ASSESSMENT OF CORRECTIVE MEASURES FOR LAS CRUCES FOOTHILLS LANDFILL, LAS CRUCES, NEW MEXICO

by

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prepared for

Las Cruces Utilities
City of Las Cruces

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City of Las Cruces

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ABBREVIATIONS

ac-ft/yr	acre-feet per year
ACM	Assessment of Corrective Measures
AML	Assessment Monitoring Level
BLM	Bureau of Land Management
CoC	constituent of concern
CSM	conceptual site model
DBSA	Daniel B. Stephens & Associates, Inc.
EPA	Environmental Protection Agency
gpm	gallons per minute
GWPS	Groundwater Protection Standard
HQ	health quotient
J&E	Johnson and Ettinger
JSAI	John Shomaker & Associates, Inc.
LCU	City of Las Cruces Utilities
MCL	maximum contaminant level
mg/L	milligrams per liter
NMAC	New Mexico Administrative Code
NMED/SWB	New Mexico Environment Department, Solid Waste Bureau
NMOSE	New Mexico Office of the State Engineer
PCE	tetrachloroethene
PSG	passive soil gas
SVE	soil vapor extraction
TCE	trichloroethene
TDS	total dissolved solids
VISL	vapor intrusion screening level
VOCs	volatile organic compounds
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter

ASSESSMENT OF CORRECTIVE MEASURES FOR LAS CRUCES FOOTHILLS LANDFILL, LAS CRUCES, NEW MEXICO

1.0 INTRODUCTION

This Assessment of Corrective Measures (ACM) for Las Cruces Foothills Landfill has been prepared based on the request of the New Mexico Environment Department, Solid Waste Bureau (NMED/SWB), for continued compliance with the Solid Waste Regulations New Mexico Administrative Code (NMAC) 20.9.9. The ACM utilizes information collected from 1990 to present at Las Cruces Foothills Landfill, including groundwater monitoring data and reports, soil vapor sampling data and reports, closure plan, and conceptual site model. The ACM addresses each of the statutory elements in NMAC 20.9.9.15.C, and will include a public meeting as required by NMAC 20.9.9.15.D.

1.1 Site History and Background

Las Cruces Foothills Landfill is located east of Las Cruces city limits in Section 11 of Township 23 South, Range 2 East, at the east end of East Lohman Avenue (Fig. 1). The landfill was in operation for approximately 15 years, from 1980 to 1995. There are no precise records of volume and types of waste deposited at the landfill, although, the fill material is approximately 40 ft below current surface grade and consists of household and construction waste. There are no records of hazardous waste delivered to this landfill. The landfill has been capped with a low hydraulic conductivity protective cover and re-contoured. Currently, the landfill has a groundwater monitoring system consisting of nine monitor wells (MW-1 through MW-9), and groundwater monitoring data have been collected for 20 years. The primary constituent of concern (CoC) in groundwater at Las Cruces Foothills Landfill is tetrachloroethene (PCE); trichloroethene (TCE), methylene chloride, and trichlorofluoromethane are also CoCs at the site. Soil vapor sampling was performed between 2014 and 2017 to characterize the nature and extent of any residual vadose zone contamination (DBSA, 2018). Groundwater monitoring is showing that the plume is becoming increasingly localized and naturally attenuating (JSAI, 2018). It has been recommended that groundwater monitoring be continued at Las Cruces Foothills Landfill on a semi-annual basis to track the extent and nature of the contaminant plume and monitor natural attenuation (JSAI, 2018).

2.0 NATURE AND EXTENT OF CONTAMINATION- NMAC 20.9.9.15.C(1)

As part of the ACM, NMAC 20.9.9.15.C(1) requires description of extent and nature of contamination. Previous monitoring, sampling, and modeling for the site have provided sufficient evidence to establish the Site Conceptual Model and extent and nature of the contaminant plume (JSAI, 2017; JSAI, 2018). The primary Contaminant of Concern (CoC) in groundwater at Las Cruces Foothills Landfill is PCE. Other detectable contaminants in groundwater include TCE, methylene chloride, and trichlorofluoromethane. The extent of the contaminant plume has been defined based on the dataset collected from the site's nine groundwater monitor wells, and the site hydrogeologic characteristics.

2.1 Geologic Model

The western edge of Las Cruces Foothills Landfill is located on the buried horst (bedrock high) that divides the Jornada del Muerto Groundwater Basin (to the east) from the Mesilla Groundwater Basin (to the west), as documented by Woodward and Myers (1997), Hawley and Kennedy (2004), and monitor well drilling at the site. The remainder of the landfill area is located east of the bedrock high (see Fig. 2).

The bedrock high is composed of black to dark gray vesicular basalt or basaltic andesite. The basalt bedrock is of very low permeability due to lack of fractures, and lack of interconnection between vesicles. A pumping test performed at site monitor well MW-1 provides an estimate of hydraulic conductivity for the basalt of 0.04 ft/day, which is about an order of magnitude lower than the hydraulic conductivity estimated for the Lower and Middle Santa Fe Group overlying the bedrock high (JSAI, 2013).

Groundwater modeling investigations by the U.S. Geological Survey (Frenzel and Kaehler, 1992) have also identified the buried horst as an impermeable barrier between the Jornada and Mesilla Groundwater Basins. Groundwater flow between the two basins has only been considered where the water table elevation is greater than the bedrock high.

Northwest to southeast trending normal faults that created the bedrock high (Fig. 2), also offset stratigraphic layers in the Lower and Middle Santa Fe Group sediments (Fig. 3). These offsetting beds also affect preferential pathways for contaminants in the vadose zone and saturated zone (groundwater) underlying the landfill.

Woodward and Myers (1997) defined the elevation of the top of the horst and areas where the top of the horst is above the water table, and these boundaries were further refined for the landfill site based on lithologic logs and water levels for site monitor wells. Logs and water levels for monitor wells MW-1 and MW-2 reveal the “gap” in the bedrock high where the water table is present in higher-permeability consolidated fine-grained sediments of the Santa Fe Group overlying the bedrock high, allowing for contaminant migration in the down-gradient direction in the saturated zone through the gap.

2.2 Preferential Pathways in Vadose Zone

The primary transport mechanism identified in the vadose zone has been the lateral and vertical migration of leachate and vapors derived from the landfill caused by the driving force of locally infiltrated storm water. Transport in the vadose zone is above the bedrock high in the Santa Fe Group sediments; therefore, the bedrock high plays little to no role in vadose zone transport.

Vapor-laden leachate was observed perched on a clay layer approximately 100 ft below land surface while drilling MW-2 (JSAI, 1999), indicating localized horizontal migration on top of low permeability layers in the Santa Fe Group sediments. Vertical migration through the vadose zone to groundwater is evidenced by contaminant detections in the groundwater monitoring system. Conceptual vadose zone migration pathways are illustrated on Figure 3, which explains the contaminant transport in the vadose zone, across hydraulic gradient of groundwater flow from the landfill and east of the bedrock high, towards MW-7. Preventing the potential for stormwater to collect and infiltrate will remove the driving force for vadose zone transport of landfill derived vapors and leachate to groundwater.

2.3 Preferential Pathways in Groundwater

The presence of the bedrock high prevents contaminant migration in the down-gradient direction in the saturated zone except through the gap in the bedrock high, because the top of bedrock is above the water table, and the bedrock is of very low permeability and acts as a barrier to flow.

The average linear tracer velocity (or groundwater velocity) has been calculated using Darcy's Law (Fetter, 1994) for contaminant transport in the saturated zone between up-gradient monitor well MW-3 and MW-2 at the western edge of the landfill (JSAI, 2013). The average linear tracer velocity (Vx) can be calculated using the following equation:

$$Vx = KI/n_e$$

Where,

K = hydraulic conductivity in ft/day

I = hydraulic gradient

n_e = effective porosity

A conservative (low) value for effective porosity of 0.05 was assumed for the velocity calculations (a lower effective porosity results in higher travel velocity). Results are presented in Table 1. The flow path beneath the landfill has a calculated linear tracer velocity of about 0.24 ft/day or 84 ft/year. The flow path down-gradient of the landfill (MW-5 to MW-9) has a calculated linear tracer velocity of about 0.003 ft/day or 1.2 ft/year.

Table 1. Results from tracer velocity calculations

flow path	hydraulic gradient (ft/ft)	average horizontal hydraulic conductivity (ft/day)	tracer velocity (ft/day)
MW-3 to MW-2	0.04	0.30	0.24
MW-5 to MW-9	0.00056	0.30	0.003

The Darcy flux can also be easily calculated for flow across the horst in the bedrock gap at MW-5 and MW-6. The Darcy flux is as follows:

$$Q = KIA$$

Where,

K = hydraulic conductivity in ft/day

I = hydraulic gradient

A = cross-sectional area in ft^2

The Darcy flux across the horst is 2 gallons per minute (gpm), when using an average saturated thickness of 20 ft, length of 1,600 ft, hydraulic gradient of 0.04 ft/ft, and horizontal hydraulic conductivity of 0.3 ft/day. Trying to capture such a small rate of flow over a 1,600 ft length would be near impossible using groundwater extraction.

2.4 Extent and Nature of Contamination in Groundwater

The constituents of concern in groundwater at Las Cruces Foothills Landfill are PCE, TCE, methylene chloride, and trichlorofluoromethane. The site includes nine groundwater monitor wells, as shown in Figure 1:

- Up-gradient monitor well MW-3
- Three monitor wells along the landfill perimeter (MW-1, MW-2, and MW-4)
- Three down-gradient monitor wells (MW-5, MW-6, and MW-9)
- Two monitor wells located across-gradient to the south of the landfill (MW-7 and MW-8)

The extensive dataset from the monitoring network has defined the horizontal extent of groundwater contamination at the site. Figures 4, 5, 6, and 7 present graphs showing historical concentrations of PCE, TCE, methylene chloride, and trichlorofluoromethane for monitor wells in which these constituents have been detected. Figures 8 and 9 present aerial photographs showing concentration contours of PCE and TCE in groundwater. In 2017, PCE was detected above the Groundwater Protection Standard (GWPS) of 0.005 milligrams per liter (mg/L) at MW-1, MW-4, MW-5, MW-6, and MW-7 (Fig. 4). The highest PCE concentration was detected at MW-7, at 0.018 mg/L. In 2017, methylene chloride was detected above the GWPS of 0.005 mg/L at MW-4 (highest concentration detected was 0.014 mg/L).

The direction of groundwater flow at the site has remained to the west-southwest (JSAI, 2018; see Fig. 1). The direction of groundwater flow controls contaminant transport in the saturated zone down-gradient of the site through the gap in the bedrock high, and towards down-gradient monitor wells MW-5, MW-6, and MW-9. PCE has been detected above the GWPS at MW-5 and MW-6, but none of the CoCs have been detected at MW-9. Thus, consistent with tracer velocity calculations, the contaminant plume has not migrated down-gradient to MW-9.

Major ion geochemistry and groundwater temperatures from the monitoring network confirm upwelling of geothermal groundwater across the bedrock high. The upwelling of geothermal groundwater has been well documented elsewhere along the Jornada Horst (Icerman and Lohse, 1983), where upwelling occurs along faults in the horst. This component of upward flow prevents downward migration of contaminants observed in the monitoring network. Therefore, the monitoring network represents the vertical extent of contamination in groundwater.

2.5 Extent and Nature of Contamination in Vadose Zone

In cooperation with John Shomaker and Associates, Inc. (JSAI) and the City of Las Cruces Utilities (LCU), Daniel B. Stephens & Associates, Inc. (DBSA) prepared a revised conceptual site model (CSM) in 2013 (DBSA, 2013). Based on the revised CSM, the vadose zone under the site is believed to contain the primary residual mass of contaminants released from the old Foothills Landfill. PCE was identified as the most widespread contaminant present at concentrations above AMLs, and is considered the principal CoC.

At the request of NMED, DBSA conducted an investigation at the site during June 2014 to characterize the vadose zone and to refine the CSM. As part of this investigation, DBSA investigated the nature and extent of residual vadose zone contamination in accordance with 20.9.9.15 C(1) NMAC, and assessed whether the potential exists for further impacts to groundwater and/or shallow soil vapor from residual contaminant mass beneath the landfill.

During the 2014 investigation, passive soil gas (PSG) data were collected to delineate the extent of contamination in shallow soils beneath the landfill cap and over the groundwater plume. The PCE mass captured by the passive collectors represents a semi-quantitative proxy measurement for PCE concentrations present in shallow soil gas. Samples of vadose zone materials were collected and analyzed for soil hydraulic properties in support of limited contaminant transport modeling. DBSA also collected quantitative soil gas concentration data from discrete depth intervals at three locations at the toe of the landfill (VP-1 through VP-3, Fig. 10), to support confirmation of transport modeling results and verification of the CSM.

Based on the findings of the field investigation and contaminant transport modeling conducted in 2014, the known residual mass of PCE remaining in the vadose zone was determined to be insufficient to further impact groundwater at concentrations above the EPA maximum contaminant level (MCL) for PCE of 5 μg/L. The placement of a cover on the landfill and the rerouting of stormwater away from the waste further minimize the possibility of PCE migrating to the water table. The refined CSM, based on results of the 2014 vadose zone characterization, remains broadly consistent with the findings of ongoing groundwater monitoring conducted at the site.

Analytical results from the 2014 vadose zone investigation indicated the presence of PCE in shallow soil gas at the southwestern margin of the site—both under the landfill cover and off-site to the southwest. PCE concentrations in soil vapor were generally observed to increase with depth, and PCE was not present at detectable concentrations in the shallow sampling zone of vapor wells VP-1 and VP-2. At the request of NMED, additional investigation of shallow soil gas was conducted during July through November 2015 to further evaluate the extent of PCE present in shallow soil vapor and assess the potential for an indoor air risk via the vapor intrusion pathway on parcels adjacent to the landfill. During the 2015 investigation, additional PSG samples were collected from the landfill cover and in areas off-site to the southwest of the landfill. With the exception of an apparent hot-spot on an adjacent parcel to the west of the landfill, captured PCE masses generally decreased away from the site and potential source areas, consistent with the CSM (Fig. 11). Active soil gas samples were also collected from four temporary, shallow collection points installed around the southwest periphery of the landfill property (SG-1 through SG-4, see Fig. 10).

In 2016, NMED requested additional assessment and monitoring of the potential vapor intrusion exposure pathway in the area southwest of the landfill (DBSA, 2017). Locations were selected in coordination with NMED and LCU for installation of permanent shallow soil gas wells. Monitoring locations were selected to verify the previous detections of PCE and provide geographic coverage of soil gas conditions between the landfill and existing residential developments, within the area of the known groundwater plume. Figure 10 shows the locations of the permanent shallow soil gas wells. Well installation details are provided in DBSA (2017).

Wells were installed and sampled in December 2016. Shallow soil gas field samples were collected from the four locations and analyzed for volatile organic compounds (VOCs). PCE was the only chlorinated VOC detected in shallow soil gas during the December 2016 investigation, and was present at concentrations ranging from 180 to 470 $\mu g/m^3$ (DBSA, 2017).

DBSA used the online Johnson and Ettinger (J&E) model to evaluate the results of the December 2016 soil gas sampling event. The screening-level J&E model is a web-based application provided by the EPA for estimating vapor intrusion from shallow soils into structures. Based on user-selected input and conservative default values, the application calculates carcinogenic risk factors and/or non-carcinogenic hazard quotients for the vapor intrusion pathway corresponding to actual sample depths and soil gas concentrations. The results of the J&E modeling analysis indicated a cancer risk of less than 1.5×10^{-7} and a health quotient (HQ) of approximately 0.03 associated with the highest reported PCE concentration from the December 2016 sampling event. These results are well below target values established by EPA and NMED for residential land use (target incremental cancer risk of 1×10^{-5} and HQ = 1.0) (DBSA, 2017). At the request of NMED and LCU, DBSA conducted follow-up soil gas sampling at the permanent wells in November 2017, with broadly consistent results (DBSA, 2018).

Concentrations of volatile constituents in shallow soil gas may fluctuate daily or seasonally based on changes in weather conditions or soil moisture, among other factors; long-term trends, such as migration or attenuation of residual contaminant masses, may also affect sampling results. Given the inherent potential variability, the soil gas data acquired to date are consistent with the CSM, and are considered likely to be representative of subsurface conditions at the sampling locations.

PCE analytical results for all shallow soil gas samples collected at the site are presented in Figure 12 and summarized graphically in Figure 13. The results of the current and previous investigations show that no quantitative soil gas analysis conducted at the site has indicated the presence of PCE concentrations in shallow soil gas above the current residential vapor intrusion screening level (VISL) of 1,390 $\mu g/m^3$. The current VISL was promulgated by NMED in March 2017 and is consistent with EPA vapor intrusion guidance. Although some temporal variability is expected in the distribution of PCE in shallow soil gas, all results indicate that PCE concentrations above the NMED VISL are not present in shallow soil gas adjacent to the old Foothills Landfill site.

3.0 ASSESSMENT OF CORRECTIVE MEASURES NMAC 20.9.9.15.C(1)-(14)

3.1 Practical Capabilities of Remedial Technologies

As specified in NMAC 20.9.9.15.C(2), this ACM considers the practical capabilities of remedial technologies in achieving compliance with groundwater protection standards and other objectives of the remedy. Practical capabilities of remedial technologies are considered in the sub-sections below in terms of corrective measures that have been taken at the site, consideration of additional corrective measures, and feasibility of additional corrective measures.

3.1.1 Corrective Measures

Corrective measures that have been taken at the site include landfill closure, cap, and re-vegetation, stormwater controls, and site monitoring including groundwater monitoring and soil vapor sampling (CDM, 1995; CDM, 2011; JSAI, 2018; DBSA, 2018). The corrective action plan and groundwater monitoring plan are in place and being followed (JSAI, 2009; JSAI, 2010). It is recommended that groundwater monitoring be continued at a reduced number of sample points, to be determined by NMED/SWB and City of Las Cruces, for effective monitoring of the contaminant plume. Groundwater monitoring is showing that the plume is becoming increasingly localized and naturally attenuating (JSAI, 2018). It is recommended that monitoring be continued at four sample points: monitor wells MW-1 and MW-7 to continue monitoring the increasingly localized and naturally-attenuating contaminant plume, MW-8 to monitor any potential contamination across-gradient from the site, and MW-9 to monitor any potential contamination down-gradient from the site. Background concentrations have been well-established for up-gradient monitor well MW-3 based on twenty years of data for this sample point. As has already been determined by NMED/SWB and City of Las Cruces, the City will continue to transition to low-flow sampling methods due to challenges related to purging sufficient volumes of water from site monitor wells during sampling.

3.1.2 Consideration of Additional Corrective Measures

Options for additional corrective measures are presented at the end of this section as required by NMAC 20.9.9.15.C. Additional corrective measures beyond continued groundwater monitoring and natural attenuation are not necessary as there is no extenuating threat to the environment, natural resources, or public safety. Site hydrogeologic characteristics, including the "bedrock high," direction of groundwater flow, flat hydraulic gradient between the site and water supply wells in the Mesilla Basin, and upwelling of geothermal groundwater, have limited mobilization of the contaminant plume. Figure 1 presents groundwater-elevation contours for the site, and top-of-bedrock elevation contours representative of the bedrock high that lies between the site and developed areas of the City of Las Cruces.

The presence of the bedrock high prevents contaminant migration in the down-gradient direction in the saturated zone except through the gap in the bedrock high, because the top of bedrock is above the water table, and the bedrock is of very low permeability and acts as a barrier to flow (JSAI, 2017).

The direction of groundwater flow at the site has remained to the west-southwest (JSAI, 2018). The direction of groundwater flow controls contaminant transport in the saturated zone down-gradient of the site through the gap in the bedrock high, and towards down-gradient monitor wells. None of the CoCs have been detected in down-gradient monitor well MW-9.

Down-gradient contaminant migration in the groundwater is limited by a relatively flat hydraulic gradient west of the bedrock high, and groundwater elevation is frequently slightly higher at MW-9 than at MW-5 and MW-6, further limiting the potential for westward migration of the contaminant plume (see Fig. 1). Figure 14 shows the location of Las Cruces Foothills Landfill site with respect to municipal water supply wells in the Mesilla Basin; note that the groundwater elevation in the closest water supply well is higher than groundwater elevations in down-gradient monitor wells MW-5, MW-6, and MW-9.

Major ion geochemistry and groundwater temperatures from the monitoring network confirm upwelling of geothermal groundwater across the bedrock high; this component of upward flow prevents downward migration of contaminants.

Groundwater monitoring results show that the plume is becoming increasingly localized and naturally attenuating (JSAI, 2018). Figure 8 shows the PCE plume localized up-gradient of MW-9. Some contaminant transport has occurred along preferential pathways in the vadose zone, across hydraulic gradient of groundwater flow and east of the bedrock high, towards MW-7. Preventing the potential for stormwater to collect and infiltrate removes the driving force for vadose zone transport of landfill-derived vapors and leachate to groundwater. The presence of the bedrock high prevents migration of contamination from the vicinity of MW-7 towards developed areas of the City of Las Cruces west of the bedrock high.

Soil vapor sampling results from 2014 to 2017 (DBSA, 2014; DBSA, 2016; DBSA, 2017; DBSA, 2018) are presented in Figures 12 and 13, and indicate the following:

- The known residual mass of PCE remaining in the vadose zone was determined to be insufficient to further impact groundwater at concentrations above the GWPS for PCE of 0.005 mg/L.
- Captured PCE masses generally decreased away from the site and potential source areas.
- No quantitative soil gas analysis conducted at the site has indicated the presence of PCE concentrations in shallow soil gas above the current residential vapor intrusion screening level (VISL) of 1,390 micrograms per cubic meter. The current VISL was promulgated by NMED in March 2017 and is consistent with US EPA vapor intrusion guidance.

The following options for additional corrective measures are presented:

1. **Groundwater Extraction and Treatment:** Under this option, contaminated groundwater would be extracted (pumped) from dedicated recovery wells in order to remove the contaminant plume and bring concentrations of CoCs below GWPS in groundwater. Extracted groundwater would be treated aboveground to standards for discharge or municipal use. A common approach to treatment would be air stripping, the process of moving air through contaminated groundwater to evaporate CoCs (EPA, 2012).
2. **Soil Vapor Extraction (SVE):** This option is based on mass transfer of any residual contamination in the vadose zone from solid (sorbed) and liquid phases into gas phase, with subsequent collection of the gas phase contamination by using vacuum blowers and extraction wells to induce gas flow in the vadose zone, and treating the contaminated soil vapor aboveground (EPA, 2012a). Common approaches to treatment would be thermal oxidation or granular activated carbon adsorption. The reasoning behind this option would be that removal of any residual contamination from the vadose zone would remove the contamination source for groundwater, accelerating the timeframe to bring concentrations of CoCs below GWPS in groundwater. A schematic diagram is presented as Figure 15.
3. **In-well Vapor Extraction for Groundwater Wells:** This option is based on extracting CoCs from groundwater in place without removing the water from the ground, and involves creation of a groundwater circulation pattern around a well through which contaminated groundwater is cycled (Kulakow, 2015). The approach generally requires well construction to include an inner and outer casing hydraulically separated from one another (for example, using a packer assembly) to ensure one-directional flow of water into the well through the lower screen in the inner well and out through an upper screen above the water table. A vacuum

blower injects air into the inner casing and aerated water rises upward through the outer casing, and is forced out of the outer casing into the formation above the water table underneath the packer assembly. Gas phase contamination is extracted from the outer casing using a vacuum blower, and treated aboveground. As with SVE, common approaches to treatment would be thermal oxidation or granular activated carbon adsorption. The reasoning behind this option would be that the circulation and evaporation of groundwater would accelerate the timeframe to bring concentrations of CoCs below GWPS in groundwater. A schematic diagram is presented as Figure 16.

4. **Continued Groundwater Monitoring and Natural Attenuation:** Groundwater monitoring and reporting have been ongoing according to the corrective action plan and groundwater monitoring plan. Ongoing natural attenuation does appear to be effective as the plume is becoming more localized and concentrations of CoCs are decreasing at a number of site monitor wells (JSAI, 2018). This option involves continuation of groundwater monitoring and reporting, and natural attenuation, with re-evaluation at a later time if remedial progress can no longer be demonstrated with this option.

3.1.3 Feasibility of Additional Corrective Measures

The previous section provides a discussion of the fact that additional corrective measures are not necessary as there is no extenuating threat to the environment, natural resources, or public safety; however, it should also be noted that additional corrective measures are generally not feasible due to site hydrogeologic characteristics. Figure 6 shows monitor well locations with respect to faults in the subsurface, and line of hydrogeologic cross-section A-A’. Figure 7 presents west-to-east hydrogeologic cross-section A-A’.

Northwest-to-southeast trending normal faults that created the bedrock high also offset stratigraphic layers in the Lower and Middle Santa Fe Group sediments, compartmentalizing groundwater at the site (Figs. 6 and 7). A number of the monitor wells completed in fine-grained consolidated sediments, volcaniclastics, and basalt bedrock at the site are low-yielding, have excessive drawdown even when pumped at low rates of 1 gpm or less, and are slow to recover (JSAI, 2018). Groundwater is relatively deep at the site, with depth to groundwater ranging from about 300 to 400 ft. Hydraulic conductivity estimates indicate very low permeability for the volcaniclastics and basalt bedrock at the site (hydraulic conductivity of less than 0.1 ft/day), and relatively low permeability for the fine- to medium-grained consolidated sediments in which groundwater occurs at the site (average 0.3 ft/day; JSAI, 2013). These factors indicate that groundwater is present in relatively insignificant quantities at the site, and preclude the recovery of any significant quantities of contaminated groundwater from the site.

Feasibility considerations specific to the options for additional corrective measures presented in the previous section:

1. **Groundwater Extraction and Treatment:** As discussed under Section 2.3, the Darcy flux across the horst is 2 gpm, when using an average saturated thickness of 20 ft, length of 1,600 ft, hydraulic gradient of 0.04 ft/ft, and horizontal hydraulic conductivity of 0.3 ft/day. Trying to capture such a small rate of flow over a 1,600-ft length would be nearly impossible using groundwater extraction. Low permeability and low flow rates preclude the successful implementation of this option. Therefore, this option is not considered feasible.

2. **Soil Vapor Extraction (SVE):** As discussed under Section 2.5, the known residual mass of PCE remaining in the vadose zone was determined to be insufficient to further impact groundwater at concentrations above the GWPS for PCE of 0.005 mg/L. This finding invalidates the reasoning behind this option, that removal of residual contamination from the vadose zone would remove the contamination source for groundwater, accelerating the timeframe to bring concentrations of CoCs below GWPS in groundwater. Therefore, this option is not considered feasible.

3. **In-well Vapor Extraction for Groundwater Wells:** Low permeability and low flow rates likely preclude the successful implementation of this option, which is typically utilized in aquifers of less-consolidated, more-permeable soils. Low permeability and low flow rates may limit groundwater circulation under this option, thereby causing it to be ineffectual. Chemical precipitates can form during the process that may clog well screens or the formation near the well and limit groundwater circulation (Kulakow, 2015). If air-stripping wells are not properly constructed, the plume may spread beyond the radius of influence of the stripping well. New well(s) with discrete upper and lower screen sections would be required even for pilot testing under this option, which would be costly due to the great depth and relatively large well diameter that would be required. While this option has been effective in significantly reducing contamination at sites with higher concentrations of CoCs (for example, sites with concentrations one order of magnitude higher than the subject site), it is unclear how effective this approach may be at sites with lower concentrations such as the subject site. For these reasons, this option is not considered feasible.

4. **Continued Groundwater Monitoring and Natural Attenuation:** This option has been and continues to be feasible based on the existing monitoring well network, the corrective action plan, and groundwater monitoring plan. Ongoing natural attenuation does appear to be effective as the plume is becoming more localized and concentrations of CoCs are decreasing at a number of site monitor wells (JSAI, 2018).

3.2 Availability of Treatment or Disposal Capacity

As specified in NMAC 20.9.9.15.C(3), this ACM considers the availability of treatment or disposal capacity for wastes managed during implementation of the remedy. Discussion under Section 3.1 above indicates that additional corrective measures for groundwater, other than continued groundwater monitoring and natural attenuation, are not necessary, nor would they be feasible. Feasible corrective measures have already been taken.

3.3 Desirability of Utilizing Technologies Not Currently Available

As specified in NMAC 20.9.9.15.C(4), this ACM considers the desirability of utilizing technologies that are not currently available, but which may offer significant advantages over available technologies in terms of effectiveness, reliability, safety, or ability to achieve remedial objectives. Discussion under Section 3.2 above indicates that additional corrective measures other than continued groundwater monitoring and natural attenuation, including those currently available or not yet available, are not necessary, nor would they be feasible. Feasible corrective measures have already been taken.

3.4 Potential Risks from Exposure to Contamination

As specified in NMAC 20.9.9.15.C(5), this ACM considers the potential risks to public health, welfare, and the environment from exposure to contamination prior to completion of the remedy. Discussion under Section 3.2 above indicates that feasible corrective measures have already been taken, and there is no extenuating threat to the environment, or public health and welfare.

3.5 Resource Value of the Aquifer

As specified in NMAC 20.9.9.15.C(6), this ACM considers the resource value of the aquifer including (a) current and future uses; (b) proximity and withdrawal rate of users; (c) groundwater quantity and quality; (d) the potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents; (e) the hydrogeologic characteristic of the facility and surrounding land; (f) groundwater removal and treatment costs; and (g) the cost and availability of alternative water supplies.

3.5.1 Current and Future Uses

Discussion under Section 3.1 above indicates low permeability in bedrock, volcaniclastics, and sediments in the saturated zone at the site. Due to low permeability, the presence of the bedrock high, and faults, groundwater at the site is not diverted for water supply, and is not considered to be a viable aquifer or connected to the productive aquifers of the Southern Jornada del Muerto Basin (located up-gradient to the north), or the Mesilla Basin (located to the west and south). As such, groundwater at the site has no current or intended future use. Given that the existing monitor wells barely make enough water to collect a water sample, the saturated zone beneath the landfill may not support the definition of “aquifer” in NMAC 20.9.2.7(8), which states “a geologic formation, group of formations, or portions of a formation capable of yielding ground water to wells or springs.”

Although groundwater occurring within the vicinity of the site is not considered to represent a viable aquifer for water supply due to low permeability, the presence of the bedrock high, and faults, the State requires consideration of all groundwater with TDS concentration of 10,000 mg/L or less for present and potential future use as domestic and agricultural water supply (20.6.2.3101.A NMAC and 20.6.2.4101.A(1) NMAC). Wells completed in the vicinity of the site would not produce adequate quantities of water for agriculture, as discussed above. Existing and planned residential areas in the vicinity are within the Las Cruces city limits and served by LCU. The city limits border the site, to the north, west, and southwest of the site. It is possible that a private entity could apply for a stock watering permit on BLM lands to the south of the site, although there do not appear to be any existing stock wells in the vicinity (NMOSE, 2019). It should also be noted that in addition to being present in very limited quantities in the vicinity of the site, the groundwater is relatively hot with temperatures ranging from 90 to 120 degrees Fahrenheit.

3.5.2 Proximity and Withdrawal Rate of Users

As discussed in Section 3.5.1 above, groundwater at the site is not diverted for water supply. The site is over 2 miles northeast of the nearest active municipal water supply well in the Mesilla Basin (LCU Well 61; see Fig. 14) with a flat hydraulic gradient in between. LCU Well 61 pumped 492 acre-feet in 2017, with an average diversion of 937 acre-ft per year (ac-ft/yr) between 2013 and 2017. Monitor well MW-9, which lies between the site and Mesilla Basin supply wells, has had no detections of VOCs such as the CoCs to-date.

There are three private supply wells or permits within 2 miles of the landfill site (Fig. 14) based on New Mexico Office of the State Engineer (NMOSE) records. The closest domestic well permit (LRG-16053) is 1.3 miles southwest the Landfill site. Well LRG-16053 was permitted in 2015 with a maximum diversion of 1 ac-ft/yr and it is unknown if the well has been drilled, and if so, what the current usage is; the well is in a residential area served by LCU. The other two private supply wells, LRG-12366 and LRG-11218, are located 1.2 miles and 1.6 miles northwest of the landfill site, respectively (see Fig. 14). Wells LRG-12366 and LRG-11218 are related to the Sonoma Ranch Golf Course, which is now reportedly watered (in part) with LCU treated wastewater. These are the only private supply wells noted within the vicinity of the site. LRG-12366 had a reported metered diversion of 6 ac-ft/yr in 2017, and an average diversion of 33 ac-ft/yr between 2013 and 2017. LRG-11218 had a reported metered diversion of 450 ac-ft/yr in 2017, and an average diversion of 342 ac-ft/yr between 2013 and 2017. Note that the site is about 4.3 miles south, and down-gradient of the nearest active supply well in the Jornada del Muerto Basin (east of the bedrock high).

3.5.3 Groundwater Quantity and Quality

Given the low permeability in bedrock, volcaniclastics, and sediments in the saturated zone at the site, groundwater does not occur in any significant quantity at the site. Water quality of the limited amount of groundwater present at the site, as analyzed at site monitor wells, is relatively good with total dissolved solids (TDS) concentrations generally below 500 mg/L, except at MW-9 located west of the site, which has elevated TDS, chloride, nickel, and chromium concentrations characteristic of geothermal groundwater (JSAI, 2018). The high groundwater temperature also creates problems for potential uses other than geothermal heating.

3.5.4 The Potential Damage to Wildlife, Crops, Vegetation, and Physical Structures Caused by Exposure to Waste Constituents

Discussion under Section 2.2 above indicates no extenuating threat to the environment, including wildlife, crops, vegetation, and physical structures. Contaminated groundwater is localized at the site and present at a depth of about 400 ft. Soil vapor sampling results indicated concentrations below the VISL.

3.5.5 The Hydrogeologic Characteristic of the Facility and Surrounding Land

Discussion under Section 2.0 above provides information on the hydrogeologic characteristics of the site. Additional information is provided in JSAI (2013, 2017, 2018).

3.5.6 Groundwater Removal and Treatment Costs

As groundwater at the site is not diverted for water supply, has no current or intended future use, there would be no need for water treatment, and no associated costs would be incurred.

3.5.7 The Cost and Availability of Alternative Water Supplies

As groundwater at the site is not diverted for water supply, there would be no need to seek replacement alternative supply.

3.6 Practicable Capability of Owner/Operator

As specified in NMAC 20.9.9.15.C(7), this ACM considers the practicable capability of the owner or operator. City of Las Cruces has access and capability to perform necessary activities at Las Cruces Foothills Landfill for safety and compliance.

3.7 Performance and Impacts of Potential Remedies

As specified in NMAC 20.9.9.15.C(8), this ACM considers the performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts and control of exposure to any residual contamination. Discussion under Section 2.2 above indicates that corrective measures have been taken, and additional corrective measures for groundwater are not necessary, nor would they be feasible. The corrective action plan and groundwater monitoring plan for the site are in place and being followed with minimal associated risk in terms of safety and exposure.

3.8 Time Requirements

As specified in NMAC 20.9.9.15.C(9), this ACM considers the time required to begin and complete the remedy. Semi-annual groundwater monitoring is ongoing, and results show that the plume is becoming increasingly localized and naturally attenuating (JSAI, 2018). Time for completion of natural attenuation has not been estimated. Figure 8 presents PCE concentrations versus time for site monitor wells. Fluctuations and overall decreasing concentrations of PCE at MW-2, MW-6, and MW-7 suggest that PCE is naturally attenuating, and the plume is becoming more localized.

3.9 Cost Requirements

As specified in NMAC 20.9.9.15.C(10), this ACM considers the costs of remedy implementation. Semi-annual groundwater sampling, laboratory analysis, and reporting have been ongoing with annual budget of approximately $20,000 to $25,000, plus labor and expenses associated with sampling activities performed by City of Las Cruces Water Quality Laboratory.

3.10 Institutional Requirements

As specified in NMAC 20.9.9.15.C(11), this ACM considers the institutional requirements for local permits or other environmental or public health requirements that may substantially affect implementation of the remedy(s). As far as the City is aware, no additional permits or requirements would be necessary for the continuation of groundwater monitoring and reporting activities at the site performed according to the corrective action plan and groundwater monitoring plan.

3.11 Interim Measures

As specified in NMAC 20.9.9.15.C(12), this ACM considers the need for interim measures in accordance with provisions of Paragraph (3) of Subsection A of 20.9.9.17 NMAC. According to NMAC 20.9.9.17.A(3), "take any interim measures necessary to ensure the protection of public health, welfare and the environment; interim measures should, to the greatest extent practicable, be consistent with the objectives of, and contribute to the performance of, any remedy that may be required pursuant to 20.9.9.16 NMAC;…"

Discussion under Section 2.2 above indicates no extenuating threat to the environment, or public health and welfare; thus, interim measures would not be necessary.

3.12 Effectiveness of Potential Corrective Measures

As specified in NMAC 20.9.9.15.C(13), this ACM provides analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives and evaluation factors of the remedy as described in 20.9.9.16 NMAC. Discussion under Section 3.2 above indicates that corrective measures have been taken, and additional corrective measures for groundwater are not necessary, nor would they be feasible. Groundwater monitoring and reporting have been ongoing according to the corrective action plan and groundwater monitoring plan. Ongoing natural attenuation does appear to be effective as the plume is becoming more localized and concentrations of CoCs are decreasing at a number of site monitor wells (JSAI, 2018). It is recommended that groundwater monitoring be continued at reduced number of sample points, to be determined by NMED/SWB and City of Las Cruces, for effective monitoring of the contaminant plume. It is recommended that monitoring be continued at four sample points: monitor wells MW-1 and MW-7 to continue monitoring the increasingly localized and naturally-attenuating contaminant plume, MW-8 to monitor any potential contamination across-gradient from the site, and MW-9 to monitor any potential contamination down-gradient from the site. Background concentrations have been well-established for up-gradient monitor well MW-3 based on twenty years of data for this sample point.

3.13 Other Relevant Factors

As specified in NMAC 20.9.9.15.C(14), this ACM considers other relevant factors. Other relevant factors with respect to the ACM were not found.

4.0 CONCLUSIONS

Corrective measures that have been taken at the site include landfill closure, cap, and re-vegetation, stormwater controls, and site monitoring including groundwater monitoring and soil vapor sampling (CDM, 1995; CDM, 2011; JSAI, 2018; DBSA, 2018). The corrective action plan and groundwater monitoring plan are in place and being followed (JSAI, 2009; JSAI, 2010). It is recommended that groundwater monitoring be continued at a reduced number of sample points, to be determined by NMED/SWB and City of Las Cruces, for effective monitoring of the contaminant plume.

Options for additional corrective measures evaluated include the following:

1. Groundwater extraction and treatment
2. Soil vapor extraction (SVE)
3. In-well vapor extraction for groundwater wells
4. Continued groundwater monitoring and natural attenuation

Results of the ACM support continued groundwater monitoring and natural attenuation as the corrective measure most appropriate for the Las Cruces Foothills Landfill.

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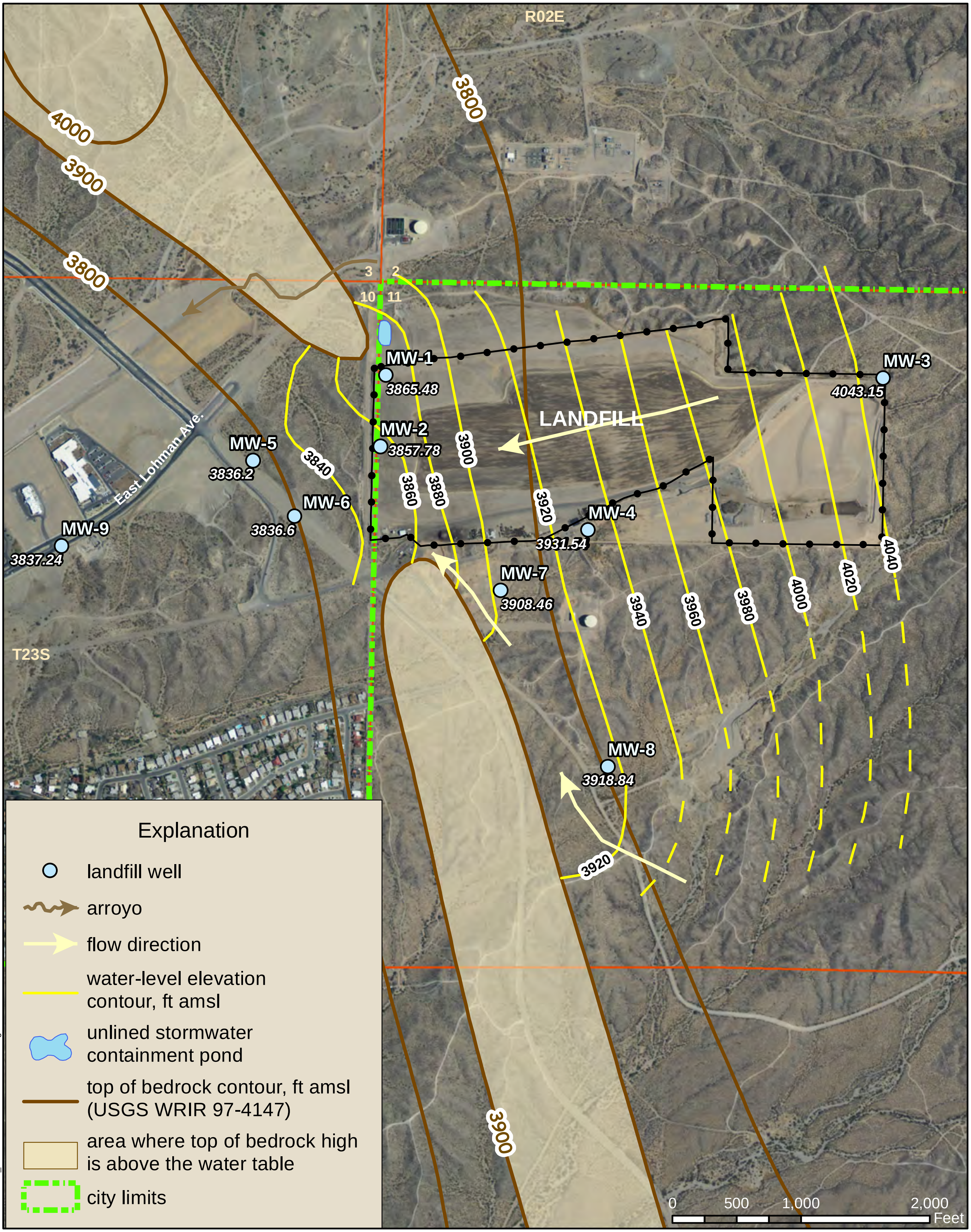
ILLUSTRATIONS



NAIP Aerial Photography date: May 2011

Figure 1. Aerial photograph showing locations of Las Cruces Foothills Landfill monitor wells, groundwater elevation contours, and direction of groundwater flow in December 2017.

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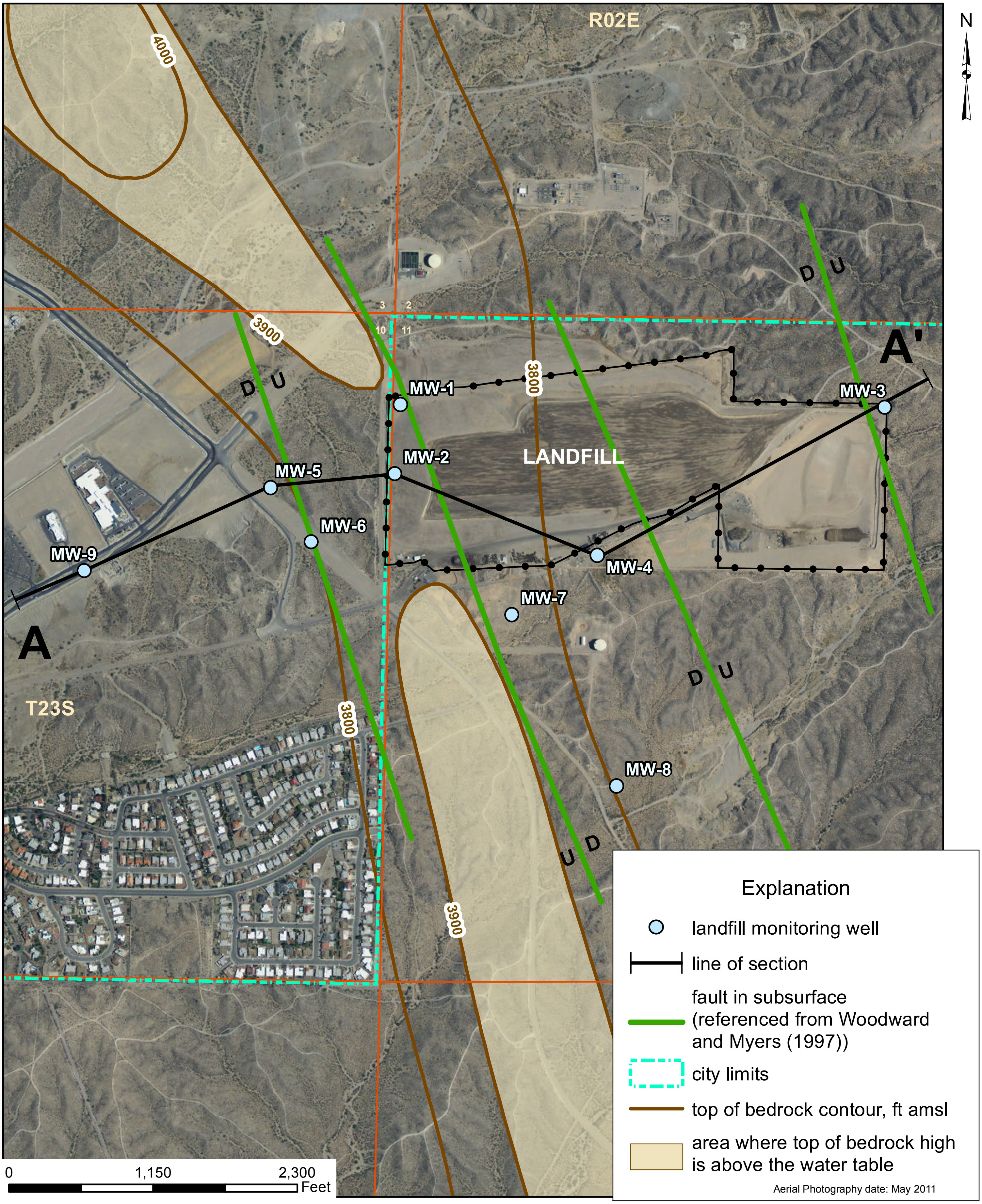


Figure 2. Aerial photograph showing locations of existing monitor wells, faults in the subsurface, line of schematic geologic cross-section A-A', and bedrock high, Las Cruces Foothills Landfill, New Mexico.

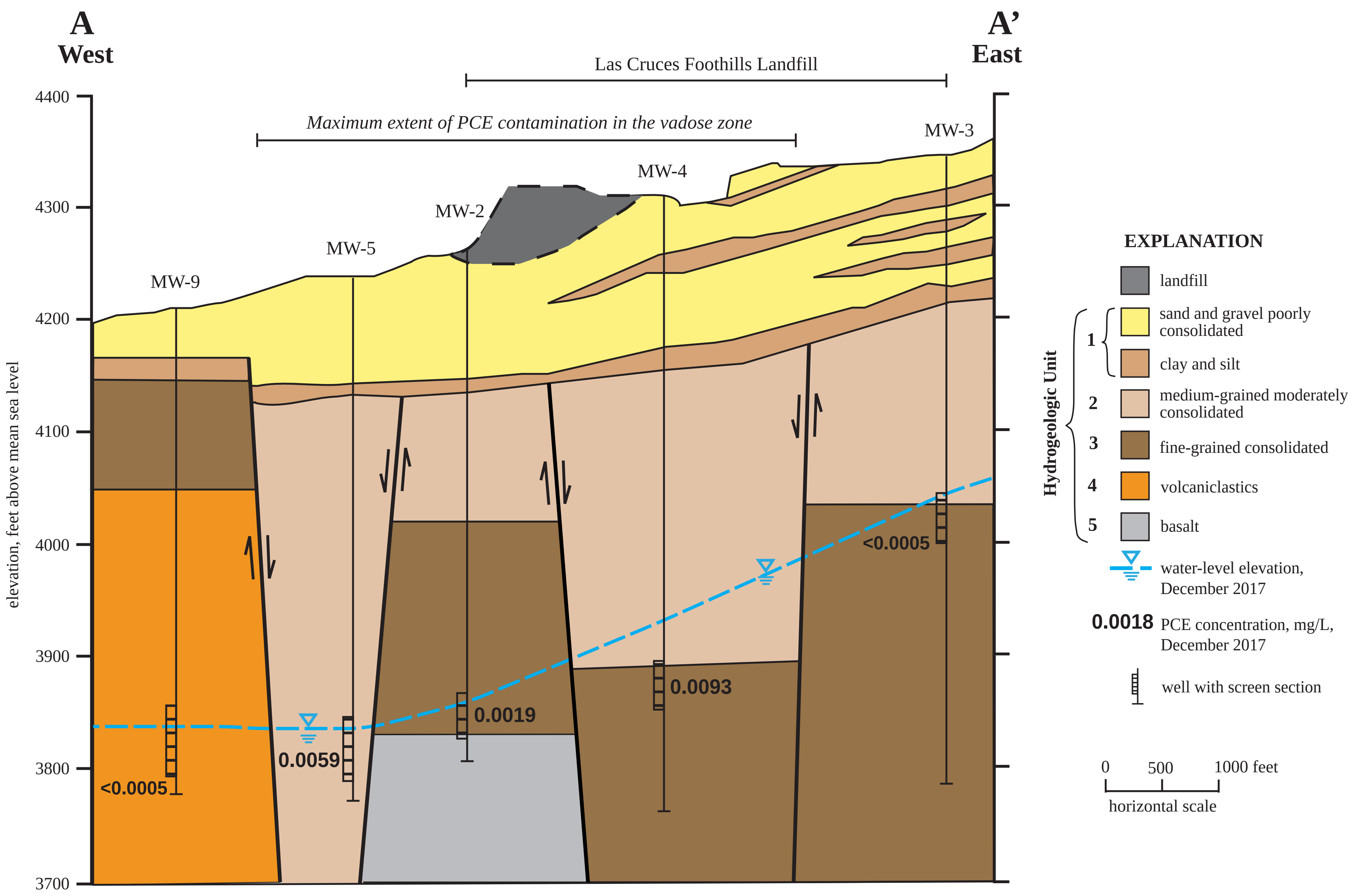


Figure 3. West to east hydrogeologic cross-section, Las Cruces Foothills Landfill, New Mexico.

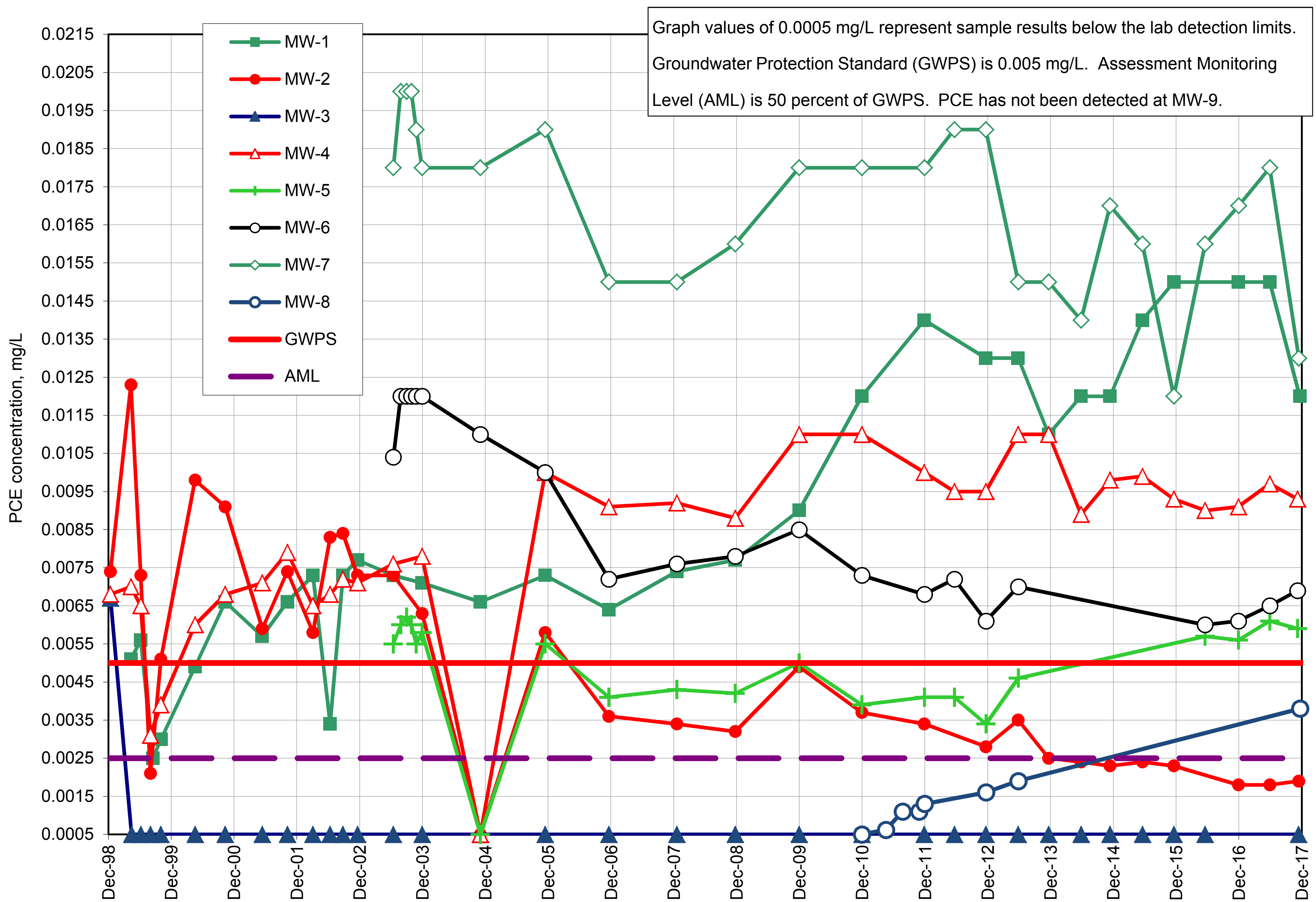


Figure 4. Graph showing tetrachloroethene (PCE) concentrations versus time for monitor wells at which PCE has been detected, Las Cruces Foothills Landfill, New Mexico.

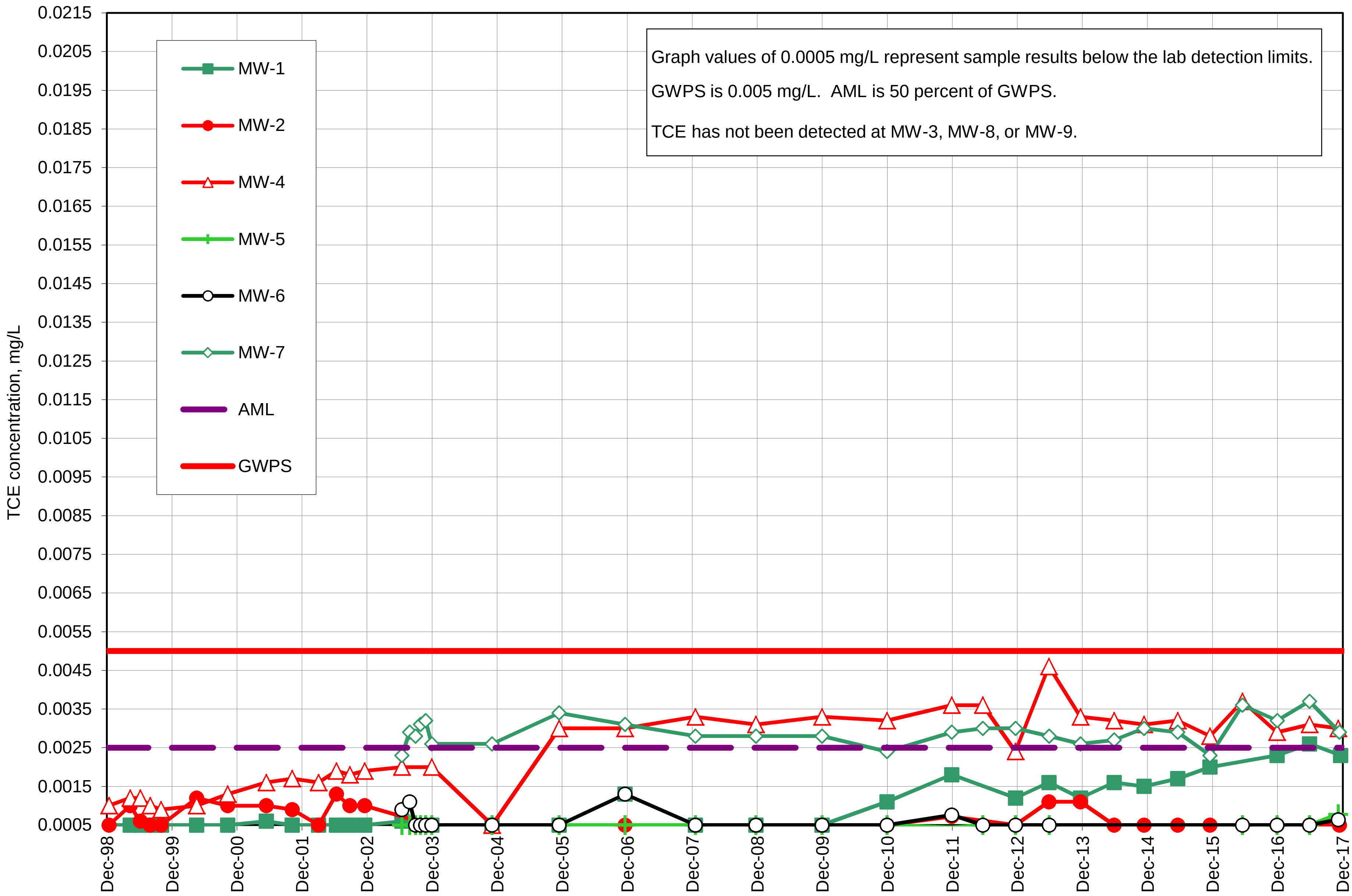


Figure 5. Graph showing trichloroethene (TCE) concentrations versus time for monitor wells at which TCE has been detected, Las Cruces Foothills Landfill, New Mexico.

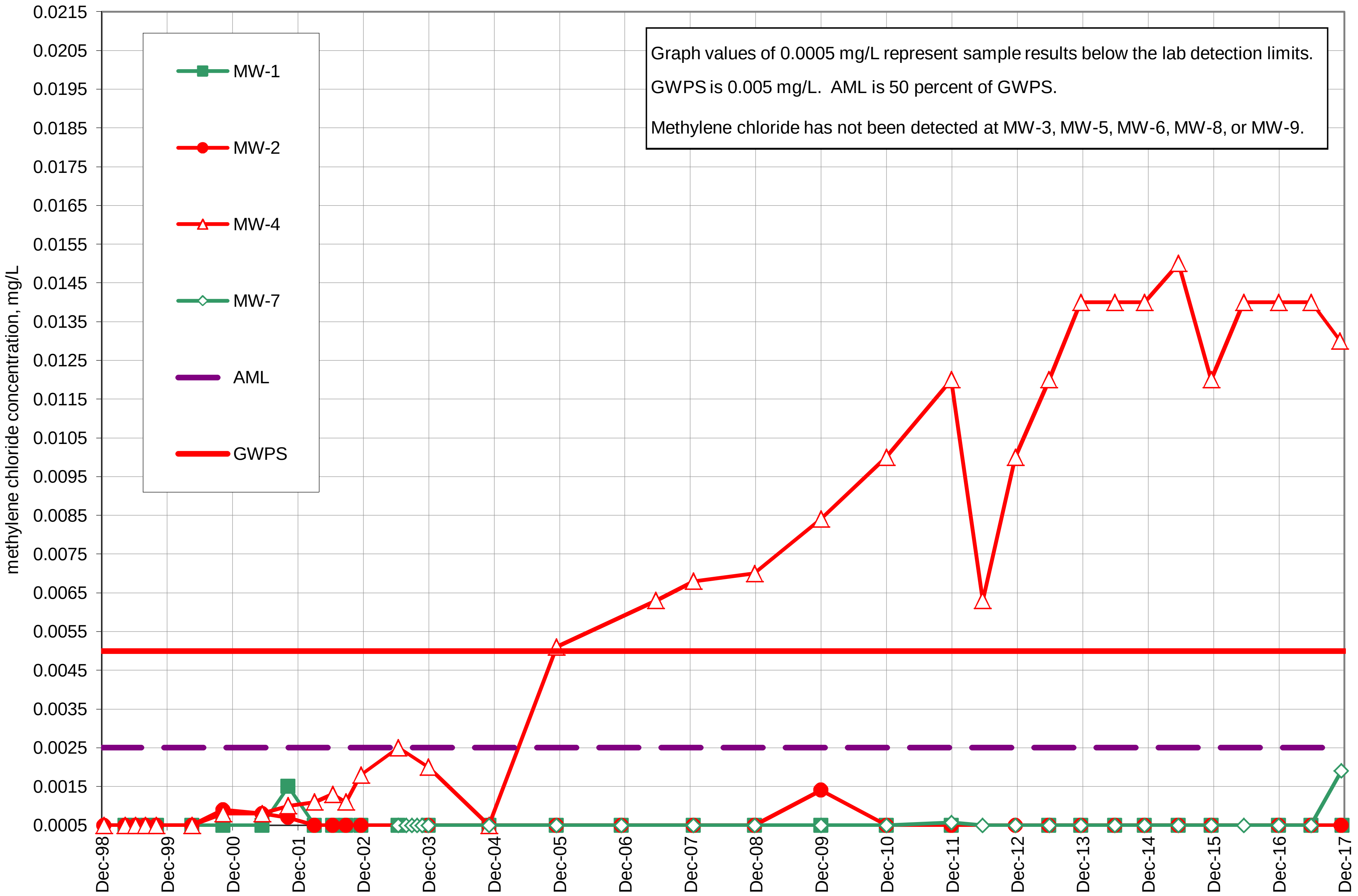


Figure 6. Graph showing methylene chloride concentrations versus time for monitor wells at which methylene chloride has been detected, Las Cruces Foothills Landfill, New Mexico.

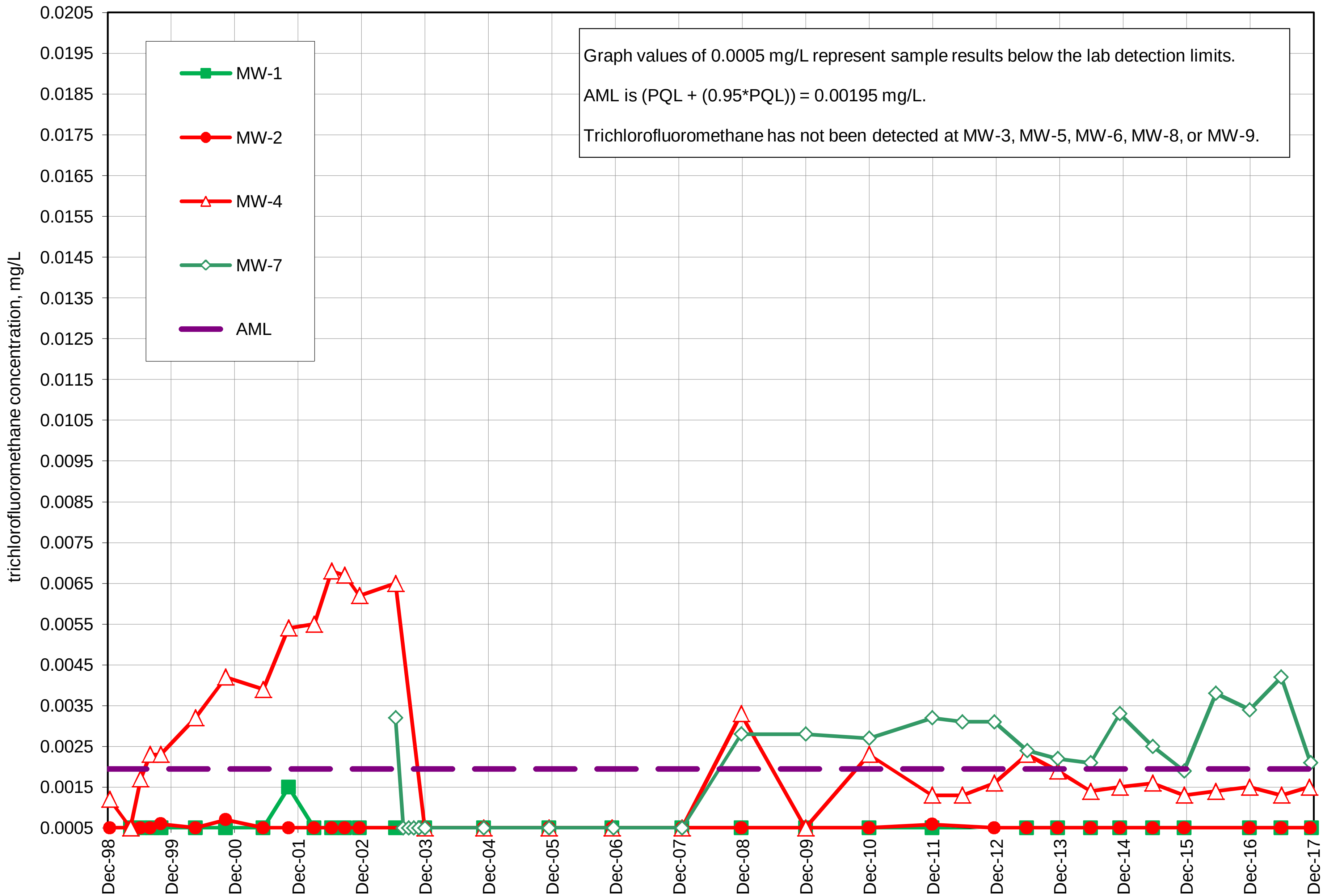
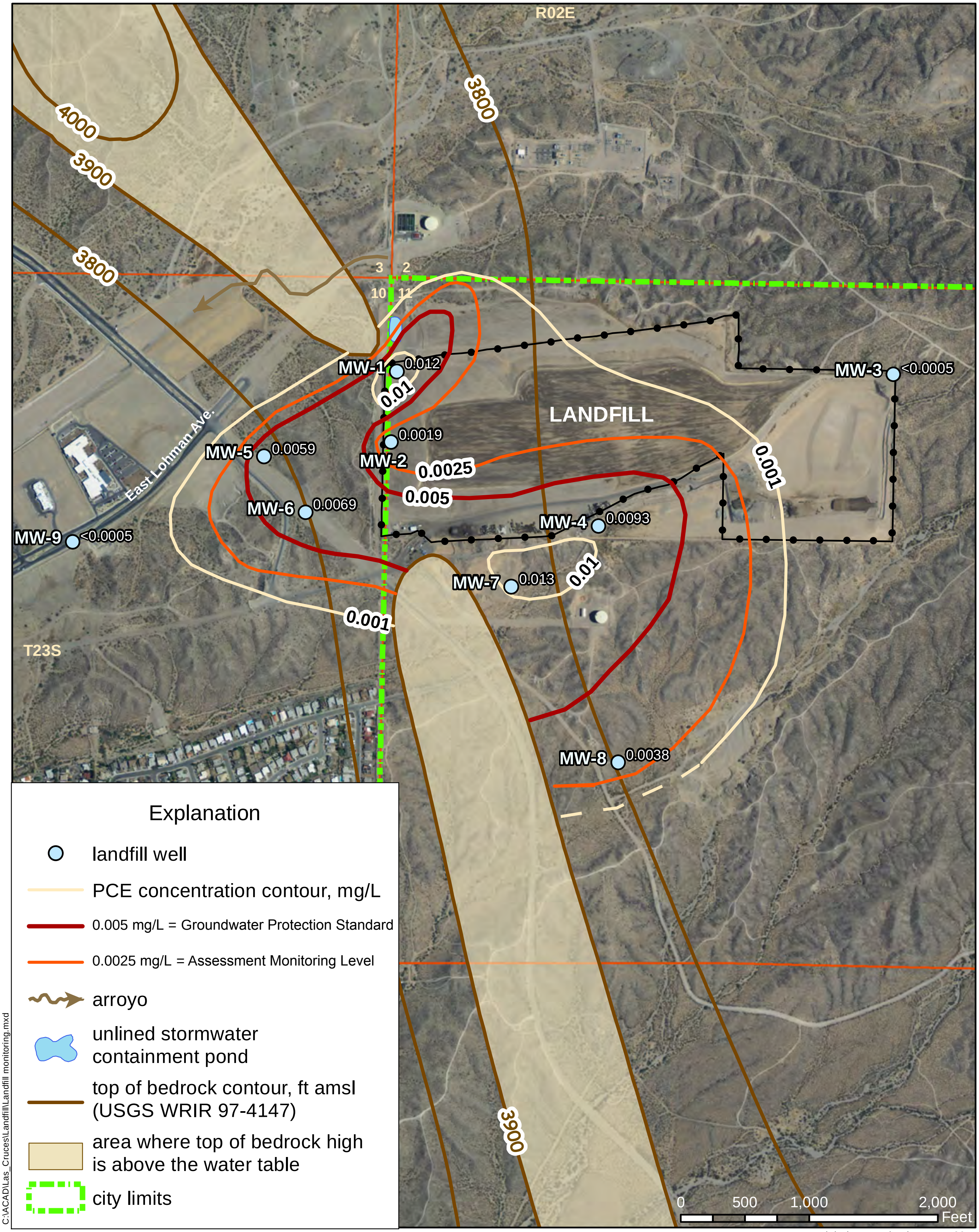


Figure 7. Graph showing trichlorofluoromethane concentrations versus time for monitor wells at which trichlorofluoromethane has been detected, Las Cruces Foothills Landfill, New Mexico.



NAIP Aerial Photography date: May 2011

Figure 8. Aerial photograph showing concentration contours of PCE in groundwater, December 2017 unless otherwise noted, Las Cruces Foothills Landfill, New Mexico.

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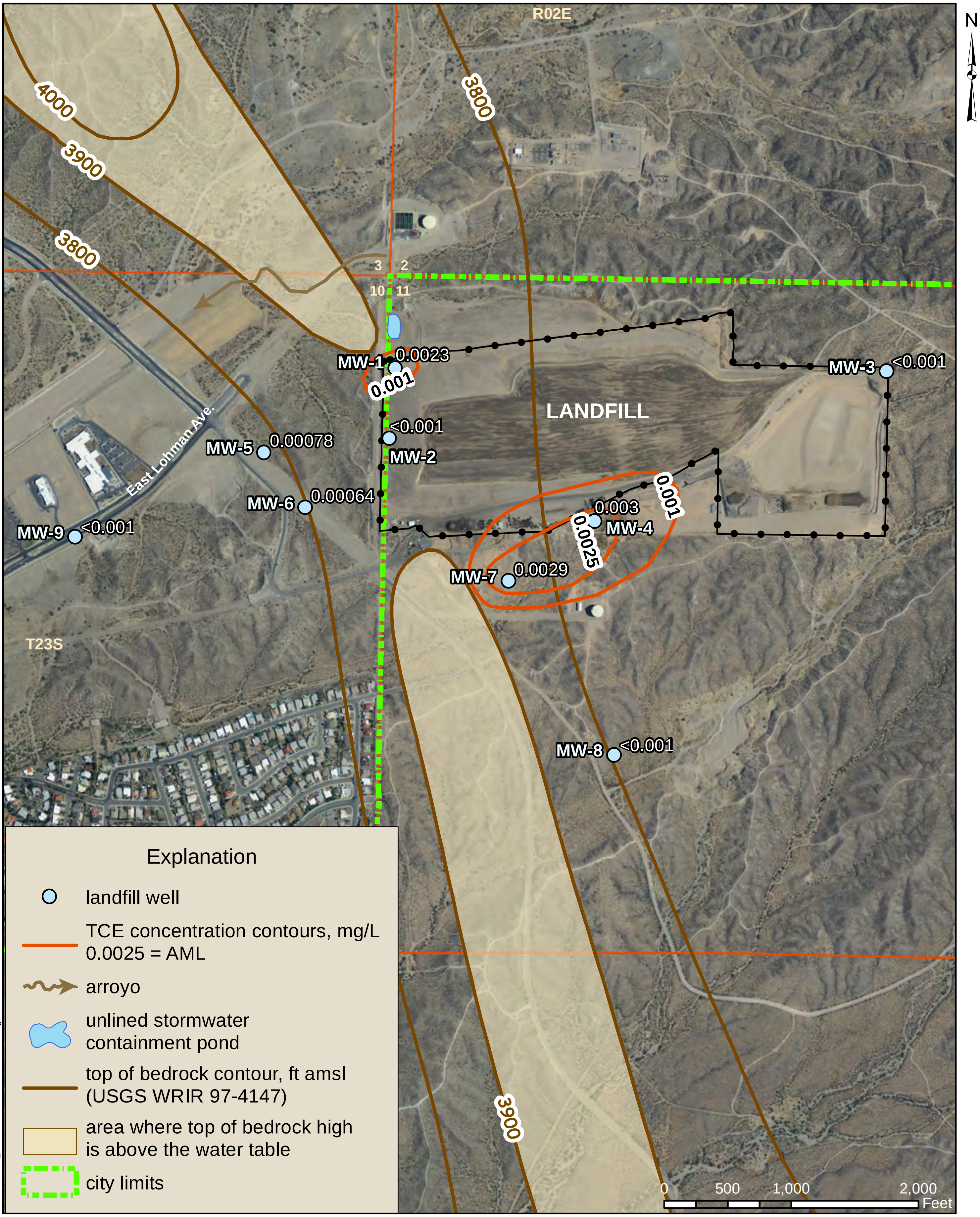


Figure 9. Aerial photograph showing concentration contours of TCE in groundwater, December 2017 unless otherwise noted, Las Cruces Foothills Landfill, New Mexico.

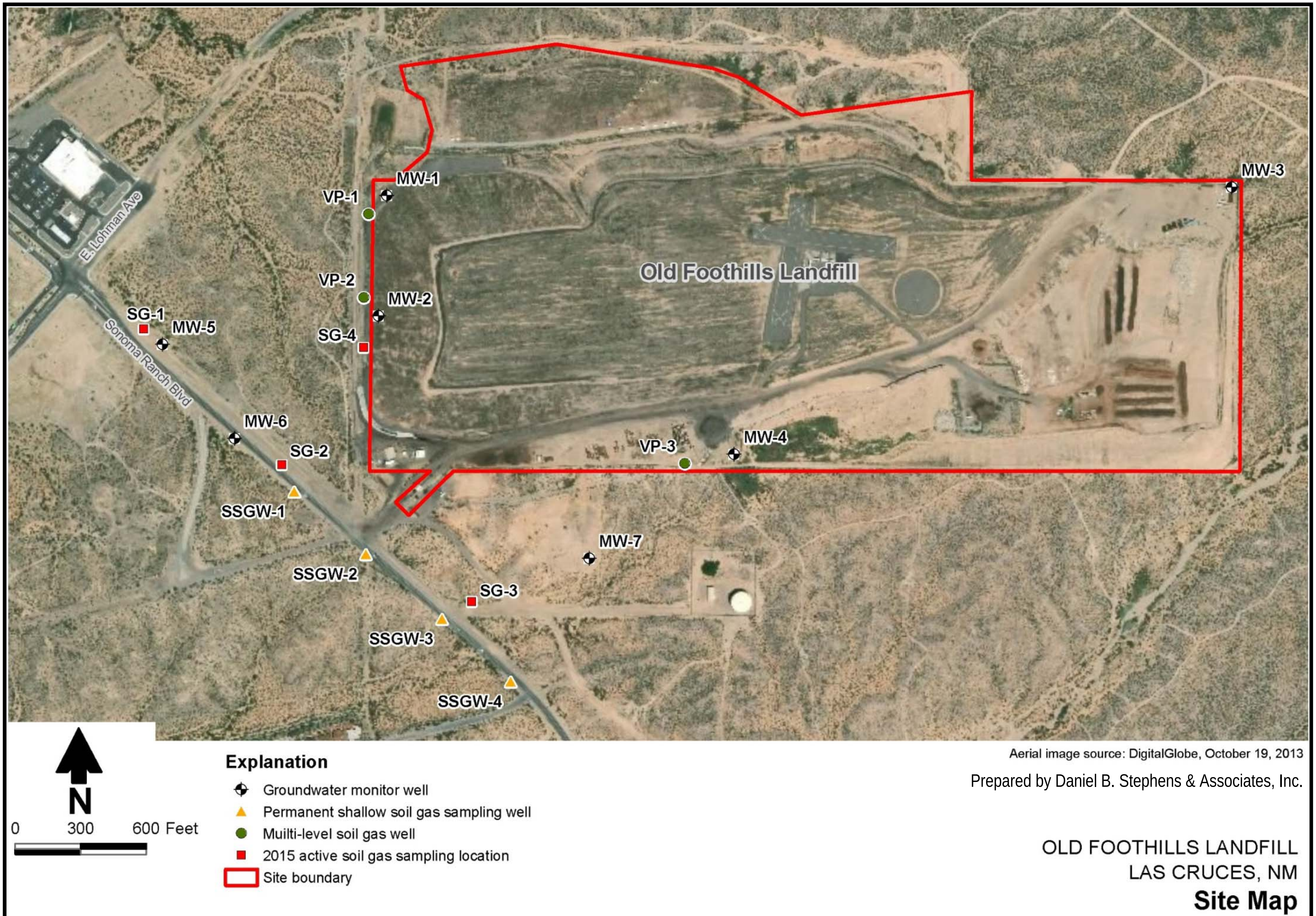
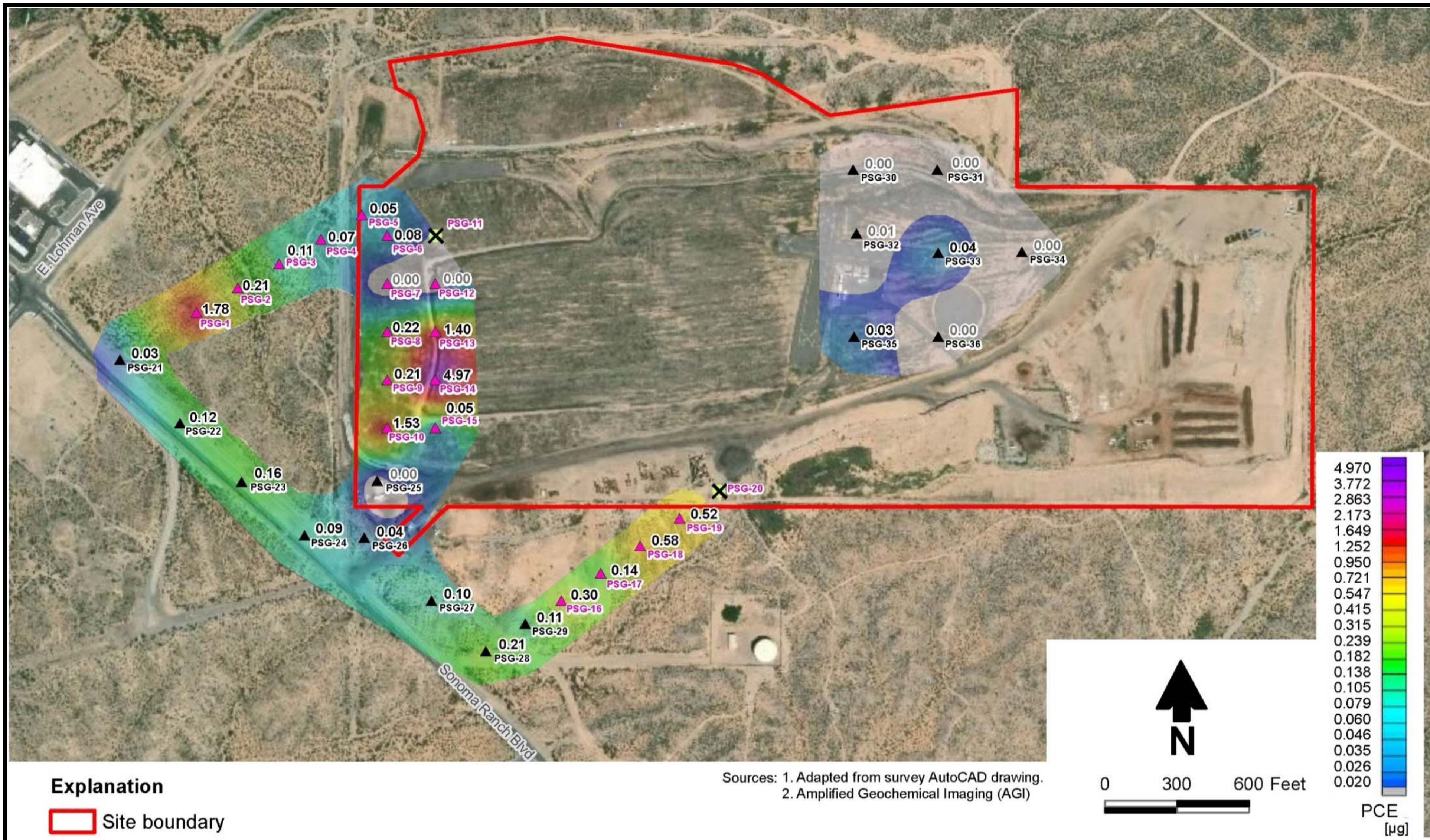


Figure 10. Aerial photograph showing soil gas sample locations, Las Cruces Foothills Landfill, New Mexico.



Explanation

Site boundary

1.40 PSG-13 2014 Passive soil gas sampling location

0.09 PSG-24 2015 Passive soil gas sampling location

2014 Passive soil gas sample location sampler damaged upon retrieval, not analyzed

Notes: 1. PCE = Tetrachloroethene
2. Passive soil gas results presented in micrograms (µg) PCE (mass)

Sources: 1. Adapted from survey AutoCAD drawing.
2. Amplified Geochemical Imaging (AGI)

Prepared by Daniel B. Stephens & Associates, Inc.

OLD FOOTHILLS LANDFILL
LAS CRUCES, NM

Passive Soil Gas Results for PCE

Figure 11. Aerial photograph showing passive soil gas results for PCE, Las Cruces Foothills Landfill, New Mexico.

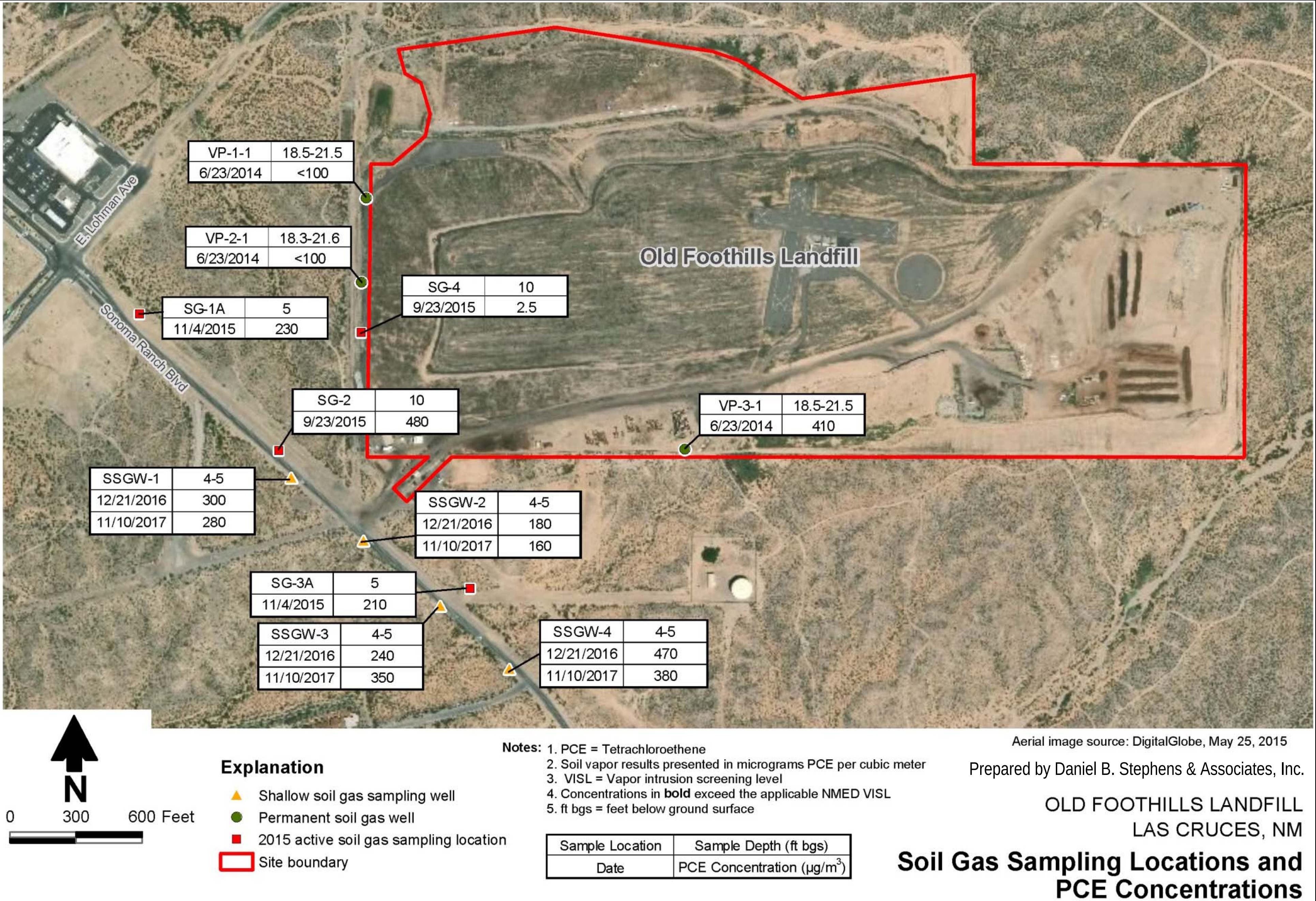


Figure 12. Aerial photograph showing concentrations of PCE in soil gas samples, 2014 to 2017, Las Cruces Foothills Landfill, New Mexico.

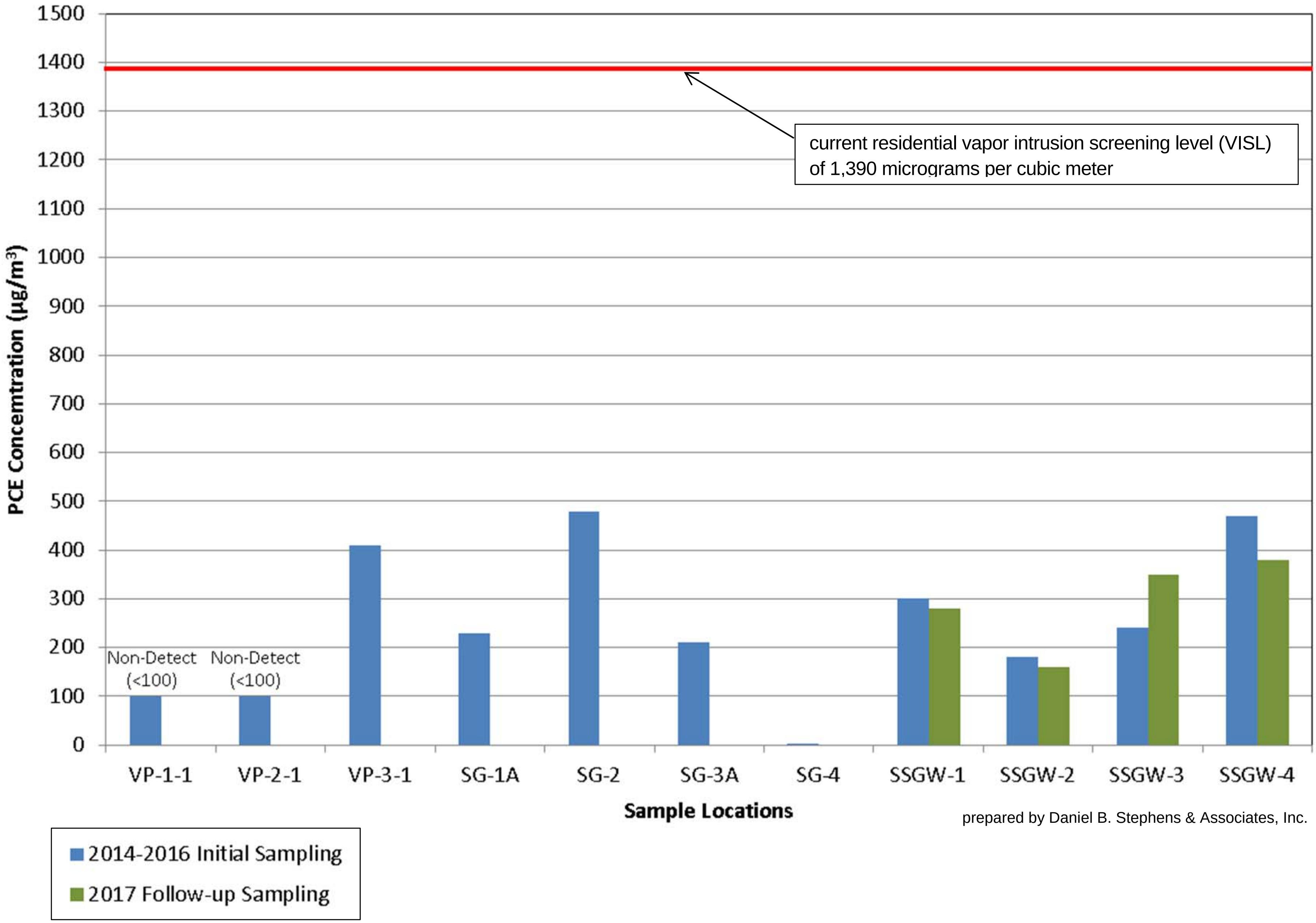


Figure 13. Graph showing PCE concentrations for shallow soil gas samples, 2014 to 2017, Las Cruces Foothills Landfill, New Mexico.

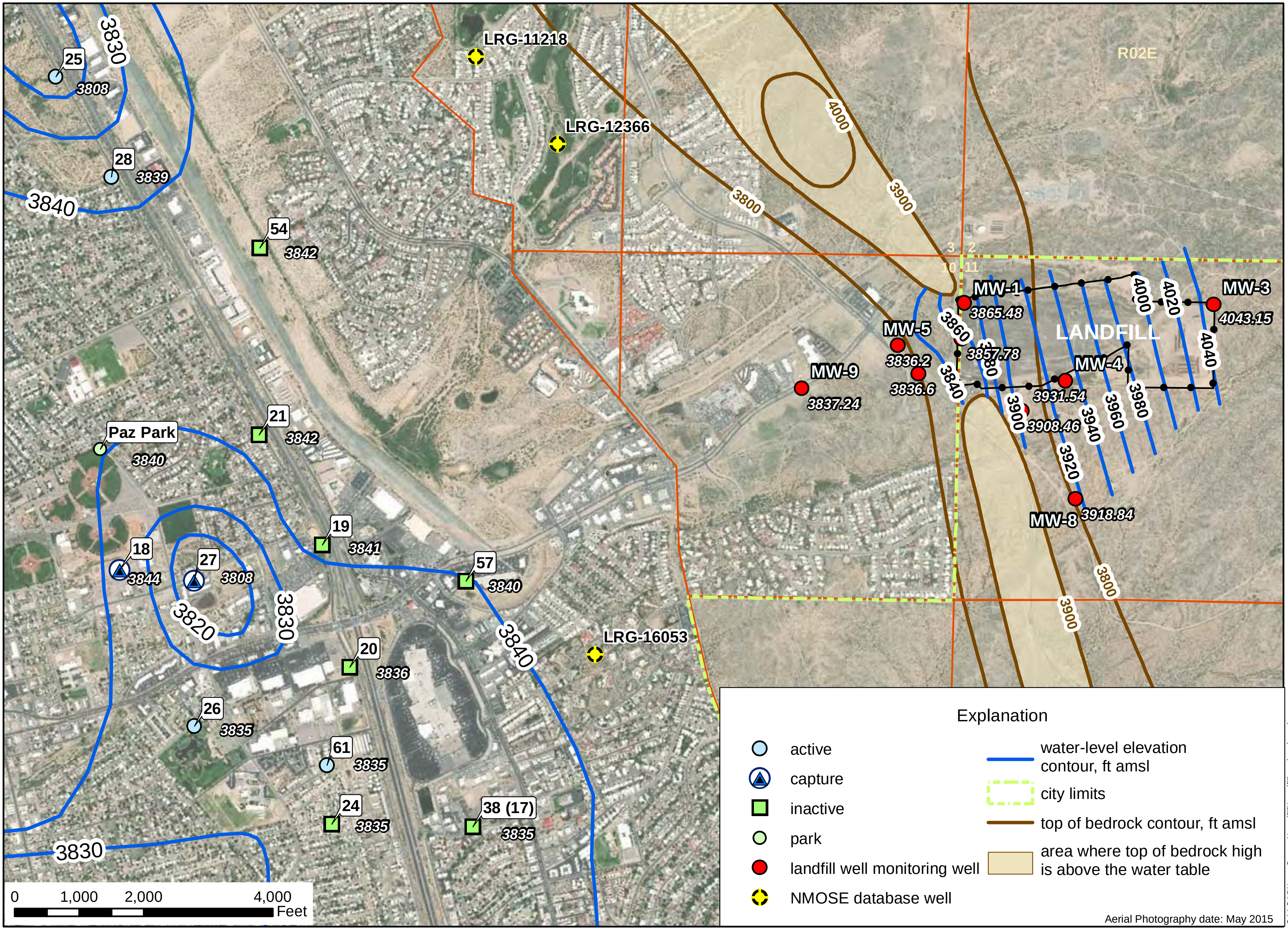


Figure 14. Aerial photograph showing Las Cruces Foothills Landfill monitor wells and groundwater elevation contours in December 2017.

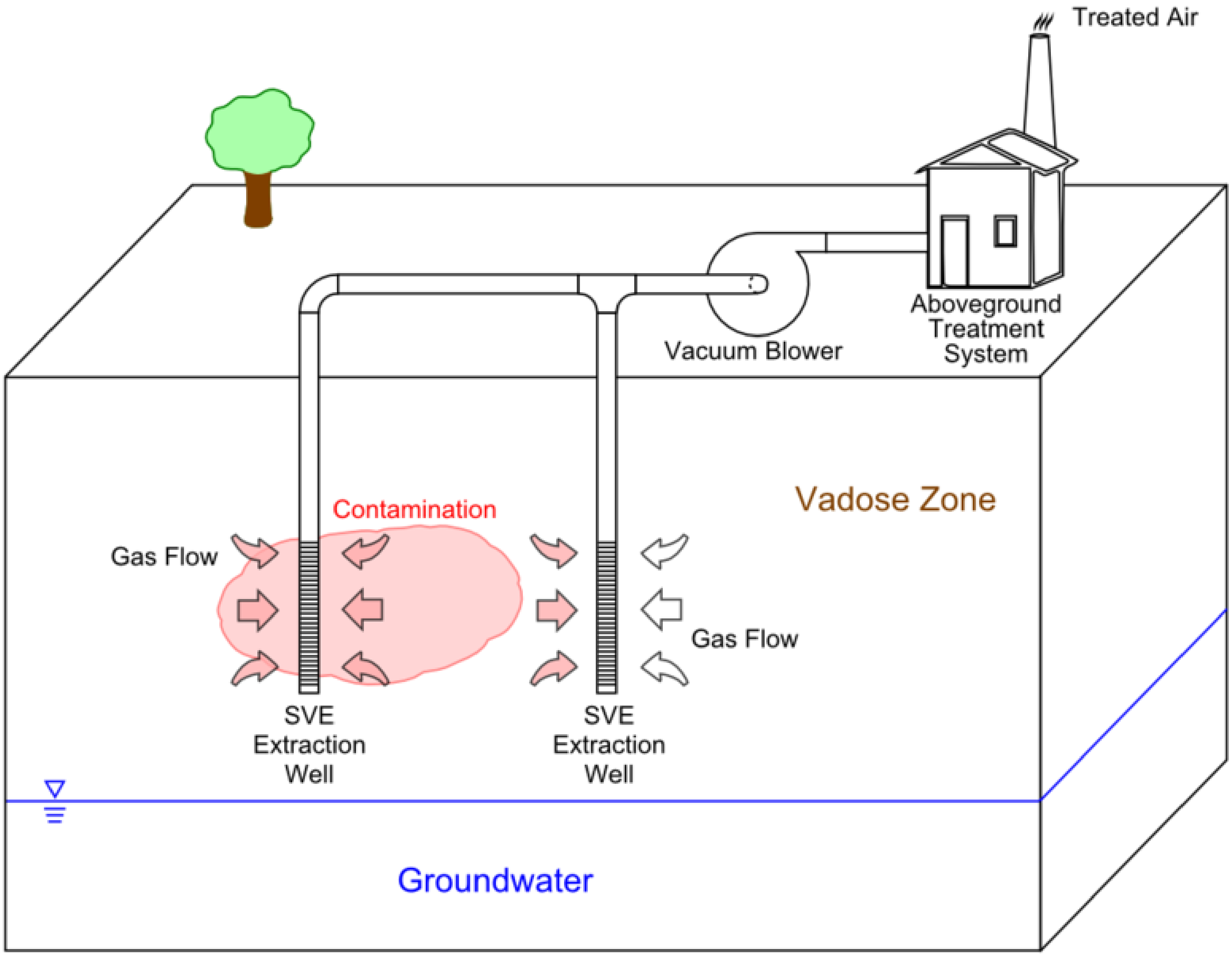


Figure 15. Schematic diagram of soil vapor extraction system for vadose zone remediation. (Source: By Gwremed - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27524589)

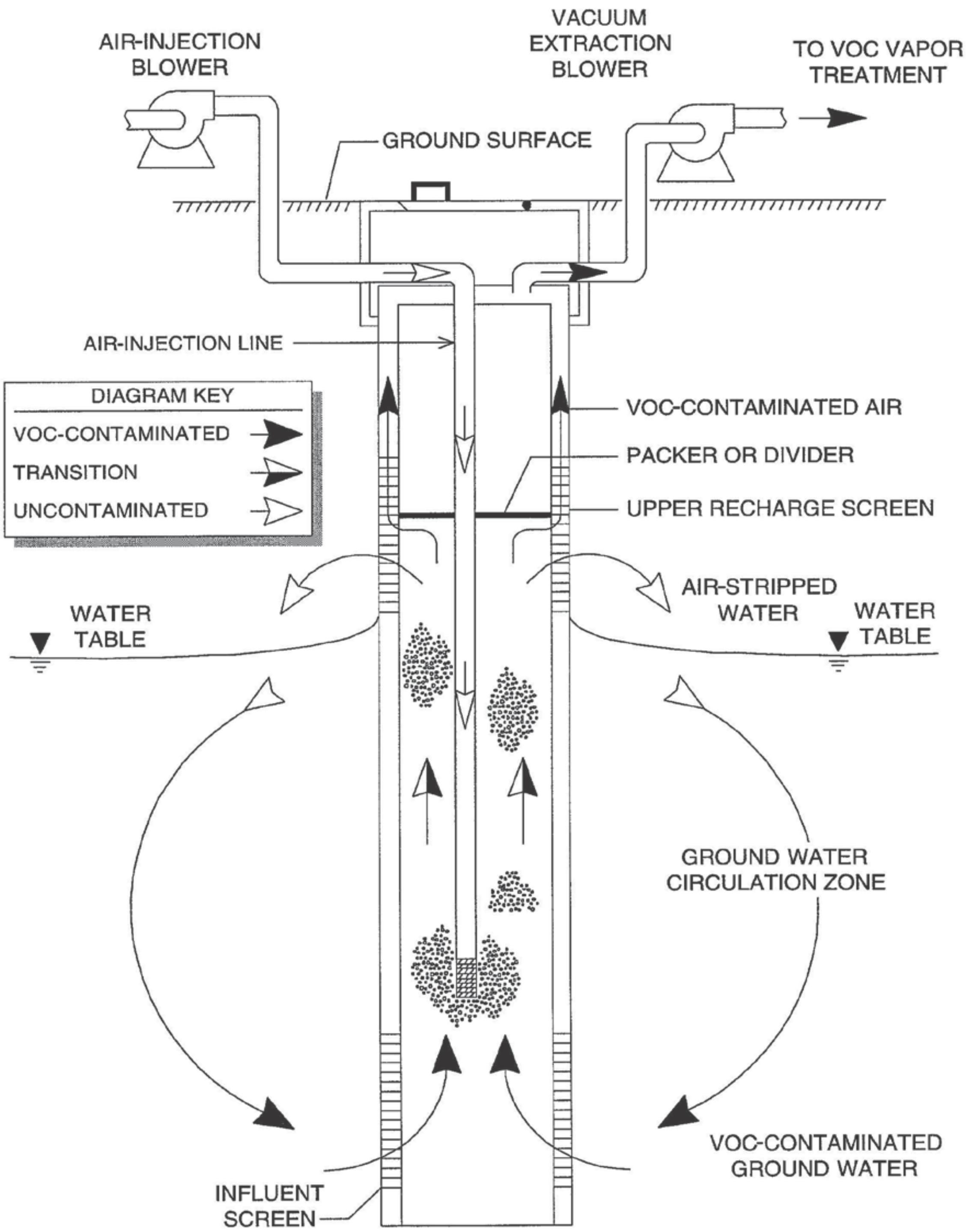


Figure 16. Schematic diagram of in-well vapor extraction process for groundwater remediation. (Source: Kulakow, 2015)