp Lejeune and when the COCs likely arrived in the Camp Lejeune water systems; (2) the likely COC losses from volatilization and sorption during water treatment and storage that were not accounted for in the ATSDR's models; (3) the scientific validity of several of the ATSDR's modeling decisions; and (4) the likely COC losses from volatilization during the filling of water buffaloes. *Id.*

Dr. Hennet Estimated a Reasonable Range of Times that PCE Likely Arrived at Well TT-26 Using Flow Paths Representative of the PCE Plume Geometry and Evolution Predicted by ATSDR's Model.

Dr. Hennet opined that elevated PCE concentrations likely first arrived at supply well TT-26 in the 1970s. D.E. 374-3 at 49. To arrive at this opinion, Dr. Hennet first *adopted the ATSDR's conceptual framework* for the development and migration of a PCE plume from ABC One-Hour Cleaners to well TT-26, including its evolution in the aquifer layers that the ATSDR modeled as layers 1 and 3. *Id.* at 49-50, 109–12 (explaining that Dr. Hennet calculated hydraulic gradient from potentiometric surfaces included in Attachment D to Dr. Hennet's report—*i.e.*, the ATSDR's modeled potentiometric surfaces for Tarawa Terrace and figures of plume geometry predicted by ATSDR). In fact, Dr. Hennet deviated from the ATSDR's approach in only two ways. First, Dr. Hennet corrected several parameter errors in the ATSDR model, which had (1) the wrong start date for ABC One-Hour Cleaners and (2) an unreasonable conclusion regarding the rate at which PCE traveled relative to groundwater due to a miscalculation and failure to use site-specific data. *Id.* at 49.

Second, Dr. Hennet selected flow paths for individual PCE molecules that are representative of the general geometry and evolution of the plume predicted ATSDR's model. *See id.* at 48-49 & Attachment D. He used those flow paths to calculate travel times for PCE arriving at well TT-26 from different parts of the plume. *Id.* at 49. Unlike the ATSDR, he did not attempt to quantify concentrations through time because, as he explained in an opinion that PLG does not challenge, there was insufficient data to do so. As his report states:

> In order to generate [contaminant] concentration estimates in the water supplies modeled, ATSDR had to make the general assumption that in the absence of [contaminant] concentration data in the water supplies prior to 1980, information on supply wells and water treatment plants would be sufficient information to extrapolate quantitatively the [contaminant] concentrations measured in the 1980s back to 1953. This assumption is deficient as it implies that there is quantitative and reliable data and information for [various parameters] for which there is very little reliable data. ATSDR professional judgment and estimates for these unknowns are not verifiable and the ATSDR model results are just a particular rendition of historic estimates for [contaminant] concentrations in the water supply of the Base. ATSDR estimates are therefore not quantitatively reliable as different plausible assumptions would lead to different results.

Id. at 69; *see also id.* at 33-34 (illustrating periods for which contaminant concentrations are unavailable). Dr. Hennet's opinions are consistent with the opinions of contemporaneous reviewers of ATSDR's model for Tarawa Terrace, such as the Navy and Dr. Prabhakhar Clement, the groundwater modeler who served on the National Research Council committee. *See* Jun. 19, 2008, Navy Letter, D.E. 370-5, at 7 ("[T]he goal of the Tarawa Terrace model is to reconstruct PCE concentrations on a monthly basis over approximately 30 years in order to conduct a health study. This is an extremely difficult goal since measured PCE concentrations are not available prior to 1982, and the historical reconstruction of monthly exposure concentrations must go back to the 1950's."); 2011 Clement Issue Paper, D.E. 372-4, at 6 ("However, due to limitations in our understanding of natural processes and due to inaccuracies in measurement methods, several complex models with many different model structures and initial conditions might fit these observations equally well.").

Because ATSDR made numerous assumptions as part of a complicated model to estimate PCE concentrations over a 30-year historic period for which there was no contaminant concentration data, its approach was scientifically unsound for the purpose of determining individual exposure levels. Dr. Hennet therefore took a different approach. He selected PCE flow paths that were representative of the ATSDR model's basic plume geometry and employed calculations based on fundamental geohydrology concepts to estimate the time it would take for PCE to arrive at well TT-26. D.E. 374-3 at 48-50. This approach provided information regarding which individuals at Tarawa Terrace may have been exposed to PCE at all. Moreover, this approach matches the approach recommended by PLG's proffered expert, Mustafa Aral, in his textbook that lists "key elements of a successful modeling effort" and includes a directive to "[s]implify the conceptual model, its mathematical interpretation and its user interface." Aral, Mustafa M, *Environmental Modeling and Health Risk*, D.E. 396-1 at 12; *see also* Konikow, Lenoard, *The Handbook of Groundwater Engineering*, Chap. 20, Groundwater Modeling, D.E. 370-2, at 20-18 - 20-19 ("In the development of a deterministic groundwater model for a specific area and purpose, an appropriate level of model complexity (or, rather, simplicity) must be selected.”).

Dr. Hennet Opined that Hadnot Point Supply Well HP-634 Was Not Contaminated with TCE Based on His Interpretation of Records and Resulting Conclusions About Disputed Facts.

Dr. Hennet opined that well HP-634 was not contaminated with TCE because contamination was not detected when HP-634 was pumping and a high reported TCE detection, which some records attributed to methylene chloride, was from a sample shipment in which vials from other contaminated wells were broken. D.E 374-3 at 65. This opinion matters because, as Dr. Hennet explained in his report, had the ATSDR used “trace or low TCE values for HP-634, as supported by the data, [this] would [have] substantially decrease[d] the COC concentrations calculated by ATSDR for the raw water.” *Id.* at 70. Rather than following this scientifically sound approach, ATSDR used the reported 1,300 ug/L TCE detection at well HP-634 to calibrate the Hadnot Point model. D.E. 372-2, ATSDR, HP/HB Supp. 6 at 14, 16 Table S6.2. The resulting model assumed that *three* TCE sources entered directly into multiple aquifer layers close to well HP-634. D.E. 371-3 at 69, 70 Table A13.

As Dr. Hennet explained, he evaluated the sampling records for well HP-634, considered the geohydrology of Camp Lejeune, and applied fundamental principles of geochemistry to conclude that HP-634 was not contaminated. D.E. 374-3 at 15-34, 56-57, 64-66. The sampling records reflect that well HP-634 was sampled five times, and TCE was detected only once, as reflected in the following summary of relevant sampling dates and reported contaminant concentrations:

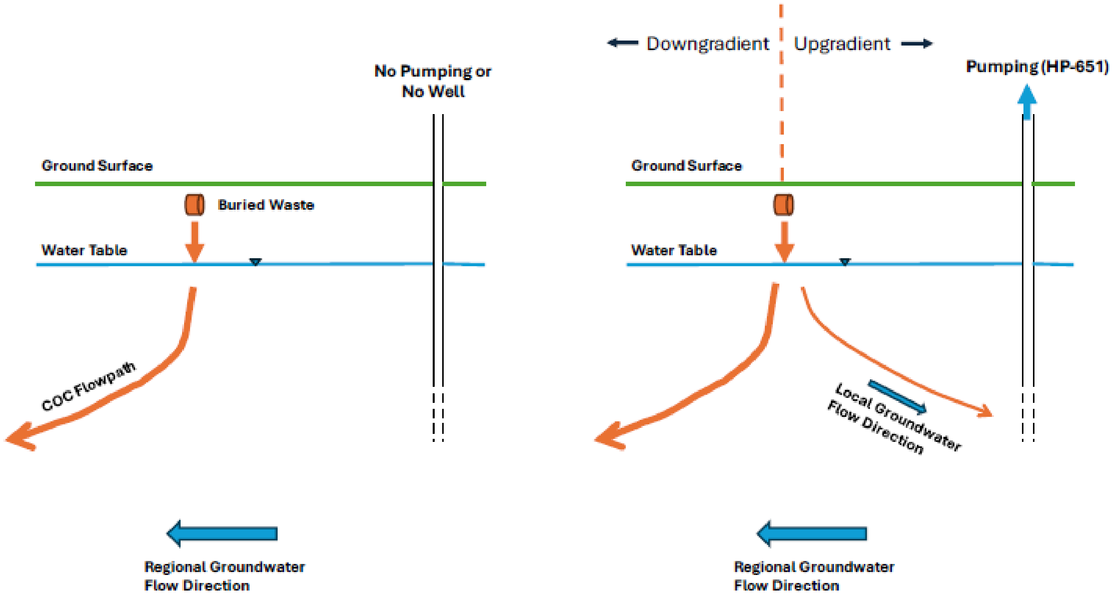
Well	**Sample Date**	**PCE (ug/L)**	**TCE (ug/L)**	**All DCEs (ug/L)**	**VC (ug/L)**	**Pumping**
HP-634	12/4/1985	None detected	None detected	None detected	None detected	Yes

HP-634	12/10/1985	None detected	None detected	2.3J	None detected	No
HP-634	1/16/1985	10	1,300	700	6.8	No
HP-634	11/12/1986	None detected	None detected	2.9	None detected	No
HP-634	1/22/1991	None detected	None detected	1.0J	None detected	No

See Ex. 1, ATSDR Hadnot Point / Holcomb Boulevard ("HP/HB") Ch. C Report, at C95 (HP-634 sampling results); D.E. 374-3 at 32, Exhibit I-9 (daily pumping of HP-634).

As the table shows, in a January 16, 1985, sample, TCE at a concentration of 1,300 micrograms per liter was reported for well HP-634. Ex. 1, ATSDR HP/HB Ch. C Report, at C95. This concentration that ATSDR used for well HP-634 far exceeded TCE detections in all other Hadnot Point supply wells except for two other wells: (1) well HP-651, which was the primary source of TCE contamination at Hadnot Point, and (2) well HP-602, which Dr. Hennet acknowledges was contaminated with TCE. *See id.* at Table C7; D.E. 374-3 at 64 ("Supply well HP-602's average measured TCE concentration over the period of the Act is 411 ug/L[.]"). In contrast to well HP-634, where TCE was typically not detected at all, TCE was repeatedly detected in wells HP-651 and HP-602 when they were operational supply wells. Ex. 1 at Table C7.

Dr. Hennet also evaluated whether HP-634 was supplying water to the Hadnot Point Water Treatment plant when it was sampled. D.E. 374-3 at 65. This is important because, as Dr. Hennet explained in his report, when wells were supplying water, their pumps could pull in water—and potentially water containing contaminants—that otherwise would have been down-gradient and tend to flow away from the well. *Id.* at 56-57. Dr. Hennet included an illustration, reproduced below, depicting this phenomenon in his report's discussion of another well, well HP-651:



Id. at 57.

The wells in the Hadnot Point system were cycled on and off to avoid intrusion of salt water or poor-quality water into the supply wells. *Id.* at 17. The only period for which daily records exist about which wells in the Hadnot Point system were supplying water reflects that well HP-634 was supplying water and had supplied water to the system for 4 of the 6 days prior to it being sampled on December 4, 1985, when contamination *was not* detected. *Id.* at 32. That HP-634 was sampled when it was pumping—and had been pumping for multiple days—was key to Dr. Hennet's analysis because it indicates that HP-634 was *not* pulling a downgradient TCE plume towards it and into the water supply.

The daily well cycling records also show that well HP-634 was *not* pumping and supplying water to the system when it was sampled on January 16, 1985, the date that one record reports a concentration of 1,300 ug/L of TCE. *Id.* at 32. In fact, the records show that well HP-634 did not pump *at all* between December 6, 1984, and February 5, 1985. *Id.* These records align with another record from a Camp Lejeune laboratory that reported that well HP-634 was "shut down

12/14/84[.]" *Id.* at 65. This evidence supports Dr. Hennet's conclusion that well HP-634 was not pulling contaminated water from a downgradient plume in January 1985 because it was no longer an active supply well. *See id.* ("One sample taken on January 16, 1985, when the well had already been shut down, reported a concentration of 1,300 ug/L for TCE."). The ATSDR water modeling reports also reflect that well HP-634 shut down in December 1984. D.E. 371-3 at 37, Fig. A5.

Dr. Hennet's opinion that well HP-634 was not contaminated with TCE is also based on the laboratory report for the January 16, 1985, result. The report identified two sample vials as "broken[,]" including a vial containing a sample from well HP-602, which Dr. Hennet acknowledged was contaminated with TCE; this caused Dr. Hennet to have concerns about sample cross contamination. D.E. 374-3 at 65. Dr. Hennet's opinion is also supported by historical records that attribute the 1,300 ug/L detection to methylene chloride contamination (rather than TCE), which is the reason that HP-634 was shut down. *Id.*

Dr. Hennet Used the Same Methodology as PLG's Expert Dr. David Sabatini to Opine that the Quantity of Contaminants of Concern Lost During the Filling of a Water Buffalo Through a Manhole Would be Similar to the Quantity Lost During Filling Through a Filler Pipe.

Dr. Hennet's opined that "[d]uring the filling of water buffaloes, a substantial portion of the [contaminants at issue] that might have been dissolved in the water would have been lost by volatilization to the air and thus removed from the water in the tank[,]" and that "[a]dditional [contaminants at issue] losses from the water in the buffaloes would have taken place due to temperature changes that forced air exchanges between the atmosphere and the air in the water buffaloes[,]" which, he explained "can be estimated." *Id.* at 74. He arrived at this opinion, as his report explains, based on basic principles of geochemistry and engineering techniques with which PLG's expert, Dr. Sabatini, agrees.

Under basic principles of geochemistry, the contaminants at issue "are highly volatile chemicals that preferentially partition to the air rather than remain[] in the water." *Id.* at 36-37. Moreover, "[t]he physical conditions for water storage . . . allow for air-water exchanges that result in COCs leaving the water for the air" at a magnitude that depends on properties of each contaminant, "including [1] the [contaminant's] affinity to volatilize to the air and [2] its solubility in water. These two properties are combined as a ratio referred to as the Henry's Law constant" which "is used to calculate the concentrations of a [contaminant] in air and water at equilibrium." *Id.* at 36–37.

Dr. Hennet applied these basic principles to calculate the amount of the COCs lost from the filling of a water buffalo through a filler pipe with a strainer using a model developed for calculating losses in a shower. *Id.* at 73-74). His report explains that "[t]he largest COC mass removal from the water is during fill-up of the tank [of a water buffalo] when conditions are ripe for volatilization, through increased contact between water and air due to the forcing of water through a strainer that generates water jets and droplets that greatly increase the surface area of the water/air interface[.]" *Id.* at 74). "The air containing COCs is expelled from the tank during filling" and filling itself "would involve spraying, splashing, and turbulent flow." *Id.*

PLG's rebuttal expert, Dr. Sabatini, agreed at his deposition that regardless of whether a water buffalo is filled via the manhole or the filler pipe, the best way to model COC losses during filling is the shower model Dr. Hennet used. Ex. 2, Sabatini Dep. at 313:20–314:19; *see* D.E. 374-3 at 74 (citing Little, J.C., 1992, *Applying the two-resistance theory to contaminant volatilization in showers,* Env't Sci. & Tech., 26(7), pp. 1341–49). Indeed, Dr. Sabatini used the shower model in his own calculation of COC losses during the filling of a water buffalo through a manhole. D.E. 349-6, Sabatini Report, at 21-22.

The only dispute between Dr. Hennet and Dr. Sabatini with respect to the method for calculating COC losses through manhole filling concerns whether to make adjustments to the input parameters of the shower model calculation in Dr. Hennet's report. Dr. Sabatini thinks that two adjustments should be made: (1) to account for a "lower area for mass transfer" due to the absence of a strainer and (2) to use a shorter time for volatilization due to increased downward water velocities. *Id.* at 21. Dr. Hennet disagrees that these adjustments are necessary because the increased splashing caused by the higher downward velocity of water in manhole filling would negate the differences that Dr. Sabatini identified. D.E. 374-2 at internally numbered 265:21–23. Dr. Hennet explained that COC losses to a water buffalo filled through a manhole are "comparable to what I calculated for the strainer," *id.* at internally numbered 265:25–266:1, because of "the large amount of aeration that [he] observed when the water buffalo was filled in 3 minutes and 23 seconds or so for 400 gallons," *id.* at internally numbered 265:21–23.

Both experts based their opinions on whether Dr. Hennet's calculation for filling through a filler pipe should be adjusted for filling through a manhole, in part, on their visual observations during the filling of a water buffalo through a manhole. *Id.* at internally numbered 121:16-19; D.E. 349-6 at 57-59.

Dr. Hennet Used Undisputed Chemical Phenomena to Opine that There Would Have Been COC Losses from Sorption During Water Treatment..

Dr. Hennet's report explains that in addition to COC losses from volatilization during water storage and treatment, COCs would also have been lost to sorption, i.e., removal from water through attachment to minerals, used in several water treatment processes. D.E. 374-3 at 46-48 (explaining that some COCs would "precipitate or sorb on the minerals"). He explains that these processes include spiractors, which remove iron and other metals by adding lime and catalyst sand to raw water. *Id.* This "results in the precipitation of minerals and mineral coatings in the spiractors[,]" which is a "water softening treatment[.]" *Id.* at 46. In addition to the intended removal of iron and other metals, "[a] portion of the COCs in the water precipitate or sorb on the minerals and are thereby removed from the water." *Id.* As minerals and COCs precipitate, the catalyst sand and lime "increase in volume" such that they have to be "fully replaced and disposed of approximately every 2 months." *Id*. When the catalyst sand and lime are replaced, the COCs that sorbed onto the precipitated metals are lost too. *Id.* Dr. Hennet describes these losses as "likely significant but less than the volatilization losses." *Id.* at 47.

Another process that removed COCs through sorption was sand filters meant to remove suspended solids from the water supply. *Id.* at 47. Because the suspended solids include remaining catalyst sand from the spiractors, and the COCs sorbed onto them, Dr. Hennet explained that COCs were lost when the filters were "backwashed" periodically "to unclog the filters from trapped solids and the backwash water is disposed to waste." *Id*. Dr. Hennet describes these losses as "likely less than the volatilization losses but non-negligible considering the high frequency of backwashing which is necessary to remove the trapped solids from the filters." *Id.*

Dr. Hennet did not quantify COC losses from either category of sorption because he had no data on COC concentrations with which to make calculations. Because no data exist, losses from sorption are *not included* in Dr. Hennet's estimates of the percentage of COCs lost during water storage and treatment. *Id.* at 48. Instead, he referenced an environmental organic chemistry textbook chapter on sorption of neutral chemicals, such as the COCs, to estimate that the losses were smaller than volatilization losses, but "likely to be significant[,]" at the spiractors and "non-negligible" at the sand filters. *Id.* at 44, 47. The chapter explains that this type of sorption to minerals, such as spiractor catalyst sand, "may become significant" and identifies chemical properties of organic chemicals and mineral surfaces that influence the extent of sorption. Ex. 4, Schwarzenbach, *Environmental Organic Chemistry*, Chapter 11 at 284-285 (1993). In fact, it specifically identifies sorption coefficients for PCE, which is one of the COCs. *Id.* at 286.

LEGAL STANDARD

An expert's testimony is admissible if it is relevant and reliable. *Neuse v. Ford Motor Company*, 848 F.3d 219, 229 (4th Cir. 2017) (citing *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 597 (1993)). Rule 702 states that an expert's testimony is reliable only if (1) "it is based upon sufficient facts or data," (2) "it is the product of reliable principles and methods," and (3) "the witness has applied the principles and methods reliably to the facts of the case." Fed. R. Evid. 702.

"Reliability is a 'flexible' inquiry that focuses on 'the principles and methodology' employed by the expert." *Sardis v. Overhead Door Corp.*, 10 F.4th 268, 281 (4th Cir. 2021) (quoting *Daubert*, 509 U.S. at 594-95). "In making its initial determination of whether proffered testimony is sufficiently reliable, the court has broad latitude to consider whatever factors bearing on validity that the court finds to be useful; the particular factors will depend upon the unique circumstances of the expert testimony involved." *Westberry v. Gislaved Gummi AB*, 178 F.3d 257, 261 (4th Cir. 1999) (citing *Kumho Tire Co. v. Carmichael*, 526 U.S. 137, 149-50 (1999)).

"However, the court should not resolve contested factual issues at the admissibility stage," *Mountain Valley Pipeline, LLL v. 0.32 Acres of Land*, 127 F.4th 427, 435 (4th Cir. 2025), as "'questions regarding the factual underpinnings of [an expert witness's] opinion affect the weight and credibility' of the witness' assessment, 'not its admissibility.'" *Bresler v. Wilmington Trust Co.*, 855 F.3d 178, 195 (4th Cir. 2017) (quoting *Structural Polymer Grp. v. Zoltek Corp.*, 543 F.3d 987, 997 (8th Cir. 2008)). "The emphasis . . . on 'sufficient facts or data' is not intended to authorize a trial court to exclude an expert's testimony on the ground that the court believes one version of the facts and not the other." *Lightfoot v. Georgia-Pacific Wood Prod., LLC*, No. 5:17-cv-616-FL, 2018 WL 6729636 at *2 (E.D.N.C. Dec. 21, 2018) (quoting Fed. R. Evid. 702, Advisory Committee Notes (2000)). Thus, "the court need not determine that the expert testimony a litigant seeks to offer into evidence is irrefutable or certainly correct. As with all other admissible evidence, expert testimony is subject to being tested by '[v]igorous cross-examination, presentation of contrary evidence, and careful instruction on the burden of proof.'" *Westberry*, 178 F.3d at 261 (quoting *Daubert*, 509 U.S. at 596).

ARGUMENT

I. Dr. Hennet Selected Flow Paths That Were Representative of the PCE Plume Geometry Predicted By the ATSDR and Determined Hydraulic Gradient Based on His Interpretation of the Data. Therefore, There is No Basis to Exclude His Opinion Regarding PCE Arrival Time at Tarawa Terrace.

PLG's complaint regarding Dr. Hennet's opinion on PCE arrival time at Tarawa Terrace well TT-26 is limited to the particular flow paths that Dr. Hennet selected. D.E. 374 at 13 ("Dr. Hennet does not provide a basis in his report for these flow paths being 'representative[.]'"). Dr. Hennet used three flow paths to determine a reasonable range of travel times. In one flow path, Dr. Hennet calculated the time for PCE to travel the horizontal distance between ABC One-Hour Cleaners and well TT-26 primarily in the shallow aquifer of layer 1. In another flow path, Dr. Hennet calculated the travel time for equal horizontal travel in layers 1 and 3. And, and in a third flow path, Dr. Hennet calculated the travel time for horizontal travel primarily in the deeper aquifer of layer 3. D.E. 374-3 at 49-50, 105-07. These three flow paths represented the general pathways predicted by the ATSDR's model of the PCE plume's geometry and evolution, as shown in the ATSDR's simulated plume figures reproduced in Dr. Hennet's report. *Id.* at 110-11.

Contrary to PLG's assertions, Dr. Hennet repeatedly explained his method for selecting these three representative flow paths at his deposition. After directing Dr. Hennet's attention to the page of his report with an illustration of the representative flow paths, the following colloquy occurred:

> Q: How did you choose those three travel pathways at 25, 20, and 15?
>
> A: Well, I calculated the time it would take for the contaminant PCE dissolved in groundwater to travel to the well from ABC Cleaner, and ***I used as a basis a simplified setup which is the same as the ATSDR model used, the same layers, the same thickness of each layer, the same permeability in each layer and such.***
>
> And what I did as a hydrogreologist and a geochemist, I applied the fundamental equations of formulas of evaluating fate and transport when you don't have data to illustrate that basically you can get answers that are different from what ATSDR has done as far as the travel time that are as valid and even more in this case, because ATSDR made mistakes and errors in what they did at Tarawa Terrace on the parameters.
>
> I used parameters that were the same as in the Hadnot Point model, and I used [them] to calculate the retardation for those travel time. I relied on the site-specific data that the ATSDR did not consider even though it did exist.
>
> So nobody knows what happened in the domain where you have no data with any degree of reasonable scientific certainty. You have many ways that you can calculate travel times to arrive to a well.
>
> ***The thing I want to say, in this case, you are trying to calculate travel times for a period of 30 years during which you have zero data for the contamination arriving at the well. And you have two or three years – well, you have some data, and that data is a huge portal, if you wish, because it has a huge range. It goes from zero to hundreds.***
>
> ***So ultimately you have many ways to get through that portal. This is one way. This way here, is there's no fundamental error like in, like ATSDR has. It's a Tarawa Terrace model. And it is actually something that is – that I would rely on to give you what is a range, a reasonable range, and that's what I did.***

D.E. 374-2 at internally numbered 266:20–268:23 (emphasis added).

PLG then specifically asked why Dr. Hennet's flow paths were representative of what occurs with contamination at well TT-26. In response, Dr. Hennet explained that he selected flow paths conforming to plume migration in layers 1 and 3 that was predicted by the ATSDR's model. He specifically stated:

> Q: What makes your three path flows representative of what actually occurred with contamination at well TT-26?
>
> A: ***This is the setup that – this setup, those layers, the permeability is in each one of those layers. The thickness of those layers in directly from the ATSDR model. I am not trying to critique those. I am just adopting them*** just to show if you do a calculation in the same framework that the ATSDR model is and you do it without mistakes or errors, you actually can get a representation that is like this.
>
> ***So it gives you representative travel time within a large range, which is meant to show that you don't have a single model that would tell you the truth because you don't know where the truth is when you don't have data.***
>
> Q: What makes the three pathways you chose representative of what occurred at TT-26?
>
> A: ***Well, similarly to what the ATSDR model represent, you have transport in layer one, and you have transport in layer three.*** And in order to go to the well, you have to basically end up in layer three because the well is screened in layer three, not in layer one.
>
> ***Now between the source, which is the ABC Cleaner, all the way to the well, you have basically many ways for the groundwater to get there. You don't go there through one single pathway.*** So that's why I choose some pathways, one which would go a short period of time in layer one and some of that contamination would go through the less permeable layer down to layer three and continue in layer three.
>
> I have another pathway that is closer to the well, and I have another pathway that is in between. Those are basically estimates that give you a range of travel time of this situation.

D.E. 374-2 at internally numbered 270:13–271: 25 (emphasis added).

PLG's insistence that Dr. Hennet "failed to identify or articulate a reliable methodology in support of his selection of 'representative flow paths,'" overlooks the entirety of Appendix D to his report and his clear deposition testimony that he selected flow paths from the source to TT-26 that were representative of the basic PCE plume geometry determined by the ATSDR's groundwater modeling at Tarawa Terrace. D.E. 374 at 14. Furthermore, multiple PLG experts have opined that the ATSDR's simulated PCE concentrations, which derive from that same plume geometry, are "correct," "reliable," etc. *Id.* at 13-14; *see* D.E. 368 at 12 (United States' *Daubert* motion collecting citations). Therefore, in using the ATSDR's published reports on predicted plume geometry and evolution, Dr. Hennet "point[ed] to some objective source—a . . . published article in a reputable scientific journal or the like—to show that [he] ha[s] followed the scientific method, as it is practiced by (at least) a recognized minority of scientists in [his] field." *Daubert*, 43 F.3d at 1318–19; *see also Funderburk v. S.C. Elec. & Gas Co.*, 395 F.Supp.3d 695, 702, 720–21 (D.S.C. July 23, 2019) (denying motion to exclude expert testimony where movant "takes no issue with the reliability of that underlying data, only [the challenged expert's] interpretation and characterization of the event"). Dr. Hennet's selection of flowpaths for his opinion therefore meets Rule 702's admissibility threshold for reliability.

This is similar to the conclusion reached by the Western District of North Carolina in *Browder v. State Farm Fire and Casualty Company*, No. 1:20-cv-26, 2021 WL 2517681 (W.D.N.C. June 18, 2021). There, the court denied a defendant's motion to exclude testimony from a professional engineer about his opinions on the cause of structural damage to a home. *Id.* at *1. The defendant alleged that the opinions of plaintiff's expert were "not based on reliable principles or methodologies." *Id.* at *5. The court evaluated the challenged expert's "methodologies in comparison to those methods used by the other engineers who inspected Plaintiffs' home." *Id.* at *6. The court noted that four engineers had inspected the home, and "[w]hen considering the methodologies of the other three engineers, with whom Defendant does not raise an issue, [the challenged engineer]'s techniques appear to be similar." *Id.* It concluded that "[b]ecause [the challenged engineer]'s methods are very similar to those of the other engineers, his methods likely have acceptance within a relevant scientific community." *Id.*

That is precisely the situation facing this Court with respect to Dr. Hennet's selection of flow paths. Both Parties' experts used flow paths through the ATSDR's conceptual model of the aquifer between ABC One-Hour Cleaners and well TT-26 to calculate PCE arrival times. *See* D.E. 369-11, Konikow Report, at 30; D.E. 374-3 at 49-50. Dr. Hennet then selected flow paths representative of the PCE plume geometry predicted by the ATSDR's models to calculate time for PCE to travel from ABC One-Hour Cleaners to well TT-26.[1]

Dr. Konikow offers a rebuttal opinion that a "more critical flow path" for PCE is travel in the shallow aquifer of layer 1 for the entire 1,000 horizontal feet between the PCE source at ABC One-Hour Cleaner to well TT-26. D.E. 369-11 at 29. But this is a difference of opinion, not a difference in methodology. Both Dr. Hennet and Dr. Konikow selected paths representative of possible ways a PCE molecule could travel to well TT-26. *Id.*; D.E. 374-3 at 49-50. Dr. Hennet explained that unlike Dr. Konikow, however, he was not estimating the earliest time at which an individual PCE molecule could possibly arrive at TT-26 under unrealistic conditions, but rather, "a reasonable range" of times for PCE to arrive based on the ATSDR's predicted plume evolution.[2]

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[1] Conspicuously absent from PLG's motion is a challenge to Dr. Hennet's methodology of estimating arrival of PCE at well TT-26 using travel time calculations along representative flow paths. They cannot make such an argument because their expert, Dr. Konikow, employed the same method, but selected a different flow path. D.E. 369-11, Konikow Report, at 30 ("It is more likely that the travel distance in the shallower aquifer for much of the contaminated shallow groundwater would be more than 800 ft and the corresponding travel distance in the pumped aquifer would be less than 200 ft[.]. . . For this critical flow path, the travel time would be much less than 15 years – on the order of 3.5 to 5 years.").

[2] Prior to becoming an expert for PLG, Dr. Konikow thought it could have taken up to two years for PCE to reach the aquifer below ABC Cleaners before it even began traveling to well TT-26, which he thought likely occurred before 1968, but possibly later. D.E. 369-4 at 47:17-48:18.

D.E. 349-3 at internally numbered 268:22–23; *see also* D.E. 374-3 at 49 ("A PCE groundwater plume gradually developed in the pumped aquifer and ultimately led to the contamination of well TT-26, which is screened (open to allow groundwater to flow into the well) in the pumped aquifer. . . . The transport of dissolved PCE in the shallow aquifer (L1 . . .), through the low permeability clay layer (L2), and then through the pumped aquifer (L3) to supply well TT-26 took several years. . . . [Calculations] along three representative flow paths yields travel time for PCE between ABC Cleaners and TT-26 that are in the 15 to 25 years range.").

PLG also challenges Dr. Hennet's use of a constant hydraulic gradient, meaning the water pressure that drives the flow of groundwater, in his calculated PCE travel times along each representative flow path by mistakenly claiming that "Dr. Hennet does not and cannot explain why these large variations in hydraulic gradient, which can be readily estimated, should be disregarded." D.E. 374 at 13; *see* D.E. 374-3 at 16 ("The ability of groundwater to move depends on the aquifer permeability and the pressure gradient (hydraulic gradient). . . . The hydraulic gradient is what drives the flow of groundwater."). Contrary to PLG's representation, Dr. Hennet explained at his deposition that there were multiple reasons why he did not vary hydraulic gradient. First, he explained that the increased hydraulic gradient from well pumping would only occur "as you get very close to the well," and "before you get [PCE] close to the well, you would have a long way to go." D.E. 374-2 at internally numbered 269:19-21. Furthermore, Dr. Hennet explained that an increasing hydraulic gradient would "be less marked in layer one" which was where PCE traveled primarily in the flow path that resulted in earlier arrival at TT-26. *Id.* at internally numbered 269:10-13. These physical realities are reflected in ATSDR's figures showing simulated potentiometric levels—*i.e.*, levels of equal hydraulic gradient—that Dr. Hennet included in Attachment D to his report. In those figures, ATSDR's simulated potentiometric levels change less quickly between ABC One-Hour Cleaners and well TT-26 in aquifer layer 1 than they do in layer 3. D.E. 374-3 at 109-10.

Finally, Dr. Hennet explained that "you have several things that you can say that would slightly accelerate or diminish" the travel time for PCE, including "things that would actually make [the travel times] longer." D.E. 374-2 at internally numbered 269:14-17. When Dr. Hennet tried to explain at his deposition phenomena that would extend PCE travel times (which also influenced his decision not to include adjustments for pumping-related acceleration), PLG cut him off. *Id.* at internally numbered 270:1-12 ("A: On the other end, on the other end, things that would actually elongate the time of travel are two major things. The first one – Q: Let me withdraw.").

PLG's complaints about the way in which Dr. Hennet calculated PCE travel times amount to nothing more than a disagreement with how he interpreted the available data about hydraulic gradients between ABC One-Hour Cleaner's and well TT-26. But "[a]n expert's opinion is not 'rendered inadmissible' when he disagrees with another's 'opinions and testing methods.'" *Browder v. State Farm Fire & Casualty Co.*, 2021 WL 2517681 at *7 (W.D.N.C. June 18, 2021) (quoting *Refrigeration Supplies, Inc. v. Acadia Ins. Co.*, No. 4:19-cv-2210, 2020 WL 7397002 at *1104 (E.D. Mo. Dec. 17, 2020).

In sum, both Dr. Hennet and Dr. Konikow calculated PCE arrival times using flow paths based on ATSDR's conceptual model of the aquifer, and Dr. Hennet selected flow paths based on the ATSDR's predicted plume geometry. Dr. Hennet's hydraulic gradient determinations are based on his interpretation of the available data given his expertise in the field. PLG has failed to raise an appropriate basis for exclusion of Dr. Hennet's opinion regarding the arrival of PCE at Tarawa Terrace well TT-26.

II. Dr. Hennet Concluded that Well HP-634 Was Not Contaminated with TCE Based on His Interpretation of Historical Records. Therefore, There is No Basis to Exclude His Opinion.

PLG does not challenge Dr. Hennet's methodology for concluding that well HP-634 was not contaminated with TCE; nor do they claim that Dr. Hennet had insufficient facts or data to reach that conclusion. These are the appropriate bases for an admissibility challenge. *See Mountain Valley Pipeline, LLL v. 0.32 Acres of Land*, 127 F.4th 427, 435 (4th Cir. 2025) ("the correct inquiry at the admissibility stage is . . . only whether the expert's methodology was reliable and was based on sufficient facts or data"); *see also* D.E. 374 at 10-12. Instead, PLG takes issue with Dr. Hennet's interpretation of the historical data relevant to contamination in and around well HP-634. Some of their complaints are logical fallacies, such as their straw-man argument that well HP-634's sample vial was not reported among those from the January 16, 1985, sample set that the laboratory noted were broken on receipt. That is true, but as Dr. Hennet explained at his deposition, among the broken vials was a sample from the TCE-contaminated well, HP-602, which was shipped with the sample from well HP-634, providing a plausible source of contamination for the sample from well HP-634. *Id.* at 10; D.E. 374-2, at internally numbered page 195:19–24. Some records additionally reflect that a sample vial from well HP-651, the driver of TCE contamination at Hadnot Point, was also broken. Ex. 2, Hennet Dep. Ex. 18 at 7.

Similarly, PLG's argument that HP-634 must have been contaminated with TCE, because ATSDR's Hadnot Point-Holcomb Boulevard *model* showed that HP-634 was impacted by TCE in the groundwater, is circular. D.E. 374 at 11. Because the ATSDR calibrated its model to the 1,300 ug/L (very likely inaccurate) TCE sample from HP-634, the ATSDR assumed that three distinct TCE contamination sources existed close to well HP-634 and placed them in their model. *See* D.E.

D.E. 371-3 at 69, Table A13. This inevitably and obviously resulted in TCE impacting HP-634 in the ATSDR's model.

Other PLG complaints concern the relative probative value of various historical documents. *See, e.g.*, D.E. 374 at 10 ("Dr. Hennet provides no explanation as to why summary reports should be trusted or believed over the primary source laboratory report."). Still other complaints accuse Dr. Hennet of inconsistently interpreting historical data but fail to acknowledge important differences in thse data. For example, PLG argues that it is inconsistent for Dr. Hennet to opine that well HP-634 was not contaminated with TCE while failing to also opine that TT-26 was not contaminated even though both wells showed similar variation in measured concentrations. *Id.* at 11. This argument ignores the fact that well TT-26's high PCE concentrations were from samples taken when it was an active supply well, but its low PCE concentrations were from samples taken after it had been permanently shut down; this is consistent with the pumping of the well pulling the contaminant plume towards TT-26. In contrast, well HP-634 had been shut down and was not pumping at the time of the high TCE detection; this detection is inconsistent with the theory that the pumping well was pulling a contaminant plume towards HP-634.[3] *See* D.E. 374-3 at 57) (explaining how *pumping* wells can pull contaminant sources to them that would otherwise be downgradient); D.E. 370-3, ATSDR Tarawa Terrace Ch. A, at 34, Table A6 (TT-26 service dates).

None of these complaints are valid bases to exclude Dr. Hennet's opinions under Rule 702 because they all depend on resolving contested factual underpinnings of his opinions. "[T]he court

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[3] Records of daily well pumping operations do not exist for Tarawa Terrace, though dates when wells entered into and out of service largely to exist, and TT-26 remained an active supply well when high PCE concentrations were detected in it. D.E. 370-3 at 33-34 & Table A6 (discussing available well operation data).

should not resolve contested factual issues at the admissibility stage[,]" *Mountain Valley Pipeline, LLL v. 0.32 Acres of Land*, 127 F.4th 427, 435 (4th Cir. 2025), because "'questions regarding the factual underpinnings of [an expert witness's] opinion affect the weight and credibility' of the witness' assessment, 'not its admissibility.[,]'" *Bresler v. Wilmington Trust Co.*, 855 F.3d 178, 195 (4th Cir. 2017) (quoting *Structural Polymer Grp. V. Zoltek Corp.*, 543 F.3d 987, 997 (8th Cir. 2008)).[4] Rule 702's "emphasis . . . on 'sufficient facts or data' is not intended to authorize a trial court to exclude an expert's testimony on the ground that the court believes one version of the facts and not the other." *Lightfoot v. Georgia-Pacific Wood Prod., LLC*, No. 5:17-cv-616-FL, 2018 WL 6729636, at *2 (E.D.N.C. Dec. 21, 2018) (quoting Fed. R. Evid. 702 advisory committee's notes to 2000 amendment). Instead, "the correct inquiry at the admissibility stage is ... only whether the expert's methodology was reliable and was based on sufficient facts or data ..." *Mountain Valley Pipeline, LLL v. 0.32 Acres of Land*, 127 F.4th 427, 435 (4th Cir. 2025). Because PLG does not challenge Dr. Hennet's actual methodology and because Dr. Hennet had sufficient facts and data to reach his conclusion, his opinion is admissible.

Given the legal framework, the case on which PLG relies is clearly inapposite. In *In re Lipitor (Atorvastatin Calcium) Marketing, Sales Practices and Products Liability Litigation*, 892 F.3d 624 (2018), the Fourth Circuit upheld a district court's decision to exclude testimony from an expert who adopted a statistical analysis *method* only after obtaining an unfavorable result with another statistical analysis method, then applied the results of the cherry-picked method in a subsequent analysis. *Id.* at 634. The reasoning did not turn on a dispute about historical facts or

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[4] Because disputed facts cannot form the basis of a valid motion to exclude expert testimony under Rule 702, the United States has not moved to exclude PLG's experts' ill-conceived rebuttal opinions that HP-634 was contaminated.

the proper interpretation of historical data. *Id.* Here, the central issue is a dispute on a historical fact about whether an anomalous sampling measurement from well HP-634 was accurate. Such "'questions regarding the factual underpinnings of [an expert witness's] opinion affect the weight and credibility' of the witness' assessment, 'not its admissibility,'" so PLG's argument fails. *Bresler* 855 F.3d at 195 (quoting *Structural Polymer Grp.*, 543 F.3d at 997).

III. Dr. Hennet Estimated COC Losses From Filling a Water Buffalo Through a Manhole By Employing the Same Methodology He Applied to Filling a Water Buffalo Through a Filler Pipe Which Was Also Used By PLG's Expert. Therefore, His Opinion Should Not Be Excluded.

PLG claims that Dr. Hennet's conclusion that COC losses from filling a water buffalo through a manhole were comparable to those from filling a water buffalo through a filler pipe were based on "his observation of one water buffalo in 2025[,]" from which he "took no measurements, collected no data, and performed no calculations[.]" D.E. 374 at 6. This is patently incorrect. Dr. Hennet's method for estimating COC losses at water buffaloes filled through a manhole involved calculating losses using a method developed for showers. This method is explained in Dr. Hennet's report, and it is the same method used by PLG's expert, Dr. Sabatini. *See* Ex. 3, Sabatini Dep. at 313:20–314:19; D.E. 374-3 at 74 (citing Little, J.C., 1992, *Applying the two-resistance theory to contaminant volatilization in showers,* Env't Sci. & Tech., 26(7), pp. 1341–49); D.E. 349-6 at 21-22. Dr. Hennet's observation of the filling of a water buffalo through a manhole only confirmed that his filler pipe COC loss calculations were equally applicable. Dr. Hennet's opinion was therefore "based on scientific, technical other specialized *knowledge* and not on belief or speculation, and inferences [were] derived using scientific or other valid methods." D.E. 374 at 6 (quoting *Oglesby v. General Motors Corp.*, 190 F.3d 244, 250 (4th Cir. 1999)).

PLG's reliance on cases excluding expert testimony that is based "solely on visual observations" is misplaced. D.E. 374 at 6–7. The "visual estimates" case that PLG cites bears little resemblance to Dr. Hennet's observation of aeration or splashing in the filling of a water buffalo through a manhole. In *Precision Fabrics Group, Inc.*, v. *Tietex Int'l, Ltd.*, No. 1:13-cv- 645, 2016 WL 6839394 (M.D.N.C., Nov. 21, 2016), an expert claimed to have *observed with the naked eye* "near microscopic swelling of a 45-micron sized film" and used this super-human observation in a method that "is not proven to produce reliable results." *Id.* at *8. Those circumstances are much different than Dr. Hennet's observation of the aeration of water in the filling of a water buffalo through a manhole and his determination of how that might affect his calculation of losses of filling of a water buffalo through a filler pipe. The importance of aeration, as both Dr. Hennet and Dr. Sabatini acknowledge, is that it increases the surface area between air and water, which increases the rate of COC losses. D.E. 374-2 at 262:12-266:1; Ex. 3, Sabatini Dep. At 88:20-25. Dr. Hennet did not claim that he could see the COCs, only the aeration. *Id.*

Indeed, the court in *Precision Fabrics* recognized that "[i]n some instances visual observation could produce a reliable result." *Id.* It simply concluded that *microscopic swelling* was not such an instance. *Id.*; *cf. Ruark v. BMW of North America, LLC*, No. CIV.A ELH-09-2738, 2014 WL 351640, at *10 (D. Md. Jan. 30, 2014) (allowing expert testimony where expert "did not conduct any trace analysis or other scientific testing on the scuff marks, however. Instead, [the expert] simply made the visual observation that the scuff marks appeared to match aspects of the hat."). Because PLG does not challenge Dr. Hennet's actual methodology in calculating COC losses—which is the same as Dr. Sabatini's—Dr. Hennet's opinion is admissible.

Further, the Court should not consider PLG's discovery-based arguments for excluding Dr. Hennet's opinion because they are irrelevant to admissibility of Dr. Hennet's opinion under Fed. R. Evid. 702. Magistrate Judge Jones already denied PLG's discovery-based motion seeking to exclude Dr. Hennet's opinions based on his observations during his February 2025 site visit to

Camp Lejeune, including the filling of a water buffalo through a manhole. *See* D.E. 380 (order denying motion to exclude Dr. Hennet's opinion from February 2025 site visit); *compare* D.E. 374 at 5-6 *with* D.E. 349. Judge Jones found that "PLG cannot really show surprise" at the information Dr. Hennet learned from his site visit and that "Dr. Hennet did not change his opinions based on the February Site Visit." D.E. 380 at 9. He further found that at least some of the need to consider manhole-based filling was PLG's fault in disclosing late factual information with their rebuttal expert's report. *Id.* Judge Jones ruled that exclusion was inappropriate, and any prejudice to PLG from Dr. Hennet's opinions related to his February 2025 site visit would be cured with additional deposition time with Dr. Hennet, which Judge Jones ordered. *Id.* at 9. PLG did not appeal Magistrate Judge Jones's order under the local rules, and PLG has made no attempt to connect it to reliability under Rule 702, so the Court should not consider PLG's rehashed discovery argument now. *See* Local R. Civ. P. 72.4(a)(1) (appeals from a magistrate judge's order must be filed within 14 days of service).

IV. Dr. Hennet Concluded that There Would Have Been Sorption Losses During Treatment Based on Published Literature and 30 Years of Experience as a Ph.D. Geochemist Studying the Fate and Transport of Organic Chemicals in the Environment. Therefore, His Opinion Should Not Be Excluded.

Dr. Hennet concluded that a non-negligible or significant portion of COCs were lost to sorption during water treatment. This opinion was primarily based on chemical phenomena recognized by PLG's own experts and described in a textbook that Dr. Hennet cited, which referenced one of the same COCs at issue in this case. *Compare* D.E. 374 at 7-9 *with* D.E. 374-3 at 47-48. Dr. Hennet also relied on his extensive education and experience studying the fate of the COCs and other organic chemicals in the environment to qualitatively opine on the magnitude of COC losses. Because of insufficient data, Dr. Hennet acknowledged that he could not quantify the losses. D.E. 374-3 at 47.

To determine whether COCs would have been lost to sorption during water treatment, Dr. Hennet studied the water treatment systems historically employed at Camp Lejeune, considered the nature of COCs found in the systems, and applied fundamental geochemical sorption concepts. *Id.* at 20-23, 25, 46-47. Dr. Hennet relied on his professional experience to *qualitatively* assess the magnitude of COC losses in accordance with the factors described in the cited textbook. *Id.* at 46-47. PLG's expert, Dr. Sabatini, acknowledged that COC losses to sorption would have occurred, but disagreed with Dr. Hennet's *qualitative* assessment of the extent of sorption losses based on Dr. Sabatini's own professional judgment. *See* D.E. 374-5 at 12-13 (concluding sorption losses would be negligible); Ex. 3, Sabatini Dep. at 220:22-221:2 (agreeing that TCE sorption on inorganic materials removed in the spiractor would be negligible or minor), 222:2-12 (agreeing with the possibility of TCE sorption on inorganic surfaces). Dr. Hennet's reliance on a textbook confirming that nonpolar chemicals like the COCs sorb onto minerals like the spiractors catalyst sands provides "some objective source . . . show[ing] that [he] ha[s] followed the scientific method, as it is practiced by (at least) a recognized minority of scientists in [his] field[,]" meeting Rule 702's reliability threshold for admissibility. *Daubert*, 43 F.3d at 1318–19; *see also Funderburk*, 395 F.Supp.3d at 702, 720–21 (denying motion to exclude expert testimony where movant "takes no issue with the reliability of that underlying data, only [the challenged expert's] interpretation and characterization of the event.").

PLG's contrary arguments are unsound. PLG incorrectly claims that the textbook chapter that Dr. Hennet cited does not support the conclusion that a portion of COCs were removed by sorption onto minerals during water treatment. D.E. 374 at 8-9. That chapter, which PLG did not provide to the Court, discusses "neutral organic chemicals," and Dr. Hennet's report explains the COCs are such neutral organic chemicals. D.E. 374-3 at 25. Further, the chapter specifically states that sorption of such chemicals onto mineral surfaces "may become significant." Ex. 4, Schwarzenbach at 284. The chapter also lists a sorption coefficient for one of the specific COCs that is at issue in this case. *Id.* at 286.

PLG similarly claims that Dr. Hennet failed to explain whether sorption losses are "intended" or "incidental" to treatment or that he failed to comment on retention time. These complaints are irrelevant because they do not affect Dr. Hennet's *qualitative* opinions that losses occurred. D.E. 374 at 8-9.

Furthermore, Dr. Hennet is obviously qualified to offer opinions about sorption of organic chemicals, including the COCs, to minerals based on his extensive education and experience in geochemistry, and, in particular, the fate of organic chemicals. Dr. Hennet holds a Doctor of Philosophy in Geochemistry from Princeton University in addition to university degrees in hydrogeology and geology. D.E. 374-3 at 80. He is also a licensed professional geoscientist in Texas and a certified professional geological scientist from the American Institute of Professional Geologists. *Id.* He is a member of both the American Chemical Society and the Association of Groundwater Scientists and Engineers, has numerous publications in the fields of organic geochemistry, and has "more than 30 years of research and profession experience" specializing "in evaluating the origin, fate, and transport of organic . . . chemicals in the environment." *Id.* at 80. This education and experience are precisely of the sort that allow Dr. Hennet to conclude that the fate of some of the dissolved organic COCs that entered water treatment plants at Camp Lejeune was sorption onto the sands and suspended solids they encountered during water treatment.

CONCLUSION

For the foregoing reasons, the Court should deny PLG's motion to exclude Dr. Remy Hennet's opinions that: (1) PCE likely arrived at Tarawa Terrace water supply well TT-26 in the 1970s, (2) Hadnot Point water supply well HP-634 was not contaminated with TCE, (3) COC losses at water buffaloes filled through the manhole were comparable to losses at water buffaloes filled through filler pipes, and (4) there were COC losses to sorption during water treatment.

Dated: June 4, 2025

Respectfully Submitted,

JONATHAN GUYNN
Deputy Assistant Attorney General
Civil Division

J. PATRICK GLYNN
Director, Torts Branch

BRIDGET BAILEY LIPSCOMB
Chief, Camp Lejeune Section

ADAM BAIN
Special Litigation Counsel

HAROON ANWAR
GIOVANNI ANTONUCCI
ALANNA HORAN
KAILEY SILVERSTEIN
Trial Attorneys

/s/ Allison M. O'Leary
ALLISON M. O'LEARY
MI Bar No. P78427
Trial Attorney, Torts Branch
Environmental Tort Litigation Section
United States Department of Justice
P.O. Box 340, Ben Franklin Station
Washington, D.C. 20044
E-mail: allison.o'leary@usdoj.gov
Telephone: (202) 374-0045

Attorney inquiries to DOJ regarding CLJA:
(202) 353-4426

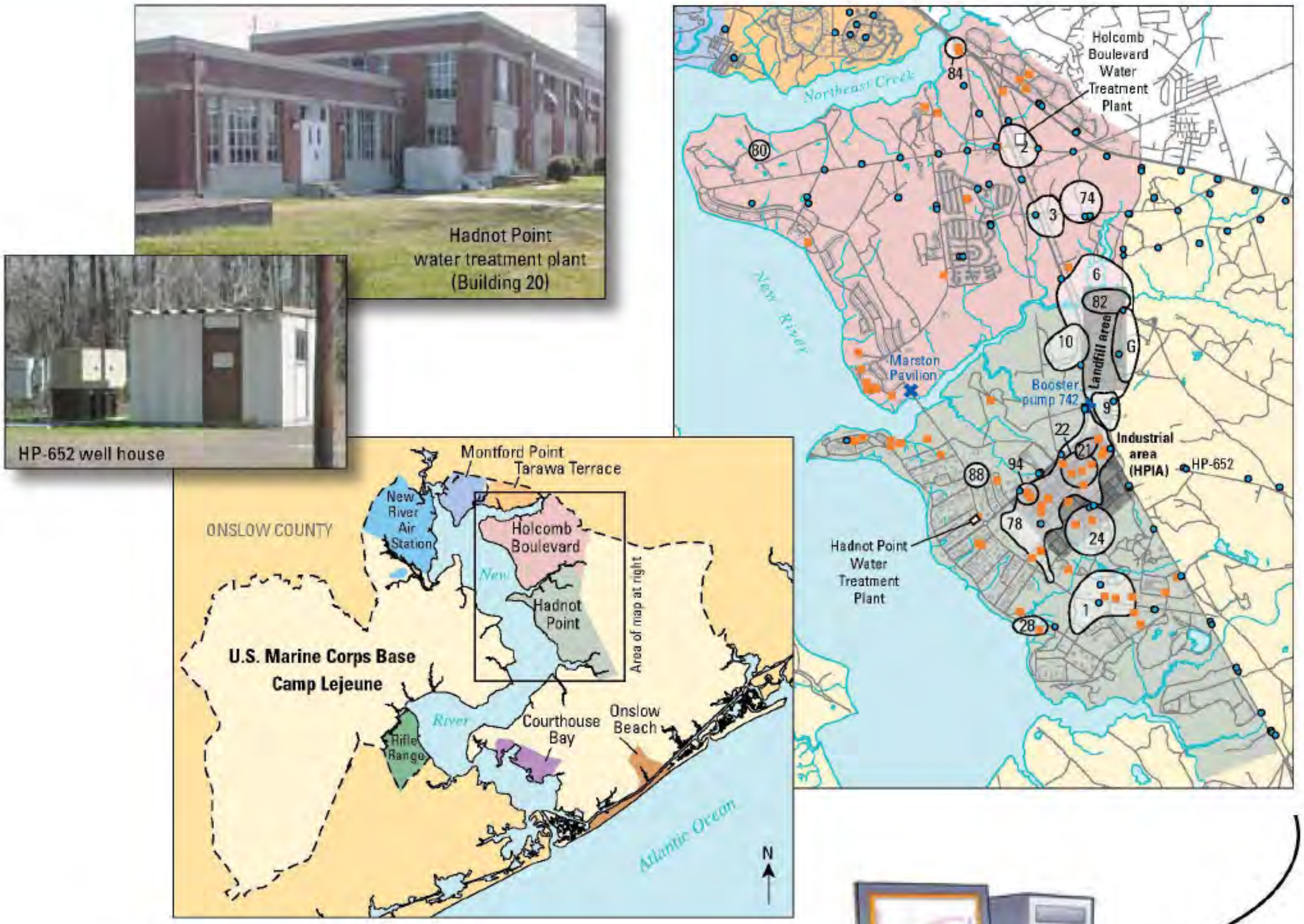
CERTIFICATE OF SERVICE

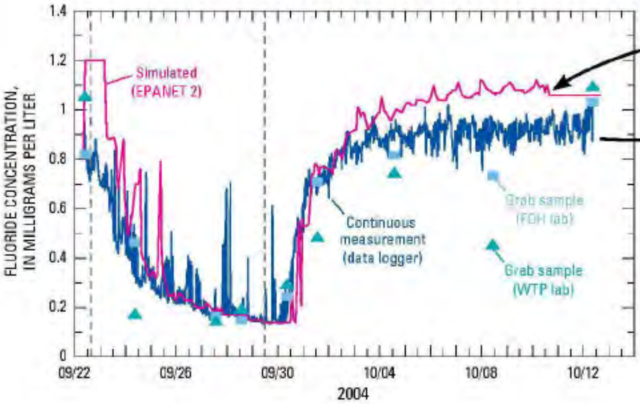
I hereby certify that on June 4, 2025, a copy of the foregoing document was served on all counsel of record by operation of the court's electronic filing system and can be accessed through that system.

/s/ Allison M. O'Leary
ALLISON M. O'LEARY

Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina

Chapter C: Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites





Atlanta, Georgia – October 2010

Front cover: Historical reconstruction process using data, information sources, and water-modeling techniques to estimate historical contaminant concentrations.

Maps: U.S. Marine Corps Base Camp Lejeune, North Carolina; Holcomb Boulevard and Hadnot Point areas showing extent of sampling at installation restoration program sites (white numbered areas), above-ground and underground storage tank sites (orange squares), and water-supply wells (blue circles).

Photograph (upper): Hadnot Point water treatment plant (Building 20).

Photograph (lower): Well house building for water-supply well HP-652.

Graph: Measured fluoride data and simulation results for Paradise Point elevated storage tank (S-2323) for tracer test of the Holcomb Boulevard water-distribution system, September 22–October 12, 2004; simulation results obtained using EPANET 2 water-distribution system model assuming last-in first-out plug (LIFO) flow storage tank mixing model. [WTP lab, water treatment plant water-quality laboratory; FOH lab, Federal Occupational Health Laboratory]

Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina

Chapter C: Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites

By Robert E. Faye, Barbara A. Anderson, René J. Suárez-Soto, and Jason B. Sautner

Agency for Toxic Substances and Disease Registry
U.S. Department of Health and Human Services
Atlanta, Georgia

October 2010

Authors

Robert E. Faye, MSCE, PE
Civil Engineer/Hydrologist
Robert E. Faye and Associates, Inc.
Consultant to Eastern Research Group, Inc.
Lexington, Massachusetts

Barbara A. Anderson, MSEnvE, PE
Environmental Health Scientist
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry
Atlanta, Georgia

René J. Suárez-Soto, MSEnvE, EIT
Environmental Health Scientist
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry
Atlanta, Georgia

Jason B. Sautner, MSCE, EIT
Environmental Health Scientist
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry
Atlanta, Georgia

For additional information write to:

Project Officer
Exposure-Dose Reconstruction Project
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry
4770 Buford Highway, Mail Stop F-59
Atlanta, Georgia 30341-3717

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Foreword

The Agency for Toxic Substances and Disease Registry (ATSDR), an agency of the U.S. Department of Health and Human Services, is conducting an epidemiological study to evaluate whether in utero and infant (up to 1 year of age) exposures to volatile organic compounds (such as trichloroethylene, tetrachloroethylene, and benzene) in drinking water at U.S. Marine Corps Base Camp Lejeune, North Carolina, were associated with specific birth defects and childhood cancers. The study includes births occurring during the period 1968–1985 to women who were pregnant while they resided in family housing at the base. During 2004, the study protocol received approval from the Centers for Disease Control and Prevention Institutional Review Board and the U.S. Office of Management and Budget.

Historical exposure data needed for the epidemiological case-control study are limited. To obtain estimates of historical exposure, ATSDR is using water-modeling techniques and the process of historical reconstruction. These methods are used to quantify concentrations of particular contaminants in finished water and to compute the level and duration of human exposure to contaminated drinking water.

Eight water-distribution systems have supplied or currently (2010) are supplying drinking water to family housing and other facilities at U.S. Marine Corps Base Camp Lejeune, North Carolina. The three distribution systems of interest to this study—Tarawa Terrace, Hadnot Point, and Holcomb Boulevard—have historically supplied drinking water to the majority of family housing units at the Base. During 2007–2009, ATSDR published historical reconstruction results for Tarawa Terrace and vicinity. Results for Hadnot Point, Holcomb Boulevard, and vicinity—based on information gathering, data interpretations, and water-modeling analyses—are now presented as another series of ATSDR reports supporting the current health study. These reports provide comprehensive descriptions of information, data analyses and interpretations, and modeling results used to reconstruct historical contaminant levels in drinking water within the service areas of the Hadnot Point and Holcomb Boulevard water treatment plants and vicinities. Each topical subject within the historical reconstruction process is assigned a chapter letter. Specific topics for each chapter report are listed below:

- **Chapter A:** Summary of Findings
- **Chapter B:** Geohydrologic Framework of the Brewster Boulevard and Castle Hayne Aquifer Systems and the Tarawa Terrace Aquifer and Confining Unit
- **Chapter C:** Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites
- **Chapter D:** Occurrence of Selected Contaminants in Groundwater at Above-Ground and Underground Storage Tank (AST/UST) Sites
- **Chapter E:** Physical, Chemical, and Fate Properties of Selected Contaminants in Soil and Groundwater and Computations of Contaminant Mass in Soil and Groundwater
- **Chapter F:** Descriptions and Characterizations of Water-Supply Well Capacities, Histories, and Drinking Water
- **Chapter G:** Descriptions and Characterizations of Water-Level Data and Groundwater Flow for the Brewster Boulevard and Castle Hayne Aquifer Systems and the Tarawa Terrace Aquifer and Confining Unit
- **Chapter H:** Development and Application of a Methodology to Characterize Present-Day and Historical Water-Supply Well Operations within the Hadnot Point and Holcomb Boulevard Service Areas

- **Chapter I:** Theory, Development, and Application of Linear Control Model Methodology to Reconstruct Historical Contaminant Concentrations at Selected Water-Supply Wells Within the Hadnot Point and Holcomb Boulevard Service Areas
- **Chapter J:** Simulation of Three-Dimensional Groundwater Flow
- **Chapter K:** Simulation of Three-Dimensional Groundwater Flow and Contaminant Fate and Transport in the Vicinity of the Hadnot Point Industrial Area
- **Chapter L:** Simulation of the Migration of Light Nonaqueous Phase Liquids (LNAPL) in the Vicinity of the Hadnot Point Industrial Area
- **Chapter M:** Simulation of Three-Dimensional Groundwater Flow and Contaminant Fate and Transport in the Vicinity of the Hadnot Point Landfill Area
- **Chapter N:** Simulation of Three-Dimensional Groundwater Flow and Contaminant Fate and Transport in the Vicinity of Holcomb Boulevard Water-Supply Well HP-645
- **Chapter O:** Simulation of Three-Dimensional Multispecies and Multiphase Contaminant Fate and Transport in the Vicinity of Hadnot Point Industrial Area, Hadnot Point Landfill, and Holcomb Boulevard Water-Supply Well HP-645
- **Chapter P:** Field Tests, Data Analyses, and Simulation of the Distribution of Drinking Water with Emphasis on Intermittent Transfers of Drinking Water Between the Hadnot Point and Holcomb Boulevard Water-Distribution Systems
- **Chapter Q:** Supplemental Information

An electronic version of this report, *Chapter C: Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites*, will be made available on the ATSDR Camp Lejeune Web site at *http://www.atsdr.cdc.gov/sites/lejeune/index.html*. Readers interested solely in a summary of this report or any of the other reports can refer to *Chapter A: Summary of Findings*, which also will be available on the ATSDR Web site.

Contents

Figures

Tables (all tables are in back of report)

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square yard (yd^2)	0.8361	square meter (m^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
	Flow rate	
gallon per minute (gpm)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per year (gal/yr)	0.003785	cubic meter per year (m^3/yr)
million gallons per day (MGD)	0.04381	cubic meter per second (m^3/s)
	Mass	
pound per year (lb/yr)	0.45359	kilogram per year
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton, long (2,240 lb)	1.016	megagram (Mg)

Concentration Conversion Factors

Unit	To convert to	Multiply by
microgram per liter (µg/L)	milligram per liter (mg/L)	0.001
microgram per liter (µg/L)	milligram per cubic meter (mg/m^3)	1
microgram per liter (µg/L)	microgram per cubic meter (µg/m^3)	1,000

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

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

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

Glossary and Abbreviations

Definitions of terms and abbreviations used throughout this report are listed below.

— A —

AST Above-ground storage tank

ATSDR Agency for Toxic Substances and Disease Registry

— B —

B Constituent detected in blank sample.

bgs Below ground surface

biodegradation Transformation of substances into new compounds through biochemical reactions or the actions of microorganisms, such as bacteria. Typically expressed in terms of a rate constant or half-life (USEPA 2004). The new compounds are referred to as degradation by-products [for example, TCE, *trans*-1,2-DCE, and vinyl chloride (VC) are degradation by-products of tetrachloroethylene (PCE)]

BTEX Benzene, toluene, ethylbenzene, and xylene; a group of VOCs found in petroleum hydrocarbons, such as gasoline, and other common environmental contaminants

BBUAQ Brewster Boulevard upper aquifer

BBUCU Brewster Boulevard upper confining unit

BBLAQ Brewster Boulevard lower aquifer

BBLCU Brewster Boulevard lower confining unit

— C —

CERCLA The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, also known as Superfund

CLW Camp Lejeune water document

CPT Cone penetration test

— D —

D Sample dilution required

DCE

DCE	dichloroethylene
1,1-DCE	1,1-dichloroethylene or 1,1-dichloroethene
1,2-DCE	1,2-dichloroethylene or 1,2-dichloroethene
cis-1,2-DCE	*cis*-1,2-dichloroethylene or *cis*-1,2-dichloroethene
trans-1,2-DCE	*trans*-1,2-dichloroethylene or *trans*-1,2-dichloroethene

DDT Dichlorodiphenyltrichloroethane, a synthetic pesticide; its use in the United States was banned in 1972

degradation *See* biodegradation

density The mass per unit volume of material, expressed in terms of kilograms per cubic meter or grams per cubic centimeter

DNAPL Dense nonaqueous phase liquids; a class of environmental contaminants that have a specific gravity greater than water (Huling and Weaver 1991). Immiscible (nonmixing) DNAPLs exist in the subsurface as a separate fluid phase in the presence of air and water. DNAPLs can vaporize into air and slowly dissolve into flowing groundwater. Examples of DNAPLs include chlorinated solvents, creosote, coal tar, and PCBs (Kueper et al. 2003)

DVD Digital video disc

— E —

E Constituent concentration exceeds calibration range of GC/MS instrument

epidemiological study A study to determine whether a relation exists between the occurrence and frequency of a disease and a specific factor such as exposure to a toxic compound found in the environment

exposure Pollutants or contaminants that come in contact with the body and present a potential health threat

— F —

fate and transport Also known as mass transport; a process that refers to how contaminants move through, and are transformed in, the environment

FFCA Federal Facilities Compliance Act of 1992

finished water Groundwater that has undergone treatment at a water treatment plant and is delivered to a person's home

FS Feasibility Study

ft Foot or feet

— G —

gal Gallon or gallons

GIS Geographic information system

gpm Gallons per minute

GPS Global positioning system

GC/MS Gas chromatograph/Mass spectrometer

— H —

historical reconstruction A diagnostic analysis used to examine historical characteristics of groundwater flow, contaminant fate and transport, water-distribution systems, and exposure

HPIA Hadnot Point Industrial Area

HPFF Hadnot Point Fuel Farm

HSWA Hazardous and Solid Waste Amendments of 1984

— I —

IAS Initial Assessment Study

IR Installation Restoration

IRP Installation Restoration Program

— J —

J Estimated concentration

— K —

kg Kilogram

— L —

LCHAQ Lower Castle Hayne aquifer

LCHCU Lower Castle Hayne confining unit

LNAPL Light nonaqueous phase liquids

— M —

MGD Million gallons per day

mg/L Milligram per liter; 1 part per million (ppm), a unit of concentration

MCHAQ Middle Castle Hayne aquifer

MCHCU Middle Castle Hayne confining unit

— N —

NA Constituent concentration not determined, or analytical result is unknown

NACIP Navy Assessment and Control of Installation Pollutants

NAD 83 North American Datum of 1983

ND Constituent not detected

NGVD 29 National Geodetic Vertical Datum of 1929

NPL National Priorities List; the USEPA's official list of uncontrolled hazardous waste sites which are to be cleaned up under the Superfund legislation

— P —

PCB Polychlorinated biphenyl

PCE Tetrachloroethene, tetrachloroethylene, 1,1,2,2-tetrachloroethylene, or perchloroethylene; also known as PERC® or PERK®

PHA Public health assessment; an evaluation conducted by ATSDR of data and information on the release of hazardous substances into the environment in order to assess any past, present, or future impact on public health

potentiometric level A level to which water will rise in a tightly cased well

— R —

R Analytical result is unreliable

RCRA Resource Conservation and Recovery Act of 1976

RI Remedial Investigation

RI/FS Remedial Investigation/Feasibility Study

ROD Record of decision

— S —

SARA Superfund Amendments and Reauthorization Act of 1981

SEAR Surfactant-enhanced aquifer remediation

SI Site Investigation

SR Highway or state route

— T —

TCE 1,1,2-trichloroethene, or 1,1,2-trichloroethylene, or trichloroethylene

TPH Total petroleum hydrocarbons

TTAQ Tarawa Terrace aquifer

TTCU Tarawa Terrace confining unit

— U —

UCHLU Upper Castle Hayne aquifer lower unit

UCHRBU Upper Castle Hayne aquifer–River Bend unit

UCHRBU&LU Upper Castle Hayne aquifer–River Bend and Lower units

USEPA U.S. Environmental Protection Agency

USGS U.S. Geological Survey

USMCB U.S. Marine Corps Base

UST Underground storage tank

— V —

variability Observed differences attributable to heterogeneity or diversity in a model parameter, an exposure parameter, or a population

VC Vinyl chloride or chloroethene

VOC Volatile organic compound; an organic chemical compound (chlorinated solvent) that has a high enough vapor pressure under normal circumstances to significantly vaporize and enter the atmosphere. VOCs are considered environmental pollutants, and some may be carcinogenic

— W —

water-distribution system A water-conveyance network consisting of hydraulic facilities, such as wells, reservoirs, storage tanks, high-service and booster pumps, and a network of pipelines for delivering drinking water

water table Also known as the phreatic surface; the surface where the water pressure is equal to atmospheric pressure

WTP Water treatment plant

—Symbols—

< Constituent concentration is less than detection limit. Number following the "<" is the detection limit.

µg/kg Microgram per kilogram; 1 part per billion (ppb); a unit of concentration used in soil sampling

µg/L Microgram per liter; 1 part per billion (ppb), a unit of concentration used in groundwater sampling

Note: The maximum contaminant level (MCL) is a legal threshold limit set by the USEPA on the amount of a hazardous substance that is allowed in drinking water under the Safe Drinking Water Act; usually expressed as a concentration in milligrams or micrograms per liter. Effective dates for MCLs are as follows: trichloroethylene (TCE) and vinyl chloride (VC), January 9, 1989; tetrachloroethylene (PCE) and *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), July 6, 1992 (40 CFR, Section 141.60, Effective Dates, July 1, 2002, ed.)

Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina

Chapter C: Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites

By Robert E. Faye,[1] Barbara A. Anderson,[2] René J. Suárez-Soto,[2] and Jason B. Sautner[2]

Abstract

Eight water-distribution systems have supplied or currently (2010) are supplying drinking water to family housing and other facilities at U.S. Marine Corps Base (USMCB) Camp Lejeune, North Carolina. The three distribution systems of interest to this study—Tarawa Terrace, Hadnot Point, and Holcomb Boulevard—have historically supplied drinking water to the majority of family housing units at the Base. Two of the three water-distribution systems were contaminated with volatile organic compounds (VOCs). Groundwater within the Tarawa Terrace water treatment plant (WTP) service area was contaminated mostly with tetrachloroethylene (PCE). Groundwater within the Hadnot Point WTP service area was contaminated mostly with trichloroethylene (TCE), as well as PCE and refined petroleum products (BTEX). Most of the groundwater within the Holcomb Boulevard WTP service area remained uncontaminated. Discovery of contaminated water supplies at USMCB Camp Lejeune initiated a series of assessments of groundwater contamination within the Hadnot Point WTP and Holcomb Boulevard WTP service areas. Assessments began in 1984, and monitoring continues to date (2010) at several locations. Ultimately, assessments of groundwater contamination were conducted at a total of 18 Installation Restoration (IR) Program sites within the Hadnot Point and Holcomb Boulevard service areas. As reported in numerous site assessment and monitoring reports, subsurface contamination by various VOCs of interest, including PCE, TCE, benzene, and vinyl chloride, was delineated through the construction and sampling of hundreds of monitor wells and the sampling and analyses of surface and subsurface soil samples and surface-water and stream sediment samples. Substantial groundwater contamination by VOCs was determined at 9 of the 18 IR sites. Concentrations of TCE were detected in groundwater at 13 of 18 IR sites, ranging from 1.2 micrograms per liter (µg/L) to 180,000 µg/L. Similarly, PCE was detected in groundwater at 8 of 18 IR sites at concentrations ranging from less than 1.0 µg/L to 170,000 µg/L. Concentrations of benzene in groundwater were detected at 10 of 18 IR sites at concentrations ranging from less than 1.0 µg/L to 29,000 µg/L. Of a total of 30 water-supply wells contaminated or potentially contaminated by VOCs because of construction and proximity to contaminated IR sites, VOCs were determined in 11 wells by sampling and analyses. An additional 13 of the 30 supply wells were abandoned and destroyed prior to 1984 and could not be sampled. In the contaminated water-supply wells, detected TCE concentrations ranged from less than 1.0 µg/L to 18,900 µg/L, and PCE concentrations ranged from 3.2 µg/L to 400 µg/L. Corresponding concentrations of benzene ranged from 1.6 µg/L to 720 µg/L. At several IR sites located near active supply wells, VOC contamination was determined in the subsurface at depths greater than 140 feet. Concentrations of TCE detected in finished water at the Hadnot Point WTP ranged from 1.2 µg/L to 1,400 µg/L. Concentrations of PCE detected in finished water at the Hadnot Point WTP ranged from 15 µg/L to 100 µg/L. Benzene contamination also was detected in Hadnot Point WTP water, although the treatment status was unknown. Benzene concentrations in water at the Hadnot Point WTP ranged from 1.0 µg/L to 2,500 µg/L.

This report, Chapter C, is one of approximately 16 reports planned to describe and summarize groundwater data and water-modeling results necessary to estimate spatial and temporal distributions of contaminant-specific concentrations in drinking-water supplies within the Hadnot Point and Holcomb Boulevard WTP service areas. These contaminant-specific concentrations are necessary to complete ATSDR's current health study of birth defects and specific childhood cancers and to determine possible associations between adverse health effects and contaminated drinking water at USMCB Camp Lejeune. Most of the data tabulated and described in this report were obtained from USMCB Camp Lejeune IR Administrative Records and files of the U.S. Geological Survey and were extracted and summarized from thousands of documents, hundreds of individual site reports, approximately 120 site- and well-location maps, and more than 400 well-bore and geophysical logs.

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[1] Consultant to Eastern Research Group, Inc., Lexington, Massachusetts.

[2] Agency for Toxic Substances and Disease Registry, Atlanta, Georgia.

Background and Environmental History

U.S. Marine Corps Base (USMCB) Camp Lejeune is located in the Coastal Plain of North Carolina, in Onslow County, south of the City of Jacksonville and about 70 miles northeast of the City of Wilmington, North Carolina. The focus of this investigation is the areas served by the water distribution networks supplied by the Hadnot Point and Holcomb Boulevard water treatment plants (WTPs), herein called the study area. In general, the study area is bordered on the north by Northeast Creek and North Carolina Highway 24 (SR 24), to the west by New River, to the south by Frenchs Creek, and generally to the east by the drainage divides of upstream tributaries of Wallace and Frenchs Creeks (Plate 1).

The current health study of birth defects and specific childhood cancers by the Agency for Toxic Substances and Disease Registry (ATSDR) requires estimates or direct knowledge of contaminant concentrations in finished water[3] delivered to family housing within the study area. When direct knowledge of contaminant concentrations in finished water is unavailable, historical reconstruction is used to provide estimates of contaminant concentrations. Characteristically, historical reconstruction includes the application of simulation tools, such as models, to re-create or represent past conditions (Rodenbeck and Maslia 1998; McLaren/Hart-ChemRisk 2000; Costas et al. 2001; Maslia et al. 2001; Reif et al. 2003; Kopecky et al. 2004). At USMCB Camp Lejeune, historical reconstruction methods include linking materials mass balance (mixing) and water-distribution system models to groundwater-flow and fate and transport models (Maslia et al. 2009). Groundwater fate and transport models are based to a large degree on groundwater-flow velocities or specific discharges simulated by a groundwater-flow model. Data necessary for the construction of a groundwater-flow model are the vertical and spatial (vertical and horizontal) distribution of aquifers and confining units and their respective hydraulic characteristics, such as hydraulic conductivity and specific storage. Construction of fate and transport models also requires knowledge of temporal, spatial, and vertical occurrences of specific contaminant constituents within water-bearing units open to water-supply and other observation wells, and physical, chemical, and fate properties of specific contaminants of concern.

This report provides a detailed accounting of the known occurrences of contaminants of concern and their related degradation products in groundwater at selected sites within the service areas of the Hadnot Point and Holcomb Boulevard WTPs, USMCB Camp Lejeune, North Carolina. Concentrations of these constituents in water-supply wells and in finished water of the Hadnot Point WTP also are described. Collectively, these data provide most of the base of information necessary to construct the fate and transport models used to simulate (reconstruct) historical concentrations of contaminants within the water-distribution systems serviced by the Hadnot Point and Holcomb Boulevard WTPs. Additionally, this report provides a detailed summary of historical information useful to ongoing and future exposure and health studies at USMCB Camp Lejeune, including a chronology of residential housing areas served by the Hadnot Point and Holcomb Boulevard WTPs, annual operational capacities of the WTPs, locations and construction details of water-supply wells and water-quality monitor wells, and a summary and discussion of relevant environmental investigations at 18 individual sites within the study area where contaminated groundwater occurred or was thought to have occurred.

Housing Areas

Family housing areas currently (2010) served by the Hadnot Point and Holcomb Boulevard WTPs are Berkeley Manor, Hospital Point, Midway Park, Paradise Point, and Watkins Village (Plate 1). In 1999, a total of 2,158 individual housing units were located in these areas (ECG, Inc. 1999). Bachelor housing in the study area is located in the vicinity of Hadnot Point between River Road/Julian C. Smith Road and McHugh Boulevard (Plate 1). The current (2010) number of bachelor housing units is not available.

Construction of family housing at USMCB Camp Lejeune began in 1942, in conjunction with other major infrastructure components at the base, such as roads, WTPs, and the water-distribution network. Midway Park and Paradise Point were the first housing units constructed, followed in 1947 by Hospital Point Housing, Berkeley Manor in 1961, and Watkins Village in 1978. Housing at Paradise Point was improved and expanded during 1947, 1948, and 1962 (Scott R. Williams, USMCB Camp Lejeune, electronic communication, September 3, 2008). A chronology of family housing unit construction and corresponding population is listed in Table C1. Family housing occupancy rate was 95 percent or greater in 1998 (ECG, Inc. 1999), and similar rates probably have prevailed at USMCB Camp Lejeune since the base was established. Thus since 1963, the population of family housing in the study area has been continuously maintained at about 4,000 to 8,000 residents, depending on the number of available housing units (Table C1). In 1999, the number of occupants of bachelor housing in the study area totaled 13,427 personnel. Of these, 13,129 personnel were served by the Hadnot Point WTP (ECG, Inc. 1999). The resident bachelor population includes permanently assigned personnel as well as a substantial number of short-term transient personnel and, as such, probably varies significantly from month to month and year to year.

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[3] For this study, finished drinking water is defined as groundwater that has undergone treatment at a WTP and was subsequently delivered to a family housing unit or other facility.

Water Treatment Plants

The Hadnot Point WTP (Building 20) was constructed probably during 1941 and 1942, along with much of the original infrastructure of the Base. Original capacity of the Hadnot Point WTP was 7.3 million gallons per day (MGD) (Harned et al. 1989). By May 1986 the reported plant capacity was 5.0 MGD, followed by 5.9 MGD in 1987 (Naval Facilities Engineering Command, 1986; Harned et al. 1989). Present-day (2010) capacity is probably about 5.0 MGD. Annual rates of finished water delivered by the Hadnot Point WTP are listed in Table C2. Rates listed for years 1942, 1944, 1948, and 1953 are reported as "max. delivered to plant" or "max. amount delivered to plant" and ranged from 4.8 to 6.0 MGD [unknown author, USMCB Camp Lejeune, Raw Water Supply Data, written communication, 1969(?)]. Between 1959 and 1988, the average annual rate of finished water supplied by the Hadnot Point WTP generally ranged between 3.0 and 5.2 MGD [unknown author, U.S. Geological Survey, Raw Water Treated, Hadnot Point WTP, 1959–1988, written communication, 1989(?)]. Between 1974 and 1986, following initial construction of the Holcomb Boulevard WTP, the average annual rate of finished water supplied by the Hadnot Point WTP declined significantly and ranged between 3.0 and 3.8 MGD (Harned et al. 1989). Between 1994 and 1998, the annual finished water production from the Hadnot Point WTP averaged about 2.9 MGD (ECG, Inc. 1999). The service area of the Hadnot Point WTP currently (2009) includes the Hospital Point family housing area, billeting facilities for a large number of bachelor officers and enlisted personnel, the Hadnot Point Industrial Area (HPIA), and the Frenchs Creek area (Plate 1). The population served by the Hadnot Point WTP during March 1987 totaled 37,134 personnel (Harned et al. 1989). This number probably included permanent and transient military personnel and civilian personnel assigned to various offices and facilities throughout the Hadnot Point WTP service area.

Until the summer of 1972, all finished water distributed to bachelor and family housing units and all other facilities within the study area was supplied by the Hadnot Point WTP (Building 20). Subsequent to 1972, finished water distributed to Berkeley Manor, Midway Park, Paradise Point, and Watkins Village family housing areas was supplied by the Holcomb Boulevard WTP (Building 670) (Plate 1). Also included in the Holcomb Boulevard WTP service area are the current U.S. Naval Hospital, the Camp Lejeune high school, and the Brewster Boulevard junior high school (Plate 1).

The Holcomb Boulevard WTP began operations during the summer of 1972 with a capacity of about 2 MGD (Table C3) (Scott A. Brewer, USMCB Camp Lejeune, written communication, September 29, 2005).[4] The treatment capacity of the plant was increased to 5 MGD probably during 1986 and 1987 (Naval Facilities Engineering Command, Atlantic Division, 1986, Camp Lejeune Water Document CLW #4938). Average annual rates of finished water delivered by the Holcomb Boulevard WTP between 1975 and 1998 ranged between 0.7 and 2.5 MGD. Annual delivery rates for this period are listed in Table C3. Finished water supplies from the Tarawa Terrace WTP to Tarawa Terrace family housing were significantly reduced in February 1985 following the discovery of contamination by volatile organic compounds (VOCs) in several Tarawa Terrace supply wells and the subsequent removal of these wells from active service (Faye and Green 2007). To supplement Tarawa Terrace water supplies, deliveries of finished water from the Holcomb Boulevard WTP to Tarawa Terrace began during the summer of 1985 with the completion of a connecting pipe line. All Tarawa Terrace supply wells were removed from service by February or March 1987. At that time, the Holcomb Boulevard WTP service area was increased to include all of Tarawa Terrace family housing and, by connection, the Camp Knox trailer park. The Holcomb Boulevard WTP service area was further increased later in 1987 to include the area formerly served by the Montford Point WTP and related supply wells (Maslia et al. 2007) (Plate 1). By March 1987, the resident and transient population served by the Holcomb Boulevard WTP totaled 17,297 persons (Harned et al. 1989). The Holcomb Boulevard water-distribution system is linked to the Hadnot Point water-distribution system near McHugh Boulevard and Wallace Creek (Marston Pavilion valve) and near Holcomb Boulevard and Wallace Creek at booster pump 742 (Plate 1; Naval Facilities Engineering Command, Atlantic Division 1986; ECG, Inc. 1999). For operational reasons, the two water-distribution systems are rarely connected—exceptions being some interconnections that occurred during the late spring and early summer months of 1978–1986, as noted in WTP log books (Camp Lejeune water documents CLW #6774–#8761).

Chronology of Supply-Well Construction and Activity

The first wells that supplied the Hadnot Point WTP were completed by the fall of 1942 and were numbered sequentially from 1 to 21 (HP-601 to HP-621, Plate 1, Table C4). Wells HP-624, HP-625, HP-626, HP-627, HP-628, and HP-629 were completed probably during 1951 to 1953 to expand total water-supply capacity. During 1947, supply wells M-1 and M-2, which had formerly served only Midway Park family housing and immediate vicinity, were connected to the Hadnot Point WTP distribution system, and the Hadnot Point WTP began serving the Midway Park area (unknown author, "Technical Report and Recommendations for Additions and Improvements to the Hadnot Point Fresh Water System at the Marine Barracks, Camp Lejeune," written communication, October 13, 1950). Between 1953 and 1960, supply wells HP-630, HP-631, HP-632, HP-633, HP-634, HP-635, HP-636, LCH-4006, and LCH-4007 were added to the Hadnot Point WTP raw water distribution network to increase total system

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[4] Based on information contained in the written communication from USMCB Camp Lejeune, the start of continuous operations at the Holcomb Boulevard WTP is estimated to be about June 1972.

capacity and to replace abandoned wells. Supply well HP-607 was abandoned, probably about 1955 (unknown author, USMCB Camp Lejeune, Water Treatment Plant Well Pump Data, written communication, February 19, 1957), and was ultimately replaced by well HP-630. Supply wells LCH-4006 and LCH-4007 probably replaced wells M-1 and M-2 by 1956 or 1957. Supply well HP-604 was abandoned during 1957 and was replaced during 1969 by well HP-637 [unknown author, USMCB Camp Lejeune, Raw Water Supply Data, written communication, 1969(?)]. Between 1962 and 1969 use of supply wells HP-624, HP-628, HP-629, HP-630, and HP-631 was terminated because the wells were "becoming filled with sand and gravel" [unknown author, USMCB Camp Lejeune, Raw Water Supply Data, written communication, 1969(?)]. Supply wells HP-638, HP-639, HP-640, HP-641, HP-642, HP-651, and HP-652 were added to the Hadnot Point WTP raw water supply probably between 1969 and 1972. Between 1978 and 1986, supply wells HP-607 (new), HP-622, HP-623, HP-629 (new), HP-639 (new), HP-653, HP-654, HP-655, HP-660, HP-661, HP-662, HP-663, HP-709, HP-710, HP-711, HP-5186, and LCH-4009 were added to the Hadnot Point WTP raw water distribution network to replace abandoned wells and to maintain raw water-supply capacity. (Water-supply well HP-660 is consistently and incorrectly referred to in many data sources as supply well HP-601.) The term "new" included parenthetically with the names of supply wells HP-607, HP-629, and HP-639 along with other wells listed herein, in Table C4, and in other tables indicates that the particular well is the second well so named to supply the Hadnot Point WTP. Similarly, when "old" is included parenthetically with a well name listed in tables or in this text, the well is the first well so named to supply the Hadnot Point WTP. The most recent period of Hadnot Point WTP supply-well completions occurred between 1994 and 2000 when wells HP-585, HP-595, HP-596, HP-611 (new), HP-612 (new), HP-614 (new), and HP-621 (new) were added to the raw water-supply network. Location coordinates for all historical and currently active (2010) water-supply wells within the study area are listed in Table C4.

The Holcomb Boulevard WTP began operations during the summer of 1972 with a capacity of 2 MGD and was immediately supplied by wells HP-643, HP-644, HP-645, HP-646, HP-647, HP-648, HP-649, and HP-650 (Table C4, Plate 1). The treatment capacity of the plant was increased to 5 MGD probably during 1986 and 1987 (Naval Facilities Engineering Command, Atlantic Division, 1986; Camp Lejeune Water Document CLW #4938). Between 1985 and 1986, potential raw water deliveries to the Holcomb Boulevard WTP were significantly increased with the completion of wells HP-698, HP-699, HP-700, HP-701, HP-703, HP-704, HP-705, HP-706, HP-707, and HP-708. By 1991, well HP-645 was no longer in service (Geophex, Ltd. 1991). Supply wells HP-617 (new), HP-618 (new), and HP-619 (new) were constructed during 1994. Well HP-706 was probably abandoned about 1998. Supply wells HP-557, HP-558, and HP-584 were completed during 1998 to 2000, probably to supplement raw water deliveries to the Holcomb Boulevard WTP and to replace abandoned wells.

Contaminants of Concern

Contaminant VOCs of interest to this study are generally classified as chlorinated alkenes and gasoline components. The chlorinated alkenes of interest are tetrachloroethylene (PCE), also known as PERC® or tetrachloroethene; trichloroethylene (TCE), also called trichloroethene; and their degradation products. The gasoline components of interest are benzene, toluene, ethylbenzene, and xylene, collectively known as BTEX. PCE, TCE, and their degradation products are commonly grouped with compounds called dense nonaqueous phase liquids (DNAPLs). As such, the densities of DNAPLs are greater than the density of water, and DNAPLs are characterized by an enhanced potential for downward vertical migration when occurring in the subsurface. The BTEX components are grouped with compounds commonly called light nonaqueous phase liquids (LNAPLs). These compounds are characterized by densities less than the density of water, and their downward vertical migration in the subsurface is generally limited to the vicinity of the water table.

PCE and TCE in solution in groundwater commonly degrade under anaerobic conditions by a process called reductive dechlorination (Lawrence 2007). TCE can occur in groundwater as a degradation product of PCE or as contamination from an original source or sources. TCE degrades to three compounds—most commonly to *cis*-1,2-dichloroethylene (*cis*-1,2-DCE) and less commonly to *trans*-1,2-dichloroethylene (*trans*-1,2-DCE) and 1,1-dichloroethylene (1,1-DCE). These compounds, in turn, all degrade to vinyl chloride. Degradation occurs along pathways of dechlorination activity, more to less. Degradation of BTEX components is not considered in this report. Contaminants of primary concern to this study are PCE, TCE, vinyl chloride, and benzene.

Contaminant Source Areas

The introduction of contaminant compounds to the soil and groundwater within the study area at USMCB Camp Lejeune occurred intentionally and unintentionally. The introduction of BTEX components to the subsurface was largely unintentional and resulted from accidental spills and leaks from above-ground and underground storage tanks (ASTs and USTs, respectively) and related connecting pipes and valves. Such tanks commonly contained refined petroleum products such as heating oil, gasoline, and diesel fuel. The introduction of PCE to the subsurface probably was the unintentional result of leaks from USTs and wastewater discharge lines as well as the intentional disposal of "still bottoms" and dry filters and possibly liquid PCE in drums and other containers to landfills, temporary pits, and disposal trenches. "Still bottoms" and dry filters are common by-products of dry-cleaning processes and typically contain high concentrations of PCE. Of the contaminants of interest to this study, TCE, PCE, and BTEX components occur most frequently within the study area. Pathways of TCE introduction to the subsurface are probably highly similar to those described previously for PCE with respect to unintentional leaks from storage tanks and wastewater discharge lines and the intentional disposal of liquid wastes in landfills and in temporary pits and trenches.

Major source areas for contaminants within the study area are disposal sites such as landfills and trenches, vehicle maintenance facilities, dry-cleaning establishments, and large storage tanks and tank farms that contain refined petroleum products. Possible source areas were first identified in 1982–1983 during an initial study conducted to assess sites at USMCB Camp Lejeune that could pose a potential threat to human health and the environment caused by past hazardous materials operations (Water and Air Research, Inc. 1983). A total of 76 disposal or potentially contaminated sites were identified where hazardous materials had possibly been mishandled or subjected to inappropriate disposal. Each site was formally designated a "disposal site" and assigned a name and number. These names and numbers were maintained as site identifiers through subsequent investigations; however, the term "disposal site" was later changed to Installation Restoration (IR) site. Ultimately, a total of 94 IR sites were identified by the mid-1990s (Baker Environmental, Inc. 1996c). The numbers and respective names assigned to IR sites within the Hadnot Point and Holcomb Boulevard study area are listed in Table C5. Locations of IR sites, by number, are shown on Plate 1 and in Figure C1. In addition, two sites within the study area that contained AST and UST facilities were co-located with IR sites and also were subjects of site assessments related to subsurface and groundwater contamination by BTEX components. Accordingly, investigations of BTEX contamination resulting from leaking ASTs and USTs at sites 84 and 94 are also summarized in this report, and corresponding site names and tank designations are listed in Table C6. Note that assessments of subsurface and groundwater contamination at IR sites are conducted under the auspices of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and various amendments to this act, particularly the Superfund Amendments and Reauthorization Act of 1986 (SARA), which resulted in the creation of the Installation Restoration Program (IRP) at Department of Defense facilities (DLA Environmental Protection Manual, 1991). Similarly, investigations of subsurface and groundwater contamination by refined petroleum products, such as BTEX components, caused by leaking above-ground or underground storage tanks are authorized by the Resource Conservation and Recovery Act (RCRA) of 1976, as amended by the Hazardous and Solid Wastes Amendments Act (HSWA) of 1984 and the Federal Facilities Compliance Act (FFCA) of 1992 (U.S. Environmental Protection Agency, 2009).

Major landfills and IR sites were located throughout the study area; however, most were located between Wallace and Frenchs Creeks (Figure C1). Site 1 represents several dispersed disposal areas located north of Frenchs Creek and north and south of McHugh Boulevard between Daly Road and Gonzalez Boulevard (Plate 1). Sites 6 and 82, a major landfill, are located immediately south of Wallace Creek between Piney Green Road and Holcomb Boulevard within storage/disposal lot 203 and were the likely sources of TCE and PCE to at least one water-supply well (HP-651, Table C4). Site 10, the original base landfill, is located south of Wallace Creek between Holcomb Boulevard and Bearhead Creek (Plate 1). Less extensive disposal sites, areally, are located at an old creosote injection plant immediately east of Holcomb Boulevard and supply well HP-613 (site 3; Plate 1). Site 74 is located east of Holcomb Boulevard between the creosote injection area and Piney Green Road. Disposal at the latter two sites, as well as at parts of the HPIA (sites 21 and 24; Plate 1), probably was to temporary pits and trenches. Major vehicle maintenance facilities were located mostly within the HPIA, the northeast to southwest trending rectangular area bordered to the east by Sneads Ferry Road, to the north by Holcomb Boulevard, to the west by Gum Street, and to the south by Louis Road (sites 21, 22, 24, 78, and 94) (Figure C1, Plate 1). Vehicle maintenance facilities were likely sources of TCE to several water-supply wells located around the perimeter of the HPIA. A large tank farm used to store gasoline and diesel fuel was located in the north-central part of the HPIA (Site 22). Leaks and spills from this tank farm and from the area of Site 94 were major sources of BTEX contamination to groundwater at the HPIA and vicinity. The single major dry-cleaning facility within the study area was in Building 25, located east of McHugh Boulevard between Post Lane and Virginia Dare Drive (Site 88). Dry-cleaning operations at Building 25 were a major source of PCE contamination to groundwater at USMCB Camp Lejeune. These areas and their immediate vicinities were the subject of investigations of soil and groundwater contamination by VOCs beginning in 1982 (Water and Air Research, Inc. 1983). Groundwater contamination by BTEX components and/or PCE and TCE was discovered at several locations at this time, resulting in the establishment of monitor well networks and the periodic monitoring of groundwater contamination and water levels. Monitoring began in 1984 and continues currently (2010) at several sites (Environmental Science and Engineering, Inc. 1990; Baker Environmental, Inc. 2004; CH2M Hill, Inc. 2009). Attempts to remediate groundwater contamination at several IR sites began about 1995 (Baker Environmental, Inc. 1996c). Site histories and respective results of investigations of groundwater contamination pertinent to this study are summarized in the "Installation Restoration Program Site Investigations and Histories" section of this report.

Note that IR site locations, shown as shaded areas on Plate 1 and accompanied by a respective number, are approximate and generally based on the areal extent of monitor wells installed at each site. As such, a particular IR site boundary, as shown on Plate 1, may not exactly conform to the site boundary formally defined by the IR Program

Contaminants in Supply Wells

Supply wells near several areas where contaminated groundwater was initially discovered were sampled for contaminants, beginning in July 1984 (Environmental Science and Engineering, Inc. 1985). Sample collection from water-supply wells and subsequent analyses continued frequently during December 1984 and January and February 1985 (Camp Lejeune Water Documents CLW #4552–#4556;

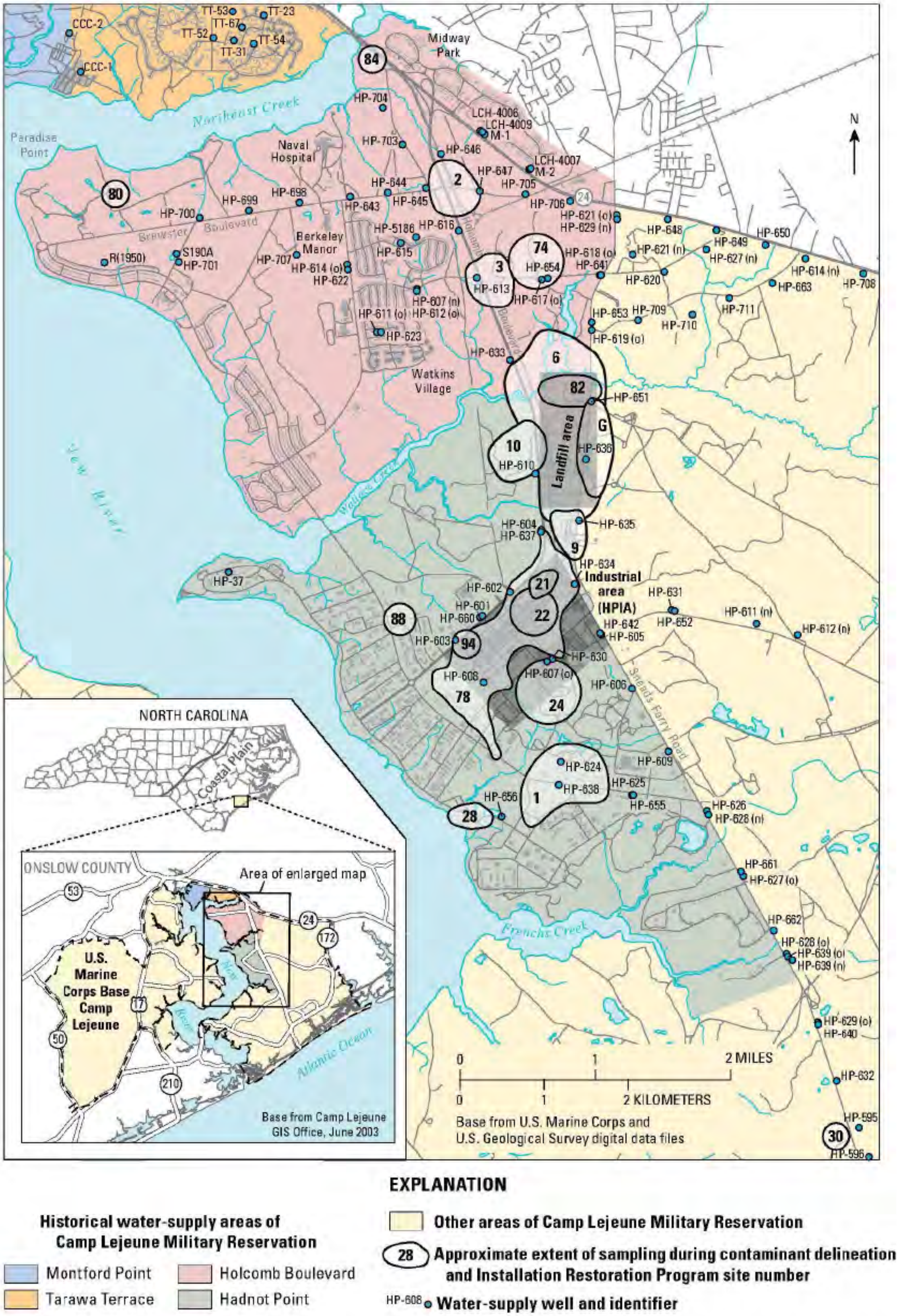

Figure C1. Installation Restoration Program site locations within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

R.D. Crowson, Testing of Potable Water Wells and Water Treatment Plant, written communication, January 8, 1985; CERCLA Administrative Record file #149). Monitoring of groundwater quality at supply wells continued with varying frequency until the early 1990s (E.A. Betz, Drinking Water Well Monitoring, written communication, August 7, 1990; CERCLA Administrative Record file #354, Environmental Science and Engineering, Inc. 1992a,b). Groundwater-quality monitoring continued at selected wells until 2001 (Bionomics Laboratory, Inc. 1995; Geological Resources, Inc. 2002; Camp Lejeune Water Documents CLW #2703, #2798, #2930, #2955). Water-quality monitoring at supply wells occurred subsequent to 2001, but results are not reported herein. Analytical results obtained after 2001 can be obtained by formal request to the Environmental Management Division, USMCB Camp Lejeune.

Concentrations of PCE, TCE, and several of their degradation products are listed in Table C7 for wells that supply or have supplied the Hadnot Point WTP. Corresponding concentrations of BTEX components are listed in Table C8. Of the chlorinated alkenes of interest, TCE was most frequently noted above detection limits in water samples at concentrations ranging from about 1.0 microgram per liter (μg/L) to more than 18,000 μg/L (Table C7). TCE occurred consistently in wells located at or immediately adjacent to the HPIA (Site 78), including in wells HP-602, HP-603, HP-608, HP-634, HP-637, and HP-660 (Plate 1, Table C7). TCE also was noted on a single occasion in well HP-652, located about 1 mile (mi) east of the HPIA (Plate 1). The highest concentration of TCE (18,900 μg/L) in water-supply wells occurred in well HP-651, located adjacent to Piney Green Road and immediately east of storage/disposal lot 203 (Sites 6 and 82, Figure C1, Plate 1). TCE was also detected in supply well HP-653 (5.5 μg/L), located adjacent to Piney Green Road and north of Wallace Creek and about 1 mi north of supply well HP-651 (Plate 1). PCE was detected in supply wells in the same areas as TCE, but was detected less frequently than TCE. PCE was detected at the HPIA in wells HP-660 and HP-602 and near storage/disposal lot 203 in well HP-651. Concentrations of PCE ranged from about 1.0 to 400 μg/L (Table C7). Note that concentrations of vinyl chloride occurred in supply wells HP-602 and HP-651, indicating that PCE and/or TCE degradation pathways were substantially complete within the volume of aquifers influenced by pumping at these wells. (Statements herein indicating that degradation pathways were complete do not imply that the source or sources of original contaminant had been completely degraded, only that sufficient time had elapsed such that biodegradation processes within the aquifer had proceeded along several possible pathways to the production of an unknown mass of vinyl chloride.[5])

Occurrences of BTEX components in supply wells sampled were substantially less frequent than those noted for TCE and PCE but also occurred in the HPIA in wells HP-602 and HP-608 and near storage/disposal lot 203 in well HP-651 (Table C8, Plate 1). Of the BTEX components observed in supply wells, benzene occurred most frequently and was detected at concentrations ranging from about 2.0 to 700 μg/L. Toluene concentrations ranged from about 1.0 to 12 μg/L. Ethylbenzene was detected once at supply well HP-602 at a concentration of 8.0 μg/L. Water-supply wells HP-643, HP-644, HP-646, HP-647, HP-648, and HP-650, which serve the Holcomb Boulevard WTP, were also sampled during January 1985; no contaminants were detected at concentrations greater than 10 μg/L (Camp Lejeune Water Documents CLW #5621–#5626) (Tables C9, C10). Because of VOC contamination, service was permanently terminated at several water-supply wells—HP-602 (11/30/1984), HP-608 (12/6/1984), HP-634 (12/14/1984), HP-637 (12/14/1984), HP-651 (2/4/1985), HP-652 (2/8/1985), HP-653 (2/8/1985), and HP-660 (12/6/1984) (Camp Lejeune Water Documents CLW #4913, #4971).

Contaminants in Water Treatment Plants

The occurrence of contaminants in wells supplying the Hadnot Point WTP indicates that finished water from the WTP was also contaminated with chlorinated alkenes and BTEX components. The fact that the Hadnot Point WTP was substantially contaminated with PCE and TCE was well known to USMCB Camp Lejeune by May 1982 (Camp Lejeune Water Document CLW #5182); however, the Base did not initiate sampling of raw and finished water at the Hadnot Point WTP until early December 1984 (E. Betz, USMCB Camp Lejeune, written communication, February 26, 1985; Camp Lejeune Water Documents CLW #4546–#4557) (Tables C11, C12). Contaminants greater than detection limits occurred infrequently at this time at the WTP, although sampling and analyses were relatively frequent through December 1984 and during February through December 1985.

Beginning in May 1982, PCE concentrations in samples from finished and untreated water collected at the Hadnot Point WTP ranged from less than 1.0 to 100 μg/L (Table C11). Corresponding concentrations of TCE ranged from about 1 to 1,400 μg/L; however, the high concentration value of 1,400 μg/L was reported as unreliable because the cap sealing the sample bottle was found to be loose prior to analysis of the sample (Camp Lejeune Water Document CLW #3300). During January 1985, occurrences of *trans*-1,2-DCE were detected in several samples ranging in concentration from about 1.0 to 150 μg/L. Vinyl chloride was detected in a single sample, occurring at a concentration of about 3.0 μg/L. This sample also contained relatively high concentrations of PCE, TCE, and *trans*-1,2-DCE (Table C11). Benzene and toluene were detected in samples collected only during November and December 1985 (Table C12). Benzene was in three samples, and concentrations ranged from 1.0 to 2,500 μg/L. Toluene was in two samples, and concentrations ranged from 10 to 100 μg/L (Camp Lejeune Water Document CLW #1356).

Somewhat by coincidence, an occurrence of local BTEX contamination in a reservoir at the Holcomb Boulevard WTP resulted in the sampling and analyses of finished water for TCE

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[5] Description of degradation pathways of VOCs and BTEX compounds are presented in Lawrence (2007).

and *trans*-1,2-DCE at several locations within the Holcomb Boulevard WTP distribution network (Fred Hill, USMCB Camp Lejeune, Report of Investigation or Inspection-water system, written communication, January 29, 1985). Because of the time required to purge the Holcomb Boulevard WTP of the BTEX components, finished water from the Hadnot Point WTP was delivered to the Holcomb Boulevard WTP distribution network during most of the period from January 27, 1985, to February 7, 1985. At the times of sampling on January 29 and January 31, 1985, finished water supplied to the Holcomb Boulevard WTP distribution network had originated entirely from the Hadnot Point WTP (Camp Lejeune Water Document CLW #4546) (Table C13). During January 31, 1985, concentrations of TCE within the Holcomb Boulevard WTP distribution network ranged from 24 to 1,148 µg/L, depending on location. Corresponding concentrations for *trans*-1,2-DCE ranged from 7.4 to 407 µg/L. These concentrations, for the most part, are in sharp contrast to concentrations described previously in samples of Hadnot Point WTP raw and finished water obtained during December 1984 (Table C11). Such differences were possibly caused by the raw water supply to the WTP originating from uncontaminated and contaminated wells, respectively, prior to the time of sampling.

Daily records of operating wells supplying water to the Hadnot Point WTP during January 28–February 4, 1985, indicate that, of the contaminated supply wells listed in Tables C7 and C8, only well HP-651 was operating during this period (Camp Lejeune Water Documents CLW #1121–#1122). In fact, supply well HP-651 is recorded as operating every day during this period, with the exception of February 4, 1985. Reference to analyses of water samples obtained from supply well HP-651 on January 16 and February 4, 1985 (Table C7) indicate that high concentrations of TCE and *trans*-1,2-DCE occurred consistently in water samples from this well. Thus, after accounting for dilution from uncontaminated supply wells, well HP-651 is isolated as the single (or at least the most prominent) source of contaminants observed in the Holcomb Boulevard WTP distribution network during January 29–31, 1985.

Prior to 1985, comprehensive incidents of contaminated water supplies, similar to those represented by data listed in Table C13, were not observed. Regardless of the lack of data, incidents of contamination similar to those represented in Table C13 probably occurred fairly frequently within the Hadnot Point WTP distribution network and, prior to 1972, within much of the current (2010) distribution network served by the Holcomb Boulevard WTP. If contaminated supply wells were operated routinely, then incidents of contamination within the water-distribution networks probably occurred routinely, as well. The major objective of historical reconstruction at USMCB Camp Lejeune is to simulate such incidents of distribution network contamination as accurately and reasonably as possible.

Placement on National Priorities List

USMCB Camp Lejeune was placed on the U.S. Environmental Protection Agency's (USEPA) National Priorities List (NPL) on November 4, 1989. A Federal Facilities Agreement with the Department of Navy, USEPA Region IV, and the North Carolina Department of Environment, Health, and Natural Resources was completed on February 4, 1991, and placed all contaminant investigation and remediation activities at USMCB Camp Lejeune under the oversight of the CERCLA and RCRA (Environmental and Safety Designs, Inc. 1996; Baker Environmental, Inc. 1999a). In accordance with Congressional mandate, once a site is placed on the NPL, ATSDR is responsible for conducting and publishing a public health assessment (PHA). A PHA is an evaluation conducted by ATSDR of data and information on the release of hazardous substances into the environment in order to assess any past, present, or future effects on public health. During 1997, ATSDR completed and published a PHA for USMCB Camp Lejeune[6] (ATSDR 1997).

Methods and Scope of Study

Completion of this study required the review, extraction, and compilation of pertinent data from hundreds of source documents. Document sources used for this report were obtained largely from USMCB Camp Lejeune CERCLA IR Administrative Records and files of the U.S. Geological Survey. In addition, relevant data were extracted from hundreds of Camp Lejeune Water documents (CLWs), the identification numbers of which are listed under data sources, mainly in Tables C7–C13. [See Maslia et al. (2007) for a digital video disc (DVD) containing copies of most source documents used for this study.]

IRP site assessment, site characterization, and site investigation reports, along with CLW documents, were the major sources of historical supply well and groundwater contaminant data used for this study. Data presented in IRP reports generally are the earliest comprehensive evaluations of groundwater contamination and contaminant source characterization at individual IR sites and, as such, represent site conditions prior to the onset of site remediation. The spatial and subsurface distribution of contaminant mass and contaminant concentration data in source areas prior to remediation are critical end points for the historical reconstruction process, in particular, the calibration of groundwater fate and transport models, and, as such, are the major emphasis of IR site narratives and tabulations included herein. Post-remediation monitoring data are also described and tabulated where such information further enhances knowledge of contaminant mass distribution and concentrations in the subsurface in source areas. Accordingly,

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[6] On September 9, 2010, ATSDR removed the 1997 Camp Lejeune PHA from its Web site. In the 13 years since the 1997 PHA was published, additional information has emerged related to exposures to VOCs in drinking water at Camp Lejeune. Due in part to the ongoing historical reconstruction analyses, ATSDR has learned that communities serviced by the Holcomb Boulevard water-distribution system were exposed to contaminated water for a longer period than was used in the 1997 evaluation contained in the PHA. Also, at the Camp Lejeune site, benzene was present in some water-supply wells that were shut down sometime prior to 1985, and this information was not included in the 1997 PHA. Refer to the ATSDR Web site for additional details (*http://www.atsdr.cdc.gov/sites/lejeune/index.html*).

monitor well data at individual IR sites, related well-location maps, and similar information, such as the results of hydropunch and geoprobe investigations included herein, are inclusive in time either to the termination of data collection at the site or to about year 2004. Groundwater and well data at IR sites for years up to and including 2004 are inclusive of the vast majority of site data available at any site and are considered sufficient to undertake water modeling investigations necessary for historical reconstruction.

Determining location coordinates at numerous monitor wells and other data-collection locations throughout the study area was a major part of the data compilation process. Maps showing data-collection locations were identified for each IR site of interest and rectified using standard geographic information system (GIS) methods. As few as four and as many as ten control points were used to rectify each map, depending on the areal coverage and cultural detail portrayed on the particular map. Control points included road intersections, bridge-stream intersections, and corners of prominent buildings. Location coordinates of control points were determined from topographic maps, rectified maps, and aerial photographs contributed by USMCB Camp Lejeune. Rectification of many maps accomplished for this project was made possible by maps and aerial photographs contributed by the U.S. Marine Corps. A total of 118 maps were rectified for this study, resulting in the extraction of location coordinates for more than 600 monitor wells, numerous soil borings, and other data-collection locations.

Additional data necessary for the construction of a groundwater-flow model of the study area were also reviewed and compiled as a part of this study and included monitor and supply-well construction data, groundwater levels, aquifer- and slug-test results, and stage data at various stream locations.

Although VOCs are the contaminants of primary interest to this study, other contaminants such as pesticides were frequently observed in surface and subsurface soils in conjunction with VOCs in groundwater. The methods and locations of pesticide disposal probably mimicked VOC disposal at several IR sites. Pesticides such as dichlorodiphenyltrichloroethane (DDT), DDT metabolites, and chlordane do not readily degrade in the subsurface. Accordingly, occurrences of these pesticides in surface and subsurface soils at IR sites possibly also correspond to historical VOC disposal areas and, as such, are briefly described herein, along with concentrations of VOCs of interest. In addition, several IR sites are drained by ditches and streams which are likely lines of discharge for contaminated groundwater. Thus, results of surface-water and related sediment analyses for selected VOCs and pesticides are also briefly described herein in order to definitively identify the respective drainage ditch or stream as a line of groundwater discharge.

The concentrations and occurrence of other constituents, such as semi-volatile compounds and metals, in groundwater and soils were also determined at most IR sites within the study area. These constituents are not discussed herein.

Note that this report is not intended to be a complete or even a substantial summary or representation of all IRP activities at any IR site described herein. Rather, the report is intended to provide sufficient bases of information in support of ATSDR's historical reconstruction–epidemiological study. Accordingly, remediation and/or monitoring efforts at IR sites after 2004 are neither considered nor discussed herein. At most IR sites within the study area, post-2004 remediation efforts, such as collection of soil and groundwater data, groundwater monitoring, etc., continue to the present day (2010). Results of these continuing investigations can be obtained by formal request to the Environmental Management Division, USMCB Camp Lejeune, and by referring to any of several USMCB Camp Lejeune Final Site Management Plans (for example, CH2M Hill, Inc. 2009).

Geohydrologic Framework

Ancillary to this study was the expansion of the geohydrologic framework described for the Tarawa Terrace study area by Faye (2007a) to the entire Hadnot Point–Holcomb Boulevard study area. More than 400 borehole and test boring logs were extracted from IR site assessments and similar reports and used in conjunction with geophysical logs at supply wells to identify various components of the geohydrologic framework (Table C14). Preliminary maps showing the thickness and altitude at the top of each geohydrologic unit were subsequently developed from these point data and used to identify the water-bearing units contributing to the open intervals of monitor and supply wells. These maps and related data will be published subsequent to this report as Chapter B of the ATSDR Hadnot Point–Holcomb Boulevard report series, published in support of the current health study at USMCB Camp Lejeune. Titles of the various chapter reports are listed in the Foreword section of this report.

Fourteen aquifers and confining units were identified for this study within the Hadnot Point–Holcomb Boulevard study area and were named after local cultural features where the units were first identified or as subdivisions of the Castle Hayne Formation (Harned et al. 1989; Geophex, Ltd. 1994, Appendixes E, F). Named geohydrologic units and unit thicknesses are listed in Table C14. Sediments correlated with the Brewster Boulevard aquifer and confining unit by Faye (2007) between Northeast and Wallace Creeks thicken considerably south of Wallace Creek and were subdivided, for purposes of this study, into two aquifers and two confining units, all assigned to the Brewster Boulevard aquifer system. With the exception of the Brewster Boulevard aquifer system, geohydrologic units listed in Table C14 correspond, with minor changes, one-to-one to units previously identified and described by Faye (2007) between Northeast and Wallace Creeks.

The base of the Lower Castle Hayne aquifer is at the top of the Beaufort confining unit and corresponds, within most of the study area, to the base of freshwater flow. Freshwater is defined herein as water containing a concentration of total dissolved solids less than 10,000 milligrams per liter (mg/L). The top of freshwater flow occurs everywhere at the water table, the depth to which fluctuates seasonally over a range of about 10 feet (ft) or less. Depending on location, whether highland or lowland, the water table generally occurs in the lower or upper part of the Brewster Boulevard aquifer system, respectively, or within the Tarawa Terrace aquifer.

Aquifers of the Castle Hayne aquifer system comprise the major water-bearing units of the study area and are composed largely of fine silty and clayey sand and sandy limestone. Confining units are clay, sandy clay, or silty clay. For detailed descriptions of framework geometry and well, borehole, and geophysical data used to define the geohydrologic framework between Northeast and Wallace Creeks, refer to Chapter B of the Tarawa Terrace report series (Faye 2007).

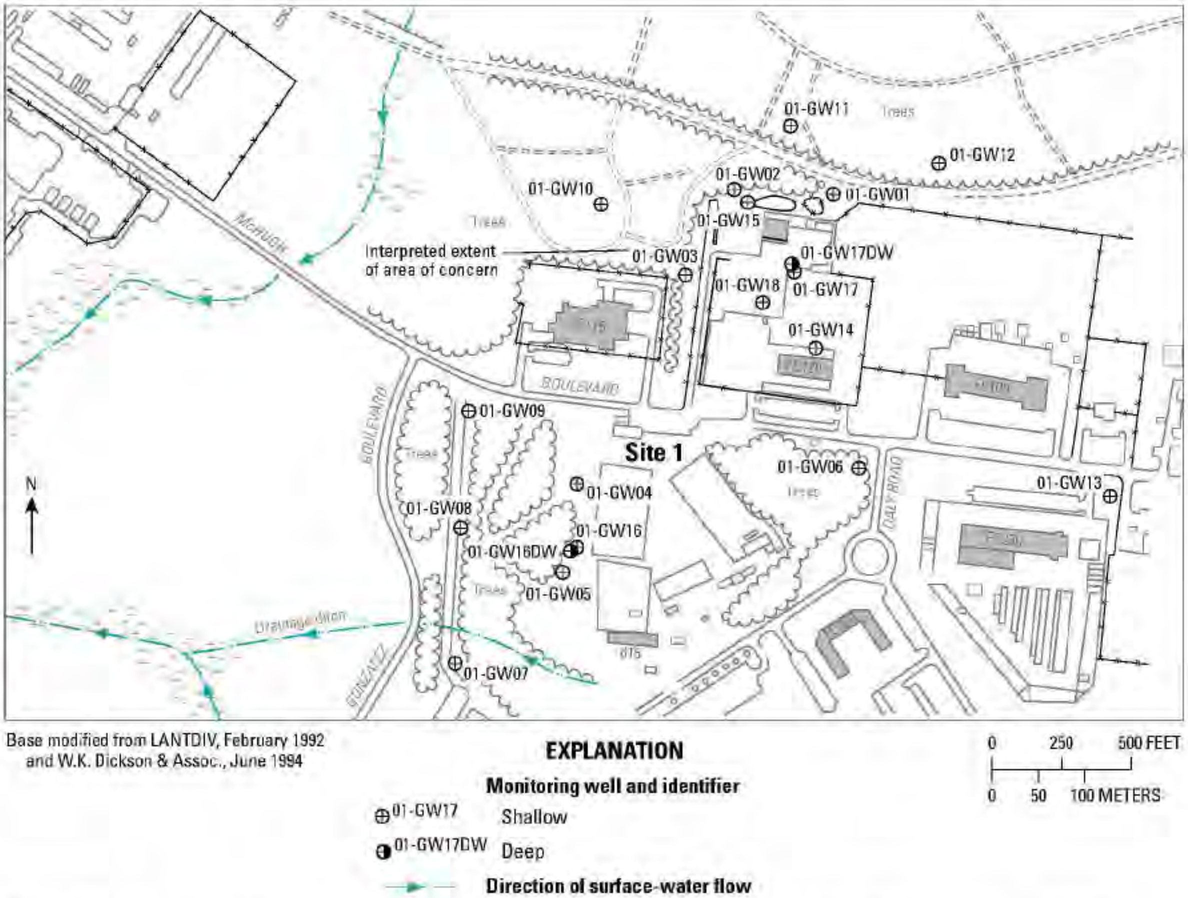
Installation Restoration Program Site Investigations and Histories

An Initial Assessment Study (IAS) of possible contaminant occurrence in soils and groundwater at USMCB Camp Lejeune was initiated by the Navy Assessment and Control of Installation Pollutants (NACIP) Program during 1982–1983 (Camp Lejeune Water Document CLW #3455; Water and Air Research, Inc. 1983). The IAS identified 76 potentially contaminated (disposal) sites where hazardous materials had possibly been mishandled or subjected to inappropriate disposal. Of these locations, 22 sites were recommended for additional investigation and were included in a later Confirmation Study (Environmental Science and Engineering, Inc. 1985). This first phase of the Confirmation Study, termed the Verification Step, began in 1984 and included Sites 1, 2, 6, 9, 21, 22, 24, 28, 30, and 74 within the study area (Figure C1, Plate 1, Table C5). Monitor well networks were established at several of these sites, and water-quality monitoring was initiated. Several Hadnot Point WTP supply wells were also sampled at this time (July 1984) (Tables C7, C8). In 1986, the NACIP program was converted to the IRP, with requirements that IRP plans and procedures conform to USEPA standards and regulations (Camp Lejeune Water Document CLW #1821). Under the IRP, the IAS became the Preliminary Assessment/Site Investigation (PA/SI). Similarly, the Confirmation Study begun in 1984 was transformed to a Remedial Investigation/Feasibility Study (RI/FS). As part of the RI/FS, additional rounds of sampling began in November 1986 and continued into March 1987 at all IR sites in the study area that were part of the original Confirmation Study (Environmental Science and Engineering, Inc. 1990). This second phase of the Confirmation Study also included a Confirmation Step and was generally followed by a Verification Step. Several water-supply wells located near the HPIA were also sampled at this time, and additional monitor wells were constructed at several sites (Environmental Science and Engineering, Inc. 1987). A separate part of the Confirmation Study termed a Characterization Step focused entirely on the HPIA and included additional sampling at monitor wells, construction of additional monitor wells, a soil gas survey, and a comprehensive aquifer test of water-bearing units open to nearby water-supply wells (Environmental Science and Engineering, Inc. 1988a). During or about 1988, comprehensive remedial investigations and site assessments of soil and groundwater contamination began at individual IR sites within the HPIA and elsewhere within the study area. Remedial investigations were sometimes followed by various "supplemental" investigations or "focused" remedial investigations, all of which ultimately devolved, at most locations, into routine water-quality sampling and water-level monitoring. Monitoring generally occurred on a quarterly or semiannual schedule.

The following subsections of this report include short narratives about contaminant disposal or spill histories at individual IR sites within the study area and corresponding summaries of groundwater investigation results pertinent to this study. Tabulated monitor well construction and contaminant concentration data, as well as one or more associated site maps, complement each of the site narratives. Table C5 contains an index of the IR sites and corresponding data tables and figures; Figure C1 and Plate 1 show the locations of the IR sites. References to "surface soil samples" in the following subsections refer to soil samples collected at depths generally ranging from ground surface to 1 or 2 ft below ground surface (bgs). Corresponding references to "subsurface soil samples" refer to soil samples generally collected below the surface soil samples (1 to 2 ft bgs) and above the water table.

Installation Restoration Site 1—French Creek Liquids Disposal Area

Installation Restoration Site 1 is composed of two general areas. The north disposal area is located north of the intersection of McHugh Boulevard and Daly Road, east of water-supply well HP-624 (Plate 1), north of Buildings FC115 and FC120, and immediately south of unnamed secondary roads and tank tracks (Figures C1, C2). The south disposal area is located south of McHugh Boulevard and between Daly Road and Gonzalez Boulevard (Baker Environmental, Inc. 1995ckm) (Figure C2, Plate 1). Various facilities within these areas were used for vehicle maintenance, equipment and material storage, and storage of refined petroleum products. Equipment wash facilities were also located in the vicinity of the north and south disposal areas, and all were equipped with oil/water separators. The north area separators discharged to drainage ditches and ultimately to a retention pond. The south area separators discharged to a drainage ditch and ultimately to Cogdels Creek and New River (Figure C2, Plate 1). Vehicle maintenance and equipment and material storage have been ongoing at Site 1, probably since the 1940s. Liquid wastes generated by maintenance operations, including battery acids, oil, and lubricants, were routinely discharged to surface soils in wooded or grassy



Base modified from LANTDIV, February 1992
and W.K. Dickson & Assoc., June 1994

Figure C2. Monitor well locations at Installation Restoration Site 1—French Creek liquids disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1997i).

areas near the maintenance facilities. Disposal methods may have routinely included the digging of shallow holes, which were backfilled following disposal. Acid waste disposal areas and petroleum product disposal areas were probably not congruent and are not well defined. The total areas of the north and south disposal locations generally are delimited by the locations of monitor wells (Figure C2). However, suspected disposal locations possibly encompass an area of 7 or 8 acres. The total volume of petroleum wastes discharged to Site 1 is estimated between 5,000 and 20,000 gallons (gal). Corresponding volumes of battery acid waste range between 1,000 and 10,000 gal (Water and Air Research, Inc. 1983).

Investigations of groundwater contamination by VOCs at Site 1 began during the NACIP-sponsored IAS described previously and continued during the Verification and Confirmation Steps of the follow-up Confirmation Study (Water & Air Research, Inc. 1983; Environmental Science and Engineering, Inc. 1985, 1987, 1992a). Six shallow monitor wells open to the Brewster Boulevard aquifer system were constructed during the Confirmation Study (01-GW01–01-GW06) and were sampled for selected VOCs during July 1984 and November 1986 (Tables C15–C17). In July 1991, soil samples were collected at 18 locations in the vicinity of the south disposal area prior to grading and subsequent building construction. With the exception of a trace quantity of toluene at a concentration of 1.0 microgram per kilogram (µg/kg), which was detected in a surface soil sample near the intersection of Daly Road and McHugh Boulevard (Figure C2), no VOCs of interest to this study were determined at this time in any soil samples. Additional groundwater samples were collected during April 1993. Groundwater analyses were limited to a selected number of analytical parameters, mostly metals, and are not described herein.

A final RI was conducted in 1994 resulting in the construction of 13 additional shallow monitor wells open to the Brewster Boulevard aquifer system (01-GW07–01-GW17) and completion of two deep wells open to the Upper Castle Hayne aquifer (01-GW16DW, 01-GW17DW) (Table C15). Groundwater samples were collected during April 1994 at all newly installed monitor wells and analyzed for numerous VOCs, including BTEX components, PCE, TCE, DCE, and vinyl chloride (Tables C16, C17) (Baker Environmental, Inc. 1995km).

Of the VOCs of interest in groundwater at Site 1, TCE occurred most frequently, ranging in concentration from about 1 to 27 µg/L (Table C16). Concentrations of PCE occurred consistently below detection limits in all monitor wells, with the exception of a concentration of about 7 µg/L in monitor well 01-GW05, sampled during July 1984. Degradation of probably TCE at Site 1 is apparent from concentrations of total 1,2-DCE and vinyl chloride, particularly in well 1GW10. Concentrations of total *trans*-1,2-DCE ranged from 10 to 23 µg/L in well 01-GW10 and occurred consistently in all samples collected between 1994 and 2000. Corresponding concentrations of vinyl chloride ranged from an estimated 1.0 to 4.0 µg/L. Disposal of PCE and particularly TCE at Site 1 was not discussed in published site histories (Water and Air Research, Inc. 1983) but apparently did occur at least one time (Table C16).

With the exception of the occurrence of xylenes in monitor well 01-GW12, concentrations of BTEX components at Site 1 occurred only in trace quantities or ranged below detection limits in all monitor wells (Table C17). In monitor well 01-GW12, total xylenes concentrations ranged from 3.0 to 280 µg/L and occurred consistently between 1994 and 1998. An estimated concentration of total xylenes of 0.78 µg/L was also detected in monitor well 01-GW01 during January 1998. Concentrations of benzene were never above detection limits. Toluene and ethylbenzene were detected during August 1995 in monitor well 01-GW12, each at an estimated concentration of 4.0 µg/L.

Also during the RI, a total of 124 soil samples were collected at 54 locations within Site 1. Volatile organic compounds of interest to this study (TCE and toluene) were detected in subsurface soils during April 1994 in trace amounts at two locations, both of which are in the vicinity of the northern disposal area. TCE was detected at an estimated concentration of 3.0 µg/kg between 13 and 15 ft bgs in a borehole near the northwest corner of Building FC120 (Figure C2). Toluene was detected at an estimated concentration of 1.0 µg/kg between 9 and 11 ft bgs in a core obtained during the drilling of monitor well 01-GW17DW.

Pesticides occurred infrequently in surface- and subsurface soil samples at Site 1. Concentrations of DDT and DDT metabolites ranging from about 2 to 12 µg/kg occurred in surface samples between land surface and 1 ft bgs at locations later occupied by monitor wells 01-GW08, 01-GW12, and 01-GW17. In subsurface samples, DDT and DDT metabolites occurred in concentrations ranging from about 2 to 120 µg/kg in several boreholes at depths ranging from 1 to 7 ft bgs. A DDT concentration of about 8.0 µg/kg was detected between 9 and 11 ft bgs in a core obtained during the drilling of monitor well 01-GW17. With two exceptions, all locations of DDT occurrence in surface and subsurface soil samples were located in the northern disposal area (Baker Environmental, Inc. 1995k).

Following completion of the final RI, an FS was initiated to address remediation of groundwater contamination at Site 1. In 1995, a remediation approach was selected and included in a final Record of Decision (ROD) between the Department of the Navy and the U.S. Marine Corps, the North Carolina Department of Environment, Health, and Natural Resources, and USEPA Region IV (Baker Environmental, Inc. 1995ac). Implementation of the ROD included a reliance on semiannual monitoring of groundwater conditions to observe attenuation of contaminant constituents (Tables C16, C17). Summaries of monitoring results were published in a series of reports beginning in 1995 (Environmental Science and Engineering, Inc. 1985, 1987; Baker Environmental, Inc. 1995ko, 1996m, 1997hi, 1998n; Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 1998, 2000bgh; CH2M Hill, Inc. and Baker Environmental, Inc. 2001e). Monitor well 01-GW05 was abandoned by 1995 and was replaced by monitor well 01-GW18 (Baker Environmental, Inc. 1996l). Many monitor wells were sampled periodically following implementation of the ROD up to year 2000. Wells 01-GW05 and 01-GW06 were abandoned for sampling purposes after 1986. Wells 01-GW04, 01-GW07, 01-GW08, 01-GW13, 01-GW14, and 01-GW16DW were apparently abandoned for sampling purposes shortly after construction in 1994. Monitor wells 01-GW01, 01-GW02, 01-GW03, 01-GW10, 01-GW11, 01-GW12, 01-GW17, and 01-GW17DW were monitored consistently from the time of construction to 1998 and 2000.

Installation Restoration Site 2—Former Nursery Day-Care Center (Building 712)

Installation Restoration Site 2 is located just east and slightly north of the intersection of Brewster and Holcomb Boulevards (Figure C3, Plate 1). The site was used from 1945 to 1958 for the storing, handling, and dispensing of pesticides and was used later as a children's day-care center (Environmental Science and Engineering, Inc. 1990). Pesticide volumes distributed from Site 2 are reported to have included Baygon, Chlordane [100 gallons per year (gal/yr) of 40-percent powder], DDT (750 to 1,000 gal per day of 5- to 15-percent solution], Diazinon (25 gal per month), Dieldrin (less than 100 pounds per year), Dursban (stored but not used), Lindane (less than 10 gal/yr of 1-percent solution), Malathion (100 gal/yr), Mirex (stored but not used), Silvex (stored but not used), 2,4-D (1,000 gal/yr of 1- to 100-percent solution), and 2,4,5-T (50 gal/yr; 1 year only). Estimated total contaminated area is 6,625 square feet (ft^2), including the playground located in the vicinity of Building 712 (6,300 ft^2), and 325 ft^2 of pesticide mixing and equipment washing areas (Water and Air Research, Inc. 1982).

During 1957 or 1958, pesticide storage and mixing were moved to Building 1105 at the HPIA (Water and Air Research, Inc. 1982), and Building 712 at Site 2 was later converted to a children's day-care center. DDT, chlordane, and other organochlorine insecticides were detected in surface soil samples collected during the IAS in 1982, and the day-care center was closed.

Groundwater sampling at Site 2 began during the IAS in August 1984 with the construction of five shallow monitor wells open to the Brewster Boulevard aquifer system (02-GW01–02-GW05, Table C18, Figure C3). Additional sampling occurred during the Verification Steps of the Confirmation Study in December 1986 and March 1987, respectively (Environmental Science and Engineering, Inc. 1990). Although pesticides at Site 2 were the analytes of greatest interest during the Confirmation Study and later RI

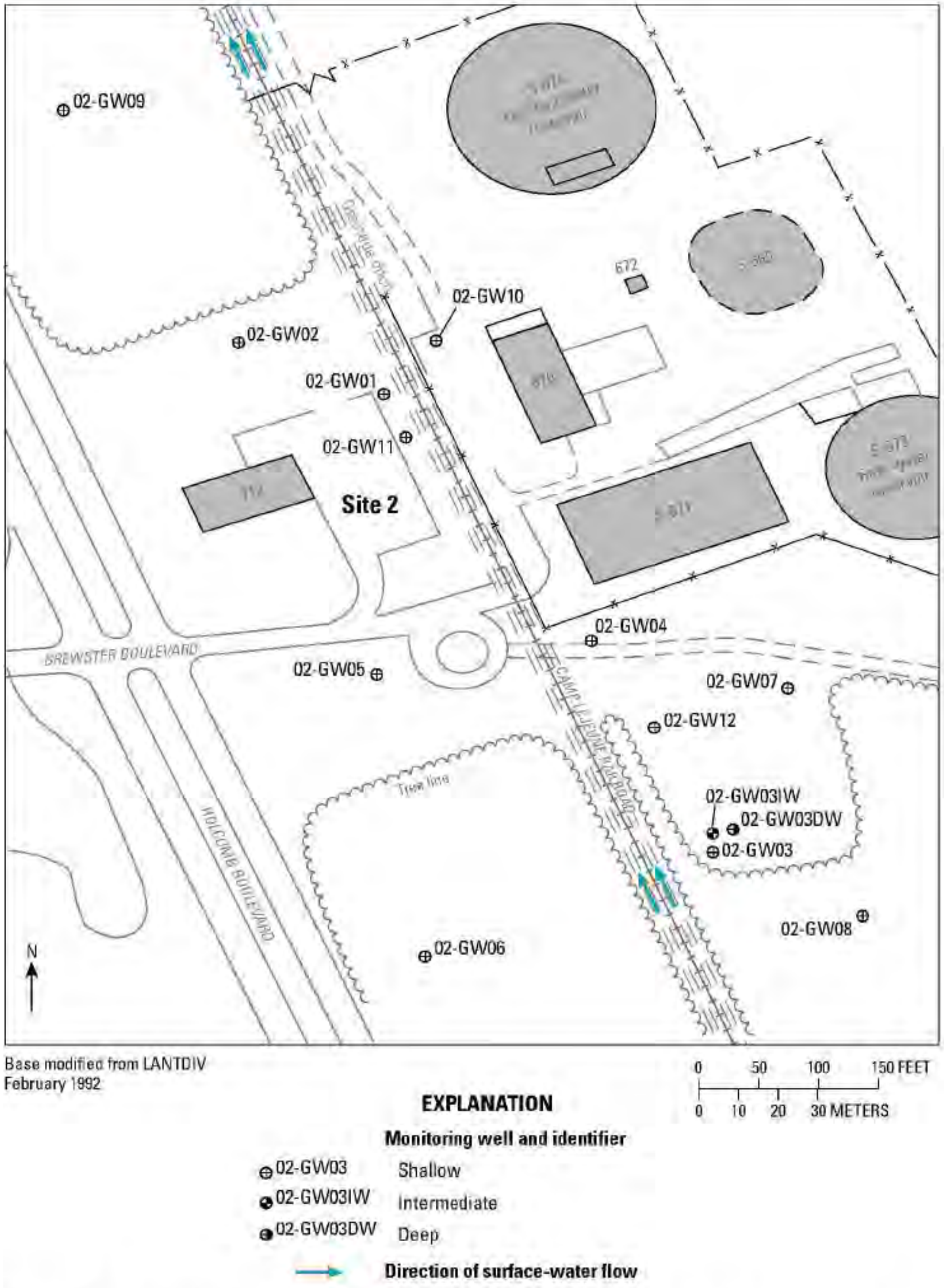


Figure C3. Monitor well locations at Installation Restoration Site 2—former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1997g).

(Baker Environmental, Inc. 1994h), concentrations of contaminants of interest to this study, such as PCE, TCE, and the BTEX components, were also determined during the Confirmation Study in December 1986 and March 1987 (Tables C19, C20) and continued to be determined as part of subsequent groundwater monitoring. Following completion of the final RI, an FS was initiated to address remediation of groundwater contamination at Site 2. In 1994, a remediation approach was selected and included in a final ROD between the Department of the Navy and the U.S. Marine Corps, the North Carolina Department of Environment, Health, and Natural Resources, and USEPA Region IV (Baker Environmental, Inc. 1994ef). Requirements of the ROD at Site 2 were the removal of contaminated soil (Baker Environmental, Inc. 1994f; OHM Remediation Services Corp. 1995). Subsequently, monitoring of groundwater conditions at Site 2 occurred routinely on a quarterly or semiannual basis. Monitoring results were published in a series of reports beginning in 1996 (Baker Environmental, Inc. 1996k, 1997fg, 1998lm, 1999fi; Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000af, 2001a, 2002a; Baker Environmental, Inc. and CH2M Hill, Inc. 2002hi, 2003; CH2MHill, Inc. and Baker Environmental, Inc. 2001cd; Engineering and Environment, Inc. and Michael Baker Jr., Inc. 2004c; Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2003a, 2004) (Tables C19, C20). After October 1996, monitor wells 02-GW01, 02-GW02, 02-GW04, and 02-GW06 were abandoned with respect to the collection of samples for water-quality analyses, largely as a result of questions regarding the integrity of well construction. During the summer of 1995, well 02-GW03DW was added to the sampling network to monitor the occurrence of contaminants in the Upper Castle Hayne aquifer–River Bend unit (Figure C3, Tables C18–C20) (Baker Environmental, Inc. 1996k). Because of poor construction integrity, well 02-GW03DW was abandoned by early 1997 (Baker Environmental, Inc. 1997g). At about the same time, the area of surveillance was expanded with the addition of monitor wells 02-GW10 and 02-GW11, which were constructed open to the Brewster Boulevard aquifer system (Baker Environmental, Inc. 1997f). Additional expansion of the surveillance network was accomplished by early 1997 to include monitor wells 02-GW03IW, open to the Tarawa Terrace aquifer, and 02-GW12, open to the Brewster Boulevard aquifer system. Monitor well 02-GW09 was removed from the water-quality sampling network by April 1997 (Baker Environmental, Inc. 1997g). Monitor well 02-GW11 apparently was abandoned after October 1998.

PCE and TCE in groundwater at Site 2 were detected infrequently in several monitor wells and at low concentrations (Table C19). Concentrations of PCE greater than detection limits occurred during 1997 and 1998 in monitor wells 02-GW03, 02-GW03IW, 02-GW08, 02-GW10, and 02-GW12 and ranged only from an estimated 1 to 10 μg/L. Concentrations of TCE occurred only in monitor wells 02-GW03, 02-GW05, and 02-GW07 during 1997 and 2002 and ranged from an estimated 3.0 to 7.0 μg/L.

BTEX components at Site 2 were detected in most monitor wells, including 02-GW01, 02-GW02, 02-GW03, 02-GW03IW, 02-GW03DW, 02-GW07, 02-GW08, and 02-GW12 (Table C20). Concentrations of ethylbenzene and total xylenes occurred most frequently and were greatest in wells 02-GW03 and 02-GW12. Concentrations of ethylbenzene were detected in monitor well 2GW03 during most sampling events between December 1986 and January 2004 and ranged from less than 1.0 to about 730 μg/L. Corresponding concentrations of total xylenes ranged from 140 to about 7,000 μg/L. Substantial concentrations of ethylbenzene and total xylenes were also frequently noted in well 02-GW12, ranging from an estimated 1.0 to 14 μg/L and from an estimated 3.0 to 260 μg/L, respectively. Total xylenes were also determined in several samples in monitor well 02-GW03IW at concentrations less than 5.0 μg/L and once in well 02-GW03DW at a concentration of 0.1 μg/L. Well 02-GW03IW was open to the Tarawa Terrace aquifer at interval 50–60 ft bgs. Similarly, well 02-GW03DW was open to the Upper Castle Hayne aquifer–River Bend unit between 90 and 100 ft bgs (Figure C3). The occurrence of BTEX (LNAPL) components at such depths indicates substantial downward vertical migration from the water table had occurred at the site prior to the onset of monitoring in 1997. Such migration was probably largely by advection along downward vertical head gradients caused by pumping from nearby supply wells HP-616, HP-645, HP-646, and HP-647 (Plate 1). The relatively large concentrations of BTEX components observed at water-supply well HP-645 during November 1986 and February 1987 (Table C10) are possibly related to the same BTEX source or sources noted at Site 2. Benzene and toluene were determined in monitor wells at Site 2 only infrequently and at substantially lower concentrations compared to concentrations of ethylbenzene and total xylenes (Table C20). Although published histories make no mention of storage or disposal of contaminants other than pesticides at Site 2, the occurrence of PCE, TCE, and BTEX components in the shallow and deep subsurface indicates that these contaminants were present at the site, but infrequently and in smaller quantities with respect to PCE and TCE and in substantial quantities with respect to BTEX components.

Concentrations of DDT and metabolites of DDT in groundwater samples from monitor wells were small and generally but not entirely isolated to the vicinity of Building 670. Concentrations in monitor well 02-GW09, north of Site 2, ranged from 0.73 to 1.5 μg/L. Concentrations in monitor well 02-GW08, south of Site 2, ranged from about 4 to 9.4 μg/L. In monitor wells 02-GW10 and 02-GW11, in the immediate vicinity of Building S670, concentrations ranged from about 0.1 to 2.0 μg/L.

In addition to groundwater sampling, sediment samples were collected for analyses during the IAS and the Confirmation Study from a drainage ditch that parallels the Camp Lejeune Railroad along the eastern boundary of Site 2 (Figure C3). The ditch drains to the north-northwest toward Overs Creek and ultimately to Northeast Creek (Plate 1). Sediment samples were collected in August 1984 and December 1986 at locations upstream and downstream of the defined Site 2 area. Metabolites of DDT and DDT were detected at both locations and ranged in concentration from about 100 to 4,000 μg/kg. Concentrations were generally greatest in the upstream samples. Two surface-water samples were collected in December 1986 in the drainage ditch at locations congruent with the collection of sediment samples. Concentrations of DDT and DDT metabolites were detected in both samples at less than 1.0 μg/L. The upstream location was located approximately 100 ft west of monitor well 2GW04 and immediately west of the tracks of the Camp Lejeune Railroad. The downstream sample was located about 200 ft north of Building 670. Additional sediment samples were collected as part of the RI during April 1993 at three locations along Overs Creek and at 21, mostly paired, locations along the drainage ditch that parallels the tracks of the Camp Lejeune Railroad. Samples were collected at depths of 6 to 12 inches bgs. At Overs Creek, concentrations of DDT and metabolites of DDT in sediments ranged from 11 to 460 μg/kg. Concentrations generally decreased in the downstream direction. Concentrations of DDT and DDT metabolites in sediment samples collected along the drainage ditch ranged from about 11 to 700,000 μg/kg. Concentrations were greatest opposite Building 670 (Figure C3) and decreased substantially to the north toward Overs Creek and to the south to the vicinity of monitor well 02-GW03. No pesticides were detected in water samples collected from Overs Creek. Metabolites of DDT and DDT were determined in only one water sample from the drainage ditch at concentrations of 0.76 and 2.3 μg/L, respectively. The sample location was about 300 ft north of Building 670.

A total of 64 locations in the immediate vicinity of Site 2, as well as north and south of the site, were selected for the collection of surface and subsurface soil samples during the final RI. The pesticides DDT and metabolites of DDT and, to a lesser degree, chlordane occurred ubiquitously in soil samples throughout and near the site. Concentrations of DDT and DDT metabolites in surface soil samples collected between 0 and 6 inches bgs were greatest between Building 712 and the Camp Lejeune Railroad in a former mixing pad area and were as high as 3,000,000 μg/kg. Subsurface soil samples were collected between 2 and 6 ft bgs. Concentrations of DDT and DDT metabolites were as high as 130,000 μg/kg in subsurface soil and also were greatest in the vicinity of the former mixing pad area (Baker Environmental, Inc. 1994h). Such conditions indicate that pesticide occurrences in the subsurface probably occurred as a result of small accidental spills, drainage from equipment washing, and disposal of excess or dated materials (Environmental Science and Engineering, Inc. 1990).

Installation Restoration Site 3—Old Creosote Site (Also Known as the Sawmill Site)

The old creosote plant was located directly east of supply well HP-613 and the Camp Lejeune Railroad (Figure C4, Plate 1). The site was active during 1951 and 1952 to supply treated ties for the construction of the Camp Lejeune Railroad. Logs were cut into ties at the onsite sawmill and were pressure treated with hot creosote. The creosote was stored nearby in a railroad tank car. The creosote plant and sawmill were dismantled and sold following completion of the railroad. Total site area is about 5 acres. Published site histories indicate that creosote was not disposed of onsite (Baker Environmental, Inc. 1996f; Halliburton NUS 1992a).

Following the dismantling and sale of the sawmill and creosote plant, Site 3 was apparently used as a disposal site for mess hall grease, transformer oil, and drums of an unknown material, possibly pesticides. Several trenches approximately 130 ft long and 30 ft wide were constructed at the site and used for disposal (Wallace Eakes, trip report, written communication, February 3, 1983; CERCLA Administrative Record file #93).

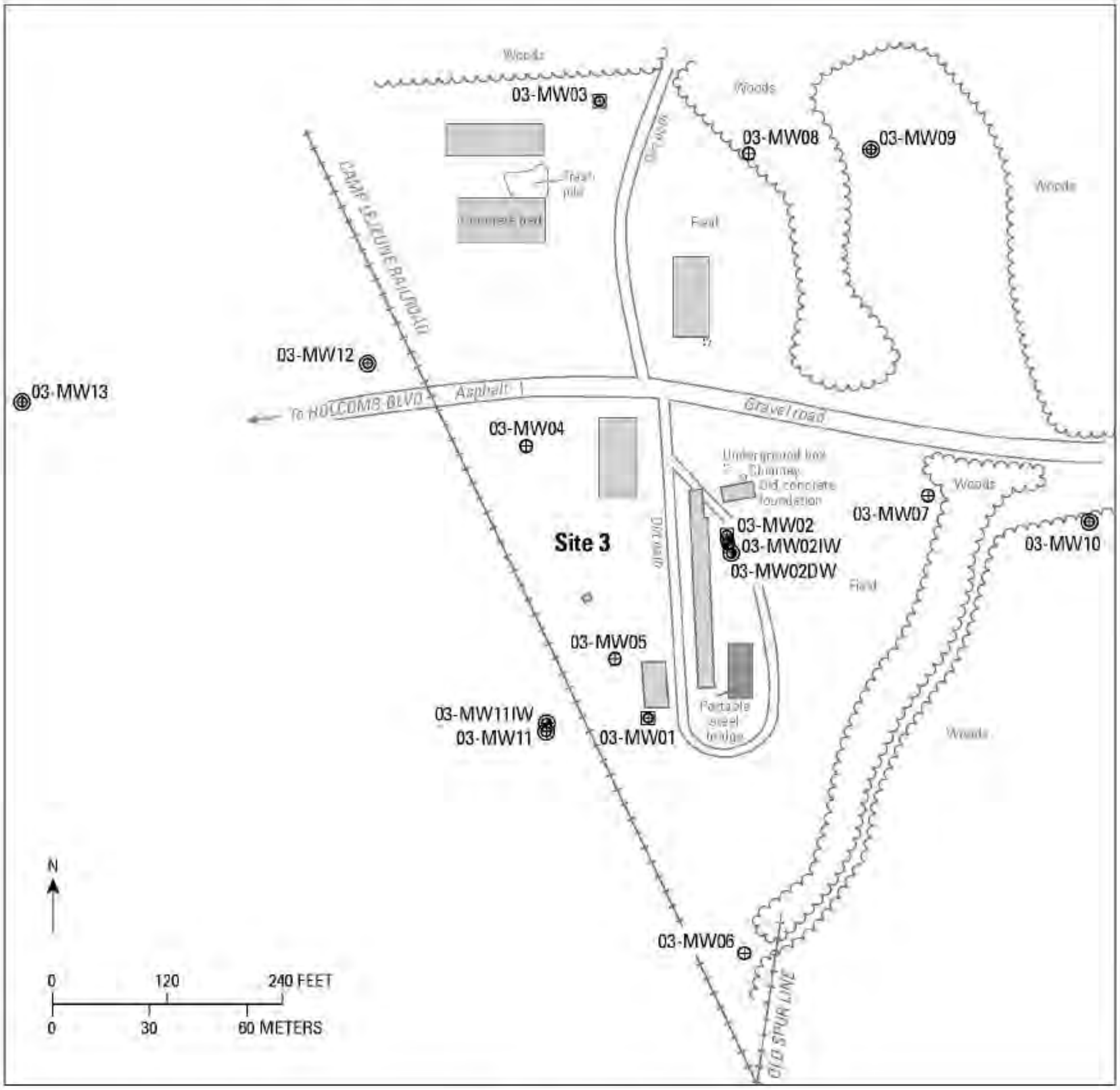
Groundwater sampling at Site 3 began during the summer of 1991 in conjunction with a Site Investigation (SI) (Haliburton NUS 1992a). Monitor wells 03-MW01–03-MW03 were constructed during June 1991 and were open to the Brewster Boulevard aquifer system (Figure C4, Table C21). Water samples collected in these wells at this time were not analyzed for contaminants of interest to this study; however, the groundwater sample collected in monitor well 03-MW02 did contain several polyaromatic hydrocarbons (PAHs; also known as polycyclic aromatic hydrocarbons and polynuclear aromatic hydrocarbons) in concentrations greater than 1,000 μg/L. Samples collected in monitor wells 03-MW01 and 03-MW03 did not contain concentrations of PAH compounds above detection limits.

Sixteen surface soil and subsurface soil samples also were collected at this time for PAH analysis, two each from five soil boring locations and two each during the construction of each monitor well. Collection depth of the surface samples was 0 to 2 ft bgs. Collection depth of the subsurface samples varied between 3 and 17 ft bgs. The soil sample collected during the construction of monitor well 03-MW02 at a depth of 15 to 17 ft bgs contained total PAH concentrations greater than 35,000 μg/kg. Surface-soil samples collected in the vicinity of well 03-MW02 at depths ranging from 0 to 2 ft bgs also contained several PAH compounds at concentrations greater than 1,000 μg/kg (Haliburton NUS 1992a).

Collection of groundwater and soil samples and subsequent analyses for contaminants of interest to this study began during the RI in September 1994 and continued to the completion of the RI during July 1995. Monitor wells 03-MW04–03-MW13 were constructed during this period (Figure C4, Table C21). Most newly constructed wells were open to the Brewster Boulevard aquifer system; however, wells 03-MW02IW and 03-MW11IW were constructed open to the Tarawa Terrace aquifer between 71.5 and 87 ft bgs. Well 03-MW02DW was constructed open to the Upper Castle Hayne aquifer–River Bend unit between 125 and 140 ft bgs. Surface-soil and/or subsurface soil samples were collected during the construction of each monitor well.

Groundwater samples were collected in monitor wells on three occasions between December 1994 and July 1995. PCE, TCE, and related constituents occurred infrequently throughout Site 3 in low concentrations or in concentrations below detection limits (Table C22). Concentrations of PCE in all monitor wells ranged from below detection limits to 22 μg/L in well 03-MW11IW. This sample was obtained from the Tarawa Terrace aquifer as was the sample in monitor well 03-MW02IW, which contained PCE at a concentration of 9.3 μg/L. Detection of PCE also occurred in well 03-MW02DW from the Upper Castle Hayne aquifer–River Bend unit (6.1 μg/L). An estimated concentration of TCE was detected in a sample from well 03-MW02IW at 1.0 μg/L. Concentrations of *cis*-1,2-DCE greater than detection limits were also determined in well 03-MW02IW at 0.4 and 0.7 μg/L. The maximum TCE concentration at Site 3 of 11 μg/L was detected in well 03-MW11IW from the Tarawa Terrace aquifer.

Components of BTEX occurred in several monitor wells at Site 3. Benzene concentrations above detection limits



EXPLANATION

Monitoring well and identifier

03-MW03 ⊡ Shallow (installed prior to the remedial investigation conducted in October 1994)

03-MW06 ⊕ Shallow (installed during the second phase of the soil investigation, November 15 through November 22, 1994)

● 03-MW02IW Intermediate (installed during the second phase of the soil investigation, November 15 through November 22, 1994)

03-MW11 ◎ Shallow (installed during the third phase of the soil investigation, June 12 through June 29, 1995)

03-MW11IW ◉ Intermediate (installed during the third phase of the soil investigation, June 12 through June 29, 1995)

◉ 03-MW02DW Deep (installed during the third phase of the soil investigation, June 12 through June 29, 1995

Figure C4. Monitor well locations at Installation Restoration Site 3—old creosote site, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1997a).

ranged from an estimated 1.7 µg/L in monitor well 03-MW02 to an estimated 40 µg/L in well 03-MW08 (Table C23). BTEX components occurred most frequently in the Brewster Boulevard upper aquifer in monitor well 03-MW02, where total BTEX concentrations ranged from an estimated 1.0 to about 60 µg/L. Total BTEX included concentrations of benzene, toluene, ethylbenzene, and total xylenes. Concentrations of total BTEX decreased from high to low between 1999 and 2004. BTEX components also occurred at Site 3 in the Tarawa Terrace aquifer (03-MW02IW) and the Upper Castle Hayne aquifer–River Bend unit (03-MW02DW) (Baker Environmental, Inc. 1996f). The occurrence of DNAPL and BTEX (LNAPL) components at depths ranging from 72 to 140 ft (Table C21) indicates substantial downward vertical migration from the water table had occurred at Site 3 prior to the onset of monitoring in 1994 (Tables C22, C23). Such migration probably occurred largely by advection along downward vertical head gradients caused by pumping from nearby supply wells, probably HP-613, HP-617, and HP-654. BTEX components in the subsurface at Site 3 possibly occurred originally as spills or leaks from ASTs used to store fuel to heat creosote for the pressure treatment of railroad ties.

Contamination of groundwater by PCE, TCE, and related constituents possibly occurred from disposal in trenches constructed at Site 3. Detection of PAH compounds also occurred in monitor wells open to the Brewster Boulevard aquifer system, the Tarawa Terrace aquifer, and the Upper Castle Hayne aquifer–River Bend unit. Within the Brewster Boulevard aquifer system, total PAH concentrations ranged from an estimated 5.0 µg/L in well 03-MW07 to 1,923 µg/L in well 03-MW02. In well 03-MW02IW, open to the Tarawa Terrace aquifer, total PAH concentrations ranged from an estimated 48 to 244 µg/L. Within the Upper Castle Hayne aquifer–River Bend unit, the maximum total PAH concentration detected was 3,895 µg/L in well 03-MW02DW (Baker Environmental, Inc. 1996f).

A total of 51 surface soil samples were collected during the RI at Site 3 at depths of 0 to 1 ft bgs and analyzed for PAH constituents and several BTEX components. With the exception of several locations used for background analyses, all sampling locations were located between the woods boundary shown in Figure C4 and the tracks of the Camp Lejeune Railroad. Estimated low concentrations of toluene (2.0 µg/kg) were detected in the immediate vicinity of monitor wells 03-MW02IW and 03-MW13. Ethylbenzene was detected in the vicinity of well 03-GW02 at estimated concentrations of 2.0 and 6.0 µg/kg. Similar analyses for PAH constituents and BTEX components were conducted for 28 subsurface soil samples collected at varying depths, depending on the location of the water table. Toluene was detected in samples at or in the vicinity of well 03-MW02IW at concentrations of 18 µg/kg (5 to 7 ft bgs) and 423 µg/kg (7 to 9 ft bgs). The maximum total PAH concentration in the subsurface was 402,300 µg/kg (7 to 9 ft bgs) and occurred in the immediate vicinity of monitor wells 03-MW02DW and 03-MW02IW.

Following completion of the final RI, an FS was initiated to address remediation of groundwater contamination at Site 3 (Baker Environmental, Inc. 1996b). In 1998, a remediation approach was selected and included in a final ROD between the Department of the Navy and the U.S. Marine Corps, the North Carolina Department of Environment, Health, and Natural Resources, and USEPA Region IV (Baker Environmental, Inc. 1997a). Implementation of the ROD included a reliance on semiannual monitoring of groundwater conditions at Site 3 to observe attenuation of contaminant concentrations (Tables C22, C23). Monitoring results were published in a series of reports beginning in 1998 (Baker Environmental, Inc. 1998f, 1999gh; Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000ci, 2003; Baker Environmental, Inc. and CH2M Hill, Inc. 2001c, 2002cjk; CH2M Hill, Inc. and Baker Environmental, Inc. 2001a; CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2001b; Engineering and Environment, Inc. and Michael Baker Jr., Inc. 2004d; Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2003b). Most monitor wells were sampled periodically following completion of the RI and the adoption of the ROD (Tables C22, C23). Wells 03-MW01, 03-MW03, 03-MW04, 03-MW05, 03-MW08, 03-MW09, 03-MW10, and 03-MW12 were abandoned for sampling purposes after 1995 for a variety of reasons, including questions regarding the integrity of well construction and insufficient development of the well following construction.

Concentrations of PCE, TCE, and related degradation products were detected infrequently in Site 3 monitor wells during routine monitoring between years 1995 and 2004 (Table C22). Detections of PCE occurred in several monitor wells during years 1998 and 1999 at concentrations ranging from an estimated 3.0 to 22 µg/L. Concentrations of TCE were detected less frequently between 1995 and 2004 and were generally lower than corresponding PCE concentrations, ranging from an estimated 1.0 to 11 µg/L. In 2004, degradation products 1,1-DCE and *cis*-1,2-DCE were detected in monitor well 03-MW02IW at estimated concentrations of 0.4 µg/L .

Concentrations of BTEX components were frequently observed above detection limits in several monitor wells between 1995 and 2004. All BTEX components were consistently detected in monitor well 03-MW02 during 1994 and 1995 at concentrations ranging from an estimated 1.7 to 34 µg/L. Benzene was detected in low concentrations ranging from an estimated 0.1 to 0.3 µg/L in well 03-MW02IW during 2002–2004. Benzene, toluene, and total xylenes were detected in monitor wells 03-MW07 and 03-MW08 during December 1994 at concentrations ranging from an estimated 5 to 40 µg/L.

Installation Restoration Site 6—Storage/Disposal Lots 201 and 203

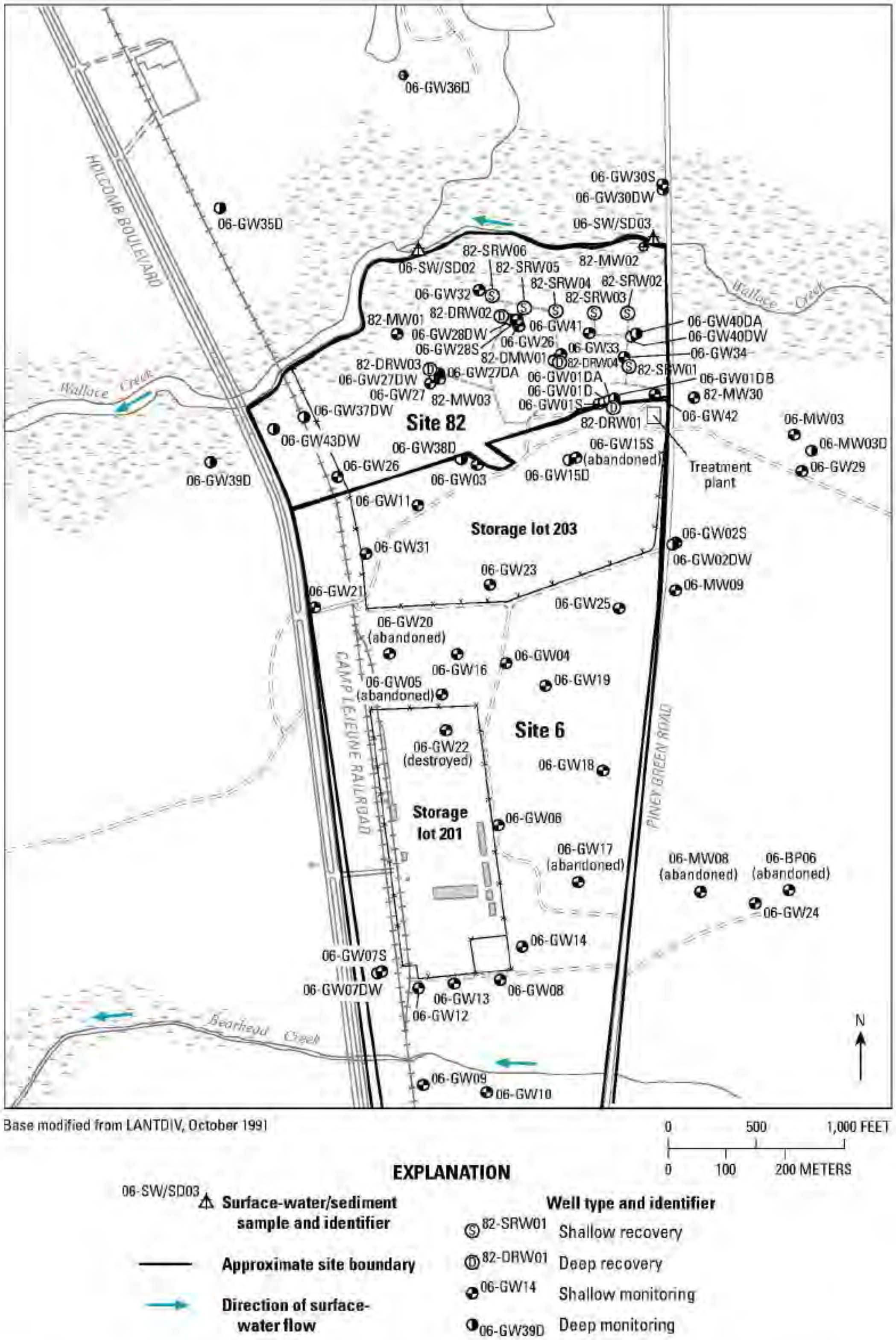
Storage/disposal lots 201 and 203, termed lot 201 or lot 203 in the following text, are located south of Wallace Creek and within the triangular area north of the intersection of Holcomb Boulevard and Piney Green Road (Figure C5, Plate 1). Lot 203 is located north of lot 201 and is separated from lot 201 by wooded areas and a west-east trending secondary road. The boundaries of both lots are explicitly defined by encircling fences (Figure C5). Lot 201 encompasses an estimated area of 25 acres; lot 203 encompasses an estimated area of 46 acres (Water and Air Research, Inc. 1983). Wooded areas generally surround both lots and may have been occasionally used for waste disposal. The wooded area between the northern boundary of lot 203 and Wallace Creek generally corresponds to IR Site 82 (Figures C1 and C5, Plate 1). IR Site 9 is located immediately south of lot 201. The environmental histories of Sites 9 and 82 are described herein in forthcoming sections.

Lot 203 was actively used for waste disposal, probably as early as the 1940s. Active waste disposal at lot 203 was probably ongoing as late as 1981 (F.W. Mount, Defense Property Disposal Office Inspection General Discrepancy, written communication, May 28, 1991; Camp Lejeune Water Documents CLW #6002, #6003) and was terminated by 1991 (Baker Environmental, Inc. 1992b). Storage of military supplies and equipment was ongoing at lot 201 in 1992 and possibly continues to date (2010). No disposal activities were documented at lot 201; however, the lot reportedly was previously used for the storage of pesticides and transformers (Baker Environmental, Inc. 1992b). The pesticide DDT reportedly was disposed of in the southeastern part of lot 203 (Baker Environmental, Inc. 1992b). Otherwise, waste disposal at lot 203 was not documented, and no information is available regarding what materials were disposed of, the volumes of disposed materials, or the disposal locations within the lot area. A site reconnaissance by Baker Environmental, Inc. (1992b) resulted in the detection of various empty and full 55-gal drums littering the surface of lot 203 along with ordnance, crates of metal cleaner, shredded tires, empty ASTs, batteries, unlabeled drums, and many types of other materials. Drums were observed in several groups of 20 or less throughout the site. According to various labels, drums contained or had contained lubricants, petroleum products, and corrosives. Anecdotal reports of waste handling at lot 203 include disposal of polychlorinated biphenyls (PCBs), cleaning solvents, electrolytes from used batteries, and waste oils (Baker Environmental, Inc. 1993k).

Investigations of groundwater contamination at Site 6 began in October 1986, during the Characterization Step of the NACIP Confirmation Study, with the construction of eight monitor wells open to the Brewster Boulevard aquifer system (06-GW01S, 06-GW02S, 06-GW03, lot 203; 06-GW04–06-GW07S, 06-GW08, lot 201; Figure C5, Table C24). Groundwater sampling for VOCs of interest to this study began in November 1986 (Tables C25, C26). Additional sampling for VOCs in groundwater occurred during January 1987 and during the final Site Assessment–Characterization Study in January 1991 (Environmental Science and Engineering, Inc. 1987, 1992b). The final RI at Site 6 began during 1992 and resulted in the construction of and sample collection in 19 additional shallow monitor wells (06-GW09–06-GW23, 06-GW25, 06-GW26, and 06-GW26S) and 5 deep monitor wells (06-GW01D, 06-GW02DW, 06-GW07DW, 06-GW27DW, and 06-GW28DW) (Figure C5, Table C24). Two sampling rounds were accomplished during the RI—one during the fall of 1992 and one during the spring of 1993 (Tables C25, C26).

Following completion of the final RI and a final FS, several approaches were selected to remediate contaminated groundwater at Site 6, including groundwater extraction and treatment, implementation of long-term groundwater monitoring, implementation of vapor extraction methods to enhance volatization of VOCs within contaminated soils, and excavation of soil contaminated with PCBs and pesticides. These and other remediation methods were included in an ROD between the Department of Navy and the U.S. Marine Corps, the State of North Carolina, and USEPA Region IV, which was signed in 1993 (Baker Environmental, Inc. 1993ef). Subsequently, groundwater monitoring occurred routinely on a quarterly, semiannual, or annual basis in most monitor wells. Results of groundwater monitoring were published in a series of reports beginning in 1992 (Environmental Science and Engineering, Inc. 1992b; Baker Environmental, Inc. 1993k, 1997e, 1998ghi, 1999de; Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000e; CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000b; Baker Environmental, Inc. and CH2M Hill, Inc. 2001a, 2002b; Michael Baker Jr., Inc. and CH2M Hill, Inc. 2003; Engineering and Environment, Inc. and Michael Baker Jr., Inc. 2004b; Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2004). A report summarizing the final basis of design for site remediation was completed in 1994 (Baker Environmental, Inc. 1994a).

Numerous tables listing concentrations of BTEX components and PCE, TCE, and related degradation products are included in the foregoing list of reports and indicate that concentrations of PCE and TCE in groundwater occurred above detection limits in much of the eastern part of Site 6 as well as throughout much of adjacent Site 82. The number 1 monitor well array is located within lot 203 near the boundary of Sites 6 and 82 in the northeastern part of Site 6 (Figure C5). Monitor wells in the number 1 array include 06-GW01S (open to the Brewster Boulevard aquifer system), 06-GW01D (open to the Upper Castle Hayne aquifer–River Bend unit), and wells 06-GW01DA and 06-GW01DB (open to the Middle Castle Hayne aquifer). TCE and PCE were detected in each well of the array. Concentrations of TCE were greatest in well 06-GW01D, open to the Upper Castle Hayne aquifer–River Bend unit between 103 and 112 ft bgs, and ranged, at various times, between 6,400 and 180,000 μg/L. Corresponding concentrations of total 1,2-DCE and vinyl chloride ranged between 730 and 36,000 μg/L and between 10 and 800 μg/L,



Base modified from LANTDIV, October 1991

EXPLANATION

06-SW/SD03 ⚠ **Surface-water/sediment sample and identifier**

Approximate site boundary

Direction of surface-water flow

Well type and identifier

Ⓢ 82-SRW01	Shallow recovery
Ⓓ 82-DRW01	Deep recovery
● 06-GW14	Shallow monitoring
◑ 06-GW39D	Deep monitoring

Figure C5. Monitor well locations at Installation Restoration Sites 6 and 82—storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from CH2MHill Federal Group, Ltd. and Baker Environmental, Inc. 2000b).

respectively, indicating that degradation pathways were essentially complete at Site 6 as early as 1993 (Table C25). Concentrations of PCE detected in monitor well 06-GW01D ranged between an estimated 210 and 2,000 μg/L. Concentrations of TCE detected in monitor wells 06-GW01DA and 06-GW01DB, open to the Middle Castle Hayne aquifer, ranged from less than 1.0 to 160 μg/L. Corresponding PCE concentrations were 1.0 μg/L and an estimated 2.9 μg/L, respectively. Other monitor wells within or adjacent to lot 203 that contained concentrations of PCE and/or TCE greater than detection limits were 06-GW02DW, 06-GW03, 06-GW15D, 06-GW21, 06-GW23, and 06-GW38D (Figure C5, Table C25). Concentrations of TCE in these wells ranged from less than 1.0 to 34 μg/L. Concentrations of TCE as great as 160 μg/L in those wells open to the Middle Castle Hayne aquifer at Site 6 indicate substantial contamination of groundwater within lot 203 at depths in excess of 200 ft bgs (Tables C24, C25). The number 1 monitor well array is located only about 500 ft from supply well HP-651 (Tables C3, C24). The contaminants noted at Site 6 in wells 06-GW01D and 06-GW01DA, within the Upper Castle Hayne aquifer–River Bend unit and Middle Castle Hayne aquifer, respectively, probably are a major source of the TCE and PCE detected in well HP-651 (Table C7) and, consequently, are also the likely source of TCE and *trans*-1,2-DCE detected throughout the Holcomb Boulevard water-supply network during January and February 1985 (Table C13). Similarly, the same source or nearby sources are probably the origin of the TCE detected in supply well HP-653 during January 1985 and November 1986 (Table C7). Supply well HP-653 is located approximately 3,100 ft directly north of monitor well 06-GW01D (Plate 1).

The distribution of BTEX components in groundwater at lot 203 somewhat mirrored that of the chlorinated alkenes. Concentrations of all BTEX components were above detection limits at various times in monitor well 06-GW01D. Benzene was most commonly observed at concentrations ranging from less than 1.0 to 8.0 μg/L. Benzene, ethylbenzene, and total xylenes also were detected in monitor well 06-GW01S between years 1986 and 2004. The maximum concentration of benzene in this well was 3.1 μg/L. Components of BTEX also were detected at least once in monitor wells 06-GW03 and 06-GW11. Concentrations in these wells were 1.0 μg/L or less.

The fact that BTEX components, an LNAPL, and concentrations of PCE, TCE, and related degradation products were detected in well 06-GW01D, a deep well open to the Upper Castle Hayne aquifer–River Bend unit at more than 100 ft bgs, indicates that downward vertical migration was largely by advection along downward vertical head gradients. Such gradients were probably caused by pumping at nearby supply well HP-651 and, to a lesser degree, pumping at wells HP-610, HP-619, HP-633, HP-636, and HP-653, when they were active. Pumping, particularly at supply well HP-651, probably also enhanced the downward vertical migration of DNAPLs PCE, TCE, and related degradation products detected in the Middle Castle Hayne aquifer in monitor wells 06-GW01DA and 06-GW01DB (Figure C5, Table C25).

In addition to the groundwater samples collected at lot 203 during the Characterization Step of the NACIP Study, two surface-water samples were collected from Wallace Creek during November 1986—one sample each upstream and downstream of Piney Green Road (Figure C5, Plate 1). Vinyl chloride and *trans*-1,2-DCE were detected in samples from both locations at concentrations of 1.9 and 3.6 μg/L and 6.4 and 35 μg/L, respectively, upstream and downstream. A concentration of 26 μg/L of TCE was detected at the downstream location (Environmental Science and Engineering, Inc. 1992b). Two surface-water samples also were collected during January 1991 from Wallace Creek—one upstream at Piney Green Road and one downstream at Holcomb Boulevard. A concentration of 5.0 μg/L of TCE was detected in the downstream sample (Baker Environmental, Inc. 1993k).

A total of 11 surface-water sampling locations were established at Wallace Creek during the final RI at Site 6, and 6 of these bordered Site 82 at intervals from just upstream of Piney Green Road to just downstream of Holcomb Boulevard. With respect to these six locations, toluene, 1,2-DCE, TCE, and PCE were determined in one or more samples during August 1992. TCE and 1,2-DCE occurred most frequently ranging in concentration from 3.0 to 98 μg/L and 2.0 to 85 μg/L, respectively. Concentrations were greatest about 750 ft upstream of Holcomb Boulevard. Concentrations of pesticides above detection limits were not observed in surface-water samples from Wallace Creek during the final RI. Surface-water samples also were collected during the final RI at seven locations from Bearhead Creek, located south of lot 201 (Plate 1), during August and October 1992. Concentrations of pesticides and VOCs of interest to this study were not observed greater than detection limits in water samples from the Bearhead Creek locations (Baker Environmental, Inc. 1993eik).

Two staff gages were established at Wallace Creek during the final RI—one upstream at Piney Green Road and the other downstream at the Camp Lejeune Railroad (Figure C5, Plate 1). Water levels at the gages observed once during April 1993 were 1.2 and 1.0 ft above NGVD 29, respectively.

Sediment samples were collected during the final RI from the streambeds of Wallace and Bearhead Creeks, congruent with most of the surface-water sampling locations mentioned previously. Sediments were collected at several depths at each location; however, the depths were not recorded (Baker Environmental, Inc. 1993k). At Wallace Creek, concentrations of DDT and DDT metabolites were detected in 15 of 33 sediment samples, inclusive of 9 of 11 sampling locations. Concentrations ranged from 4.8 to 1,200 μg/kg. Of the VOCs of interest, total 1,2-DCE was detected at one location at a concentration of 31 μg/kg, and TCE was detected at one location at concentrations of 7.0 and 23 µg/kg. Of the BTEX components, concentrations of total xylenes occurred above detection limits at two locations at 26 µg/kg and an estimated 120 µg/kg. Toluene occurred at two locations at estimated concentrations of 4.0 and 5.0 µg/kg (Baker Environmental, Inc. 1993ei).

Streambed sediments were also collected at 7 of 15 locations at Bearhead Creek. Concentrations of DDT and metabolites of DDT were detected in 11 of 20 samples inclusive of 4 locations ranging from 5.7 µg/kg to an estimated 220 µg/kg. Chlordane was detected at a single location at an estimated concentration of 14 µg/kg. Of the chlorinated alkenes of interest, TCE concentrations above detection limits occurred in streambed sediment samples from two Bearhead Creek locations at an estimated 5.0 µg/kg and 120 µg/kg. PCE was detected once at an estimated concentration of 3.0 µg/kg. BTEX components that occurred above detection limits in sediment samples from Bearhead Creek included an estimated concentration of 57 µg/kg of ethylbenzene at a single location. Benzene also was detected at a single location at an estimated concentration of 5.0 µg/kg. Total xylenes were detected at two locations at estimated concentrations of 5.0 and 380 µg/kg (Baker Environmental, Inc. 1993ei).

At lot 201, contaminants of interest to this study occur in monitor wells only infrequently and in substantially lower concentrations compared to groundwater conditions at lot 203. Concentrations of PCE, TCE, and most related degradation products occurred above detection limits in monitor well 06-GW16 at various times between 1992 and 2004. Maximum observed concentrations of TCE and total 1,2-DCE were 17 and 33 µg/L, respectively (Table C25). An estimated concentration of 2.0 µg/L of vinyl chloride was detected during January 1993, indicating that degradation pathways were essentially complete within the source area contributing to that volume of the Brewster Boulevard aquifer system sampled by the well. TCE was detected twice in well 06-GW07DW during November 1992 and March 1993 at concentrations of 1.2 and 2.1 µg/L, respectively. Well 06-GW07DW is open to the Upper Castle Hayne aquifer–River Bend unit between 90.5 and 99.5 ft bgs (Table C24). PCE concentrations greater than detection limits were determined twice in monitor well 06-GW22 during October 1992 and March 1993 at 1.2 and 1.4 µg/L, respectively.

Groundwater contamination by BTEX components was observed at only one location at lot 201 in monitor well 06-GW16. Concentrations of all BTEX components, with the exception of ethylbenzene, were above detection limits in this well at least once between 1992 and 2004, ranging from an estimated 0.2 to 9.0 µg/L (Table C26). The concentrations of PCE, TCE, and related degradation products, as well as BTEX components, in monitor well 06-GW16 indicate that the well is located near a possible inactive VOC disposal area.

Surface-soil samples and subsurface soil samples were collected periodically at Site 6, beginning with the Verification Step of the Confirmation Study during August 1984. Ten samples were collected each at lots 201 and 203 from 0 to 3 ft bgs and were analyzed only for DDT and metabolites of DDT. Sample locations are unknown. Detections of pesticides ranged in concentration from less than 1.0 to 770 µg/kg (Environmental Science and Engineering, Inc. 1985). Numerous surface and subsurface samples were obtained during the final RI at lots 201 and 203 and were analyzed for pesticides as well as VOCs of interest to this study and PCBs. A total of 120 surface soil samples were collected at lot 201, and sample locations were concentrated in the southern and northeastern parts of the lot. Analyses of soil samples included determinations of DDT, metabolites of DDT, and chlordane, as well as VOCs; however, not all samples were analyzed using the same constituent schedule. The pesticide DDT and DDT metabolites were detected throughout the sampled parts of lot 201. Concentrations in surface samples ranged from about 3.0 to 1,200,000 µg/kg and occurred above detection limits in 62 of 96 samples. In subsurface samples, concentrations of DDT and metabolites of DDT at lot 201 ranged from less than 1.0 to 460,000 µg/kg and occurred above detection limits in 55 of 106 samples. Chlordane occurred in 1 of 96 surface samples at an estimated concentration of 8.9 µg/kg. No VOC concentrations occurred above detection limits in surface samples. In subsurface samples, PCE was detected in one sample in the southeastern part of lot 201 at an estimated concentration of 4.0 µg/kg. BTEX components were detected in one sample in the same area at concentrations ranging from 2,800 to 54,000 µg/kg.

At lot 203, surface soil and subsurface soil samples were collected throughout the site during the final RI at 74 locations, including a ravine area in the north-central part of the lot; most of the locations were in the eastern part of the lot. Concentrations of DDT and DDT metabolites occurred above detection limits in surface samples throughout most of the sampled area in 37 of 66 samples. Concentrations ranged from about 3.4 to 2,100 µg/kg. Chlordane was detected in 4 of 66 surface samples at concentrations ranging from 2.3 to 160 µg/kg. Of the VOCs of interest to this study, a single toluene concentration of 7.0 µg/kg was determined above detection limits in 1 of 28 surface samples. With respect to subsurface samples, concentrations of DDT and metabolites of DDT at lot 203 occurred above detection limits in 10 of 73 samples. Concentrations ranged from an estimated 3.6 to 470 µg/kg. Chlordane was detected in 1 of 73 samples at an estimated concentration of 140 µg/kg. No VOCs of interest to this study were determined above detection limits in subsurface samples at lot 203 during the final RI (Baker Environmental, Inc. 1993eik).

Installation Restoration Site 9—Fire Fighting Training Pit

The fire fighting training pit, Site 9, is located immediately south of lot 201 and Bearhead Creek between Piney Green Road and Holcomb Boulevard (Figure C1, Plate 1). The immediate site area is approximately 2 acres. Fire training at Site 9 began in the 1960s and continued in operation until at least 1983 (Water and Air Research, Inc. 1983). Initially, fire training activities were conducted in an unlined pit. In 1981, an asphalt liner was installed in the training pit (approximately 8 acres) along with an oil-water separator. Approximately 30,000 gal of used oils, contaminated fuels, and solvents were burned annually during training exercises (Water and Air Research, Inc. 1983; Environmental Science and Engineering, Inc. 1990; Baker Environmental, Inc. 1993m).

Investigations of groundwater contamination at Site 9 began during the Confirmation Study between 1984 and 1986 with the construction of monitor wells 09-GW01, 09-GW02, and 09-GW03 open to the Brewster Boulevard aquifer system (Table C27, Figure C6). Several rounds of groundwater sample collection in these wells occurred between 1984 and 1987, resulting in the detection of no VOCs of interest to this study (Tables C28, C29). The final RI at Site 9 began during 1992 and resulted in the construction of monitor wells 09-GW04–09-GW08 during September 1992. Monitor well 09-GW04 is not shown in Figure C6 and is located approximately 820 ft southeast of well 09-GW01. Well 09-GW07D was constructed open to the Upper Castle Hayne aquifer–River Bend Unit between 100 and 109 ft bgs. Other wells constructed during the final RI were open to the Brewster Boulevard aquifer system (Table C27). Groundwater sampling in these monitor

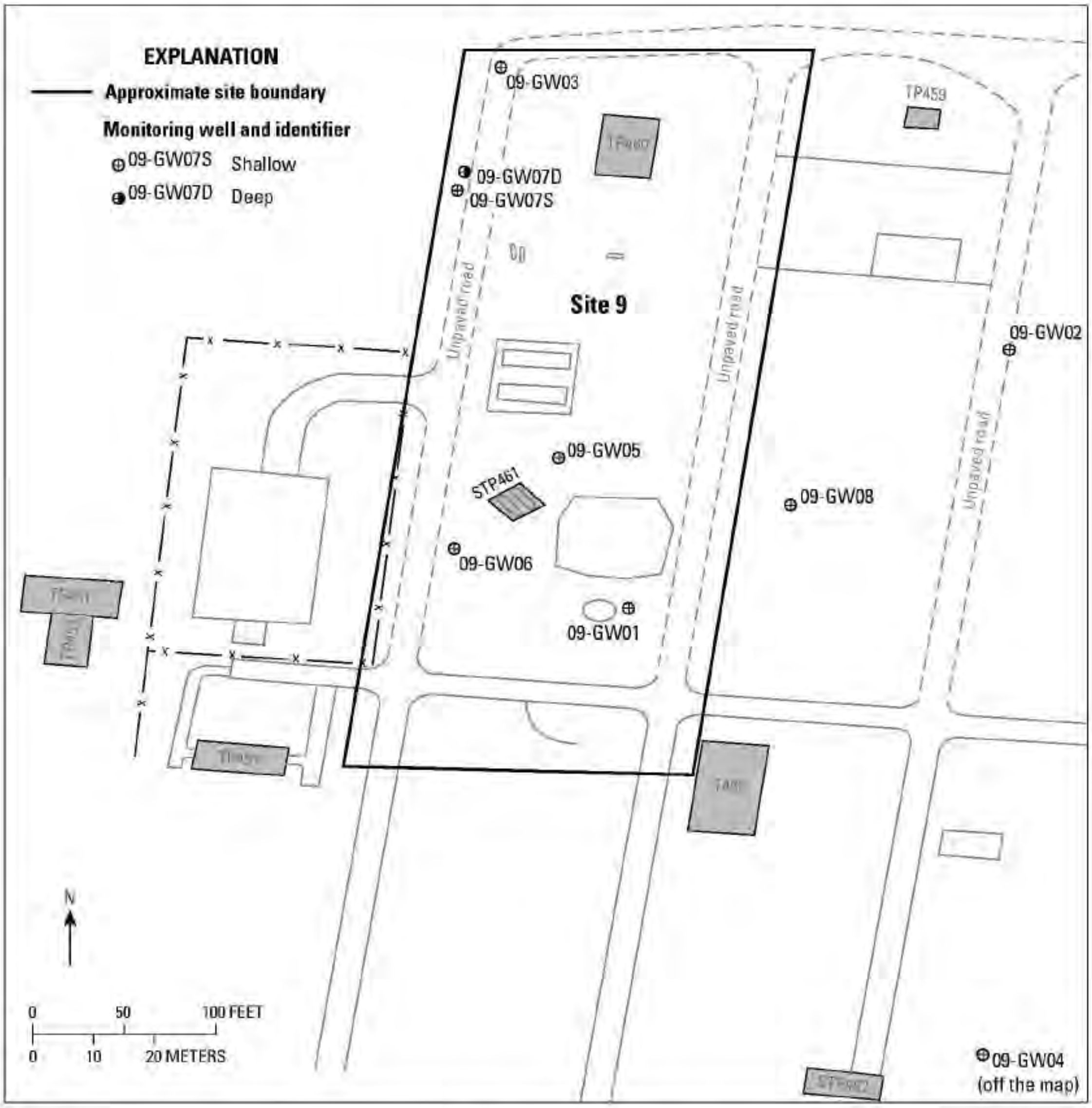


Figure C6. Monitor well locations at Installation Restoration Site 9—fire fighting training pit, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1993b).

wells occurred during October and November 1992 and March 1993. Of the VOCs of interest to this study, a single TCE concentration of 1.2 µg/L occurred above detection limits in well 09-GW07D. Concentrations of BTEX components above detection limits occurred in wells 09-GW06 and 09-GW08 during October 1992 and March 1993. Concentrations ranged from less than 1.0 to 14 µg/L (Tables C28, C29). Concentrations of DDT and DDT metabolites were determined above detection limits in monitor well 09-GW01 during March 1993, ranging from an estimated 0.13 to 1.0 µg/L. Following completion of the final RI and an FS for Site 9, an ROD between the Department of Navy and the U.S. Marine Corps, the State of North Carolina, and USEPA Region IV was signed in 1993 (Baker Environmental, Inc. 1993ef). No additional groundwater monitoring occurred at Site 9 following implementation of the ROD.

Surface soil and subsurface soil samples were collected at Site 9 during the final RI in 1993. Samples were collected at 58 locations throughout Site 9. Depth intervals were not reported; however, surface samples probably were collected between 0 and 6 inches bgs. With respect to surface samples, PCE was detected in one of seven samples at a concentration of 21 µg/kg. The sample location was approximately midway between monitor wells 09-GW05 and 09-GW07S (Figure C6). Toluene was detected also in one of seven samples at an estimated concentration of 2.0 µg/kg. Sample location was in the southwestern corner of Site 9. Concentrations of DDT and DDT metabolites were detected in a total of 5 of 7 samples at concentrations ranging from an estimated 3.3 to 570 µg/kg. The location of maximum concentration was near the location where PCE also was detected. With respect to subsurface soil samples, sampling depths were not recorded; however, sample depth was probably within 5 ft above the water table, based on sampling methods at other IR sites. PCE concentrations occurred above detection limits in 2 of 25 samples at an estimated 2.0 and 3.0 µg/kg. Concentrations of BTEX components in 25 subsurface samples were not above detection limits. Concentrations of DDT and DDT metabolites above detection limits were determined in 7 of 25 samples ranging from 4.0 to 62 µg/kg. Chlordane was detected in one sample at an estimated concentration of 2.9 µg/kg.

Installation Restoration Site 10—Original Base Landfill

The original base landfill (Site 10) is located just west of Holcomb Boulevard and lots 201 and 203 (Sites 6 and 82) and about midway between Wallace and Bearhead Creeks (Figure C1, Plate 1). The area of the original landfill is reported to be approximately 5–10 acres (Baker Environmental, Inc. 2001bc). The IAS reported that the landfill area was a disposal location for construction debris and burn area and probably operated prior to the 1950s. When disposal at the site was terminated is unknown. Records indicating the types and volumes of various debris deposited at the site are also unavailable. Following the IAS, Site 10 was identified as an area not in need of additional investigation (Water and Air Research, Inc. 1983; Baker Environmental, Inc. 2001bc). In 1994, two marines conducting night maneuvers fell into an open trench and came in contact with an "oily substance." Because both marines developed a skin rash as a result of this exposure and because Site 10 was considered a possible location for the open trench, additional investigations were conducted at the Site 10 area, beginning with an expedited characterization study in 1995.

Location of the expedited characterization study was limited to a small area near the southwestern boundary of Site 10 (Figure C7). Groundwater samples were collected at this time in three temporary wells open to the Brewster Boulevard upper aquifer [Table C30, 10-TW01 (old)–10-TW03 (old)]. Groundwater samples were obtained from intervals just below the water table probably using direct push or Geoprobe methods. No VOC concentrations of interest to this study were determined above detection limits in these samples. Surface-soil samples also were collected during the expedited characterization study at five locations between land surface and 0.5 ft bgs. Subsurface soil samples were collected at the same locations at depth intervals of 1–3, 3–5, and 7–9 ft bgs. No VOC concentrations of interest to this study were determined above detection limits in any surface or subsurface soil samples. However, concentrations of DDT and metabolites of DDT were determined above detection limits in several surface soil samples ranging from an estimated 3.4 to 9.5 µg/kg. A DDT concentration of 8.2 µg/kg was detected in one subsurface soil sample at a depth range of 3–5 ft bgs.

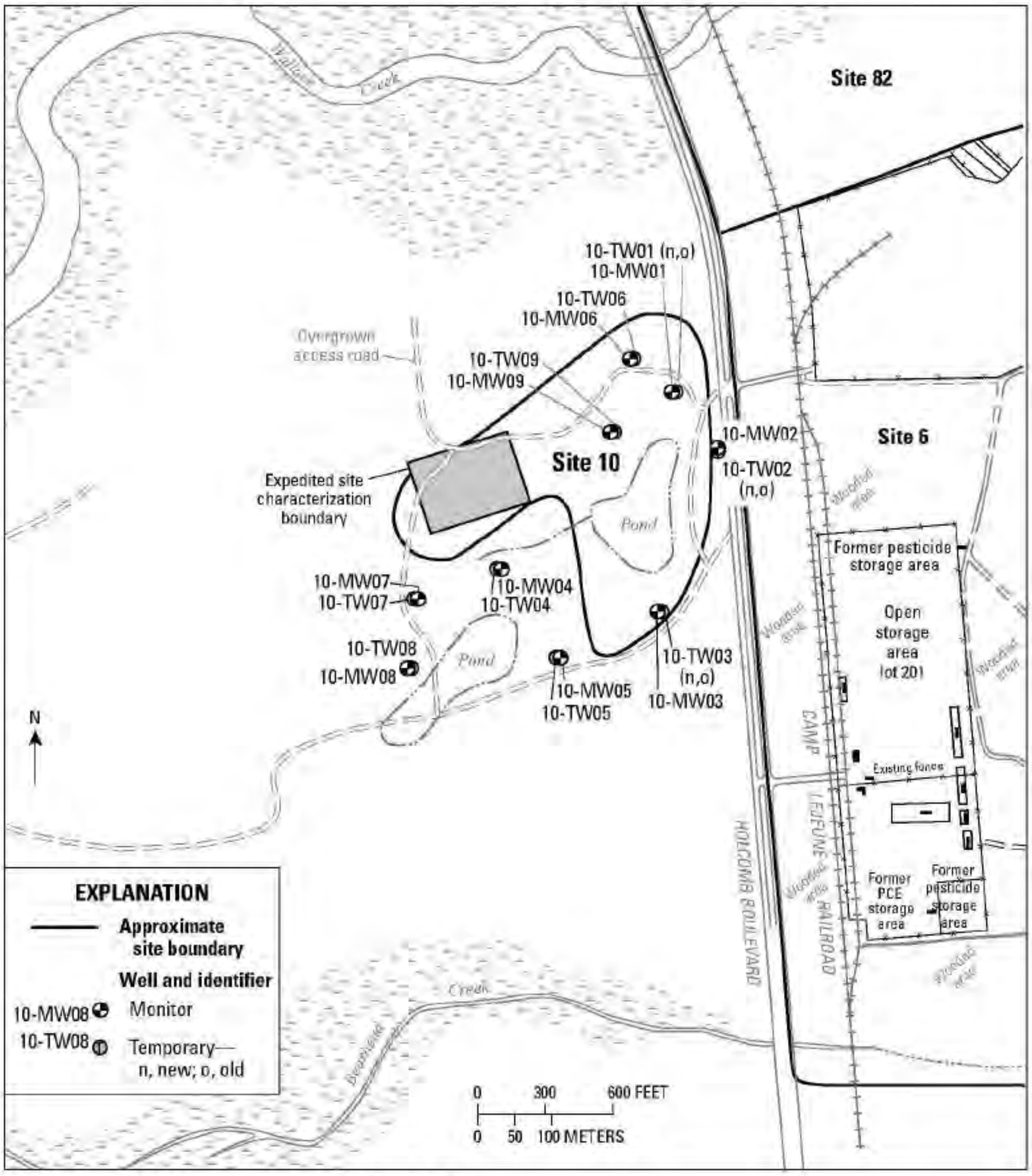
A final site characterization study at Site 10 was conducted in two phases—Phase I was during March 1998, and Phase II was during February and March 2001 (Baker Environmental, Inc. 2001bc). During Phase I, nine temporary monitor wells [10-TW01 (new)–10-TW09, Table C30] were constructed open to the Brewster Boulevard upper aquifer, and surface soil samples were collected between land surface and 1 ft bgs at 25 locations (Figure C7). Subsurface soil samples were collected at 23 locations in conjunction with surface soil samples at depths ranging from 3–5 ft bgs to 5–7 ft bgs. Surface-water and sediment samples also were collected at two small ponds located within Site 10.

Of the VOCs of interest to this study, none were determined above detection limits in monitor wells during Phase I (Tables C31, C32). During the Phase II investigations, an additional six monitor wells were constructed at Site 10 (10-MW02–10-MW04, 10-MW06, 10-MW08, 10-MW09, Table C30) open to the Brewster Boulevard upper aquifer. Wells constructed during Phase II were permanent monitor wells, were located at six of the locations formerly occupied by temporary wells, and were named accordingly. Samples collected in these wells were not analyzed for VOC contaminants of interest to this study; therefore, only Phase I results are reported herein.

Concentrations of TCE and 1,1-DCE were above detection limits at two locations and one location, respectively, in surface soil samples proximate to test wells 10-TW01 and 10-TW02. Concentrations of TCE were estimated at 2.3 and

2.4 µg/kg. The single detection of 1,1-DCE occurred at a concentration of 2.6 µg/kg. Of the BTEX components detected in surface soil samples, benzene occurred once at an estimated concentration of 4.9 µg/kg at the same location near test well 10-TW02 where TCE and 1,1-DCE also were detected. Toluene was detected in surface soils at 11 of 25 locations throughout Site 10 at concentrations ranging from an estimated 1.3 to 8.3 µg/kg. Concentrations of DDT and DDT metabolites occurred above detection limits at two locations at 3.1 and 6.2 µg/kg. Of the VOCs of interest detected in subsurface soils, only toluene was observed at two locations near test well 10-TW06. Estimated concentrations were 2.0 and 2.6 µg/kg. Concentrations of DDT and DDT metabolites were not observed above detection limits in subsurface soils. Toluene was the only VOC of interest that occurred in surface-water samples. Toluene occurred above detection limits in a single sample from each pond at an estimated concentration of 1.3 µg/L. Concentrations of toluene also occurred above detection limits in all six sediment samples collected at the two ponds, ranging from an estimated 7.4 to 97 µg/kg. Concentrations of DDT above detection limits occurred in two sediment samples from the southernmost pond. The DDT concentration at both locations was an estimated 4.0 µg/kg.

Following completion of the Phase II investigations, no additional groundwater monitoring occurred at Site 10.

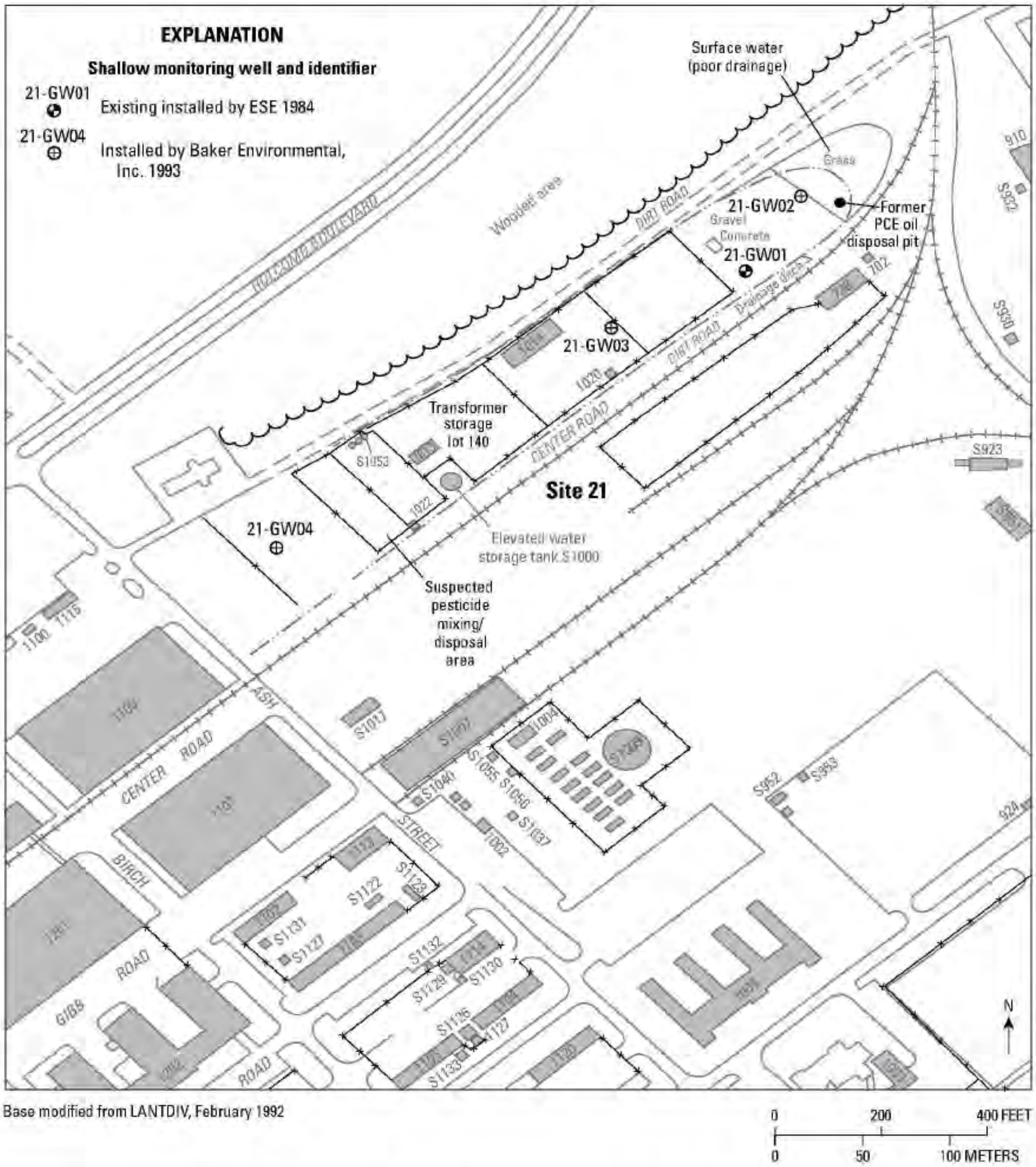


Base modified from U.S. Marine Corps Base Camp Lejeune, North Carolina

Figure C7. Monitor well locations at Installation Restoration Site 10—original base landfill, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 2001c).

Installation Restoration Site 21—Transformer Storage Lot 140

IR Site 21, transformer storage lot 140, is located at the northeast corner of the HPIA and is bounded by Ash Street to the west, Center Road to the south, and an unnamed dirt road to the north (Figure C8, Plate 1). The perimeter of storage lot 140 is bordered by a generally rectangular fence of approximate dimensions 220 by 890 ft, encompassing approximately 4.5 acres. Total site area is about 7 acres. A drainage ditch near the fence surrounds the site and receives runoff from the site during substantial rainfall. Between 1958 and 1977, the site was used for pesticide mixing and equipment washing. Estimated wash discharge was about 350 gal per week. The mixing and wash area was probably located in the southwest corner of the lot. During 1950–1951, an onsite pit located in the northeast corner of the lot was used for disposal of transformer oils. Dimensions of the pit were 25 or 30 ft long



Base modified from LANTDIV, February 1992

Figure C8. Monitor well locations at Installation Restoration Site 21—transformer storage lot 140, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1994g).

by 6 ft wide by 8 ft deep. Sand was used to cover free standing oil at the bottom of the pit (Baker Environmental, Inc. 1994f; Environmental and Safety Designs, Inc. 1995).

The Confirmation Study at Site 21 consisted of a Verification Step and a Confirmation Step. During the Verification Step, in August 1984, 16 soil borings were obtained between land surface and 2 ft bgs at generally regular intervals along the fence that defines the perimeter of lot 140. Samples were collected inside and outside the perimeter fence. Concentrations of VOCs of interest to this study were not determined in soil samples during the Confirmation Study at Site 21. Concentrations of DDT and DDT metabolites above detection limits were determined in all soil samples, ranging from 0.6 to 2,100 μg/kg. No PCBs were determined above detection limits in any soil samples. During the Confirmation Step, in November 1986, soil samples at eight additional locations were collected near the bordering fence. The exact locations of these sampling sites are unknown; however, collection probably occurred along the long dimensions of the perimeter fence, four locations per side. At each location, samples were collected at depths ranging from land surface to 1 ft, 1 to 3 ft, 3 to 5 ft, and at 5 ft bgs. Concentrations of DDT and DDT metabolites were observed above detection limits at five of the eight locations, ranging from 28 to 5,080 μg/kg and occurred at all depth intervals. Chlordane concentrations were observed above detection limits at two locations at 118 and 203 μg/kg (Environmental Science and Engineering, Inc. 1987).

During the Verification Step, a single monitor well, 21-GW01, was constructed open to the Brewster Boulevard aquifer system (Table C33). Concentrations of contaminants of interest to this study were first determined in this well during the Confirmation Step in November 1986, and none were observed above detection limits (Tables C34, C35). Concentrations of DDT, DDT metabolites, and chlordane also occurred below detection limits in this well during the Confirmation Step. Monitor well 21-GW01 was sampled again during the final RI for the HPIA in January 1991 with similar results (Environmental Science and Engineering, Inc. 1991, 1992a).

A final RI at Site 21 was accomplished between May and December 1993. Soil borings were advanced at 34 locations throughout Site 21, 3 of which were converted to monitor wells (21-GW02–21-GW04, Figure C8, Table C33). All monitor wells were constructed open to the Brewster Boulevard aquifer system.

Concentrations of BTEX components were detected in groundwater at monitor well 21-GW02 during May 1993, ranging from an estimated 77 to 1,300 μg/L (Table C34). In addition, an estimated TCE concentration of 41 μg/L was detected in a sample from monitor well 21-GW02 (Table C35). With these exceptions, no other VOCs of interest to this study were detected in groundwater at Site 21. Concentrations of DDT, DDT metabolites, or chlordane also were not observed above detection limits in groundwater at Site 21 at this time (Baker Environmental, Inc. 1994g).

During the final RI, surface soil samples were collected between land surface and 6 inches bgs. Subsurface soil samples were collected at varying depths ranging from 2 to 12 ft bgs. Of the VOCs of interest to this study, only concentrations of BTEX components were observed above detection limits in subsurface soils at one location in the southwestern part of Site 21. Concentrations of BTEX components ranged from an estimated 37 to 3,400 μg/kg.

Concentrations of DDT and DDT metabolites occurred above detection limits in surface soils at 18 of 34 locations ranging from 3.6 μg/kg to an estimated 34,000 μg/kg. Pesticide concentrations occurred throughout the Site 21 area and were greatest in the southwestern part of the site. Chlordane concentrations were detected in surface soils at six locations, also in the southwestern part of Site 21, and ranged from an estimated 4.6 to 4,000 μg/kg. Concentrations of DDT and DDT metabolites detected in subsurface soils ranged from an estimated 4.6 to 2,800 μg/kg and occurred at six locations in the central and southwestern parts of the site. A chlordane concentration of 15 μg/kg occurred in a single subsurface soil sample, also in the southwestern part of Site 21.

Sediment samples were collected at 15 locations distributed at generally equal distances along the drainage ditch near the fence that surrounds the lot 140 area. Two sediment samples were collected at each location between land surface and 1 ft bgs. Concentrations of DDT and DDT metabolites were observed above detection limits at 12 of the 15 sample locations, ranging from an estimated 4.2 to 3,500 μg/kg. Chlordane concentrations were detected in drainage ditch sediments at four locations, ranging from an estimated 3.8 to 960 μg/kg (Baker Environmental, Inc. 1994g).

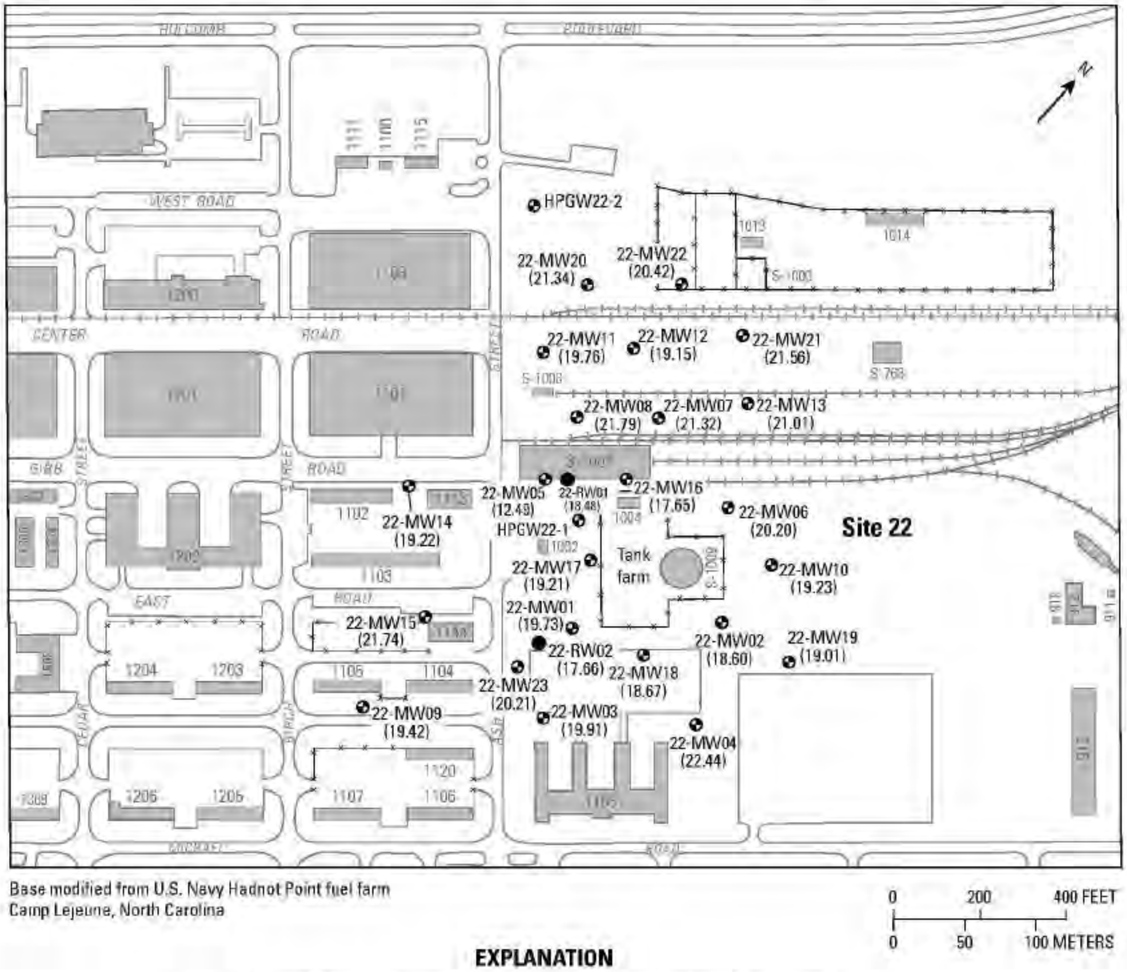
Following completion of the RI and an FS for Site 21, an ROD between the Department of Navy, the U.S. Marine Corps, the State of North Carolina, and USEPA Region IV was signed in 1994 (Baker Environmental, Inc. 1994bd). No further groundwater monitoring that included VOCs of interest to this study occurred at Site 21 following implementation of the ROD.

Installation Restoration Site 22—Industrial Area Tank Farm

IR Site 22 is formally named the Hadnot Point Industrial Area fuel farm (HPFF) or Hadnot Point tank farm and is located within the east-central part of the HPIA northeast of Ash Street and southeast of Site 21 (Figures C1, C9). The HPFF was constructed about 1941 and consisted of 15 fuel storage tanks: 1 AST with a capacity 600,000 gal, 6 USTs with capacities of 12,000 gal each, and 8 USTs with capacities of 15,000 gal each. The large AST contained diesel fuel; the other tanks contained gasoline, unleaded gasoline, and kerosene. Fuel inventory records indicate that approximately 20,000 to 30,000 gal of losses occurred from the tank farm during eight recorded loss events between 1979 and 1987. The largest loss of 20,000 to 30,000 gal occurred during 1979 when unknown quantities of diesel and unleaded fuel were accidently discharged, probably largely to the subsurface.

Other losses ranged in volume from about 50 to 1,600 gal and consisted largely of unleaded gasoline. Records of fuel losses prior to 1979 are not available. Fuel losses were probably the result of leaks from transfer lines and related valves rather than directly from tanks (O'Brien and Gere Engineers, Inc. 1988). Groundwater model simulations of floating petroleum volume (using the SpillCad model) by Baker Environmental, Inc., during 1995 and 1996 further refined estimates of fuel losses at the HPFF. Model results indicated that the fuel volume present in the HPFF subsurface was estimated to be more than 830,000 gal, with 500,000 gal being recoverable because of soil and fluid properties (Catlin Engineers and Scientists 2010, UST Management Web Portal File #01185, p. 526–562; Baker Environmental, Inc., written communication, January 21, 1997; CERCLA Administrative Record File #1866). During 2001, CH2M Hill, Inc., conducted an order-of-magnitude mass analysis to quantify remediation progress. The total fuel mass in the subsurface at the HPFF was estimated by this approach to range from 400,000 gal to 1,100,000 gal (CH2M Hill, Inc. 2001).

Characterization of groundwater contamination in the vicinity of the HPFF began during the IAS when Site 22 was identified as a potential threat to the environment and human health (Water and Air Research, Inc. 1983). During the Verification Step of the Confirmation Study, in 1984, monitor wells HPGW22-1 and HPGW22-2 were constructed open to the Brewster Boulevard aquifer system at the HPFF and directly west of Site 21 (Figure C9, Table C36) (Environmental Science and Engineering, Inc. 1985). Analyses of groundwater samples collected from these wells during July 1984 indicated that individual BTEX components occurred in the shallow groundwater at the HPFF at concentrations ranging from



Base modified from U.S. Navy Hadnot Point fuel farm
Camp Lejeune, North Carolina

EXPLANATION

Well and identifier—Number in parentheses is groundwater elevation, in feet above mean sea level. Corrected December 15, 1989

22-MW05 (12.49) ● Monitor well

● 22-RW-2 (17.66) 6-inch well installed December 1989

Figure C9. Monitor well locations at Installation Restoration Site 22—Industrial Area tank farm (HPFF), U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from O'Brien and Gere Engineers, Inc. 1990).

3,800 to 27,000 µg/L (HPGW22-1, Table C37). A groundwater investigation aimed directly at characterizing the extent of BTEX contamination at the HPFF began in February 1988 with the construction and sampling of additional monitor wells 22-MW01–22-MW20, all open to the Brewster Boulevard aquifer system (Table C36). During April 1988, concentrations of all BTEX components greater than detection limits were determined in most of these wells (Table C37). Toluene concentrations ranged from 1.0 to 110,000 µg/L and occurred in 16 of 20 wells, most notably northwest and southeast of the large AST S-1009 (Figure C9). Benzene concentrations also were detected in 16 of 20 wells and ranged from 1.0 to 29,000 µg/L with a similar distribution. The thickness of free-phase BTEX was measured periodically between March 1988 and December 1989 (Table C38). Positive BTEX thicknesses ranged from more than 15 ft at monitor well 22-MW16 to less than 1.0 ft at wells 22-MW07 and 22-MW15. Lobes of substantial free-phase thickness occurred northwest and southeast of AST S-1009 (O'Brien and Gere Engineers, Inc. 1988). Of the chlorinated alkenes of interest to this study, only PCE and TCE were observed in Site 22 monitor wells at concentrations greater than detection limits. Concentrations of TCE were detected in wells 22-MW20 and HPGW22-2, at 1.0 and 5.0 µg/L, respectively. The single occurrence of PCE occurred in well 22-MW03 at a concentration of 4.0 µg/L (Table C39). The BTEX components observed in monitor wells at Site 22 are likely the source or sources of BTEX concentrations determined in supply well HP-602 during sample collections in November and December 1984 and later in 1986 and 1991 (Table C8).

Following completion of the groundwater characterization at Site 22 by O'Brien and Gere Engineers, Inc. (1988), additional groundwater samples were collected and analyzed in conjunction with the preliminary design of a product recovery system for the HPFF (O'Brien and Gere Engineers, Inc. 1990). Results of these analyses are not available. By 1993, IRP investigations of groundwater contamination at Site 22 were integrated with similar and proximate investigations at Sites 21 and 78, and subsequent groundwater sample collection at Site 22 as part of IRP investigations occurred only at monitor well HPGW22-1 (Table C37). Because BTEX components were the major sources of subsurface and groundwater contamination at Site 22, subsequent investigations of contamination at the site were conducted under the auspices of RCRA, as amended in 1984 and 1992.

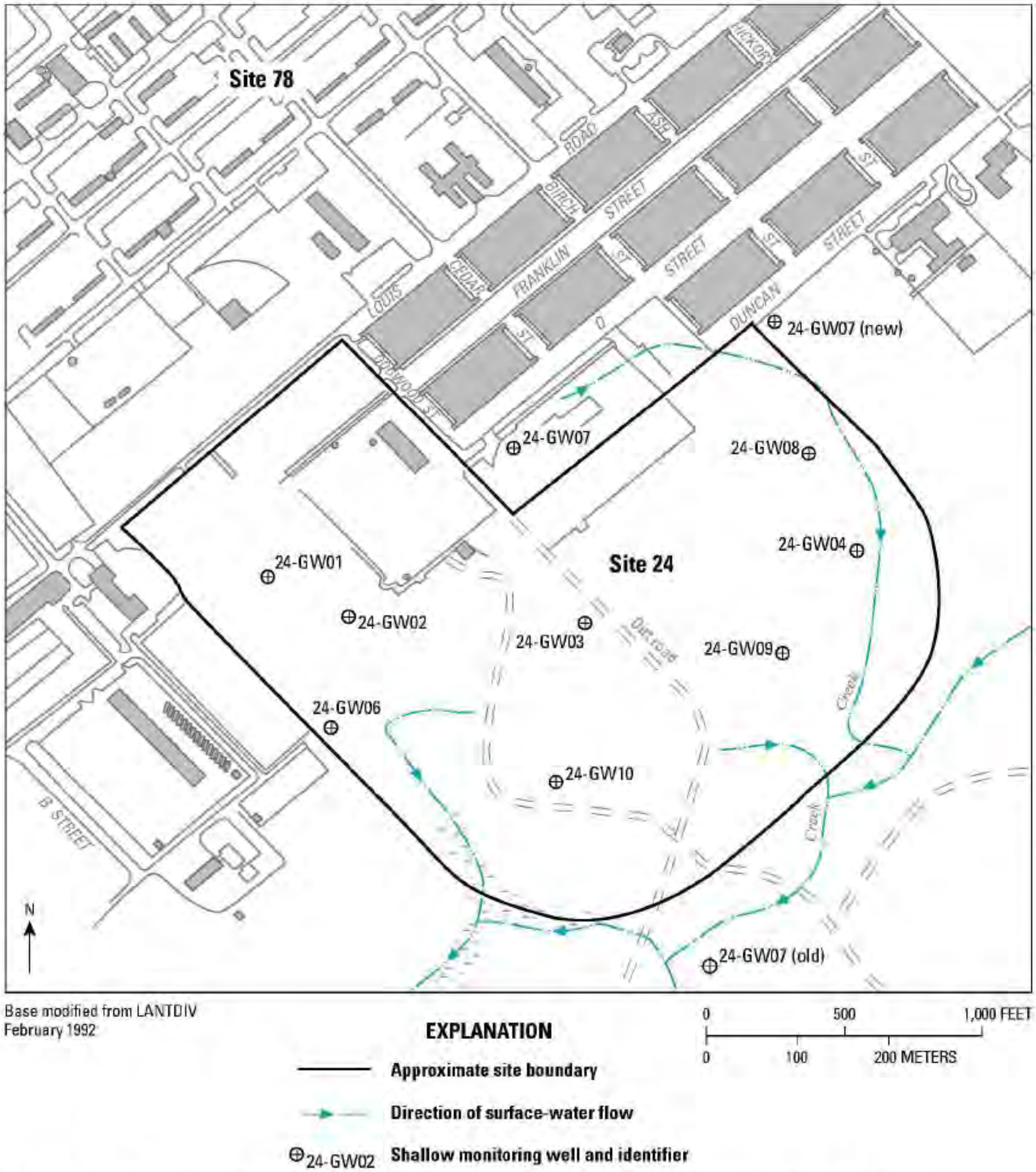
Installation Restoration Site 24—Industrial Area Fly Ash Dump

IR Site 24 is located adjacent to the southern boundary of the HPIA and extends southeast to include contributing areas to several tributaries of Cogdels Creek (Figures C1 and C10, Plate 1). Much of the northern boundary of Site 24 is formed by streets within the HPIA, namely Louis, Dogwood, and Duncan Streets. Site area is approximately 100 acres (Baker Environmental, Inc. 1994b).

From the late 1940s to 1980, Site 24 was used as a disposal area for fly ash, cinders, solvents, used furniture-stripping compounds, sewage sludge, and spiractor sludge from WTPs. During the 1960s, construction debris was reportedly disposed of at the site. Ash and cinders were dumped on the ground surface during 1972 to 1979. Solvents used to clean boilers were poured onto the ash piles (Baker Environmental, Inc. 1994b).

Investigations of groundwater contamination at Site 24 began during the Verification Step of the Confirmation Study in July 1984 when monitor wells 24-GW01–24-GW05 were constructed open to the Brewster Boulevard aquifer system and subsequently sampled (Table C40). Sediment and surface-water samples were collected at about the same time at two locations on Cogdels Creek, upstream and downstream of Site 24 (Environmental Science and Engineering, Inc. 1985). Two additional monitor wells, 24-GW06 and 24-GW07 (old), were constructed during the Confirmation Step of the Confirmation Study during 1986, also open to the Brewster Boulevard aquifer system, and were sampled during December 1986 and March 1987. Sediment and surface-water samples also were collected during the Confirmation Step at Cogdels Creek at the two locations sampled during the Verification Step as well as at two additional locations (Environmental Science and Engineering, Inc. 1987) (Tables C40–C42). A final RI was conducted at Site 24 during 1993 resulting in the construction and sampling of four additional monitor wells open to the Brewster Boulevard aquifer system [24-GW07 (new)–24-GW10]. Surface and subsurface soil samples also were collected at 37 locations throughout Site 24 during the final RI. Surface samples were collected between land surface and 6 inches bgs. Subsurface samples were collected at several intervals per location between 1.5 and 14 ft bgs (Environmental Science and Engineering, Inc. 1985, 1987; Baker Environmental, Inc. 1994g).

During the Verification and Confirmation Steps of the Confirmation Study, analyses of samples collected at monitor wells 24-GW01–24-GW05, with the exception of one analysis for benzene, indicated that concentrations of all VOCs of interest to this study were below detection limits. Similar results were obtained during the final RI during 1993 and during subsequent periodic groundwater monitoring (Tables C41, C42). A concentration of benzene of 3.0 µg/L was detected in monitor well 24-GW05 during July 1984 (Figure C10). Analyses of surface-water samples collected at the upstream location near monitor well 24-GW02 during August 1984 indicated that only concentrations of *trans*-1,2-DCE and TCE were observed above detection limits at 2.7 µg/L and 7.1 µg/L, respectively. No concentrations of VOCs of interest to this study were detected above detection limits at the downstream station located downstream of monitor well 24-GW07 (old) (Figure C10). Sediment samples were analyzed only for metals, and results are not reported herein. Monitor wells 24-GW01–24-GW07 (new) were apparently



Base modified from LANTDIV
February 1992

Figure C10. Monitor well locations at Installation Restoration Site 24—Industrial Area fly ash dump, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1997d; Environmental and Safety Designs, Inc. 1995).

abandoned for sampling purposes after 1993 (Environment and Safety Designs, Inc. 1995).

Analyses of surface and subsurface soil samples collected during the final RI during 1993 indicated that pesticides occurred in soils throughout Site 24. Concentrations of DDT and DDT metabolites were observed above detection limits in surface soils at 12 of 37 locations ranging from 2.2 to 350 µg/kg. Maximum concentrations occurred in the northeastern part of Site 24 in the immediate vicinity of monitor well 24-GW08. Chlordane concentrations in surface soils occurred above detection limits at 8 of 37 locations and ranged from 2.5 µg/kg to an estimated 26 µg/kg. Occurrences were most frequent in the northeastern part of the site. In subsurface soils, concentrations of DDT and DDT metabolites also occurred throughout Site 24 at 8 of 37 locations and ranged from an estimated 4.0 to 220 µg/kg. The maximum concentration also occurred in the immediate vicinity of monitor well 24-GW08. Chlordane concentrations above detection limits were not observed in subsurface soil samples. Although not described in site histories, several areas of Site 24, in particular the northeastern parts of the site, were possibly areas of pesticide disposal.

Following completion of the final RI, an FS was initiated to address remediation of groundwater contamination at Site 24 (Baker Environmental, Inc. 1994b). In 1994, a remediation approach was selected and included in a final ROD between the Department of the Navy and the U.S. Marine Corps, the North Carolina Department of Environment, Health, and Natural Resources, and USEPA Region IV (Baker Environmental, Inc. 1994d). Implementation of the Record of Decision included a reliance on quarterly and semiannual monitoring of groundwater conditions at Site 24 (Tables C41, C42). Monitoring results were published in a series of reports beginning in 1996 (Baker Environmental, Inc. 1996ij, 1997cd, 1998k).

Installation Restoration Site 28—Industrial Area Burn Dump

IR Site 28 is located east of the New River near the Hadnot Point wastewater treatment facility (Figures C1 and C11, Plate 1). The site area occurs generally west of Gonzales Boulevard and extends to the east and west banks of Cogdels Creek (Figure C11). Site 28 was operated as a burn area for solid wastes including trash, oil-based paints, and construction debris. Burn operations were active between 1946 and 1971. In 1971, burn operations ceased, and the area was graded and seeded with grass. The area occupied by burned debris and disposed waste is approximately 23 acres. Depths of waste range from 5 to 10 ft bgs and represent a volume of approximately 185,000 to 375,000 cubic yards (Baker Environmental, Inc. 1995l).

Investigations of groundwater contamination at Site 28 began in July 1984, during the Verification Step of the Confirmation Study, when monitor wells 28-GW01–28-GW03 were constructed open to the Brewster Boulevard aquifer system and sampled (Tables C43–C45). Surface-water and sediment samples were collected during August 1984 at two locations from Cogdels Creek—upstream where Cogdels Creek is near Site 28 and downstream near the confluence of Cogdels Creek and New River. During the Confirmation Step of the Confirmation Study, in 1986, an additional monitor well, 28-GW04, was constructed, also open to the Brewster Boulevard aquifer system. Wells 28-GW01–28-GW04 were sampled during December 1986. Surface-water and sediment samples also were collected at three locations along Cogdels Creek—upstream, downstream, and proximate to Site 28—during the Confirmation Step. Well 28-GW04 was sampled again during March 1987, also during the Confirmation Step (Environmental Science and Engineering, Inc. 1985, 1987).

During the Confirmation Study, concentrations of several VOCs of interest to this study were determined above detection limits in groundwater, including TCE, *trans*-1,2-DCE, and vinyl chloride, all in monitor well 28-GW01 (old) (Table C44). Concentrations of vinyl chloride were 13 and 22 μg/L, which are relatively large when compared to TCE concentrations, indicating that degradation pathways were substantially complete at the time of sampling. Concentrations of TCE greater than detection limits also were observed in surface-water samples collected from the upstream and downstream locations on Cogdels Creek at 1.3 and 1.1 μg/L, respectively. Concentrations of BTEX components above detection limits were not observed in any groundwater or surface-water samples (Table C45). During the Verification Step, in 1984, extremely low concentrations of DDT and DDT metabolites were detected in each monitor well and ranged from 0.007 to 0.22 μg/L.

Metabolites of DDT and DDT also were detected during the Verification Step in sediment samples collected from both the upstream and downstream locations on Cogdels Creek at concentrations ranging from 0.5 to 84 μg/kg. Concentrations were consistently greatest at the upstream location. Chlordane concentrations were not detected in groundwater, surface-water, or sediment samples during the Verification Step.

During the Confirmation Step in 1986, DDT, DDT metabolites, and chlordane were not detected in groundwater or surface-water samples. A DDT metabolite concentration was observed above detection limits in two sediment samples from Cogdels Creek at 61.9 and 243 μg/kg. The highest concentration occurred at the station located near and slightly upstream of Site 28. At the same time, chlordane concentrations were observed above detection limits in all sediment samples from Cogdels Creek and ranged from 298 to 595 μg/kg. Concentrations were greatest in the sample collected near and slightly downstream of Site 28 (Environmental Science and Engineering, Inc. 1985, 1987).

To prepare for a final RI, a third round of groundwater sampling in monitor wells 28-GW01 (old)–28-GW04 was conducted during April 1993 (Tables C44, C45). With the exception of the sample collected in well 28-GW01 (old), concentrations of VOCs of interest to this study were all below detection limits. Well 28-GW01 (old) contained estimated concentrations of total 1,2-DCE and vinyl chloride at 2.0 and 6.0 μg/L, respectively (Table C44). A DDT metabolite was also detected in well 28-GW01 (old) at a concentration of 0.24 μg/L.

Surface-water and sediment sample collection occurred during May 1993 at 15 stations located along the entire length of Cogdels Creek and its major tributaries upgradient of Site 28 and at 3 locations bordering the New River adjacent to Site 28. The most upstream station was located near the western end of Duncan Street at the south central part of the HPIA. The downstream-most station was located near the confluence of Cogdels Creek and the New River. Two sediment samples were collected at each of the 18 collection locations between land surface and 1 ft bgs. Five of 18 surface-water samples collected from Cogdels Creek and the New River during May 1993 contained concentrations of several VOCs of interest greater than detection limits. TCE was detected in four samples at a maximum concentration of 47 μg/L, and total 1,2-DCE was detected in one sample at an estimated concentration of 6 μg/L. Ethylbenzene occurred in one

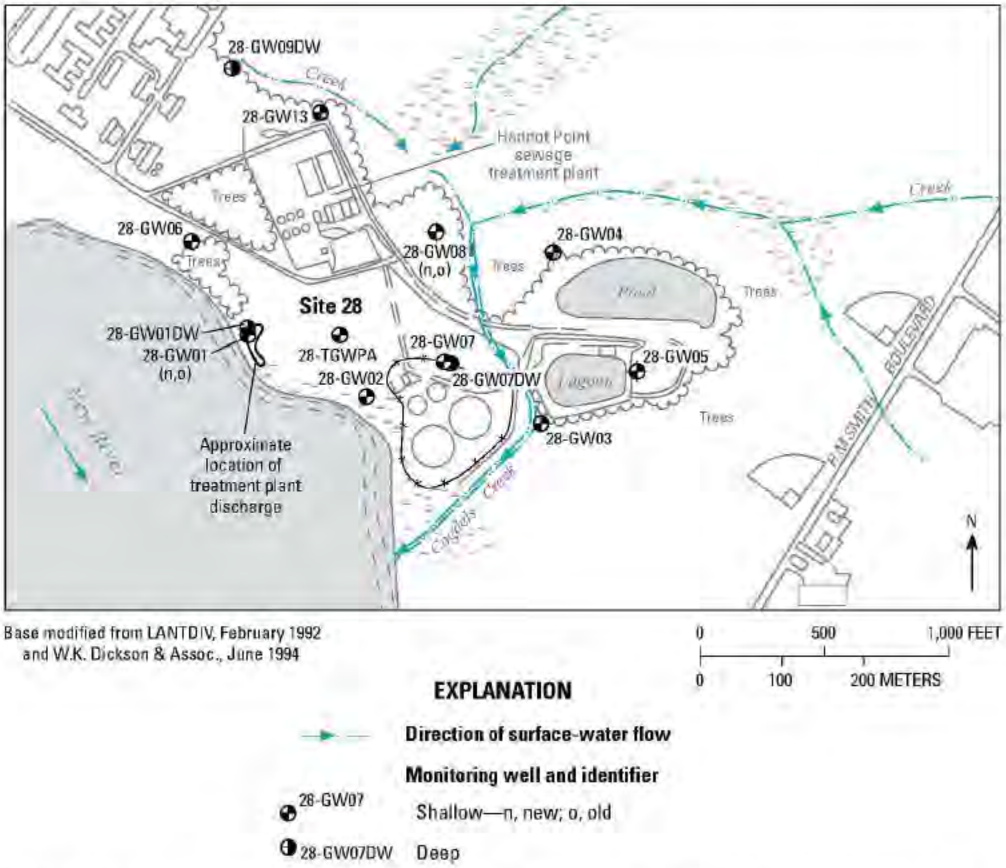


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Figure C11. Monitor well locations at Installation Restoration Site 28—Industrial Area burn dump, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1998n).

sediment sample at an estimated concentration of 16 µg/kg. Concentrations of DDT and DDT metabolites occurred above detection limits in 17 of 36 sediment samples and ranged from 4.4 to an estimated 350 µg/kg. Chlordane was detected in 4 of 36 sediment samples at concentrations ranging from an estimated 2.5 to 6.3 µg/kg (Baker Environmental, Inc. 1995l).

Analytical results for surface-water and sediment sample collection at Cogdels Creek and New River during May 1993 and reported for Site 28 were accomplished in conjunction with the final RI at Site 78. Tables of positive detections of contaminants determined in surface-water and sediment samples from Cogdels Creek and New River during May 1993 were published in Baker Environmental, Inc. (1994g).

The final RI was conducted at Site 28 during 1993–1994 (Baker Environmental, Inc. 1995l). Additional monitor wells were constructed during April 1994, including wells 28-GW01DW, 28-GW07DW, and 28-GW09DW open to the Upper Castle Hayne aquifer–River Bend unit (Table C43) between 111 and 132 ft. Other wells constructed included a replacement for original well 28-GW01 (old) and wells 28-GW05–28-GW08, 28-GW13, and test well 28-TGWPA, all probably open to the Brewster Boulevard aquifer system. A fourth round of sampling in all existing and newly installed monitor wells occurred during the final RI during April and May 1994. Surface-water and sediment samples were collected at seven stations along Cogdels Creek and its tributaries during March 1994. Two sediment samples were collected at each location between land surface and 1 ft bgs. To assess suspected disposal practices, 47 soil borings were advanced during the final RI distributed throughout the Site 28 area. Surface soil samples were collected at each location to a depth of 1 ft bgs. Five subsurface soil samples were collected at each location between 1 and 11 ft bgs. Soil sampling was accomplished during March 1994 (Baker Environmental, Inc. 1995l). In addition to groundwater, surface-water, sediment, and soil sampling, three staff gages were established on Cogdels Creek to determine water-surface altitudes. Measurements made during May 1994 indicated upstream and downstream altitudes of 0.88 and 0.85 ft above NGVD 29, respectively.

Of the monitor wells sampled during April and May 1994, only samples collected in wells 28-GW07 and 28-TGWPA contained VOCs of interest (BTEX) at concentrations greater than detection limits. Concentrations of BTEX components ranged from 2.0 to 19 µg/L (Table C45).

All BTEX components were detected with the exception of benzene. Concentrations of DDT and DDT metabolites in groundwater were detected in 6 of 12 wells and ranged from an estimated 0.05 to 9.0 µg/L. An estimated chlordane concentration of 0.049 µg/L was detected in well 28-GW08.

With respect to VOCs detected in surface-water and sediment samples collected at and along Cogdels Creek and its tributaries during March 1994, no VOC concentrations of interest to this study were determined above detection limits. Concentrations of DDT metabolites were observed above detection limits in surface water at one Cogdels Creek station adjacent to Site 28 at 0.04 and 0.05 µg/L. Concentrations of DDT and DDT metabolites also were detected in Cogdels Creek sediments at seven of seven stations ranging from an estimated 4.3 to 450 µg/Kg. Chlordane concentrations greater than detection limits were observed in Cogdels Creek sediments at four of seven stations, ranging from an estimated 2.6 to 8.4 µg/kg.

Of the VOCs of interest that occurred in surface and subsurface soil samples at Site 28, only PCE was detected at a single location at an estimated concentration of 5.0 µg/kg at a depth of 5 to 7 ft bgs. On the other hand, occurrences of pesticides were ubiquitous throughout the site. Concentrations of DDT and DDT metabolites greater than detection limits occurred in surface soils at 28 of 47 locations ranging from an estimated 2.7 to 1,400 µg/kg. Corresponding concentrations of chlordane occurred at 15 of 47 locations and ranged from an estimated 1.2 to 130 µg/kg. Occurrences of pesticides in subsurface soils were substantially less frequent compared to occurrences in surface soils. Concentrations of DDT and DDT metabolites were detected in subsurface soils at 19 of 47 locations ranging from an estimated 3.0 to 1,600 µg/kg. Chlordane concentrations were detected in subsurface soils at 5 of 47 locations ranging from an estimated 2.7 to 45 µg/kg (Baker Environmental, Inc. 1995l).

Following completion of the final RI, an ROD for Site 28 was implemented between the Department of the Navy and the U.S. Marine Corps, the North Carolina Department of Environment, Health, and Natural Resources, and USEPA Region IV (Baker Environmental, Inc. 1995e). Implementation of the ROD included a reliance on quarterly and semiannual monitoring of groundwater conditions at Site 28 during 1996–2001. Groundwater samples collected from Site 28 monitor wells during this period were analyzed mostly for metals concentrations and did not consider VOCs of interest to this study. Monitoring results were published in a series of reports beginning in 1996 (Baker Environmental, Inc. 1996m, 1997hi; Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 1998, 2000bgh; Baker Environmental, Inc. and CH2M Hill, Inc. 2001b; CH2M Hill, Inc. and Baker Environmental, Inc. 2001e). Monitor well 28-GW08 (old) was abandoned following the RI and was replaced for sampling purposes by well 28-GW08 (new) during August 1995 (Table C43).

Installation Restoration Site 30—Sneads Ferry Road Fuel Tank Sludge Disposal Area

Installation Restoration Site 30 is located in the southern part of the study area within the headwaters of Frenchs Creek and about 1 mile southwest of supply wells HP-629 (old) and HP-640 (Figures C1 and C12, Plate 1). Prior to 1983, Site 30 reportedly was used by a private contractor to wash and clean empty fuel storage tanks from off-site locations. The tanks contained refined petroleum products such as gasoline, waste sludge, and possibly cleaning solvents. The estimated area of disposal is approximately 7,500 square yards (approximately 1.5 acres) (Baker Environmental, Inc. 1995j).

Investigations of groundwater contamination at Site 30 began during the first Verification Step of the Confirmation Study in July 1984 with the construction and sampling of monitor well 30-GW01 (Environmental Science and Engineering, Inc. 1985) and continued until the completion of the second Verification Step of the Confirmation Study during 1987 (Tables C46–C48) (Environmental Science and Engineering Inc. 1987). Monitor well 30-GW02 was constructed during the Confirmation Step of the Confirmation Study in December 1986 (Table C46). Along with groundwater samples collected from monitor wells, sediment and surface-water samples also were collected during the Confirmation Step at a single station on Frenchs Creek, located on the creek generally opposite and slightly north of monitor well 30-GW02. Groundwater sampling preliminary to and in support of planning for an RI was conducted during April 1993 (Tables C47, C48) (Baker Environmental, Inc. 1993p). An RI was conducted at Site 30 during March through early May 1994 resulting in the construction of monitor well 30-GW03 and piezometer 30-PZ01. In addition to groundwater samples collected from the monitor wells and piezometer, surface and subsurface soil samples were collected at 20 locations during the RI, along with surface-water and sediment samples at two locations on Frenchs Creek (Baker Environmental, Inc. 1995jo).

No concentrations of PCE, TCE, related degradation products, or BTEX components were observed greater than detection limits in any groundwater sample collected at Site 30 (Tables C47, C48). Similar results were obtained with respect to all surface-water and sediment samples collected at Frenchs Creek as well as soil samples collected within the Site 30 area during the RI.

Following completion of the RI, a final ROD for Site 30 was implemented between the Department of the Navy and the U.S. Marine Corps, the North Carolina Department of Environment, Health, and Natural Resources, and USEPA Region IV (Baker Environmental, Inc. 1995e). Implementation of the ROD resulted in no further remedial actions or environmental monitoring at Site 30.

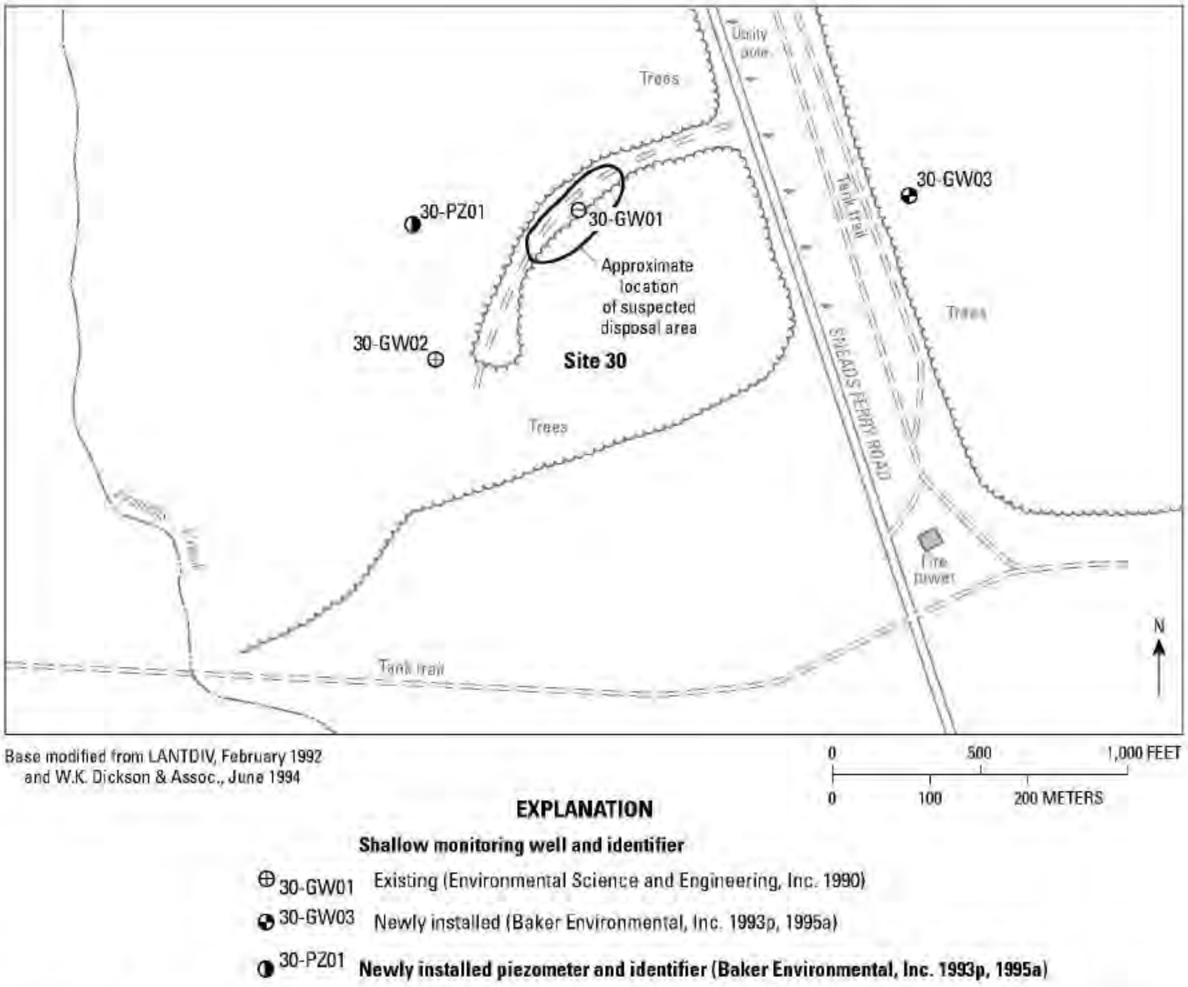

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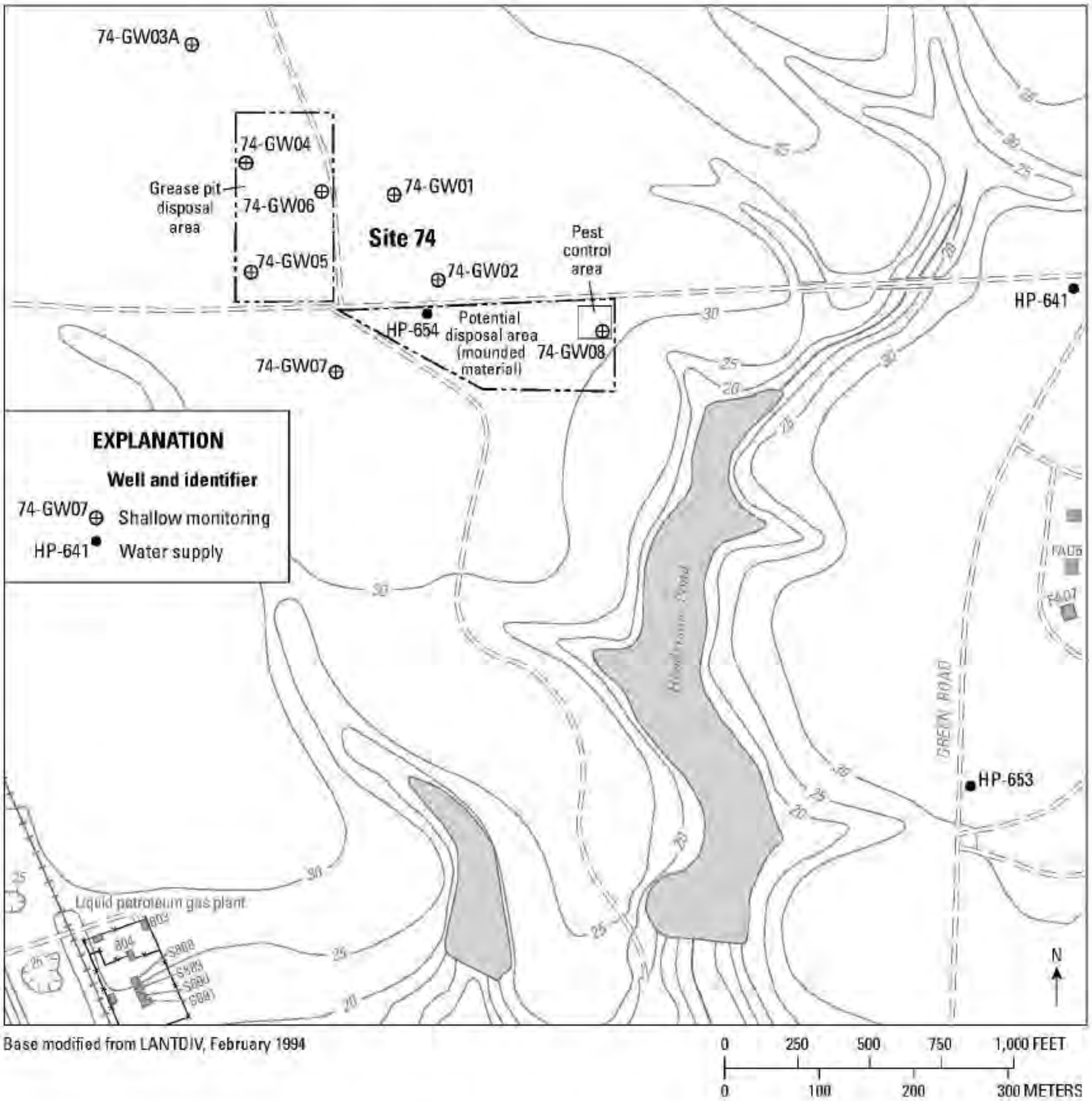
Figure C12. Monitor well locations at Installation Restoration Site 30—Sneads Ferry Road fuel tank sludge disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1995j).

Installation Restoration Site 74—Mess Hall Grease Pit Area

The mess hall grease pit disposal area covers the northern part of Site 74 and is located approximately one-half mile east of Holcomb Boulevard and north and slightly west of supply well HP-654 (Figures C1 and C13, Plate 1). A possible disposal area and pest control area are in the southern part of Site 74 and are located immediately east of supply well HP-654, between supply wells HP-654 and HP-641 (Figure C13, Plate 1). Mess hall grease and food waste were deposited in several rectangular pits within the northern part of Site 74 from the early 1950s until 1960. Approximate dimensions of the disposal pit area were 135 ft long by 30 ft wide by 12 ft deep. Total area of the northern part of Site 74 is approximately 5 acres. Total area of the southern part of Site 74 is approximately 4 acres. Records indicate that at least on one occasion an attempt was made to burn materials deposited in the pits within the northern part of the site, probably using a volatile refined petroleum product, but the attempt failed. Whether the effort to burn the waste occurred prior to or after the waste was washed out of the pits during Hurricane Hazel in 1954 is unknown. The quantity of grease deposited at the site also is unknown. Pesticide-soaked bags and drums, possibly containing pesticides and/or PCBs, were deposited at or near the grease disposal pits, probably prior to 1960. An estimated 500 gal of pesticides were released into the



Base modified from LANTDIV, February 1994

Figure C13. Monitor well locations at Installation Restoration Site 74—mess hall grease pit disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1995b).

subsurface from the deposition of the bags along with approximately 2,200 gal of pesticides and 1,100 gal of PCBs from the drums (Wallace Eakes, trip report, written communication, February 3, 1983; Baker Environmental, Inc. 1995i; Environmental and Safety Designs, Inc. 1995; CERCLA Administrative Record file #93).

Investigations of contaminated groundwater at Site 74 began during the Verification Step of the Confirmation Study in 1984 with the installation of monitor wells 74-GW01 and 74-GW02 (Table C49). Well 74-GW03 was installed during the Confirmation Step of the Confirmation Study in 1986. Monitor well 74-GW03 is not shown in Figure C13 but is located approximately 260 ft north and 150 ft west of well 74-GW03A. Each well was constructed open to the Brewster Boulevard aquifer system. Groundwater samples collected during July 1984 in wells 74-GW01 and 74-GW02 were analyzed only for pesticides. A trace quantity of a DDT metabolite was detected in well 74-GW02. Two soil borings were augured by hand during August 1984 in the pest control area. Three samples were collected at each location between land surface and 3 ft bgs. Concentrations of DDT and/or DDT metabolites were observed above detection limits in all six samples ranging from 0.4 to 260 μg/kg. Concentrations of chlordane were not detected (Environmental Science and Engineering, Inc. 1985). Groundwater samples also were collected in the three monitor wells during the Confirmation Step in December 1986 and were analyzed for pesticides as well as for VOCs of interest to this study. Neither pesticides nor VOCs of interest were observed in groundwater at this time at concentrations greater than detection limits. Similar results were obtained from analysis of a sample collected from monitor well 74-GW02 during March 1987 (Tables C50, C51) (Environmental Science and Engineering, Inc. 1987).

A final RI was conducted at Site 74 from January through March 1994. Additional monitor wells 74-GW03A and 74-GW04–74-GW08 were constructed at this time open to the Brewster Boulevard aquifer system and were sampled during February 1994. No pesticides or VOCs of interest to this study were determined at concentrations greater than detection limits in any well at this time (Tables C49–C51, Baker Environmental, Inc. 1995h). Geophysical surveys using electromagnetic terrain conductivity and magnetometer surveys were completed at Site 74 prior to the RI. Survey results located a drum disposal trench immediately north of the previously identified grease disposal pit. Monitor well 74-GW06, open to the Brewster Boulevard upper aquifer, was placed within or immediately adjacent to the drum disposal trench defined by the geophysical surveys.

For purposes of collecting and analyzing soils data, Site 74 was subdivided into three areas—Area 1, the grease pit disposal and drum trench disposal area (FDA), composing the northern part of the site; Area 2, the potential disposal area (PDA); and Area 3, the pest control area (FPA), in the southern part of the site. A total of 38 boreholes were advanced in the northern part of Site 74 for the collection of surface and subsurface soil samples. Surface soil samples were collected between land surface and 1 ft bgs. Subsurface soil samples were collected at 2-foot intervals between 1 ft bgs and the water table. Corresponding borehole locations in the southern part of Site 74 numbered 9 at the pest control area and 17 at the potential disposal area. These numbers also include several boreholes located away from potentially contaminated areas to collect background data. Soil samples also were collected during the construction of monitor wells. Surface-water and sediment samples were collected at two upstream stations and one downstream station at Henderson pond (Figure C13) (Baker Environmental, Inc. 1995i). Sediment samples were collected between land surface and 1 ft bgs.

Of the VOCs of interest observed in surface soils, TCE was detected at 5 of 60 locations at estimated concentrations ranging from 2.0 to 8 μg/kg. Four occurrences of TCE were within or adjacent to the drum trench disposal area. A single occurrence was south of the pest control area (Figure C13). Concentrations of BTEX components greater than detection limits were observed in surface soils at 3 of 60 locations ranging from an estimated 1.0 to 6 μg/kg. All components were observed, with the exception of benzene. Concentrations of DDT and DDT metabolites were detected in surface soils at 31 of 60 locations ranging from an estimated 0.31 to 3,840 μg/kg. Chlordane concentrations greater than detection limits occurred at 8 of 60 borehole locations and ranged from an estimated 0.39 to 1,680 μg/Kg. The majority of pesticide occurrences (22) were at boreholes located in the northern part of Site 74. Regarding subsurface soils, no concentrations of VOCs of interest were observed greater than detection limits. Concentrations of DDT and DDT metabolites in subsurface soils occurred at 9 of 47 locations and ranged from an estimated 0.34 to 21.4 μg/kg. Chlordane concentrations greater than detection limits were not observed in subsurface soils. Surface-water samples collected at Henderson Pond contained no concentrations of VOCs or pesticides of interest greater than detection limits. Of the sediment samples collected at Henderson Pond, an estimated concentration of TCE at 8.0 μg/kg was detected in one upstream sample. Concentrations of DDT and DDT metabolites were detected in both upstream sediment samples at Henderson Pond at an estimated 0.82 and 1.85 μg/kg, respectively (Baker Environmental, Inc. 1995ghi).

Following completion of the final RI, an FS was initiated to address remediation of groundwater contamination at Site 74 (Baker Environmental, Inc. 1995b). An ROD between the Department of the Navy and the U.S. Marine Corps, the North Carolina Department of Environment, Health, and Natural Resources, and USEPA Region IV was signed in 1995 and required periodic monitoring of groundwater conditions at Site 74 (U.S. Environmental Protection Agency, written communication, EPA review comments, October 1, 2009). Reports documenting the results of groundwater monitoring at Site 74 following the implementation of the ROD can be obtained by formal request to the Environmental Management Division, USMCB Camp Lejeune, North Carolina.

Installation Restoration Site 78—Hadnot Point Industrial Area

The HPIA was constructed prior to 1940 and is the center of industrial activity within the Hadnot Point–Holcomb Boulevard study area. Industrial activities that occur at a variety of HPIA facilities include vehicle service and maintenance, warehousing, auto body painting and maintenance, and heavy equipment maintenance. A variety of multipurpose storage facilities include active USTs and solvent storage areas (Baker Environmental, Inc. 1994b). The HPIA/Site 78 is bounded to the northwest by Holcomb Boulevard, to the southwest by the McHugh Boulevard/Main Service Road, and to the northeast by Sneads Ferry Road (Figure C14, Plate 1). The southeastern boundary is somewhat diffuse but is generally defined by Duncan Street (Figure C15). Contained within or immediately adjacent to Site 78 are Sites 21, 22, and 24 (Figure C14). Site 94 is located in the extreme southwest corner of Site 78 immediately east of Gum Street and bounded generally by the locations of monitor wells 78-GW05–78-GW07 (Figure C15). Total area of Site 78 is approximately 590 acres. Most of the HPIA area is paved; however, relatively small areas of lawn occur between buildings and around the periphery of roads and buildings.

Investigations of groundwater contamination at and adjacent to the HPIA began during the Verification Step of the Confirmation Study during 1984 at Sites 21, 22, and 24 and were described previously herein. Investigations specific to Site 78 began during a Characterization Step of the Confirmation Study in 1986. Construction of monitor wells 78-GW01–78-GW29 began in October 1986 and was completed by July 1987 (Table C52). All shallow wells were completed open to the Brewster Boulevard aquifer system. Wells of intermediate and deep construction were advanced at locations 9, 17, and 24 and were open to the Tarawa Terrace aquifer and then to the Upper Castle Hayne aquifer–River Bend unit (Figure C14, Table C52). The siting of monitor wells was facilitated by sampling soil gas at several storage and maintenance facilities.

Groundwater samples were collected in all existing monitor wells between January and August 1987 and were analyzed for all VOCs of interest to this study (Tables C53 and C54). Results of the Confirmation Study further refined the known area of groundwater contamination caused by BTEX components in the vicinity of the Hadnot Point fuel farm (Site 22) and identified other areas of groundwater contamination at the HPIA, particularly (1) in the vicinity of Building 902 in the northeastern part of Site 78 adjacent to monitor well 78-GW24-1 and Sneads Ferry Road, (2) near Building 1601 at the location of monitor well 78-GW09 (old), and (3) in the vicinity of Building 1202, generally defined by the locations of monitor wells 78-GW15, 78-GW17-1, and 78-GW18. Based on soil gas sample analyses, groundwater contamination near Buildings 902 and 1202 originated largely from subsurface disposal of waste solvents. Subsurface disposal of waste solvents as well as BTEX components apparently caused groundwater contamination near Building 1601. To a large degree, soil gas results were substantiated by groundwater data from monitor wells determined during 1987.

During the Confirmation Study, concentrations of TCE greater than detection limits at well 78-GW09-1 (old) were 5,000 and 6,100 μg/L during January and March 1987 (Table C53). Several BTEX components also were observed in well 78-GW09-1 (old) at this time at concentrations of 1,100 and 2,500 μg/L (Table C54). Similar results were obtained in well 78-GW24-1, where concentrations of *trans*-1,2-DCE were detected at 4,300 μg/L and 6,400 μg/L and benzene was observed at a concentration of 2.0 μg/L (Tables C53, C54). Concentrations of vinyl chloride detected during the Confirmation Study at well 78-GW24-1 were 190 μg/L and 250 μg/L, indicating that degradation pathways were essentially complete within the volume of water sampled by the well. An additional result of the Confirmation Study was the closure of supply wells HP-602, HP-608, HP-634, and HP-660, all located within or adjacent to the perimeter of the HPIA (Tables C7 and C8, Plate 1).

Additional investigations of soil and groundwater contamination at Site 78, termed a Supplemental Characterization Step, were initiated during 1990 and 1991 to determine the extent of contamination within soils and the "shallow aquifer," termed herein the Brewster Boulevard aquifer system, and underlying "intermediate" and "deep" water-bearing units, termed herein the Tarawa Terrace aquifer and units of the Upper Castle Hayne aquifer system, respectively (Tables C14 and C52). Whether or not the Supplemental Characterization Step was part of the Confirmation Study is unknown. Additional wells of relatively intermediate and deep construction were advanced during the Supplemental Characterization Step, including wells 78-GW04-2, 78-GW30-2, 78-GW31-2, and 78-GW32-2, open to the Tarawa Terrace aquifer between 64 ft and 78 ft bgs, and wells 78-GW04-3, 78-GW30-3, 78-GW31-3, and 78-GW32-3, open to the Upper Castle Hayne aquifer and/or zones equivalent to the local confining unit between 140 and 153 ft bgs. The new intermediate, deep, and other existing shallow wells were sampled during January 1991. Samples were analyzed for all VOCs of interest as well as for pesticides. Similar analytical schedules were applied at this time to samples collected in supply wells HP-602, HP-603, HP-634, HP-637, HP-642, HP-651, HP-652, HP-653, and HP-660 (Tables C7, C8). Concentrations of BTEX components greater than detection limits were observed in most intermediate wells during the 1991 sampling event. A maximum concentration of benzene of 27 μg/L occurred in well 78-GW32-2. Of the chlorinated alkenes of interest in intermediate wells, only total 1,2-DCE and vinyl chloride were observed at concentrations greater than detection limits in well 78-GW30-2. The reported concentration of both constituents was 12 μg/L (Table C53).

Also at this time, 30 soil borings were advanced in the vicinity of Buildings 902, 1202, and 1601 where soil gas analyses had previously indicated substantial groundwater contamination. Three soil samples were collected at each borehole at depths ranging from land surface to 12 ft bgs and analyzed

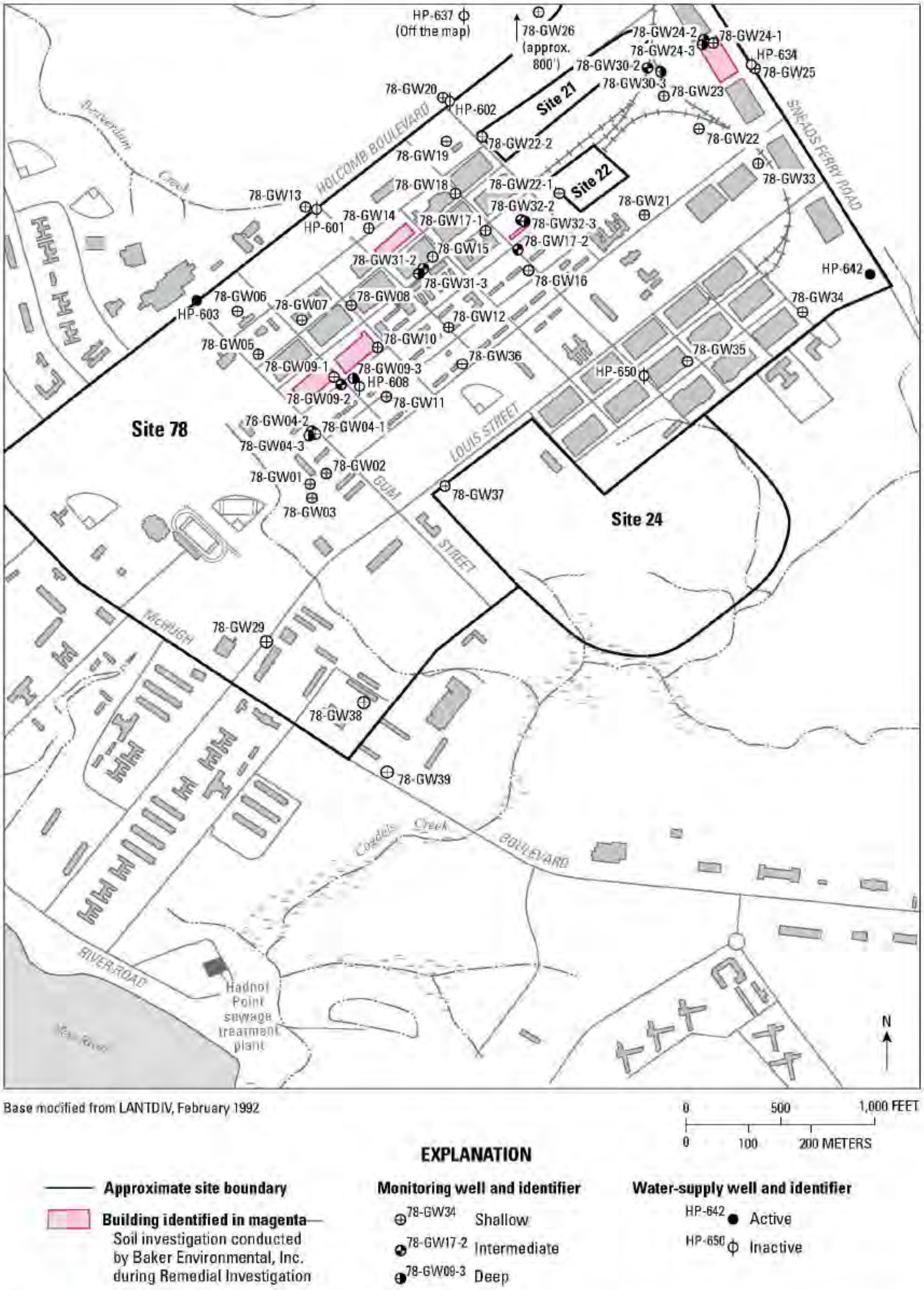


Figure C14. Site boundaries and monitor well locations at Installation Restoration Site 78—Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1994b).

for selected VOCs of interest to this study as well as for pesticides. Of the VOCs of interest, concentrations of TCE greater than detection limits occurred most frequently in 7 of 90 samples and ranged from an estimated 2.0 to 120 µg/kg. Concentrations of BTEX components greater than detection limits occurred in 4 of 90 samples, ranging from an estimated 1.0 to 580 µg/kg. Concentrations of DDT and DDT metabolites greater than detection limits were observed in 3 of 90 samples, ranging from 22 to 140 µg/kg. No chlordane concentrations greater than detection limits were determined in any soil sample (Environmental Science and Engineering, Inc. 1991).

Following the Supplemental Characterization Step investigations, an interim RI was begun during 1992 to further evaluate the nature and extent of groundwater contamination within the Brewster Boulevard aquifer system at the HPIA. No additional field data were collected during this investigation (Baker Environmental, Inc. 1992a). Also during 1992, a Pre-investigation Study was conducted in preparation for an RI/FS at Site 78. Groundwater samples were obtained for analyses in several deep monitor wells as well as at several abandoned supply wells in the vicinity of Site 78 (Baker Environmental, Inc. 1994b). Results of these analyses were not published in available reports. Geophysical investigations conducted during the Pre-investigation Study indicated the probable existence of USTs within Site 78 at Buildings 903, 1502, and 1601. No USTs were indicated at Buildings 1202 or 1709 (Baker Environmental, Inc. 1994b).

Field investigations related to a final RI at Site 78 began during April 1993 and continued into December 1993. Monitor wells 78-GW33–78-GW39 were constructed during the final RI, all open to the Brewster Boulevard aquifer system. Well 78-GW09-1 (new) was constructed to replace 78-GW09-1 (old). Samples were collected in several wells at Site 78 during May and December 1993 and were analyzed for all VOCs of interest to this study as well as selected pesticides. With the exception of wells 78-GW09-1 (new), 78-GW23, and 78-GW24-1, VOCs of interest detected in the newly constructed and existing wells were small or below detection limits. Concentrations of TCE detected in wells 78-GW09-1 (new) and 78-GW23 were 2,100 and 57 µg/L, respectively. Concentrations of *cis*-1,2-DCE detected in wells 78-GW23 and 78-GW24-1 were an estimated 14,000 and 3,400 µg/L, respectively (Figures C14 and C15, Table C53). Contours of total chlorinated solvents within the Brewster Boulevard aquifer system at the HPIA determined during the final RI are shown in Figure C16. The solvents delineated within the Brewster Boulevard aquifer system in the northern part of the HPIA are possibly the source of TCE and related degradation products observed in supply wells HP-602, HP-634, and possibly HP-652 during 1984–1991. Similarly, the solvents delineated in this aquifer in the southern part of the HPIA are the possible source or sources of TCE and related degradation products observed in supply well HP-608 during 1984–1986 (Figures C14–C16, Table C7). All BTEX components were observed in several monitor wells during the final RI sample collection during 1991 and 1993. Benzene was detected most frequently at concentrations ranging from 2.0 µg/L in well 78-GW21 to 51 µg/L in well 78-GW24-1 (Table C54). Benzene was detected in deep well 78-GW31-3 at an estimated concentration of 15 µg/L and in intermediate well 78-GW32-2 at a concentration of 27 µg/L. All BTEX components were detected in well 78-GW32-2 at concentrations ranging from an estimated 2.0 µg/L of ethylbenzene to 31 µg/L of toluene. Monitor well 78-GW31-3 was constructed open to the Upper Castle Hayne aquifer system at an interval of 140–153 ft bgs. Well 78-GW32-2 was open to the Tarawa Terrace aquifer between 65 and 78 ft bgs. The occurrence of BTEX (LNAPL) components at such depths indicates substantial downward vertical migration from the water table had occurred at the site prior to the onset of monitoring in 1993. Such migration was probably largely by advection along downward vertical head gradients caused by pumping from nearby supply wells HP-601, HP-602, HP-634, HP-642, and, depending on the timing of BTEX occurrence in the shallow subsurface, pumping at supply wells HP-607 and HP-630. Concentrations of DDT and DDT metabolites observed in Site 78 monitor wells were less than detection limits during May 1993. A single detection of chlordane occurred in monitor well 78-GW09-3 at an estimated concentration of 0.11 µg/L.

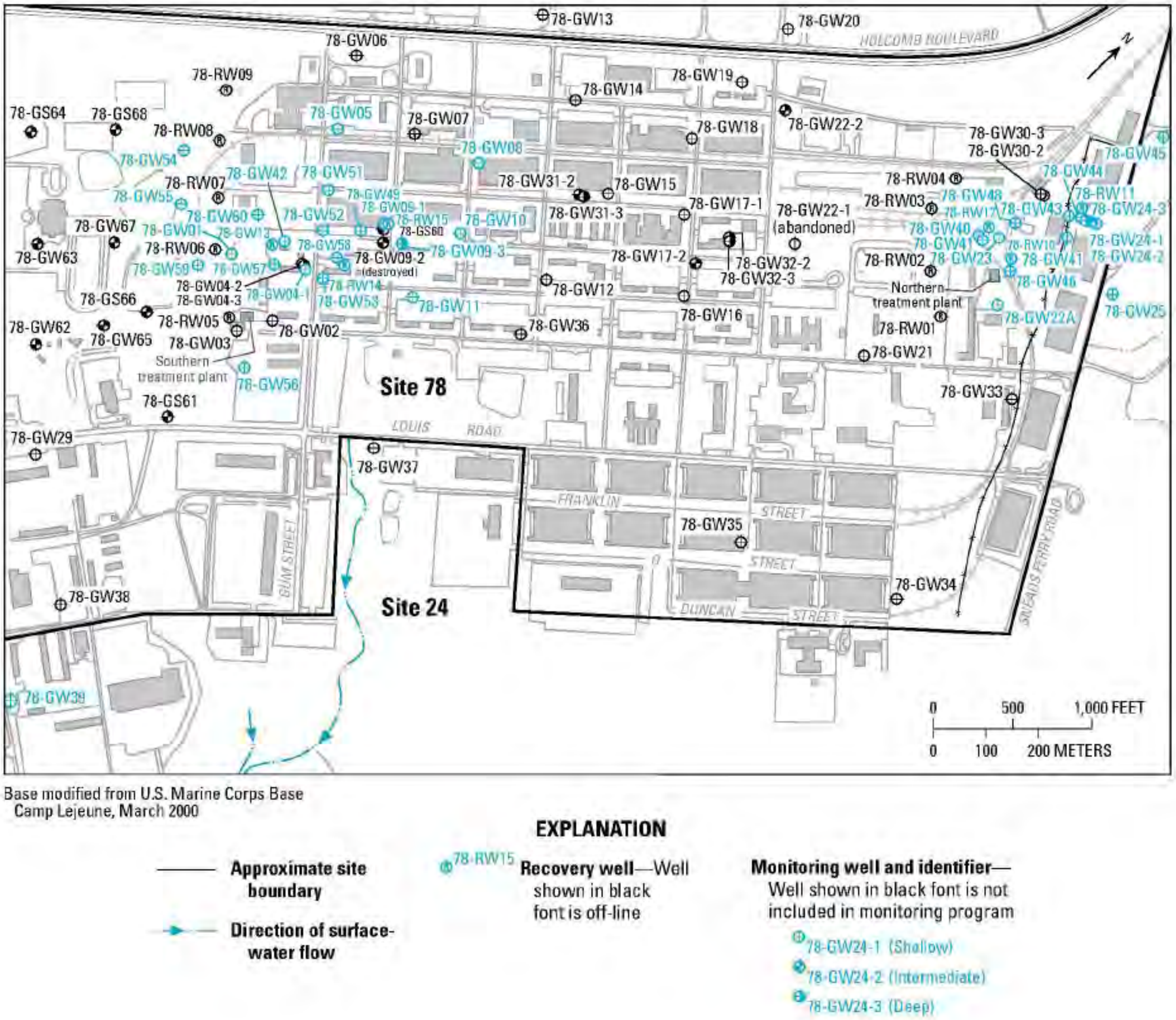
Surface-water and sediment samples were collected at 7 stations located on Beaverdam Creek and 15 stations along Cogdels Creek and its tributaries during May 1993 (Figure C14). Two surface-water and sediment collection stations also were located east of Cogdels Creek along a short unnamed tributary and adjacent to the New River opposite Site 28. Results of the collection and subsequent analyses of surface-water and sediment samples at Cogdels Creek and New River were summarized with respect to previous investigations at Site 28. A toluene concentration of an estimated 3.0 µg/L was detected in a surface-water sample in the unnamed tributary east of Cogdels Creek. At the seven stations located on Beaverdam Creek, no VOCs of interest were detected either in surface-water or sediment samples. Concentrations of DDT and DDT metabolites were detected in sediments at five of seven Beaverdam Creek locations at concentrations ranging from an estimated 4.8 to 93 µg/kg. Concentrations of chlordane in Beaverdam Creek sediments occurred greater than detection limits at three of seven locations and ranged from 2.4 µg/kg to an estimated 5.6 µg/kg.

Surface and subsurface soil samples also were collected at several locations within the HPIA during the final RI. Sample locations were generally near or adjacent to building locations, including Buildings 903, 1103, 1300, 1502, 1601, and 1608. With the exception of Building 1608, these buildings are outlined in magenta on Figure C14. Building 1608 is located across East Road opposite Building 1601 (Figure C14). Thirty soil borings were advanced. Surface soil samples were collected between land surface and 6 inches bgs. Subsurface soil samples were collected at 1- or 2-ft intervals between about 1 ft bgs to near the water table. Concentrations of VOCs of interest were determined greater than detection limits in surface soils at Buildings 1103 and 1502. Toluene and xylenes were detected at Building 1103 at estimated concentrations of 9 and 10 µg/kg, respectively. An estimated concentration of 2.0 µg/kg of total 1,2-DCE was observed in a surface soil sample at Building 1502. Concentrations of DDT and DDT metabolites were detected at each building location, frequently in more than one borehole, and ranged from an estimated 3.7 to 16,000 µg/kg. Chlordane concentrations were determined greater than detection limits at Building 1103 at an estimated 12 µg/kg and at 1,900 µg/kg. Regarding the subsurface samples, concentrations of ethylbenzene and total xylenes were detected between 6 and 7 ft bgs at Building 1601 at an estimated 35 µg/kg and at 450 µg/kg, respectively. Concentrations of total 1,2-DCE were detected at an estimated 6.0 and 16 µg/kg at Building 903. Concentrations of DDT and DDT metabolites greater than detection limits occurred in subsurface soils in at least one borehole at each building, with the exception of Building 903. Concentrations ranged from an estimated 1.3 to 9.7 µg/kg. Maximum depth of occurrence was 9 ft bgs. Concentrations of chlordane were not detected in subsurface soils. Subsurface soil samples also were collected during the construction of monitor wells. Of the VOCs of interest, only toluene was detected at an estimated concentration of 3.0 µg/kg at a depth of 14 ft bgs in the borehole of well 78-GW39. A DDT metabolite was detected in the borehole of well 78-GW37 at concentrations of 42 and 48 µg/kg. Maximum depth of occurrence was 8 ft bgs (Baker Environmental, Inc. 1994b).

Following completion of the RI and a final FS, several approaches were selected to remediate contaminated groundwater at Site 78, including groundwater extraction and treatment and implementation of long-term groundwater monitoring. These and other remediation methods were included in an ROD between the Department of Navy and the U.S. Marine Corps, the State of North Carolina, and USEPA Region IV signed in 1994 (Baker Environmental, Inc. 1994bd). Subsequently, groundwater monitoring occurred routinely on a quarterly, semiannual, or annual basis at most monitor wells, including newly constructed monitor wells. Results of groundwater monitoring and results of VOC extraction from the shallow aquifer were published in a series of reports beginning in 1996 (Baker Environmental, Inc. 1996ij, 1997cd, 1998jk, 1999bc, 2002a; CH2M Hill Federal Group Ltd. and Baker Environmental, Inc. 2000a, 2001a; Baker Environmental, Inc. and CH2M Hill, Inc. 2002a; Baker Environmental, Inc., CH2M Hill, Inc., and CDM Federal Programs Corp. 2003; Michael Baker Jr., Inc. and CH2M Hill Federal Group, Ltd. 2003; Engineering and Environment, Inc. and Michael Baker Jr., Inc. 2004a).

By December 1994, north and south VOC extraction networks were in place and operating at Site 78 (Figure C15). Wells related to the north extraction network were 78-RW01N–78-RW04N. Corresponding wells constructed for the south extraction network were 78-RW05S–78-RW09S. All wells were constructed open to the Brewster Boulevard aquifer system. By July–November 1996, only wells 78-RW10N and 78-RW11N were active at the north extraction network. Wells 78-RW01N–78-RW04N were inactive at that time because of limited VOC collection and possibly were abandoned as extraction wells. At the south extraction network, wells 78-RW05S–78-RW08S were active, and well 78-RW09S was inactive. During October 1996, wells 78-RW10N and 78-RW11N pumped at a combined rate of 5.8 gallons per minute (gpm). The corresponding combined pumping rate at the south extraction network for wells 78-RW05S–78-RW08S was 14 gpm (Baker Environmental, Inc. 1996j). Between July and December 1997, combined pumping rates at the north extraction network ranged from 1.9 to 3.6 gpm. Corresponding rates at the south extraction network were 2.3 to 16.4 gpm (Baker Environmental, Inc. 1998k). The combined pumping rate at the north extraction network remained little changed from June 1999 through August 2002. The cumulative weight of VOCs removed from the Brewster Boulevard aquifer system by the north extraction network as of August 2002 was 64.5 pounds. The combined pumping rate at the south extraction network between June 1999 and August 2002 varied from about 1 to 16 gpm. The cumulative weight of VOCs removed by the south extraction network by January 2000 was about 9 pounds. Apparently, the south extraction network was inoperative between about January 2000 and May 2002. The cumulative weight of VOCs removed by the south extraction network by August 2002 was 23.3 pounds (Baker Environmental, Inc. and CH2M Hill, Inc. 2000a, 2002a; CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000a).

Following completion of the north and south extraction networks in 1994, additional monitor wells (78-GW40–78-GW78), small-diameter piezometers (78-PZ01–78-PZ12), and test wells (78-S-TW01–78-S-TW13) were constructed between 1995 and 2003 to further refine knowledge of the extent of VOC contamination at the HPIA and evaluate the performance of the extraction networks (Figure C14, Table C52). Additional extraction wells were constructed and added to the north and south extraction networks—wells 78-RW10N–78-RW12N and 78-RW13S–78-RW15S, respectively. A detailed study of the vertical and areal extent of VOC contamination in the immediate vicinities of the north and south extraction networks was accomplished during June 2002 when Geoprobe samples were collected at numerous locations. In general, three to five water samples were collected at each location at depths ranging from about 20 to 50 ft. These data were combined with monitor well data to construct sections portraying subsurface conditions across the north and south contaminated areas. For example, locations of section lines *A–A′*, *B–B′*, and *C–C′* assembled for the north area are shown in Figure C17. The vertical distribution of TCE along these section lines is shown in Figure C18. Concentrations of TCE ranging from below detection limits to more than 200 µg/L are shown to occur at depth with a high degree of spatial continuity throughout the northern contaminated area. Zones of relatively high concentration are separated by zones of relatively low concentration along each section. Such variations are possibly caused by aquifer and confining unit heterogeneity, particularly the variability of horizontal and vertical hydraulic conductivity within the Brewster Boulevard aquifer system.



Base modified from U.S. Marine Corps Base Camp Lejeune, March 2000

Figure C15. Extraction and monitor well locations at Installation Restoration Site 78—Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Michael Baker, Jr. Inc. and CH2M Hill Federal Group, Ltd. 2003).

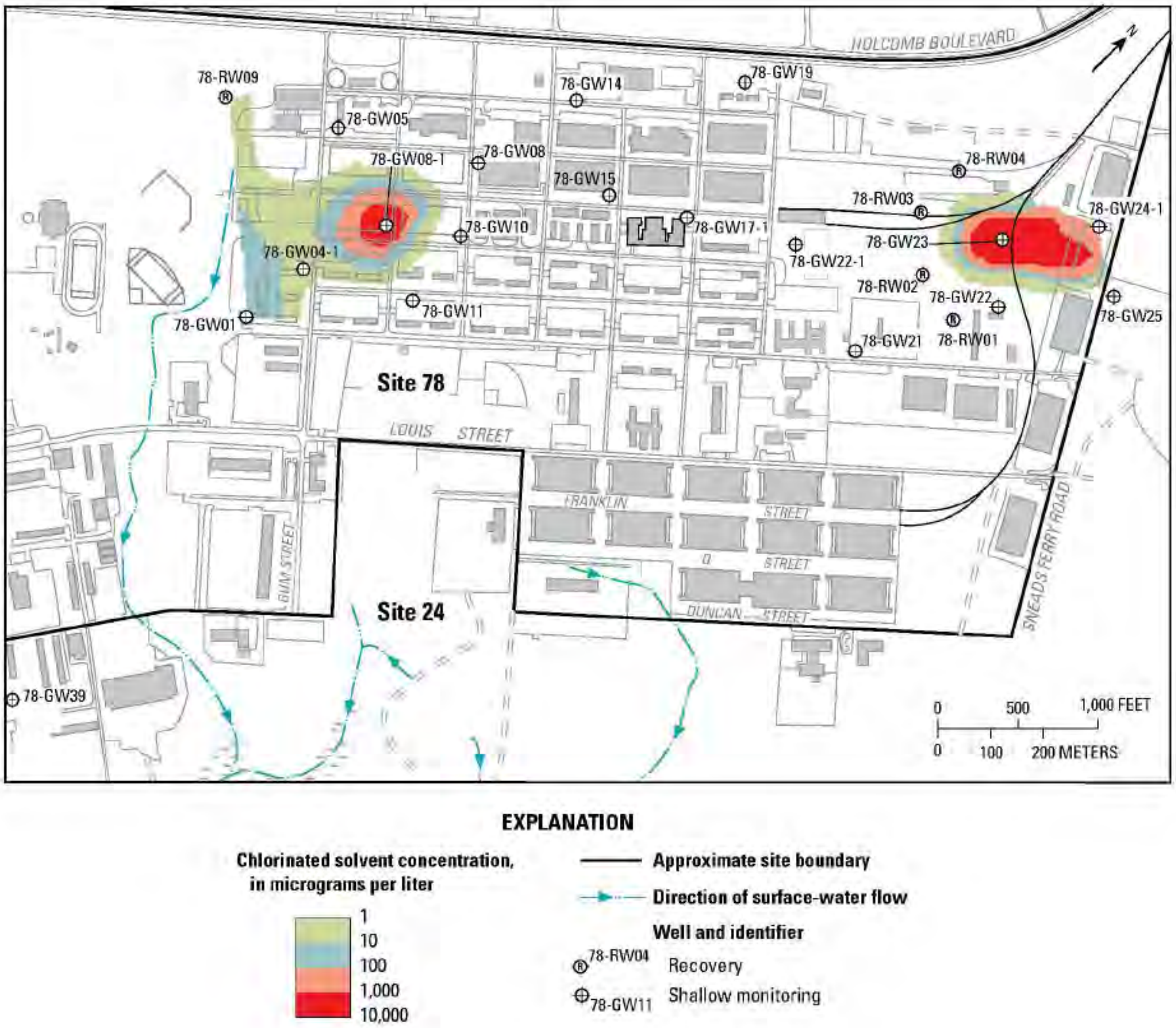


Figure C16. Chlorinated solvent concentrations during 1996 at Installation Restoration Site 78—Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1996j).

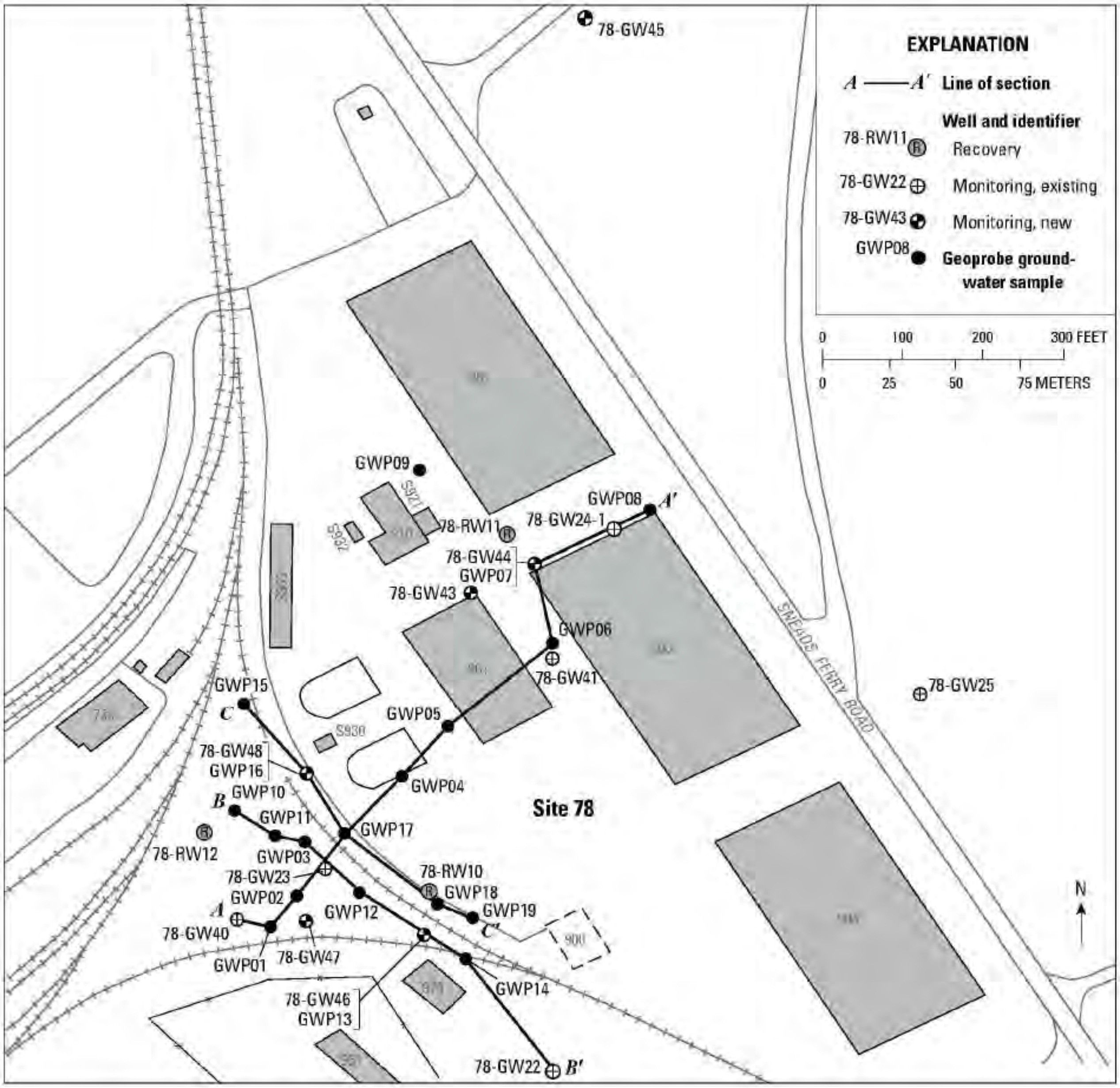


Figure C17. Locations of section lines *A–A′*, *B–B′*, and *C–C′* at the north contaminated area, Installation Restoration Site 78—Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental Inc., CH2M Hill Federal Group Ltd., and CDM Federal Programs Corp. 2003).

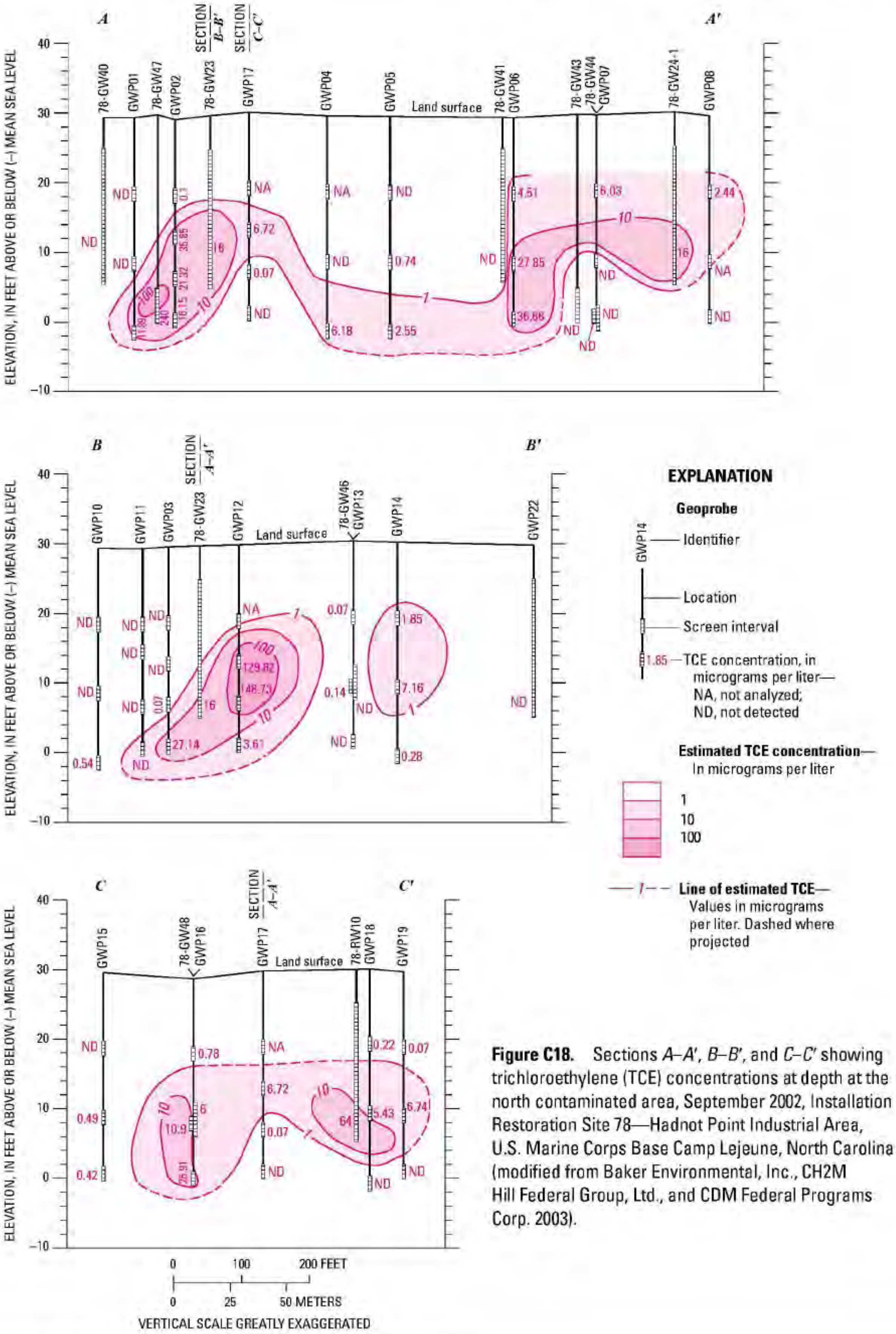


Figure C18. Sections *A–A′*, *B–B′*, and *C–C′* showing trichloroethylene (TCE) concentrations at depth at the north contaminated area, September 2002, Installation Restoration Site 78—Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc., CH2M Hill Federal Group, Ltd., and CDM Federal Programs Corp. 2003).

Installation Restoration Site 80—Paradise Point Golf Maintenance Area

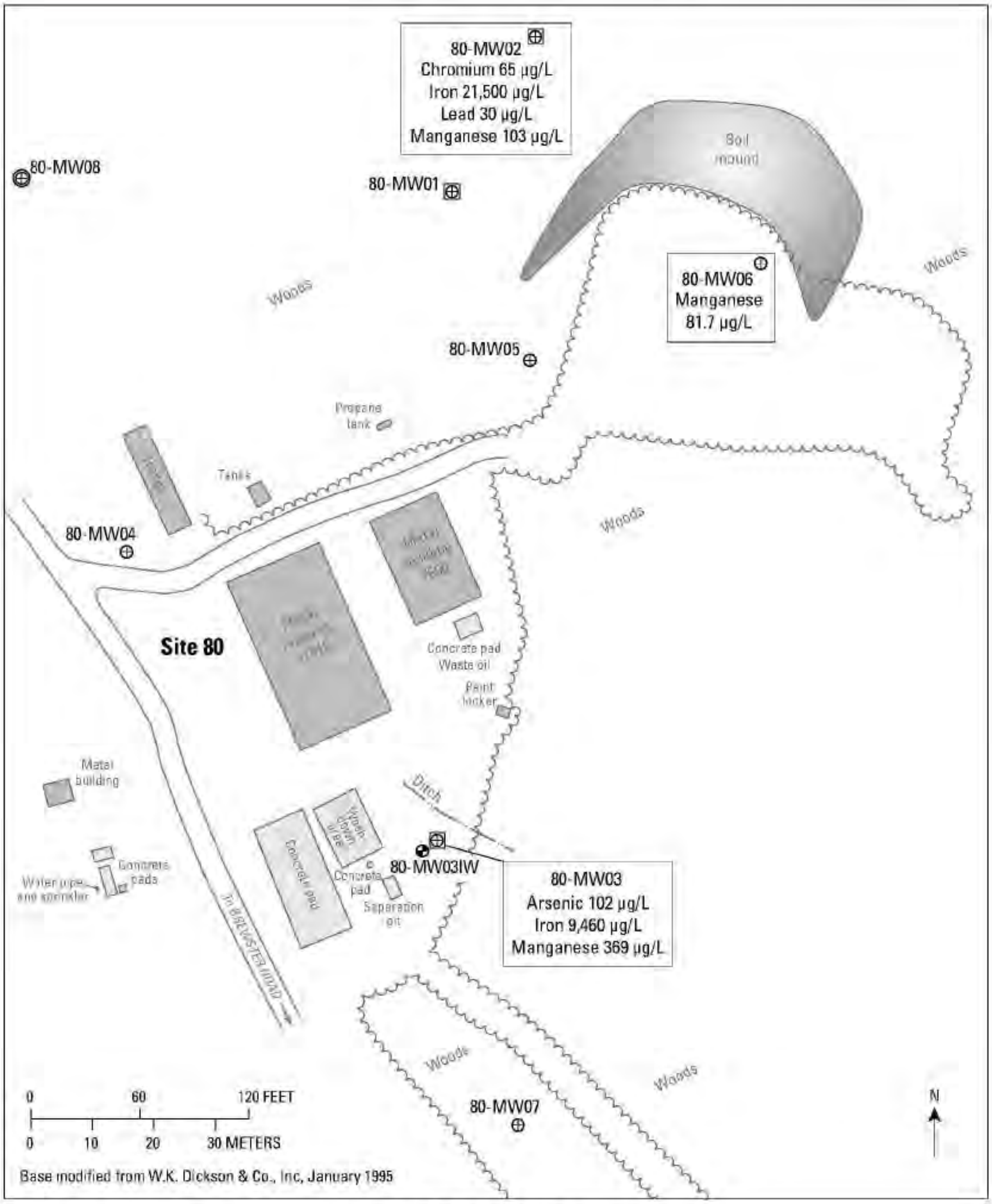
The Paradise Point golf maintenance area is located about midway between Brewster Boulevard and Northeast Creek and approximately three-quarters of a mile east of New River (Figure C1, Plate 1). As of 1991, Site 80 was used and had been used as (1) a maintenance area for equipment used to maintain the base golf courses, (2) a pesticide mixing and wash area, (3) an equipment wash area, (4) a storage area for golf course debris, such as brush and lawn clippings, and (5) a disposal area for abandoned mechanical equipment. Total site area is about 1 acre. Site 80 occupies a highland area on the divide between Northeast Creek and the New River and is drained by a shallow drainage ditch along its eastern periphery (Haliburton NUS 1992b; Baker Environmental, Inc. 1996e).

Investigations of groundwater contamination at Site 80 began during a site inspection in 1991. Seven soil borings were advanced to near the water table, including three borings converted to monitor wells 80-MW01–80-MW03, constructed open to the Tarawa Terrace aquifer between 10 and 22 ft bgs (Figure C19, Table C55). Fourteen subsurface soil samples were obtained from the soil borings—two from each borehole (one between land surface and 2 ft bgs and one at or slightly above the water table). Three surface soil samples also were collected between land surface and 6 inches bgs at a soil mound near the eastern periphery of the site. Seven additional soil samples were collected between land surface and 2 ft bgs at various locations to determine background conditions. In addition, sediment and surface-water samples were collected in the drainage ditch at five and three locations, respectively. Groundwater and soil samples were collected and analyzed during June 1991. Concentrations of components of BTEX were greater than detection limits in monitor well 80-MW03; concentrations ranged from 5.0 to 180 μg/L. Toluene concentrations were greater than detection limits in two surface-water samples at 30 and 110 μg/L. No pesticides were detected in groundwater, surface water, or subsurface soil samples at Site 80. Concentrations of DDT and DDT metabolites were detected in 5 of 10 surface soil samples ranging from 13 to 700 μg/kg. Chlordane was detected in 1 of 10 surface soil samples at a concentration of 60 μg/kg (Haliburton NUS 1992b; Baker Environmental, Inc. 1996d).

A final RI began at Site 80 during October 1994 and continued until July 1995. Shallow monitor wells 80-MW04–80-MW07 were constructed open to the Tarawa Terrace aquifer between 11 and 27.5 ft bgs during November 1994. Intermediate well 80-MW03IW also was constructed during November 1994 open to the Upper Castle Hayne aquifer–River Bend unit between 57 and 72 ft bgs. Monitor wells 80-MW01–80-MW07 were sampled during November 1994. An additional shallow well, 80-MW08, was constructed during June 1995 open to the Tarawa Terrace aquifer between 10 and 25 ft bgs and was sampled during July 1995 (Tables C55–C57). Of the groundwater samples analyzed for VOCs, no VOCs of interest to this study were observed greater than detection limits (Tables C56, C57). The pesticides DDT and DDT metabolites were detected in a sample from well 80-MW04 during November 1994 at estimated concentrations of 0.58 and 2.2 μg/L, respectively.

A total of 114 surface soil samples and 51 subsurface soil samples were collected at Site 80 during two sampling rounds in November 1994 and June 1995. Fifty-five of the surface soil samples were collected in a small area in the northwestern part of the site called the "lawn area" because of suspected contamination from a septic absorption system leach field. Surface soil samples were collected between land surface and 1 ft bgs. Subsurface soil samples were collected between 1 ft bgs to just above the water table. Of the 34 surface soil samples analyzed for VOCs, no VOCs of interest to this study were observed greater than detection limits. Of the 55 surface soil samples submitted for pesticide analyses, DDT and DDT metabolites were detected in 45 samples at concentrations ranging from an estimated 0.6 to 260,000 μg/kg (Baker Environmental, Inc. 1996de). With respect to concentrations of VOCs of interest to this study in subsurface soil samples collected during the final RI, none were determined greater than detection limits in any of 45 samples submitted for analyses. Metabolites of DDT and DDT were detected in 18 of 45 subsurface soil samples at concentrations ranging from an estimated 1.1 μg/kg to an estimated 510 μg/kg. Chlordane concentrations were not observed greater than detection limits in any sample.

Remediation of contamination at Site 80 was proposed following completion of the final RI and was based on the excavation and removal of soils contaminated with pesticides at several areas of concern (Baker Environmental, Inc. 1995q). Successful removal of contaminated soils probably negated the need for additional monitoring at Site 80, and routine monitoring for groundwater conditions was terminated after 1995. An ROD between the Department of the Navy and the U.S. Marine Corps, the North Carolina Department of Environment, Health, and Natural Resources, and USEPA Region IV was signed in 1997. The ROD stipulated that no further remedial action was required at IR Site 80 (Robert A. Lowder, U.S. Marine Corps Camp Lejeune, written communication, review comments, this report, September 23, 2009).



Base modified from W.K. Dickson & Co., Inc, January 1995

EXPLANATION

Shallow monitoring well and identifier

80-MW01 ⊞ Installed prior to remedial investigation conducted in October 1994

80-MW05 ⊕ Installed during the first part of groundwater investigation, November 1 through November 7, 1994

80-MW08 ⊕ Installed during the second part of groundwater investigation, June 12 through June 14, 1995

● 80-MW03IW **Intermediate monitoring well and identifier**—Installed during the first part of groundwater investigation, November 1 through November 7, 1994

Figure C19. Monitor well locations at Installation Restoration Site 80—Paradise Point golf maintenance area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 1996e). [Note: sample concentrations shown in micrograms per liter (µg/L)]

Installation Restoration Site 82—VOC Disposal Area at Piney Green Road

The history of waste disposal at Site 82 closely parallels the history of Site 6 discussed previously herein. Site 82 is bounded to the south by the northern boundary of Site 6, to the north by Wallace Creek, and to the west and east by Holcomb Boulevard and Piney Green Road, respectively (Figure C5). Site area is approximately 30 acres (Haliburton NUS 1992c). The area that would later be designated Site 82 was observed during the final RI at Site 6 to be littered with surface debris, such as empty and rusted drums near monitor wells 06-GW01 and 06-GW01D (Figure C5) (Baker Environmental, Inc. 1992b, 1993e).

The locations of monitor wells 82-MW01–82-MW03 and 82-MW30 are shown in Figure C5 in conjunction with Site 6 monitor wells. Monitor wells shown in Figure C5 in the Site 82 area with names printed in blue and whose names are prefaced by DR and SR are wells 82-DRW01–82-DRW04 and 82-SRW01–82-SRW06 listed in Tables C58–C60. Monitor well 82-MW31 is not shown in Figure C5 but was reportedly constructed near supply well HP-653. Construction information for this well is not available, but the well is possibly abandoned supply well HP-619 (old) (Haliburton NUS 1992c) (Tables C4 and C58, Plate 1). Other monitor wells constructed at Site 82 but not shown in Figure 5 are 82-DP01 and 82-DP02 (near 06-GW01D), 82-SP01 and 82-SP02 (near 06-GW34), and 82-TW01–82-TW03 (near 06-GW32). These wells were installed as observation wells for a large-scale aquifer test and were not sampled for groundwater contaminants (Figure C5) (Baker Environmental, Inc. 1998a).

Investigations of groundwater contamination specifically dedicated to Site 82 began during 1991 with a Site Inspection by Haliburton NUS (1992c). Monitor wells 82-MW01–82-MW03 and 82-MW30 were constructed open to the Brewster Boulevard aquifer system and sampled during June 1991. No VOCs of interest to this study were observed greater than detection limits in these monitor wells at this time (Tables C59, C60). Concentrations of DDT, DDT metabolites, and chlordane also were not detected. Six surface-water and colocated sediment sampling stations were established at Wallace Creek—three stations immediately north of Site 82 including one immediately downstream of Piney Green Road, two stations upstream of Piney Green Road, and one station between Holcomb Boulevard and the Camp Lejeune Railroad. Surface-water and sediment samples were collected during June 1991. Of the VOCs of interest that occurred in surface water, TCE, total 1,2-DCE, and vinyl chloride were detected at one or more stations at concentrations ranging from 6.0 to 74 μg/L. No pesticides of interest were detected. Total 1,2-DCE was detected at every station. No BTEX components were detected. Regarding the sediment samples, concentrations of total 1,2-DCE were greater than detection limits at each of the three stations directly north of Site 82 and ranged from 14 to 57 μg/kg. A metabolite of DDT was detected at two of these stations at concentrations of 30 and 69 μg/kg. A total of 26 subsurface soil borings were obtained from 6 boreholes and 3 monitor well borings generally distributed throughout the eastern part of Site 82. Two to five samples were obtained from each borehole between 4 and 17 ft bgs. Eighteen soil samples were selected for analyses. Concentrations of two VOCs of interest were observed above detection limits in 2 of 18 samples. Total 1,2-DCE and toluene occurred at 13 and 9.0 μg/kg, respectively. Concentrations of DDT and DDT metabolites were observed greater than detection limits in 1 of 18 samples, ranging from an estimated 77 to 110 μg/kg.

Following completion of the Site Investigation and a final FS, several approaches were selected to remediate contaminated groundwater at Site 82, including groundwater extraction and treatment, implementation of long-term groundwater monitoring, implementation of vapor extraction methods to enhance volatization of VOCs within contaminated soils, and excavation of soil contaminated with PCBs and pesticides. These and other remediation methods were included in an ROD between the Department of Navy and the U.S. Marine Corps, the State of North Carolina, and USEPA Region IV signed in 1993 (Baker Environmental, Inc. 1993ef). Subsequently, groundwater monitoring occurred routinely on a quarterly, semiannual, or annual basis at most monitor wells. Results of groundwater monitoring were published in a series of reports beginning in 1997 (Environmental Science and Engineering, Inc. 1992b; Baker Environmental, Inc. 1997e, 1998ghi, 1999de; Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000e; CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000b; Baker Environmental, Inc. and CH2M Hill, Inc. 2001a, 2002b; Michael Baker Jr., Inc. and CH2M Hill, Inc. 2003; Engineering and Environment, Inc. and Michael Baker Jr., Inc. 2004b; Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2004). A report summarizing the final basis of design for site remediation was completed in 1994 (Baker Environmental, Inc. 1994a).

Implementation of the extraction and treatment provisions of the ROD at Site 82 required the construction of six shallow and four deep extraction wells. Deep wells 82-DRW01–82-DRW04 were constructed during 1995 and 1996 open to the Upper Castle Hayne aquifer–River Bend unit between 80 and 110 ft bgs. Shallow wells 82-SRW01–82-SRW06 were constructed during the same period open to either the Brewster Boulevard aquifer system or the Tarawa Terrace aquifer (Table C58) (James A. Dunn, Jr., OHM Remediation Services Corp., Relocation of Additional Extraction Wells, written communication, April 1, 1996; Baker Environmental, Inc. 1998a). A treatment plant for the extracted groundwater was constructed between Piney Green Road and the number 1 monitor well array at Site 6 (Baker Environmental, Inc. 1994a). Groundwater extraction from shallow and deep wells commenced during October 1996 and continued with occasional interruptions for maintenance until at least October 2004. The cumulative weight of total VOCs removed by extraction wells by October 2004 was approximately 166,000 pounds (Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2004). Estimates of total VOCs extracted by weight after July 2001 were based on the sum of concentrations of all organic volatile constituents detected in the samples collected in extraction wells during a designated month. Prior to July 2001, total VOCs extracted were estimated based on the concentrations of selected constituents (Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2004). Concentrations of BTEX components in the shallow and deep extraction wells at Site 82 were consistently small or below detection limits in all wells. A benzene concentration of 11 µg/L was detected in several samples from deep well 82-DRW02 and is the maximum concentration of a BTEX component determined in any extraction well between 1998 and 2004. Pumping rates from extraction wells during 1997 ranged between 24 and 48 gpm at the shallow wells and between 75 and 81 gpm at the deep wells (Baker Environmental, Inc. 1997e). Between January 1996 and July 2004, pumping rates at extraction wells 82-DRW01–82-DRW03 ranged between 25 and 50 gpm. At well 82-DRW04, the pumping rate was comparatively constant at about 150 gpm. Pumping rates at the shallow wells during the same period ranged between 0.1 and 4.5 gpm (Michael Baker Jr., Inc. and Engineering and Environment Inc. 2004).

Sampling in extraction wells for contaminant analyses began in April 1998 and continued periodically until at least July 2004. Analytical schedules included only VOCs and metals. Concentrations of PCE, TCE, and related degradation products greater than detection limits occurred consistently and frequently in all extraction wells during this period (Table C59). High concentrations of TCE and total 1,2-DCE occurred in each of the deep extraction wells open to the Upper Castle Hayne aquifer. Concentrations of TCE ranged from 1,800 µg/L in well 82-DRW03 to 71,000 µg/L in well 82-DRW01. Corresponding concentrations of total 1,2-DCE ranged from 1,200 µg/L in well 82-DRW03 to 20,000 µg/L in well 82-DRW02. Similar contaminant concentrations occurred in shallow wells 82-SRW01–82-SRW06.

Concentrations of total VOCs in Site 6 and Site 82 monitor and extraction wells published during July 2002 and July 2004 were used, along with lithologic data, to create sections representing subsurface conditions between Wallace Creek and the number 2 well array at Site 6 (Figures C20–C22). During both years, the highest VOC (DNAPL) concentrations are shown to occur between extraction well 82-DRW02 and monitor well 06-GW01DA at depths ranging from 80 to 120 ft bgs. These depths are equivalent to the Tarawa Terrace aquifer and Upper Castle Hayne aquifer–River Bend unit at Site 82. Note also the general absence of confining unit lithologies such as clays and silts recorded in the background of the section diagrams. The dominant subsurface lithologies appear to be fine to medium sand, shells, and limestone. The absence of an extensive and competent confining unit at Sites 6 and 82 probably facilitated the downward migration of the originally shallow VOC mass to depths corresponding to the open intervals of nearby supply wells such as HP-651. Substantial downward migration of the center of the VOC mass appears to have occurred between 2002 and 2004 despite remediation efforts, as the base of the closed 10,000-µg/L contour during July 2004 is approximately 40 ft lower than during July 2002 (Figures C21, C22). Concentration contour maps of TCE distributions within the combined Brewster Boulevard lower aquifer and the Tarawa Terrace aquifer and within the Upper Castle Hayne aquifer–River Bend unit during January 2000 at IR Sites 6 and 82 are shown in Figures C23 and C24, respectively, and approximate the vertical representation of TCE plumes shown in sections in Figures C21 and C22.

Surface-water and sediment sample collection and analysis for VOCs from several stations at Wallace Creek directly north of Site 82 were initiated during January 2000 and continued periodically until July 2004. A total of 21 samples were collected during this period. Concentrations of all BTEX components in surface-water samples were less than detection limits with the exceptions of an estimated 0.10 µg/L of benzene during January 2004 and an estimated 5.0 µg/L of toluene during January 2002 (Baker Environmental, Inc. and CH2M Hill, Inc. 2002g; Engineering and Environment, Inc. and Michael Baker Jr., Inc. 2004b). Concentrations of PCE, TCE, and related degradation products were detected in several surface-water samples, generally at low concentrations. Concentrations of total 1,2-DCE occurred most frequently ranging from an estimated 0.4 to 22 µg/L in five samples. Concentrations of TCE ranged from an estimated 4.0 to 22 µg/L in three samples. The occurrence of VOCs in sediment samples from Wallace Creek was similar to occurrences in surface water. Concentrations of total 1,2-DCE occurred in four samples ranging from an estimated 1.0 to 8.0 µg/kg. Concentrations of TCE also occurred in four samples ranging from an estimated 2.0 to 7.0 µg/kg. Toluene was detected in two samples at estimated concentrations of 6.0 and 8.0 µg/kg (CH2M Hill Federal Group, Ltd and Baker Environmental, Inc. 2000b; Baker Environmental, Inc. and CH2M Hill, Inc. 2001a, 2002bg; Michael Baker Jr., Inc. and Ch2M Hill, Inc. 2003; Engineering and Environment, Inc. and Michael Baker Jr., Inc. 2004b; Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2004).

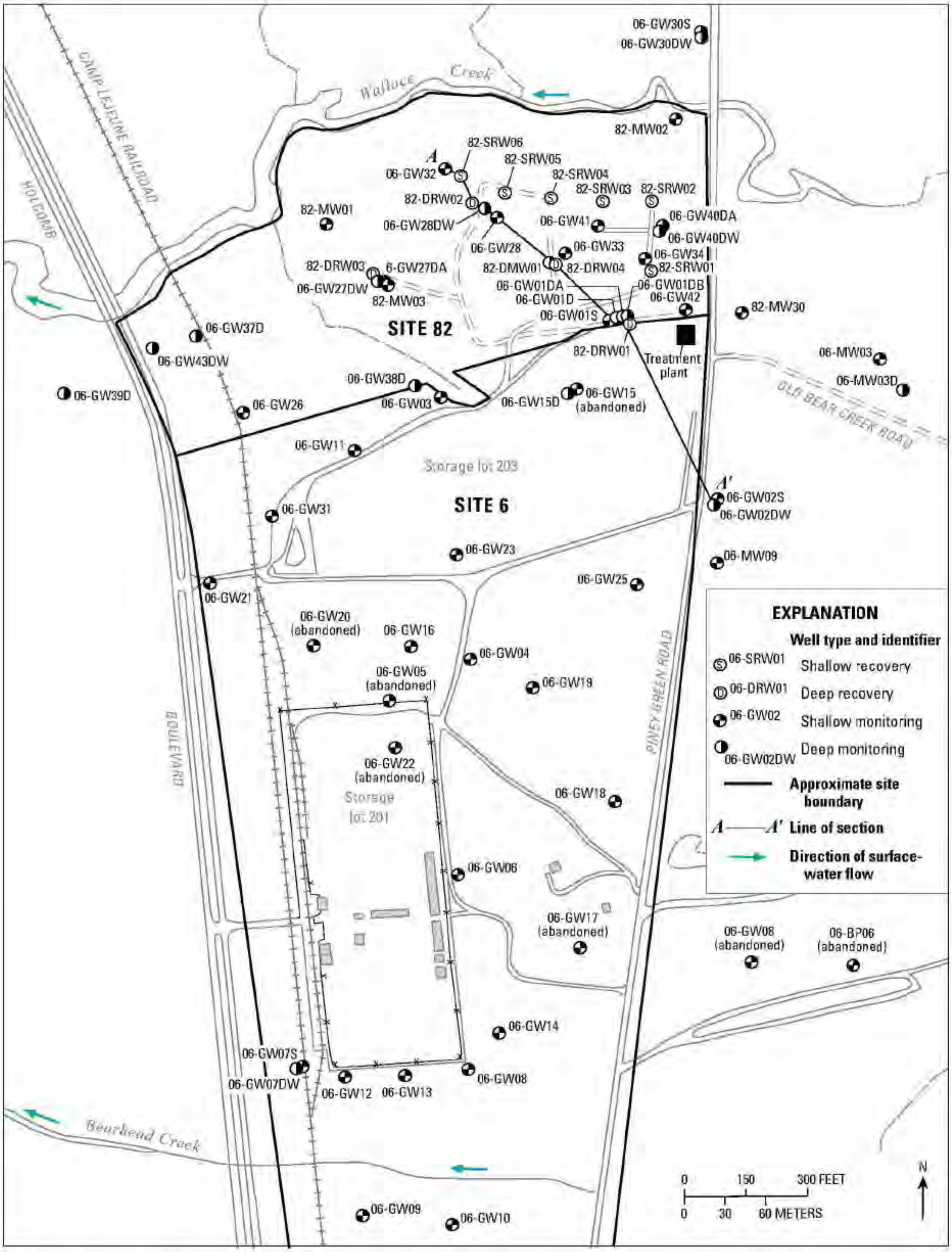


Figure C20. Location of section line *A–A'* at the VOC disposal area at Piney Green Road, Installation Restoration Sites 6 and 82, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2004). [VOC, volatile organic compound]

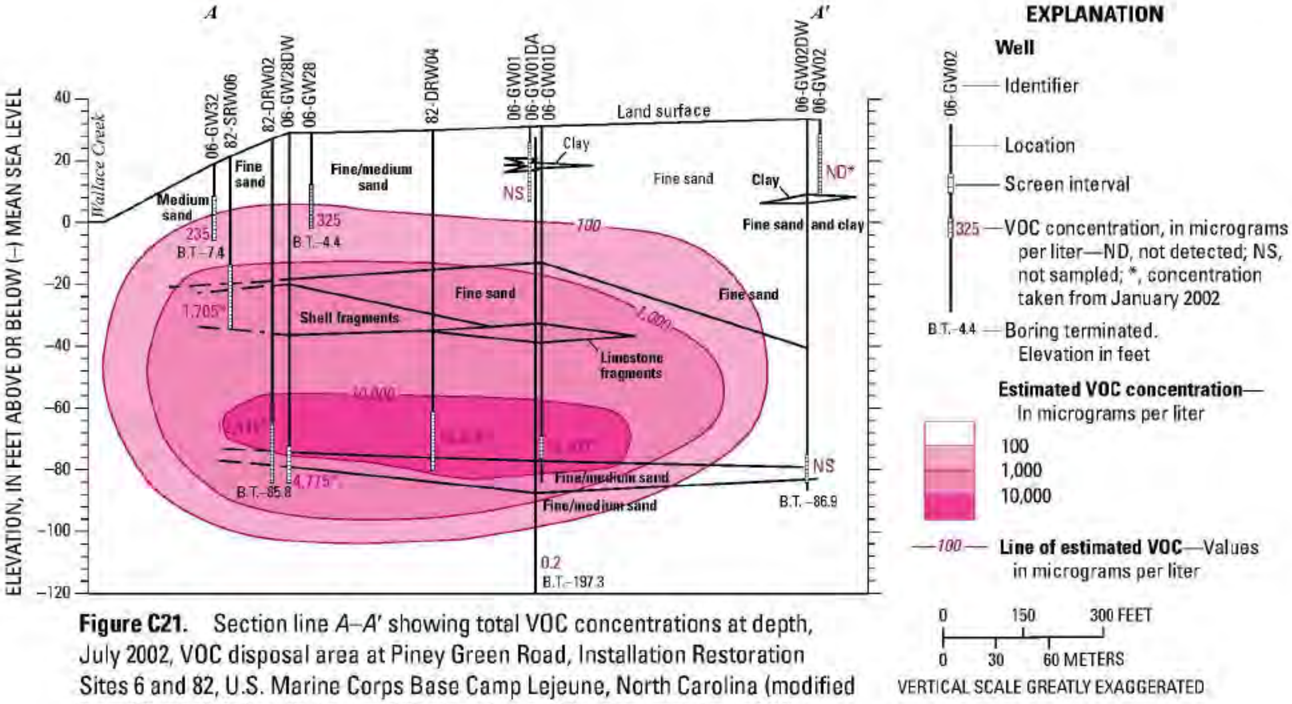


Figure C21. Section line *A–A′* showing total VOC concentrations at depth, July 2002, VOC disposal area at Piney Green Road, Installation Restoration Sites 6 and 82, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2004).

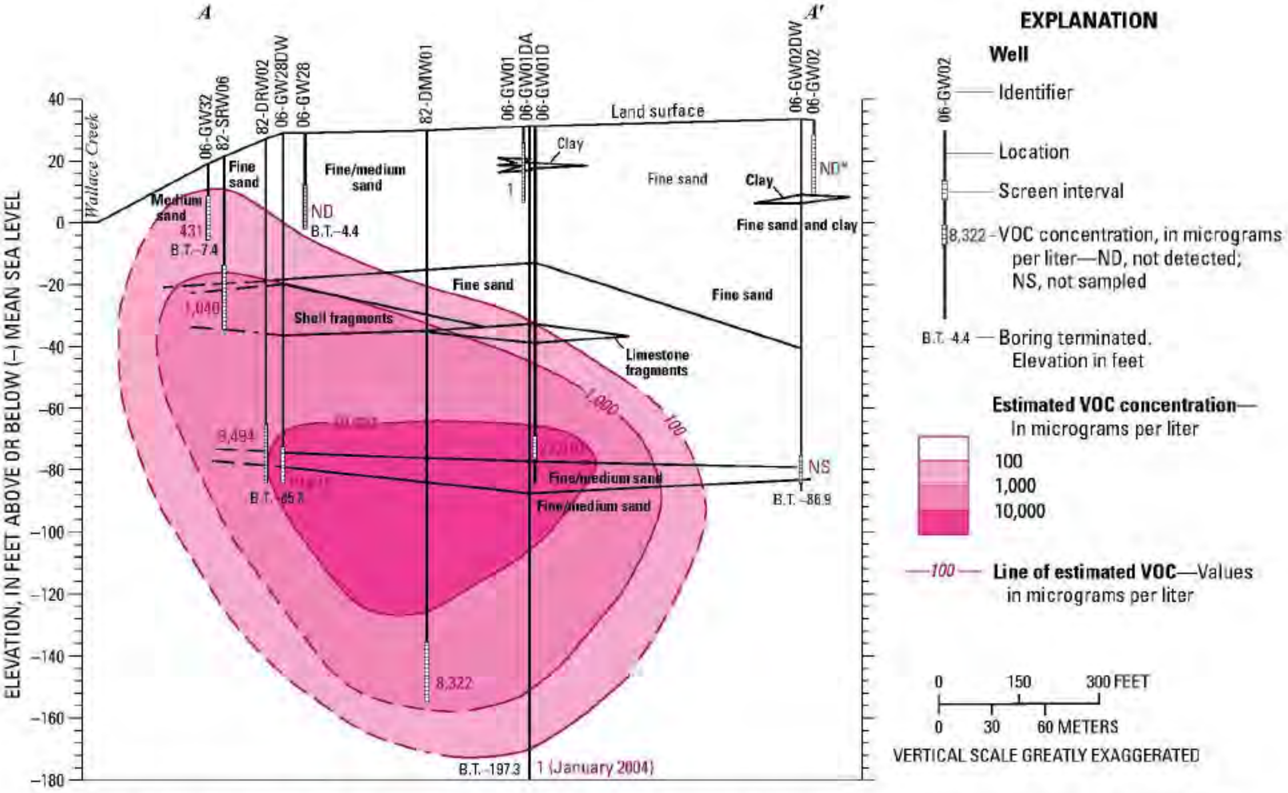
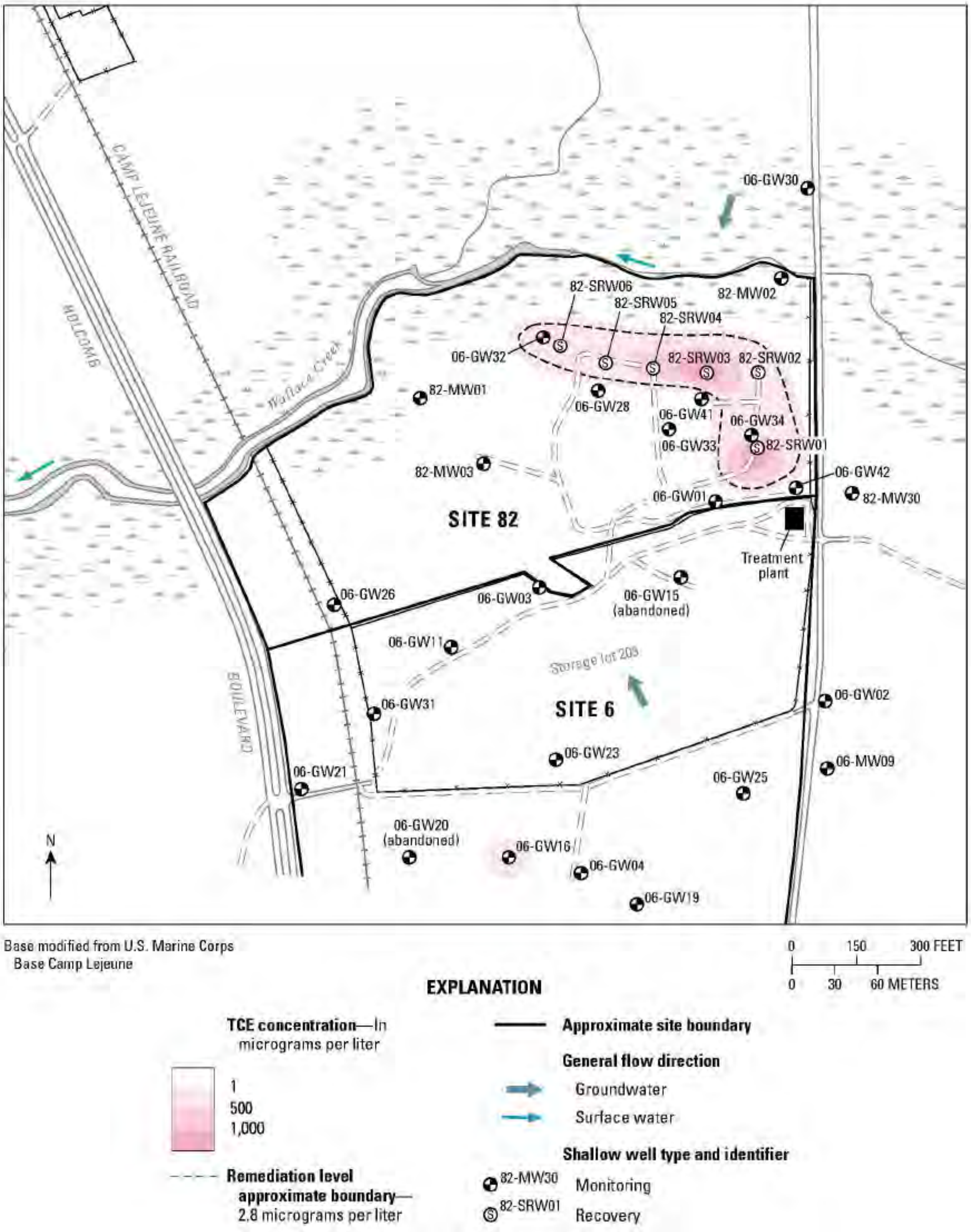


Figure C22. Section line *A–A′* showing total VOC concentrations at depth, July 2004, VOC disposal area at Piney Green Road, Installation Restoration Sites 6 and 82, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2004).



Base modified from U.S. Marine Corps Base Camp Lejeune

Figure C23. Trichloroethylene (TCE) distribution within the Brewster Boulevard lower aquifer and the Tarawa Terrace aquifer, Installation Restoration Sites 6 and 82, January 2000, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from CH2M Hill Federal Group, Ltd and Baker Environmental, Inc. 2000b).

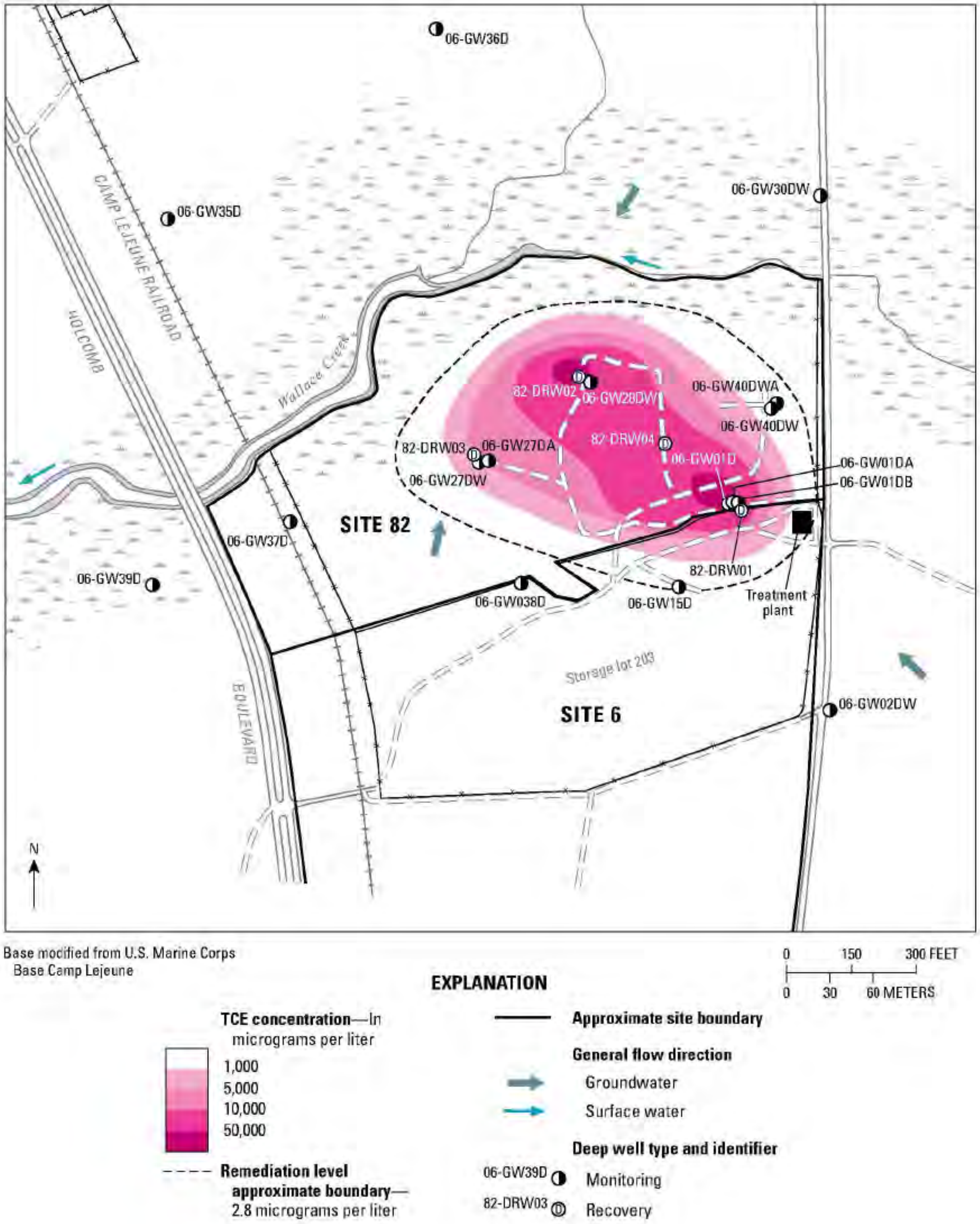
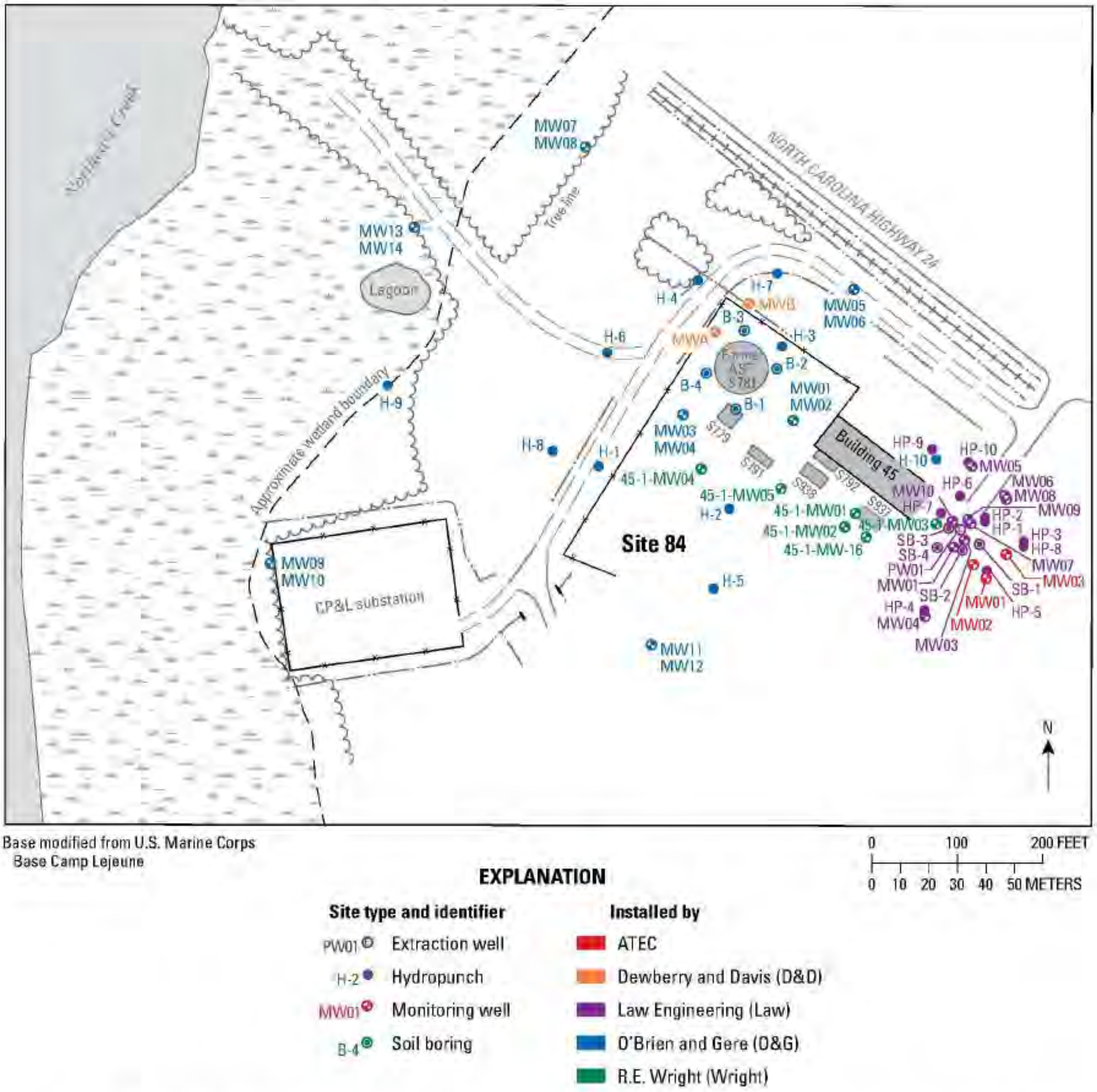


Figure C24. Trichloroethylene (TCE) distribution within the Upper Castle Hayne aquifer—River Bend unit, Installation Restoration Sites 6 and 82, January 2000, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from CH2M Hill Federal Group, Ltd and Baker Environmental, Inc. 2000b).

Installation Restoration Site 84/Building 45 Area—(Tank S781; Leaking Underground Storage Tank—USTs S941-1 and S941-2)

IR Site 84 is located immediately southwest of SR 24 in the northernmost part of the study area. Northeast Creek borders the entire western boundary of Site 84 (Figures C1, C25). Soil and groundwater contamination at Site 84 was caused primarily by accidental leakage of refined petroleum products from storage tank S781, located near the center of the site, and two smaller USTs, S941-1 and S941-2, located southeast of Building 45, which is a heavy equipment maintenance and storage building. Some limited contamination from PCBs was suspected after finding and removing approximately 20 transformers from a lagoon located on the site. The transformer disposal was probably related to the operation of a nearby Carolina Power and Lighting electric substation.

Tank S781 was in place when the Marine Corps acquired the property in the early 1940s and was previously used to store fuel oil for power generation. The USMCB Camp Lejeune used tank S781 to store waste oils primarily related to diesel engine maintenance and repair. Tank S781 was emptied in 1988, and leakage of waste oils possibly occurred during the emptying process. Tank capacity was 176,000 gal.



Base modified from U.S. Marine Corps
Base Camp Lejeune

Figure C25. Monitor well and hydropunch locations at Installation Restoration Site 84—Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Baker Environmental, Inc. 2001a).

Tank S941-1 contained diesel fuel, and tank S941-2 contained gasoline. Tank capacities were 6,000 and 550 gal, respectively. Both tanks were installed in 1941. A leak test during June 1990 indicated a line leak related to UST tank S941-2 at a rate of about 0.10 gal per hour. Apparently, tank S941-1 was removed in October 1992 (Law Engineering and Environmental Services 1994). Tank S941-2 was removed in July 1999 (J.A. Jones Environmental Services Company 1999).

Investigations of groundwater contamination at Site 84 by Dewberry and Davis (1991) began during November 1990 with the construction of two monitor wells in the immediate vicinity of tank S781. The location of these wells was reported as northwest and north-northwest of the tank and near the perimeter fence and probably are wells MW-A and MW-B shown on Figure C25 and reported in O'Brien and Gere Engineers, Inc. (1992, 1993) (Table C61). Monitor wells MW-A and MW-B were constructed open to the Brewster Boulevard aquifer system (Table C61). Groundwater samples were collected in these wells, probably shortly after construction in November 1990, and reportedly contained concentrations of VOCs of interest to this study no greater than detection limits. Soil samples were collected at several depths between land surface and 4 or 5 ft bgs during construction of wells MW-A and MW-B and at seven locations near tank S781, probably also during November 1990. Concentrations of total petroleum hydrocarbons (TPH) occurred in four samples from four locations and ranged from 20,000 to 2,400,000 μg/kg. The maximum soil TPH concentration occurred between 0 and 2 ft bgs in the borehole for monitor well MW-A (Dewberry and Davis 1991).

Additional investigations of groundwater and soil contamination at Site 84 were accomplished during 1991 by O'Brien and Gere Engineers, Inc. (1992). Field activities completed by December 1991 included (1) the construction of monitor wells AST-S781-MW01–AST-S781-MW14, (2) completion of soil data collection during monitor well construction at the seven deep well locations and four other locations (B-1 to B-4), and (3) groundwater sample collection using hydropunch (direct push) methods at ten locations (Figure C25, Table C61). Even-numbered monitor wells were constructed open to the Tarawa Terrace aquifer between 17 and 30 ft bgs and were paired with an odd-numbered shallow well open to the Brewster Boulevard aquifer system. Two soil samples were collected from each of the four soil boring locations and each of the seven deep monitor well locations. Results of the hydropunch investigations indicated that concentrations of VOCs of interest to this study occurred below detection limits at all locations; therefore, results are not reported herein in detail. Concentrations of PCE, TCE, and related degradation products and BTEX components in groundwater samples collected in monitor wells during December 1991 were less than detection limits in all but three locations. A concentration of 2.0 μg/L of total 1,2-DCE occurred in monitor well AST-S781-MW04 (Table C63). Ethylbenzene and toluene occurred in monitor wells AST-S781-MW03 and AST-S781-MW12, respectively, at concentrations of 16 μg/L and 2.0 μg/L, respectively (Table C62). Concentrations of TPH determined in soil samples ranged from 11,000 to 12,000,000 μg/kg. Maximum or near maximum TPH concentrations occurred in borehole B-4 between 4 and 11 ft bgs. During sample collection at borehole B-4, free-phase BTEX was noted in the samples collected at 4, 6, and 9 ft bgs. Concentrations of TPH were also high (255,000 μg/kg) in the sample collected in the borehole of monitor well AST-S781-MW04 between 14 and 16 ft bgs (O'Brien and Gere Engineers, Inc. 1992).

An additional 12 soil borings were completed during October 1992 by O'Brien and Gere Engineers, Inc. (1993) at locations near tank S781 as well as in a field north and northwest of the tank area. Two soil samples were collected in each borehole to a depth of 15 ft bgs. Concentrations of TPH determined in the soil samples from the tank area were similar to those determined during the previous investigation. Concentrations of TPH in soil samples from the field area ranged from less than detection limits to 59,000 μg/kg. Concentrations of TPH in 6 of 14 soil samples from 7 locations in the field area were less than detection limits and were less than 10,000 μg/kg in 3 samples.

Generally coincident with the work of O'Brien and Gere Engineers, Inc. (1992) at Site 84 was the investigation by American Testing and Engineering Corporation (1992) regarding leaking USTs S941-1 and S941-2 located northeast of Building 780 (not shown on Figure C25) and southeast of Building 45. Three shallow monitor wells were constructed in the immediate vicinity of the USTs during August 1991 open to the Brewster Boulevard aquifer system. These wells are identified in Tables C61–C63 as UST-Bldg45-MW01—UST-Bldg45-MW03 followed by "ATEC" in parentheses. For laboratory analysis, a single soil sample was collected just above the water table during monitor well construction. Each sample was contaminated with BTEX components ranging in concentration from 49 μg/kg of ethylbenzene in borehole UST-Bldg45-MW03 to 17,000 μg/kg of total xylenes in borehole UST-Bldg45-MW01. Groundwater samples collected in each monitor well also contained BTEX components ranging in concentration from less than detection limits for ethylbenzene in well UST-Bldg45-MW02 to 16,000 μg/L of toluene in well UST-Bldg45-MW01 (American Testing and Engineering Corporation 1992). The groundwater contamination by BTEX components in the vicinity of tank S941-2 resulted in the removal of the two USTs in October 1992 and the excavation of approximately 105 cubic yards of soil in the immediate vicinity of the tanks. During the excavation and closure process, free-phase BTEX was noted in the excavation cavity of UST S941-1 (Law Engineering and Environmental Services, Inc. 1996).

In April 1992, Law Engineering, Inc. (1993) completed a Leaking Underground Storage Tank Site Assessment at UST S941-2. Thirteen borings were completed at this time that included the collection of at least 16 surface and subsurface soil samples, including samples collected during the construction of monitor wells. Subsurface soil samples were collected at various depths between 1.5 and 10 ft bgs, depending on location. In addition, 10 hydropunch samples of shallow groundwater were collected, and

19 monitor wells (UST-Bldg45-MW04–UST-Bldg45-MW22) and one extraction well (UST-Bldg45-PW01) were constructed. Wells UST-Bldg45-MW06, UST-Bldg45-MW09, UST-Bldg45-MW21, and UST-Bldg45-MW22 were constructed as deep wells open to the Tarawa Terrace aquifer between 45 and 50.7 ft bgs. Other shallow wells were open to the Brewster Boulevard aquifer system and possibly the uppermost part of the Tarawa Terrace aquifer. Locations of monitor wells, hydropunch samples, and soil borings were mostly southeast of Building 45 and between Building 45 and the access road that intersects SR 24 to the northeast (Figure C25, Tables C61, C64). BTEX components were measured infrequently at concentrations greater than detection limits in soil and groundwater samples. TPHs were detected twice in soil borings at the location of monitor well UST-Bldg45-MW19 between 2 and 4 ft bgs and at boring SB-3 between 3 and 4.5 ft bgs (Figure C25). Concentrations of TPH were 1.6 and 700 µg/kg, respectively. Concentrations of BTEX components detected at hydropunch locations are listed in Table C64. Concentrations of each BTEX component were greatest at location HP-4, near monitor well UST-Bldg45-MW04, and ranged from 3.2 µg/L of ethylbenzene to 83 µg/L of toluene. Concentration trends with depth were not apparent (Table C64). Concentrations of BTEX components greater than detection limits in monitor wells ranged from 0.7 µg/L of toluene in well UST-Bldg45-MW16 to 3,800 µg/L of benzene in well UST-Bldg45-MW15. All BTEX components were detected in wells UST-Bldg45-MW15, UST-Bldg45-MW18, and UST-Bldg45-PW01; several were at concentrations greater than 500 µg/L (Table C62). Free-phase BTEX thickness was measured periodically in monitor well UST-Bldg45-MW02 between January 1994 and June 1995 and in monitor well UST-Bldg45-MW03 between January and September 1994 (Table C65). Free-phase thickness measured in well UST-Bldg45-MW02 in January 1994 was about 2.3 ft and declined to 0.02 ft by June 1995. The maximum free-phase BTEX thickness measured in well UST-Bldg45-MW03 was about 0.5 ft in January 1994. Between March 1994 and June 1995, about 8.4 gal of free-phase BTEX were recovered at Site 84 (Law Engineering and Environmental Services, Inc. 1996).

A pre-RI at Site 84 was undertaken during 1995 and 1998 to collect additional groundwater data and evaluate the extent and degree of contaminant concentrations in soils, water, and sediments of the onsite lagoon and adjacent Northeast Creek. Soil, sediment, and groundwater samples were collected during October 1995 and were analyzed only for PCBs. Twenty surface soil samples were collected from 10 boreholes located adjacent to and around the periphery of the onsite lagoon. Samples were collected between land surface and 1 ft bgs. The PCB compound Aroclor-1260 was detected at every borehole location at concentrations ranging from 110 to 12,000 µg/kg. PCBs were not detected in four sediment and surface-water samples collected at the same time from the lagoon. Concentrations of PCBs in four sediment and surface-water samples collected adjacent to and in Noetheast Creek also were determined below detection limits at this time. Groundwater samples collected in a temporary monitor well immediately adjacent to the lagoon and in wells AST-S781-MW07 and AST-S781-MW13 also contained no concentrations of PCBs greater than detection limits.

During April 1998, an additional 62 surface soil samples were collected from 31 locations adjacent to and somewhat removed from the periphery of the lagoon. Samples were collected between land surface and 1 ft bgs. Twenty-eight samples were selected for laboratory analyses. Of these, a total of 17 samples contained concentrations of PCBs greater than detection limits, ranging from an estimated 62 to 200,000 µg/kg. Surface-water and sediment samples also were collected at this time from three lagoon locations. No PCBs were detected in the surface-water samples. Toluene and total xylenes were detected in one surface-water sample, however, at concentrations of 2.7 and 3.5 µg/L, respectively. An estimated concentration of 910 µg/kg of total xylenes was determined in one sediment sample collected at the same location. Sediments collected at two lagoon locations contained the PCB compound Aroclor-1260 at concentrations of 4,300 and 5,900 µg/kg.

One sediment and four surface-water samples also were collected at locations adjacent to and in Northeast Creek during April 1998 and were analyzed only for PCB compounds. No PCBs were determined greater than detection limits in the surface-water samples. The PCB compound Aroclor-1260 was detected in the single sediment sample at a concentration of 40,000 µg/kg. Groundwater samples were collected at six monitor wells during April 1998 and analyzed for all VOCs of interest to this study. Benzene and ethylbenzene were both detected in wells AST-S781-MW03 and AST-S781-MW04 at concentrations of an estimated 3.4 µg/L and 3.4 µg/L and 1.5 µg/L and 6.7 µg/L, respectively (Figure C25; Tables C61–C63) (Baker Environmental, Inc. 1998de). Concentrations of PCE, TCE, and their degradation products were not detected.

Project plans for a final RI at Site 84 were published in June 2001 (Baker Environmental, Inc. 2001a). Field data collection as part of the final RI/FS began during July and August 2001. Direct push technology was used to obtain 149 surface and subsurface soil samples at 85 locations. Surface soil samples were collected between land surface and 1 ft bgs. Subsurface samples were collected from 1.0 ft bgs to within 0.5 ft of the water table. Direct push locations were concentrated in the vicinity of Building 45 and tank S781, the onsite lagoon, and between Site 84 and SR 24 northwest to Northeast Creek. An additional eight subsurface soil samples were collected during the drilling and construction of eight monitor wells (MW16–MW23) (Table C61). Subsurface soil samples were collected from the boreholes directly above the water table. The additional eight monitor wells were constructed open to the Brewster Boulevard aquifer system and the Tarawa Terrace aquifer. Not all soil samples were selected for analysis, and not all samples were analyzed using the same analytical schedule. No surface-water or sediment samples were collected during the final RI.

Occurrences of VOCs of interest detected in groundwater samples during the final RI were limited to one sample containing TCE, two samples containing BTEX components, and two monitor wells, MW17 and MW22 (Figure C25; Tables C62, C63). Ethylbenzene was detected in both wells at concentrations of an estimated 0.60 and 3.6 µg/L, respectively. The sample collected in monitor well MW17 also contained an estimated concentration of 0.19 µg/L of TCE and 1.8 µg/L of total xylenes. No PCBs occurred in groundwater samples at any locations at this time at concentrations greater than detection limits. Concentrations of DDT and metabolites of DDT greater than detection limits occurred in monitor wells MW16, MW18, and MW20 and ranged from an estimated 0.023 to 0.044 µg/L.

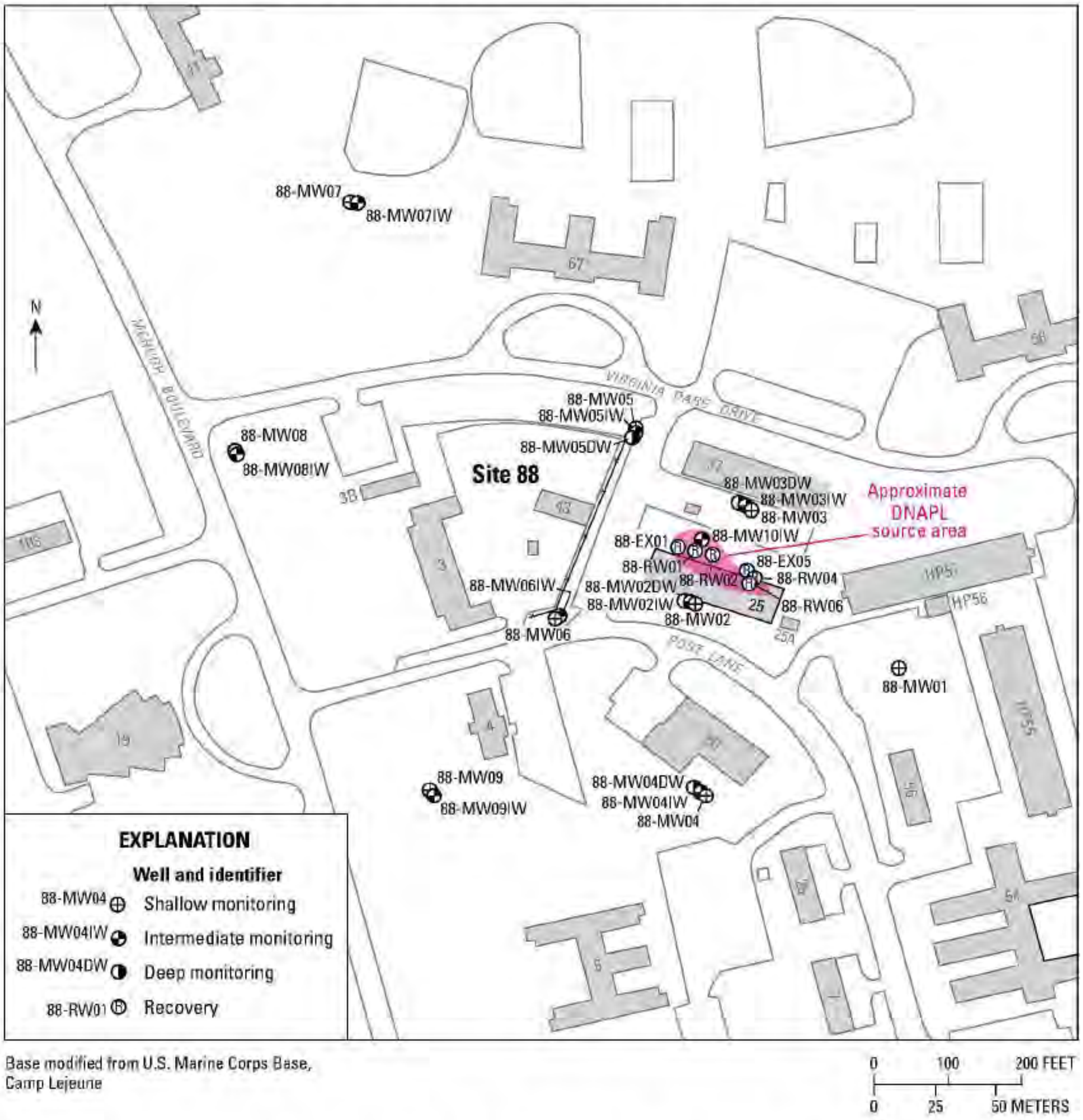
Surface soil samples were analyzed only for ethylbenzene and total xylenes, of the VOCs of interest to this study. Ethylbenzene was detected in 1 of 26 surface soil samples at an estimated concentration of 330 µg/kg. Xylenes were detected in 2 of 26 surface soil samples at estimated concentrations of 8.7 and 120 µg/kg. Detections occurred in samples collected in the vicinity of tank S781 and in the vicinity of Northeast Creek. Concentrations of the PCB component Aroclor-1260 were determined greater than detection limits in 68 of 95 surface soil samples ranging from an estimated 18 to 200,000 µg/kg. Occurrences were ubiquitous throughout the sampled area. The pesticides DDT and DDT metabolites were detected in 7 of 24 surface soil samples at concentrations ranging from 1.9 µg/kg to an estimated 3,000 µg/kg. Concentrations of chlordane greater than detection limits occurred in 10 of 24 surface soil samples ranging from an estimated 2.0 to 58,000 µg/kg. Most occurrences of pesticides were in samples collected around the perimeter of Building 45.

The BTEX components and total 1,2-DCE were the only VOCs of interest detected in subsurface soil samples. Total 1,2-DCE was detected in 1 of 24 subsurface soil samples at an estimated concentration of 91 µg/kg. The sample was collected about 50 ft southwest of tank S781. Of the BTEX components, ethylbenzene was determined most frequently in 5 of 24 subsurface soil samples. Concentrations of ethylbenzene greater than detection limits ranged from an estimated 0.89 to 1,300 µg/kg. The maximum concentration of a BTEX component was 3,100 µg/kg of total xylenes. Most occurrences of BTEX components in subsurface soils occurred in samples collected in the vicinity of Building 45. The PCB compound Aroclor-1260 was determined in 11 of 39 subsurface soil samples. Concentrations greater than detection limits ranged from an estimated 13 to 45,000 µg/kg and occurred most frequently in samples collected in the vicinity of Building 45 and northwest of tank S781. Chlordane concentrations greater than detection limits occurred in 8 of 33 subsurface soil samples ranging from an estimated 3.3 to 18,000 µg/kg. Detections of chlordane occurred in samples collected in the vicinity of Building 45 and near the periphery of the onsite lagoon. Concentrations of DDT and metabolites of DDT greater than detection limits occurred in 7 of 33 subsurface soil samples and ranged from an estimated 1.7 to 120 µg/kg. Locations of occurrences were similar to those recorded for chlordane (Baker Environmental, Inc. and CH2M Hill, Inc. 2002d,e,f).

Following completion of the final RI, a final FS was initiated to determine the appropriate methodology to remediate groundwater and soil contamination at Site 84 and adjacent areas (Baker Environmental, Inc. and CH2M Hill, Inc. 2002d). Reports that describe results of groundwater monitoring at Site 84 following completion of the final RI in 2001 and final FS can be obtained by a formal request to the Environmental Management Division, USMCB Camp Lejeune, North Carolina.

Installation Restoration Site 88—Building 25

Building 25 served as the only base dry-cleaning facility from 1943 until at least 1998 (Environmental and Safety Designs, Inc. 1995; Thomas H. Burton, Environmental Management Division, USMCB Camp Lejeune, written communication, April 26, 2001). The solvent used for dry cleaning was changed in 1970 from the LNAPL Varsol to PCE. Building 25 is located directly east of McHugh Boulevard and northwest of Holcomb Boulevard (Figures C1, C26, Plate 1). Building dimensions are 180 ft long and 50 ft wide. In 1983, PCE use for dry cleaning at Building 25 was approximately 34 tons, or about 5,000 gal. Solvent losses during dry cleaning were reported to occur only as a result of volatilization during the dry cycle. Solvent was reclaimed by filtration and distillation. Spent filters from the distillation process were dried at high temperatures, bagged, and removed to a landfill (Environmental and Safety Designs, Inc. 1995). Spent PCE also was reportedly disposed of in floor drains connected to the sewer system. Five 750-gal USTs used to store dry-cleaning solvents were reportedly installed behind Building 25 during the 1940s. The tanks were removed during November 1995. Soil contamination by Varsol and PCE was identified at this time, and groundwater contamination was suspected. From the 1970s to the mid-1980s, additional storage of PCE occurred in several 150-gal ASTs located outside Building 25 (Baker Environmental, Inc. 1995d, 1996hl, 1998co; Environmental and Safety Designs, Inc. 1995).



Base modified from U.S. Marine Corps Base, Camp Lejeune

Figure C26. Monitor well locations at Installation Restoration Site 88—Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from CH2M Hill, Inc. and Baker Environmental, Inc. 2001b). [DNAPL, dense nonaqueous phase liquids; See Figure C27 for enlargement of Building 25 area]

Investigations of groundwater contamination at Site 88 began during the removal of the aforementioned five USTs located along the northern perimeter of Building 25. To follow up on observations of soil contamination made during removal of the USTs, test monitor wells 88-TW01–88-TW04 were constructed near the perimeter of Building 25—three in the vicinity of the removal area (88-TW01–88-TW03) and one on the opposite side of the building (88-TW04). A single soil sample was collected for analysis at each borehole during drilling between 3 and 8 ft bgs. Each monitor well was constructed open to the Brewster Boulevard upper aquifer (Table C66). Concentrations of PCE were detected in all monitor wells during November 1995 and ranged from 416 to 29,200 μg/L. Total 1,2-DCE also was detected in groundwater samples at this time from monitor wells 88-TW02 and 88-TW03 at concentrations of 154 μg/L and 10,000 μg/L, respectively. A single concentration of TCE greater than detection limits was determined in monitor well 88-TW03 at 2,750 μg/L (Tables C67, C69). Concentrations of PCE in the soil samples ranged from less than 5.0 to 55 μg/kg. No pesticides were detected in the monitor wells.

An RI sample strategy plan was developed during early 1993 to determine the extent of groundwater contamination at Building 25. The plan recommended a two-phase investigation such that soil borings and temporary monitor wells would be established during Phase I along with groundwater sampling using direct push technologies. Phase II would include the construction of permanent monitor wells and groundwater sampling (Baker Environmental, Inc. 1996l).

The Phase I investigation was conducted during July and August 1996. A total of 19 soil samples were collected in borings that were later converted to temporary monitor wells. Most monitor wells were constructed in the immediate vicinity of Building 25. All temporary shallow monitor wells were constructed open to the Brewster Boulevard upper aquifer. Temporary intermediate wells (IW) were constructed open to the Brewster Boulevard lower aquifer (88-TW04IW–88-TW19IW) (Tables C66, C67). Concentrations of PCE in groundwater greater than detection limits occurred in 15 of 19 monitor wells and ranged from 0.10 μg/L to more than 53,700 μg/L. Concentrations in five samples exceeded 1,000 μg/L. Concentrations of TCE were detected in 10 of 19 monitor wells ranging from 0.2 μg/L to more than 3,000 μg/L. The concentration of *cis*-1,2-DCE detected at monitor well 88-TW15 was 3,725 μg/L. Concentrations of PCE were detected in three of the four intermediate monitor wells, indicating vertically downward migration of the DNAPL compounds in the vicinity of Building 25. Concentrations of PCE were not detected in intermediate well 88-TW19IW, which was located approximately 600 ft northwest of Building 25 near McHugh Boulevard (Table 69). Concentrations of PCE greater than detection limits also were determined in 13 of 18 soil samples and ranged from 0.10 μg/kg to about 238 μg/kg. Concentrations of TCE were detected in 6 of 18 soil samples ranging from 0.10 to 8.5 μg/kg (Table 67). Concentrations of BTEX components in the soil or groundwater greater than detection limits were not reported during the Phase I investigations (Table C70) (Baker Environmental, Inc. 1996h).

Following an analysis of the Phase I results, tasks necessary to complete Phase II were developed and published (Baker Environmental, Inc. 1997b). All field data collection for the Phase II investigation was completed during April and May 1997. An additional 18 temporary monitor wells were constructed during April 1997 (88-TW20–88-TW28IW) (Table C66). The shallow wells were constructed open to the Brewster Boulevard upper aquifer through to the upper part of the Brewster Boulevard lower aquifer. The intermediate (IW) wells were constructed open to the base of the Brewster Boulevard lower aquifer. Permanent monitor wells also were installed during the Phase II investigations (88-MW01–88-MW10IW) (Figure C26, Table C66). Screen intervals constructed for the permanent shallow and intermediate (IW) monitor wells were open to the Brewster Boulevard upper and lower aquifers, respectively, similar to those described previously for the correspondingly named temporary wells. Several deep wells (DW) also were constructed open to the Tarawa Terrace aquifer.

Shallow, intermediate, and deep wells were constructed in close proximity at several locations to create well clusters. Water-level measurements at these clusters obtained during several periodic measurements between May and July 1997 consistently indicated a vertically downward potentiometric gradient throughout Site 88 between the Brewster Boulevard aquifer system and the Tarawa Terrace aquifer. Within the Brewster Boulevard aquifer system, substantial vertically downward potentiometric gradients also occurred between the Brewster Boulevard upper and lower aquifers. The temporary wells were abandoned for monitoring purposes by July 1997.

Additional sampling for groundwater contaminants in newly constructed permanent and temporary monitor wells during Phase II further defined the areal and vertical extent of PCE migration in the vicinity of Site 88. Concentrations of PCE and related degradation products were not observed greater than detection limits in any of the deep monitor wells open to the Tarawa Terrace aquifer between 80 and 97 ft bgs. Estimated concentrations of 5.0 and 7.0 μg/L of 1,1-DCE were detected in intermediate monitor wells 88-MW05IW and 88-MW07IW, respectively (Table C69). Accordingly, results of the Phase I and Phase II investigations indicated substantial soil and groundwater contamination by PCE and PCE degradation products largely within the shallow Brewster Boulevard upper aquifer, with the greatest concentrations occurring immediately north and northwest of Building 25 (Baker Environmental, Inc. 1998c). In addition, a layer of clay and silty clay was observed consistently at a depth of about 20 ft bgs during soil borings for well construction during Phases I and II. The lack of PCE contamination in the intermediate and deep wells open to the Brewster Boulevard lower aquifer and Tarawa Terrace aquifer and the substantial accumulation of PCE and PCE related degradation products at high concentrations in the Brewster Boulevard upper aquifer at Site 88 indicate that this clay layer is a competent aquitard, preventing further downward migration of DNAPLs. For this study, this clay layer is considered equivalent to the Brewster Boulevard upper confining unit. Additional soil borings (88-SB01–88-SB06) and cone penetration tests (CPTs) were conducted during May and November 1997 to further define the extent and thickness of the clay aquitard (Table C67). Location coordinates of the 88-SB borings and CPT investigation locations are listed in Table C67 (Baker Environmental, Inc. 1998c).

Immediately following completion of Phase II of the RI, investigations were undertaken during the latter half of 1997 to characterize the extent of soil and groundwater contamination specifically in the vicinity of the DNAPL source area determined during the RI. Soil borings 88-IS01–88-IS31 were completed within the Brewster Boulevard upper aquifer using direct push technology during July and August 1997 (88-IS01–88-IS13) and November 1997 (88-IS14–88-IS31) (Figure C27, Table C67). Borings were located within about 50 ft of the northwestern third of Building 25 as well as within Building 25. Borings 88-IS05, 88-IS09, and 88-IS29–88-IS31, obtained inside of Building 25, all contained PCE at depths ranging from about 2 to 19 ft bgs. Concentrations of PCE in interior soil samples ranged from 24 to 4,361 µg/kg (Table C68). Soil samples obtained exterior to Building 25 also contained PCE concentrations at depths ranging from near land surface to about 20 ft bgs. A concentration trend with depth was not obvious, but the highest concentrations, ranging to more than 25,000 µg/kg, occurred below 15 ft bgs (Table C68). The influence of the clay and silty clay aquitard noted previously probably accounts, at least partially, for the accumulation of relatively excessive concentrations of PCE with greater depth (Figures C28–C29). Boring logs created during the

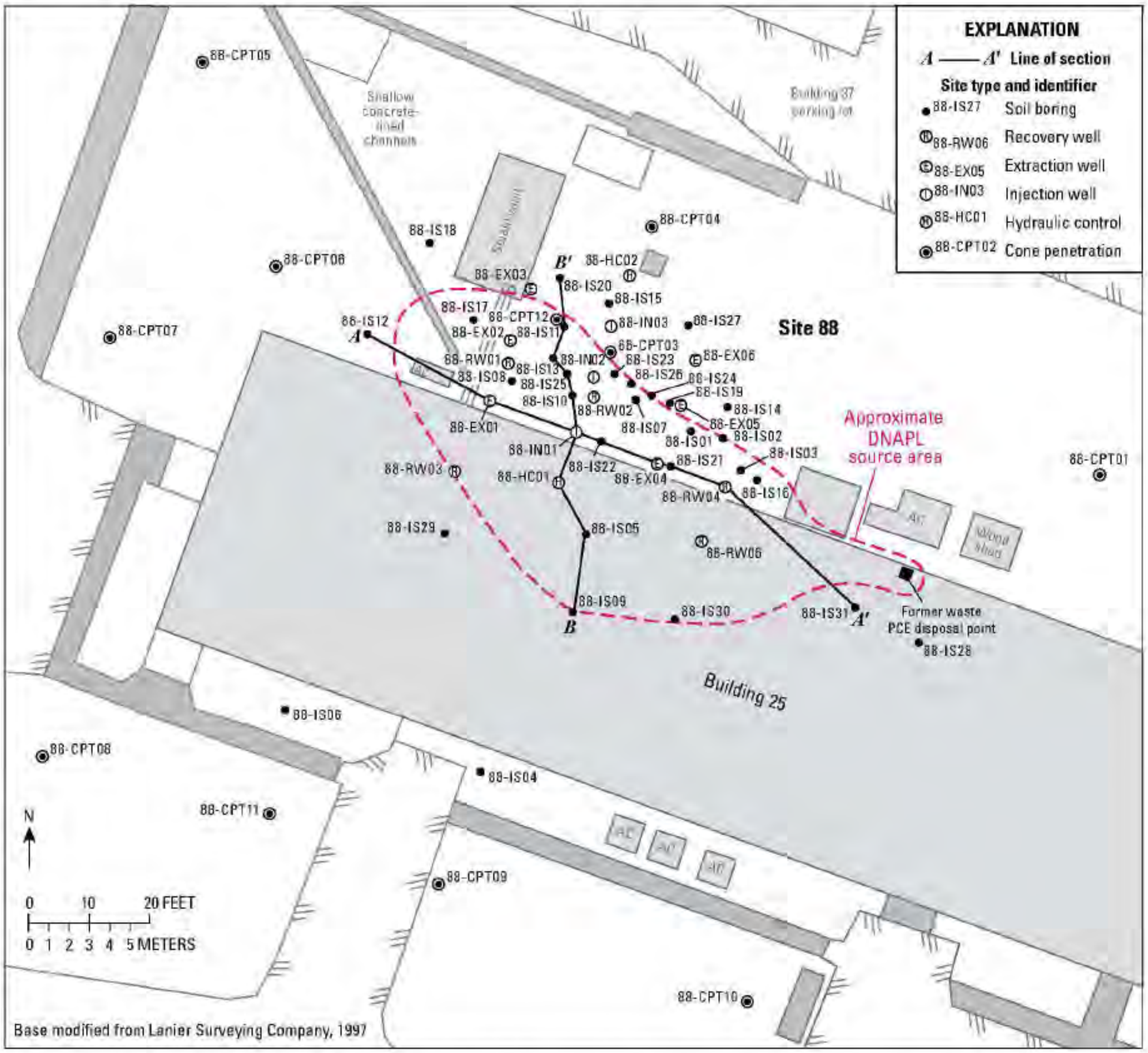


Figure C27. Locations of section lines *A–A′* and *B–B′* at Building 25, Installation Restoration Site 88, U.S. Marine Corps Base Camp Lejeune, North Carolina (Modified from Duke Engineering Services, Inc. and Baker Environmental, Inc. 1999a).

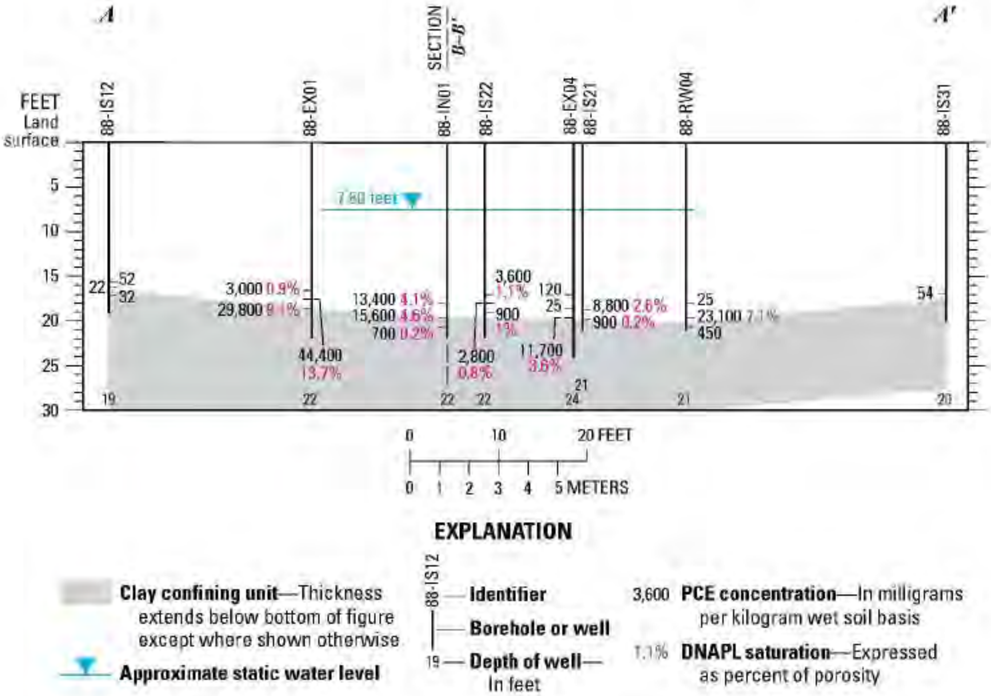


Figure C28. Section line *A–A′* showing PCE concentrations at depth, Building 25, Installation Restoration Site 88, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Duke Engineering Services, Inc. and Baker Environmental, Inc. 1999a).

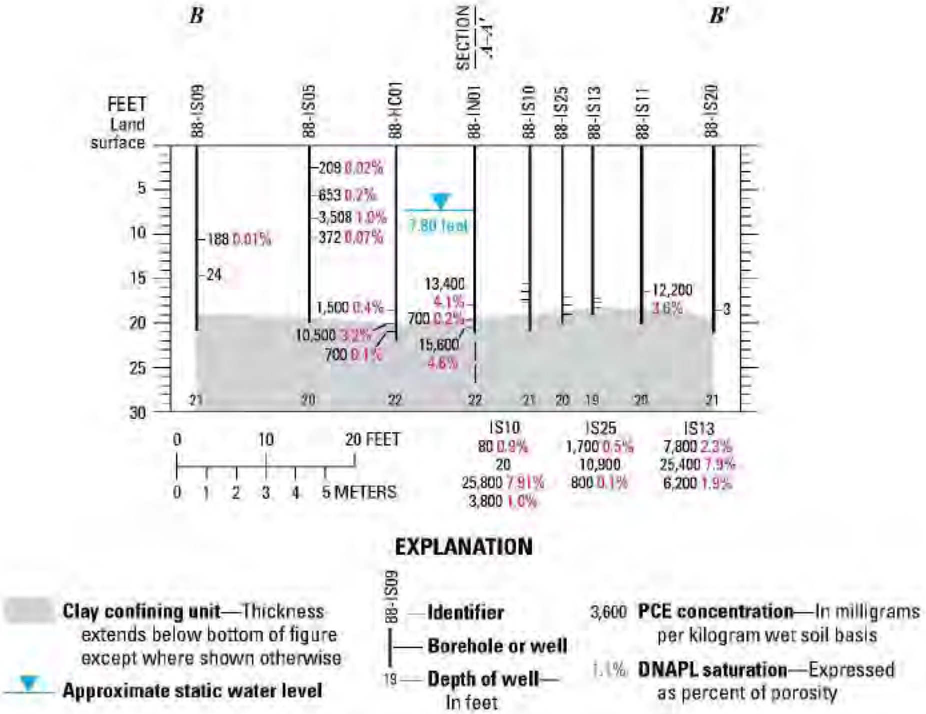


Figure C29. Section line *B–B′* showing PCE concentrations at depth, Building 25, Installation Restoration Site 88, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Duke Engineering Services, Inc. and Baker Environmental, Inc. 1999a).

collection of soil samples have notes about "strong chemical odors" and "strong hydrocarbon smells," and similar observations were made at or in the immediate vicinity of the water table. These observations were later related to the occurrence of Varsol, which apparently had leaked from the USTs formerly located nearby and had accumulated at the water table.

Additional wells 88-IW01, 88-RW01, and 88-RW02 were constructed open to the Brewster Boulevard upper aquifer during August 1997 as discharge and observation wells for an aquifer test (Table C66). Following construction, concentrations of PCE determined at wells 88-RW01 and 88-RW02 were 170,000 and 150,000 µg/L, respectively (Table C69) (Duke Engineering and Services, Inc. and Baker Environmental, Inc. 1999a).

The discovery of Varsol at Site 88 prompted a separate investigation to characterize the occurrence and extent of Varsol contamination of soil and groundwater. The source area and extent of Varsol contamination in groundwater were highly coincident in space with the PCE source area noted previously (Figures C27, C28), indicating that leaking USTs were also a possible source of subsurface PCE contamination near Building 25. Varsol concentrations were detected in 6 of 16 soil samples collected at IS boreholes (Table C67) and ranged from 27 to 4,900 µg/kg. Varsol concentrations detected in groundwater ranged from 360 to 4,900 µg/L (Baker Environmental, Inc. 1998o).

A network of monitor, injection, and extraction wells was designed to test remediation alternatives at Site 88, including an interwell tracer test designed to test the feasibility of using surfactants to dissolve and extract free-phase DNAPLS. Additional wells necessary to implement extraction and the tracer test were constructed largely during December 1997. Extraction wells (88-EX01–88-EX06) were constructed within and around the northern perimeter of the DNAPL source area. Tracer injection wells (88-IN01–88-IN02), hydraulic control wells (88-HC01–88-HC02), and recovery wells (88-RW01–88-RW06) were located within the DNAPL source area as well as interior to Building 25 to facilitate interpretation of test results. Later, wells 88-EX04R and 88-MW10IW were constructed, respectively, as a replacement for well 88-EX04 and to monitor test results below the clay aquitard (Brewster Boulevard upper confining unit). Wells 88-WP01AQT and 88-WP02AQT were constructed within the clay aquitard also to monitor test conditions (Table C66). Free-phase DNAPL was encountered and measured following construction of several of these wells (Table C70). Tests of the DNAPL extraction network using six extraction wells (88-EX01–88-EX06, Table C66) were conducted during January and February 1998, resulting in the removal of an undetermined volume of DNAPL that was possibly as much as 60 gal.

The interwell tracer test was initiated during May 1998 and continued for 40 days. Final results of the tracer test confirmed the RI and later characterizations of DNAPL occurrence at Site 88 and provided the bases for the design of a surfactant-enhanced aquifer remediation (SEAR) demonstration project. The estimated pore volume affected by the interwell tracer test was 4,800 gal. Of this volume, an estimated 74 to 88 gal was DNAPL (Baker Environmental, Inc. 1998c; Duke Engineering and Services, Inc. and Baker Environmental, Inc. 1999a). A sampling and analysis plan for the SEAR demonstration project was completed by March 1999. The SEAR demonstration began in April 1999 and continued through August 1999 (Duke Engineering and Services, Inc. and Baker Environmental, Inc. 1999ab). A total of 268,000 gal of water was extracted during the demonstration at the six extraction wells at an average rate of 1.0 gpm. Of the volume removed, approximately 32 gal was PCE solubilized in groundwater and 44 gal was free-phase PCE. Routine monitoring at permanent monitor wells began in July 1999 during the SEAR demonstration and continued into 2001 (Tables C68, C70; Baker Environmental, Inc. and CH2M Hill, Inc. 2000b; Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000j, 2001b; CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2001c; CH2M Hill, Inc. and Baker Environmental, Inc. 2001b). A final RI work plan for Site 88 was published by CH2M Hill, Inc. (2003). Documents and reports that describe the results of groundwater monitoring and other remediation activities at Site 88 following publication of the final RI work plan can be obtained by a formal request to the Environmental Management Division, USMCB Camp Lejeune, North Carolina.

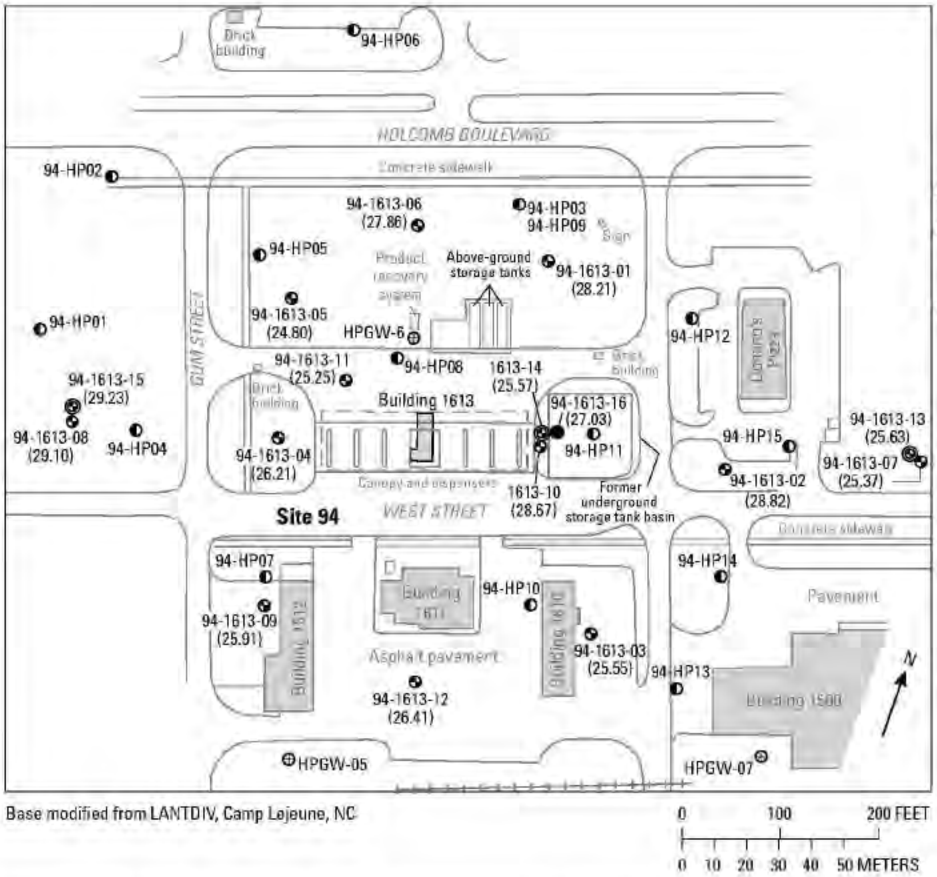
Analyses for pesticides in groundwater were not determined at Site 88. Numerous analyses for concentrations of BTEX components in groundwater were accomplished; however, only toluene was observed greater than detection limits at temporary well 88-TW22IW at a concentration of 7.0 µg/L (Table C71).

Installation Restoration Site 94/Building 1613 Area Leaking Underground Storage Tank—USTs 1613-1–1613-4

Building 1613 is located in the far southwest corner of the HPIA and serves as the Base Exchange Service Station (Figures C1 and C30, Plate 1). Refined petroleum products were stored at Building 1613 in one 10,000-gal UST, two 30,000-gal USTs, and one 9,000-gal UST. The USTs were reportedly installed during the 1950s and were removed during January 1995. Soil contamination by refined petroleum products was observed during the UST removal process and caused the implementation of a Site Assessment (Richard Catlin and Associates, Inc. 1996a).

Groundwater samples at 15 hydropunch (direct push) locations were collected and analyzed at the beginning of the site assessment (April 1995) as a guide to locate permanent monitor wells (Figure C30). Substantial concentrations of BTEX components greater than detection limits were observed at hydropunch locations 94-HP08 and 94-HP11, located in the immediate vicinity of the pump island at the service station, and ranged from 1,100 to 20,700 µg/L (Figure C30, Table C72). These concentrations indicated that the source of groundwater BTEX contamination at Site 94 was probably leakage from one or more of the four USTs previously installed at the pump island or possibly from pressure lines connecting the USTs and service pumps. A concentration of 1.1 µg/L of 1,1-DCE was detected at the 94-HP10 location, and 29.2 µg/L of TCE was detected in the sample collected at location 94-HP01D (Table C73). The source of the TCE and 1,1-DCE is unknown but possibly originates in Building 1500, southeast of Building 1613, which houses a base laundry facility and is a storage area for dry-cleaning solvents.

The installation of monitor wells at Site 94 occurred during April 1994 and included 14 wells constructed open to the Brewster Boulevard aquifer system (94-Bldg1613-01—94-Bldg1613-12, 94-Bldg1613-15, and 94-Bldg1613-16) and two wells probably open to the Tarawa Terrace aquifer (94-Bldg1613-13 and 94-Bldg1613-14) between 45 and 50 ft (Table C74). Concentrations of BTEX components greater than detection limits were observed in only three wells—94-Bldg1613-10, 94-Bldg1613-11, and 94-Bldg1613-16 (Table C75). Concentrations of all BTEX components were observed in wells 94-Bldg1613-10 and 94-Bldg1613-11. Maximum concentrations of all components occurred in well 94-Bldg1613-10, located immediately adjacent to the pump island, and ranged from 804 to 9,290 µg/L. A BTEX free-phase recovery system was operating at Site 94 during the site assessment and was centered on monitor well 78-GW06 (HPGW-6 in Figure C30). Recovery began during November 1994, at which time the thickness of free-phase BTEX product in well 78-GW06 was approximately 6.0 ft (Richard Catlin and Associates, Inc. 1996ab). By February 1996,



Base modified from LANTDIV, Camp Lejeune, NC

Figure C30. Monitor well and hydropunch locations at Installation Restoration Site 94—Building 1613 area, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Richard Catlin and Associates, Inc. 1996a).

approximately 340 gal of BTEX free-phase liquids had been recovered. Analyses for PCE, TCE, and related degradation products were below detection limits or concentrations were not determined at most Site 94 monitor wells. However, TCE was determined in monitor wells 94Bldg1613-09 and 94Bldg1613-13—94Bldg1613-16 at concentrations ranging from 1.3 to 79 μg/L. TCE concentrations in wells 94Bldg1613-13—94Bldg1613-15 occurred in samples collected during May 1995 and September 2003 and increased in wells 94Bldg1613-13 and 94Bldg1613-15 during that period. Degradation products 1,1-DCE, *trans*-1,2-DCE and *cis*-1,2-DCE also were observed in these monitor wells at the same time ranging in concentration from 0.70 to 38 μg/L (Table C76). Pesticide concentrations in groundwater were not determined at Site 94.

Site G—Proposed Camp Lejeune Landfill

Site G is located east of IR Sites 6 and 82 within a triangular-shaped area bounded on the west by Piney Green Road, to the north by Wallace Creek, and to the east and south by Shell Rock Road (Figures C1 and C31, Plate 1). Investigations of possible groundwater contamination at Site G began in 1991 during a preliminary site study. Monitor wells G-MW01 and G-MW02 were constructed at that time. Construction features of these wells are unknown, but they were probably installed open to the Brewster Boulevard aquifer system. Small concentrations of pesticides were detected in monitor well G-MW01 at the time. Seven soil borings were advanced during the 1991 investigation, but the borehole locations and analytical results of samples, if any, are unknown.

A Site Characterization Study began during 1992 and included the advancement of 11 soil borings, construction of 7 monitor wells (G-MW03D–G-MW09), and construction of 2 piezometers (G-BP08–G-BP09) (Table C77). Monitor wells and probably the piezometers were constructed open to the Brewster Boulevard aquifer system. Samples collected in existing monitor wells during May 1992 were analyzed for pesticides and VOCs. No VOC contaminant or pesticide concentrations greater than detection limits were observed in any sample (Tables C78, C79). After 1992, several Site G monitor wells were periodically monitored in conjunction with routine monitoring at Sites 6 and 82 (Baker Environmental, Inc. 1993k; Michael Baker Jr., Inc. and CH2M Hill, Inc. 2003; Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2004). A sample collected in well G-MW03S during July 2004 contained an estimated concentration of 0.30 μg/L of toluene. A sample collected from the same well in January 2003 contained an estimated 0.60 μg/L of TCE (Tables C78, C79).

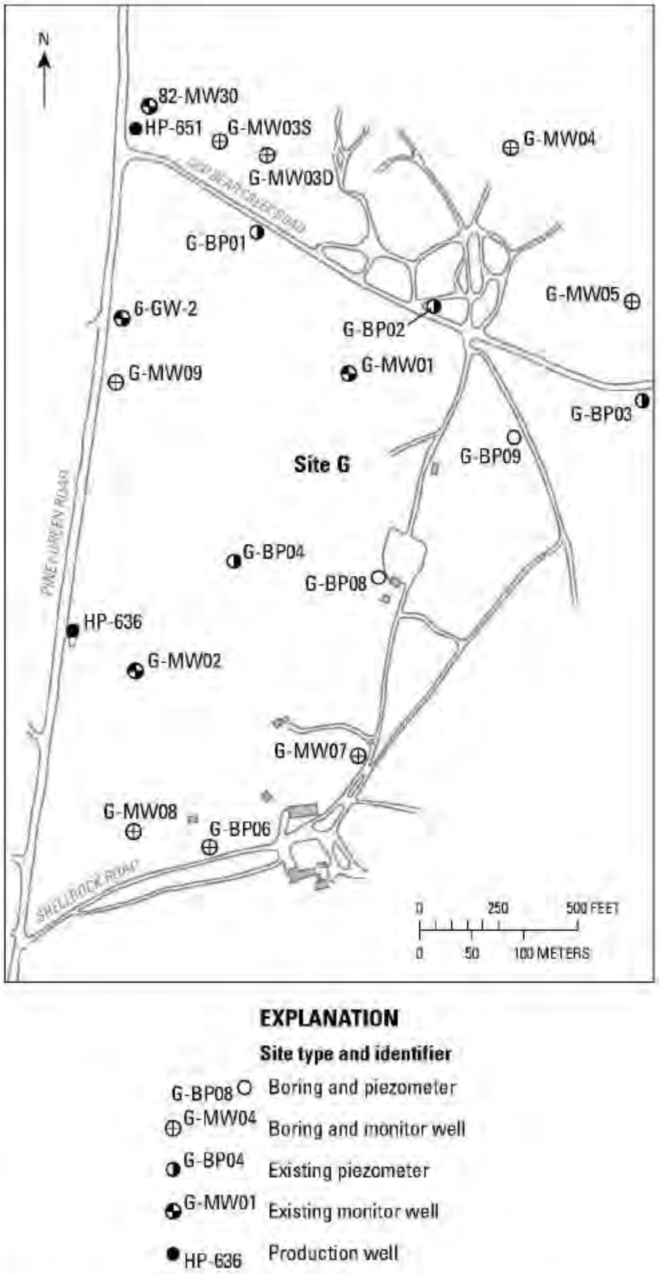


Figure C31. Monitor well and borehole locations at Site G—proposed Camp Lejeune landfill, U.S. Marine Corps Base Camp Lejeune, North Carolina (modified from Dewberry and Davis 1992).

Discussion

The accuracy of coordinates assigned to data-collection locations listed in several tables in this report are subject to uncertainty largely caused by the scale and rendition of published maps. Additional uncertainty was caused by inconsistent nomenclature used to identify data-collection locations. For example, at several IR sites, different identifiers were assigned to identical monitor wells. Conversely, duplicate identifiers also were assigned to different monitor wells at other sites. Maps showing the locations of monitor wells published in a particular IR site report frequently were rendered with a different base and different scale compared to similar maps published in other reports related to the same IR site and showing locations of identical wells. In general, maps included in reports published later in time were more accurate than maps included in reports published earlier in time. Such differences often resulted in as many as six coordinate pairs determined for a single data-collection location. Efforts to "ground truth" data-collection locations were not part of this study's methods and scope. Regardless, many monitor wells listed herein have been destroyed, and hydropunch, CPT, and soil boring locations could only have been recovered for a short time following data collection. Such activities occurred several years to perhaps a decade or longer prior to the beginning of this study. Accordingly, determining the most accurate location to assign to a data-collection location was based generally on a qualitative evaluation of map accuracy, such as date of publication, and the cultural and topographic detail apparent in the map base. Given these limitations of map quality and accuracy, monitor well, hydropunch, and soil boring location coordinates listed in several tables in this report are probably accurate to within 100 ft at most locations and possibly accurate to within 25 ft or 50 ft at many locations.

Location coordinates for many modern Hadnot Point WTP and Holcomb Boulevard WTP supply wells were based on previous global positioning system (GPS) surveys accomplished and published by USMCB Camp Lejeune (AH Environmental Consultants 2002). Location coordinates of these wells are probably accurate to within 25 ft or less. Location coordinates of older abandoned and destroyed wells were partly determined using rectified maps of historical water-supply well locations and partly using detailed site-specific drawings of well locations, all supplied by USMCB Camp Lejeune. Location coordinates of historical and abandoned supply-well locations are probably accurate within a range of 50 to 100 ft (Table C4).

Construction of monitor wells and the methods and techniques of collecting water samples possibly affected the analytical results and thus the characterization of in situ groundwater quality described herein. Most monitor wells constructed for this study were open to the shallow Brewster Boulevard aquifer system and were designed to include the water table within the open interval of the well. Screen openings at monitor wells ranged from 5 to 25 ft in length and typically were 10 to 20 ft in length. Screen lengths of this dimension probably are appropriate when groundwater contaminants are completely mixed within the aquifer volume sampled by the well. However, LNAPL liquids, such as BTEX components, typically accumulate at or near the water table at unspecified thicknesses. Monitor wells at IR sites were typically purged of 3 to 6 casing volumes prior to sampling. In wells where screen openings are 10 ft or more and include the water table, such methods may result in dilution of LNAPL liquids within the sampled interval and a poor characterization of LNAPL concentrations within the subsurface. Similar arguments also apply to DNAPL liquids, such as PCE, which accumulate at depth, possibly below the open interval of the monitor well.

Of major concern to this study are the reported contaminant concentrations at water-supply wells (Tables C7–C10). Many of the water-supply wells that contained contaminants were located along the perimeter of the HPIA (Sites 21, 22, and 78) and in the vicinity of storage/disposal lot 203 (Sites 6 and 82, Figure C1 and Plate 1). As such, these wells likely were located near the edges or fringes of major contaminant plumes (Figures C16, C20–C24). Water-supply wells within the Hadnot Point–Holcomb Boulevard study area typically were continuously operated for 12 to 24 hours at a time. Where a substantial contaminant mass occurred within the radius of influence of the operating well, such as at Site 82, the mass would migrate toward the pumping well, probably in progressively increasing quantities determined by the period of continuous operation. Thus, contaminant concentrations at the wellhead would dynamically increase with increasing time of well operation. Although sampling methods at supply wells are poorly documented, particularly for samples collected during the NACIP program and during late 1984 and early 1985, methods probably included purging supply wells of 3 to 6 casing volumes prior to sampling, similar to later methods used at monitor wells. For example, consider an inactive well of 10-inch internal diameter that pumps at 150 gpm and contains a water column of 200 ft. A single casing volume of this well contains about 820 gal. At a pumping rate of 150 gpm, 1 casing volume would be removed from this well in less than 6 minutes; 6 casing volumes would be removed in about 30 minutes. Thus, the sampling method poorly replicates, at best, actual operational conditions. Also, where the supply well is located near a contaminant plume, the contaminant concentration determined in the water sample collected in the "standard" manner may not represent at all the average concentrations at the wellhead during 12 to 24 hours of operation. A field example that possibly demonstrates contaminant migration toward an actively pumping well and consequent dynamic changes in contaminant concentration at the wellhead occurred at supply well HP-651 between January 16, 1985, and February 4, 1985 (Table C7). The TCE concentration determined in a sample collected in well HP-651 on January 16, 1985 was 3,200 μg/L. At this time, the well was inactive and had been inactive during the previous 8 days. Beginning on January 21, 1985, supply well

HP-651 was continuously operated until February 4, 1985, at which time water samples collected from the well contained TCE concentrations of 17,600 µg/L and 18,900 µg/L. This increase in contaminant concentration at the wellhead likely was caused by different operational conditions prior to sampling (Camp Lejeune Water Documents CLW #6590–#6593; Table C7). Note that during routine sampling of Camp Lejeune water-supply wells during September 1995, sampling protocols required that approximately half of the wells be pumped continuously for at least 24 hours prior to sampling (Bionomics Laboratory, Inc. 1995).

Summary and Findings

Findings of this study are summarized in Table C80 and on Figures C32–C34. For the contaminants of concern, maximum concentrations are listed by Installation Restoration (IR) site in Table C80 along with (1) the date the water sample was collected; (2) a brief characterization of the contaminant source or sources contributing to the sampled well, described as dispersed, plume, or off-site; (3) the water-bearing units at the IR site containing contaminants; and (4) the water-supply wells possibly affected by groundwater contamination at the IR site. Maximum concentrations were extracted from the various IR site data tables listed in this report and refer to sample collections and analyses that occurred between 1984 and 2004.

Concentrations of all contaminants of concern occur only at Sites 6, 78, and 82. Each of these sites probably contains a plume or plumes containing most or all of the contaminants of concern. Groundwater contamination occurs at greatest depth also in the vicinity of Site 6, extending to the Middle Castle Hayne aquifer at depths of approximately 200 or more feet below ground surface (ft bgs) (Table C24). Groundwater contamination also occurs at considerable depth at Sites 78 and 82, extending to the Upper Castle Hayne aquifer–Lower unit and Upper Castle Hayne aquifer–River Bend unit at depths of about 150 and 80 ft bgs, respectively.

Contaminants of concern also occur at depth (Upper Castle Hayne aquifer–River Bend unit) in relatively small concentrations at Sites 2 and 3. The occurrence of contaminants at such depths, particularly LNAPLs such as benzene, indicates induced vertically downward migration probably caused by pumping at nearby supply wells. With these exceptions, groundwater contamination appears to be largely confined to the Brewster Boulevard aquifer system and the Tarawa Terrace aquifer at most IR sites. The contaminant trichloroethylene (TCE) occurs most frequently at 13 of 18 IR sites, followed by benzene which occurs at 10 sites, and tetrachloroethylene (PCE) which occurs at 8 sites. Vinyl chloride occurs least at only six sites. The maximum concentration of TCE occurs at Site 6 at 180,000 micrograms per liter (µg/L), which is more than double the second greatest concentration of 71,000 µg/L of TCE, which occurs at nearby Site 82. The maximum PCE concentration occurs at IR Site 88 at 170,000 µg/L and is far greater than the second greatest concentration of 6,300 µg/L, which occurs at Site 6. Because vinyl chloride is a degradation product of PCE and TCE, patterns of vinyl chloride occurrence and maximum concentrations conform closely to those mentioned previously for PCE and TCE. The maximum vinyl chloride concentration of 6,700 µg/L occurs at Site 78, followed by concentrations of 910 µg/L and 800 µg/L at Sites 88 and 6, respectively. Positive maximum concentrations of benzene range from 0.40 to 29,000 µg/L, and are greatest in the vicinities of Sites 22, 78, 84, and 94, all of which probably contain plumes of BTEX components.

Water-supply wells most adversely affected by groundwater contamination at IR sites were probably those located in the vicinities of the Hadnot Point Industrial Area (HPIA) and Sites 6 and 82. A total of 15 supply wells were constructed in the immediate vicinity and east of the HPIA. Of these, sample analyses indicate that contamination occurred in six wells during or following July 1984. The likely source of this contamination is the various plumes of contaminants mentioned previously that occur within or immediately adjacent to the HPIA. Similarly, five water-supply wells were constructed adjacent to or in the vicinity of Sites 6 and 82. Of these, sample analyses indicated contamination in three wells during or following January 1985. Well HP-651, located adjacent to storage/disposal lot 203 (Sites 6 and 82), was by far the most adversely affected of the five wells. Of the 30 individual water-supply wells possibly affected by groundwater contamination (Table C80), analyses of samples collected in 11 wells indicated contamination at the wellhead. A total of 13 wells were removed from service prior to 1984 and could not be sampled. Note that analyses of samples collected in well HP-706 during 1995 and 2001 indicated contamination of the well by BTEX components, specifically benzene. The source of BTEX that ultimately contaminated supply well HP-706 is not a known IR site and is not discussed herein.

Groundwater sample locations and related contaminant concentrations for PCE, TCE, and benzene within the study area are mapped in Figures C32–C34. Information shown in the figures closely parallels the previous discussions related to Table C80. High contaminant concentrations are shown for PCE and TCE at the HPIA (Sites 6 and 82) and at Site 88. Similarly, high concentrations of benzene are shown in the vicinity of the HPIA and at Sites 84 and 94. In particular, note the locations of many supply wells along Brewster Boulevard, Sneads Ferry Road, and SR 24. Most of these wells are modern wells (post 1995) and were deliberately constructed to avoid known locations of groundwater contamination.

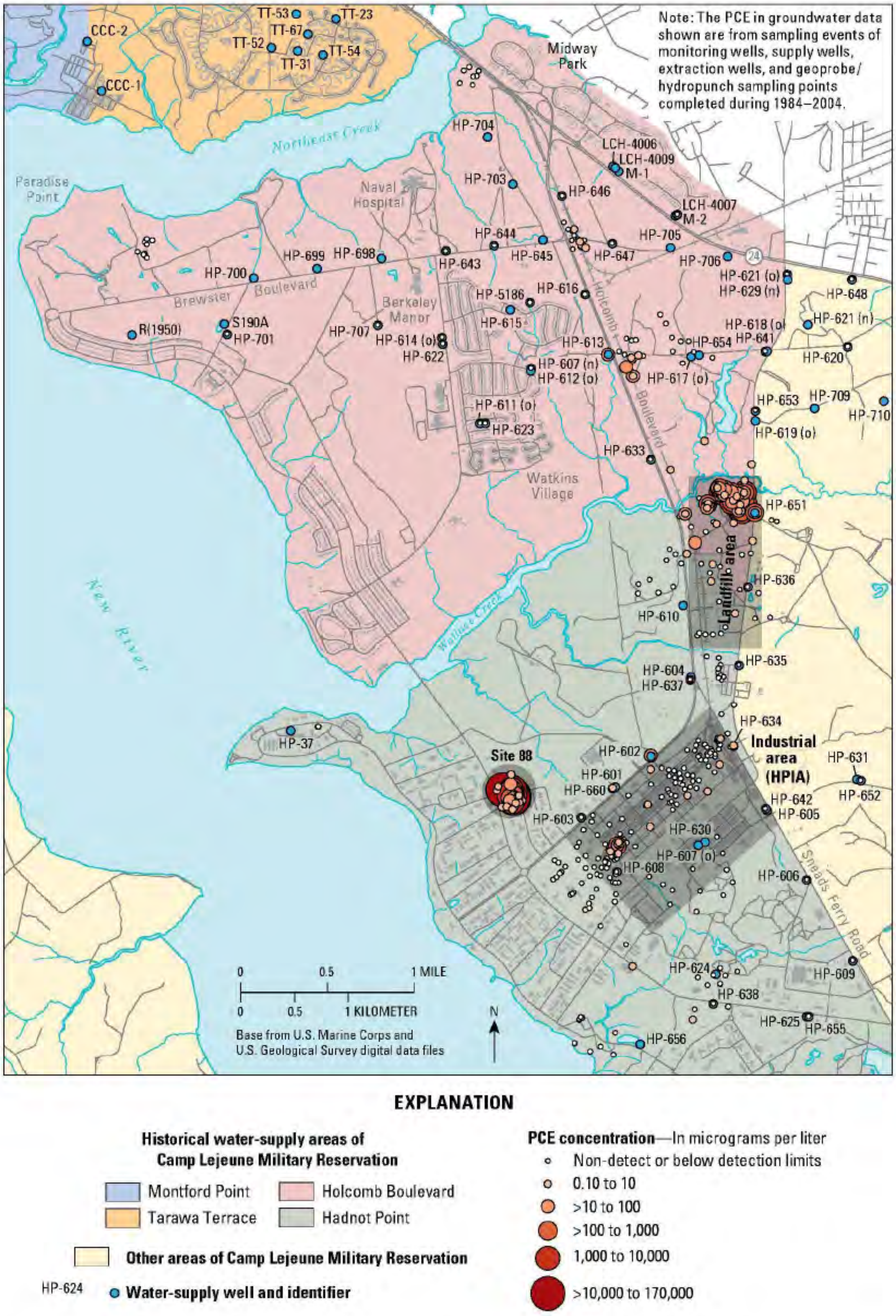


Figure C32. Groundwater sample locations for tetrachloroethylene (PCE) and ranges of PCE concentration in monitor and supply wells within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

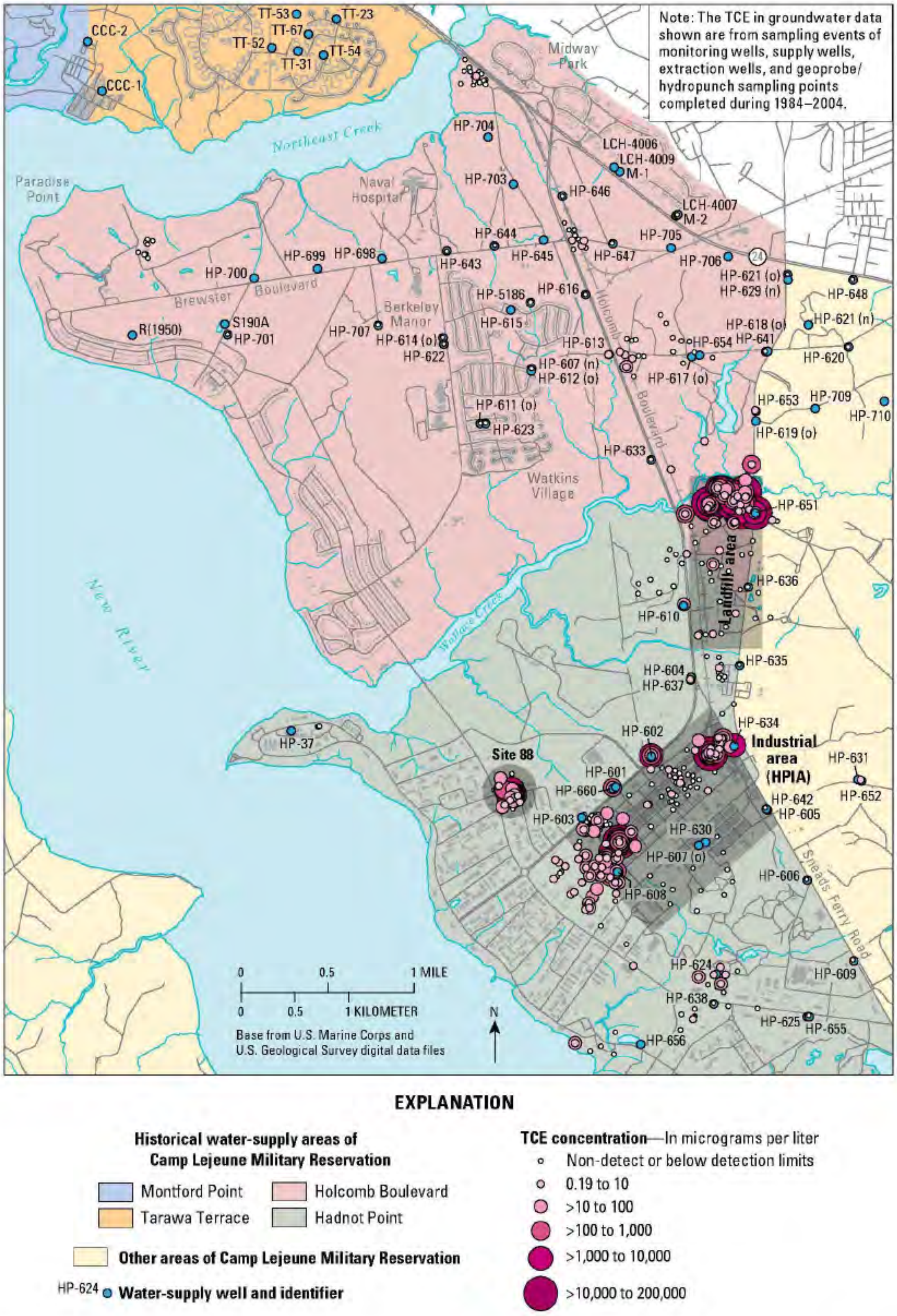
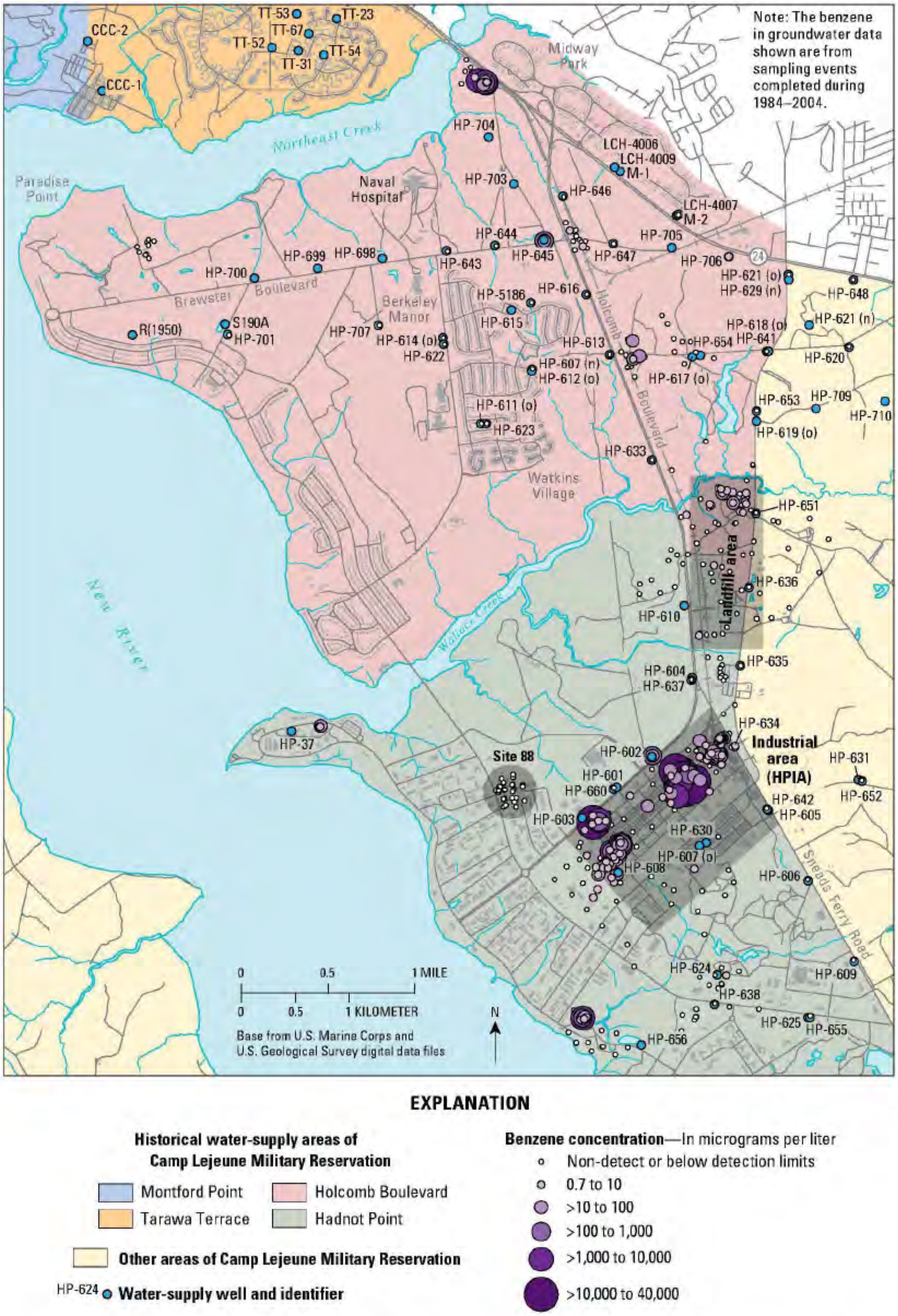


Figure C33. Groundwater sample locations for trichloroethylene (TCE) and ranges of TCE concentration in monitor and supply wells within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.



Note: The benzene in groundwater data shown are from sampling events completed during 1984–2004.

Base from U.S. Marine Corps and U.S. Geological Survey digital data files

Figure C34. Groundwater sample locations for benzene and ranges of benzene concentration in monitor and supply wells within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

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Tables C1–C80

Table C1. Chronology of Hadnot Point and Holcomb Boulevard family and bachelor housing construction and contemporary populations, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, not available]

Housing area	Year built	Number of units	Type of units	Resident population[1]
Bachelor Housing	NA	NA	NA	NA/13,427
Berkeley Manor	1962/1963	677	Single	2,721/2,486
Hospital Point	1947	24	Single (?)	NA/86
Midway Park	1942/1943	699	Single and duplex	1,726/1,809
Paradise Point	1942	5	Single	
	1947	100	Single	
	1948	67	Single	
	1962	123	Single	
	1999	(total) 510	Single	1,854/1,665
Watkins Village	1978/1979	250	Townhouses	1,342/1,347

[1] The first number is the resident population indicated by hand-written notes on the maps listed below under Data sources. The second number is the resident population in 1999 reported by ECG, Inc. (1999, Appendix 2)

Data sources:

ECG, Inc. 1999

U.S. Marine Corps Base Camp Lejeune
Map of Berkeley Manor area, June 30, 1979
Map of Midway Park housing area and Naval Hospital, July 31, 1984
Map of Officer Quarters, Paradise Point area, July 31, 1984
Map of Watkins Village, June 30, 1979

Scott R. Williams, U.S. Marine Corps Base Camp Lejeune, written communication, September 9, 2008

Table C2. Average annual rate of treated finished water delivered by the Hadnot Point Water Treatment Plant, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[WTP, water treatment plant; MGD, million gallons per day; N/A, not available]

Year	Average annual rate of treated finished water delivered by the Hadnot Point WTP, in MGD
1942	[1]5.0
1943	N/A
1944	[1]4.8
1945	N/A
1946	N/A
1947	N/A
1948	[1]5.5
1949	N/A
1950	N/A
1951	N/A
1952	N/A
1953	[1]6.0
1954	N/A
1955	N/A
1956	N/A
1957	N/A
1958	N/A
1959	[2]4.90
1960	[2]4.92
1961	[2]4.97
1962	[2]5.07
1963	[2]5.17
1964	[2]4.60
1965	[2]4.69
1966	[2]4.72
1967	[2]4.80
1968	[2]4.34
1969	N/A
1970	N/A
1971	[2]4.13
1972	N/A
1973	N/A
1974	[2]3.50
1975	[2]3.39
1976	[2]3.75
1977	[2]3.69
1978	[2]3.71
1979	[2]3.42
1980	[2]3.46
1981	[2]3.37
1982	[2]3.43
1983	[2]3.21
1984	[2]3.54
1985	[2]3.23
1986	[2]3.00
1987	[2]3.85
1988	[2]3.34
1989	[3]2.94
1990	[3]2.81
1991	[3]2.70
1992	[3]2.72
1993	[3]2.58
1994	[4]3.04
1995	[4]3.02
1996	[4]2.85
1997	[4]2.79
1998	[4]2.96

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[1] Unknown author, U.S. Marine Corps Base Camp Lejeune, Raw Water Supply Data, "max. amount delivered to plant," written communication, 1969(?)

[2] Unknown author, U.S. Geological Survey, Raw Water Treated, Hadnot Point WTP, written communication, 1989(?)

[3] Camp Lejeune Water Document CLW #5004, Monthly Potable Self-Supplied Water, written communication, 1994(?)

[4] ECG, Inc. 1999

Table C3. Average annual rate of treated finished water delivered by the Holcomb Boulevard Water Treatment Plant, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[WTP, water treatment plant; MGD, million gallons per day; N/A, not available]

Year	Average annual rate of treated finished water delivered by the Holcomb Boulevard WTP, in MGD
1972	N/A
1973	N/A
1974	N/A
1975	[1]0.71
1976	[1]0.78
1977	[1]0.93
1978	[1]1.12
1979	[1]1.05
1980	[1]1.04
1981	[1]1.17
1982	[1]1.23
1983	[1]1.26
1984	[1]1.22
1985	[1]1.26
1986	[1]1.23
1987	[1]1.89
1988	[1]2.20
1989	[2]2.14
1990	[2]2.25
1991	[2]2.04
1992	[2]2.24
1993	[2]2.26
1994	[3]2.47
1995	[3]2.37
1996	[3]2.27
1997	[3]2.10
1998	[3]1.98

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[1] Unknown author, U.S. Geological Survey, Raw Water Treated, Holcomb Boulevard WTP, written communication, 1989(?)

[2] Camp Lejeune Water Document CLW #5004, Monthly Potable Self-Supplied Water, written communication, 1994(?)

[3] ECG, Inc. 1999

Table C4. Construction, location, and contributing aquifer data for Hadnot Point Water Treatment Plant and Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, LCHAQ—Lower Castle Hayne aquifer, LCHCU—Lower Castle Hayne confining unit, local CU—local confining unit, MCHAQ—Middle Castle Hayne aquifer, MCHCU—Middle Castle Hayne confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHRBU&LU—Upper Castle Hayne aquifer River Bend and Lower units; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screened interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HP-37[6] AKA E-1	341418	2489651	9.2	8/2/1942	102	52–82 92–102	TTAQ UCHRBU
HP-557[4] AKA HB-557 AKA #1	352980	2519748	[3]39	12/9/1998	240	130–155 200–230	UCHLU MCHAQ
HP-558[4] AKA #2	353451	2521375	[3]41	1/20/1999	272	152–177 202–217 252–262	UCHLU MCHCU MCHAQ
HP-584[4] AKA HB-584 AKA #706A	354041	2525065	[3]37	10/17/2000	271	205–235 257–267	MCHAQ
HP-585 AKA 609A	316410	2515140	[3]44	8/10/2000	125	85–125	BBUCU BBLAQ
HP-595 AKA Sneads Ferry #1	319705	2514271	42.0	8/11/1997	255	165–180 200–240 245–255	TTAQ
HP-596 AKA Sneads Ferry #2	318559	2514652	[3]45	5/27/1997	210	100–110 120–150 160–200	BBLAQ BBLCU TTAQ
HP-601 AKA DTA #1	339693	2499568	23.0	9/1/1941	200	45–60 95–100 115–130 175–195	BBLCU TTCU UCHRBU&LU
HP-602 AKA DTA #2	340638	2500652	25.0	11/29/1941	160	70–80 100–105 120–125 145–150 155–160	TTAQ, TTCU UCHRBU&LU Local CU
HP-603 AKA DTA #3	338762	2498518	24.8	12/1/1941	195	70–80 100–110 130–140 160–170 190–195	TTAQ, TTCU UCHRBU&LU MCHAQ
HP-604 AKA DTA #4 and USGS observation well #1	343071	2501865	31.2	1941(?)	195	90–105 125–135 155–165 185–195	UCHRBU&LU MCHAQ
HP-605 AKA DTA #5 and Well #3 HPIA aquifer test	338997	2504185	30.3	11/1/1941	201	67–77 117–127 147–167 181–191	BBLCU, TTAQ UCHRBU&LU MCHCU MCHAQ
				11/12/1986	92	N/A	TTAQ
HP-606 AKA DTA #6	336849	2505409	31.8	12/1/1941	220	80–90 110–120 140–150 170–180 200–210	TTAQ UCHRBU&LU MCHAQ

Table C4. Construction, location, and contributing aquifer data for Hadnot Point Water Treatment Plant and Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, LCHAQ—Lower Castle Hayne aquifer, LCHCU—Lower Castle Hayne confining unit, local CU—local confining unit, MCHAQ—Middle Castle Hayne aquifer, MCHCU—Middle Castle Hayne confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHRBU&LU—Upper Castle Hayne aquifer River Bend and Lower units; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screened interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HP-607 (old) AKA DTA #7	337925	2502102	29.0	1942(?)	190	60–70 90–100 120–130 150–160 180–190	BBLCU, TTCU UCHRBU&LU MCHCU
HP-607(new)	352494	2496994	[3]31	8/21/1984	200	115–135 163–175 190–200	UCHRBU&LU MCHAQ
HP-608 AKA DTA #8	337098	2499607	29.9	3/24/1942	161.5	62–82 92–102 122–132 152–162	TTAQ, TTCU UCHRBU&LU
HP-609 AKA DTA #9	334393	2506828	29.3	4/14/1942	150	65–80 100–110 130–150	BBLAQ, TTAQ
HP-610 AKA DTA #10	345268	2501654	27.9	4/20/1942	190	60–70 90–110 130–140 180–190	TTAQ UCHRBU&LU MCHAQ
HP-611 (old) AKA DTA #11	350816	2495437	31.0	6/27/1942	161	61–71 91–101 121–136 156–161	TTAQ UCHRBU&LU MCHAQ
				2/27/1985		61–73 88–109 129–141	
HP-611 (new) AKA Lyman Road #1	339383	2510267	40.0	4/1/1997	218	107–198	UCHRBU&LU Local CU MCHCU
HP-612 (old) AKA DTA #12	352428	2496995	31.8	6/22/1942	190	60–70 90–95 115–120 140–145 155–160 170–175 185–190	TTAQ UCHRBU&LU MCHAQ
HP-612 (new) AKA Lyman Road #2	338959	2511877	42.0	4/29/1997	210	120–200	UCHRBU&LU Local CU MCHCU
HP-613 AKA DTA #13	352946	2499350	21.2	5/15/1942	150	60–70 90–95 115–120 130–135 145–150	TTAQ UCHRBU&LU

Table C4. Construction, location, and contributing aquifer data for Hadnot Point Water Treatment Plant and Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, LCHAQ—Lower Castle Hayne aquifer, LCHCU—Lower Castle Hayne confining unit, local CU—local confining unit, MCHAQ—Middle Castle Hayne aquifer, MCHCU—Middle Castle Hayne confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHRBU&LU—Upper Castle Hayne aquifer River Bend and Lower units; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screened interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HP-614 (old) AKA DTA #14	353455	2494270	31.4	8/1/1942	166.6	58–68 89–99 118–128 147–167	UCHRBU&LU MCHAQ
HP-614 (new) AKA #4	353675	2512183	[3]39	12/20/1994	183	118–138 140–150 158–178	UGHRBU&LU Local CU
HP-615 AKA DTA #15	354285	2496367	30.7	7/2/1942	158	60–70 90–100 110–130 148–158	TTCU UCHRBU&LU Local CU
HP-616 AKA DTA #16	354772	2498638	33.3	8/3/1942	170	95–115 130–140 160–170	UCHRBU&LU MCHAQ
HP-617 (old)	352879	2501888	[3]32	1942 (?)	N/A	N/A	UCHRBU&LU (?)
HP-617 (new)[4] AKA #1	353622	2523411	[3]41	9/14/1994	265	205–260	MCHAQ
HP-618 (old) AKA USGS well HP-614A	353039	2504201	35.7	1942(?) 11/15/1986	N/A 38.6	N/A N/A	TTAQ (?) UCHRBU&LU (?) BBLAQ(?)
HP-618 (new)[4] AKA #2	352211	2517893	[3]30	9/26/1994	230	180–230	MCHAQ
HP-619 (old)	350899	2503845	29.9	1942(?)	N/A	N/A	TTAQ (?) UCHRBU&LU (?)
HP-619 (new)[4] AKA #3	352646	2515872	[3]39	11/1/1994	211	125–155 181–201	UCHRBU&LU Local CU MCHAQ
HP-620	353181	2506668	35.0	1942(?)	54	46–54	TTAQ (Karst)
HP-621 (old)	355383	2504816	40.8	10/21/1942	77	57–77	TTAQ
HP-621 (new) AKA #5	353846	2505434	[3]38	5/17/1995	180	120–140 150–170	UCHRBU&LU
HP-622	353257	2494310	31.1	5/19/1983	227	105–120 150–170 217–227	UCHRBU MCHAQ
HP-623	350823	2495593	29.8	5/25/1983	205	65–75 115–135 182–197	TTAQ UCHRBU&LU Local CU MCHAQ
HP-624 AKA Test Well E	333975	2502633	17.5	1951	150	50–60 80–100 120–130 135–145	BBLAQ, BBLCU TTAQ TTCU

Table C4. Construction, location, and contributing aquifer data for Hadnot Point Water Treatment Plant and Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, LCHAQ—Lower Castle Hayne aquifer, LCHCU—Lower Castle Hayne confining unit, local CU—local confining unit, MCHAQ—Middle Castle Hayne aquifer, MCHCU—Middle Castle Hayne confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHRBU&LU—Upper Castle Hayne aquifer River Bend and Lower units; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screened interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HP-625 AKA Test Well B	332687	2505415	24.7	Before April 1953	205	78–93 104–114 132–147 190–200	BBLCU, TTAQ TTCU UCHRBU
HP-626 AKA Test Well C	332058	2508327	26.0	Before 1953	205	58–63 82–92 108–123 129–139 144–154	BBLAQ, BBLCU TTAQ TTCU (?)
HP-627 (old) AKA Test Well D	329529	2509747	30.7	Before 1953	163	65–75 92–102 117–122 133–158	BBLAQ, BBLCU TTAQ
HP-627 (new) AKA #6	354035	2508321	[3]35	5/7/1995	175	105–135 145–165	UCHRBU&LU MCHCU
HP-628 (old) AKA Test Well A	326487	2511431	15.5	1951	160	54–59 64–74 94–104 114–134 150–155	BBLAQ, BBLCU TTAQ
HP-628 (new)	331932	2508385	[3]20	10/2/1984	150	60–70 85–89 110–120 135–145	BBLAQ, TTAQ
HP-629 AKA Test Well F	323807	2512647	29.8	1951	169	60–80 95–100 116–126 149–164	BBLAQ, BBLCU TTAQ
HP-629 (new)	355226	2504808	41.2	3/8/1983	230	60–70 125–140 160–165	TTAQ UCHRBU&LU
HP-630	338021	2502304	29.3	1954 (?)	176	53–68 88–93 108–118 128–143 153–163	BBLCU, TTCU UCHRBU&LU Local CU
HP-631	339933	2506952	[3]31	3/9/1954	225	61–76 86–91 142–147	BBLCU, TTAQ Local CU
HP-632	321532	2513376	[3]36	2/14/1957	200	N/A	BBLAQ (?) TTAQ (?)

Table C4. Construction, location, and contributing aquifer data for Hadnot Point Water Treatment Plant and Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, LCHAQ—Lower Castle Hayne aquifer, LCHCU—Lower Castle Hayne confining unit, local CU—local confining unit, MCHAQ—Middle Castle Hayne aquifer, MCHCU—Middle Castle Hayne confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHRBU&LU—Upper Castle Hayne aquifer River Bend and Lower units; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screened interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HP-633	349702	2500647	25.6	1959	205	55–65 75–80 95–105 123–133 138–143 158–168 178–183 195–205	TTAQ UCHRBU&LU MCHAQ
HP-634	340948	2503179	30.8	10/13/1959	215	65–75 78–83 88–93 98–103 112–122 129–134 140–145 158–168	TTAQ, TTCU UCHRBU&LU Local CU
HP-635	343426	2503346	20.2	1959	210	65–75 93–108 122–127 136–146 152–157 172–177 187–192	TTAQ UCHRBU&LU MCHCU MCHAQ
HP-636	345819	2503608	28.8	10/22/1959	225	90–100 115–120 130–135 140–150 158–163 170–175 185–190 200–210	TTCU UCHRBU&LU MCHCU MCHAQ
HP-637	342990	2501856	33.1	1969	175	90–98 100–114 120–128 140–148 156–172	UCHRBU&LU MCHAQ
HP-638	333067	2502563	25.9	6/30/1969	196	106–114 126–134 150–158 162–170 176–184 188–196	TTAQ UCHRBU
HP-639 (old)	326404	2511456	17.0	1969 (?)	182	62–70 85–93 120–132 136–148 155–163 168–176	BBLAQ, TTAQ TTCU

Table C4. Construction, location, and contributing aquifer data for Hadnot Point Water Treatment Plant and Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, LCHAQ—Lower Castle Hayne aquifer, LCHCU—Lower Castle Hayne confining unit, local CU—local confining unit, MCHAQ—Middle Castle Hayne aquifer, MCHCU—Middle Castle Hayne confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHRBU&LU—Upper Castle Hayne aquifer River Bend and Lower units; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screened interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HP-639 (new)	326190	2511579	18.7	1981	N/A	N/A	TTAQ (?) UCHRBU&LU (?)
HP-640	323749	2512653	29.5	1969	180	64–72 76–80 92–100 112–120 130–134 140–148 157–165 172–176	BBLAQ, BBLCU TTAQ
HP-641	353038	2504147	36.2	9/5/1971	178	108–118 128–150 158–168	TTCU UCHRBU&LU
HP-642	339034	2504141	32.5	9/13/1971	210	112–124 136–144 157–163 174–178 188–196	UCHRBU&LU Local CU MCHCU MCHAQ
HP-643[4]	356093	2494391	29.0	3/16/1971	270	88–98 135–150 260–265	UCHRBU&LU LCHAQ
HP-644[4] AKA HB-644	356265	2495875	30.7	7/30/1971	255	85–100 235–250	UCHRBU LCHAQ
HP-645[4] AKA HB-645	356438	2497358	27.4	8/11/1971	245	90–100 138–148 230–240	UCHRBU&LU MCHAQ
HP-646[4] AKA HB-646	357770	2497948	29.5	6/23/1971	270	90–100 240–250 255–265	UCHRBU MCHAQ LCHCU (?)
HP-647[4] AKA HB-647	356335	2499469	30.3	12/15/1970	200	105–115 138–143 175–190	UCHRBU MCHAQ
HP-648[4] AKA HB-648	355229	2506806	33.3	8/19/1971	265	107–122 245–260	UCHRBU MCHAQ
HP-649[4] AKA HB-649	354769	2508706	37.9	10/13/1971	284	126–136 159–164 205–210 232–237 274–279	UCHRBU&LU MCHAQ
HP-650[4]	354220	2510613	37.4	11/10/1971	179	128–133 140–150 155–165 169–174	UCHRBU&LU

Table C4. Construction, location, and contributing aquifer data for Hadnot Point Water Treatment Plant and Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, LCHAQ—Lower Castle Hayne aquifer, LCHCU—Lower Castle Hayne confining unit, local CU—local confining unit, MCHAQ—Middle Castle Hayne aquifer, MCHCU—Middle Castle Hayne confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHRBU&LU—Upper Castle Hayne aquifer River Bend and Lower units; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screened interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HP-651	348083	2503829	32.0	11/10/1971	199	125–135 140–155 189–194	UCHRBU&LU MCHAQ
HP-652	339894	2507078	32.9	1/18/1972	193	128–138 148–158 163–168 173–178	UCHRBU&LU
HP-653	351211	2503838	31.3	7/15/1978	250	105–140 155–185	UCHRBU&LU MCHAQ
HP-654	352912	2502123	34.2	5/16/1978		75–95 120–130 150–185	TTAQ UCHRBU MCHAQ
HP-655	332690	2505472	25.8	5/8/1981	147	N/A	TTAQ (?) UCHRBU (?)
HP-656[6]	331839	2500311	213	N/A	N/A	N/A	N/A
HP-660	339652	2499482	23.8	11/21/1983	187	94–97 108–140 175–187	TTCU UCHRBU&LU
HP-661	329695	2509656	29.0	3/29/1983	140	50–65 87–102 125–135	BBLAQ, TTAQ
HP-662	327419	2510912	[3]16	8/18/1983	230	121–131 134–146 185–195 215–220 225–230	TTAQ UCHRBU&LU
HP-663 AKA #14	352709	2510880	[3]36	5/5/1986	180	130–180	UCHRBU&LU Local CU
HP-698[4] AKA #1	355871	2492416	[3]23	12/16/1985	124	84–124	UCHRBU&LU Local CU
HP-699[4] AKA #2	355567	2490438	[3]23	2/3/1986	124	84–124	UCHRBU&LU Local CU
HP-700[4] AKA #3	355278	2488526	[3]20	2/20/1986	130	100–130	UCHRBU&LU
HP-701[4] AKA #4	353547	2487696	[3]21	3/3/1986	100	70–100	UCHRBU&LU
HP-703[4] AKA #5	358143	2496446	[3]28	3/6/1985	146	85–100 121–136	UCHRBU&LU
HP-704[4] AKA #6	359582	2495665	[3]26	3/8/1986	124	84–114	UCHRBU&LU Local CU
HP-705[4] AKA #7	356209	2501256	[3]36	4/15/1986	160	120–160	UCHRBU&LU Local CU
HP-706[4] AKA #8	355944	2502989	[3]40	4/21/1986	176	126–176	UCHRBU&LU Local CU

Table C4. Construction, location, and contributing aquifer data for Hadnot Point Water Treatment Plant and Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, LCHAQ—Lower Castle Hayne aquifer, LCHCU—Lower Castle Hayne confining unit, local CU—local confining unit, MCHAQ—Middle Castle Hayne aquifer, MCHCU—Middle Castle Hayne confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHRBU&LU—Upper Castle Hayne aquifer River Bend and Lower units; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screened interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HP-707[4] AKA #9	353837	2492298	[3]26	3/13/1986		80–140	UCHRBU&LU Local CU
HP-708[4] AKA #10	353096	2514446	39.8	8/28/1985	226	126–176	UCHRBU&LU Local CU
HP-709 AKA #11	351280	2505651	[3]26	3/20/1986	170	110–140	UCHRBU&LU Local CU
HP-710 AKA #12	351493	2507772	[3]32	4/8/1986	170	110–140	UCHRBU&LU
HP-711 AKA #13	352140	2509201	[3]36	3/11/1986	150	110–150	TTCU UCHRBU
HP-5186	354532	2496971	[3]30	12/17/1985	175	95–112 125–137 155–169	UCHRBU&LU
LCH-4006	358664	2499516	[3]33	1956	N/A	N/A	UCHRBU (?)
LCH-4007	357219	2501452	40.6	12/15/1956	150	55–65 70–75 80–90 95–100 110–120 125–135 140–150	TTAQ TTCU UCHRBU&LU Local CU MCHCU
LCH-4009	358539	2499677	32.8	5/16/1983	140	90–114 116–134	UCHRBU Local CU
M-1 AKA LCH-1	358656	2499538	32.7	9/16/1941	125	25–40 60–70 75–95 115–125	BBLCU, TTAQ TTCU UCHRBU
M-2 AKA LCH-2	357175	2501411	41.2	3/30/1942	145.25	49–59 69–99 120–130 140–145	TTAQ, TTCU UCHRBU&LU Local CU
R(1950)[5]	353534	2484804	[3]21	3/25/1942	100	50.42–60.42 80–100	UCHRBU
S190A[5]	353872	2487628	[3]20	6/6/1988	135	82–122	UCHRBU Local CU

[1] See Plate 1 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

[4] Well supplies Holcomb Boulevard Water Treatment Plant

[5] Irrigation well

[6] Well probably was never connected to water treatment plant

Table C5. Installation Restoration sites within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[VOC, volatile organic compound]

Site number[1]	Site name	Page number of site narrative	Associated contaminant data tables	Associated figure(s)
1	French Creek liquids disposal area	C10	C15–C17	C2
2	Former nursery day-care center (Building 712)	C12	C18–C20	C3
3	Old creosote site	C15	C21–C23	C4
6	Storage/disposal lots 201 and 203	C18	C24–C26	C5, C20–C24
9	Fire fighting training pit	C22	C27–C29	C6
10	Original base landfill	C23	C30–C32	C7
21	Transformer storage lot 140	C25	C33–C35	C8
22[2]	Industrial Area tank farm	C26	C36–C39	C9
24	Industrial Area fly ash dump	C28	C40–C42	C10
28	Industrial Area burn dump	C30	C43–C45	C11
30	Sneads Ferry Road fuel tank sludge disposal area	C32	C46–C48	C12
74	Mess hall grease pit disposal area	C34	C49–C51	C13
78	Hadnot Point Industrial Area	C36	C52–C54	C14–C18
80	Paradise Point golf maintenance area	C44	C55–C57	C19
82	VOC disposal area at Piney Green Road	C46	C58–C60	C5, C20–C24
84	Tank S781/Building 45 area	C52	C61–C65	C25
88	Building 25	C56	C66–C71	C26–C29
94	Building 1613	C61	C72–C76	C30
G[3]	Proposed Camp Lejeune landfill	C62	C77–C79	C31

[1] See Figure C1 and Plate 1 for location

[2] Monitor wells merged with Site 78

[3] Not an Installation Restoration site. Several monitor wells merged with Site 6

Table C6. Above-ground and underground storage tank sites within the Hadnot Point–Holcomb Boulevard study area subject to remedial investigation and co-located with Installation Restoration Program sites, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[AST, above ground storage tank; UST, underground storage tank]

Site name	Tank designation
Building 45 area	AST S-781
	UST S-941-1
	UST S-941-2
Building 1613 area	UST 1613-1
	UST 1613-2
	UST 1613-3
	UST 1613-4

Table C7. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in Hadnot Point Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*Trans*-1,2-DCE	*Cis*-1,2-DCE	Total 1,2-DCE	VC
HP-585	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-595	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-596	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-602	7/6/1984	<1.9	<1.4	<1.3	7.8	NA	NA	<0.9
	11/30/1984	24	1,600	2.4J	630	NA	NA	18
	12/10/1984	<500	540	<500	380	NA	NA	<500
	12/13/1984	3.2	300	NA	110	NA	NA	NA
	12/14/1984	<50	340	<50	230	NA	NA	<50
	2/4/1985	1.5J	38	<10	74	NA	NA	<10
	11/12/1986	<4.1	2.2	<2.8	14	NA	NA	<4.9
	1/22/1991	<5.0	0.7J	<5.0	NA	NA	12	<10
HP-603	12/4/1984	<10	4.6J	<10	<10	NA	NA	<10
	12/12/1984	<10	<10	<10	<10	NA	NA	<10
	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	8/11/1988	<10	<10	<10	<10	NA	NA	<10
	6/26/1990	<5.0	<5.0	<5.0	NA	NA	NA	<10
	1/22/1991	<5.0	1.0J	<5.0	NA	NA	<5.0	<10
	9/20/1995	<0.50	3.0	<0.50	<0.50	2.4	NA	<0.50
HP-606	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-607 (new)	6/26/1990	<5.0	<5.0	<5.0	NA	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-608	12/4/1984	<10	110	<10	5.4J	NA	NA	<10
	12/10/1984	<10	13	<10	2.4J	NA	NA	<10
	2/4/1985	<10	9.0	<10	<10	NA	NA	<10
	11/12/1986	<4.1	66	<2.8	8.5	NA	NA	<4.9
HP-609	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-610	2/4/1985	<10	<10	<10	<10	NA	NA	<10
	10/1/1992	<1.0	37	NA	NA	NA	NA	<2.0
HP-611 (old)	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-611 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-612 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-613	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-614 (old)	1/16/1985	<10	<10	<10	<10	NA	NA	<10

Table C7. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in Hadnot Point Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*Trans*-1,2-DCE	*Cis*-1,2-DCE	Total 1,2-DCE	VC
HP-614 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-616	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/2/1996	<0.30	<0.10	NA	NA	NA	NA	<0.10
	7/24/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-620	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-621 (old)	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-621 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-622	6/26/1990	<5.0	<5.0	<5.0	NA	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-623	6/26/1990	<5.0	<5.0	<5.0	NA	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-627 (old)	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-627 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-628	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-629 (new)	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-632	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-633	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-634	12/4/1984	<10	<10	<10	<10	NA	NA	<10
	12/10/1984	<10	<10	<10	2.3J	NA	NA	<10
	1/16/1985	10	1,300	<10	700	NA	NA	6.8
	11/12/1986	<4.1	<1.9	<2.8	2.9	NA	NA	<4.9
	1/22/1991	<5.0	<5.0	<5.0	NA	NA	1.0J	<10
HP-635	7/5/1984	<1.5	<1.2	<1.1	<1.0	NA	NA	<0.8
	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-636	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	4/11/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0

Table C7. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in Hadnot Point Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*Trans*-1,2-DCE	*Cis*-1,2-DCE	Total 1,2-DCE	VC
HP-637	12/4/1984	<10	<10	<10	<10	NA	NA	<10
	12/10/1984	<10	<10	<10	<10	NA	NA	<10
	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	1/22/1991	<5.0	0.90J	<5.0	NA	NA	<5.0	<10
	8/26/1992	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
HP-638	7/5/1984	<1.5	<1.2	<1.1	<1.2	NA	NA	<0.8
	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-639 (old)	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-640	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-641	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-642	12/4/1984	<10	<10	<10	<10	NA	NA	<10
	12/10/1984	<10	<10	<10	<10	NA	NA	<10
	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	8/11/1988	<10	<10	<10	<10	NA	NA	<10
	1/22/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-651	1/16/1985	386	3,200	187	3,400	NA	NA	655
	2/4/1985	307	17,600	<200	8,070	NA	NA	179
	2/4/1985	400	18,900	<200	7,580	NA	NA	168
	11/12/1986	45	32	7.0	140	NA	NA	140
	1/22/1991	53	13	2.0J	NA	NA	75	70
HP-652	1/16/1985	<10	9.0	<10	<10	NA	NA	<10
	11/12/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/22/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-653	1/16/1985	<10	5.5	<10	<10	NA	NA	<10
	11/12/1986	<4.1	2.6	<2.8	<1.6	NA	NA	<4.9
	1/22/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
HP-654	2/4/1985	<10	<10	<10	<10	NA	NA	<10
	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-655	1/16/1985	<10	<10	<10	<10	NA	NA	<10
HP-660	12/4/1984	5.0J	210	<10	88	NA	NA	<10
	12/10/1984	4.4J	230	<10	99	NA	NA	<10
	1/16/1985	<10	26	<10	8.8	NA	NA	<10
	11/12/1986	<4.1	<1.9	<2.8	<1.6	NA	NA	<4.9
	1/22/1991	<5.0	1.0J	<5.0	NA	NA	2.0J	<10

Table C7. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in Hadnot Point Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*Trans*-1,2-DCE	*Cis*-1,2-DCE	Total 1,2-DCE	VC
HP-661	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-662	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-663	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-709	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-710	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-711	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-5186	6/26/1990	<5.0	<5.0	<5.0	NA	NA	NA	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
LCH-4007	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
LCH-4009	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50

[1] See Plate 1 for location

Data sources:

Camp Lejeune Water Documents #1093, #1094, #1652, #1654, #1796–#1800, #1818–#1823, #4546–#4557, #5512–#5515, #5518–#5520, #5595–#5631, #5637, #5638, #5639, #5640, #5646, #5647, #5648, #5649, #5650, #5651, #5652, #5656, #5670, #5671

CERCLA Administrative Record file #273, #318, #354, #388, #1501, #1516, #1731

Baker Environmental, Inc. 1995o

Bionomics Laboratory, Inc. 1995

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Table C8. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in Hadnot Point water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
HP-585	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-595	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-596	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-602	7/6/1984	380	10	8.0	NA
	11/30/1984	120	5.4J	<10	NA
	12/10/1984	720	<500	<500	NA
	12/13/1984	<1.0	<1.0	<2.0	NA
	12/14/1984	230	12J	<50	NA
	2/4/1985	<10	<10	<10	NA
	11/12/1986	50	<6.0	<7.2	<12
	1/22/1991	17	<5.0	<5.0	<5.0
HP-603	12/4/1984	<10	<10	<10	NA
	12/10/1984	<10	<10	<10	NA
	1/16/1985	<10	<10	<10	NA
	8/11/1988	<10	<10	<10	<10
	6/26/1990	<5.0	<5.0	<5.0	<5.0
	1/22/1991	<5.0	<5.0	<5.0	<5.0
	9/20/1995	<0.50	<0.50	<0.50	<0.50
HP-606	1/16/1985	<10	<10	<10	NA
	9/20/1995	<0.50	<0.50	<0.50	<0.50
HP-607 (new)	6/26/1990	<5.0	<5.0	<5.0	<5.0
	9/20/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-608	12/4/1984	3.7J	<10	<10	NA
	12/10/1984	4.0J	<10	<10	NA
	2/4/1985	1.6	<10	<10	NA
	11/12/1986	<4.4	<6.0	<7.2	<12
HP-609	1/16/1985	<10	<10	<10	NA
	9/20/1995	<0.50	<0.50	<0.50	<0.50
HP-610	2/4/1985	<10	<10	<10	NA
	10/1/1992	NA	<1.0	NA	<1.0
HP-611 (old)	1/16/1985	<10	<10	<10	NA
HP-611 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-612 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-613	1/16/1985	<10	<10	<10	NA
	9/20/1995	<0.50	<0.50	<0.50	<0.50
HP-614 (old)	1/16/1985	<10	<10	<10	NA
HP-614 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50

Table C8. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in Hadnot Point water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
HP-616	1/16/1985	<10	<10	<10	NA
	8/1/1995	<0.10	<0.10	<0.10	NA
	11/1/1995	<0.10	<0.10	<0.10	NA
	2/1/1996	<0.10	<0.10	<0.10	NA
	5/2/1996	<0.10	<0.10	<0.10	NA
	7/24/1996	<0.50	<0.50	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	<0.50
	9/20/1995	<0.50	<0.50	<0.50	<0.50
HP-620	1/16/1985	<10	<10	<10	NA
	9/19/1995	<0.50	<0.50	<0.50	<0.50
HP-621 (old)	1/16/1985	<10	<10	<10	NA
HP-621 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-622	6/26/1990	<5.0	<5.0	<5.0	<5.0
	9/20/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-623	6/26/1990	<5.0	<5.0	<5.0	<5.0
	9/20/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-627 (old)	1/16/1985	<10	<10	<10	NA
HP-627 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-628	9/20/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-629 (new)	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-632	1/16/1985	<10	<10	<10	NA
HP-633	1/16/1985	<10	<10	<10	NA
	9/20/1995	<0.50	<0.50	<0.50	<0.50
HP-634	12/10/1984	<10	<10	<10	NA
	1/16/1985	<10	<10	<10	NA
	11/12/1986	<4.4	<6.0	<7.2	<12
	1/22/1991	<5.0	<5.0	<5.0	<5.0
HP-635	7/5/1984	<0.3	<0.5	<0.9	NA
	1/16/1985	<10	<10	<10	NA
HP-636	1/16/1985	<10	<10	<10	NA
	4/11/1994	<2.0	<2.0	<2.0	<2.0
HP-637	12/10/1984	<10	<10	<10	NA
	1/16/1985	<10	<10	<10	NA
	1/22/1991	<5.0	<5.0	<5.0	<5.0

Table C8. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in Hadnot Point water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
HP-638	7/5/1984	<0.3	<0.5	<0.9	NA
	1/16/1985	<10	<10	<10	NA
HP-639 (old)	1/16/1985	<10	<10	<10	NA
HP-639 (new)	1/16/1985	<10	<10	<10	NA
HP-640	1/16/1985	<10	<10	<10	NA
	9/20/1995	<0.50	<0.50	<0.50	<0.50
HP-641	1/16/1985	<10	<10	<10	NA
HP-642	12/10/1984	<10	<10	<10	NA
	1/16/1985	<10	<10	<10	NA
	8/11/1988	<10	<10	<10	<10
	1/22/1991	<5.0	<5.0	<5.0	<5.0
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-651	1/16/1985	<10	<10	<10	NA
	2/7/1985	<10	<10	<10	NA
	2/7/1985	<10	<10	<10	NA
	11/12/1986	<4.4	<6.0	<7.2	<12
	1/22/1991	<5.0	0.9J	<0.5	<0.5
HP-652	1/16/1985	<10	<10	<10	NA
	11/12/1986	<1.0	<6.0	<7.2	<12
	1/22/1991	<5.0	<5.0	<5.0	<5.0
	9/20/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-653	1/16/1985	<10	<10	<10	NA
	11/12/1986	<4.4	<6.0	<7.2	<12
	1/22/1991	<5.0	<5.0	<5.0	<5.0
HP-654	2/4/1985	<10	<10	<10	NA
	9/19/1995	<0.50	<0.50	<0.50	<0.50
HP-655	1/16/1985	<10	<10	<10	NA
HP-660	12/4/1984	<10	<10	<10	NA
	12/10/1984	<10	<10	<10	NA
	1/16/1985	<10	<10	<10	NA
	11/12/1986	<4.4	<6.0	<7.2	<12
	1/22/1991	<5.0	<5.0	<5.0	<5.0
HP-661	9/20/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-662	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-663	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50

Table C8. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in Hadnot Point water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
HP-709	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-710	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-711	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-5186	6/26/1990	<5.0	<5.0	<5.0	<5.0
	9/20/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
LCH4007	1/16/1985	<10	<10	<10	NA
	9/19/1995	<0.50	<0.50	<0.50	<0.50
LCH4009	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50

[1] See Plate 1 for location

Data sources:

Camp Lejeune Water Documents #1093, #1094, #1652, #1654, #1796, #1800, #1818–#1823, #4546–#4557, #5512–#5515, #5518–#5520, #5595–#5631, #5637, #5638, #5639, #5640, #5646, #5647, #5648, #5649, #5650, #5651, #5652, #5656, #5670, #5671

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Environmental Science and Engineering, Inc. 1985, 1992a,b

Geological Resources, Inc. 2002

Greenhorne and O'Mara 1994

J.R. Bailey, U.S. Marine Corps Base Camp Lejeune, Remedial Investigation/Feasibility Study (RI/FS) at the U.S. Marine Corps Base Camp Lejeune, North Carolina, written communication, June 5, 1987 (CERCLA Administrative Record file #318)

Table C9. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*Trans*-1,2-DCE	*Cis*-1,2-DCE	Total 1,2-DCE	VC
HP-557	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-558	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-584	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-617 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-618 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-619 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-643	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-644	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-645	2/4/1985	<10	<10	<10	<10	NA	NA	<10
HP-646	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/2/1996	<0.10	<0.10	NA	NA	NA	NA	<0.10
	7/24/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-647	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/2/1996	<0.10	<0.10	NA	NA	NA	NA	<0.10
	7/24/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-648	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-649	2/4/1985	<10	<10	<10	<10	NA	NA	<10
HP-650	1/16/1985	<10	<10	<10	<10	NA	NA	<10
	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-698	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-699	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-700	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50

Table C9. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*Trans*-1,2-DCE	*Cis*-1,2-DCE	Total 1,2-DCE	VC
HP-701	6/26/1990	<5.0	<5.0	<5.0	NA	NA	NA	<10
	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-703	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-704	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-705	9/21/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-706	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
HP-707	6/26/1990	<5.0	<5.0	<5.0	NA	NA	NA	<10
HP-708	9/19/1995	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	NA	<0.50

[1] See Plate 1 for location

Data sources:

Camp Lejeune Water Documents CLW #1653, #2955, #2956, #4546–#4557, #5516, #5517, #5621–#5626

CERCLA Administrative Records files #354, #1706, #1731, #1773

Elizabeth.A. Betz, U.S. Marine Corps Base Camp Lejeune, Drinking Water Well Monitoring, written communication, August 7, 1990 (CERCLA Administrative Records file #354)

Baker Environmental, Inc. 1996l, 1997f

Bionomics Laboratory, Inc. 1995

Geological Resources, Inc. 2002

Table C10. Summary of analyses for benzene, toluene, ethylbenzene, and xylene in water samples collected in Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
HP-557	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-558	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-584	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-617 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-618 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-619 (new)	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-643	1/16/1985	<10	<10	<10	NA
	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-644	1/16/1985	<10	<10	<10	NA
	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-645	2/4/1985	<10	<10	<10	NA
	11/6/1986	20	7.5	ND	ND
	2/17/1987	290	15	38	36
HP-646	1/16/1985	<10	<10	<10	NA
	2/1/1996	<0.10	<0.20	<0.10	NA
	5/2/1996	<0.10	<0.10	<0.10	NA
	7/24/1996	<0.50	<0.50	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-647	1/16/1985	<10	<10	<10	NA
	8/1/1995	<0.10	<0.10	<0.10	NA
	11/1/1995	<0.10	<0.10	<0.10	NA
	2/1/1996	<0.10	<0.10	<0.10	NA
	5/2/1996	<0.10	<0.10	<0.10	NA
	7/24/1996	<0.50	<0.50	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-648	1/16/1985	<10	<10	<10	NA
	9/19/1995	<0.50	<0.50	<0.50	<0.50
HP-649	2/4/1985	<10	<10	<10	NA
HP-650	1/16/1985	<10	<10	<10	NA
	9/19/1995	<0.50	<0.50	<0.50	<0.50
HP-698	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-699	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50

Table C10. Summary of analyses for benzene, toluene, ethylbenzene, and xylene in water samples collected in Holcomb Boulevard Water Treatment Plant water-supply wells, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
HP-700	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-701	6/26/1990	<5.0	<5.0	<5.0	<5.0
	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-703	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-704	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-705	9/21/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50
HP-706	9/19/1995	0.60	<0.50	<0.50	<0.50
	1/13/1998	6.1	NA	NA	NA
HP-707	6/26/1990	<5.0	<5.0	<5.0	<5.0
HP-708	9/19/1995	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50

[1] See Plate 1 for location

Data sources:

Camp Lejeune Water Documents CLW #1653, #2955, #2956, #4546–#4557, #5516, #5517, #5621–#5626

CERCLA Administrative Records files #354, #1706, #1731, #1773

Elizabeth A. Betz, U.S. Marine Corps Base Camp Lejeune, Drinking Water Well Monitoring, written communication, August 7, 1990

Baker Environmental, Inc. 1996l, 1997f

Bionomics Laboratory, Inc. 1995

Geological Resources, Inc. 2002

Table C11. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected at the Hadnot Point Water Treatment Plant, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration]

Sample date	Concentration, in micrograms per liter						
	PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
5/27/1982[1]	15	1,400	NA	NA	NA	NA	NA
7/27/1982[2]	100	NA	NA	NA	NA	NA	NA
7/27/1982[3]	<1.0	19	NA	NA	NA	NA	NA
7/27/1982[4]	<1.0	21	NA	NA	NA	NA	NA
12/4/1984[4]	3.9J	200	<10	83	NA	NA	NA
12/4/1984[3]	<10	46	<10	15	NA	NA	NA
12/12/1984[4]	<10	2.3J	<10	2.3J	NA	NA	<10
12/13/1984[5]	<10	<10	<10	<10	NA	NA	<10
12/14/1984[3]	<10	<10	<10	<10	NA	NA	<10
12/14/1984[3]	<10	<10	<10	<10	NA	NA	<10
12/15/1984[3]	<10	<10	<10	<10	NA	NA	<10
12/16/1984[3]	<10	<10	<10	<10	NA	NA	<10
12/17/1984[3]	<10	<10	<10	<10	NA	NA	<10
12/18/1984[3]	<10	<10	<10	<10	<10	<10	<10
12/19/1984[5]	<10	<10	<10	<10	<10	<10	<10
12/19/1984[6]	NA	1.2	NA	NA	NA	NA	NA
2/5/1985[5]	7.5J	429	<10	150	NA	NA	2.9J
6/18/1985[5]	<10	<10	<10	<10	NA	NA	<10
6/24/1985[5]	<10	<10	<10	<10	NA	NA	<10
7/1/1985[5]	<10	<10	<10	<10	NA	NA	<10
7/8/1985[5]	<10	<10	<10	<10	NA	NA	<10
7/31/1985[5]	<10	<10	<10	<10	NA	NA	<10
8/19/1985[5]	<10	<10	<10	<10	NA	NA	<10
9/11/1985[5]	<10	<10	<10	<10	NA	NA	<10
9/17/1985[5]	<10	<10	<10	<10	NA	NA	<10
9/24/1985[5]	<10	<10	<10	<10	NA	NA	<10
10/30/1985[5]	<10	<10	<10	<10	NA	NA	<10
3/3/1986[4]	<10	<10	<10	<10	NA	NA	<10
3/11/1986[4]	<10	<10	<10	<10	NA	NA	<10
4/16/1986[4]	<10	<10	<10	<10	NA	NA	<10
4/21/1986[4]	<10	<10	<10	<10	NA	NA	<10
5/5/1986[4]	<10	<10	<10	<10	NA	NA	<10
5/12/1986[4]	<10	<10	<10	<10	NA	NA	<10
5/19/1986[4]	<10	<10	<10	<10	NA	NA	<10
5/27/1986[4]	<10	<10	<10	<10	NA	NA	<10
6/2/1986[4]	<10	<10	<10	<10	NA	NA	<10
6/9/1986[4]	<10	<10	<10	<10	NA	NA	<10
6/16/1986[4]	<10	<10	<10	<10	NA	NA	<10
6/25/1986[4]	<10	<10	<10	<10	NA	NA	<10
7/1/1986[4]	<10	<10	<10	<10	NA	NA	<10
7/9/1986[4]	<10	<10	<10	<10	NA	NA	<10
7/14/1986[4]	<10	<10	<10	<10	NA	NA	<10
7/21/1986[4]	<10	<10	<10	<10	NA	NA	<10
7/28/1986[4]	<10	<10	<10	<10	NA	NA	<10

Table C11. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected at the Hadnot Point Water Treatment Plant, U.S. Marine Corps Base Camp Lejeune, North Carolina. —Continued

[NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration]

Sample date	Concentration, in micrograms per liter						
	PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
8/4/1986[4]	<10	<10	<10	<10	NA	NA	<10
12/16/1986[3]	<10	<10	<10	<10	NA	NA	<10
12/23/1987[5]	<0.5	0.20	<0.5	<0.5	NA	NA	<0.5
1/11/1988[5]	<10	<10	<10	<10	NA	NA	<10
3/2/1988[5]	NA	<0.5	<0.5	NA	NA	NA	<0.5
5/11/1988[5]	NA	<0.5	<0.5	NA	NA	NA	<0.5
8/11/1988[5]	<10	<10	<10	<10	NA	NA	<10
9/15/1988[5]	NA	<0.5	<0.5	NA	NA	NA	<0.5
5/9/1989[5]	NA	<0.5	<0.5	NA	NA	NA	<0.5
8/8/1989[5]	NA	<0.5	<0.5	NA	NA	NA	<0.5
11/6/1989	NA	0.9	<0.5	NA	NA	NA	<0.5
6/26/1990[4]	<5.0	<5.0	<5.0	NA	NA	NA	<10
6/26/1990[3]	<5.0	<5.0	<5.0	NA	NA	NA	<10
2/13/1991[5]	<0.5	<0.5	<0.5	<0.5	<0.5	NA	<0.5
5/20/1991[5]	NA	<0.5	<0.5	NA	NA	NA	<0.5
8/5/1991[5]	NA	<0.5	<0.5	NA	NA	NA	<0.5
11/4/1991[5]	NA	<0.5	<0.5	NA	NA	NA	<0.5

[1] Water sample collected at Building NH-1; data reported as unreliable

[2] Water sample collected at Building FC-530

[3] Untreated water

[4] Treated water

[5] Treatment status unknown

[6] Sample collected at Building FC-540

Data sources:

Camp Lejeune Water Documents #1796–#1800, #1819, #3300, #4550, #5111, #5138 ,#5140, #5155, #5182, #5466, #5482, #5525, #5635, #5636, #4550, #5653, #5657, #5660, #5661, #5662, #5663, #5666, #5668, #5842, #5853, #5859, #5885

Elizabeth A. Betz, U.S. Marine Corps Base Camp Lejeune, written communication, August 7, 1990 (CERCLA Administrative Record file #354)

JTC Environmental Consultants, Inc., 1986-1987

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #87w8817-1, written communication, February 8, 1988

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis, written communication, March 5, 1988 (date is analysis completion date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #88w1451-1, written communication, May 19, 1988

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #88w2901-1, written communication, September 28, 1988 (date is analysis completion date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis, written communication, May 9, 1989 (date is sample collection date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #89w7311-2, written communication, August 10, 1989 (date is analysis completion date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #89w8793, written communication, November 18, 1989

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #91w7876-1, written communication, February 22, 1991 (date is analysis report date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #91w9770-1, written communication, June 4, 1991 (date is analysis report date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #91w2148-1, written communication, September 19, 1991 (date is analysis report date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #91w3938-1, written communication, November 25, 1991 (date is analysis report date)

Table C12. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected at the Hadnot Point Water Treatment Plant, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Sample date	Concentration, in micrograms per liter			
	Benzene	Toluene	Ethylbenzene	Total xylene
12/4/1984[1]	<10	<10	<10	NA
12/4/1984[2]	<10	<10	<10	NA
12/12/1984[1]	<10	<10	<10	NA
12/14/1984[2]	<10	<10	<10	NA
12/18/1984[2]	<10	<10	<10	NA
12/19/1984[3]	<10	<10	<10	NA
2/7/1985[3]	<10	<10	<10	NA
6/18/1985[3]	<10	<10	<10	NA
6/24/1985[3]	<10	<10	<10	NA
7/1/1985[3]	<10	<10	<10	NA
7/8/1985[3]	<10	<10	<10	NA
7/31/1985[3]	<10	<10	<10	NA
8/19/1985[3]	<10	<10	<10	NA
9/11/1985[1]	<10	<10	<10	NA
9/17/1985[3]	<10	<10	<10	NA
9/24/1985[3]	<10	<10	<10	NA
10/30/1985[3]	<10	<10	<10	NA
11/19/1985[3]	2,500	100	NA	NA
12/10/1985[3]	38	10	NA	NA
12/18/1985[3]	1.0	NA	NA	NA
3/3/1986[1]	<10	<10	<10	<10
3/11/1986[1]	<10	<10	<10	<10
4/16/1986[1]	<10	<10	<10	<10
4/21/1986[1]	<10	<10	<10	<10
5/5/1986[1]	<10	<10	<10	<10
5/12/1986[1]	<10	<10	<10	<10
5/19/1986[1]	<10	<10	<10	<10
5/27/1986[1]	<10	<10	<10	<10
6/2/1986[1]	<10	<10	<10	<10
6/9/1986[1]	<10	<10	<10	<10
6/16/1986[1]	<10	<10	<10	<10
6/25/1986[1]	<10	<10	<10	<10
7/1/1986[1]	<10	<10	<10	<10
7/9/1986[1]	<10	<10	<10	<10
7/14/1986[1]	<10	<10	<10	<10
7/21/1986[1]	<10	<10	<10	<10
7/28/1986[1]	<10	<10	<10	<10
8/4/1986[1]	<10	<10	<10	<10
12/16/1986[1]	<10	<10	<10	<10
12/23/1987[3]	<0.5	<0.5	<0.5	<0.5

Table C12. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected at the Hadnot Point Water Treatment Plant, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Sample date	Concentration, in micrograms per liter			
	Benzene	Toluene	Ethylbenzene	Total xylene
3/2/1988[3]	<0.5	NA	NA	NA
5/11/1988[3]	<0.5	NA	NA	NA
8/11/1988[3]	<10	<10	<10	<10
9/15/1988[3]	<0.5	NA	NA	NA
5/9/1989[3]	<0.5	NA	NA	NA
8/8/1989[3]	<0.5	NA	NA	NA
11/6/1989	<0.5	NA	NA	NA
6/26/1990[1]	<5.0	<5.0	<5.0	<5.0
6/26/1990[2]	<5.0	<5.0	<5.0	<5.0
2/13/1991[3]	<0.5	<0.5	<0.5	<0.5
5/20/1991[3]	<0.5	NA	NA	NA
8/5/1991[3]	<0.5	NA	NA	0.73
11/4/1991[3]	<0.5	NA	NA	NA

[1] Treated water

[2] Untreated water

[3] Treatment status unknown

Data sources:

Camp Lejeune Water Documents #1356, #1796–#1800, #1819, #5111, #5138, #5140, #5155, #5466, #5482, #5525, #5635, #5636, #5653, #5657, #5666, #5668, #5842, #5853, #5859, #5885

Elizabeth A. Betz, U.S. Marine Corps Base Camp Lejeune, written communication, August 7, 1990 (CERCLA Administrative Report file #357)

JTC Environmental Consultants, Inc., 1986–1987

Oxford Laboratories, Inc., Hadnot Point WTP water system analysis #87w8817-1, written communication, February 8, 1988

Oxford Laboratories, Inc., Hadnot Point WTP water system analysis, written communication, March 5, 1988 (date is analysis completion date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #88w1451-1, written communication, May 19, 1988

Oxford Laboratories, Inc., Hadnot Point WTP water system analysis #88w2901-1, written communication, September 28, 1988 (date is analysis completion date)

Oxford Laboratories, Inc., Hadnot Point WTP water system analysis, written communication, May 9, 1989 (date is sample completion date)

Oxford Laboratories, Inc., Hadnot Point WTP water system analysis #88w2901-1, written communication, August 10, 1989 (date is analysis completion date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #89w8783, written communication, November 18, 1989

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #91w7876, written communication, February 22, 1991 (date is analysis report date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #91w9770, written communication, June 4, 1991 (date is analysis report date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #91w2148-1, written communication, September 19, 1991 (date is analysis report date)

Oxford Laboratories, Inc., Hadnot Point WTP water sample analysis #91w3938-1, written communication, November 25, 1991 (date is analysis report date)

Table C13. Summary of analyses for trichloroethylene (TCE) and *trans*-1,2-dichloroethylene (*trans*-1,2-DCE) at locations within the Holcomb Boulevard Water Treatment Plant distribution network, January 29–February 7, 1985, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; WTP, water treatment plant]

Sample location	Date	Time	Concentration, in micrograms per liter	
			TCE	*trans*-1,2-DCE
2212 Paradise Point	1/29/1985	1315	1,041	NA
Building #670, reservoir		1405	8.2	NA
Building #670, upstream of reservoir		1420	340	NA
2212 Paradise Point, cold water	1/31/1985	1235	725	249
2212 Paradise Point, hot water		1235	613	201
Tank S-2323		1253	407	159
Hydrant near 2204 Paradise Point		1300	840	308
2600 Paradise Point		1306	891	332
Hydrant near Tank S830		1315	849	340
5677 Berkeley Manor		1330	981	369
5531 Berkeley Manor		1335	906	335
Tank SLCH 4004		1349	318	108
Building #670, top of reservoir		1400	27	7.6
Building #670, bottom of reservoir		1410	24	7.4
Building #670, middle of reservoir		1417	26	7.8
Building #20		1433	900	321
Building #5400, Berkeley Manor School		NA	1,148	407
Building #20	2/5/1985[1]	NA	429	150
Building #20 finished water	2/7/1985[2]	NA	17	5.3
Building #20 filter effluent #1		NA	< 2.0	< 2.0
Building #20 filter effluent #2		NA	< 2.0	< 2.0
Building #20 influent		NA	< 2.0	< 2.0
Building #670 finished water reservoir		NA	< 2.0	< 2.0
Building #670 filter effluent #1		NA	< 2.0	< 2.0
Building #670 filter effluent #2		NA	< 2.0	< 2.0
Building #670 influent		NA	< 2.0	< 2.0
Hydrant near 2204 Paradise Point		NA	32	9.0
Building #5400, Berkeley Manor School		NA	135	45

[1] See Table C11 for complete analysis

[2] Holcomb Boulevard WTP was reactivated on February 4, 1985. Flushing of entire Holcomb Boulevard WTP and Hadnot Point WTP distribution systems was initiated (Camp Lejeune Water Document CLW #4547)

Data sources:

Camp Lejeune Water Documents #1119–#1123, #1434–#1439, #4514–#4516, #4546–#4548, #5369–#5371, #5525, #6590–6592

Table C14. Geohydrologic units and unit thickness within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[Units are listed shallowest to deepest and youngest to oldest; N/A, not available]

Geohydrologic unit	Thickness range, in feet
Brewster Boulevard aquifer system	
Brewster Boulevard upper aquifer	3 to 38
Brewster Boulevard upper confining unit	1 to 22
Brewster Boulevard lower aquifer	11 to 48
Brewster Boulevard lower confining unit	3 to 30
Tarawa Terrace aquifer	8 to 86
Tarawa Terrace confining unit	11 to 40
Castle Hayne aquifer system	
Upper Castle Hayne aquifer–River Bend unit	20 to 70
Local confining unit	8 to 22
Upper Castle Hayne aquifer–Lower unit	11 to 34
Middle Castle Hayne confining unit	12 to 30
Middle Castle Hayne aquifer	62 to 123
Lower Castle Hayne confining unit	18 to 38
Lower Castle Hayne aquifer	73 to 96
Beaufort confining unit	N/A

Table C15. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 1, French Creek liquids disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
01-GW01	333927	2502925	13.3	1984	24.0	NA	BBUAQ(?), BBLAQ(?)
01-GW02	333936	2502570	15.7	1984	23.0	9.0–23.0	BBUAQ, BBUCU, BBLAQ
01-GW03	333627	2502391	19.7	1984	23.0	9.0–23.0	BBUAQ, BBUCU, BBLAQ
01-GW04	332890	2501996	22.9	1984	31.5	17.5–31.5	BBUCU(?), BBLAQ
01-GW05	332567	2501935	22.4	1984	31.0	17.0–31.0	BBUCU(?), BBLAQ
01-GW06	332970	2503007	25.1	1984	29.6	N/A	BBUCU(?), BBLAQ(?)
01-GW07	332234	2501551	20.2	4/12/1994	24.7	10.1–24.7	BBUAQ, BBUCU
01-GW08	332716	2501579	19.4	4/12/1994	24.4	10.1–24.4	BBUAQ, BBUCU, BBLAQ(?)
01-GW09	333130	2501612	14.9	4/10/1994	20.1	6.2–20.4	BBUAQ, BBUCU, BBLAQ
01-GW10	333867	2502095	15.3	4/11/1994	23.4	9.1–23.4	BBUAQ, BBUCU, BBLAQ
01-GW11	334163	2502775	10.4	4/10/1994	16.7	2.1–16.4	BBUAQ, BBUCU, BBLAQ
01-GW12	334048	2503302	13.8	4/10/1994	17.4	3.1–17.4	BBUAQ, BBUCU, BBLAQ
01-GW13	332899	2503901	29.5	4/9/1994	30.4	16.0–30.4	BBUAQ, BBUCU, BBLAQ
01-GW14	333385	2502858	[3]21	N/A	N/A	N/A	BBUAQ(?), BBLAQ(?)
01-GW15	333895	2502616	[3]15	N/A	N/A	N/A	BBUAQ(?), BBLAQ(?)
01-GW16	332660	2501994	20.7	4/13/1994	26.4	12.1–26.4	BBUAQ, BBUCU, BBLAQ
01-GW16DW	332642	2501970	20.8	5/4/1994	122.0	107.0–122.0	UCHRBU
01-GW17	333651	2502776	20.1	4/19/1994	24.4	10.0–24.4	BBUAQ, BBUCU, BBLAQ
01-GW17DW	333674	2502775	19.1	5/7/1994	105.0	105.0–120.0	UCHRBU
01-GW18	333538	2502665	[3]21	8/15/1995	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ

[1] See Figure C2 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data sources:

CERCLA Administrative Record files #1499, #1505, #1771, #2592

Baker Environmental, Inc. 1995k,m,p, 1997h

Table C16. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 1, French Creek liquids disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
01-GW01	7/5/1984	<1.5	2.0	<1.0	1.0	NA	NA	<0.8
	11/18/1986	<4.1	4.6	<2.8	3.4	NA	NA	<4.9
	4/15/1993	<10	<10	<10	NA	NA	<10	<10
	4/22/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
	8/15/1995	NA	<10	NA	NA	NA	<10	NA
	7/28/1996	<10	<10	<10	NA	NA	<10	<10
	2/23/1997	<10	<10	<10	NA	NA	<10	<10
	8/8/1997	<10	<10	<10	NA	NA	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
01-GW02	7/5/1984	<1.5	1.3	<1.0	<1.0	NA	NA	<0.8
	11/18/1986	<4.1	3.2	<2.8	<1.6	NA	NA	<4.9
	4/15/1993	<10	<10	<10	NA	NA	<10	<10
	4/22/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
	8/15/1995	NA	<10	NA	NA	NA	<10	NA
	7/30/1996	<10	<10	<10	NA	NA	<10	<10
	2/23/1997	<10	<10	<10	NA	NA	<10	<10
	8/8/1997	<10	<10	<10	NA	NA	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
01-GW03	7/5/1984	<1.5	<1.2	<1.1	<1.0	NA	NA	<0.8
	11/19/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	4/15/1993	<10	<10	<10	NA	NA	<10	<10
	4/22/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
	8/15/1995	NA	<10	NA	NA	NA	<10	NA
	7/30/1996	<10	<10	<10	NA	NA	<10	<10
	2/23/1997	<10	<10	<10	NA	NA	<10	<10
	8/8/1997	<10	<10	<10	NA	NA	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
01-GW04	7/5/1984	<1.5	<1.1	<1.0	<1.0	NA	NA	<0.8
	11/18/1986	<4.1	<1.9	<2.8	<1.6	NA	NA	<4.9
	4/15/1993	<10	<10	<10	NA	NA	<10	<10
	4/24/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
	4/24/1994	NA	ND	NA	NA	NA	ND	ND
01-GW05	7/7/1984	6.8	5.2	1.1	2.4	NA	NA	<0.8
	11/18/1986	<4.1	2.2	2.8	2.4	NA	NA	<4.9

Table C16. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 1, French Creek liquids disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
01-GW06	7/5/1984	<1.7	<1.3	<1.2	<1.2	NA	NA	<0.9
	11/18/1986	<4.1	<1.9	<2.8	<1.6	NA	NA	<4.9
	4/15/1993	<10	<10	<10	NA	NA	<10	<10
	4/23/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW07	4/24/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW08	4/24/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW09	4/24/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW10	4/24/1994	<2.0	4.0	<2.0	NA	NA	10	2.0
	11/11/1994	NA	8.0J	2.0J	NA	NA	21	4.0J
	8/15/1995	NA	4.0J	NA	NA	NA	23	NA
	7/28/1996	<10	<10	<10	NA	NA	19	<10
	2/23/1997	<10	3.0J	<10	NA	NA	16	<10
	8/8/1997	<10	<10	<10	NA	NA	16	<10
	1/21/1998	<5.0	1.6J	<5.0	NA	NA	14	<10
	10/25/1998	<5.0	2.0J	<5.0	NA	NA	16	2.0J
	7/30/1999	<5.0	<5.0	<5.0	<5.0	12	12	1.0J
	10/23/1999	<5.0	12.0	<5.0	<5.0	18	18	<2.0
	1/12/2000	<5.0	<5.0	<5.0	<5.0	16	16	<2.0
	4/13/2000	<5.0	<5.0	<5.0	<5.0	12	12	<2.0
	7/15/2000	<5.0	<5.0	<5.0	<5.0	14	14	1.0J
	10/21/2000	<5.0	<5.0	<5.0	<5.0	11	11	<2.0
01-GW11	4/24/1994	<2.0	1.0J	<2.0	NA	NA	<2.0	<2.0
	11/12/1994	NA	ND	ND	NA	NA	ND	ND
	8/15/1995	NA	<10	NA	NA	NA	<10	NA
	7/28/1996	<10	<10	<10	NA	NA	<10	<10
	2/23/1997	<10	<10	<10	NA	NA	<10	<10
	8/8/1997	<10	<10	<10	NA	NA	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
01-GW12	4/24/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
	11/12/1994	NA	ND	ND	NA	NA	ND	ND
	8/15/1995	NA	<10	NA	NA	NA	<10	NA
	7/28/1996	<10	<10	<10	NA	NA	<10	<10
	2/23/1997	<10	<10	<10	NA	NA	<10	<10
	8/8/1997	<10	<10	<10	NA	NA	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10

Table C16. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 1, French Creek liquids disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
01-GW13	4/23/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW14	4/24/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW15	4/23/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW16	4/24/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW16DW	5/9/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
01-GW17	4/24/1994	<2.0	27	<2.0	NA	NA	1.0J	<2.0
	11/16/1994	NA	18	ND	NA	NA	ND	ND
	8/15/1995	NA	<10	NA	NA	NA	<10	NA
	7/31/1996	<10	<10	<10	NA	NA	<10	<10
	2/24/1997	<10	3.0J	<10	NA	NA	<10	<10
	8/8/1997	<10	<10	<10	NA	NA	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/28/1998	<1.0	2.0	<1.0	NA	NA	<1.0	<1.0
	7/30/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/19/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/12/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/13/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/14/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/20/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
01-GW17DW	5/25/1994	<10	<10	<10	NA	NA	<10	<10
	8/15/1995	NA	<10	NA	NA	NA	<10	NA
	7/31/1996	<10	<10	<10	NA	NA	<10	<10
	2/24/1997	<10	<10	<10	NA	NA	<10	<10
	8/8/1997	<10	<10	<10	NA	NA	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
01-GW18	8/15/1995	NA	<10	NA	NA	NA	<10	NA

[1] See Figure C2 for location

Data sources:

CERCLA Administrative Record files #387, #388, #1499, #1501, #1749, #1771, #1772, #2017, #2592, #2602A, #2611A, #3310, #3414

Baker Environmental, Inc. 1995k,o,p, 1996m, 1997h,i, 1998n

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 1998, 2000b,h

CH2M Hill, Inc. and Baker Environmental, Inc. 2001e

Environmental Science and Engineering, Inc. 1985, 1987

Table C17. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 1, French Creek liquids disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
01-GW01	7/5/1984	0.50	<0.50	NA	NA
	11/18/1986	<0.02	<6.0	<7.2	<12
	4/15/1993	<10	<10	<10	<10
	4/22/1994	<2.0	<2.0	<2.0	<2.0
	8/15/1995	NA	<10	<10	<10
	7/28/1996	<10	<10	<10	<10
	2/23/1997	<10	<10	<10	<10
	8/8/1997	<10	<10	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	0.76J
01-GW02	7/5/1984	<0.30	<0.50	NA	NA
	11/18/1986	<0.02	<6.0	<7.2	<12
	4/15/1993	<10	<10	<10	<10
	4/22/1994	<2.0	<2.0	<2.0	<2.0
	8/15/1995	NA	<10	<10	<10
	7/30/1996	<10	<10	<10	<10
	2/23/1997	<10	<10	<10	<10
	8/8/1997	<10	<10	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	<5.0
01-GW03	7/5/1984	<0.30	<0.60	NA	NA
	11/19/1986	<0.02	<6.0	<7.2	<12
	4/15/1993	<10	<10	<10	<10
	4/22/1994	<2.0	<2.0	<2.0	<2.0
	8/15/1995	NA	<10	<10	<10
	7/30/1996	<10	<10	<10	<10
	2/23/1997	<10	<10	<10	<10
	8/8/1997	<10	<10	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	<5.0
01-GW04	7/5/1984	<0.30	<0.50	NA	NA
	11/18/1986	<0.02	<6.0	<7.2	<12
	4/15/1993	<10	<10	<10	<10
	4/24/1994	<2.0	<2.0	<2.0	<2.0
01-GW05	7/7/1984	<0.30	<0.60	NA	NA
	11/18/1986	<0.02	<6.0	<7.2	<12

Table C17. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 1, French Creek liquids disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
01-GW06	7/5/1984	<0.30	NA	NA	NA
	11/18/1986	<0.02	<6.0	<7.2	<12
	4/15/1993	<10	<10	<10	<10
	4/23/1994	<2.0	<2.0	<2.0	<2.0
01-GW07	4/24/1994	<2.0	<2.0	<2.0	<2.0
01-GW08	4/24/1994	<2.0	<2.0	<2.0	<2.0
01-GW10	4/24/1994	<2.0	<2.0	<2.0	<2.0
	11/11/1994	NA	NA	NA	ND
	8/15/1995	NA	<10	<10	<10
	7/28/1996	<10	<10	<10	<10
	2/23/1997	<10	<10	<10	<10
	8/8/1997	<10	<10	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	<5.0
	10/25/1998	<5.0	<5.0	<5.0	<5.0
	7/30/1999	<5.0	<5.0	<5.0	<5.0
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	1/12/2000	<5.0	<5.0	<5.0	NA
	4/13/2000	<5.0	<5.0	<5.0	<5.0
	7/15/2000	<5.0	<5.0	<5.0	<5.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0
01-GW11	4/24/1994	<2.0	<2.0	<2.0	<2.0
	11/12/1994	NA	NA	NA	ND
	8/15/1995	NA	<10	<10	<10
	7/28/1996	<10	<10	<10	<10
	2/23/1997	<10	<10	<10	<10
	8/8/1997	<10	<10	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	<5.0
01-GW12	4/24/1994	<2.0	<2.0	<2.0	3.0
	11/12/1994	NA	NA	NA	19
	8/15/1995	NA	4.0J	4.0J	150
	7/28/1996	<10	<10	<10	6.0J
	2/23/1997	<10	<10	<10	<10
	8/8/1997	<10	<10	<10	280
	1/21/1998	<5.0	<5.0	<5.0	<5.0

Table C17. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 1, French Creek liquids disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
01-GW13	4/23/1994	<2.0	<2.0	<2.0	<2.0
01-GW14	4/24/1994	<2.0	<2.0	<2.0	<2.0
01-GW16	4/24/1994	<2.0	<2.0	<2.0	<2.0
01-GW16DW	5/9/1994	<2.0	<2.0	<2.0	<2.0
01-GW17	4/24/1994	<2.0	<2.0	<2.0	<2.0
	11/16/1994	NA	NA	NA	ND
	8/15/1995	NA	<10	<10	<10
	7/31/1996	<10	<10	<10	<10
	2/24/1997	<10	<10	<10	<10
	8/8/1997	<10	<10	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	<5.0
	10/28/1998	<1.0	<1.0	<1.0	<1.0
	7/30/1999	<5.0	<5.0	<5.0	<5.0
	10/19/1999	<5.0	<5.0	<5.0	<5.0
	1/12/2000	<5.0	<5.0	<5.0	NA
	4/13/2000	<5.0	<5.0	<5.0	<5.0
	7/14/2000	<5.0	<5.0	<5.0	<5.0
	10/20/2000	<5.0	<5.0	<5.0	<5.0
01-GW17DW	5/25/1994	<10	<10	<10	<10
	8/15/1995	NA	<10	<10	<10
	7/31/1996	<10	<10	<10	<10
	2/24/1997	<10	<10	<10	<10
	8/8/1997	<10	<10	<10	<10
	1/21/1998	<5.0	<5.0	<5.0	<5.0
01-GW18	8/15/1995	NA	<10	<10	<10

[1] See Figure C2 for location

Data sources:

CERCLA Administrative Record files #387, #388, #1499, #1501, #1749, #1771, #1772, #2017, #2592, #2602A, #2611A, #3310, #3414

Baker Environmental, Inc. 1995k,o,p, 1996m, 1997h,i, 1998n

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 1998, 2000b,h

CH2M Hill, Inc. and Baker Environmental, Inc. 2001e

Environmental Science and Engineering, Inc. 1985, 1987

Table C18. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, TTAQ—Tarawa Terrace aquifer, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
02-GW01	356697	2498264	32.3	6/ /1984	25.0	10.0–25.0	BBLAQ, BBLCU
02-GW02	356743	2498140	31.9	1986	25.0	10.0–25.0	BBLAQ, BBLCU
02-GW03	356251	2498534	33.0	1986	25.0	10.0–25.0	BBLAQ, BBLCU
02-GW03IW	356271	2498535	[3]33	2/21/1997	N/A	50.0–60.0	TTAQ
02-GW03DW	356275	2498552	33.1	4/23/1993	100.0	90.0–100.0	UCHRBU
02-GW04	356457	2498435	30.7	1986	25.0	10.0–25.0	BBLAQ, BBLCU
02-GW05	356421	2498248	31.8	1986	25.0	10.0–25.0	BBLAQ, BBLCU
02-GW06	356143	2498281	31.8	4/24/1993	12.5	2.6–12.6	BBLAQ
02-GW07	356413	2498604	31.6	4/22/1993	13.0	3.0–13.0	BBLAQ
02-GW08	356191	2498658	31.9	4/23/1993	12.5	2.5–12.5	BBLAQ
02-GW09	356966	2498000	32.6	4/24/1993	13.0	3.0–13.0	BBLAQ
02-GW10	356749	2498310	32.5	2/ /1994	13.5	3.5–13.5	BBLAQ
02-GW11	356570	2498318	33.9	2/ /1994	14.0	1.0–14.0	BBLAQ
02-GW12	356375	2498488	31.5	2/21/1997	23.0	3.0–23.0	BBLAQ, BBLCU

[1] See Figure C3 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data sources:

CERCLA Administrative Record files #387, #1273, #1706, #1774

Baker Environmental, Inc. 1994i, 1996l, 1997g

Environmental Science and Engineering, Inc. 1987

Table C19. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
02-GW01	12/2/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	8/1/1995	<0.10	<0.10	<.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/23/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
02-GW02	12/2/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/3/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/23/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
02-GW03	12/2/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/3/1987	<30	<30	<28	<16	NA	NA	<10
	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/23/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/23/1997	6.6J	<25	<25	NA	NA	<25	<50
	4/20/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/27/1998	<100	<100	<100	NA	NA	<100	<100
	4/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	10/23/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/4/2001	<100	<100	<100	<100	<100	<100	<40
	4/20/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	3.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

Table C19. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
02-GW03D	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/2/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/2/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/25/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
02-GW03IW	4/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/23/1997	10	<5.0	<5.0	NA	NA	<5.0	<10
	4/20/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/25/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	10/23/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
02-GW04	12/2/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/3/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/23/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
02-GW05	12/2/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/3/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/23/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50

Table C19. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
02-GW05—Continued	10/22/1997	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/20/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/25/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	10/23/1999	<5.0	4.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/29/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
02-GW06	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/23/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
02-GW07	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/23/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/23/1997	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/20/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/25/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	10/23/1999	<5.0	7.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/29/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

Table C19. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
02-GW08	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/1/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/24/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/23/1997	7.7	<5.0	<5.0	NA	NA	<5.0	<10
	4/20/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/27/1998	1.0J	<5.0	<5.0	NA	NA	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	10/23/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
02-GW09	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/2/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/25/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/3/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
02-GW10	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/2/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/3/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/25/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/23/1997	3.5J	<5.0	<5.0	NA	NA	<5.0	<10
	4/20/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/25/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	10/23/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

Table C19. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
02-GW11	8/1/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	11/2/1995	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	2/2/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	5/2/1996	<0.10	<0.10	<0.30	<0.10	NA	NA	<0.10
	7/23/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/23/1997	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/20/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/25/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0
02-GW12	4/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/23/1997	8.6	<5.0	<5.0	NA	NA	<5.0	<10
	4/20/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/25/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	10/23/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

[1] See Figure C3 for location

Data sources:

CERCLA Administrative Record files #387, #1273, #1706, #1773, #1774, #1793, #2296, #2310, #2328, #2610A, #3288, #3289, #3290, #3293, #3294, #3419, #3462, #3466

Baker Environmental, Inc. 1994h, 1996l, 1997f,g, 1998l,m, 1999f,i

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000a,f, 2001a, 2002a

Baker Environmental, Inc. and CH2M Hill, Inc. 2002i, 2003

CH2M Hill, Inc. and Baker Environmental, Inc. 2001c,d

Engineering and Environment, Inc. and Micahel Baker, Jr., Inc. 2004c

Environmental Science and Engineering, Inc. 1987

Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2003a

Table C20. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; D, sample dilution required; J, estimated concentration; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
02-GW01	12/2/1986	<1.0	<6.0	<7.2	NA
	8/1/1995	<0.10	<0.10	0.9	<0.60
	11/2/1995	<0.10	<0.10	1.1	<0.80
	2/1/1996	<0.10	<0.10	0.4	<0.10
	5/3/1996	<0.10	<0.10	0.7	<0.60
	7/23/1996	<0.50	<0.50	1.0	<0.50
	10/1/1996	<0.50	<0.50	<0.50	<0.50
02-GW02	12/2/1986	<1.0	<6.0	<7.2	NA
	3/3/1987	<1.0	<6.0	<7.2	NA
	8/1/1995	<0.10	<0.10	<0.10	<0.10
	11/2/1995	0.40	<0.10	<0.10	<0.10
	2/1/1996	<0.10	<0.10	<0.10	<0.10
	5/3/1996	<0.20	<0.10	<0.10	<0.10
	7/23/1996	<0.50	<0.50	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	<0.50
02-GW03	12/2/1986	<1.0	12	330	NA
	3/3/1987	<10	<60	510	NA
	5/20/1993	NA	7.0	93E	510E
	8/1/1995	0.30	3.4	<0.10	1,100
	11/2/1995	<0.10	2.1	60.2	672
	2/1/1996	<0.10	1.4	64.2	593
	5/3/1996	<0.10	1.3	60.7	564
	7/23/1996	<0.50	3.0	130	1,200
	10/1/1996	<0.50	6.0	220	2,100
	4/25/1997	<0.50	7.0	170	1,600
	10/23/1997	<25	7.9J	230	2,000
	4/20/1998	<5.0	5.5	140	1,500D
	10/27/1998	<100	<100	460	1,300
	4/17/1999	<5.0	7.0	130	840D
	10/23/1999	<5.0	5.0	140	1,100
	4/15/2000	<5.0	12	350D	3,000D
	10/21/2000	<5.0	7.0	730D	7,000D
	4/4/2001	<100	<100	360	3,200
	4/20/2002	<5.0	<5.0	69	380
	7/30/2002	<5.0	<5.0	13	140
	1/28/2003	<5.0	0.80J	37	310
	7/26/2003	<5.0	1.0J	93B	880JD
	1/24/2004	<5.0	0.80J	67	560

Table C20. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; D, sample dilution required; J, estimated concentration; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
02-GW03DW	8/1/1995	<0.10	0.30	<0.10	<0.30
	11/2/1995	<0.10	<0.20	<0.10	0.10
	2/2/1996	<0.10	<0.20	<0.10	<0.10
	5/2/1996	<0.10	<0.40	<0.20	<0.60
	7/25/1996	<0.50	<0.50	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	<0.50
02-GW03IW	4/25/1997	<0.50	<0.50	<0.50	4.0
	10/23/1997	<5.0	<5.0	<5.0	1.6J
	4/20/1998	<5.0	<5.0	<5.0	3.0J
	10/25/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<15
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0
	1/28/2003	<5.0	<5.0	<1.0	2.0J
	7/26/2003	<5.0	<5.0	<5.0	0.90J
	1/24/2004	<5.0	<5.0	0.20J	0.60J
02-GW04	12/2/1986	<1.0	<6.0	<7.2	NA
	3/3/1987	<1.0	<6.0	<7.2	NA
	8/1/1995	<0.10	<0.10	<0.10	<0.30
	11/2/1995	<0.10	<0.20	<0.10	<0.10
	2/1/1996	<0.10	<0.10	<0.10	<0.10
	5/3/1996	<0.10	<0.10	<0.10	<0.10
	7/23/1996	<0.50	<0.50	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	<0.50
02-GW05	12/2/1986	<1.0	<6.0	<7.2	NA
	3/3/1987	<1.0	<6.0	<7.2	NA
	8/1/1995	<0.10	<0.10	<0.10	<0.10
	11/2/1995	<0.10	<0.10	0.10	<0.10
	2/1/1996	<0.10	<0.20	<0.10	<0.10
	5/3/1996	<0.10	<0.10	<0.10	<0.10
	7/23/1996	<0.50	<0.50	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	<0.50
	4/25/1997	<0.50	<0.50	<0.50	<0.50
	10/22/1997	<5.0	<5.0	<5.0	<5.0

Table C20. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; D, sample dilution required; J, estimated concentration; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
02-GW05—Continued	4/20/1998	<5.0	<5.0	<5.0	<5.0
	10/25/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<15
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0
	1/29/2003	<5.0	<5.0	<5.0	<5.0
	7/26/2003	<5.0	<5.0	<5.0	<5.0
	1/24/2004	<5.0	<5.0	<5.0	<15
02-GW06	8/1/1995	<0.10	<0.10	<0.10	<0.10
	11/2/1995	<0.10	<0.10	<0.10	<0.10
	2/1/1996	<0.10	<0.20	<0.10	<0.10
	5/3/1996	<0.10	<0.10	<0.10	<0.10
	7/23/1996	<0.50	<0.50	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	<0.50
02-GW07	8/1/1995	<0.10	<0.10	<0.10	0.50
	11/2/1995	<0.10	<0.20	<0.10	<0.10
	2/1/1996	<0.10	<0.20	<0.10	<0.10
	5/3/1996	<0.10	<0.10	<0.10	<0.10
	7/23/1996	<0.50	<0.50	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	<0.50
	4/25/1997	<0.50	<0.50	<0.50	2.0
	10/23/1997	<5.0	<5.0	<5.0	<5.0
	4/20/1998	<5.0	<5.0	<5.0	6.5
	10/25/1998	<5.0	<5.0	<5.0	24
	4/17/1999	<5.0	<5.0	<5.0	18
	10/23/1999	<5.0	<5.0	<5.0	10
	4/15/2000	<5.0	<5.0	<5.0	4.0J
	10/21/2000	<5.0	<5.0	<5.0	<5.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0
	1/29/2003	<5.0	<5.0	<1.0	<5.0
	7/26/2003	<5.0	<5.0	<5.0	<5.0
	1/24/2004	<5.0	<5.0	<5.0	<15

Table C20. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; D, sample dilution required; J, estimated concentration; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
02-GW08	8/1/1995	<0.10	<0.10	<0.10	<0.10
	11/2/1995	<0.10	<0.20	<0.10	0.30
	2/1/1996	<0.10	<0.10	<0.10	<0.10
	5/3/1996	<0.10	<0.10	0.40	<0.10
	7/24/1996	<0.50	<0.50	<0.50	<0.50
	10/2/1996	<0.50	<0.50	<0.50	<0.50
	4/25/1997	<0.50	0.60	<0.50	<0.50
	10/23/1997	<5.0	<5.0	<5.0	<5.0
	4/20/1998	<5.0	<5.0	<5.0	<5.0
	10/27/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<15
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0
	10/21/2000	<5.0	<5.0	<5.0	<5.0
	4/4/2001	<5.0	<5.0	<5.0	<5.0
	4/20/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	7.0	15
	1/28/2003	<5.0	<5.0	<5.0	9.0
	7/26/2003	<5.0	0.30J	<5.0	5.0
	1/24/2004	<5.0	0.20J	<5.0	<15
02-GW09	8/1/1995	<0.10	<0.10	<0.10	<0.10
	11/2/1995	<0.10	<0.20	<0.10	<0.10
	2/2/1996	<0.10	<0.10	<0.10	<0.10
	5/3/1996	<0.10	<0.10	<0.10	<0.10
	7/25/1996	<0.50	<0.50	<0.50	<0.50
	10/3/1996	<0.50	<0.50	<0.50	<0.50
02-GW10	8/1/1995	<0.10	<0.10	<0.10	<0.10
	11/2/1995	<0.10	<0.30	<0.10	<0.10
	2/2/1996	<0.10	<0.10	<0.10	<0.10
	5/3/1996	<0.10	<0.10	<0.10	<0.10
	7/25/1996	<0.50	<0.50	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	<0.50
	4/25/1997	<0.50	0.50	<0.50	<0.50
	10/23/1997	<5.0	<5.0	<5.0	<5.0
	4/20/1998	<5.0	<5.0	<5.0	<5.0
	10/25/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<15
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	4/15/2000	<5.0	<5.0	<5.0	<5.0

Table C20. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 2, former nursery day-care center (Building 712), U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; D, sample dilution required; J, estimated concentration; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
02-GW11	8/1/1995	<0.10	<0.10	<0.10	<0.10
	11/2/1995	<0.10	<0.10	<0.10	<0.10
	2/2/1996	<0.10	<0.10	<0.10	<0.10
	5/2/1996	<0.10	<0.10	<0.10	<0.10
	7/23/1996	<0.50	<0.50	<0.50	<0.50
	10/1/1996	<0.50	<0.50	<0.50	<0.50
	4/25/1997	<0.50	0.50	<0.50	<0.50
	10/23/1997	<5.0	<5.0	<5.0	<5.0
	4/20/1998	<5.0	<5.0	<5.0	<5.0
	10/25/1998	<5.0	<5.0	<5.0	<5.0
02-GW12	4/25/1997	<0.50	<0.50	<0.50	15
	10/23/1997	<5.0	<5.0	3.2J	49
	4/20/1998	<5.0	<5.0	5.2	71
	10/25/1998	<5.0	<5.0	14	53
	4/17/1999	<5.0	<5.0	8.0	97
	10/23/1999	<5.0	<5.0	<5.0	3.0J
	4/15/2000	<5.0	<5.0	7.0	77
	10/21/2000	<5.0	<5.0	5.0	72
	4/4/2001	<5.0	<5.0	<5.0	<5.0
	4/20/2002	<5.0	<5.0	17	260
	7/30/2002	<5.0	<5.0	<5.0	14
	1/28/2003	<5.0	0.40J	12	180
	7/26/2003	<5.0	0.40J	3.0JB	69
	1/24/2004	<5.0	<5.0	1.0J	21

[1] See Figure C3 for location

Data sources:

CERCLA Administrative Record files #387, #1273, #1706, #1773, #1774, #1793, #2296, #2310, #2328, #2610, #3288, #3289, #3290, #3293, #3294, #3419, #3462, #3466

Baker Environmental, Inc. 1994h, 1996l, 1997f,g, 1998l,m, 1999i,f

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000a,f, 2001a, 2002a

Baker Environmental, Inc. and CH2M Hill, Inc. 2002i, 2003

CH2M Hill, Inc. and Baker Environmental, Inc. 2001d

Engineering and Environment, Inc. and Michael Baker, Jr., Inc. 2004c

Environmental Science and Engineering, Inc. 1987

Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2003

Table C21. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 3, old creosote site, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, TTAQ—Tarawa Terrace aquifer,UCHRBU&LU—Upper Castle Hayne aquifer–River Bend and Lower units]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
03-MW01	352563	2500000	31.4	6/12/1991	24.5	14.5–24.5	BBUCU, BBLAQ
03-MW02	352823	2500068	32.4	6/12/1991	16.8	6.8–16.8	BBUAQ, BBUCU
03-MW02DW	352801	2500072	32.2	6/28/1995	140.0	125–140	UCHRBU&LU
03-MW02IW	352813	2500068	32.5	1/16/1994	87.0	71.5–86.5	TTAQ
03-MW03	353411	2499911	29.4	6/11/1991	17.8	7.8–17.8	BBUAQ, BBUCU
03-MW04	352927	2499859	30.9	11/17/1994	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
03-MW05	352639	2499963	31.8	11/19/1994	33.0	18.0–33.0	BBUCU, BBLAQ
03-MW06	352246	2500114	27.9	11/19/1994	22.0	7.0–22.0	BBUAQ, BBUCU, BBLAQ
03-MW07	352902	2500267	31.0	11/19/1994	14.0	4.0–14.0	BBUAQ
03-MW08	353356	2500064	30.1	11/20/1994	18.0	3.0–18.0	BBUAQ, BBUCU
03-MW09	353376	2500187	31.5	6/13/1995	19.0	4.0–19.0	BBUAQ, BBUCU
03-MW10	352883	2500432	32.4	6/14/1995	18.5	3.5–18.5	BBUAQ, BBUCU
03-MW11	352531	2499898	30.7	6/15/1995	31.5	16.5–31.5	BBUCU, BBLAQ
03-MW11IW	352544	2499897	30.3	6/29/1995	87.0	72.0–87.0	TTAQ
03-MW12	353025	2499695	27.7	6/13/1995	20.0	5.0–20.0	BBUAQ, BBUCU, BBLAQ
03-MW13	352933	2499347	20.8	6/14/1995	21.5	6.5–21.5	BBUAQ, BBUCU, BBLAQ

[1] See Figure C4 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

Data sources:

CERCLA Administrative Record files #206, #1699, #1700

Baker Environmental, Inc. 1996a,f,g

Table C22. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 3, old creosote site, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; R, analytical result is unreliable; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
03-MW01	7/13/1995	<10	<10	<10	NA	NA	<10	<10
	9/28/1995	<10	<10	<10	NA	NA	<10	<10
03-MW02	7/13/1995	<10	<10	<10	NA	NA	<10	<10
	9/28/1995	<10	<10	<10	NA	NA	<10	<10
	7/22/1998	8.5	<5.0	<5.0	NA	NA	<5.0	<10
	1/18/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/26/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0R	<5.0R	<5.0R	<5.0R	<5.0R	<5.0R	<2.0R
	1/24/2004	<5.0	<5.0	<10	<5.0	<5.0	NA	<2.0
03-MW02DW	12/3/1994	<10	<10	<10	NA	NA	<10	<10
	7/13/1995	<10	<10	<10	NA	NA	<10	<10
	9/28/1995	<10	<10	<5.0	NA	NA	<5.0	<10
	7/20/1998	6.1	<5.0	<5.0	<5.0	NA	NA	<10
	1/18/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2000	<5.0	<5.0	<10	NA	<5.0	<10	<2.0
03-MW02IW	6/12/1995	<10	1.0J	1.0J	NA	NA	<10	<10
	9/29/1995	<10	<10	<10	NA	NA	<10	<10
	7/20/1998	9.3	<5.0	<5.0	NA	NA	<5.0	<10
	1/18/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/26/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	2.0J	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	0.70J	<5.0	<2.0
	7/26/2003	<5.0R	<5.0R	<5.0R	<5.0R	<5.0R	<5.0R	<2.0R
	1/24/2004	<5.0	<5.0	0.40J	<5.0	0.40J	NA	<2.0

Table C22. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 3, old creosote site, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; R, analytical result is unreliable; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
03-MW03	7/13/1995	<10	<10	<10	NA	NA	<10	<10
	9/29/1995	<10	<10	<10	NA	NA	<10	<10
03-MW04	7/11/1995	<10	1.0J	<10	NA	NA	<10	<10
	9/28/1995	<10	<10	<10	NA	NA	<10	<10
03-MW05	7/11/1995	<10	<10	<10	NA	NA	<10	<10
	9/28/1995	<10	<10	<10	NA	NA	<10	<10
03-MW06	7/12/1995	<10	<10	<10	NA	NA	<10	<10
	9/28/1995	<10	<10	<10	NA	NA	<10	<10
	7/19/1998	11	<10	<10	NA	NA	<10	<10
	1/18/1999	3.0J	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/26/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0R	<5.0R	<5.0R	<5.0R	<5.0R	<5.0R	<2.0R
	1/24/2004	<5.0	<5.0	<10	<5.0	<5.0	NA	<2.0
03-MW07	12/1/1994	<10	<10	<10	NA	NA	<10	<10
	7/12/1995	<10	<10	<10	NA	NA	<10	<10
	9/28/1995	<10	<10	<10	NA	NA	<10	<10
	7/19/1998	10	<10	<10	NA	NA	<10	<10
03-MW08	12/1/1994	<10	<10	<10	NA	NA	<10	<10
	7/11/1995	<10	<10	<10	NA	NA	<10	<10
	9/29/1995	<10	<10	<10	NA	NA	<10	<10
03-MW09	7/13/1995	<10	<10	<10	NA	NA	<10	<10
	9/29/1995	<10	<10	<10	NA	NA	<10	<10
03-MW10	7/12/1995	<10	<10	<10	NA	NA	<10	<10
	9/29/1995	<10	<10	<10	NA	NA	<10	<10
03-MW11	7/12/1995	<10	<10	<10	NA	NA	<10	<10
	9/29/1995	<10	<10	<10	NA	NA	<10	<10
	7/22/1998	12	<10	<10	NA	NA	<10	<10
	1/18/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

Table C22. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 3, old creosote site, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; R, analytical result is unreliable; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
03-MW11—Continued	7/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/26/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	2.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/26/2003	<5.0R	<5.0R	<5.0R	<5.0R	<5.0R	<5.0R	<2.0R
	1/24/2004	<5.0	<5.0	<10	<5.0	<5.0	NA	<2.0
03-MW11IW	7/12/1995	<10	<10	<10	NA	NA	<10	<10
	9/28/1995	<10	<10	<10	NA	NA	<10	<10
	7/22/1998	22	<10	<10	NA	NA	<10	<10
	1/18/1999	<5.0	11	<5.0	<5.0	<5.0	NA	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
03-MW12	7/12/1995	<10	1.0J	<10	NA	NA	<10	<10
	9/29/1995	<10	<10	<10	NA	NA	<10	<10
03-MW13	7/13/1995	<10	1.0J	<10	NA	NA	<10	<10
	9/29/1995	<10	<10	<10	NA	NA	<10	<10
	7/19/1998	11	<10	<10	NA	NA	<10	<10
	1/18/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

[1] See Figure C4 for location

Data sources:

CERCLA Administrative Record files #1699, #1700, #2320, #2334, #2605A, #2613, #3325, #3326, #3328, #3329, #3331, #3332, #3471, #3522
Baker Environmental, Inc. 1996f,g, 1998f, 1999g,h
Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000c,i, 2003
Baker Environmental, Inc. and CH2M Hill, Inc. 2001c, 2002j,k
CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2001b
Engineering and Environment, Inc. and Michael Baker Jr., Inc., 2004d
Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2003b

Table C23. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 3, old creosite site, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; R, analytical result is unreliable]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
03-MW01	7/13/1995	<10	<10	<10	<10
	9/28/1995	<10	<10	<10	<10
03-MW02	7/13/1995	<10	<10	<10	<10
	9/28/1995	3.0J	11	10	20
	7/22/1998	1.7J	8.7	13	31
	1/18/1999	<5.0	11	15.0	34
	8/1/1999	<5.0	12	16	32
	1/15/2000	<5.0	9.0	14	34
	7/30/2000	<5.0	<5.0	<5.0	4.0J
	1/13/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0
	1/26/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	0.30J	<5.0	<5.0
	1/28/2003	0.20J	0.50J	<1.0	3.0J
	7/26/2003	<5.0R	0.5R	0.3R	<1.0R
	1/24/2004	<5.0	0.20J	0.40J	0.50J
03-MW02DW	12/3/1994	11J	4.0J	<10	7.0J
	7/13/1995	3.0J	15J	14J	32J
	9/28/1995	<10	<10	<10	<10
	7/20/1998	<5.0	<5.0	<5.0	<5.0
	1/18/1999	<5.0	<5.0	<5.0	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0
	7/30/2000	<5.0	<5.0	<5.0	<5.0
03-MW02IW	6/12/1995	<10	2.0J	<10	<10
	9/29/1995	<10	<10	<10	<10
	7/20/1998	<5.0	<5.0	<5.0	<5.0
	1/18/1999	<5.0	<5.0	<5.0	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/30/2000	<5.0	<5.0	<5.0	<5.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0
	1/26/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	0.30J	<5.0	<5.0	<5.0
	1/28/2003	0.20J	<5.0	<5.0	<5.0
	7/26/2003	<5.0R	0.20R	<5.0R	<5.0R
	1/24/2004	0.10J	<5.0	<5.0	<15

Table C23. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 3, old creosite site, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; R, analytical result is unreliable]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
03-MW03	7/13/1995	<10	<10	<10	<10
	9/29/1995	<10	<10	<10	<10
03-MW04	7/11/1995	<10	<10	<10	<10
	9/28/1995	<10	<10	<10	<10
03-MW05	7/11/1995	<10	<10	<10	<10
	9/28/1995	<10	<10	<10	<10
03-MW06	7/12/1995	<10	<10	<10	<10
	9/28/1995	<10	8.0J	1.0J	<10
	7/19/1998	<5.0	<5.0	<5.0	<5.0
	1/18/1999	<5.0	<5.0	<5.0	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/15/2000	<5.0	<5.0	<5.0	<5.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0
	1/26/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0
	1/28/2003	<5.0	<5.0	<1.0	2.0J
	7/26/2003	<5.0R	<5.0R	<5.0R	<5.0R
	1/24/2004	<5.0	<5.0	<5.0	<15R
03-MW07	12/1/1994	13J	5.0J	<10	6.0J
	7/12/1995	<10	<10	<10	<10
	9/28/1995	<10	<10	<10	<10
	7/19/1998	<5.0	<5.0	<5.0	<5.0
03-MW08	12/1/1994	40J	10J	<10	9.0J
	7/11/1995	<10	<10	<10	<10
	9/29/1995	<10	<10	<10	<10
03-MW09	7/13/1995	<10	<10	<10	<10
	9/29/1995	<10	<10	<10	<10
03-MW10	7/12/1995	<10	<10	<10	<10
	9/29/1995	<10	<10	<10	<10
03-MW11	7/12/1995	<10	<10	<10	<10
	9/29/1995	<10	<10	<10	<10
	7/22/1998	<5.0	<5.0	<5.0	<5.0
	1/18/1999	<5.0	<5.0	<5.0	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/15/2000	<5.0	<5.0	<5.0	<5.0

Table C23. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 3, old creosite site, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; R, analytical result is unreliable]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
03-MW11—Continued	1/13/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0
	1/26/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0
	7/26/2003	<5.0R	<5.0R	<5.0R	<5.0R
	1/24/2004	<5.0	<5.0	<5.0	<15R
03-MW11IW	7/12/1995	<10	<10	<10	<10
	9/28/1995	<10	<10	<10	<10
	7/22/1998	<5.0	<5.0	<5.0	<5.0
	1/18/1999	<5.0	<5.0	<5.0	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0
	7/15/2000	<5.0	<5.0	<5.0	<5.0
03-MW12	7/12/1995	<10	<10	<10	<10
	9/29/1995	<10	<10	<10	<10
03-MW13	7/13/1995	<10	<10	<10	<10
	9/29/1995	<10	<10	<10	<10
	7/19/1998	<5.0	<5.0	<5.0	<5.0
	1/18/1999	<5.0	<5.0	<5.0	<5.0
	8/1/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/15/2000	<5.0	<5.0	<5.0	<5.0

[1] See Figure C4 for location

Data sources:

CERCLA Administrative Record files #1700, #2320, #2334, #2605A, #2613, #3325, #3326 #3328, #3329, #3331, #3332, #3471, #3522

Baker Environmental, Inc. 1996g, 1998f, 1999g,h

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000c,i, 2003

Baker Environmental, Inc. and CH2M Hill, Inc. 2001c, 2002j,k

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2001b

Engineering and Environment, Inc. and Michael Baker Jr., Inc. 2004d

Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2003b

Table C24. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, MCHAQ—Middle Castle Hayne aquifer, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHLU—Upper Castle Hayne aquifer–Lower unit; Topo, altitude estimated from topographic map; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
06-GW01D	348137	2503363	32.8 Topo ± 28 ft	10/8/1992	112.5	102.7–112.5	UCHRBU
06-GW01DA	348320	2503384	32.7 Topo ± 25 ft	4/13/1993	230	220.0–229.6	MCHAQ
06-GW01DB	348124	2503419	32.6	9/10/1993	262	242–262	MCHAQ
06-GW01S	348127	2503343	32.8	10/21/1986	25	5–25	BBUAQ, BBUCU, BBLAQ
06-GW02DW	347220	2503760	35.1	10/14/1992	119	108.1–118.1	TTCU(?), UCHRBU
06-GW02S	347214	2503751	36.2	10/21/1986	25	5–25	BBUAQ, BBUCU, BBLAQ
06-GW03	347739	2502666	29.1	10/24/1986	25	5–25	BBUAQ, BBUCU, BBLAQ
06-GW04	346437	2502778	25.5	10/22/1986	25	5–25	BBUAQ, BBUCU, BBLAQ
06-GW05	346233	2502452	23.3	10/22/1986	25	5–25	BBUAQ, BBUCU, BBLAQ
06-GW06	345360	2502750	24.4	10/23/1986	25	5–25	BBUAQ, BBUCU, BBLAQ
06-GW07DW	344336	2502082	17.4	10/6/1992	100.5	90.5–99.5	TTCU(?), UCHRBU
06-GW07S	344414	2502106	15.6	10/24/1986	25	5–25	BBUAQ, BBUCU, BBLAQ
06-GW08	344392	2502799	20.5	10/23/1986	25	5–25	BBUAQ, BBUCU, BBLAQ
06-GW09	343675	2502352	18.6 Topo ± 9 ft	9/25/1992	19.1	5.3–18.7	BBLAQ
06-GW10	343645	2502726	17.2 Topo ± 12 ft	9/23/1992	18	3.8–17.5	BBLAQ
06-GW11	347504	2502329	32.4	10/12/1992	18.7	4–18.4	BBUAQ
06-GW12	344362	2502314	17.0	9/24/1992	18	3.8–17.6	BBUAQ, BBUCU (?)
06-GW13	344366	2502549	18.1	9/24/1992	18	3.8–17.6	BBUAQ, BBUCU (?)
06-GW14	344589	2502928	25.5	10/6/1992	22	7.5–21.7	BBUAQ, BBUCU, BBLAQ
06-GW15D	347767	2503174	25.2	4/6/1993	155	145.0–154.5	UCHLU
06-GW15S	347784	2503211	26.1	10/10/1992	20	5.4–19.7	BBUAQ, BBUCU, BBLAQ
06-GW16	346496	2502546	24.9	10/11/1992	20	5.4–19.8	BBUAQ, BBUCU, BBLAQ
06-GW17	345001	2503233	25.7	9/25/1992	17.8	2.3–17.1	BBUAQ, BBUCU (?)
06-GW18	345731	2503377	26.5	9/25/1992	18.5	4.3–18.1	BBUAQ, BBUCU, BBLAQ
06-GW19	346289	2503020	25.2	10/6/1992	20	5.2–19.2	BBUAQ, BBUCU, BBLAQ
06-GW20	346519	2502192	22.5 Topo ± 27 ft	10/8/1992	19.7	4.8–19.4	BBUAQ, BBUCU, BBLAQ
06-GW21	346816	2501743	27.9	9/24/1992	22.5	7.5–22.0	BBUAQ, BBUCU, BBLAQ
06-GW22	345993	2502502	24.5	9/24/1992	19.5	4.7–19.0	BBUAQ, BBUCU, BBLAQ
06-GW23	346933	2502738	24.5	10/12/1992	23	8.4–22.7	BBUAQ, BBUCU, BBLAQ
06-GW24	344834	2504094	[3]37	N/A	N/A	N/A	N/A
06-GW25	346792	2503435	32.1	10/7/1992	23.5	8.9–23.2	BBUAQ, BBUCU, BBLAQ
06-GW26	347656	2501883	20.9 Topo ± 25 ft	10/9/1992	20	5.0–19.7	BBUAQ, BBUCU
06-GW27	348269	2502478	[3]26	N/A	N/A	N/A	N/A
06-GW27DA	348303	2502436	22.9	8/5/1993	236	226–236	MCHAQ

Table C24. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, MCHAQ—Middle Castle Hayne aquifer, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit, UCHLU—Upper Castle Hayne aquifer–Lower unit; Topo, altitude estimated from topographic map; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
06-GW27DW	348316	2502449	22.5	10/12/1992	110	100.1–109.1	UCHRBU
06-GW28DW	348677	2502849	28.7 Topo ± 25 ft	10/20/1992	114.5	104.7–113.6	UCHRBU
06-GW28S	348623	2502900	27.6	10/9/1992	32	17.5–37.5	BBUCU(?), BBLAQ
06-GW29	347697	2504429	[3]37	N/A	N/A	N/A	N/A
06-GW30DW	349532	2503730	9.9	3/4/1993	100	90.0–99.6	UCHRBU
06-GW30S	349553	2503728	9.9	10/10/1992	20	5.3–19.7	BBUAQ, BBUCU, BBLAQ
06-GW31	347162	2502005	27.8	4/1/1993	27	11.4–26.6	BBUAQ, BBUCU, BBLAQ
06-GW32	348840	2502690	19.6	4/1/1993	27	11.3–26.6	BBUAQ(?), BBUCU, BBLAQ
06-GW33	348457	2503167	20.0 Topo ± 15 ft	4/1/1993	22	6.2–21.6	BBUAQ(?), BBUCU, BBLAQ
06-GW34	348434	2503483	29.0	3/5/1993	35	19.3–34.6	BBUCU(?), BBLAQ
06-GW35D	349394	2501254	12.0	3/7/1993	105	95.0–104.6	UCHRBU
06-GW36D	350271	2502282	15.6 Topo ± 20 ft	4/1/1993	95	75.3–94.6	TTAQ, TTCU, UCHRBU
06-GW37DW	348037	2501703	14.0	4/1/1993	95	76.1–94.6	TTCU(?), UCHRBU
06-GW38D	347788	2502571	29.3	8/27/1993	275	255–275	MCHAQ
06-GW39D	347729	2501175	12.3	7/30/1993	203	190–200	MCHAQ
06-GW40DA	348584	2503544	25.8	12/4/1994	246	230–245	MCHAQ
06-GW40DW	348563	2503536	16.6	12/6/1994	116	100–115	UCHRBU
06-GW41	348576	2503291	24.1	11/16/1998	23	8–23	BBUCU(?), BBLAQ
06-GW42	348171	2503658	31.2	11/16/1998	32	17–32	BBUCU(?), BBLAQ
06-MW03D AKA G-MW03D	347811	2504501	34.0	4/1/1993	118	97.5–117.6	TTCU, UCHRBU
06-MW43DW AKA 06-GW43DW	347960	2501527	[3]10	5/15/2001	90	75–90	TTCU(?), UCHRBU

[1] See Figure C5 or C20 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data sources:

CERCLA Administrative Record files #125, #273, #345, #387, #1272, #1615, #2297, #2337, #2802, #3276

Baker Environmental, Inc. 1992b, 1993g,h,k,m, 1999d

Baker Environmental, Inc. and CH2M Hill, Inc. 2001a

Dewberry and Davis, 1992

Environmental Science and Engineering, Inc. 1987, 1992b

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW01D	11/4/1992	630	58,000J	ND	NA	NA	5,600J	ND
	3/23/1993	920	50,000	51	NA	NA	26,000	800J
	10/27/1997	1,600	140,000D	<1,000	NA	NA	36,000D	520J
	1/15/1998	2,000J	170,000	<5,000	NA	NA	36,000	<10,000
	4/16/1998	1,300J	110,000	<2,500	NA	NA	30,000	<5,000
	7/23/1998	1,200JD	110,000BD	47	NA	NA	24,000D	320E
	1/16/1999	390	180,000	72	7,600	18,000	NA	520
	7/29/1999	980JD	59,000D	35	3,800D	10,000D	14,000D	330E
	1/18/2000	990EJ	49,000D	32	3,300D	8,800D	12,000D	310E
	7/30/2000	880D	43,000	<5.0	6,200	16,000D	23,000D	360D
	1/15/2001	790D	49,000D	20	4,300D	11,000D	16,000D	91
	7/18/2001	6,500	48,000	21	3200	8,000	11,000	110
	1/15/2002	210J	8,200	7.0	450	1,400	1,800	36
	7/31/2002	270R	6,800R	4.0J	280R	930R	1,200R	14
	1/24/2003	<280	6,400	4.0J	230J	630	870	13
	1/20/2004	370JD	12,000D	5.0J	210JD	520D	730JD	10J
	7/26/2004	610DJ	20,000D	9.0	560DJ	1,700DJ	NA	31
06-GW01DA	5/3/1993	2.9	160	<1.0	NA	NA	100	<1.0
	10/24/1997	<10	2.1J	<10	NA	NA	<10	<10
	1/15/1998	<5.0	0.93J	<5.0	NA	NA	<5.0	<10
	4/16/1998	<5.0	13	<5.0	NA	NA	2.3J	<10
	1/15/1999	<5.0	13	<5.0	<5.0	<5.0	NA	<5.0
	1/13/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/31/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2003	<5.0	2.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/20/2004	<5.0	0.60J	<5.0	<5.0	<5.0	<10	<2.0
06-GW01DB	10/24/1997	<10	<10	<10	NA	NA	<10	<10
	1/15/1998	1.0J	<5.0	<5.0	NA	NA	<5.0	<10
	4/16/1998	<5.0	7.5	<5.0	NA	NA	<5.0	<10
	1/15/1999	<5.0	7.0	<5.0	<5.0	<5.0	NA	<5.0
	1/19/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/31/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/20/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW01S	11/19/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/21/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10.0
	10/24/1992	2.9	1.0	ND	NA	NA	ND	ND
	3/23/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	10/24/1997	12	<10	<10	NA	NA	<10	<10
	1/15/1998	2.8J	<5.0	<5.0	NA	NA	<5.0	<10
	4/16/1998	<5.0	1.4J	<5.0	NA	NA	<5.0	<10
	7/24/1998	9.3	<5.0	<5.0	NA	NA	<5.0	<10
	1/15/1999	6.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/28/1999	2.0J	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/20/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/26/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
06-GW02DW	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10.0
	11/3/1992	1.4	ND	ND	NA	NA	ND	ND
	3/21/1993	<1.0	<4.0	<1.0	NA	NA	<1.0	<1.0
	10/27/1997	<10	<10	<10	NA	NA	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
06-GW02S	11/20/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/21/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	NA	<10.0
	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10.0
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW03	11/20/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/22/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	NA	<10.0
	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10.0
	10/22/1992	0.9J	ND	ND	NA	NA	ND	ND
	3/22/1993	<1.0	<14	<1.0	NA	NA	<1.0	<1.0
	10/25/1997	<10	<10	<10	NA	NA	1.5J	<10
	1/15/1998	1.3J	<5.0	<5.0	NA	NA	4.6J	<10
	4/17/1998	<5.0	0.76J	<5.0	NA	NA	<5.0	<10
	7/24/1998	7.3	1.1J	<5.0	NA	NA	<5.0	<10

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW03—Continued	1/16/1999	<5.0	< 5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/29/1999	<5.0	<5.0	<5.0	<5.0	3.0J	3.0J	<2.0
	1/13/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2000	<10	<10	<10	<10	<10	<10	<4.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
06-GW04	11/19/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/21/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	NA	<10.0
	10/21/1992	ND	ND	ND	NA	NA	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW05	11/19/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/21/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	NA	<10.0
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW06	11/19/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/22/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	NA	<10.0
	3/20/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW07DW	11/4/1992	ND	1.2	0.6J	NA	NA	ND	ND
	3/19/1993	<1.0	2.1	<1.0	NA	NA	<1.0	<1.0
06-GW07S	11/20/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/22/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	NA	<10.0
	3/19/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW08	11/20/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/22/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	NA	<10.0
	3/20/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW09	3/19/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW10	3/20/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW11	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	1/21/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW12	3/20/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW13	10/20/1992	ND	ND	ND	NA	NA	ND	ND
	3/20/1993	<1.0	1.2	<1.0	NA	NA	<1.0	<1.0
06-GW14	10/22/1992	ND	ND	ND	NA	NA	ND	ND
	3/20/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW15D	5/3/1993	1.0	34	<1.0	NA	NA	9.1	<1.0
	7/26/1997	<10	<10	<10	NA	NA	<10	<10
	10/29/1997	<10	<10	<10	NA	NA	<10	<10
	1/19/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	6.0	<5.0	<5.0	<5.0	NA	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	8/1/2002	<5.0	0.8J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/20/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
06-GW15S	10/23/1992	ND	1.9	ND	NA	NA	6.4	ND
	3/21/1993	<1.0	8.0	<1.0	NA	NA	6.4	<1.0
06-GW16	10/21/1992	ND	ND	ND	NA	NA	ND	ND
	3/21/1993	1.2	<1.2	<1.0	NA	NA	<1.0	<1.0
	7/27/1997	<10	<10	<10	NA	NA	<10	<10
	10/23/1997	<500	<500	<500	NA	NA	<500	<500
	1/19/1998	<100	<100	<100	NA	NA	<100	<200
	1/15/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/29/1999	<5.0	15B	<5.0	<5.0	<5.0	<5.0	<2.0
	1/17/2000	<5.0	4.0J	<5.0	3.0J	3.0J	6.0	<2.0
	7/12/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0	<5.0	3.0J	<2.0
	7/29/2002	<5.0	<5.0	<5.0	3.0J	<5.0	3.0J	<2.0
	1/21/2003	<5.0	0.80J	<5.0	17	16	33.0	2.0J
	1/20/2004	4.0J	17.0	<5.0	1.0J	1.0J	2.0J	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
06-GW17	10/22/1992	ND	ND	ND	NA	NA	ND	ND
	3/20/1993	2.6	<1.0	<1.0	NA	NA	<1.0	<1.0
	7/27/1997	<10	<10	<10	NA	NA	<10	<10
	10/26/1997	<10	<10	<10	NA	NA	<10	<10

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW17—Continued	1/17/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/17/1998	<5.0	2.3J	<5.0	NA	NA	<5.0	<10
06-GW18	3/20/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW19	3/20/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW20	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW21	10/22/1992	1.1	0.5J	ND	NA	NA	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	7/27/1997	<10	<10	<10	NA	NA	<10	<10
	10/26/1997	<10	<10	<10	NA	NA	<10	<10
	1/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
06-GW22	10/22/1992	1.2	ND	ND	NA	NA	ND	ND
	3/22/1993	1.4	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW23	10/22/1992	ND	0.6J	ND	NA	NA	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/29/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
06-GW25	10/23/1992	ND	ND	ND	NA	NA	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW26	10/23/1992	ND	ND	ND	NA	NA	ND	ND
	3/22/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
06-GW27DA	7/23/1997	<10	<10	<10	NA	NA	<10	<10
	10/29/1997	<10	<10	<10	NA	NA	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/15/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/16/1999	<5.0	14	NA	<5.0	<5.0	NA	<5.0
	1/13/2000	<5.0	6.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/31/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/23/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2004	<5.0	0.4J	<5.0	<5.0	<5.0	<10	<2.0
06-GW27DW	11/3/1992	ND	18,000	ND	NA	NA	5,800	ND
	3/23/1993	18	22,000	55	NA	NA	30,000	250J
	7/22/1997	<10	3,400	11	NA	NA	4,800	110
	10/29/1997	<500	2,900	<500	NA	NA	4,300	84J

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW27DW—Continued	1/18/1998	<100	3,500	<100	NA	NA	4,400	<200
	4/16/1998	<5.0	3,400D	8.4	NA	NA	4,400D	97
	7/24/1998	17J	3,000	<120	NA	NA	3,100	74J
	1/16/1999	<5.0	2,100	4.0J	600	1,800	NA	43
	7/29/1999	<5.0	1,100D	<5.0	200D	710D	920D	22
	1/13/2000	<5.0	1,900D	4.0J	600D	1,400D	1,900D	32
	7/30/2000	<5.0	790D	<5.0	200	480D	660D	<2.0
	1/14/2001	<25	530	<25	35	110	140	<10
	7/18/2001	<5.0	390	<5.0	26	79	100	3.0
	1/13/2002	<5.0	110	<5.0	3.0J	16	19	1.0J
	7/30/2002	<5.0	100	<5.0	2.0J	14J	16	<2.0
	1/23/2003	<5.0	96	<5.0	<5.0	16	16	0.60J
	1/22/2004	0.60J	86	28	12	52	63	2.0J
	7/26/2004	0.40J	54	21	9.0	41	NA	1.0J
06-GW28DW	11/3/1992	ND	3,600	ND	NA	NA	500	ND
	3/23/1993	42	9,100	12	NA	NA	5,800	100J
	7/25/1997	<250	1,100	<250	NA	NA	550	<250
	10/28/1997	140J	9,600D	<500	NA	NA	3,500D	75J
	1/16/1998	49J	4,100	<120	NA	NA	1,400	<250
	4/18/1998	15J	1,200	<50	NA	NA	440	<100
	7/24/1998	50J	3,300	<120	NA	NA	1,200	<250
	1/17/1999	51	4,200	12	450J	1,300	NA	58
	7/29/1999	200JD	5,200D	20	1,200D	3,600D	4,900D	170D
	1/19/2000	180	26,000D	45	3,200D	8,800D	12,000D	370E
	7/30/2000	12	1,400D	3.0J	170	430D	580D	<2.0
	1/14/2001	370D	22,000D	16	1,900D	4,800D	6,800D	86
	7/18/2001	690	19,000	11	NA	6,000	NA	66
	1/13/2002	480	8,600	11	1,200	2,700	3,900	93
	8/1/2002	240	2,300	7.0J	260	830	1,100	28J
	1/24/2003	650B	13,000	<250	1,300	3,400	4,700	81J
	1/22/2004	1,100D	17,000D	37	2,400D	6,100D	8,400D	220JD
	7/26/2004	1,200D	12,000D	4.0J	1,700D	4,600D	NA	150
06-GW28S	10/23/1992	26	120	ND	NA	NA	16	ND
	3/18/1993	1.0	4.0	<1.0	NA	NA	1.8J	<1.0
	7/25/1997	7.0J	22.0	<10	NA	NA	<10	<10
	10/26/1997	37	49	<10	NA	NA	15	<10
	1/16/1998	24	39	<5.0	NA	NA	12	<10
	4/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/24/1998	7.2	3.8J	<5.0	NA	NA	<5.0	<10
	1/15/1999	68	230	<5.0	18	55	NA	<5.0

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW28S—Continued	7/29/1999	4.0J	8.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/19/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	25	45	<5.0	<5.0	12	12	<2.0
	7/10/2001	51J	110J	<5.0	8.0	28	36	<2.0
	1/13/2002	5.0J	14	<5.0	<5.0	3.0J	3.0J	<2.0
	7/29/2002	87	110	<5.0	15.0	49	64	<2.0
	1/24/2003	88	100	<5.0	16.0	44	61	<2.0
	1/22/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/26/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
06-GW30DW	3/23/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	7/24/1997	<10	<10	<10	NA	NA	<10	<10
	10/25/1997	<10	<10	<10	NA	NA	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
06-GW30S	10/23/1992	ND	ND	ND	NA	NA	ND	ND
	3/22/1993	1.1	<1.0	<1.0	NA	NA	<1.0	<1.0
	7/24/1997	<10	<10	<10	NA	NA	<10	<10
	10/25/1997	3.4J	<10	<10	NA	NA	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/25/1998	3.3J	0.98J	<5.0	NA	NA	<5.0	<10
	1/16/1999	<5.0	150	<5.0	8.0	10	NA	<5.0
	7/28/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2003	6.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
06-GW31	3/6/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2003	15.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

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Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW32	3/18/1993	74	1,500	<1.0	NA	NA	2,200	8.6J
	7/27/1997	<10	2,800	<10	NA	NA	1,500	<10
	10/26/1997	33J	<50	<50	NA	NA	320	<50
	1/16/1998	2.1J	26	<5.0	NA	NA	10	<10
	4/16/1998	<5.0	1.3J	<5.0	NA	NA	<5.0	<10
	7/24/1998	11	15	<5.0	NA	NA	6	<10
	1/15/1999	10	210	<5.0	29	82	NA	<5.0
	7/29/1999	<5.0	44	<5.0	4.0J	17	21	<2.0
	1/16/2000	<5.0	84	<5.0	10	35	44	<2.0
	7/11/2000	<5.0	100	<5.0	12	38	50	<2.0
	1/10/2001	<5.0	39	<5.0	5.0J	17	22	<2.0
	7/10/2001	10	1,000	<5.0	94	380	470	8.0
	1/14/2002	<5.0	25	<5.0	<5.0	7.0	10	<2.0
	7/29/2002	<5.0	120	<5.0	13	41.0	55	<2.0
	1/21/2003	<5.0	14J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2004	1.0J	29	<5.0	4.0J	10.0	14	<2.0
	7/26/2004	12	200D	<5.0	36	180.0	NA	2.0J
06-GW33	3/18/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	7/27/1997	<10	<10	<10	NA	NA	<10	<10
	10/24/1997	5.0J	<10	<10	NA	NA	<10	<10
	1/16/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/15/1998	<5.0	0.96J	<5.0	NA	NA	<5.0	<10
	7/25/1998	13.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/15/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	7/28/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2001	<5.0	120	<5.0	23	94	120	<2.0
	1/14/2002	6.0	180	<5.0	32	150	180	<2.0
	7/29/2002	<5.0	94	<5.0	11	54	66	<2.0
	1/21/2003	0.50J	88	<5.0	5.0J	30	35	<2.0
	1/22/2004	<5.0	6.0	<5.0	<5.0	0.40J	0.40J	<2.0
	7/28/2004	<5.0	5.0	<5.0	<5.0	0.50J	NA	<2.0
06-GW34	3/18/1993	1,200	610	1.3	NA	NA	410	<1.0
	7/24/1997	170J	310	<250	NA	NA	<250	<250
	10/24/1997	120	400	<100	NA	NA	170	<100
	1/16/1998	120	510	<25	NA	NA	200	<50

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW34—Continued	4/16/1998	170D	250D	<5.0	NA	NA	130	<10
	7/23/1998	88JD	170BD	<12	NA	NA	<64JD	<25
	1/15/1999	350	440	<5.0	56	110	NA	<5.0
	7/28/1999	4,100	470J	<500	<500	<500	<500	<200
	1/12/2000	560D	250D	<5.0	30	66	96	<2.0
	7/11/2000	6,000D	160	<5.0	19	140	160	<2.0
	1/10/2001	850D	200	<5.0	19	44	62	<2.0
	7/11/2001	380J	96	<5.0	21	36	57	<2.0
	1/14/2002	1,800	100	<5.0	18	250	270	<2.0
	7/29/2002	2,400	240	<5.0	33	200	280	<2.0
	1/21/2003	6,300	150	<5.0	13	160	180	<2.0
	1/22/2004	1,000D	33	<5.0	3.0J	41	44	<2.0
	7/26/2004	1,200D	34	<5.0	3.0J	30	NA	<2.0
06-GW35D	3/22/1993	<1.0	3.1J	<1.0	NA	NA	<1.0	<1.0
	7/27/1997	<10	<10	<10	NA	NA	<10	<10
	10/26/1997	<10	<10	<10	NA	NA	<10	<10
	1/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/19/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2003	0.50J	3.0J	<5.0	<5.0	0.90J	<5.0	<2.0
	1/22/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
06-GW36D	3/30/1993	<1.0	6.4	<1.0	NA	NA	3.4	<1.0
	7/27/1997	<10	<10	<10	NA	NA	<10	<10
	10/25/1997	<10	<10	<10	NA	NA	<10	
	1/19/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/19/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/15/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2003	3.0J	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2004	<5.0	0.90J	<5.0	<5.0	0.30J	0.30J	<2.0

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW37DW	3/23/1993	<1.0	60	<1.0	NA	NA	120	<1.0
	7/23/1997	<50	88	<50	NA	NA	230	<50
	10/25/1997	<50	8J	<50	NA	NA	230	16J
	1/19/1998	<5.0	7	<5.0	NA	NA	260	27
	4/19/1998	<10	3.1J	<10	NA	NA	210	17J
	7/25/1998	15	91	<10	NA	NA	340	<10
	1/16/1999	7.0	10	<5.0	3.0J	270	NA	30
	7/29/1999	<25	260	<25	60	320	380	11
	1/16/2000	<5.0	<5.0	2.0J	<5.0	470D	470D	39
	7/30/2000	<10	<10	<10	<10	240	240	<4.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	500D	510D	35
	7/10/2001	<5.0	<5.0	3.0J	<5.0	1,300	1,300	38
	1/13/2002	<5.0	49	<5.0	11	420	430	30
	7/29/2002	23	26	<5.0	5.0	330	400	35
	1/21/2003	<5.0	<5.0	2.0J	2.0J	380	380	31
	1/22/2004	<5.0	4.0J	5.0J	7.0	770D	780D	66
	7/28/2004	<5.0	9.0	4.0J	20.0	940D	NA	53
06-GW38D	7/27/1997	<10	<10	<10	NA	NA	<10	<10
	10/27/1997	<10	<10	<10	NA	NA	<10	<10
	1/16/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/17/1998	<5.0	2.5J	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	29	<5.0	3.0J	5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2003	<5.0	2.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
06-GW40DA	10/28/1997	<10	<10	<10	NA	NA	<10	<10
	1/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/17/1998	<5.0	4.4J	<5.0	NA	NA	<5.0	<10
06-GW40DW	7/24/1997	<10	<10	<10	NA	NA	<10	<10
	10/28/1997	<10	<10	<10	NA	NA	<10	<10
	1/18/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/17/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/18/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	1/19/2000	<5.0	14	<5.0	<5.0	4.0J	4.0J	<2.0
	1/15/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	8/1/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2004	<5.0	0.60J	<5.0	<5.0	<5.0	<10	<2.0

Table C25. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; D, sample dilution required; B, detected in blank; E, concentration exceeds calibration range of GC/MS instrument; R, analytical result is unreliable; AKA, also known as]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
06-GW41	1/15/1999	<5.0	9.0	<5.0	<5.0	<5.0	<5.0	<5.0
	7/29/1999	<5.0	3.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/12/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0	3.0J	3.0J	<2.0
	7/29/2002	6.0	17	<5.0	11	24J	35.0	<2.0
	1/21/2003	<5.0	2.0J	<5.0	<5.0	3.0J	3.0J	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/26/2004	<5.0	0.70J	<5.0	<5.0	0.60J	NA	<2.0
06-GW42	1/15/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	1/12/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2004	<5.0	<5.0	<5.0	<5.0	0.60J	0.60J	<2.0
	7/26/2004	<5.0	0.30J	<5.0	<5.0	0.40J	NA	<2.0
06-MW43DW AKA 06-GW43DW	7/28/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2004	<5.0	<5.0	<5.0	<5.0	0.20J	<10	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	0.30J	NA	<2.0

[1] See Figure C5 or C20 for location

Data sources:

CERCLA Administrative Record files #193, #236, #273, #387, #1272, #1781, #1978, #2037, #2300, #2322, #2337, #2599A, #2609A, #3165, #3276, #3277, #3278, #3410, #3637

Baker Environmental, Inc. 1993k, 1994a, 1997e, 1998g,h,i, 1999de

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000e

Baker Environmental, Inc. and CH2M Hill, Inc. 2001a, 2002b,g

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000b

Michael Baker, Jr., Inc. and CH2M Hill, Inc. 2003

Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2004

Environmental Science and Engineering, Inc. 1987, 1992b

Haliburton NUS, 1992c

Unknown Author, 1991

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW01D	11/4/1992	ND	ND	48	ND
	3/23/1993	6.7J	1.4	52	2.1
	10/27/1997	<1,000	<1,000	<1,000	<1,000
	1/15/1998	<5,000	<5,000	<5,000	<5,000
	4/16/1998	<2,500	<2,500	<2,500	<2,500
	7/23/1998	7.9	1.9J	2.2J	3.9J
	1/16/1999	8.0	<5.0	<5.0	<5.0
	7/29/1999	4.0J	<5.0	<5.0	NA
	1/18/2000	3.0J	<5.0	<5.0	<5.0
	7/30/2000	4.0J	<5.0	<5.0	<5,000
	1/15/2001	<5.0	<5.0	<5.0	<5.0
	7/18/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	0.20J	0.20J	<5.0	<5.0
	1/24/2003	2.0J	<5.0	<5.0	<5.0
	1/20/2004	0.5J	<5.0	0.4J	0.5J
	7/26/2004	6.0	<5.0	0.70J	2.0J
06-GW01DA	5/3/1993	<1.0	<1.0	<1.0	<1.0
	10/24/1997	<10	<10	<10	<10
	1/15/1998	<5.0	<5.0	<5.0	<5.0
	4/16/1998	<5.0	<5.0	<5.0	<5.0
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	1/13/2000	<5.0	<5.0	<5.0	<5.0
	1/15/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	<5.0	0.20J	<5.0	<5.0
	1/24/2003	<5.0	<5.0	<5.0	<5.0
	1/20/2004	<5.0	<5.0	<5.0	<15
06-GW01DB	10/24/1997	<10	<10	<10	<10
	1/15/1998	<5.0	<5.0	<5.0	<5.0
	4/16/1998	<5.0	<5.0	<5.0	<5.0
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	1/19/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	<5.0	<5.0	<5.0	<5.0
	1/24/2003	<5.0	<5.0	<5.0	<5.0
	1/20/2004	<5.0	<5.0	<5.0	<15
06-GW01S	11/19/1986	3.1	<6.0	<7.2	NA
	1/21/1987	<1.0	<6.0	<7.2	NA
	6/27/1991	<5.0	<5.0	<5.0	<5.0
	10/24/1992	ND	ND	ND	1.4
	3/23/1993	<1.0	<1.0	<1.0	<1.0
	10/24/1997	<10	<10	<10	<10
	1/15/1998	<5.0	<5.0	<5.0	<5.0

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW01S—Continued	4/16/1998	<5.0	<5.0	<5.0	<5.0
	7/24/1998	<5.0	<5.0	<5.0	<5.0
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	7/28/1999	<5.0	<5.0	<5.0	NA
	1/13/2000	<5.0	<5.0	<5.0	<5.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/20/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	<5.0	<5.0	0.20J	0.90J
06-GW02DW	6/27/1991	<5.0	<5.0	<5.0	<5.0
	11/3/1992	ND	ND	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	<1.0
	10/27/1997	<10	<10	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	<5.0
	4/18/1998	<5.0	<5.0	<5.0	<5.0
06-GW02S	11/20/1986	<1.0	<6.0	<7.2	NA
	1/21/1987	<1.0	<6.0	<7.2	NA
	1/19/1991	<5.0	<5.0	<5.0	<5.0
	6/27/1991	<5.0	<5.0	<5.0	<5.0
	3/21/1993	<1.0	<1.0	<1.0	<1.0
06-GW03	11/20/1986	<1.0	<6.0	<7.2	NA
	1/22/1987	<1.0	<6.0	<7.2	NA
	1/19/1991	<5.0	<5.0	<5.0	<5.0
	6/27/1991	<5.0	<5.0	<5.0	<5.0
	10/22/1992	ND	ND	ND	ND
	3/22/1993	<1.0	<1.0	<1.0	<1.0
	10/25/1997	<10	<10	<10	<10
	1/15/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1998	<5.0	<5.0	<5.0	<5.0
	7/24/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/29/1999	<5.0	<5.0	<5.0	NA
	1/13/2000	<5.0	<5.0	<5.0	<5.0
	7/12/2000	<10	<10	<10	<10
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/21/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	<5.0	<5.0	0.50J
06-GW04	11/19/1986	<1.0	<6.0	<7.2	NA
	1/21/1987	<1.0	<6.0	<7.2	NA
	1/19/1991	<5.0	<5.0	<5.0	<5.0
	10/21/1992	ND	ND	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	<1.0

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW05	11/19/1986	<1.0	<6.0	<7.2	NA
	1/21/1987	<1.0	<6.0	<7.2	NA
	1/19/1991	<5.0	<5.0	<5.0	<5.0
	3/21/1993	<1.0	<1.0	<1.0	<1.0
06-GW06	11/19/1986	<1.0	<6.0	<7.2	NA
	1/22/1987	<1.0	<6.0	<7.2	NA
	1/19/1991	<5.0	<5.0	<5.0	<5.0
	3/20/1993	<1.0	<1.0	<1.0	<1.0
06-GW07DW	11/4/1992	0.6J	0.6J	0.6J	0.6J
	3/19/1993	<1.0	<1.0	<1.0	<1.0
06-GW07S	11/20/1986	<1.0	<6.0	<7.2	NA
	1/22/1987	<1.0	<6.0	<7.2	NA
	1/19/1991	<5.0	<5.0	<5.0	<5.0
	3/19/1993	<1.0	<1.0	<1.0	<1.0
06-GW08	11/20/1986	<1.0	<6.0	<7.2	NA
	1/22/1987	<1.0	<6.0	<7.2	NA
	1/19/1991	<5.0	<5.0	<5.0	<5.0
	3/20/1993	<1.0	<1.0	<1.0	<1.0
06-GW09	3/19/1993	<1.0	<1.0	<1.0	<1.0
06-GW10	3/20/1993	<1.0	<1.0	<1.0	<1.0
06-GW11	6/27/1991	<5.0	<5.0	<5.0	<5.0
	3/21/1993	<1.0	<1.0	<1.0	<1.0
	1/21/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	<5.0	<5.0	1.0J
06-GW12	3/20/1993	<1.0	<1.0	<1.0	<1.0
06-GW13	10/20/1992	ND	ND	ND	ND
	3/20/1993	<1.0	<1.0	<1.0	<1.0
06-GW14	10/22/1992	ND	ND	ND	ND
	3/20/1993	<1.0	<1.0	<1.0	<1.0
06-GW15D	5/3/1993	<1.0	<1.0	<1.0	<1.0
	7/26/1997	<10	<10	<10	<10
	10/29/1997	<10	<10	<10	<10
	1/19/1998	<5.0	<5.0	<5.0	<5.0
	4/18/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	8/1/2002	<5.0	<5.0	<5.0	<5.0
	1/24/2003	<5.0	<5.0	<5.0	<5.0
	1/20/2004	<5.0	<5.0	<5.0	<15
06-GW15S	10/23/1992	ND	ND	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	<1.0

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW16	10/21/1992	ND	ND	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	<1.0
	7/27/1997	<10	<10	<10	<10
	10/23/1997	<500	<500	<500	<500
	1/19/1998	<100	<100	<100	<100
	1/15/1999	<5.0	6.0	<5.0	<5.0
	7/29/1999	<5.0	<5.0	<5.0	NA
	1/17/2000	9.0	<5.0	<5.0	<5.0
	7/12/2000	9.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	3.0J	2.0J	<5.0	<5.0
	1/20/2004	4.0J	0.20J	<5.0	2.0J
	7/28/2004	0.20J	<5.0	<5.0	<15
06-GW17	10/22/1992	ND	ND	ND	ND
	3/20/1993	<1.0	<1.0	<1.0	<1.0
	7/27/1997	<10	<10	<10	<10
	10/26/1997	<10	<10	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1998	<5.0	<5.0	<5.0	<5.0
06-GW18	3/20/1993	<1.0	<1.0	<1.0	<1.0
06-GW19	3/20/1993	<1.0	<1.0	<1.0	<1.0
06-GW20	3/21/1993	<1.0	<1.0	<1.0	<1.0
06-GW21	10/22/1992	ND	ND	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	<1.0
	7/27/1997	<10	<10	<10	<10
	10/26/1997	<10	<10	<10	<10
	1/18/1998	<5.0	<5.0	<5.0	<5.0
	4/18/1998	<5.0	<5.0	<5.0	<5.0
06-GW22	10/22/1992	ND	ND	ND	ND
	3/22/1993	<1.0	<1.0	<1.0	<1.0
06-GW23	10/22/1992	ND	ND	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	<1.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/29/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	<5.0	<5.0	<15
06-GW25	10/23/1992	ND	ND	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	<1.0
06-GW26	10/23/1992	ND	ND	ND	ND
	3/22/1993	<1.0	<1.0	<1.0	<1.0

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW27DA	7/23/1997	<10	<10	<10	<10
	10/29/1997	<10	<10	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	<5.0
	4/15/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	1/13/2000	<5.0	<5.0	<5.0	<5.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	<5.0	<5.0	<5.0	<5.0
	1/23/2003	<5.0	<5.0	<10	<10
	1/22/2004	<5.0	<5.0	<5.0	<15
06-GW27DW	11/3/1992	ND	ND	ND	ND
	3/23/1993	<1.0	<1.0	<1.0	<1.0
	7/22/1997	<10	<10	<10	<10
	10/29/1997	<500	<500	<500	<500
	1/18/1998	<100	<100	<100	<100
	4/16/1998	<5.0	<5.0	<5.0	<5.0
	7/24/1998	<120	<120	<120	<120
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/29/1999	<5.0	<5.0	<5.0	NA
	1/13/2000	2.0J	<5.0	<5.0	<5.0
	7/30/2000	<5.0	<5.0	<5.0	<5.0
	1/14/2001	<25	<25	<25	<25
	7/18/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0
	1/23/2003	0.50J	0.80J	<10	<10
	1/22/2004	0.50J	12	<5.0	<15
	7/26/2004	0.80J	<5.0	<5.0	<15
06-GW28DW	11/3/1992	ND	ND	ND	ND
	3/23/1993	ND	ND	2.0	ND
	7/25/1997	<250	<250	<250	<250
	10/28/1997	<500	<500	<500	<500
	1/16/1998	<120	<120	<120	<120
	4/18/1998	<50	<50	<50	<50
	7/24/1998	<120	<120	<120	<120
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/29/1999	<5.0	<5.0	<5.0	NA
	1/19/2000	<5.0	<5.0	<5.0	<5.0
	7/30/2000	<5.0	<5.0	<5.0	<5.0
	1/14/2001	19	<5.0	<5.0	<5.0
	7/18/2001	19	<5.0	<5.0	<5.0
	1/13/2002	19	<5.0	<5.0	<5.0
	8/1/2002	<5.0	0.30J	<5.0	<5.0

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW28DW—Continued	1/24/2003	32J	<250	<50	<89
	1/22/2004	28	0.50J	0.50J	2.0J
	7/26/2004	20	0.50J	0.70J	3.0J
06-GW28S	10/23/1992	ND	ND	ND	ND
	3/18/1993	<1.0	<1.0	<1.0	<1.0
	7/25/1997	<10	<10	<10	<10
	10/26/1997	<10	<10	<10	<10
	1/16/1998	<5.0	<5.0	<5.0	<5.0
	4/18/1998	<5.0	<5.0	<5.0	<5.0
	7/24/1998	<5.0	<5.0	<5.0	<5.0
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	7/29/1999	<5.0	<5.0	<5.0	NA
	1/19/2000	<5.0	<5.0	<5.0	<5.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/24/2003	<5.0	0.40J	<10	2.0J
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	<5.0	<5.0	<5.0	<15
06-GW30DW	3/23/1993	<1.0	<1.0	<1.0	<1.0
	7/24/1997	<10	<10	<10	<10
	10/25/1997	<10	<10	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	<5.0
	4/18/1998	<5.0	<5.0	<5.0	<5.0
06-GW30S	10/23/1992	ND	ND	ND	ND
	3/22/1993	<1.0	<1.0	<1.0	<1.0
	7/24/1997	<10	<10	<10	<10
	10/25/1997	<10	<10	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	<5.0
	4/18/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/28/1999	<5.0	<5.0	<5.0	NA
	1/16/2000	<5.0	<5.0	<5.0	<5.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	0.20J	<5.0	<15

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW31	3/6/1993	<1.0	<1.0	<1.0	<1.0
	6/27/1991	<5.0	<5.0	<5.0	<5.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/21/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	<5.0	<5.0	<15
06-GW32	3/18/1993	1.4	<1.0	<1.0	<1.0
	7/27/1997	<10	<10	<10	<10
	10/26/1997	<50	<50	<50	<50
	1/16/1998	<5.0	<5.0	<5.0	<5.0
	4/16/1998	<5.0	<5.0	<5.0	<5.0
	7/24/1998	<5.0	0.98J	<5.0	<5.0
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	7/29/1999	<5.0	<5.0	<5.0	NA
	1/16/2000	<5.0	<5.0	<5.0	<5.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	0.20J	<5.0	<5.0	<15
06-GW33	3/18/1993	<1.0	<1.0	<1.0	<1.0
	7/27/1997	<10	<10	<10	<10
	10/24/1997	<10	<10	<10	<10
	1/16/1998	<5.0	<5.0	<5.0	<5.0
	4/15/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	7/28/1999	<5.0	<5.0	<5.0	NA
	1/13/2000	<5.0	<5.0	<5.0	<5.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	0.50J	<5.0	<15

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW34	3/18/1993	<1.0	<1.0	<1.0	<1.0
	7/24/1997	<250	<250	<250	<250
	10/24/1997	<100	<100	<100	<100
	1/16/1998	<25	<25	<25	<25
	4/16/1998	<5.0	<5.0	<5.0	<5.0
	7/23/1998	<12	<12	<12	<12
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	7/28/1999	<500	<500	<500	NA
	1/12/2000	<5.0	<5.0	<5.0	<5.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	0.30J	0.20J	<5.0	<15
06-GW35D	3/22/1993	<1.0	<1.0	<1.0	<1.0
	7/27/1997	<10	<10	<10	<10
	10/26/1997	<10	<10	<10	<10
	1/18/1998	<5.0	<5.0	<5.0	<5.0
	4/19/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0
	1/22/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
06-GW36D	3/30/1993	<1.0	<1.0	<1.0	<1.0
	7/27/1997	<10	<10	<10	<10
	10/25/1997	<10	<10	<10	<10
	1/19/1998	<5.0	<5.0	<5.0	<5.0
	4/19/1998	<5.0	<5.0	<5.0	<5.0
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW37DW	3/23/1993	<1.0	<1.0	<1.0	<1.0
	7/23/1997	<50	<50	<50	<50
	10/25/1997	7.8J	<50	<50	<50
	1/19/1998	6.9	<5.0	<5.0	<5.0
	4/19/1998	5.3J	<10	<10	<10
	7/25/1998	7.7J	<10	<10	<10
	1/16/1999	4.0J	<5.0	<5.0	<5.0
	7/29/1999	<25	<25	<25	NA
	1/16/2000	3.0J	<5.0	<5.0	<5.0
	7/30/2000	<10	<10	<10	<10
	1/10/2001	3.0J	<5.0	<5.0	<5.0
	7/10/2001	3.0J	<5.0	<5.0	<5.0
	1/13/2002	5.0J	<5.0	<5.0	<5.0
	7/29/2002	3.0J	<5.0	<5.0	<5.0
	1/21/2003	3.0J	<5.0	<5.0	<5.0
	1/22/2004	6.0	<5.0	<5.0	<15
	7/28/2004	8.0	0.40J	<5.0	<15
06-GW38D	7/27/1997	<10	<10	<10	<10
	10/27/1997	<10	<10	<10	<10
	1/16/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/30/2002	<5.0	<5.0	<5.0	<5.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0
	1/21/2004	<5.0	<5.0	<5.0	<15
06-GW40DA	10/28/1997	<10	<10	<10	<10
	1/18/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1998	<5.0	<5.0	<5.0	<5.0
06-GW40DW	7/24/1997	<10	<10	<10	<10
	10/28/1997	<10	<10	<10	<10
	1/18/1998	<5.0	<5.0	<5.0	<5.0
	4/17/1998	<5.0	<5.0	<5.0	<5.0
	1/18/1999	<5.0	<5.0	<5.0	<5.0
	1/19/2000	<5.0	<5.0	<5.0	<5.0
	1/15/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	8/1/2002	<5.0	<5.0	<5.0	<5.0
	1/24/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15

Table C26. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 6, storage/disposal lots 201 and 203, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
06-GW41	1/15/1999	<5.0	<5.0	<5.0	<5.0
	7/29/1999	<5.0	<5.0	<5.0	NA
	1/12/2000	<5.0	<5.0	<5.0	<5.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/23/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	<5.0	<5.0	<5.0	<15
06-GW42	1/15/1999	<5.0	<5.0	<5.0	<5.0
	7/28/1999	<5.0	<5.0	<5.0	NA
	1/12/2000	<5.0	<5.0	<5.0	<5.0
	7/11/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/14/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	<5.0	<5.0	<5.0	<15
06-MW43DW AKA 06-GW43DW	7/28/1999	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	<5.0	<5.0	<15

[1] See Figure C5 or C20 for location

Data sources:

CERCLA Administrative Record files #193, #236, #273, #387, #1272, #1781, #1978, #2037, #2300, #2322, #2337, #2599A, #2609A, #3165, #3276, #3277, #3278, #3410, #3637

Baker Environmental, Inc. 1993k, 1994a, 1997e, 1998g,h,i, 1999de

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000e

Baker Environmental, Inc. and CH2M Hill, Inc. 2001a, 2002bg

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000b

Michael Baker, Jr., Inc. and CH2M Hill, Inc. 2003

Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2004

Environmental Science and Engineering, Inc. 1987, 1992b

Haliburton NUS 1992c

Unknown author 1991

Table C27. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 9, fire fighting training pit, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
09-GW01	342970	2502820	28.5	1984	25.0	10–25	BBUAQ
09-GW02	343192	2502720	25.7	1984	21.0	N/A	BBUAQ
09-GW03	343432	2502781	23.9	11/ /1986	[3]25	[4]10–25	BBUAQ, BBUCU(?)
09-GW04	342217	2503183	28.3	9/23/1992	20.3	6.3–20.3	BBUAQ
09-GW05	343113	2502785	28.0	9/22/1992	18.3	4.2–18.5	BBUAQ
09-GW06	343041	2502726	28.7	9/23/1992	19.7	4.9–19.3	BBUAQ
09-GW07D	343333	2502729	26.6	9/29/1992	110	100–109	UCHRBU
09-GW07S	343321	2502720	26.2	9/23/1992	21.5	7.1–21.0	BBUAQ
09-GW08	343070	2502890	26.0	9/23/1992	18.4	3.5–18.0	BBUAQ

[1] See Figure C6 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated depth. See Figure 6-2, Environmental Science and Engineering, Inc. 1990

[4] Estimated interval. See Figure 6-2, Environmental Science and Engineering, Inc. 1990

Data sources:

CERCLA Administrative Record files #125, #214, #387, #388, #720, #1272, #1559, #1615

Baker Environmental, Inc. 1993g,k,l,m,n

Environmental Sciences and Engineering, Inc. 1985, 1987, 1990

Table C28. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 9, fire fighting training pit, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
09-GW01	7/5/1984	<1.6	<1.2	<1.1	<1.1	NA	NA	<0.80
	11/19/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
09-GW02	7/5/1984	<1.6	<1.2	<1.1	<1.1	NA	NA	<0.80
	11/19/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
09-GW03	11/18/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	9/21/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
09-GW04	3/8/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
09-GW05	3/8/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
09-GW06	10/25/1992	ND	ND	ND	NA	NA	ND	ND
	3/8/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
09-GW07D	11/3/1992	ND	ND	ND	NA	NA	ND	ND
	3/8/1993	<1.0	1.2	<1.0	NA	NA	<1.0	<1.0
09-GW07S	3/8/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
09-GW08	10/25/1992	ND	ND	ND	NA	NA	ND	ND
	3/9/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0

[1] See Figure C6 for location

Data sources:

CERCLA Administrative Record files #387, #388, #1272

Baker Environmental, Inc. 1993k

Environmental Sciences and Engineering, Inc. 1985, 1987

Table C29. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 9, fire fighting training pit, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
09-GW01	7/5/1984	<0.30	<0.50	<1.0	NA
	11/19/1986	<1.0	<6.0	<7.2	NA
	3/9/1993	<1.0	<1.0	<1.0	<1.0
09-GW02	7/5/1984	<0.30	<0.50	<1.0	NA
	11/19/1986	<1.0	<6.0	<7.2	NA
	3/9/1993	<1.0	<1.0	<1.0	<1.0
09-GW03	11/18/1986	<1.0	<6.0	<7.2	NA
	1/21/1987	<1.0	<6.0	<7.2	NA
	3/9/1993	<1.0	<1.0	<1.0	<1.0
09-GW04	3/8/1993	<1.0	<1.0	<1.0	<1.0
09-GW05	3/8/1993	<1.0	<1.0	<1.0	<1.0
09-GW06	10/25/1992	<0.5	<0.5	<0.5	0.9J
	3/8/1993	<1.0	<1.0	<1.0	<1.0
09-GW07D	11/3/1992	ND	ND	ND	ND
	3/8/1993	<1.0	<1.0	<1.0	<1.0
09-GW07S	3/8/1993	<1.0	<1.0	<1.0	<1.0
09-GW08	10/25/1992	<0.5	<0.5	<0.5	ND
	3/9/1993	<1.0	2.2	3.4	14

[1] See Figure C6 for location

Data sources:

CERCLA Administrative Record files #387, #388, #1272

Baker Environmental, Inc. 1993k

Environmental Sciences and Engineering, Inc. 1985, 1987

Table C30. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 10, original base landfill, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBUAQ, Brewster Boulevard upper aquifer; BBUCU, Brewster Boulevard upper confining unit]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
10-MW02	346534	2501587	27.0	2/27/2001	17.2	7.0–17.0	BBUAQ
10-MW03	345831	2501347	21.6	2/27/2001	13.3	3.0–13.0	BBUAQ
10-MW04	346037	2500627	17.1	2/28/2001	12.6	2.0–12.0	BBUAQ
10-MW06	346952	2501230	18.7	2/27/2001	13.6	3.0–13.0	BBUAQ
10-MW08	345608	2500261	20.8	2/28/2001	14.0	4.0–14.0	BBUAQ
10-MW09	346633	2501145	16.6	2/28/2001	11.0	1.0–11.0	BBUAQ
10-TW01 (old)	346242	2500252	[3]16	9/26/1995	8.0	5.0–8.0	BBUAQ(?)
10-TW02 (old)	346294	2500388	[3]15	9/26/1995	15.0	12.0–15.0	BBUAQ(?)
10-TW03 (old)	346129	2500396	[3]17	9/26/1995	15.0	12.0–15.0	BBUAQ(?)
10-TW01 (new)	346802	2501411	26.2	3/18/1998	16.0	6.0–16.0	BBUAQ
10-TW02 (new)	346530	2501583	27.0	3/18/1998	14.0	4.0–14.0	BBUAQ
10-TW03 (new)	345825	2501343	22.0	3/18/1998	12.0	2.0–12.0	BBUAQ
10-TW04	346037	2500626	17.6	3/18/1998	7.0	2.0–7.0	BBUCU
10-TW05	345640	2500887	23.1	3/18/1998	14.0	4.0–14.0	BBUAQ
10-TW06	346953	2501226	18.6	3/19/1998	12.0	2.0–12.0	BBUAQ
10-TW07	345909	2500273	28.0	3/19/1998	18.0	8.0–18.0	BBUAQ
10-TW08	345609	2500260	20.7	3/19/1998	14.0	4.0–14.0	BBUAQ
10-TW09	346632	2501140	16.6	3/19/1998	6.0	1.0–6.0	BBUAQ

[1] See Figure C7 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data sources:

CERCLA Administrative Record files #3061, #3266

Baker Environmental, Inc. 2001b,c

Table C31. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 10, original base landfill, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
10-TW01 (old)	9/26/1995	<10	<10	<10	NA	NA	<10	<10
10-TW02 (old)	9/26/1995	<10	<10	<10	NA	NA	<10	<10
10-TW03 (old)	9/26/1995	<10	<10	<10	NA	NA	<10	<10
10-TW01 (new)	3/22/1998	<10	<10	<10	NA	NA	<10	<10
10-TW02 (new)	3/22/1998	<10	<10	<10	NA	NA	<10	<10
10-TW03 (new)	3/22/1998	<10	<10	<10	NA	NA	<10	<10
10-TW04	3/22/1998	<10	<10	<10	NA	NA	<10	<10
10-TW05	3/22/1998	<10	<10	<10	NA	NA	<10	<10
10-TW06	3/22/1998	<10	<10	<10	NA	NA	<10	<10
10-TW07	3/23/1998	<10	<10	<10	NA	NA	<10	<10
10-TW08	3/23/1998	<10	<10	<10	NA	NA	<10	<10
10-TW09	3/22/1998	<10	<10	<10	NA	NA	<10	<10

[1] See Figure C7 for location

Data sources:

CERCLA Administrative Record file #3266

Baker Environmental, Inc. 2001b

Table C32. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 10, original base landfill, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
10-TW01 (old)	9/26/1995	<10	<10	<10	<10
10-TW02 (old)	9/26/1995	<10	<10	<10	<10
10-TW03 (old)	9/26/1995	<10	<10	<10	<10
10-TW01 (new)	3/22/1998	<10	<10	<10	<10
10-TW02 (new)	3/22/1998	<10	<10	<10	<10
10-TW03 (new)	3/22/1998	<10	<10	<10	<10
10-TW04	3/22/1998	<10	<10	<10	<10
10-TW05	3/22/1998	<10	<10	<10	<10
10-TW06	3/22/1998	<10	<10	<10	<10
10-TW07	3/23/1998	<10	<10	<10	<10
10-TW08	3/23/1998	<10	<10	<10	<10
10-TW09	3/22/1998	<10	<10	<10	<10

[1] See Figure C7 for location

Data sources:

CERCLA Administrative Record file #3266

Baker Environmental, Inc. 2001b

Table C33. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 21, transformer storage lot 140, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
21-GW01	340959	2502039	29.7	1984	25.3	[3]10–25	BBUAQ, BBUCU, BBLAQ
21-GW02	341099	2502100	31.3	5/4/1993	19.5	9.7–18.7	BBUAQ, BBUCU, BBLAQ(?)
21-GW03	340805	2501753	29.1	5/4/1993	18.0	8.3–17.2	BBUAQ, BBUCU, BBLAQ(?)
21-GW04	340307	2501140	27.8	5/6/1993	15.0	5.2–14.2	BBUAQ, BBUCU

[1] See Figure C8 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated interval. See Section E–E', Environmental Science and Engineering, Inc. 1988a

Data sources:

CERCLA Administrative Record files #124, #258, #387, #522, #1271, #1516

Baker Environmental, Inc. 1994f,g

Environmental and Safety Designs, Inc. 1995

Environmental Science and Engineering, Inc. 1987, 1988a, 1992a

Table C34. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 21, transformer storage lot 140, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
21-GW01	11/21/1986	NA	<6.0	<7.2	NA
	1/24/1991	<5.0	<5.0	<5.0	<5.0
21-GW02	5/20/1993	77J	210J	540J	1,300J
21-GW03	5/21/1993	ND	ND	ND	ND

[1] See Figure C8 for location

Data sources:

CERCLA Administrative Record files #387, #388, #522, #1517

Baker Environmental, Inc. 1994g

Environmental Science and Engineering, Inc. 1985, 1987, 1991

Table C35. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 21, transformer storage lot 140, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected, detection or quantitation limit unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
21-GW01	11/21/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	1/24/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
21-GW02	5/20/1993	ND	41J	ND	ND	ND	NA	ND
21-GW03	5/21/1993	ND	ND	ND	ND	ND	NA	ND

[1] See Figure C8 for location

Data sources:

CERCLA Administrative Record files #387, #522, #1517

Baker Environmental, Inc. 1994g

Environmental Science and Engineering, Inc. 1987, 1991

Table C36. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 22, Industrial Area tank farm, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
HPGW22-1 AKA 22_22-1	339740	2501585	29.0	1984	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
HPGW22-2 AKA 22_22-2	340154	2501031	26.2	1984	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW01	339573	2501718	28.3	2/24/1988	17.0	7.0–17.0	BBUAQ
22-MW02	339809	2501960	30.0	2/24/1988	18.0	7.0–17.0	BBUAQ
22-MW03	339367	2501802	29.0	2/25/1988	15.0	5.0–15.0	BBUAQ
22-MW04	339588	2502080	29.8	2/25/1988	15.0	5.0–15.0	BBUAQ
22-MW05	339792	2501434	28.5	2/25/1988	15.0	5.0–15.0	BBUAQ
22-MW06	340026	2501789	27.8	3/1/1988	17.0	5.0–15.0	BBUAQ
22-MW07	340071	2501495	28.4	3/1/1988	17.0	5.0–15.0	BBUAQ
22-MW07R	N/A	N/A	N/A	12/14/1989	15.0	5.0–15.0	BBUAQ
22-MW08	339959	2501383	27.8	3/1/1988	17.0	5.0–15.0	BBUAQ
22-MW08R	N/A	N/A	N/A	12/14/1989	15.0	5.0–15.0	BBUAQ
22-MW09	339116	2501482	28.8	2/25/1988	15.0	5.0–15.0	BBUAQ
22-MW10	340033	2501940	28.1	2/25/1988	15.0	5.0–15.0	BBUAQ
22-MW11 AKA BOGW11	340014	2501237	26.5	3/2/1988	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW12 AKA BOGW12	340158	2501386	26.9	3/7/1988	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW13	340281	2501716	28.8	3/9/1988	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW14	339578	2501217	27.7	3/8/1988	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW15	339367	2501442	28.3	3/8/1988	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW16	339951	2501560	28.4	3/10/1988	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW17	339717	2501638	29.5	3/9/1988	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW18	339635	2501874	29.9	3/11/1988	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
22-MW19	339838	2502137	29.4	3/14/1988	25.0	5.0– 25.0	BBUAQ, BBUCU, BBLAQ
22-MW20 AKA BOMW20	340181	2501167	26.8	1988	25.0	4.0–24.0	BBUAQ, BBUCU, BBLAQ
22-MW21	340352	2501585	26.7	12/14/1989	19.0	9.0–19.0	BBUAQ, BBUCU
22-MW22	340326	2501329	27.5	12/14/1989	15.0	5.0–15.0	BBUAQ, BBUCU
22-MW23	339433	2501686	27.3	12/14/1989	18.0	8.0–18.0	BBUAQ, BBUCU
22-RW01	339830	2501477	28.6	12/12/1989	34.0	9.0–34.0	BBUAQ, BBUCU, BBLAQ
22-RW02	339541	2501714	29.0	12/13/1989	33.0	8.0– 33.0	BBUAQ, BBUCU, BBLAQ

[1] See Figure C9 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

Data sources:

CERCLA Administrative Record files #382, #1516

Environmental Science and Engineering, Inc. 1992a

O'Brien and Gere Engineers, Inc. 1990

Table C37. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 22, Industrial Area tank farm, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
HPGW22-1	7/6/1984	17,000	27,000	3,800	NA
	1/9/1987	12,000	15,000	1,800	9,000
	3/8/1987	10,000	18,000	<7,200	<12,000
	5/27/1987	13,000	24,000	<7,200	<12,000
	1/18/1991	7,900	16,000	1,900J	9,800
	5/21/1993	9,200J	18,000J	3,000J	16,000J
	7/9/1995	17,700	14,800	< 1.0	NA
	10/24/1995	9,590	27,300	2,490	NA
	1/17/1996	11,800	28,100	4,230	NA
	4/10/1996	4,900	9,100	800	NA
	7/17/1996	9,500	19,000	2,300	11,000
	10/9/1996	8,500	2,000	18,000	10,000
HPGW22-2	7/6/1984	<0.30	<0.60	<1.0	NA
	1/9/1987	<1.0	<6.0	<7.2	<12
	3/8/1987	<1.0	<6.0	<7.2	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/24/1991	<5.0	<5.0	<5.0	<5.0
22-MW01	4/20/1988	19,000	36,000	3,200	21,000
22-MW02	4/20/1988	29,000	110,000	11,000	48,000
22-MW03	4/20/1988	<1.0	2	<1.0	4.0
22-MW04	4/20/1988	<1.0	<1.0	<1.0	2.0
22-MW05	4/20/1988	<1.0	<1.0	<1.0	2.0
22-MW06	4/20/1988	600	1,700	1,600	7,100
22-MW07	4/21/1988	28,000	26,000	2,800	12,000
22-MW08	4/20/1988	19	1	<1.0	<1.0
22-MW09	4/20/1988	<1.0	<1.0	2.0	8.0
22-MW10	4/20/1988	51	1.0	9.0	14
22-MW11	4/20/1988	1.0	1.0	<1.0	1.0
22-MW12	4/21/1988	19,000	17,000	1,500	8,400
22-MW13	4/20/1988	2.0	2.0	2.0	8.0
22-MW14	4/20/1988	6	<1.0	<1.0	2.0
22-MW15	4/21/1988	4,700	18,000	2,400	13,000
22-MW16	4/21/1988	28,000	28,000	1,900	12,000
22-MW17	4/21/1988	11,000	13,000	2,500	9,100
22-MW18	4/21/1988	24,000	42,000	1,900	12,000
22-MW19	4/21/1988	21	150	53	130
22-MW20	4/21/1988	60	160	79	96

[1] See Figure C9 for location

Data sources:

CERCLA Administrative Record files #124, #258, #382, #388, #522, #1517, #1777, #1778
Baker Environmental, Inc. 1994g, 1996i,j
Environmental Science and Engineering, Inc. 1985, 1988a, 1991
O'Brien and Gere Engineers, Inc. 1990
Water and Air Research, Inc. 1983

Table C38. Summary of BTEX free-phase measurements in monitor wells at Installation Restoration Site 22, Industrial Area tank farm, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[BTEX: benzene, toluene, ethylbenzene, and xylene; N/A, not available]

Site name[1]	Sample date	BTEX free-phase thickness, in feet
22-MW01	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW02	3/15/1988	2.97
	4/20/1988	3.17
	11/6/1989	3.34
	12/15/1989	3.08
22-MW03	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW04	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW05	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW06	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW07	3/15/1988	N/A
	4/20/1988	0.35
	11/6/1989	NA
	12/15/1989	NA
22-MW08	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW09	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW10	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW11	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW12	3/15/1988	4.33
	4/20/1988	9.81
	11/6/1989	8.70
	12/15/1989	6.89
22-MW13	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW14	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW15	3/15/1988	0.86
	4/20/1988	0.24
	11/6/1989	0.00
	12/15/1989	0.00
22-MW16	3/15/1988	14.85
	4/20/1988	15.34
	11/6/1989	15.07
	12/15/1989	14.91
22-MW17	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW18	3/15/1988	4.59
	4/20/1988	5.10
	11/6/1989	5.29
	12/15/1989	4.77
22-MW19	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00
22-MW20	3/15/1988	0.00
	4/20/1988	0.00
	11/6/1989	0.00
	12/15/1989	0.00

[1] See Figure C9 for location

Data sources:

CERCLA Administrative Record files #382, #417

O'Brien and Gere Engineers, Inc. 1988, 1990

Table C39. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 22, Industrial Area tank farm, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
HPGW22-1	7/6/1984	<1.2	<1.0	<0.90	<0.80	NA	NA	<0.60
	1/9/1987	<30	<30	<28	<16	NA	NA	<10
	3/8/1987	<2,000	<1,000	<2,800	<1,600	NA	NA	<1,000
	5/27/1987	<2,000	<1,000	<2,800	<1,600	NA	NA	<1,000
	1/18/1991	<5.0	5.0J	<5.0	NA	NA	<5.0	<10
	5/21/1993	ND	ND	ND	ND	ND	NA	ND
	7/9/1995	<0.5	<0.5	<0.5	<0.5	NA	NA	<0.5
	10/25/1995	<25	<25	<25	<25	NA	NA	<25
	1/19/1996	<25	<25	<25	<25	NA	NA	<25
	4/9/1996	<0.5	<0.5	<0.5	<0.5	NA	NA	<0.5
HPGW22-2	7/6/1984	<2.0	<1.4	<1.3	<1.3	NA	NA	<0.90
	1/9/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	3/8/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/24/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
22-MW01	4/20/1988	<1,000	<1,000	NA	NA	NA	NA	NA
22-MW02	4/20/1988	<1,000	<1,000	NA	NA	NA	NA	NA
22-MW03	4/20/1988	4.0	<1.0	NA	NA	NA	NA	NA
22-MW04	4/20/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW05	4/20/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW06	4/20/1988	<100	<100	NA	NA	NA	NA	NA
22-MW07	4/20/1988	<1,000	<1,000	NA	NA	NA	NA	NA
22-MW08	4/20/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW09	4/20/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW10	4/20/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW11	4/20/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW12	4/21/1988	<1,000	<1,000	NA	NA	NA	NA	NA
22-MW13	4/20/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW14	4/20/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW15	4/21/1988	<1,000	<1,000	NA	NA	NA	NA	NA
22-MW16	4/21/1988	<1,000	<1,000	NA	NA	NA	NA	NA
22-MW17	4/21/1988	<100	<100	NA	NA	NA	NA	NA
22-MW18	4/21/1988	<1,000	<1,000	NA	NA	NA	NA	NA
22-MW19	4/21/1988	<1.0	<1.0	NA	NA	NA	NA	NA
22-MW20	4/21/1988	<1.0	1.0	NA	NA	NA	NA	NA

[1] See Figure C9 for location

Data sources:

CERCLA Administrative Record files #124, #258, #382, #388, #522, #1517, #1777, #1778

Baker Environmental, Inc. 1994g, 1996i,j

Environmental Science and Engineering, Inc. 1985, 1988a, 1991

O'Brien and Gere Engineers, Inc. 1990

Water and Air Research, Inc. 1983

Table C40. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 24, Industrial Area fly ash dump, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit; NA, not available]

Site name[1]	Location coordinates[2] North	Location coordinates[2] East	Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
24-GW01	336692	2501024	15.8	7/ /1984	22.4	[4]7.0–22.0	BBUAQ, BBUCU, BBLAQ
24-GW02	336531	2501313	11.4	7/ /1984	20.6	[4]5.0–20.0	BBUAQ, BBUCU, BBLAQ
24-GW03	336501	2502167	13.8	7/ /1984	21.9	[4]6.0–21.0	BBUAQ, BBUCU, BBLAQ
24-GW04	336772	2503141	16.5	7/ /1984	24.3	[4]9.0–24.0	BBUAQ, BBUCU
24-GW05	337190	2501933	24.6	7/ /1984	NA	NA	BBUAQ (?), BBLAQ (?)
24-GW06	336099	2501244	9.7	1986	27.7	NA	BBUAQ (?), BBLAQ (?)
24-GW07 (old)	335180	2502240	[3]7.5	1986	NA	NA	BBUAQ (?), BBLAQ (?)
24-GW07 (new)	337662	2502854	27.4	4/25/1993	18.0	7.7–17.2	BBUAQ, BBUCU
24-GW08	337152	2502970	23.6	4/25/1993	19.0	9.1–18.2	BBUAQ, BBUCU
24-GW09	336379	2502872	13.8	4/26/1993	12.5	2.6–11.7	BBUAQ
24-GW10	335884	2502053	17.3	4/26/1993	18.0	8.0–17.2	BBUAQ, BBUCU

[1] See Figure C10 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

[4] Estimated interval. See Section D–D', Environmental Science and Engineering, Inc. 1987

Data sources:

CERCLA Administrative Record files #124, #387, #522, #1271

Baker Environmental, Inc. 1994f,g

Environment and Safety Designs, Inc. 1995

Environmental Science and Engineering, Inc. 1987

Table C41. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 24, Industrial Area fly ash dump, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit.; NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
24-GW01	12/3/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
24-GW02	12/3/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
24-GW03	12/3/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
24-GW04	12/3/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
24-GW05	12/3/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
24-GW06	3/4/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
24-GW07	3/4/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
24-GW08	6/2/1993	ND	ND	ND	ND	ND	NA	ND
	7/10/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/9/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/3/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/26/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
24-GW09	6/2/1993	ND	ND	ND	ND	ND	NA	ND
	7/11/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/9/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/3/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/26/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
24-GW10	6/2/1993	ND	ND	ND	ND	ND	NA	ND
	7/11/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/9/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/4/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/26/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50

[1] See Figure C10 for location

Data sources:

CERCLA Administrative Record files #387, #522, #1777, #1778, #1779, #1780, #1977

Baker Environmental, Inc. 1994g, 1996i,j, 1997c,d, 1998k

Environmental Science and Engineering, Inc. 1987

Table C42. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 24, Industrial Area fly ash dump, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected, detection or quantitation limit unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
24-GW01	7/7/1984	<0.40	NA	NA	NA
	12/3/1986	NA	<6.0	<7.2	NA
24-GW02	7/7/1984	<0.40	NA	NA	NA
	12/3/1986	NA	<6.0	<7.2	NA
24-GW03	7/7/1984	<0.40	NA	NA	NA
	12/3/1986	NA	<6.0	<7.2	NA
24-GW04	7/7/1984	<0.60	NA	NA	NA
	12/3/1986	NA	<6.0	<7.2	NA
24-GW05	7/7/1984	3.0	NA	NA	NA
	12/3/1986	NA	<6.0	<7.2	NA
24-GW06	12/3/1986	NA	<6.0	<7.2	NA
	3/4/1987	NA	<6.0	<7.2	NA
24-GW07 (old)	12/3/1986	NA	<6.0	<7.2	NA
	3/4/1987	NA	<6.0	<7.2	NA
24-GW08	6/2/1993	ND	ND	ND	ND
	7/10/1996	<0.50	<0.50	<0.50	<0.50
	10/9/1996	<0.50	<0.50	<0.50	<0.50
	2/3/1997	<0.50	<0.50	<0.50	<0.50
	4/26/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
24-GW09	6/2/1993	ND	ND	ND	ND
	7/11/1996	<0.50	<0.50	<0.50	<0.50
	10/9/1996	<0.50	<0.50	<0.50	<0.50
	2/3/1997	<0.50	<0.50	<0.50	<0.50
	4/26/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
24-GW10	6/2/1993	ND	ND	ND	ND
	7/11/1996	<0.50	<0.50	<0.50	<0.50
	10/9/1996	<0.50	<0.50	<0.50	<0.50
	2/4/1997	<0.50	<0.50	<0.50	<0.50
	4/26/1997	<0.50	<0.50	<0.50	<0.50
	8/11/1997	<0.50	<0.50	<0.50	<0.50

[1] See Figure C10 for location

Data sources:

CERCLA Administrative Record files #124, #387, #522, #1777, #1778, #1779, #1780, #1977

Baker Environmental, Inc. 1994g, 1996i,j, 1997c,d, 1998k

Environment and Safety Designs, Inc. 1995

Environmental Science and Engineering, Inc. 1987

Table C43. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 28, Industrial Area burn dump, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, TTCU—Tarawa Terrace confining unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
28-GW01 (old)	331847	2498323	4.8	1984	16.5	2.5–16.5	BBUAQ, BBUCU, BBLAQ
28-GW01 (new)	331849	2498323	4.8	4/20/1994	17.0	2.5–16.2	BBUAQ, BBUCU, BBLAQ
28-GW01DW	331870	2498323	5.5	4/23/1994	133.0	117–132	TTCU(?), UCHRBU
28-GW02	331604	2498802	3.8	1984	21.7	7.74–21.74	BBUAQ, BBUCU, BBLAQ
28-GW03	331507	2499512	3.6	1984	20.8	6.8–20.8	BBUAQ, BBUCU, BBLAQ
28-GW04	332165	2499566	4.4	1986	29.0	N/A	BBLAQ(?)
28-GW05	331719	2499911	15.6	4/7/1994	24.0	7.0–24.0	BBUAQ, BBUCU, BBLAQ
28-GW06	332194	2498094	17.2	4/7/1994	30.0	15–29.3	BBUAQ, BBUCU, BBLAQ
28-GW07	331751	2499119	3.8	4/8/1994	18.0	2.5–17.5	BBUAQ, BBUCU, BBLAQ
28-GW07DW	331745	2499147	3.6	4/26/1994	131.0	114–129	TTCU(?), UCHRBU
28-GW08 (old)	332239	2499096	11.6	1994	24.0	7.9–22.7	BBUAQ, BBUCU, BBLAQ
28-GW08 (new)	332239	2499096	11.6	8/14/1995	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
28-GW09DW	332857	2498262	4.5	4/12/1994	126.0	111–126	TTCU(?), UCHRBU
28-GW13	332690	2498621	[3]6	1994	N/A	N/A	BBLAQ(?)
28-TGWPA	331865	2498693	[3]17	1994	N/A	N/A	BBLAQ(?)

[1] See Figure C11 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data sources:

CERCLA Administrative Record files #1500, #1749, #2592

Baker Environmental, Inc. 1995l,p, 1996n

Table C44. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 28, Industrial Area burn dump, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
28-GW01 (old)	7/7/1984	<2.1	15	<1.4	38	NA	NA	22
	12/16/1986	<3.0	4.9	<2.8	14	NA	NA	13
	4/14/1993	<10	<10	<10	NA	NA	2.0J	6.0J
	4/25/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW01DW	5/7/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW02	7/7/1984	<1.9	<1.4	<1.3	<1.3	NA	NA	<1.0
	12/16/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	4/14/1993	<10	<10	<10	NA	NA	<10	<10
	4/20/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW03	7/7/1984	<2.3	<1.7	<1.6	<1.5	NA	NA	<1.0
	12/11/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<10
	4/14/1993	<10	<10	<10	NA	NA	<10	<10
	4/21/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW04	12/11/1986	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/4/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	4/14/1993	<10	<10	<10	NA	NA	<10	<10
	4/20/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW05	4/23/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW06	4/21/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW07	4/21/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW07DW	5/8/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW08 (old)	4/21/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW09DW	4/25/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-GW13	4/21/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
28-TGWPA01	4/20/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0

[1] See Figure C11 for location

Data sources:

CERCLA Administrative Record files #387, #388, #1130, #1500, #1505

Baker Environmental, Inc. 1993o, 1995l,m

Environmental Science and Engineering, Inc. 1985, 1987

Table C45. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 28, Industrial Area burn dump, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
28-GW01 (old)	7/7/1984	<4.0	<0.6	<1.0	NA
	12/16/1986	<1.0	<6.0	<7.2	<12
	4/14/1993	<10	<10	<10	<10
28-GW01 (new)	4/25/1994	<2.0	<2.0	<2.0	<2.0
28-GW01DW	5/7/1994	<2.0	<2.0	<2.0	<2.0
28-GW02	7/7/1984	<0.3	<0.6	<1.0	NA
	12/16/1986	<1.0	<6.0	<7.2	<12
	4/14/1993	<10	<10	<10	<10
	4/20/1994	<2.0	<2.0	<2.0	<2.0
28-GW03	7/7/1984	<0.4	<0.7	<1.0	NA
	12/11/1986	<1.0	<6.0	<7.2	<12
	4/14/1993	<10	<10	<10	<10
	4/21/1993	<2.0	<2.0	<2.0	<2.0
28-GW04	12/11/1986	<1.0	<6.0	<7.2	<12
	3/4/1987	<1.0	<6.0	<7.2	<12
	4/14/1993	<10	<10	<10	<10
	4/20/1994	<2.0	<2.0	<2.0	<2.0
28-GW05	4/23/1994	<2.0	<2.0	<2.0	<2.0
28-GW06	4/21/1994	<2.0	<2.0	<2.0	<2.0
28-GW07	4/21/1994	<2.0	3.0	<2.0	<2.0
28-GW07DW	5/8/1994	<2.0	<2.0	<2.0	<2.0
28-GW08 (old)	4/21/1994	<2.0	<2.0	<2.0	<2.0
28-GW09DW	4/21/1994	<2.0	<2.0	<2.0	<2.0
28-GW13	4/21/1994	<2.0	<2.0	<2.0	<2.0
28-TGWPA	4/20/1994	<2.0	2.0	5.0	19

[1] See Figure C11 for location

Data sources:

CERCLA Administrative Record files #387, #388, #1130, #1500, #1505

Baker Environmental, Inc. 1993o, 1995l,m

Environmental Science and Engineering, Inc. 1985, 1987

Table C46. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 30, Sneads Ferry Road fuel tank sludge disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBUAQ, Brewster Boulevard upper aquifer]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer
	North	East					
30-GW01	318873	2513451	42.6	7/ /1984	21.5	6.5–21.5	BBUAQ
30-GW02	318381	2512971	36.8	12/ /1986	26.0	11.0–26.0	BBUAQ
30-GW03	318911	2514554	40.5	3/24/1994	17.5	2.5–17.5	BBUAQ
30-PZ01	318829	2512887	32.5	3/23/1994	25.0	20.0–25.0	BBUAQ

[1] See Figure C12 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

Data sources:

CERCLA Administrative Record files #388, #1498, #1505

Baker Environmental, Inc. 1995j,m

Environmental Science and Engineering, Inc. 1985

Table C47. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 30, Sneads Ferry Road fuel tank sludge disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
30-GW01	7/6/1984	<2.0	<1.4	<1.3	<1.3	<0.8	NA	<1.0
	12/4/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	4/13/1993	<10	<10	<10	NA	NA	<10	<10
	4/21/1994	<2.0	<2.	<2.	NA	NA	<2.0	<2.0
30-GW02	12/4/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	3/6/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	4/13/1993	<10	<10	<10	NA	NA	<10	<10
	4/21/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0
30-GW03	4/21/1994	<2.0	<2.0	<2.0	NA	NA	<2.0	<2.0

[1] See Figure C12 for location

Data sources:

CERCLA Administrative Record files #387, #388, #1130, #1501

Baker Environmental, Inc. 1993o, 1995o

Environmental Science and Engineering, Inc. 1985, 1987

Table C48. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 30, Sneads Ferry Road fuel tank sludge disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
30-GW01	7/6/1984	<0.3	<0.6	<1.0	NA
	12/4/1986	<1.0	<6.0	<7.2	<12
	4/13/1993	<10	<10	<10	<10
	4/21/1994	<2.0	<2.0	<2.0	<2.0
30-GW02	12/4/1986	<1.0	<6.0	<7.2	<12
	3/6/1987	<1.0	<6.0	<7.2	<12
	4/13/1993	<10	<10	<10	<10
	4/21/1994	<2.0	<2.0	<2.0	<2.0
30-GW03	4/21/1994	<2.0	<2.0	<2.0	<2.0

[1] See Figure C12 for location

Data sources:

CERCLA Administrative Record files #387, #388, #1130, #1501
Baker Environmental, Inc. 1993o, 1995o
Environmental Science and Engineering, Inc. 1985, 1987

Table C49. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 74, mess hall grease pit disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
74-GW01 AKA 74MW01	353331	2501819	33.2	6/ /1984	[3]24	[4]9–24	BBUAQ, BBUCU
74-GW02 AKA 74MW02	353013	2591971	33.1	6/ /1984	[3]26	[4]11–26	BBUAQ, BBUCU
74-GW03	354145	2500946	33.1	1986	[3]25	[4]10–25	BBUAQ, BBUCU
74-GW03A	353878	2501115	33.4	1/18/1994	18.0	8.0–18.0	BBUAQ
74-GW04	353437	2501304	32.7	1/18/1994	19.5	9.5–19.5	BBUAQ
74-GW05	353028	2501327	32.8	1/11/1994	16.5	6.0–16.5	BBUAQ
74-GW06	353337	2501567	31.6	1/11/1994	26.0	15.5–26.0	BBUAQ, BBUCU
74-GW07 AKA 74MW07	352655	2501624	32.4	2/18/1994	16.5	6.5–16.5	BBUAQ
74-GW08	352836	2502538	28.4	2/18/1994	23.0	13.0–23.0	BBUAQ, BBUCU

[1] See Figure C13 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated depth. See Figure 74-2, Environmental and Safety Designs, Inc. 1995

[4] Estimated interval. See Figure 74-2, Environmental and Safety Designs, Inc. 1995

Data sources:

CERCLA Administrative Record files #124, #387, #1524, #1543, #3428
Baker Environmental, Inc. 1995g,i
Environmental and Safety Designs, Inc. 1995
Environmental Science and Engineering, Inc. 1984, 1987

Table C50. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 74, mess hall grease pit disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
74-GW01	12/4/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	2/16/1994	<10	<10	<10	NA	NA	<10	<10
74-GW02	12/4/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	3/4/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	2/16/1994	<10	<10	<10	NA	NA	<10	<10
74-GW03	12/4/1986	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
74-GW03A	2/16/1994	<10	<10	<10	NA	NA	<10	<10
74-GW04	2/16/1994	<10	<10	<10	NA	NA	<10	<10
74-GW05	2/16/1994	<10	<10	<10	NA	NA	<10	<10
74-GW06	2/16/1994	<10	<10	<10	NA	NA	<10	<10
74-GW07	2/22/1994	<10	<10	<10	NA	NA	<10	<10
74-GW08	2/22/1994	<10	<10	<10	NA	NA	<10	<10

[1] See Figure C13 for location

Data sources:

CERCLA Administrative Record files #387, #1525
Baker Environmental, Inc. 1995h
Environmental Science and Engineering, Inc. 1987

Table C51. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 74, mess hall grease pit disposal area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
74-GW01	12/4/1986	< 1.0	< 6.0	< 7.2	NA
	2/16/1994	< 10	< 10	< 10	< 10
74-GW02	12/4/1986	< 1.0	< 6.0	< 7.2	NA
	3/4/1987	< 1.0	< 6.0	< 7.2	NA
	2/16/1994	< 10	< 10	< 10	< 10
74-GW03	12/4/1986	< 1.0	< 6.0	< 7.2	NA
74-GW03A	2/16/1994	< 10	< 10	< 10	< 10
74-GW04	2/16/1994	< 10	< 10	< 10	< 10
74-GW05	2/16/1994	< 10	< 10	< 10	< 10
74-GW06	2/16/1994	< 10	< 10	< 10	< 10
74-GW07	2/22/1994	< 10	< 10	< 10	< 10
74-GW08	2/22/1994	< 10	< 10	< 10	< 10

[1] See Figure C13 for location

Data sources:

CERCLA Administrative Record files #387, #1525
Baker Environmental, Inc. 1995h
Environmental Science and Engineering, Inc. 1987

Table C52. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, Local CU—local confining unit, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
78-Bldg900_UST01	340599	2502739	29.5	1995	50.0	45.0–50.0	BBLCU, TTAQ (?)
78-Bldg900_UST02	340491	2502444	29.5	1995	13.9	3.9–13.9	BBUAQ
78-Bldg900_UST03	340654	2502666	29.2	1995	50.0	45.0–50.0	BBLCU, TTAQ (?)
78-Bldg900_UST04	340657	2502669	29.2	1996	14.0	4.1–14.1	BBUAQ
78-Bldg900_UST05	340660	2502768	29.3	1996	14.0	4.1–14.1	BBUAQ
78-Bldg900_UST06	340538	2502721	30.1	1996	13.2	3.2–13.2	BBUAQ
78-Bldg900_UST07	340546	2502806	[3]37	N/A	N/A	N/A	BBUAQ (?)
78-Bldg902_P01	341270	2502816	N/A	1/29/1993	25 (?)	15–25 (?)	BBUAQ, BBUCU
78-Bldg902_P02	341240	2502892	N/A	1/29/1993	23 (?)	13–23 (?)	BBUAQ, BBUCU
78-Bldg902_RW01	341293	2502855	N/A	1/30/1993	25.0	10–24.85	BBUAQ, BBUCU
78-Bdg1611_UG1A	338815	2498889	[3]22	N/A	N/A	N/A	N/A
78-GW01	337222	2499145	30.6	10/31/1986	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
78-GW02	337018	2499576	30.0	11/4/1986	25.0	5.0–20.0	BBUAQ, BBUCU, BBLAQ
78-GW03	336765	2499494	29.7	11/4/1986	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
78-GW04-1 AKA MW4	337457	2499549	29.1	11/4/1986	25.0	4.5–24.5	BBUAQ, BBCU
78-GW04-2 AKA MW4-2	337543	2499463	29.1	12/ /1990	78.0	65.0–78.0	TTAQ
78-GW04-3 AKA MW4-3	337577	2499436	28.7	12/ /1990	153.0	140.0–153.0	Local CU, UCHLU
78-GW05 AKA MW5	338211	2499027	26.5	11/4/1986	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
78-GW06	338641	2498839	25.5	11/18/1986	25.0	5.0–25.0	BBUAQ, BBUCU
78-GW07 AKA MW7	338538	2499392	25.7	11/18/1986	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
78-GW08 AKA MW8	338709	2499778	25.6	11/6/1986	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
78-GW09-1(Old) AKA MW9	337998	2499701	26.8	11/6/1986	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
78-GW09-1(New)	338073	2499643	[3]27	12/9/1993	24.0	6.6–21.6	BBUAQ, BBUCU, BBLAQ
78-GW09-2 AKA MW9-2	337995	2499690	25.6	7/1/1987	75.3	55.3–75.3	BBLCU, TTAQ
78-GW09-3 AKA MW9-3	337981	2499832	24.8	7/20/1987	150.0	130.0–150.0	UCHRBU, Local CU,
78-GW10 AKA MW10	338309	2500046	26.0	11/6/1986	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
78-GW11 AKA MW11	337865	2500178	25.8	11/18/1986	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ

Table C52. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, Local CU—local confining unit, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
78-GW12 AKA MW12	338457	2500632	27.7	11/18/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW13	339567	2499458	23.6	11/17/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW14	339391	2499956	25.1	11/5/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW15 AKA MW15	339109	2500535	26.8	11/6/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW16 AKA MW16	339006	2501332	30.2	11/19/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW17-1 AKA MW17	339371	2500975	27.9	11/6/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW17-2 AKA MW17-2	339198	2501229	29.7	6/24/1987	73.3	53.3 – 73.3	BBLCU, TTAQ
78-GW17-3	339236	2501288	[3]31	7/17/1987	150.0	130.0 – 150.0	UCHRBU, Local CU,
78-GW18	339766	2500665	27.0	11/19/1986	25.0	N/A	BBUAQ(?), BBUCU, BBLAQ
78-GW19	340220	2500628	27.0	11/6/86	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW20	340704	2500752	22.8	11/6/86	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW21	339539	2502400	31.4	11/10/86	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW22	340395	2502740	30.5	11/4/86	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW22A	340372	2502763	30.4	1995?	N/A	N/A	BBUAQ(?), BBUCU(?), BBLAQ(?)
78-GW23	340686	2502468	30.3	11/5/86	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW24-1	341181	2502845	30.8	11/12/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW24-2	341169	2502808	30.8	6/9/1987	76.6	56.6 – 76.6	BBLCU, TTAQ
78-GW24-3	341153	2502785	30.6	6/18/1987	148.2	128.2 – 148.2	UCHRBU, Local CU,
78-GW25	340951	2503205	30.4	11/5/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW26	342950	2501860	32.6	11/5/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW29	335465	2499141	26.4	11/17/1986	25.0	5.0 – 25.0	BBUAQ, BBUCU, BBLAQ
78-GW30-2	340967	2502302	30.0	12/ /1990	78.0	65.0 – 78.0	TTAQ

Table C52. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, Local CU—local confining unit, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
78-GW30-3	340929	2502409	30.0	12/ /1990	153.0	140.0–153.0	Local CU
78-GW31-2 AKA MW31-2	339118	2500537	26.5	12/ /1990	78.0	65.0–78.0	TTAQ
78-GW31-3 AKA MW31-3	338983	2500417	26.4	12/ /1990	153.0	140.0–153.0	Local CU
78-GW32-2 AKA MW32-2	339494	2501261	27.0	12/ /1990	77.0	64.0–77.0	TTAQ
78-GW32-3 AKA MW32-3	339474	2501278	27.3	12/ /1990	153.0	140.0–153.0	UCHRBU
78-GW33	340015	2503216	29.9	5/18/1993	14.0	4.0–13.1	BBUAQ
78-GW34	338591	2503614	29.9	5/18/1993	13.0	2.9–12.0	BBUAQ
78-GW35	338155	2502669	29.2	5/18/1993	20.0	9.8–18.9	BBUAQ, BBUCU(?)
78-GW36	338123	2500767	26.9	5/18/1993	18.0	8.1–17.2	BBUAQ, BBUCU(?)
78-GW37	336951	2500612	18.2	5/19/1993	14.0	3.8–13.1	BBUAQ
78-GW38	334862	2499896	25.9	5/19/1993	29.0	18.9–28.0	BBLAQ
78-GW39	334207	2500098	16.8	1993	20.0	10.0–20.0	BBUAQ, BBUCU, BBLAQ
78-GW40	340651	2502400	29.3	2/6/1998	24.0	4.4–24.0	BBUAQ, BBUCU, BBLAQ
78-GW41	340991	2502751	28.8	2/6/1998	23.8	4.5–23.8	BBUAQ, BBUCU, BBLAQ
78-GW42	337497	2499302	28.0	2/7/1998	23.2	3.9–23.2	BBUAQ, BBUCU, BBLAQ
78-GW43	341094	2502655	30.2	9/ /2000	30.0	25.0–30.0	BBLAQ
78-GW44	341133	2502739	30.5	9/ /2000	31.2	27.5–31.2	BBLAQ
78-GW45	341921	2502820	28.9	9/ /2000	25.0	20.0–25.0	BBLAQ
78-GW46	340618	2502618	30.7	9/ /2000	23.0	18.0–23.0	BBUCU
78-GW47	340644	2502481	30.1	9/ /2000	30.0	25.0–30.0	BBLAQ
78-GW48	340855	2502482	29.4	9/ /2000	23.0	18.0–23.0	BBUCU
78-GW49	337800	2499623	25.9	2001	30.5	25.5–30.5	BBLAQ
78-GW50	337500	2499057	29.6	2001	23.0	18.0–23.0	BBUCU
78-GW51	337929	2499266	27.3	2001	24.0	19.0–24.0	BBLAQ
78-GW52	337716	2499418	27.6	2001	32.0	27.0–32.0	BBLAQ
78-GW53	337500	2499620	28.2	2001	27.0	22.0–27.0	BBLAQ
78-GW54	337465	2498441	29.5	2001	24.0	19.0–24.0	BBUCU
78-GW55	337213	2498668	29.4	2001	23.5	18.5–23.5	BBLAQ
78-GW56	336753	2499673	29.5	2001	29.6	24.6–29.6	BBLAQ
78-GW57	337344	2499351	29.6	2001	28.0	23.0–28.0	BBLAQ
78-GW58	337660	2499606	[3]28	2001	28.0	23.0–28.0	BBLAQ
78-GW59	337012	2499008	28.4	2001	25.0	20.0–25.0	BBLAQ
78-GW60	337987	2499685	27.1	6/ /2002	31.0	25.0–31.0	BBLAQ

Table C52. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, Local CU—local confining unit, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
78-GW61	336184	2499555	24.4	6/ /2002	29.0	24.0–29.0	BBLAQ
78-GW62	335934	2498649	25.8	6/ /2002	30.0	25.0–30.0	BBLAQ
78-GW63	336394	2498200	28.2	6/ /2002	29.0	24.0–29.0	BBLAQ
78-GW64	336857	2497671	27.1	6/ /2002	28.0	23.0–28.0	BBLAQ
78-GW65	336309	2498856	28.1	6/ /2002	32.0	27.0–32.0	BBLAQ
78-GW66	336559	2498989	27.5	6/ /2002	29.5	24.5–29.5	BBLAQ
78-GW67	336742	2498540	29.5	6/ /2002	32.5	27.0–32.5	BBLAQ
78-GW68	337253	2498035	28.2	6/ /2002	28.0	23.0–28.0	BBLAQ
78-GW69	341165	2502749	[3]29	6/ /2002	N/A	N/A	BBLAQ(?)
78-GW70	341161	2502726	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW71	341120	2502710	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW72	341149	2502672	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW73	337881	2499631	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW74	337901	2499655	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW75-1	337927	2499686	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW75-2	337926	2499685	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW76	337974	2499708	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW77	337927	2499637	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-GW78	337953	2499672	[3]29	1/ /2003	N/A	N/A	BBLAQ(?)
78-N-TW01	340513	2502175	[3]32	7/24/1997	22.0	2.0–22.0	BBUAQ, BBUCU, BBLAQ
78-N-TW02	340498	2502328	[3]30	7/25/1997	24.2	4.5–24.2	BBUAQ, BBUCU, BBLAQ
78-N-TW03	340659	2502146	[3]31	7/25/1997	26.0	6.0–26.0	BBUAQ, BBUCU, BBLAQ
78-N-TW04	340698	2502367	[3]32	7/26/1997	27.0	7.0–27.0	BBUAQ, BBUCU, BBLAQ
78-N-TW05	340886	2502373	[3]31	7/26/1997	25.0	5.0–25.0	BBUAQ, BBUCU, BBLAQ
78-N-TW06	340601	2502614	[3]30	7/24/1997	24.0	4.0–24.0	BBUAQ, BBUCU, BBLAQ
78-N-TW07	340785	2502515	[3]30	7/26/1997	24.5	4.5–24.5	BBUAQ, BBUCU, BBLAQ
78-N-TW08	340978	2502779	[3]29	7/25/1997	24.5	4.5–24.5	BBUAQ, BBUCU, BBLAQ
78-N-TW09	340830	2502731	[3]29	7/25/1997	24.0	4.0–24.0	BBUAQ, BBUCU, BBLAQ
78-N-TW10	341320	2502997	[3]30	7/25/1997	23.0	3.0–23.0	BBUAQ, BBUCU, BBLAQ
78-N-TW11	340900	2503075	[3]30	7/25/1997	29.0	9.0–29.0	BBUAQ, BBUCU, BBLAQ
78-N-TW12	340646	2502383	[3]31	2/5/1998	16.0	6.0–16.0	BBUAQ

Table C52. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, Local CU—local confining unit, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
78-N-TW13	341083	2502740	[3]29	2/6/1998	14.0	4.0 – 14.0	BBUAQ
78-PZ01	337933	2499704	[3]28	6/ /2002	N/A	N/A	N/A
78-PZ02	337923	2499685	[3]28	6/ /2002	N/A	N/A	N/A
78-PZ03	337925	2499742	[3]28	6/ /2002	N/A	N/A	N/A
78-PZ04	337904	2499761	[3]27	6/ /2002	N/A	N/A	N/A
78-PZ05	337982	2499698	[3]28	6/ /2002	N/A	N/A	N/A
78-PZ06	338249	2499071	[3]27	6/ /2002	N/A	N/A	N/A
78-PZ07	337220	2498928	[3]25	6/ /2002	N/A	N/A	N/A
78-PZ08	337190	2498924	[3]26	6/ /2002	N/A	N/A	N/A
78-PZ09	337262	2498918	[3]25	6/ /2002	N/A	N/A	N/A
78-PZ10	337283	2498901	[3]25	6/ /2002	N/A	N/A	N/A
78-PZ11	337239	2498958	[3]25	6/ /2002	N/A	N/A	N/A
78-PZ12	337234	2498988	[3]25	6/ /2002	N/A	N/A	N/A
78-RW-01N	340144	2502600	[3]29	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-02N	340325	2502410	[3]29	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-03N	340609	2502101	[3]31	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-04N	340795	2501992	[3]29	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-10N	340676	2502626	[3]29	Before 7/ /1995	35.0	15.0 – 35.0	BBLAQ
78-RW-11N	341178	2502708	[3]32	1995(?)	35.0	15.0 – 35.0	BBLAQ
78-RW-12N	340724	2502465	[3]31	1995(?)	N/A	N/A	N/A
78-RW-05S	336911	2499403	[3]26	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-06S	336976	2499119	[3]25	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-07S	337243	2498933	[3]25	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-08S	337587	2498662	[3]25	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-09S	337849	2498402	[3]26	1994	35.0	15.0 – 35.0	BBLAQ
78-RW-13S	337434	2499262	[3]29	Before 7/ /2000	N/A	N/A	BBLAQ(?)
78-RW-14S	337649	2499663	[3]28	1998	N/A	N/A	BBLAQ(?)
78-RW-15S	337945	2499729	[3]28	1998	N/A	N/A	BBLAQ(?)
78-S-TW01	337215	2499307	[3]29	7/23/1997	23.0	3.0 – 23.0	BBUAQ, BBUCU, BBLAQ
78-S-TW02	337397	2499260	[3]29	7/23/1997	23.0	3.0 – 23.0	BBUAQ, BBUCU, BBLAQ
78-S-TW03	337994	2498469	[3]27	7/24/1997	24.5	4.5 – 24.5	BBUAQ, BBUCU, BBLAQ
78-S-TW04	338371	2498595	[3]26	7/24/1997	24.5	4.5 – 24.5	BBUAQ, BBUCU, BBLAQ
78-S-TW05	337594	2499598	[3]28	7/24/1997	24.5	4.5 – 24.5	BBUAQ, BBUCU, BBLAQ
78-S-TW06	337767	2499355	[3]29	7/22/1997	23.0	3.0 – 23.0	BBUAQ, BBUCU, BBLAQ

Table C52. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, Local CU—local confining unit, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
78-S-TW07	337806	2499550	[3]29	7/23/1997	27.0	7.0 – 27.0	BBUAQ, BBUCU, BBLAQ
78-S-TW08	337758	2499790	[3]28	7/22/1997	28.0	8.0 – 28.0	BBUAQ, BBUCU, BBLAQ
78-S-TW09	338001	2499461	[3]29	7/23/1997	25.5	5.5 – 25.5	BBUAQ, BBUCU, BBLAQ
78-S-TW10	338246	2499721	[3]28	7/23/1997	27.0	7.0 – 27.0	BBUAQ, BBUCU, BBLAQ
78-S-TW11	337977	2499927	[3]27	7/24/1997	30.0	10.0 – 30.0	BBUAQ, BBUCU, BBLAQ
78-S-TW12	338090	2499832	[3]27	7/23/1997	29.0	9.0 – 29.0	BBUAQ, BBUCU, BBLAQ
78-S-TW13	337389	2499250	[3]27	2/5/1998	12.5	2.5 – 12.5	BBUAQ

[1] See Figure C14, C15, or C16 for location. Locations of wells TW01–TW13 not shown

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data sources:

CERCLA Administrative Record files #258, #1271, #1503, #1516, #1777, #1977, #2304, #2608A, #3271, #3272, #3273, #3409, #3453

Baker Environmental, Inc. 1993p, 1994f, 1996j, 1998j,k

Baker Environmental, Inc. and CH2M Hill, Inc. 2000a, 2002a

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc., 2000a, 2001a

Engineering and Environment, Inc. and Michael Baker, Jr., Inc. 2004a

Environmental Science and Engineering, Inc. 1988a, 1992a

Michael Baker, Jr., Inc. and CH2M Hill Federal Group, Ltd. 2003

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-Bldg900_UST01	7/23/2002	NA	NA	NA	NA	NA	NA	NA
78-Bldg900_UST02	7/23/2002	NA	NA	NA	NA	NA	NA	NA
78-Bldg900_UST03	7/23/2002	NA	NA	NA	NA	NA	NA	NA
78-Bldg900_UST04	7/23/2002	NA	NA	NA	NA	2.0J	NA	NA
78-Bldg900_UST05	7/23/2002	NA	NA	NA	NA	NA	NA	NA
78-Bldg1611_UG1A	7/23/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-GW01	1/9/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/8/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/16/1991	<5.0	91	<5.0	NA	NA	73	<10
	12/9/1993	NA	62	ND	NA	NA	27	ND
	7/9/1995	<0.50	40.8	<0.50	<0.50	NA	NA	<0.50
	10/25/1995	<0.50	34.9	<0.50	<0.50	NA	NA	<0.50
	1/18/1996	<1.0	44.1	<1.0	<1.0	NA	NA	<1.0
	4/11/1996	<0.50	37	<0.50	<0.50	<0.50	NA	<0.50
	7/17/1996	<0.50	NA	0.50	NA	NA	18	<0.50
	10/9/1996	<2.0	21	<0.50	NA	NA	5	<0.50
	2/4/1997	<0.50	12	<0.50	NA	NA	3	<0.50
	4/30/1997	<0.50	18	<0.50	NA	NA	4	<0.50
	8/11/1997	<0.50	21	<0.50	NA	NA	10	<0.50
	2/6/1998	<5.0	14	<5.0	NA	NA	3.9J	<10
	7/27/1998	<5.0	35	<5.0	NA	NA	7.9	<10
	1/19/1999	<5.0	7.0	<5.0	<5.0	4.0J	NA	<5.0
	7/27/1999	<5.0	5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/9/2000	<5.0	11	<5.0	<5.0	4.0J	4.0J	1.0J
	7/17/2000	<5.0	6.0	<5.0	<5.0	5.0	5.0	<2.0
	1/9/2001	<5.0	17	<5.0	<5.0	3.0J	3.0J	<2.0
	5/17/2001	<5.0	25	<5.0	<5.0	6.0	6.0	<2.0
	10/10/2001	<5.0	27	<5.0	<5.0	8.0	8.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	21	<5.0	<5.0	7.0J	7.0J	<2.0
	1/27/2003	<5.0	23	<5.0	<5.0	6.0	6.0	<2.0
	1/25/2004	<5.0	15	0.20J	0.40J	6.0	6.0J	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW02	1/9/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/8/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/16/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	8/8/1997	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0
78-GW03	1/9/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/8/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/16/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	8/9/1997	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0
78-GW04-1	1/9/1987	<3.0	3.4	<2.8	1.9	NA	NA	<1.0
	3/8/1987	<3.0	2.2	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	7.7	<2.8	4.4	NA	NA	<1.0
	1/11/1991	<5.0	0.9J	<5.0	NA	NA	<5.0	<10
	5/23/1993	ND	2.0J	ND	ND	ND	NA	ND
	7/9/1995	<0.50	4.0	<0.50	<0.50	NA	NA	<0.50
	10/25/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	8.0	<0.50	<0.50	NA	NA	<0.50
	4/12/1996	<0.50	6.7	0.7	<0.50	NA	NA	2.0
	7/15/1996	<0.50	2.0	<0.50	NA	NA	NA	<0.50
	10/6/1996	<2.0	4.0	<0.50	NA	NA	0.6	<0.50
	2/2/1997	<0.50	8.0	<0.50	NA	NA	2.0	<0.50
	4/27/1997	<0.50	7.0	<0.50	NA	NA	2.0	<0.50
	8/9/1997	<0.50	6.0	<0.50	NA	NA	1.0	<0.50
	2/8/1998	<5.0	<5.0	2.9J	NA	NA	<5.0	<10
	7/25/1998	<5.0	3.0J	<5.0	NA	NA	0.92J	<10
	1/17/1999	<5.0	6.0	<5.0	<5.0	3.0J	NA	<5.0
	7/18/1999	<5.0	4.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/17/2000	<5.0	11	<5.0	<5.0	6.0	6.0	<2.0
	7/17/2000	<5.0	4.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2001	<5.0	9.0	<5.0	<5.0	3.0J	3.0J	<2.0
	5/17/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/10/2001	<5.0	3.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	5.0J	0.4J	4.0J	4.0J	1.0J	<2.0
	1/25/2004	<5.0	100	2.0J	<5.0	4.0J	4.0J	<2.0
78-GW04-2	1/11/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/23/1993	ND	ND	ND	ND	ND	NA	ND
78-GW04-3	5/24/1993	ND	ND	ND	ND	ND	NA	ND

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW05	1/12/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/8/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/10/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/22/1993	ND	ND	ND	ND	ND	NA	ND
	7/9/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/25/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/11/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/17/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/6/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	1/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/18/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/16/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW06	1/12/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/8/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/10/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
78-GW07	1/12/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/9/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
78-GW08	1/13/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/27/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/8/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/22/1993	ND	ND	ND	ND	ND	NA	ND
	7/9/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/25/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/11/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/14/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/8/1996	<0.50	<0.50	<0.50	NA	NA	NA	<0.50
	2/4/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
	2/8/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/25/1998	<5.0	57	<5.0	NA	NA	5.7	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/18/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/16/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW09-1 (old)	1/14/1987	<300	5,000	<280	740	NA	NA	<100
	3/9/1987	<750	6,100	<700	<400	NA	NA	<250
	5/28/1987	<200	<100	<280	2,700	NA	NA	<1.0
	1/17/1991	< 5.0	14,000	<5.0	NA	NA	1,200	<10
78-GW09-1 (new)	12/9/1993	NA	2,100D	280D	NA	NA	2,400D	ND
	7/10/1995	<0.50	910	<0.50	6.8	NA	NA	<0.50
	10/25/1995	<10	1,100	101	<10	NA	NA	<10
	1/18/1996	<8.3	946	128	13.3	NA	NA	<8.3
	4/11/1996	<0.50	320	120	7.1	NA	NA	<0.50
	7/11/1996	<0.50	NA	NA	NA	NA	NA	<0.50
	10/4/1996	<0.50	490	36	NA	NA	170	<0.50
	2/2/1997	<5.0	640	78	NA	NA	220	<5.0
	4/27/1997	<5.0	580	140	NA	NA	300	<5.0
	8/9/1997	<5.0	920	91	NA	NA	570	<5.0
	2/8/1998	<10	360	16	NA	NA	91	<20
	7/25/1998	<5.0	0.74J	<5.0	NA	NA	5.7	<10
	1/17/1999	<5.0	130	52	<5.0	38	NA	<5.0
	7/17/1999	<5.0	240D	40	<5.0	71	71	<2.0
	1/17/2000	<5.0	200	33	<5.0	46	46	<2.0
	7/17/2000	<5.0	180D	28	<5.0	37	37	<2.0
	1/12/2001	<5.0	140	12	<5.0	18	18	<2.0
	5/17/2001	<5.0	170	18	<5.0	23	23	<2.0
	10/11/2001	<5.0	140	16	<5.0	22	22	<2.0
	1/11/2002	<5.0	160	22	<5.0	18	18	<2.0
	7/24/2002	<5.0	160	8.0	<5.0	17J	17J	<2.0
	1/25/2003	<5.0	120	5.0J	<5.0	8.0	8.0	<2.0
	1/27/2004	<5.0	0.70J	<5.0	<5.0	<5.0	<10	0.90J

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW09-2	8/6/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/8/1991	<5.0	<5.0	<5.0	NA	NA	11	<10
	5/23/1993	ND	ND	ND	ND	ND	NA	ND
	7/12/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	11/6/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/20/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/11/1996	<2.0	<0.50	<0.50	NA	NA	2.0	<0.50
	10/4/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	NA	NA	4.0	<0.50
	4/27/1997	<0.50	<0.50	<0.50	NA	NA	3.0	<0.50
	8/9/1997	<0.50	<0.50	<0.50	NA	NA	5.0	<0.50
	2/8/1998	<5.0	<5.0	<5.0	NA	NA	4.3J	<10
	7/25/1998	<5.0	<5.0	<5.0	NA	NA	1.5J	<10
	1/18/1999	<5.0	<5.0	<5.0	<5.0	10	NA	<5.0
78-GW09-3	8/6/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	5/22/1993	ND	ND	ND	ND	ND	NA	ND
	7/12/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	11/5/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/21/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/15/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/4/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/27/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/8/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/25/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/18/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/19/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW10	1/14/1987	<3.0	7.4	<2.8	<1.6	NA	NA	<1.0
	3/9/1987	<3.0	8.6	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/9/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/9/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/25/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/12/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/16/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/5/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/3/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/28/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/7/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/25/1998	<5.0	42B	<5.0	NA	NA	5.4	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/15/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW11	1/14/1987	<3.0	49	<2.8	12	NA	NA	<1.0
	3/9/1987	<3.0	34	<2.8	7.2	NA	NA	<1.0
	5/28/1987	<3.0	24	<2.8	6.0	NA	NA	<1.0
	1/9/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/10/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/25/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/12/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/15/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/8/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/5/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW11—Continued	2/5/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/26/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW12	1/14/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1987	3.6	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/9/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/23/1993	ND	ND	ND	ND	ND	NA	ND
78-GW13	1/14/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/12/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
78-GW14	1/14/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/10/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/23/1993	ND	ND	ND	ND	ND	NA	ND
	7/10/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/26/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/11/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/12/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/5/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/27/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/8/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/26/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/16/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW15	1/15/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/9/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/8/1991	<5.0	4.0J	<5.0	NA	NA	7.0	<10
	5/24/1993	1.0	1.0	ND	ND	ND	NA	ND
	7/14/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/7/1996	<2.0	0.90	<0.50	NA	NA	<0.50	<0.50
	2/5/1997	<0.50	1.0	<0.50	NA	NA	<0.50	<0.50
	4/30/1997	<0.50	1.0	<0.50	NA	NA	<0.50	<0.50
	8/9/1997	<0.50	1.0	<0.50	NA	NA	<0.50	<0.50
	2/6/1998	<5.0	1.1J	<5.0	NA	NA	<5.0	<10
	7/26/1998	<5.0	0.89J	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/20/2001	<5.0	8.0	<5.0	<5.0	88	88	1.0J
78-GW16	1/15/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/10/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/9/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
78-GW17-1	1/15/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/8/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/7/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/24/1993	ND	ND	ND	ND	ND	NA	ND
	7/12/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/26/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/10/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/15/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/7/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/9/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/26/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW17-2	8/5/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/8/1991	<5.0	<5.0	<5.0	NA	NA	1.0J	<10
	5/23/1993	ND	ND	ND	ND	ND	NA	ND
78-GW17-3	8/5/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
78-GW18	1/15/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	3/10/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	12/9/1993	NA	ND	ND	NA	NA	ND	ND
78-GW19	1/16/1987	<3.0	6.0	<2.8	2.5	NA	NA	<1.0
	3/10/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/11/1991	2.0J	2.0J	<5.0	NA	NA	0.8J	<10
	5/23/1993	1.0	1.0	ND	ND	ND	NA	ND
	7/10/1995	<0.50	1.5	<0.50	<0.50	NA	NA	<0.50
	10/26/1995	0.80	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	0.70	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/10/1996	0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/16/1996	0.80	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/5/1996	0.80	<0.50	<0.50	NA	NA	<0.50	<0.50
78-GW20	1/16/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/10/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/12/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
78-GW21	1/16/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/10/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	5/28/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/17/1991	<5.0	3.0J	<5.0	NA	NA	<5.0	<10
	5/21/1993	ND	2.0	ND	ND	ND	NA	ND
	7/9/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/25/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/10/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/17/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/3/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/3/1997	<5.0	<5.0	<0.50	NA	NA	<5.0	<10
	4/28/1997	<5.0	<5.0	<0.50	NA	NA	<5.0	<10
	8/10/1997	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	2/5/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/28/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW21—Continued	1/17/1999	0.9J	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
78-GW22	1/19/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/11/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	5/29/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/18/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
78-GW22A	7/9/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/25/1995	<25	<25	<25	<25	NA	NA	<25
	1/19/1996	<25	<25	<25	<25	NA	NA	<25
	4/9/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/17/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/4/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/5/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/28/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	7.0	<0.50
	2/5/1998	0.95J	<5.0	<5.0	NA	NA	<5.0	<10
	7/27/1998	<0.50	<0.50	<0.50	NA	NA	<5.0	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0	5.0	5.0	<2.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/23/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW23	1/19/1987	<30	830	<28	830	NA	NA	<10
	3/11/1987	<200	13,000	<280	6,100	NA	NA	<100
	5/29/1987	<200	4,300	<280	7,100	NA	NA	<100
	1/18/1991	<5.0	3,700	<5.0	NA	NA	8,900	<10
	5/23/1993	ND	440J	ND	190J	14,000J	NA	ND
	7/12/1995	<0.50	39.4	<0.50	248	NA	NA	54
	10/25/1995	<1.3	53.9	4.2	18.7	NA	NA	80.9
	1/17/1996	<25	72	219	<25	NA	NA	180
	4/9/1996	<50	<50	<50	130	NA	NA	360
	7/14/1996	<2.0	NA	5.0	NA	NA	NA	NA

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW23—Continued	10/4/1996	<2.0	40	2.0	NA	NA	6,200	200
	2/5/1997	<5.0	57	4.0	NA	NA	7,900	360
	4/28/1997	<50	<50	<50	NA	NA	9,500	340
	8/10/1997	<0.50	62	4	NA	NA	10,000	590
	2/5/1998	<620	<620	<620	NA	NA	11,000	<560
	7/26/1998	<25	430J	<25	NA	NA	8,400D	61
	1/17/1999	<5.0	17	<5.0	140	7,000	NA	360J
	7/17/1999	<5.0	21	<5.0	120	6,200D	6,200D	380D
	1/17/2000	<5.0	21	<5.0	140	8,100D	8,300D	490D
	7/17/2000	<5.0	13	<5.0	99	7,900D	8,100D	470D
	10/19/2000	<5.0	16	<5.0	130	9,400D	9,600D	480D
	1/11/2001	<5.0	14	<5.0	92	4,500D	2,800	190
	7/12/2001	<5.0	<5.0	6.0	55	5,000	5,000	500
	1/24/2002	<5.0	<12	6.0	62	2,100	2,100	360
	7/22/2002	<5.0	8.0	<5.0	57	1,500	1,600	190
	1/25/2003	<5.0	8.0	0.40J	67	1,600	1,700	190
	1/23/2004	<5.0	5.0	<5.0	92	2,100D	2,200D	310
78-GW24-1	1/19/1987	<300	57	<280	6,400	NA	NA	190
	3/11/1987	<200	<100	<280	4,300	NA	NA	<100
	5/29/1987	<200	<100	<280	4,000	NA	NA	250
	1/8/1991	<5.0	180	65	NA	NA	42,000D	<25,000
	5/24/1993	ND	ND	7.0	140	3,400	NA	97
	7/9/1995	<0.50	6.4	<0.50	4.9	NA	NA	<0.50
	10/25/1995	<1.3	21.1	<1.3	12.8	NA	NA	11.1
	1/21/1996	<1.3	19.2	<1.3	8.5	NA	NA	5.7
	4/9/1996	<0.50	34	<0.50	8	NA	NA	3.6
	7/16/1996	<0.50	NA	<0.50	NA	NA	NA	10
	10/3/1996	<2.0	20	<0.50	NA	NA	120	6.0
	2/4/1997	<0.50	19	<0.50	NA	NA	120	<0.50
	4/29/1997	<0.50	17	<0.50	NA	NA	130	4.0
	8/10/1997	<0.50	28	0.7	NA	NA	220	7.0
	2/7/1998	<10	12	<10	NA	NA	94	<20
	7/25/1998	<5.0	12D	<5.0	NA	NA	330D	5.7JD
	1/16/1999	<5.0	14	<5.0	18	360	NA	25
	7/17/1999	<5.0	13	<5.0	<5.0	810D	830D	31
	1/17/2000	<5.0	10	<5.0	10	190	200	8.0
	7/17/2000	<5.0	14	<5.0	13	260D	260D	11.0
	10/19/2000	<5.0	16	<5.0	14	340D	350D	10.0
	1/11/2001	<5.0	15	<5.0	8.0	150	160	7.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW24-1—Continued	7/12/2001	<5.0	<5.0	20	10	750	780	<2.0
	1/10/2002	<5.0	26	<5.0	18	350	360	12
	7/22/2002	<5.0	20	1.0J	16	340	320	5.0
	1/28/2003	<5.0	14	<5.0	9.0	200	200	3.0
	1/28/2003	<1.0	8.0J	<1.0	5.0J	120	120J	1.0J
	1/23/2004	<5.0	24	0.40J	9.0	150	150	4.0
	1/23/2004	<1.0	24	0.50J	8.0	140	150	4.0
	1/23/2004	<1.0	25	0.30J	8.0	140	150	4.0
78-GW24-2	8/6/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/8/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/24/1993	ND	ND	ND	ND	<5.0	NA	ND
	7/12/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	11/5/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/21/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/16/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/17/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/3/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/4/1997	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/7/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/25/1998	<5.0	0.72JB	<5.0	NA	NA	<5.0	<10
	7/25/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/16/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/22/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW24-3	8/6/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	5/24/1993	ND	ND	ND	1.0	3.0	NA	ND
	7/12/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	11/5/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/21/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/16/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW24-3—Continued	7/15/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/4/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/4/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/30/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/7/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/16/1999	9.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/22/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW25	1/19/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/11/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/29/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/18/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/9/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/24/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/9/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/16/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/3/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/5/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	4/28/1997	<0.50	<0.50	<0.50	NA	NA	0.7	<0.50
	8/10/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/5/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/28/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/16/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/23/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW26	1/19/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	3/12/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	5/29/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	12/9/1993	NA	ND	ND	NA	NA	ND	ND
78-GW29	1/20/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	3/12/1987	<3.0	<3.0	<2.8	<1.6	NA	NA	<1.0
	5/29/1987	<3.0	<1.0	<2.8	<1.6	NA	NA	<1.0
	1/19/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
78-GW30-2	1/10/1991	<5.0	<5.0	<5.0	NA	NA	12	12
	12/9/1993	NA	ND	ND	NA	NA	12	33
78-GW30-3	12/9/1993	NA	ND	ND	NA	NA	ND	ND
78-GW31-2	1/17/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/24/1993	ND	3.0	ND	ND	<5.0	NA	ND
78-GW31-3	5/24/1993	ND	ND	ND	ND	1.0J	NA	ND
	7/12/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	11/6/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/20/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/11/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/8/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
78-GW32-2	1/12/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	5/23/1993	ND	ND	ND	ND		NA	ND
78-GW32-3	5/23/1993	ND	6.0	ND	ND	ND	NA	ND
78-GW35	6/3/1993	ND	ND	ND	ND	ND	NA	ND
78-GW37	6/3/1993	ND	ND	ND	ND	ND	NA	ND
78-GW38	6/3/1993	ND	ND	ND	ND	ND	NA	ND
78-GW39	6/3/1993	1.0	ND	ND	ND	ND	NA	ND
	7/18/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/9/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/5/1997	0.7	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/30/1997	0.8	<0.50	<0.50	NA	NA	<0.50	<0.50
	8/10/1997	0.7	<0.50	<0.50	NA	NA	<0.50	<0.50
	2/8/1998	1.4J	<5.0	<5.0	NA	NA	<5.0	<10
	2/26/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW39—Continued	1/9/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/21/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/23/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2003	0.60J	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/26/2004	0.70J	0.30J	<5.0	<5.0	<5.0	<10	<2.0
78-GW40	2/9/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/26/1998	<5.0	25	<5.0	NA	NA	2.1J	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/22/2002	<5.0	<5.0	<5.0	<5.0	1.0J	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	1.0J	<5.0	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW41	2/9/1998	<5.0	<5.0	<5.0	NA	NA	3.5J	<10
	7/26/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	1/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0	5.0J	5.0J	<2.0
	1/28/2002	<5.0	<5.0	<5.0	<5.0	6.0	6.0	4.0
	1/25/2003	<5.0	1.0J	<5.0	<5.0	6.0	6.0	7.0
	1/23/2004	<5.0	0.7J	<5.0	0.20J	9.0	9.0J	0.5J
78-GW42	2/9/1998	<5.0	9.7	0.81J	NA	NA	30	25
	7/26/1998	<5.0	7.8	<5.0	NA	NA	7.7	2.1J
	1/17/1999	<5.0	<5.0	17	<5.0	27	NA	6.0
	7/17/1999	<5.0	33	<5.0	<5.0	59	59	<2.0
	1/17/2000	<5.0	60	4.0J	<5.0	91	91	<2.0
	1/12/2001	<5.0	280D	11	<5.0	490D	380	7.0
	5/18/2001	<5.0	480D	18	<5.0	960D	960D	12
	10/9/2001	<5.0	940	20	<5.0	1,900	1,900	18
	1/24/2002	<5.0	240	25	<5.0	520	530	21
	7/23/2002	<5.0	320	22	1.0J	830	830	30
	1/25/2003	<5.0	280J	20J	2.0J	710J	710J	37J
	1/25/2004	<5.0	250D	34	4.0J	910D	910D	120

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW43	10/19/2000	<5.0	<5.0	<5.0	8.0	65	73	270D
	1/11/2001	<5.0	<5.0	<5.0	6.0	46	52	210D
	7/12/2001	<5.0	<5.0	<5.0	7.0	53	60	180
	1/10/2002	<5.0	<5.0	<5.0	5.0	24	29	180
	7/23/2002	<5.0	<5.0	<5.0	6.0	52	58	150
	1/28/2003	<5.0	2.0J	<5.0	8.0	78	85	190
	1/28/2003	<1.0	<1.0	<1.0	7.0	100	110	180
	1/23/2004	<5.0	0.70J	<5.0	6.0	110	120	120
	1/23/2004	<1.0	0.80J	<1.0	7.0	120	130	180
78-GW44	10/19/2000	<5.0	<5.0	<5.0	26	200	230	5,000D
	1/11/2001	<5.0	<5.0	<5.0	26	520D	320	6,700D
	7/12/2001	<5.0	<5.0	<5.0	36	2,700	2,800	5,800
	1/10/2002	<5.0	<5.0	<5.0	40	890	930	2,300
	7/22/2002	<5.0	<5.0	0.5J	21	620	620	1,900
	1/28/2003	<5.0	<5.0	<5.0	44	1,000	1,100	2,400
	1/28/2003	<1.0	<1.0	0.9J	34	980	1,000	1,600
	1/23/2004	<5.0	<5.0	0.20J	16J	170D	230J	2,400D
	1/23/2004	<1.0	<1.0	<1.0	18J	170	240J	1,900
78-GW45	10/19/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/23/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW46	10/19/2000	<5.0	<5.0	<5.0	<5.0	3.0J	3.0J	<2.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0	3.0J	3.0J	<2.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0	9.0	9.0	<2.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0	14	14	1.0J
	7/23/2002	<5.0	<5.0	<5.0	<5.0	27	27	2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	17	17	1.0J
	1/23/2004	<5.0	0.60J	<5.0	0.50J	17	18	4.0
78-GW47	10/19/2000	<5.0	240D	<5.0	6.0	260D	270D	4.0
	1/11/2001	<5.0	44	<5.0	<5.0	61	61	1.0J
	7/12/2001	<5.0	45	45	<5.0	98	100	2.0J
	1/24/2002	<5.0	<10	<5.0	<5.0	7.0	7.0	<2.0
	7/23/2002	<5.0	<5.0	<5.0	<5.0	1.0J	1.0J	<2.0
	1/25/2003	<5.0	3.0J	<5.0	<5.0	1.0J	<5.0	<2.0
	1/23/2004	<5.0	6.0	<5.0	<5.0	<5.0	<10	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW48	10/19/2000	<5.0	6.0	<5.0	<5.0	22	22	52
	1/11/2001	<5.0	<5.0	<5.0	<5.0	18	19	43
	7/12/2001	<5.0	4.0J	<5.0	<5.0	17	19	37
	1/24/2002	<5.0	<5.0	<5.0	<5.0	15	15	35
	7/23/2002	<5.0	<5.0	<5.0	0.80J	16	16	24
	1/25/2003	<5.0	0.80J	<5.0	1.0J	16	17	20
	1/23/2004	<5.0	0.30J	0.30J	3.0J	41	44	67
78-GW49	5/19/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/9/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/27/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW50	5/18/2001	<5.0	<5.0	<5.0	<5.0	7.0	7.0	<2.0
	10/15/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	4.0J	<2.0
	7/23/2002	<5.0	<5.0	<5.0	<5.0	6.0	6.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	2.0J	2.0J	<2.0
	1/27/2004	<5.0	0.20J	<5.0	<5.0	2.0J	3.0J	0.40J
78-GW51	5/20/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	0.50J	<5.0	<5.0	<2.0
	1/25/2004	<5.0	0.40J	<5.0	<5.0	<5.0	<10	<2.0
78-GW52	5/18/2001	<5.0	8,300D	8.0	75	1,700D	1,800D	7.0
	10/9/2001	6.0	8,000	8.0	17	1,800	1,800	6.0
	1/11/2002	<5.0	3,000	12	<5.0	950	950	10
	7/24/2002	<5.0	2,900	6.0	16	840	850	<2.0
	1/25/2003	1.0J	2,700	7.0	23	850	870	4.0
	1/27/2004	0.50J	3,100D	9.0	23	690D	710D	<2.0
78-GW53	5/20/2001	<5.0	9.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/10/2001	<5.0	13	<5.0	<5.0	<5.0	<5.0	<2.0
	1/11/2002	<5.0	23	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	27	<5.0	<5.0	3.0J	3.0J	<2.0
	1/26/2004	<5.0	12	<5.0	<5.0	1.0J	1.0J	<2.0
78-GW54	5/20/2001	<5.0	9.0	<5.0	<5.0	11	12	<2.0
	10/15/2001	<5.0	10	<5.0	<5.0	11	11	<2.0
	1/11/2002	<5.0	9.0	<5.0	<5.0	10	10	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW54—Continued	7/24/2002	<5.0	8.0	<5.0	<5.0	8.0	8.0	<2.0
	1/26/2003	<5.0	5.0	<5.0	<5.0	7.0	7.0	<2.0
	1/25/2004	<5.0	6.0	0.30J	0.50J	6.0	7.0J	0.50J
78-GW55	5/20/2001	<5.0	5.0J	<5.0	<5.0	11	12	<2.0
	10/15/2001	<5.0	9.0	<5.0	<5.0	12	12	<2.0
	1/11/2002	<5.0	9.0	<5.0	<5.0	11	11	<2.0
	7/24/2002	<5.0	11	<5.0	<5.0	10	10	<2.0
	1/26/2003	<5.0	7.0	<5.0	<5.0	8.0	8.0	<2.0
	1/25/2004	<5.0	4.0J	<5.0	0.50J	7.0	8.0J	0.50J
78-GW56	5/18/2001	<5.0	8.0	<5.0	<5.0	3.0J	3.0J	<2.0
	10/15/2001	<5.0	11	<5.0	<5.0	4.0J	4.0J	<2.0
	1/11/2002	<5.0	15	<5.0	<5.0	4.0J	4.0J	<2.0
	7/24/2002	<5.0	8.0	<5.0	<5.0	3.0J	3.0J	<2.0
	1/27/2003	<5.0	5.0J	<5.0	<5.0	3.0J	3.0J	<2.0
	1/26/2004	<5.0	16	<5.0	0.40J	4.0J	4.0J	0.20J
78-GW57	5/18/2001	<5.0	42	27	6.0	140	150	200
	10/10/2001	<5.0	60	42	5.0J	190	190	830
	1/11/2002	<5.0	68	49	6.0	170	170	200
	7/24/2002	<5.0	20	19	2.0J	120	120	200J
	1/27/2003	<5.0	12	18	2.0J	120	120	190
	1/25/2004	<5.0	11	18	3.0J	110	120	160D
78-GW58	5/18/2001	<50	<50	<50	<50	<50	<50	<20
	10/15/2001	<5.0	<5.0	<5.0	<5.0	5.0	5.0	<2.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0	4.0J	4.0J	<2.0
	7/23/2002	<5.0	<5.0	<5.0	<5.0	5.0J	5.0J	<2.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0	4.0J	4.0J	<2.0
	1/27/2004	<5.0	<5.0	<5.0	<5.0	3.0J	3.0J	<2.0
78-GW59	5/20/2001	<5.0	47	35	9.0	560D	570D	780D
	10/15/2001	<5.0	50	30	4.0J	200	200	360
	1/11/2002	<5.0	62	31	5.0	190	200	140
	7/24/2002	<5.0	90	11	3.0J	190	190	160
	1/25/2003	<5.0	81	12	3.0J	150	150	170
	1/25/2004	<5.0	22	18	4.0J	140	140	200D
78-GW60	7/25/2002	<5.0	1,800	2.0J	<5.0	14	14	<2.0
	1/28/2003	<5.0	3,100J	2.0J	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<1.0	2,800	<1.0	<1.0	18J	18J	<2.0
	1/26/2004	<5.0	4,900D	<5.0	<5.0	7.0	7.0J	<2.0
	1/26/2004	0.60J	5,100	<1.0	<1.0	<1.0	<2.0	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

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Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW61	7/25/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	1/25/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-GW62	7/25/2002	<5.0	1.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
78-GW63	7/25/2002	<5.0	0.8	<5.0	<5.0	3.0	3.0	<2.0
	1/26/2003	<5.0	<5.0	<5.0	<5.0	3.0J	3.0J	<2.0
	1/25/2004	<5.0	<5.0	<5.0	<5.0	1.0J	1.0J	<2.0
78-GW64	7/25/2002	<5.0	0.6J	<5.0	<5.0	0.6J	<5.0	<2.0
	1/26/2003	<5.0	<5.0	<5.0	<5.0	1.0J	<5.0	<2.0
	1/25/2004	<5.0	<5.0	<5.0	<5.0	4.0J	4.0J	0.30J
78-GW65	7/25/2002	<5.0	20	4.0J	2.0J	150	210	33
	1/25/2003	<5.0	23	3.0J	1.0J	190	190	26
	1/25/2004	<5.0	24	6.0	2.0J	190D	230	44
78-GW66	7/25/2002	<5.0	19	6.0	1.0J	120	120	55
	1/25/2003	<5.0	21	6.0	1.0J	130	130	61
	1/25/2004	<5.0	23	11	3.0J	150	150	97
78-GW67	7/25/2002	<5.0	8.0	0.40J	<5.0	49	49	1.0J
	1/26/2003	<5.0	8.0	0.30J	0.80J	49	50	0.90J
78-GW68	7/25/2002	<5.0	6.0	<5.0	2.0J	38	41	1.0J
	1/26/2003	<5.0	4.0J	<5.0	2.0J	31	33	0.80J
	1/25/2004	<5.0	2.0J	<5.0	1.0J	12	13	1.0J
78-GW69	1/29/2003	<1.0	<1.0	<1.0	7.0	82	88	610
	1/23/2004	<1.0	<1.0	<1.0	7.0J	68J	75J	560
78-GW70	1/29/2003	<1.0	<1.0	0.90J	24	530	550	1,200
	1/23/2004	<1.0	<1.0	0.50J	21J	230	340J	1,100
78-GW71	1/29/2003	<1.0	<1.0	0.60J	9.0	210	260	410
	1/23/2004	<1.0	<1.0	0.30J	6.0J	140J	150J	500
78-GW72	1/29/2003	<1.0	<1.0	0.80J	18	300	360	150
	1/23/2004	<1.0	2.0	1.0	18	400	420	210
78-GW73	1/30/2003	67	<1.0	<1.0	<1.0	5.0	5.0	<2.0
	1/27/2004	140	<1.0	<1.0	<1.0	15	15	<2.0
78-GW74	1/30/2003	39	3,000	<1.0	8.0	950	950	<2.0
	1/26/2004	4.0	500	<1.0	<1.0	190	190	<2.0
78-GW75-1	1/30/2003	1.0	1,600	<1.0	3.0	410	410	<2.0
	1/26/2004	<1.0	3,600	<1.0	41	3,400	3,400	<2.0
	1/26/2004	<1.0	3,800	<1.0	46	3,400	3,500	<2.0
78-GW75-2	1/30/2003	6.0	8,800	2.0	16	1,900	1,900	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

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Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-GW76	1/30/2003	<1.0	7,200	1.0	6.0	460	460	<2.0
	1/30/2003	1.0	8,000	1.0	7.0	390	390	<2.0
	1/26/2004	2.0	3,400	2.0	49.0	4,200	4,200	<2.0
78-GW77	1/30/2003	0.5J	410	2.0	<1.0	3.0	3.0	<2.0
	1/26/2004	<1.0	550	<1.0	<1.0	<1.0	<2.0	<2.0
78-GW78	1/30/2003	<1.0	<1.0	<1.0	<1.0	6.0	6.0	<2.0
	1/26/2004	<1.0	160J	<1.0	4.0J	480	480	<2.0
78-N-TW01	7/26/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-N-TW02	7/28/1997	<0.50	<0.50	<0.50	NA	NA	2.0	<0.50
78-N-TW03	7/26/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-N-TW04	7/26/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-N-TW05	7/26/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-N-TW06	7/25/1997	<0.50	0.8	<0.50	NA	NA	3.0	<0.50
78-N-TW07	7/26/1997	<0.50	<0.50	<0.50	NA	NA	9.0	15
78-N-TW08	7/25/1997	<0.50	20	<0.50	NA	NA	50	<0.50
78-N-TW09	7/25/1997	<0.50	8.0	<0.50	NA	NA	4.0	<0.50
78-N-TW10	7/26/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-N-TW11	7/26/1997	<0.50	13	<0.50	NA	NA	2.0	<0.50
78-N-TW12	2/8/1998	<10	<10	<10	NA	NA	<10	<20
78-N-TW13	2/6/1998	<5.0	<5.0	<5.0	NA	NA	4.0J	,10
78-RW01N	7/13/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/29/1995	<50	<50	<0.50	<50	NA	NA	<50
	1/18/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/10/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/17/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/6/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-RW02N	7/13/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/26/1995	<12.5	<12.5	<12.5	<12.5	NA	NA	<12.5
	1/18/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/10/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/10/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/4/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-RW03N	7/9/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/28/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	1/18/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/16/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/18/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/7/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-RW04N	7/13/1995	<0.50	0.6	<0.50	<0.50	NA	NA	<0.50
	10/27/1995	<25	<25	<25	<25	NA	NA	<25
	1/18/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/11/1996	<0.50	0.70	<0.50	<0.50	NA	NA	<0.50
	7/17/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
	10/7/1996	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-RW10N	7/13/1995	<0.50	55.9	<0.50	3.1	NA	NA	<0.50
	10/25/1995	<0.50	8.7	<0.50	<0.50	NA	NA	<0.50
	1/17/1996	<2.0	15.4	<2.0	<2.0	NA	NA	<2.0
	4/9/1996	<0.50	23	<0.50	<0.50	NA	NA	1.8
	1/17/2000	<5.0	140	<5.0	<5.0	190D	190D	21
	7/17/2000	<5.0	100	<5.0	<5.0	200	200	3.0
	1/11/2001	<5.0	64	<5.0	<5.0	96	96	<2.0
	7/12/2001	<5.0	140	<5.0	<5.0	640	650	8.0
	1/24/2002	<5.0	73B	<5.0	<5.0	110	110	5.0
	1/28/2003	<5.0	110	<5.0	2.0J	180	190	6.0
	1/23/2004	<5.0	72	0.40J	2.0J	130	130	<2.0
78-RW11N	7/13/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	192
	10/25/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	85.3
	1/17/1996	<0.50	1.3	3.3	1.5	NA	NA	488
	4/9/1996	<0.50	1.4	<0.50	12	NA	NA	1,300
	1/17/2000	<5.0	<5.0	<5.0	9.0	290D	290D	<2.0
	7/17/2000	<5.0	<5.0	<5.0	3.0J	160	160	190D
	1/11/2001	<5.0	<5.0	<5.0	5.0J	180	180	540D
	7/12/2001	<5.0	<5.0	<5.0	7.0	190	200	1,200
	1/24/2002	<5.0	<5.0	<5.0	3.0J	100	110	150
	7/24/2002	<5.0	<5.0	<5.0	2.0J	68J	69J	110
	1/28/2003	<5.0	0.60J	<5.0	9.0	180	220	440
	1/28/2003	<1.0	<1.0	0.30J	9.0	200	210	280
	1/23/2004	<5.0	<5.0	<5.0	0.70J	13	13	110
	1/23/2004	<1.0	<1.0	<1.0	0.70J	16	16	110
78-RW12N	1/17/2000	<5.0	6.0	<5.0	<5.0	10	10	<2.0
	7/17/2000	<5.0	430D	<5.0	14	1,200D	1,200D	16
	1/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2001	<5.0	1,100	<5.0	18	2,300	2,400	25
	1/24/2002	<5.0	80	<5.0	3.0J	140	140	4.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0	1.0J	1.0J	<2.0
	1/25/2003	<5.0	28	<5.0	<5.0	41	41	<2.0
	1/23/2004	<5.0	2.0J	<5.0	<5.0	2.0J	2.0J	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-RW05S	7/14/1995	<0.50	7.9	<0.50	1.4	NA	NA	<0.50
	10/26/1995	<0.50	9.1	<0.50	<0.50	NA	NA	<0.50
	1/19/1996	<0.50	18	<0.50	1.7	NA	NA	<0.50
	4/9/1996	<0.50	13	<0.50	<0.50	NA	NA	<0.50
	1/17/2000	<5.0	49	<5.0	<5.0	33	33	<2.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2001	<5.0	42	<5.0	<5.0	50	50	16
	5/20/2001	<5.0	120	<5.0	<5.0	120	130	45
	10/25/2001	<5.0	140	4.0J	<5.0	150	150	82
	1/28/2002	<5.0	36	4.0J	<5.0	48	48	17
78-RW06S	7/13/1995	<0.50	6.6	<0.50	1.2	NA	NA	<0.50
	10/26/1995	<0.50	17.2	<0.50	<0.50	NA	NA	<0.50
	1/19/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/9/1996	<0.50	74	<0.50	1.8	NA	NA	<0.50
	1/17/2000	<5.0	36	3.0J	<5.0	100	100	23
	7/17/2000	<5.0	<5.0	10	<5.0	77	77	<2.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/26/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2002	<5.0	<9.0	<5.0	<5.0	9.0	9.0	<2.0
	1/26/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-RW07S	7/13/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/29/1995	<0.50	7.9	<0.50	2.6	NA	NA	<0.50
	1/19/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/9/1996	<0.50	12	<0.50	5.1	NA	NA	<0.50
	1/17/2000	<5.0	7.0	<5.0	<5.0	7.0	7.0	<2.0
	7/17/2000	<5.0	5.0J	<5.0	<5.0	7.0	7.0	<2.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0	8.0	8.0	<2.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	10/26/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/24/2002	<5.0	<8.0	<5.0	<5.0	18	18	<2.0
	1/26/2003	<5.0	2.0J	<5.0	<5.0	3.0J	3.0J	<2.0
	1/25/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-RW08S	7/13/1995	<0.50	6.7	<0.50	4.8	NA	NA	1.3
	10/26/1995	<12.5	<12.5	<12.5	13.1	NA	NA	<12.5
	1/19/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/9/1996	<0.50	17	<0.50	6.8	NA	NA	<0.50
	1/17/2000	<5.0	6.0	<5.0	<5.0	6.0	6.0	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-RW08S—Continued	7/17/2000	<5.0	6.0	<5.0	20	20	<5.0	<2.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	5/20/2001	<5.0	5.0	<5.0	<5.0	3.0J	3.0J	<2.0
	10/26/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2002	<5.0	10	<5.0	<5.0	5.0J	5.0J	<2.0
	1/26/2003	<5.0	4.0J	<5.0	<5.0	2.0J	2.0J	<2.0
	1/25/2004	<5.0	0.2J	<5.0	<5.0	<5.0	<10	<2.0
78-RW09S	7/13/1995	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	10/28/1995	<0.50	2.2	<0.50	0.7	NA	NA	<0.50
	1/19/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	4/17/1996	<0.50	<0.50	<0.50	<0.50	NA	NA	<0.50
	7/18/1996	<0.50	<0.50	<0.50	NA	NA	2.0	<0.50
	10/7/1996	<2.0	<0.50	<0.50	NA	NA	<0.50	<0.50
	1/12/2001	<5.0	3.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	5/20/2001	<5.0	2.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	10/25/2001	<5.0	3.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/28/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/26/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/25/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
78-RW13S	1/18/2000	<5.0	68	3.0J	<5.0	42	42	2.0
	7/17/2000	<5.0	31	3.0J	<5.0	220D	220D	3.0
	1/12/2001	<5.0	88	10	2.0J	740D	590	28
	5/18/2001	<5.0	96	14	3.0J	780	780D	41
	10/25/2001	<5.0	130	16	3.0J	1,800	1,800	52
	1/24/2002	<5.0	120	12	4.0J	790	790	46
	1/27/2003	<5.0	94	7.0	3.0J	560	560	45
	1/25/2004	<5.0	31	6.0	1.0J	180D	180D	23
78-RW14S	1/9/2001	<5.0	<5.0	<5.0	<5.0	4.0J	4.0J	<2.0
	5/18/2001	<5.0	<5.0	<5.0	<5.0	3.0J	3.0J	<2.0
	10/25/2001	<5.0	8.0	<5.0	<5.0	22	22	<2.0
	1/24/2002	<5.0	<19	<5.0	<5.0	6.0	6.0	<2.0
	7/25/2002	<5.0	1.0J	<5.0	<5.0	4.0J	4.0J	0.40J
	1/27/2003	<5.0	<5.0	<5.0	<5.0	2.0J	2.0J	<2.0
	1/25/2004	0.40J	<5.0	<5.0	<5.0	2.0J	2.0J	<2.0

Table C53. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, constituent not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
78-RW15S	1/17/2000	<5.0	8,600D	<5.0	<5.0	600D	600D	<2.0
	7/17/2000	<5.0	91	<5.0	<5.0	83	83	<2.0
	1/12/2001	3.0J	3,900D	<5.0	<5.0	46.0	46.0	<2.0
	5/20/2001	4.0J	6,500D	<5.0	<5.0	82	82	<2.0
	10/25/2001	4.0J	2,600	<5.0	<5.0	490	490	<2.0
	1/24/2002	<5.0	1,000	<5.0	<5.0	360	390	<2.0
	7/24/2002	8.0	3,800	0.80J	22	1,300	1,300	<2.0
	1/28/2003	2.0J	3,700	2.0J	19	2,200	2,200	<2.0
	1/28/2003	<20	2,800	<20	16J	2,000	2,000	<40
	1/25/2004	0.50J	280D	<5.0	2.0J	420D	420D	<2.0
	1/26/2004	<1.0	280	0.60J	2.0	420	420	<2.0
78-S-TW01	7/24/1997	<0.50	34	6.0	NA	NA	99	45
78-S-TW02	7/24/1997	<0.50	15	0.8	NA	NA	63	28
78-S-TW03	7/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-S-TW04	7/25/1997	<0.50	6.0	<0.50	NA	NA	<0.50	<0.50
78-S-TW05	7/25/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-S-TW06	7/23/1997	<0.50	<0.50	8.0	NA	NA	20	<0.50
78-S-TW07	7/24/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-S-TW08	7/24/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-S-TW09	7/24/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-S-TW10	7/24/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-S-TW11	7/24/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-S-TW12	7/24/1997	<0.50	<0.50	<0.50	NA	NA	<0.50	<0.50
78-S-TW13	2/6/1998	<17	28	<17	NA	NA	370	220

[1] See Figure C14, C15, or C16 for location. Locations of wells TW01–TW13 not shown

Data sources:

CERCLA Administrative Record files #258, #522, #1517, #1777, #1778, #1779, #1780, #1977, #2304, #2321, #2338, #2598A, #2608A, #3272, #3273, #3409, #3453

Baker Environmental, Inc. 1994g, 1996i,j, 1997c,d, 1998j,k, 1999b,c

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000d

Baker Environmental, Inc. and CH2M Hill, Inc. 2000a, 2002a

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000a

Engineering and Environment, Inc. and Michael Baker, Jr., Inc. 2004a

Michael Baker, Jr., Inc. and CH2M Hill Federal Group, Ltd. 2003

Environmental Science and Engineering, Inc. 1988a, 1991

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-Bldg900_UST01	7/23/2002	0.30J	NA	NA	NA
78-Bldg900_UST02	7/23/2002	13	34	180	140
78-Bldg900_UST03	7/23/2002	0.20J	NA	NA	NA
78-Bldg900_UST04	7/23/2002	270	100	540	990
78-Bldg900_UST05	7/23/2002	1.0J	0.7J	NA	NA
78-Bldg1611_UG1A	7/23/1997	<0.50	<0.50	<0.50	<0.50
78-GW01	1/9/1987	43	100	12	62
	3/8/1987	3.9	12	<7.2	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/16/1991	<5.0	<5.0	<5.0	<5.0
	12/9/1993	ND	ND	NA	ND
	7/9/1995	<1.0	<1.0	<1.0	NA
	10/25/1995	<0.50	<0.50	<0.50	NA
	1/18/1996	<1.0	<1.0	<1.0	NA
	4/1/1996	<0.50	0.90	<0.50	NA
	7/17/1996	<0.50	<5.0	<0.50	<0.50
	10/9/1996	<0.50	0.80	<0.50	<0.50
	2/4/1997	<0.50	<0.50	<0.50	<0.50
	4/30/1997	<0.50	<0.50	<0.50	<0.50
	8/11/1997	<0.50	<0.50	<0.50	<0.50
	2/6/1998	<5.0	<5.0	<5.0	<5.0
	7/27/1998	<5.0	<5.0	<5.0	<5.0
	1/19/1999	<5.0	<5.0	<5.0	<5.0
	7/27/1999	<5.0	<5.0	<5.0	<5.0
	1/19/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0
	5/17/2001	<5.0	<5.0	<5.0	<5.0
	10/10/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	0.5J	0.5J	<5.0	NA
	1/27/2003	0.40J	<5.0	<5.0	<5.0
	1/25/2004	0.40J	<5.0	<5.0	<15
78-GW02	1/9/1987	12	38	<7.2	28
	3/8/1987	<1.0	<6.0	<7.2	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/16/1991	<5.0	<5.0	<5.0	<5.0
	8/8/1997	<0.50	<0.50	<0.50	<0.50
	5/22/1993	ND	ND	ND	ND

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW03	1/9/1987	1.4	<6.0	8.2	<12
	3/8/1987	<1.0	<6.0	9.0	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/16/1991	<5.0	<5.0	<5.0	<5.0
	8/9/1997	<0.50	<0.50	<0.50	<0.50
78-GW04-1	1/12/1987	25	35	<7.2	<12
	3/8/1987	3.2	8.2	<7.2	<12
	5/27/1987	1.6	<6.0	<7.2	<12
	1/11/1991	<5.0	<5.0	<5.0	<5.0
	5/23/1993	ND	ND	ND	ND
	7/9/1995	<1.0	<1.0	<1.0	NA
	10/25/1995	<0.50	<0.50	<0.50	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/12/1996	<0.50	1.0	<0.50	NA
	7/15/1996	<0.50	<0.50	<0.50	<0.50
	10/6/1996	<0.50	<0.50	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	<0.50
	4/2/1997	<0.50	<0.50	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	<0.50
	2/8/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/18/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	5/17/2001	<5.0	<5.0	<5.0	<5.0
	10/9/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	0.20J	<5.0	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-GW04-2	1/11/1991	<5.0	1.0J	<5.0	<5.0
	5/23/1993	5.0J	ND	ND	ND
78-GW04-3	5/24/1993	30J	ND	ND	ND

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW05	1/12/1987	<1.0	<6.0	<7.2	<12
	3/8/1987	<1.0	<6.0	<7.2	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/10/1991	<5.0	<5.0	<5.0	<5.0
	5/22/1993	ND	ND	ND	ND
	7/9/1995	<1.0	<1.0	<1.0	NA
	10/25/1995	<0.50	1.2	<0.50	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/11/1996	<0.50	1.7	<0.50	NA
	7/17/1996	<0.50	<0.50	<0.50	<0.50
	10/6/1996	<0.50	<0.50	<0.50	<0.50
	1/2/2001	<5.0	<5.0	<5.0	<5.0
	5/17/2001	<5.0	<5.0	<5.0	<5.0
	10/16/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/23/2003	<5.0	<5.0	<5.0	<5.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/23/2004	<5.0	<5.0	<5.0	<15
78-GW06	1/12/1987	<1.0	<6.0	<7.2	<12
	3/8/1987	<1.0	<6.0	<7.2	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/10/1991	<5.0	<5.0	<5.0	<5.0
78-GW07	1/12/1987	<1.0	<6.0	<7.2	<12
	3/9/1987	<1.0	<6.0	<7.2	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/9/1991	<5.0	<5.0	<5.0	<5.0
78-GW08	1/13/1987	<1.0	<6.0	<7.2	<12
	3/9/1987	<1.0	<6.0	<7.2	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/8/1991	<5.0	<5.0	<5.0	<5.0
	5/22/1993	ND	ND	ND	ND
	7/9/1995	<1.0	<1.0	<1.0	NA
	10/25/1995	<0.50	<0.50	<0.50	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/11/1996	<0.50	1.4	<0.50	NA
	7/14/1996	<0.50	<0.50	<0.50	<0.50
	10/8/1996	<0.50	<0.50	<0.50	<0.50
	2/4/1997	<0.50	<0.50	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	<0.50

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW08— Continued	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/8/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/18/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0
	10/16/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/27/2004	<5.0	<5.0	<5.0	<15
78-GW09-1 (old)	1/14/1987	<100	<600	1,100	2,500
	3/9/1987	<250	<1,500	<1,800	<3,000
	5/28/1987	<100	<600	<720	4,000
	1/17/1991	<5.0	330J	700	3,300
78-GW09-1 (new)	12/9/1993	ND	ND	NA	ND
	7/10/1995	<1.0	<1.0	<1.0	NA
	10/25/1995	<10	<10	<10	NA
	1/18/1996	<8.3	<8.3	<8.3	NA
	4/11/1996	<0.50	<0.50	<0.50	NA
	7/11/1996	<0.50	<0.50	<0.50	<0.50
	10/4/1996	<0.50	<0.50	<0.50	<0.50
	2/2/1997	<5.0	<5.0	<5.0	<5.0
	4/27/1997	<5.0	<5.0	<5.0	<5.0
	8/9/1997	<0.50	<0.50	<0.50	<0.50
	2/8/1998	<10	<10	<10	<10
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0
	5/18/2001	<5.0	<5.0	<5.0	<5.0
	10/11/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/27/2004	0.20J	<5.0	<5.0	<15

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW09-2	8/6/1987	<1.0	<6.0	<7.2	<12
	1/8/1991	<5.0	<5.0	<5.0	<5.0
	5/23/1993	6.0	ND	ND	ND
	7/12/1995	<1.0	<1.0	<1.0	NA
	11/6/1995	<0.50	<0.50	<0.50	NA
	1/20/1996	<0.50	<0.6	<0.50	NA
	4/17/1996	<0.50	0.80	<0.50	NA
	7/11/1996	<0.50	<0.50	<0.50	<0.50
	10/4/1996	<0.50	<0.50	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	<0.50
	4/27/1997	<0.50	<0.50	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	<0.50
	2/8/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	0.70J	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
78-GW09-3	8/6/1987	<1.0	<6.0	<7.2	<12
	5/22/1993	ND	ND	ND	ND
	7/12/1995	<1.0	<1.0	<1.0	NA
	11/5/1995	<0.50	<0.50	<0.50	NA
	1/21/1996	<0.50	<0.6	<0.50	NA
	4/17/1996	<0.50	1.6	<0.50	NA
	7/15/1996	<0.50	<0.50	<0.50	<0.50
	10/4/1996	<0.50	<0.50	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	<0.50
	4/27/1997	<0.50	<0.50	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	<0.50
	2/8/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/18/1999	<5.0	<5.0	<5.0	<5.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0
	5/19/2001	<5.0	<5.0	<5.0	<5.0
	10/11/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/27/2004	<5.0	<5.0	<5.0	<15

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW10	1/14/1987	<1.0	<6.0	<7.2	<12
	3/9/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/9/1991	<5.0	<5.0	<5.0	<5.0
	7/9/1995	<1.0	<1.0	<1.0	NA
	10/25/1995	<0.50	<0.50	<0.50	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/12/1996	<0.50	1.0	<0.50	NA
	7/16/1996	<0.50	<0.50	<0.50	<0.50
	10/5/1996	<0.50	<0.50	<0.50	<0.50
	2/3/1997	<0.50	<0.50	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/7/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	0.66J	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0
	10/15/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/27/2004	<5.0	<5.0	<5.0	<15
78-GW11	1/14/1987	<1.0	<6.0	<7.2	<12
	3/9/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/9/1991	<5.0	<5.0	<5.0	<5.0
	7/10/1995	<1.0	<1.0	<1.0	NA
	10/25/1995	<0.50	<0.50	<0.50	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/12/1996	<0.50	1.1	<0.50	NA
	7/15/1996	<0.50	<0.50	<0.50	<0.50
	10/8/1996	<0.50	<0.50	<0.50	<0.50
	2/5/1997	<0.50	<0.50	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/5/1998	<5.0	<5.0	<5.0	<5.0

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW11—Continued	7/26/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0
	10/11/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/27/2004	<5.0	<5.0	<5.0	<15
78-GW12	1/14/1987	<1.0	<6.0	<7.2	<12
	3/9/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/9/1991	<5.0	<5.0	<5.0	<5.0
	5/23/1993	ND	ND	ND	ND
78-GW13	1/14/1987	<1.0	<6.0	<7.2	<12
	3/9/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/12/1991	<5.0	<5.0	<5.0	<5.0
78-GW14	1/14/1987	<1.0	<6.0	<7.2	<12
	3/9/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/10/1991	<5.0	<5.0	<5.0	<5.0
	5/23/1993	ND	ND	ND	ND
	7/9/1995	1.3	<1.0	<1.0	NA
	10/26/1995	<0.50	<0.50	<0.50	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/11/1996	<0.50	0.7	<0.50	NA
	7/12/1996	<0.50	<0.50	<0.50	<0.50
	10/5/1996	<0.50	<0.50	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	<0.50
	4/27/1997	<0.50	<0.50	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	<0.50
	2/8/1998	<5.0	<5.0	<5.0	<5.0
	7/26/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW15	1/15/1987	<1.0	<6.0	<7.2	<12
	3/9/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/8/1991	<5.0	<5.0	<5.0	<5.0
	5/24/1993	ND	ND	ND	ND
	7/14/1996	<0.50	<0.50	<0.50	NA
	10/7/1996	<0.50	<0.50	<0.50	<0.50
	2/5/1997	<0.50	<0.50	<0.50	<0.50
	4/30/1997	<0.50	<0.50	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	<0.50
	2/6/1998	<5.0	<5.0	<5.0	<5.0
	7/26/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0
78-GW16	1/15/1987	<1.0	<6.0	<7.2	<12
	3/10/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/9/1991	<5.0	<5.0	<5.0	<5.0
78-GW17-1	1/15/1987	<1.0	<6.0	<7.2	<12
	3/10/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/7/1991	<5.0	<5.0	<5.0	<5.0
	5/24/1993	ND	ND	ND	ND
	7/12/1995	<1.0	<1.0	<1.0	NA
	10/26/1995	<0.50	<0.50	<0.50	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/10/1996	1.5	5.9	<0.50	NA
	7/15/1996	<1.0	<1.0	<1.0	NA
	10/7/1996	<0.50	<0.50	<0.50	<0.50
	2/2/1997	<0.50	<0.50	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	<0.50
	8/9/1997	<0.50	<0.50	<0.50	<0.50
	2/9/1998	<5.0	<5.0	<5.0	<5.0
	7/26/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW17-2	8/5/1987	<1.0	<6.0	<7.2	<12
	1/8/1991	3.0J	<5.0	<5.0	<5.0
	5/23/1993	ND	ND	ND	ND
78-GW17-3	8/5/1987	<1.0	<6.0	<7.2	<12
78-GW18	1/15/1987	<1.0	<6.0	<7.2	<12
	3/10/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	12/9/1993	ND	ND	ND	BD
78-GW19	1/16/1987	<1.0	<6.0	<7.2	<12
	3/10/1987	<1.0	<6.0	<7.2	<12
	5/27/1987	<1.0	<6.0	<7.2	<12
	1/11/1991	<5.0	<5.0	<5.0	<5.0
	5/23/1993	ND	ND	ND	ND
	7/10/1995	<1.0	<1.0	<1.0	NA
	10/26/1995	<0.50	<0.50	<0.50	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/10/1996	<0.50	<0.50	<0.50	NA
	7/16/1996	<0.50	<0.50	<0.50	<0.50
	10/5/1996	<0.50	<0.50	<0.50	<0.50
78-GW20	1/16/1987	<1.0	<6.0	<7.2	<12
	3/10/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
78-GW21	1/16/1987	<1.0	<6.0	<7.2	<12
	3/10/1987	<1.0	<6.0	<7.2	<12
	5/28/1987	<1.0	<6.0	<7.2	<12
	1/12/1991	<5.0	<5.0	0.90J	5.0
	5/21/1993	2.0	ND	ND	ND
	7/9/1995	<1.0	<1.0	<1.0	NA
	10/25/1995	<0.50	1.4	<0.50	NA
	1/17/1996	<0.50	0.8	<0.50	NA
	4/10/1996	<0.50	<0.50	<0.50	NA
	7/17/1996	<0.50	<0.50	<0.50	<0.50
	10/3/1996	<0.50	<0.50	<0.50	<0.50
	2/3/1997	<0.50	<0.50	<0.50	<0.50
	4/28/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/5/1998	<5.0	<5.0	<5.0	<5.0
	7/28/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW22	1/16/1987	<1.0	<6.0	<7.2	<12
	3/11/1987	<1.0	<6.0	<7.2	<12
	5/29/1987	<1.0	<6.0	<7.2	<12
	1/18/1991	<5.0	<5.0	<5.0	<5.0
78-GW22A	7/9/1995	1.2	<1.0	<1.0	NA
	10/25/1995	<25	<25	<25	NA
	1/19/1996	<25	<25	<25	NA
	4/9/1996	<0.50	<0.50	<0.50	NA
	7/17/1996	<0.50	<0.50	<0.50	<0.50
	10/4/1996	<0.50	<0.50	<0.50	<0.50
	2/5/1997	<0.50	<0.50	<0.50	<0.50
	4/28/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	0.8	0.6	<0.50	<0.50
	2/5/1998	<5.0	<5.0	<5.0	<5.0
	2/27/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0
	7/23/2002	<5.0	<5.0	<5.0	<5.0
	1/25/2003	<5.0	0.20J	0.10J	<5.0
	1/23/2004	<5.0	<5.0	<5.0	<15
78-GW23	1/19/1987	<10	<60	<72	<120
	3/11/1987	<100	<600	<720	<1,200
	5/29/1987	<100	<600	<720	<1,200
	1/18/1991	24	13	9.0	41
	5/23/1993	ND	ND	5.0J	28J
	7/12/1995	30	1.6	7.3	NA
	10/25/1995	23	5.4	35.5	NA
	1/17/1996	<25	<25	<25	NA
	4/9/1996	16	3.5	24	NA
	7/14/1996	17	4.0	9.0	57
	10/4/1996	16	3.0	7.0	51
	2/5/1997	16	3.0	7.0	46
	4/28/1997	<50	<50	<50	<50
	8/10/1997	17	4.0	7.0	50
	2/5/1998	<620	<620	<620	<620
	7/26/1998	18J	9.4J	9.7J	61

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW23—Continued	1/17/1999	18	4.0J	8	57
	7/17/1999	16	4.0J	10	68
	1/17/2000	16	4.0J	9.0	56
	7/17/2000	14	4.0J	8.0	69
	10/19/2000	17	4.0J	8.0	74
	1/11/2001	14	3.0J	5.0	51
	7/12/2001	11	3.0J	8.0	46
	1/24/2002	11	4.0J	8.0	56
	7/22/2002	12	<5.0	10	73
	1/25/2003	10	3.0J	6.0	49
	1/23/2004	11	2.0J	2.0J	39
78-GW24-1	1/19/1987	2.0	<600	<720	<1,200
	3/11/1987	<100	<600	<720	<1,200
	5/29/1987	<100	<600	<720	<1,200
	1/8/1991	3.0J	13	3.0J	10
	5/24/1993	51	2.0	ND	1.0
	7/9/1995	1.4	<1.0	<1.0	NA
	10/25/1995	<1.3	<1.3	<1.3	NA
	1/21/1996	<1.3	<1.5	<1.3	NA
	4/9/1996	<0.50	<0.50	<0.50	NA
	7/16/1996	0.6	0.7	<0.50	<0.50
	10/3/1996	<0.50	<0.50	<0.50	<0.50
	2/4/1997	<0.50	<0.50	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/7/1998	<10	<10	<10	<10
	7/25/1998	<5.0	1.5JD	<5.0	<5.0
	1/16/1999	<5.0	4.0J	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	10/19/2000	<5.0	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/10/2002	<5.0	<5.0	<5.0	<5.0
	7/22/2002	0.40J	<5.0	<5.0	0.60J
	1/28/2003	0.40J	0.30J	<5.0	<5.0
	1/28/2003	0.20J	<1.0	<1.0	<1.0
	1/23/2004	3.0J	<5.0	<5.0	<15
	1/23/2004	0.30J	<1.0	<1.0	<3.0
	1/23/2004	0.30J	<1.0	<1.0	<3.0

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW24-2	8/6/1987	<1.0	<6.0	<7.2	<12
	1/8/1991	<5.0	<5.0	<5.0	<5.0
	5/24/1993	ND	ND	ND	ND
	7/12/1995	<1.0	2.1	<1.0	NA
	11/5/1995	<0.50	<0.50	<0.50	NA
	1/21/1996	<0.50	<0.6	<0.50	NA
	4/16/1996	4.8	15	3.5	NA
	7/17/1996	<0.50	<0.50	<0.50	<0.50
	10/3/1996	<0.50	<0.50	<0.50	<0.50
	2/4/1997	<0.50	<0.50	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/7/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/10/2002	<5.0	<5.0	<5.0	<5.0
	7/22/2002	<5.0	<5.0	<5.0	<5.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0
	1/23/2004	<5.0	<5.0	<5.0	<15
78-GW24-3	8/6/1987	<1.0	<6.0	<7.2	<12
	5/24/1993	35	ND	ND	ND
	7/12/1995	<1.0	<1.0	<1.0	NA
	11/5/1995	<0.50	<0.50	<0.50	NA
	1/12/1996	<0.50	<0.6	<0.50	NA
	4/16/1996	<0.50	0.8	<0.50	NA
	7/15/1996	<0.50	<0.50	<0.50	<0.50
	10/4/1996	<0.50	0.8	<0.50	<0.50
	2/4/1997	<0.50	<0.50	<0.50	<0.50
	4/29/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/7/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/16/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW24-3—Continued	1/9/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/10/2002	<5.0	<5.0	<5.0	<5.0
	7/22/2002	<5.0	<5.0	<5.0	<5.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0
	1/23/2004	<5.0	<5.0	<5.0	<15
78-GW25	1/19/1987	<1.0	<6.0	<7.2	<12
	3/11/1987	<1.0	<6.0	<7.2	<12
	5/29/1987	<1.0	<6.0	<7.2	<12
	1/18/1991	<5.0	<5.0	<5.0	<5.0
	7/9/1995	<1.0	<1.0	<1.0	NA
	10/24/1995	1.4	6.0	1.4	NA
	1/17/1996	<0.50	<0.50	<0.50	NA
	4/9/1996	<0.50	<0.50	<0.50	NA
	7/17/1996	<0.50	<0.50	<0.50	<0.50
	10/3/1996	<0.50	<0.50	<0.50	<0.50
	2/5/1997	<0.50	<0.50	<0.50	<0.50
	4/28/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/5/1998	<5.0	<5.0	<5.0	<5.0
	7/28/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/10/2002	<5.0	<5.0	<5.0	<5.0
	7/23/2002	<5.0	<5.0	<5.0	<5.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0
	1/23/2004	<5.0	<5.0	<5.0	<15
78-GW26	1/19/1987	<1.0	<6.0	<7.2	<12
	3/12/1987	<1.0	<6.0	<7.2	<12
	5/29/1987	<1.0	<6.0	<7.2	<12
	1/19/1991	<5.0	<5.0	<5.0	<5.0
	1/12/1991	<5.0	<5.0	<5.0	<5.0
	12/9/1993	ND	ND	ND	ND
78-GW29	1/20/1987	<1.0	<6.0	<7.2	<12
	3/12/1987	<1.0	<6.0	<7.2	<12
	5/29/1987	<1.0	<6.0	<7.2	<12

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW30-2	1/10/1991	2.0J	2.0J	0.70J	2.0J
	12/9/1993	7.0J	3.0J	NA	3.0J
78-GW30-3	12/9/1993	ND	ND	NA	ND
78-GW31-2	1/17/1991	<5.0	<5.0	<5.0	1.0J
	5/24/1993	ND	ND	ND	ND
78-GW31-3	5/24/1993	15J	ND	ND	ND
	7/12/1995	<1.0	<1.0	<1.0	NA
	11/6/1995	<0.50	<0.50	<0.50	NA
	1/20/1996	<0.50	<0.50	<0.50	NA
	4/17/1996	<0.50	1.1	<0.50	NA
	7/11/1996	<0.50	<0.50	<0.50	<0.50
	10/8/1996	<0.50	<0.50	<0.50	<0.50
78-GW32-2	1/12/1991	27	31	2.0J	8.0
	5/22/1993	ND	ND	ND	ND
78-GW32-3	5/23/1993	ND	ND	ND	ND
78-GW35	6/3/1993	ND	ND	ND	ND
78-GW37	6/3/1993	ND	ND	ND	ND
78-GW38	6/3/1993	ND	ND	ND	ND
78-GW39	6/3/1993	ND	ND	ND	ND
	7/18/1996	<0.50	1.0	<0.50	0.7
	10/9/1996	<0.50	<0.50	<0.50	<0.50
	2/5/1997	<0.50	<0.50	<0.50	<0.50
	4/30/1997	<0.50	<0.50	<0.50	<0.50
	8/10/1997	<0.50	<0.50	<0.50	<0.50
	2/8/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/18/1999	<5.0	<5.0	<5.0	<5.0
	1/15/2000	<5.0	<5.0	<5.0	<5.0
	7/16/2000	<5.0	<5.0	<5.0	<5.0
	1/9/2001	<5.0	<5.0	<5.0	<5.0
	5/21/2001	<5.0	<5.0	<5.0	<5.0
	10/16/2001	<5.0	<5.0	<5.0	<5.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0
	7/23/2002	<5.0	<5.0	<5.0	NA
	1/27/2003	<5.0	<5.0	<5.0	<5.0
	1/26/2004	<5.0	<5.0	<5.0	<15

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW40	2/9/1998	<5.0	<5.0	<5.0	0.79J
	7/26/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0
	7/22/2002	<5.0	<5.0	<5.0	<5.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/23/2004	<5.0	<5.0	<5.0	<15
78-GW41	2/9/1998	<5.0	<5.0	<5.0	0.73J
	7/26/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/17/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/28/2002	<5.0	<5.0	<5.0	<5.0
	1/25/2003	0.30J	<5.0	<5.0	<5.0
	1/23/2004	0.40J	<5.0	<5.0	<15
78-GW42	2/9/1998	4.4J	0.90J	<5.0	<5.0
	7/26/1998	<5.0	<5.0	<5.0	<5.0
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	7/18/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0
	5/18/2001	<5.0	<5.0	<5.0	<5.0
	10/9/2001	2.0J	<5.0	<5.0	<5.0
	1/11/2002	2.0J	<5.0	<5.0	<5.0
	7/23/2002	2.0J	0.30J	<5.0	NA
	1/25/2003	2.0J	0.30J	<10	<10
	1/25/2004	3.0J	0.60J	<5.0	<15
78-GW43	10/19/2000	<5.0	3.0J	<5.0	7.0
	1/11/2001	<5.0	2.0J	<5.0	7.0
	7/12/2001	<5.0	3.0J	<5.0	7.0
	1/10/2002	<5.0	3.0J	<5.0	8.0
	7/23/2002	1.0J	3.0J	<5.0	<8.0
	1/28/2003	2.0J	3.0J	2.0J	<10
	1/28/2003	2.0J	3.0	2.0	9.0
	1/23/2004	1.0J	1.0J	2.0J	5.0J
	1/23/2004	1.0	2.0	1.0	5.0

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW44	10/19/2000	3.0J	11	<5.0	8.0
	1/11/2001	<5.0	9.0	<5.0	10
	7/12/2001	4.0J	9.0	<5.0	11
	1/10/2002	3.0J	8.0	<5.0	9.0
	7/22/2002	3.0J	8.0	<5.0	<6.0
	1/28/2003	4.0J	7.0	2.0J	<10
	1/28/2003	3.0	7.0	1.0	9.0
	1/23/2004	2.0J	2.0J	0.20J	3.0J
	1/23/2004	2.0J	2.0J	0.20J	3.0J
78-GW45	10/19/2000	<5.0	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/28/2002	<5.0	<5.0	<5.0	<5.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/23/2004	<5.0	<5.0	<5.0	<15
78-GW46	10/19/2000	290D	14	100	320
	1/11/2001	100	3.0J	32	46
	7/12/2001	950	20	540	350
	1/24/2002	170	3.0J	39	77
	7/23/2002	94	2.0J	27	27
	1/25/2003	79	1.0J	27	20
	1/23/2004	76	0.60J	17	10J
78-GW47	10/19/2000	3.0J	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/24/2002	4.0J	<5.0	<5.0	<5.0
	7/23/2002	4.0J	<5.0	<5.0	2.0J
	1/25/2003	5.0J	<5.0	<5.0	<10
	1/23/2004	3.0J	<5.0	<5.0	0.60J
78-GW48	10/19/2000	22	70	140	710D
	1/11/2001	19	62	120	440D
	7/12/2001	18	59	100	510
	1/26/2002	17	49	100	520
	7/23/2002	14	40	100	470
	1/25/2003	14	43	96	440
	1/23/2004	19	72	96	520
78-GW49	5/19/2001	<5.0	<5.0	<5.0	<5.0
	10/9/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/27/2004	<5.0	<5.0	<5.0	<15

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW50	5/18/2001	<5.0	<5.0	<5.0	<5.0
	10/15/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/23/2002	<5.0	<5.0	<5.0	NA
	1/27/2003	<5.0	<5.0	<5.0	<5.0
	1/27/2004	<5.0	<5.0	<5.0	<15
78-GW51	5/18/2001	<5.0	<5.0	<5.0	<5.0
	10/10/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	<5.0	0.50J	<10	<10
	1/25/2004	<5.0	<5.0	0.30J	<15
78-GW52	5/18/2001	1,200D	26	23	21
	10/9/2001	1,300	24	22	23
	1/11/2002	650	30	18	27
	7/24/2002	510	19	10	NA
	1/25/2003	520	17	<10	NA
	1/27/2004	570D	4.0J	12	5.0J
78-GW53	5/20/2001	<5.0	<5.0	<5.0	<5.0
	10/10/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	3.0j	<5.0	9.0
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/26/2004	<5.0	<5.0	<5.0	<15
78-GW54	5/20/2001	<5.0	<5.0	<5.0	<5.0
	10/15/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/26/2003	<5.0	0.20J	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-GW55	5/20/2001	<5.0	<5.0	<5.0	<5.0
	10/15/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	9.0	4.0J	17
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/26/2003	<5.0	0.20J	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-GW56	5/18/2001	<5.0	<5.0	<5.0	<5.0
	10/15/2001	<5.0	<5.0	<5.0	<5.0
	1/11/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	NA
	1/27/2003	<5.0	<5.0	<5.0	<5.0
	1/26/2004	<5.0	<5.0	<5.0	<15

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW57	5/18/2001	8.0	<5.0	<5.0	<5.0
	10/10/2001	13	<5.0	<5.0	<5.0
	1/11/2002	24	<5.0	<5.0	<5.0
	7/24/2002	42	0.6J	<5.0	NA
	1/27/2003	23	0.40J	<10	<10
	1/25/2004	6.0	<5.0	<5.0	<15
78-GW58	5/18/2001	1,000	14,000D	2,400D	11,000D
	10/15/2001	440	16,000	3,000	13,000
	1/11/2002	250	6,400	1,300	5,800
	7/23/2002	200J	4,400	860	NA
	1/27/2003	280	6,800	1,600	7,000
	1/27/2004	270DJ	6,300DJ	1,500DJ	6,600DJ
78-GW59	5/20/2001	13	<5.0	<5.0	<5.0
	10/15/2001	9.0	<5.0	<5.0	<5.0
	1/11/2002	10	<5.0	<5.0	<5.0
	7/24/2002	0.4J	<5.0	<5.0	NA
	1/25/2003	4.0J	<5.0	<5.0	<5.0
	1/25/2004	4.0J	0.20J	<5.0	<15
78-GW60	7/25/2002	<5.0	1,400	1,600	NA
	1/28/2003	<5.0	980J	1,600J	7,600J
	1/28/2003	<1.0	900	1,500	7,100
	1/26/2004	<5.0	750D	1,500D	7,400D
	1/26/2004	<1.0	870	1,700	8,000
78-GW61	7/25/2002	<5.0	<5.0	<5.0	NA
	1/25/2003	<5.0	<5.0	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-GW62	7/25/2002	<5.0	<5.0	<5.0	NA
	1/28/2003	<5.0	<5.0	<5.0	0.40J
78-GW63	7/25/2002	<5.0	<5.0	<5.0	NA
	1/26/2003	<5.0	<5.0	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-GW64	7/25/2002	<5.0	<5.0	<5.0	NA
	1/26/2003	<5.0	<5.0	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-GW65	7/25/2002	1.0J	<5.0	<5.0	NA
	1/25/2006	1.0J	<5.0	<5.0	<5.0
	1/25/2004	0.90J	<5.0	<5.0	<15
78-GW66	7/25/2002	2.0J	<5.0	<5.0	NA
	1/25/2006	2.0J	<5.0	<5.0	NA
	1/25/2004	2.0J	<5.0	<5.0	<15

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-GW67	7/25/2002	<5.0	<5.0	<5.0	NA
	1/26/2003	<5.0	<5.0	<5.0	<5.0
78-GW68	7/25/2002	<5.0	<5.0	<5.0	NA
	1/26/2003	<5.0	<5.0	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-GW69	1/29/2003	3.0	1.0	<1.0	<2.0
	1/23/2004	2.0J	0.60J	<1.0	0.80J
78-GW70	1/29/2003	2.0	2.0	<1.0	3.0
	1/23/2004	1.0J	0.90J	<1.0	0.90J
78-GW71	1/29/2003	2.0	0.40J	1.0J	0.70J
	1/23/2004	1.0J	0.20J	<1.0	<3.0
78-GW72	1/29/2003	1.0	<1.0	<1.0	0.60J
	1/23/2004	1.0	<1.0	<1.0	<3.0
78-GW73	1/30/2003	<1.0	<1.0	16	98(?)
	1/27/2004	<1.0	<1.0	4.0	49
78-GW74	1/30/2003	370	2,300	700	2,700
	1/26/2004	3,200	9,600	1,100	4,200
78-GW75-1	1/30/2003	5,500	14,000	1,600	6,500
	1/26/2004	3,200	7,800	1,800	6,700
	1/26/2004	3,100	7,200	1,600	6,600
78-GW75-2	1/30/2003	560	1,400	550	2,300
78-GW76	1/30/2003	<1.0	50	250	4,100
	1/30/2003	<1.0	49	230	3,800
	1/26/2004	<1.0	71	280	4,000
78-GW77	1/30/2003	11	1,400	730	2,200
	1/26/2004	34	3,200	2,000	7,800
78-GW78	1/30/2003	150	3,700	1,700	6,000
	1/26/2004	150J	9,500	2,200	8,600
78-N-TW01	7/26/1997	<0.50	<0.50	<0.50	<0.50
78-N-TW02	7/28/1997	6.0	<0.50	<0.50	5.0
78-N-TW03	7/26/1997	<0.50	<0.50	<0.50	<0.50
78-N-TW04	7/26/1997	<0.50	<0.50	<0.50	<0.50
78-N-TW05	7/26/1997	<0.50	<0.50	<0.50	<0.50
78-N-TW06	7/25/1997	34	19	22	83
78-N-TW07	7/26/1997	38	14	100	640
78-N-TW08	7/25/1997	<0.50	<0.50	<0.50	<0.50
78-N-TW09	7/25/1997	<0.50	<0.50	<0.50	<0.50
78-N-TW10	7/26/1997	<0.50	<0.50	<0.50	<0.50

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-N-TW11	7/26/1997	<0.50	<0.50	<0.50	<0.50
78-N-TW12	2/8/1998	7.8J	41	190	890D
78-N-TW13	2/6/1998	<5.0	<5.0	<5.0	<5.0
78-RW01N	7/13/1995	<1.0	<1.0	<1.0	NA
	10/29/1995	<50	<50	<50	NA
	1/18/1996	<0.50	<0.50	<0.50	NA
	4/10/1996	<0.50	<0.50	0.6	NA
	7/17/1996	<0.50	<0.50	<0.50	<0.50
	10/6/1996	<0.50	<0.50	<0.50	<0.50
78-RW02N	7/13/1995	<1.0	<1.0	<1.0	NA
	10/26/1995	<12.5	<12.5	<12.5	NA
	1/18/1996	<0.50	<0.50	<0.50	NA
	4/10/1996	<0.50	<0.50	0.6	NA
	7/10/1996	<0.50	<0.50	<0.50	<0.50
	10/4/1996	<0.50	<0.50	<0.50	<0.50
78-RW03N	7/9/1995	1.7	<1.0	<1.0	NA
	10/28/1995	<0.50	<0.50	<0.50	NA
	1/18/1996	<0.50	<0.50	<0.50	NA
	4/16/1996	<0.50	0.9	<0.50	NA
	7/18/1996	<0.50	<0.50	<0.50	NA
	10/7/1996	<0.50	<0.50	<0.50	<0.50
78-RW04N	7/13/1995	<1.0	<0.50	<0.50	NA
	10/27/1995	<25	<25	<25	NA
	1/18/1996	<0.50	<0.50	<0.50	NA
	4/11/1996	<0.50	1.0	<0.50	NA
	7/17/1996	<0.50	<0.50	<0.50	<0.50
	10/7/1996	<0.50	<0.50	<0.50	<0.50
78-RW10N	7/13/1995	451	66.2	54.7	NA
	10/25/1995	118	12.5	175	NA
	1/17/1996	106	9.8	62.4	NA
	4/9/1996	81	10	33	NA
	1/17/2000	220D	18	85	120
	7/17/2000	200	9.0	69	180
	1/11/2001	29	<5.0	4.0J	20
	7/12/2001	120	<5.0	4.0J	8.0
	1/24/2002	160	4.0J	71	60
	1/28/2003	190	2.0J	45	17
	1/23/2004	180	1.0J	23	4.0J

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-RW11N	7/13/1995	1.2	1.4	<1.0	NA
	10/25/1995	<0.50	<0.50	<0.50	NA
	1/17/1996	1.3	1.3	<0.50	NA
	4/9/1996	1.3	<0.50	0.76	NA
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	<5.0	<5.0	<5.0	<5.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	0.8J	<5.0	<5.0	<5.0
	1/28/2003	<5.0	<5.0	<10	<10
	1/28/2003	2.0	0.80J	0.30J	1.0
	1/23/2004	0.40J	<5.0	<5.0	<15
	1/23/2004	0.40J	<1.0	<1.0	<3.0
78-RW12N	1/17/2000	<5.0	<5.0	<5.0	2.0J
	7/17/2000	5.0J	<5.0	<5.0	<5.0
	1/11/2001	<5.0	<5.0	<5.0	<5.0
	7/12/2001	7.0	<5.0	<5.0	4.0J
	1/24/2002	<5.0	<5.0	<5.0	<5.0
	7/24/2002	<5.0	<5.0	<5.0	<5.0
	1/25/2003	<5.0	<5.0	<10	<10
	1/23/2004	<5.0	<5.0	<5.0	<15
78-RW05S	7/14/1995	<1.0	<1.0	<1.0	NA
	10/26/1995	<0.50	<0.50	<0.50	NA
	1/19/1996	1.0	<0.50	<0.50	NA
	4/9/1996	<0.50	1.0	<0.50	NA
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0
	5/20/2001	<5.0	<5.0	<5.0	4.0J
	10/25/2001	5.0J	<5.0	<5.0	4.0J
	1/28/2002	<5.0	<5.0	<5.0	<5.0
78-RW06S	7/13/1995	<1.0	<1.0	<1.0	NA
	10/26/1995	<0.50	<0.50	<0.50	NA
	1/19/1996	<0.50	<0.6	<0.50	NA
	4/9/1996	<0.50	<0.50	<0.50	NA
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/13/2001	<5.0	<5.0	<5.0	<5.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-RW06S—Continued	10/26/2001	<5.0	<5.0	<5.0	<5.0
	1/24/2002	<5.0	<5.0	<5.0	<5.0
	1/26/2003	<5.0	<5.0	<5.0	0.80J
	1/25/2004	<5.0	<5.0	<5.0	<15
78-RW07S	7/13/1995	1.4	1.4	<1.0	NA
	10/29/1995	<0.50	<0.50	<0.50	NA
	1/19/1996	<0.50	<0.6	<0.50	NA
	4/9/1996	<0.50	<0.50	<0.50	NA
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0
	5/20/2001	<5.0	<5.0	<5.0	<5.0
	10/26/2001	<5.0	<5.0	<5.0	<5.0
	1/24/2002	<5.0	<5.0	<5.0	2.0J
	1/26/2003	<5.0	<5.0	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-RW08S	7/13/1995	1.5	1.8	<1.0	NA
	10/26/1995	<12.5	<12.5	<12.5	NA
	1/19/1996	<0.50	<0.6	<0.50	NA
	4/9/1996	<0.50	<0.50	<0.50	NA
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/12/2001	<5.0	<5.0	<5.0	<5.0
	5/17/2001	<5.0	<5.0	<5.0	<5.0
	10/26/2001	<5.0	<5.0	<5.0	<5.0
	1/28/2002	<5.0	<5.0	<5.0	<5.0
	1/26/2003	<5.0	<5.0	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15
78-RW09S	7/13/1995	<1.0	<1.0	<1.0	NA
	10/28/1995	<0.50	<0.50	<0.50	NA
	1/19/1996	<0.50	<0.50	<0.50	NA
	4/17/1996	<0.50	1.3	<0.50	NA
	7/18/1996	<0.50	<0.50	<0.50	<0.50
	10/7/1996	<0.50	<0.50	<0.50	<0.50
	1/20/2001	<5.0	<5.0	<5.0	<5.0
	5/17/2001	<5.0	<5.0	<5.0	<5.0
	10/25/2001	<5.0	<5.0	<5.0	<5.0
	1/28/2002	<5.0	<5.0	<5.0	<5.0
	1/26/2003	<5.0	<5.0	<5.0	<5.0
	1/25/2004	<5.0	<5.0	<5.0	<15

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-RW13S	1/18/2000	<5.0	<5.0	<5.0	6.0
	7/17/2000	<5.0	<5.0	<5.0	<5.0
	1/12/2001	3.0J	<5.0	<5.0	<5.0
	5/18/2001	3.0J	<5.0	<5.0	<5.0
	10/25/2001	3.0J	<5.0	<5.0	<5.0
	1/24/2002	3.0J	<5.0	2.0J	9.0
	1/27/2003	2.0J	7.0	<10	15.0
	1/25/2004	2.0J	<5.0	<5.0	1.0J
78-RW14S	1/12/2001	5.0	89	280D	1,200D
	5/18/2001	<5.0	10	39	110
	10/25/2001	9.0	34	190	330
	1/24/2002	5.0	24	140	270
	7/25/2002	11	80	20	470
	1/27/2003	2.0J	17	<10	87
	1/25/2004	5.0J	72	31	280
78-RW15S	1/17/2000	<5.0	120	190	2,000D
	7/17/2000	<5.0	<5.0	<5.0	42
	1/12/2001	<5.0	9.0	48	920D
	5/20/2001	<5.0	12	78	3,400D
	10/25/2001	<5.0	6.0	70	1,200
	1/24/2002	<5.0	7.0	46	680
	7/24/2002	61	290	190	1,200
	1/28/2003	140	380	290	1,400
	1/28/2003	110	310	230	1,100
	1/25/2004	<5.0	7.0	21	140
	1/26/2004	<1.0	6.0	19	140

Table C54. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 78, Hadnot Point Industrial Area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[J, estimated concentration; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; ND, not detected; D, sample dilution required; B, detected in blank]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
78-S-TW01	7/24/1997	4.0	<0.50	<0.50	<0.50
78-S-TW02	7/24/1997	3.0	<0.50	<0.50	<0.50
78-S-TW03	7/25/1997	<0.50	<0.50	<0.50	11
78-S-TW04	7/22/1997	2.0	<0.50	<0.50	<0.50
78-S-TW05	7/25/1997	160	53	700	1,100
78-S-TW06	7/25/1997	2.0	1.0	3.0	5.0
78-S-TW07	7/24/1997	<0.50	<0.50	<0.50	<0.50
78-S-TW08	7/24/1997	<0.50	<0.50	<0.50	<0.50
78-S-TW09	7/24/1997	<0.50	<0.50	<0.50	<0.50
78-S-TW10	7/24/1997	<0.50	<0.50	<0.50	<0.50
78-S-TW11	7/24/1997	<0.50	<0.50	<0.50	<0.50
78-S-TW12	7/24/1997	<0.50	<0.50	<0.50	<0.50
78-S-TW13	2/6/1998	<17	<17	<17	<17

[1] See Figure C14, C15, or C16 for location. Locations of wells TW01–TW13 not shown

Data sources:

CERCLA Administrative Record files #258, #522, #1517, #1777, #1778, #1779, #1780, #1977, #2304, #2321, #2338, #2598A, #2608A, #3272, #3273, #3409, #3453

Baker Environmental, Inc. 1994g, 1996i,j, 1997c,d, 1998j,k, 1999b,c

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000d

Baker Environmental, Inc. and CH2M Hill, Inc. 2000a, 2002a

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000a

Engineering and Environment, Inc. and Michael Baker, Jr., Inc. 2004a

Michael Baker, Jr., Inc. and CH2M Hill Federal Group, Ltd. 2003

Environmental Science and Engineering, Inc. 1988a, 1991

Table C55. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 80, Paradise Point golf maintenance area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLCU—Brewster Boulevard lower confining unit, TTAQ—Tarawa Terrace aquifer, UCHRBU—Upper Castle Hayne aquifer–River Bend unit]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
80-MW01	356371	2485201	15.7	6/16/1991	20.2	10.0–20.0	BBLCU, TTAQ
80-MW02	356456	2485245	17.2	6/16/1991	22.0	12.0–22.0	BBLCU, TTAQ
80-MW03	356013	2485194	14.6	6/13/1991	14.8	4.8–14.8	BBLCU, TTAQ
80-MW03IW	355988	2485152	14.4	11/5/1994	72.0	57.0–72.0	UCHRBU
80-MW04	356067	2484971	13.7	11/3/1994	26.5	11.5–26.5	BBLCU, TTAQ
80-MW05	356293	2485251	16.2	11/4/1994	27.0	12.0–27.0	BBLCU, TTAQ
80-MW06	356415	2485411	17.1	11/5/1994	27.0	11.0–27.0	BBLCU, TTAQ
80-MW07	355886	2485254	16.2	11/4/1994	27.5	12.5–27.5	BBLCU, TTAQ
80-MW08	356233	2484893	15.0	6/13/1995	25.0	10.0–25.0	BBLCU, TTAQ

[1] See Figure C19 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

Data sources:

CERCLA Administrative Record files #329, #1697

Baker Environmental, Inc. 1996e

Haliburton NUS, 1992b

Table C56. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 80, Paradise Point golf maintenance area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
80-MW01	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	11/20/1994	<10	<10	<10	NA	NA	<10	<10
80-MW02	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	11/21/1994	<10	<10	<10	NA	NA	<10	<10
80-MW03	6/16/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	11/20/1994	<10	<10	<10	NA	NA	<10	<10
80-MW03IW	12/3/1994	<10	<10	<10	NA	NA	<10	<10
80-MW04	11/19/1994	<10	<10	<10	NA	NA	<10	<10
80-MW05	11/20/1994	<10	<10	<10	NA	NA	<10	<10
80-MW06	11/20/1994	<10	<10	<10	NA	NA	<10	<10
80-MW07	11/19/1994	<10	<10	<10	NA	NA	<10	<10
80-MW08	7/14/1995	NA	NA	NA	NA	NA	NA	NA

[1] See Figure C19 for location

Data sources:

CERCLA Administrative Record files #329, #1697

Baker Environmental, Inc. 1996e

Haliburton NUS 1992b

Table C57. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 80, Paradise Point golf maintenance area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
80-MW01	6/27/1991	< 5.0	< 5.0	< 5.0	< 5.0
	11/20/1994	< 10	< 10	< 10	< 10
80-MW02	6/27/1991	< 5.0	< 5.0	< 5.0	< 5.0
	11/21/1994	< 10	< 10	< 10	< 10
80-MW03	6/16/1991	< 5.0	180	5.0	21
	11/20/1994	< 10	< 10	< 10	< 10
80-MW03IW	12/3/1994	< 10	< 10	< 10	< 10
80-MW04	11/19/1994	< 10	< 10	< 10	< 10
80-MW05	11/20/1994	< 10	< 10	< 10	< 10
80-MW06	11/20/1994	< 10	< 10	< 10	< 10
80-MW07	11/19/1994	< 10	< 10	< 10	< 10
80-MW08	7/14/1995	NA	NA	NA	NA

[1] See Figure C19 for location

Data sources:

CERCLA Administrative Record files #329, #1697

Baker Environmental, Inc. 1996e

Haliburton NUS 1992b

Table C58. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[VOC, volatile organic compound; NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, TTAQ—Tarawa Terrace aquifer, TTCU—Tarawa Terrace confining unit, UCHLU—Upper Castle Hayne aquifer–Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; AKA, also known as; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
82-DMW01[4] AKA DMW-1	348383	2503129	[3]15	N/A	N/A	135–155	UCHLU
82-DP01	348089	2503210	[3]29	3/ /1995	100	80–100	TTAQ
82-DP02	347836	2503298	[3]27	3/ /1995	100	80–100	TTAQ
82-DRW01[4]	348098	2503431	[3]30	1995	N/A	80–100	TTCU(?), UCHRBU
82-DRW02[4]	348703	2502795	[3]25	1996	N/A	90–110	TTCU(?), UCHRBU
82-DRW03[4]	348351	2502402	[3]23	1996	N/A	90–110	TTCU(?), UCHRBU
82-DRW04[4]	348391	2503128	[3]15	1996	N/A	90–110	UCHRBU
82-MW01	348523	2502130	6.1	6/17/1991	14.2	4–14	BBLAQ
82-MW02	349073	2503529	3.7	6/17/1991	13.2	3–13	BBLAQ
82-MW03	348220	2502375	22.0	6/18/1991	21.5	11–21	BBLAQ
82-MW30	348087	2503799	29.7	1991(?)	25.0	N/A	BBLAQ(?)
82-MW31	351137	2503789	31.0	N/A	N/A	N/A	N/A
82-SP01	348381	2503504	[3]25	12/ /1995	35	15–35	BBLAQ
82-SP02	348351	2503503	[3]26	12/ /1995	35	15–35	BBLAQ
82-SP03	348361	2503602	[3]27	12/ /1995	35	15–35	BBLAQ
82-SRW01[4]	348361	2503516	[3]26	3/ /1995	35	15–35	BBLAQ
82-SRW02[4]	348700	2503512	[3]4	1996	35	15–35	TTAQ
82-SRW03[4]	348673	2503322	[3]5	1996	35	15–35	TTAQ
82-SRW04[4]	348726	2503118	[3]15	1996	35	15–35	BBLAQ
82-SRW05[4]	348781	2502930	[3]22	1996	35	15–35	BBLAQ
82-SRW06[4] (old)	348826	2502756	[3]21	1996	35	15–35	BBLAQ
82-SRW06[4] (new)	348826	2502756	[3]21	2000	55	35–55	BBLAQ
82-TW01	348969	2502692	[3]6	N/A	N/A	N/A	N/A
82-TW02	349010	2502636	[3]4	N/A	N/A	N/A	N/A
82-TW03	348983	2502760	[3]9	N/A	N/A	N/A	N/A

[1] See Figure C5 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

[4] Well assigned to Site 6 in Camp Lejeune Water (CLW) documents and CERCLA Administrative Record files published after 1998

Data sources:

CERCLA Administrative Record files #125, #1272, #2013, #2337, #2547, #2609A, #3276, #3278

Baker Environmental, Inc. 1993k,m, 1998a, 1999d

Baker Environmental, Inc. and CH2M Hill, Inc. 2001a, 2002b

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 200b

James A. Dunn, Jr., OHM Remediation Services Corp., written communication, April 1, 1996

Table C59. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[VOC, volatile organic compound; D, sample dilution required; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; B, detected in blank; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; R, analytical result is unreliable; ND, constituent not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
82-DRW01[2]	4/17/1998	1,300	35,000D	<500	NA	NA	9,300	<500
	7/28/1998	1,400	36,000	<1,000	NA	NA	10,000	<2,000
	10/19/1998	<2,000	24,000	<2,000	NA	NA	4,900	<2,000
	1/15/1999	790J	21,000	29	990J	2,900	NA	120
	4/17/1999	1,200D	27,000D	19	2,000D	5,400D	NA	95
	7/28/1999	1,700	31,000	<1,000	2,300	5,700	8,000	<400
	10/23/1999	2,500D	71,000D	19	3,400	9,000D	7,300	64
	1/17/2000	2,400D	35,000D	20	3,000D	7,400D	10,000D	87
	7/13/2000	1,600D	25,000D	19	2,700D	5,700D	7,700D	77
	1/10/2001	3,800D	36,000D	15	3,400D	9,300D	13,000D	54
	7/10/2001	4,600J	34,000	18	4,000	11,000	15,000	69
	1/15/2002	1,400	15,000	12	1,100	3,100	4,200	60
	1/27/2003	1,200	14,000	10	1,200	2,800	4,000	41
	1/22/2004	740D	9,600D	8.0	960D	2,200D	NA	27
	7/26/2004	860D	11,000D	6.0J	790D	2,000D	NA	20J
82-DRW02[2]	4/16/1998	1,000	23,000D	<500	NA	NA	12,000	270J
	7/24/1998	780D	19,000BD	20	NA	NA	8,200D	140
	10/19/1998	<1,000	14,000	<1,000	NA	NA	4,600	<1,000
	1/17/1999	520	11,000	20	1,600	4,100	NA	160
	4/17/1999	640	12,000	<500	1,500	4,000	NA	160J
	7/29/1999	760	14,000D	<100	1,900	4,400D	6,100D	170
	10/21/1999	1,000D	26,000D	25	3,300D	8,800D	7,700	160
	1/17/2000	1,700D	45,000D	29	5,900D	14,000D	20,000D	220E
	7/13/2000	610JD	20,000D	25	2,400D	6,400D	8,800D	200E
	1/10/2001	1,800D	12,000D	26	4,400D	11,000D	16,000D	160
	7/10/2001	670J	19,000	18	2,200J	5,500	7,800	110
	1/15/2002	530	7,400	16	1,100	3,100	4,200	100
	1/22/2003	620	7,300	12	1,000	2,700	3,700	68
	1/22/2004	540D	5,500D	21	1,200D	2,700D	NA	77
	7/26/2004	590D	5,000D	13	740D	2,100D	NA	48
82-DRW03[2]	4/16/1998	36J	8,800	<250	NA	NA	5,600	110J
	7/24/1998	<5.0	84	<5.0	NA	NA	53	<10
	10/19/1998	<500	6,400	<500	NA	NA	3,100	<500
	1/16/1999	520	6,500	14	1,200	3,000	NA	66
	4/17/1999	16	6,000D	14	1,100D	2,600D	NA	95
	7/28/1999	23	7,400D	16	1,200D	2,900D	4,100D	77
	10/23/1999	21	12,000D	17	2,100	5,000D	4,800	75
	1/17/2000	7.0	5,500D	21	1,000D	2,400D	3,400D	52
	7/13/2000	14	6,100D	20	3,000D	5,900D	8,800D	150

Table C59. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[VOC, volatile organic compound; D, sample dilution required; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; B, detected in blank; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; R, analytical result is unreliable; ND, constituent not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
82-DRW03[2]—Continued	1/10/2001	12	14,000D	18	2,400D	5,600D	8,000D	83
	7/10/2001	18	9,600	15	2,600	5,700	8,200	70
	1/15/2002	14	2,500	14	590	1,800	2,400	59
	7/31/2002	16	2,900R	14	750R	1,800R	2,500R	34
	1/27/2003	14	2,300	10	480	1,200	1,700	29
	1/22/2004	8.0	1,800D	13	450D	940D	NA	23
	7/26/2004	13.0	2,000D	14	320D	780D	NA	23
82-DRW04[2]	4/16/1998	<620	20,000	<620	NA	NA	7,600	<620
	7/28/1998	150J	21,000	<1,000	NA	NA	7,700	<2,000
	10/19/1998	<1,000	21,000	<1,000	NA	NA	6,300	<1,000
	1/15/1999	1,100	15,000	34	1,100	2,800	NA	240
	4/17/1999	56	17,000D	17J	1,600	4,400D	NA	130
	7/29/1999	79	22,000D	16	1,800D	5,000D	6,100D	110
	10/23/1999	99	24,000D	18	3,000D	7,700D	6,600	110
	1/17/2000	110	33,000D	19	3,300D	7,600D	11,000D	140
	7/13/2000	130	17,000D	18	1,700D	4,700D	6,400D	130
	1/10/2001	140	9,000D	18	3,300D	8,400D	12,000D	100
	7/11/2001	490J	22,000	82	2,700	7,600	10,000	120
	1/15/2002	200	9,300	15	1,000	2,600	3,600	98
	7/31/2002	190	8,000R	14	880R	2,600R	3,500R	60
	1/27/2003	1,900	8,400	18	950	2,300	3,200	79
	1/22/2004	180	6,700D	13	920D	2,100D	NA	68
	7/26/2004	190	6,000D	16	570D	1,500D	NA	40
82-MW01	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/23/1992	ND	ND	ND	NA	NA	ND	ND
	3/23/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
82-MW02	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/24/1992	ND	ND	ND	NA	NA	ND	1.6
	3/23/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	7/27/1997	<10	<10	<10	NA	NA	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	4/15/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/25/1998	8.3	<5.0	<5.0	NA	NA	<5.0	<10
	1/16/1999	<5.0	38	<5.0	<5.0	<5.0	NA	<5.0
	7/28/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/12/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0

Table C59. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[VOC, volatile organic compound; D, sample dilution required; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; B, detected in blank; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; R, analytical result is unreliable; ND, constituent not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
82-MW02—Continued	7/11/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	0.30J
82-MW03	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	3/23/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	7/23/1997	<10	<10	<10	NA	NA	<10	<10
	1/17/1998	1.1J	<5.0	<5.0	NA	NA	<5.0	<10
	4/15/1998	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	7/24/1998	13	1.2J	<5.0	NA	NA	<5.0	<10
	1/16/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0
	7/28/1999	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/12/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/22/2003	<5.0	1.0J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/21/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/26/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
82-MW30	3/22/1993	<1.0	1.5J	<1.0	NA	NA	<1.0	<1.0
82-MW31	6/27/1991	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
82-SRW01[2]	4/22/1998	560	1,600	<50	NA	NA	620	<100
	7/23/1998	680D	2,300BD	<120	NA	NA	1,100D	<120
	10/19/1998	360	850D	<50	NA	NA	230	<50
	1/15/1999	680	770	<5.0	89	170	NA	<5.0
	4/17/1999	1100	530	<50	61	150	NA	<50
	1/17/2000	2,400D	1,600D	2.0J	180	550D	790D	<2.0
	7/13/2000	2,100JD	3,600D	3.0J	570E	2,500JD	2,500JD	<2.0
	1/10/2001	2,900D	1,200D	<5.0	62	150	210	<2.0
	7/10/2001	1,600	920J	<5.0	82	200	280	<2.0
	1/15/2002	300J	5,500	11	1,700	4,300	6,000	3.0
	7/31/2002	2,100	1,800	<250	400	1,100J	1,500J	<100
	1/27/2003	1,900	1,200	3.0J	380J	870	1,200	0.50J
	1/22/2004	1,900D	190D	0.60J	32	100	140	<2.0
	7/26/2004	3,900D	320D	<5.0	55	160	NA	<2.0

Table C59. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[VOC, volatile organic compound; D, sample dilution required; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; B, detected in blank; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; R, analytical result is unreliable; ND, constituent not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
82-SRW02[2]	4/22/1998	28	230	<10	NA	NA	190	<20
	7/28/1998	28	280	<12	NA	NA	410	<25
	1/15/1999	8.0	30	<5.0	6.0	25	NA	<5.0
	4/17/1999	6.0	90	<5.0	33	100	NA	2.0J
	10/25/1999	1,100D	24,000D	25	3,300D	8,700D	7,500	160
	1/17/2000	18	74	<5.0	20.0	71	91	<2.0
	7/13/2000	75	840JD	<5.0	200E	920JD	920JD	15
	1/10/2001	3.0J	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/18/2001	14	140	<5.0	54	150	200	4.0
	1/15/2002	18	140	<5.0	60	160	220	8.0
	1/27/2003	26	250	0.60J	120	260	340	25
	1/22/2004	150	310D	1.0J	170	340D	490D	13
	7/26/2004	43	90	<5.0	28	75	NA	1.0J
82-SRW03[2]	4/22/1998	130	1,600	<100	NA	NA	1,500	<100
	7/28/1998	100	1,200	<50	NA	NA	1,500	<100
	10/19/1998	350	2,100	<100	NA	NA	1,500	<100
	1/15/1999	180	520	<5.0	270	860	NA	22
	4/17/1999	220D	1,300D	2.0J	430D	1,100D	NA	10
	7/28/1999	370	2,900	<100	940	2,900	3,800	50
	10/23/1999	21	110	<5.0	27	99	120	<2.0
	1/17/2000	210	1,400	<50	460	1,200	1,700	25
	7/13/2000	72	2,200D	<5.0	660D	2,700D	3,300D	NA
	1/15/2001	66	1,500D	<5.0	640D	1,400D	1,700D	18
	7/10/2001	62	400	<5.0	160	2,000	2,500	11
	1/15/2002	53	520	<5.0	160	780	850	16
	7/31/2002	18	300R	1.0J	86	490R	570R	8.0
	1/27/2003	50	350	2.0J	120	540	670	23
	1/22/2004	42	510D	2.0J	230D	790D	1,000D	21
	7/26/2004	58	530D	2.0J	190	700D	NA	22
82-SRW04[2]	4/23/1998	360	2,800	<170	NA	NA	2,100	<330
	7/28/1998	190	1,400	<100	NA	NA	1,100	<200
	10/19/1998	87	650	<50	NA	NA	720	<50
	1/15/1999	86	960	<5.0	280	1,500	NA	79
	4/17/1999	80	450D	<10	90	350	NA	7.0J
	7/29/1999	560	1,100D	<50	410	1,300	1,700	25
	10/23/1999	82	6,500D	7.0	990D	6,100D	3,200	74
	1/17/2000	130	570D	<5.0	97	340D	430D	12
	7/13/2000	87	550D	<5.0	91	310D	390D	16
	1/10/2001	57	550D	<5.0	94	320D	390D	12

Table C59. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[VOC, volatile organic compound; D, sample dilution required; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; B, detected in blank; E, concentration exceeds calibration range of gas chromatograph/mass spectrometer; R, analytical result is unreliable; ND, constituent not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
82-SRW04[2]—Continued	7/10/2001	56	1,100	<5.0	60	720	880	9.0
	1/15/2002	49	180	<5.0	55	180	210	11
	7/31/2002	29	240R	0.4J	29	180	210	5.0
	1/27/2003	43	260	1.0J	50	210	310	9.0
	1/22/2004	36	320D	1.0J	72	290D	410D	15.0
	7/26/2004	14	310D	0.90J	44	240D	NA	9.0
82-SRW05[2]	4/23/1998	120	410	<25	NA	NA	470	<50
	7/28/1998	130	340	<20	NA	NA	380	<40
	10/19/1998	45	70	<2.0	NA	NA	<2.0	<2.0
	1/17/1999	64	200	<5.0	19	300	NA	8.0
	4/17/1999	86	240D	<5.0	<5.0	220D	NA	3.0J
	7/29/1999	130	360	<25	30	280	310	6.0J
	10/23/1999	50	87	<5.0	3.0J	40	44	<2.0
	1/17/2000	110	350D	<5.0	34	310D	340D	8.0
	7/13/2000	61	240D	<5.0	25	190	210	6.0
	1/10/2001	72	350D	<5.0	27	320D	340D	7.0
	7/10/2001	120	1,200	<5.0	12	660	690	6.0
	1/15/2002	72	200	<5.0	21	200	220	6.0
	7/31/2002	53	210	<10	14	180	200	2.0J
	1/22/2003	71	200	0.90J	17	490	610	3.0
	1/22/2004	170	390D	2.0J	84	240D	350	3.0
	7/26/2004	45	150	0.80J	9.0	140	NA	3.0
82-SRW06[2] (new)	1/17/2000	<5.0	120D	<5.0	20	89	110	4.0
	1/15/2001	130	2,600D	<5.0	140	1,300D	1,600D	15
	7/10/2001	120	1,200	<5.0	78	180	260	<2.0
	1/15/2002	42	1,000	2.0J	150	480	570	21
	7/31/2002	320R	1,600R	3.0J	190	690R	880R	12
	1/22/2003	200	1,200	2.0J	160	490	610	10
	1/22/2004	250D	980D	4.0J	220D	700D	930D	16
	7/26/2004	100	490D	1.0J	93	270D	NA	8.0

[1] See Figure C5 for location

[2] Well assigned to Site 6 in Camp Lejeune Water (CLW) documents and CERCLA Administrative Record files published after 1998

Data sources:

CERCLA Administrative Record files #236, #1272, #1781, #2037, #2300, #2322, #2337, #2599A, #2609A, #3276, #3277, #3278, #3410, #3637
Baker Environmental, Inc. 1993k, 1994a, 1997e, 1998g,h, 1999d,e
Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000e
Baker Environmental, Inc. and CH2M Hill, Inc. 2001a, 2002b,g
CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000b
Michael Baker, Jr., Inc. and CH2M Hill, Inc. 2003
Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2004

Table C60. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[VOC, volatile organic compound; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
82-DRW01[2]	4/17/1998	<500	<500	<500	<500
	7/28/1998	<1,000	<1,000	<1,000	<1,000
	10/19/1998	<2,000	<2,000	<2,000	NA
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	4/17/1999	2.0J	<5.0	<5.0	2.0J
	7/28/1999	<1,000	<1,000	<1,000	NA
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/13/2000	<5.0	<5.0	<5.0	3.0J
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	3.0J	<5.0	<5.0	2.0J
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	1/27/2003	1.0J	<10	0.70J	3.0J
	1/22/2004	0.70J	0.70J	0.50J	3.0J
	7/26/2004	0.80J	0.90J	0.50J	<15
82-DRW02[2]	4/16/1998	<500	<500	<500	<500
	7/24/1998	8.0	<5.0	<5.0	<5.0
	10/19/1998	<1,000	<1,000	<1,000	NA
	1/17/1999	11	<5.0	<5.0	<5.0
	4/17/1999	<500	<500	<500	<1,500
	7/29/1999	<100	<100	<100	NA
	10/21/1999	10	<5.0	<5.0	<5.0
	1/17/2000	11	<5.0	<5.0	<5.0
	7/13/2000	10	<5.0	<5.0	<5.0
	1/10/2001	11	<5.0	<5.0	<5.0
	7/10/2001	11	<5.0	<5.0	<5.0
	1/15/2002	<10	<5.0	<5.0	<5.0
	1/22/2003	10	0.20J	0.20J	1.0J
	1/22/2004	9.0	0.20J	0.30J	0.90J
	7/26/2004	8.0	<5.0	0.30J	<15
82-DRW03[2]	4/16/1998	<250	<250	<250	<250
	7/24/1998	<5.0	<5.0	<5.0	<5.0
	10/19/1998	<500	<500	<500	NA
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	4/17/1999	1.0J	<5.0	<5.0	<15
	7/28/1999	<5.0	<5.0	<5.0	NA
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/13/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0

Table C60. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[VOC, volatile organic compound; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
82-DRW03[2]—Continued	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	2.0J	<5.0	<5.0	<5.0
	1/27/2003	2.0J	<5.0	<5.0	<5.0
	1/22/2004	1.0J	<5.0	<5.0	<15
	7/26/2004	1.0J	<5.0	<5.0	<15
82-DRW04[2]	4/16/1998	<620	<620	<620	<620
	7/28/1998	<1,000	<1,000	<1,000	<1,000
	10/19/1998	<1,000	<1,000	<1,000	NA
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<50	<50	<50	<150
	7/29/1999	<5.0	<5.0	<5.0	NA
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/13/2000	3.0J	<5.0	<5.0	<5.0
	1/10/2001	5.0J	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	11	<5.0	<5.0	<5.0
	7/31/2002	8.0	0.20J	<5.0	<5.0
	1/27/2003	9.0	<10	<5.0	<5.0
	1/22/2004	8.0	<5.0	<5.0	<15
	7/26/2004	7.0	<5.0	<5.0	<15
82-MW01	10/23/1992	ND	ND	ND	ND
	3/23/1993	<1.0	<1.0	<1.0	<1.0
82-MW02	10/24/1992	ND	ND	ND	ND
	3/23/1993	<1.0	<1.0	<1.0	<1.0
	7/27/1997	<10	<10	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	<5.0
	4/15/1998	<5.0	<5.0	<5.0	<5.0
	7/25/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/28/1999	<5.0	<5.0	<5.0	NA
	1/12/2000	<5.0	<5.0	<5.0	<5.0
	7/12/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/11/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	1/21/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	0.20J	<5.0	<15

Table C60. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[VOC, volatile organic compound; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
82-MW03	3/23/1993	<1.0	<1.0	<1.0	<1.0
	7/23/1997	<10	<10	<10	<10
	1/17/1998	<5.0	<5.0	<5.0	<5.0
	4/15/1998	<5.0	<5.0	<5.0	<5.0
	7/24/1998	<5.0	<5.0	<5.0	<5.0
	1/16/1999	<5.0	<5.0	<5.0	<5.0
	7/28/1999	<5.0	<5.0	<5.0	NA
	1/13/2000	<5.0	<5.0	<5.0	<5.0
	7/12/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/13/2002	<5.0	<5.0	<5.0	<5.0
	7/29/2002	<5.0	<5.0	<5.0	<5.0
	1/22/2003	<5.0	<5.0	<5.0	<5.0
	1/21/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	<5.0	0.30J	<5.0	<15
82-MW30	3/22/1993	<1.0	<1.0	<1.0	<1.0
82-SRW01[2]	4/22/1998	<50	<50	<50	<50
	7/23/1998	<120	<120	<120	<120
	10/19/1998	<50	<50	<50	NA
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<50	<50	<50	<150
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/13/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	<250	<250	<250	<250
	1/27/2003	0.30J	<5.0	<5.0	<5.0
	1/22/2004	0.20J	<5.0	<5.0	<15
	7/26/2004	0.40J	<5.0	<5.0	<15
82-SRW02[2]	4/22/1998	<10	<10	<10	<10
	7/28/1998	<12	<12	<12	<12
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<15
	10/25/1999	10	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/13/2000	<5.0	<5.0	<5.0	<5.0

Table C60. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[VOC, volatile organic compound; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
82-SRW02[2]—Continued	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/18/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	1/27/2003	<5.0	<10	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	<5.0	<5.0	<5.0	<15
82-SRW03[2]	4/22/1998	<100	<100	<100	<100
	7/28/1998	<50	<50	<50	<50
	10/19/1998	<100	<100	<100	NA
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<15
	7/28/1999	<100	<100	<100	NA
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<50	<50	<50	<50
	7/13/2000	<5.0	<5.0	<5.0	<5.0
	1/15/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	<5.0	<5.0	<5.0	<5.0
	1/27/2003	<5.0	<5.0	<5.0	<5.0
	1/22/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	<5.0	<5.0	<5.0	<15
82-SRW04[2]	4/23/1998	<170	<170	<170	<170
	7/28/1998	<100	<100	<100	<100
	10/19/1998	<50	<50	<50	NA
	1/15/1999	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<10	<10	<10	<30
	7/29/1999	<50	<50	<50	NA
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/13/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	<5.0	<5.0	<5.0	<5.0
	1/27/2003	0.20J	<5.0	<5.0	<5.0
	1/22/2004	0.10J	<5.0	<5.0	<15
	7/26/2004	0.10J	<5.0	<5.0	<15

Table C60. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 82, VOC disposal area at Piney Green Road, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[VOC, volatile organic compound; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
82-SRW05[2]	4/23/1998	<25	<25	<25	<25
	7/28/1998	<20	<20	<20	<20
	10/19/1998	<2.0	<2.0	<2.0	NA
	1/17/1999	<5.0	<5.0	<5.0	<5.0
	4/17/1999	<5.0	<5.0	<5.0	<15
	7/29/1999	<25	<25	<25	NA
	10/23/1999	<5.0	<5.0	<5.0	<5.0
	1/17/2000	<5.0	<5.0	<5.0	<5.0
	7/13/2000	<5.0	<5.0	<5.0	<5.0
	1/10/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	1.0J	<10	<10	<10
	1/22/2003	1.0J	<5.0	<5.0	<5.0
	1/22/2004	0.70J	<5.0	<5.0	<15
	7/26/2004	0.80J	<5.0	<5.0	<15
82-SRW06[2]	1/17/2000	<5.0	<5.0	<5.0	<5.0
(new)	1/15/2001	<5.0	<5.0	<5.0	<5.0
	7/10/2001	<5.0	<5.0	<5.0	<5.0
	1/15/2002	<5.0	<5.0	<5.0	<5.0
	7/31/2002	2.0J	<5.0	<5.0	<5.0
	1/22/2003	1.0J	<5.0	<5.0	<5.0
	1/22/2004	1.0	<5.0	<5.0	<15
	7/26/2004	0.50J	<5.0	<5.0	<15

[1] See Figure C5 for location

[2] Well assigned to Site 6 in Camp Lejeune Water (CLW) documents and CERCLA Administrative Record files published after 1998

Data sources:

CERCLA Administrative Record files #236, #1272, #1781, #2037, #2300, #2322, #2337, #2599A, #2609A, #3276, #3277, #3278, #3410, #3637

Baker Environmental, Inc. 1993k, 1994a, 1997e, 1998g,h, 1999de

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000e

Baker Environmental, Inc. and CH2M Hill, Inc. 2001a, 2002b,g

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2000b

Michael Baker, Jr., Inc. and CH2M Hill, Inc. 2003

Michael Baker, Jr., Inc. and Engineering and Environment, Inc. 2004

Table C61. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 84, Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[Names in parentheses refer to corporations or companies that installed the well: ATEC—American Testing and Engineering Corp. 1992, Baker—Baker Environmental Inc. and CH2M Hill Inc. 2002e, D&D—Dewberry and Davis 1991, Jones—J.A. Jones Environmental Services Company 1999, Law—Law Engineering Inc. 1993, O&G—O'Brien and Gere Engineers Inc. 1992, Wright—R.E. Wright Associates Inc. 1994; NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, TTAQ—Tarawa Terrace aquifer; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
45-1-MW01 (Wright)	361298	2495380	[3]20	Before 1/5/1993	N/A	N/A	BBLAQ(?)
45-1-MW02 (Wright)	361281	2495372	[3]20	Before 1/5/1993	N/A	N/A	BBLAQ(?)
45-1-MW03 (Wright)	361294	2495483	[3]20	Before 1/5/1993	N/A	N/A	BBLAQ(?)
45-1-MW04 (Wright)	361339	2495184	[3]15	Before 1/5/1993	N/A	N/A	BBLAQ(?)
45-1-MW05 (Wright)	361313	2495287	[3]18	Before 1/5/1993	N/A	N/A	BBLAQ(?)
MW15 (Baker)	361295	2495541	21.8	7/31/2001	N/A	N/A	BBLAQ
MW16 (Baker)	361519	2495466	20.1	7/31/2001	20.0	10.0–20.0	TTAQ
MW17 (Baker)	361448	2495309	16.5	7/31/2001	17.5	7.5–17.5	BBLAQ, TTAQ
MW18 (Baker)	361204	2495590	22.8	8/1/2001	15.0	5.0–15.0	BBLAQ
MW19 (Baker)	361296	2495251	18.3	8/1/2001	19.0	9.0–19.0	BBLAQ, TTAQ
MW20 (Baker)	361584	2495131	8.6	8/1/2001	12.0	2.0–12.0	BBLAQ, TTAQ
MW21 (Baker)	361258	2495406	21.4	8/2/2001	15.0	5.0–15.0	BBLAQ, TTAQ
MW22 (Baker)	361414	2495374	19.9	8/3/2001	22.0	8.0–22.0	BBLAQ, TTAQ
MW23 (Baker)	361951	2494960	5.3	8/3/2001	12.0	2.0–12.0	BBLAQ, TTAQ
AST-S781-MW01 (O&G)	361436	2495348	[4]22.3	12/4/1991	20.0	5.0–20.0	BBLAQ, BBLCU, TTAQ
AST-S781-MW02 (O&G)	361436	2495348	[4]22.1	12/5/1991	30.0	20.0–30.0	TTAQ
AST-S781-MW03 (O&G)	361430	2495235	[4]18.6	12/4/1991	15.0	5.0–15.0	BBLAQ, BBLCU, TTAQ
AST-S781-MW04 (O&G)	361430	2495235	[4]18.4	12/5/1991	30.0	20.0–30.0	TTAQ
AST-S781-MW05 (O&G)	361589	2495398	[4]19.1	12/5/1991	15.0	5.0–15.0	BBLAQ, BBLCU, TTAQ
AST-S781-MW06 (O&G)	361589	2495398	[4]18.1	12/6/1991	30.0	20.0–30.0	TTAQ
AST-S781-MW07 (O&G)	361717	2495105	[4]8.7	12/6/1991	15.0	5.0–15.0	BBLAQ, BBLCU, TTAQ
AST-S781-MW08 (O&G)	361717	2495105	[4]8.9	12/6/1991	30.0	20.0–30.0	TTAQ
AST-S781-MW09 (O&G)	361217	2494823	[4]12.9	12/9/1991	15.0	5.0–15.0	BBLAQ, BBLCU, TTAQ
AST-S781-MW10 (O&G)	361217	2494823	[4]12.9	12/9/1991	30.0	20.0–30.0	TTAQ
AST-S781-MW11 (O&G)	361168	2495225	[4]19.1	12/9/1991	15.0	5.0–15.0	BBLAQ, BBLCU, TTAQ
AST-S781-MW12 (O&G)	361168	2495225	[4]19.2	12/10/1991	30.0	20.0–30.0	TTAQ

Table C61. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 84, Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[Names in parentheses refer to corporations or companies that installed the well: ATEC—American Testing and Engineering Corp. 1992, Baker—Baker Environmental Inc. and CH2M Hill Inc. 2002e, D&D—Dewberry and Davis 1991, Jones—J.A. Jones Environmental Services Company 1999, Law—Law Engineering Inc. 1993, O&G—O'Brien and Gere Engineers Inc. 1992, Wright—R.E. Wright Associates Inc. 1994; NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, TTAQ—Tarawa Terrace aquifer; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
AST-S781-MW13 (O&G)	361610	2494936	[4]8.9	12/11/1991	12.0	2.0–12.0	BBLAQ, BBLCU, TTAQ
AST-S781-MW14 (O&G)	361610	2494936	[4]8.9	12/10/1991	27.0	17.0–27.0	TTAQ
AST-S781-MWA (D&D) AKA MPMW-1	361523	2495253	11.3	11/27/1990	23.0	8.0–23.0	BBLAQ, BBLCU, TTAQ
AST-S781-MWB (D&D) AKA MPMW-2	361560	2495277	11.7	11/28/1990	18.0	5.0–18.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW01 (ATEC)	361246	2495574	[3]23	8/26/1991	14.6	2.2–14.6	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW02 (ATEC)	361260	2495563	[3]23	8/26/1991	14.5	2.2–14.5	BBLAQ, BBLCU TTAQ
UST-Bldg45-MW03 (ATEC)	361269	2495590	[3]23	8/26/1991	20.0	2.5–20.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW04 (Law)	361145	2495545	[3]22	Before 1/5/1993	21.0	6.0–21.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW05 (Law)	361406	2495558	[3]21	Before 1/5/1993	19.5	4.5–19.5	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW06 (Law)	361360	2495631	[3]20	Before 1/5/1993	50.0	45.0–50.0	TTAQ
UST-Bldg45-MW07 (Law)	361308	2495583	[3]22	Before 1/5/1993	23.0	3.0–23.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW08 (Law)	361356	2495636	[3]20	Before 1/5/1993	19.0	4.0–19.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW09 (Law)	361312	2495579	[3]21	Before 1/5/1993	50.0	45.0–50.0	TTAQ
UST-Bldg45-MW10 (Law)	361308	2495552	[3]22	Before 1/5/1993	18.0	3.0–18.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW11 (Law)	361202	2495617	[3]24	Before 12/2/1993	15.5	5.5–15.5	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW12 (Law)	361166	2495527	[3]22	Before 12/2/1993	16.0	6.0–16.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW13 (Law)	361207	2495416	[3]20	Before 12/2/1993	16.0	6.0–16.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW14 (Law)	361254	2495286	[3]18	Before 1/11/1994	16.0	6.0–16.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW15 (Law)	361316	2495343	[3]19	Before 1/11/1994	16.0	6.0–16.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW16 (Law)	361277	2495399	[3]21	Before 12/2/1993	16.0	6.0–16.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW17 (Law)	361365	2495544	[3]22	Before 1/11/1994	14.8	4.8–14.8	BBLAQ, BBLCU, TTAQ

Table C61. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 84, Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[Names in parentheses refer to corporations or companies that installed the well: ATEC—American Testing and Engineering Corp. 1992, Baker—Baker Environmental Inc. and CH2M Hill Inc. 2002e, D&D—Dewberry and Davis 1991, Jones—J.A. Jones Environmental Services Company 1999, Law—Law Engineering Inc. 1993, O&G—O'Brien and Gere Engineers Inc. 1992, Wright—R.E. Wright Associates Inc. 1994; NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBLCU—Brewster Boulevard lower confining unit, TTAQ—Tarawa Terrace aquifer; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
UST-Bldg45-MW18 (Law)	361272	2495544	[3]23	Before 1/11/1994	16.0	6.0–16.0	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW19 (Law)	361241	2495675	[3]22	Before 1/11/1994	13.5	3.5–13.5	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW20 (Law)	361294	2495650	[3]21	Before 1/11/1994	14.5	4.5–14.5	BBLAQ, BBLCU, TTAQ
UST-Bldg45-MW21 (Law)	361260	2495281	[3]18	Before 1/11/1994	50.0	45.0–50.0	TTAQ
UST-Bldg45-MW22 (Law)	361111	2495586	[3]23	Before 1/11/1994	50.7	45.7–50.7	TTAQ
UST-Bldg45-PW01 (Law)	361295	2495567	[3]22	Before 1/5/1993	23.0	3.0–23.0	BBLAQ, BBLCU, TTAQ

[1] See Figure C25 for location. Site names are truncated on Figure C25, and they are color-coded by corporation or company that installed the wells. Law wells MW11–MW22 and Baker wells MW15–MW23 are not shown

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

[4] Altitude at top of casing

Data sources:

- CERCLA Administrative Record files #125, #269, #3018, #3269
- Leaking Underground Storage Tank Site Assessment report files #730, #742
- American Testing and Engineering Corporation, 1992
- Baker Environmental, Inc. 2001a
- CH2M Hill, Inc. and Baker Environmental, Inc. 2002
- Law Engineering, Inc. 1993
- Law Engineering and Environmental Services, Inc. 1996
- O'Brien and Gere Engineers, Inc. 1992

Table C62. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 84, Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[Names in parentheses refer to corporations or companies who installed the well: ATEC—American Testing and Engineering Corp. 1992, Baker—Baker Environmental Inc. and CH2M Hill Inc. 2002f, Law—Law Engineering Inc. 1993, O&G—O'Brien and Gere Engineers Inc. 1992; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
MW16 (Baker)	8/4/2001	<0.16	NA	<0.12	<0.33
MW17 (Baker)	8/6/2001	<0.16	NA	0.06J	1.8
MW18 (Baker)	8/4/2001	<0.16	NA	<0.12	<0.33
MW19 (Baker)	8/4/2001	<0.16	NA	<0.12	<0.33
MW20 (Baker)	8/5/2001	<0.16	NA	<0.12	<0.33
MW21 (Baker)	8/5/2001	<0.16	NA	<0.12	<0.33
MW22 (Baker)	8/5/2001	<0.16	NA	3.6	<0.33
MW23 (Baker)	8/6/2001	<0.16	NA	<0.12	<0.33
AST-S781-MW01 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
AST-S781-MW02 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
AST-S781-MW03 (O&G)	12/12/1991	<10	<10	16	<30
	4/23/1998	3.4J	<10	3.6J	<10
AST-S781-MW04 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
	4/23/1998	1.5J	<10	6.7J	<10
AST-S781-MW05 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
AST-S781-MW06 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
AST-S781-MW07 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
	4/22/1998	<10	<10	<10	<10
AST-S781-MW08 (O&G)	12/12/1991	<10	<10	<10	<30
	4/22/1998	<10	<10	<10	<10
AST-S781-MW09 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
AST-S781-MW10 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
AST-S781-MW11 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
	4/23/1998	<10	<10	<10	<10
AST-S781-MW12 (O&G)	12/12/1991	<1.0	2.0	<1.0	<3.0
	4/23/1998	<10	<10	<10	<10
AST-S781-MW13 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
AST-S781-MW14 (O&G)	12/12/1991	<1.0	<1.0	<1.0	<3.0
UST-Bldg45-MW01 (ATEC)	8/28/1991	9,800	16,000	1,000	4,700
UST-Bldg45-MW02 (ATEC)	8/28/1991	290	69	<5.0	83
UST-Bldg45-MW03 (ATEC)	8/28/1991	10	<5.0	<5.0	22
UST-Bldg45-MW04 (Law)	1/5/1993	ND	ND	ND	ND
UST-Bldg45-MW05 (Law)	1/5/1993	ND	ND	ND	ND
UST-Bldg45-MW06 (Law)	1/5/1993	ND	ND	ND	ND
UST-Bldg45-MW07 (Law)	1/5/1993	ND	ND	ND	ND
UST-Bldg45-MW08 (Law)	1/5/1993	ND	ND	ND	ND
	8/6/2001	<0.16	NA	<0.12	<0.33
UST-Bldg45-MW09 (Law)	1/5/1993	ND	ND	ND	ND
	8/5/2001	<0.16	NA	<0.12	<0.33

Table C62. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 84, Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[Names in parentheses refer to corporations or companies who installed the well: ATEC—American Testing and Engineering Corp. 1992, Baker—Baker Environmental Inc. and CH2M Hill Inc. 2002f, Law—Law Engineering Inc. 1993, O&G—O'Brien and Gere Engineers Inc. 1992; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; ND, not detected]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
UST-Bldg45-MW10 (Law)	1/5/1993	ND	ND	1.6	1.6
	8/5/2001	<0.16	NA	<0.12	<0.33
UST-Bldg45-MW11 (Law)	12/2/1993	ND	ND	ND	ND
UST-Bldg45-MW12 (Law)	12/2/1993	ND	ND	ND	ND
UST-Bldg45-MW13 (Law)	12/2/1993	ND	ND	ND	ND
UST-Bldg45-MW14 (Law)	1/11/1994	ND	ND	ND	ND
UST-Bldg45-MW15 (Law)	1/11/1994	3,800	1,700	800	3,600
UST-Bldg45-MW16 (Law)	12/3/1993	ND	0.70	ND	1.3
UST-Bldg45-MW17 (Law)	1/11/1994	ND	ND	ND	ND
UST-Bldg45-MW18 (Law)	1/11/1994	1,200	74	84	230
UST-Bldg45-MW19 (Law)	1/11/1994	ND	ND	ND	ND
UST-Bldg45-MW20 (Law)	1/11/1994	ND	8.2	4.8	ND
UST-Bldg45-MW21 (Law)	1/11/1994	ND	ND	ND	ND
UST-Bldg45-MW22 (Law)	1/11/1994	ND	ND	ND	ND
UST-Bldg45-PW01 (Law)	1/5/1993	87	700	70	1,900

[1] See Figure C25 for location. Site names are truncated on Figure C25, and they are color-coded by corporation or company that installed the wells. Law wells MW11–MW22 and Baker wells MW16–MW23 are not shown

Data sources:

CERCLA Administrative Record files #269, #270, #2636A, #3268
Leaking Underground Storage Tank Site Assessment report files #730, #742
American Testing and Engineering Corporation, 1992
Baker Environmental, Inc. 1998e
Baker Environmental, Inc. and CH2M Hill, Inc. 2002e
Law Engineering and Environmental Services, Inc. 1996
O'Brien and Gere Engineers, Inc. 1992, 1993

Table C63. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans* 1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 84, Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[Names in parentheses refer to corporations or companies who installed the well: Baker—Baker Environmental Inc. and CH2M Hill Inc. 2002f, Law—Law Engineering Inc. 1993, O&G—O'Brien and Gere Engineers Inc. 1992; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
MW16 (Baker)	8/4/2001	NA	<0.14	NA	NA	NA	NA	NA
MW17 (Baker)	8/6/2001	NA	0.19J	NA	NA	NA	NA	NA
MW18 (Baker)	8/4/2001	NA	<0.14	NA	NA	NA	NA	NA
MW19 (Baker)	8/4/2001	NA	<0.14	NA	NA	NA	NA	NA
MW20 (Baker)	8/5/2001	NA	<0.14	NA	NA	NA	NA	NA
MW21 (Baker)	8/5/2001	NA	<0.14	NA	NA	NA	NA	NA
MW22 (Baker)	8/5/2001	NA	<0.14	NA	NA	NA	NA	NA
MW23 (Baker)	8/6/2001	NA	<0.14	NA	NA	NA	NA	NA
AST-S781-MW01 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
AST-S781-MW02 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
AST-S781-MW03 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	4/23/1998	<10	<10	<10	NA	NA	<10	<10
AST-S781-MW04 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	2.0	<1.0
	4/23/1998	<10	<10	<10	NA	NA	<10	<10
AST-S781-MW05 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
AST-S781-MW06 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
AST-S781-MW07 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	4/22/1998	<10	<10	<10	NA	NA	<10	<10
AST-S781-MW08 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	4/22/1998	<10	<10	<10	NA	NA	<10	<10
AST-S781-MW09 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
AST-S781-MW10 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
AST-S781-MW11 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	4/23/1998	<10	<10	<10	NA	NA	<10	<10
AST-S781-MW12 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	4/23/1998	<10	<10	<10	NA	NA	<10	<10
AST-S781-MW13 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0

Table C63. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans* 1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 84, Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[Names in parentheses refer to corporations or companies who installed the well: Baker—Baker Environmental Inc. and CH2M Hill Inc. 2002f, Law—Law Engineering Inc. 1993, O&G—O'Brien and Gere Engineers Inc. 1992; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
AST-S781-MW14 (O&G)	12/12/1991	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
UST-Bldg45-84-MW07 (Law)	8/6/2001	NA	<0.14	NA	NA	NA	NA	NA
UST-Bldg45-84-MW08 (Law)	8/6/2001	NA	<0.14	NA	NA	NA	NA	NA
UST-Bldg45-84-MW09 (Law)	8/5/2001	NA	<0.14	NA	NA	NA	NA	NA
UST-Bldg45-84-MW10 (Law)	8/5/2001	NA	<0.14	NA	NA	NA	NA	NA

[1] See Figure C25 for location. Site names are truncated on Figure C25, and they are color-coded by corporation or company that installed the wells. Baker wells MW16–MW23 are not shown

Data sources:

CERCLA Administrative Record files #269, #270, #2636A, #3268

Baker Environmental, Inc. 1998e

Baker Environmental, Inc. and CH2M Hill, Inc. 2002e

O'Brien and Gere Engineers, Inc. 1992, 1993

Table C64. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected at hydropunch locations at Installation Restoration Site 84, Tank S781/Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[Names in parentheses refer to corporations or companies who installed the well: Law—Law Engineering Inc. 1993; NGVD 29, National Geodetic Vertical Datum of 1929; contributing aquifer: BBLAQ—Brewster Boulevard lower aquifer, TTAQ—Tarawa Terrace aquifer; ND, not detected; NA, constituent concentration not determined or analytical result is unknown]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Sample interval, in feet below land surface	Sample date	Contributing aquifer	Concentration, in micrograms per liter			
	North	East					Benzene	Toluene	Ethyl-benzene	Total xylene
HP-1 (Law)	361308	2495566	[3]22	8.5–10.0	1993	BBLAQ	ND	ND	ND	ND
HP-2 (Law)	361312	2495566	[3]22	NA	1993	BBLAQ(?)	NA	NA	NA	NA
HP-3 (Law)	361391	2495506	[3]21	16.0–19.0	1993	BBLAQ	ND	1.3	ND	ND
HP-4 (Law)	361199	2495495	[3]22	25.5–27.0	1993	TTAQ	64	83	3.2	17
HP-5 (Law)	361250	2495566	[3]23	8.5–10.0	1993	BBLAQ	ND	0.7	ND	ND
HP-6 (Law)	361338	2495538	[3]22	8.5–10.0	1993	BBLAQ	ND	ND	ND	ND
HP-7 (Law)	361317	2495515	[3]22	8.5–12.0	1993	BBLAQ	ND	0.8	ND	ND
HP-8 (Law)	361284	2495608	[3]21	8.5–10.0	1993	BBLAQ	ND	0.6	ND	ND
HP-9 (Law)	361279	2495609	[3]21	22.0–23.5	1993	TTAQ	1.0	1.3	ND	ND
HP-10 (Law)	361377	2495548	[3]21	28.2–29.7	1993	TTAQ	ND	0.8	ND	ND

[1] See Figure C25 for location. Site names are color-coded by corporation or company that installed the wells

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data source:

Leaking Underground Storage Tank Site Assessment report file #742

Law Engineering and Environmental Services, Inc. 1996

Table C65. Summary of BTEX free-phase measurements in monitor wells at Installation Restoration Site 84, Building 45 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[Names in parentheses refer to corporations or companies who installed the well: ATEC—American Testing and Engineering Corp. 1992; BTEX, benzene, toluene, ethylbenzene, and xylene]

Site name[1]	Sample date	BTEX free-phase thickness, in feet
UST-Bldg45-MW02 (ATEC)	1/11/1994	2.29
	9/6/1994	0.61
	9/12/1994	1.06
	9/19/1994	0.80
	9/26/1994	0.66
	2/3/1995	0.15
	2/6/1995	0.15
	2/9/1995	0.00
	2/13/1995	0.00
	2/21/1995	0.00
	6/5/1995	0.02
UST-Bldg45-MW03 (ATEC)	1/11/1994	0.50
	9/12/1994	0.02

[1] See Figure C25 for location. Site names are truncated on Figure C25, and they are color-coded by corporation or company that installed the wells

Data source:

Leaking Underground Storage Tank Site Assessment report file #742

Law Engineering and Environmental Services, Inc. 1996

Table C66. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, TTAQ—Tarawa Terrace aquifer; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
88-EX01	339427	2496473	25.6	12/3/1997	20.0	15.0–19.5	BBUAQ
88-EX02	339440	2496476	25.6	12/3/1997	21.2	16.1–20.7	BBUAQ
88-EX03	339451	2496479	25.6	12/4/1997	19.9	14.6–19.1	BBUAQ
88-EX04	339420	2496500	25.7	12/4/1997	21.1	16.2–20.8	BBUAQ
88-EX04R	339417	2496502	25.7	3/23/1998	19.7	14.8–19.4	BBUAQ
88-EX05	339428	2496504	25.2	12/4/1997	21.8	16.5–21.1	BBUAQ
88-EX06	339438	2496506	25.5	12/5/1997	20.4	15.2–19.8	BBUAQ
88-HCO1	339411	2496484	26.4	N/A	22.7	11.4–20.5	BBUAQ
88-HCO2	339454	2496495	25.9	12/9/1997	20.4	7.5–12.0	BBUAQ
88-IN01	339422	2496487	25.5	12/8/1997	22.5	7.54–11.54	BBUAQ
88-IN02	339433	2496490	25.5	12/8/1997	19.7	7.02–11.02	BBUAQ
88-IN03	339444	2496492	25.8	12/8/1997	20.0	7.4–11.4	BBUAQ
88-IW01	339428	2496495	25.6	8/20/1997	18.5	14.2–18.7	BBUAQ
88-MW01	339268	2496740	26.5	5/1/1997	22.0	7.0–22.0	BBUAQ, BBUCU, BBLAQ
88-MW02	339347	2496489	26.6	5/2/1997	23.0	8.0–23.0	BBUAQ, BBUCU, BBLAQ
88-MW02DW	339364	2496466	26.6	4/20/1997	97.0	92.0–97.0	TTAQ, TTCU
88-MW02IW	339353	2496481	26.6	5/3/1997	50.0	45.0–50.0	BBLAQ
88-MW03	339503	2496545	25.9	5/1/1997	15.0	5.0–15.0	BBUAQ
88-MW03DW	339508	2496540	25.9	4/30/1997	85.0	80.0–85.0	TTAQ
88-MW03IW	339499	2496563	25.9	5/1/1997	50.0	45.0–50.0	BBLAQ
88-MW04	339076	2496489	23.1	5/2/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-MW04DW	339090	2496474	25.0	4/18/1997	85.0	80.0–85.0	TTAQ, TTCU
88-MW04IW	339079	2496481	25.0	5/2/1997	50.0	45.0–50.0	BBLAQ
88-MW05	339618	2496406	24.6	5/3/1997	23.0	8.0–23.0	BBUAQ, BBUCU, BBLAQ
88-MW05DW	339601	2496397	24.7	4/22/1997	80.0	80.0–85.0	TTAQ, TTCU
88-MW05IW	339608	2496405	24.7	5/3/1997	50.0	45.0–50.0	BBLAQ
88-MW06	339340	2496286	24.6	5/4/1997	23.0	8.0–23.0	BBUAQ, BBUCU, BBLAQ
88-MW06IW	339346	2496294	24.6	5/4/1997	50.0	45.0–50.0	BBLAQ
88-MW07	339944	2496027	23.6	5/6/1997	22.0	7.0–22.0	BBUAQ, BBUCU, BBLAQ
88-MW07IW	339945	2496042	23.7	5/5/1997	50.0	45.0–50.0	BBLAQ
88-MW08	339583	2495865	23.2	5/7/1997	20.0	5.0–20.0	BBUAQ, BBUCU, BBLAQ
88-MW08IW	339572	2495868	23.1	5/7/1997	50.0	45.0–50.0	BBLAQ
88-MW09	339080	2496100	22.1	5/5/1997	21.0	6.0–21.0	BBUAQ, BBUCU, BBLAQ
88-MW09IW	339071	2496110	22.0	5/5/1997	50.0	45.0–50.0	BBLAQ
88-MW10IW	339442	2496487	25.8*	NA	39.0	34.2–38.7	BBLAQ
88-MWRAB1	339675	2496307	[3]25	N/A	47.3	45.75–47.25	BBLAQ
88-MWRAB6	339651	2496337	[3]25	N/A	47.3	45.75–47.25	BBLAQ
88-RW01	339435	2496475	25.5	8/19/1997	20.0	15.1–19.3	BBUAQ
88-RW02	339430	2496488	25.5	8/19/1997	20.0	14.6–19.1	BBUAQ
88-RW03	339417	2496467	26.5	N/A	22.0	6.8–10.7	BBUAQ

Table C66. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, TTAQ—Tarawa Terrace aquifer; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
88-RW04	339417	2496511	25.8	N/A	23.4	7.6–12.1	BBUAQ
88-RW06	339406	2496507	26.5	N/A	21.1	7.8–12.3	BBUAQ
88-TW01	339409	2496512	[3]26	11/12/1995	N/A	14.6–16.6	BBUAQ
88-TW02	339434	2496477	25.8*	11/12/1995	N/A	14.6–16.6	BBUAQ
88-TW03	339430	2496438	25.9	11/12/1995	N/A	14.6–16.6	BBUAQ
88-TW04	339353	2496455	26.5	11/12/1995	N/A	14.6–16.6	BBUAQ
88-TW04IW	339352	2496459	26.5	8/16/1996	50.0	45.0–50.0	BBLAQ
88-TW05	339225	2496434	25.7	8/16/1996	15.0	5.0–15.0	BBUAQ
88-TW05IW	339228	2496433	26.0	8/18/1996	50.0	45.0–50.0	BBLAQ
88-TW06	339496	2496512	25.6	8/16/1996	15.0	5.0–15.0	BBUAQ
88-TW07	339309	2496617	26.5	8/16/1996	15.0	5.0–15.0	BBUAQ
88-TW08	339548	2496377	24.7	8/16/1996	15.0	5.0–15.0	BBUAQ
88-TW08IW	339541	2496376	24.7	8/18/1996	44.0	39.0–44.0	BBLAQ
88-TW09	339353	2496363	25.7	8/16/1996	18.0	8.0–18.0	BBUAQ
88-TW10	339402	2496594	[3]26	8/17/1996	15.0	5.0–15.0	BBUAQ
88-TW11	339211	2496647	26.1	8/17/1996	15.0	5.0–15.0	BBUAQ
88-TW12	339187	2496531	26.6	8/17/1996	20.0	10.0–20.0	BBUAQ
88-TW13	339262	2496340	25.2	8/17/1996	19.0	9.0–19.0	BBUAQ
88-TW14	339413	2496633	26.1	8/17/1996	15.0	5.0–15.0	BBUAQ
88-TW15	339408	2496330	24.7	8/17/1996	18.0	8.0–18.0	BBUAQ
88-TW16	339085	2496245	23.9	8/18/1996	17.0	7.0–17.0	BBUAQ
88-TW17	338997	2496424	25.0	8/18/1996	19.0	9.0–19.0	BBUAQ
88-TW18	339264	2496021	22.3	8/19/1996	15.0	5.0–15.0	BBUAQ
88-TW19	339573	2495863	23.2	8/20/1996	18.0	8.0–18.0	BBUAQ
88-TW19IW	339577	2495861	23.2	8/19/1996	50.0	45.0–50.0	BBLAQ
88-TW20	339139	2496176	23.0	4/14/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-TW20IW	339130	2496170	23.0	4/14/1997	50.0	45.0–50.0	BBLAQ
88-TW21	339333	2496128	23.8	4/15/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-TW21IW	339325	2496100	23.9	4/15/1997	50.0	45.0–50.0	BBLAQ
88-TW22	339583	2496135	23.4	4/15/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-TW22IW	339596	2496140	23.3	4/15/1997	50.0	45.0–50.0	BBLAQ
88-TW23	339756	2496376	24.0	4/16/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-TW23IW	339760	2496365	24.0	4/16/1997	50.0	45.0–50.0	BBLAQ
88-TW24	339814	2496102	24.3	4/16/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-TW24IW	339820	2496110	24.2	4/16/1997	50.0	45.0–50.0	BBLAQ
88-TW25	339995	2496391	24.7	4/17/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-TW25IW	340078	2496390	24.7	4/17/1997	50.0	45.0–50.0	BBLAQ
88-TW26	339738	2496689	25.8	4/17/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-TW26IW	339700	2496690	25.8	4/17/1997	50.0	45.0–50.0	BBLAQ
88-TW27	339525	2495957	22.6	4/29/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ

Table C66. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, TTAQ—Tarawa Terrace aquifer; N/A, not available]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
88-TW27IW	339576	2495960	22.7	4/29/1997	50.0	45.0–50.0	BBLAQ
88-TW28	339693	2495975	24.4	4/29/1997	25.0	10.0–25.0	BBUAQ, BBUCU, BBLAQ
88-TW28IW	339700	2496000	24.6	4/29/1997	50.0	45.0–50.0	BBLAQ
88-WP01AQT	339439	2496484	25.6*	6/26/1998	23.0	22.0–23.0	BBLAQ
88-WP02AQT	339440	2496485	25.6*	6/26/1998	25.0	24.0–25.0	BBLAQ

[1] See Figures C26 and C27 for location. Test well (TW) locations are not shown

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data sources:

CERCLA Administrative Record files #1738, #1747, #2020, #2032, #2302, #2324, #2598, #3187, #3188

Baker Environmental, Inc. 1996h,l, 1998b,c

CH2M Hill, Inc. 2003

Duke Engineering and Services, Inc. and Baker Environmental, Inc. 1998, 1999a, 2000

OHM Remediation Services Corp. 1996a

Table C67. Location coordinates and land-surface altitude at soil boring locations at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Vertical Geodetic Datum of 1929]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29
	North	East	
88-CPT01	339429	2496571	[3]26
88-CPT02	339440	2496536	[3]26
88-CPT03	339441	2496492	[3]26
88-CPT04	339466	2496498	[3]26
88-CPT05	339487	2496425	[3]25
88-CPT07	339434	2496411	[3]25
88-CPT08	339356	2496402	[3]25
88-CPT09	339341	2496466	[3]26
88-CPT10	339325	2496516	[3]26
88-IS01	339427	2496505	[3]26
88-IS02	339426	2496510	[3]26
88-IS03	339420	2496513	[3]26
88-IS04	339362	2496472	[3]26
88-IS05	339403	2496488	[3]26
88-IS06	339370	2496441	[3]26
88-IS07	339432	2496495	[3]26
88-IS08	339434	2496475	[3]26
88-IS09	339387	2496487	[3]26
88-IS10	339432	2496486	[3]26
88-IS11	339444	2496484	[3]26
88-IS12	339440	2496453	[3]26
88-IS13	339440	2496483	[3]26
88-IS14	339434	2496511	[3]26
88-IS15	339451	2496491	[3]26
88-IS16	339421	2496516	[3]26
88-IS17	339445	2496469	[3]26
88-IS18	339458	2496462	[3]26
88-IS19	339433	2496501	[3]26
88-IS20	339454	2496483	[3]26
88-IS21	339421	2496501	[3]26
88-IS22	339425	2496491	[3]26
88-IS23	339437	2496492	[3]26
88-IS25	339437	2496485	[3]26
88-IS26	339435	2496495	[3]26
88-IS28	339395	2496543	[3]26
88-IS29	339411	2496471	[3]26
88-IS30	339399	2496504	[3]26
88-IS31	339400	2496532	[3]26
88-SB01	339319	2496555	[3]26
88-SB02	339296	2496550	[3]26
88-SB03	339380	2496490	[3]26
88-SB04	339449	2496427	[3]25
88-SB05	339447	2496342	[3]25
88-SB06	339294	2496363	[3]25

[1] See Figure C27 for location. 88-SB01–88-SB06 are not shown in Figure C27

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

Data sources:

- CERCLA Administrative Record files #1979, #2020, #2324
- Baker Environmental, Inc. 1998c
- Duke Engineering and Services, Inc. and Baker Environmental, Inc. 1999a
- OHM Remediation Services Corp. 1996a

Table C68. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in soil samples collected in monitor well boreholes at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Sample depth or interval, in feet below land surface	Concentration, in micrograms per kilogram							
			PCE	TCE	Total DCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
88-CPT01	11/15/1997	15.2	ND	ND	ND	NA	NA	NA	NA	NA
88-CPT02	11/15/1997	17.2	ND	ND	ND	NA	NA	NA	NA	NA
88-CPT03	11/15/1997	18.2	32	ND	ND	NA	NA	NA	NA	NA
88-CPT04	11/15/1997	18.2	60	ND	ND	NA	NA	NA	NA	NA
88-CPT05	11/15/1997	19.5	1.3	ND	ND	NA	NA	NA	NA	NA
88-CPT07	11/15/1997	17.0	3.9	0.3	ND	NA	NA	NA	NA	NA
88-CPT08	11/15/1997	21.0	8.0	0.3	ND	NA	NA	NA	NA	NA
88-CPT09	11/15/1997	17.6	3.0	ND	ND	NA	NA	NA	NA	NA
88-CPT10	11/15/1997	18.4	0.5	ND	ND	NA	NA	NA	NA	NA
88-EX01	12/3/1997	16.5	3,013	ND	ND	NA	NA	NA	NA	NA
		17.5	44,352	ND	ND	NA	NA	NA	NA	NA
		18.5	29,763	ND	ND	NA	NA	NA	NA	NA
88-EX03	12/4/1997	16.0	1.2	ND	ND	NA	NA	NA	NA	NA
		17.5	19	ND	ND	NA	NA	NA	NA	NA
		19.0	96	ND	ND	NA	NA	NA	NA	NA
88-EX04	12/4/1997	17.0	122	1.8	2.2	NA	NA	NA	NA	NA
		18.5	25	ND	ND	NA	NA	NA	NA	NA
		19.5	11,743	ND	ND	NA	NA	NA	NA	NA
88-EX05	12/4/1997	18.0	2.3	ND	0.40	NA	NA	NA	NA	NA
		19.0	0.8	ND	3.1	NA	NA	NA	NA	NA
		20.0	86	ND	ND	NA	NA	NA	NA	NA
88-EX06	12/5/1997	16.5	0.7	ND	0.5	NA	NA	NA	NA	NA
		18.0	0.8	ND	ND	NA	NA	NA	NA	NA
		19.0	0.5	ND	ND	NA	NA	NA	NA	NA
88-HCOI	12/8/1997	18.5	1,540	ND	ND	NA	NA	NA	NA	NA
		20.0	10,489	ND	ND	NA	NA	NA	NA	NA
		21.0	712	ND	ND	NA	NA	NA	NA	NA
88-HCO2	12/9/1997	16.0	1.2	0.10	0.10	NA	NA	NA	NA	NA
		17.0	17	9.4	0.10	NA	NA	NA	NA	NA
		18.5	25	0.20	ND	NA	NA	NA	NA	NA
88-IN01	12/8/1997	18.0	13,406	ND	ND	NA	NA	NA	NA	NA
		19.5	15,553	ND	ND	NA	NA	NA	NA	NA
		20.5	708	ND	ND	NA	NA	NA	NA	NA
88-IN03	12/8/1997	16.0	5.2	0.10	0.60	NA	NA	NA	NA	NA
		17.5	2.7	ND	ND	NA	NA	NA	NA	NA
		19.0	18	0.20	ND	NA	NA	NA	NA	NA
88-IS01	7/27/1997	5.2–5.3	ND	ND	19	NA	NA	NA	NA	[2]1.8
	7/27/1997	8.0–8.25	72.8	6.9	43.3	NA	NA	NA	NA	ND
	7/27/1997	8.5–8.75	101.4	38.6	49.9	NA	NA	NA	NA	ND
	7/27/1997	10.0–10.25	114	8.4	35.1	NA	NA	NA	NA	ND

Table C68. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in soil samples collected in monitor well boreholes at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Sample depth or interval, in feet below land surface	Concentration, in micrograms per kilogram							
			PCE	TCE	Total DCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
88-IS02	7/27/1997	8.0–8.25	13.1	2.1	15.1	NA	NA	NA	NA	[2]0.33
	7/27/1997	8.5–8.75	0.7	3.0	3.2	NA	NA	NA	NA	ND
	7/27/1997	8.8–9.1	64.8	ND	49.5	NA	NA	NA	NA	[2]0.98
	7/27/1997	16.3–16.4	0.1	ND	ND	NA	NA	NA	NA	ND
88-IS03	7/27/1997	2.5–2.75	16.9	0.5	ND	NA	NA	NA	NA	ND
	7/27/1997	5.8–6.0	1.2	ND	ND	NA	NA	NA	NA	ND
	7/27/1997	7.5–7.75	7.2	ND	0.2	NA	NA	NA	NA	ND
88-IS04	7/27/1997	12.0–12.2	7.3	ND	ND	NA	NA	NA	NA	ND
88-IS05	7/27/1997	2.5–2.7	209	ND	ND	NA	NA	NA	NA	ND
	7/27/1997	5.6–5.8	653	ND	ND	NA	NA	NA	NA	ND
	7/27/1997	8.1–8.3	3,508	ND	ND	NA	NA	NA	NA	ND
	7/27/1997	10.2–10.4	372	25.4	ND	NA	NA	NA	NA	ND
88-IS06	7/27/1997	9.1–9.3	3.2	ND	ND	NA	NA	NA	NA	ND
88-IS07	7/27/1997	5.0–5.2	0.1	ND	3.6	NA	NA	NA	NA	[2]3.5
	7/27/1997	8.5–8.7	195	6.9	81.5	NA	NA	NA	NA	[2]4.8
	7/27/1997	10.9–11.1	58	4.0	32.6	NA	NA	NA	NA	ND
	7/27/1997	18.3–18.5	1,901	ND	ND	NA	NA	NA	NA	ND
88-IS08	7/27/1997	4.6–4.8	1,268	133	ND	NA	NA	NA	NA	ND
	7/27/1997	7.2–7.4	1,577	258	ND	NA	NA	NA	NA	ND
	7/27/1997	17.5–17.75	13,748	ND	ND	NA	NA	NA	NA	ND
	7/27/1997	18.6 18.8	5,997	ND	ND	NA	NA	NA	NA	ND
	7/27/1997	19.3–19.5	2,617	ND	ND	NA	NA	NA	NA	ND
88-IS09	7/27/1997	10.5–10.7	188	ND	ND	NA	NA	NA	NA	ND
	7/27/1997	14.6–14.8	24	ND	ND	NA	NA	NA	NA	ND
88-IS10	7/27/1997	15.3–15.5	80	3.7	3.7	NA	NA	NA	NA	ND
	7/27/1997	16.1–16.4	20	0.6	0.8	NA	NA	NA	NA	ND
	7/27/1997	17.1–17.3	25,829	ND	ND	NA	NA	NA	NA	ND
	7/27/1997	17.7–17.8	3,841	ND	ND	NA	NA	NA	NA	ND
88-IS11	7/27/1997	16.3–16.5	12,169	ND	ND	NA	NA	NA	NA	ND
88-IS12	8/19/1997	15.5–15.7	52	ND	ND	NA	NA	NA	NA	ND
	8/19/1997	16.0–16.2	22	0.2	ND	NA	NA	NA	NA	ND
	8/19/1997	16.2–16.5	NA	NA	NA	NA	NA	NA	NA	NA
	8/19/1997	17.0–17.2	32	ND	ND	NA	NA	NA	NA	ND
88-IS13	8/19/1997	8.5–9.0	NA	NA	NA	NA	NA	NA	NA	ND
	8/19/1997	17.0–17.2	7,760	ND	ND	NA	NA	NA	NA	ND
	8/19/1997	17.5–17.7	25,411	ND	ND	NA	NA	NA	NA	ND
	8/19/1997	18.0–18.2	6,226	ND	ND	NA	NA	NA	NA	NA

Table C68. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in soil samples collected in monitor well boreholes at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Sample depth or interval, in feet below land surface	Concentration, in micrograms per kilogram							
			PCE	TCE	Total DCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
88-IS14	11/18/1997	18.0	0.05	ND	ND	NA	NA	NA	NA	NA
88-IS15	11/18/1997	19.0	3.4	0.05	ND	NA	NA	NA	NA	NA
88-IS16	11/19/1997	18.5	3,261	ND	ND	NA	NA	NA	NA	NA
88-IS17	11/19/1997	18.0	5,930	ND	ND	NA	NA	NA	NA	NA
88-IS18	11/19/1997	18.4	5.4	0.1	ND	NA	NA	NA	NA	NA
88-IS19	11/19/1997	17.4	0.1	ND	ND	NA	NA	NA	NA	NA
88-IS20	11/19/1997	18.5	2.9	ND	ND	NA	NA	NA	NA	NA
88-IS21	11/20/1997	18.7	908	ND	ND	NA	NA	NA	NA	NA
		19.7	8,763	ND	ND	NA	NA	NA	NA	NA
88-IS22	11/20/1997	17.0	3,603	ND	ND	NA	NA	NA	NA	NA
		18.0	2,815	ND	ND	NA	NA	NA	NA	NA
		19.0	909	ND	ND	NA	NA	NA	NA	NA
88-IS23	11/20/1997	17.5	9.3	ND	ND	NA	NA	NA	NA	NA
		18.2	1,476	ND	ND	NA	NA	NA	NA	NA
		19.0	311	ND	ND	NA	NA	NA	NA	NA
88-IS25	11/21/1997	17.0	1,709	ND	ND	NA	NA	NA	NA	NA
		18.0	10,851	ND	ND	NA	NA	NA	NA	NA
		19.0	814	ND	ND	NA	NA	NA	NA	NA
88-IS26	11/21/1997	17.0	208	ND	ND	NA	NA	NA	NA	NA
		17.7	1,611	ND	ND	NA	NA	NA	NA	NA
		18.5	106	ND	ND	NA	NA	NA	NA	NA
88-IS29	11/22/1997	18.8	4,361	ND	ND	NA	NA	NA	NA	NA
88-IS30	11/22/1997	18.8	3,212	ND	ND	NA	NA	NA	NA	NA
88-IS31	11/22/1997	16.8	54	ND	ND	NA	NA	NA	NA	NA
88-IW01	8/20/1997	4.0–4.5	138	ND	ND	NA	NA	NA	NA	ND
	8/20/1997	9.0–9.5	NA	NA	NA	NA	NA	NA	NA	NA
	8/20/1997	17.5–17.7	33,572	ND	ND	NA	NA	NA	NA	ND
	8/20/1997	18.0–18.2	5,140	ND	ND	NA	NA	NA	NA	ND
	8/20/1997	18.0–18.5	NA	NA	NA	NA	NA	NA	NA	NA
	8/20/1997	18.5–18.7	2	ND	22	NA	NA	NA	NA	ND
88-MW02DW	4/20/1997	9.0–11.0	4.0J	<13	NA	<13	NA	NA	NA	<13
		11.0–13.0	260	<13	NA	<13	NA	NA	<13	<13
88-MW03DW	4/30/1997	3.0–5.0	<12	<12	NA	<12	NA	NA	<12	<12
		7.0–9.0	<12	<12	NA	<12	NA	NA	<12	<12
88-MW04DW	4/18/1997	11.0–13.0	<12	<12	NA	<12	NA	NA	<12	<12
		13.0–15.0	<13	<13	NA	<13	NA	NA	<13	<13
88-MW05DW	4/22/1997	9.0–11.0	7.0J	<12	NA	<12	NA	NA	<12	<12
		11.0–13.0	3,500	16	NA	<12	NA	NA	12J	<12

Table C68. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in soil samples collected in monitor well boreholes at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Sample depth or interval, in feet below land surface	Concentration, in micrograms per kilogram							
			PCE	TCE	Total DCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
88-MW06IW	5/4/1997	11.0–13.0	<11	<11	NA	<11	NA	NA	<11	<11
		13.0–15.0	<12	<12	NA	<12	NA	NA	<12	<12
88-88RW01	8/19/1997	9.5–10.0	NA	NA	NA	NA	NA	NA	NA	NA
	8/19/1997	17.0–17.2	31	ND	ND	NA	NA	NA	NA	ND
	8/19/1997	18.0–18.2	11,337	ND	ND	NA	NA	NA	NA	ND
	8/19/1997	20.0–20.2	1,483	ND	ND	NA	NA	NA	NA	ND
88-RW02	8/19/1997	9.0–9.5	NA	NA	NA	NA	NA	NA	NA	NA
	8/19/1997	17.0–17.2	16	ND	ND	NA	NA	NA	NA	ND
	8/19/1997	18.0–18.2	1,049	ND	ND	NA	NA	NA	NA	ND
	8/19/1997	18.0–18.5	NA	NA	NA	NA	NA	NA	NA	NA
	8/19/1997	18.5–18.7	4,634	ND	ND	NA	NA	NA	NA	ND
88-RW03	12/9/1997	21.6	287	1.7	ND	NA	NA	NA	NA	NA
88-RW04	12/9/1997	18.0	25	0.10	ND	NA	NA	NA	NA	NA
		19.5	23,057	ND	ND	NA	NA	NA	NA	NA
		20.5	448	ND	ND	NA	NA	NA	NA	NA
88-SB01	4/20/1997	3.0–5.0	200	<17	NA	<17	NA	NA	<17	<17
88-SB02	5/7/1997	7.0–9.0	<12	<12	NA	<12	NA	NA	<12	<12
		9.0–11.0	<12	<12	NA	<12	NA	NA	<12	<12
88-SB03	4/20/1997	3.0–5.0	56J	3.0	NA	<11	NA	NA	<11	<11
88-SB04	5/6/1997	7.0–9.0	38	16	NA	<12	NA	NA	<12	<12
	5/6/1997	9.0–11.0	24	380	NA	<12	NA	NA	240	<12
88-SB05	5/6/1997	9.0–11.0	<11	<11	NA	<11	NA	NA	<11	<11
	5/6/1997	11.0–13.0	<12	<12	NA	<12	NA	NA	<12	<12
88-SB06	5/6/1997	7.0–9.0	<12	<12	NA	<12	NA	NA	<12	<12
	5/6/1997	9.0–11.0	<12	<12	NA	<12	NA	NA	<12	<12
88-TW01	11/12/1995	3.0–8.0	13	<6.0	NA	NA	NA	NA	<6.0	NA
88-TW02	11/12/1995	3.0–8.0	55	<6.0	NA	NA	NA	NA	<9.0	NA
88-TW03	11/12/1995	3.0–8.0	36	<6.0	NA	NA	NA	NA	<6.0	NA
88-TW04	11/12/1995	3.0–8.0	<5.0	<5.0	NA	NA	NA	NA	<5.0	NA
88-TW04IW	8/16/1996	6.0–8.0	14.8	0.20	NA	NA	<1.0	<1.0	NA	<100
		20.0–22.0	1.5	0.10	NA	NA	<1.0	<1.0	NA	<100
88-TW05	8/15/1996	6.0–8.0	1.2	0.10	NA	NA	<1.0	<1.0	NA	<100
88-TW06	8/16/1996	4.0–6.0	0.40	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW07	8/16/1996	4.0–6.0	0.10	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW08	8/16/1996	4.0–6.0	237.8	0.80	NA	NA	<1.0	<1.0	NA	<100
88-TW09	8/17/1996	6.0–8.0	22.6	3.3	NA	NA	<1.0	<1.0	NA	<100
		10.0–12.0	3.1	0.5	NA	NA	<1.0	<1.0	NA	<100

Table C68. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in soil samples collected in monitor well boreholes at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; J, estimated concentration; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Sample depth or interval, in feet below land surface	Concentration, in micrograms per kilogram							
			PCE	TCE	Total DCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
88-TW10	8/17/1996	4.0–6.0	<1.0	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW11	8/17/1996	2.0–4.0	<1.0	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW12	8/17/1996	8.0–10.0	<1.0	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW13	8/17/1996	5.0–7.0	1.5	<1.0	NA	NA	<1.0	<1.0	NA	<100
		9.0–11.0	0.90	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW14	8/17/1996	4.0–6.0	0.30	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW15	8/17/1996	8.0–10	11.6	8.5	NA	NA	<1.0	21	NA	<100
88-TW16	8/18/1996	7.0–9.0	0.20	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW17	8/18/1996	7.0–9.0	0.20	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW18	8/20/1996	4.0–6.0	<1.0	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW19	8/20/1996	6.0–8.0	<1.0	<1.0	NA	NA	<1.0	<1.0	NA	<100
88-TW20IW	4/22/1997	6.0–8.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
		8.0–10.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
88-TW21IW	4/15/1997	10.0–12.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
		12.0–14.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
88-TW22IW	4/15/1997	8.0–10.0	10	<1.0	NA	<10	<10	<10	NA	<100
		10.0–12.0	399	13	NA	<10	<10	32	NA	<100
88-TW23IW	4/16/1997	8.0–10.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
		10.0–12.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
88-TW24IW	4/16/1997	8.0–10.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
		10.0–12.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
88-TW25IW	4/17/1997	12.0–14.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
		14.0–16.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
88-TW26IW	4/17/1997	8.0–10.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
		10.0–12.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
88-TW27IW	4/29/1997	8.0–10.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
		10.0–12	<1.0	<1.0	NA	<10	<10	<10	NA	<100
88-TW28IW	4/29/1997	10.0–12.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100
		12.0–14.0	<1.0	<1.0	NA	<10	<10	<10	NA	<100

[1] See Figures C26 and C27 for location. Test well (TW) locations are not shown

[2] Uncorrected for soil water content

Data sources:

CERCLA Administrative Record files #217, #1738, #1747, #2020, #2032, #2324

Baker Environmental, Inc. 1996h, 1998b,c

Duke Engineering and Services, Inc. 1997

Duke Engineering and Services, Inc. and Baker Environmental, Inc. 1999a

OHM Remediation Services Corp. 1996a

Table C69. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 88, Building 25 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; D, sample dilution required]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
88-MW01	5/15/1997	NA	NA	<10	NA	NA	<10	NA
	7/27/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/18/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/14/2001	3.0J	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
88-MW02	5/15/1997	NA	NA	<10	NA	NA	<10	NA
	7/27/1999	1,200D	130	<5.0	<5.0	31	NA	<2.0
	1/18/2000	10,000	370J	<5.0	<5.0	29	29	<2.0
	7/18/2000	15,000D	190	<5.0	<5.0	30	30	<2.0
	1/16/2001	11,000D	80	<5.0	<5.0	13	13	<2.0
	7/14/2001	74	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
88-MW02DW	5/15/1997	NA	NA	<10	NA	NA	<10	NA
88-MW02IW	5/15/1997	NA	NA	<10	NA	NA	<10	NA
	7/27/1999	4,900D	1,000D	<5.0	<5.0	64	NA	<2.0
	1/18/2000	7,500	270J	<5.0	<5.0	81J	81J	<2.0
	7/18/2000	13,000D	590D	<5.0	<5.0	78	78	<2.0
	1/16/2001	9,400D	310J	<5.0	<5.0	60	60	<2.0
	7/14/2001	11,000	700	<5.0	<5.0	92	92	<2.0
88-MW03	5/14/1997	NA	NA	<10	NA	NA	<10	NA
88-MW03DW	5/14/1997	NA	NA	<10	NA	NA	<10	NA
88-MW03IW	5/14/1997	NA	NA	<10	NA	NA	<10	NA
88-MW04	5/14/1997	NA	NA	<10	NA	NA	<10	NA
	7/27/1999	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/18/2000	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
	7/14/2001	5.0J	<5.0	<5.0	<5.0	<5.0	<5.0	<2.0
88-MW04DW	5/14/1997	NA	NA	<10	NA	NA	<10	NA
88-MW04IW	5/14/1997	NA	NA	<10	NA	NA	<10	NA
88-MW05	5/13/1997	NA	NA	<10	NA	NA	<10	NA
	7/27/1999	6,500D	46	<5.0	<5.0	23	NA	<2.0
	1/18/2000	5,700	38J	<5.0	<5.0	23J	23J	<2.0
	7/18/2000	8,600D	35	<5.0	25	18	18	<2.0
	1/16/2001	5,200D	19	<5.0	<5.0	11	11	<2.0
88-MW05DW	5/13/1997	NA	NA	<10	NA	NA	<10	NA
88-MW05IW	5/13/1997	NA	NA	5.0J	NA	NA	<10	NA
	7/27/1999	3,400D	2,100D	11	24	1,800D	NA	<2.0
	1/18/2000	3,900	2,600	10	20	1,900	1,900	<2.0
	7/18/2000	6,400D	3,900D	12	25	3,000D	3,000D	<2.0
	1/16/2001	6,200D	4,600D	11	36	4,200D	2,300	1.0J

Table C69. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 88, Building 25 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; D, sample dilution required]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
88-MW06	5/15/1997	NA	NA	<10	NA	NA	<10	NA
88-MW06IW	5/15/1997	NA	NA	<10	NA	NA	<10	NA
88-MW07	5/18/1997	NA	NA	<10	NA	NA	<10	NA
88-MW07IW	5/18/1997	NA	NA	7.0J	NA	NA	<10	NA
	7/27/1999	<5.0	53	7.0	9.0	94	NA	3.0
	1/18/2000	<5.0	48	6.0	9.0	83	91	2.0J
	7/18/2000	<5.0	48	5.0	8.0	76	84	1.0J
	1/16/2001	<5.0	38	5.0J	8.0	72	80	<2.0
	7/14/2001	<5.0	47	<5.0	7.0	58	65	<2.0
88-MW08	5/16/1997	NA	NA	<10	NA	NA	<10	NA
88-MW08IW	5/16/1997	NA	NA	<10	NA	NA	<10	NA
88-MW09	5/16/1997	NA	NA	<10	NA	NA	<10	NA
88-MW09IW	5/16/1997	NA	NA	<10	NA	NA	<10	NA
	7/27/1999	4.0J	60	<5.0	5.0	37	NA	<2.0
	1/18/2000	<5.0	46	<5.0	3.0J	21	24	<2.0
	7/18/2000	<5.0	52	<5.0	3.0J	17	20	<2.0
	1/16/2001	<5.0	44	<5.0	<5.0	11	11	<2.0
	7/14/2001	<5.0	68	<5.0	7.0	58	65	<2.0
88-MW10IW	5/16/2000	290	160	<5.0	<5.0	44	NA	<2.0
88-RW01	8/22/1997	170,000	3,200	NA	NA	NA	11,000	NA
	5/16/2000	43,000	690	<500	<500	7,900J	NA	910
88-RW02	8/22/1997	150,000	3,500	NA	NA	NA	10,000	NA
	5/16/2000	89,000	NA	<500	<500	1,200	NA	750
88-TW01	11/12/1995	1,620	<100	NA	NA	NA	<10	NA
	8/1/1996	157.2	17.7	NA	<1.0	4.0	<1.0	<50
88-TW02	11/12/1995	416	<50	NA	NA	NA	154	NA
	8/1/1996	649.1	81.5	NA	9.0	445	NA	<50
88-TW03	11/12/1995	4,190	2,750	NA	NA	NA	10,000	NA
	8/1/1996	14,090	838	NA	6.0	1,184	NA	<50
88-TW04	11/12/1995	29,200	<1,250	NA	NA	NA	<1,250	NA
	8/1/1996	32,839	230	NA	1.0	63	NA	<50
88-TW04IW	8/16/1996	21	5.5	NA	<1.0	21	NA	<50
88-TW05	8/16/1996	1,382	20.8	NA	<1.0	3.0	NA	<50
88-TW05IW	8/18/1996	1,143	71.2	NA	1.0	89	NA	<50
88-TW06	8/17/1996	<0.10	<0.10	NA	<1.0	<1.0	NA	<50
88-TW07	8/17/1996	0.20	<0.10	NA	<1.0	<1.0	NA	<50
88-TW08	8/17/1996	53,704	341.2	NA	2.0	271	NA	<50
88-TW08IW	8/18/1996	1,314	823	NA	11	883	NA	<50
88-TW09	8/17/1996	969.2	70.8	NA	<1.0	14	NA	<50

Table C69. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 88, Building 25 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration; D, sample dilution required]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
88-TW10	8/18/1996	0.10	0.20	NA	<1.0	<1.0	NA	<50
88-TW11	8/17/1996	1.3	0.20	NA	<1.0	<1.0	NA	<50
88-TW12	8/17/1996	1.5	<0.10	NA	<1.0	<1.0	NA	<50
88-TW13	8/18/1996	44.3	0.6	NA	<1.0	<1.0	NA	<50
88-TW14	8/18/1996	0.1	<0.10	NA	<1.0	<1.0	NA	<50
88-TW15	8/18/1996	4,932	3,031	NA	38	3,725	NA	<50
88-TW16	8/18/1996	0.2	<0.10	NA	<1.0	<1.0	NA	<50
88-TW17	8/20/1996	0.2	<0.10	NA	<1.0	<1.0	NA	<50
88-TW18	8/20/1996	<0.10	<0.10	NA	<1.0	<1.0	NA	<50
88-TW19	8/20/1996	<0.10	<0.10	NA	<1.0	<1.0	NA	<50
88-TW19IW	8/20/1996	<0.10	<0.10	NA	<1.0	<1.0	NA	<50
88-TW20	4/21/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW20IW	4/21/1997	0.30	7.1	<0.10	<1.0	<1.0	NA	<50
88-TW21	4/21/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW21IW	4/21/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW22	4/21/1997	54,882	125	<0.10	2.0	126	NA	<50
88-TW22IW	4/21/1997	26,592	13	0.30	2.0	81	NA	<50
88-TW23	4/21/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW23IW	4/21/1997	15.8	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW24	4/21/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW24IW	4/20/1997	<0.10	<0.1 0	<0.10	<1.0	<1.0	NA	<50
88-TW25	4/21/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW25IW	4/21/1997	0.30	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW26	4/21/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW26IW	4/21/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW27	4/30/1997	<0.10	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW27IW	4/30/1997	0.40	<0.10	<0.10	<1.0	<1.0	NA	<50
88-TW28	4/30/1997	<0.10	0.70	<0.1	<1.0	<1.0	NA	<50
88-TW28IW	4/30/1997	0.30	4.1	1.9	<1.0	1.0	NA	<50

[1] See Figures C26 and C27 for location. Test well (TW) locations are not shown

Data sources:

CERCLA Administrative Record files #217, #1747, #2032, #2302, #2606A, #2614A, #3159, #3188, #3341, #3343

Baker Environmental, Inc. 1996h,l, 1998b

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000j, 2001,b

Baker Environmental, Inc. and CH2M Hill, Inc. 2000b

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2001c

Duke Engineering and Services, Inc. 1997

Duke Engineering and Services, Inc. and Baker Environmental, Inc. 1998, 1999b

Table C70. Summary of tetrachloroethylene (PCE) free-phase measurements in monitor wells at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[>, greater than]

Site name[1]	Sample date	PCE free product thickness, in feet
88-EX01	1998	1.60
88-EX02	1998	>0.3
88-EX04	7/22/2002	1.66
88-EX04R	7/22/2002	0.54
88-HC0I	1998	>0.3
88-IN01	1998	0.30
88-RW01	1998	>0.3
	7/22/2002	0.41
88-RW02	1998	0.50
	7/22/2002	0.06
88-RW03	7/22/2002	0.01
88-RW04	1998	2.80
88-RW06	1998	2.30

[1] See Figures C26 and C27 for location

Data sources:

CERCLA Administrative Record files #2324, #3187

Duke Engineering and Services, Inc. and Baker Environemental, Inc. 1999a

CH2M Hill, Inc. 2003

Table C71. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
88-MW01	7/27/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	7/18/2000	<5.0	<5.0	<5.0	<5.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0
88-MW02	7/27/1999	<5.0	<5.0	<5.0	<1,000
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	7/18/2000	<5.0	<5.0	<5.0	<5.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0
88-MW02IW	7/27/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0
88-MW04	7/27/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	7/18/2000	<5.0	<5.0	<5.0	<5.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2002	<5.0	<5.0	<5.0	<5.0
88-MW05	7/27/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	7/18/2000	<5.0	<5.0	<5.0	<5.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0
88-MW05IW	7/27/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	7/18/2000	<5.0	<5.0	<5.0	<5.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0
88-MW07IW	7/27/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0
88-MW09IW	7/27/1999	<5.0	<5.0	<5.0	<5.0
	1/18/2000	<5.0	<5.0	<5.0	<5.0
	1/16/2001	<5.0	<5.0	<5.0	<5.0
	7/14/2001	<5.0	<5.0	<5.0	<5.0

Table C71. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 88, Building 25, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[<, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
88-88TW05	8/28/1996	<10	<10	<10	<10
88-TW05IW	8/27/1996	<10	<10	<10	<10
88-TW08	8/28/1996	<10	<10	<10	<10
88-TW08IW	8/28/1996	<10	<10	<10	<10
88-TW09	8/27/1996	<10	<10	<10	<10
88-TW19	8/27/1996	<10	<10	<10	<10
88-TW19IW	8/27/1996	<10	<10	<10	<10
88-TW20	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW20IW	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW21	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW21IW	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW22	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW22IW	4/21/1997	<2.0	7.0	<2.0	<2.0
88-TW23	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW23IW	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW24	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW24IW	4/20/1997	<2.0	<2.0	<2.0	<2.0
88-TW25	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW25IW	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW26	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW26IW	4/21/1997	<2.0	<2.0	<2.0	<2.0
88-TW27	4/30/1997	<2.0	<2.0	<2.0	<2.0
88-TW27IW	4/30/1997	<2.0	<2.0	<2.0	<2.0
88-TW28	4/30/1997	<2.0	<2.0	<2.0	<2.0
88-TW28IW	4/30/1997	<2.0	<2.0	<2.0	<2.0

[1] See Figures C26 and C27 for location. Test well (TW) locations are not shown

Data sources:

CERCLA Administrative Record files #1747, #2032, #2606A, #2614A, #3341, #3343

Baker Environmental, Inc. 1996h, 1998b

Baker Environmental, Inc. and CH2M Hill Federal Group, Ltd. 2000j, 2001b

Baker Environmental, Inc. and CH2M Hill, Inc. 2000b

CH2M Hill Federal Group, Ltd. and Baker Environmental, Inc. 2001c

Table C72. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected at hydropunch locations at Installation Restoration Site 94, Building 1613 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Location coordinates[2]		Land surface altitude, in feet above NGVD 29	Sample interval, in feet below land surface	Sample date	Contributing aquifer or confining unit	Concentration, in micrograms per liter			
	North	East					Benzene	Toluene	Ethyl-benzene	Total xylene
94-HP01	338380	2498555	[3]30	7–11	3/28/1995	BBUAQ	<0.5	4.2	0.60	<1.5
94-HP01D	338380	2498555	[3]30	17–20	3/29/1995	BBUCU, BBLAQ	<0.5	12.9	0.80	2.0
94-HP02	338549	2498511	[3]26	13–17	3/30/1995	BBUAQ, BBUCU	<0.5	0.90	ND	2.7
94-HP03	338808	2498845	[3]26	15–19	4/12/1995	BBUCU, BBLAQ	<0.5	<0.5	<0.5	<1.5
94-HP04	338365	2498696	[3]26	11–15	4/6/1995	BBUAQ, BBUCU	<0.5	<0.5	<0.5	<1.5
94-HP05	338590	2498676	[3]26	11–15	4/6/1995	BBUAQ, BBUCU	<0.5	10.6	0.80	2.1
94-HP06	338831	2498604	[3]21	15–19	4/12/1995	BBUCU, BBLAQ	<0.5	<0.5	<0.5	<1.5
94-HP07	338340	2498891	[3]26	7–10	4/5/1995	BBUAQ	<0.5	12.8	4.0	149
94-HP08	338603	2498850	[3]26	13–16	4/5/1995	BBUAQ, BBUCU	[4]17,300	[4]20,700	[4]2,140	[4]10,800
94-HP09	338808	2498845	[3]26	11–15	4/5/1995	BBUAQ, BBUCU	2.9	11.2	1.1	3
94-HP10	338499	2499115	[3]26	16–20	4/6/1995	BBUCU, BBLAQ	<0.5	21.6	1.3	<1.5
94-HP11	338677	2499052	[3]26	11–15	4/6/1995	BBUAQ, BBUCU	7,700	[4]10,800	1,100	5,420
94-HP12	338837	2499053	[3]27	11–15	4/5/1995	BBUAQ, BBUCU	<0.5	14.4	1.4	2.4
94-HP13	338533	2499282	[3]27	12–15	4/6/1995	BBUAQ, BBUCU	<0.5	9.0	<0.5	<1.5
94-HP14	338653	2499244	[3]27	12–15	4/5/1995	BBUAQ, BBUCU	0.60	1.6	<0.5	<1.5
94-HP15	338803	2499213	[3]26	12–15	4/5/1995	BBUAQ, BBUCU	<0.5	44.9	1.7	55.1

[1] See Figure C30 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Estimated altitude

[4] Minimum concentration

Data source:

CERCLA Administrative Record files #76, #90

Richard Catlin and Associates, Inc. 1996a,b

Table C73. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected at hydropunch locations at Installation Restoration Site 94, Building 1613 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected]

Site name[1]	Sample date	Sample interval, in feet below land surface	Concentration, in micrograms per liter						
			PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
94-HP01	3/28/1995	7–11	NA	ND	ND	ND	NA	NA	NA
94-HP01D	3/29/1995	17–20	NA	29.2	ND	0.90	NA	NA	NA
94-HP02	3/30/1995	13–17	NA	ND	ND	ND	NA	NA	NA
94-HP03	4/12/1995	15–19	NA	ND	ND	ND	NA	NA	NA
94-HP04	4/6/1995	11–15	NA	ND	ND	ND	NA	NA	NA
94-HP05	4/6/1995	11–15	NA	ND	ND	ND	NA	NA	NA
94-HP06	4/12/1995	15–19	NA	ND	ND	ND	NA	NA	NA
94-HP07	4/5/1995	7–10	NA	ND	ND	ND	NA	NA	NA
94-HP08	4/5/1995	13–16	NA	ND	ND	ND	NA	NA	NA
94-HP09	4/5/1995	11–15	NA	ND	ND	ND	NA	NA	NA
94-HP10	4/6/1995	16–20	NA	ND	1.1	ND	NA	NA	NA
94-HP11	4/6/1995	11–15	NA	ND	ND	ND	NA	NA	NA
94-HP12	4/5/1995	11–15	NA	ND	ND	ND	NA	NA	NA
94-HP13	4/6/1995	12–15	NA	ND	ND	ND	NA	NA	NA
94-HP14	4/5/1995	12–15	NA	ND	ND	ND	NA	NA	NA
94-HP15	4/5/1995	12–15	NA	ND	ND	ND	NA	NA	NA

[1] See Figure C30 for location

Data sources:

CERCLA Administrative Record files #76, #90

Richard Catlin and Associates, Inc. 1996a,b

Table C74. Construction, location, and contributing aquifer data for monitor wells at Installation Restoration Site 94, Building 1613 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
94-Bldg1613-01	338789	2498888	25.7	4/10/1995	20.0	5.0–20.0	BBUAQ, BBUCU
94-Bldg1613-02	338744	2499181	26.3	4/10/1995	20.0	5.0–20.0	BBUAQ, BBUCU
94-Bldg1613-03	338531	2499191	26.0	4/11/1995	15.4	5.4–15.4	BBUAQ, BBUCU
94-Bldg1613-04	338475	2498807	24.2	4/11/1995	15.0	5.0–15.0	BBUAQ, BBUCU
94-Bldg1613-05	338592	2498715	22.8	4/11/1995	15.0	5.0–15.0	BBUAQ, BBUCU
94-Bldg1613-06	338731	2498760	25.9	4/11/1995	20.0	10.0–20.0	BBUAQ
94-Bldg1613-07	338882	2499329	23.4	4/12/1995	18.5	8.5–18.5	BBUAQ
94-Bldg1613-08	338347	2498639	27.1	4/12/1995	16.0	8.0–16.0	BBUAQ, BBUCU
94-Bldg1613-09 AKA MW09	338334	2498918	26.0	4/13/1995	15.1	5.1–15.1	BBUAQ, BBUCU
94-Bldg1613-10	338641	2499016	26.7	4/18/1995	18.0	8.0–18.0	BBUAQ, BBUCU
94-Bldg1613-11	338563	2498818	26.0	4/18/1995	20.6	10.6–20.6	BBUAQ, BBUCU
94-Bldg1613-12 AKA MW12	338377	2499089	27.0	4/18/1995	20.4	10.4–20.4	BBUAQ, BBUCU
94-Bldg1613-13	338881	2499314	23.6	4/13/1995	50.0	45.0–50.0	BBLCU, TTAQ(?)
94-Bldg1613-14	338646	2499013	25.6	4/17/1995	49.5	44.5–49.5	BBLCU, TTAQ(?)
94-Bldg1613-15	338356	2498629	27.2	4/17/1995	41.0	36.0–41.0	BBLAQ
94-Bldg1613-16	338653	2499022	25.0	4/18/1995	N/A	5.0–35.0	BBUAQ, BBUCU, BBLAQ

[1] See Figure C30 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

Data sources:

CERCLA Administrative Record files #76, #90

Richard Catlin and Associates, Inc. 1996a,b

Table C75. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Installation Restoration Site 94, Building 1613 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
94-Bldg1613-01	5/3/1995	ND	ND	ND	ND
94-Bldg1613-02	5/3/1995	ND	ND	ND	ND
94-Bldg1613-03	5/3/1995	ND	ND	ND	ND
94-Bldg1613-04	5/3/1995	ND	ND	ND	ND
94-Bldg1613-05	5/3/1995	ND	ND	ND	ND
94-Bldg1613-06	5/3/1995	ND	ND	ND	ND
94-Bldg1613-07	5/3/1995	ND	ND	ND	ND
94-Bldg1613-08	5/3/1995	ND	ND	ND	ND
94-Bldg1613-09	5/3/1995	ND	ND	ND	ND
AKA MW09	7/23/1997	<0.50	<0.50	<0.50	<0.50
94-Bldg1613-10	5/3/1995	804	6,780	1,280	9,290
94-Bldg1613-11	5/3/1995	8.8	4.3	2.3	18.9
94-Bldg1613-12	5/3/1995	ND	ND	ND	ND
AKA MW12	7/23/1997	<0.50	<0.50	<0.50	<0.50
94-Bldg1613-13	5/3/1995	ND	ND	ND	ND
94-Bldg1613-14	5/3/1995	ND	ND	ND	ND
94-Bldg1613-15	5/3/1995	ND	ND	ND	ND
94-Bldg1613-16	5/3/1995	5.0	2.4	ND	44.8

[1] See Figure C30 for location

Data sources:

CERCLA Administrative Record files #76, #90

Richard Catlin and Associates, Inc. 1996a,b

Table C76. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Installation Restoration Site 94, Building 1613 area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NA, constituent concentration not determined or analytical result is unknown; ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
94-Bldg1613-01	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-02	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-03	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-04	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-05	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-06	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-07	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-08	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-09	5/3/1995	NA	32	ND	1.1	NA	NA	NA
	7/23/1997	< 0.50	< 0.50	< 0.50	NA	NA	< 0.50	< 0.50
94-Bldg1613-10	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-11	5/3/1995	NA	ND	ND	ND	NA	NA	NA
94-Bldg1613-12	5/3/1995	NA	ND	ND	ND	NA	NA	NA
	7/23/1997	< 0.50	< 0.50	< 0.50	NA	NA	< 0.50	< 0.50
94-Bldg1613-13	5/3/1995	NA	37	ND	1.2	NA	NA	NA
	9/29/2003	NA	54	NA	0.55	6.7	NA	NA
94-Bldg1613-14	5/3/1995	NA	79	0.70	5.6	NA	NA	NA
	9/29/2003	NA	35	NA	0.84	8.1	NA	NA
94-Bldg1613-15	5/3/1995	NA	16	ND	ND	NA	NA	NA
	9/29/2003	NA	21	NA	< 0.27	38	NA	NA
94-Bldg1613-16	5/3/1995	NA	1.3	ND	ND	NA	NA	NA

[1] See Figure C30 for location

Data sources:

CERCLA Administrative Record files #76, #90

Richard Catlin and Associates, Inc. 1996a,b

Table C77. Construction, location, and contributing aquifer data for monitor wells at Site G, proposed Camp Lejeune landfill, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[NGVD 29, National Geodetic Vertical Datum of 1929; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, BBUCU—Brewster Boulevard upper confining unit, TTCU—Tarawa Terrace confining unit,UCHRBU—Upper Castle Hayne aquifer–River Bend unit; N/A, not available; AKA, also known as]

Site name[1]	Location coordinates[2]		Land-surface altitude, in feet above NGVD 29	Completion date	Finished well depth, in feet	Screen interval, in feet below land surface	Contributing aquifer or confining unit
	North	East					
G-BP01	347672	2504379	35.7	N/A	N/A	N/A	N/A
G-BP02	347303	2505185	38.5	N/A	N/A	N/A	N/A
G-BP03	346826	2506138	34.8	N/A	N/A	N/A	N/A
G-BP04	346147	2504316	36.8	N/A	N/A	N/A	N/A
G-BP06	344876	2504300	36.4	4/28/1992	25	15–25	BBUAQ
G-BP07[3]	345631	2503937	27.7	4/14/1992	N/A	N/A	BBLAQ(?)
G-BP08	345989	2504914	38.0	1992(?)	N/A	N/A	BBLAQ(?)
G-BP09	346651	2505516	39.6	1992(?)	N/A	N/A	BBLAQ(?)
G-BP10[4]	347001	2504808	35.9	4/15/1992	N/A	N/A	BBLAQ(?)
G-MW01	347001	2504808	[5]36	1991	N/A	N/A	BBUAQ(?), BBLAQ(?)
G-MW02 AKA 06-MW02	345631	2503937	[5]28	1991	N/A	N/A	BBUAQ(?), BBLAQ(?)
G-MW03D AKA 06-MW03D	347811	2504501	34.2	4/1/1993	118	97.5–117.6	TTCU, UCHRBU
G-MW03S AKA 06-MW03S	347850	2504348	29.0	4/22/1992	25	15–25	BBUCU, BBLAQ(?)
G-MW04	347925	2505460	26.1	4/22/1992	25	15–25	BBUCU, BBLAQ(?)
G-MW05	347274	2506033	35.3	4/22/1992	25	15–25	BBUAQ, BBUCU
G-MW06	346261	2505757	37.4	4/17/1992	25	15–25	BBUAQ, BBUCU
G-MW07	345188	2504832	34.2	4/21/1992	25	15–25	BBUAQ, BBUCU
G-MW08 AKA 06-MW08	344849	2503833	28.6	4/21/1992	25	15–25	BBUAQ. BBUCU
G-MW09 AKA 06-MW09	346832	2503699	42.9	4/22/1992	25	15–25	BBUAQ

[1] See Figure C31 for location

[2] Location coordinates are North Carolina State Plane coordinates, North American Datum of 1983

[3] Borehole near monitor well G-MW02

[4] Borehole near monitor well G-MW01

[5] Estimated altitude

Data sources:

Baker Environmental, Inc. 1993k,m, 1999d

CERCLA Administrative Record files #125, #345, #1272, #2337

Dewberry and Davis 1992

Table C78. Summary of analyses for tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (*trans*-1,2-DCE), *cis*-1,2-dichloroethylene (*cis*-1,2-DCE), total 1,2-dichloroethylene (total 1,2-DCE), and vinyl chloride (VC) in water samples collected in monitor wells at Site G, proposed Camp Lejeune landfill, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[ND, constituent not detected; NA, constituent concentration not determined or analytical result is unknown; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, concentration is estimated]

Site name[1]	Sample date	Concentration, in micrograms per liter						
		PCE	TCE	1,1-DCE	*trans*-1,2-DCE	*cis*-1,2-DCE	Total 1,2-DCE	VC
G-BP06	10/24/1992	ND	ND	ND	NA	NA	ND	ND
	3/22/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
G-MW01	5/5/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
G-MW02	5/5/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
G-MW03S	5/5/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	3/23/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
	1/22/2003	<5.0	0.60J	<5.0	<5.0	<5.0	<5.0	<2.0
	1/20/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/28/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
G-MW03D	1/20/2004	<5.0	<5.0	<5.0	<5.0	<5.0	<10	<2.0
	7/26/2004	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<2.0
G-MW04	5/5/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
G-MW05	5/5/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
G-MW06	5/5/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
G-MW07	5/5/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
G-MW08	5/5/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	3/22/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0
G-MW09	5/6/1992	<5.0	<5.0	<5.0	NA	NA	<5.0	<10
	10/24/1992	ND	ND	ND	NA	NA	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0

[1] See Figure C31 for location

Data sources:

- CERCLA Administrative Record files #345, #1272, #3410, #3637
- Dewberry and Davis, 1992
- Baker Environmental, Inc. 1993k
- Michael Baker Jr., Inc. and CH2M Hill, Inc. 2003
- Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2004

Table C79. Summary of analyses for benzene, toluene, ethylbenzene, and total xylene in water samples collected in monitor wells at Site G, proposed Camp Lejeune landfill, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[ND, constituent not detected; <, constituent concentration is less than detection limit. Number following the "<" sign is the detection limit; J, estimated concentration]

Site name[1]	Sample date	Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylene
G-BP06	10/24/1992	ND	ND	ND	ND
	3/22/1993	<1.0	<1.0	<1.0	<1.0
G-MW01	5/5/1992	<5.0	<5.0	<5.0	<5.0
	10/24/1992	ND	ND	ND	ND
G-MW02	5/5/1992	<5.0	<5.0	<5.0	<5.0
	3/21/1993	<1.0	<1.0	<1.0	<1.0
G-MW03S	5/5/1992	<5.0	<5.0	<5.0	<5.0
	3/23/1993	<1.0	<1.0	<1.0	<1.0
	1/22/2003	<5.0	<5.0	<5.0	<5.0
	1/20/2004	<5.0	<5.0	<5.0	<15
	7/28/2004	<5.0	0.30J	<5.0	<15
G-MW03D	1/20/2004	<5.0	<5.0	<5.0	<15
	7/26/2004	<5.0	<5.0	<5.0	<15
G-MW04	5/5/1992	<5.0	<5.0	<5.0	<5.0
G-MW05	5/5/1992	<5.0	<5.0	<5.0	<5.0
G-MW06	5/5/1992	<5.0	<5.0	<5.0	<5.0
G-MW07	5/5/1992	<5.0	<5.0	<5.0	<5.0
G-MW08	3/22/1993	<1.0	<1.0	<1.0	<1.0
G-MW09	5/6/1992	<5.0	<5.0	<5.0	<5.0
	10/24/1992	ND	ND	ND	ND
	3/21/1993	<1.0	<1.0	<1.0	<1.0

[1] See Figure C31 for location

Data sources:

CERCLA Administrative Record files #345, #1272, #3410, #3637
Dewberry and Davis 1992
Baker Environmental, Inc. 1993k
Michael Baker Jr., Inc. and CH2M Hill, Inc. 2003
Michael Baker Jr., Inc. and Engineering and Environment, Inc. 2004

Table C80. Summary of analyses for groundwater contaminants of concern and related contaminant source characterizations and affected water-supply wells within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[Contaminant: PCE— tetrachloroethylene, TCE—trichloroethylene, VC—vinyl chloride; µg/L, microgram per liter; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, MCHAQ—Middle Castle Hayne aquifer, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer-Lower unit, UCHRBU—Upper Castle Hayne aquifer-River Bend unit; J, estimated concentration; IR, Installation Restoration Program site; BDL, below detection limits; N/A, constituent concentration at site is consistently below detection limits. Data are not applicable; D, sample dilution required]

Site number[1]	Groundwater contaminants of concern	Maximum observed concentration, in µg/L	Sample date	Contaminant source characterization	Water-bearing units containing contaminants[2]	Water-supply wells possibly affected by site contaminants[3]
1	PCE	6.8	7/7/1984	dispersed	BBUAQ	[4]HP-624
	TCE	27	4/24/1994	dispersed	BBLAQ	[6]HP-638
	VC	4.0J	11/11/1994	dispersed	—	—
	Benzene	BDL	N/A	N/A	—	—
2	PCE	10	10/23/1997	dispersed	BBLAQ	[4]HP-616
	TCE	7.0	10/23/1999	dispersed	TTAQ	[7]HP-645
	VC	BDL	N/A	N/A	UCHRBU	[6]HP-646
	Benzene	0.40	11/2/1995	plume[5] (?) off site	—	[6]HP-647
3	PCE	22	7/22/1998	dispersed or off site	BBUAQ	[6]HP-613
	TCE	11	1/18/1999	small plume (?)	BBLAQ	[4]HP-617
	VC	BDL	N/A	N/A	TTAQ	[6]HP-654
	Benzene	40J	12/1/1994	small plume (?)	UCHRBU	—
6	PCE	6,300	1/21/2003	plume	BBUAQ, BBLAQ	[7]HP-610
	TCE	180,000	1/16/1999	plume	TTAQ, UCHRBU	[4]HP-619
	VC	800J	3/23/1993	plume	UCHLU, MCHAQ	[4]HP-635
	Benzene	32J	1/24/2003	plume (?)	—	[7]HP-651
						[7]HP-653
9	PCE	BDL	N/A	N/A	UCHRBU	—
	TCE	1.2	3/8/1993	dispersed	—	—
	VC	BDL	N/A	N/A	—	—
	Benzene	BDL	N/A	N/A	—	—
10	PCE	BDL	N/A	N/A	N/A	—
	TCE	BDL	N/A	N/A	N/A	—
	VC	BDL	N/A	N/A	N/A	—
	Benzene	BDL	N/A	N/A	N/A	—
21	PCE	BDL	N/A	N/A	BBUAQ	[7]HP-602
	TCE	41J	5/20/1993	plume[8] (?) off site	BBLAQ	[4]HP-604
	VC	BDL	N/A	N/A	—	[7]HP-637
	Benzene	77J	5/20/1993	plume[9] (?) off site	—	—
22	PCE	4.0	4/20/1988	plume[8] off site	BBUAQ	[7,9]HP-602
	TCE	5.0J	1/18/1991	plume[8] off site	BBLAQ	[4]HP-607
	VC	BDL	N/A	N/A	—	[4]HP-630
	Benzene	29,000	4/20/1988	plume	—	—
24	PCE	BDL	N/A	N/A	BBUAQ(?)	[4]HP-607
	TCE	BDL	N/A	N/A	BBLAQ(?)	[4]HP-630
	VC	BDL	N/A	N/A	—	—
	Benzene	3.0	7/7/1984	dispersed or off site	—	—

Table C80. Summary of analyses for groundwater contaminants of concern and related contaminant source characterizations and affected water-supply wells within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[Contaminant: PCE— tetrachloroethylene, TCE—trichloroethylene, VC—vinyl chloride; µg/L, microgram per liter; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, MCHAQ—Middle Castle Hayne aquifer, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer-Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; J, estimated concentration; IR, Installation Restoration Program site; BDL, below detection limits; N/A, constituent concentration at site is consistently below detection limits. Data are not applicable; D, sample dilution required]

Site number[1]	Groundwater contaminants of concern	Maximum observed concentration, in µg/L	Sample date	Contaminant source characterization	Water-bearing units containing contaminants[2]	Water-supply wells possibly affected by site contaminants[3]
28	PCE	BDL	N/A	N/A	BBUAQ	—
	TCE	15	7/7/1984	dispersed	BBLAQ	—
	VC	22	7/7/1984	dispersed	—	—
	Benzene	BDL	N/A	N/A	—	—
30	PCE	BDL	N/A	N/A	N/A	—
	TCE	BDL	N/A	N/A	N/A	—
	VC	BDL	N/A	N/A	N/A	—
	Benzene	BDL	N/A	N/A	N/A	—
74	PCE	BDL	N/A	N/A	N/A	[6] HP-613
	TCE	BDL	N/A	N/A	N/A	[4] HP-617
	VC	BDL	N/A	N/A	N/A	[6] HP-654
	Benzene	BDL	N/A	N/A	N/A	—
78	PCE	140	1/27/2004	plume[8]	BBUAQ	[4] HP-601, [7] HP-602
	TCE	14,000	1/17/1991	plume[8]	BBLAQ	[7] HP-603, [7] HP-604
	VC	6,700D	1/11/2001	plume	TTAQ	[4] HP-605, [4] HP-607
	Benzene	5,500	1/30/2003	plume[10]	UCHRBU	[7] HP-608, [4] HP-630
					UCHLU	[4] HP-631, [7] HP-634 [4] HP-635 [7] HP-637 [6] HP-642 [7] HP-652 [7] HP-660
80	PCE	BDL	N/A	N/A	N/A	—
	TCE	BDL	N/A	N/A	N/A	—
	VC	BDL	N/A	N/A	N/A	—
	Benzene	BDL	N/A	N/A	N/A	—
82	PCE	4,600J	7/10/2001	plume	BBUAQ	[7] HP-610
	TCE	71,000D	10/23/1999	plume	BBLAQ	[4] HP-619
	VC	270J	4/16/1998	plume	TTAQ	[4] HP-633
	Benzene	11	1/17/1999	plume (?)	—	[7] HP-651
						[7] HP-653
84	PCE	BDL	N/A	N/A	BBLAQ	[6] HP-704
	TCE	0.19J	8/6/2001	dispersed	TTAQ	—
	VC	BDL	N/A	N/A	—	—
	Benzene	3,800	1/11/1994	small plume (?)	—	—

Table C80. Summary of analyses for groundwater contaminants of concern and related contaminant source characterizations and affected water-supply wells within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[Contaminant: PCE— tetrachloroethylene, TCE—trichloroethylene, VC—vinyl chloride; µg/L, microgram per liter; BBLAQ—Brewster Boulevard lower aquifer, BBUAQ—Brewster Boulevard upper aquifer, MCHAQ—Middle Castle Hayne aquifer, TTAQ—Tarawa Terrace aquifer, UCHLU—Upper Castle Hayne aquifer-Lower unit, UCHRBU—Upper Castle Hayne aquifer–River Bend unit; J, estimated concentration; IR, Installation Restoration Program site; BDL, below detection limits; N/A, constituent concentration at site is consistently below detection limits. Data are not applicable; D, sample dilution required]

Site number[1]	Groundwater contaminants of concern	Maximum observed concentration, in µg/L	Sample date	Contaminant source characterization	Water-bearing units containing contaminants[2]	Water-supply wells possibly affected by site contaminants[3]
88	PCE	170,000	8/21/1997	small plume	BBUAQ	[4] HP-601
	TCE	4,600D	1/16/2001	small plume	BBLAQ	[7] HP-603
	VC	910	5/16/2000	small plume	—	[7] HP-660
	Benzene	BDL	N/A	N/A	—	—
94	PCE	BDL	N/A	N/A	BBUAQ	[4] HP-601
	TCE	79	5/3/1995	plume[10] (?) off site	—	[7] HP-603
	VC	BDL	N/A	N/A	—	[7] HP-608
	Benzene	17,300	4/5/1995	small plume	—	[7] HP-660

[1] See Figure C1 for location

[2] All BTEX components (benzene, toluene, ethylbenzene, and xylene) were considered when defining a water-bearing unit as contaminated. Water-bearing units are listed by site only and are not related to a specific contaminant of concern on this table

[3] Water-supply wells possibly affected by contaminants are listed by site only and are not related to a specific contaminant of concern or water-bearing unit on this table

[4] Well removed from service prior to beginning of Initial Assessment Study and was never sampled for contaminants of concern. Well contamination suspected because of proximity to known contaminant source or sources and depth of screen openings

[5] Occurrence of BTEX components in groundwater is possibly related to BTEX contamination of groundwater in the vicinity of supply well HP-645. See Table C10

[6] Well contamination suspected because of proximity to known contaminant source or sources and depth of screen openings

[7] Contaminant concentrations in well determined by analysis of water samples. See Tables C7–C10

[8] Groundwater contamination by PCE or TCE is possibly related to plumes of chlorinated solvents in the northern and southern parts of the Hadnot Point Industrial Area. See Figure C16

[9] Well contamination by benzene is possibly related to fuel spills or leaks at the Hadnot Point fuel farm. See Figure C9 and Table C37

[10] Groundwater contamination by benzene is possibly related to fuel spills or leaks at the Hadnot Point fuel farm (Figure C9) or near Building 1613 (Figure C30)

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter C: Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites

Printed on recycled paper

EXHIBIT 2

File - Lab info prepared by E. Bilz 2-26-85
1133

CHRONOLOGY

Summer 84	NACIP sampled 22 wells identified as potential problems due to proximity.
30 Nov 84	Received results (ESE study). Well 602 positive for benzene. 602 was shut down and resampled.
4 Dec 84	Sampled Hadnot Point Water Plant (HP) raw and treated water, plus wells 601, 603, 608, 634, 637 and 642 because of their proximity to 602.
6 Dec	Received test results (Table [1]). Wells 601, 602, 608, raw and treated water positive for Trichloroethylene (TCE), trans-1,2-Dichloroethylene (DCE), and Tetrachloroethylene (PCE). Wells 602 and 608 also showed other Volatile Organic Chemicals (VOCs). Wells 601 and 608 were shut down.
10 Dec	Sampled HP treated water, plus Wells 601, 602, 608, 634, 637 and 642
13 Dec	Took Quality Control (QC) samples of 602, split three ways.
13-19 Dec	Took daily samples of HP raw water.
14 Dec	Received results of 10 Dec 84 sampling (Table [2]). Treated water levels dropped. Wells 634 and 637, previously showing nothing, showed significant levels of Methylene Chloride(MC). 634 and 637 were shut down.
19 Dec	Took a distribution sample from HP. Location was FC-540, far point from plant.
21 Dec	Received results of daily HP samples (Table [3]), plus JTCs QC sample and FC-540. The QC samples from JTC and Grainger (received later) confirmed the presence of TCE and DCE.
16 Jan 85	Sampled all operating wells for HP and Holcomb Blvd Water Plant (HB). 37 wells.
23 Jan	Sampled all operating wells for Onslow Beach (OB), Courthouse Bay (CHB), Camp Johnson (CJ) and Tarawa Terrace (TT) water plants. 21 wells.
27 Jan	Base Chief of Staff detected gasoline smell in water in quarters, serviced by Holcomb Blvd plant and reservoir.
27 Jan	Reservoir flushed initially. Later, drained reservoir, shutdown HB plant, scrubbed reservoir with high pressure hoses. Housing areas and mainside are now being served by HP.
29 Jan	Sampled all operating wells for Marine Corps Air Station-New River (MCAS) and Rifle Range (RR). 25 wells.
	Sampled finished water at HB (plant still shut down). Sampled

EXHIBIT
18
Hornak

	Chief of Staff quarters (now being served with HP).
31 Jan 85	Received results of 29 Jan 85 sampling (Table [4]). Sampled finished water at HP distribution pump, HB reservoir, and points in Paradise Pt and Berkeley Manor housing areas (still served by HP).
1 Feb 85	Samples delivered to State Laboratory. Analysis run on most samples (finished 4 Feb 85)
4 Feb	Received results of 16 Jan 85 Well sampling (Table [5]). Wells 602, 608, and 645 were broken. Wells 634 and 651 show significant levels of TCE, DCE, PCE, and Vinyl Chloride. Wells 652 and 653 showed trace amounts of TCE. Well 651 was shut down. Received results of 31 Jan 85 sampling (Table [6]). The following wells were sampled: 602, 608, 610, 654, 645, 649 and two samples at 651. Reactivated HB. Began flushing entire distribution systems served by both HB and HP.
5 Feb	A treated sample from HP, HB, TT, CJ, MCAS was taken. Wells 203 and 191 at MCAS were resampled.
6 Feb	The 4 & 5 Feb 85 sampling were shipped to JTC.
7 Feb	Sampled raw and finished water at both plants and two samples from HB distribution system. Received results of 23 Jan 85 Well sampling (Table [7]).
8 Feb	Received results of 15 wells of the 29 Jan 85 sampling (Table [8]). Received results of 7 Feb 85 sampling (Table [9]). Received results of the duplicate sampling of 651 on 4 Feb 85, (Table [10]).
12 Feb	Resampled TT plant, TT-26, and TT New Well Received results of HP and TT plant sampling on 5 Feb 85, (Table [11]).
14 Feb	Received results of TT resampling on 12 Feb 1985, (Table [12]).
19 Feb	Resampled TT plant, TT-26 and TT New Well, split two ways.
20 Feb	Sampled treated water at OB, CHB, RR. Sampled Well M-168 at CJ. Resampled CHB new well. Shipped one TT set from 19 Feb 85 to State Lab. Shipped 20 Feb 85 samples to JTC.

21 Feb 85	Shipped other TT set from 19 Feb 85 to JTC.
	Resampled HP and HB treated, BM-5400 and hydrant at MOQ 2204; and sampled Bldg 65 lab with Mike Bell from State.
22 Feb	Received results of 19 Feb 1985 sampling run by State Laboratory (Table [13]).
25 Feb	Received results of 19 Feb 85 sampling run by JTC (Table [13]).

Abbreviations for Following Tables

Trans-1,2-Dichloroethylene	DCE
Tetrachloroethylene (Perchloroethylene)	PCE
Trichloroethylene	TCE
Benzene	B
1,1-Dichloroethylene	11D
Toluene	T
Vinyl Chloride	VC
Methylene Chloride	MC
None Detected	ND

Notes for Following Tables

1. Results from hard copy in LANTNAVFACENGCOM LTR of 8 Jan 1985 (Not from PHONCON) received NREAD 11 Feb 85.
2. Results from hard copy received 11 Feb 85 from State Laboratory.
3. Results from hard copy in LANTNAVFACENGCOM LTR of 12 Feb 85 (Not from PHONCON) received NREAD 15 Feb 85.
4. Results from hard copy in LANTNAVFACENGCOM LTR of 14 Feb 85 (Not from PHONCON) received NREAD 19 Feb 85.
5. Results from hard copy in LANTNAVFACENGCOM LTR of 19 Feb 85 (Not from PHONCON) received NREAD 21 Feb 85.

All results are reported in parts per billion (ppb)

TABLE [1]

LAB: JTC   Sampled: 4 Dec '84   Detection Limit: 10ppb

Sample Point	DCE	PCE	TCE	B	11D	T	VC	THM
HP Treated	83	3.9	200	ND	ND	ND	ND	P
HP Raw	15	ND	46	↕	↕	↕	↕	P
601	88	5.0	210	ND	ND	ND	ND	
602 (11/30/84)	630	24	1600	120	2.4	5.4	18	
603	ND	ND	ND	ND	ND	ND	ND	
608	5.4	↑	11.0	3.7	↑	↑	↑	
634	ND	│	ND	ND	│	│	│	
637	↕	↓	↕	↕	↓	↓	↓	
642	ND	ND	ND	ND	ND	ND	ND	

See Note 1.

TABLE [2]

LAB: JTC   Sampled: 10 Dec 84   Detection Limit: 10ppb

Sample Point	DCE	PCE	TCE	B	MC	THM
601	99	ND	230	ND	10	
602	380	↑	540	720	ND	
603	ND	│	ND	ND	7.0	
608	2.4	│	13	4.0	14	
634	2.3	│	ND	ND	130	
637	ND	│	↕	↑	270	
642	ND	↓	ND	↓	38	
HP Treated	2.3	ND	2.3	ND	ND	P

See Note 1.

TABLE [3]
Hadnot Point Raw Water

LAB: JTC   Detection Limit: 10ppb

Sample Point	DCE	PCE	TCE	MC	THM
12/4/84	15	ND	46	ND	P
12/13/84	ND	↑	ND	54	P
12/14/84	↑	│	↑	ND	P
12/15/84	│	│	│	↑	P
12/16/84	│	│	│	│	P
12/17/84	│	│	│	│	P
12/18/84	↓	↓	↓	↓	P
12/19/84	ND	ND	ND	ND	P
12/19/84(FC540)	ND	ND	1.2	ND	P

See Note 1.

TABLE [4]

LAB: NC State Sampled: 29 Jan 85 Detection Limit: 50ppt

Sample Point	TCE	EDB(Ethylene dibromide)
HB Before Reservoir	339.8	ND
HB After Reservoir	8.2	↕
MOQ 2212	1040.9	ND
Gas Sample	ND	

See Note 2.

Table [5]

LAB: JTC Sampled: 16 January 1985 Detection Limit: 10ppb

Well	DCE	TCE	PCE	VC	11D
601	8.8	26	ND	ND	ND
634	700	1300	10	6.8	ND
651	3400	3200	386	655	187
652	ND	9.0	ND	ND	ND
653	ND	5.5	ND	ND	ND

None Dectected:

603
606
609
611
613
614
616
620
621
627
632
633
635
636
637
638
639(OLD)
639(NEW)
640
641
642
643
644
646
647
648
650
655
LCH 4007

Broken Samples:

602
608
645
651

See Note 3.

TABLE [6]

NORTH CAROLINA DEPARTMENT OF HUMAN RESOURCES
DIVISION OF HEALTH SERVICES
OCCUPATIONAL HEALTH LABORATORY

COMPANY:Camp Lejeune Water System
ADDRESS:Camp Lejeune, Jacksonville, N.C.
SERVICE REQUESTED:VOLATILE ORGANIC ANALYSIS
SAMPLE TAKEN ON:1/31/85
SAMPLE TAKEN BY:Betsy Betz
SUBMITTED TO LABORATORY:2/1/85
SUBMITTED BY:Betsy Betz

DATE OF ANALYSIS:2/1-4/85
ANALYSED BY:John L. NeaL

DATE REPORTED:2/4/85

RESULTS IN PPB (ug/liter)

LOCATION	DICHLOROETHYLENE	TRICHLOROETHYLENE
Bldg 20	321.3	900.0
Bldg 670 Bottom	7.4	24.1
MOQ 2212 Cold Water	249.4	724.6
Bldg 670 Top	7.6	26.8
MOQ 2212 Hot Water	201.2	612.9
Bldg 670 Middle	7.8	25.8
Tank SLCH 4004	107.5	318.3
Hydrant MOQ 2204	307.6	839.7
Hydrant Elev. Tank S-830	340.0	849.0
Tank S-2323	159.0	407.1
BM 5677	368.7	981.3
BM 5531	335.0	905.5
Bldg PP 2600	332.4	890.9
Bldg 5400	406.6	1,148.4

COMMENTS:

Also identified in all samples were chloroform, dichloromethane, and two (2) unidentified peaks possibly dibromomethane and bromoform. Total Trihalomethanes <<100.0 PPB.

REPORTED BY: John L. Neal

cc. Charles Rundgren, Water Supply Branch
Mike Bell, ERO
✓Fred Hill, ERO
Environmental Epidemiology

TABLE [7]

Well Analysis by JTC

Sampled: 23 Jan 85

System	Well	DCE	TCE	PCE	VC	THM
CHB	A-5	ND	ND	ND	ND	P
TT	TT-26	92	57	158	27	
TT	New	11	5.8	132	ND	

None Detected:

BB-44
BB-220
BB-221
CHB New Well
BA-164
BA-190
M-142
M-192
M-267
M-628
M-629
M-630
TT-25
TT-30
TT-31
TT-52
TT-54
TT-67

See Note 4

TABLE [8]

Well Analysis by JTC

Sampled: 29 Jan 85

Well	TCE
4150	2.5

None Detected:

100
190
201
325
502
504
604
700
TC-1000
1001
1251
1253
1254
1255
1256
5001
5009
131
4140
RR-45
RR-47
RR-97

See Note 5

TABLE [9]

NORTH CAROLINA DEPARTMENT OF HUMAN RESOURCES
DIVISION OF HEALTH SERVICES
OCCUPATIONAL HEALTH LABORATORY

COMPANY: Camp Lejeune Water System
ADDRESS: Camp Lejeune, Onslow County
SAMPLE TAKEN ON: 02/07/85
SAMPE TAKEN BY: J. Fred Hill
SUBMITTED TO LABORATORY: 02/08/85
SUBMITTED BY: J. Fred Hill, E. Betz

DATE OF ANALYSIS: 02/08/85
ANALYSED BY: John L. Neal, Vicki Painter

DATE REPORTED: 02/08/85

RESULTS IN PPB (ug/L)

LOCATION	trans 1,2-DCE	CHC13	DCBM	TCE	DBCM
Bldg. 20 Res. Fin. Water	5.3	10.3	6.3	16.8	3.4
Bldg. 20 Filter Eff.#1	<2.0	6.8	4.3	<2.0	2.0
Bldg. 20 Filter Eff.#2	<2.0	9.1	5.7	3.4	3.4
Bldg. 20 Influent	<2.0	5.0	4.0	<2.0	1.5
Bldg. 670 Res. Fin. Water	<2.0	14.84	8.3	<2.0	3.6
Bldg. 670 Filter Eff.#1	<2.0	11.45	6.1	<2.0	1.2
Bldg. 670 Filter Eff.#2	<2.0	10.03	5.8	<2.0	1.2
Bldg. 670 Influent	<2.0	8.1	4.9	<2.0	1.7
MOQ 2204 Hydr. Dis. Sys.	9.0	23.92	10.74	32.4	4.5
Bldg. 5400 Ber. Man. Sch.	44.8	24.49	10.83	135.1	5.0

COMMENTS: trans 1,2-DCE is trans 1,2-dichloroethylene, CHC13 is Chloroform, DCBM is dichlorobromomethane, TCE is trichloroethylene, and DBCM is dibromochloromethane. Samples analysed by purge and trap method utilizing Hall detector in the halogen mode.

REPORTED BY: John L. Neal

cc. Charles Rundgren, Water Supply Branch
Mike Bell, ERO
✓J. Fred Hill, ERO
Environmental Epidemiology

TABLE [10]

Duplicates of 651

Sampled: 4 Feb 1985 LAB: JTC

	#1	#2
DCE	7580	8070
PCE	400	397
TCE	18900	17600
VC	168	179

TABLE [11]

Sampled: 5 Feb 85 LAB: JTC

	TCE	DCE	PCE
HP	429	150	ND
TT	12	ND	215

TABLE [12]

Sampled: 12 Feb 85 LAB: JTC

	PCE	TCE	DCE	B
TT-26	3.8	ND	ND	ND
TT New Well	37	1.8	1.9	6.5
TT Plant	ND	ND	ND	ND

See Note 5

Table [13]

Sampled: 19 Feb 85

	TT-Treated		TT-New Well		TT-26	
	State	JTC	State	JTC	State	JTC
DCE	ND	ND	Trace	13	Trace	9.5
PCE	ND	↑	26.17	ND	55.17	64
Benzene	NA	↓	ND	6.3	ND	ND
TCE	ND	ND	53.53	ND	3.91	4.1

NA=Not Analyzed

Gas Chromatograph Summary

The pending orders with Perkin-Elmer were placed by P & C on 20 Feb 85. Perkin-Elmer promised delivery in three weeks (14 Mar 85). On 21 Feb 85 the Service Rep, who will install our GC, called. He stated that he would try to speed up the requisitions. He said as soon as the gas filters and driers came in to call him and make an appointment for installing GC (should not have to wait more than a week). As soon as we have an appointment for installation, then Perkin-Elmer will schedule the on-base training class.

Running Samples

Standards are on order from EPA.

Quality Control Check samples for certification are on order from the State of North Carolina.

When all is set up, using one technician, Seven samples a day could be analyzed. That would be the maximum the lab could run. That is not including collection. Seven samples a day would be starting with analysis at 0800. A hour a sample is the analysis rate. Only one sample can be run at a time. At least one standard a day should be run, taking an hour for it.

Gas Chromatograph Status

Requirements for Installation

1. Ventilation - Completed by Base Maintenance on 7 Feb 85.

2. Gas Supplies
   Safety Rack for Gas Cylinders - Built by Base Maintenance on 14 Feb 85.
   Hole for Gas Lines - Finished by Base Maintenance on 19 Feb 85.
   Gas Cylinders - Received from National Welders by 20 Feb 85
   Gas Regulators - Received from National Welders by 20 Feb 85.
   Gas Filters 7 Drier - Ordered from Perkin-Elmer on 20 Feb 85 (Pending).

3. Electrical Supply - Installed by Base Maintenance on 13 Feb 85

Requirements for Operation

1. Flow Meter for regulating gas - Ordered from Perkin-Elmer on 20 Feb 85 (Pending).

2. Packed Columns, which are the sample reaction tubes that are specific for parameters - Ordered from Perkin-Elmer on 20 Feb 85 (Pending).

UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA
SOUTHERN DIVISION

IN RE: CAMP LEJEUNE)
WATER LITIGATION,)
)
) Case No.
) 7:23-CV-00897

VIDEO DEPOSITION OF
DAVID SABATINI, PH.D, PE, BCEE

TAKEN ON BEHALF OF THE UNITED STATES

IN OKLAHOMA CITY, OKLAHOMA

ON APRIL 11, 2025, AT 9:03 A.M.

REPORTED BY: LANA L. LEDFORD, CSR

A P P E A R A N C E S

For the Plaintiffs:

Laura J. Baughman
Devin Bolton (Via Zoom)
WEITZ & LUXENBERG
700 Broadway
New York, New York 10003
(212)558-5915
lbaughman@weitzlux.com

For the Defendants:

Alanna Horan
1100 L St
Washington, KC 20005
alanna.r.horan@usdoj.gov

Allison O'Leary
310 New Bern Avenue
Raleigh, North Carolina 27601
allison.o'leary@usdoj.gov

ALSO PRESENT VIA ZOOM:

Deanna Havai, Motley Rice
Giovanni Antonucci (DOJ)
Haroon Anwar (DOJ)
Kailey Silverstein (DOJ)
Dennis Reich
Morris Maslia, PE
Remy Hennet, PE
Zina Bash, Keller Postman

VIDEOGRAPHER: Stesha Ferguson

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GOVERNMENT EXHIBITS

Page 105, Line 23: Testimony marked at the request of Ms. Baughman

S T I P U L A T I O N S

It is hereby stipulated and agreed by and between the parties hereto, through their respective attorneys, that the deposition of DAVID SABATINI, PhD., PE, BCEE may be taken on behalf of the UNITED STATES on APRIL 11, 2025, in OKLAHOMA CITY, OKLAHOMA, by Lana L. Ledford, Certified Shorthand Reporter for the State of Oklahoma, pursuant to notice and Federal Rules of Civil Procedure.

* * * * * *

THE VIDEOGRAPHER: This is the videotaped deposition of David Sabatini. Today's date is April 11, 2025, and we are on the record at 9:03 a.m. Will counsel please state their appearances for the record.

MS. BAUGHMAN: Laura Baughman for the Plaintiffs.

MS. HORAN: Alanna Horan here on behalf of the United States, and I'm joined by my colleague, Allison O'Leary.

MS. HORAN: Good morning, Dr. Sabatini.

DR. SABATINI: Good morning.

MS. HORAN: I'm sorry. I think we need to do the oath first.

THE VIDEOGRAPHER: The court reporter will now swear the witness.

DAVID SABATINI, Ph.D, PE, BCEE,
of lawful age, being first duly sworn, deposes and says in reply to the questions propounded as follows:

* * * * * * *

EXAMINATION

BY MS. HORAN:

Q Good morning, Dr. Sabatini. Could you please state your full name for the record?

A David Allen Sabatini.

Q And what is your current address?

A Current...

Q Address.

A Address.

1632 Crestmont, C-r-e-s-t-m-o-n-t, Avenue, Norman, Oklahoma 73069.

Q And do you currently have a work office that you go to on a regular basis?

A I'm an emeritus professor so I have an office I go to several times a week.

Q And where is that office?

A It's at the University of Oklahoma.

Q Have you been deposed before?

A I was deposed once before about 40 years ago on work that I did for the railroad. But that was a short hour-or-two-long deposition about work that I had done.

Q And I understand it was 40 years ago. But to the best of your recollection, what was that deposition about?

A It was about railroad right-of-way, and a farmer had built a dike to try and prevent flooding onto his land which was encroaching upon increased water levels on the railroad right-of-way -- the railroad elevated tracks. So the concern was what they did would have damage -- what the farmer had done would damage railroad property.

Q And were you in your capacity as an expert in that case?

A I was -- it was based on work I had done for the railroad. So I was testifying to work I had done for the railroad.

Q And you've only been deposed that one time?

A That's the only time. Once.

Q So as, I think you know, I represent the United States in this matter. And you understand that you're obligated to tell the truth today?

A Yes.

Q A court reporter is taking down everything that we say. It's important that you answer verbally. For example, you must say "yes" or "no" rather than nodding or shaking your head.

Does that work?

A Yes.

Q Off to a good start.

Please talk at a reasonable pace. The pace I'm speaking at is fine. You seem to speak at a very reasonable pace as well. But just to make sure that the court reporter can take down everything we say. Fair?

A Fair.

Q We'll do our best not to interrupt each other just so the court reporter, again, can take down all of our complete questions and your complete answer. So I just ask that you please wait until I finish my question before you start to answer, and I will do my best not to interrupt you when you're speaking as well.

Is that fair?

A Fair.

Q Once the deposition is complete, you'll be -- you'll be given the opportunity to read the transcript of your testimony and make any corrections, and then you'll be asked to sign it.

Do you understand that?

A Understood.

Q Only you are testifying today. You must answer to the best of your ability. And I just ask that you not ask other people for their help in answering any questions today.

Fair?

A Understood.

Q If you do not understand a question, please let me know and I'll do my best to clarify the question. If you don't ask for clarification, I will assume that you understood the question.

Is that fair?

A Fair.

Q Is there any reason why you're unable to give your most truthful and accurate testimony today?

A No.

Q What did you do to prepare for your deposition today?

A I reviewed my expert rebuttal report and associated reports.

Q What do you mean by "associated reports"?

A I reviewed Hennet's expert report that I was responding to. And I reviewed the AH Environmental report that was pivotal. And I reviewed the Nakasone paper that fed into the losses over the weir and the spiractor. And the McKone paper and the shower experiment.

Q So other than reviewing your expert report, Dr. Hennet's report, the AH Environmental report, the Nakasone study, and the McKone study, did you review any other documents in preparation for your deposition today?

A Possibly, in general. Just background information. But not specific -- not to my recollection. Oh, I reviewed Hennet's deposition. That would have been specific.

Q Did you review any other depositions beyond Dr. Hennet's?

A That's not -- not to my recollection.

Q Did you meet with anyone to prepare for your deposition today?

A I met with counsel yesterday to go over being the first time as an expert, in preparation.

Q And for how long did you meet with counsel yesterday?

A We met for two or three hours in the morning and then hour or two in the afternoon.

Q Besides Ms. Baughman, who I believe --

A Yes.

Q -- may have been the counsel you were with yesterday --

A Yes. Yes.

Q -- was anyone else present for that

prep?

A Not in person.

Q Who joined you remotely?

A Devin Bolton and Kevin Dean.

Q Have you testified in court before?

A No.

Q And I believe you said this is your first time serving as an expert witness in a case?

A Yes. Correct.

Q Have you read the complaint in this case?

A I'm sorry? The...

Q The complaint.

A Yes. Early on, I did, as I recall. The complaint. What -- refresh my memory of the complaint.

Q Sure.

So a complaint is a document wherein the Plaintiffs state what their allegations are.

Do you recall reading a document like that at any point?

A I think I may have, several years ago.

Q And to the best of your understanding, what are the Plaintiffs' allegations in this case?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Not remembering, specifically, the document, I'd be hesitant to speak to that.

Q (BY MS. HORAN) Sure.

So setting aside the complaint document, just generally, what is your understanding of what the Plaintiffs' claims are in this case?

MS. BAUGHMAN: Object to the form.

THE WITNESS: It's kind of an open-ended question. Can you be more specific?

Q (BY MS. HORAN) I'm just trying to understand what -- what you believe the Plaintiffs' allegations are. It's not -- it's just your understanding.

A Okay.

Q And it could come from any source kind of. You've -- sounds like you've been working on this for -- for a while, based on your billing records. So really just generally, what your understanding is.

MS. BAUGHMAN: Same objection.

THE WITNESS: The -- that there was groundwater contamination that resulted in drinking water contamination and that there was exposure as a result.

Q (BY MS. HORAN) Do you personally know anyone with a pending lawsuit or administrative claim against the United States related to their time at Camp Lejeune?

A No.

Q Do you know -- or strike that.

Have you ever spoken, in person or via email, with a man named Ernest Hunt?

A I'm sorry? With...

Q With a man named Ernest Hunt.

A I've had no personal contact.

Q Have you ever spoken, in person or via email, with a man named Mark Cagiano?

A No.

Q Have you ever spoken, in person or via email, or text message, phone, any of those, with a man named Jerry Ensminger?

A No.

Q Have you ever spoken, in person or via email, phone, any form of communication, with a man named Mike Partain?

A No.

Q When were you retained in this matter?

A It was in April of -- two years ago.

Q So April 2023?

A '23. Yes.

Q And how did you -- or strike that.

You were retained by the Bell Legal Group; is that right?

A Yes.

Q And do you recall if they contacted you or if you contacted them?

A They contacted me.

Q Had you previously worked with anyone from the Bell Legal Group?

A No.

Q Do you recall the name of the attorney that called you?

A Pat Telan. T-e-l-a-n.

Q Not exclusive to the Bell Legal Group, but have you ever worked with any of the counsel in this case before?

A No.

Q Giving your best estimate, roughly how many hours have you spent working on this case?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I'd have to refer to my records. I don't recall a specific -- a number.

Q (BY MS. HORAN) And you've been billing hours since April of 2023. Is that fair?

A Yes.

Q And your billing records would be the best place to find out how many hours you've worked on the case?

A Yes.

(Government Exhibit 1 marked for identification)

Q (BY MS. HORAN) I'm marking as Exhibit 1. This is a document with the Bates CL_PLG-Expert_Sabatini_0000002426. And it runs through the Bates ending in 2443.

MS. BAUGHMAN: So what she's reading is just the number at the bottom.

THE WITNESS: Okay.

MS. BAUGHMAN: Okay.

THE WITNESS: Okay.

MS. BAUGHMAN: He doesn't know. Just so he understands. Okay.

Q (BY MS. HORAN) And if you have any questions like that, please feel free to ask them.

A Thank you.

Q We want to make sure you're on the same page as me.

A Thank you.

Q Dr. Sabatini, do you recognize these as your billing records?

A Yes.

MS. HORAN: So I'll just put on the record, I've looked and I've only been able to find billing records for the calendar year 2024. So we would just request the records from April '23 to December '23, and then any from 2025.

MS. BAUGHMAN: So to the best of my knowledge, there aren't any from 2023. You can ask him, but I'm not aware of them. And I don't think they exist for 2025 yet.

THE WITNESS: Yeah. I've not --

MS. BAUGHMAN: But you can ask him --

THE REPORTER: Wait. One at a time, please.

MS. BAUGHMAN: Yeah. Remember, don't -- only --

THE WITNESS: I'm sorry.

MS. BAUGHMAN: -- one person at a time.

THE WITNESS: I'm sorry.

MS. BAUGHMAN: And you should only speak when she asks you a question. Okay?

THE WITNESS: Okay.

MS. BAUGHMAN: All right. Go ahead.

MS. HORAN: Sure.

Q (BY MS. HORAN) I think -- did you bill in 2023 calendar year?

A From the best of my knowledge, yes.

Q So there would be a record of that billing that you did in 2023; correct?

A That would be my understanding.

MS. HORAN: Okay. So we just request those documents.

Q (BY MS. HORAN) And you have not billed for 2025 yet?

A No.

Q Okay. And since January, roughly how many hours do you think you've worked on this case?

A I'd have to refer to my records.

Q Sure.

Looking at your billing records, prior to receiving the DOJ reports in December of 2024, you had drafted and finalized an expert report.

Fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I had worked on a document. Yes.

Q (BY MS. HORAN) And in your billing records, you refer to that document as expert report. Fair?

A In the billing. Yes.

Q And you did not file that expert report in this case; correct?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I'd have to defer to counsel.

Q (BY MS. HORAN) You don't know one way or the other whether that document was ever filed?

A To my knowledge, it --

MS. BAUGHMAN: Objection to form.

What do you mean filed? We don't file expert reports.

MS. HORAN: That's a fair correction.

MS. BAUGHMAN: Okay.

Q (BY MS. HORAN) Do you know if that document was ever provided to the United States?

A No. No. I mean not to my knowledge.

Q The first page of the Exhibit 1.

A Okay.

Q The second billing line is for January 9.

Do you see that?

A Yes.

Q And it's for .5 hours, and it says, "Prep for 1/23 trip."

A Yes.

Q Where was that trip to?

A The trip did not happen.

Q Where was the trip anticipated to be?

A The trip was --

MS. BAUGHMAN: Wait. Hold on. I'm going to object and just refer, for your sake, and for Dr. Sabatini, to case management order number 17 which says that communications between expert and counsel are not discoverable.

So to the extent you need to answer any question about why a trip didn't take place, that's privileged --

THE WITNESS: Okay.

MS. BAUGHMAN: -- if it was a communication with counsel.

Go ahead.

MS. HORAN: Are you claiming privilege over where the trip was to?

MS. BAUGHMAN: Only if he has to rely on communications with counsel to answer the questions.

MS. HORAN: Okay.

Q (BY MS. HORAN) I'll ask you, Dr. Sabatini, but please don't answer if you have to rely on your communication with counsel to answer it.

A Okay.

Q Where was the trip that you were prepping for on January 9th to?

A That would cause me to rely upon communications from counsel.

Q Okay.

MS. BAUGHMAN: I might have said the wrong CMO. Just for the record, it's case management order 17. I don't -- I'm not sure if that's what I said. Just -- just to correct that. But go ahead.

MS. HORAN: Sure.

Q (BY MS. HORAN) And Dr. Sabatini, we'll go throughout the whole day. So to the extent I ask you a -- I might not know.

A Uh-huh.

Q So to the extent I ask you a question and you have to rely on your communications with counsel to answer it, that rule applies throughout the whole day.

A Thank you.

Q Okay. Could you please turn to the document ending -- or the page ending in 2438?

A 2438.

Q The last three entries on that page for June.

Do you see those?

A Yes.

Q And the entry next to June 11th says, "Consider additional calculations/analytical solutions."

Do you see that?

A Yes.

Q And the June 25th entry says, "Sample calculations-mass/concentrations-Tarawa Terrace."

Do you see that?

A Yes.

Q And the June 28th entry says, "Sample calculations-HPIA/HPLF."

Do you see that?

A Yes.

Q HPIA. What does that stand for?

A Hadnot Point Industrial Area.

Q And HPLF. What does that stand for?

A Hadnot Point Land Fill.

Q Could you turn to the last page, the page ending in 43?

A (Witness complies.)

Q The last billing entry for December 31st says, "Finalizing rebuttal report/Zoom call with Morris Maslia."

Do you see that?

A Yes.

Q Did you finalize your rebuttal report on December 31st or did you continue to work in -- work on it into January?

A I -- as I recall, we had an extension which allowed additional time.

Q So you continued to work on it into January. Fair?

A I don't recall specifically because I was targeting the earlier completion date. So I don't recall. I think -- believe I did do some additional work.

Q And the answer to that question would be in your billing records. Fair?

A Yes.

Q What is your practice with how often you bill the attorneys?

A Initially, it was I sent monthly. And then at some point last year, Lori Mertz recommended quarterly. So I transitioned toward quarterly billing towards the end of last year.

Q And you haven't billed for Q1 of 2025 yet?

A No.

Q Do you anticipate doing that soon?

A Probably sometime in the future.

MS. HORAN: We would just request those when they become available.

Q (BY MS. HORAN) The second half of the last entry on Page 43 says, "Zoom call with Morris Maslia."

When did you first meet Morris Maslia?

MS. BAUGHMAN: Hold on one second. Just -- just to be clear. So you know. Okay? Case management order 17 says you don't talk about your communications with --

THE WITNESS: Right.

MS. BAUGHMAN: -- other experts. But when you --

THE WITNESS: When. Time.

MS. BAUGHMAN: You can answer that question. Okay? Go ahead.

THE WITNESS: Okay. Thank you.

I've not met Morris Maslia in person.

Q (BY MS. HORAN) When did you first speak with Morris Maslia?

A As I recall, there was a general information Zoom with --

MS. BAUGHMAN: Just when.

THE WITNESS: When. When. Thank you.

In mid to late '23.

Q (BY MS. HORAN) And do you recall who else was on that Zoom in end of 2023?

A There were multiple people, but I don't recall. That was so long ago.

Q And roughly how many times have you spoken with Morris Maslia since then?

A Two times. At most, three.

Q Besides Morris Maslia, to the best you can recall, have you spoken with any other Plaintiffs' experts?

A Not that I recall. I'm trying to think through. No.

Q You don't recall ever speaking with a man named Dr. Aral Mustafa?

A No.

Q Have you ever spoken with Dr. Konikow?

A No. Well, not related to this case.

Q Had you previously worked with Dr. Konikow?

A Well, I was trying to -- I may have met him at a conference years ago.

Q Do you recall ever speaking with Jones or Davis?

A No.

Q Did you have any help in preparing your expert report? And again, I'm not asking about attorneys.

MS. BAUGHMAN: So not lawyers. Anyone else.

THE WITNESS: Say again?

MS. BAUGHMAN: Okay. She's asking you if you had help preparing your report, but she's not talking about any lawyers or anyone who's employed by a lawyer.

THE WITNESS: No.

Q (BY MS. HORAN) So no grad students or anything?

A No.

Q Okay. Did you write your expert report yourself?

A Yes.

Q Okay. You can put Exhibit 1 to the side.

A (Witness complies.)

MS. BAUGHMAN: So we just keep, like, a stack because sometimes she might go back to these. Okay.

THE WITNESS: Okay.

(Government Exhibit 2 marked for identification)

Q (BY MS. HORAN) I'm marking as Exhibit 2 -- this is a document with the title Expert Rebuttal Report of David Sabatini Ph.D, PE, BCEE, January 14, 2025.

Take as long as you'd like to flip through it, but do you recognize this as your written expert report that you submitted in this case?

A Yes. At least the cover page certainly. I assume the rest of the document.

Q Do you want to flip through it just to make sure it's all there?

A Sure. Let me...

MS. BAUGHMAN: Do you want him to look at every page or what do you want him to do?

MS. HORAN: Just generally.

THE WITNESS: Make sure there's -- this

looks -- it looks complete. Yes.

Q (BY MS. HORAN) All right. And this is the report that you reviewed in preparation for your deposition today?

A Yes.

Q Having reviewed your report in preparation for today, are there any corrections to the opinions you offered that you would like to make?

A No.

Q You can set that to the side.

A (Witness complies.)

(Government Exhibit 3 marked for identification)

Q (BY MS. HORAN) I'm marking as Exhibit 3 -- this is a document with the title January 2025 Rebuttal Expert Report of David Sabatini Supplemental Amended Materials Considered List dated April 9, 2025.

Dr. Sabatini, does -- do you recognize this document?

A Yes.

Q Have you seen it before?

A Yes.

Q And you recognize this as your supplemental materials considered list. Fair?

A Yes.

Q We -- does this include all of the materials you reviewed as an expert?

A To the best of my knowledge, yes. I mean, there were so many documents, but yes, this -- yes.

Q Is there anything you've reviewed since April 9th that you would like to add to this list today?

A No.

Q So the materials considered list that we originally received in January went to Page 8, and then everything from Page 9 onward was added to the April 9, 2025 list.

Is that your understanding that there was an update on April 9th?

A That's my understanding. Yes.

Q So since filing your report in January of 2025, you've since reviewed these 21 pages of materials? Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yes.

Q (BY MS. HORAN) And when did you first receive the information -- or strike that.

When did you first receive the documents on Pages 9 through 30 of this list?

A I don't recall.

Q Did you review any of the materials on Page 9 through 30 of your materials considered list prior to submitting your rebuttal report in January?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I may have, but I don't recall.

Q (BY MS. HORAN) Have you reviewed all of the materials, all 30 pages of these materials?

A To varying degrees, yes.

Q The materials in -- listed on Page 9 through 30 are not directly cited in your rebuttal report.

Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: To the best of my recollection.

Q (BY MS. HORAN) Could you turn to Page 11? It starts on Page 11 at the very bottom. Or strike that. It's actually on Page 12.

On Page 12 of your materials considered list, you have a number of depositions listed.

Do you see that?

A Yes.

Q You mentioned that you reviewed Dr. Hennet's deposition in preparation for today. Looking at this list now, did you review any other depositions in preparation for today?

A I looked at the deposition of Ernest Hunt and Mark Cagiano.

Q Have you read all of the depositions listed on Page 12?

A To varying degrees.

Q When you say "to varying degrees," what -- what do you mean?

A Some in detail and some just briefly. Some were more pertinent than others.

Q Have you attended any depositions in this matter?

MS. BAUGHMAN: Objection to form.

Do you mean in person or...

Q (BY MS. HORAN) No. Remotely or in person. At all in any way. Phone call.

A Yes.

Q Which ones have you attended remotely, in person, or a phone call?

A One.

Q And which one was that?

A Hennet.

Q The materials you have listed on Page 9 --

A I don't know if this is worth commenting. Some of these CLJs may have been in my appendix. I'm not sure.

Q When you say appendix, Dr. Sabatini, are you referring to the water buffalo Appendix A?

A Yes.

Q Now, that has its own materials considered list.

A Okay.

Q Is that fair? Or -- you're welcome to look at your report next to you if you'd like.

A Yes.

Q So are those separate materials considered lists or is this materials considered list inclusive of all of your documents?

MS. BAUGHMAN: If you know.

THE WITNESS: Yeah, I -- I'm not clear. I'm not sure. Trying to be comprehensive.

Q (BY MS. HORAN) Sure.

Why did you provide a second materials considered list with your Appendix A as opposed to just one for the entire report?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I'm not sure. Can you --

Q (BY MS. HORAN) Sure.

A I'm not sure the question.

Q Sure.

So your Appendix A has a materials considered list -- and again, you're welcome to look at it.

A Yeah.

Q Why did you decide to provide its own materials considered list with your Appendix A --

MS. BAUGHMAN: Objection to form.

Q (BY MS. HORAN) -- separate from the one attached to your report?

MS. BAUGHMAN: Objection to form.

Well, this wasn't attached to his report. Exhibit 3 was not attached to his report. So I'm going to object to that.

MS. HORAN: Sure.

Q (BY MS. HORAN) So separate from the one that was on April 9th, you have a materials considered list affixed to your Appendix A.

A Yeah.

Q Is that fair?

A These were pertinent to the report, and my only --

MS. BAUGHMAN: It's a reference list; it's not a materials considered list. So I'm going to object to that.

THE WITNESS: I guess the only thing I was trying to comment, I didn't know if -- in an effort to be comprehensive, if some of these might have also been listed here.

Q (BY MS. HORAN) Okay. So you're not sure?

A No.

Q Okay. Since submitting your expert report in January of 2025, why did you decide to review the documents in Pages 9 through 30?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I don't recall.

Q (BY MS. HORAN) Okay. You can set that aside.

A (Witness complies.)

Q Could you turn to Exhibit B of -- of Exhibit 2 which is your expert report? I believe it is your resumé.

A My vitae?

Q Yes.

Any changes since you've submitted this

vitae in December of 2024?

A I believe not. I don't think there's any articles. Book six is almost released. But I don't think it's yet released. On Page 3. Book six. So that may have an April date on it.

Q And that's Surfactant Formulation Engineering Using HLD and NAC.

A Yes.

Q That book.

A Yes.

Q And you're a co-author on that book?

A Yes.

Q Other than that that book might have been released by now, anything else that you can think of?

A Minor detail, but then a couple of the chapters in that book will also -- dates will be updated.

Q Sure.

A So co-edited, co-authored the book, and then several chapters in the book.

Q Sure.

Anything else?

A No.

Q Presently, your professional roles

include the associate director of the Institute for Applied Surfactant Research, you are an adjunct professor at the University of Ethiopia, and one university in Thailand.

A Correct.

Q And you are a partner at Surfactant Associates.

A Yes.

Q Is that an accurate summary of your present professional roles?

A Yes.

Q In this case are you contracted directly and personally with the Plaintiffs' leadership group or is it through an entity?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I'm sorry. Ask again.

Q (BY MS. HORAN) Sure.

So are you contract -- let me rephrase.

You have a role in a number of organizations. Is your contract to do work on this case with one of those entities and then you work on it or is it with -- directly with you?

A Directly with me.

Q And you received a bachelor's degree in civil engineering from the University of Illinois in 1981?

A Correct.

Q And you received a master's degree in civil engineering from Memphis State in 1985?

A Correct.

Q And you received a Ph.D from Iowa State University in 1989?

A Correct.

Q What is your Ph.D in?

A It's in civil engineering. With an environmental emphasis.

Q What does that mean?

A Within civil engineering, there's structural engineering, geotechnical engineering, transportation engineering, and environmental engineering. So my specialty was in the environmental engineering side of civil engineering.

Q You have a paper listed. "Sorption and transport of Atrazine Alachlor and Fluorescent Dyes in Alluvial Aquifer Sands."

Was that your Ph.D thesis?

A Yes. Part of it.

Q What was the other part? If you could identify it for us.

A I'd have to remember back at my papers, but there was another paper that was published out of my dis-- but it was same topic.

Q Was it published around the same time?

A Yes.

Q After your Ph.D, you became an assistant professor and then a full professor at the University of Oklahoma?

A Assistant, and then associate, and then full. Yes.

Q And I believe you said now, you're a professor emeritus?

A Emeritus. Yes. No problem.

Q Sorry about that.

A No problem.

Q And do you still teach classes?

A Yes.

Q What classes do you teach?

A I teach a course on fundamentals of water security, quantity, quality, and equity in a changing climate.

Q Anything else?

A That's the only university course I teach. I teach a short course to industry.

Q And what course is that?

A It's fundamental and applied aspects of surfactants.

Q And you teach that to the industry you said?

A Yes.

Q So what does that mean?

A We go to industries that -- as associate director of the Institute for Applied Surfactant Research, we have industrial sponsors of our institute and they ask us to come and teach a two-and-a-half-day short course at their company. And we'll go -- my colleague and I go and we team teach -- trade off teaching -- for two and a half days, this course to chemical companies.

Q In either of those courses, the one to students or the one to industry, do you talk about Camp Lejeune?

A Briefly in the water security, in one lecture, I briefly mention that -- I talk about superfund and show a map of the United States of all the superfund sites. And then I mention that Camp Lejeune is one of those contaminated sites.

Q Besides that one mention in terms of superfund sites --

A No. That's all.

Q No.

Is there a PowerPoint or anything you put together for that class?

A Yes.

Q We would just request a copy of that PowerPoint.

A Okay.

MS. BAUGHMAN: Well, we'll talk about that later. I don't -- you didn't -- I mean there was no official request for that so I don't think we'll be providing that. But you can follow up with me. I didn't see a document request for such a document.

MS. HORAN: Sure. We can deal with that on the back end, but we just request it.

THE WITNESS: Okay.

Q (BY MS. HORAN) And you as a professor emeritus --

MS. BAUGHMAN: Emeritus.

Q (BY MS. HORAN) Emeritus.

THE WITNESS: Yeah.

Q (BY MS. HORAN) -- are you retired from your role as a professor or do you -- is that considered a retirement role or how does that work?

MS. BAUGHMAN: Objection to -- objection to the form.

THE WITNESS: It's my -- I don't -- I don't know how to say this. Quazi retired.

Q (BY MS. HORAN) Quazi retired.

Do you still get a salary from the University of Oklahoma?

A When I teach a course, I do. But not on a monthly -- when I'm not teaching a course, I don't.

Q You're a professional engineer; correct?

A Correct.

Q And you've taken and passed both of the professional engineer tests?

A Yes.

Q Have you ever failed a test to become a professional engineer?

A No.

Q Your report has David Sabatini, Ph.D, PE, BCEE on the front.

The PE stands for professional engineer?

A Correct.

Q What does the BCEE stand for?

A It stands for board certified environmental engineer.

Q And could you describe for me what that licensing or certification is?

A It's through the associate -- American Association of Environmental Engineering and Scientists. And it's -- you can gain that designation either by taking a written and an oral exam -- or if you're considered a person of eminence, your record can gain you that recognition.

Q And when did you receive that recognition?

A Oh, goodness.

Q More than 20 years ago? More than ten?

A I'd say 15 to 20 years ago. In that range. I'd have to look to my records.

Q Sure.

And you would look at your resumé to find that out?

A Say again.

Q Or where -- where would you look to find that information out?

A I guess I don't have it on my resumé. I think I do have my PE. But anyway, I'm not sure.

Q Other than your professional engineering licensure and your BCEE certification or licensure, do you have any other licenses?

A No.

Q You've worked on projects regarding cleanup at military bases; correct?

A Correct.

Q And which projects have you worked on?

A Oh, there's a range. Hill Air Force Base. Dover Air Force Base. What's the one in California? Naval Air Station. Those are -- there are several. I'd have to look at my records to remember.

Q Where -- where would you look to remember?

A Should be in my...

Q It should be in your resumé?

A Yeah.

Q Okay. You mentioned Hill. Could you describe your role in that project?

A The -- it was a research project to look at developing advanced technologies for cleaning up groundwater contamination.

Q You mentioned Dover. Could you describe --

A The same -- same type. We developed a technology in the laboratory and approved successful so then we went to these field sites to demonstrate.

Q You said "we". Who did you work with on this project?

A Well, colleagues at the University of Oklahoma.

Q Okay. And you mentioned one in California.

A Yeah.

Q What was your role in that?

A Same. Field demonstration.

Q How did you become involved in the Hill project?

A We competed nationally for a large research grant to take our technology from the laboratory into the field. It was funded by the Environmental Protection Agency.

Q Is that the same way you became involved with the Dover project? Or how did you become involved there?

A That was the same program funding.

Q And is that the same with the California project?

A Yes. That -- I'd have to look back at my records. But yes, the same general. That may have actually been our company. We started a company, Surbec Environmental, that was implementing our technology. That may have been a Surbec project.

Q And the "we" is your colleagues at the University of Oklahoma still?

A Yes.

Q You mentioned receiving funding from the EPA; correct?

A Correct.

Q Have you ever received funding or grants from any other government agency?

A Yes. Department of Defense. Department of Energy. As I recall.

Q Did the grant you received from the Department of Defense have anything to do with groundwater?

A Remediation. Yes.

Q And what was that grant related to?

A I'd have to look back in my -- I'd have to look -- same. I don't recall the specific details. That's 30 years ago. Twenty-five years ago.

Q Sure.

And then the -- do you recall what the

grant funding from the Department of Energy was for?

A It's all related to the groundwater remediation.

Q Were you involved in the groundwater contaminant cleanup at Camp Lejeune?

A Say again.

Q Were you involved in the groundwater contaminant cleanup or remediation at Camp Lejeune?

A No.

Q Did you ever compete for a grant to be involved in the Camp Lejeune contaminant cleanup?

A No. Not to my knowledge.

Q To the best of your memory, were you ever asked to be involved in the contaminant cleanup at Camp Lejeune?

A No.

Q Do you know anyone who was involved in the contaminant cleanup at Camp Lejeune?

A Not to my knowledge.

Q Have you ever personally served in the military?

A No.

Q Have you ever been to a military base?

A The bases that we described.

Q So part of your work with Hill, Dover, and the project in California was you going to the base.

A We were physically implementing the technology at those sites.

Q Other than your -- through your professional work on Hill, Dover, and the California base, can you recall ever visiting any other military bases?

A Tinker Air Force Base in Oklahoma City. Military base in Germany where I taught a short course, but that base was being closed. That's all I can remember.

Q What was the course you taught in Germany?

A It was on groundwater contamination remediation.

Q And you said it was -- the base was being closed? Is that fair?

A Say again.

Q Did you say that the base was being closed?

A Yeah. They were -- yes.

Q Were you there to help them close the

base?

A No. No.

Q Why were you there?

A As part of reverting their base back to the home country, there was value added in terms of buildings, but there was value detracted by virtue of contamination. And so the personnel were gaining understanding of contamination remediation to help understand that aspect of the base reversal.

Q Have you ever been to Camp Lejeune?

A No.

Q Do you have any training or hist- -- or strike that.

Do you have any training or education in history?

A History? No.

Q Do you have any formal training or education in historical military practices?

A No.

MS. BAUGHMAN: Wait. Wait. Did you want to amend your answer?

THE WITNESS: Well, I mean, I've taken several -- I guess it's not training. I've taken several courses on Lincoln from history. And I'm writing a book on Lincoln and engineering. So I don't know if that constitutes the degree of -- and I guess I would say when we do research, we -- it depends upon what you mean by history. When we do research, we have to research the history of what we're working on to be able to build upon it. So anyway. That's -- I guess that's what I wanted to say.

Q (BY MS. HORAN) Sure.

And your -- I believe you said your -- you've studied the Lincoln era and you're writing a book on the Lincoln era.

Are there any other eras of history or military history that you've spent more time interested in?

A In saying that Lincoln was an engineer, one of my advisors on my book said, well, write about the engineering presidents. And three of those were military academy graduates. So I've studied their time period and their history. So I don't know if that fits in to what you're talking about or not. But that would be Grant, Eisenhower, and Carter.

Q So have you spent any time studying or received any education on historical military practices from the 1950s to the 1980s?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Well, Eisenhower is in that period, but I guess I'd say no.

Q (BY MS. HORAN) Have you ever taught any courses on history?

A I've given seminars. Not semester-long courses, but I've given seminars on Lincoln. Leadership Lincoln and engineering. Lincoln's faith journey.

Q Other than seminars on Lincoln, have you taught any other history seminars or courses?

A I teach a Bible class at church which gets into a lot of history. But other than that, I'd say no.

Q Could you turn back to Exhibit 2 which is your report? Actually, I think you still have it in front of you.

A I'm sorry. Which?

Q Your report. You've got it in front of you.

A Okay. I thought you mentioned a page number.

Q I'm going to get there. If you could turn to Page 1 of Exhibit 2, the last sentence reads, "My background and experience sufficiently and uniquely qualify me to comment on the fate of contaminants in Camp Lejeune water treatment plants and distribution systems as well as the ultimate delivery of contaminated drinking water to marines and their family members."

Did I read that correct?

A Correct.

Q So you're not offering opinions in this case on the fate and transport of contaminants in the groundwater at Camp Lejeune.

Fair?

A Correct.

MS. BAUGHMAN: Object to the form.

THE WITNESS: Correct.

Q (BY MS. HORAN) And you're not offering opinions on the fate and transport of contaminants through the soil at Camp Lejeune; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Correct.

Q (BY MS. HORAN) You can set that exhibit aside.

A (Witness complies.)

Q When was the first time you became aware of the water modeling happening related to Camp Lejeune?

A After I was contacted about the case.

Q So when this -- or strike that.

When the water modeling was happening in the early 2000s, you were unaware of it.

Is that fair?

A Correct.

Q Have you read the ATSDR reports on water modeling done at Camp Lejeune?

A Yes. Well, yes. There are many, many, many reports. And I've read many of them. The ones focused on -- yes.

Q Which -- to the best of your memory, which ones have you read or what was the subject matter of the reports that you've read?

MS. BAUGHMAN: Objection. Object to the form.

THE WITNESS: Certainly read the summary reports for both, in detail. And then some of the other supporting ones. I'd have to look back to remember.

Q (BY MS. HORAN) And would all of the reports that you've read relating to the ATSDR water modeling be on your updated materials considered list?

A Yes.

Q I'm happy to have you look at that list. It should be next to you.

A This list? (Indicating)

Q Yes. So that's Exhibit 3 that you have in front of you now. So could you identify which of the ATSDR reports you've read in detail?

MS. BAUGHMAN: So those are listed throughout the documents. You'll have to go page by page and just look at -- because they're not separated by these are the ATSDR. So it's listed by the -- the first author.

THE WITNESS: So you're asking me just to look through the list and try and recall.

Q (BY MS. HORAN) Sure. Exactly.

MS. BAUGHMAN: The question is, if he's read them or reviewed them?

MS. HORAN: Uh-huh.

MS. BAUGHMAN: Okay.

MS. HORAN: The question is whether --

Q (BY MS. HORAN) Which ATSDR reports, sitting here today, do you recall reading in detail?

MS. BAUGHMAN: In detail. Okay. Object

to the form.

THE WITNESS: There's so many of them it's hard to remember which specific ones.

Q (BY MS. HORAN) Just what you can remember, Dr. Sabatini.

MS. BAUGHMAN: Take your time.

THE WITNESS: Okay. On Page 2. I'm really hard-pressed to remember just specifics, but I do remember several.

Q (BY MS. HORAN) Well, perhaps --

MS. BAUGHMAN: Wait. Were you finished answering?

THE WITNESS: Yes. I'm -- I might be able to identify the few specifically, but I'm not sure I'll be able to identify all that I've reviewed.

Q (BY MS. HORAN) Sure. If you could identify the few specifically, that would be great.

A Okay. I remember the Faye, et. al. Faye on Page 2.

Q All of those?

A No, no. I'm...

Q Okay.

A As I recall, the best of my recollection

-- I don't want to speculate. I think F and C. 2007. 2008. Really I think it's the...

Specifically, ATSDR you asked?

Q Uh-huh.

A I guess the -- Page 4. There may have been others that I'm missing. Page 4, Maslia 2005 Expert Peer -- Peer Review Panel. Maslia 2009 Expert Panel. Maslia Chapter A, 2007. Maybe Chapter I. 2013. Chapter A.

So those -- just to highlight some.

Q Sure.

A Some of the ones.

And some I looked at in lesser details. Those would be the ones I recall looking at in detail.

Q Sure.

And you mentioned also looking in detail of the summaries of both Hadnot Point and Tarawa Terrace?

A I think those were the As.

Q Sure.

A As I recall.

Q You can set that aside.

A (Witness complies.)

Q But again, if you ever need it during

the deposition, feel free to take a look at it.

A Okay. Thank you.

Q Other than your opinion that the ATSDR model indirectly accounts for VOC losses during the water treatment storage and distribution, you are not offering opinions on the ability of ATSDR water model to determine historic contaminant exposure levels in the water supply for individuals; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: There's a lot to that statement. Could you repeat that?

Q (BY MS. HORAN) Sure.

Other than your opinion that the ATSDR model indirectly accounts for VOC losses, you're not offering any opinions on the ability of ATSDR's water model to determine historic contaminant exposure leaves in the water supply for individuals who lived at Camp Lejeune.

MS. BAUGHMAN: Objection to form.

THE WITNESS: I'm not sure if my second opinion which says that they did use treated water to calibrate their model may fall in to what you're saying.

Q (BY MS. HORAN) Sure.

So other than that opinion --

A Other than my three opinions.

Q Sure. And only your second opinion relates to the ATSDR model. Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: To the extent that it demonstrates that treated water samples were used in the -- in the analysis.

Q (BY MS. HORAN) Sure.

A Correct.

Q Your opinion 1 does not reference the ATSDR water modeling; correct?

A No.

Q And your opinion 3 does not reference the ATSDR modeling; correct?

A Correct.

Q So other than your second opinion which references the ATSDR model, you're not offering any other opinions on the ability of ATSDR's water model to determine historic contaminant exposure levels in the water supply for individuals who lived or worked at Camp Lejeune.

Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Excluding the impact this

might have had, no. I agree.

Q (BY MS. HORAN) We've been going about an hour. Would you like to take a short break?

MS. BAUGHMAN: Just if you need it. If you're good to go, we can keep going.

THE WITNESS: We can go a little bit longer.

Q (BY MS. HORAN) Okay. And I don't remember if I said this at the beginning, but if I didn't, if you ever need a break, happy to take it whenever you would like it.

A Thank you.

Q I just ask that if the question is pending, you just answer the question and then we'll take the break.

A Sounds good.

Q Okay. You've read the expert report of Dr. Alex Spiliotopoulos; correct?

A I glanced at it.

Q And you haven't offered any opinions in your report commenting on Dr. Spiliotopoulos --

A Oh, his report. I'm sorry.

(Simultaneous crosstalk)

THE REPORTER: Wait. Any opinions in your report.

MS. HORAN: Commenting on Dr. Spiliotopoulos's opinions.

THE WITNESS: And I -- I should restate what I said. I was -- when you asked the question, I was thinking his deposition.

No, I did read his report fully.

Q (BY MS. HORAN) And you haven't offered any opinions in your report commenting on Dr. Spiliotopoulos's opinions in his report; correct?

A Correct.

Q You can -- if you can open your report again which is Exhibit 2. And turn to Page 2.

A (Witness complies.)

Q The second paragraph says, to start, "My methodology for assessing Dr. Hennet's expert report opinions 2, 10, and 13..."

Do you see that?

A Yes.

Q So you've only assessed Dr. Hennet's opinions 2, 10, and 13?

A Correct.

Q You did not assess Dr. Hennet's other opinions; correct?

A Correct.

Q And you agree with Dr. Hennet that there would be VOC losses during the storage distribution -- strike that.

You agree with Dr. Hennet that there would be VOC losses during the storage treatment and distribution of water at Camp Lejeune; correct?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I agree that there was a potential for losses.

Q (BY MS. HORAN) And your disagreement with Dr. Hennet is in the amount of VOC losses at the water treatment plants and its reservoirs.

Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: In -- yes.

Q (BY MS. HORAN) And you agree with Dr. Hennet that there would be VOC losses through the use of water buffaloes.

Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: The potential for losses. Yes.

Q (BY MS. HORAN) You said, "The potential for losses." What do you mean by that?

A The -- the potential is there. It's a

question of the magnitude of the losses.

Q Sure.

So there would be losses. And your disagreement with Dr. Hennet is in how much of the losses.

A The degree --

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yeah. The degree.

Q (BY MS. HORAN) And as to water buffaloes, your disagreement with Dr. Hennet again is in the amount of losses through the filling and use of the water buffaloes.

Fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Correct.

Q (BY MS. HORAN) Throughout today, if I refer to VOCs or contaminants of concern, then I'm referring, collectively, to PCE, TCE, Benzine, 12TDCE, and BC .

Do you understand that?

A Yes.

Q And if I'm referring to one of those contaminants of concern, then I'll call it by name.

Does that work for you?

A You'll refer to it as...

Q If I'm referring to one of those contaminants, I'll just use its name.

Is that fair?

A Sounds good.

(Government Exhibit 4 marked for identification)

Q (BY MS. HORAN) I'm marking as Exhibit 4 -- this is a document with a Bates CL_PLG-expert_Sabatini_0000002424.

Dr. Sabatini, have you seen these before?

A Yes.

Q And what are they?

A They are my notes.

Q And what are they your notes from?

A Notes from my conversation with Chris Mattingly.

Q And who is Chris Mattingly?

A Chris Mattingly is the director of water utilities for the City of Norman and formerly operated the Norman Water Treatment Plant.

Q Is Mr. Mattingly retired?

A Say again.

Q Is he retired?

A No.

Q What is his role now?

A He's currently -- he's currently the Norman director of water utilities.

Q And you met with Mr. Mattingly on December 18, 2024. Is that fair?

A Correct.

Q And did you write these notes in your meeting with Mr. Mattingly or did you get home and write them later in time?

A Sometimes, I take notes, and then to make them more presentable, I rewrite them.

Q Is that what you did with these?

A I don't -- I don't recall. Likely.

Q Did you meet with Mr. Mattingly in person or was it via the phone?

A It was on the phone.

Q And why -- or strike that.

Did -- did you reach out to Mr. Mattingly to talk to him?

A Yes.

Q And why -- what was the purpose of your reaching out to Mr. Mattingly?

A The main purpose was because of the recarbonation basin operation.

Q And what did you want to ask Mr.

Mattingly about the recarbonation basin?

A Relative to the operation of a recarbonation basin, the CO2 injection into the recarbonation basin.

Q So did you want to know how much CO2 was injected or what -- what was your -- finding out how it worked? What was your goal?

A Hennet -- Hennet had suggested that there be significant losses during recarbonation, and as I recall, he used the analogy of air stripping. And I knew that air stripping has a very high air-to-water ratio to promote air stripping where as I know in recarbonation basin, you're trying to dissolve all the carbon dioxide into the water.

So I wanted to get a handle on kind of that carbon dioxide-to-water ratio versus an air-to-water ration in an air stripper.

Q And is that -- the fifth bullet you have --

A Right.

Q -- on this list is about the recarbonation basin.

A Correct.

Q Is that the notes you have in reference to your questions about recarbonation basin?

A That was helpful information he provided.

Q Have you ever seen a recarbonation basin --

A Oh, yes.

Q -- basin at a water treatment plant?

A Yes. Many.

Q And where was that?

A Oh. Of the 30 some water treatment plants I visited on many -- well, Norman, for sure. I'd have to go back through my memory bank to remember the other ones. But it's a common process. You add --

MS. BAUGHMAN: Just -- just she asked where.

THE WITNESS: Yeah. Yeah. It's a common process.

Q (BY MS. HORAN) You said you've been to roughly 30 water treatment plants?

A Around that. I -- yes.

Q Was that in your capacity as a professor at the University of Oklahoma in your professional --

A Yes.

Q Other than to talk about the recarbonation basin, did you have any other purpose in talking to Mr. Mattingly?

A Yes.

Q And what were those?

A General operating conditions for basins at the treatment plant. But that was not guiding me so much for Camp Lejeune. That was just more general background information.

Q And what, to the best of your memory, did you ask him?

A I asked about operation of the raw water, clear well, and water tower basins.

Q And what did he tell you?

A Just what's on the document.

Q And that's bullet number 2 on your notes?

A Yes.

Q And that reads "Asked about water" -- strike that.

The notes -- the second bullet reads, "Asked about raw water, clear well, and water towers-confirmed that they are all enclosed; not open at the top with no forced air exchange."

Did I read that correctly?

A Correct.

Q What did you mean when you wrote "no forced air exchange"?

A They were vented, but there was not forced air going through the -- the vessels.

Q And when you say "forced air", you mean there was no fan or something like that?

A Correct.

Q But you did understand that they were vented.

A Yes.

Q What made you believe that the information you received from Mr. Mattingly would be applicable to Camp Lejeune?

A To get a handle on the recarbonation basin as a contrast to Hennet's suggestion that it was analogous to an air stripper.

Q And why did you believe that what Chris Mattingly had to say about a recarbonation would be applicable to that at Camp Lejeune?

A I didn't expect it would be directly applicable, but I expected it to be order of magnitude that it would -- where as an air stripper has a very high air-to-water ratio, this was much lower CO2-to-water ratio.

Q And the water ratio that Mr. Mattingly told you about was 1 to 20 or less?

A Right.

Q Do you know if Mr. Mattingly has ever been to Camp Lejeune?

A No. Not to my knowledge.

Q Going back to your second bullet, why did you ask Chris Mattingly about whether the water towers were enclosed?

A Just curious. To confirm my understanding.

Q Your second bullet, going back to the no forced air exchange, you would agree that a lack of forced air exchange is consistent with tanks with regular changes in water levels?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) Sure.

You would agree that a lack of forced air exchange is consistent with tanks with regular changes in water levels?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Ventilation allows the water level to go up and down without changing the pressure in the system.

Q (BY MS. HORAN) And you agree that vented tanks with regular change in water levels will experience air exchange without force?

MS. BAUGHMAN: Object to the form.

THE WITNESS: To a degree.

Q (BY MS. HORAN) What do you mean when you say "to a degree"?

A The -- there would be -- as the water level goes down, the air would enter to replace. As the water level goes up, the air would escape. But that's not complete exchange of the air.

Q You would agree that a lack of forced air exchange is consistent with a vented tank; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) A lack of forced air exchange is consistent with a vented tank.

MS. BAUGHMAN: Object to the form.

THE WITNESS: No, I would not.

Q (BY MS. HORAN) And why not?

A Repeat -- repeat it one more time.

Q Sure.

You would agree that a lack of forced air exchange is consistent with a tank being vented.

A No.

MS. BAUGHMAN: Object to the form.

THE WITNESS: To me, forced air exchange is what happens in an air stripper where you're intentionally sweeping air through the system continuously to encourage vent -- the volatilization. And that's not what's happening when the water level goes up and down in a tank with venting.

Q (BY MS. HORAN) But you would agree that if a tank does not have forced air exchange, the air -- as the water levels go up and down, there has to be a way for the air to escape via --

A Yes.

Q -- a vent.

So you would agree that structurally, if there's no forced air exchange, then it would be consistent that the tank would have a vent.

MS. BAUGHMAN: Object to the form

Q (BY MS. HORAN) Is that fair?

THE WITNESS: No, I would not.

Forced air, to me, is you're -- you have some kind of a fan or pump or something that's forcing the air. When the water level goes up and down, that's just natural; that's not forced. I would not agree with the terminology "forced air exchange" to what happens as the water level goes up and down in a reservoir.

Q (BY MS. HORAN) Sure.

And when you have a reservoir where the water's going to go up and down in level, the air has to escape somehow.

A Correct.

Q And the way for it to escape would be through a vent.

Fair?

A Last part again.

Q The way for the water -- or strike that.

The way for the air to escape as the water levels are rising and dropping throughout time would be through a vent.

A Correct. But that's natural. That's not forced. It happens naturally as the water level goes up and down. There's no energy put into the system to force that to happen.

Q And the water -- strike that.

And the air going through the vent as the water level rises and drops is also natural.

A That's what I'm saying.

MS. BAUGHMAN: Object to the form.

Yeah.

THE REPORTER: I'm sorry. Repeat. That's what I'm...

THE WITNESS: That's what I am saying is, that's a natural. That's not a forced.

Q (BY MS. HORAN) Sure.

I think I might have already asked you this, but I can't remember. Have you been to Camp Lejeune?

A No.

Q So you wrote your rebuttal report without inspecting the Hadnot Point or Holcomb Boulevard water treatment systems.

Fair?

A In -- correct.

Q And you wrote your report without examining any of the reservoirs or water tanks at Camp Lejeune?

A Any of the...

Q Reservoirs or water tanks at Camp Lejeune.

A Correct.

Q And you've never inspected any of the spiractors at Camp Lejeune?

A Correct.

Q Have you ever personally inspected a water buffalo?

A No.

Q Have you ever seen a water buffalo in person?

A I likely have on my visits to military bases to do the remediation research.

Q As part of your work in this case, you have not --

A No.

Q -- personally inspected a water buffalo?

MS. BAUGHMAN: Try to wait until she finishes her whole question before you answer.

THE WITNESS: Thank you.

MS. BAUGHMAN: The court reporter has a hard --

THE WITNESS: Sorry.

MS. BAUGHMAN: -- time. Okay.

Q (BY MS. HORAN) Do you have any memory of ever observing the filling of a water buffalo at any of the military bases where you may have seen one?

A No.

Q Prior to submitting your rebuttal

report, had you ever taken any actions to visit Camp Lejeune?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) Sure.

Prior to submitting your rebuttal report, had you ever taken any actions or asked to visit Camp Lejeune?

A No.

Q So you did not think it was important to go to Camp Lejeune in order to offer your opinions in your rebuttal report.

Fair?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I had the information at hand that I needed.

Q (BY MS. HORAN) Sitting here today, do you want to visit Camp Lejeune?

A Say that again.

Q Sitting here today, do you want to visit Camp Lejeune?

A Want to or need to?

Q We'll start with want and then we can go to need.

A I always like to tour water treatment

plants. I don't need to.

Q You don't need to.

So there's no need for you to visit Camp Lejeune for the opinions that you've offered in this case?

MS. BAUGHMAN: Object to the form.

THE WITNESS: The only reason I would want to is in response to Hennet's visit in February.

Q (BY MS. HORAN) And what about Dr. Hennet's visit in February would make you want to go to Camp Lejeune?

A Because he was rebutting my rebuttal through his visit. And so while I didn't need -- I had all the information I needed in the AH documents to do my calculations. Given that he went on a rebuttal to my rebuttal trip, it would be nice to have the same opportunity.

Q And what information do you hope to gain from that visit that you don't have today?

MS. BAUGHMAN: Object to the form.

THE WITNESS: We don't really know exactly what Hennet did and who he talked to and what he saw. So it would be just to have that same background information that he had.

Q (BY MS. HORAN) Did anything from that Dr. -- or strike that.

You attended Dr. Hennet's deposition; correct? And you've read it?

A Right. Correct.

Q And you've received the photos that Dr. Hennet took at that visit; correct?

A Correct.

Q And you've reviewed the photos of his measurements that he took at Camp Lejeune?

A Correct. To my knowledge. Correct.

Q And so if I'm -- what, for your calculations information, would you seek to get at Camp Lejeune if you were to visit?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) What -- for your calculations and opinions, what specific information would you seek to get from the visit at Camp Lejeune?

MS. BAUGHMAN: Object to the form.

THE WITNESS: My calculations were based upon AH's extensive study and I felt that I had all the information I needed. Nothing that I have seen -- I -- I really don't know what Hennet

-- there wasn't report associated with his visit so I don't know what all he did or what all it meant. So I don't really anticipate -- I don't see that there would be any changes -- I don't -- I'm confident in my calculations as they stand today.

Q (BY MS. HORAN) Your water treatment plant opinions are related to Hadnot Point and Tarawa Terrace.

Fair?

A Say again.

Q Your water treatment plant opinions are related to Hadnot Point and Tarawa Terrace.

Fair?

A Yes. Correct.

Q And you agree that the water going through the water treatment plant at Holcomb Boulevard was not contaminated with VOCs; right?

MS. BAUGHMAN: Object to the form.

During what timeframe?

MS. HORAN: Ever.

THE WITNESS: Yeah, it's --

Laura, I -- please stick to form and foundation.

THE WITNESS: To the -- all the

information I've seen suggests that's true. That's correct. Through the water treatment plant.

Q (BY MS. HORAN) Yes. That was the question.

A That's just different than the distribution system.

Q Yes. The question was just related to the water treatment plant.

A Just wanted to clarify that.

Q Yep.

And you agree that the wells that supplied water to the water treatment plant at Holcomb Boulevard were never determined to be contaminated with VOCs.

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: That's outside the scope of my report.

Q (BY MS. HORAN) So you have no opinion on that sitting here today?

A I'd have to review the documents to -- to make a statement on that.

Q I'm about to switch topics. Are you still good or do you want to take a little break?

A We can go a little bit longer.

Q Okay.

Your report uses Coke bottles to show how Henry's Law works.

Do you recall that?

A Yes. It's a common teaching method I use when I talk about volatilization in air stripping.

Q So you use the Coke analogy as a teacher as well?

A Students 20 years later remember it.

Q And the general premise is that the Coke and the head space in the Coke bottle reach an equilibrium of carbon dioxide which is different than that found outside the bottle because of the bottle barrier between the inside of the bottle and the outside of the bottle.

A Correct.

Q And if you leave the cap off the Coke, the CO2 will reach equilibrium with the ambient air and go flat; correct?

A Correct.

Q And the reason that a flat Coke doesn't fizz is that the ratio of concentration of carbon dioxide left in the Coke to the concentration of the carbon dioxide in the ambient air is equal to Henry's constant for carbon dioxide.

Fair?

A That's -- that equilibrium is achieved. Correct.

Q The cap of a Coke is similar to a vent in that if you cut a vent into the side of the bottle, it'll have the same effect as taking the cap off.

MS. BAUGHMAN: Object to the form.

Q (BY MS. HORAN) Is that fair?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) Sure.

If you cut a vent in the side of a Coke bottle, it would have the same impact as taking the cap off.

MS. BAUGHMAN: Object to the form.

THE WITNESS: I disagree.

Q (BY MS. HORAN) And why is that?

A Has to do with the area. So if you put a small hole in the Coke bottle, that's different than taking the cap off.

Q Sure.

But CO2 would still go through the small hole or vent. Is that fair?

A To a lesser degree. Much lesser degree.

And part of the -- part of the breakdown -- well, part of -- the pressure of the CO2 in that head space is different from the VOC levels in the area that we're talking about.

Q Even with a small hole in a Coke bottle, over time, will it eventually reach equilibrium with the ambient air outside the bottle?

A Over an extended time.

Q And most people have probably experienced that before when they've picked up a can of Coke and it was flat.

Fair?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I guess there's that rare occasion.

Q (BY MS. HORAN) How much time does it take for a Coke with a vent -- or strike that.

How much time would it take for a Coke with the cap off to equilibrate and go flat?

A I -- I couldn't say.

Q And I think I understand this, but your opinion is that it would be a shorter amount of time than if it was just a pinhole in the side of the Coke bottle.

A Yes.

Q And if you had something in between a pinhole and the whole cap off, that would fall somewhere in between on the timeframe of how long it would take to equilibrate.

MS. BAUGHMAN: Object to the form.

THE WITNESS: In general, I would agree.

Q (BY MS. HORAN) Another example you use in your report is heat flow wherein heat flow is lost from the home in proportion to the temperature difference between the inside and outside the home surface area and the insulation in the home.

Do you remember that?

A Yes.

Q And the heat is lost due to diffusion?

A Yes.

Q And the water equivalent of this would be a sealed bucket wherein the water is warmer than the outside air?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) The water equivalent to the home example you have in your report would be a sealed bucket wherein the water is warmer than the outside air.

MS. BAUGHMAN: Object to the form.

THE WITNESS: In general. Yes.

Q (BY MS. HORAN) Would you agree that in a sealed bucket wherein the water is warmer than the outside air, if the water was being mixed in the bucket, then the heat loss is not fully diffusion controlled?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) Sure.

Would you agree that in a sealed bucket wherein the water is warmer than the outside air, if the water is being mixed in the bucket, then the heat loss is not fully diffusion controlled?

MS. BAUGHMAN: Object to the form.

THE WITNESS: This is all very speculative. Depends upon lots of factors.

Q (BY MS. HORAN) What are the factors?

A I'd need to know more about the situation you're describing.

Q What would you need to know?

A Well, explain to me further the bucket. Is it full of water? Is it water and air? Is --

I need to know more details.

Q So you would need to know the amount of water in the bucket?

A The amount and the -- I'd just need to know the whole system. I'd have to have a schematic of volume of water, volume of air, what kind of mixing, et cetera.

Q So if it's a -- if everything is controlled -- so it has the same amount of water in it and the only difference is that it's being mixed, would you then agree that the heat loss is not fully diffusion controlled?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Ultimately, it's diffusion. Mixing -- well, ultimately, it's diffusion.

Q (BY MS. HORAN) Is there anything -- agree that it would be faster when mixing?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say again.

Q (BY MS. HORAN) Would you agree that the diffusion would be faster when the water is being mixed?

A I wouldn't agree that diffusion would be faster. Diffusion's a molecular property.

Q Do you agree that the loss of heat would
be faster when the water is being mixed?

MS. BAUGHMAN: Object to the form.

THE WITNESS: It all -- it's all
speculative. I can envision cases where it would
be and maybe other cases where -- I mean if it's
uniform temperature throughout, then mixing would
have little limited impact.

Q (BY MS. HORAN) And when you say
"uniform throughout", are you talking about the
water in the bucket or are you talking about the
temperature outside?

A Water in the bucket. Well, both
actually.

Q Okay. So you do not agree that if the
water in the bucket's being mixed, then the heat
loss would be faster than if the water was
stationary.

MS. BAUGHMAN: Object to the form.

THE WITNESS: I'd have to know the
situation again. But diffusion is -- would be
independent -- the diffusion process itself would
be independent of the mixing.

Q (BY MS. HORAN) The rate of
diffusion-controlled volatilization losses for

immobile water body does not apply to flowing mixing water; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) The rate of diffusion-controlled volatilization losses for immobile water body does not apply to flowing or mixing water; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: One more time.

Q (BY MS. HORAN) The rate of diffusion-controlled volatilization losses for immobile water body --

A Immobile...

Q An immobile water body does not apply to flowing or mixing water; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: For an im- -- I'm trying to parse the nuances of the question. For --

MS. BAUGHMAN: I'm going to object to the form.

THE WITNESS: One more time.

MS. BAUGHMAN: If you don't understand, you can tell her that.

THE WITNESS: Yeah. It's -- well,

there's nuances in the question.

Q (BY MS. HORAN) What are the nuances in the question that are --

A Clarify -- read it one more time.

Q Sure.

The rate of diffusion-controlled volatilization losses for immobile water body does not apply to flowing mixing water; correct?

A Immobile water body --

Q Uh-huh.

MS. BAUGHMAN: Mobile or immobile?

Q (BY MS. HORAN) Immobile.

A Im- -- okay. Immobile.

I'd have to disagree.

Q So it's your opinion that the rate of diffusion-controlled volatilization losses would be the same for both immobile water bodies and flowing or mixing water.

MS. BAUGHMAN: Object to the form.

THE WITNESS: Same two-film transfer concept applies in both cases. There are -- there are other nuances.

Q (BY MS. HORAN) And the rate would be the same for both immobile water bodies and flowing mixing water?

MS. BAUGHMAN: Object to the form.

THE WITNESS: What do you mean by "rate"?

Q (BY MS. HORAN) The rate of diffusion-controlled volatilization losses would be the same for both immobile water bodies and flowing, mixing water.

Is that your opinion?

MS. BAUGHMAN: Same objection.

THE WITNESS: That's a very broad question. It all comes down to interfacial area and so that's what it's a function of. So I mean, if you're talking about a lake versus a stream -- is that what you're getting at?

Q (BY MS. HORAN) I'm just asking about the -- the baseline principle.

MS. BAUGHMAN: Object to the form.

THE WITNESS: I'd have to have more details to answer the question.

Q (BY MS. HORAN) If the water mixes, would it increase the facial area?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Depends upon what you mean by mixing. If it's splashing, then that could have an increase on the area. It depends.

Q (BY MS. HORAN) What if there -- or strike that.

You describe a two-film mass transfer process in your report on Page 5. This is Exhibit 2.

Do you see what you've marked as equation 3-3?

A Yes.

Q Would this equation 3-3 apply to the rate of volatilization losses for a body of water with mixing?

A Yes.

Q Would it, in your opinion, accurately predict, or over predict, or under predict the rate of volatilization losses for a body of water with mixing?

MS. BAUGHMAN: Object to the form.

THE WITNESS: If you quantify all the parameters correctly, it would be accurate.

Q (BY MS. HORAN) If you had a bucket of water with TCE dissolved into it and you didn't mix it, is it your opinion that the losses would be diffusion controlled?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Bucket of water with TCE

in it.

Q (BY MS. HORAN) Uh-huh. But you're not mixing it.

A No mixing. Well, it would be diffusion and film transfer.

Q Diffusion and film transfer would be the two processes that would control the losses?

A Correct.

Q And assuming you have a spinning propeller in the bottom of that, that mix the water around, would volatilization be increased?

A Would it be...

Q Increased.

MS. BAUGHMAN: Object to the form.

THE WITNESS: It could be.

Q (BY MS. HORAN) And when you say it could be, what would be the factors that would increase it?

A If the mixing keeps the concentration more uniform throughout the system, then it would help reduce diffusion limitations.

Q Anything else?

A (Shakes head.)

Q Do you know how much water enters the reservoir at Camp Lejeune per day?

MS. BAUGHMAN: Object to the form.

THE WITNESS: It's in the report.

Q (BY MS. HORAN) Oh. Where was that?

A How much water enters the...

Q Reservoir at Camp Lejeune per day.

MS. BAUGHMAN: Object to the form.

THE WITNESS: Yeah. That's all documented in the AH -- the water treatment. And they have the -- that's information that's in the report.

Q In your expert report --

A No.

Q -- or in the AH Environmental?

A AH Environmental.

Q Okay. And you relied upon what AH Environmental put in their report about that?

A Correct.

Q And is it your understanding that AH Environmental also says how much water exits the reservoir at Camp Lejeune per day?

A Say again. That...

Q That the AH Environmental report also says how much water exits the reservoir at Camp Lejeune per day.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Specifically, that's -- what goes in comes out.

Q (BY MS. HORAN) Can you describe the process for how water moves through the Camp Lejeune water treatment plant?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Described in the schematics.

Q (BY MS. HORAN) Which schematic are you referencing?

A For example, 3-1 in my report. Page 3.

Q So you agree that the water goes through the raw water reservoir, into the spiractors, into the recarbonation basin, through the gravity filters, and then into the finished water reservoir?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Correct.

Q (BY MS. HORAN) And that's for the Hadnot Point --

A Right.

Q -- water treatment plant; correct?

A And the next figure's for -- and these are just from -- well, from AH. And I believe Hennet had these in his as well.

Q Do you agree that the reservoir mixes water?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Say again.

Q (BY MS. HORAN) The reservoir mixes water.

MS. BAUGHMAN: Object to the form.

THE WITNESS: No.

Q (BY MS. HORAN) And what's your basis for not agreeing that the reservoir mixes water?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Well, when you say "mixes water," I mean, in a water treatment plant, mixing has a propeller that man- -- forcefully mixes the water.

Q (BY MS. HORAN) And it's your understanding that Camp Lejeune does not forcefully mix water in the reservoirs?

A That's my understanding.

Q And you would agree that there are VOC losses at the spiractors at Camp Lejeune; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Calculations indicate as much.

Q (BY MS. HORAN) And you would agree that there are VOC losses at the sand filters at Camp Lejeune?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I'm sorry. At the...

Q (BY MS. HORAN) The sand filters.

MS. BAUGHMAN: Object to the form.

THE WITNESS: I deem that to be negligible, as did Hennet.

Q (BY MS. HORAN) So yes, but a small amount? Or --

MS. BAUGHMAN: Object to the form.

Q (BY MS. HORAN) -- what do you mean when you say "negligible"?

A As possibility, but it's very minor. Negligible.

Q Would you agree that there are VOCs lost in the treated water reservoirs?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Possibility, but likely very minor.

Q (BY MS. HORAN) Would you agree that there are VOC losses in the water towers?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Possibly, but very minor.

Q (BY MS. HORAN) And when you say "possibly," what -- what do you mean?

A Any -- it's certainly possible that there might be some minor losses.

Q Would you mind if we take a break at this point?

A Sure.

Q Thank you.

THE VIDEOGRAPHER: We're off the record at 10:47 a.m.

(Short break from 10:47 a.m. to 11:00 a.m.)

THE VIDEOGRAPHER: We're back on the record at 11:00 a.m.

Q (BY MS. HORAN) Welcome back, Dr. Sabatini.

A Thank you.

Q You understand you're still under oath?

You're still under oath.

A Thank you. Yes. Understood.

Q Right before the break --

A And is now a good time to --

MS. BAUGHMAN: No. You -- no. Just answer her questions.

THE WITNESS: Okay.

Q (BY MS. HORAN) Right before the break, you said -- or I think I understood. I had asked you if you would agree that the reservoir mixes water, and you had referenced a mechanical mixing.

Do you recall that?

A When you -- when you -- yes, I do.

Q Okay. The water reservoirs at Camp Lejeune, setting aside mechanical mixing, would organically mix; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Depends upon what you mean by "organically mix."

Q (BY MS. HORAN) Sure.

So as water is drawn into the reservoir, it will -- the flow rates and the -- or the changes in flow rates in the diffusion will move the water around in the reservoir; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: To a certain degree.

Q (BY MS. HORAN) And when water is pulled out of the raw water reservoirs, or any of reservoirs, it will again mix the water in the reservoir; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: To a very limited degree.

Q (BY MS. HORAN) And why would that be limited?

A Because when we talk about reactor design, there's a well-mix system where you have widespread mixing. What you're describing would be more minor, localized mixing.

Q Would it mix throughout the entire water reservoir? Or when you say limited local, what did you mean?

MS. BAUGHMAN: Object to the form.

THE WITNESS: My vision would be if the water enters, there might be a little bit of mixing right there. But that wouldn't necessarily mix throughout the basin. It would be localized to the inlet.

Q (BY MS. HORAN) And is the same -- your understanding or opinion the same for where water is drawn out of the reservoir?

MS. BAUGHMAN: Object to the form.

THE WITNESS: To a lesser degree even. That would be less even than at the inlet. Typically, it's flowing out by gravity.

Q (BY MS. HORAN) And as that gravity pulls the water out, would it mix around the reservoir?

MS. BAUGHMAN: Object to the form.

THE WITNESS: To a much lesser degree.

Q (BY MS. HORAN) Other than the expert reports produced in this case and the AH Environmental report, do you recall relying on any other sources to learn about the structure of the water treatment plants at Tarawa Terrace or Hadnot Point?

MS. BAUGHMAN: Object to the form.

THE WITNESS: And you mentioned -- the two you mentioned were...

Q (BY MS. HORAN) Other expert reports or the AH Environmental report.

MS. BAUGHMAN: Object to the form.

THE WITNESS: There were some CLWs that provided some information.

Q (BY MS. HORAN) And what -- could you describe what those documents either were or what information was contained in them, to the best of your recollection?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Oh, I'd have to go back and review my notes. But well, some of it, I guess, is in my report in terms of the concentrations, pre-treatment and post-treatment plant. Some of that was from the CLW. There was information on water level variations in a reservoir that was a CLW.

Q (BY MS. HORAN) So prior to submitting your expert report, it was your understanding that the water levels in the water reservoirs would fluctuate?

A Yes.

MS. BAUGHMAN: Object to the form.

THE WITNESS: Yes, I recognize there would be some up and down.

Q (BY MS. HORAN) Do you recall if you ever looked at any building schematics for the water treatment plants?

A Building schematics meaning?

Q You're an engineer so I think I'll defer to you on what you would consider a --

A Well, I --

Q -- building schematic.

A Well, I looked at some schematics for unit processes in the -- in the treatment system. I didn't look at schematics for the fit building that the processes were in.

Q Do you recall looking at any design plans?

A In -- in -- in general, I do. Yes. I think even in -- seems like there's one description of updating the plant.

Q Other than updating the plant, do you recall viewing any other design plans for the water treatment plants --

MS. BAUGHMAN: Object to the form.

Q (BY MS. HORAN) -- at Camp Lejeune?

A I'd have to go back and look through my notes.

Q Could you turn to Page 3 of your report which is Exhibit 2?

A (Witness complies.)

Q Figure 3-1 we already talked about, but that's the Hadnot Point water treatment plant schematic.

A Yes.

Q In the paragraph above, you say, "Not shown in Figure 3-1 is the 300,000 gallon water tower filled from the finished water reservoir."

Do you see that?

A Yes.

Q And what source did you rely upon in reaching the conclusion that there was only one water tower at Hadnot Point?

MS. BAUGHMAN: Object to the form.

THE WITNESS: The AH Environmental.

Q (BY MS. HORAN) Sitting here, anything besides the AH Environmental?

A Say again.

Q Sitting here today, do you recall relying on anything other than the AH --

A No.

Q -- Environmental for that proposition?

A No.

Q Okay. When you reviewed Dr. Hennet's report, did you review the underlying documents that he relied upon as well?

MS. BAUGHMAN: Object to the form.

THE WITNESS: There were -- yes. Well, I specifically remember several documents.

(Government Exhibit 5 marked for identification)

MS. HORAN: I'm handing to the witness a document that I'll mark as Government Exhibit 5, and it's Bates number CLJA_watermodeling_07-0000003171, and it runs through the Bates ending in 3184.

Q (BY MS. HORAN) Dr. Sabatini, I'll give you a minute to -- to page through it. But have you seen this document before?

A Parts of it look familiar. Parts of it look familiar.

Q You see the first page, the Bates ending in 171, says, "Hadnot Point Building Number 20 --

A Yes.

Q -- capacity 5MGD. With 40 deep wells lime softening plant."

Do you see that?

A Yes.

Q Do you have any reason to doubt that this is an accurate schematic of the Hadnot Point Water Treatment Plant?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: I have no idea where this came from. So I'm -- it's hard for me to comment on -- on -- ask the question again.

Q (BY MS. HORAN) Sure.

I was just wondering if you had any reason to doubt its accuracy having looked at it.

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: Not knowing where it came from, I'd have to know more details to...

Q (BY MS. HORAN) Do you see on the first page there are five spiractors?

A Yes.

Q And do you see that there are five sand filters?

A Yes.

Q And those numbers align with the numbers included in Figure 3-1 of your report. And you're -- I'm happy to let you look through your report as well.

A Yes.

MS. BAUGHMAN: Object to the form.

THE WITNESS: Yes.

Q (BY MS. HORAN) Do you see that document -- or Exhibit 5 has four elevated water storage tanks?

A Yes.

Q Do you know how many elevated water storage tanks Hadnot Point water distribution had throughout time?

A I relied upon the AH Environmental.

Q You can set Exhibit 5 aside.

A (Witness complies.)

Q The Hadnot Point Water Treatment Plant has an 800,000 water -- raw water reservoir.

Do you agree?

A That's my understanding.

Q And you agree that that reservoir is vented?

A That would be the normal course. Yes.

MS. HORAN: I'm handing the witness what I'll mark as Exhibit 6. And this has Bates number Hennet_USA_0000000010. And Bates ending in 25, 30, and 31.

(Government Exhibit 6 marked for identification)

Q (BY MS. HORAN) Dr. Sabatini, have you seen these images before?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: I'm -- they look similar to something I've seen before.

Q (BY MS. HORAN) Could you turn to the Bates ending in 31?

MS. BAUGHMAN: Object to the form.

Counsel, to the extent these are the pictures that Dr. Hennet took in February 2005 [sic] --

THE WITNESS: '25.

MS. BAUGHMAN: -- we've got a pending motion to exclude those from the case. So I'll let you ask limited questions with the understanding that we may -- I would like the court reporter to note that this may be separated -- I would like it to be separated and marked because we're going to move to exclude testimony about this assuming our -- our motion is granted. If our motion is granted.

Go ahead.

MS. HORAN: Sure.

MS. BAUGHMAN: Because we don't know the foundation of this. Dr. Hennet wasn't asked questions about these. There's no report about them.

MS. O'LEARY: Objections are limited to form and foundation.

MS. BAUGHMAN: I understand.

MS. O'LEARY: We just said --

MS. BAUGHMAN: Not if -- not if it has to do with a motion pending before the court. I'm allowed to explain the basis of that motion.

And by the way, you're not the lawyer. She's the one who's supposed to be speaking here. One lawyer.

Please mark this because we're going to move to exclude testimony about this -- about this exhibit.

Go ahead.

MS. HORAN: Okay. Are you done?

MS. BAUGHMAN: Done.

MS. HORAN: Okay.

Q (BY MS. HORAN) Could you please turn to the one ending in 31? Do you see that? Okay.

Do you see there are two vents in this image?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: Yes.

Q (BY MS. HORAN) Are those vents that you've seen similar to other vents you've seen on the top of a water reservoir?

A In general, yes.

Q And then could you turn to the Bates ending in 30?

A Which one? 30?

Q Yeah.

A (Witness complies.)

Q And do you see a vent in the image?

A Yes.

Q And is that vent similar to the vents you would have seen or expect to see on top of a water reservoir?

A Same. In general, yes.

Q Could you turn to Image 10 which is the first page.

A Number -- which number?

Q 10. It's the first page.

A 10.

Q Yeah.

And do you see a picture of a vent?

A Yes.

MS. BAUGHMAN: Objection. Form and foundation.

Q (BY MS. HORAN) And is this a vent the type you would expect to see on top of a water treatment reservoir?

MS. BAUGHMAN: Same objections.

THE WITNESS: At times.

Q (BY MS. HORAN) And you can see some measurements for the -- along the right side of it. Fair?

MS. BAUGHMAN: Objection. Form and foundation.

Q (BY MS. HORAN) Do you see that?

A Yes.

Q Is that the size and shape that you would expect to see of a vent atop a water treatment reservoir?

A It varies, but not atypical.

Q And then could you turn to Page 25 which is the second page in the document?

A (Witness complies.)

Q Is this also the -- or do you see a vent in the image?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: This one's a lot less clear. What it's showing.

Q (BY MS. HORAN) And why is this one less clear what it's showing?

MS. BAUGHMAN: Same objections.

THE WITNESS: The others all seem to be -- this one seems to...

Q (BY MS. HORAN) Ah. So is this just a different shaped vent?

MS. BAUGHMAN: Objection. Form and foundation.

Q (BY MS. HORAN) Is that what you're referencing?

A I'm not sure what this one is.

Q Have you ever seen a vent that looks like the vent in Image 25?

A I'm not sure what this is.

Q Do you know one way or the other whether this looks like a vent?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I'd need to -- I'd need to know more to comment on this one.

Q (BY MS. HORAN) What would you need to know, Dr. Sabatini?

A Where is it? What is it? What's it's purpose?

Q Does this structure in Image 25 look like something that could vent a water treatment reservoir?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: Based on this picture, I can't comment.

Q (BY MS. HORAN) Okay. You can put those aside.

A (Witness complies.)

Q I rent -- -- strike that.

A vented raw water reservoir will maintain an atmospheric pressure; correct?

MS. BAUGHMAN: Objection to form.

THE WITNESS: In general, yes.

Q (BY MS. HORAN) You would agree that the VOCs in the water at a vented raw water reservoir will dissipate to reach equilibrium with the VOCs in the atmosphere at the ratio of Henry's constant?

A Say that one more time.

Q Sure.

You would agree that the VOCs in the water at a vented raw water reservoir will dissipate to reach equilibrium with the VOCs in the atmosphere at the ratio of Henry's constant?

A I would not agree.

Q And why not?

A Because there's a kinetic aspect, time-dependent aspect. So given enough time, I would agree. Given enough time to reach equilibrium. But the kinetics determine how close you're able to get to equilibrium in a limited amount of time.

Q Sure.

So the equilibrium would be attached to the rate at which the air could flow through the vents of the raw water reservoir.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) The time it would take to reach equilibrium would be controlled in some manner by the rate of flow of air through the vents.

We can move on.

A Say again.

Q I'll withdraw the question. We can move on.

In your Coke analogy, having a vented raw water reservoir is similar to having the cap off of a Coke bottle; correct?

A No.

Q Why not?

A What you just described would be saying that the entire top of the reservoir was opened.

Q So your disagreement of a vent -- of comparing a vented raw water reservoir and the cap of a Coke bottle is the difference in size?

A Yeah, the -- the extent to which it's opened to the atmosphere.

Q Could you -- what -- strike that.

The -- would a vented raw water reservoir be similar to having a straw in a Coke bottle?

A No.

Q And why not?

A Well, for one thing, to have the straw in the Coke bottle, you have the lid off.

Q Oh, sure. Okay.

So you -- you've sliced a perfectly sized --

A If you drilled a -- well...

Q -- hole into the -- if you drilled a hole into the cap bottle for a straw, would that be sufficient?

A That would -- a very small hole.

Q Okay. So having a vented raw water reservoir is similar to having a Coke bottle with a straw-sized hole drilled into the cap.

MS. BAUGHMAN: Objection to the form.

THE WITNESS: A very small hole in the lid of the Coke bottle. Just look at --

Q (BY MS. HORAN) You would agree that the water towers are vented; correct?

A Correct.

Q And you agree that the water towers will maintain atmospheric pressure?

A Over time. Correct.

Q And you agree that the VOCs in the water at the vented water towers will dissipate to reach equilibrium at the VOCs in the atmosphere at a ratio of Henry's constant?

MS. BAUGHMAN: Object to the form.

THE WITNESS: No.

Refer back to the kinetic discussion from before.

Q (BY MS. HORAN) So your disagreement is in the speed at which it will occur?

A (Nods head.)

Q But it will occur; correct?

MS. BAUGHMAN: Object to the form.

Q (BY MS. HORAN) Or I can -- let me rephrase.

A Given an --

MS. BAUGHMAN: She wants to rephrase it so let her do that.

THE WITNESS: Okay.

Q (BY MS. HORAN) With sufficient time, the VOCs in the water at the vented water tower will dissipate to reach equilibrium with the VOCs in the atmosphere at the ratio of Henry's constant.

MS. BAUGHMAN: Object to the form.

THE WITNESS: I disagree because there's not sufficient time.

Q (BY MS. HORAN) And if there were sufficient time, would you agree?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I'm tempted to go into teaching mode here.

Q (BY MS. HORAN) Just answer the ques- -- if that --

A No, it's not.

Q Please, go ahead.

A It's not the same.

Q Okay. So a vented water tower, even with days, weeks --

A It --

MS. BAUGHMAN: Wait. Let her finish.

Q (BY MS. HORAN) -- even with however much time, would never equilibrate with the atmosphere at Henry's constant.

MS. BAUGHMAN: Object to the form.

THE WITNESS: Depends upon how you define "sufficient time." Given an infinite amount of time, yes. Or not even infinite. I mean, given a dramatically larger time, yes.

Q (BY MS. HORAN) And a dramatically larger time than what?

A Than the detention time in the basins.

Q And I believe we got to a place where if it's a Coke bottle with a hole drilled in the top, then that would be similar to a vented water tower.

Is that fair?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Yes. There's one caveat. Where my Coke bottle analogy breaks down is the carbon dioxide in the head space is pressurized.

Q (BY MS. HORAN) Uh-huh.

A It's pressurized CO2. That's how you get the carbonation into the water. It's pressurized.

Q Uh-huh.

A Where as the VOCs in the head space above the water are not pressurized. So that's a difference between the -- that's the place where the Coke bottle analogy breaks down to water reservoirs.

Q Sure.

And in the water towers, as the water levels fluctuate throughout the day or week, the air will naturally be pushed out or sucked in to the water tower; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Right.

Q (BY MS. HORAN) And that's also different than a Coke bottle because once it's sealed, no more liquid goes in.

A Correct. Although, in one of my analogies, I suggested Coke was flowing into and out of the Coke bottle. But correct.

Q Do you know whether the water buffaloes used at Camp Lejeune from 1950 to 1987 had vents?

A Are...

Q Had vents.

MS. BAUGHMAN: Object to the form.

THE WITNESS: It depends upon what you mean by vents. They had filler caps and they had manholes. Not -- not vents, to my knowledge, of the nature that -- I'm not sure. I'm unclear.

(Government Exhibit 7 marked for identification)

Q (BY MS. HORAN) I'm marking as Exhibit 7 -- this is a document with the Bates Brigham_USA_00000044016. And it runs through the Bates ending in 4038.

MS. BAUGHMAN: Which number is this one?

MS. HORAN: 7.

THE WITNESS: 7.

Q (BY MS. HORAN) And I'll represent this is a document that you -- it's on your materials list. But it's -- I did cut off -- it didn't print off of the document so this is a shortened version of it.

Have you seen this before, to the best of your recollection?

A Looks -- looks familiar.

Q And you agree this is for the M107 water buffaloes?

A Say again.

Q This is for the M107 water buffaloes?

A I'm looking for that designation.

Q If you turn to Page 4017. The --

A Oh, down there. Seems to be for the trailer.

Q So is it trailer tank water one, one half-ton two-wheel 400-gallon, and then it says M107A1, M107A2, M107A2C.

A Okay.

Q Do you see that?

A Yes.

Q Okay. Could you turn to the page ending in 4031?

A (Witness complies.)

Q And do you see the top of the page, it says C, the letter, M107 series water tank trailer?

A Yes.

Q Okay. And then a little bit further down the page, there's a key and a chart. And the second thing listed is the component vent.

Do you see that?

A Yes.

Q And the description of the vent is "allows air circulation in the tank".

Do you see that?

A Yes.

Q And do you see that that is keyed to number 21?

A Yes.

Q And number 21 in the image points to the water buffalo just in front of the manhole.

A Yes.

Q Okay. Do you agree that the M107 water buffalo series had vents?

MS. BAUGHMAN: Object to the form. Foundation.

THE WITNESS: Based on this document, that seems to be the suggestion.

Q (BY MS. HORAN) Did you consider, in

your calculations, water buffaloes having any vents?

A Not a vent specific, but with the filler pipe and the manhole acting as a venting basis.

Q Would the manhole continue to vent the water even after it's closed?

A No.

Q Would you -- do you know, one way or the other, whether the vent in this image would allow the water to continue to be vented even after the manhole is closed?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: Say again.

Q (BY MS. HORAN) Sure.

So the vent in this image that says "allows air circulation in tank," do you know whether that is, I guess, a permanent vent or whether...

A I'm -- I'm not sure.

Q In your opinion -- in preparing your opinions on water buffaloes, did you do any work to determine whether any other models had vents or when they were installed?

MS. BAUGHMAN: Object to the form.

THE WITNESS: We looked at the different forms over time. Not specifically looking for an individual component, but looking at the overall nature of the water buffaloes.

Q (BY MS. HORAN) And do you recall looking at whether those components included a vent?

MS. BAUGHMAN: Object to the form.

THE WITNESS: No. Not that I recall. I'd have to go back and look at my -- have to go back and look at my materials.

Q (BY MS. HORAN) Sure.

A Because a vent seems -- anyway. Go ahead.

Q So turning -- turning to water flow. So the water flows in -- the water system at Camp Lejeune flows from water towers into the distribution system where it eventually ends up in peoples' homes.

Is that fair?

A Yeah. That would be the -- correct.

Q And then between the time that the water leaves the tap and when it's ingested, there would be some additional VOC losses.

Is that fair?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: That's hard to say. There's that possibility, but it's hard to know without more details.

Q (BY MS. HORAN) It would depend on the time that the water is out of the tap and the way the water's used.

Is that fair?

A And the spray and the surface area and time.

Q And if the water is boiled when it's exposed to the atmosphere, the losses will occur faster than if it's left exposed to the atmosphere at room temperature.

Is that fair?

A Would typically be the case.

Q And when the water is mixed, losses will occur faster than if it's left exposed to the atmosphere and not mixed.

Fair?

MS. BAUGHMAN: Objection to form. Foundation.

THE WITNESS: In general, yes.

Q (BY MS. HORAN) And Henry's Law would

continue to govern equilibrium concentrations?

A Say again.

Q Henry's Law would continue to govern the equilibrium concentrations?

A Henry's Law governs the equilibrium concentration. But always have to remember kinetics.

Q Sure.

And because there are essentially no VOCs in the atmosphere, Henry's Law dictates that the water exposed to the atmosphere will lose essentially all VOCs.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Again, that's a time-dependent question.

Q (BY MS. HORAN) And given sufficient time, the answer is yes?

MS. BAUGHMAN: Objection to form.

THE WITNESS: And then the question is, what is sufficient time? So yes. Given an ultimate amount of time, that would be the case.

Q (BY MS. HORAN) You agree that the water treatment plant will not add VOCs to the water.

A It's -- it's hard to imagine how that would be. No, I agree that that's very, very,

very unlikely.

Q Have you ever been involved with a project or experienced anything where a water treatment plant added VOCs to the water?

A No.

Q I want to turn to the AH Environmental report that is attached to your report. So I'm turning back to Exhibit 2. And you have it attached to your report as Exhibit D.

I think we've mostly been doing this, but if I refer to the AH Environmental report, you'll understand I mean Exhibit D of your report; correct?

A (Nods head.)

Q Is that yes?

A Correct. Sorry. Correct.

Q When did you first read this report?

A Oh, that would be probably -- roughly a year ago.

Q And I -- where did you -- strike that.

Did you find this on the Internet?

A No.

Q Was this provided to you?

A Yes.

Q Do you -- so this doesn't have any Bates numbers on it. Do you understand what Bates numbers are?

A I'm sorry?

Q Do you -- so a Bates number. Are you familiar with that term?

A I've become familiar with it.

Q Fair enough.

In your AH Environmental report, the -- the one that you received did not have Bates --

A No.

Q -- numbers on it either? This is --

A Yeah, this is what I received.

Q Okay. I believe, earlier, you testified to having spoken with Mr. Maslia a handful of times.

Was counsel present for all of those meetings?

A Say again.

Q When you spoke with Mr. Maslia --

A Maslia. Yes.

Q -- was counsel present for those meetings?

A Yes.

Q Could you turn to Page 1-1 of the AH Environmental report?

A (Witness complies.)

Q Okay. The final paragraph, first sentence, reads, "AH Environmental Consultants, Inc., AH, was retained by MCB Camp Lejeune under contract number DACW5603R1013 to assist ATSDR in obtaining information required for the modeling efforts in the epidemiological study."

Did I read that correctly?

A Yes.

Q Do you agree with AH Environmental Consultants that an estimation of VOC removal at the water treatment plant would be important information, even required, for the modeling efforts of epidemiological studies at Camp Lejeune?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: Say that again.

Q (BY MS. HORAN) Sure.

Do you agree --

MS. BAUGHMAN: Can you show him where it says that? I don't see where it says that in the document. Important and required information.

MS. HORAN: Well, it says, "Obtaining information required for the modeling efforts," in 1-1. Do you see the first sentence in the last paragraph, Laura?

MS. BAUGHMAN: (Nods head.)

MS. HORAN: Okay. I'm going to ask my question.

Q (BY MS. HORAN) Do you agree with AH Environmental Consultants that an estimation of VOC removal at the water treatment plant is required information for the modeling efforts in the epidemiological study at Camp Lejeune?

MS. BAUGHMAN: Objection form; objection foundation.

THE WITNESS: I agree that that statement's in the document.

Q (BY MS. HORAN) And do you personally agree with that?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: Depending upon the degree of volatilization.

Q (BY MS. HORAN) Is it your understanding that the purpose of the water modeling efforts at Camp Lejeune were in support of epidemiological studies?

MS. BAUGHMAN: Objection. Form,

foundation.

THE WITNESS: That was beyond the scope of my expertise or involvement.

Q (BY MS. HORAN) So you have no opinion on the purpose of the water modeling at Camp Lejeune?

A My understanding was it was related to potential exposures. But that's the extent of my understanding.

Q Exposures in the sense of epidemiological studies? Or individuals? Or what do you mean when you say "exposures"?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: My involvement was focused on the water quality. So I wasn't involved in the specifics of what was going to happen beyond that.

Q (BY MS. HORAN) When you say your involvement was in the water quality, what do you mean by that?

A Well, what we're talking about. My expert report.

Q Oh, okay. And you don't intend to offer any opinion in court about that purpose of the water modeling.

A Say again.

Q You don't intend to offer any opinion in court on the purpose of the water modeling?

A Not beyond what's in my expert report.

Q Okay. You can set that aside. Or, I guess, actually turn to Page 7.

A 7?

Q Yeah. Of your report. Which is Exhibit 2.

A (Witness complies.)

Q So looking at your first opinion which begins on Page 7, you opine that only minor VOC losses occurred in these systems.

Do you see that?

A Correct.

Q And "these systems" refers to storage treatment and distribution of water at Camp Lejeune?

A Correct.

Q You underline the word "minor".

Do you see that?

A Yes.

Q Why?

A Show its contrast to Hennet's

substantial.

Q And you define minor as less than 6 to 12 percent VOC loss.

Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: It's a relative term to substantial. Yes.

Q (BY MS. HORAN) You're not a toxicologist, are you?

A No. Say again.

Q You're not a toxicologist?

A No, I'm not. No.

Q And you're not a medical doctor?

A No.

Q So when you say that 6 to 12 percent VOC loss is minor, you're not speaking about in terms of someone's exposure.

Is that fair?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: That's beyond the scope of my efforts.

Q (BY MS. HORAN) You're not qualified to make the assessment of 6 to 12 percent VOC loss as minor, are you?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Well, from a water chemistry perspective which is a focus of my work, I would consider that minor. And that was the extent of my focus.

Q (BY MS. HORAN) Sure.

And you're not making the assessment that 6 to 12 percent VOC loss is minor in the context of someone's exposure; correct?

A That's beyond my expertise and involvement.

Q And when you say 6 to 12 percent is minor, how did you come to the determination that that's minor?

MS. BAUGHMAN: Objection to form.

THE WITNESS: It was in response to Hennet's substantial. Suggestion that there was substantial losses. Also just -- well, I think actually AH Environmental said negligible -- said 10 percent was negligible losses in their expert review panel meeting. So minor, in a way, is more generously negligible.

Q (BY MS. HORAN) So are you repeating someone else's characterization or --

A Yes.

Q -- is it your characterization as minor?

A AH Environmental represented Pomm- -- Pommerenk or -- his name -- in the 2005 expert panel -- was asked about losses. And said 90 percent goes through, 10 percent losses, and consider that negligible.

Q So when you wrote "minor" in your report, you were adopting what you believed to be Mr. Pommerenk's characterization --

MS. BAUGHMAN: Objection to form.

Q (BY MS. HORAN) -- or what an I --

MS. BAUGHMAN: Objection to form.

THE WITNESS: I wasn't adopting, no. I was saying, in a relative sense, these losses to me seemed minor relative to Hennet, relative to Pommerenk, et cetera. I felt justified in choosing the term minor.

Q (BY MS. HORAN) If you -- so you put in your report -- and this is on Page 6.

A 6?

Q 6. Yeah. So just to go over it.

The last sentence of the first bullet says, "Rather than 15 to 32 percent losses by Dr. Hennet's calculations, I estimate less than 6 to 12 percent losses for the range of VOCs."

Do you see that sentence?

A Yes.

Q Page 14 of your report, Table 5.3, is your calculations for losses.

Fair?

A Yes.

Q None of those numbers are less than 6.

A Well --

Q Fair?

A None of the numbers listed in the table.

MS. BAUGHMAN: I'm going to object to the form.

THE WITNESS: Granted, I rounded 6.3 down to 6 which is mathematically...

Q (BY MS. HORAN) Sure.

But none of your numbers come up as less than 6. Is that fair?

MS. BAUGHMAN: Objection to the form.

THE WITNESS: They do to the extent that I say less than 1 percent in the storage tanks and less than 1 in other losses.

Q (BY MS. HORAN) So when you were saying, on Page 6, you estimate less than 6 to 12 percent losses for the range of VOCs, you were breaking that to include individual components of your overall calculation?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Those individual components are included in the 6.3 value.

Q (BY MS. HORAN) Sure.

I'm just -- I'm just wondering why you included less than 6 if the lowest number I see on your chart is --

A Yeah.

Q -- 6.3.

Is it just a typo? I mean, I'm just --

A It's -- you could -- from Table 5.3, I'm saying the lowest value might have been less than 6. 6.3, 6. So I was just carrying that forward to my summary statement.

Q Okay. So you used less than 6 percent because Table 5.3 for benzine says less than 6.3.

A Correct.

Q Okay. As you've used it in your report, how do you define raw water?

A Water --

MS. BAUGHMAN: Objection to form.

THE WITNESS: Water -- generally, in the water treatment industry, raw water is the water coming into the water treatment plant.

Q (BY MS. HORAN) So raw water as defined in your report is pre-treatment.

Fair?

A Yes.

Q It's your opinion that assumptions that Dr. Hennet made in his calculations are what led to the overestimation of his VOC loss calculations.

Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Say again.

Q (BY MS. HORAN) It's your opinion that assumptions that Dr. Hennet -- I'll start again.

Is it your opinion that assumptions in Dr. Hennet's calculations led to overestimation?

A Assumptions of value that he assume -- values he assumed.

Q On Page 7 of your report, Figure 5.1 -- I think you have it in front of you. As to Hadnot Point, you agree that VOCs would be lost in the raw water storage reservoirs?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Possibility for minor losses.

Q (BY MS. HORAN) And in the schematic

which is Figure 5.1, there's losses at each stage of Hadnot Point except for the supply wells and the water distributions to your homes.

Is that fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: One more time. I'm sorry.

Q (BY MS. HORAN) Sure.

Figure 5.1 on your report.

A (Indicating.)

Q Yep.

VOCs would be lost at each stage except for the supply wells and the water distribution in the houses, but every other stage shown in that image would incur VOC losses.

Fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Possibly. It's a possibility. Minor losses.

Q (BY MS. HORAN) And when you say "a possibility of minor losses," do your calculations -- is it just you're disputing the volume of losses or that they would happen at all?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Just calculations indicate

that the losses that are possible would be very minor.

Q (BY MS. HORAN) And why would they only be possible?

A Say again.

Q Why would the losses only be possible based on your calculations?

A Why would they only be possible?

Q Right.

Wouldn't your calculations suggest that they're probable?

A Minor --

MS. BAUGHMAN: Objection to form.

THE WITNESS: Minor losses.

Q (BY MS. HORAN) Sure.

So there would be at least minor -- or strike that.

It's your opinion that there would be at least minor losses in all of the areas shown in Figure 5.1 except supply wells and water distribution.

MS. BAUGHMAN: Objection to form.

Q (BY MS. HORAN) Is that fair?

THE WITNESS: I'd say there's a possibility of minor losses. That doesn't mean necessarily that there will be -- they may be negligible.

Q (BY MS. HORAN) And even if they were negligible, there would be some loss.

Fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yeah, if you consider neg- -- I wouldn't necessarily consider negligible losses some losses, but there might be minor negligible losses.

Q (BY MS. HORAN) You've used the term "negligible". How do you determine what's negligible in this field?

A That's probably a relative term. Well, not relative. I mean it's -- I would consider less than 1 percent, for example, is negligible.

Q And is that negligible in your --

A Of course, I say that, and AH considered -- referred to 10 percent loss as negligible. So it's hard to pin that down. It depends.

Q The negligible losses that you -- or strike that.

When you say negligible losses, are you saying negligible in your capacity as a professional engineer or are you saying negligible in the context of determining someone's overall exposure as it relates to health?

A No. Water -- drinking water treatment perspective.

Q Okay. So you're not saying negligible in the sense of how it might impact someone's overall exposure as it determines --

A That's beyond my -- (simultaneous crosstalk)

THE REPORTER: As it determines what?

MS. HORAN: Any type of health issue.

THE WITNESS: Sorry.

That's beyond my expertise to comment on.

Q (BY MS. HORAN) Okay. Could you turn to the AH Environmental report on Page 5-1?

A (Witness complies.) Yes.

Q Do you see the last paragraph? The second sentence reads, "The only significant VOC removals must have occurred at the spiractor effluent pipe where the falling water undergoes some aeration."

Do you see that?

A Yes.

Q Do you agree with AH Environmental that significant VOC removals would occur at the spiractor effluent pipe?

MS. BAUGHMAN: Objection to form.

THE WITNESS: "Significant's" a relative term. I read what they're saying is, the only quantifiable losses unless they use the word "significant".

So what do you mean when you say "significant"? So I think what they meant by "significant" was later in the expert meeting, they referred to these losses as minor negligible. But here, they're saying the potential loss -- as I read what they're saying, my interpretation is they're saying, of potential losses, this was the one that was most evidenced.

Q (BY MS. HORAN) And do you agree that there's -- the most evidenced losses would be at the spiractor effluent pipe?

A Yes.

Q Okay. And those numbers -- or strike that.

The amount of losses at the VO -- strike that.

The amount of VOC losses at the

spiractor effluent pipe would not be negligible.
Fair?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Under these conditions.

Q (BY MS. HORAN) Is that yes?

A Yes. Not negligible. Again, that term negligible -- because again, in their 2005 expert panel review, they referred to this level of losses as minor negligible. So it -- it's a relative term.

Q So turning back to your report on Page 7.

A Okay.

Q Looking at Figure 5.1. Of the structures identified in that schematic, the structure with the most significant VOC losses would be the spiractor.
Fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Based on the analysis and calculations, that would be fair.

Q (BY MS. HORAN) Okay. Turning to your opinion on spiractor which begins on Page 8 -- and you're, of course, welcome to reference your report at any point during the deposition.

A Thank you.

Q Your opinion on the percentage loss of TCE and PCE differs from Dr. Hennet's in that you find that the effluent fall height is 1 foot and Dr. Hennet used 2 feet.

Is that fair?

A That's correct.

Q Other than the fall height, is there anything about Dr. Hennet's opinion related to VOC losses at spiractors that you disagree with?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Not in terms of the calculation, no. I would qualify that by saying I did comment that the spiractor water converges in the center versus weir where it would be flowing over the edge. And so it's not a difference with Dr. Hennet's calculation, but it is a qualification to the method applied.

Q (BY MS. HORAN) Sure.

And on Page 9, in the paragraph -- the last full paragraph, nine lines down.

A Right. Yeah.

Q You say, "Thus, while I am not aware of a better approach than Nakasone 1987 for making this estimate, it is my opinion the estimated values of VOC losses will be conservative higher than actually experienced."

A Correct.

Q Did I read that correctly?

A Correct.

Q And so in materials of the weir that you just described --

A No.

Q -- you're not aware of a better approach for adding it to this calculation.

A No. Correct.

Q So you and Dr. Hennet essentially agree on the methodology for calculating spiractor losses and you disagree about one input.

Is that fair?

A Correct.

Q And you conclude that AH Environmental used 1 foot for the water drop in the spiractor effluent pipe, and that's justified.

Is that fair?

A Correct.

Q You're not offering any independent assessment of the effluent pipe fall height.

A Correct.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Correct.

Q (BY MS. HORAN) Is there any information besides the AH Environmental report that you relied on in determining the fall height of 1 foot is more justified?

A No.

Q Did you review the photos in AH Environmental's report and determine for yourself that the fall height was 1 foot or did you rely on AH Environmental's analysis?

A I reviewed the figures and understood the reasons for why they selected the 1-foot fall height.

Q AH Environmental determined the spiractor effluent pipe diameter was 12 inches.

Do you agree?

A That's the number that they used. Correct.

Q Do you know precisely how they made that measurement?

MS. BAUGHMAN: Objection to form.

THE WITNESS: It's in -- what I know is it's in their document.

Q (BY MS. HORAN) And sitting here today, what's your understanding of how they made that measurement?

MS. BAUGHMAN: Objection to form. Foundation.

THE WITNESS: They made it based upon a flowing system where they were able to see the constricted water down gradient reducing the fall height, and they made an estimate based upon the visual observation. It's my understanding. And I think that's documented, and probably best to actually go there.

I forget exactly where it is in the report where they describe -- here it is. Page 3-7.

Q (BY MS. HORAN) Uh-huh.

A The fall height was estimated visually based on recent photographs. And then on -- so you see that?

Q I do. Yes. So --

MS. BAUGHMAN: Were you finished?

THE WITNESS: No.

Q (BY MS. HORAN) Oh.

A I'm sorry.

So then if we go to Figure 4-1, Page 4-2.

Q Uh-huh.

A You see a Hadnot Point spiractor showing the evidence of the downstream constriction limiting the fall height versus --

Q Sorry. Where are you looking?

A 4- -- Figure 4-1.

Q Yes. Oh, you're saying this image shows that to you. You're not pointing to text in the report.

A No, no.

Q Okay.

A I'm sorry. I'm looking at the figures.

Q Okay.

A And there -- well, in the text, they do say they -- I've lost over where they say that. But they picked 1 foot. But the pictures they're relying upon, 4-1, you can see that the water isn't free flowing in like it is in 4-3.

Q Uh-huh.

A And so Holcomb Boulevard, they said they did get the 2-foot drop fall height where as in Hadnot Point, because of the downstream constriction from the recarbonation basin, that back -- what I'll call back water, water wasn't able to flow freely out of this pipe because of that. And so we have the 1-foot drop.

Q For Figure 4-1, do you know whether gravity filters were being backwashed when this photo was taken?

A No. That's 4-2. They point out that 4-2 was after backwash filter went -- so that clearly dem -- they were clearly demonstrating the additional impact of the backwashing the filters. With that -- well, I'll leave it at that.

Q So I -- the -- I think -- so I understand on 3-7, you pointed me to language that says that the fall height was estimated visually. But I believe -- do you know how they measured the pipe diameter?

A No, I do not.

Q Okay. So we're at 12:05. Do we want to take a break for lunch?

A I can go a little bit longer or --

MS. BAUGHMAN: If you want to, we can. It's up to you.

He's willing to go.

So you decide.

THE WITNESS: Go another 15 minutes or so. Fifteen, 20 minutes.

Q (BY MS. HORAN) Sure. We can keep

going. Okay.

Okay. So you agree that AH Environmental did not measure the Hadnot Point effluent fall height; they just visually estimated it. Fair?

MS. BAUGHMAN: Objection to form. Foundation.

THE WITNESS: I would say that they made a measurement based on a visual -- they made a measurement based on a visual product.

Q (BY MS. HORAN) Sure.

They didn't measure it. They made a visual estimation. Fair?

A They didn't go out and measure it. They measured it from the picture which is a measurement in and of itself.

Q Sure.

But they didn't go into the field, as far as you're aware, and measure it with a measuring tape. Fair?

A Not to my knowledge. But I'll add that a measurement on an empty pipe is of less value than a measurement on a flowing pipe. Because an empty pipe doesn't give you the indication of the -- what we're seeing in Figure 4-1. The important value is how far does that water fall before it hits bottom, the water.

Q Uh-huh.

A And that's the volatilization. And so just measuring the pipe -- measuring the fall height, for example, from Figure 3-2, you have no indication of where the water level is dropping to in that pipe. You don't have any idea of the actual fall height. All you know is what's the dimension for an empty spiractor effluent pipe.

So for me, a visual measurement from a picture, we're actually seeing the constricted water decreasing the fall height is more valuable than a measurement on an empty pipe where you have no idea what it was like under operating conditions.

Q Do you know if AH Environmental estimated based on image of a pipe being used or an empty pipe?

A Let's find their discussion. Okay. Just above Figure 4.4-1. Okay. So let's start with only a small vortex.

Do you see that?

Q Uh-huh.

A Formed over the submerged effluent pipe

4-1 on one spiractor and they developed an nappe after a backwash filter went back online. Because of the downstream recarbonation basin at that plant, available head does not appear to allow fall height of greater than 1 foot. And so -- indicating that they were taking into account the downstream recarbonation basin reducing the fall height. Then they go on to say, however, at Holcomb Boulevard -- because there was no recarbonation basin, water falls 2 feet.

Q So based on 4.1, you determined that it was reasonable for there to be a 1-foot fall height at Hadnot Point based on this image?

MS. BAUGHMAN: Objection to form.

THE WITNESS: That confirmed in my mind their decision to go with a 1-foot fall height versus Figure 4-3 for Holcomb Boulevard where there's no evidence of that back -- that constriction reducing the fall height they said there would be 2 feet.

Q (BY MS. HORAN) Okay. And how they determined the 1 foot, what image did you use from AH Environmental besides -- or maybe there's none.

Did you use any images besides 4.1 to

confirm your belief that 1 foot was a reasonable estimation?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Figure 4.1 confirmed in my mind why they chose a 1-foot fall height. And I know they were -- they had a longer term contract at this site. So I trusted that, being professional engineers, they were taking appropriate measures to make these determinations.

Q (BY MS. HORAN) Could you turn to 3-8?

A 3-8?

Q Yeah.

A Yes.

Q You see the image says Hadnot Point Water Treatment Plant spiractor effluent pipe, 1941, 1942?

A Correct.

Q Is it your understanding that AH Environmental is representing that this image was taken in 1941 or '42? Or what's your understanding of that?

MS. BAUGHMAN: I'm sorry. Are you on Page 3-8 or Figure 3-8?

MS. HORAN: Page 3-8.

THE WITNESS: Page 3-8.

MS. BAUGHMAN: Okay. Thank you.

THE WITNESS: Can you ask that again?

Q (BY MS. HORAN) Sure.

You see the figure says Hadnot Point water treatment plant -- well, it says WTP -- spiractor effluent pipe 1941 to 1942?

A (Nods head.)

Q Is it your understanding that AH Environmental is representing that this photo was taken in 1941 or '42 or what -- what do they mean by that?

Do you know?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: I couldn't speak to that.

Q (BY MS. HORAN) Have you ever personally measured a spiractor pipe?

A No.

Q Do you know if it's even possible to measure the fall height of a spiractor while it's in use?

A Say that again.

Q Is it even -- strike that.

Is it possible to measure the fall

height of a spiractor effluent pipe while the spiractor is in use?

A I mean I guess, theoretically, it would be possible. But if you look at the -- looking for the schematic. So if you look at Figure 3-1.

Q Uh-huh.

A On Page 3-7.

Q Yep.

A The effluent pipe is in the center of a 10-foot diameter reactor. So that would make it -- certainly would -- certainly be possible.

Q And it's also in the middle of a 22-foot drop. Fair?

A Correct. Correct.

Q So to measure an effluent pipe from a spiractor, you have to figure out how to get some type of measurement perched over a 22-foot drop in the middle of a 10-foot wide metal container of sorts.

Is that fair?

A Well, let's look at Page 2-9. Figure 2-4.

Q Uh-huh.

A I mean, if we're talking about the realms of possibility.

Q How would you go about measuring a spiractor effluent pipe while a spiractor is in use, to determine the fall height?

A Well, I might take a picture.

Q All right. You would take a picture?

A I might. I mean that...

Q And from Image 2.4 -- or Figure 2.4 on 2-9 that you pointed us to, can you figure out the fall height from this image? Or what type of image would you need?

A No, no. Not this picture itself. Let me -- the picture that they have here would be one way to approach it. The --

MS. BAUGHMAN: You have to say what "here" is.

THE WITNESS: I'm sorry. Figure 4-1. Sorry.

Q (BY MS. HORAN) So if an image of -- like 4-1 was sent to you, you could figure out the fall height based on this image alone?

MS. BAUGHMAN: Objection to form.

THE WITNESS: That would be -- that would be one approach. Probably be a safer approach. But you could potentially try to rig up some kind of a -- I don't know. Today, maybe we'd use a drone.

MS. BAUGHMAN: You have to explain what you're looking at when you say that.

THE WITNESS: Oh, I'm sorry. Figure 2-4 Page 2-9.

If we're trying to get that, you could rig up some kind of mechanism and try and figure that out.

Q (BY MS. HORAN) What mechanism would you rig up?

A I'd have to think about it.

Q Well, it might be a good time for lunch then.

A Okay.

MS. HORAN: Can we go off the record, please?

THE VIDEOGRAPHER: Off the record. 12:16 p.m.

(Lunch break from 12:16 p.m. to 1:16 p.m.)

THE VIDEOGRAPHER: We're back on the record at 1:16 p.m.

MS. BAUGHMAN: Okay. I just want to put on the record, before we start, that I stated, off the record, a few minutes ago, that the materials considered list -- that there's some confusion about that in that the vast majority of the documents that start at Page 9 of 30, additional materials considered, are materials that were provided well -- a year or more -- let me see -- at least six months before Dr. Sabatini's rebuttal report was prepared, and are background materials not specifically relied upon for the volatilization opinions or any opinion in his rebuttal report, exception being the ones that are -- didn't exist at the time which are depositions, and another exception being a document with the Bates stamp CLW0000005176 through 5182. And --

MS. HORAN: Could you read the title of the document? Because I think --

MS. BAUGHMAN: Grainger Laboratories Inc., Letter of August 10, 1982. It's possible this was disclosed earlier, but if not, then that might be one that's new that hadn't been disclosed before as something that Dr. Sabatini is relying on that does relate to volatilization.

So in other words, we received -- the reason I'm saying this is we received an email from Adam Bain which I read during lunch that complains about the new documents and the reliance list, and the point being that with the exception of one document, and with the exception of documents that didn't exist at the time that the rebuttal report was submitted to the -- to the government, there is only one new document. Which I can give you a copy of now, if you want. And the rest of this is pure background information about Camp Lejeune not specifically relied upon for his opinions.

Now, there could be -- I'll say one caveat. There could be an overlap in that documents on Pages 1 through 8 may be duplicative of documents from 9 through 30. If it's in 1 through 8, what I've said does not apply.

MS. HORAN: Okay. Sure. Yeah, could you give us the copy of the document? And I believe you said, during the break, that there were three. Is it just the one --

MS. BAUGHMAN: It's just the one.

MS. HORAN: -- or were there three?

MS. BAUGHMAN: It's just the one, but the one has different parts to it, if that makes sense. Like --

MS. HORAN: Well, I'll look at it.

MS. BAUGHMAN: You'll see. It's one.

MS. HORAN: Okay.

Q (BY MS. HORAN) Welcome back, Dr. Sabatini.

A Thank you. Hope you had a good lunch.

Q I hope you did as well.

A Thank you. Stella Nova. One of my family's favorites.

Q Yeah. Good for you.

Have -- you understand you're still under oath to tell the truth?

A Yes.

Q Okay. And when we left right before the break, we were talking about how one could go about measuring the spiractor fall pipe while the spiractor is being used. So while there's water in it. And I -- do you have any new or -- thoughts on how one would go about doing that?

A Not beyond what we discussed before and not -- not beyond that. No.

Q Okay. And you've never measured a spiractor while it's filled or unfilled.

Is that fair?

A No.

Q No, you have never done it?

A I have not done that.

Q Okay. Did AHE or you measure the relative elevation between the recarbonation basin water level and the effluent pipe rim level?

A I can't speak for AH. I assume that they did a thorough analysis of all the systems as they document at the beginning of their report. That they studied all basins and all plans and schematics and everything. So I can't speak to what they did. But I did not.

Q Turning to your report which was marked as Exhibit 2, if we turn to Page 9 -- I'll let you get there. Table 5.2. In Table 5.2, you compare AH Environmental and Dr. Hennet's loss calculations.

Fair?

A I compare AH Environmental's corrected numbers based upon the transposed exponent that Hennet noted. So yes, it's AH's numbers versus Hennet's numbers, but AH's corrected numbers.

Q Thank you for that clarification.

And then you adopt AH's clarified numbers for your own calculations.

Fair?

A Adopt the 1-foot fall height which leads to the same -- same numbers.

Q Sure.

So you used the numbers in Table 5.2 that are attributed to AH Environmental for your calculation --

A Those are actually my -- sorry. Pause before I answer.

MS. BAUGHMAN: Wait until she finishes, and pause and answer.

THE WITNESS: Count to three. One, two, three.

I -- I adopted my corrected -- the number's actually my calculations based upon AH's 1-foot fall height.

Q (BY MS. HORAN) Okay. And using a 2-foot -- as opposed to a 1-foot -- fall height nearly doubles the losses; correct?

A It has -- approaching that effect.

Q Turning to -- back to the AH Environmental report in Figure 5 -- 4.2 which is on Page 4-3.

A Okay.

Q Do you see that Figure 4.2 shows a -- a nappe?

A Yes.

Q And did you see Figure 4.3 right below it has a more regular water sheet?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yes. Non-constricted.

Q (BY MS. HORAN) And did you notice that the Hadnot Point effluent pipe has a heavy crust deposit compared to the none or less deposit on the Holcomb Boulevard pipe?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Ask again.

Q (BY MS. HORAN) Did you notice that the -- there's a heavier crust deposit for the Hadnot Point effluent pipe -- which is Figure 4.42 -- compared to the no or less deposit in the Holcomb Boulevard pipe which is 4-3?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: Yeah, I wouldn't be able to make that discernment based upon this picture.

Q (BY MS. HORAN) Could a crust on a effluent pipe be responsible for the nappe?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I would refer back to Figure 4-1. Which doesn't have -- show the same nappe. And AH attributes the difference between

4-1 and 4-2 to the backwashing of the filters.

Q (BY MS. HORAN) So let's turn back to that. On 4-2, in the -- the text above it on Page 4-2.

A Oh, on Page 4-2. I was on Figure 4-2. Okay.

Q Yep.

The text above it, there's a sentence that reads, "Only a small vortex formed over the submerged effluent pipe, Figure 4-1, on the one spiractor, and then developed a nappe after a backwash filter went back online, Figure 4-2."

Do you see that?

A Yes.

Q Okay. Is it your understanding that for Figure 4-1 was when the backwash water was being filtered through the effluent pipe?

A No.

Q What is your understanding?

A I know that when the backwash filter -- when a filter's being backwashed, more water is forced through fewer systems. And so that -- you get a backup of water, a constriction, as they described. And so it's clear to me the difference between 4-1 and 4-2 is the constriction due to the hydraulics of the filter being backwashed resulting in the nappe, Figure 4-2.

Q So it's your opinion that the nappe is from the backwashed water --

A That the --

Q -- and the vortex is when there's no backwash water.

MS. BAUGHMAN: Objection to form.

THE WITNESS: When -- in the absence of the backwash constriction.

Q (BY MS. HORAN) So turning back to 4-2, the language where it says -- the second half of the sentence I previously read, "And then developed a nappe after a backwashed filter went back online."

Doesn't that suggest to you that the nappe was formed after the backwashed filter was back on?

A Yeah, I don't understand that wording. I would -- so Figure 4-1, the way I interpreted it, was at the end of the backwash process, just as they were putting it back online, that's when they would have had the greatest impact of a backwashed filter on the hydraulics. And so that

-- that's when you'd get the maximum hydraulic impact. So from a hydraulics perspective, that's how I would interpret that sentence.

Q So why would there be more constriction when there's not backwashing?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Now, my comment would be that there would be more constriction when there was a filter being backwashed.

Q (BY MS. HORAN) And more constriction would be the development of a vortex; correct?

A No. No. You would have more -- it would be harder for the water to go through the pipe so you would get more backup of the water in the pipe, and you'd have this scenario, 4-2, versus the scenario in 4-1.

Q When you say more "water in the pipe," do you mean the -- which part -- part of the pipe are you referencing there?

A The pipes flowing between the basins.

Q So when the spiractor has more water in it. Or are you talking about the effluent pipe?

A Right. Because one filter's offline. All the water's having to go through the other filters creating a constriction and a build-up of water prior to that point.

Q Okay.

A For me, looking at this picture, Figure 4-1 to 4-3 tells, to me, a big story. In that obviously, you have less free fall of water in the Hadnot Point effluent pipe than you have in the Holcomb Boulevard.

Q So just looking at the two, though, of Hadnot Point, one has a -- Figure 1 is shown as having a vortex in the description and Figure 4-2 is it shown as having a nappe in the -- in the description.

Do you agree with that?

A Yes.

Q Okay. And it's your opinion that when the backwash filter is back online, there would be a vortex and not a nappe.

MS. BAUGHMAN: Objection to form.

THE WITNESS: I couldn't speak to the vortex -- to the nap. But what I -- what is clear to me is that there's less free fall in the 4-2 than the 4-1, and there's less free fall in 4-1 than in 4 -- Figure 4-3.

Q (BY MS. HORAN) Sure.

But what is your understanding of the

process as it relates to the backwash filter, whether it was on or off, or how it was being used, for Figure 4-1?

A My understanding is, at the end of the backwash cycle, they have the greatest impact on the effluent pipe from the spiractor. And when that backwash filter was brought back online, the hydraulics changed back to the previous condition.

Q Why would you have less free fall when the water is less backed up in the spiractor effluent pipe?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Say again.

Q (BY MS. HORAN) Why would you have less free fall when the water is less backed up in the spiractor effluent pipe?

A No. What I was saying, there would be more water backed up. And so the -- you would have less free fall because there was more water being backed up.

Q And when there's -- is it your opinion that Figure 4-1 shows more or less free fall than Figure 4-2?

A My impression would be more. Just based on visual observation.

Q So just so I understood that correctly, your opinion is that 4-1 shows more free fall than Figure 4-2? Or did I get that wrong?

A That would be my visual observation.

Q Okay. Turning to Page 3-11 of the AH Environmental report.

Dr. Sabatini, do you remember earlier this morning, we talked about mixing in the reservoirs?

A (Nods head.)

Q The first full paragraph on 3-11. Do you see it reads, "In a quiescent tank, e.g., raw and finished water reservoirs, filter beds, and spiractors, the water is assumed to be well mixed, and the bulk concentration of a contaminant is equal to the effluent concentration and can be estimated from a material balance. VOC volatilization is a first-order rate process and the remaining fraction of a chemical can be expressed as follows." And then it has an equation.

Do you see that?

A Yes.

Q Do you see that AH Environmental assumed that the reservoirs would be well mixed?

A It depends upon what you mean by "well mixed." Certainly, the spiractor, I would agree, was extremely well mixed because of all the flow coming in. The reservoirs -- as the water comes into that reservoir, you have a certain amount of energy that causes that flow to go into the reservoir. So you could get a degree of mixing from that. Which would be, I might choose to say mix -- a degree of mixing as opposed to well mixed. To me, well mixed, from a reactor design perspective, means you have some kind of a turbine or something mixing the water to get it well mixed.

So I can imagine that what they're trying to say is that the water coming in creates a degree of mixing. But I probably wouldn't choose to use the term "well mixed."

Q And that's because you would only use the term "well mixed" if there was some kind of mechanical process involved?

A Yes. Mechanical or -- you can achieve it in different ways, but not just water flowing into a -- a basin. And part of that assumption makes the calculations easier.

Q Could you turn back to Figure 4-2? Which is Page 4-3.

A (Witness complies.)

Q Would you agree that Figure 4-2 which shows the development of a nappe, that the -- it would imply -- or strike that.

Would you agree that Figure 4-2 which shows a nappe -- a nappe would imply more surface area for water-to-air contact?

A Say that again.

Q Sure.

Do you see 4-2 creates a nappe?

A Yes. I...

Q Okay. And would you agree that a nappe will create more surface area for water-to-air contact?

A That's a hypothetical question.

Q Why is that a hypothetical question, Dr. Sabatini?

A Well, visually, you may see more area towards the top of the pipe, but there's less free fall which has area associated with it as well. So it would be harder for me to definitively say what the combined impact would be.

Q I'm -- so I'm not asking about the combined impact. I'm just asking about the -- the nappe creation.

A Well --

Q At the top of the pipe, would that create additional surface-to-air contact with water?

MS. BAUGHMAN: Objection to the form.

THE WITNESS: I'd have to study that more.

Q (BY MS. HORAN) You said you couldn't make an overall assessment because the fall height might be lower because the pipe would be more full.

Why would a -- the creation of a nappe mean that the pipe was more full?

A I would --

MS. BAUGHMAN: Objection to form.

THE WITNESS: I would attribute that to the -- again, to the downstream constriction causing the -- causing that condition.

Q (BY MS. HORAN) Okay. Turning next to storage tanks, you agree with Dr. Hennet's use of the approach laid out in Thomas, 1990 as opposed to the approach used by AH Environmental;

correct?

A The same that AH Environmental used and Hennet used, yes. I...

Q And you --

MS. BAUGHMAN: Well, I'm going to object to the form and object as non-responsive. I don't think he heard the question.

THE WITNESS: Oh, I'm sorry.

MS. BAUGHMAN: Because he answered something different from what you asked.

THE WITNESS: Can you rephrase the question?

Q (BY MS. HORAN) I thought you answered it, but I will ask it again.

You agree with Dr. Hennet's use of the more generalized approach laid out in Thomas, 1990 as opposed to the approach that was used by AH Environmental; correct?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Yeah, I'd have to go back and refresh my memory on the terminology.

Q (BY MS. HORAN) Okay. Could you turn to Page 10 of your report?

A (Witness complies.)

Q The second paragraph suggests that --

A Yeah. That's what I --

MS. BAUGHMAN: Wait. Wait. Wait.

THE WITNESS: I'm sorry.

MS. BAUGHMAN: Let her finish.

THE WITNESS: Sure. I'm sorry.

Q (BY MS. HORAN) -- suggests that AH Environmental used the Southworth approach, and you did not agree that that was the appropriate approach. You agreed rather with Dr. Hennet that their more generalized approach was better.

Correct?

A Yes.

Q Okay. On that same page, the first sentence of the second full paragraph says, "The approaches outlined in Thomas, 1990 are for systems open to the atmosphere, e.g., a pond, lake, or river. In contrast, the Camp Lejeune water treatment tanks, from raw water to clear well to water towers, are covered. They are not open to the atmosphere."

Did I read that correctly?

A That's correct.

Q Is it your opinion -- or strike that.

Dr. Sabatini, you agree that the water treatment tanks, from raw water to clear well to water towers, would experience air exchange through venting?

A As the water level goes up and down, there would be atmospheric air. As water level goes down, then atmospheric air would replace that amount of water that went down. Yes.

So in terms of my terminology, what I meant by open to the atmosphere was completely open, like a lake, versus a cover that has small inter -- or has intermittent vents that's not completely open.

Q But you would agree that the water treatment tanks have some ability to interact with the open atmosphere through these vents.

Fair?

A There is a degree of interaction with the atmosphere.

Q Had you seen any photos of the treatment tanks at Camp Lejeune prior to submitting your expert report?

A I relied upon the AH Environmental documents. I'm trying to remember if I had or not. I don't recall.

Q How did you determine that the Camp Lejeune water treatment tanks were not open to the atmosphere?

A That was my impression from the information I had at hand.

Q Anything in particular?

A Well, for one thing, I've never known them to be open to the atmosphere. That's just allowing for surface contamination of your water.

Q Do you know whether there are any drying beds at Camp Lejeune?

A I'm sorry. Whether there are...

Q Drying beds.

A No, I don't.

Q Prior to issuing your report, did you do anything to try to find out whether there were drying beds at Camp Lejeune?

A That wasn't critical to my calculations.

Q And why wasn't that critical to your calculations?

A It didn't bear in to the losses of concern.

And I might just add to that. I didn't find such information in Hennet's report either.

(Government Exhibit 8 marked for identification)

Q (BY MS. HORAN) So I'm marking as Government Exhibit 8 -- this is a document, EPA

Region 8 Drinking Water Tech Tips.

Dr. Sabatini, have you seen this document before?

A It doesn't look familiar.

MS. BAUGHMAN: Do you have the date, by the way? It doesn't --

MS. HORAN: No. I don't have a date.

MS. BAUGHMAN: Okay.

Q (BY MS. HORAN) Do you see the paragraph at the top that starts "Finished water storage sanitary protection"?

MS. BAUGHMAN: I'm going to -- you can take your time and read the document, if you've never seen it before, before you answer questions.

THE WITNESS: (Reviews document.)

Okay.

Q (BY MS. HORAN) Do you see the paragraph at the top of the document? The first full paragraph? The second sentence reads -- or did you have a chance to read that whole paragraph?

A Yes.

Q Do you disagree with anything in that paragraph?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Not in my general -- do you have a specific question about the paragraph?

Q (BY MS. HORAN) That was my question. When you read it, was there anything that you disagreed with?

MS. BAUGHMAN: Object to the form.

You can carefully read the whole thing before you answer.

MS. HORAN: Laura, I'd like him to --

MS. BAUGHMAN: He -- this is his first deposition.

MS. HORAN: I know. And I --

Q (BY MS. HORAN) I'm not pushing you, Dr. Sabatini --

A Yeah.

Q -- on any document all day.

A Yeah, I just read it quickly --

Q Sure.

A -- not realizing you were...

Q Yeah. Take your time.

A (Reviews document.)

Okay. In this first reading, it all seems appropriate.

Q Okay. Do you see the second sentence reads, "The air pressure inside of a tank is always trying to equalize with the air pressure outside as the water level rises and falls in the tank"?

Do you see that?

A Yes.

Q Do you agree with that?

A Yes.

Q Okay. You can put that aside.

A By the way, this reminds me back to the water buffalo and the vent.

Q Sure.

A It would seem somewhat analogous. You have a small vent pipe on a big surface area water tank to help equalize pressures.

Q Sure.

A In the same way that you have here.

Q An air exchange would happen in the same way.

A Through the same way.

Q Through the vent; correct?

A Yeah. In -- as water level rises and falls. Not forced ventilation.

Allergies. I don't know if you can hear it in my voice. I can.

Q If you need a break, let us know.

A A lozenge.

MS. O'LEARY: Just also, there's some water if you'd like.

THE WITNESS: Thank you. Very kind. Thank you.

MS. BAUGHMAN: This is yours, too, if you need it.

Q (BY MS. HORAN) You would agree that fluctuation will occur every day in both the water reservoirs and the towers; correct?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Under normal course of operation, you would expect that. Although, that one CLW showed there were days -- hours and days where there were minimal fluctuation in a water reservoir.

Q (BY MS. HORAN) What CLW are you referencing?

A Well, I don't have that with me right now, but it was...

Q Could you just describe the document, to the best of your recollection?

A Yeah. It was a document that showed every four-hour water elevations in a storage tank over the course of, I think, seven or eight days. And so it showed the water level fluctuations. It varied from zero to 2 feet maximum over the seven to eight days. And the average water fluctuation was 1 foot.

Q And where did you first see that document or -- strike that.

When did you first see that document?

A I don't recall exactly.

Q Do you recall if it was before or after you submitted your expert report?

A I believe before. Yes. I believe before.

Q Do you know if you cite that document in your report?

A Not sure if I did or not. I don't see it listed.

Q So I guess based on this document, is it your understanding that the fluctuation is, on average, 1 foot per day in the Camp Lejeune reservoirs? Or did I misunderstand that?

A In this one set of data that they collected, that was the case.

Q Do you recall when the data was from?

A '85.

Q '85?

A Yeah. It's what I recall.

Q And was the data from a reservoir or water tower? Both?

A Reservoir is what I recall. Yeah, reservoir.

Q How much fluctuation is there per day at a Camp Lejeune water tower, if you know?

A I don't recall.

Q The -- I understand -- or strike that.

You're -- what you've told me today that there -- it's your understanding that there's 1-foot fluctuations in the Camp Lejeune water reservoirs.

How does that impact your opinions, as to reservoirs, in your report?

A In my analysis, I assumed that there would be some fluctuation. I guess that's the answer. I assumed. So I took that into account. There would be a certain level of water fluctuation.

Q Sure.

And would it matter if it was 1 foot or 2 feet of fluctuation for your opinion?

A Not -- not -- no.

Q So the amount of fluctuation is not a

pertinent -- or the quantification of the amount of fluctuation is not a pertinent factor, to your opinion, as to reservoirs?

A Not in that range that you just mentioned. Now, if the tank emptied and went from empty to full, the magnitude of the fluctuation could make a difference. But the other big difference is -- well, I'll stop there. That answers your question.

Q How about -- would -- would a 3-feet fluctuation make an impact to your opinion?

A I'd say no. Because there's other factors that go into it.

Q A moment ago, you said, well, the other big factor is, but I'll stop there.

What is the other big difference that you were alluding to?

MS. BAUGHMAN: Objection to form.

THE WITNESS: The Thomas method, lake opened to the atmosphere, you have air movement over the surface. And that increases the volatilization rate where as in a covered tank, even vented, you don't have air flowing over the surface like you would in a -- in a lake. And so that's another factor that goes into the volatilization rate in the Thomas method.

Q (BY MS. HORAN) Sure.

Do you know how many times per day the water levels change at Camp Lejeune in the reservoirs?

MS. BAUGHMAN: Objection to form.

THE WITNESS: The CLW I referred to provided some every-four-hour information, as I recall, in the '85 timeframe. It gives some indication of that.

Q (BY MS. HORAN) Do you know how fast the water is flowing in the reservoirs or in the water tanks?

A I don't know that number off the top of my head. It's something I could calculate, but I don't know that number off the top of my head.

Q Did you calculate it for your opinions?

A No.

Q And why not?

A Because it's not part of the -- the Thomas method takes detention time into consideration.

Q So instead of determining the flow rate, you determined detention time?

A That was what -- that's what feeds into the...

Q Do you know how much water flows through a Camp Lejeune water reservoir per day?

A I can refer to my report. Or actually, I guess AH Environmental. So it's in the report.

Q In the AH Environmental report?

A Yes.

Q We've talked about mixing in the reservoirs. Did you take mixing in the reservoirs into account when you were doing your calculations for the water reservoirs?

MS. BAUGHMAN: Objection to form. Foundation.

THE WITNESS: The Thomas method assumes completely mixed systems. So to that -- yes, I did.

Q (BY MS. HORAN) Could you identify where, in your report, you address the reservoir depth fluctuations? Are they in your report?

A No.

Q No. Okay.

The flow -- as the water flows through the reservoirs and tanks, would it induce turbulence in the water?

A As it flows through the reservoir, no.

There might be -- no. As it flows through the reservoir.

Q How do you know there would be no turbulence?

A As the water enters the reservoir, there may be a little splashing. But just the nature of the reservoir is such that you wouldn't -- from a hydraulics perspective, you wouldn't see turbulence.

Q You say, "The Nature of the reservoir." What do you mean by that?

A Just the tension time. The dimensions of the basin. Just from a reactor engineering perspective.

Q Have you ever observed the water flow through a water reservoir?

A No. I have not. But I've done hydraulic analyses of such basins.

Q What do you mean by you've done hydraulic analyses of such --

A Well, that's part of hydraulic -- of the --

MS. BAUGHMAN: Wait. Wait. Let her finish.

THE WITNESS: Sorry. Sorry.

MS. BAUGHMAN: Go ahead and ask again. I don't know if it's on the record.

Q (BY MS. HORAN) What do you mean by such -- hydraulic analyses of such basins?

A It's part of what you do in design of treatment plants is, you do reactor engineering analyses. Hydraulic analyses.

Q Have you ever designed a water treatment plant?

A Yes. Based on -- I teach classes on design of water treatment plants.

Q And what class is that?

A Physical chemical processes for water treatment.

Q Do you still teach that class today?

A As an emeritus professor, I no longer teach that class. So I last taught it -- well, I no longer teach that class.

Q When did you last teach it, Dr. Sabatini?

A Just before I retired. So three years ago.

Q And was that a class that you taught every semester?

A Say again.

Q Did you teach that every semester?

A Every year. Every year or every other year.

Q And other than teaching a class, have you ever designed a water treatment plant that was built?

A Not as a practicing consulting engineer. I've consulted with former students who were designing water treatment plants. But not myself. I understand all the basic principles.

MS. BAUGHMAN: Would you mind if we take a quick break?

MS. HORAN: Not at all.

MS. BAUGHMAN: Thank you.

MS. HORAN: We can go off the record.

THE VIDEOGRAPHER: Off the record. 1:59 p.m.

(Short break from 1:59 p.m. to 2:06 p.m.)

THE VIDEOGRAPHER: We're back on the record at 2:06 p.m.

Q (BY MS. HORAN) Dr. Sabatini, I believe you mentioned that your water storage tank calculations took into account some depth fluctuations of the reservoirs.

A Say again. Some...

Q Sure.

I believe you said earlier that your calculations as -- under storage tanks took in some reservoir depth fluctuations.

A I assumed that that was the case when I went through my calculations.

Q And how did you take those into account in your calculation?

A I just assumed that that was the case that -- that's implicit in the Thomas method, was that there's air for volatilization to occur into.

Q I'm marking as Exhibit 9. This is Volatilization from Water, by Richard G. Thomas.

(Government Exhibit 9 marked for identification)

Q (BY MS. HORAN) Dr. Sabatini, do you recognize this as the document you've been referencing as Thomas today?

A Yes. Appears to be the same document. Yes.

Q Great.

So you've seen this before?

A Yes.

Q Okay. Could you turn to 15-4?

A Okay. (Witness complies.)

Q The first full paragraph, the third sentence reads, "In the atmosphere, vertical diffusion is usually more rapid than in the water and chemicals are transported from the interface quickly."

Do you see that?

A Yes.

Q Do you agree?

A I agree that molecules diffuse faster in the air than in water. Yes.

Q So that means that once VOCs volatilize out of the water, they'll diffuse upwards quickly. Fair?

A Depends upon what you mean by quickly. That's where the two-film transfer equation comes in, in terms of mass transfer across that interface.

Q They'll diffuse more quickly than if they were in the water.

Is that fair?

A Yes. They -- molecules diffuse more quickly in air than in water.

Q And that will cause the concentration gradient at the water air surface to stay higher than if the VOCs did not quickly diffuse upwards.

Fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: In the general principle, yes. That's fair.

Q (BY MS. HORAN) And that will cause the rate of volatilization to be faster than it would be if the VOCs did not quickly diffuse upwards; correct?

MS. BAUGHMAN: Objection to form.

THE WITNESS: The questions seem to be hitting on fairly fundamental concepts. But yes.

Q (BY MS. HORAN) And because that gradient is the delta C in the two-film mass transfer equation in your report which is the equation 3-3 I believe you just referenced, and when the delta C increases, the rate of mass transfer J will also increase; correct?

A Say that again. As the delta...

Q Sure. And if you would like to open your report to look at the equation, that would be fine, too. It's equation 3-3 in your report.

A Sure. Yeah. Thank you. Very familiar with that equation.

Q Do you have it in front of you?

A Yes.

Q Okay. Because the gradient is the delta C in the two-film mass transfer equation in your report which you have in front of you and when delta C increases, the rate of mass transfer which is J will also increase; correct?

A Yes. Correct.

Q Okay. Turning back to Exhibit 9 which is the Thomas study, could you turn to Page 15-20?

A (Witness complies.)

Q You relied on table 15-3 to determine that .0046 is the proper oxygen reaeration coefficient for ponds; correct?

A Yes.

Q And you agree with Dr. Hennet that ponds are the proper example to use.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yes.

Q (BY MS. HORAN) Was that yes?

A Yes.

Q How did you reach that determination?

A Between the alternatives -- lake, river, and pond -- pond is most appropriate.

Q And why was the pond the most appropriate?

A More similar -- in this range of options, it's more similar to the reservoir situation.

Q In what way?

A Size.

Q Anything besides size?

A Size would be surface area.

Q That's it?

A Yes.

Q Okay. And you used the .0046 oxygen re -- reaeration coefficient to reduce Dr. Hennet's calculations of volatilization by about 58 percent. Fair?

And again, you're welcome to look back at your report.

A Reduce them 2 -- 2.58 times his estimates. Yes.

Q And you agree that Thomas, 1990, the literature values for oxygen reaeration coefficients for ponds is between .0046 and .0096.

Do you see that?

A Literature values?

Q Yes.

A Yes.

Q So you use the lowest literature value for ponds possible. Fair?

A Fair.

Q And ponds don't have flowing water. Is that fair?

A Generally, no. They may. But generally not.

Q And flower -- flowing water causes greater reaeration; correct?

A Correct.

Q And that's why in Table 15-3, the values for rivers are up to two orders of magnitudes greater than ponds. Fair?

A Fair.

Q And you agree that water storage tanks do experience some water flow; correct?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I would say more in the mode of pond than river certainly.

Q (BY MS. HORAN) But they do experience water flow. Fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Well, depends upon what you mean by flow. It's -- I mean there is some minor movement across the -- the tank. So yes.

Q (BY MS. HORAN) Well, every day, a water storage tank or reservoir has water coming in and water going out.

A That's true.

Q Fair?

A Correct.

Q So every day, there's new water that appears that flows through the system. Fair?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Fair.

Q (BY MS. HORAN) And ponds don't necessarily have water that flows in and flows out of them on a daily basis leading to fluctuations. Fair?

MS. BAUGHMAN: Objection to the form.

THE WITNESS: It depends. To a lesser degree than a river or lake certainly.

Q (BY MS. HORAN) And how would you compare it to a water reservoir in terms of flow between a pond and a water reservoir?

A Probably comparable to more. Probably more.

Q The water reservoir has more flow than a pond?

A Well, that's hard to say. I need to

have more of the parameters.

Q What parameters would you need?

A Well, what particular pond? What ponds did they use for this study? What were the conditions in that pond? So it would be hard for me to make a general statement.

Q Okay. So sitting here today, you don't have an opinion on whether a water reservoir wherein water flows in and out every day has more or less flow than a pond?

A In general, I would agree, but I wouldn't want to make that as an overall conclusion in all cases.

Q Sure.

So there may be exceptions. But generally, you agree.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Sure. I agree.

But I might add, back to your analogy to the river, more than the flowing of the water, it's the ripples and the surface area that's associated with that that would have the impact.

Q (BY MS. HORAN) So you're saying it's the ripples in a --

A Ripples or waves or undulations that

increase the surface area for mass transfer.

Q Sure.

So can we call that turbulence at the top?

MS. BAUGHMAN: Objection to form.

THE WITNESS: As a hydraulic person, "turbulence" has a very --

Q (BY MS. HORAN) Okay.

A -- specific meaning.

Q Okay.

A Laminar flow. Turbulent flow. So...

Q Sure.

So what were the terms that you used? Ripple?

A I said ripples and waves surface area.

Q Do you know whether water that flows through a water reservoir or a water tank, as it comes in and out throughout the day, would create ripples or waves?

A That would be extremely hard. No, I would -- I would say not.

Q And why would you say no?

A Just the nature of the flow system.

Q And what about the nature of the flow system leads you to say no?

A Just the -- well, laminar turbulent flow conditions. They'd be very much in the laminar flow regime.

Q And why is that?

A Because of the velocities and the nature of the flow.

Q But you've never seen inside a water reservoir to determine whether there are any ripples or waves across the top as it's filled throughout the day.

Fair?

A I have not. But the engineering calculations suggest as much.

Q You would consider a water treatment plant reservoir that can accommodate 5 million gallons of water treatment per day to have a limited flow?

A To say -- I'm sorry. Repeat. To...

Q You would consider a water treatment plant reservoir that can accommodate 5 million gallons of water treated per day to have a limited water flow?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Not a limited water flow. Limited water velocity.

Q (BY MS. HORAN) What is the difference between water flow and water velocity?

A Flow is gallons per day. Volume per time is flow. Velocity is flow divided by area which gives you a velocity of feet per -- feet per second. So if -- if you have a large flow but a large area, you have a smaller velocity.

Q Okay. So if -- so you would say that a water reservoir that has 5 million -- can take 5 million gallons of water per day would have a low velocity but high flow?

MS. BAUGHMAN: Objection to form.

Q (BY MS. HORAN) Did I understand that correctly?

A Again, you can take the flow and divide it by the area to get the velocity. So if you have a big flow but a big area, your velocity doesn't have to be that great.

Q Do you know what the velocity of the water at the Hadnot Point Water Treatment Plant is in the reservoir?

A I could calculate it, but I don't know that off the top of my head. But all this -- my discussion of velocity is related to laminar versus turbulent flow conditions. You're asking about turbulence.

Q Sure.

And you're saying that these are more laminar which is more like a pond. Fair?

A Right.

Q Okay. And do you know what the area of a Hadnot Point water treatment reservoir is?

A It's in the -- it's in their report.

Q And without doing the calculations to determine velocity of the flow in and out of the reservoirs, how did you determine that it was more like a pond than a river or a lake?

A Just engineering judgment. I mean it's -- I didn't feel -- just my -- I made the same assumption that Hennet did and AH Environmental did. I saw no reason to view it differently from how they viewed it.

Q Sure.

Except for you and Dr. Hennet disagree on what oxygen reaer- coefficient -- fair? To use.

A But for the pond.

Q Sure.

A We did differ on this discussion.

Q So for -- without doing the calculations to determine the velocity, how did you determine that the best oxygen reaeration coefficient was the lowest possible value for a pond?

A Because unlike a pond which is open to the atmosphere with a breeze flowing over it, the reservoir has no breeze flowing over it.

Q Any other factors that led you to choose the lowest possible oxygen reaer- -- reaeration coefficient?

A That -- that was the main one. That was the -- that was the reason.

Q Did you consider the velocity of the water in any capacity when you were making that determination?

A Just as Hennet and AH Environmental, I followed the Thomas approach.

Q Sure.

But when -- in choosing which coefficient to use in Thomas 1990, you've told me that the -- the largest reason you chose the lowest coefficient was because there was no air flow across the top like a pond. And I'm wondering if you considered at all the velocity of the water traveling in and out of a water treatment reservoir, if that factored into your decision --

A It's not a part of -- it's not a part after the Thomas. So...

Q So no?

A No. Not beyond the context that it's incorporated into the Thomas approach.

Q Dr. Hennet, to the best you can recall, did not use the highest available oxygen reaeration coefficient found in the literature for ponds.

Fair?

A I'd have to look back and remember what value he used.

Q And when you were doing your calculations, you took into account that the tanks and water reservoirs are vented; correct?

A Correct.

A Another -- I'm looking now. He used .008 --

Q Uh-huh.

A -- which if we're looking at the Thomas method Table 15-3 on Page 15-20, that is the only number and a calculated value. So I also used the literature value. And his calculated value is towards the high end of the literature value range. So in response to your earlier question.

Q Sure.

And the higher range of the literature value is point point -- excuse me -- .0096.

A 96.

Q Okay. And Dr. Hennet used .008.

A 8.

Q Fair?

A Fair.

Q Okay. So it's lower than the highest value by .0016. Fair?

A Fair.

Q Okay. Could you turn to 15-8?

A (Witness complies.)

Q The last paragraph begins, "In view of these observations and the difficulty of performing in-situ volatilization experiments, it is not possible to quantify the error in the calculated values of the volatilization rate constants."

Do you see that?

MS. BAUGHMAN: I -- you said 15-8 -- 18?

MS. HORAN: Uh-huh. 15-8.

MS. BAUGHMAN: Oh. I'm on the wrong page.

THE WITNESS: Okay. I see the sentence. Yes.

Q (BY MS. HORAN) Do you agree?

A I have to defer to the document. So I agree that's what the document says.

Q In your professional capacity, do you agree with that statement?

MS. BAUGHMAN: Objection to form.

THE WITNESS: To agree that's their interpretation, I would agree.

Q (BY MS. HORAN) The paragraph continues. "The lake example indicates that the error may be as large as a factor of 10, although laboratory data suggests that it could be much less. When one is applying the results of calculations to actual environmental situations, it would probably be advisable to assume that the value -- values of volatilization rate may be high by a factor of 10 at most, and low by a smaller factor of possibly three."

Do you see that?

A Yes.

Q And you see that they are discussing an example of a lake?

A Yes.

Q You see this is based on it not being possible to quantify the error to the calculated values of the volatilization rate constants.

So this is about error. Fair?

A About...

Q Error.

A Error in the estimates. Yes.

Q "Agree that Thomas is saying that for lakes, losses should be assumed to fall somewhere within a range that is somewhere between three times smaller than the calculated and 10 times bigger than the calculated."

MS. BAUGHMAN: Objection to form.

THE WITNESS: Says the air may be as large as a factor of 10 in the volatilization rate.

Q (BY MS. HORAN) Sure.

And then the second sentence says, "When one is applying the results of calculations to actual environmental situations, it would be -- it would probably be advisable to assume that the values of volatilization rate may be high by a factor of 10 at most, and low by a smaller factor of possibly three."

A So the estimates may be 10 times too

high.

Q That's your interpretation of that?

A Yes.

Q So you don't believe that Thomas is saying that for lakes, losses should be assumed to fall somewhere between a range that's three times smaller than calculated or ten times bigger than calculated.

MS. BAUGHMAN: Objection to form.

THE WITNESS: I -- that's not my interpretation. No.

Q (BY MS. HORAN) In your opinion, you applied the lowest pond oxygen reaeration coefficient and assumed, based on a lake example, that the volatilization rate may be overstated by a factor of ten.

Fair?

MS. BAUGHMAN: Objection to form.

Q (BY MS. HORAN) And you're welcome to look at your report.

A Say that again.

Q In your opinion, you applied the lowest pond aeration -- reaeration coefficient -- let me start over. Strike that.

In your opinion, you applied the lowest

pond oxygen reaeration coefficient and assumed, based on a lake example, that the volatilization rate may be overstated by a factor of ten.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yes.

Q (BY MS. HORAN) And you cite Thomas 1990 for the premise that Dr. Hennet's calculations should be further reduced to 10 percent of his calculations.

Fair?

A Correct.

Q Page 11 of your report. The first full paragraph, the second sentence says, "Given the disparity between the covered tanks of Camp Lejeune and the assumption of reservoirs open to the atmosphere in Thomas 1990, the calculation errors would obviously be on the high side."

Do you see that?

A Yes.

Q Thomas is not about reservoirs. Is that -- do you agree?

A You're referring to my sentence there.

Q Yes. I think it might just be an error --

A As a water resource engineer, I would

call a lake a reservoir. We often talk about reservoir engineering in terms of lakes and surface bodies. So I'm using the -- I'm using a more general water resource term there to refer to a lake or...

So I wasn't implying that it was the same as a tank at the water treatment.

Q And you considered that all of the water reservoirs at Camp Lejeune -- and I mean -- when I say "water reservoirs", I'm talking about the -- the water reservoirs in the water treatment plant.

A Yes. Thank you.

Q Okay. And you took into account that the water reservoirs and the water tanks were vented when you offered your opinion that the volatilization rate was overstated by a factor of ten.

Correct?

A Yes.

Q Turning to your opinion on recarbonation basins. Would use of the recarbonation basin as designed contribute to the loss of VOCs at Camp Lejeune?

MS. BAUGHMAN: Objection to form.

THE WITNESS: One more time. I'm sorry.

Q (BY MS. HORAN) Sure.

Would use of the recarbonation basin as designed contribute to the loss of VOCs at Camp Lejeune?

A It's possible.

Q Why is it possible?

A Well, on any of the basins, could possibly open to the atmosphere. Could result in volatilization. The detention time in the recarbonation basin was very low. So that would minimize the opportunity.

Q Any other reason?

A Not beyond what we've already discussed.

Q If the water -- did you do a calculation on what percentage of TCE would have been lost from the water being recarbonated as the recarbonations were designed at Camp Lejeune?

A Say again.

Q Sure.

Did you do a calculation to determine what percentage of TCE would have been lost from the -- if the recarbonation basins were used as designed?

A Not a calculation. Hennet assigned zero loss.

Q Do you know if the recarbonation basin is open to the atmosphere?

A It's my understanding.

Q You've referenced Peter Pommerenk a couple times, I think, in this deposition.

A The -- yes.

Q Who is Peter Pommerenk?

A To my knowledge, he's AH Environmental person that was part of the project and part of the expert panel of 2005.

Q Outside of your knowledge of his work with Camp Lejeune, are you familiar with any of his other work?

A No.

Q I'm handing -- or marking as Exhibit 10. This is a document with a Bates 00897_PLG_00000066207. And it runs through the Bates 6365.

(Government Exhibit 10 marked for identification)

Q (BY MS. HORAN) Dr. Sabatini, have you seen this before?

A Yes.

Q And you recognize this as the expert panel assessing ATSDR's method and analyses from

April 29th to the 30th 2009?

A Yes.

Q Turning to Page 111. And that's just the regular page number. The last paragraph, the sixth line down, it begins, "Where as VOC removal."

Do you see that sentence?

A Say again. Where...

Q So six lines down, there's a sentence that begins, "Where as VOC removal."

A Yes.

Q Do you see that?

A (No response.)

Q Okay. So do you see that that reads, "Where as VOC removal from other unit processes at the plant was incidental and probably minor, substantial removal more than 90 percent might have occurred in the recarbonation basin. As with an aeration process, the gas injection creates substantial turbulence and mixing, and can facilitate partitioning and removal of the contaminants from the liquid phase. Therefore, it is recommended that research be conducted to determine when the recarbonation was operated, under what conditions, gas flow rate, et cetera, and what the likely rate of VOC removal was."

Did you see that?

A Yes.

Q So in addition to Dr. Hennet, you also disagree with Dr. Pommerenk that a recarbonation basin can remove a substantial amount of VOCs more than 90 percent.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yes.

Q (BY MS. HORAN) Do you know whether ATSDR ever followed Dr. Pommerenk's recommendation to research when the recarbonation basin was operated, under what conditions, and a likely rate of VOC removal?

A I can't speak to that. I -- I don't know one way or the other.

Q You would agree that there's no direct reference to VOC losses at the recarbonation basin in the formula ATSDR used to determine monthly VOC levels at Camp Lejeune?

MS. BAUGHMAN: Objection to form and foundation.

THE WITNESS: That's a rather sweeping statement. Can you state it again?

Q (BY MS. HORAN) Would you agree that

there's no direct reference to VOC losses at the recarbonation basin in the formula ATSDR used to determine monthly VOC levels at Camp Lejeune?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I -- I can't say yes or no to that. I don't know either way. I'm...

Q (BY MS. HORAN) Have you seen any documents or anything suggesting one way or the other whether the recarbonation basin was considered or not?

MS. BAUGHMAN: Objection. Form, foundation.

THE WITNESS: The AH Environmental report.

Q (BY MS. HORAN) So, sorry.

In the ATSDR formula, have you seen any documents or any information that suggests whether the recarbonation basin was considered or not?

MS. BAUGHMAN: Objection. Form; foundation.

Can you show him the -- the ATSDR formula you're talk -- I don't know what formula you mean. What are you referring to? Object to the form. Object to foundation.

Q (BY MS. HORAN) So I'm -- I'm thinking of the formula that they used to come up with their numbers.

Do you know --

MS. BAUGHMAN: I don't know where that is.

Object to the form. Object to foundation.

Q (BY MS. HORAN) Dr. Sabatini, do you know whether ATSDR directly considered the recarbonation basin in determining the monthly VOC levels at Camp Lejeune?

MS. BAUGHMAN: Objection, form; objection, foundation.

THE WITNESS: No.

Q (BY MS. HORAN) Have you ever seen a recarbonation basin that was operating?

A Yes.

Q Where?

A Norman, Oklahoma, to begin with. Many times.

Q And is that -- why were you looking at the recarbonation basin in Norman, Oklahoma?

A As -- take classes on field trips there. Visit there. It was a part of a -- water treatment studies, et cetera.

Q And how large is the recarbonation basin at the Norman, Oklahoma water treatment plant?

A I couldn't speak to the dimensions, but the water treatment plant is 10 million gallons per day. So it would be the size of one or two of these tables.

Q Thirty feet in length?

A Yeah, maybe. Twenty feet. That would be -- I probably shouldn't guesstimate.

Q Do you know how much carbon dioxide bubbled into an operating recarbonation basin reaches the surface?

A How much it...

Q How much of the carbon dioxide bubbled into an operating recarbonation basin reaches the water surface.

A No. Not quantitatively. I can see visually.

Q And visually, what percentage would you suggest?

A Be hard to put a number to that. But again, the goal is for it to dissolve. Some of it makes it to the surface.

Q And you, sitting here today, don't have an opinion on what percentage makes it to the surface?

A Would be hard-pressed to -- that's in part why I asked...

Q Are you looking for the notes from Chris Mattingly? Exhibit 4.

A The -- so that really doesn't address how much makes it to the surface. But the ratio is dramatically different from, say, a stripping operation.

Q Okay. So sitting here today, you don't have a percentage -- or an opinion on what percentage makes it to the surface --

A I wouldn't know -- (simultaneous crosstalk) wouldn't know at this point. No.

Q No.

You can set aside Exhibit 10.

A (Witness complies.)

I will say that on the recarbonation, it seemed like there was another issue of just how long it was operated.

Q Yeah. Do you know if ATSDR ever looked into how long it was operated for?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Not -- not to my

knowledge.

Q (BY MS. HORAN) As part of your expert work in this case, did you ever look into how far -- or how long the recarbonation basin was operated for?

A Just studying the reports that were available.

Q And what did you find in the reports that were available about whether the recarbonation --

A The lack of knowledge -- (simultaneous crosstalk)

THE REPORTER: I'm sorry. Start over.

Q (BY MS. HORAN) Whether the recarbonation basin was in operation.

A Now I've forgotten the question.

Q Okay. We'll start from the top.

Did you, as part of your work in this case, ever look into whether and how long the recarbonation basins were in operation?

A Just looking at the available documents.

Q And what available documents are you referencing?

A AH Environmental report. Hennet's report.

Q And did you find anything about whether the recarbonation basins were in operation?

A Just a lack of knowledge.

Q You agree that if the recarbonation basin wasn't used, there would have been losses of VOCs at the recarbonation basin; correct?

A Possible losses. Yes.

Q Would you agree that there were probable losses at the recarbonation basin?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Speculating. But potential would be greater than just water flowing through the basin.

Q (BY MS. HORAN) When you were at the Norman, Oklahoma water treatment plant, could you see bubbles reaching the surface at the recarbonation basin when it was operating?

A A limited number. Yes.

Q I want to turn next to sorption. Which your opinion on sorption begins on Page 12 of your report, if you'd like to -- to take a look.

So when I say "sorption", I'm meaning both adhesion of VOC molecules to material surface and VOC molecules permeating into the bulk of material.

Fair?

A Say that one more time.

Q Sure.

A Please.

Q When I say "sorption", I mean both adhesion of VOC molecules to material surface and VOC molecules permeating into the bulk of material.

Fair?

A Fair.

Q Does sorption occur at the water treatment plants at Camp Lejeune?

A Say again.

Q Does sorption occur at the water treatment plants at Camp Lejeune?

MS. BAUGHMAN: Objection to form.

THE WITNESS: That would be speculation.

Q (BY MS. HORAN) You don't know?

A I have not quantified it. My professional judgment would be it would be very minor, but I have not -- I -- to my knowledge, no one else has quantified it.

Q Is there organic material in the spiractor solids?

A The spiractor is designed to remove

hardness as a inorganic precipitant.

Q Is that a yes or a no?

A So that would be the dominant thing present in the spiractor.

Q So you agree that there is organic material in the spiractor solids?

A I'd be speculating. It's -- I'd be speculating.

Q Sitting here today, you don't know one way or the other whether there's organic material in the spiractor solids?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I guess my statement would be it's predominantly inorganic material. If there were -- happened to be inorganic material, it would be very minor in my estimation.

Q (BY MS. HORAN) And what is that based off of? What is that assessment based off of?

A That the reason the spiractor there is to remove inorganic materials. Hardness.

Q So your experience with other --

A Water treatment.

Q With water treatment plants.

A Yes.

Also, I would add to that if it were

lake water, there might be more natural organic matter associated with the lake water. Low levels. But since this is groundwater, I'd even expect lower -- I wouldn't -- wouldn't expect there to be organic matter present.

Q So it's your opinion that there would not be organic material in the raw water at Camp Lejeune.

Am I understanding that?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Based upon the groundwater source, I would expect it to be very limited to negligible.

Q (BY MS. HORAN) If you assume that the spiractor solids contain some organic material, would some TCE sorb to that material?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: Yeah, that's very speculative. I'd need to know what kind of organic matter. If it's just humic and fulvic plant decay or is it biochars or -- I would expect not.

Q (BY MS. HORAN) You would expect that the TCE would not sorb to the organic material in the spiractor solids?

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: It's all very speculative. I would expect that if there were inorganic matter present matter, if, it would be minor and -- and not that absorptive for these compounds because of the nature of the organic material.

Q (BY MS. HORAN) You mentioned it matters what type of organic material would be in the spiractor, and you listed a few.

Would TCE only sorb to some of those or would TCE sorb to all of the organic materials that you listed?

A Depends.

Q On what?

A Well, again, on the nature of the organic material. Could be negligible. Could be minor. Depending upon the nature of the organic material.

Q In your PhD, you studied sorption of organic chemicals in a sand aquifer.

Fair?

A Fair.

Q Any sorption taking place there?

A Yeah, those are -- yes.

Q Is there sorption taking place in the filter beds that have to be backwashed to remove clogging?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Again, you're removing inorganic materials in the backwashing. Fines that have made it out of the spiractor to the filter beds. So we'd be talking about the same materials. So the same --

Q (BY MS. HORAN) So yes?

A Same comments from before would apply.

Q You mentioned before -- well, strike that.

Do you know, or in your studies, have you determined whether TCE sorbs to organic material?

A Trying to remember. We looked specifically at TCE. We looked at a number of different compounds. Certainly would have the potential to.

Q And I believe you said it would be negligible or minor. Am I remembering that correctly?

A Based on the inorganic materials being removed in the spiractor, that would be my expectation.

Q Okay. So there would be some sorption of TCE in the inorganic material, and it's your opinion that it would be minor or negligible?

MS. BAUGHMAN: Objection to form.

THE WITNESS: We're assuming that there is any organic material to begin with.

Q (BY MS. HORAN) Yes. I'm asking you to make that assumption.

A Which I'm uncomfortable making.

Q Why is that?

A Well, just I'm not anticipating for groundwater that that would become an issue. But none the less, if somehow, that happened to be the case, you could imagine some potential sorption.

The other factor is the timeframe involved. Kinetics of its sorption.

Q Why does the timeframe matter?

A Because it -- you mentioned if -- if it has to diffuse into the matrix to get to the sorption site, that takes time.

Q So why would -- strike that.

But how would the time impact whether

TCE can sorb to organic material?

A It may not have time. Even if there were organic material and even if the TCE did absorb, there may not be sufficient time to achieve the potential sorption.

Q Is there any sorption on inorganic surfaces?

A The Schwartzenbach paper referenced some level of sorption to inorganic materials, but for highly hydrophobic compounds.

Q So is that a yes?

A There is that possibility.

Q Is there any coprecipitation on the mineral that precipitate in the spiractor?

A Coprecipitant of...

Q On the mineral that precipitate in the spiractors. The VOC.

MS. BAUGHMAN: Object to the form.

THE WITNESS: VOCs don't precipitate. The minerals would precipitate. So VOCs wouldn't precipitate.

Q (BY MS. HORAN) Would there be any coprecipitation on the mineral with the VOC that precipitate in the spiractor?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Ask that one more time.

Q (BY MS. HORAN) Would there be -- do you know if anthracite is part of the sand filter medium?

A I'd have to look at the document.

Q So sitting here today, you don't know one way or the other?

A I don't recall.

Q Assuming that there is --

A Well, let me -- to that point.

Q Sure.

A AH says it's a dual filter media. Filter media consisted of 26 inches of sand on top of 18 inches of gravel. So AH says no.

Q So you believe there's no anthracite as part of the sand filter medium?

A According -- rephrase the question.

Q It's your understanding that there's no anthracite as part of the sand filter medium?

A That's according to AH.

Q Okay. Assuming that there is anthracite, would anthracite sorb some of the TCE?

MS. BAUGHMAN: Objection to form and foundation.

THE WITNESS: I have to not put on my teacher hat here and talk about the difference between anthracite and activated carbon.

Very minimal.

Q (BY MS. HORAN) Would VOCs --

MS. BAUGHMAN: Wait. Wait.

THE WITNESS: Because -- because -- I am going to go into a little bit of my teacher mode.

Anthracite is a carbon-based mineral material like activated carbon, but the difference is activated carbon has been activated to give it an extremely high surface area where as anthracite has not been activated. So while it is a carbonaceous material, it would -- has dramatically less, if -- if any absorption, minor relative to activated carbon.

It's the explanation I had to give to my chemical engineering colleagues.

Q (BY MS. HORAN) So it would be less than if it was active carbon, but there would be some sorption.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Possibly. Possibly.

Q (BY MS. HORAN) Would VOCs coprecipitant with minerals in the spiractor?

A I just struggle with the concept of VOCs precipitating. Coprecipitating to me is incorporated into the mineral. Another mineral being incorporated in with a mineral.

So based -- based on the way the question is phrased, I'm confused by the question.

Q Would VOCs come out of the water with minerals in the spiractor?

A One more time. I'm sorry. I keep asking you to repeat, but...

Q No. That's okay.

A Thank you for your patience.

Q No. Thank you for ensuring that you understand the question.

Would VOCs come out of the water with minerals in the spiractor?

MS. BAUGHMAN: Objection to form and foundation.

THE WITNESS: I would not envision them being enmeshed with the precipitant. I would say no.

Q (BY MS. HORAN) And why wouldn't you envision it?

A Because they're dissolved in solution

versus precipitates.

Q And when you say dissolved in solution, you mean water?

A In water. Yes.

Q You state that the backwash water, after settling, may be reused at the plant.

Do you recall that?

A Yes.

Q Do you know if that was the case at the Hadnot Point water treatment plant?

A No.

I'll say comments in response to Hennet's suggestions of these items.

Q So you don't know if that was the case at the Hadnot Point water treatment plant?

A I don't. No.

Q So you would agree that that would lower the losses even though there's no data supporting that?

MS. BAUGHMAN: Objection to form, foundation.

THE WITNESS: Can you ask that again?

Q (BY MS. HORAN) Do you agree that bringing this conservative element into your opinion would lower the losses even if there's no data supporting that?

MS. BAUGHMAN: Same objections.

THE WITNESS: I'm tempted to say that I was responding to a suggestion that had no supporting data.

Q (BY MS. HORAN) So you assumed the opposite without any data?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I would say I was taking a more systematic approach to trying to address the question that was raised by someone else.

Q (BY MS. HORAN) So I'm about to switch topics. Are you good to keep going or did you want to take a break?

MS. BAUGHMAN: It's up to you.

THE WITNESS: Go for a little bit longer.

MS. BAUGHMAN: Okay. If you want to keep going. Sure.

Q (BY MS. HORAN) Turning to your second opinion which is -- starts on Page 14 of your report.

A Have we moved off the first opinion?

Q I believe so. Did -- yes.

A Because there was one comment I'd like to offer.

Part of what reinforced my assessments -- well, it leads into the second opinion so let's go to the second opinion.

MS. BAUGHMAN: It's really best if she just asks the questions and you answer.

THE WITNESS: Yeah.

MS. BAUGHMAN: Okay.

THE WITNESS: Let's go to the second opinion.

Q (BY MS. HORAN) So the -- the second opinion begins on Page 14 of your report to the extent you're following along.

You would agree the ATSDR model does not directly account for VOC losses from the Camp Lejeune water treatment plant; correct?

MS. BAUGHMAN: Objection to form.

THE WITNESS: I was turning to the page here. I'm sorry.

Q (BY MS. HORAN) Sure.

You would agree the ATSDR model does not directly account for VOC losses from the Camp Lejeune water treatment plant.

MS. BAUGHMAN: Objection to form.

THE WITNESS: I would agree that it is

indirectly incorporated.

Q (BY MS. HORAN) Sure. Not directly.

Fair?

A I guess not explicitly, but implicitly.

Q Have you read Mr. Maslia's rebuttal report?

A Ms. --

Q Mr. Maslia's rebuttal report.

A I'm -- I'm sure I have.

Why do you ask?

MS. BAUGHMAN: She's going to get to it. Hold on.

Q (BY MS. HORAN) I'm marking as Exhibit 11. This is Mr. Maslia's rebuttal report.

(Government Exhibit 11 marked for identification)

THE WITNESS: Okay.

Q (BY MS. HORAN) Could you turn to Page 31, please?

A (Witness complies.)

Okay.

Q So beginning on Page 27, Mr. Maslia offers a section volatilization of VOCs during the water treatment process.

Do you see that?

A Yes.

Q Okay. And you agree that the ATSDR determined that VOC losses at the water treatment plant were negligible, and therefore, made the decision not to include them.

A I'm sorry. I was looking at Page 27.

Q Sure. Yeah, if you could just turn to Page 31.

A Okay. (Witness complies.)

Q Okay. The last sentence of the first full paragraph --

A Okay.

Q -- reads, "In light of the conclusions of AH Environmental consultants 2004 and the recommendation of its expert panels, ATSDR made the decision to consider any potential VOC losses from storage treatment and distribution as negligible."

Did I read that correctly?

A Yes.

Q Do you know what the ATSDR's decision to consider the losses as negligible meant with respect to the ATSDR model?

A What do you mean by that?

Q The ATSDR made the decision to consider the losses negligible. Fair?

A (Nods head.)

Q Do you know what impact that had on the ATSDR model?

MS. BAUGHMAN: Objection to form and foundation.

THE WITNESS: Well, I guess I would respond to that by virtue of my second opinion, that they did use post-treatment values in their model, finalizing their model.

Q (BY MS. HORAN) So you believe that their decision to consider them negligible meant that indirect consideration, as you've explained in your opinion, do.

MS. BAUGHMAN: Objection to the form.

THE WITNESS: I guess I would say yes, that they consider them implicitly through the use of those data.

Q (BY MS. HORAN) Do you know how ATSDR came to the conclusion that these losses were negligible?

MS. BAUGHMAN: Objection to form.

THE WITNESS: No. My impression is just what's here. That they took this -- I mean this is what I would say is that they took the input of Pommerenk -- if I'm saying his name right --

in this expert panel to support their approach.

Q (BY MS. HORAN) Do you know what the -- well, I might have asked you this before, but I can't quite remember.

Do you know what the purpose of the ATSDR water model was?

A You did ask that before.

MS. BAUGHMAN: Objection. Form and foundation.

THE WITNESS: My impression is to get a handle on VOC measurements -- VOC estimates in the drinking water.

Q (BY MS. HORAN) Would you agree that if you are trying to determine an individual's actual exposure to contaminants, it would be important to be as accurate as possible?

MS. BAUGHMAN: Objection to form. Foundation.

THE WITNESS: That's a generic question. Depends upon what you mean by "accuracy".

Q (BY MS. HORAN) How would you use accuracy when you're determining an individual's actual exposure to contaminants?

MS. BAUGHMAN: Objection to form; foundation; outside the scope.

THE WITNESS: There's always uncertainty in data. So accuracy is -- is a challenging thing to achieve. Obviously, you want to be as -- want to do as good a job as you can.

Q (BY MS. HORAN) You can set that report aside.

A By the way, to your earlier question, have I seen this, yes, I did review this.

Q Oh, okay. Great. Thank you for clarifying.

If you wanted someone to know what their contaminant exposure was and whether it may have caused an illness, it would be important to be as accurate as possible; correct?

MS. BAUGHMAN: Objection. Form and foundation, and outside the scope.

THE WITNESS: Thought we kind of asked and answered that question. Certainly want to be as -- do as good a job as you can.

Q (BY MS. HORAN) And you wouldn't want to be 5 or 10 percent off. Fair?

MS. BAUGHMAN: Objection. Form; foundation; outside the scope.

THE WITNESS: I guess that depends, in part, upon how the data is being used. What the epidemiologists and toxicologists need for their side of the assessment.

Q (BY MS. HORAN) Is it your opinion that treatment losses were indirectly accounted for because some values of treated water were used in the calibration process?

A They were used in the model. Finalizing the model. Yes.

Q What do you mean "finalizing the model"?

A I'm -- whether it's calibration validation or when it was in the process that they used the data. And that wasn't my focus. I did know that they used it in their -- finalizing their model, however they used it, in that regard.

Q And you're not sure if it was calibration or validation. Is that fair?

A That was beyond the scope of my expert report. So...

Q How did you determine that the data was considered -- well, strike that.

A I'll look back at my --

MS. BAUGHMAN: She -- she said, "Strike that." That means she's not asking you that.

THE WITNESS: Okay.

MS. HORAN: So you're good.

Q (BY MS. HORAN) Could you please turn to your report, Exhibit 2, on Page 16?

A I'm sorry. Which page?

Q 16.

A (Witness complies.) Yes.

Q The last sentence of Section 2 is bolded. It reads, "Thus, for both the Tarawa Terrace and Hadnot Point systems, treated water samples were used in the calibration process" --

A Yeah.

Q -- "and the ATSDR did consider such losses in the treatment system."

A Yeah.

Q Did -- did I read that correctly?

A Yes.

Q So it's your opinion that because the values were used in a calibration process, they were indirectly considered in the ATSDR.

A Yes.

Q Okay. Is it your opinion that VOC treatment losses were accurately accounted for in the ATSDR model?

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yes.

Q (BY MS. HORAN) If you'd turn to Page 14.

A (Witness complies.)

Q Starting with your Opinion 2 as to Hadnot Point, you state, "In fact, in his expert report, Maslia points out that the reconstructed concentrations versus the observed data in Table 1.7.15 Table 5-5 in this report demonstrates successful level for calibration indicating that the treated water samples were used in the final calibration step for Hadnot Point."

Do you see that sentence?

A Yes.

Q And that sentence -- part of that sentence is a direct quote from Mr. Maslia's report. Fair?

A Yes. I assume.

MS. BAUGHMAN: That's the rebuttal; not the original report.

THE WITNESS: Oh, okay.

Q (BY MS. HORAN) We'll --

A Yes.

Q -- look at his report in a moment.

It's your understanding, having now reread this part of your report, that for Hadnot

Point, the data points were used for level 4 calibration.

Is that fair?

A It's my understanding.

Q Do you mean that the model parameters were adjusted to fit the water distribution system data?

MS. BAUGHMAN: Objection. Form; foundation; outside the scope.

THE WITNESS: That wasn't part of my -- that wasn't part of my assessment, the model itself. How the model was calibrated.

Q (BY MS. HORAN) Do you know if any parameters were adjusted in light of the level -- or the data from the water distribution system?

A It's beyond my scope.

Q Are you offering the opinion that the Hadnot Point level 4 calibration was successful?

A My opinion --

MS. BAUGHMAN: Objection to form; foundation.

THE WITNESS: My opinion states that they incorporated these parameters in their process. I have not offered an opinion as to beyond that.

Q (BY MS. HORAN) So are you offering -- so you're not offering an opinion on whether the level 4 calibration was successful.

MS. BAUGHMAN: Objection. Form; foundation.

THE WITNESS: Well, my opinion states that...

Q (BY MS. HORAN) Well, you've quoted Mr. Maslia as saying a successful level 4 calibration, and I'm wondering if you're adopting that opinion or not.

A I'm not --

MS. BAUGHMAN: Objection to form; foundation.

I'm sorry. Where does -- I don't -- I'm looking for the word "successful".

MS. HORAN: It's the last row of Page 14. It says, "Demonstrates successful level 4 calibration" --

MS. BAUGHMAN: Gotcha.

MS. HORAN: -- "as part of the quote from Mr. Maslia's report."

Q (BY MS. HORAN) And I'm trying to understand if you're adopting that.

MS. BAUGHMAN: Objection to form.

THE WITNESS: What do you mean by "adopting"?

Q (BY MS. HORAN) Well --

A I'm agreeing with his professional judgment.

Q So you agree with Mr. Maslia that it was a successful level 4 calibration.

A That's his area of expertise and so I agree with his assessment.

Q Did you do anything to independently verify whether the level 4 calibration was successful?

A That was beyond the scope of my work.

Q Are you offering the opinion that the use of some treated water data points in the level 4 calibration means that the model accurately captured VOC losses at the water treatment plant?

MS. BAUGHMAN: Objection to form.

THE WITNESS: My opinion speaks for itself. That's the only opinion I have is what is stated.

Q (BY MS. HORAN) Yeah.

So my question is, whether that opinion means that the use of some water data points from the water treatment plant means that the model accurately captures the VOC losses at the water treatment plant.

MS. BAUGHMAN: Objection. Form; foundation.

THE WITNESS: My opinion is response to Hennet's opinion that losses were not accounted for. So my opinion counters Hennet's opinion that there wasn't consideration of treated water.

Q (BY MS. HORAN) So you're not offering any opinion about whether the VOC losses were accurately -- or the use of some data in level 4 calibration means that it was done accurately or done well to include -- strike that.

I'm going to start over.

You're not offering the opinion that the use of some treated water data sample points in the level 4 calibration means that the model accurately captured the VOC losses at the water treatment plant. You're only offering the opinion that you believe they were indirectly considered.

MS. BAUGHMAN: Objection to form.

THE WITNESS: Yeah, that's my opinion. Certainly, I would say -- well, that's my opinion, as stated here. I think, certainly, there was value added by doing so. That the model -- but my opinion is directed at Hennet's assessment.

Q (BY MS. HORAN) What do you mean there was value added by doing so?

A Just countering Hennet's suggestion that there was a lack in the model because it did not incorporate such data.

Q So -- I'm about to use another document. Would it be okay if we just take a quick break?

MS. BAUGHMAN: Of course.

THE VIDEOGRAPHER: We're off the record at 3:21 p.m.

(Short break from 3:21 p.m. to 3:34 p.m.)

THE VIDEOGRAPHER: We're back on the record at 3:34 p.m.

Q (BY MS. HORAN) I'm marking as Government Exhibit 12, this is the expert report of Morris Maslia, dated October 25, 2024.

(Government Exhibit 12 marked for identification)

Q (BY MS. HORAN) And if you could turn to Page 84.

A 8-4?

Q Yes.

A (Witness complies.)

Q The second full paragraph reads, "the reconstructed concentrations versus the observed data in Table 7.15 and Figure 7.25 demonstrate successful level 4 calibration as the observed data from the Hadnot Point Water Treatment Plant represents a separate unique data set that has been used, assessed, the goodness of fit of the calibrated Hadnot Point Holcomb Boulevard models."

Do you see that?

A Yes.

Q And that sentence is the sentence that you pulled the quote out in your report.

Is that fair?

A Looks right. Just to double check.

Q And that was on the bottom of Page 14 of your report.

A Yes.

Q Having read the rest of the sentence, is it still your understanding that the data in Table 7.15 was used in calibration of the Hadnot Point Holcomb Boulevard model?

A Well, maybe in terminology of calibration and validation. So I would say yes.

Q You can set aside Mr. Maslia's report.

A (Witness complies.)

Q If two water samples are taken simultaneously, one for raw water and one from the treated water, would the samples concentrations inform on treatment losses?

A Say that again.

Q Sure.

If two water samples are taken simultaneously, one is from the raw water and one is from the treated water, would the sample concentrations inform on treatment losses?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Conform?

Q (BY MS. HORAN) Would they inform on treatment losses. Sorry.

MS. BAUGHMAN: Object to the form.

THE WITNESS: Under steady state conditions, yes.

Q (BY MS. HORAN) Are you familiar with the concept of a tracer sample?

A Define what you mean by tracer sample. I'm -- I'm familiar with the concept of tracers.

Q What is a tracer that you're familiar with?

A Well, there are a number of different tracers. For groundwater, for analyzing the hydraulics of a system in a water treatment plant.

Q Are you familiar with the concept of a tracer sample where you would identify -- create a sample in the raw water and then allow it to go through the water treatment plant and then test it again when it's through the treatment process?

A Yes.

Q Okay. Do you know if any tracer samples were done at Hadnot Point Water Treatment Plant?

A Not to my knowledge.

Q And you agree that tracer samples would inform on treatment losses at a water treatment plant?

A Depends upon how you do the tracer study.

Q So if you do the tracer study where you begin the tracer and the raw water and measure it and then the water goes through the water treatment plant, then you remeasure the tracer in the treated water plant reservoir, would you agree that that would inform on treatment losses?

A Well, it depends upon the tracer. What kind of tracer are you talking about?

Q What kind of tracer would you use in that type of project?

A That depends upon what you're trying to achieve.

Q You're trying to measure VOC losses.

A Then under steady state conditions, yes.

Q Why say at steady state simultaneous samples would inform on treatment losses?

A Say again. Why?

Q Sure.

I believe you said earlier that at steady state, simultaneous samples would inform on treatment losses.

Fair? Do you recall that testimony?

A Well, there are several things working in these questions. I guess I'm curious what you're ultimately trying to get to. Typically when we do a tracer study at a water treatment plant, we're trying to analyze the hydraulics of a basin, and so we would introduce something like chloride, and we would put it in and we'd measure it coming out and that would tell us something about how ideal the reactor is.

What you seem to be talking about is

putting in a volatile chemical at the inlet and then measuring its concentration.

Q So you -- the -- the measurement would be the VOCs. I'm not offering any opinion on what substance you would add to become the tracer.

A Okay. Now, what I mean by steady state is you have a constant flow coming in, you have a constant operating process, and you have a constant flow going out. And so you have a steady of concentration of chemical in the inlet and then you have a steady concentration coming out the other side and then you can do a comparison.

But if you're introducing something and it's being diluted and it's going through other processes, it's not yet at steady state with the system, then that wouldn't give you the same information.

Q So your steady state assumes that the levels of contaminants of VOCs would be coming into the water treatment plant at the same level.

A That you're -- you're -- relatively the -- yes. Relatively the same. You're not -- you're not introducing something all at once and then watching its appearance the other end.

Q And what if you didn't have a steady concentration of VOCs at the inlet to the water treatment plant, for example, because wells were being turned on and off?

MS. BAUGHMAN: Object to the form, foundation, incomplete hypothetical.

THE WITNESS: Yeah, it's a hypothetical. You'd have to take that into consideration.

Q (BY MS. HORAN) So if there was not a steady state, in other words, meaning that the VOCs were not at a constant level coming into the water treatment plant, would two samples that were taken simultaneously, one from the raw water and one for the treated water, inform on treatment losses?

MS. BAUGHMAN: Object to the form. Foundation.

THE WITNESS: Yes. Yes.

Q (BY MS. HORAN) So even without a steady state, the answer's yes?

A Well, depends upon how nonsteady state you're saying. Generally, you have -- generally, you have fairly steady state conditions. If you wouldn't want to do such a study when you per --

perturbated the system all at once. That wouldn't be the best time to do such an analysis.

Q Do you know if the VOCs at Camp Lejeune were in a steady state?

MS. BAUGHMAN: Object to the form.

Q (BY MS. HORAN) Entering the Hadnot Point or Tarawa --

THE REPORTER: Repeat.

MS. HORAN: Entering the Hadnot Point or Tarawa Terrace water treatment plants.

MS. BAUGHMAN: Object to the form.

THE WITNESS: I could imagine there were times when there were fluctuations, but I can imagine times when all the wells were -- when the wells were operating continuously some period of time you would approach steady state.

Q (BY MS. HORAN) In your report on Page 15, you point to three datasets. One on July 27, 1982, and two on December 4, 1984, that show insight into the fate of VOCs at the Hadnot Point Water Treatment Plant.

Is that fair?

A Yes.

Q And you say that while admittedly a small dataset, the data provide further support for the minor to negligible VOC losses, you propose.

Fair?

A Yes.

Q Okay. Turning to the TCE sample from December 4, 1984, do you see that in Table 5-5?

A Do I see that as --

Q Do you see it in Table 5-5?

A Yes.

Q Okay. And do you see that for the untreated water, there was 46 micrograms of TCE?

A Yes.

Q And for the treated water, there was 200 micrograms of TCE?

A Yes.

Q So comparing these two data points from December 4, 1984, the treated water had over 400 percent TCE of the untreated water.

Is that fair?

A In these numbers, yes. Or I mean, it's larger. Haven't done the 400 percent. But yes.

Q And you would agree that this is not a tracer sample?

A That I couldn't say.

Q Have you ever, in your professional

experience, seen a time where a water treatment plant increased a VOC concentration by about 400 percent?

A No.

Q And you would agree that if you traced the 46 micrograms of TCE through the water treatment plant, the measurement would be lower as treated water.

Fair?

MS. BAUGHMAN: Objection; form, foundation.

THE WITNESS: I would say it would be -- there's no reason to expect it to be higher. It could possibly be lower.

Q (BY MS. HORAN) And your calculations, if you turn to Page 14, say it would be roughly 7.2 percent lower?

MS. BAUGHMAN: Objection to form.

THE WITNESS: That would be the -- yes.

Q (BY MS. HORAN) How does comparing the treated and untreated sample of TCE from December 4th support your opinion that there were losses of 7.2 percent at the Hadnot Point Water Treatment Plant?

A The data informed me that there were not losses. Were not occurred.

Q You think the Hadnot Point Water Treatment Plant did not have any losses of VOCs?

A The data does not suggest -- there's no data to support that there was significant losses.

Q Is there data to support that there were not significant losses?

A The data I point to here indicate that there -- there's no evidence to support significant losses. So to me, that provides evidence. It provides evidence to support the conclusion.

Q So -- sorry, Dr. Sabatini. Are you saying that there was 7. -- your estimate is that there would be 7.2 losses of TCE from the water treatment plants or that there would be no losses from the water treatment plants?

MS. BAUGHMAN: Object to the form.

THE WITNESS: My calculations estimate 7.2 percent and the data -- these data suggest that the losses were negligible.

Q (BY MS. HORAN) How does 46 micrograms of TCE in the untreated water and 200 micrograms of TCE in the treated water suggest that the losses were negligible?

A There's no indication of losses.

Q But you would agree that these are not tracer samples.

Fair?

MS. BAUGHMAN: Objection; form. Asked and answered three or four times.

Q (BY MS. HORAN) Fair? Yes?

A I'm sorry?

Q We can -- I can withdraw that question.

Next to the TCE numbers for December 4, 1984, the third column which is reconstructed, do you see the November 1984 shows 639 micrograms of TCE in the simulated model?

A November of 1984?

Q Yeah. So the December 4, 1984, data samples that we've been talking about of TCE are compared to -- in the chart to the reconstructed model for November 1984 which had 639 micrograms --

A Yes.

Q -- of TCE.

Do you see that?

A I see that in the table.

Q And it's your opinion that simulated

reconstructed values account for the water treatment losses.

Fair?

MS. BAUGHMAN: Object to the form.

THE WITNESS: My opinion is that the ATSDR model did indirectly incorporate treated water samples in its analysis. That's my opinion.

Q Sorry. It did or did not?

A It did.

Q It did. Okay.

So looking -- do you know how much time it takes TCE to be out of a water treatment plant after contaminated wells stop pumping?

MS. BAUGHMAN: Object to the form. Foundation.

THE WITNESS: That's a very open-ended question.

Do I know?

Q (BY MS. HORAN) How much time it takes for TCE to leave a water treatment plant after contaminated wells stop pumping?

MS. BAUGHMAN: Object to the form. Object to foundation.

THE WITNESS: That's an open-ended

question. I mean, not off the top of my head, no.

Q (BY MS. HORAN) Would you expect it to be days or weeks or hours?

MS. BAUGHMAN: Same objections. Incomplete hypothetical.

THE WITNESS: I would have to do -- I'd have to have more information and do some calculations to make a conjecture.

Q (BY MS. HORAN) Have you seen any data showing how much time it takes TCE to be out of a water treatment plant after contaminated wells stop pumping?

MS. BAUGHMAN: Objection, form. Objection, foundation. Incomplete hypothetical.

THE WITNESS: Same -- same response as before.

Q (BY MS. HORAN) I just asked if you've seen any data on it.

MS. BAUGHMAN: Same objections.

THE WITNESS: No.

Q (BY MS. HORAN) Agree that when a contaminated well stops pumping, the percentage of water from that well will gradually decrease in the raw, untreated reservoirs?

A Say that one more time. Lots of hypotheticals here.

Q When a contaminated well stops pumping, the percentage of water from that well will gradually decrease in the raw, untreated reservoirs; correct?

A Sure.

Q Turning to Tarawa Terrace. On Page 16 of your report, the last sentence of the first full paragraph reads, "once again, the fact that Tarawa Terrace level 4 calibration included treated water samples demonstrates the ATSDR indirectly considered losses during water treatment and distribution."

Did I read that correctly?

A Yes.

Q And if you could turn back to Mr. Maslia's report which has been marked as Exhibit 12. And turning to Page 60.

A 6-0?

Q Yes.

You see at Table 7.12 that says, "Computed and observed tetrachloroethylene concentrations in water samples collected at the Tarawa Terrace Water Treatment Plant and calibration target range."

A Yes.

Q So I believe your report -- and you're welcome to look at it again -- identifies one set of data from July 28th that has raw untreated water.

One second.

A Yes.

Q Okay. Other than the one dataset you've identified in your report from July 28, 1982, can you tell if there was -- or do you know if any of the other data points in 7.12 are of treated water?

A I -- it may be -- I think the March 12, 1985, has a denotion of upstream and downstream of water treatment plant.

Q Sorry. Which date?

A What was the question again?

Q Yeah. Can you tell which of these samples were -- other than the one you've identified through using CLW 606, were from upstream and downstream? And you're saying -- did you say -- I just missed the date.

A So those were the two that I used comparison.

Q Uh-huh.

A And then the text.

Q Okay. And you point to the July 28, 1982, when the raw water was 76 micrograms and the treated water was 82 micrograms as supporting your opinion that the water treatment process would produce minor VOC losses.

A Yes.

Q How does an increase in PCE in the treated water show that there would be minor VOC losses at the Tarawa Terrace Water Treatment Plant?

A Similar to the discussion before that indicated -- did not indicate losses. There was not evidence of losses.

Q So it's your opinion that if upstream water has higher VOCs than downstream water, it's indicative that there are minor losses in a water treatment plant?

A Say upstream and downstream.

Q Sure. If there's -- if the -- the finish water and the water -- the treated water has higher micrograms of PCE than the untreated water, --

A Yes.

Q -- it's your opinion that that's indicative that there are minor losses at the water treatment plant?

A It does not -- certainly does not suggest that there were losses.

Q Do you know what percentage of water in the raw, untreated water samples at Tarawa Terrace on July 28, 1982, came from supply well Tarawa Terrace 26?

MS. BAUGHMAN: Objection, form and foundation.

THE WITNESS: Not off the top of my head. I'd have to look at records.

Q (BY MS. HORAN) What records would you look at to determine that?

A I'd have to study back through the reports.

Q Do you know if it was the same percentage of Tarawa Terrace 26?

MS. BAUGHMAN: Objection, form.

THE WITNESS: At this point, I don't know.

Q (BY MS. HORAN) Do you still have Mr. Maslia's report in front of you?

A Yes.

Q Okay. Great.

A I'm remembering now as well there was a COW where -- of Camp Lejeune Water Treatment Plant person commented on levels being very similar on either side of the water treatment plant.

I'm sorry. That's -- that -- I'm sorry. Go ahead.

Q Was that a document that you saw prior to submitting your expert report, or was that after you submitted your expert report?

MS. BAUGHMAN: If you remember.

THE WITNESS: I don't recall.

MS. HORAN: Thank you, Laura, but please keep it to form and foundation.

Q (BY MS. HORAN) Do you know the primary source of PCE at Tarawa Terrace? Do you know which well it was?

MS. BAUGHMAN: Objection, form and foundation. Outside the scope.

THE WITNESS: In my general background reading, I saw the dry cleaner and there were I think three different wells that were contaminated, but I don't remember the numbers.

Q (BY MS. HORAN) Looking at Table 7.12 in

Maslia's report on Page 60. The day that you compare the two samples, so July 28, 1982, the simulated value that's compared to that is 112 micrograms.

Is that fair?

A That's what the table says.

Q If you could turn to page 59.

A (Witness complies.)

Q Do you -- the first sentence of the last full paragraph reads, "the results shown in Figure 7.13 and Table 7.12 represent the calibrated model being compared to a separate dataset than that used for the calibration of the model, Figure 7.14."

Do you see that sentence?

A Yes.

Q You agree that the observed data in table 7.12 was not used for calibration of the Tarawa Terrace Water Treatment Plant?

A 7.13. I'm going back and looking at the --

Q Go ahead. Yeah. Take your time.

A So appears to me there's a calibration validation aspect to this which are both part of the verification. In my understanding both part of the verification process.

Q Your report -- you can turn back to it if needed -- talks about calibration. It doesn't talk about validation.

Fair?

A I was reusing the terminology that Maslia was using.

Fair.

Q It's fair.

So if you turn to your report on page 16, your first paragraph indicates that the data in Table 7.12 was used to calibrate the Tarawa Terrace model.

A I was referring to Maslia's terminology. But calibration validation part of the verification process.

Q Okay. Where do you say -- strike that.

Your report indicates that the -- the data in Table 7.12 was used as the Tarawa Terrace level 4 calibration.

Fair?

A Relying upon Maslia's report. Yes.

Q And now having reviewed Maslia's report again, the -- the data in Table 7.12 was not used in the Tarawa Terrace calibration.

Fair?

MS. BAUGHMAN: Objection, form and foundation.

THE WITNESS: It seems to be mincing -- calibration validation to me are part of the model verification process.

Q (BY MS. HORAN) You did not write that in your report.

Fair?

You said that the data in Table 7.12 was used for calibration. You don't talk about validation; correct?

A Correct.

Q So in your opinion on Page 16 when you said thus, for both, and it's bolded in the middle of the page -- "thus, for both the Tarawa Terrace and Hadnot Point systems, treated water samples were used in the calibration process and ATSDR did consider such losses in the treatment system."

Did I read that correctly?

A Correct.

Q And having now reviewed Maslia's report, data -- treated water samples were not used in the calibration process for Tarawa Terrace.

Fair?

MS. BAUGHMAN: Objection, form foundation.

THE WITNESS: May be a choice of terminology calibration versus validation.

Q (BY MS. HORAN) You understand calibration to mean the same thing as validation?

MS. BAUGHMAN: Objection, form.

THE WITNESS: I see them both as part of the model verification process.

Q (BY MS. HORAN) And where does Maslia in his report talk about validation -- of using this data for validation?

A That I -- I'd have to go back and review his reports.

Q Okay. So can you agree with me that the data -- the treated water samples in Table 7.12 were not used to calibrate the Tarawa Terrace model?

MS. BAUGHMAN: Objection, form and foundation.

THE WITNESS: It's -- from Maslia's report, that seems -- seems to be correct.

Q (BY MS. HORAN) And if the Tarawa Terrace -- the ATSDR did not use treated water samples to calibrate the Tarawa Terrace model, then they did not indirectly account for VOC losses during the water treatment storage and distribution.

MS. BAUGHMAN: Objection, form.

MS. HORAN: Laura, please stop shaking your head.

MS. BAUGHMAN: I wasn't shaking my head, for the record.

THE WITNESS: My opinion says -- my opinion doesn't speak to calibration.

Q (BY MS. HORAN) The last sentence bolded.

A 5.2 my opinion --

MS. BAUGHMAN: He wasn't finished. Can you let him finish his answer, please.

MS. HORAN: Sure.

THE WITNESS: 5.2 my opinion --

Q (BY MS. HORAN) Uh-huh.

A -- says that model indirectly counted for VOC losses and so I -- I feel like my opinion stands because they were considered.

Q Sure. And your opinion, too, rests upon all of your analysis for both Hadnot Point and Tarawa Terrace is -- rests on the belief that the data was used in a calibration process; correct?

MS. BAUGHMAN: Objection, form. Objection, foundation.

THE WITNESS: Calibration, validation to me both point to model being -- accounting for the losses.

Q (BY MS. HORAN) And you don't talk about validation in your expert report.

MS. BAUGHMAN: Objection, form. Asked and answered about five times already.

THE WITNESS: I was re -- I was using Maslia's terminology when he said calibration.

Q (BY MS. HORAN) When he said calibration, you understood that to mean calibration or validation?

MS. BAUGHMAN: Objection to the form.

THE WITNESS: Had he used the term validation, I would have been equally comfortable pointing to validation. Whether used for calibration or validation for me in either, both cases it was accounted for in the model.

Q (BY MS. HORAN) And you don't know sitting here today whether ATSDR used the data in Table 7.12 in the Tarawa Terrace model for validation.

MS. BAUGHMAN: Objection, form.

THE WITNESS: All I can do is refer to Maslia's report and how he used the information.

Q (BY MS. HORAN) Okay. I want to turn next to your opinions on water buffaloes. Final opinion.

A And I guess as we leave --

MS. BAUGHMAN: No, no. She didn't ask you a question. Okay? Unless you feel like you had to correct something.

THE WITNESS: Okay.

Q (BY MS. HORAN) You agree with Dr. Hennet that there would be additional losses from the water treatment plant as the water buffalo is filled; correct?

A Correct.

Q So I want to actually turn first to your Appendix A which is response to reports of Remy J.C. Hennet and J. Brigham regarding water buffaloes.

Do you have that open?

Why did you attach a second expert report to your original expert report instead of just submitting one?

MS. BAUGHMAN: Object to the form.

To the extent that requires conversations with counsel, I'm instructing you not to answer per the order CMO 17 that we talked about earlier.

THE WITNESS: Okay.

Q (BY MS. HORAN) Can you answer that question without disclosing your conversations with counsel?

A No.

Q Are the opinions contained in Appendix A opinions you hold as an expert?

A Yes.

Q Did you write Appendix A yourself?

A Yes. It's my work product.

Q And if you turn -- so if I reference Appendix A, you'll understand that I mean your water buffalo --

A Yes.

Q -- opinions?

Okay. Appendix A has its own references list. Sitting here today, is the references list complete, or is there anything you'd like to add?

A Nothing to add.

Q In forming these opinions, you did not rely on any historical books.

Is that fair?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Historical book.

Q (BY MS. HORAN) Books on history. Textbooks on history.

A No.

Q You didn't rely on any historical studies?

A No.

Q How did you go about collecting documentation to form your opinions and conclusions in Appendix A?

A I reached out to legal staff and asked to help me identify documents pertinent to this, and then synthesized the material from those documents.

Q Outside of reaching out to counsel, did you do any independent searches for documents in Google or at a library or any of that?

A The materials that I was provided was -- were sufficient for me, so I didn't need to do personal, if that's what you're asking.

Q So you didn't do any additional research into documents outside of those that were provided to you by counsel.

Fair?

A Correct.

Q And you said that the documents you received were sufficient. How did you make that determination?

A They helped us to document the progression in water buffaloes over time.

Q Did you speak with anyone -- and I'm not asking about questions -- or conversations with counsel -- but any experts in the field or any members who have been part of the military about your opinions in Appendix A as part of your research in forming them?

A No.

Q You have received both the depositions of Mr. Hunt and Mr. Cagiano.

Fair?

A Read those. Yes.

Q And having read Mr. Hunt's deposition transcript, did anything jump out at you?

A Say again.

MS. BAUGHMAN: Objection. Object to the form.

Q (BY MS. HORAN) Having read Mr. Hunt's deposition transcript, did anything jump out at you as relevant to your opinions in this case?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Just -- not separate from what's in the document.

Q (BY MS. HORAN) So when you say the document, you mean Appendix A?

A Appendix A.

Q And when you read Mr. Cagiano's deposition transcript, did that have any impact on the opinions that you're offering in your Appendix A?

MS. BAUGHMAN: Object to the form.

THE WITNESS: No.

Q (BY MS. HORAN) Have you -- I'm sorry.

A Not beyond -- again, not beyond -- no.

Q Are you aware that Mr. Hunt and Mr. Cagiano have been deposed twice in this case?

A I believe --

Q You're welcome to look at your reliance list.

A I knew -- I knew there was a first interaction with them and then there was a deposition that followed.

Q Do you know if they were deposed prior to submitting your expert report?

A Well, I know -- let me refer to the document. What's it called in here?

Q You're -- you're welcome to look at your reliance list which is Exhibit 3 or the reference list. I'll represent to you I haven't seen that you've seen or reviewed their original deposition transcript from prior to submitting your report.

A I know they had affidavits.

Q Uh-huh.

A Yes. I know more that they -- they had affidavits before my report.

Q And are you aware that they had also been deposed before your report?

A I don't recall.

Q And if you had those deposition transcripts, those would be on either your reliance list or your references list?

A Yes. They...

Q Turning to Page 2. The last sentence of the first full paragraph says, "based on my review of historical documentation as discussed below, I disagree in part with Drs. Hennet and Brigham regarding how water buffaloes were filled at Camp Lejeune over time.

Do you see that?

A Yes.

Q What parts do you agree with Dr. Hennet and Brigham?

MS. BAUGHMAN: Objection to the form.

THE WITNESS: That they were filled. They were filled from stand pipes that -- and I have to refer back to -- I don't have Brigham's -- I remember Brigham had a number of things in his report that I agreed with.

Q (BY MS. HORAN) So you agree that they were filled via stand pipes?

A Well, that was -- yes. Stand pipes or at times suggestions was maybe fire hydrants.

Q Do you have any opinion on where the stand pipes or fire hydrants that the water buffaloes were filled were located on base?

A Just based on what's in the depositions and in the location to the industrial area where they said they were often filled.

Q Do you understand that there are parts of the base such as Camp Johnson wherein the plaintiffs have not alleged contamination of the water treatment system?

A Say that again.

Q Do you understand that there are parts of the base wherein the plaintiffs have not alleged that there was contamination, and one of those would be Camp Johnson.

Just as --

A I'm not aware of that.

Q Okay. Is your opinion in Appendix A based on any -- strike that.

What knowledge, skill, experience, training, or education do you have such that your review of historical documentation on water buffalo filling would assist the judge in understanding how water buffaloes were filled between 1953 and 1987?

MS. BAUGHMAN: Object to the form.

THE WITNESS: In general, as a researcher we know how to review documents and synthesize information to get a background to work from when we're proposing our research. So those skills translate into trying to develop an outline of the background of what water -- water buffaloes how they transitioned over time based upon publicly available documents.

Q (BY MS. HORAN) Anything else?

A No. I guess that would be the main thing we talked before about my interest in

Lincoln, in history.

Q You said as a researcher. Do you mean as a -- in your capacity as an engineer? Strike -- strike that.

You're a civil engineer; correct?

A Correct.

Q Okay. When you said researcher, did you mean researcher in your capacity as a civil engineer, or what did you mean?

A Specifically to the research, that would be the case. I guess to my Lincoln hobby, I've taken several courses in history and had to do historical research relative to Lincoln documents. Of course, they weren't using water buffaloes in Lincoln's time. But...

Q Prior to this litigation, what was your experience with water buffaloes?

A Virtually none.

Q You say virtually none. Is that -- I think you talked it earlier you might have seen a few on a base?

A I might have seen a few on being -- I'm sorry. Pause, pause, pause.

I might have seen them when working on military bases for remediation projects.

Q But you never saw a water buffalo when used or being filled?

A Not being filled, no.

Q Prior to this litigation, had you ever read a manual on water buffaloes?

A No.

Q Prior to this litigation had you ever read a manual on how to fill a water buffalo?

A No.

Q Are you aware that the plaintiffs have a historian expert?

A Yes.

Q Have you met Dr. Longley or spoken with him on the phone or Zoom or email?

A No.

Q Have you read his reports?

A Yes.

Q Do you recall if you read his report before or after you submitted your rebuttal report?

A Before.

Q Earlier, you mentioned -- and consistent with your report -- that water buffaloes on base can be filled via a stand pipe with a fill hose or a fire hydrant.

Are there any other sources where a water buffalo would be filled on base that you're aware of?

A Not that I'm aware of.

Q A water buffalo filled via fire hydrant would have a lower fill time; correct?

A That would be the expectation. Certainly. Yes.

Q And there would be a lower fill time because of a higher flow rate there?

A Correct.

Q And a higher flow rate would cause more turbulence when filling the water buffalo.

Fair?

A Expect more splashing. I would use the word splashing. Because, again, turbulence -- laminar flow, turbulent flow, but yes.

Q Splashing is the preferred term?

A Not a highly technical term, but yes.

Q Fair enough.

And the splashing when filling a water buffalo or -- strike that.

The increased splashing when filling a water buffalo with a higher flow rate would lead to more VOC losses.

Is that fair?

A You'd have more surface area -- you'd have somewhat more surface area for mass transfer, so you'd expect that. You would have less time for volatilization in the downstream flow, but splashing would potentially add some more surface area.

Q I want to turn first to the M 106 model. And again, your report's in front of you. Please reference it as needed.

A What page?

Q If you could turn to Page 5.

A 5?

Q Uh-huh.

A (Witness complies.)

Q You agree that the M 106 -- strike that.

Throughout this next section, I might refer to a water buffalo just by its technical name like M 106 or M 107. You'll understand when I use one of those that I'm talking about that version of the water buffalo.

Fair?

A Fair.

Q Okay. You agree that the m 106 has a filler hatch and strainer; correct?

A Correct.

Q And you agree that the M 106 water buffalo could be filled through the hatch and strainer?

A Correct. Well, the 106 has a -- looks like a hand pump that can fill through the filler hatch. Figure 2.

Q Uh-huh.

A Yes.

Q Yep.

Is there -- okay. Yeah.

So you agree that the water buffalo could be filled through the hatch and strainer; correct?

A Correct.

Q And you said that there was a bell hose -- a bell strainer for the M106?

A Inserted into the filler.

Q Sure.

Is there any reason to think that the top of the filler hatch could not open so that it could be filled from the top?

MS. BAUGHMAN: Objection, form.

THE WITNESS: Say again.

Q (BY MS. HORAN) Sure.

The -- the filler hatch for the M 106.

A Yes.

Q Do you agree that you could open the filler hatch and fill the water buffalo through that hatch?

A As opposed to through the pump?

Q Yes.

A Certainly possible. I mean, it seems to be possible.

Q Turning to Page 7, you see Figure 5 is the M106 filling instructions from October of 1951?

A On Page 7. The --

Q Yeah. So what you're pointing to, but if you look at the bottom, it says Figure 5.

A Okay.

Q And it's the M 106 filling instructions --

A Okay.

Q -- for 1951.

Okay. And the section that you have highlighted in your report says operation of regular equipment of water tank trailer M 106.

Do you see that?

A Say again.

Q The top --

A Top. Yeah.

Q -- of Figure 5 says operation of regular equipment of water tank trailer M 106; correct?

A Yes.

Q And right below that 32, it says 32, loading and unloading water tank.

Do you see that?

A Yes.

Q And you would agree that these are essentially instructions on how to fill a M 106 water buffalo?

A Yes.

Q Okay. And B says loading tank from overhead free-flowing source.

Do you see that?

A Yes.

Q And C says loading tank from source from which water must be pumped.

A Yes.

Q Agree that for C, the M 106 water pump is attached to the filler hatch?

A Say again.

Q Yeah.

For instructions C.

A C.

Q Yes.

A Yeah. Okay.

Q You agree that that's instructions for the water pump which is attached to the filler hatch?

A Yes.

Q Okay. On Page 7 right below that image, the second sentence, you say the fill point moved from the manhole cover to the filler hatch with the introduction of this model when using an overhead free-flowing source.

Do you see that?

A Yes.

Q Okay. Could you turn to Page 15 of your report?

A 16?

Q 15.

A 15.

Q Okay. The first sentence of the first full paragraph says, the phrase of interest in the filling instructions which was used in several earlier water buffalo technical manuals is free-flowing source. A free-flowing source implies gravity fed which suggests the fill hatch was never intended to be filled with a high pressure, high flow hose that was tapped into the base's water distribution system.

Did I read that correctly?

A Yes.

Q Okay. So a free-flowing source implies gravity fed. That's your understanding?

A That would be one understanding of that. Yes.

Q So if you turn back to Page 7.

A Yes.

Q And input that analysis into Figure 5, phrase B would read loading tank from overhead gravity fed source.

Fair?

A I'm sorry. Say that again.

Q Sure.

So I believe on Page 15, you come to the conclusion that free-flowing source means that it was gravity fed.

Is that fair?

A That's -- that's one interpretation of that term. Yes.

Q So if you turn back to the instructions you've identified in Figure 5.

A Uh-huh.

Q And you see Section B says loading tank from --

A Okay.

Q -- overhead free-flowing source.

A Yes.

Q So if you input your analysis into that, it would read loading tank from overhead gravity fed source.

A That would be one interpretation. Yes.

Q So what type of source is an overhead gravity fed source?

A Well, if you had a water tank, an elevated water tank, that would provide pressure to have overhead flow.

Q So if you were essentially dumping one tank into the fill hatch?

A If you were near the water treatment plant or near one of the water towers associated with water treatment plant, then that elevated water tank would provide free-flowing water without requiring a separate pump.

Q Anything else you can think of that would qualify as an overhead gravity fed source?

A That would be the one that would come to mind. An elevated storage tank.

Q Have you ever seen any indication through your research that water buffaloes were filled through an overhead storage tank?

A Well, that's part of any distribution system. And we talked before about the water treatment plants and the different elevated water tanks. So those provide pressure to the water distribution system. And so that would be gravity fed. You pump water up into the elevated storage tank like every city has and then the water from the elevated storage tank flows by gravity through the distribution system.

Q So where would the hose that goes to the filler hatch be located?

A So you would have a water distribution line buried in the ground and the elevated storage tank would be pressurizing the water in that water distribution line. Then you would have the stand pipe tapping into that buried water distribution line coming up.

Q Got it.

So an overhead free-flowing source could be the fill pipe --

A Yep.

Q -- could be the stand pipe.

A Yep.

Q Okay. So for Figure 5, Section B, that could be how you fill it via a stand pipe.

A Correct.

Q Okay. You would agree that the M 106 water loading instructions do not direct a marine to fill the water buffalo through a manhole.

A Correct. Do not. Correct.

Q Yeah.

Okay. On Page 7, the last paragraph, the next iteration after the M 106 was the M 107, and you agree that that had a filler hatch and strainer; correct?

A Correct.

Q And you agree that --

A And a manhole cover.

Q And a manhole cover. Fair enough.

You agree that the M107 could be filled via the filler hatch and strainer; correct?

A Could be. Yes.

Q If you turn to Page 14 of your report.

A (Witness complies.)

Q You see Figure 17 says August 1972 M107 fill process?

A Yes.

Q And that above that, the text that you've written says in the August 1972 edition, which supersedes the October 1964 edition shown above, the fill process switches from being done through the filler hatch to the manhole cover as described in the text below.

Do you see that sentence?

A Yes.

Q So it wasn't until 1972 that there was any reference to filling the water buffalo through the manhole cover, the M 107; correct?

A Not -- not in terms of the manholes. No.

Q If you turn to Page 15.

A 1-5?

Q Yes.

The last sentence says, in the 1972 edition, the text specifically calls out that when filling through the manhole cover, a pressure pump can be used which is equivalent to water flow pressure like that's supplied by the water distribution system.

Fair?

A Yes.

Q And you agree that prior to 1972, the water buffalo could have been filled through the filler hatch using the stand pipe.

A Could have been, yes.

For convenience, I imagine they might have preferred filling it through the manhole, but certainly the filler hatch was what was in the manual.

Q You said for convenience, you might imagine that they would fill them through the manhole.

What is that based off of?

A Ease of opening the manhole, the -- if you look at that strainer, the -- would be easier to put the pipe over a big manhole than over that small filler hatch. The ability of the filler hatch to accommodate the high flows. A number of things. I could imagine.

Q But you agree that the filler hatch could accommodate the pressure from the stand pipe?

MS. BAUGHMAN: Objection, form.

THE WITNESS: I agree that you could certainly use the stand pipe to fill through the filler hatch. I question whether that strainer would allow that volume of water to come through un-- unhindered.

Q (BY MS. HORAN) Um.

A That there might be backsplashing.

Q Do you have any documents that suggest that prior to 1972, marines, as a matter of course -- strike that.

Turning to Page 21 of your report. And I think this is what you were getting at. You state at the top of it, for those M 107s earlier than 1972, it is my position that these units more likely than not would -- would have also been filled through the manhole cover.

Correct?

A That's correct. That's stated.

Q And that's what you were just alluding to; correct?

A Correct.

Q Okay. And your basis for that is Mr. Hunt's affidavit. The filler hatch being able -- well, strike that.

Number 2 says the filler hatch, as outlined in several of the manuals, is designated for free-flowing water supplies and earlier versions fed by a hand pump; correct?

A Correct.

Q And so we've established that the filler hatch, when it said overhead free-flowing source, meant it could be a stand pipe; correct?

A Could be. Correct.

Q Okay. And then the third point you list is that from 1968 to 1972, there were water buffaloes that could only be filled through the manhole cover.

Fair?

A Correct.

Q Other than these three data points, is there anything else that you've relied upon in determining that marines would only have ever filled water buffaloes through the manhole cover?

MS. BAUGHMAN: Objection to the form.

THE WITNESS: It impressed me why would you fill highly treated drinking water through a strainer. So that's what got me puzzled about that and wanted to pursue this further to see what the documentation said and see what some of the experience was.

It impressed me that as in the early versions there was a hand pump. That that was more likely used for filling from a lake or some source that had debris.

Q (BY MS. HORAN) And you agree that the earlier versions or the versions pre 1972 do not mention filling the water buffalo through the manhole cover.

A That's correct.

Q But they do reference filling the manhole through the filler hatch.

Fair?

MS. BAUGHMAN: Objection, form.

THE WITNESS: Say that again.

Q (BY MS. HORAN) The manuals pre 1972 reference filling the water buffalo through the filler hatch.

Fair?

A Correct.

Q Okay. In Number 1 of this, you state, on a regular basis, he, meaning Mr. Hunt, observed the filling of M107 water buffaloes and all of those he observed were filled through the manhole cover.

Do you see that?

A Yes.

Q Have you read Mr. Hunt's deposition?

A Yes.

Q Are you aware that he said he saw it filled less than ten times?

A I'd have to look back at my notes.

(Government Exhibit 13 marked for identification)

Q (BY MS. HORAN) I'm marking as Exhibit 13 this is the deposition of Ernest David Hunt from March 11, 2025.

Could you turn to Page 33?

A Whoops. Guess I got two of them. Sorry.

Q No, it's okay. Could you actually keep this one? Because it's the one with the sticker.

A 30 -- 33 again?

Q Yes.

So there's four pages on one. So I guess it's --

A Yeah. I've got it.

Q Okay. So beginning on line 23, it says:

> "QUESTION: Do you recall roughly how many times you witnessed a water buffalo being filled at Camp Lejeune?"

If you turn to the next page,

> "ANSWER: Just a few times. I don't really -- I don't recall

the number.

"QUESTION: Would you say less than 10? Less than 20? Less than 100? Do you have any --

"ANSWER: Less than -- less than 10."

A Uh-huh.

Q Does the fact that Mr. Hunt observed a water buffalo being filled less than ten times impact your opinion in any way that water buffaloes prior to 1972 were likely filled only through the manhole?

A No.

Q Could you turn to page 29 of the --

A Whoops.

Q Yeah. Sorry.

A I jumped the gun.

Q Page 29.

A 29?

Q Uh-huh.

A (Witness complies.)

Q So beginning on line 18, it reads:

"QUESTION: Okay. So this record has you starting at Camp Lejeune on March 17 of

'65. And if you turn the
page around, you will see
that it has you leaving on
October 7th of '66.
"ANSWER: Correct.
"QUESTION: Does this sound
about right to you?
"ANSWER: Yes."

And then -- Okay.

And you were aware that Mr. Hunt saw water buffaloes being filled less than ten times between March of 1965 and October of 1966.

Fair?

A Yes.

Q Does that change your conclusion in any way, that water buffaloes prior to 1972 were likely filled only through the manhole?

A No.

Q Could you turn to Page 8 of your report?

A 8?

Q Uh-huh.

A (Witness complies.)

Q The middle of the page reads filling the M107 A1 is still directed to be done through the filler hatch as described in Figure 7 below.

Do you see that?

A Yes.

Q You agree that nothing in the loading the water tank instructions for the M 107 A1 directs filling the water buffalo through a manhole cover; correct?

MS. BAUGHMAN: Objection, form.

THE WITNESS: In these guidelines, correct.

Q (BY MS. HORAN) You've identified Figure 7 as the M 107 A1 filling instructions.

A Correct.

Q And you agree that nothing in Figure 7 directs you to fill the tank through the manhole cover; correct?

A Correct.

Q Turning to Page 9, you agree that the M 149 had a filler hatch and strainer; correct?

A Yes.

Q And you agree that the M 149 could be filled through the hatch and strainer?

A Could be. Yes.

Q If you turn to Page 12 of your report.

A (Witness complies.)

Q Are you there?

A Yes.

Q Okay. The text in the middle of the report says, the significance of this note is that as early as December of 1968, the Army is acknowledging that the M 149 A1 was not equipped with a strainer and the use of a strainer became optional for the M 149 in cases where the strainer was damaged or found defective.

Did I read that correctly?

A Yes.

Q Have you found any documentation that prior to December of 1968 the use of strainers in water buffaloes was optional if they were damaged or defective?

A Say that again.

Q Have you found any documentation that prior to December of 1968, the use of strainers in water buffaloes was optional if they were found damaged or defective?

A No. Not to my knowledge. No.

Q So at least from 1953 to December of 1968, the manuals instructing how to load water into a water buffalo instructed filling through the filler hatch.

Fair?

A Fair.

Q And from 1953 to December of 1968, the manuals instructing how to load water into a water buffalo did not mention filling a water buffalo through the manhole; correct?

A Correct.

Q On Page 9, the first -- and you can correct me if I'm wrong -- manual that I was able to identify from your report for the M1 --

A I'm sorry. Where? On Page 9?

Q Yeah. Page 9.

A Okay.

Q Just generally.

A Okay. I thought you were pointing to something.

Q Do you know when the first M149 A1 became available?

A I would have to look back through. Off the top of my head, no, but I'd have to look back through.

Q So in -- on Page 9, you have Figure 10 which shows both the M149 and the M149 A1, and that's attributed to June of 1971.

Do you agree?

A I'm not tracking. Trying to track what you said here on the page here.

Q Sorry.

A You said on Page 9.

Q Yeah. So on Page 9, it says the illustration below, Figure 10.

A Okay.

Q Is from a manual from June of 1971.

A Uh-huh.

Q Fair?

A Fair.

Q Okay.

A With and without the filler hatch.

Q On Page 12, the text in the middle, the first sentence of the second paragraph says, "In 1970, the M149 A1 underwent a tank design change."

How did you determine that happened in 1970?

A I'd have to look back at my -- have to look back at my sources. I don't recall right now.

Q Okay. Turning to Pages 19 and 20. You identified via inventory that Camp Lejeune had M149 and M107 water buffaloes; correct?

A Say again. M --

Q M107 A2, M107, and then M149 water buffaloes.

Fair?

A M129.

Q 129?

A Is that what you said?

Q No. Sorry.

Okay. Figure 22 of your report identifies as part of the 1968 equipment that there were M107 and M107 A2 water buffaloes.

A Yes.

Q Fair?

A Okay. Yes. I misunder -- misheard you.

Q And then if you turn to Figure 23, you've identified that the 1999 inventory had M149 water buffaloes.

A Yes.

Q You state in -- you state in Page 20 -- the second to last sentence of the first paragraph says, "This supports that the base was transitioning from M107 to the M149 A1s during the 1970s."

Did I read that correctly?

A Yes.

Q Did you find any documentation

supporting that the M149 A1 was in inventory at Camp Lejeune beyond Mr. Cagiano's affidavit?

A Beyond...

Q Sure.

So was there anything other than Mr. Cagiano's deposition -- excuse me, affidavit, any other documents you found supporting that Camp Lejeune transitioned from M107s to M149 A1s during the 1970s?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Shows up on this inventory. What's the date on this inventory? '99. Not that I recall.

Q (BY MS. HORAN) In 19 -- the Figure 23, you say 19 -- from 1999. Do you see that?

A That's the indication.

Q You agree that that says M149, but does not indicate M149 A1.

Fair?

A That's correct.

Q For determining the fill time, you determined that it likely took between two or three minutes to fill a water buffalo.

Fair?

A Fair.

Q And is that -- or that's through the manhole; correct?

A Correct.

Q Did you determine the fill time through the strainer?

A No.

(Government Exhibit 14 marked for identification)

Q (BY MS. HORAN) I'm marking as Exhibit 14 -- this is Camp Lejeune Justice Act Litigation Rebuttal Report of Kyle Longley.

And Dr. Sabatini, could you please turn to Page 23.

A 27?

Q 23.

A 23. I was going to say 27 is this.

(Witness complies.)

Q Three lines up from the bottom of that paragraph, the sentence reads, "The marines could fill the water buffaloes at Hadnot Point in 10 to 20 minutes."

Do you see that?

A Yes.

Q Do you know what source Mr. Longley was using for that position, or that statement?

A Well, he -- no. He has a reference

there, but that seems to be for the next sentence.

Q And that reference is to the Ensminger oral history?

A Yeah. Seems to be for the following sentence.

Q But you disagree with Dr. Longley that it wouldn't take 10 to 20 minutes to fill a water buffalo at Hadnot Point?

A Through the manhole. Now, through the strainer -- yeah, I would envision it would take longer through the strainer because it would accept -- I imagine my professional judgment is it could not handle as fast a flow.

Q So does this indicate to you that some marines filled the water buffaloes through the fill hatch?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I couldn't speculate.

Q (BY MS. HORAN) You can put that aside, Dr. Sabatini.

MS. HORAN: We've been going for about an hour and a half. Would you mind taking just a 10-minute break?

THE WITNESS: Sure. Sure.

THE VIDEOGRAPHER: We are off the record at 5:02 p.m.

(Short break from 5:02 p.m. to 5:12 p.m.)

THE VIDEOGRAPHER: We're back on the record at 5:12 p.m.

Q (BY MS. HORAN) Turning to your report, not the Appendix A, on Page 19, you show calculations for water buffaloes in Table 5.6.

Is that fair?

A Fair.

Q And you use the same study as Dr. Hennet to do your calculations in Table 5.6; correct?

A Correct.

Q And that's the McKone and Knezovich 1991 study?

A Correct.

Q One of the edits you make to the McKone and Knezovich study is that the fall height in your opinion should be .4 meters instead of 1.6 meters used in the study.

Is that fair?

A Restate that.

Q Sure.

One of the edits you make to the McKone and Knezovich study is that the fall height in your opinion should be .4 meters instead of 1.6 meters that they used in the study.

A In applying it to the water buffaloes. Correct. Not that McKone should have used .4 meters.

Q Ah.

A Adjusting his results to this situation.

Q Sure.

And your proposed 75 percent reduction due to differences in fall height relies on the assumption that the fall height is directly proportional to volatile loss; correct?

A Correct.

Q And what's your basis for that assumption?

A Time of volatilization.

Q So the fall height would be directly related to the time. Fair?

A Correct.

Q Turning back to your Appendix A on Page 21. Do you see Figure 24 is showing that the water buffalo is being filled from just outside the manhole cover?

A Meaning that the pipe -- yes.

Q And if you look at Figure 25, the water buffalo is being filled about half a person size over the manhole.

Fair?

A Correct.

Q Okay. Are Figure 24 and Figure 25, in your opinion, representative of filling operations of water buffaloes at Camp Lejeune?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Represented from other sites but could well be examples of what it might look like. I might also add Figure 27 to the discussion.

Q (BY MS. HORAN) Sure.

And Figure 27 shows a water buffalo being filled via fire hydrant with the fire hydrant hose just on the lip of the manhole cover.

Is that fair?

A It's hard to tell. The pipe may not be inserted. Either way.

Q Would -- if you turn to Figure 25, the fact that the stand pipe fill hose is at least two feet above the manhole cover, impact your calculations for fall height as done in your expert report?

A Potentially.

Q And how potentially would they impact your calculations?

A Would be additional time for volatilization in the travel distance. I might add as another data point, Hennet's deposition, he mentioned that the filling of the water buffalo, he observed the water -- the fill pipe was near the entrance to the manhole.

Q And you saw the photos from Dr. Hennet's February visit where he observed the water buffalo being filled?

A I saw photos. I'm not sure -- I don't recall exactly all the -- the specifics. But yes, I saw photos.

Q And you read the testimony or listened to the testimony of Dr. Hennet about his viewing of water buffaloes in the February 2025 visit.

Fair?

A In the February visit. Yes.

Q And having seen those photos and read that testimony, does it have any impact on any of your opinions in your report?

MS. BAUGHMAN: Object to the form.

THE WITNESS: No.

Q (BY MS. HORAN) Turning back to your report on Page 19. Row 3 says assuming downward velocities are the same.

Do you see that?

A Yes.

Q What did you mean by that?

A I assume that the -- I assume that the shower experiments translated to the water buffalo filling except the only -- the only adjustment that was necessary was the, I'll say fall height distance. I don't want to confuse fall height with fall height from the spiractor.

Q A lot of fall heights today.

Does a vertical strainer spread the water more efficiently compared to a showerhead?

A Oh, that's -- it could go either way.

Q And why could it go either way?

A I mean, it's -- that's speculation. Showerhead has tiny nozzles that direct the water intentionally out. Where as a strainer is just there to remove debris. The openings in the strainer grid coarser than the fine orifices in the showerhead.

Q Have you seen a strainer from a water buffalo in person?

A No.

Q Have you seen a water buffalo in person?

MS. BAUGHMAN: Objection. Asked and answered.

THE WITNESS: Yeah, no.

MS. HORAN: Okay.

A I've answered that before, but no.

Q (BY MS. HORAN) Could you turn to Page 6 of your Appendix?

A (Witness complies.)

Q Do you see Figure 4? And you've highlighted Number 22.

A Yes.

Q Which is the strainer element.

A Yes.

Q And you would say that that strainer element has holes, more or less than a showerhead?

A I'm sorry. Would --

Q Does the strainer in Figure 2 - identified as 22 in Figure 4 have more or less holes --

A Holes.

Q -- than a showerhead.

A I would say more.

Q Would you agree that the strainer would have a larger spray pattern than a showerhead?

MS. BAUGHMAN: Object to the form.

THE WITNESS: No.

Q (BY MS. HORAN) Why not?

A No.

Q Yeah. Why -- why not?

A Why not? The -- well, it even says here this is to remove sediment. So I -- just my professional judgment would be that it would not.

Q So if you attach a fill hose to the strainer on 22, wouldn't water come out of the strainer holes throughout the entire strainer, as long as it's not submerged?

A Yes.

Q And so the strainer holes at the top, the water will come out and go all the way to the bottom or wherever the filling process is in the water buffalo.

Fair?

A Fair.

Q And so it would be more efficient at volatilization of TCE than assumed in your calculations, so long as the strainer was not submerged.

Fair?

MS. BAUGHMAN: Objection to the form. Foundation.

THE WITNESS: It's an interesting argument. I just followed Hennet's approach. I didn't adjust -- I didn't adjust the spray diameter from what Hennet used.

Q (BY MS. HORAN) But you --

A For filling through the strainer.

MS. HORAN: Could you repeat my question?

THE REPORTER: "And so it would be more efficient at volatilization of TCE than assumed in your calculations, so long as the strainer was not submerged."

MS. BAUGHMAN: Objection to form.

THE WITNESS: I didn't do calculations. The only adjustment I made was for the time not for spray or -- I assumed the same spray pattern that Hennet did in the filler hatch calculation.

Q (BY MS. HORAN) So sitting here today, you don't have any opinion on whether the strainer in a water buffalo would be more efficient at volatilization of TCE than assumed in your report?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I would say that I followed the same approach that Hennet followed.

Q (BY MS. HORAN) Did you do any analysis to determine whether the -- strike that.

Assuming that the water strainer would have a larger spray pattern than a showerhead, it would have a higher -- greater volatilization because of a greater surface air between -- greater surface area between the air and the water.

MS. BAUGHMAN: Object to the form.

THE WITNESS: That's speculative. I wouldn't care to comment on not seeing data or evidence. And again, I'll just refer back to, I followed the same approach that Hennet did relative to the strainer. Just adjusting for time.

Q (BY MS. HORAN) In your report, you then switch to talking about filling through the manhole cover, which begins on Page 20 of your report. Prior to issuing your opinion, you had watched a YouTube video where water buffaloes were filled correct?

A Say that again.

Q Prior to issuing your rebuttal report, you had watched a YouTube video where water buffaloes were being filled; correct?

A Yes.

Q And the video showed splashing and aeration while the water buffalo was being filled.

Fair?

A Yes.

Q And volatilization losses happen relatively more in the presence of splashing and aeration.

Fair?

MS. BAUGHMAN: Object to the form.

THE WITNESS: Depends upon the degree of splashing. It's surface area again. So if the splashing creates some additional surface area, there's additional possibility for volatilization.

Q (BY MS. HORAN) An increase in surface area between the air and water will increase volatilization; correct?

A Correct.

Q After you determine --

A Maybe just add one point to that. The

shower hitting the floor would cause splashing. And so there's a degree of the splashing that you're describing that was inherent in the shower experiment that I was working from.

Q And did you take that into consideration in your analysis in any way other than following McKone?

A That, to me, helped account for splashing that might have occurred filling through the manhole.

Q Was there any analysis that you did to compare the splashing in a manhole with the splashing accounted for in the shower experiment?

A No.

Q Do you know if there's more or less splashing in filling a water buffalo through the manhole than in a shower?

A I would have to assess that. But I would -- you have certain amount of water hitting the floor and agitating. So I couldn't comment on the relative amount, but I would consider them in the same category.

Q But you haven't done an assessment of that yet?

A No. No.

Q When you determined that a water buffalo was filled through the manhole, did you do any analysis to determine if the shower is still the most apt analogy?

A Whether the shower was --

Q Still the most appropriate analogy.

A I did look for other approaches. But I found that -- in my searching, I found that Hennet's approach was -- I could adjust that approach.

Q What other approaches did you look into?

A I looked for -- from a faucet. And then the kitchen is one example that I looked at.

Q Can you remember any other things you looked at, sitting here today?

A Well, I mean, I searched. I searched -- so anything that I could have found that would have been similar to a faucet, a bath tub or something of that nature.

Q Would you agree that filling a water buffalo through the manhole cover is more similar to a bath tub?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I think the -- I mean what I had to work on, I was responding to Hennet's report. And so I adapted his approach for the situation at hand.

Q (BY MS. HORAN) Sure.

And you determined -- you introduced some new facts. And I'm wondering if when you introduced those new facts, that changed any analysis in where you determined that a -- filling a water buffalo is more similar -- through the manhole -- is more similar to filling a bath tub than a shower.

MS. BAUGHMAN: Object to the form.

THE WITNESS: That would be speculation.

Q (BY MS. HORAN) Well, no. I'm asking if you considered it.

A Well, yeah, I mean I'd just have to speculate. There's -- you could see similarities and differences. But in the absence of being able to find such an approach, I went with the -- I -- I adapted to Hennet's approach.

Q Do you know whether the EPA has ever studied VOC losses through filling a bath tub?

MS. BAUGHMAN: Object to the form. Foundation.

THE WITNESS: Not to my knowledge. I wasn't -- I did a search and wasn't able to find such information.

Q (BY MS. HORAN) What in your model accounts for the splashing of the water and the general movement of the water --

A Agitation.

Q Agitation.

-- when you fill through the manhole?

A I'll refer back to the shower -- two things. The shower water hitting the floor and -- that agitation. I also included a -- in my Table 20 -- on Page 22.

Q Uh-huh.

A I introduced a line 4 which Hennet did not include in his analysis. Losses doing daily use of the water buffaloes. And so that was an attempt to account for additional losses. In an attempt to be conservative.

Q Anything else? Any other way you accounted for splashing and agitation?

A Just those two factors.

Q I believe you said earlier that you thought that the fact that a strainer on a water buffalo intended to remove sediment would be consistent with the strainer holes being smaller than a shower.

A Say again.

Q I -- earlier, you testified that it was your understanding that the strainer in a water buffalo would be used to remove sediment.

Do you recall that?

A I was -- actually referring to that in that one caption. It says sediment removal.

Q And what impact would that have on the size of the holes compared to a shower? Would they be larger or smaller?

A Size of a hose compared to a shower. I'm not sure I understand the relationship.

Q Sure.

So if you have a strainer that's designed to filter out sediment, would you expect the holes in the strainer to be larger or smaller than those in a showerhead?

A It would depend upon what size of sediment was being removed. I could see it going either way. I'd have to -- I'd have to see a -- a strainer.

Q Do you know what sediment would have been removed from the water buffaloes strainer?

A I could imagine that it was -- no, I don't. But I could imagine, if you're filling from a lake or a pond, you're trying to remove sediment from that water source would be my impression.

Q And if you're removing sediment from a lake or a pond, would the strainer holes be larger or smaller than those in a showerhead?

A I could see that going either way. I could see a case where it might be smaller and I could see a case where it might be larger. The smaller it is, the harder it would be for the water to get through the strainer. So as the holes get -- the holes, or I would say grid, in the strainer get smaller and smaller, create more and more resistance of water flow and would be harder to fill through that strainer.

Q And the smaller the holes, the larger the surface area of the water going through it?

A Could be.

Q You state that the higher velocity during filling via the manhole leads to 33 percent less volatilization due to less time falling from the pipe.

Fair?

A You're referring to my calculations?

Q Yes.

A That -- that adds to the fall height and the -- yes. Can you restate the question?

Q Sure.

You state that a higher velocity during filling via the manhole will lead to a 33 percent less volatilization due to less time falling from the pipe.

A We're talking through the manhole now?

Q Uh-huh.

A And you're referring to my calculations?

Q Correct.

A I think the 33 -- it's a combination of the spray diameter and the time the fall -- the time for volatilization.

Q A higher velocity would also create more aeration upon impact.

Fair?

A And that comes back to the analogy of the shower experiment where the water hitting the floor of the shower would cause splashing.

Q If a water buffalo was used for more than one day in the field, would the loss of TCE be higher than you estimated for half a day or one day?

MS. BAUGHMAN: Object to the form.

THE WITNESS: That's speculative. So again, if it was used for...

Q (BY MS. HORAN) More than one day.

A That could increase volatilization.

Q Did you account for temperature changes of the water and air in the water buffaloes?

A I assume that could go both ways. Lower temperatures would have one effect; higher temperatures would have another effect.

Q So did you account for it in your model?

A I assumed that that evened out because it could go both ways.

Q Earlier, you recall we were talking about calibration and validation of the model with your Opinion 2. Is it your understanding that calibration and validation are synonymous?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I'd have to defer to the -- I'd have to defer to the experts in that area. The people that were doing that part of the work. That was not my focus.

Q (BY MS. HORAN) You've read Dr. Konikow's expert report and his deposition?

A Yes.

Q Do you agree with Dr. Konikow that a

model cannot be validated?

MS. BAUGHMAN: Object to the form. Foundation.

THE WITNESS: I'd have to review the context of his report and -- to see what you're referring to.

Q (BY MS. HORAN) Isn't it the case that calibration validation of a model are distinct processes?

MS. BAUGHMAN: Object to the form. Lack of foundation.

THE WITNESS: Again, I'd have to defer to those that focused on that aspect of the project.

Q (BY MS. HORAN) Have you ever calibrated or validated a model?

A Define model. Yes, I have. But -- in my experimental work, we develop models and we validate them.

Q If you defer to the experts such as Mr. Maslia, then you would agree that Tarawa Terrace wasn't calibrated with treated water samples.

Fair?

MS. BAUGHMAN: Object to the form. Foundation.

THE WITNESS: I'm sorry. I keep asking you to repeat questions. Please, one more time.

Q (BY MS. HORAN) Sure.

If you defer to the experts, as you've stated, then you would agree that Tarawa Terrace wasn't calibrated with treated water samples.

A No, I would not agree with that statement.

Q Do you recall looking at Mr. Maslia's report earlier today? We looked at Mr. Maslia's report earlier today in regards to Tarawa Terrace. It stated that the model was not calibrated using the treated water samples; correct?

A I'm not in a position to comment on calibration validation. I defer to those that were focused on that aspect of the project.

Q Sure.

And if you were incorrect and the Tarawa Terrace model by ATSDR was not calibrated using treated water samples, then the ATSDR model for Tarawa Terrace would not indirectly account for VOC losses at the water treatment plant.

MS. BAUGHMAN: Object to the form. Foundation and asked and answered.

THE WITNESS: Yes. I agree.

Q (BY MS. HORAN) Earlier in this deposition, you stated that you had seen the photos from Dr. Hennet's visit and read deposition testimony about his February 2025 visit.

Do you recall that?

A I read his deposition. That included discussion about that visit.

Q And part of that was Dr. Hennet's measurement of the Hadnot Point spiractor.

Fair?

A Correct.

Q And you understood Dr. Hennet's measurements of the spiractor that he conducted in February 2025?

MS. BAUGHMAN: Objection to form and foundation.

THE WITNESS: Yeah, it's -- there wasn't documentation to his pictures. So I can't say that I fully under -- that I understood what exactly was done.

Q (BY MS. HORAN) So through his photos and testimony, you were not able to fully understand how Dr. Hennet measured the spiractor at Hadnot Point?

A No. I will comment that it was an empty, non-operating -- no chance to see the constricted water reducing the fall height. So to me, the AH photos that incorporate those are -- are valuable.

Q And sitting here today, do you have any methodology that you could use to measure a spiractor fall height while the spiractor is in use?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I have no question that it could be done.

Q (BY MS. HORAN) Do you know how to do it?

A I can't say -- I can't say how exactly I would do it, but given time and resources, it could be done.

Q During the breaks today, have you spoken with counsel about any substance related to your testimony?

A Just a reminder to let you finish a question, to pause. So we had discussions in that nature.

Q Anything else related to the substance of your testimony?

A Nothing substantive. Just the procedural-type issues.

Q Okay. Dr. Sabatini, thank you very much for your time today.

A Thank you.

MS. HORAN: I will pass the witness.

MS. BAUGHMAN: And how much time's left?

THE VIDEOGRAPHER: We are at six hours and 58 minutes.

EXAMINATION

BY MS. BAUGHMAN:

Q Dr. Sabatini, I have some questions for you. Okay. First, let's -- let's talk about Exhibit 3. If you can pull that up. Pull that from your materials.

A Say again.

Q Exhibit 3. That's the supplemental and amended materials considered list.

A One. Got them mixed up. This one.

Q Okay. All right. Did you prepare the supplemental/amended materials considered list dated April 9, 2025?

A Legal staff prepared this for me.

Q Okay. I want to -- turn, please, to

Page 9 where it says, additional materials considered.

A (Witness complies.)

Q Okay. Now, turn -- well, first of all, I just want you to look at the volume, or the number of documents, from Page 9 to Page 30. Just flip through.

A Okay.

Q Did you review this volume or this number of new documents between the time that you signed your report on January 14, 2025 and to April 9, 2025?

A No.

Q Okay. In that timeframe, from after you signed your report January 4 -- 14, 2025 until today, can you identify new documents that you reviewed that you had not reviewed prior to finalizing and signing your report?

A I think there was just the CLW mentioned. Other than -- other than maybe a CLW, no.

Q Okay. Well, you -- to be fair, there are depositions that didn't exist before.

A I'm sorry. I'm sorry.

Q And you reviewed those depositions;

right?

A Yes. Yes. I'm sorry. Yes. Yes.

Q So other than the depositions that didn't exist before January 14, 2025 and a CLW document that you've referenced, can you think of any other document you reviewed after signing your report that's new?

A No. Not to my recollection. No.

Q Okay. Do you know why there's this -- and especially, the number of Bates-stamped documents -- do you know why there's so many documents from Page 9 to Page 30 of Exhibit 3?

MS. HORAN: Objection. Foundation.

THE WITNESS: Background information that did not play into my rebuttal report. Much -- much of it.

Q (BY MS. BAUGHMAN) Okay. So to the best of your knowledge, other than the one CLW document and the depositions that have been taken after January 14, 2025, are there any new documents that you're relying on for your rebuttal report that you reviewed after signing your report?

A No.

Q Okay. Just to refresh your

recollection. December 9, 2024. That's the date of Dr. Hennet's report. And the date of your report is January 14, 2025. In that timeframe, is there a reason why you did not request to go to Camp Lejeune for a site visit?

A I felt we -- with the AH report and Hennet's report, I had the data, the information I needed to make my assessment, my calculations. And I actually -- the AH values from 2004 were meaningful to me. Felt they were more relevant than anything I might see in 2025.

Q Why is that?

A Just more representative of what was there in -- decades ago. They also operating -- show the spiractor in operation which is important in terms of the fall height.

Q Being AH did that?

A Yes.

Q Okay. All right. We'll get to that in a few minutes.

Can you pull out -- can you pull out Exhibit 7 for me?

A 7?

Q Yes.

A Okay.

Q So if you remember, defense counsel asked you a question about a vent --

A Yes.

Q -- on the -- the water buffalo --

A Correct.

Q -- using that document.

Does this vent that's on the water buffalo change your calculations and opinions regarding volatilization from the water buffaloes?

A No.

Q Why not?

A This is similar to the -- if you will, this is similar to the vents on the reservoirs at the water treatment plant. Allows water to escape as water is filled up -- air to escape as water is filled up to the valves. Air to -- prevents pressurization in the vessel.

Q What affect would it have to volatilization?

A It would -- it's not -- there's not -- causing air to flow over the water in a way that would increase volatilization.

Q Okay. You made a statement earlier today in response to defense counsel's questions.

You said something like, given an ultimate amount of time, VOCs leave water.

Do you recall saying that?

A Yes.

MS. HORAN: Objection to form.

Q (BY MS. BAUGHMAN) What do you mean by "ultimate amount of time"?

A An extreme amount of time much, much greater than what's practical in a water treatment plant reservoir.

Q So both you and Dr. Hennet used -- what's the name of the -- the calculation that you used? Here.

A For the -- the fall height or --

Q No, no. Here. The volatilization from water. It's in Thomas.

A Thomas.

Q Okay. If VOCs leave water just from having -- from being exposed to air, why is the Thomas method necessary?

A Henry's law calculates -- tells us where it would happen at equilibrium, but we're often far from equilibrium in practice. And so the whole reason that AH and Hennet used the Thomas method is to recognize that in practical applications, we're often far from equilibrium and so we have to use a kinetic-based model to account for volatilization.

Q Okay. So if you look at Exhibit 9, if you could turn to Table 15-3.

MS. HORAN: What page is that?

THE WITNESS: Say again.

Q (BY MS. BAUGHMAN) Table 15-3.

A Okay.

Q It's the same table defense counsel asked you about in her questions.

A Okay.

MS. HORAN: Think it's on Page 15-20.

THE WITNESS: Page 15-20.

Q (BY MS. BAUGHMAN) And do you recall that you were asked a number of questions about the fact that Dr. Hennet used .008 --

A Yes.

Q -- for the oxygen reaeration coefficient? Correct?

A Correct.

Q Look at -- under river. What's the first literature value reported for an oxygen aeration coefficient for river?

A 0.008.

Q The same one that -- used by Dr. Hennet?

A Yeah.

Q Okay. I want to ask you a few questions about recarbonation basins. There's a recarbonation basin at Hadnot Point; is that correct?

A Yes.

Q Actually, let's look at the schematic that you have in your report. Make sure we're talking about the same thing. Okay.

MS. HORAN: What page?

Q (BY MS. BAUGHMAN) If you could turn to Page 3, Figure 3-1.

A (Witness complies.) Yes.

Q Okay. So Figure 3-1, Hadnot Point water treatment plant in your report, you took that from AH Environmental report; is that right?

A Correct.

Q Okay. And it shows the recarbonation basin after the spiractors; correct?

A Correct.

MS. HORAN: Objection to the form.

Q (BY MS. BAUGHMAN) Okay. Was the recarbonation basin operating in 2025?

MS. HORAN: Objection to form.

Foundation.

THE WITNESS: No.

Q (BY MS. BAUGHMAN) How do you know that?

A Not to my knowledge. No.

Q How do you know that?

A That's the indication -- I'm sorry. In 20- --

Q '25.

A Yeah. To my knowledge, no.

Q Okay. What about in 2004, when AH Environmental was out investigating and seeing -- making site visits to the Hadnot Point water treatment plant? Was the recarbonation basin operating?

A According to the report --

MS. HORAN: Objection to the form; foundation.

THE WITNESS: According to the report, no.

Q (BY MS. BAUGHMAN) Okay. Since we got the objection, let's turn to the AH Environmental report. It's attached to your report. And if you could turn to Page 2-8.

A 2-8. (Witness complies.)

Q Read the first sentence on 2-8, please.

A "At some unknown time in the past decades, the plant operators discontinued recarbonation."

Q Okay. And that's stated in the --

A 2004.

Q -- in the 2004 report of AH?

A Yes.

Q Okay. And have you -- in all of your work that you've done in this case, have you seen any indication in any document, including Dr. Hennet's report, that indicates that the recarbonation basin was used at any time from the decades prior to 2004 until 2025?

A No.

Q Okay. So while we're talking about the recarbonation basin -- we're on Page 4-2 -- I want to -- well, turn to Page 4-2 of AH 2004 report that's attached to your report.

A (Witness complies.)

Q And this is what I want to ask you. Even though the recarbonation basin wasn't running, what role did it play in terms of your calculations regarding volatilization at the Hadnot Point water treatment plant?

A The AH indicates that the recarbonation basin created a constriction that caused water to back up in the effluent pipe of the spiractor and reduced the fall height. And so even though it was no longer operating as a recarbonation basin, water was still flowing through it to get from the spiractors to the filters.

Q This statement on Page 4-2 of AH. Can you read the sentence that starts "because of the downstream recarbonation basin"? Can you read that?

A Because of the downstream recarbonation basin at the plant, the available head loss --

Q The available --

A -- the available head does not appear to allow fall height of greater than approximately 1 foot.

Q And?

A And the effluent pipe is likely to be flowing full.

Q Okay. What does that mean, the available head? What's the available head that does not appear to allow fall height of greater than 1 foot? What's that available head mean?

A That's just the energy of being able to -- the fall height that the water can go.

Q Okay. And so what is it about the Hadnot Point water treatment plant that's not allowing the fall height to be greater than 1 foot?

A The recarbonation basin creating a blockage, if you will, to the water flowing.

Q And if -- if the water treatment plant is not running and the spiractor is empty, would one be able to see the fact that the fall height can't be greater than 1 foot?

MS. HORAN: Objection to form.

THE WITNESS: No. You couldn't -- you can only determine that under hydraulic flowing conditions.

Q (BY MS. BAUGHMAN) Okay.

A Then as we said before, Figure 4-3 shows a nice demonstration of what it looks like without the back. Holcomb Boulevard that didn't have the restriction has a much cleaner, deeper fall height.

Q Okay. So just for the record, did Holcomb Boulevard have a recarbonation basin?

A No.

Q Okay. And so you're saying Figure 4-3 shows what -- what -- the fall would look like --

or what the flow would look like at the spiractor without a recarbonation basin.

A With a 2-foot fall height.

Q Okay.

A And AH points that out in their document.

Q Okay.

A They say, on Page 4-2, if I might, "However, Holcomb Boulevard water treatment plant, because of the absence of recarbonation, water falls approximately 2 feet to the bottom of the pipe section."

MS. BAUGHMAN: Can I -- do you have any stickers over there?

THE REPORTER: (Hands exhibit stickers to Ms. Baughman.)

MS. BAUGHMAN: Thank you.

What's our next one? Next exhibit?

MS. O'LEARY: We're at 14.

MS. BAUGHMAN: 14 is next?

MS. O'LEARY: No. 15.

MS. BAUGHMAN: 15. Thank you.

MS. HORAN: Do you want to just do Plaintiffs' Exhibit 1?

MS. BAUGHMAN: It does say Plaintiffs'

Exhibit. You want me to start with 1, then?

MS. HORAN: Yeah, I think that would probably be cleaner.

MS. BAUGHMAN: Okay. All right.

(Plaintiffs' Exhibit 1 marked for identification)

MS. HORAN: Do you have a copy of it for me?

MS. BAUGHMAN: Yes. But I'm just not quite ready yet.

MS. HORAN: Oh, Sorry.

MS. BAUGHMAN: Give me a second.

Q (BY MS. BAUGHMAN) If you could turn to Page 16 of your report which is Exhibit 2.

A (Witness complies.)

Q Okay. I'm going to turn your attention to the second full paragraph where you refer to Maslia's table -- and this is in the context -- this is discussing your Opinion Number 2; correct?

A Say again. This is...

Q Okay. So just for context, we're talking about Opinion Number 2 here.

A 2. Correct.

Q Okay. And in this Page 16, the second full paragraph, you reference a document CLW606 regarding the July 28, 1982 samples.

Do you see that?

MS. HORAN: Objection to form.

THE WITNESS: Yes.

Q (BY MS. BAUGHMAN) Okay. So I'm going to hand you what I've marked Plaintiffs' Exhibit 1. And is Plaintiffs' Exhibit 1 CLW606 that you referenced in your report at Page 16?

A Yes.

Q It is? Okay.

So in your report, you're referring to samples of the Hadnot Point water treatment plant taken on July 28, 1982; correct?

MS. HORAN: Objection to form.

I think you meant Tarawa Terrace.

MS. BAUGHMAN: Thank you. Let me -- let me -- let me try that again.

Q (BY MS. BAUGHMAN) On your report on Page 16, when you're referring to CLW606, you're referring to July 28, 1982 samples taken at Tarawa Terrace.

A Yes. Tarawa Terrace. Yes.

Q And they're both raw water and treat water; correct?

A Yes. Correct.

Q And what were the findings?

A The raw water was 76 and the treated water was 82.

Q Okay. Samples taken on the same day?

A Yes. That's --

Q Okay. And you cited Exhibit 1, CLW606, in support of that proposition; correct?

A Correct.

MS. HORAN: Objection to form.

Q (BY MS. BAUGHMAN) Okay. I want to turn your attention to -- well, first of all, the first page of 606. This tells -- who wrote this document? Who's the author?

MS. HORAN: Objection to form; foundation.

MS. BAUGHMAN: What's the objection to asking who the author is so I can -- so I can rephrase the question, what's the objection?

MS. HORAN: So I mean, we can all read what this document says, but I don't know if what he's --

MS. BAUGHMAN: So what's wrong with the form?

MS. HORAN: -- his understanding of this is.

MS. BAUGHMAN: Okay. Okay.

Q (BY MS. BAUGHMAN) Dr. Sabatini, who is the author of Exhibit 1, CLW606?

MS. HORAN: Same objection.

THE WITNESS: Ms. Betz.

THE REPORTER: I'm sorry. What was the answer?

THE WITNESS: B-e-t-z.

Q (BY MS. BAUGHMAN) Okay. And what was Ms. Betz's job title, according to the document?

A Quality control lab.

Q Okay. So if you turn to the second page on Paragraph Number 8, does Ms. Betz provide any opinion regarding the significance of the raw and treated samples that you cite in your report in terms of what she thought about what that told her?

MS. HORAN: Objection to form; foundation.

THE WITNESS: Point 8, she comments on the tetrachloroethylene from Tarawa -- well, yes, she does.

Q (BY MS. BAUGHMAN) And what does she say?

A Level of tetrachloroethylene from Tarawa

Terrace system averaged --

Q Let me withdraw that.

A Okay.

Q Let me ask you this.

Do you see where she starts with "therefore"?

A Therefore. Therefore. Yes. Okay.

Q Okay. What does Ms. Betz tell us in terms of what she thought the difference was between the raw and treated samples at Tarawa Terrace?

A "Therefore, with no significant difference between raw and treated samples."

Q Okay. So what -- so Ms. Betz -- you see at the bottom, she signed this document?

A Supervisor chemist.

Q With a signature; correct?

A Correct.

Q So do you agree with Ms. Betz that there was no significant difference between the raw and treated samples at Tarawa Terrace on July 28th of 1982?

MS. HORAN: Objection to form.

THE WITNESS: Correct.

Q (BY MS. BAUGHMAN) What was your answer?

A Yes. Correct.

Q Okay. And let me ask you this. You also looked at some comparisons between raw and treated samples for Hadnot Point; correct?

A Yes. On -- yes.

Q Okay. And you discuss that on Page 15 of your report.

A Correct.

Q Okay. And defense counsel asked you some questions about the December 4, 1984 samples. But can you tell me what the results were for July 27, 1982, in terms of the difference between the raw and treated samples at Hadnot Point?

A July 27th. Nineteen and 21.

Q '82.

A Yeah. 19 micrograms per liter and 21 micrograms per liter.

Q Okay. Now, you've referenced that and several other pairs of samples taken for raw and treated on the same day for Hadnot Point; correct?

A Correct.

Q Okay. So what significance if any to your opinions is there comparing these raw untreated samples at Hadnot Point and Tarawa Terrace with regard to your Opinion Number 1?

A They were reinforced -- they validate -- they support the lack of volatilization minimal to -- minimal to negligible volatilization. They help support my calculations that the losses would be minor.

Q Okay.

A They help support my opinion which was minor losses.

Q Now, I want to go back to the AH 2004 report for a moment. Do you know what AH based its opinions and conclusions on in that report?

MS. HORAN: Object to the form.

THE WITNESS: Well, they state it upfront. So Page 1-1. Bottom paragraph. They're retained by Camp Lejeune. Scope of work included developing estimates. As part of this effort, AH conducted a literature review, a search of appropriate archives to assist in the development referenced estimates of VOC losses, removal rates.

And also in their 2005 expert panel, they discuss further the -- all that they did. Evaluating all the basins, looking for any disruptions in the basins, et cetera.

Q (BY MS. BAUGHMAN) Okay. Give me just a moment.

Okay. If you could turn to Page 2-5. Section 2.3 under water plant descriptions.

A Uh-huh.

Q What did AH base its description of the water plant on?

A Based on interviews with base personnel, site visits, examinations of design, and as-built drawings pertain to part of this project.

Q Okay. Do you know whether AH, in coming up with its opinions and conclusions regarding the extent of volatilization at the water treatment plants at Camp Lejeune, whether they took into account any kind of agitation or splashing in the tanks or the air -- or the water towers or the water reservoirs?

A In their expert report, they comment that they looked for any evidence of agitation and they narrowed it down to the things that they based their calculations on.

Q So when you say expert report --

A I'm sorry. Panel. Expert panel.

Q Okay. And when you expert panel, are

you referring to the comments by Dr. Pommerenk?

A Yes.

Q From what year?

A 2005.

Q Okay. And so what did Dr. Pommerenk say in 2005 rather about whether they took agitation into account in reaching their conclusions on volatilization?

A Said that they took all those factors into consideration in identifying where they needed to focus their calculations and their estimations.

Q Okay.

MS. BAUGHMAN: Okay. I'll pass the witness.

FURTHER EXAMINATION

BY MS. HORAN:

Q Do you know what percentage of water in any of the paired treated and untreated samples that you cited in your report -- do you know if -- what wells any of those samples came from?

A What any of those...

Q Samples came -- what wells were on when those pairs were taken. Do you know what wells were on?

A Not off the top of my head. No.

Q Do you know whether the wells or pump rates of the wells consistent at the time of any of the paired treated and untreated samples?

MS. BAUGHMAN: Object to the form.

THE WITNESS: I'd have to look in the documentation.

Q (BY MS. HORAN) So sitting here today, you don't know the answer?

A No.

Q At one point in your questioning with your counsel about the amended materials considered list, you said in reference to new documents that were added that you've reviewed since filing your rebuttal report.

The CLW you mentioned. What document were you referencing when you said that?

A I don't remember the number. It was one that -- right now, I don't recall.

MS. BAUGHMAN: I handed you what I thought it was earlier today. You can ask him if that's it.

THE WITNESS: Yeah, that's --

MS. BAUGHMAN: And to tell you the truth, that document that I handed you, the important part, is 606 which he already had.

THE WITNESS: Okay. That's it then.

Q (BY MS. HORAN) It's the 606 document that you were thinking of?

A Yes.

Q It doesn't look like that was included.

MS. HORAN: This is not intended to be a memory test. Could you just identify?

MS. BAUGHMAN: Can I see that one?

MS. HORAN: (Hands document to Ms. Baughman.)

MS. BAUGHMAN: Yeah. Thank you.

Can we go off the record for a second.

THE VIDEOGRAPHER: We're off the record at 6:13 p.m.

(Off the record from 6:13 p.m. to 6:14 p.m.)

THE VIDEOGRAPHER: We're back on the record at 6:14 p.m.

Q (BY MS. HORAN) Would you agree that if pump rate or fractive pumping of wells that were the source of contamination varied such that the system was not always at a steady state for contaminant concentration entering the water treatment plants --

MS. BAUGHMAN: Objection to the form.

Q (BY MS. HORAN) -- then the samples would not show a quantity of treatment losses?

MS. BAUGHMAN: Object.

Q (BY MS. HORAN) When I say the samples, I mean the paired samples.

A That's speculative. There's certainly that possibility.

MS. HORAN: I don't know that we need to --

Q (BY MS. HORAN) I believe you testified earlier that you had reviewed Dr. Longley's expert report. He's the historian.

A Dr...

Q Longley. He's a historian.

A Yes. Yes.

MS. HORAN: We don't -- we don't see this on the materials considered list.

MS. BAUGHMAN: I think he's confused. I think he reviewed Brigham, and he's thinking Longley. I -- I don't know that he's reviewed Longley. I don't think he has.

MS. HORAN: Well, could you follow up and follow up with us?

THE WITNESS: Longley's --

Q (BY MS. HORAN) The historian.

A Right.

Q Yeah.

MS. HORAN: Can we just -- can you just follow up with us, Laura? We'll just find out.

MS. BAUGHMAN: Hold on. Okay. Are you done?

MS. HORAN: Yeah. Nothing further.

MS. BAUGHMAN: Okay. I'll tell you, for the record -- I've confirmed it -- he's never been provided Longley. He's confused because you're saying "historian".

THE REPORTER: We're still on?

MS. BAUGHMAN: Yes. We're still on.

He's confused because you're saying historian, so he's assuming that's the historian that he had reviewed. Okay? He reviewed Brigham, and that's on the list.

MS. HORAN: We just wanted to understand the --

MS. BAUGHMAN: So I'm not going to supplement because --

MS. HORAN: That's fine.

FURTHER EXAMINATION

BY MS. BAUGHMAN:

Q How many -- let me -- I'm going to ask you a few follow-ups.

How many different historian expert reports did you review?

A One that I recall.

Q Okay. Was that Dr. Brigham?

A Yes.

Q Okay. So did you review Dr. Longley's report?

A Not to my recollection.

Q Okay. Were you confused because she used the word historian?

A Yeah. Historian. I mean....

Q Okay. Let me just ask you a couple of other things.

So you have these paired samples that you're relying on for your Opinion Number 2 which also relate to your Opinion Number 1 which you talked about earlier; right? Correct?

A Correct.

Q Okay. And you've been asked by defense counsel some questions about, well, do you know which wells were pumping and what if they changed.

What's the likelihood that that wells would be pumping differently on the same day such that it would change the results?

MS. HORAN: Objection to form.

Q (BY MS. BAUGHMAN) What's your opinion on that based on all the work --

A That seems --

Q -- based on all of the work you've done and the documents you've reviewed?

MS. HORAN: Objection; foundation.

THE WITNESS: That would seem very unlikely. Very unlikely.

Q (BY MS. BAUGHMAN) Does the concept that the different wells could have been pumping at different times on the same day change your confidence in your reliance on the paired samples to support your Opinions 1 and 2?

MS. HORAN: Objection to form.

THE WITNESS: No.

Q (BY MS. BAUGHMAN) And why is that?

A Just the unlikely nature in that it would happen on each of those episodes and each of those times.

Q (BY MS. BAUGHMAN) Okay.

MS. BAUGHMAN: I'll pass the witness.

MS. HORAN: Nothing.

MS. BAUGHMAN: Go ahead.

MS. HORAN: Nothing further.

Thank you, Dr. Sabatini, for your time today.

THE WITNESS: Thank you.

THE VIDEOGRAPHER: We're off the record at 6:19 p.m.

THE REPORTER: Can both of you right here state just for the record, your order for the transcript? Are you ordering the transcript?

MS. BAUGHMAN: Yes. But that's all with Golkow, and there's a whole leadership committee. So I want whatever we normally do. Okay.

MS. HORAN: Can we have a three-day turnaround, please?

(Deposition concluded at 6:19 p.m.)

J U R A T

STATE OF OKLAHOMA)
) SS:
COUNTY OF _________)

I, DAVID ALLEN SABATINI, PH.D, PE, BCEE, do hereby state under oath that I have read the above and foregoing deposition in its entirety, and that the same is a full, true, and correct transcription of my testimony so given at said time and place, except for the corrections noted.

____
DAVID ALLEN SABATINI, PH.D, PE, BCEE

Subscribed and sworn to before me, a Notary Public in and for the State of Oklahoma by said witness, DAVID ALLEN SABATINI, PH.D, PE, BCEE, on the _____ day of _________________ 2025.

____
Notary Public in and for the
State of Oklahoma

My Commission Expires:__________

My Commission Number:___________

C O R R E C T I O N S H E E T

NAME: DAVID ALLEN SABATINI, PH.D., PE, BCEE
CASE: IN RE: CAMP LEJEUNE WATER LITIGATION
DATE: APRIL 11, 2025
REPORTER: LANA L. LEDFORD, CSR

PG/LN	CORRECTION	REASON FOR CORRECTION
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C E R T I F I C A T E

STATE OF OKLAHOMA)
) SS:
COUNTY OF OKLAHOMA)

I, Lana L. Ledford, a Certified Shorthand Reporter within and for the State of Oklahoma, certify that DAVID ALLEN SABATINI, PH.D, PE, BCEE was sworn to testify the truth; that the deposition was taken by me in stenotype and thereafter transcribed by computer, and is a true and correct transcript of the testimony of the witness; that the deposition was taken on APRIL 11, 2025, AT 120 NORTH ROBINSON AVENUE, 4TH FLOOR, OKLAHOMA CITY, OKLAHOMA 73102; that I am not an attorney for nor relative of either party, or otherwise interested in this action.

Witness my hand and seal of office on the 16TH day of APRIL 2025.

<%824,Signature%>
____
LANA L. LEDFORD, CSR
for the State of Oklahoma
CSR #01776

Federal Rules of Civil Procedure

Rule 30

(e) Review By the Witness; Changes.

(1) Review; Statement of Changes. On request by the deponent or a party before the deposition is completed, the deponent must be allowed 30 days after being notified by the officer that the transcript or recording is available in which:

(A) to review the transcript or recording; and

(B) if there are changes in form or substance, to sign a statement listing the changes and the reasons for making them.

(2) Changes Indicated in the Officer's Certificate. The officer must note in the certificate prescribed by Rule 30(f)(1) whether a review was requested and, if so, must attach any changes the deponent makes during the 30-day period.

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EXHIBIT 4

ENVIRONMENTAL ORGANIC CHEMISTRY

RENÉ P. SCHWARZENBACH
Swiss Federal Institute of Technology (ETH)
Zürich, Switzerland
and
Swiss Federal Institute for Water Resources
and Water Pollution Control (EAWAG)
Dübendorf, Switzerland

PHILIP M. GSCHWEND
Department of Civil and Environmental Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

DIETER M. IMBODEN
Swiss Federal Institute of Technology (ETH)
Zürich, Switzerland
and
Swiss Federal Institute for Water Resources
and Water Pollution Control (EAWAG)
Dübendorf, Switzerland

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CHAPTER 11

SORPTION: SOLID–AQUEOUS SOLUTION EXCHANGE

11.1 INTRODUCTION

The process in which chemicals become associated with solid phases is generally referred to as *sorption* (either *ad*sorption onto a two-dimensional surface, or *ab*sorption into a three-dimensional matrix). This phase transfer process may involve interacting either vapor molecules or dissolved molecules with adjacent solid phases.

Sorption is extremely important because it may dramatically affect the fate and impact of chemicals in the environment. Such importance is readily understood if we recognize that structurally identical molecules behave very differently if they are surrounded by water molecules and ions as opposed to clinging onto the exterior of solids or being buried within a solid matrix (Fig. 11.1). Clearly, the environmental movements of water-borne molecules must differ from that fraction of the same kind of molecules carried by particles that settle. Additionally, only the dissolved molecules are available to collide with the interfaces leading to other environmental compartments such as air; and thus these phase transfers, for practical purposes, are limited to the dissolved species of a chemical. Finally, the chemical milieu of the solution and solid worlds differ greatly. For example, the thin layer of water surrounding silicate surfaces is typically "more acidic" than bulk water, and thus reactions involving protons or hydroxide ions proceed at different rates for sorbed molecules which are otherwise structurally identical to dissolved molecules. It is possible that molecules located within particles are substantially shaded from incident light; therefore, these molecules may not get involved with direct photochemical processes or short-lived reactive species such as $\cdot$OH (see Chapter 13). Finally insofar as molecular transfer into microorganisms is frequently a prerequisite to a substance's biodegradation, it

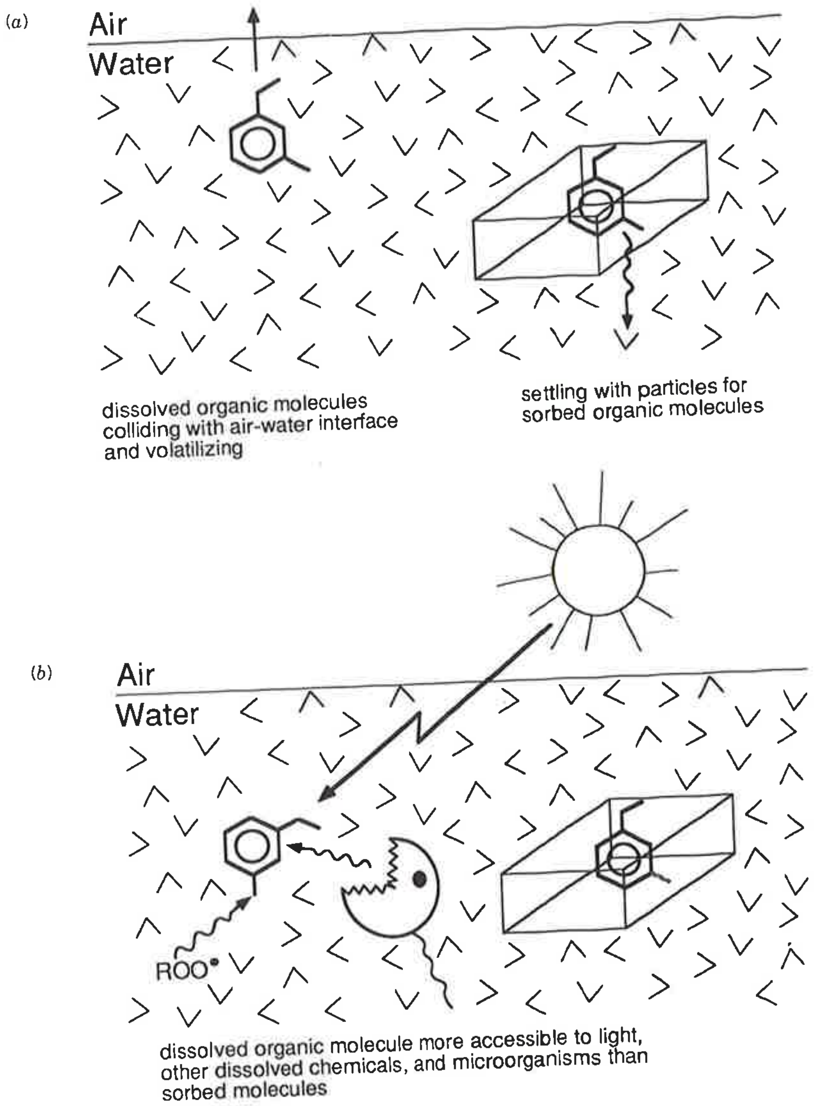


Figure 11.1 Some processes in which sorbed species behave differently than dissolved molecules of the same substance. (*a*) For example, dissolved species may undergo air–water exchange while sorbed species may sediment. (*b*) Also, dissolved species may react at different rates as compared to their sorbed counterparts.

should be recognized that the greater ease of chemical movement from solution versus from within solids to bacteria generally causes the biological decomposition of the sorbed form of the chemical to be slower than its dissolved counterpart. Hence, we must understand solid–solution exchange phenomena before we can quantify virtually any other process affecting the fate of chemicals in the environment.

Unfortunately, sorption is not always a single simple process (Westfall, 1987). Rather, some combination of interactions may be responsible for governing the association of any particular chemical (called a *sorbate*) with any particular solid (called a *sorbent*). Figure 11.2 illustrates this point for 4-chloroaniline (4-chloroaminobenzene). First, chiefly because of unfavorable free-energy costs of remaining in aqueous solution, such an organic substance may escape the water by penetrating

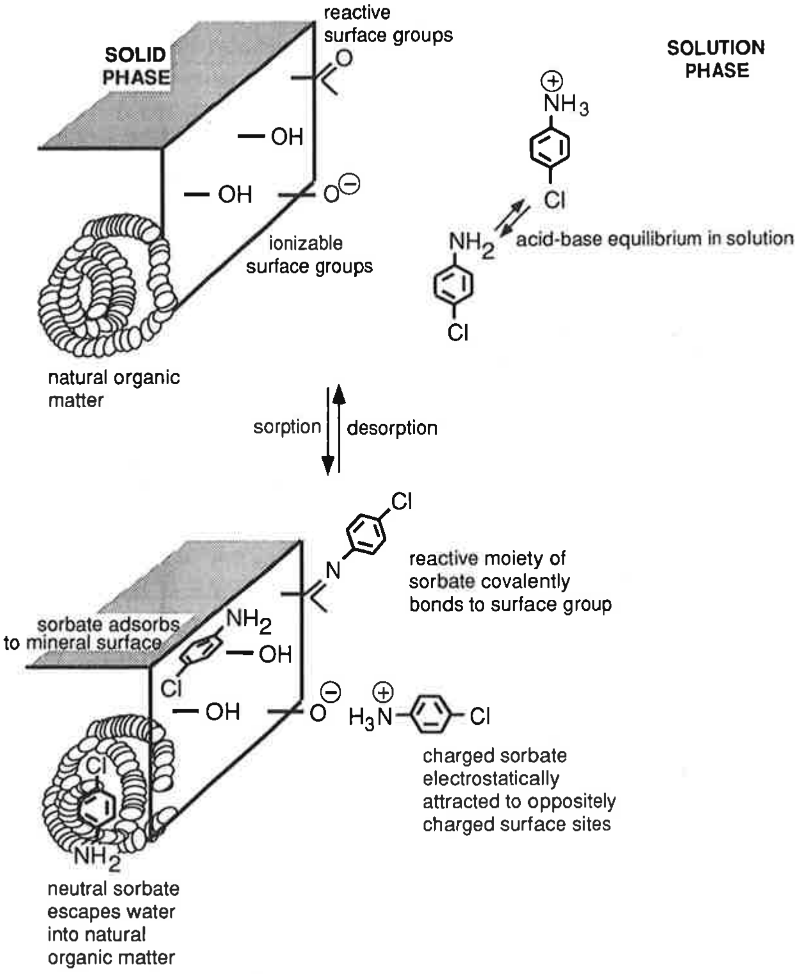


Figure 11.2 Some sorbent–sorbate interactions possibly controlling the association of a chemical with particles.

natural organic matter in the particulate phase. Additionally, such a molecule may displace water molecules from the region near the mineral surface to some extent and thereby be associated with the surface via van der Waals, dipole–dipole, and other weak intermolecular forces. These two mechanisms of sorption are general and will operate for any organic chemical and any natural solid. Additionally, if the sorbate is ionizable in the aqueous solution, then attraction to specific surface sites exhibiting the opposite charge will promote sorption of the ionic species. Finally, should the sorbate and sorbent exhibit mutually reactive moieties (e.g., in Fig. 11-2 a carbonyl group on the sorbent and an amino group on the sorbate), some portion of the chemical may actually become bonded to the solid. All of these interaction mechanisms will operate simultaneously, and the combination that dominates the overall solution–solid distribution will depend on the structural properties of the organic chemical and solid medium of interest.

In this chapter we try to visualize the sets of molecular interactions involved in each of the sorption processes. This means that we have to consider van der Waals and dipole–dipole interactions, H-bonding, ionic interactions between charged species, and specific bonding of reactive moieties and solid surface atoms or groups. With such pictures in our minds, we will seek to understand what makes various sorption mechanisms important under various circumstances. Establishing the critical molecular properties and solid characteristics will enable us to understand why certain predictive approaches may be applied. Ultimately, we should gain some feeling for what structural features of a chemical and what characteristics of solids (and solutions) are important to sorption interactions. Finally, we conclude by examining the factors limiting the rate of approach to sorption equilibrium.

11.2 QUANTIFYING THE RELATIVE ABUNDANCES OF DISSOLVED AND SORBED SPECIES: THE SOLID–WATER DISTRIBUTION RATIO K_d

When we are interested in assessing the *equilibrium* proportion of a particular chemical's presence in association with solids for any particular volume of an aquatic environment, we begin by considering how the total sorbate concentration associated with the sorbent, C_s (mol·kg^{-1}), depends on the total chemical concentration in the solution, C_w (mol·L^{-1}). Such a relationship is commonly referred to as a *sorption isotherm*. The term isotherm is used to indicate that one is considering sorption at a constant temperature. Depending on the dominating mechanism(s), sorption isotherms may exhibit different shapes (Fig. 11.3). Experimentally determined isotherms can commonly be fit with a relationship of the form

$$C_s = K \cdot C_w^n \tag{11-1}$$

This equation is known as the Freundlich isotherm; K is referred to as the Freundlich constant; and n is a measure of the nonlinearity involved. Case I in Figure 11.3 ($n < 1$) reflects the situation in which at higher and higher sorbate concentrations, it becomes more and more difficult to sorb additional molecules. This may occur in cases where

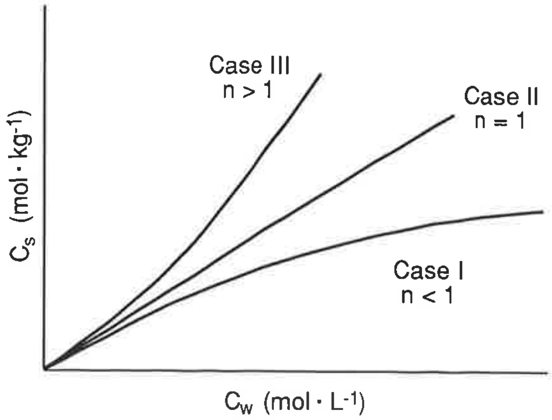


Figure 11.3 Three types of observed relationships between concentrations of a chemical in the sorbed state, C_s, and the dissolved state, C_w. All can be fit with a relationship of the form $C_s = K \cdot C_w^n$ where K and n are constants.

specific binding sites become filled or remaining sites are less attractive to the sorbate molecules. Case III ($n > 1$) describes a contrasting situation in which previously sorbed molecules lead to a modification of the surface which favors further sorption. Such effects have been seen for surface active compounds like alkyl benzene sulfonates (see Table 2.6), where the sorbent becomes coated and increasingly exhibits a nonpolar nature. Finally, Case II ($n = 1$) reflects those situations in which the attractiveness of the solid for the sorbates remains the same for all levels of C_s. This is the so-called *linear* isotherm case; one should also realize that over narrow ranges in C_w, particularly at low concentrations, both Cases I and III appear to be linear.

Let us now consider a case in which we know the *ratio* of a substance's total equilibrium concentrations in the sorbed phase and in the solution. We denote this distribution ratio with K_d:

$$K_d = \frac{C_s}{C_w} \qquad \frac{(\text{mol}\cdot\text{kg}^{-1})}{(\text{mol}\cdot\text{L}^{-1})} \tag{11-2}$$

The value of this ratio may only apply at the given solute concentration (i.e., n in Eq. 11-1 may not equal 1). In fact, inserting Eq. 11-1 into Eq. 11-2 yields

$$K_d = K \cdot C_w^{n-1} \tag{11-2a}$$

Often, one assumes that K_d is constant over some concentration range. From Eq. 11-2a we can differentiate K_d with respect to C_w, rearrange the result, and find

$$\frac{dK_d}{K_d} = (n-1)\frac{dC_w}{C_w} \tag{11-2b}$$

so this assumption about the constancy of K_d is equivalent to presuming: (a) the overall sorption process is either described by a linear isotherm ($n = 1$ in Eq. 11-1), or (b) the relative concentration variation, dC_w/C_w, is sufficiently small to guarantee that the relative K_d variation, dK_d/K_d, is also small.

Armed with such a K_d parameter for a case of interest, we may evaluate what fraction of a compound is in the water solution, f_w, in a volume containing both solids and water (but only these phases):

$$f_w = \frac{C_w \cdot V_w}{C_w V_w + C_s M_s} \tag{11-3}$$

where V_w is the volume of water (L) in total volume V_{tot}, and M_s is the mass of solids (kg) present in that same total volume. Now if we substitute the product $K_d \cdot C_w$ from Eq. 11-2 for C_s in Eq. 11-3, we have

$$\begin{aligned} f_w &= \frac{C_w V_w}{C_w V_w + K_d C_w M_s} \\ &= \frac{V_w}{V_w + K_d M_s} \end{aligned} \tag{11-4}$$

Finally, noting that we frequently refer to the quotient M_s/V_w as the solid-to-water phase ratio r_{sw} (e.g., kg·L^{-1}) in the environmental compartment of interest, we may describe the fraction of chemical in solution as a simple function of K_d and this ratio:

$$\begin{aligned} f_w &= \frac{1}{1 + (M_s/V_w) K_d} \\ &= \frac{1}{1 + r_{sw} \cdot K_d} \end{aligned} \tag{11-5}$$

Such an expression clearly indicates that for substances exhibiting a great affinity for solids (hence a large value of K_d) or in situations having large amounts of solids per volume of water (large value of r_{sw}), we predict that correspondingly small fractions of the chemical remain dissolved in the water. Note the fraction associated with solids, f_s, must be given by $(1 - f_w)$ since we assume that no other phases are present (e.g., air, other immiscible liquids).

The fraction of the total volume V_{tot} that is not occupied by solids, the so-called porosity ϕ, is often used instead of r_{sw} to characterize the solid–water phase ratio in a given system. In the absence of any gas phase (as is the case in water-saturated soil and usually in sediments and the open water column), ϕ is equal to

$$\phi = \frac{V_w}{V_{tot}} = \frac{V_w}{V_w + V_s} \tag{11-6}$$

where V_s, the volume occupied by particles, can be expressed by M_s/ρ_s, (where ρ_s is the density of the solids). Thus

$$\phi = \frac{V_w}{V_w + M_s/\rho_s} = \frac{1}{1 + r_{sw}/\rho_s} \tag{11-7}$$

Solving for r_{sw} yields the corresponding relation

$$r_{sw} = \rho_s \frac{1-\phi}{\phi} \tag{11-8}$$

It is a matter of convenience whether r_{sw} or ϕ is used.

The application of such solution- versus solid-associated speciation information may be illustrated by considering an organic chemical, say 1,4-dimethylbenzene (DMB), in a lake and in flowing groundwater. In the lake, the solid–water ratio is given by the suspended solids concentration (since $V_w \approx V_{tot}$), which is typically near $10^{-6}\,\mathrm{kg \cdot L^{-1}}$. From experience we may know that the K_d value for DMB in this case is $1\,\mathrm{L \cdot kg^{-1}}$; therefore we can see that virtually all of this compound is in the dissolved form in the lake:

$$f_w = \frac{1}{1 + 10^{-6} \cdot 1} \approx 1$$

In the groundwater situation, ρ_s for aquifer solids is about $2.5\,\mathrm{kg \cdot L^{-1}}$ (e.g., quartz density is 2.65); ϕ is often between 0.2 and 0.4. If our particular groundwater situation has ϕ of 0.2, r_{sw} is $10\,\mathrm{kg \cdot L^{-1}}$. Hence, we predict that the fraction of DMB in solution, assuming again a K_d of $1\,\mathrm{L \cdot kg^{-1}}$, is drastically lower than in the lake:

$$f_w = \frac{1}{1 + 10 \cdot 1} \simeq 0.09$$

So we deduce that only one DMB molecule out of 11 will be in the moving groundwater at any instant (Fig. 11.4). This result has implications for the fate of the DMB in that subsurface environment. If DMB sorptive exchange between the aquifer solids and the water is fast relative to the groundwater flow and if sorption is reversible, we can conclude that the whole population of DMB molecules moves at one eleventh the rate of the water. The phenomenon of diminished transport speed relative to the water seepage velocity is referred to as retardation; and it is quantified using a retardation factor which is simply f_w^{-1}.

Many situations require us to know something about the distribution of a chemical between a solution and solids. Our task then is to see how we can get K_d values suited for the cases that concern us. As we will see, these K_d values are determined by the structures of the sorbates as well as the composition of the aqueous phase and the sorbents.

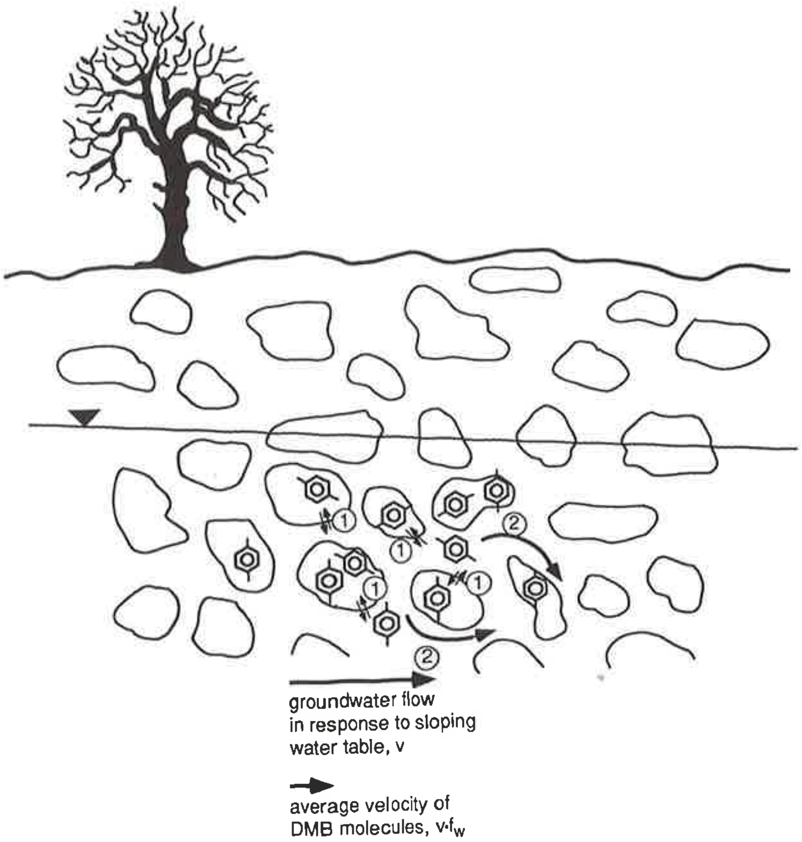


Figure 11.4 Illustration of the retardation of 1,4-dimethylbenzene (DMB) transport in groundwater due to: (1) reversible sorptive exchange between water and solids, and (2) limiting transport of DMB to that fraction remaining in the flowing water. As dissolved molecules move ahead they become sorbed and stopped, while molecules sorbed at the rear return to the water and catch up. Thus, overall transport of DMB is slower than that of the water itself.

11.3 THE COMPLEX NATURE OF K_d's

The prediction of K_d for any particular combination of organic chemical and solids in the environment can be difficult, but fortunately many situations appear reducible to fairly simple limiting cases. We begin by emphasizing that the way we defined K_d means that we may have lumped together many chemical species in each phase. For example, referring again to Figure 11.2, we recognize that the total concentration of 4-chloroaniline in the sorbed phase combines the contributions of molecules in many different sorbed forms. Even the solution in this case contains both a neutral and a charged species of this chemical. Thus the distribution ratio for this case would have to be written

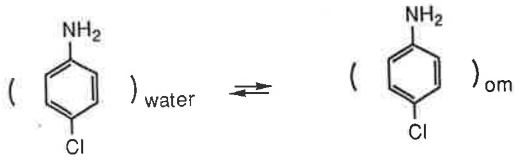
$$K_d = \frac{C_{om} \cdot f_{om} + C_{min} \cdot A + C_{ie} \cdot \sigma_{ie} \cdot A + C_{rxn} \cdot \sigma_{rxn} \cdot A}{C_{w,neut} + C_{w,ion}} \qquad (11\text{-}9)$$

where

C_{om} is the concentration of sorbate associated with the natural organic matter ($mol \cdot kg^{-1}$ om),
f_{om} is the weight fraction of solid which is natural organic matter (kg $om \cdot kg^{-1}$ solid),
C_{min} is the concentration of sorbate associated with the mineral surface ($mol \cdot m^{-2}$),
A is the area of mineral surface per mass of solid [$m^2 \cdot kg^{-1}$ solid),
C_{ie} is the concentration of ionized sorbate drawn toward positions of opposite charge on the solid surface ($mol \cdot mol^{-1}$ surface charges),
σ_{ie} is the net concentration of suitably charged sites on the solid surface (mol surface $charges \cdot m^{-2}$),
C_{rxn} is the concentration of sorbate bonded in a reversible reaction to the solid ($mol \cdot mol^{-1}$ rxn sites),
σ_{rxn} is the concentration of reactive sites on the solid surface (mol rxn $sites \cdot m^{-2}$),
$C_{w,neut}$ is the concentration of uncharged chemical in solution ($mol \cdot L^{-1}$), and
$C_{w,ion}$ is the concentration of the charged chemical in solution ($mol \cdot L^{-1}$).

It is possible that some of the terms in Eq. 11-9 also deserve further subdivision. For example, $C_{min} \cdot A$ may reflect a linear combination of the interactions of several mineral surfaces present in a particular soil or sediment with a single sorbate. Thus, a soil consisting of montmorillonite, kaolinite, iron oxide, and quartz mineral components may actually have $C_{min} \cdot A = C_{mont} \cdot a \cdot A + C_{kao} \cdot b \cdot A + C_{iron\ ox} \cdot c \cdot A + C_{quartz} \cdot d \cdot A$ where the parameters a, b, c, and d are the area fractions exhibited by each mineral type. Similarly, $C_{rxn} \cdot \sigma_{rxn} \cdot A$ may reflect bonding to several different kinds of moieties, each with its own reactivity with the sorbate (e.g., chloroaniline). For now, we will work from the simplified expression which is Eq. 11-9, primarily because there are little data available allowing rational subdivisions of soil or sediment differentially sorbing organic chemicals beyond that reflected in this equation.

It is very important to realize that only particular combinations of species in the numerator and denominator of complex K_d expressions like that of Eq. 11-9 are involved in any one exchange process. For example, in the case of 4-chloroaniline

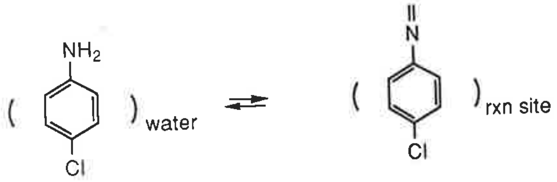


(11-10)

reflects the molecular interchange between the uncharged chloroaniline species dissolved in water and the species in the particulate natural organic phase with the same molecular structure. Similarly, the combination

(11-11)

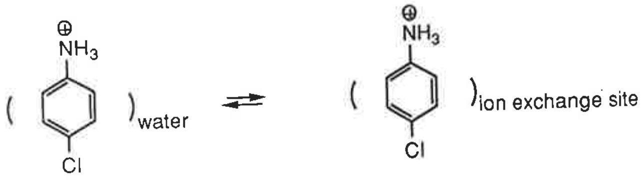
would indicate the exchange of uncharged chloroaniline molecules from aqueous solution to the available mineral surfaces. Each of these exchanges is characterized by a unique free energy difference reflecting the equilibria shown as Eqs. 11-10 and 11-11. Similarly, the exchange of



(11-12)

should be considered if it is the neutral sorbate which can react with components of the solid. Note that such specific binding to a particular solid phase moeity may prevent rapid desorption, and therefore such sorbate–solid associations may cause part or all of the sorption process to appear irreversible on some timescale of interest.

So far we have considered sorptive interactions in which the neutral chloroaniline species was involved. In contrast, it is the charged chloroaniline species that is important in the ion exchange process:



(11-13)

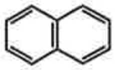
Again, we emphasize this solution–solid exchange has to be described using the appropriate equilibrium expression relating corresponding species in each phase. The influence of each sorption mechanism on the overall K_d is weighted by the availability of the respective sorbent property (i.e., f_{om}, A, σ_{ie}, σ_{rxn}, or A) in the total solid. By combining information on the individual equilibria (e.g., Eqs. 11-10 through Eq. 11-13) with these sorbent properties, we can develop versions of the complex K_d expression (Eq. 11-9) which take into account the structure of the chemical we are considering. In the following sections, we discuss these individual equilibrium relationships.

11.4 SORPTION OF NEUTRAL ORGANIC CHEMICALS TO SOILS AND SEDIMENTS

Role of the Natural Organic Matter

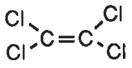
We begin by treating the case of *neutral organic chemicals* distributing themselves between an aqueous solution and natural solids. Our major emphasis involves nonpolar compounds constructed primarily from carbon, hydrogen and halogen atoms such as those shown below:

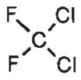
Naphthalene



Isooctane

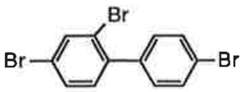
Tetrachloroethylene



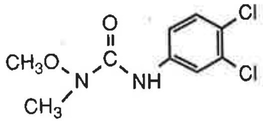


Freon-12

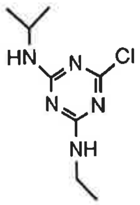
2,4,4′-Tribromobiphenyl



However, much of the following treatment also applies for more polar, but still neutral, chemicals like



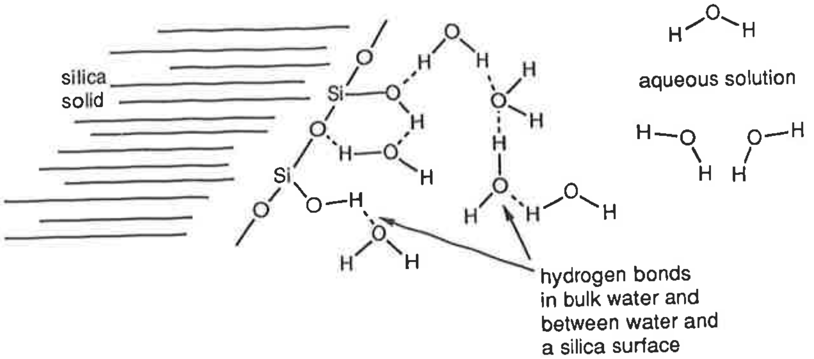
Linuron
(a phenyl urea herbicide)



Atrazine
(a chloro-s-triazine herbicide)

As we have seen in discussing the aqueous solubilities of nonpolar compounds (Chapter 5), these molecules do not "enthusiastically" dissolve in water. This incompatibility principally arises because water molecules change their overall H-bonding to their surroundings when they are forced to interface with such nonpolar solutes or nonpolar structural subunits of compounds like linuron and atrazine.

In like manner, most natural minerals are polar and expose a combination of hydroxy- and oxy-moieties to their exterior. Naturally, then, these polar surfaces strongly favor interactions which allow them to form hydrogen bonds—such as with liquid water:



As a result, replacing the water molecules at such a mineral surface by nonpolar organic compounds is unfavorable from an energetic point of view, despite the sorption-favoring activity coefficients of these solutes in the water.

On the other hand, penetration of neutral organic chemicals into any natural organic matter included in the solid phase does not require displacement of tightly bound water molecules. This solid organic phase material may include recognizable biopolymers like proteins, lignin, and cellulose, but also a menagerie of macromolecules from the partial degradation and crosslinking of organic residues remaining from organisms or photochemical reactions. Naturally, the structure of such altered materials will depend on the ingredients supplied by the particular organisms living in or near the water or soil and will tend to be somewhat randomized depending on what particular substituents have been altered and where crosslinking has happened to occur. For example, soil scientists (Schnitzer and Khan, 1972; Stevenson, 1976) have deduced that the recalcitrant remains of woody terrestrial plants make up a major portion of the natural organic matter in soils. Such materials also make up an important fraction of organic matter suspended in freshwaters (Liao et al., 1982). Similarly, marine chemists believe that the natural organic matter, suspended in the oceans at sites far from land, consists of altered biomolecules such as amino acids, sugars, and triglycerides that have been linked together (Hedges, 1977; Stuermer and Payne, 1976; Harvey et al., 1983). At intermediate locales, such as large lakes and estuaries, the natural organic material in sediments and suspended in water appears to derive from a variable mixture of terrestrial organism and planktonic organism remains (Hedges and Parker, 1976; Sigleo et al., 1982; Hedges et al., 1984; Thurman, 1985). These altered complex organic substances are typically referred to as *humic substances* if they are soluble or extractable in aqueous base, and *humin or kerogen* if they are not. The humic substances are further subdivided into *fulvic acids* if they are soluble in both acidic and basic solutions and *humic acids* if they are not soluble in acidic conditions but are soluble at high pHs. Such materials are predominantly made of carbon (about 40–50% by weight), but some have nearly as many oxygens as carbons included in their structures (Table 11.1). Thus, they are not as polar as water, especially since they can only be involved in H-bonding at limited points on their structures (e.g., carboxy, phenoxy, hydroxy, and carbonyl substituents); but they are not as nonpolar as hydrocarbons or chlorinated hydrocarbons either, since they

TABLE 11.1 Properties of Natural Organic Matter Relevant to Sorption

	Mole Ratio				Moles H-bonding Substituents per kg				Molecular Mass Range (amu)	Reference
	C	H	N	O	ether	keto	hydroxy	carboxy		
Proteins	10	15	4	2					$1 \times 10^4 - 1 \times 10^5$ (cytochrome c to serum γ-globulin)	5
Cellulose (*linear* polymer)	10	16	0	8	1.2	0	1.9	0	$3 \times 10^5 - 4 \times 10^6$ (cotton)	2
Lignin	10	11	0.1	3						2
Fulvic acids										
Dissolved (river)	10	12	0.2	6		2	9	6	1×10^3	3
Soils	10	8	0.1	7	0.1	3.1	6.9	9.1		1
Humic acids										
Dissolved (river)	10	11	0.3	6				4.3	$2 \times 10^3 – 5 \times 10^3$	3
Sedimentary (lake)	10	13	0.9	5						4
Soils	10	12	0.6	4	0.3	4.4	4.9	4.5	$1 \times 10^3 – 2 \times 10^5$	1,4
Humin	10	19	0.5	11						2

References: 1. Khan, 1980. 2. Garbarini and Lion, 1986. 3. Thurman, 1985. 4. Schnitzer and Khan, 1972. 5. Oser, 1965.

f_{oc}

0.5

0.6

(0.588)

do have oxygens and a few nitrogens in their structures. Such natural organic matter occurs in a very broad spectrum of molecular sizes from the smallest fulvic acids of about 1000 amu (corresponding to spheres of about 2 nm diameter) to the huge complexes of solid kerogen. The important point is that when these natural organic constituents are associated with particles (and even when they remain suspended as nonsettling particles called colloids in aqueous solution), they offer a relatively nonpolar environment into which a hydrophobic compound may escape without undue competition with water.

In light of this discussion, we may not be too surprised to find that nonreactive, neutral chemicals show greater solid–water distribution ratios for soils or sediments that contain high amounts of natural organic matter, as illustrated for pyrene in Figure 11.5. Additionally, we see in this figure that when f_{om} approaches zero, K_d (pyrene) is very small. (Note: f_{om} is often determined by measurement of organic carbon (oc); as a result, it is often discussed using a parameter called f_{oc}, or fraction organic carbon, with units kg oc$\cdot$kg^{-1} solid. As shown by the materials listed in Table 11.1, natural organic matter is typically made up of about half carbon, so f_{om} approximately equals $2 \cdot f_{oc}$.)

Consequently, we conclude that we only need to consider sorption of neutral nonpolar organic compounds to the natural organic matter as long as f_{om} is "significant". A more precise definition of "significant" will emerge below as we consider competing sorption mechanisms. For now, we realize that in this type of case, $C_s \approx C_{om} \cdot f_{om}$. Since chemicals like pyrene cannot ionize, C_w is equal to $C_{w,neut}$. Thus the composite

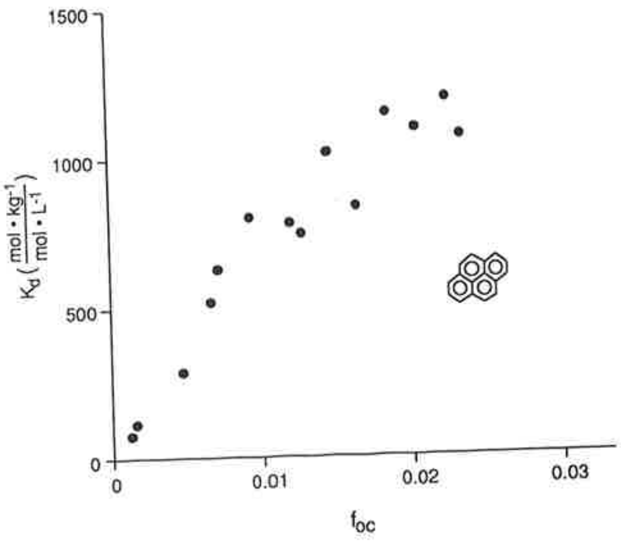


Figure 11.5 Observed increase in solid–water distribution ratios for a hydrophobic compound, pyrene, as a function of the organic matter content of the solid (measured as organic carbon, $f_{oc} \simeq 1/2\, f_{om}$) in a variety of soils and sediments. Data from Means et al. (1980).

K_d (Eq. 11-9) simplifies to

$$K_d = \frac{C_{om} \cdot f_{om}}{C_{w,neut}} \tag{11-14}$$

The Organic Matter—Water Partition Coefficient, K_{om}

To ascertain what controls the ratio of C_{om} to $C_{w,neut}$ for various situations, we consider briefly the molecular environment of a neutral organic molecule sorbed by natural organic matter. We picture this natural organic material to exist in large part as organic chains coiled into globular units, much like globular proteins, and to occur in somewhat isolated patches coating mineral solids (Fig. 11.6). Such coiling is brought about because the natural organic matter minimizes the hydrophobic surface area it exposes to the aqueous solution. Because of the "porous" nature of such flexible macromolecules, nonpolar sorbates can physically penetrate between the chains and find themselves "dissolved" in the nonaqueous medium (Fig. 11.6). Note that such sorbent associations are not limited to the interfacial area where the water solvent contacts the natural organic sorbent. Indeed, since the sorbate goes *into* the "volume" of the sorbent, this process may be referred to as an *ab*sorption (from Latin, *ab*, away from, and *sorbere*, to suck). The entry of nonpolar sorbates into the natural organic matter amounts to mixing these components as in solutions.

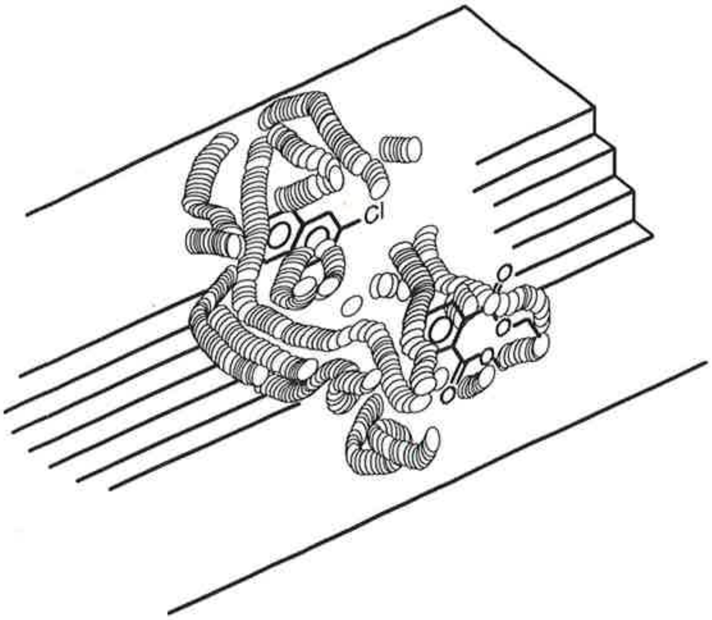


Figure 11.6 Conceptualization of nonpolar organic sorbates (here, 2-chloronaphthalene and diethylphthalate) associated with natural organic matter in a solid phase.

Thus we can imagine the organic sorbate is distributing itself between two immiscible solutions, and we may define a partition coefficient which reflects the ratio of these concentrations:

$$K_{\mathrm{om}} = \frac{C_{\mathrm{om}}}{C_{\mathrm{w,neut}}} \; \frac{(\mathrm{mol \cdot kg_{om}^{-1}})}{(\mathrm{mol \cdot L_{water}^{-1}})} \tag{11-15}$$

which is analogous to what we defined for organic solvent–water partitioning (Eq. 7-1). In defining K_{om} this way, we have led to a new expression for the solid–water distribution ratio of such neutral, nonpolar chemicals:

$$K_d = \frac{f_{\mathrm{om}} \cdot C_{\mathrm{om}}}{C_{\mathrm{w,neut}}} \tag{11-14}$$

$$= f_{\mathrm{om}} \cdot K_{\mathrm{om}} \tag{11-16}$$

This formulation will prove to be very convenient because it is broken into two parts: f_{om}, which is a property of the soil or sediment sorbent, and K_{om}, which is primarily a characteristic of the organic chemical sorbate.

Given our conceptualization of hydrophobic neutral chemical absorption as two solutions competing for the sorbate, we can deduce several important results. First, considering C_{om} and $C_{\mathrm{w,neut}}$ to be solution concentrations, we may rewrite the equilibrium partition coefficient expression (Eq. 11-15):

$$K_{\mathrm{om}} = \frac{x_{\mathrm{om}} \cdot \bar{V}_{\mathrm{om}}^{-1} \cdot \rho_{\mathrm{om}}^{-1}}{x_{\mathrm{w}} \cdot \bar{V}_{\mathrm{w}}^{-1}} \tag{11-17}$$

where x_{om} (mol sorbate·mol^{-1} om) and x_{w} (mol sorbate·mol^{-1} water) refer to the mole fraction concentrations in the organic matter and aqueous solutions, respectively; $\bar{V}_{\mathrm{om}}$ (L om·mol^{-1} om) and $\bar{V}_{\mathrm{w}}$ (L water·mol^{-1} water) are the molar volumes of the two phases, and ρ_{om} (kg om·L^{-1} om) is the organic matter density. Choosing the pure liquid of the sorbate to serve as the reference state, we may use the relation $x = \gamma^{-1}$ to rewrite Eq. 11-17:

$$K_{\mathrm{om}} = \frac{\gamma_{\mathrm{w}} \cdot \bar{V}_{\mathrm{w}}}{\gamma_{\mathrm{om}} \cdot \bar{V}_{\mathrm{om}} \cdot \rho_{\mathrm{om}}} \tag{11-18}$$

where γ_{om} is the activity coefficient reflecting the incompatibility of the sorbate associated with the natural organic matter as compared to in solution with a liquid of itself. Again, this result is analogous to what we had before for partitioning between organic solvents and water (see Eq. 7-4).

Now, for a given chemical sorbate and a particular soil or sediment, all the terms on the right-hand side of Eq. 11-18 may be virtually constant for all concentrations of the hydrophobic sorbate in water. As we saw before, γ_{w} is practically independent of C_{w} for neutral nonpolar compounds (see Section 6.2); and since $\bar{V}_{\mathrm{w}}$, $\bar{V}_{\mathrm{om}}$, and ρ_{om} are properties of the solution and solid phase which are generally unaffected by the

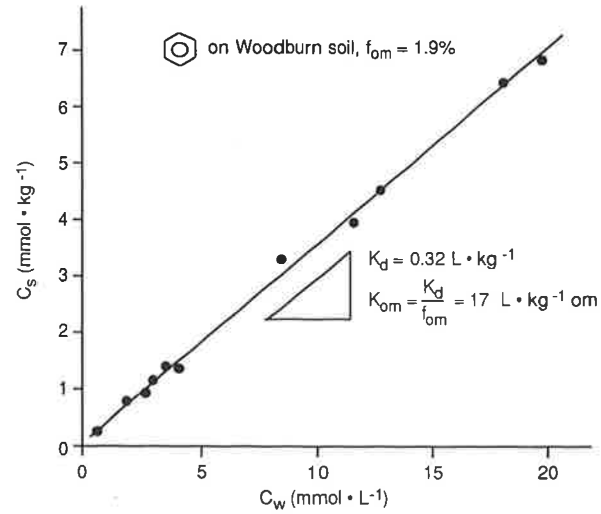


Figure 11.7 Linear variation of sorbed benzene concentration C_s with aqueous benzene concentration C_w up to 85% of benzene's solubility in water. Data from Chiou et al. (1983).

presence of submillimolar levels of neutral nonpolar compounds, these inputs to Eq. 11-18 may reasonably by presumed constant. Finally, the activity coefficient of a sorbate in natural organic matter may not be too much above 1 if this material can be as accommodating as a solvent like octanol (recall Table 7.1); and therefore it should not change much if more and more organic sorbate is mixed into this particular phase. Thus, one can expect K_{om} to remain constant for a particular sorbate–sorbent combination at all concentrations of the compound in the water. This means that the solid–water distribution ratio K_d must also remain invariant (i.e., a linear isotherm), since the product $f_{om} \cdot K_{om}$ does not change. This is seen experimentally, as shown in Figure 11.7 for benzene absorption on a soil. Here we see the concentration of benzene associated with this particular soil increased linearly as the levels of this compound in the water were increased. The slope of this graph yields the solid–water distribution ratio for this case:

$$K_d(\text{benzene, Woodburn soil}) = \frac{C_s}{C_w} = 0.32 \frac{\text{mol} \cdot \text{kg}^{-1}\ \text{soil}}{\text{mol} \cdot \text{L}^{-1}\ \text{water}} \tag{11-19}$$

And realizing that the natural organic matter of the soil ($f_{om} = 0.019$) was predominately responsible for benzene sorption, we may also calculate

$$\begin{aligned} K_{om}(\text{benzene}) &= \frac{K_d(\text{benzene, Woodburn soil})}{f_{om}(\text{Woodburn soil})} \\ &= 17 \frac{\text{mol} \cdot \text{kg}^{-1}\ \text{om}}{\text{mol} \cdot \text{L}^{-1}\ \text{water}} \end{aligned} \tag{11-20}$$

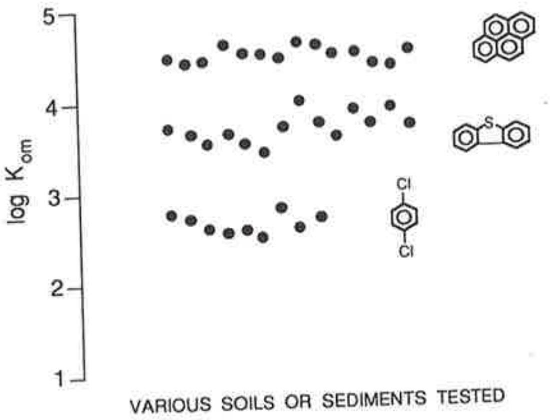


Figure 11.8 Similarity of log K_{om} values observed for particular nonpolar organic chemicals absorbing to a wide variety of soils and sediments. Data from Means et al. (1980), Hassett et al. (1980), Schwarzenbach and Westall (1981), and Chiou et al. (1983).

When one examines the K_{om} values for a single neutral nonpolar chemical sorbing to a variety of soils and sediments, one typically finds almost the same K_{om} result. Figure 11.8 shows such constancy of K_{om} for three chemicals: 1,4-dichlorobenzene, dibenzothiophene, and pyrene, sorbing to many soils and sediments. This near constancy of K_{om} values for a nonpolar organic chemical can be interpreted by considering Eq. 11-18. First, it is obvious that the numerator, $\gamma_w \cdot \bar{V}_w$, does not change for different sorbents. If the composition of natural organic matter does not vary much from the point of view of acting as a solvent for neutral nonpolar chemicals, then for a variety of sediments and soils, the product $\gamma_{om} \cdot \bar{V}_{om} \cdot \rho_{om}$ may also be similar. Much of the variability shown in Figure 11.8 is due to substantially different analytical techniques used by various investigators, but some is probably caused by differences in the polarity of the natural organic matter investigated (Garbarini and Lion, 1986; Chiou et al., 1987; Gauthier et al., 1987). But even including such variability, for any one chemical it seems log K_{om} is a constant within ± 0.3 log K_{om} units ($\pm$ a factor of 2 in K_{om}).

Linear Free Energy Relationships to Estimate K_{om}'s Now we may consider what factor(s) governs the magnitude of the K_{om} for a particular neutral nonpolar sorbate. For a series of compounds absorbing into the natural organic matter of a single soil or sediment (hence $\bar{V}_w$, $\bar{V}_{om}$ and ρ_{om} in Eq. 11-18 held constant), we need to evaluate the sizes of their γ_w's and γ_{om}'s. This is very similar to the situation we discussed before regarding organic solvent–water partitioning (Chapter 7). Since the organic sorbates are much more similar to the natural organic matter than to the water in terms of polarity and ability to interact with their surroundings via intermolecular attractions, we expect the γ_w's will be much larger than γ_{om}'s, and that the γ_{om}'s will not be much greater than 1. Once again, this is analogous to what we encountered in the case of organic chemical partitioning between octanol and water (Table 7.1). Since the γ_{om}'s are near 1, they will not vary much from organic chemical to chemical; in contrast, we know that various neutral organic chemicals exhibit γ_w's that vary by orders of magnitude (see Chapter 5). Consequently, differences, in K_{om} from chemical to chemical primarily arise from corresponding differences in their γ_w's.

A major result of realizing the strong relationship of K_{om}'s and γ_w's for a series of organic sorbates is that we deduce that the free energy driving this absorption is determined largely by the excess free energy of aqueous solution (i.e., $\Delta G_{\text{sorption to om}} \sim \Delta G_s^e$). This situation is therefore well suited to a free energy relationship between $\Delta G_{\text{absorption}}$ and ΔG_s^e. Indeed, plots of log K_{om} ($= -\Delta G_{\text{absorption}}/2.303\ RT$) versus log C_w^{sat} (l, L) ($= -\Delta G_s^e/2.303RT - \log \bar{V}_w$) for various sets of organic compounds show strong inverse correlations of the form (Table 11.2)

$$\log K_{om} = -a \cdot \log C_w^{sat}(\text{l, L}) + b \qquad (11\text{-}21)$$

where K_{om} is given in units of (mol·kg^{-1} om/mol·L^{-1} water) and C_w^{sat} has units of (mol·L^{-1} water). For different sets of sorbates, different values of the coefficients a and b are seen and this undoubtedly reflects systematic variations in the compatibility of compound classes with the natural organic matter. Nonetheless, an overall strong inverse correlation of log K_{om} with log C_w^{sat}(l, L) exists as shown in Figure 11.9.

Since K_{om} and C_w^{sat}(l, L) properties of sorbates are related, it follows that any other

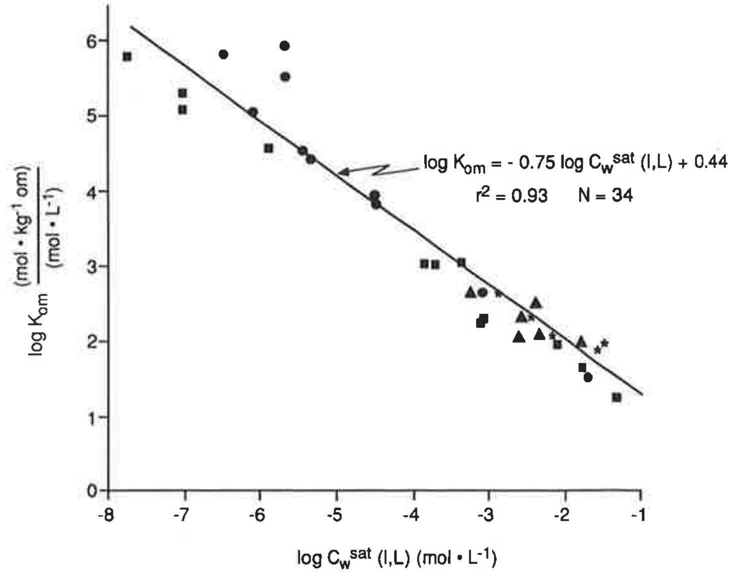


Figure 11.9 Inverse relationship of log K_{om} and log (liquid) aqueous solubility of neutral organic compounds: (●) aromatic hydrocarbons, (■) chlorinated hydrocarbons, (▲) chloro-*S*-triazines, and (*) phenyl ureas (data compiled by Karickhoff, 1981). See Table 11.2 for correlations for individual compound classes.

TABLE 11.2 LFERs Between log K_{om} and log $C_w^{sat}(l, L)$ or log K_{ow}[a]

		$\log K_{om} = -a \cdot \log C_w^{sat}(l, L) + b$ $(L \cdot kg^{-1}\, om)(mol \cdot L^{-1})$			(r^2)	Compound Class
Eq. 11-21a	$a =$	0.93	$b =$	−0.17	(0.92)	Aromatic hydrocarbons
Eq. 11-21b		0.70		+0.35	(0.99)	Chlorinated hydrocarbons
Eq. 11-21c		0.41		+1.20	(0.54)	Chloro-*S*-triazines
Eq. 11-21d		0.56		+0.97	(0.94)	Phenyl ureas
		$\log K_{om} = c \cdot \log K_{ow} + d$ $(L \cdot kg^{-1}\, om)(L_{water} \cdot L_{octanol}^{-1})$				
Eq. 11-22a	$c =$	1.01	$d =$	−0.72	(0.99)	Aromatic hydrocarbons
Eq. 11-22b		0.88		−0.27	(0.97)	Chlorinated hydrocarbons
Eq. 11-22c		0.37		+1.15	(0.93)	Chloro-*S*-triazines
Eq. 11-22d		1.12		+0.15	(0.93)	Phenyl ureas
Eq. 11-22e		0.81		−0.25	(0.98)	Chlorophenols

[a] Data from Karickhoff, 1981 and Schellenberg et al., 1984.

chemical property which is related to $C_w^{sat}(l, L)$ must also correlate with K_{om}. For example, log K_{om} should be directly related to log K_{ow} [inversely proportional to log $C_w^{sat}(l, L)$, see Chapter 7]. Table 11.2 also shows the values of the slope and intercept of relationships for compound classes of the form

$$\log K_{om}\left[\frac{\text{mol}\cdot\text{kg}^{-1}\,\text{om}}{\text{mol}\cdot\text{L}^{-1}\,\text{water}}\right] = c\cdot\log K_{ow}\left[\frac{\text{mol}\cdot\text{L}^{-1}\,\text{octanol}}{\text{mol}\cdot\text{L}^{-1}\,\text{water}}\right] + d \qquad (11\text{-}22)$$

Again, the values of this equation's coefficients vary between compound classes, but the overall trend is strong (Fig. 11.10).

Such linear free-energy relationships (Eqs. 11-21 and 11-22) provide one of the best means with which we can use well-known physical chemical properties of neutral chemicals [e.g., $C_w^{sat}(l, L)$ and K_{ow}] to estimate the magnitude of K_{om} for a compound of interest. Obviously, one obtains a somewhat more accurate estimate if one uses a correlation equation based on a set of chemicals from the sorbate's own compound class; however, without this kind of information, a reasonable K_{om} estimate can be obtained from expressions averaging results from many compound classes (like those illustrated in Figs. 11.9 and 11.10):

$$\log K_{om}\left[\frac{\text{mol}\cdot\text{kg}^{-1}\,\text{om}}{\text{mol}\cdot\text{L}^{-1}\,\text{water}}\right] \simeq -0.75\log C_w^{sat}(l, L)(\text{mol}\cdot\text{L}^{-1}\ \text{water}) + 0.44 \qquad (11\text{-}23)$$

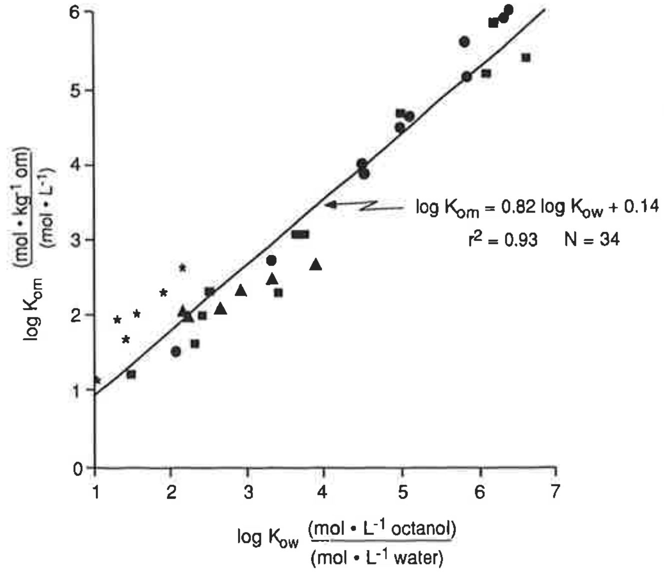


Figure 11.10 Relationship of log K_{om} and log K_{ow} for a series of neutral organic compounds: (●) aromatic hydrocarbons, (■) chlorinated hydrocarbons, (▲) chloro-*S*-triazines, and (*) phenyl ureas (data compiled by Karickhoff, 1981). See Table 11.2 for correlations of each compound class.

or

$$\log K_{\mathrm{om}}\left[\frac{\mathrm{mol\cdot kg^{-1}\ om}}{\mathrm{mol\cdot L^{-1}\ water}}\right] \simeq +0.82 \log K_{\mathrm{ow}}\left[\frac{\mathrm{mol\cdot L^{-1}\ octanol}}{\mathrm{mol\cdot L^{-1}\ water}}\right] + 0.14 \qquad (11\text{-}24)$$

Reversibility and Competitive Effects of Neutral Compound Sorption to Natural Organic Matter Our image of neutral chemical interactions with the natural organic matter of particles suggests that such sorption must be *reversible.* We see that the only "bonds" that are made between the sorbate and the natural organic sorbent are through relatively weak intermolecular attractions. Thus, to desorb these nonpolar chemicals, only small activation energies are needed to separate these compounds from their points of solid attachment. This reversibility has been demonstrated experimentally for nonpolar compounds like polycyclic aromatic hydrocarbons and nonpolar insecticides (Karickhoff et al., 1979), PCB congeners (Gschwend and Wu, 1985), and solvents like tetrachloroethylene and toluene (Garbarini and Lion, 1985). Additionally, many nonpolar chemicals can partition between water and the available volume of natural organic matter at the same time and without getting in each others' way (Karickhoff et al., 1979; Chiou et al., 1983). We refer to this as *noncompetitive* sorption. As was the case for organic solvent–water partitioning, this implies that so little nonpolar chemical enters the organic phase that the overall properties of the natural organic matter do not change and the resultant intermolecular interactions within the medium remain essentially constant.

Effect of Temperature on K_{om} Since we envision neutral compound absorption to be like a solvent–water partitioning process, we can immediately deduce the likely effect of conditions such as temperature on K_{om}. First, as we recall from our discussions of aqueous solubility, over a narrow temperature range, the logarithm of a chemical's aqueous activity coefficient varies according to (see Section 5.4)

$$\ln \gamma_{\mathrm{w}} = \frac{\Delta H_{\mathrm{s}}^{\mathrm{e}}}{RT} + \text{constant} \qquad (11\text{-}25)$$

Thus, the variation in γ_{w} with temperature will depend on the magnitude of $\Delta H_{\mathrm{s}}^{\mathrm{e}}$. Typically, small nonpolar solutes like benzene exhibit small values of $\Delta H_{\mathrm{s}}^{\mathrm{e}}$, but within any one family of compounds (e.g., PAHs or alcohols), we saw that $\Delta H_{\mathrm{s}}^{\mathrm{e}}$ steadily increased as the nonpolar molecular surface area of contact with the water solvent increased. A similar expression should apply for γ_{om}.

$$\ln \gamma_{\mathrm{om}} = \frac{\Delta H_{\mathrm{s,om}}^{\mathrm{e}}}{RT} + \text{constant} \qquad (11\text{-}26)$$

where $\Delta H_{\mathrm{s,om}}^{\mathrm{e}}$ is the excess enthalpy of the sorbate's mixing with natural organic matter. If the natural organic matter can approximately mimic the van der Waals attractions over the molecular surface that the sorbate enjoyed in a pure liquid of itself, then the change in enthalpy of dissolution into natural matter from the pure organic liquid will be quite small. This result, in turn, implies that γ_{om} is not particularly sensitive to temperature.

Since $\bar{V}_w$ and $\bar{V}_{om}$ vary only slightly with temperature, the effect of temperature on K_{om} values will chiefly arise from its impact on γ_w. Although very little data is available to check this conclusion, the literature does support it. First, Chiou et al. (1979) reported very small heats of absorption for organic chemicals frequently used as solvents, consistent with their small heats of solution in water. Also, Wu and Gschwend (1986) observed ΔH_{abs} of 1,2,3,4-tetrachlorobenzene to be about $-15\,\mathrm{kJ \cdot mol^{-1}}$. Although the heat of solution of this compound has not been directly measured, it can be estimated using Eq. 5-18, the known (liquid) solubility of this compound ($10^{-4.20}$ M or 1.14×10^{-6} mol fraction), and an estimate of ΔS_s^e of $-56\,\mathrm{J \cdot mol^{-1} K^{-1}}$ (see Table 5-3). Thus,

$$\begin{aligned} \Delta H_s^e &\simeq -RT \ln x_w + T\Delta S_s^e \\ &= -(8.31\,\mathrm{J \cdot mol^{-1} K^{-1}})(293\,\mathrm{K})(\ln 1.14 \times 10^{-6}) \\ &\quad + (293\,\mathrm{K})(-56\,\mathrm{J \cdot mol^{-1} K^{-1}}) \\ &= 33\,\mathrm{kJ \cdot mol^{-1}} - 16\,\mathrm{kJ \cdot mol^{-1}} \\ &= +17\,\mathrm{kJ \cdot mol^{-1}} \end{aligned} \tag{11-27}$$

For the process removing the solute from the sorbent, this enthalpy would be negative in approximate agreement with the observed enthalpy of sorption ($-15\,\mathrm{kJ \cdot mol^{-1}}$). Consequently, it appears reasonable to expect K_{om} to vary in an equal, but opposite, manner as the neutral chemical's liquid solubility in water. For large nonpolar compounds like pyrene exhibiting $\Delta H_s^e \simeq +25\,\mathrm{kJ \cdot mol^{-1}}$, we then anticipate an *exothermic* $\Delta H_{abs} \approx -25\,\mathrm{kJ \cdot mol^{-1}}$. Such enthalpy effects imply pyrene's sorption to natural particles should decrease as we increase temperature:

$$\begin{aligned} \frac{K_{om}(T_1 = 293\,K)}{K_{om}(T_2 = 283\,\mathrm{K})} &\simeq \frac{\gamma_w(293\,\mathrm{K})}{\gamma_w(283\,\mathrm{K})} \\ &\simeq \exp\left[\frac{\Delta H_s^e}{R}\left(\frac{1}{293} - \frac{1}{283}\right)\right] \\ &\simeq 0.7 \end{aligned} \tag{11-28}$$

That is, warming a solid–water suspension by 10°C results in an estimated 30% diminished absorption coefficient as a consequence of correspondingly decreased activity coefficient for pyrene in water.

Effect of Dissolved Salts on K_{om} Since solvated inorganic ions would not be expected to interfere or compete with the penetration of nonpolar organic compounds into natural organic matter, one can reasonably assume that salts affect the values of K_{om} primarily through the γ_w term also. As we saw in Chapter 5, a quantitative description of the impact of dissolved salts on aqueous solubilities (and hence γ_w's) was provided by the Setschenow relationship; a transformation of this formula (Eq. 5-22) yields

$$C_{\mathrm{w,salt}}^{\mathrm{sat}} = C_{\mathrm{w}}^{\mathrm{sat}} \cdot 10^{-K^{\mathrm{s}}[\mathrm{salt}]} \qquad (11\text{-}29)$$

Since K_{om} values are predictable from a chemical's $C_{\mathrm{w}}^{\mathrm{sat}}(1, \mathrm{L})$, we may substitute Eq. 11-29 into Eq. 11-21 to characterize how K_{om} changes in the presence of dissolved salts:

$$\begin{aligned}
\log K_{\mathrm{om,salt}} &= -a \cdot \log(C_{\mathrm{w,salt}}^{\mathrm{sat}}) + b \\
&= -a \cdot \log(C_{\mathrm{w}}^{\mathrm{sat}} \cdot 10^{-K^{\mathrm{s}}[\mathrm{salt}]}) + b \\
&= -a \cdot \log C_{\mathrm{w}}^{\mathrm{sat}} - a \cdot (-K^{\mathrm{s}}) \cdot [\mathrm{salt}] + b \\
&= \log K_{\mathrm{om}} + a \cdot K^{\mathrm{s}} \cdot [\mathrm{salt}] \qquad (11\text{-}30)
\end{aligned}$$

where $K_{\mathrm{om,salt}}$ is the organic matter–water partition coefficient when the aqueous solution contains dissolved salts. The second term on the right-hand side of Eq. 11-30 quantifies the magnitude of change we expect for individual cases. As we saw in Table 11.2, a values are typically between 0.5 and 1 for various compound classes, and from Table 5.6 we recall K^{s} was about 0.1–0.4 depending on the chemical of interest. Thus we may expect $\log K_{\mathrm{om,salt}}$ in a salty solution like seawater ($[\mathrm{salt}] \simeq 0.6$ M) to be higher than $\log K_{\mathrm{om}}$ by about $\{(0.5 \text{ to } 1) \cdot (0.1 \text{ to } 0.4) \cdot [0.6]\}$ or 0.03–0.24 log units. This amounts to increasing $K_{\mathrm{om,salt}}$ over K_{om} by only several percent for relatively small and polar neutral organic compounds (i.e., a nearer to 0.5 and K^{s} nearer to 0.1) and by a factor approaching 2 for large, very nonpolar sorbates (i.e., a close to 1 and K^{s} around 0.4).

As was the case for the effects of temperature on K_{om}, there is not much data to verify these results. Karickhoff et al. (1979) found that pyrene sorption coefficients increased by 15% in going from pure water to sodium chloride solution concentration of 0.34 M. We may compare the effectiveness of Eq. 11-30 by estimating what we would expect for this case. First, for aromatic hydrocarbons Eq. 11-21a suggests a value of a to be 0.93; from Table 5.6 we see that a suitable value for $K^{\mathrm{s}}(\mathrm{pyrene, NaCl})$ would be 0.29. Thus we may estimate for this case:

$$\begin{aligned}
\log K_{\mathrm{om,salt}}(\text{pyrene, 0.34 M NaCl}) &= \log K_{\mathrm{om}}(\text{pyrene}) \\
&\quad + (0.93)(0.29)(0.34) \\
&= \log K_{\mathrm{om}}(\text{pyrene}) + 0.09 \qquad (11\text{-}31)
\end{aligned}$$

This predicts that the organic matter–water partition coefficient of pyrene with 0.34 M NaCl would be about 24% higher than the corresponding case without dissolved salt, a result not too different than that which was observed. This discrepancy (15% observed versus 24% predicted) may indicate other factors are at play, such as salts causing changes in the coiling of the natural organic matter and concomitant changes in its solvency for neutral organic sorbates (i.e., changing γ_{om}). However, the prediction of Eq. 11-31 looks reasonable to a very good first approximation, and one probably rightly concludes that typical levels of dissolved salts do not cause major changes in K_{om} values.

Influence of Cosolvents on K_{om} Sometimes we may be concerned with the sorption of neutral organic compounds to soils from solutions in which a substantial concentration of organic solvent is also present. This could occur, for example, at a groundwater site where water-miscible liquids like acetone or methanol were codisposed with other organic chemicals. In such a case, the tendency of the organic chemicals to sorb to the soil's organic matter might be changed by the organic cosolvent's effects on γ_{om} and γ_{w}. The inclusion of substantial amounts of the cosolvent into the soil's natural organic matter would influence γ_{om}, but since these activity coefficients are near 1 to start with, such effects are probably not too big. However, as we discussed in Chapter 5, the presence of cosolvents can greatly change a chemical's aqueous solubility. Using our knowledge of that effect, we are already in a position to estimate the importance of cosolvent to K_{om} values.

First, we recall Eq. 5-32 and convert to a molar basis to describe the influence of a cosolvent on a sorbate's solubility:

$$\log C_{\mathrm{mix}}^{\mathrm{sat}} = \log C_{\mathrm{w}}^{\mathrm{sat}} + \log \frac{\bar{V}_{\mathrm{w}}}{\bar{V}_{\mathrm{mix}}} + \frac{0.5 f_{\mathrm{c}} N(\sigma_{\mathrm{t:w}} - \sigma_{\mathrm{t:c}})(\mathrm{HSA})}{2.303\,RT} \tag{11-32}$$

where $C_{\mathrm{mix}}^{\mathrm{sat}}$ is the solubility in an aqueous solution containing an organic cosolvent (mol·L^{-1} mixed solution), $\bar{V}_{\mathrm{mix}}$ is the molar volume of the mixed solution (L mixed solution·mol^{-1} total solvents), and the other terms remain as defined previously (see Section 5.4).

Using this result in our relationship between K_{om} and $C_{\mathrm{w}}^{\mathrm{sat}}$ (Eq. 11-21), we arrive at:

$$\begin{aligned}
\log K_{\mathrm{om,mix}} &= -a \cdot \log (C_{\mathrm{mix}}^{\mathrm{sat}}) + b \\
&= -a \cdot \left(\log C_{\mathrm{w}}^{\mathrm{sat}} + \log \frac{\bar{V}_{\mathrm{w}}}{\bar{V}_{\mathrm{mix}}} + \frac{0.5 f_{\mathrm{c}} N(\sigma_{\mathrm{t:w}} - \sigma_{\mathrm{t:c}})(\mathrm{HSA})}{2.303\,RT} \right) + b \\
&= \log K_{\mathrm{om}} - a \cdot \left[\log \frac{\bar{V}_{\mathrm{w}}}{\bar{V}_{\mathrm{mix}}} + \frac{0.5 f_{\mathrm{c}} N(\sigma_{\mathrm{t:w}} - \sigma_{\mathrm{t:c}})(\mathrm{HSA})}{2.303\,RT} \right]
\end{aligned} \tag{11-33}$$

This equation first suggests that the natural organic matter–water partition coefficients will change because of differences in the solution's molar volume from that of water. Also, the third term on the right-hand side of Eq. 11-33 indicates that the attractiveness of the cosolvent–water mixture for maintaining the sorbate in solution will lower $\log K_{\mathrm{om,mix}}$ relative to $\log K_{\mathrm{om}}$.

A brief calculation exemplifies the magnitude of these effects. Suppose we were interested in the sorption of anthracene (HSA = 202 Å^2) from an aqueous solution containing 10% methanol by volume. First, we could calculate that $\bar{V}_{\mathrm{mix}} \approx 0.0185$ L·mol^{-1} total by assuming the methanol and water mix with no change in total volume. Thus the term $\log(\bar{V}_w/\bar{V}_{mix})$ is quite small (≈ 0.01). Next, to estimate the importance of the second term in brackets of Eq. 11-33, we apply Eq. 11-33 with $(\sigma_{t:w} - \sigma_{t:c})$ taken as $52 \times 10^{-7}\ \mathrm{J/cm^2}$:

$$a \cdot \left(\frac{0.5 f_c N(\sigma_{t:w} - \sigma_{t:c})(\mathrm{HSA})}{2.303\, RT} \right) =$$

$$(0.93) \cdot \frac{0.5 \cdot 0.1 \cdot 6.02 \times 10^{23}\ \dfrac{\text{molecules}}{\text{mol}} \cdot \left(52 \times 10^{-7}\ \dfrac{\mathrm{J}}{\mathrm{cm^2}} \right) \left(202 \times 10^{-16}\ \dfrac{\mathrm{cm^2}}{\text{molecule}} \right)}{2.303 \cdot 8.31\ (\mathrm{J/mol \cdot K}) \cdot 293\ \mathrm{K}}$$

$$= 0.52 \qquad (11\text{-}34)$$

This result implies that $K_{om,mix}$(pyrene, 10% methanol) is lower than the corresponding K_{om}(pyrene) by a factor of $10^{-0.52}$ or 0.30. Experiments by Nkedi-Kizza et al. (1985) observed anthracene's K_{om} to decrease by a factor of 0.4 under these conditions. These investigators demonstrated that this approach for estimating the influence of cosolvents on K_{om} appears to work well for cosolvent fractions less than 25%.

Sorption of Neutral Chemicals to Organic Colloids Until now, we have not been concerned about the size of the particles with which the nonpolar chemicals became associated. This factor is generally not critical unless we are interested in sorption kinetics (see Section 11.7) or when we are concerned with separating the particles from suspensions. Such a separation becomes important if we are trying to measure contaminant concentrations in the dissolved versus sorbed phases or if we are interested in predicting how a chemical might be carried by moving water. In these cases, one often finds that the smallest of particles, called *colloids*, are not separable from the water. Thus, chemicals of interest to us would occur in the fluid both as truly dissolved species and as molecules associated with very small particles or macromolecules.

Colloids are microparticles or macromolecules that are small enough to move primarily by Brownian motion, as opposed to gravitational settling, and are large enough to provide a microscopic "environment" into or onto which molecules of interest to us can escape the aqueous solution. This means colloids range from about a few nanometers to around a few micrometers in dimension. Based on this perception, organic colloids in natural waters would include humic substances and proteins, viruses and nonmotile bacteria, and organic coatings on very small inorganic particles (e.g., aluminosilicates, iron oxides).

A variety of approaches have been used to demonstrate that colloidal organic matter may serve to absorb nonpolar organic chemicals much like the organic materials associated with larger soil and sediment particles. For example, Chiou et al. (1986) have shown that the "apparent solubility" of compounds like DDT or PCB congeners is increased in solutions containing humic substances over that seen for pure water alone (Fig. 11.11). The interpretation of these data is that the true aqueous solubility is not affected, but rather the additional nonpolar chemical molecules are associated

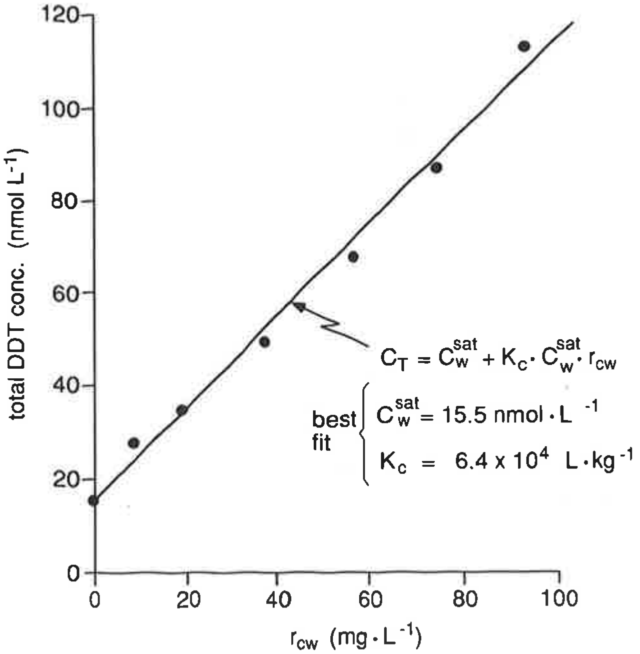


Figure 11.11 Increase in total DDT concentration in aqueous solution as a function of concentration of humic colloids, r_{cw} (data of Chiou et al., 1986). Interpreting the total DDT as a sum of truly dissolved DDT (C_w^{sat}) and DDT bound to colloids ($K_c C_w^{sat} r_{cw}$) fits the data very well.

with the humic colloids. Similarly, Carter and Suffet (1982) have shown that DDT associates with humic materials retained within dialysis tubing.

Much as we saw before for large sediment and soil particles, the tendency for different organic chemicals to associate with organic colloids is directly related to the aqueous activity coefficient of the chemicals. This should not be too surprising since it is largely the same types of organic matter, whether attached to large mineral grains or dispersed as colloidal suspensions, which are acting as absorbents. Some indications exist which show that there is some decrease in colloidal sorbent effectiveness, especially as the organic matter becomes more polar as reflected in C/O ratios (Chiou et al., 1986; Garbarini and Lion, 1986; Gauthier et al., 1987; Chin and Weber, 1989). Nonetheless, K_{om} values for colloidal organic matter generally appear similar to these reported for larger particulate organic matter.

The association of nonpolar chemicals with colloidal organic matter results in several very important effects on the behavior of those compounds. First, the organic molecules in a colloidal suspension exhibit a tendency to leave the suspension and move into adjacent gaseous phases only in proportion to the truly dissolved fraction of molecules (i.e., proportional to their fugacity). This has been seen in a dynamic system such as that employed by Mackay et al. (1979), where bubbled solutions transmitted the chemicals to the headspace at diminished rates when colloid association became important. Similarly, Brownawell (1986) observed diminished PCB congener vapor pressures over seawater suspensions of colloids compared to seawater solutions devoid of organic colloids. It is clear from these data that nonpolar chemicals distribute themselves between truly dissolved and colloid-bound states, and that the dissolved species dictate equilibria with other phases. Consequently, when we are interested in colloid-containing solutions that exchange chemicals into the air, we must recognize that the air–water distribution ratio (D_{aw}) describing the concentrations in each phase has the form

$$D_{\mathrm{aw}} = \frac{C_{\mathrm{a}}}{C_{\mathrm{w}} + C_{\mathrm{c}} \cdot r_{\mathrm{cw}}} \tag{11-35}$$

where C_{c} is the concentration of chemical associated with colloids per mass of colloid ($\mathrm{mol \cdot kg^{-1}}$ colloids) and r_{cw} is the mass of colloids per volume of solution (kg colloids$\cdot\mathrm{L}^{-1}$). If we define a sorption coefficient for the colloids analogous to that for larger particles (Eq. 11-1),

$$K_{\mathrm{c}} = \frac{C_{\mathrm{c}}}{C_{\mathrm{w}}} \tag{11-36}$$

we may combine Eqs. 11-35 and 11-36 to get

$$\begin{aligned} D_{\mathrm{aw}} &= \frac{C_{\mathrm{a}}}{C_{\mathrm{w}} + K_{\mathrm{c}} C_{\mathrm{w}} r_{\mathrm{cw}}} \\ &= K_{\mathrm{H}} \cdot (1 + K_{\mathrm{c}} r_{\mathrm{cw}})^{-1} \end{aligned} \tag{11-37}$$

where K_{H} is the "true" Henry's Law constant reflecting the equilibrium between the truly dissolved species and its vapor molecules. We should note that the term $(1 + K_{\mathrm{c}} r_{\mathrm{cw}})^{-1}$ is simply the fraction of molecules remaining dissolved in this case. Thus the air–water distribution ratio is simply the true K_{H} multiplied by the fraction of molecules participating in air–water exchange. This result indicates that when colloids are quite abundant in a solution (high r_{cw}) or the chemical–colloid combination of interest exhibits a large K_{c}, we should expect air–water partitioning to diverge substantially from the simple situation quantified by K_{H} alone.

Another important ramification of such colloid binding of nonpolar chemicals is that this process diminishes the tendency of such substances to bioaccumulate in aquatic organisms. Leversee et al. (1983) showed this for the uptake of polycyclic aromatic hydrocarbons by *Daphnia*, a freshwater zooplankter. Also, colloid association changes the light-processing characteristics of nonpolar chemicals. For example, Gauthier et al. (1986, 1987) and Backhus and Gschwend (1990) have shown how association of aromatic hydrocarbons with organic colloids diminishes their ability to fluoresce. Clearly, organic chemicals behave differently in many ways when associated with colloids than when they are dissolved in water.

A final major consequence of nonpolar chemical sorption by organic colloids involves efforts to distinguish experimentally the abundances in sorbed and dissolved forms. In batch sorption tests, when we try to separate water from all particles in a soil or sediment suspension, it is practically impossible not to include some colloids with the water. Such colloids go through typical filters and are difficult to sediment, even with intensive centrifugation. As a result, experimental attempts to assess solid–water distribution coefficients virtually always measure colloid-bound molecules with the dissolved ones in the aqueous separate. For that matter, to some extent some water (and associated solute molecules) always remains with the solid separates. As a result, the subsequent processing of measured chemical concentrations for the purpose of K_d calculations should recognize the possibility of such cross-over phases:

$$K_d^{\text{apparent}} = \frac{C_s + C_w V}{C_w + C_c r_{cw}} \tag{11-38}$$

where

C_s is the sorbate concentration on the separated particles ($\text{mol}\cdot\text{kg}^{-1}$),
C_w is the solute concentration in the water ($\text{mol}\cdot\text{L}^{-1}$),
V is the volume of water left with the separated particles ($\text{L}\cdot\text{kg}^{-1}$),
C_c is the sorbate concentration on the colloids ($\text{mol}\cdot\text{kg}^{-1}$), and
r_{cw} is the colloid mass remaining with the bulk of the water ($\text{kg}\cdot\text{L}^{-1}$).

If the solid–water distribution coefficient, defined in Eq. 11-1 as $K_d = C_s \cdot C_w^{-1}$, applies for the separated particles, and we again use a second coefficient, $K_c = C_c \cdot C_w^{-1}$, which applies for the colloidal particles that are not separated from the water, then we may rewrite Eq. 11-38 as

$$K_d^{\text{apparent}} = \frac{K_d + V}{1 + K_c r_{cw}} \tag{11-39}$$

This expression indicates that the apparent solid–water distribution coefficient will only equal the "true" one (as defined by Eq. 11-1) if $V \ll K_d$ and if $K_c r_{cw} \ll 1$. For compounds that do not sorb extensively (low K_d), this result suggests that experimental data may be erroneously high (Fig. 11.12). For chemicals that do tend to sorb (high K_c) and in situations where colloidal phases are substantial (high r_{cw}), batch observations of solid–water partitioning will indicate results lower than K_d (Fig. 11.12). These phase separation difficulties are probably one of the major explanations for the so-called "solids concentration effect" in which K_d appears to decrease with greater and greater loads of total solids (and colloids) in batch sorption systems. Most likely, there is no change in the relative abundances of sorbing nonpolar molecules as the proportions of water and particles are varied (Gschwend and Wu, 1985).

An interesting spinoff of this recognition of colloids in laboratory experiment aqueous phases is the realization that such microparticles and macromolecules undoubtedly exist in natural waters too. As a consequence, one must be concerned

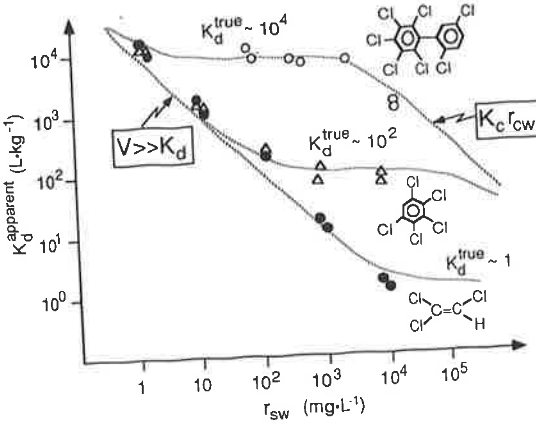


Figure 11.12 Effects of incomplete phase separations on apparent K_d's of three nonpolar sorbates studied as a function of solids-to-water ratio, r_{sw}, using sediment from the Missouri River with $f_{oc} = 0.72\%$ (data from Gschwend and Wu, 1985, and Gschwend, Brownawell, and Wu, unpublished). Model lines through data are for Eq. 11-39, assuming $V = 0.2 \, \text{mL} \cdot \text{g}^{-1}$ and $r_{cw} = 0.02 \, r_{sw}$. Only the horizontal portions of the curves reflect "true" K_d's.

that some portion of the molecules of interest moving with fluid flows are attached to colloids (e.g., Enfield et al., 1989). There is evidence that hydrophobic chemicals like PCBs exist in the surface waters of the Great Lakes, not just as dissolved molecules, but also in association with colloidal phases (Baker et al., 1986). Thus to predict the fate of such chemicals, we may need to consider transport both as dissolved and sorbed-to-colloids forms, and we may need to evaluate transformations remembering that colloid-bound molecules are not free to participate like truly dissolved ones.

11.5 SORPTION OF NEUTRAL ORGANIC CHEMICALS TO POLAR MINERAL SURFACES

In some environments, solids in aquatic systems do not include important amounts of natural organic matter. Consequently, association of organic solutes, especially hydrophobic ones, with mineral surfaces may become significant. This situation exists in groundwater environments where the organic fraction of the aquifer solids is very small (Schwarzenbach and Westall, 1981; Banerjee et al., 1985; Piwoni and Banerjee, 1989). Additionally, clay walls and liners are often used to isolate organic wastes buried below ground; and we may be interested in not only the impact of this low-permeability material on the subsurface hydraulics, but also its suitability for binding organic pollutants and preventing their passage offsite (Boyd et al., 1988). Also, sorption to mineral surfaces may be important when dealing with surface-catalyzed transformations (Ulrich and Stone, 1989). Finally, laboratory glass surfaces and sampling vessels may sorb hydrophobic compounds from aqueous solutions, confusing subsequent data interpretation. Thus, some consideration of the magnitude of the distribution ratio of such compounds between the mineral surface and water and the factors affecting this ratio are in order.

Several investigators have reported "binding" of neutral organic compounds to mineral surfaces (Table 11.3). Although somewhat limited and typically normalized to the mass rather than the surface area of sorbent, these data suggest the following generalizations. First, coarser particles (e.g., silica sand) exhibit less binding than corresponding finer particles made of the same material (e.g., porous silica adsorption of lindane). This is presumably due to the influence of the solid surface area which obviously differs between fine and coarse particles of the same material. Thus, values of sorption coefficients for minerals ($K_{\mathrm{min}} = C_{\mathrm{min}}/C_{\mathrm{w}}$) may be more useful if they are normalized to the solid's surface area rather than its mass (i.e., K_{min} in units like moles per square meter per moles per liter). The second tendency we see is that for any one sorbent, binding increases within a series of sorbates as a function of their aqueous activity coefficients. Therefore, to predict mineral binding as a function of sorbate properties, it appears that, as for absorption into natural organic matter, we should use characteristics related to γ_{w}.

Another clue as to the nature of nonionic compound binding to mineral surfaces comes from studies on the effect of temperature on this process. Increasing the system temperature resulted in diminished sorption in three studies (Mills and Biggar, 1969b; Boucher and Lee, 1972; and van Bladel and Moreale, 1974), indicating that the overall process in these cases was exothermic. Since the dissolution of such nonpolar compounds in water is generally an endothermic process (recall Table 5.4), we may reasonably anticipate that some of this energy yield on mineral sorption came from the removal of those chemicals from aqueous solution. Indeed, in all three studies noted above, after accounting for solution enthalpies, the remaining steps in mineral binding of nonpolar sorbates proved to be energetically neutral or even slightly endothermic. From these results it appears that strong molecule:surface interactions are not involved. Unless some moiety is added which can specifically interact with atoms on a solid's surface, the differential extent of mineral adsorption from one chemical to another may be due chiefly to the variations in their aqueous activity coefficients.

A brief description of the chemical nature of mineral surfaces may help us interpret these neutral–chemical sorption phenomena. Most major minerals expose a surface to the exterior which consists of hydroxyls protruding into the medium from a checkboard plane of electron-deficient atoms (e.g., Si, Al, Fe) and electron-rich ligands (e.g., oxygen, carbonate) (Fig. 11.13*a*). Like water molecules, these surface hydroxyls and ligands prefer to form hydrogen bonds with the molecules adjacent to the mineral surface. We can use data on pure liquid:silica solid attractions reported by Fowkes (1964) to understand the strength of such molecule:surface interactions (Fig. 11.13*b*). While all sorbates are attracted to the surface by van der Waals or dispersive forces, as functional groups capable of dipole:dipole interaction and H-bonding are added, incrementally stronger attractions per unit surface area of silica are observed. Interestingly, from the point of view of the particular series of sorbates shown in Figure 11.13*b*, the attraction energy per molecule remains nearly constant. The relatively

TABLE 11.3 **Observed Values of K_{min} for Nonionic Organic Compounds and Inorganic Solids**

Adsorbent[a]	Sorbate	$\log \gamma_w^{sat}$	K_{min} $[mol \cdot kg^{-1} \cdot (mol \cdot L^{-1})^{-1}]$	Reference[b]
Porous silica				
20°C, 500 m^2/g	Chlorobenzene	4.09	4	1
	1,4-Dichlorobenzene	4.85	6	
	1,2,4-Trichlorobenzene	5.39	8	
	1,2,4,5-Tetrachlorobenzene	6.09	12	
20°C, 890 m^2/g	γ-1,2,3,4,5,6-Hexachloro-cyclohexane (lindane)	5.45	7	2
	β-1,2,3,4,5,6-Hexachloro-cyclohexane	4.99	2	
20°C, 400 m^2/g	Tetrachloroethylene	4.78	13	3
23–27°C, 200 m^2/g	Nitrotoluene	4.04	5	4
23–27°C, 250 m^2/g	1,4-Dichlorobenzene	4.85	3.4	
23–27°C, 1.6 m^2/g	Pentachlorobenzene	6.69	26	
Silica sand				
5°C	γ-1,2,3,4,5,6-Hexachloro-cyclohexane (lindane)	5.45	0.1	5
	Dieldrin	6.72	2	6
	Aldrin	7.20	1.5	
Silica beads				
22°C, 0.6 m^2/g	Pyrene	7.09	0.7	7
γ-Alumina				
20°C, 120 m^2/g	Chlorobenzene	4.09	0.6	1
	1,4-Dichlorobenzene	4.85	0.9	
	1,2,4-Trichlorobenzene	5.39	1.5	
	1,2,4,5-Tetrachlorobenzene	6.09	2.2	

1,4-Dichlorobenzene	4.85	
1,2,4-Trichlorobenzene	5.39	1.5
1,2,4,5-Tetrachlorobenzene	6.09	2.2

Kaolinite				
20°C, 12 m^2/g	Chlorobenzene	4.09	0.6	1
	1,4-Dichlorobenzene	4.85	1.1	
	1,2,4-Trichlorobenzene	5.39	2.4	
	1,2,4,5-Tetrachlorobenzene	6.09	4.9	
Unknown	Aldrin	7.20	3	6
22°C, 12 m^2/g	1,2,4-Trichlorobenzene	5.39	0.3	7
	Pyrene	7.09	50	
	Perylene	8.1	1.3×10^5	
	Methyl perylene	8.7	2.0×10^5	
Montmorillonite	Aldrin	7.20	3	6
Ca–Montmorillonite				
20°C	γ-1,2,3,4,5,6-Hexachlorocyclohexane (lindane)	5.45	3	2
	β-1,2,3,4,5,6-Hexachlorocyclohexane	4.99	4	
26.5°C, 760 m^2/g	Fenuron	2.32	8	8
	Monuron	3.13	13	
Na–montmorillonite				
25°C, 610 m^2/g	Diuron	4.16	23	9
	Fenuron	2.32	14	
	Monuron	3.13	24	
26.5°C, 760 m^2/g	Fenuron	2.32	8	8
	Monuron	3.13	13	
800 m^2/g	Phenol	1.7	0.2	10
	Ethanol	~0	0.2	
	1,4-Dioxane	~0	0.5	
	Urea	~0	0.6	

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[a] Temperature and surface area, if known.

[b] 1. Schwarzenbach and Westall, 1981. 2. Mills and Biggar, 1969a. 3. Estes et al., 1988. 4. Szecsody and Bales, 1989. 5. Boucher and Lee, 1972. 6. Yaron et al., 1967. 7. Backhus, 1990. 8. van Bladel and Moreale, 1974. 9. Bailey et al., 1968. 10. Zhang et al., 1990.

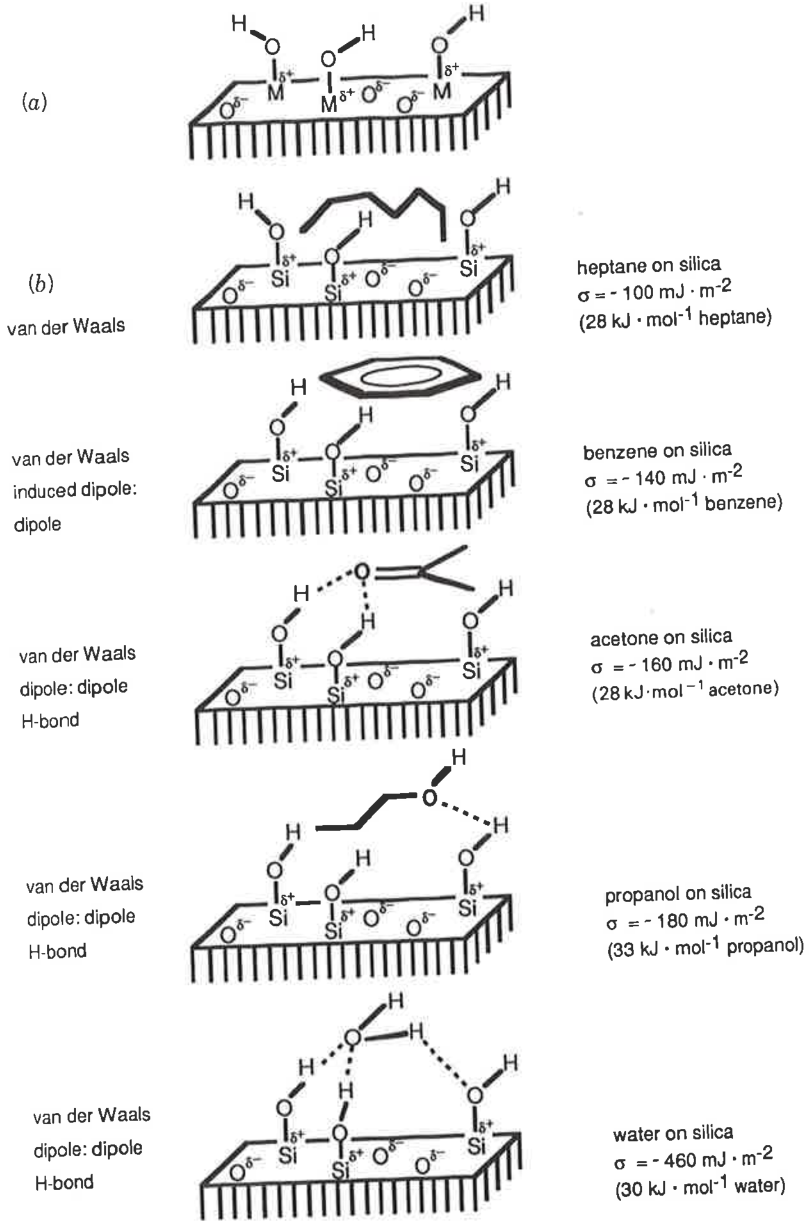

Figure 11.13 (*a*) A schematic view of a mineral surface exhibiting loci of partial positive charges where metal atoms occur (M), partial negative charges where linking anions occur (shown as oxygen atoms), and hydroxyl substituents extending to the exterior. (*b*) Interactions of organic chemicals wetting silica surfaces and a measure of the interaction strengths derived from surface tension data (Fowkes, 1964).

small water molecules make up what they lack in dispersive attraction by using H-bonding. Thus, one anticipates that water is extremely favored in competitions with nonionic organic sorbates for positions on such minerals surfaces, and the energy change on adsorbing such organic chemicals directly to the solid must also reflect the desorption of water from the same area.

The strong interactions of water molecules with solid surfaces causes the water molecules near the surface to be oriented. This organizing effect seems to extend for several layers of water out toward the bulk medium (Drost-Hansen, 1969; Etzler and White, 1987). Thus, a complete image of organic chemical "binding" to minerals from aqueous solutions, especially for nonpolar compounds (i.e., the ones least able to displace adsorbed water), may need to include the advantage gained upon transfer of these compounds into the ordered water layer immediately adjacent to solid surfaces. The volume of this so-called "vicinal water" per mass of sorbent would be directly related to the intraparticle porosity and surface area and consequently should be greater for porous silica ($\sim 0.5\,\mathrm{mL/g}$) than for quartzite sand ($< 0.01\,\mathrm{mL/g}$) and greater for expandable montmorillonite ($\sim 1\,\mathrm{mL/g}$) than for the two-layer clay kaolinite ($< 0.02\,\mathrm{mL/g}$). Such volumes may approach a milliliter per gram in highly porous solids (Ogram et al., 1985; Mikhail et al., 1968a, b) and may reflect the water's behavior for nanometers away from the solid surface. In view of this concept of vicinal water, nonpolar "binding" to minerals may involve not only the exchange of organic sorbates with water molecules at the surface, but also the partitioning between relatively disorganized bulk water and this special volume of ordered water near the solid's surface.

In light of these observations, we may be able to find linear free-energy relationships which are suitable for estimating new K_{min} values. If the tendency of sorbates to escape aqueous solutions is an important factor, as it appears from the very limited available data, we expect the free energy of sorption of neutral organic compounds on minerals to be inversely related to the free energy of aqueous dissolution of those same (liquid) chemicals. This expectation is supported by the available data (Fig. 11.14) when we examine $\log K_{\mathrm{min}}$ (proportional to the sorption free energy) versus $\log \gamma_{\mathrm{w}}$ (reflecting the free energy of dissolution). For both silica and kaolinite sorbents, a correlation is seen of the form

$$\log K_{\mathrm{min}}(\mathrm{L\cdot m^{-2}}) \simeq a\cdot\log\gamma_{\mathrm{w}} + b \qquad (11\text{-}40)$$

where a and b are fitted coefficients. One recent study found that $a \simeq 1.4$ and $b \simeq -11$ for a small set of organic sorbates interacting with silica and kaolinite (Backhus, 1990). Of course, one should not necessarily infer that this expression applies for other mineral types (e.g., carbonates, iron oxides). Although the data are very few and exhibit substantial scatter, this result does suggest it may be feasible to predict mineral surface binding coefficient from properties like $\gamma_{\mathrm{w}}^{\mathrm{sat}}$, $C_{\mathrm{w}}^{\mathrm{sat}}(\mathrm{l,L})$ or K_{ow} of the sorbates.

Based on this limited understanding of the magnitudes of K_{min} values, one may be tempted to try to predict the conditions under which nonpolar chemical sorption to mineral surfaces dominates association with natural organic matter (i.e.,

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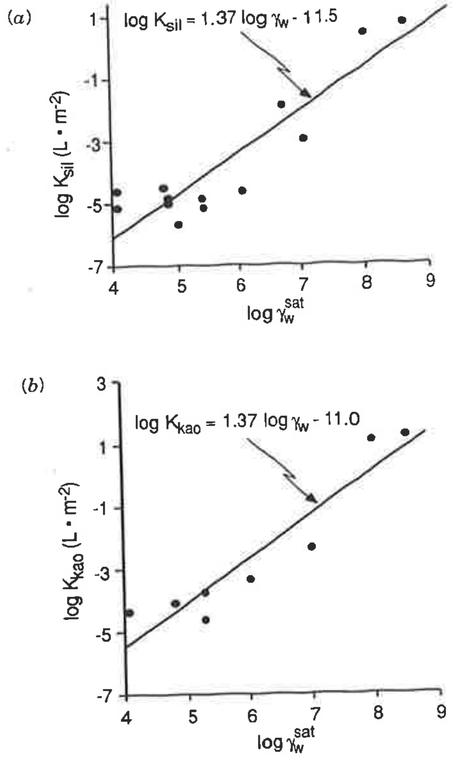


Figure 11.14 Relationship of log K_{min} and log γ_w as illustrated by the data of Yaron et al. (1967), Mills and Biggar (1969a), Schwarzenbach and Westall (1981), Estes et al. (1988), Szecsody and Bales (1989), and Backhus (1990): (*a*) for silica sorbents and (*b*) for kaolinite sorbents.

$A \cdot K_{\mathrm{min}} > f_{\mathrm{om}} \cdot K_{\mathrm{om}}$). However, since sorption of nonpolar sorbates to mineral surfaces is an adsorption phenomenon, it is probably subject to competitive effects arising from the presence of other sorbates. Included in this competition for space on mineral surfaces is the natural organic matter itself. These natural materials are known to attach to kaolinite, iron oxides, and other minerals, especially when the inorganic surfaces are positively charged (Tipping, 1981; Davis, 1982). As a consequence, the available mineral surface area may be inversely related to f_{om}. Thus, we must know not only when $A \cdot K_{\mathrm{min}} > f_{\mathrm{om}} \cdot K_{\mathrm{om}}$, but also how A varies with f_{om} in the system.

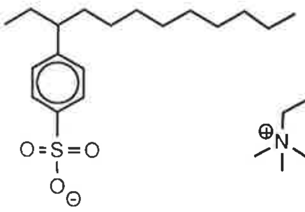
Some empirical approaches have been suggested to indicate when mineral surface sorption of nonpolar compounds starts to become important. First, sorption data appear to fit the pattern exhibited by pyrene in Fig. 11.5 as long as $f_{\mathrm{om}} > 0.002$ to 0.004 (Schwarzenbach and Westall, 1981; Banerjee et al., 1985). Below this cutoff, the influences of mineral surfaces start to be felt. On the other hand, experiments to test for the extent of sorption before and after soil organic carbon oxidation indicate that this natural organic matter continues to play an important role even to virtually unmeasurable levels (Karickhoff, 1984; Lion et al., 1990). Unfortunately, these "thresholds" appear to vary as a function of the sorbate's hydrophobicity (Karickhoff, 1984; Banerjee et al., 1985). Competition between sorption to natural organic matter and to mineral surfaces is probably also a function of other soil or sediment properties, such as the proportion of swelling clays present with their very large specific surface areas (Karickhoff, 1984). Thus, the ratio of A to f_{om} is undoubtedly important. In sum, at f_{om} less than about 0.002 we should begin to consider sorption to mineral surfaces as contributing to the total picture, but this additional sorption mechanism may or may not become dominating depending on the properties of the sorbate and solid mixture of interest.

11.6 ADSORPTION OF IONIZABLE ORGANIC CHEMICALS FROM AQUEOUS SOLUTIONS

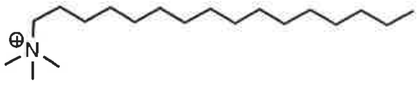
Influences of Charged Moieties Present in Organic Compounds on K_d

Now we begin to consider organic species that exhibit at least one ionic group in their structure (e.g., $—COO^-$, $—NH_3^+$, $—SO_3^-$). Much of the work on this topic has been performed by investigators interested in surfactants, since the inclusion of a charged moiety on an otherwise nonpolar chemical skeleton renders the resultant compound *amphiphilic* (part liking water, part disliking water) and capable of participating in many interesting interfacial phenomena. Also, a good deal of progress has been made by researchers studying the chemistry of inorganic surfaces (e.g., metal oxides) and how these minerals are affected by organic *ligands* (compounds that bind metals; from the Latin *ligare*: to bind).

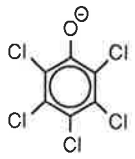
When organic chemicals include structural components that are ionized, for example,



3-Dodecylbenzene sulfonate (anionic detergent)



Hexadecyl trimethyl ammonium (cationic detergent, disinfectant)



Pentachlorophenolate (wood preservative)

a variety of new effects become important insofar as the interactions of these sorbates with solid surfaces are concerned. This is largely due to two phenomena that we have not considered for neutral sorbates: (1) the electrostatic interactions of charged

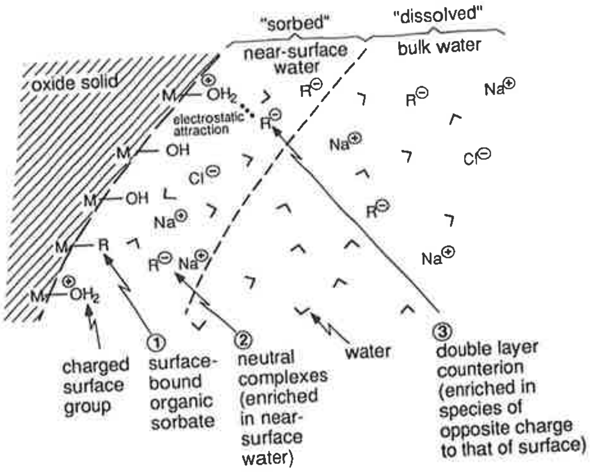


Figure 11.15 A positively charged oxide particle in water attracts anionic species including organic ones (e.g., R^-) to the near-surface water. Some of these anionic species may also react with the surface, displacing other ligands (e.g., H_2O or OH^-), to form surface-bound sorbate. M in the solid refers to atoms like Si, Al, or Fe.

molecules with charged sites on the sorbent (i.e., giving rise to the product $C_{ie} \cdot \sigma_{ie} \cdot A$ in the numerator of Eq. 11-9), and (2) exchange reactions with ligands previously bound to the solid (i.e., contributing to the terms $C_{rxn} \cdot \sigma_{rxn} \cdot A$ is Eq. 11-9).

First, owing to the ubiquitous phenomenon of ionizable surface groups on wet particles, virtually every solid presents a charged surface to the aqueous solution. If this surface charge is of opposite sign (e.g., positive) to that exhibited by an organic functional group (e.g., negative), then there will be an electrostatic attraction (ΔG_{elect}) between the organic sorbate in the bulk solution and the particle surface (Fig. 11.15). Such organic ions will accumulate in the thin film of water surrounding the particle as part of the population of charges in solution balancing the charges on the solid surface. Conversely, organic molecules with charges of like sign as the surface will be repulsed from the near-surface water. These electrostatic effects act similarly for all charged sorbates.

The second interaction involves chemical bonding of the organic compound to the surface or to some component of the solid phase. As depicted in Fig. 11.15, this may involve displacing some ligand previously bound to the surface (e.g., OH^- in Fig. 11.15). Alternatively, such a reaction could look more like the condensation reaction shown in Figure 11.2. Such a surface reaction involves another free energy change (ΔG_{rxn}). *We must note that a surface reaction forms a second sorbed species which is distinct from like-structured organic ions dissolved in the near-surface water* (e.g., $M-R \neq M-OH_2^+ \ldots R^-$).

Finally, we will find that some charged organic compounds include a sufficiently large hydrophobic portion in their structure that transfer into near-surface (i.e., vicinal) water is favored (i.e., due to a negative $\Delta G_{hydrophob}$) even in the absence of surface

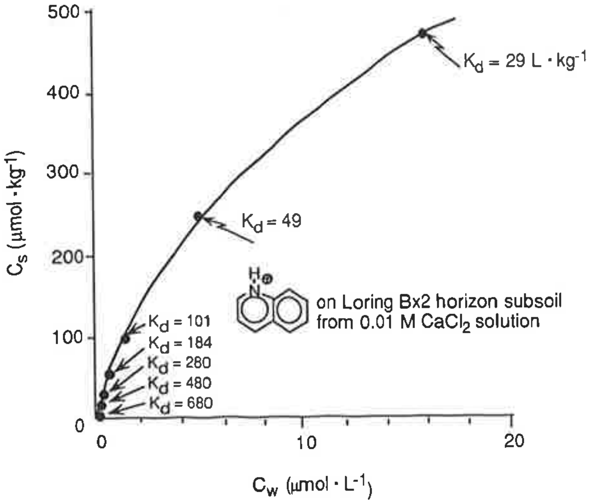


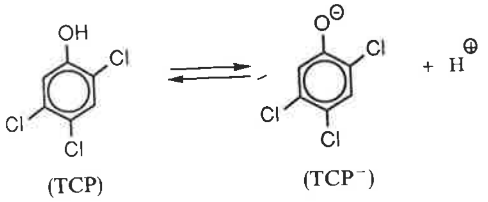
Figure 11.16 Nonlinear sorption isotherm exhibited by quinoline on a subsoil of $f_{om} \simeq 0.48\%$, surface area $\simeq 30.5\ m^2/g$, and cation exchange capacity of 8.4 mmol/100g (data from Zachara et al., 1986).

charges or reactive surface sites. Such sorption requires the cotransfer of a counterion (e.g., Na^+ with R^- in Fig. 11.15) to maintain local electroneutrality.

Experiments typically show that the isotherms of charged organic sorbates are decidedly nonlinear (Fig. 11.16). Said another way, the solid–water distribution ratio changes markedly as a function of the sorbate's own dissolved concentration. The extent of solid association of charged organic compounds also varies as a function of factors like solution pH, since this property governs both the presence of charges on mineral surfaces and the fraction of sorbate in an ionized form. Solution ionic strength and ionic composition also affect the sorption of charged organic chemicals, especially if inorganic ions compete with organic ones for binding sites. Obviously, the mineral composition of the sorbent is a key factor. Not surprisingly, all of these factors make the *a priori* estimation of charged organic chemical sorption to natural soils and sediments much more difficult and complex than for neutral compounds where everything is usually reducible to a few key factors (e.g., γ_w and f_{om}). In the following sections, we examine in more detail the nature of the interactions of charged molecules with charged surfaces and discuss how we might estimate the extent of such (ad)sorption.

Influence on K_d of Organic Compound Speciation in Solution

Before we discuss the sorbate–sorbent interactions that control charged organic species sorption, let us briefly examine the impact of solution pH on the sorption of substances that can be protonated or deprotonated to varying extents depending on their pK_a (recall Chapter 8). As a result of rapid acid–base interconversion, the solution may contain two (or more) organic species, a neutral one, and its conjugate acid or base. Each of these solution species will be involved in its own sorptive exchange phenomena as we noted before (e.g., Eqs. 11-10 through 11-13). Thus, we must begin analyzing ionizable chemical sorption by realizing what fraction of that chemical occurs in its charged, as opposed to its neutral form. For example, if we consider sorption of phenolic compounds like 2,4,5-trichlorophenol ($pK_a = 6.94$):



(11-41)

we may calculate that the fraction of this compound in the neutral form at any pH is (after Eq. 8-16):

$$\alpha_a = \frac{1}{1 + K_a/[H^+]} \qquad (11\text{-}42)$$

Similarly, the proportion present as the charged species is

$$(1 - \alpha_a) = \frac{K_a/[H^+]}{1 + K_a/[H^+]} \qquad (11\text{-}43)$$

Now *we proceed by evaluating the solid interactions of each of these dissolved species separately*. In this case, we anticipate that the neutral species will sorb to natural solids containing natural organic matter just like any other nonionic organic chemical (recall Eq. 11-16):

$$K_d(\mathrm{TCP}) = \frac{[\mathrm{TCP}]_{\mathrm{om}}}{[\mathrm{TCP}]_{\mathrm{w}}} \cdot f_{\mathrm{om}} \qquad (11\text{-}44)$$

where $[\mathrm{TCP}]_{\mathrm{om}}$ is the concentration of the nonionized trichlorophenol in the solid organic matter, and $[\mathrm{TCP}]_{\mathrm{w}}$ is the concentration of the nonionized trichlorophenol in the water. We may similarly define for the anionic phenolate species:

$$K_d(\mathrm{TCP}^-) = \frac{[\mathrm{TCP}^-]_{\mathrm{om}}}{[\mathrm{TCP}^-]_{\mathrm{w}}} \cdot f_{\mathrm{om}} \qquad (11\text{-}45)$$

where, in this case, we assume the major sorption mechanism for the phenolate is dissolution into natural organic matter. Next, we may reasonably expect that the presence of a charge on the deprotonated phenol species will cause this molecule to be much more water-soluble than its conjugate acid. Therefore, such ionized phenol molecules exhibit correspondingly less tendency to go from solution into particulate organic matter:

$$K_{om}(\mathrm{TCP}^-) \ll K_{om}(\mathrm{TCP}) \tag{11-46}$$

We would expect $K_{om}(\mathrm{TCP}^-)$ to be about three orders of magnitude less than $K_{om}(\mathrm{TCP})$ since the K_{ow} of phenolate is about that much less than the K_{ow} of the corresponding phenol (see Chapter 8 or fragment constants in Lyman et al., 1982). If the phenolate species does not sorb by another major mechanism besides dissolving in the natural organic matter, and this appears to be true for many natural solids which are primarily negatively charged at natural water pH's, then we may estimate the total sorption of the trichlorophenol using a distribution ratio:

$$K_d(\mathrm{TCP\ plus\ TCP}^-) = \frac{([\mathrm{TCP}]_{om} + [\mathrm{TCP}^-]_{om}) \cdot f_{om}}{[\mathrm{TCP}]_w + [\mathrm{TCP}^-]_w} \tag{11-47}$$

where we have written K_d as the ratio of all major sorbed species divided by the sum of all the forms in the water (TCP_w and TCP_w^-). Rearranging and substituting with the K_a and K_{om} expressions defined above, we deduce

$$K_d(\mathrm{TCP\ plus\ TCP}^-) = \frac{\left[\dfrac{[\mathrm{TCP}]_{om}}{[\mathrm{TCP}]_w} + \dfrac{[\mathrm{TCP}^-]_{om}}{[\mathrm{TCP}]_w}\right] \cdot f_{om}}{1 + \dfrac{[\mathrm{TCP}^-]_w}{[\mathrm{TCP}]_w}} \tag{11-48}$$

$$= \frac{\left[\dfrac{[\mathrm{TCP}]_{om}}{[\mathrm{TCP}]_w} + \dfrac{[\mathrm{TCP}^-]_{om} \cdot K_a}{[\mathrm{TCP}^-]_w[\mathrm{H}^+]}\right] \cdot f_{om}}{1 + \dfrac{K_a}{[\mathrm{H}^+]}} \tag{11-49}$$

$$= \frac{[K_{om}(\mathrm{TCP}) + K_{om}(\mathrm{TCP}^-) \cdot K_a/[\mathrm{H}^+]] \cdot f_{om}}{1 + \dfrac{K_a}{[\mathrm{H}^+]}} \tag{11-50}$$

As long as we are interested in cases where the solution pH is less than about two units above the acid's $\mathrm{p}K_a$ (i.e., $K_a/[\mathrm{H}^+] \ll 1{,}000$), then we may neglect the involvement of TCP^- with the particulate organic matter:

$$K_d(\mathrm{TCP\ plus\ TCP}^-) \simeq \frac{K_{om}(\mathrm{TCP}) \cdot f_{om}}{1 + \dfrac{K_a}{[\mathrm{H}^+]}} \tag{11-51}$$

This result is equivalent to

$$K_d(\text{TCP plus TCP}^-) = \alpha_a \cdot K_d(\text{TCP}) \tag{11-52}$$

Equation 11-52 implies that sorption of this trichlorophenol isomer will depend not only on the tendency of the ionized phenol to associate with particulate organic matter [K_d(TCP)], but also on the fraction (α_a) of nondissociated species in aqueous solution at a given pH. The accuracy of this result is illustrated in Figure 11.17. Using a lake sediment of f_{om} near 19%, Schellenberg and co-workers (1984) measured the solid–water distribution coefficient of 2,4,5-trichlorophenol at several solution pH's. They saw diminished sorption at higher pH, and this trend in K_d closely mirrored the change in TCP present in its protonated form. Further, the K_d found at pH's well below TCP's pK_a matched the result these investigations expected for nonionized TCP sorption to the particulate organic matter.

When the solution pH is such that the anionic species finally becomes much more abundant than its neutral counterpart in solution, we cannot neglect the sorption of TCP^- (Jafvert, 1990; Jafvert et al., 1990). Unfortunately $K_{om}(TCP^-)$ is not constant at all solution pH's and ionic conditions. In some part this is due to the variation in solid charging as solution pH changes, causing differential electrostatic repulsions at varying pH. Various ions (e.g., Ca^{2+} versus Na^+) also affect the value of K_{om}(anions) owing to the differential formation of ion pairs [e.g., $Ca^{2+}(\text{phenolate}^-)_2$].

Thus in cases where an organic chemical may be present as more than one species in solution, we must consider the sorptive interactions of each of these species. We

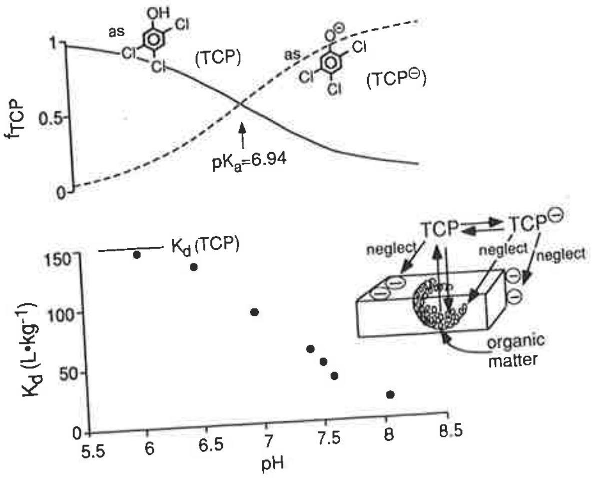
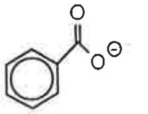


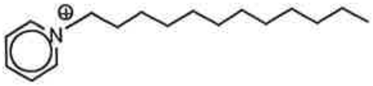
Figure 11.17 2,4,5-Trichlorophenol ionization (upper) and sorption to a lake sediment (lower) as a function of solution pH (data from Schellenberg et al., 1984). Inset indicates the importance of TCP interaction with particulate organic matter, in this case, relative to other sorption processes for TCP or TCP^-.

may often find that the overall solid–water distribution coefficient can be estimated from information on the dominant sorption interaction and the fraction of molecules available to participate in that interaction. In the following sections we focus on the processes governing the sorption of ionized organic species, thereby enabling us to determine when sorbed species besides nonionized molecules in natural organic matter become dominant.

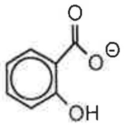
Sorption of Charged Organic Species

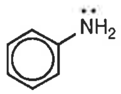
Let us continue our discussion by evaluating the sorption of the *charged organic species themselves.* We first examine cases where specific chemical reactions (i.e., bond breaking and making) with the solid are *not* important to K_d. For example, for now we consider "monodentate" compounds like benzoate or unreactive ones such as dodecylpyridinium:





but not bidentate ones like salicylate or compounds like aniline with its reactive amine moiety:





We make this distinction because "monodentate" compounds (i.e., those with a "single tooth" with which to bond to atoms on the surface of solids) seem to sorb more as counterions dissolved in the near-surface thin film of water than as surface-bound species. The "polydentate" compounds like salicylate form, not only the near-surface counterion species, but also nonnegligible quantities of surface-bound sorbates (Yost et al., 1990). Quaternary ammonium compounds like dodecyl pyridinium do not retain any nonbonded electrons with which to bond to components of the solid phase, in contrast to aniline which can react with carbonyl moieties included in particulate organic matter (Hsu and Bartha, 1976). Before we can treat surface-bound forms, it is useful to know how to handle electrostatic influences in isolation.

Surface Charges on Solids in Water To evaluate the importance of charged organic compound interchange between the bulk aqueous solution and the thin layer of water surrounding a charged particle (Fig. 11.18), we need to know how many charges are on the surfaces of solids. The adjacent surficial layer of water (i.e., Region II in Fig. 11.18) contains an excess of ions, called counterions (e.g., Na^+ in Fig. 11.18), that carry charge equal in magnitude and opposite in sign to that exhibited by the particle surface (i.e., Region I in Fig. 11.18). The thickness of this ion-rich water layer, which is sometimes called the *diffuse double layer*, varies inversely with the ionic strength

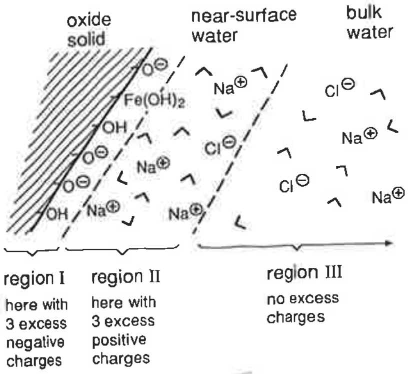


Figure 11.18 A schematic view of the accumulation of counterions in a narrow solution volume adjacent to charged particle surfaces. Region I depicts the charged surface layer formed by reactions of surface groups with acids or bases (e.g., $M—OH + OH^- \rightleftharpoons M—O^- + H_2O$) and with certain strongly sorbed ions [e.g., $M—O^- + Fe(OH)_2{}^+ \rightleftharpoons M—O—Fe(OH)_2$]. Region II is the diffuse double layer in which counterions (e.g., Na^+) accumulate in excess over bulk solution concentrations to match the net charge on the solid surface. Region III is the aqueous solution outside the diffuse double layer where electroneutrality is achieved by the sum of cation charges equaling the sum of anion charges.

of the solution. The e^{-1} characteristic width is given by $0.28 \times I^{-0.5}$ nm, where I is the solution's ionic strength in molar units (Morel, 1983). For typical ionic compositions of natural waters (10^{-3}–0.5 M), this means that most [i.e., $(1 - e^{-1}) \cdot 100\% = 63\%$] of the counterions are packed into a layer of water between 0.3 and 10 nm thick, and nearly all [i.e., $(1 - e^{-3}) \cdot 100\% = 95\%$] are within 1–30 nm of the surface. It is worth noting that this range is very similar to the 1–10 nm range believed to reflect ordered vicinal water (Drost-Hansen, 1969); thus, this is indeed a very special microscopic water environment.

For charged species that do not react with the surface, we recognize that the extent of their accumulation in this layer of water is caused at least in part by electrostatic attractions or repulsions (ΔG_{elect}). A major factor in governing these attractions is the abundance of charges on the particle's surface. Several kinds of surfaces can be envisioned; here we especially consider: (1) oxides or oxyhydroxides, (2) aluminosilicates or clay minerals, and (3) natural organic matter.

For natural solids that are *oxides or oxyhydroxides* (e.g., quartz, SiO_2; goethite, FeOOH; alumina, Al_2O_3), their water-wet surface is covered by hydroxyl groups (recall Fig. 11.13). These hydroxyl moieties can undergo proton-exchange reactions with the aqueous solution much like dissolved acids:

$$\text{surface}{\equiv}M{-}OH_2^+ \rightleftharpoons \text{surface}{\equiv}M{-}OH + H^+ \qquad (11\text{-}53)$$

$$\text{surface}{\equiv}M{-}OH \rightleftharpoons \text{surface}{\equiv}M{-}O^- + H^+ \qquad (11\text{-}54)$$

where M refers to an atom like Si, Fe, or Al at the particle surface, and $\equiv$ refers to the attachments of that atom to the solid. We may define acid–base equilibrium constants for those reactions:

$$K_{a1} = \frac{[{\equiv}\mathrm{MOH}][\mathrm{H}^+]}{({\equiv}\mathrm{MOH}_2^+]} \qquad (11\text{-}55)$$

$$K_{a2} = \frac{[{\equiv}\mathrm{MO}^-][\mathrm{H}^+]}{[{\equiv}\mathrm{MOH}]} \qquad (11\text{-}56)$$

These surface acid equilibrium constants differ from their solution counterparts in that they reflect both an *intrinsic* reactivity of the particular O—H bond and an electrostatic free energy of moving H^+ to and from a charged surface:

$$K_{a1} = K_{a1}^{\mathrm{int}} \cdot e^{F\psi/RT} \qquad (11\text{-}57)$$

$$K_{a2} = K_{a2}^{\mathrm{int}} \cdot e^{F\psi/RT} \qquad (11\text{-}58)$$

where

F is the Faraday constant (96,485 $C \cdot mol^{-1}$),
ψ is the surface potential relative to the bulk solution (V or $J \cdot C^{-1}$),
R is the molar gas constant (8.31 $J \cdot mol^{-1} K^{-1}$), and
T is the absolute temperature (K).

At higher and higher pH's, ψ becomes less and less positive as reaction 11-53 proceeds to the right and more and more negative as reaction 11-54 continues to the right. This variation in surface charge buildup makes it increasingly more difficult to move H^+ away from an oxide surface as solution pH is increased. The magnitude of this effect is calculated with the exponential terms in Eqs. 11-57 and 11-58.

It is also possible for some other inorganic species (e.g., Fe^{+3} or $PO_4{}^{-3}$) to bond with the surface [e.g., $Fe(OH)_2{}^+$ bound in Region I of Fig. 11.18); in such a case, these inorganic ions along with H^+ and OH^- are responsible for establishing the extent of charging on the solid surface. The combination of ions responsible for this charge formation are called "potential (ψ) determining." For now, we neglect specific inorganic adsorption other than H^+ and OH^- and their effects on surface charge (e.g., see Dzombak and Morel, 1990, for examples of specific sorption and its associated impact on surface charge for hydrous ferric oxide).

For the case at hand, it is easy to see that the abundance of $\equiv MOH_2{}^+$ and $\equiv MO^-$ species on the solid surface control the surface's charge. The concentration of this charge, σ_{ie} (mol charges$\cdot m^{-2}$) can be estimated (neglecting other specifically sorbed species):

$$\sigma_{ie} = [{\equiv}\mathrm{MOH}_2{}^+] - [{\equiv}\mathrm{MO}^-] \qquad (11\text{-}59)$$

where the surface species concentrations are given in units of mole per meter squared of exposed surface. When these two surface species are present in equal concentration, the surface exhibits zero net charge (also $\psi = 0$); we call the solution pH that establishes this condition, the pH of zero point of charge, or $\mathrm{pH_{zpc}}$. This $\mathrm{pH_{zpc}}$ can be calculated if we know the intrinsic acidities of $\equiv\mathrm{MOH_2}^+$ and $\equiv$MOH:

$$[\equiv\mathrm{MOH_2}^+] = [\equiv\mathrm{MO}^-] \qquad \text{at } \mathrm{pH_{zpc}} \tag{11-60}$$

Substituting from Eqs. 11-55 to 11-58 and recalling $\psi_{\mathrm{zpc}} = 0$, we have

$$[\equiv\mathrm{OH}][\mathrm{H}^+]_{\mathrm{zpc}}(K_{\mathrm{a1}}^{\mathrm{int}})^{-1} = [\equiv\mathrm{OH}][\mathrm{H}^+]_{\mathrm{zpc}}^{-1}(K_{\mathrm{a2}}) \tag{11-61}$$

Simplifying Eq. 11-61 allows us to relate $\mathrm{pH_{zpc}}$ and the intrinsic acidities of the surface:

$$[\mathrm{H}^+]_{\mathrm{zpc}}^2 = K_{\mathrm{a1}}^{\mathrm{int}} K_{\mathrm{a2}}^{\mathrm{int}} \tag{11-62}$$

$$[\mathrm{H}^+]_{\mathrm{zpc}} = (K_{\mathrm{a1}}^{\mathrm{int}} K_{\mathrm{a2}}^{\mathrm{int}})^{0.5} \tag{11-63}$$

$$\log\,[\mathrm{H}^+]_{\mathrm{zpc}} = 0.5\,(\log K_{\mathrm{a1}}^{\mathrm{int}} + \log K_{\mathrm{a2}}^{\mathrm{int}}) \tag{11-64}$$

$$\mathrm{pH_{zpc}} = 0.5\,(\mathrm{p}K_{\mathrm{a1}}^{\mathrm{int}} + \mathrm{p}K_{\mathrm{a2}}^{\mathrm{int}}) \tag{11-65}$$

Equation 11-65 shows that an oxyhydroxide's $\mathrm{pH_{zpc}}$ is midway between the intrinsic $\mathrm{p}K_\mathrm{a}$'s of its surface groups. Now, when the aqueous solution pH is below the $\mathrm{pH_{zpc}}$, we have the condition $[\equiv\mathrm{OH_2}^+] > [\equiv\mathrm{O}^-]$, and the solid exhibits a net positive surface charge. Conversely, when we are above the solid's $\mathrm{pH_{zpc}}$, then $[\equiv\mathrm{O}^-] > [\equiv\mathrm{OH_2}^+]$, the surface is negatively charged, and it becomes increasingly so at higher pH.

Our task now is to estimate the concentration of surface charge for cases that interest us as a function of solid and solution properties. Table 11.4 shows how this can be done by solving for the abundances of the important surface species, $\equiv\mathrm{OH_2}^+$ and $\equiv\mathrm{O}^-$, using two sets of information: (1) knowledge of the intrinsic acidities for the oxide of interest, and (2) the feedback relationship of surface potential on surface charge density. Figure 11.19 illustrates the results of such calculations on charge density at pH's below and above an oxide's $\mathrm{pH_{zpc}}$ for aqueous solutions of $I = 0.001$ and 0.5 M. These results may be understood with a specific example. If we were interested in iron oxide with a $\mathrm{p}K_{\mathrm{a1}}^{\mathrm{int}}$ of 7 (Table 11.5) and a surface hydroxyl density of $2 \times 10^{-6}\,\mathrm{mol \cdot m^{-2}}$, we could estimate that this solid would have about $2 \times 10^{-7}\,\mathrm{mol \cdot m^{-2}}$ of positive charges on its surface at pH 6 in freshwater of $\mathrm{I} = 10^{-3}$ M (i.e., ~10% as $\mathrm{M{\equiv}OH_2}^+$ in Fig. 11.19). In salty water of $I = 0.5$ M and pH = 6, the same solid would have a little more than $1 \times 10^{-6}\,\mathrm{mol \cdot m^{-2}}$ of positive charges (i.e., ~50% as $\mathrm{M{\equiv}OH_2}^+$ in Fig. 11.19). If the solution pH was 7 instead of 6, the surface charge density would decrease by about a factor of 2. It would not be until pH was increased to above 8 [$\mathrm{pH_{zpc}} = 0.5(7 + 9) = 8$] that this solid would start to show a net negative surface charge. Table 11.5 shows some other important oxide minerals common in aquatic environments, their typical surface areas, and their

TABLE 11.4 Estimating the Surface Charge σ_{ie} of Oxides When H^+ and OH^- Are the Potential-Determining Ions

$$\sigma_{ie}(\text{mol charges}\cdot m^{-2}) = [\equiv MOH_2{}^+] - [\equiv MO^-] \tag{11-59}$$

where

$[\equiv MOH_2{}^+]$ is the concentration of protonated surface sites ($mol\cdot m^{-2}$), and
$[\equiv MO^-]$ is the concentration of deprotonated surface sites ($mol\cdot m^{-2}$).

When $[\equiv MOH_2{}^+] > [\equiv MO^-]$, σ_{ie} is positive, indicating a net positive surface charge; conversely, when the $[\equiv MO^-] > [\equiv MOH_2{}^+]$, σ_{ie} is negative and its absolute value reflects the concentration of negative sites.

Using acidity relationships (Eqs. 11-55 through 11-58)

$$\sigma_{ie} = [\equiv MOH][H^+]K_{a1}^{-1} - [\equiv MOH][H^+]^{-1}K_{a2} \tag{11-66}$$

$$\sigma_{ie} = [\equiv MOH][H^+](K_{a1}^{int})^{-1}e^{-F\psi/RT} - [\equiv MOH][H^+]^{-1}K_{a2}^{int}e^{F\psi/RT} \tag{11-67}$$

where

K_{a1}^{int} and K_{a2}^{int} are the intrinsic equilibrium constants quantifying the extent of proton exchange in the absence of charging the surface,
ψ is the surface potential ($V = J\cdot C^{-1}$),
R is the molar gas constant ($8.31\ J\cdot deg\ K^{-1}\ mol^{-1}$),
T is the absolute temperature (K), and
F is the Faraday constant ($96{,}485\ C\cdot mol^{-1}$).

The surface charge and surface potential are related (Stumm and Morgan, 1981):

$$\psi = \frac{2RT}{zF}\sinh^{-1}\left[\left[\frac{\pi F^2 10^{-3}}{2\varepsilon RTI}\right]^{0.5}\sigma_{ie}\right] \tag{11-68}$$

where

z is the valence of ions in the background electrolyte (e.g., NaCl, $z = 1$),
ε is the dielectric constant of water ($7.2 \times 10^{-10}\ C\cdot V^{-1}m^{-1}$ at 25°C), and
I is the solution ionic strength ($mol\cdot L^{-1}$; 10^{-3} is needed to convert L to m^3).

Substituting Eq. 11-68 into 11-67 yields:

$$\sigma_{ie} = [\equiv MOH][H^+](K_{a1}^{int})^{-1}\exp\left(-\frac{2}{z}\sinh^{-1}\left[\left[\frac{\pi F^2 10^{-3}}{2\varepsilon RTI}\right]^{0.5}\sigma_{ie}\right]\right)$$
$$-[\equiv MOH][H^+]^{-1}(K_{a2}^{int})\exp\left(+\frac{2}{z}\sinh^{-1}\left[\left[\frac{\pi F^2 10^{-3}}{2\varepsilon RTI}\right]^{0.5}\sigma_{ie}\right]\right) \tag{11-69}$$

(Continued)

TABLE 11.4 *(Continued)*

Well below the pH_{zpc} ($[\equiv MOH_2{}^+] \gg [\equiv MO^{-1}]$), Eq. 11-69 simplifies to:

$$\sigma_{ie} = [\equiv MOH][H^+](K_{a1}^{int})^{-1} \exp\left(-\frac{2}{z}\sinh^{-1}\left[\left[\frac{\pi F^2 10^{-3}}{2\varepsilon RTI}\right]^{0.5} \sigma_{ie}\right]\right) \qquad (11\text{-}70a)$$

or

$$\log \sigma_{ie} + \frac{2}{2.303z}\sinh^{-1}\left[\left[\frac{\pi F^2 10^{-3}}{2\varepsilon RTI}\right]^{0.5} \sigma_{ie}\right] - \log\left[[\equiv MOH_0] - |\sigma_{ie}|\right] = -pH + pK_{a1}^{int} \qquad (11\text{-}70b)$$

At $T = 25°C$, $I = 10^{-3}$ M, a 1:1 background electrolyte ($z = 1$), and with an initial hydroxyl site density ($\equiv MOH_0$) of 2×10^{-6} mole/m^2, this becomes:

$$\log \sigma_{ie} + 0.868 \sinh^{-1}(9.05 \times 10^7 \sigma_{ie}) - \log(2 \times 10^{-6} - |\sigma_{ie}|) = -pH + pK_{a1}^{int} \qquad (11\text{-}71)$$

which can be solved for σ_{ie} at pH's below the solid's pK_{a1}^{int}.

At $T = 25°C$, $I = 0.5$ M, a 1:1 background electrolyte, and with an initial hydroxyl site density of 2×10^{-6} mole/m^2, this becomes:

$$\log \sigma_{ie} + 0.868 \sinh^{-1}(4.05 \times 10^6 \sigma_{ie}) - \log(2 \times 10^{-6} - |\sigma_{ie}|) = -pH + pK_{a1}^{int} \qquad (11\text{-}72)$$

Conversely, well above pH_{zpc} ($[\equiv MO^-] \gg [\equiv MOH_2{}^+]$), we have from 11-67:

$$\log \sigma_{ie} + \left(\frac{2}{2.303z}\sinh^{-1}\left[\left[\frac{\pi F^2 10^{-3}}{2\varepsilon RTI}\right]^{0.5} \sigma_{ie}\right]\right) + \log\left[[\equiv MOH_0] - |\sigma_{ie}|\right] = -pH + pK_{a2}^{int} \qquad (11\text{-}73)$$

At $T = 25°C$, $I = 0.5$ M, a 1:1 background electrolyte, and with an initial hydroxyl site density of 2×10^{-6} mole/m^2, this becomes:

$$\log(-\sigma_{ie}) - 0.868 \sinh^{-1}(9.05 \times 10^7 \sigma_{ie}) - \log(2 \times 10^{-6} - |\sigma_{ie}|) = pH - pK_{a2}^{int} \qquad (11\text{-}74)$$

In the cases where pH is between pK_{a1}^{int} and pK_{a2}^{int}, both parts of the right-hand side of Eq. 11-69 must be evaluated.

In the special case near the oxide's pH_{zpc} where ψ is small (absolute value less than 25 mV) and with a low ionic strength, Eq. 11-68 becomes:

$$\psi = \frac{2.303\,RT}{F}(pH_{zpc} - pH) \qquad (11\text{-}75)$$

and we may estimate the solid's surface charge density:

$$\sigma_{ie} = [6.40 \times 10^{-10}(T \cdot I \cdot 10^3)^{0.5}] \sinh[1.15\, z(pH_{zpc} - pH)] \qquad (11\text{-}76)$$

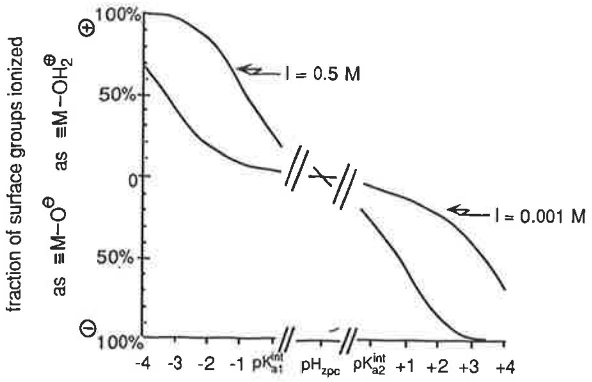


Figure 11.19 Variation of surface charge on a solid oxide (25° C) due to protonation and deprotonation of surface hydroxyls (at $2 \times 10^{-6}\,\mathrm{mol \cdot m^{-2}}$) as a function of solution pH for (a) $I = 0.5$ M of a dissolved salt with both the cation and the anion exhibiting one charge (1:1 electrolyte) and (b) $I = 0.001$ M 1:1 electrolyte. Note the breaks in the curves between unspecified values of pK_{a1}^{int} and pK_{a2}^{int}.

intrinsic acidity constants. Typically, surface charge densities in the range of 10^{-6} to $10^{-8}\,\mathrm{mol \cdot m^{-2}}$ are seen for oxides, and this implies that 10^{-6}–10^{-8} moles of counter-ions, including some charged organic molecules, will accumulate opposite each meter squared of surface area due to electrostatic attractions. This property of surfaces is sometimes referred to as the oxide's *c*ation *e*xchange *c*apacity (CEC) or *a*nion *e*xchange *c*apacity (AEC). Note again, this treatment neglects the influence of specifically sorbed ions which would neutralize some of this surface charge [e.g., $Fe(OH)_2{}^+$ bound in Region I of Fig. 11.18].

Clay minerals present a different case with regard to assessing their surface charge. These mixed aluminum oxides and silicon oxides (thus aluminosilicates) expose two kinds of surface to the external media, and therefore the same particles may exhibit both a CEC and an AEC at the same time (Table 11.5). First, the edges of these flakey-shaped minerals are somewhat like aluminum oxides in their behavior and respond to pH changes in solution much like pure aluminum oxides (e.g., pH_{zpc} of kaolinite edge ~7, Williams and Williams, 1978). The consequent anion exchange capacity observed empirically for clays is near 1×10^{-2} mole/100 g for a wide variety of clays (Grim, 1968), but this value changes with solution pH and ionic strength. On the other hand, the faces of these platey particles have a "siloxane" structure (—Si—O—Si—) which does not leave any free hydroxyl groups (—Si—OH) to participate in proton exchange reactions with the bulk solution. Instead, the faces exhibit a charge due to cation substitutions for the aluminum or silicon atoms within the internal structure. These "isomorphic" substitutions often involve cations of lower total positive charge (e.g., Al^{+3} for Si^{+4} or Mg^{+2} for Al^{+3}). The result is a fixed and permanent charge deficiency that looks like a negative surface charge to the surrounding solution. Empirical measures of this negative surface charge or CEC are

TABLE 11.5 Sorbent Properties of "Pure Solids" Commonly Present in Aquatic Environments[a]

Category		Specific Surface Area ($m^2 \cdot g^{-1}$)	CEC ($mol \cdot m^{-2}$)	AEC ($mol \cdot m^{-2}$)	pK_{a1}^{int}	pK_{a2}^{int}	pH_{zpc}	Ref.[b]
Sorbent	Compositions							
Oxides								
Quartz	SiO_2	0.14	9×10^{-8}*		(−3)	7	2.0	1, 2
Amorphous silica	SiO_2	500	9×10^{-8}*		(−3)	7	2.0	1, 2
Goethite	α-FeOOH	46		2×10^{-8}*	6	9	7.5	2
Amorphous iron oxide	$Fe(OH)_3$	600		5×10^{-8}*	7	9	8	2, 4, 5
Alumina	Al_2O_3	15		8×10^{-8}*	7	10	8.5	2
Gibbsite	$Al(OH)_3$	120	2×10^{-8}*		5	8	6.5	2,6
Aluminosilicates								
Na–montmorillonite	$Na_3Al_7Si_{11}O_{30}(OH)_6$	600–800	0.9 to 2×10^{-6}	3 to 4×10^{-7}			2.5	6,7
Kaolinite	$Al_2Si_2O_5(OH)_4$	12	0.2 to 1×10^{-5}	0.6 to 2×10^{-5}			4.6	
Illite	$KAl_3Si_3O_{10}(OH)_2$	65–100	1 to 6×10^{-6}	3×10^{-7}				
Organic								
Humus	$C_{10}H_{12}N_{0.4}O_6$	1	1 to 10×10^{-3}					8, 9
Carbonate								
Calcite	$CaCO_3$	1		9×10^{-6}			8–9.5	10, 11

[a] Calculated CEC and AEC values (*) assume solution pH = 7, ionic strength of 10^{-3} M, $T = 293$ K, solid-site density of 2×10^{-6} $mol \cdot m^{-2}$, and use of Eq. 11-69 or 11-76. Intrinsic acidity constants are rounded off to the nearest unit.

[b] References: 1. Parks (1965). 2. Schindler and Stumm (1987). 3. Mikhail et al. (1968a, b). 4. Tipping (1981). 5. Dzombak and Morel (1990). 6. Davis (1982). 7. Grim (1968) 8. Chiou et al. (1990). 9. Khan (1980). 10. Zullig and Morse (1988). 11. Somasundaran and Agar (1967).

made by assessing the maximum concentrations of weakly bound cations such as ammonium, NH_4^+, that can be sorbed. Table 11.5 shows the results of such cation exchange capacity tests on three common clays, montmorillonite, illite, and kaolinite. Expandable three-layer clays like montmorillonite exhibit the highest CEC's near 1×10^{-1} mol/100 g (Grim, 1968) or 1.4×10^{-6} moles of charged sites per meter squared (assuming a specific surface area of 700 m^2/g). On the other extreme, two-layer kaolinite clays exhibit the lowest CEC's of about 1×10^{-2} mol/100 g (Grim, 1968). This is chiefly due to their greatly reduced specific surface areas compared to the expandable three-layer clays, since per unit area these kaolinites actually have greater charge density, $\sim 10^{-5}$ mol/m^2.

Particulate natural organic matter may also contribute to the assemblage of charged sites of solids in water. This is mostly due to ionization reactions of carboxyl groups (—COOH), and at higher pH values, phenolic groups (aromatic ring —OH), which have been found at about 1–10 mM per gram of natural organic matter. Depending on the surrounding molecular environment, the carboxyl moieties exhibit pK_a's ranging from about 3 to 6. Consequently, the extent of charge buildup in the organic portion of natural particles will vary as a function of pH.

Still other solid phases, like carbonates, are common in nature, and these materials also exhibit surface charging. Realizing there will almost always be charges on particle surfaces submerged in water, we can now examine their impact with regard to sorbing ionized organic chemicals from solution.

Sorption of Organic Counterions to Single Solids by Ion Exchange Mechanisms

Let us now proceed to examine the quantities of organic ions that associate through ion exchange with a single type of solid surface in aqueous solution. For example, we consider the case of adding ethyl ammonium chloride ($CH_3CH_2NH_3Cl$; pK_a of the alkyl ammonium ~ 10) to a 10^{-2} M NaCl solution at pH 6 which also contains suspended montmorillonite particles. We do not need to consider ammonium ion ($CH_3CH_2NH_3^+$) bond formation with the clay surface, nor must we be concerned with neutral amine absorption into particulate organic matter in this case, since we have chosen solids which lack this phase. Consequently, the solid–water distribution coefficient involves only

$$K_d(\text{ethyl amine plus ethyl ammonium ions}) = \frac{[\text{ethyl ammonium ions near clay surface}]}{[\text{ethyl ammonium ions in solution}]} \qquad (11\text{-}77)$$

at pH's (i.e., < 8) where we can assume that the positively charged species is much more abundant than its neutral conjugate base both in solution and near the clay surface. Before we added any alkyl ammonium salt, the negative surface charges of the clay were balanced by an excess of hydrated sodium cations relative to hydrated chloride ions accumulated in the thin film of water surrounding the particles (Fig. 11.18). When we add a small quantity of the alkyl ammonium salt to the suspension (insufficient to change the ionic strength), an ion exchange reaction occurs

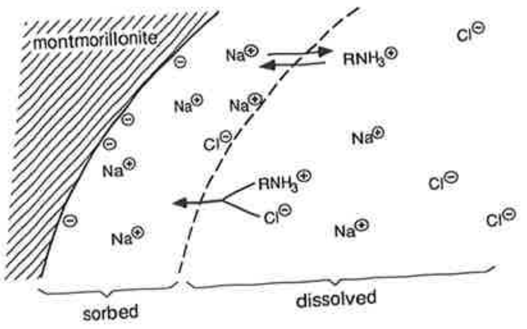


Figure 11.20 Illustration of two types of transfer enabling organic ammonium ions to collect near a negatively charged solid surface: exchange with Na^+ or cotransfer with Cl^-.

(Fig. 11.20):

$$RNH_3{}^+ + Na{:}surface \rightleftharpoons RNH_3{:}surface + Na^+ \tag{11-78}$$

resulting in some of the ammonium ions exchanging with Na^+ counterions in Region II near the solid's surface (the colon here indicates association without bond formation and $R = CH_3CH_2$). We can write an equilibrium constant expression for this ion exchange reaction:

$$K_{ie} = \frac{[RNH_3{:}surface][Na^+]}{[RNH_3{}^+][Na{:}surface]} \tag{11-79}$$

where we have used concentrations in place of activities. (A complete equilibrium expression would include activity coefficients for the charged species; however, since this equation involves monovalent ions both in the bulk medium and near the surface, such activity coefficients virtually cancel one another out in the equilibrium quotient.) K_{ie} reflects the preference of organic sorbate relative to the competing sorbates, in this case Na^+. Recognizing that the accumulaton of counterion cations around the negatively charged particles must be a constant equal to the product of the surface charge density σ_{ie} ($mol \cdot m^{-2}$) and the specific particle surface area A ($m^2 \cdot kg^{-1}$), we can write

$$\sigma_{ie} \cdot A = [RNH_3{:}surface] + [Na{:}surface] \tag{11-80}$$

where $[RNH_3{:}surface]$ and $[Na{:}surface]$ have units of moles per kilogram. We can now eliminate the term in $[Na{:}surface]$ from the equilibrium constant expression 11-79:

$$K_{ie} = \frac{[RNH_3{:}surface][Na^+]}{[RNH_3^+](\sigma_{ie} \cdot A - [RNH_3{:}surface])} \tag{11-81}$$

Rearranging this expression, we find

$$[\mathrm{RNH_3{:}surface}] = \frac{(\sigma_{\mathrm{ie}}\cdot A)(K_{\mathrm{ie}})[\mathrm{RNH_3}^+]}{[\mathrm{Na}^+] + (K_{\mathrm{ie}})[\mathrm{RNH_3}^+]} \tag{11-82}$$

or more generally,

$$\begin{bmatrix}\text{organic ion}\\ \text{at surface}\end{bmatrix} = \frac{\sigma_{\mathrm{ie}}\cdot A\cdot K_{\mathrm{ie}}[\text{organic ion in solution}]}{[\text{competing ion}] + K_{\mathrm{ie}}[\text{organic ion in solution}]} \tag{11-83}$$

In terms of the particular example at hand, Eq. 11-82 says that the concentration of bound alkyl ammonium ion varies as we change the concentration of the dissolved species (Fig. 11-21*a*). At low organic ion concentrations ($[\mathrm{Na}^+] \gg K_{\mathrm{ie}}[\mathrm{RNH_3}^+]$), the bound-to-dissolved *ratio* is almost constant:

$$K_{\mathrm{d}} \simeq \begin{pmatrix}\text{total net}\\ \text{surface charge}\end{pmatrix}\cdot\begin{pmatrix}\text{equilibrium}\\ \text{constant}\end{pmatrix}\cdot\begin{pmatrix}\text{competing cation}\\ \text{concentration}\end{pmatrix}^{-1} \tag{11-84}$$

On the other hand, at high levels of $\mathrm{RNH_3}^+$, the bound counterion concentrations asymptotically approach a constant value set by the total surface charge density (in this case, the cation exchange capacity of the clay). At these elevated charged organic sorbate levels, the bound-versus-dissolved distribution ratio actually declines, and the isotherm is hyperbolic (Fig. 11-21*a*). An isotherm having this shape is generally referred to as a *Langmuir isotherm*:

$$[\text{Sorbed}] = \frac{[\text{maximum sorbed}]\,K_{\mathrm{Langmuir}}[\text{dissolved}]}{1 + K_{\mathrm{Langmuir}}[\text{dissolved}]} \tag{11-85}$$

where in this case $[\text{maximum sorbed}] = \sigma_{\mathrm{ie}}\cdot A$, and $K_{\mathrm{Langmuir}} = K_{\mathrm{ie}}/[\text{competing ion}]$.

We can confirm the direct relationship (expected from Eq. 11-84) of the bound-to-dissolved distribution ratio with the surface charge density for low concentrations of organic sorbate ions by examining the results of Fuerstenau and Wakamatsu (1975). In this case, alumina was used as a positively charged sorbent ($\mathrm{pH_{zpc}} \simeq 8.5$) and dodecylsulfonate anions were exchanged with background chloride ions for ion exchange sites on this solid as a function of solution pH. (Alkyl sulfonates, $\mathrm{R{-}SO_3}^-$, do not appear to participate in substantial ligand exchange reactions with alumina.) Based on Eq. 11-69, we calculate how the alumina's surface charge density σ should have decreased with increasing pH (Fig. 11-22*a*). Using these results, we anticipate that K_{d}(dodecylsulfonate)$\cdot A^{-1}$ should be lowest at high pH when σ is lowest, and this is exactly what these workers observed (Fig. 11-22*b*). The direct correlation of these observed $(K_{\mathrm{d}}\cdot A^{-1})$'s with the calculated σ_{ie}'s yields a slope which, when adjusted by the competing chloride concentration, suggests K_{ie} is between 20 and 50. This implies the dodecylsulfonate was accumulated in the diffuse double layer surrounding the alumina relative to its bulk solution concentration more than an order of

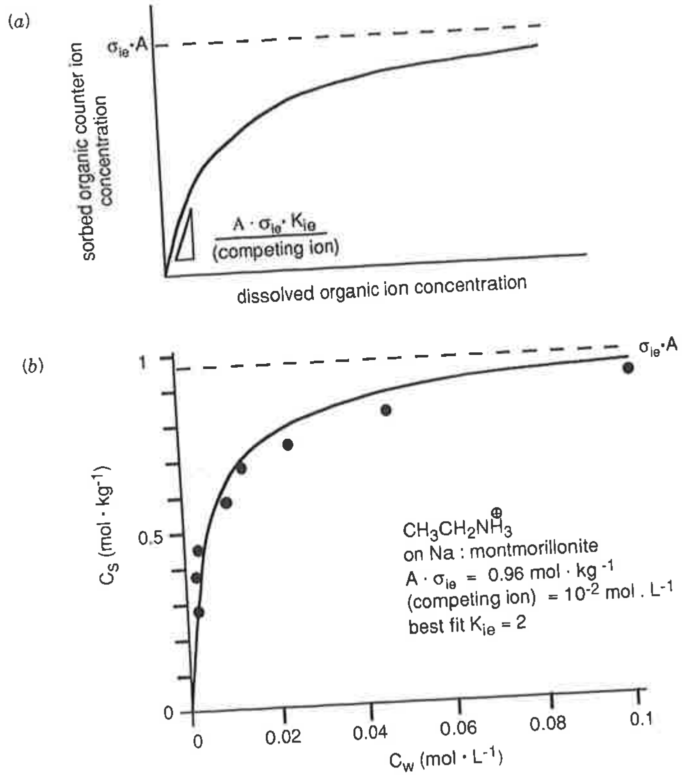


Figure 11.21 (*a*) Schematized Langmuir isotherm showing the variation of sorbed organic counterions (i.e., those within the near surface water layer) as dissolved (or bulk solution) organic ion concentration changes: $\sigma_{\text{ie}} \cdot A$ is the total surface charge density; K_{ie} is the exchange reaction equilibrium constant; and (competing ion) is the concentration of competing counterions. (*b*) For the specific case of ethyl ammonium sorption to montmorillonite, a Langmuir isotherm with best fit $K_{\text{ie}} = 2$ matches the experimental data well (data from Cowan and White, 1958).

magnitude more preferentially than the inorganic chloride adsorbate ($\Delta G_{\text{ads}} \simeq 7$–10 kJ·mol^{-1}). These findings clearly illustrate the direct effect of the particle's surface charge density on the extent of adsorption of organic counterions. We should note that at the point where [organic ion] $\simeq$ [competing ion], further increases in [organic ion] cause substantial changes in the solution ionic strength. Were we considering an oxide surface, such an important change in the solution would result in a concomitant slow increase in the surface charge (recall Eq. 11-68 in Table 11.4). Obviously, this effect on σ_{ie} would feed back into the extent of sorption.

Now let's examine the effectiveness of such a modeling approach for ethyl

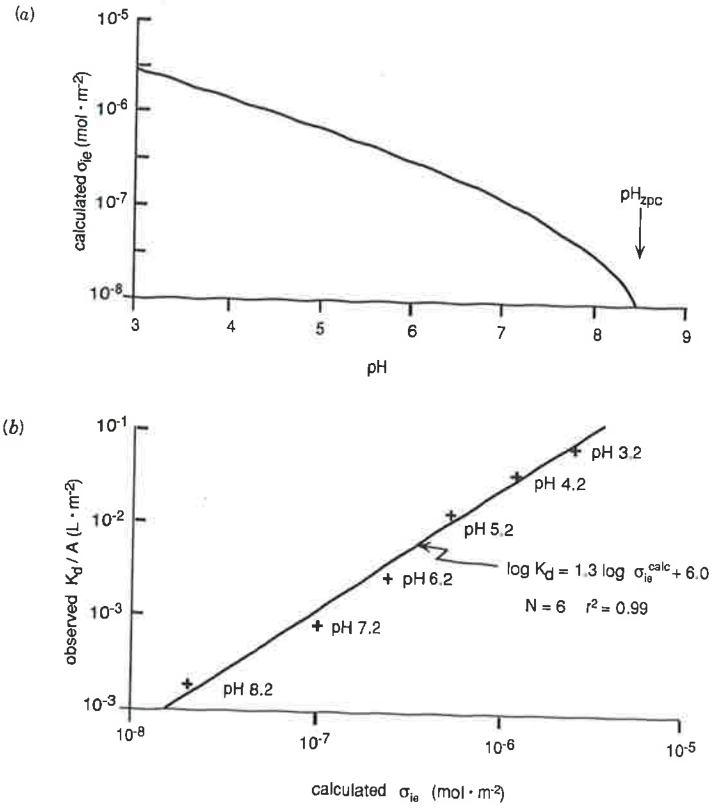


Figure 11.22 (*a*) Expected variation of the surface charge density σ_{ie} of alumina as a function of pH ($I = 2 \times 10^{-3}$ M, $T = 25°$C, $[\equiv \text{MOH}]_0 = 5 \times 10^{-6}$ mol·m^{-2}). (*b*) Direct relationship between observed sorption of dodecyl sulfonate on alumina (Fuerstenau and Wakamatsu, 1975) and calculated σ_{ie}.

ammonium sorption to a Na–montmorillonite (Cowan and White, 1958). These workers measured the CEC ($= \sigma_{ie} \cdot A$) of their clay sorbent to be nearly 1 mol·kg^{-1} (recall that this surface charge is not sensitive to solution ionic strength like the oxides, since it arises principally from isomorphic substitutions). Working with $[\text{Na}^+] = 10^{-2}$ M, the observed isotherm data can be nicely fit with $K_{ie} = 2$ (Fig. 11-21*b*). Since $K_{ie} = 1$ would imply no preference between the sodium and the alkyl ammonium ions, this fit value of K_{ie} indicates only a little selection of the organic cation over the sodium ion, presumably because of the hydrophobicity of the ethyl substituent. We also deduce that for ethyl ammonium concentrations less than about 10^{-2} M (i.e., less than the Na$^+$ concentration) we have a constant K_d(ethyl ammonium ion) of about 200 (mol·kg^{-1})(mol·L^{-1})$^{-1}$ [$= \sigma_{ie} \cdot A \cdot K_{ie}$(competing ion)$^{-1}$ $= \text{CEC} \cdot K_{ie} \cdot [\text{Na}^+]^{-1}$]. Obviously, solutions of lower competing cation concentrations would allow the sorbed-to-dissolved ratio to be even greater. Given the ionic strength of 10^{-2} M, we recognize the characteristic length of the diffuse double layer is about 3 nm; together with an estimate of this montmorillonite's surface area ($\sim 700\ \mathrm{m^2/g}$), we can calculate that this distribution ratio corresponds to about 60 ($\mathrm{mol \cdot L^{-1}}$ double layer water)$\cdot$($\mathrm{mol \cdot L^{-1}}$ bulk water)$^{-1}$. Clearly, the electrostatic attraction of the negatively charged clay faces is concentrating cations like ethyl ammonium ions in the water near the particles. In addition, as also indicated by the dodecylsulfonate sorption to alumina, we recognize that the rest of the organic structure (R) plays a role in determining the magnitude of K_{ie}.

Effects of Sorbate Hydrophobicity Thus our problem involves the question of how various hydrophobic portions of charged organic sorbates influence their sorption. Presumably the sorbate's chemical structure determines the preference of the sorbate for the near-particle water region versus the bulk solution. Cowan and White (1958) investigated the sorption of a series of alkyl ammonium ions to the same Na–montmorillonite (Fig. 11-23). A very interesting pattern emerged: *the longer the alkyl chain, the steeper was the initial isotherm slope*. Exactly parallel results have been seen for sorption of other amphiphiles, for example, negatively charged *n*-alkyl benzene sulfonates binding to positively charged alumina particles (Somasundaran et al., 1984). Further, *above about eight carbons in the chain, the extent of binding*

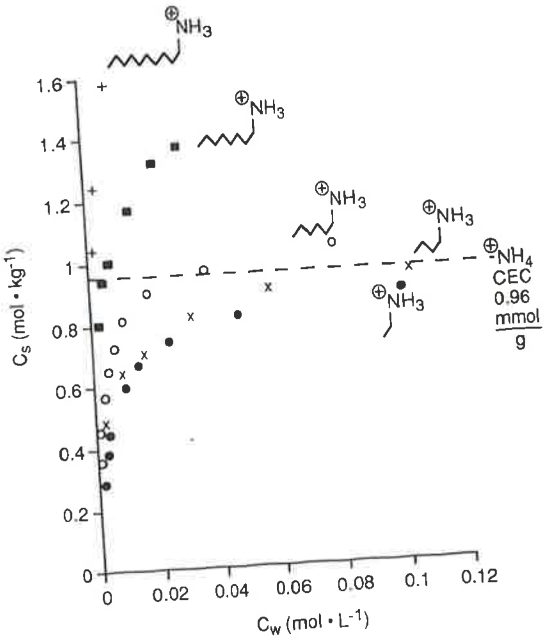


Figure 11.23 Adsorption isotherms for a series of alkyl ammonium compounds on sodium montmorillonite (adapted from Cowan and White, 1958). The horizontal dashed line indicates the cation exchange capacity of the clay.

could far exceed the clay's cation exchange capacity. Using quartz as a sorbent, Somasundaran et al. (1964) showed that chain lengths of about 10 carbons or more in alkyl ammonium ions could bind to the particles enough to reverse the particles' surface charge (i.e., convert negatively charged particles to positively charged ones by including counterions within what we called Region I in Fig. 11.18). These effects are undoubtedly due to the increasing hydrophobicity of the longer and longer chains. By favoring chemical partitioning to the near surface (e.g., into near surface water as we saw in Section 11.5) from the bulk solution, hydrophobic forces augment the electrostatic forces and thereby enhance the tendency of the sorbates to collect near the particle surface (Somasundaran et al., 1984). Thus, we anticipate little differences in sorption for organic chemicals due to moieties of like charge (e.g., —COO^- vs. $\text{—SO}_3{}^-$), since the electrostatic attraction to a surface is fairly nonselective; but we do expect substantial variations between sorbates if they differ in the hydrophobicity of their nonpolar parts (analogous to Eq. 11-40 for neutral sorbates associating with minerals).

To provide an estimate of K_{ie} suitable for use in Eq. 11-83, let us try to isolate the contribution of the sorbate's hydrophobicity using some available data. First, recalling the ion exchange equilibrium expression,

$$K_{\text{ie}} = \frac{[\text{RNH}_3\text{:surface}][\text{Na}^+]}{[\text{RNH}_3{}^+][\text{Na:surface}]} \tag{11-79}$$

we see that this can be considered to consist of two individual partitioning processes, one for $\text{RNH}_3{}^+$ and the other for Na^+. Each of these species finds itself distributed between the bulk solution and the near-surface environment according to the respective free energy differences. For the sodium ion, this free energy difference consists of only an electrostatic contribution. The solid–water ratio is therefore given by

$$\begin{aligned} \frac{[\text{Na:surface}]}{[\text{Na}^+]} &= \exp(-\Delta G_{\text{elect}}/RT) \\ &= \exp(-zF\psi/RT) \end{aligned} \tag{11-86}$$

In contrast, the alkyl ammonium ions are driven to the surface, not only by electrostatic forcing, but also by a hydrophobic effect:

$$\begin{aligned} \frac{[\text{RNH}_3\text{:surface}]}{[\text{RNH}_3{}^+]} &= \exp[(-\Delta G_{\text{elect}} - \Delta G_{\text{hydrophob}})/RT] \\ &= \exp[(-zF\psi - \Delta G_{\text{hydrophob}})/RT] \end{aligned} \tag{11-87}$$

Here we assume that the Na^+ and the $\text{RNH}_3{}^+$ ions experience the same electrostatic attractions to the surface, although we know that factors like differences in solvation have some effect. Substituting Eqs. 11-86 and 11-87 into Eq. 11-79 yields

$$\begin{aligned} K_{\mathrm{ie}} &= \exp\left[(-zF\psi - \Delta G_{\mathrm{hydrophob}})/RT\right]/\exp(-zF\psi/RT) \\ &= \exp(-\Delta G_{\mathrm{hydrophob}}/RT) \end{aligned} \tag{11-88}$$

Equation 11-88 indicates that the preference in ion exchange for organic ions over inorganic ones of the same valency (i.e., $z = 1$ for both sorbates) is mostly due to factors directing the organic sorbate to escape solution in bulk water. If we could evaluate this $\Delta G_{\mathrm{hydrophob}}$ as a function of chemical structure, we could estimate K_{ie} for various organic sorbates competing with inorganic ions that do not bond with the surface.

Since this hydrophobic effect appears to regularly increase with the size of the nonpolar part of the chemical structure (Cowan and White, 1958; Somasundaran et al., 1984), we may reasonably propose this energy term is composed of contributions from each of the nonpolar parts of the structure. Consequently, we expect for the alkyl ammonium ions studied by Cowan and White (1958),

$$\Delta G_{\mathrm{hydrophob}} = m \cdot \Delta G_{-\mathrm{CH_2}-} \tag{11-89}$$

where m is the number of methylene ($-\mathrm{CH_2}-$) groups in each sorbate's alkyl chain, and $\Delta G_{-\mathrm{CH_2}-}$ is the hydrophobic contribution made by each methylene driving these sorbates into the diffuse double layer–vicinal water layer.

Thus, the total free energies directing these organic ions to distribute between the montmorillonite surface region and the bulk water would be

$$\begin{aligned} \Delta G_{\mathrm{ads}} &= -RT\ln(K_{\mathrm{d}} \text{ of } \mathrm{RNH_3}^+) = -RT\ln\left(\frac{[\mathrm{RNH_3{:}surface}]}{[\mathrm{RNH_3}^+]}\right) \\ &= zF\psi + m \cdot \Delta G_{-\mathrm{CH_2}-} \end{aligned} \tag{11-90}$$

Figure 11-24 shows the variation in ΔG_{ads} for these alkyl ammonium ions (when these organic sorbates are present at levels much less than Na^+) as a function of the number of methylenes in the alkyl chains. The least-squares correlation line through the data yields

$$\Delta G_{\mathrm{ads}} = -10.9 - m \cdot 0.75 \qquad (\mathrm{kJ \cdot mol^{-1}}) \tag{11-91}$$

This result implies that the alkyl ammonium ions experienced an electrostatic attraction to the clay surface corresponding to

$$zF\psi \approx -10.9\,\mathrm{kJ \cdot mol^{-1}} \tag{11-92}$$

or that $\psi \simeq -0.11$ V. Also, we see $\Delta G_{-\mathrm{CH_2}-} = -0.75\,\mathrm{kJ \cdot mol^{-1}}$. Examination of the variation in aqueous solubilities for compound classes like alkanes or alcohols

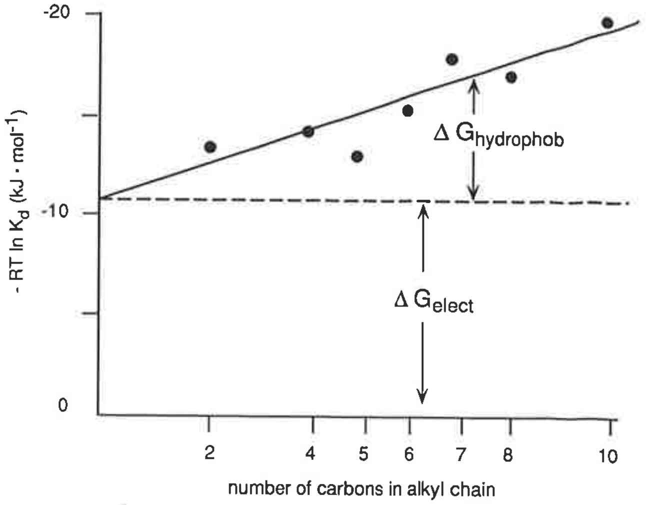


Figure 11.24 Variation in observed ion exchange free energy change ($-RT\ln K_d$) for a series of alkyl ammonium ions associating with a sodium montmorillonite. All K_d's taken at low organic ion concentrations. The least-squares fit line yields an intercept of $-10.9\,\text{kJ}\cdot\text{mol}^{-1}$ and a slope of $0.75\,\text{kJ}\cdot\text{mol}^{-1}$ per methylene group (data from Cowan and White, 1958).

(Chapter 5) as a function of additional methylene groups reveals that ΔG_s^e changes by almost $4\,\text{kJ}\cdot\text{mol}^{-1}$ for each increase in chain length. Thus, the $\Delta G_{-\text{CH}_2-}$ contributing to ΔG_{ads} in Eq. 11-91 corresponds to "a relief" of about 20% of the excess free energy of aqueous solution per methylene group. Somasundaran et al. (1984) noted that inclusion of the phenyl group in alkyl aryl sulfonates increases the ion exchange sorption tendency of these amphiphiles to a degree corresponding to lengthening the alkyl chain by 3–4 methylene groups. This is consistent with increasing the nonpolar structure's hydrophobicity to the same extent [i.e., $\Delta\log K_{\text{ow}}(\text{phenyl}) \simeq 1.68$ and $\Delta\log K_{\text{ow}}(3\text{–}4 \text{ methylenes}] \simeq 1.59$ to 2.12). Thus, we may be justified in estimating the hydrophobic contribution to K_{ie} for charged organic sorbates as a fraction, say 20%, of the excess free energy of aqueous solution in the corresponding hydrocarbon:

$$K_{\text{ie}} = \exp(-\Delta G_{\text{hydrophob}}/RT) \tag{11-88}$$

$$\simeq \exp(+0.2\Delta G_s^e/RT) \tag{11-93}$$

$$\simeq \exp\left(+0.2\cdot\left(RT\ln\frac{55.3}{C_w^{\text{sat}}(\text{l},\text{L})}\right)\Big/RT\right) \tag{11-94}$$

$$\simeq 2.2[C_w^{\text{sat}}(\text{l},\text{L})]^{-0.2} \tag{11-95}$$

The data of Cowan and White (1958) yield the empirical result

$$K_{ie} = 1.1(C_w^{sat})^{-0.19} \tag{11-96}$$

using the solubilities of the corresponding alkanes. Such expressions predict that K_{ie} of decyl amine to be 19 (Eq. 11-96) or 45 (Eq. 11-95), since $10^{-6.57}$ M is the liquid solubility of decane. Cowan and White (1958) observed K_{ie}(decyl amine) to be 36. There is little doubt that hydrophobic phenomena are playing a role in determining the extent of amphiphilic sorption; however, a great deal more work is necessary before approaches such as Eq. 11-95 or 11-96 are proven to be robust.

Multisite, Multimechanism Sorption Because the sorbed concentration can exceed $\sigma_{ie} \cdot A$ (Fig. 11-23), and the observation that real-world sorbents are not well fit with a single Langmuir isotherm (Fig. 11-25), we must consider other sorptive mechanisms in addition to the ion exchange one portrayed in Eq. 11-78. For example, recognizing the need to maintain electroneutrality near the solid's surface, a second exchange process has been postulated (Brownawell et al., 1990), which for our alkyl ammonium case would look like

$$RNH_3^+ + Cl^- \rightleftharpoons RNH_3{:}Cl \quad \text{ion pair formation in solution} \tag{11-97a}$$

$$RNH_3{:}Cl + \text{surface} \rightleftharpoons RNH_3{:}Cl{:}\text{surface} \quad \text{sorption} \tag{11-97b}$$

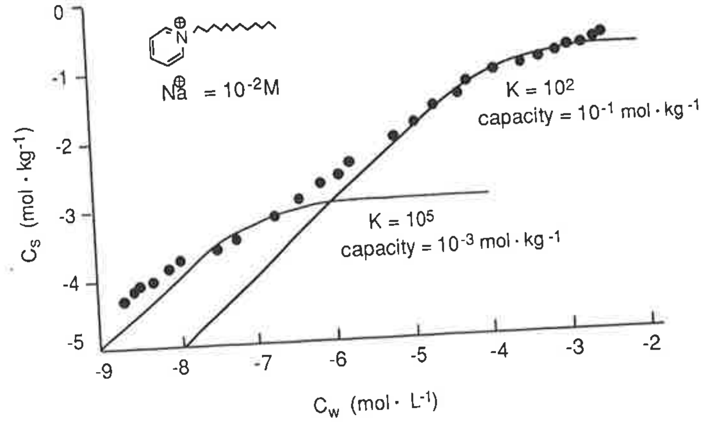


Figure 11.25 Observed sorption of dodecylpyridinium on a soil (EPA—12) exhibiting an overall cation exchange capacity of 0.135 mol·kg^{-1}. Two Langmuir isotherms are placed on the data to illustrate how different portions of the observed isotherm may reflect the influence of different materials in the complex soil sorbent or possibly different mechanisms (data from Brownawell et al., 1990).

We note especially that *the surface need not be charged to act as a sorbent in this process.* The physical picture associated with Eqs. 11-97a and 11-97b is that the organic ion with a companion (inorganic) counterion form an ion pair and moves together into the layer of water near the particle surface (Fig. 11-20). Presumably this transfer occurs because the hydrophobic portion of the organic ion has some desire to escape the bulk water and move into the near surface water. The equilibrium expression for this *n*on-*i*on *e*xchange process is

$$K_{\mathrm{nie}} = \frac{[\mathrm{RNH_3{:}Cl{:}surface}]}{[\mathrm{RNH_3}^+][\mathrm{Cl}^-][\mathrm{surface}]} \tag{11-98}$$

where we include the activity coefficients applicable to charged species in K_{nie}. Similar to the ion exchange mechanism, this electroneutral sorption is ultimately limited by the capacity of the solid surface available to sorb the amphiphile. Thus we may write

$$\begin{aligned} \text{Total capacity} &= [\mathrm{RNH_3{:}Cl{:}surface}] + [\mathrm{surface}] \\ &= A/a \end{aligned} \tag{11-99}$$

where a is the surface area "covered" by a mole of sorbate molecules ($\mathrm{m^2 \cdot mol^{-1}}$) and A is the total available surface area of the solids ($\mathrm{m^2 \cdot kg^{-1}}$).

Substituting Eq. 11-99 into Eq. 11-98, we have

$$K_{\mathrm{nie}} = \frac{[\mathrm{RNH_3{:}Cl{:}surface}]}{[\mathrm{RNH_3}^+][\mathrm{Cl}^-](A/a - [\mathrm{RNH_3{:}Cl{:}surface}])} \tag{11-100}$$

which, upon rearrangement, yields a second Langmuir isotherm:

$$[\mathrm{RNH_3{:}Cl{:}surface}] = \frac{A/a \cdot K_{\mathrm{nie}} \cdot [\mathrm{RNH_3}^+]}{[\mathrm{Cl}^-]^{-1} + K_{\mathrm{nie}}[\mathrm{RNH_3}^+]} \tag{11-101}$$

For this mechanism, the maximum sorbed concentration is given by A/a (mole per kilogram) and K_{Langmuir} is equal to $K_{\mathrm{nie}} \cdot$[companion counterion].

Now we can see how the sorbed concentration can exceed the cation (or anion) exchange capacity for amphiphilic sorbates if we assume K_{nie} values (Fig. 11.26). The total sorption process involves both ion exchange and non-ion exchange mechanisms operating simultaneously (i.e., the cations shown in Eqs. 11-78 and 11.97; Fig. 11.20). The solid–water distribution coefficient can be deduced by summing the two contributions:

$$\begin{aligned} [\mathrm{RNH_3\ sorbed}] &= [\mathrm{RNH_3{:}surface}] + [\mathrm{RNH_3{:}Cl{:}surface}] \\ &= \frac{\sigma_{\mathrm{ie}} \cdot A \cdot K_{\mathrm{ie}}[\mathrm{RNH_3}^+]}{[\mathrm{Na}^+] + K_{\mathrm{ie}}[\mathrm{RNH_3}^+]} + \frac{A \cdot a^{-1} \cdot K_{\mathrm{nie}} + [\mathrm{RNH_3}^+]}{[\mathrm{Cl}^-] + K_{\mathrm{nie}}[\mathrm{RNH_3}^+]} \end{aligned} \tag{11-102}$$

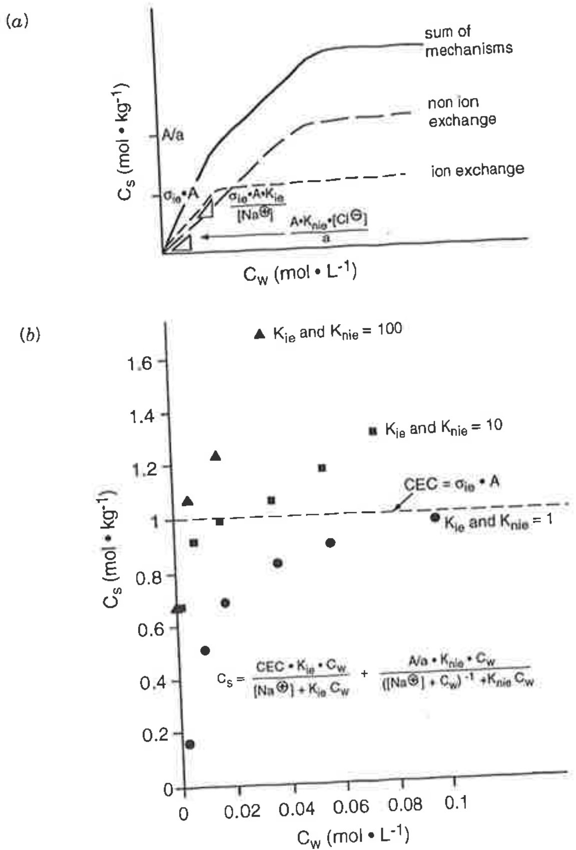


Figure 11.26 (*a*) Schematized isotherm for combination of ion exchange and nonion exchange mechanisms acting together: assumes $A/a > A \cdot \sigma_{ie}$ and $K_{ie} \cdot [Na^+]^{-1} > K_{nie} \cdot [Cl^-]$. (*b*) Calculated data points for specific cases where $K_{nie} = K_{ie}$, $\sigma_{ie} \cdot A = 1$ mol·kg^{-1}, $A/a = 4$ mol·kg^{-1}, $[Na^+] = 10^{-2}$ M, and $[Cl^-] = [Na^+] + [R^+]$. Note that $C_w = [RNH_3^+]$ and $C_s = [RNH_3\text{:surface}] + [RNH_3\text{:Cl:surface}]$.

The combined isotherm appears as a somewhat “nonsharp” hyperbola, exhibiting a linear portion at sufficiently low dissolved sorbate concentrations and a plateau at suitably high levels (Fig. 11.26*a*). At intermediate concentrations, a gradual transition results from the differential maximization of the two sorption mechanisms. Depending on the magnitudes of K_{ie} and K_{nie}, various isotherms ranging from those looking like Langmuir (when one mechanism dominates) to Freundlich relations (when both mechanisms contribute) can be found (Fig. 11.26*b*). Obviously, the shape of the isotherm an experimentalist would see depends on the range of dissolved concentrations utilized. Nonetheless, the calculated isotherm points shown in Fig. 11.26*b* look remarkably like the measured data seen by Cowan and White (1958) for the several alkyl ammoniums they tested on a single sorbent (Fig. 11.23*b*).

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Recent work (Brownawell et al., 1990) performed using soils and subsoils and examining dissolved concentrations spanning several orders of magnitude, suggests the heterogeneity of the natural sorbents is very important. It appears that, in addition to multiple sorption mechanisms acting simultaneously, one sees the influence of more than one solid surface type. Thus, the data require fits using several Langmuir isotherms, some for ion exchange interactions and possibly others for the non-ion exchange mechanism, but presumably each reflecting the involvement of different solid materials that make up the complex medium we simply call a soil, subsoil, or sediment.

Hemimicelles We conclude this discussion of amphiphilic sorption by discussing a special phenomenon called hemimicelle formation (Fuerstenau, 1956; Somasundaran et al., 1964; Chandar et al., 1983, 1987). This hemimicelle formation plays a critical role in amphiphile "sorption" to minerals when the organic ions are present at relatively high dissolved concentrations [about 0.001–0.01 of their *c*ritical *m*icelle *c*oncentrations (CMC), i.e., the level at which they self-associate in the bulk solution]. When the organic sorbate levels are low, the sorption mechanism is like the ion exchange mechanism we discussed above (Fig. 11.27, I). At some point in a titration of sorbents by micelle-forming compounds, presumably due to both electrostatic and hydrophobic effects, amphiphile concentrations build up in the near-particle region to a point where it seems likely that self-aggregation of the molecules occurs in that thin water layer (Fig. 11.27, IIa). This in turn would allow the rapid coagulation of the aggregated amphiphiles with the oppositely charged particle surface, smothering that subarea of the particle's surface charge with what have been called hemimicelles (Fig. 11.27, IIb). Electrophoretic mobility measurements clearly demonstrate the neutralization of the particle's charges in this steep portion of the isotherm, even going so far as to reverse the surface charge (e.g., Chander et al., 1987). The onset of this particle coating by hemimicelles occurs at different dissolved concentrations for various amphiphiles, but is near millimolar levels ($\gtrsim 100$ mg/L) for decyl-substituted amphiphiles and is near micromolar levels ($\gtrsim 100\ \mu$g/L) for octadecyl derivatives. In all cases, the bulk solution concentration is much less than the CMC. It appears that the elevated near-surface concentrations, derived from accumulation of these amphiphiles in the thin film of water near the particle surface by factors of 100 or more, is compensating just enough to achieve critical micelle concentrations in this near-surface water layer. Continued increase in amphiphile concentration results in the particle surface becoming increasingly coated by hemimicelles, apparently while the near-surface water maintains its concentration near that of the CMC (Fig. 11.27 II). Finally, the entire particle surface is covered with a bilayer of amphiphile molecules; the particle's surface charge is now that of the surfactant; and the addition of more amphiphile to the solution does not yield any higher sorbed loads (Fig. 11.27, III). This especially extensive degree of sorption may be the cause of macroscopic phenomena such as dispersion of coagulated colloids and particle flotation.

An Example: Calculation of K_d of a Charged Organic Chemical We conclude the discussion of sorption of charged organic sorbates by examining the situation for

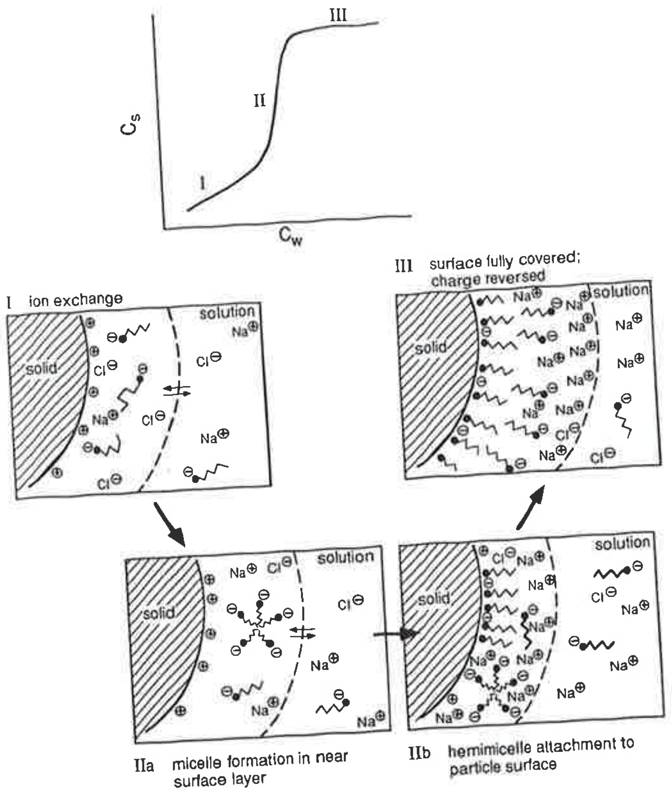

Figure 11.27 Relationship between sorbed and dissolved amphiphile concentration (upper isotherm plot). These different parts of the isotherm reflect changes in the solid surface as sorption proceeds, possibly explainable by the following: in portion (I) with low dissolved concentrations, sorption occurs via ion exchange and related mechanisms. At some point, sufficient near-surface concentration enhancement occurs that micelles form there (IIa) and rapid coagulation between oppositely charged micelles and the surface follows (IIb). When the surface becomes fully coated with such micelles, additional sorption is stopped (III). In portion II, the solid surface charge is converted from one sign to the other.

soils and sediments where both charged mineral surfaces and natural organic matter are present. The studies of Zachara et al. (1986) using quinoline as the sorbate are illustrative. This aromatic compound may occur in aqueous solution both as ionized

quinoline (log $K_{ow} = 2.0$ for neutral species, $pK_a = 4.94$ for the protonated species)

and neutral species; thus we must consider simultaneous sorption of both. Recalling

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Eq. 11-9, we may write for quinoline:

$$K_d = \frac{[Q]_{om} \cdot f_{om} + [QH^+]_{ie} \cdot \sigma_{ie} \cdot A}{[Q] + [QH^+]} \qquad (11\text{-}103)$$

where

$[Q]_{om}$ is the concentration of quinoline associated with the natural organic matter,
$[Q]_{ie}$ is the concentration of ionized quinoline opposite positions of negative charge on the solid surface,
$[Q]$ is the concentration of the dissolved neutral quinoline species, and
$[QH^+]$ is the concentration of the dissolved protonated quinoline species.

Here we assume sufficient f_{om} so that Q_{min} will be unimportant. We also assume that the structure of this substance does not enable Q_{rxn} to form. To simplify Eq. 11-103 we relate all species to the neutral dissolved concentration of quinoline, [Q]. First, using the acid–base equilibrium we express $[QH^+]$ as

$$[QH^+] = [Q][H^+](10^{+4.94}) \qquad (\text{mol} \cdot \text{L}^{-1}) \qquad (11\text{-}104)$$

Thus, information on solution pH will be necessary to calculate the fraction of quinoline present as charged molecules, and to evaluate the particle surface charge density σ_{ie}. Next, we can relate the concentration of neutral quinoline sorbed to natural organic matter to the dissolved neutral quinoline concentration via Eq. 11-15:

$$[Q]_{om} = K_{om} \cdot [Q] \qquad (\text{mol} \cdot \text{kg}^{-1}\ \text{om}) \qquad (11\text{-}105)$$

On the whole-solid basis, this sorption to the natural organic matter contributes $f_{om} \cdot K_{om} \cdot [Q]$. Using a correlation expression such as that for aromatic hydrocarbons (Eq. 11-22a), we can estimate K_{om} using quinoline's octanol–water partition constant:

$$\begin{aligned} \log K_{om} &= 1.01(\log K_{ow}) - 0.72 \qquad (11\text{-}22a) \\ &= 1.01(2.0) - 0.72 \\ &= 1.3 \\ K_{om} &= 20 \end{aligned}$$

Thus, we have for a soil of interest: $[Q_{om}] \approx f_{om} \cdot 20 \cdot [Q]$.

Finally, we must characterize QH^+ sorbed by ion exchange in terms of [Q]. For the particular studies of Zachara et al. (1986), the aqueous solution was maintained at 10^{-2} M $CaCl_2$; consequently, we consider the ion exchange reaction in which QH^+ replaces Ca^{2+}:

$$2QH^+ + Ca{:}(surf)_2 \rightleftharpoons 2QH{:}surf + Ca^{2+} \qquad (11\text{-}106)$$

The ion exchange equilibrium expression for this reaction is

$$K_{\text{ie}}(\text{mol}\cdot\text{kg}^{-1})\cdot(\text{mol}\cdot\text{L}^{-1})^{-1} = \frac{[\text{QH:surf}]^2[\text{Ca}^{2+}]}{[\text{QH}^+]^2[\text{Ca:(surf)}_2]} \qquad \text{(11-107)}$$

Note that the reaction stoichiometry gives us a K_{ie} expression somewhat different than that if Na^+ were the competing cation. To eliminate $[\text{Ca:(surf)}_2]$, we use the fact that the particle surface charge density must equal the accumulated concentrations of counterion sorbates:

$$A\cdot\sigma_{\text{ie}}(\text{mol}\cdot\text{kg}^{-1}) = [\text{QH:surf}] + 2[\text{Ca:(surf)}_2] \qquad \text{(11-108)}$$

Using this charge balance equation in Eq. 11-107, we obtain

$$K_{\text{ie}} = \frac{[\text{QH:surf}]^2[\text{Ca}^{2+}]}{[\text{QH}^+]^2(0.5)(A\cdot\sigma_{\text{ie}} - [\text{QH:surf}])} \qquad \text{(11-109)}$$

which on rearrangement yields

$$[\text{QH:surf}] = \frac{(0.5)K_{\text{ie}}\cdot\sigma_{\text{ie}}\cdot A\cdot[\text{QH}^+]^2}{[\text{QH:surf}][\text{Ca}^{2+}] + (0.5)K_{\text{ie}}\cdot[\text{QH}^+]^2} \qquad \text{(11-110)}$$

We see a result which is similar to Eq. 11-82; but owing to the double charge of calcium ions, this expression is somewhat more complex. At very low concentrations of QH^+ we have $[\text{QH:surf}]\cdot[\text{Ca}^{2+}] \gg (0.5)K_{\text{ie}}\cdot[\text{QH}^+]^2$; thus, under these conditions the ratio of bound-to-dissolved QH^+ species is constant:

$$\frac{[\text{QH:surf}]}{[\text{QH}^+]} = \left[\frac{K_{\text{ie}}\cdot\sigma_{\text{ie}}\cdot A}{2[\text{Ca}^{2+}]}\right]^{0.5} \qquad \text{(11-111)}$$

On the other hand, at high concentrations of QH^+ we see the sorbed species concentration asymptotically approaches $\sigma_{\text{ie}}\cdot A$.

We can also see how sorption via this ion exchange mechanism will be a function of pH. Using Eq. 11-104 to replace $[\text{QH}^+]$ in Eq. 11-110, we arrive at

$$[\text{QH:surf}] = \frac{(0.5)K_{\text{ie}}\sigma_{\text{ie}}A[\text{Q}]^2[\text{H}^+]^2(10^{+4.94})^2}{[\text{QH:surf}][\text{Ca}^{2+}] + (0.5)K_{\text{ie}}[\text{Q}]^2[\text{H}^+]^2(10^{+4.94})^2} \qquad \text{(11-112)}$$

Or at low concentrations of Q, and hence QH^+, we have

$$[\text{QH:surf}] = \left[\frac{K_{\text{ie}}\cdot\sigma_{\text{ie}}\cdot A}{2[\text{Ca}^{++}]}\right]^{0.5}[\text{Q}][\text{H}^+](10^{+4.94}) \qquad \text{(11-113)}$$

whereas at high concentrations of [Q] we still approach

$$[\mathrm{QH{:}surf}] = \sigma_{\mathrm{ie}} \cdot A$$

We also note for K_{ie}:

$$K_{\mathrm{ie}} = \frac{[\mathrm{QH{:}surf}]^2[\mathrm{Ca}^{2+}]}{[\mathrm{QH}^+]^2[\mathrm{Ca{:}surf}_2]} \tag{11-107}$$

$$= \frac{K_{\mathrm{d}}^2 \text{ of } \mathrm{QH}^+}{K_{\mathrm{d}} \text{ of } \mathrm{Ca}^{2+}} \tag{11-114}$$

$$= \frac{(e^{-F\psi/RT} e^{-\Delta G_{\mathrm{hydrophob}}/RT})^2}{(e^{-2F\psi/RT})} \tag{11-115}$$

$$\approx (e^{-2\Delta G_{\mathrm{hydrophob}}/RT}) \tag{11-116}$$

This result implies that the exchange of two QH^+ for Ca^{2+} will favor the organic sorbate by an amount related to the *square* of the "desire" of the nonpolar portion of the molecule to escape the bulk water in favor of the near-particle-surface solution. As we saw earlier (Eqs. 11-88 to 11-96), this led us to relate K_{ie} to $[C_{\mathrm{w}}^{\mathrm{sat}}(\mathrm{l, L})]^{-0.2}$ of the comparable hydrocarbon making up the rest of the amphiphile's structure. Using naphthalene's subcooled liquid solubility ($10^{-3.06}$ M) to estimate quinoline's K_{ie}, we find that $[(10^{-3.06})^{-0.2}]^2 \approx 20$.

With these results, we can now rewrite the distribution coefficient expression 11-103 entirely in terms of Q for situations in which there are only low levels of this sorbate:

$$K_{\mathrm{d}} = \frac{f_{\mathrm{om}}K_{\mathrm{om}}[\mathrm{Q}] + (K_{\mathrm{ie}}\,\sigma_{\mathrm{ie}} \cdot A/2[\mathrm{Ca}^{2+}])^{1/2}([\mathrm{H}^+]/K_{\mathrm{a}})[\mathrm{Q}]}{[\mathrm{Q}] + ([\mathrm{H}^+]/K_{\mathrm{a}})[\mathrm{Q}]}$$

$$= \frac{f_{\mathrm{om}}K_{\mathrm{om}} + (K_{\mathrm{ie}}\,\sigma_{\mathrm{ie}} \cdot A/2[\mathrm{Ca}^{2+}])^{1/2}([\mathrm{H}^+]/K_{\mathrm{a}})}{1 + ([\mathrm{H}^+]/K_{\mathrm{a}})} \tag{11-117}$$

At high levels of $[\mathrm{QH}^+]$ (relative to the competing cations), we have

$$K_{\mathrm{d}} = \frac{f_{\mathrm{om}}K_{\mathrm{om}}[\mathrm{Q}] + \sigma_{\mathrm{ie}} \cdot A}{[\mathrm{Q}] + ([\mathrm{H}^+]/K_{\mathrm{a}})[\mathrm{Q}]} \tag{11-118}$$

These mixed-sorption-mechanism K_{d} expressions now allow estimation of the overall extent of sorption in terms of compound properties (K_{om}, K_{ie}, K_{a}), particle properties (f_{om}, σ_{ie}, A), and solution properties ($[\mathrm{Ca}^{2+}]$, pH). They also enable a side-by-side comparison of which species dominate in the particulate and dissolved phases.

Let us now use these results to estimate solid–solution distributions of quinoline.

Zachara et al. (1986) used a B horizon soil with $f_{\mathrm{om}} \simeq 0.0048$, CEC $\simeq 8.4 \times 10^{-2}$ mol·kg^{-1}, and 0.01 M $\mathrm{CaCl_2}$ background electrolyte to examine quinoline sorption. Assuming the CEC was due to a substantial portion of clay (28% in the particle size distribution), we expect that this parameter is not sensitive to solution pH. To estimate quinoline's K_{d} for pH 4.2 and again at pH 7.5 for the situation where quinoline is present in very low concentrations, we use Eq. 11-117 and obtain

$$K_{\mathrm{d}}(\mathrm{pH}=4.2) = \frac{(0.0048)(20) + (20 \cdot 8.4 \times 10^{-2}/2 \times 10^{-2})^{1/2}(10^{-4.2}/10^{-4.94})}{1 + (10^{-4.2}/10^{-4.94})}$$

$$= \frac{0.096 + 48}{1 + 5.2} \qquad (11\text{-}119)$$

$$= 7.8\,(\mathrm{mol \cdot kg^{-1}}) \cdot (\mathrm{mol \cdot L^{-1}})^{-1}$$

and

$$K_{\mathrm{d}}(\mathrm{pH}=7.5) = \frac{(0.0048)(20) + (20 \cdot 8.4 \times 10^{-2}/2 \times 10^{-2})^{1/2}(10^{-7.5}/10^{-4.94})}{1 + (10^{-7.5}/10^{-4.94})}$$

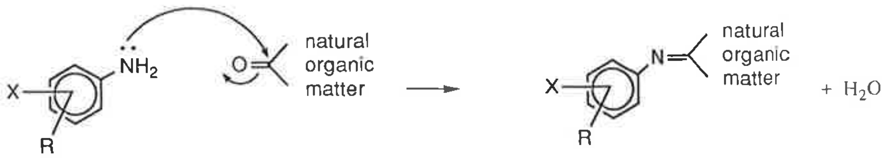
$$= \frac{0.096 + 0.025}{1 + 0.0028} \qquad (11\text{-}120)$$

$$= 0.12\,(\mathrm{mol \cdot kg^{-1}}) \cdot (\mathrm{mol \cdot L^{-1}})^{-1}$$

Zachara et al. (1986) measured $K_{\mathrm{d}}(\mathrm{pH}=4.2) = 3.5$ and $K_{\mathrm{d}}(\mathrm{pH}=7.5) = 0.75$, so it is obvious that our estimates of some inputs (e.g., σ_{ie} and K_{ie}) may not be accurate. Nonetheless we can get within a factor of a few, and even start to discern which sorption mechanisms are most important. For example, the K_{d} expressions show that at pH 4.2 most of the sorbed quinoline is accumulated through the ion exchange mechanism (i.e., the second term in the numerator is greatest), while at pH 7.5 similar amounts are sorbed to the natural organic matter and included as counterions in the film of water surrounding the particle surface.

Estimation of the Contribution of Surface Reactions

Organic Sorbate–Natural Organic Matter Reactions Until this point in the discussion, we have focused on cases where we could neglect chemical bond formation between the sorbate and materials in the solid phase. However, at least two kinds of *surface reactions* are known to be important for sorption of some chemicals (referred to as *chemisorption*). First, some organic sorbates can react with organic moieties contained within the natural organic matter of a particulate phase. Especially prominent in this regard are organic bases like substituted anilines (Hsu and Bartha, 1974, 1976). Due to their low pK_a's(~ 5), the aromatic amine functionality is mostly not protonated at natural water pH's. When compounds like 3,3′-dichlorobenzidine are mixed with sediment, they become irretrievable using organic solvents that should remove them from sorbed positions within natural organic matter or using salt solutions that should displace them from ion exchange sites (Appleton et al., 1980). Conditions that promote hydrolysis (see Chapter 12) do release much of these added aniline derivatives. Thus, it appears that reactions between the basic amine and carbonyl functionalities in the natural organic matter explain the strong sorption seen (Stevenson, 1976):



(11-121)

Such reactions often proceed slowly over hours, days, and even years, so the extent of this sorption due to organic chemical:organic chemical reactions is difficult to predict. Furthermore, such bond-forming sorption is sometimes irreversible on the timescales of interest, and we might not wish to include these effects in a K_d expression reflecting sorption equilibrium.

Organic Sorbate–Inorganic Solid Surface Reactions A second type of reaction exhibited by some organic chemicals involves bonding with atoms (e.g., metals) contained on the surface of the solid. Examples of such reactions are shown in Table 11.6. In these cases a hydroxyl bound to a metal in the solid is displaced by the organic sorbate. Given this additional sorption mechanism, the distribution coefficient becomes more complicated:

$$K_{\substack{\text{d, ion exchange}\\ \text{and surface}\\ \text{reaction}}} = \frac{\begin{bmatrix}\text{organic counterion}\\ \text{near the surface}\end{bmatrix} + \begin{bmatrix}\text{organic ion bound}\\ \text{to the surface}\end{bmatrix}}{[\text{organic ion in solution}]} \tag{11-122}$$

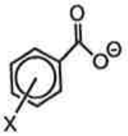
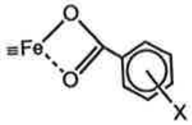
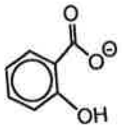
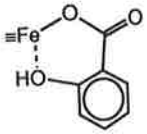
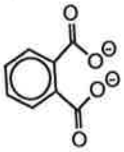
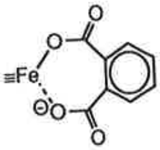
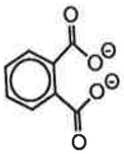
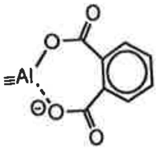
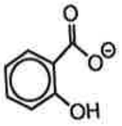
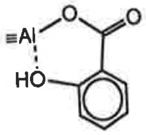
Here we assume that we can neglect neutral species, though this may not always be true. We can separate Eq. 11-122 into parts:

$$K_{\substack{\text{d, ion exchange}\\ \text{and surface}\\ \text{reaction}}} = \frac{[\text{organic counterion}]}{[\text{organic ion in solution}]} + \frac{[\text{organic ion bound to surface}]}{[\text{organic ion in solution}]} \tag{11-123}$$

and use a previous result (e.g., Eq. 11-83) to write

$$K_{\substack{\text{d, ion exchange}\\ \text{and surface}\\ \text{reaction}}} = \frac{\sigma_{\text{ie}} \cdot A \cdot K_{\text{ie}}}{[\text{competing ion}] + K_{\text{ie}}\,[\text{organic ion in solution}]} + \frac{[\text{organic ion bound to surface}]}{[\text{organic ion in solution}]} \tag{11-124}$$

TABLE 11.6 Examples of Organic Sorbates Reacting with Mineral Surfaces[a]

						Ref.[b]
$\equiv Fe-OH$	+	 Substituted Benzoates	$\rightleftharpoons$		$+ OH^-$	1
$\equiv Fe-OH$	+	 Salicylate	$\rightleftharpoons$		$+ OH^-$	2, 3
$\equiv Fe-OH$	+	 *o*-Phthalate	$\rightleftharpoons$		$+ OH^-$	2, 4
$\equiv Al-OH$	+	 *o*-Phthalate	$\rightleftharpoons$		$+ OH^-$	5
$\equiv Al-OH$	+	 Salicylate	$\rightleftharpoons$		$+ OH^-$	5

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[a] Only limited information is available regarding the bonding of species to water-wet surfaces; thus the bonding of the sorbates shown here is conjecture.

[b] 1. Kung and McBride, 1989. 2. Balistrieri and Murray, 1987. 3. Yost et al., 1990. 4. Lövgren, 1991. 5. Stumm et al., 1980.

Now our task is to develop an expression to predict the last term. To do this, we begin by writing the reaction involved:

$$\text{R:surface} + \text{L}{-}\text{M}{\equiv}\text{surface} \rightleftharpoons \text{R}{-}\text{M}{\equiv}\text{surface} + \text{L:surface} \tag{11-125}$$

where R—M≡surface and L—M≡surface are an organic compound and an inorganic ligand like —OH bonded to the solid as indicated by the hyphen. The ions

Ref.[b]

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(11-125)

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The ions

R:surface and L:surface are present at the concentrations in the immediate vicinity of the reaction site, that is, in the diffuse double layer (Region II in Fig. 11.18). Such a reaction reflects a free energy change that we will refer to as ΔG_{rxn} and a corresponding equilibrium expression:

$$K_{\mathrm{rxn}} = \frac{[\mathrm{R{-}M{\equiv}surface}][\mathrm{L{:}surface}]}{[\mathrm{R{:}surface}][\mathrm{L{-}M{\equiv}surface}]} \qquad (11\text{-}126)$$

If we can assume that there are a finite number of reactive sites on the solid, σ_{rxn} ($\mathrm{mol \cdot m^{-2}}$), then we have

$$A \cdot \sigma_{\mathrm{rxn}} = [\mathrm{R{-}M{\equiv}surface}] + [\mathrm{L{-}M{\equiv}surface}] \qquad (11\text{-}127)$$

with A equal to the specific particle surface area (meter squares per kilogram). Therefore, we can rewrite Eq. 11-126:

$$K_{\mathrm{rxn}} = \frac{[\mathrm{R{-}M{\equiv}surface}][\mathrm{L{:}surface}]}{[\mathrm{R{:}surface}](A \cdot \sigma_{\mathrm{rxn}} - [\mathrm{R{-}M{\equiv}surface}])} \qquad (11\text{-}128)$$

We also recall from Eqs. 11-86 and 11-87 that the concentrations of ions in the layer of water next to the particle surface can be related to the corresponding species in the bulk solution:

$$[\mathrm{L{:}surface}] = [\mathrm{L^-}]_{\mathrm{bulk}} \cdot e^{-\Delta G_{\mathrm{elect}}/RT} \qquad (11\text{-}129)$$

and

$$[\mathrm{R{:}surface}] = [\mathrm{R^-}]_{\mathrm{bulk}} \cdot e^{-\Delta G_{\mathrm{elect}}/RT} \cdot e^{-\Delta G_{\mathrm{hydrophob}}/RT} \qquad (11\text{-}130)$$

Using these relations in Eq. 11-128, along with Eq. 11-88, we have

$$\begin{aligned} K_{\mathrm{rxn}} &= \frac{[\mathrm{R{-}M{\equiv}surface}][\mathrm{L^-}]_{\mathrm{bulk}} e^{-\Delta G_{\mathrm{elect}}/RT}}{(A \cdot \sigma_{\mathrm{rxn}} - [\mathrm{R{-}M{\equiv}surface}])[\mathrm{R^-}]_{\mathrm{bulk}} e^{-\Delta G_{\mathrm{elect}}/RT} e^{-\Delta G_{\mathrm{hydrophob}}/RT}} \\ &= \frac{[\mathrm{R{-}M{\equiv}surface}][\mathrm{L^-}]_{\mathrm{bulk}}}{(A \cdot \sigma_{\mathrm{rxn}} - [\mathrm{R{-}M{\equiv}surface}])[\mathrm{R^-}]_{\mathrm{bulk}} K_{\mathrm{ie}}} \end{aligned} \qquad (11\text{-}131)$$

Simplifying and rearranging, we then find:

$$[\mathrm{R{-}M{\equiv}surface}] = \frac{\sigma_{\mathrm{rxn}} \cdot A \cdot K_{\mathrm{ie}} \cdot K_{\mathrm{rxn}} \cdot [\mathrm{R^-}]_{\mathrm{bulk}}}{[\mathrm{L^-}]_{\mathrm{bulk}} + K_{\mathrm{ie}} \cdot K_{\mathrm{rxn}} \cdot [\mathrm{R^-}]_{\mathrm{bulk}}}$$

Thus another Langmuir isotherm is expected with the maximum bound concentrations equal to $\sigma_{\mathrm{rxn}} \cdot A$ and the K_{Langmuir} given by $K_{\mathrm{rxn}} \cdot K_{\mathrm{ie}} \cdot [\mathrm{L^-}]_{\mathrm{bulk}}^{-1}$. This result is very similar in form to that seen before for an ion exchange process (Eq. 11-83). Returning to our overall K_d expression (Eq. 11-124), we can now write

$$K_{\substack{\text{d, ion exchange}\\ \text{and surface}\\ \text{reaction}}} = \frac{\sigma_{\text{ie}} \cdot A \cdot K_{\text{ie}}}{[\text{competing ion}] + K_{\text{ie}}[\text{organic ion}]} + \frac{\sigma_{\text{rxn}} \cdot A \cdot K_{\text{ie}} \cdot K_{\text{rxn}}}{[\text{competing ligand}] + K_{\text{ie}} \cdot K_{\text{rxn}} \cdot [\text{organic ion}]} \qquad (11\text{-}132)$$

As for nonreacting organic ions, we need information on the ion exchange tendency of the chemical of interest (K_{ie} or $\Delta G_{\text{hydrophob}}$); now we also need a means to assess K_{rxn}.

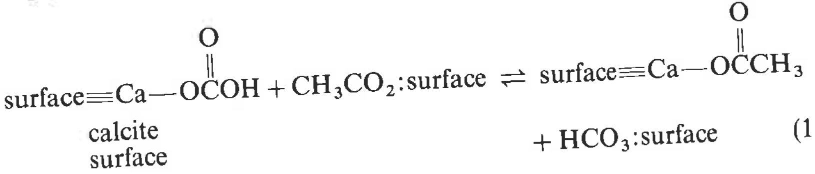
We can evaluate K_{rxn} recognizing that the tendency to form chemical linkages to solid surface atoms correlates with the likelihood of forming comparable complexes in solution (Stumm et al., 1980; Schindler and Stumm, 1987; Dzombak and Morel, 1990). That is, the free energy change associated with the exchange shown by Eq. 11-125 appears energetically similar to that for a process occurring between two dissolved components:

$$\text{M—L}^{+z} + \text{R}^- \rightleftharpoons \text{M—R}^{+z} + \text{L}^- \qquad (11\text{-}133)$$

where z + 1 would be the charge of the free metal in aqueous solution. This entirely solution-phase exchange reaction is characterized by an equilibrium constant:

$$K_{\substack{\text{ligand exchange}\\ \text{in solution}}} = \frac{[\text{M—R}^{+z}][\text{L}^-]}{[\text{M—L}^{+z}][\text{R}^-]} \qquad (11\text{-}134)$$

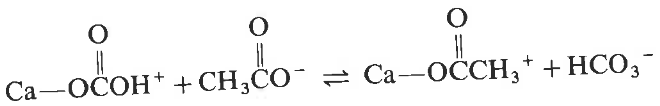
A substantial data base is available to quantify such solution equilibria (e.g., Martell and Smith, 1977; Morel, 1983). Let us examine a specific case. For example, we might be interested in the replacement of a bicarbonate ligand (HCO_3^-) by acetate ($CH_3CO_2^-$) on a calcite ($CaCO_3$) surface:



$$\underset{\substack{\text{calcite}\\ \text{surface}}}{\text{surface}{\equiv}\text{Ca}}\text{—O}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{OH} + \text{CH}_3\text{CO}_2\text{:surface} \rightleftharpoons \text{surface}{\equiv}\text{Ca—O}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{CH}_3 + \text{HCO}_3\text{:surface}$$

(11-135)

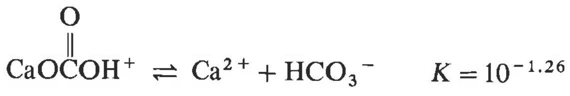
This surface reaction of acetate enables an adsorbed species to be formed which is different from acetate ions simply contained within the electric double layer. To assess this surface reaction, we examine the comparable solution case:



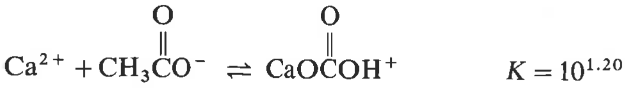
$$\text{Ca—O}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{OH}^+ + \text{CH}_3\overset{\overset{\text{O}}{\|}}{\text{C}}\text{O}^- \rightleftharpoons \text{Ca—O}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{CH}_3{}^+ + \text{HCO}_3{}^-$$

(11-136)

For the case of acetate exchange with bicarbonate in aqueous solution, we can find for aqueous solution (Morel, 1983):

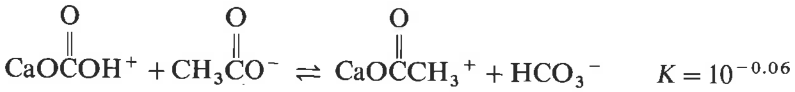


$$\mathrm{CaO}\overset{\overset{\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{OH}^+ \rightleftharpoons \mathrm{Ca}^{2+} + \mathrm{HCO_3}^- \qquad K = 10^{-1.26} \tag{11-137}$$



$$\mathrm{Ca}^{2+} + \mathrm{CH_3}\overset{\overset{\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{O}^- \rightleftharpoons \mathrm{CaO}\overset{\overset{\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{OH}^+ \qquad K = 10^{1.20} \tag{11-138}$$

and combining:



$$\mathrm{CaO}\overset{\overset{\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{OH}^+ + \mathrm{CH_3}\overset{\overset{\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{O}^- \rightleftharpoons \mathrm{CaO}\overset{\overset{\mathrm{O}}{\|}}{\mathrm{C}}\mathrm{CH_3}^+ + \mathrm{HCO_3}^- \qquad K = 10^{-0.06} \tag{11-139}$$

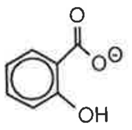
This result for the overall solution equilibrium implies that the free energy change of this particular ligand exchange in solution is near zero ($\Delta G_{\mathrm{rxn}} = -RT \ln 10^{-0.06} = 0.3\ \mathrm{kJ \cdot mol^{-1}}$). This may not be too surprising in light of the chemical similarity of bicarbonate and carboxylate anions. Further, it seems very likely that other longer-chain carboxylic acids (i.e., fatty acids) will also exhibit the similar solution-phase reactivity with calcite.

Now we make use of the very important idea that such solution-phase equilibria can be used to estimate ΔG_{rxn} for comparable surface ligand exchanges. For the specific case of acetate binding to calcite, we would estimate

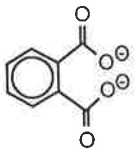
$$\Delta G_{\mathrm{rxn}} \simeq \Delta G_{\substack{\text{ligand}\\ \text{exchange}\\ \text{in solution}}} = 0.3\ \mathrm{kJ \cdot mol^{-1}} \tag{11-140}$$

Therefore, we estimate that K_{rxn} is 0.9 and use it in Eq. 11-132 for calculating K_{d} for the sorption of acetate on calcite.

The procedure for other charged organic chemicals is analogous; and by using the results in Eq. 11-132, we begin to build an overall estimate of charged organic chemical sorption to minerals. Generally, it seems that the tendencies of monodentate organic ligands (e.g., $\mathrm{RCOO^-}$, $\phi\mathrm{OH}$, $\mathrm{R\ddot{N}H_2}$) to diplace inorganic ligands at mineral surfaces is not very great, and it may be reasonable to neglect such surface-bound species when considering the overall K_{d} of such simple organic sorbates. However,



Salicylate

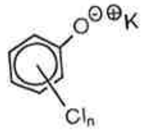


o-Phthalate

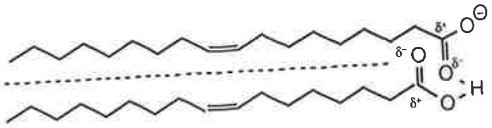
since even a small degree of adsorption can be important to the rate of heterogeneous transformations (e.g., Ulrich and Stone, 1989), in some cases we may need to deal with this. Other charged organic sorbates like salicylate or *o*-phthalate, which may form two bonds with the mineral, are much more likely to exhibit significant ΔG_{rxn} contributions to the overall ΔG_{ads} (Schindler and Stumm, 1987).

Summary Comments Regarding Sorption of Charged Organic Compounds

Before we conclude, we should note that the simple K_d formulations used here may not reflect all the possible mechanisms of charged organic chemical sorption. Frequently we assume sufficient f_{om} to neglect associations of the neutral organic species with mineral surfaces. Similarly, we presumed that charged organic molecules would not "dissolve" into natural organic matter, and Schellenberg et al. (1984) observed sorption of trichlorophenolates consistent with this picture. However, these workers also found that pentachlorophenolate exhibited K_d's far in excess of expectations. Further studies (Westall et al., 1985) indicated that this may be due to the sorptive uptake of the potassium phenolate complex or ion pair



into the natural organic matter. If true, this would require the inclusion of more species in the initial K_d formulation and also thermodynamic expressions relating these species to the phenolate dissolved. In another case, Jung et al. (1987) interpreted oleic acid adsorption to iron oxides as including some role of a neutral oleic acid:oleate complex:

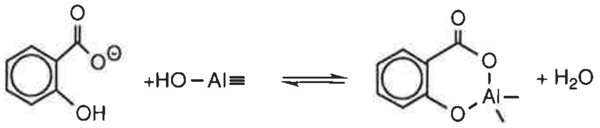


This is reminiscent of the hemimicelle cases we discussed, where now substantial aggregation in solution occurs for only pairs of molecules. Under solution conditions where these "new" species arise, obviously we must (1) adjust the starting K_d expressions to include them, and (2) utilize equilibrium information relating them to the nonassociated species.

11.7 SORPTION KINETICS

Thus far we have focused on situations in which the time was sufficient to allow solid–water exchange of chemicals to achieve equilibrium. However, sometimes we are concerned with cases where the solids do not remain in contact with the solutions of interest for long. Examples of such short-contact situations include storm-related sediment resuspensions or soil erosion events where, after calm is restored, the particles quickly settle to the sediment bed. In another case, zooplankton fecal pellets of approximately 100 μm diameter fall through a body of water at about 100 m/day, conceivably too fast to permit sorbates to establish sorption equilibrium with each depth interval of the surrounding water. Infiltrating groundwater may experience only brief contact with the soil grains by which these solutions pass. Even groundwater moving at natural slow flow rates may not always expose the aquifer solids long enough to permit complete sorption equilibrium (Roberts et al., 1986; Ball and Roberts, 1991). In all of these cases, certain molecules may simply not have enough time to exchange before the solution or the solid moves away from the other phase. Sometimes slow desorption also limits transformations like biodegradation (Rijnaarts et al., 1990).

Two types of processes could act as the bottleneck, inhibiting sorptive equilibrium. First, chemical reactions (*chemisorption*) between the sorbate and the point of association in the particles might limit the overall approach to sorptive equilibrium. An example is salicylate sorption to very small alumina particles (Kummert and Stumm, 1980). Most of the sorbed salicylate is thought to be chemically bound to the alumina surface:



(11-141)

During the short interval (< 2 h) after initial mixing of the salicylate with the alumina, dissolved salicylate concentration drops quickly and then decreases more gradually (Fig. 11.28*a*). Apparently, the rate of salicylate reaction with surface sites on the exterior of the particles is controlling the rate of overall sorption during the early portion of this timecourse. Another example of chemisorption might be slow condensation reactions of organic amines with carbonyl moieties of the solid phase natural organic matter. To quantify the kinetics of these particular chemisorption processes, one needs to deal with the rates of the individual reactions involved.

The second type of limitation occurs when the sorbate molecules do not physically have enough time to move to all the points of contact in and on the solids where they would become associated. We often refer to this physical limitation as a *mass transfer limited process*. For example, we can imagine charged sorbate molecules needing time to diffuse into a clayey floc before they can associate with oppositely charged surface sites in the interior (Fig. 11.28*b*). Similarly, we can easily see that some of the natural organic matter that absorbs nonpolar compounds may be located at somewhat inaccessible positions within silty aggregates (Fig. 11.28*c*). Even in the case of ligand exchange, as for salicylate ions, diffusion into porous alumina particles where there are more reactive sites can be slow (Fig. 11.28*a* for times greater than a few hours). Since sorptive equilibrium is only reached when each subpart of a solid has accumulated enough sorbate to itself be equilibrated with the solution on the outside, we can

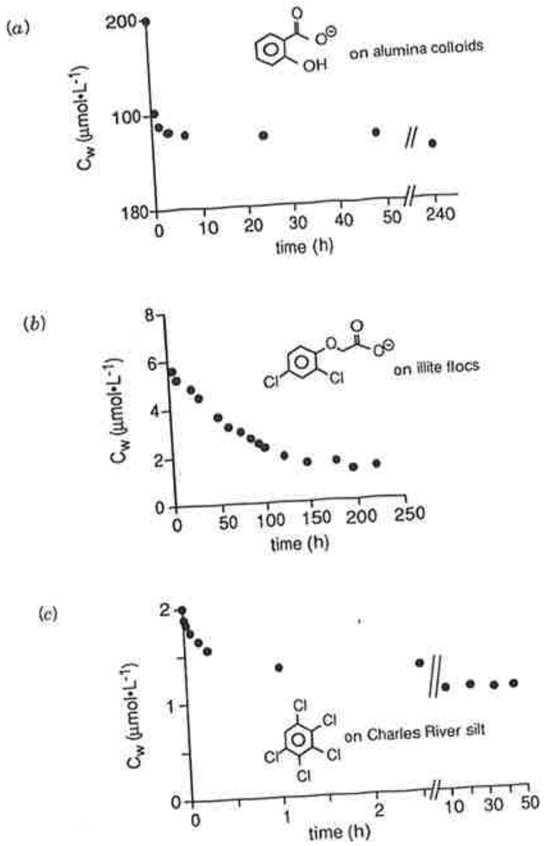


Figure 11.28 Some observed time courses of organic compounds associating with suspended solids. (*a*) Salicylate sorption to 20 nm γ-Al_2O_3 (data from Kummert and Stumm, 1980). (*b*) 2,4-D sorption to clay flocs (data from Haque et al., 1968). (*c*) Pentachlorobenzene sorption to silt-sized river sediment (data from Wu and Gschwend, 1986).

recognize that simply delivering molecules to all the internal solid "binding" sites must take a finite amount of time. Once the molecules have arrived at the particulate locations where they will be bound, then interactions may occur on the molecular scale. If the average time spent arriving at these local points of association is long compared to the time required to make these molecule-scale attachments, then we must focus on the rate of molecular penetration to the binding sites to describe the overall sorption kinetics. Many reports suggest that the molecule-scale sorbate–sorbent association is fast relative to diffusion within porous solids (e.g., Helfferich, 1962, or Adamson, 1982, regarding ion exchange; e.g., Brusseau and Rao, 1989 review of nonpolar organic chemical sorption). Therefore, in the following discussions, we focus on cases of mass transfer limitations to solid–water exchange and the resultant approach one may use to estimate overall sorption rates.

Sorption Kinetics for Mass Transfer Limited Mechanisms

We begin by noting that soil and sediment particles are often actually present as *aggregates* of individual solid phases (Fig. 11.29). Not only does this refer to the coalescence of many fine grains such as those seen in flocculated clay aggregates, but may also include parent mineral grains coated with other phases like iron oxides and natural organic matter. The resultant solids are then composed of subregions with differential capabilities to sorb organic compounds. A key exception to this extremely porous visualization involves sands or larger rocks which consist of individual grains (e.g., quartz). Even such "single solid" natural particles contain some micropores (e.g., Wood et al., 1990; Ball et al., 1990), and passing through these pores sometimes appears to be critical for accessing the quantitatively most important sorption sites.

For molecules in solution to distribute themselves between the dissolved and sorbed phases, several steps in series are required. First, there may be a mass transfer limitation due to diffusion across a poorly mixed water layer surrounding the outside of each particle (Fig. 11.29). The timescales of such external diffusion are probably on the order of seconds in most turbulent situations. Using Eq. 9-31, we can get an estimate of this timescale:

$$\tau \sim \frac{(\text{thickness of boundary layer surrounding aggregate})^2}{2D_{\text{w}}} \qquad (11\text{-}142)$$

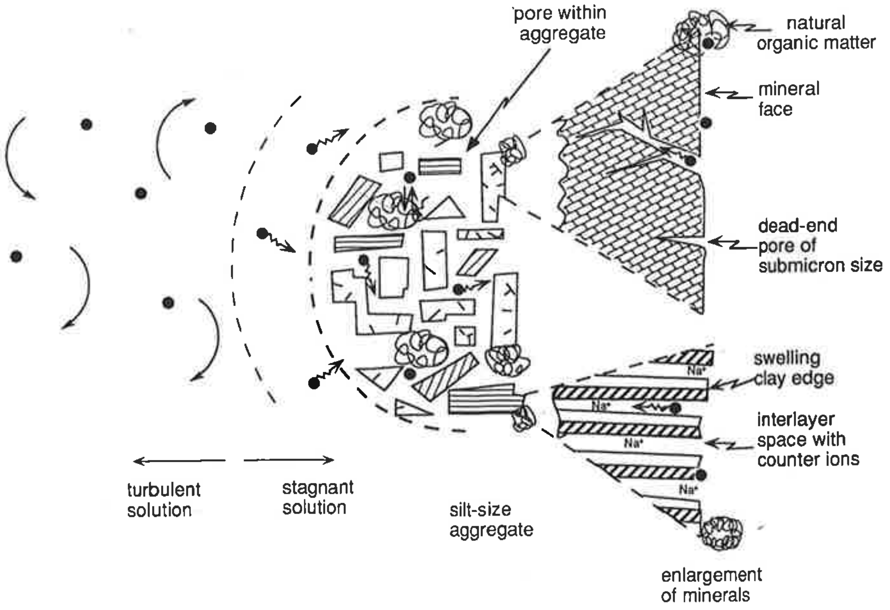


Figure 11.29 Conceptualization of the sequence of steps required to move sorbate molecules (pictured as black dots) between a turbulent solution and all the sorptive sites within a typical soil or sediment aggregate.

For relatively large particles ($> 200\,\mu m$), like sands whose surfaces are large enough to impart significant frictional interaction with the fluids, such a boundary layer thickness is probably on the order of $200\,\mu m$ in thickness. For smaller particles ($\lesssim 200\,\mu m$), the diffusion limited zone shrinks in proportion to the particle size. Thus $200\,\mu m$ might typify the largest boundary thickness we encounter. Together with a reasonable value of D_w (see Fig. 9.7), we find that external diffusion requires on the order of

$$\tau \sim \frac{(2 \times 10^{-2}\ \mathrm{cm})^2}{2(10^{-5}\ \mathrm{cm^2/s})} \qquad (11\text{-}143)$$

$$\sim 20\,\mathrm{s}$$

Obviously, if the solution outside the particles is mixed at all, there will not be much time spent by molecules reaching the aggregate exterior. In nonturbulent solutions like groundwater or sediment porewaters, the distance between grain surfaces is probably about the same as the grain size. Consequently, use of an equation analogous to Eq. 11-142 would show a timescales of diffusion in the intergranular solutions of only seconds to minutes at most. If the primary site of attachment is on the exterior surface of the particles, then the overall sorption process will be characterized by this external diffusion time plus that required to complete the local binding reaction. This is probably the appropriate image of what is controlling sorption of salicylate to alumina at early times, as we discussed above (Fig. 11.28*a*).

For many natural particles of interest (e.g., soils, suspended solids), the sorbates must continue their transport to their ultimate points of attachment by diffusing in the *immobile* fluids filling the interstices of the aggregates (Fig. 11.29; Rao et al., 1980, 1982; Wu and Gschwend, 1986, 1988; Weber et al., 1991). Generally, such pore spaces are large relative to the molecules themselves (i.e., these pores are probably about the same size as the parent particles of which the aggregate is made); thus diffusion in these spaces occurs somewhat like molecular diffusion in aqueous solution. An exception may be that some pore spaces are blocked by natural organic matter, and molecular transfer to points deeper in the aggregate interior or even deep inside the natural organic matter may require diffusion through these organic polymers (Brusseau and Rao, 1989; Brusseau et al., 1991; Brusseau and Rao, 1991). If the majority of solid sorbent is accessed after diffusion through "large pores", then the overall process may be effectively described by focusing on this step.

Other times, the bulk of the sorption occurs at quite inaccessible positions such as in *dead-end pores* or between the layers of aluminosilicate minerals (Ball and Roberts, 1991). These channels differ from those of the aggregate in that they exhibit openings that are comparable in size to the sorbate molecules of interest. This results in a *steric limitation* to diffusive transport. Also, these channels are probably not as extensively interconnected (hence the "dead-end" reference) as those between the grains making up aggregates. This also contributes to inhibiting exchange with the exterior. When the sorption sites of interest involve these kinds of solid positions, then we may consider the mass transfer to involve diffusion coefficients that are greatly

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reduced relative to the free solution values. Various reports of extremely slow desorption kinetics (decade timescales) such as those seen for residues of the soil fumigant, ethylene dibromide, appear to be best explained by release from such poorly accessible nanometer-sized pores (Steinberg et al., 1987).

Modeling Mass Transfer Limited Sorption

Since sorption kinetics experiments usually reveal an early period of extensive exchange, followed by a prolonged time of slowly proceeding uptake (or release) by particles (Leenheer and Ahlrichs, 1971; Connolly, 1980; Karickhoff, 1980; Wu and Gschwend, 1986; Brusseau and Rao, 1989; Ball and Roberts, 1991), the sorption process has been characterized with a two-box model (Karickhoff, 1980). In this conceptualization, one portion of the solid phase is taken to be rapidly equilibrated with the solution phase; the other part of the solid is described using a rate equation. One can easily extend this idea by imagining an infinite series of "boxes" in the particles, each in successively less direct contact with the exterior solution. That is the approach used here. Thus our problem entails diffusing sorbate molecules *radially* via the interconnecting porewater channels into soil or sediment aggregates. Such a picture may be well suited to cases in which most of the organic sorbate of concern will eventually be associated with relatively accessible solid phases like natural organic matter. Although real-world particles are not spherical, and the points of sorptive attachment may not be spread evenly throughout the natural particle aggregate, these characteristics are reasonable approximations.

To describe this transfer of sorbate molecules into or out of such aggregates, we first consider a single porous sphere of radius R (Fig. 11.30). The solute concentration

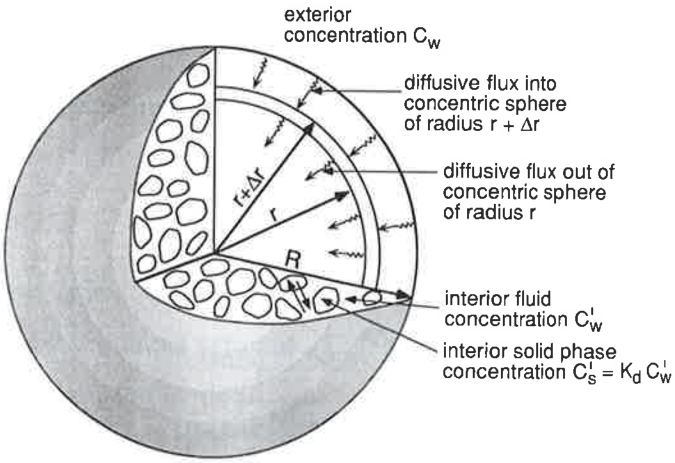

Figure 11.30 Diffusion-limited transfer into an idealized soil or sediment aggregate of radius R and interior concentrations $C'_w(r,t)$ in the water within the aggregate. Sorption is modeled using a mass balance equation for any concentric shell of thickness Δr (see Eq. 11-153 in text).

inside the aggregate pores, C'_w, is always at equilibrium with the adjacent sorbed phase, C'_s:

$$C'_s = K^*_d C'_w \tag{11-144}$$

where K^*_d is the *in situ* (microscopic) distribution coefficient. Ultimately, we are interested in the "macroscopic" distribution coefficient that relates the (macroscopic) sorbed concentration, C_s, to the dissolved concentration in the exterior water, C_w:

$$C_s(t) = K_d(t) \cdot C_w \tag{11-145}$$

where, owing to finite kinetics of macroscopic sorption, K_d is time dependent.

Note that C_s is determined as the total mass of the compound in the dried particle divided by the dry particle mass. Thus, C_s includes the dissolved fraction of the chemical in the porewater when the particles are dried. Due to the spherical symmetry, the evolving concentration distributions only depend on the radial distance r and on time t. The total concentration in the particle at distance r from the center, C_{tot}, on a particle volume basis is given by

$$C_{tot}(r) = \rho_s(1 - \phi)C'_s(r) + \phi C'_w(r) \qquad (\mathrm{mol \cdot L^{-1}}) \tag{11-146}$$

where ρ_s is the density of (dry) solid ($\mathrm{kg \cdot L^{-1}}$ solid) and ϕ is the porosity of particle aggregate (L water$\cdot \mathrm{L^{-1}}$ total).

Since C'_s and C'_w are related by Eq. 11-144, we get

$$C_{tot}(r) = [K^*_d \cdot (1 - \phi) \cdot \rho_s + \phi] \cdot C'_w(r) \tag{11-147}$$

When K^*_d, ρ_s, and ϕ are constant everywhere within the particle aggregate, the mean total concentration in the particle is

$$\bar{C}_{tot} = [K^*_d \cdot (1 - \phi) \cdot \rho_s + \phi] \cdot \bar{C}'_w \tag{11-148}$$

where

$$\bar{C}'_w = \frac{\int_0^R 4\pi r^2 \cdot C'_w(r)dr}{4\pi R^3/3} = \frac{3}{R^3}\int_0^R r^2 C'_w(r)dr \tag{11-149}$$

is the volume-weighted mean of the radial concentration field $C'_w(r)$. The (macroscopic) sorbed concentration on a particle mass basis now can be calculated:

$$C_s = \frac{\bar{C}_{tot}}{\rho_{bulk}} = \frac{\bar{C}_{tot}}{(1-\phi)\rho_s} = \left[K_d^* + \frac{\phi}{(1-\phi)\rho_s}\right]\bar{C}'_w \tag{11-150}$$

where C_s is a function of time like $\bar{C}'_w$.

To make the last step to Eq. 11-145, we have to relate the time-dependent mean concentration $\bar{C}'_w$ to the external solute concentration C_w. If the sorbate molecules only diffuse in the pores, we recognize that the change in total sorbate concentration $\bar{C}_{tot}$ is controlled by diffusive uptake through the pore fluids driven by gradients in the internal sorbate concentration C'_w. Thus, we consider our single porous sphere of radius R to have sorbate molecules diffusing through successive concentric layers (Fig. 11.30). Diffusion into or out of the sphere begins at $t = 0$, and it occurs because of a difference in concentrations between the inside porewater and the outside bulk solution. If we consider a mass balance equation for any thin concentric shell within the spherical aggregate, bounded by spheres with radius r and $r + \Delta r$, we may write

$$\frac{\partial C_{tot}}{\partial t} = \frac{\text{Flux at inner sphere} - \text{Flux at outer sphere}}{\text{shell volume}} \tag{11-151}$$

Using Eq. 9-2, multiplied by the areas of the relevant shells, to quantify the fluxes in Eq. 11-151, and assuming that dissolved concentration changes along the radial directions are responsible for diffusive transport, we have

$$\begin{aligned}\frac{\partial C_{tot}}{\partial t} &= \frac{-\left(\phi\cdot D\cdot 4\pi r^2\cdot\frac{\partial}{\partial r}(C'_w)\right) + (\phi\cdot D\cdot 4\pi(r+\Delta r)^2)\cdot\frac{\partial}{\partial r}\left(C'_w + \Delta r\frac{\partial C'_w}{\partial r}\right)}{(4/3)\pi(r+\Delta r)^3 - (4/3)\pi r^3}\\ &= \frac{-4\pi D\phi(r)^2\cdot\left(\frac{\partial C'_w}{\partial r}\right) + 4\pi D\phi(r+\Delta r)^2\left(\frac{\partial C'_w}{\partial r} + \Delta r\frac{\partial^2 C'_w}{\partial r^2}\right)}{(4/3)\pi(r+\Delta r)^3 - (4/3)\pi r^3}\end{aligned} \tag{11-152}$$

where we have estimated the concentration gradient at the radius $r + \Delta r$ to be approximated by the linear expansion, $C'_w(r+\Delta r) \simeq C'_w(r) + \Delta r\frac{\partial C'_w}{\partial r}$. We have also reduced the fluxes in proportion to the aggregate porosity ϕ to account for the diminished cross-sectional area available for diffusion. Neglecting all terms of order $(\Delta r)^2$ or $(\Delta r)^3$, we can simplify to find

$$\frac{\partial C_{tot}}{\partial t} = \phi D\left(\frac{\partial^2 C'_w}{\partial r^2} + \frac{2}{r}\frac{\partial C'_w}{\partial r}\right) \tag{11-153}$$

To use this equation we need to consider what factors dictate the magnitude of D. First, of course, we know from our physical conceptualization that we are interested in molecules diffusing in aqueous solutions in the aggregate pores; hence D should be closely related to D_w, the molecular diffusivity in water. Unlike diffusion in water though, the sorbate molecules must navigate around the various fine grains making up the skeleton of our natural particle aggregate. This elongated path issue is treated by using a tortuosity factor f which reduces D to some value below D_w. If the size of the pores is small enough to be comparable to the diffusing molecules themselves, we also need to reduce D_w again using what is called a constrictivity factor (Satterfield et al., 1973; Ball and Roberts, 1991). It is also possible that diffusion occurs, not only in the water filling the pores, but also on the walls of the component particles in a two-dimensional process called surface diffusion. Here we neglect this process because of the discontinuous nature of the aggregates.

Returning to Eq. 11-153, C_{tot} can be replaced by C'_w using Eq. 11-147. Note again that ϕ, K^*_d, and ρ_s are assumed to be spatially constant. Thus,

$$\frac{\partial C'_w}{\partial t} = D^*\left[\frac{\partial^2 C'_w}{\partial r^2} + \frac{2}{r}\frac{\partial C'_w}{\partial r}\right] \qquad \text{(11-154)}$$

with

$$D^* = \frac{\phi f D_w}{K^*_d(1-\phi)\rho_s + \phi} \qquad \text{(11-155)}$$

D^* is sometimes referred to as the effective diffusivity.

The time-dependent solution for C'_w which satisfies Eq. 11-154 is an infinite sum of exponential terms (Crank, 1975). If we consider the relative approach to equilibrium using the total mass of sorbate inside the solid phase at time t, $\bar{C}_{tot}(t)$, versus the final mass accumulated at steady-state, $\bar{C}_{tot,\infty}$, then the ratio of these sorbed phase loadings, $\bar{C}_{tot}(t)/\bar{C}_{tot,\infty}$, depends on a nondimensional parameter, $D^*\cdot t/R^2$:

$$\frac{\bar{C}_{tot}(t)}{\bar{C}_{tot,\infty}} = F\left(\frac{D^*t}{R^2}\right) \qquad \text{(11-156)}$$

where F is a monotonically increasing function with $F(0) = 0$ and $F(1) = 1$. The larger is the sorbate's effective diffusivity, the faster will be the approach to equilibrium. Conversely, the larger the particle, the slower will be the overall sorptive equilibrium since diffusion pathlengths are longer.

We can picture the corresponding concentration profiles (Fig. 11.31) for the case where the exterior solution exhibits a constant concentration C_w and the molecules are diffusing into a spherical aggregate of interest. Upon initial mixing, the outermost portion of the sphere equilibrates with the solution so that this part of the sorbent exhibits sorbed concentration $K_d \cdot C_w$. Subsequently, more interior portions of the sphere accumulate the sorbate, and it is these integrated concentrations, weighted for

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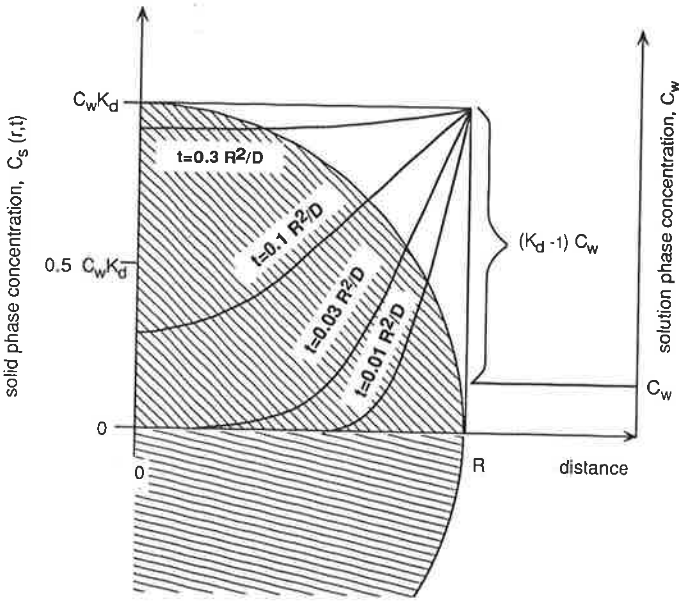

Figure 11.31 Concentration profiles resulting from the diffusion of a sorbate into a porous particle from a solution of constant concentration C_w. Successive profiles are characterized by times given as a function of R, the particle radius, and D^*, the effective diffusivity of the sorbate moving into the particle.

the concentric volumes they occupy, that correspond to the time-varying sorbed load. When $t \approx 0.03\,R^2/D^*$, the total sorbed load is about 50% of its equilibrium value, and when $t \approx 0.3\,R^2/D^*$, the process is 97% complete. Put another way, the solid phase is virtually "filled up" with sorbate (Fig. 11.31), and we might define an approximate *sorption rate constant for this case of constant exterior solution concentration:*

$$k_{\text{sorb}}(C_w = \text{constant}) \simeq \frac{\ln 2}{t_{50\%}} \simeq \frac{0.69\,D^*}{0.03\,R^2} \simeq 23\,D^*/R^2 \qquad [\mathrm{T}^{-1}] \qquad (11\text{-}157)$$

Use of such an approximate first-order rate constant yields a result similar to that obtained from the complete solution (Crank, 1975), but it underpredicts sorptive exchange at short times and overpredicts sorption at long times (Fig. 11.32).

In the cases where C_w does not remain constant in the exterior solution (because a significant portion of the dissolved load is sorbed), the expression for k_{sorb} becomes a little more complicated (Crank, 1975; Wu and Gschwend, 1988). Figure 11.33 shows how the progress of sorptive exchange proceeds for several different values of $K_d \cdot r_{sw}$ (which characterizes the proportion of the total chemical in the system eventually sorbed). As $K_d \cdot r_{sw}$ increases from the infinite bath case (i.e., $C_w = \text{constant}$), we see that the times required to reach equilibrium decrease. For cases of sorptive uptake,

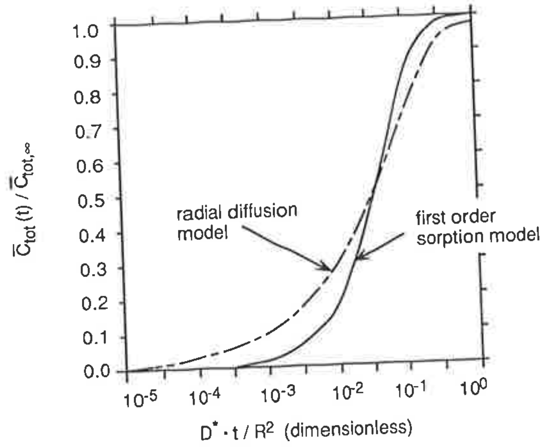

Figure 11.32 Comparison of the exact solution to the radial diffusion model of sorptive exchange from Crank (1975) with the first-order model approximation. $\bar{C}_{tot}/\bar{C}_{tot,\infty}$ is the ratio of the current average solid-phase sorbate concentration to that achieved at equilibrium; D^* is the effective diffusivity of a sorbate moving within the sorbent; R is the sorbent radius; and t is time.

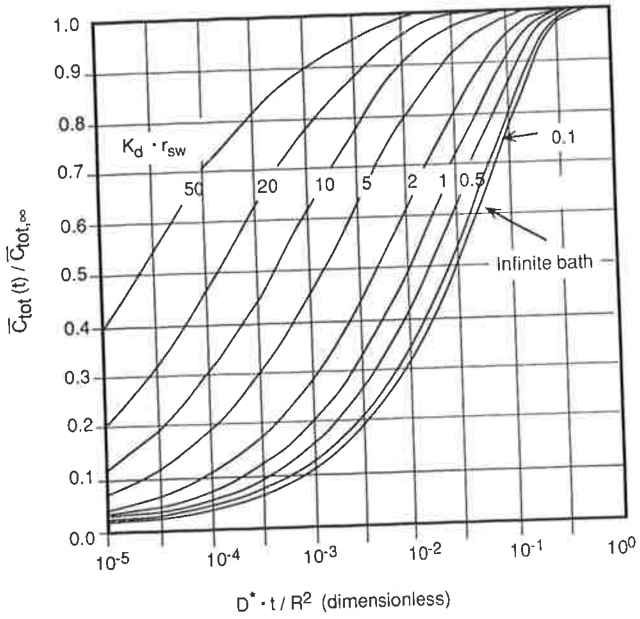

Figure 11.33 Timecourses for the diffusive uptake or release of sorbates by spherical particles suspended in closed systems. The numbers on the curves show the final ratio of the mass sorbed on solids to the mass dissolved in the solution.

this might be understood by recognizing that the gradients $\partial C'_w/\partial r$ will be steeper for longer if there are more solids or greater tendencies to sorb. For cases of desorption, this shortened time may be explained by realizing that each of the aggregates need only release a little sorbate to build up equilibrium levels in the solution.

Examining the curves for nonconstant C_w allows us to specify k_{sorb} when C_w is not a constant. For example, we may be interested in a case where $r_{sw} \cdot K_d$ is 10. To reach 50% sorption completion, we can use Figure 11.33 to see that the time required will be

$$t_{50\%}(K_d \cdot r_{sw} = 10) \simeq 4 \times 10^{-4} R^2/D^* \tag{11-158}$$

or that the approximate first-order rate constant should be

$$k_{sorb}(K_d \cdot r_{sw} = 10) \simeq \frac{D^* \ln 2}{4 \times 10^{-4} R^2} \simeq 2000\, D^*/R^2 \tag{11-159}$$

In general, the relation of k_{sorb} to $K_d \cdot r_w$, optimized to fit the midpoint of the sorptive exchange, is given (Wu and Gschwend, 1988) by

$$k_{sorb}(K_d \cdot r_{sw}) \simeq (11 \cdot K_d \cdot r_{sw} + 23)\, D^*/R^2 \tag{11-160}$$

We should reiterate that this approximate solution is well suited for describing the midregion of the solid–water exchange timecourse, but does poorly for early and late times. Use of Figure 11.33 can allow one to be more accurate at $t_{10\%}$, $t_{90\%}$, or whatever extent of approach to sorptive equilibrium is of interest.

If one believes that a retarded radial diffusion mass transfer is limiting overall sorption, as did the authors who produced the data shown in Figure 11.28*b* and *c*, we now can see how such data can be used to deduce the critical ratio R^2/D^* for situations of interest. For example, the uptake of 2,4-D by illite flocs, illustrated in Figure 11.28*b*, exhibits a $t_{50\%}$ of about 50 h. Since these particular data were obtained in experiments with $K_d \cdot r_{sw}$ of about 4, we may estimate

$$k_{sorb} \simeq \frac{\ln 2}{t_{50\%}} \simeq \frac{\ln 2}{50\,\text{h}} \sim 0.014\,\text{h}^{-1} \tag{11-161}$$

If we know the radius of the illite flocs, this result would allow us to estimate the effective diffusivity of 2,4,-D in those aggregates.

These results also enable us to understand how K_d will vary with time. First, since $\bar{C}'_w$ is proportional to $\bar{C}_{tot}$ and increases until it equals C_w, we can write

$$\bar{C}'_w = (\bar{C}_{tot}/\bar{C}_{tot,\infty})C_w \tag{11-162}$$

Inserting Eq. 11-162 into Eq. 11-150, we find

$$K_d(t) = \left(K_d^* + \frac{\phi}{(1-\phi)\rho_s}\right)(\bar{C}_{tot}/\bar{C}_{tot,\infty}) \tag{11-163}$$

$$= K_d^\infty \cdot (\bar{C}_{tot}/\bar{C}_{tot,\infty}) \tag{11-164}$$

with $K_d^\infty = K_d^* + \phi/(1-\phi)\rho_s$. Note that the second term on the right-hand side of our K_d^∞ expression simply reflects the uptake due to pore water reaching concentrations like that of the exterior solution. As for the variation of $\bar{C}_{tot}$, the value of K_d approximately represents an equilibrium condition at (e.g., five half-lives)

$$t \simeq \frac{0.3 \cdot R^2}{D^*} = 0.3 \cdot R^2 \cdot \frac{K_d^*(1-\phi)\rho_s + \phi}{\phi f D_w} \tag{11-165}$$

An Example: Calculation of the Desorption Kinetics of an Organic Chemical Let us conclude this discussion with an example calculation to see how we might evaluate sorption kinetics in a particular case. For example, suppose we are concerned that some PCB-contaminated sediments will spill and settle through a water body during dredging operations. First, we note that the volume of water involved is probably very large compared to the mass of solids that we will spill; hence $K_d \cdot r_{sw}$ is a small number. In this event, we focus our attention on the timecourse in Figure 11.33 labeled "infinite bath" where $K_d \cdot r_{sw}$ is less than 0.01. Now if we are interested in finding the time necessary to desorb half of the PCB contaminants from the settling sediment grains, we read across the chart from $\bar{C}_{tot}/\bar{C}_{tot,\infty} = 0.5$ and see an intersection with the infinite bath timecourse at $D^*t/R^2 = 0.03$. At this juncture we need to specify some of the properties of the chemicals and sediments. Suppose we have a particular PCB congener with $\log K_{ow} = 7$ and $D_w = 7 \cdot 10^{-6}\ \text{cm}^2 \cdot \text{s}^{-1}$, as well as a particular silty sediment of 100-μm diameter and organic carbon content of 4%. Assuming these dredged sediments also exhibit $\phi \cdot f \approx 0.02$ (as reported by Wu and Gschwend, 1986 for a few samples), we now calculate the time to 50% release of the PCB of interest:

$$t_{50\%} \simeq 0.03\, R^2/D^* \tag{11-166}$$

$$\simeq \frac{(0.03)(R^2)(\rho_s(1-\phi) \cdot f_{oc} \cdot K_{oc} + \phi)}{\phi f \cdot D_w} \tag{11-167}$$

$$\simeq \frac{(0.03)(50 \cdot 10^{-6}\ \text{m}^2)^2(2 \times 10^3\ \text{kg/m}^3 \cdot 0.04 \cdot 3.1\, K_{ow}^{0.72} \times 10^{-3}\ \text{m}^3/\text{kg})}{(0.02 \cdot 7 \cdot 10^{-10}\ \text{m}^2/\text{s})}$$

$$\simeq 1.5 \cdot 10^5 \cdot \text{s}^{-1} \text{ or about 2 days}$$

where we assume a bulk density $(= \rho_s(1-\phi))$ of $2\ \text{g} \cdot \text{cm}^{-3}$. Note that $[\rho_s(1-\phi)K_d]$ is much greater than any reasonable value of ϕ, so the porosity in the numerator can be neglected in our calculations. Since the time of release appears similar to that time expected for such spilled dredge particles to fall back to the bottom, one should expect a substantial release of even hydrophobic PCB congeners, but not equilibration.

Other Issues of Sorption Kinetics

The situation in which mass transfer into and out of aggregates limits the rate of sorptive exchange may be common, but this conceptualization will not cover every case where mass transfers are controlling. As alluded to earlier, sometimes the slowest process controlling sorption of organic molecules of interest to us involves their movements through pores of similar size to themselves (e.g., Wood et al., 1990; Ball and Roberts, 1991). If this is the case, we must reduce D in mass balance equations like Eq. 11-153 even further using a constrictivity factor (Satterfield et al., 1973). It is also possible that diffusion in small continuous pores occurs, not only in the water filling the pores, but also on the walls themselves (i.e., surface diffusion). Release of organic contaminants from these positions within the solids may require months to years (Coates and Elzerman, 1986; Steinberg et al., 1987; Pavlostathis and Jaglal, 1991).

Another possibility is that molecular diffusion into macromolecular organic matter may be the slowest step in the overall process in some cases (Brusseau et al., 1991; Brusseau and Rao, 1991). Due to the relatively "viscous" nature of such organic matter, the diffusion coefficients of organic sorbates moving in this polymeric matter may be significantly lower than comparable free-solution values. If the diffusion pathlengths are long enough, transfer of hydrophobic compounds into all parts of the humus of soils and similar media on other particles may control the overall sorptive exchange rate.

Until now, we have considered only linear partitioning of sorbates at each microscopic position within an aggregate. Obviously, some sorption mechanisms require us to examine cases of nonlinear surface–solution exchange. Such a case was considered in the uptake of alkyl benzene sulfonates by porous granular carbon particles (Weber and Rumer, 1965). In this situation $C'_s(r)$ was related to $C'_w(r)$ using a Langmuir isotherm to yield a result comparable to what we reached with Eq. 11-147.

We conclude this discussion of sorption kinetics by noting that the concepts of mass transfer limitation we have discussed are general. Their application to many situations, with appropriate modifications, will undoubtedly prove effective. A recent example of this is provided by Rounds and Pankow (1990), who successfully characterized organic vapor molecule–atmospheric particle exchange kinetics with a radial diffusion model.