Sewers as a Source and Sink of Chlorinated-Solvent Groundwater Contamination, Marine Corps Recruit Depot, Parris Island, South Carolina

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Abstract. Groundwater contamination by tetrachloroethene and its dechlorination products is present in two partially intermingled plumes in the surficial aquifer near a former dry-cleaning facility at Site 45, Marine Corps Recruit Depot, Parris Island, South Carolina. The northern plume originates from the vicinity of former above-ground storage tanks. Free-phase tetrachloroethene from activities in this area entered the groundwater. The southern plume originates at a nearby new dry-cleaning facility, but probably was the result of contamination released to the aquifer from a leaking sanitary sewer line from the former dry-cleaning facility. Discharge of dissolved groundwater contamination is primarily to leaking storm sewers below the water table. The strong influence of sanitary sewers on source distribution and of storm sewers on plume orientation and discharge at this site indicates that groundwater-contamination investigators should consider the potential influence of sewer systems at their sites.

INTRODUCTION

The purpose of this article is to discuss the influence of subsurface drains at Site 45, Marine Corps Recruit Depot, Parris Island, South Carolina, on the distribution and fate of the groundwater contamination. This work is important because the setting discussed is common to coastal areas. It is likely that the influences of both storm and sanitary sewers discussed here have application to other coastal areas where groundwater contamination is present. The strong influence of sanitary sewers on source distribution and of storm sewers on plume orientation and discharge at this site indicates that groundwater-contamination investigators should consider the potential influence of sewer systems at their sites.

BACKGROUND AND RELATED WORK

Volatile organic compound (VOC) groundwater contamination is present at Site 45 at Marine Corps Recruit Depot, Parris Island, South Carolina, from a former dry-cleaning facility. An above-ground storage tank (Fig. 1A) was overfilled with tetrachloroethene (PCE) on March 11, 1994, resulting in a spill that was released to the soil and groundwater (S&ME, Inc., 1994). Subsequent investigations showed groundwater contamination by PCE and dechlorination daughter products in the vicinity of the storage tanks and in down-gradient areas toward the southeast (Tetra Tech NUS, Inc., 2004, 2005), hereafter referred to as the northern plume (Fig. 1). The former dry-cleaning facility was demolished, and related structures were removed from the site in early 2001 (Tetra Tech NUS, Inc, 2004).

In late 1997, the dry-cleaning operations were moved to a new facility, approximately 39.6 meters (m) west of the former dry-cleaning building (Fig. 1). With the move to a new facility, the dry-cleaning operation switched from PCE as the cleaning solvent to a non-hazardous petroleum-based cleaner (i.e. Exxon-Mobile D-2000) that contains no chlorinated solvents, and the equipment was replaced with refrigeration for recirculation and recovery of the solvent (Center for Waste Minimization, 2000). Investigations in 2005 and 2006, however, showed the presence of a previously undetected groundwater contamination plume of chlorinated solvents, hereafter referred to as the southern plume (Tetra Tech NUS, Inc., 2005; Mark Sladic, Tetra Tech NUS, Inc., 2006, written commun.). The new plume appeared to originate at the new dry-cleaning facility, west of the former dry-cleaning facility (Fig. 1). Groundwater-flow directions were to the southeast, making it improbable that the contamination at the new dry-cleaning facility was caused by groundwater transport from the documented spill at the former dry-cleaning facility.

Storm sewers underlay Site 45 (Fig. 2) and appear to be an important influence on groundwater flow directions. The inverts of some sections of the storm sewer system at

Site 45 are below the high-tide level and below the groundwater levels. The groundwater contours in the surficial aquifer show strong curvature toward some of the storm sewers where the inverts of the sewers are deeper than the water table (Fig. 2). These data show that groundwater discharges to the storm-sewer system in those areas. Once in the storm sewer, water discharges to Ballast Creek, about 463 m from Site 45.

METHODS

This investigation used a variety of approaches to map and investigate the groundwater contamination Site 45. The distributions of groundwater contamination in the figures shown here represent data from multiple sampling events over multiple years. In the southern plume, the data include groundwater samples from temporary wells installed for this investigation on multiple dates, from temporary wells installed during a previous investigation in 2006 (Mark Sladic, 2006, Tetra Tech NUS, Inc., written commun.), and from permanent wells that were sampled in 2008 (Fig. 1). Thus, the mapped configurations of individual constituents represent generalized distributions over an approximately 2-year period rather than snapshot

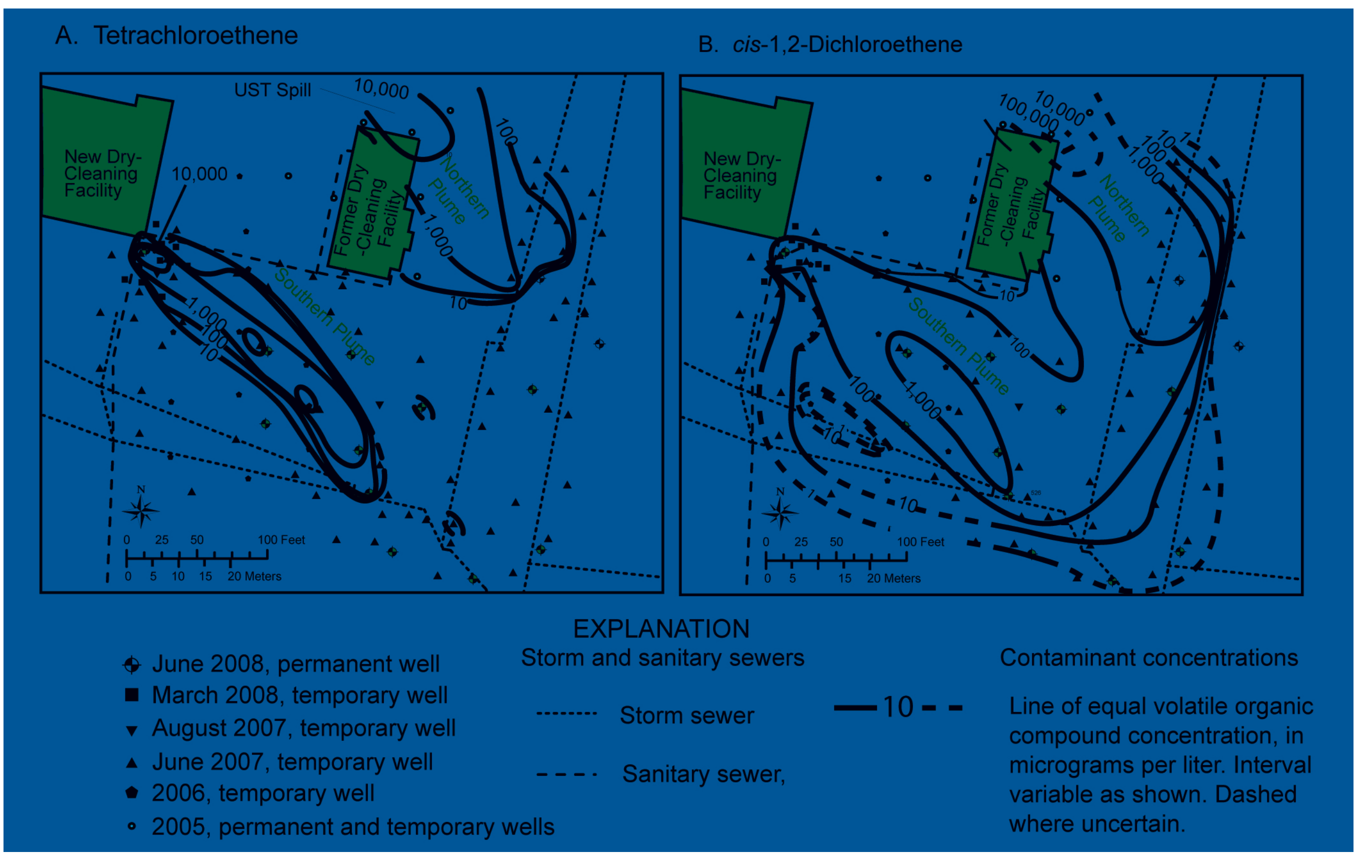

Figure 1. Tetrachloroethene and *cis*-1,2-dichloroethene in groundwater and locations of storm and sanitary sewers, Site 45, Marine Corps Recruit Depot, Parris Island, South Carolina, 2005-2008.

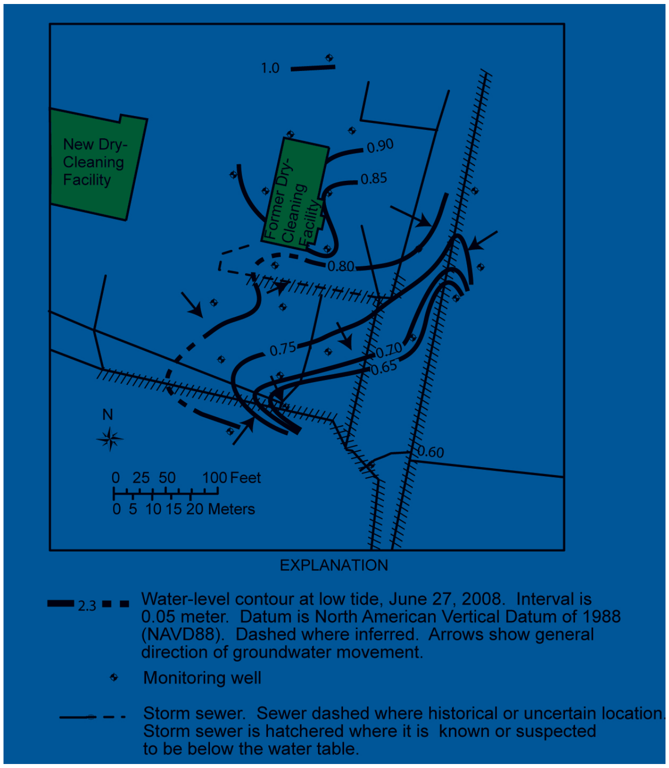

Figure 2. Water table, Site 45, Marine Corps recruit Depot, Parris Island, South Carolina.

in time. The data from the down-gradient part of the northern plume represent samples collected primarily during a single event (June 2007), but include data from a single monitoring well sampled in June 2008 (Fig. 1). Groundwater data from the vicinity of the above-ground storage tanks were collected approximately 3 years earlier during a separate investigation (Tetra Tech NUS, Inc., 2005). Groundwater samples for VOCs were collected by low-flow or multiple-casing-volume purges from both temporary and permanent monitoring wells.

Scanned images of historical as-built engineering drawings of buildings and sewer lines were imported into a geographic information system map of the site containing surveyed locations of manholes. The overlay provided the framework for generating the map of sanitary- and storm-sewer locations. A commercial in-line sewer camera was used in the sanitary sewer from the former dry-cleaning facility and in several of the storm sewers to examine sewer integrity and to confirm their connections between manholes. The elevations of the sewer inverts (bottom of the pipe entering a manhole) were determined by comparing surveyed altitudes of manholes to field tape-down measurements or to measurements from as-built engineering drawings.

Water levels in the storm sewers were monitored by Solinst Leveloggers deployed in well screens in various manholes. Groundwater levels were monitored by taking synoptic measurements of water levels in monitoring wells. All groundwater synoptic water-level measurements were done at low tide because the groundwater levels are relatively stable at low tide and change sharply during high tide, due to leakage from the tidally filled storm sewers during high tide.

Sanitary Sewer as a Contaminant Source

In the initial stage of this investigation, the USGS examined a manhole near the site of the former dry-cleaning facility. The manhole appeared to be part of an abandoned sanitary sewer system. A bucket of water poured into the manhole exited the manhole through a pipe leading toward the southeastern corner of the new dry-cleaning facility. Examination of engineering blueprints of historic and existing structures at Site 45 showed that the system was the sanitary sewer for the former dry-cleaning facility. The original sanitary sewer line, in place since the mid-1950s, appears to have extended to beneath what is now the southeastern corner of the new dry-cleaning facility and then turned about 90 degrees southward (Fig. 2). The corner of the former sanitary sewer line that extended beneath the new dry-cleaning facility was replaced by a new section of pipe sometime in the mid- to late-1990s.

The sanitary sewer line was constructed of vitrified clay. A sewer-inspection camera was used to examine the integrity of the sewer line in 2007. The camera revealed that although the existing pipe between the former and new dry-cleaning facilities contained no collapsed sections, it contained many cracks, and grass roots extended into the pipe. Thus, it is clear that the abandoned sanitary sewer is leaky.

The aquifer at the southeastern corner of the new dry-cleaning facility, where the section of the sanitary sewer was removed, contained the greatest PCE concentrations (Fig. 1), the greatest PCE/daughter-product ratios, and the lightest PCE carbon compound-specific stable isotope values in the southern plume. The direction of groundwater flow is to the southeast and the chemical data indicate that the area where the sanitary sewer was removed contains the most concentrated and least degraded parent compound in the southern plume. The southeastern corner of the new dry cleaning facility is, therefore, the likely source area for the southern plume.

The coincidence of the southern plume source area with a removed section of sanitary sewer that was part of a cracked sanitary sewer system, the existence of documented and potentially undocumented PCE spills in the former dry-cleaning facility connected to that sanitary sewer, and the lack of a viable source for the PCE spill at the new dry-cleaning facility indicate that the probable source of the contamination at that location was leakage from the sanitary sewer system. In general, sewer leaks (exfiltration) have been recognized as potential contamination sources for many years (Amick and

Burgess, 2000; Wakida and Lerner, 2004; Wolf et al., 2004; Rutsch et al., 2005; Held et al., 2006; Reynolds and Barrett, 2007). Leaking sewer lines have produced groundwater VOC contamination elsewhere (Squillace et al., 2004), including PCE contamination from dry-cleaning operations (State of Wisconsin, 1996).

Storm Sewers as a Contaminant Receptors

VOC detections in the storm sewer indicate that groundwater contamination in the northern plume discharges sections of the storm sewer below the water table. In addition, the curvature of water-table contours around parts of the storm sewer below the water table indicates movement of groundwater to the storm drain from both sides (Fig. 2).

Data from temporary wells sampled during this investigation at the down-gradient edge of the northern plume provide further evidence indicating an influence from the storm-sewer system on the groundwater-contamination distribution. Groundwater from temporary wells immediately west of the westernmost storm sewer had more than 1,000 µg/L of *cis*-1,2-dichloroethene (*c*DCE). In contrast, temporary wells screened at 2.3 to 3.5 m BLS and 3.6 to 4.4 m BLS on the eastern side of the storm drain did not contain detectable VOCs (Fig. 1). The hydraulic gradients and lack of detectable VOCs east of the storm drain indicate that the storm-sewer system probably is a main discharge zone for the northern plume and effectively limits further expansion of the main axis of contamination in the northern plume.

Data indicate that storm sewers also intercept contamination in the southern plume. Chlorinated solvents were detected in water from STS05 (30 µg/L of PCE, 100 µg/L of TCE, 70 µg/L of *c*DCE, and 7 µg/L VC of in June 2007). Thus, it appears that the storm drain below the water table in the down-gradient parts of the plume is a discharge zone for groundwater contamination (Fig. 1).

The above data indicate that the storm sewers function as discharge points for the major parts of both the northern and southern plumes. Part of the groundwater contamination may bypass some of the storm sewers below the water table; however, the bypassing concentrations are relatively low. Although substantial concentrations of VOCs are present in the groundwater near the storm sewers (more than 1,000 µg/L of TCE in the southern plume and more than 1,000 µg/L of *c*DCE in the northern plume), the groundwater that leaks into the storm sewers is subjected to dilution and volatilization effects that result in low concentrations of VOCs in water from the sampled manholes (maximum detection of 387 µg/L of *c*DCE and 183 µg/L of TCE) and at the discharge point. Thus, the storm sewers appear to be preventing substantial additional expansion of the plumes and usually discharging relatively low concentrations of VOCs (less than about 10 µg/L of total VOCs to Ballast Creek).

DISCUSSION

Groundwater contamination by tetrachloroethene and its dechlorination products is present in two partially intermingled plumes in the surficial aquifer near a former dry-cleaning facility at Site 45, Marine Corps Recruit Depot, Parris Island, South Carolina. The northern plume originates from the vicinity of former above-ground storage tanks. Free-phase tetrachloroethene from activities in this area entered the groundwater. The southern plume originates at a nearby new dry-cleaning facility, but probably was the result of contamination released to the aquifer from a leaking sanitary sewer line from the former dry-cleaning facility. Discharge of dissolved groundwater contamination is primarily to leaking storm sewers below the water table. The strong influence of sanitary sewers on source distribution and of storm sewers on plume orientation and discharge at this site indicates that groundwater-contamination investigators should consider the potential influence of sewer systems at their sites.

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