FINAL
EXPLANATION OF SIGNIFICANT DIFFERENCES
FOR

SITE C
CAMERON STATION
ALEXANDRIA, VIRGINIA

PREPARED FOR

UNITED STATES ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

PREPARED BY

URS

HERNDON, VIRGINIA

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ACRONYM LIST

μg/L	micrograms per liter
BRAC	1988 Base Realignment and Closure
COPC	chemical of potential concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
DD	Decision Document
DNA	Deoxyribonucleic acid
ESD	Explanation of Significant Differences
FFS	Focused Feasibility Study
FS	Feasibility Study
HI	Hazard Index
HHRA	human health risk assessment
IUR	inhalation unit risk
IC	institutional controls
J&E	Johnson and Ettinger
MCL	maximum contaminant level
MNA	monitored natural attenuation
NCP	National Contingency Plan
OU	Operable Unit
mg/m^3	milligrams per cubic meter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
RAGS	Risk Assessment Guidance for Superfund
RfC	reference concentrations
RI	Remedial Investigation
ROD	Record of Decision
SCL	sandy clay loam
TCE	trichloroethene
USACE	United States Army Corps of Engineers
USC	United States Code

USEPA	United States Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
VOC	volatile organic compounds
VRP	Voluntary Remediation Program
VPDES	Virginia Pollutant Discharge Elimination System

1.0 INTRODUCTION

1.1 Site Name and Location and Administrative Record

This Explanation of Significant Differences (ESD) is prepared for Site C at the former Army installation, Cameron Station, in Alexandria, Virginia. Site C is designated as contaminated groundwater believed to have been caused by a release of wastes into the installation sewer system. Site C was formerly referred to as Operable Unit 5 (OU-5). The purpose of this document is to explain the significant differences between the remedy selected in the Final Decision Document (DD) for Cameron Station (Woodward-Clyde, 1994) and the revised remedy now proposed. Figure 1-1 shows the location of Cameron Station in Alexandria, Virginia.

This ESD is prepared in accordance with Section 117(c) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended, and Section 300.435(c)(2)(i) of the National Contingency Plan (NCP). It will become part of the administrative record file for Cameron Station in accordance with the NCP, 40 CFR Section 300.825(a)(2). These laws and regulations require the lead agency to publish an ESD when the remedy to be implemented differs significantly from the remedy designed in the Record of Decision (ROD) or, in this case, the Final DD. This ESD will become part of the Administrative Record file for Cameron Station. The Administrative Record for Cameron Station is maintained at the Alexandria Library, Charles E. Beatley, Jr. Central Library, 5005 Duke Street, Alexandria, Virginia 22304.

This ESD provides a brief history of Cameron Station Site C, describes the remedy selected in the Final DD, and explains the ways in which the proposed remedy differs from the remedy selected in the Final DD. It also summarizes the lead agency's comments on the changes to the remedy and discusses compliance with the regulatory requirements cited above.

1.2 Identification of Lead and Support Agencies

The U.S. Army is the lead agency and the Virginia Department of Environmental Quality (VDEQ) is the lead regulatory agency for Cameron Station Site C. Cameron Station Site C is not listed on the National Priorities List. The U.S. Army has conducted the remediation of Site C in accordance with CERCLA, the NCP, and guidance (URS, 2007), as required by the Defense Environmental Restoration Program (10 USC 2701) and by U.S. Army regulation 200-1. This ESD has been created in accordance with CERCLA and NCP guidance for ESDs.

1.3 Rationale for ESD

The NCP requires the lead agency to publish an ESD when a remedial action will differ significantly from the final remedy selected and described in the Final DD, with respect to scope, performance, or cost. The Final DD for Cameron Station was signed by the U.S. Army in June 1994, with concurrence from VDEQ. The Final DD included six Operable Units (OUs); all OUs with the exception of OU-5 (Site C) have achieved their remedial goals and require no further action. The Final DD stated that Site C groundwater would be remediated to maximum contaminant levels (MCLs). CERCLA (as amended) regulations require that any needed response actions are performed to address unacceptable risks to human health or the environment resulting from past releases of hazardous substances. Although it is unlikely that the shallow groundwater at this site would be used as a drinking water source, the cleanup goal, as established in the Final DD, continues to be MCLs. As described in the Final DD, the selected remedy for Site C included the following:

- Contaminated groundwater will be pumped and remediated with an air stripping unit to remove volatile organic compounds (VOCs), specifically trichloroethene (TCE).
- Treated groundwater will be discharged to Backlick Run via an underground pipe.
- Vapors discharged from the air stripper will be routed through a granular activated carbon filter for removal of VOCs.

In support of the ESD, the following sections provide information on the human health risk assessment performed for Site C as well as recommendations from the Focused Feasibility Study (FFS) (URS, September 2010) and the Annual Operation and Maintenance Report for Site C (URS, 2008).

1.3.1 Overview of the 2007 Risk Assessment Update

In June 2001, a risk assessment was conducted to evaluate the potential human health risks posed by current and future exposures to the TCE plume. In response to comments received from VDEQ, the June 2001 risk assessment was updated in July 2003 and again December 2007. These revisions incorporated data generated from on-going groundwater monitoring events and from a soil gas investigation (URS, 2007). Land use at the site is currently high-density residential, and is expected to remain residential in the future. Properties within a 2-mile radius of the site are used for a mixture of commercial, residential, and industrial purposes. There is little, if any, potential for direct exposure to contaminants associated with the TCE plume for the following reasons:

- Previous investigations and remediation activities at the site have addressed soils that may have been contaminated by former installation activities. Furthermore, during

residential development, the site was covered with up to 8 feet of imported fill. Thus, exposure of residents to soils that may have been impacted by historical activities at the site is not expected.

- Groundwater does not intercept on-site bodies of surface water (i.e., Cameron Lake), or intercepts it in such small quantities as to be undetectable.
- On-site residential development is connected to the municipal water supply system, and a deed restriction on the property prohibits the current landowner and subsequent landowners from accessing or using groundwater. Thus, residential exposure to contaminants in groundwater through ingestion and dermal contact of potable water is not occurring on-site and is not expected to occur in the future.
- All existing residential development within the City of Alexandria is connected to the municipal water system, and all future development in the City is required to be connected to this system. Based on available information, significant off-site migration of the TCE plume is unlikely. Thus, off-site exposures to the TCE plume are not anticipated.

Indirect exposure of residents to constituents in the TCE plume could theoretically occur via inhalation of vapors migrating from groundwater through the soil and into homes. Homes at the site include polyethylene moisture barriers beneath the foundations, which may reduce the migration of vapors into the homes. Despite the presence of such moisture barriers, the risk assessment includes an analysis of potential exposures of residents to constituents in groundwater that might migrate into indoor air in homes with basements. Potential migration of vapors into residences with basements could be higher than for slab-on-grade buildings, due to greater proximity to groundwater. In evaluating this on-site residential scenario, the effect of the moisture barrier at blocking vapor migration is assessed by examining two cases. In the first case, it is assumed that no moisture barrier exists, in the event that a home is built in the future without a moisture barrier, or that the existing moisture barrier is completely ineffective in reducing the migration of vapors into indoor air. In the second case, it is assumed that the existing moisture barrier is partially effective in reducing convective and diffusive transport of vapors into indoor air.

For construction and utility workers at the site, exposure to constituents in groundwater could occur during major soil disturbance activities, such as digging a trench. Therefore, this risk assessment includes an analysis of risk to current and future construction/utility workers from exposure to constituents in groundwater. This exposure is assumed to occur during work in a trench that is 10 feet deep, which is the maximum depth of the existing buried utilities in the vicinity of the TCE plume. Depth to groundwater at the site ranges from 12 feet to 21 feet. In the vicinity of the TCE plume, the average depth to groundwater is typically 15 feet, or 5 feet below the assumed excavation depth. Thus, a construction/utility worker is not expected to reach the water table when

digging a trench in the vicinity of the TCE plume. However, while working in such a trench, a construction/utility worker could be exposed to vapors migrating from groundwater through soil.

This risk assessment evaluated other constituents detected in the vicinity of the TCE plume. This was accomplished by comparing the maximum detected concentration of each constituent against VDEQ screening levels for groundwater and soil gas. VDEQ risk assessment guidance recommends that contaminants with concentrations above VDEQ VRP screening levels (Tier I and Tier II) be carried through to a site-specific screening assessment (Tier III). The first tier of screening levels (Tier I) involves comparison of maximum detected concentrations with site-specific background concentrations. Tier I screening is optional and is most appropriate for naturally-occurring substances, such as metals. Therefore, a Tier I screen was not included in the risk assessment. A comparison of the maximum detected concentration for each of the constituents detected during historic groundwater monitoring (November 2003 through November 2005) to VDEQ's Tier II screening levels determined that the maximum 1,1-DCE and TCE concentrations in groundwater exceed the Tier II screening levels. Based on VDEQ VRP guidance, these two constituents were therefore considered chemicals of potential concern (COPCs) and are carried through to the Tier III screening evaluation. The COPCs in groundwater were compared with the Tier III groundwater screening levels for residents and construction/utility workers; TCE was the only site constituent for which the maximum detected concentration in groundwater exceeded the corresponding Tier III groundwater screening level for residential and construction/utility worker exposure.

In summary, the potential risks associated with the following exposure scenarios are quantified in this assessment:

- ***Residential Exposure to Indoor Air.*** Migration of volatiles from the subsurface to the basement of a residence is modeled using the Johnson and Ettinger (J&E) model, as specified by VDEQ. Two versions of the model are applied: one using the recent soil gas results as the source term, and the other using groundwater monitoring results as the source term. In assessing exposures of on-site residents to indoor air, it is conservatively assumed that vapor migrating through the foundation will accumulate only in the basement. As previously requested by VDEQ, mixing of the basement air with the upper floors is assumed not to occur, thus resulting in conservative estimates of indoor air concentrations, and exposure to vapors in the basement is assumed to occur for 12 hours per day, 350 days per year, for 30 years.
- ***Construction/Utility Worker in Trench above Water Table.*** Risks are assessed for on-site construction/utility workers exposed to volatiles migrating from groundwater through the soil into a trench above the water table. The construction/utility worker is

conservatively assumed to be exposed to vapors in the trench for 4 hours per day over a period of 125 days. Three different approaches are used to estimate the air exchange rate in the trench air in order to determine the sensitivity of the results to this parameter.

The methodology used to characterize potential risks in this assessment is based on VDEQ Voluntary Remediation Program (VRP) risk assessment guidance and is consistent with U.S. Environmental Protection Agency (USEPA) risk assessment guidance. The toxicity values used in this assessment are based on published USEPA sources and are consistent with the toxicity values published in VDEQ guidance.

The overall conclusions of the updated risk assessment are as follows:

- ***Residential exposures to groundwater constituents at the site are not expected to result in adverse human health effects.*** None of the site constituents exceed VDEQ Tier III screening levels for soil gas, indicating that residential risks associated with vapor migration is likely to be negligible. To confirm this result, VDEQ guidance suggests performing additional site-specific quantitative risk evaluation using the J&E modeling approach. Based on the soil gas data and the additional site-specific modeling, the theoretical incremental lifetime carcinogenic risk is estimated to be 4×10^{-7}, assuming a total exposure duration of 30 years. These risks are below the 1×10^{-6} target risk for individual carcinogens under the VDEQ VRP regulation, and below the acceptable carcinogenic risk range of 1×10^{-6} to 1×10^{-4} under the NCP. Thus, carcinogenic risks associated with residential exposures at the site are within the range defined as acceptable by both VDEQ and USEPA, based on the soil gas data. In addition, the residential non-cancer Hazard Index (HI) values are well below the VDEQ and USEPA target HI of 1, and thus non-carcinogenic effects would not be expected.

  TCE is the only site constituent that exceeds VDEQ residential Tier III screening levels for groundwater. Thus, additional site-specific quantitative risk evaluation was performed for TCE in accordance with the VDEQ guidance for constituents exceeding the Tier III screening levels for groundwater. Based on the maximum TCE groundwater concentration from recent sampling events (i.e., November 2003 through November 2005) and J&E modeling, the incremental lifetime carcinogenic risks for an adult including childhood exposure is estimated to be 1×10^{-4}, exceeding the VDEQ target risk of 1×10^{-6} for individual carcinogens, and at the upper end of the acceptable carcinogenic risk range under the NCP. The residential non-cancer HIs estimated with groundwater data are well below the VDEQ and USEPA target HI of 1, and thus non- carcinogenic effects would not be expected.

  The higher theoretical cancer risk estimates based on groundwater data compared to the soil gas data arise primarily because the soil stratum directly above the water table is much less permeable than characterized by the default values for sandy clay loam (SCL) in the J&E groundwater model. The use of default values for the SCL soil type in the J&E model does not completely account for the fine heterogeneity in this soil stratum that can contribute to increased vapor attenuation. It is likely that interbedded clay and silt

lenses at the site may be present near the water table and result in less upward TCE vapor flux, as reflected by the very low TCE concentrations measured in the soil gas. Overall, the results based on the soil gas data are judged to better represent site risks than the results based on the groundwater data. Thus, considering all available site data, theoretical lifetime incremental cancer risks for residents are not likely to exceed VDEQ or USEPA target risks, and adverse human health effects are not expected.

- ***Construction/utility worker exposures during trench excavation would not be expected to cause any adverse health effects.*** None of the site constituents exceed VDEQ construction worker Tier III screening levels for soil gas, indicating that site risks for the construction worker are likely to be negligible. TCE is the only site constituent that exceeds VDEQ construction worker Tier III screening levels for groundwater. Thus, additional site-specific quantitative risk evaluation for the construction worker was performed in accordance with the VDEQ guidance for constituents exceeding the Tier III screening levels for the construction worker.

  Using the maximum detected contaminant concentrations from recent groundwater sampling events for the TCE plume and the VDEQ trench model, theoretical incremental lifetime cancer risks are estimated to be below 1×10^{-6} for the construction worker and non-carcinogenic effects would not be expected. Thus, theoretical lifetime incremental cancer risks do not exceed VDEQ or USEPA target risks, and adverse human health effects are not expected.

In May 2008, the VDEQ granted its concurrence with the updated risk assessment.

In September 2011, the USEPA updated the toxicity information for TCE. For many years, only provisional toxicity data have been available for TCE. However, USEPA published new cancer and non-cancer toxicity values for TCE in EPA's Integrated Risk Information System and identified TCE as a mutagen (i.e., TCE is expected to cause irreversible changes to DNA and is likely to exhibit a greater effect in early-life versus later-life exposure).

The human health risk assessment (HHRA) for the Cameron Station Site C identified TCE as its primary inhalation COPC for soil gas and groundwater media for the construction worker and residential scenarios (ENVIRON, 2006). The 2006 HHRA pre-dates the 2011 toxicological changes for TCE. Also, USEPA published the Risk Assessment Guidance for Superfund (RAGS) Part F, Supplemental Guidance for Inhalation Risk Assessment (2009) that changes how the inhalation pathway is addressed in HHRAs. The Part F guidance recommends using the concentration of the chemical in the air as the exposure metric (mg/m3), rather than inhalation intake (expressed as mg/kg-body weight per day) of a contaminant in air based on inhalation rate and body weight when estimating risks or hazards via inhalation. The derivation of inhalation slope

factors and inhalation reference doses are biased to adult receptor exposure per USEPA's RAGS Part A (1989) guidance.

This assessment addresses how the recent toxicological changes for TCE and USEPA's inhalation guidance affect the results of the 2006 HHRA for Cameron Station Site C (ENVIRON, 2006). The following changes were made in re-calculating the HHRA results:

- Cancer and non-cancer toxicity data for TCE (Table 1) were updated (USEPA, 2012)
- Inhalation intake equations were revised to calculate exposure concentrations in accordance with EPA's RAGS Part F Inhalation Guidance (USEPA, 2009)
- TCE's potential mutagenic health effects were addressed in the lifetime exposure concentration calculations of the residential scenario (USEPA, 2005a and 2005b)

As noted in Table 1, the 2012 inhalation unit risk (IUR) for TCE is roughly 28% lower than the provisional IUR that was used in the 2006 HHRA. Table 2 (revised Table 5.10 of the 2006 HHRA) shows that the 2012 inhalation cancer risk results are lower for the construction worker and residential scenarios. The VDEQ VRP regulations cite 1×10^{-6} as a risk goal for individual carcinogens, not to exceed a site risk of 1×10^{-4} for all carcinogens (VDEQ, 2012). The 2006 and 2012 HHRA cancer risk results remain below the VRP's site risk threshold of 1×10^{-4}. The 2012 residential cancer risk results account for the early life mutagenic health effects of TCE (EPA, 2005a and 2005b).

Table 1. Revised Inhalation Toxicity Data for TCE

TCE Inhalation Toxicity Data	2006		2012	
Cancer: Inhalation Unit Risk $(\mu g/m^3)^{-1}$	1.14E-04	N	4.1E-06	I
Non-Cancer: Chronic Reference Concentration (mg/m^3)	3.50E-02	N	2.0E-03	I
Non-Cancer: Subchronic Reference Concentration (mg/m^3)	1.02E-01	I	2.0E-03	I
Notes: I = EPA's IRIS N = National Center for Environmental Assessment (NCEA) NA = Not applicable				

The chronic and subchronic reference concentrations (RfC) are higher values than the 2012 chronic RfC, which was used for the chronic residential and subchronic construction worker scenario calculations (VDEQ, 2012). The non-cancer hazard results are inversely proportional to the non-cancer toxicity data (i.e., the higher the toxicity value, the lower the non-cancer hazard result). The 2012 non-cancer hazard results are slightly higher than the 2006 non-cancer results, but are still below VRP's target non-cancer hazard index (HI) of 1 (VDEQ, 2012).

Table 2. Risk Summary for 2006 and 2012, Cameron Station Site C, Alexandria, Virginia (Revised Table 5.10 of the 2006 HHRA)

	Residential Scenario: Inhalation of Indoor Air (with Soil Gas Data)		Residential Scenario: Inhalation of Indoor Air (with Groundwater Data) (No Vapor Barrier)		Residential Scenario: Inhalation of Indoor Air (with Groundwater Data) (With Vapor Barrier)		Construction/ Utility Worker Using ACH of 2/hour	Construction/ Utility Worker Using ACH of 107/hour	Construction/ Utility Worker Using ACH of 113/hour
2012 Carcinogenic Risk	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Adult**	**Adult**
Inhalation	9.E-09	4.E-09	3.E-06	1.E-06	6.E-07	3.E-07	1.E-09	3.E-11	2.E-11
Total Risk	9.E-09	4.E-09	3.E-06	1.E-06	6.E-07	3.E-07	1.E-09	3.E-11	2.E-11
2012 Total Residential Risk	1.E-08		4.E-06		9.E-07		NA	NA	NA
2012 Non-Cancer HI	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Adult**	**Adult**
Inhalation	0.003	0.003	0.9	0.9	0.2	0.2	0.01	0.0002	0.0002
2012 Total HI	0.003	0.003	0.9	0.9	0.2	0.2	0.01	0.0002	0.0002
2006 Carcinogenic Risk	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Adult**	**Adult**
Inhalation	2.E-07	2.E-07	7.E-05	5.E-05	4.E-06	2.E-06	7.E-07	2.E-09	2.E-09
Total Risk	2.E-07	2.E-07	7.E-05	5.E-05	4.E-06	2.E-06	7.E-07	2.E-09	2.E-09
2006 Total Residential Risk	4.E-07		1.E-04		6.E-06		NA	NA	NA
2006 Non-Cancer HI	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Adult**	**Adult**
Inhalation	0.0002	0.0004	0.05	0.1	0.003	0.007	0.004	0.00001	0.00001
2006 Total HI	0.0002	0.0004	0.05	0.1	0.003	0.007	0.004	0.00001	0.00001

Notes:

ACH = air changes per hour; HI = hazard index; NA = Not applicable

While performing the 2012 HHRA calculations, a J&E indoor air modeling error was identified for a 2006 HHRA residential scenario. The 2006 HHRA used the exposure duration of 30 years for all the residential J&E modeling scenarios except for the groundwater data/with vapor barrier model run (where 24 years was used). The 2012 HHRA results used 30 years for all the residential indoor model runs; the effect on the results was minor.

Updated tables from the 2006 HHRA, which changed due to the issues discussed above, are presented in Appendix C.

1.3.2 2008 Annual Operation and Maintenance Report

The Annual Operation and Maintenance Report for Site C (URS, 2008) stated that since startup in April 1996, the Site C groundwater treatment system had processed approximately 80 million gallons of groundwater and removed approximately 33.9 pounds of TCE. An analysis of decreasing TCE concentration trends determined that the groundwater treatment system had achieved asymptotic conditions in Site C groundwater. The report concluded that the groundwater treatment system was no longer effectively treating site groundwater and recommended temporarily ceasing groundwater treatment activities. On December 8, 2008, the VDEQ accepted the conclusions and recommendations presented in the Annual Operation and Maintenance Report for Site C and approved temporarily ceasing groundwater treatment activities at the site. On May 6, 2011, the VDEQ deactivated the Site C Virginia Pollutant Discharge Elimination System (VPDES) permit.

1.3.3 2010 Focused Feasibility Study

A Focused Feasibility Study (FFS) (URS, September 2010) was prepared for Site C to evaluate potential remedial options for contaminated groundwater that would replace the use of the deactivated groundwater treatment system. Based on the evaluation of the remedial alternatives, monitored natural attenuation was selected as the preferred alternative. In September 2010, the VDEQ concurred with the recommendations presented in the FFS. This ESD documents these changes for Cameron Station Site C.

1.4 Authorizing Signatures

_____ Date: _____

Thomas E. Lederle
Deputy
Army Base Realignment and Closure Division

_____ Date: _____

Durwood Willis
Virginia Department of Environmental Quality
Office of Remediation Programs

URS

Figure 1-1
Site Location

Site C, Cameron Station, Alexandria, Virginia

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2.0 SITE HISTORY, CONTAMINATION, AND SELECTED REMEDY

2.1 Site History

Cameron Station was used as an Army installation between 1942 and 1996. Operations at Cameron Station included administrative, commissary, and Post Exchange support functions for the Commanding General of the Military District of Washington. The installation was selected for closure as part of the Base Closure and Realignment Act (Public Law 100-526), dated October 24, 1988. A Remedial Investigation (RI) and Feasibility Study (FS) for the installation was completed in 1993. Remedial actions at Cameron Station were initially investigated and evaluated during the RI/FS process. Cameron Station was categorized into 12 Operable Units (OUs), depending on the potential source of contamination. Of the 12 OUs, OU-5 is the only unit that has yet to be closed. OU-5 consisted of Buildings 2 and 3, and the original sanitary and stormwater systems, which have since been removed and replaced. Much of the liquid chemical wastes generated at Cameron Station, including photographic solutions, solvents, and other wastes from print shops, had been disposed by discharge to the sanitary sewer system (Woodward-Clyde, 1993). During the RI, low levels of trichloroethene (TCE) were detected in the groundwater samples collected between former Buildings 2 and 3. This contaminated groundwater required remediation to MCLs in accordance with the Final DD for Cameron Station (Woodward-Clyde, 1994).

In 1995, a groundwater pump and treat system was selected by the U.S. Army and approved by the U.S. Environmental Protection Agency (USEPA) as the treatment technology to remove the TCE from the groundwater. A groundwater treatment system was installed and began operation in 1996 to remediate Site C groundwater. The treatment system used an air stripper to remove chlorinated solvents from the groundwater (URS, 2007). Treated groundwater was discharged to a storm sewer catch basin in compliance with the Site C VPDES discharge permit (URS, 2008). VOCs stripped from the groundwater were treated by directing them through granular activated carbon vessels prior to discharge to the atmosphere. Figure 2-1 shows the location of the Site C groundwater treatment system shed and the groundwater extraction well, EX-3A, which conveyed groundwater to the shed for treatment.

Cameron Station was officially closed in September 1995 and transferred to a developer in December 1996. A portion of the land was deeded to the City of Alexandria for a public park. In December 2008, VDEQ approved the temporary cessation of groundwater treatment activities due to reaching an apparent asymptotic limit in the mass of TCE removed by the treatment system (URS, 2008). At the time the treatment system was deactivated, TCE concentrations in

groundwater had been reduced by an order of magnitude, but still exceeded the MCL of 5 μg/L for TCE. VDEQ deactivated the Site C VPDES permit on May 6, 2011.

A FFS was developed to identify and evaluate potential remedial options for contaminated groundwater that would replace the use of the deactivated groundwater treatment system at the site (URS, 2010). The remedial alternatives for the treatment of the groundwater contamination at Cameron Station Site C included the following:

- Alternative 1 – No Action
- Alternative 2 – Monitored Natural Attenuation (MNA) and Institutional Controls (ICs)
- Alternative 3 – Enhanced Anaerobic Bioremediation through Carbon Substrate Row Injection
- Alternative 4 – Enhanced Anaerobic Bioremediation through Carbon Substrate Grid Injection

The FFS evaluated these four remedial alternatives and recommended Alternative 2 – MNA and ICs. This alternative includes groundwater monitoring to assess the effectiveness of natural attenuation processes and ICs to ensure that potential receptors are not exposed to contaminated groundwater. This alternative was recommended because, comparatively, it is more easily implemented, significantly less costly, and may receive a higher degree of community acceptance, while providing the same level of protection for human health and the environment. This alternative is expected to achieve the site remediation goals, i.e., achieve MCLs, at all locations within the plume in less than 30 years. The FFS also noted the TCE plume is not expected to migrate off-site. The FFS indicated that the Site C groundwater treatment system could be decommissioned after the final selection of the preferred alternative.

The FFS also proposes a contingency in the event the preferred alternative does not perform as expected. If a statistical analysis of TCE concentrations in any Site C monitoring well shows a statistically significant upward trend while conducting long term monitoring of Site C, then one of the substrate injection alternatives (Alternative 3 – Enhanced Anaerobic Bioremediation through Carbon Substrate Row Injection or Alternative 4 – Enhanced Anaerobic Bioremediation through Carbon Substrate Grid Injection), as described in the FFS, would be evaluated. Following consultation with VDEQ, Army will implement Alternative 3 or Alternative 4 if necessary to reestablish conditions amenable to continued effective MNA in the area of that well as a contingency measure. This satisfies the USEPA recommendation for triggers for a

contingency remedy in the event that the selected remedy fails to function as expected (USEPA, 1999).

2.2 Site Contamination

The potential contaminant sources at Cameron Station Site C are the liquid chemical wastes that were discharged into the sanitary sewer system. This residual material escaped from the sewer system and migrated into site groundwater (Woodward-Clyde, 1993).

Reportedly, these wastes have included solutions from various photographic laboratories at the site; solvents and other wastes from print shops; chlorinated and non-chlorinated degreasers; and waste oils and antifreeze from maintenance operations (Woodward-Clyde, 1993). The storm sewer, the sanitary sewer system, and all of the buildings associated with the former Cameron Station facility that were a source of the groundwater contamination were removed during the redevelopment of the site (URS, 2007).

Groundwater samples were collected quarterly from monitoring wells beginning in June 1996 until most of these wells were destroyed between April 1997 and November 1997 due to construction activities related to commercial and residential development. Since September 1998, quarterly groundwater sampling included seven replacement monitoring wells, installed in summer 1998, and two previously existing monitoring wells that were not destroyed during development activities in 1997. These wells (MWD-06 and MWS-25) were paved over in approximately 2005. An additional monitoring well (MWS-110) was installed downgradient of the TCE plume in April 2010. Including the former groundwater extraction well, there are currently a total of nine wells present at Cameron Station. Six of these nine wells are used for quarterly groundwater sampling (MWS-101, MWS-104, MWS-105, MWD-108, MWS-110, and EX-3A) and the remaining three wells (MWD-102, MWS-103, and MWD-109) are used for collecting water level measurements. The location of Site C monitoring wells is illustrated in Figure 2-1.

2.3 Description of the Selected Remedy

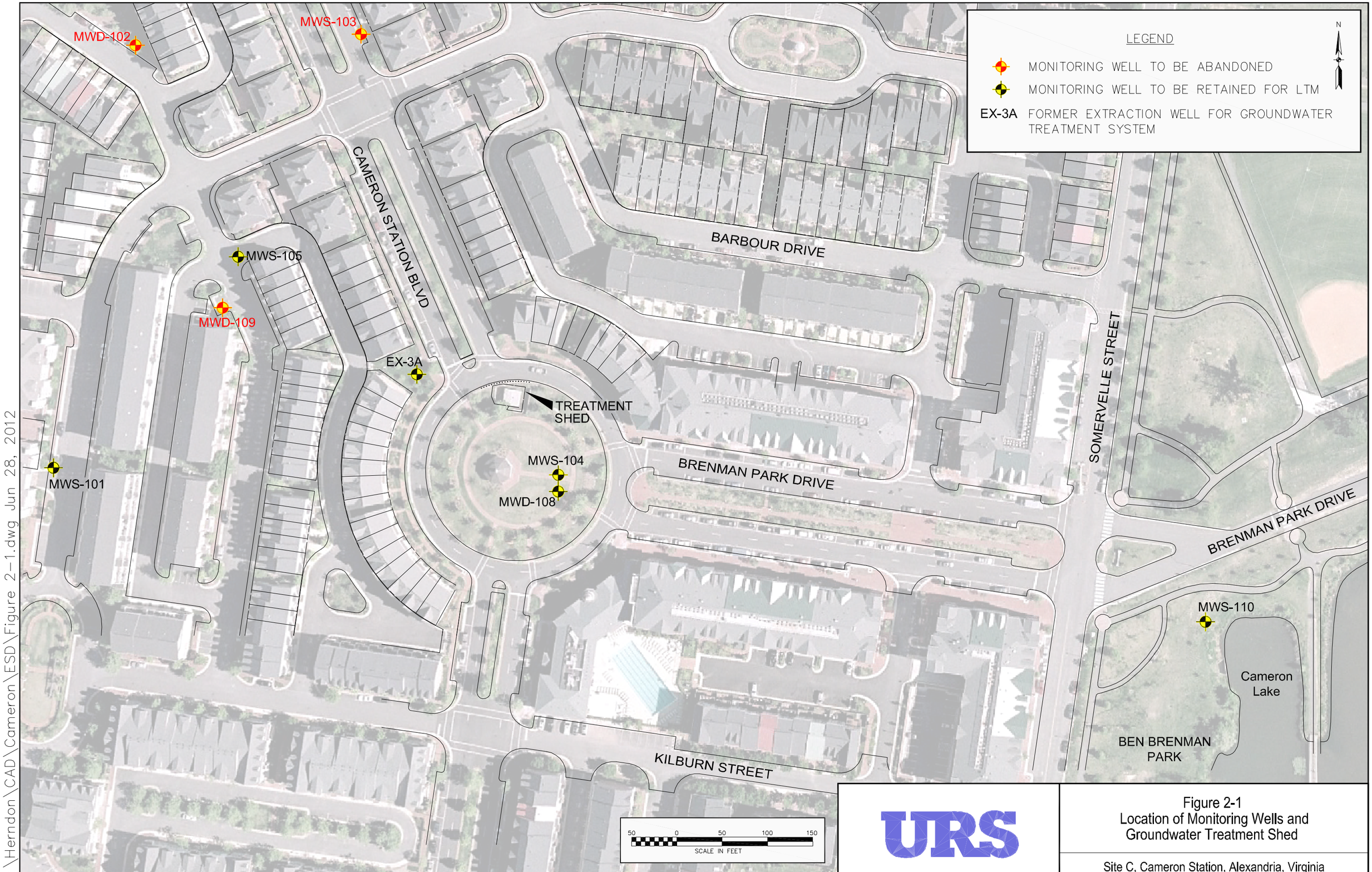
The Final DD identified the selected methods for remediating Cameron Station. The response actions in the Final DD addressed the principal threat at the site by on-site treatment of contaminated groundwater at Site C. The components of the selected for remedy at Site C included:

- Contaminated groundwater will be pumped and remediated with air stripping units to remove VOCs, specifically TCE.
- Treated groundwater will be discharged to Backlick Run via an underground pipe.

- Vapors discharged from the air stripper will be routed through a granular activated carbon filter for removal of VOCs.

The Final DD described the selected remedy as: "protective of human health and the environment, complies with Federal and State requirements that are legally applicable or relevant and appropriate to the remedial actions, and is cost effective" (Woodward-Clyde, 1994).

In 1995, a groundwater pump and treat system was selected by the U.S. Army and approved by the VDEQ as the treatment technology to remove the TCE from the groundwater. A groundwater treatment system was installed and began operation in 1996 to remediate Site C groundwater. In December 2008, VDEQ approved the temporary cessation of groundwater treatment activities due to reaching an apparent asymptotic limit in the mass of TCE removed by the treatment system (URS, 2008).



URS

Figure 2-1
Location of Monitoring Wells and Groundwater Treatment Shed

Site C, Cameron Station, Alexandria, Virginia

P:\Herndon\CAD\Cameron\ESD\Figure 2-1.dwg Jun 28, 2012

3.0 DOCUMENT BASIS

3.1 Rationale for Significant Differences

The changes described in this ESD are based on the recommendations presented in the FFS (URS, 2010), specifically the selection of MNA and ICs as the preferred remedy for Cameron Station Site C. In September 2010, the VDEQ concurred with the recommendations presented in the FFS.

3.2 Description of Significant Differences

Based on the evaluation of remedial alternatives in the FFS, MNA and ICs were selected as the preferred alternative. This alternative includes groundwater monitoring to assess the effectiveness of natural attenuation processes and ICs to ensure that potential receptors are not exposed to contaminated groundwater. The preferred alternative is expected to achieve site remediation goals at all locations within the plume in less than 30 years, which is not an unacceptable timeframe under current and reasonably anticipated future land use at Cameron Station.

A groundwater monitoring program would be developed for the full extent of the MNA period. The proposed monitoring network for the preferred alternative includes the six groundwater wells identified in Figure 2-1. Annual groundwater sampling would occur in the six specified monitoring wells. The groundwater monitoring program will be reviewed and modified, as necessary, as new data are obtained during the monitoring period. The ICs consist of deed restrictions on the properties within the site and City of Alexandria ordinances that prohibit the use of shallow groundwater where a municipal water supply is available. These ICs have been in place at the site for over a decade (URS, 2007). The deed restrictions will be maintained until the concentrations of contaminants at the site allow for unlimited use and unrestricted exposure.

As discussed in the FFS, the preferred alternative does not involve any active remediation of the plume and relies on natural attenuation processes. Over time, these natural degradation processes gradually reduce the overall mass of contaminants in the groundwater. The preferred alternative differs from the original selected remedy because it does not include an active remediation measure. If a statistical analysis of TCE concentrations in any Site C monitoring wells show a statistically significant upward trend while conducting groundwater monitoring of Site C, then one of the substrate injection alternatives (Alternative 3 – Enhanced Anaerobic Bioremediation through Carbon Substrate Row Injection or Alternative 4 – Enhanced Anaerobic Bioremediation through Carbon Substrate Grid Injection), as described in the FFS, would be

evaluated and, if required by VDEQ, considered for implementation in the area of that well as a contingency measure. This satisfies the USEPA recommendation for triggers for a contingency remedy in the event that the selected remedy fails to function as expected (USEPA, 1999).

The total anticipated cost of MNA and ICs is $445,000 (URS, 2010).

3.3 Groundwater Modeling and Statistical Analysis

As recommended in the FFS, the USACE performed additional groundwater modeling and statistical analysis on TCE concentrations present in Site C monitoring wells. This analysis included groundwater monitoring data collected through February 2012. The results of the TCE plume modeling and associated statistical analysis is presented below.

3.3.1 BIOCHLOR Model

BIOCHLOR is a natural attenuation screening model used to assess the feasibility of MNA as a remedial approach for plumes of dissolved-phase chlorinated VOCs in groundwater. The BIOCHLOR model (Aziz, et. al., 2002) was utilized to predict the behavior of the TCE plume in the groundwater at Cameron Station Site C under natural flow conditions (i.e., after termination of groundwater pump and treat activities in December 2008). Except where noted in Appendix A of the ESD, the methodology and data input parameters used in the BIOCHLOR modeling analysis discussed in the FFS (URS, 2010) were retained for the May 2012 BIOCHLOR update. Whereas the BIOCHLOR model presented in the FFS relied on groundwater monitoring data collected through January 2010, the updated BIOCHLOR model utilized groundwater monitoring data collected through February 2012. The updated BIOCHLOR model also incorporated data from downgradient monitoring well MWS-110, which had not been installed at the time the FFS was completed.

In summary, the updated BIOCHLOR model evaluated the predicted TCE concentrations from four site locations within the plume and predicted that TCE concentrations at these locations would reach the MCL for TCE (0.005 mg/L) by approximately 2029. TCE concentrations found in groundwater east of monitoring well MWS-110 was predicted not to exceed the MCL for TCE at any time.

In the FFS, BIOCHLOR predicted the MCL for TCE would just be reached at 1000 feet from monitoring well MWS-104 and the MCL would be achieved site wide by the year 2035. The updated BIOCHLOR model predicted slightly more favorable results that the MCL for TCE

would not be exceeded past 800 feet from the same monitoring well and the MCL would be achieved site wide by the year 2032.

Lastly, the USACE compared the BIOCHLOR predicted concentration of TCE at monitoring well MWS-110 (approximately 750 feet from the source) in 2011, with the actual collected groundwater monitoring data for MWS-110. The average TCE concentration of the 4 groundwater monitoring samples collected in 2011 is 0.004 mg/L. This observed result is very similar to the predicted concentration of 0.003 mg/L. However, this is an average, and there is variability in the data, with individual data points both above and below the MCL (0.005 mg/L). The updated BIOCHLOR model shows that in principle where only groundwater transport of the TCE is occurring, the TCE concentrations should be on a slight upward trend at MWS-110, peaking at 0.005 mg/L in 2029-2032, then decreasing eventually to a non-detectable level.

3.3.2 Mann-Kendall Report

The Mann-Kendall statistical technique was recommended as a tool for determining if trends are present in analytical data (USEPA, 2009). The Mann-Kendall test was performed to evaluate potential trends in TCE concentrations at various monitoring wells located at Cameron Station Site C. Statistical data trends can be increasing, decreasing, or exhibit no trend at all. Whereas the Mann-Kendall test presented in the FFS relied on groundwater monitoring data collected through January 2010, the June 2012 Mann-Kendall test update utilized groundwater monitoring data collected through February 2012. The updated Mann-Kendall analysis focused on those two monitoring wells (MWS-104 and MWS-105) that were included in the prior Mann-Kendall analysis, plus it added one monitoring well (MWS-110) that was installed after completing the FFS.

The updated Mann-Kendall analysis reexamined two scenarios initially presented in the FFS. The first scenario used a TCE data set from March 2007 through February 2012. This scenario uses a greater number of historical data points to determine if a statistical trend is present. The second scenario used data collected from January 2009 through February 2012, reflecting the period after the groundwater treatment system was shut down in December 2008. A detailed report of the updated Mann-Kendall analysis is included in Appendix B.

The updated Mann-Kendall test, performed with TCE monitoring data from March 2007 through February 2012 (first scenario), indicates that a decreasing trend exists in the TCE concentration data from monitoring wells MWS-104 and MWS-105. In the initial analysis, included in the FFS, well MWS-104 showed a decreasing trend in TCE concentrations and no trend was found

in well MWS-105 during the time interval from 2007 to 2010. The updated Mann-Kendall test, performed with TCE monitoring data from January 2009 through February 2012 (second scenario) indicates that a decreasing trend exists in the TCE concentration data in well MWS-104, and no trend exists in the TCE concentration data in wells MWS-105 and MWS-110. In the FFS Mann-Kendall analysis, neither well MWS-104 nor well MWS-105 exhibited a significant trend in the post-remediation dataset, and MWS-110 was not assessed since it had not yet been installed. In conclusion, the updated Mann-Kendall analysis showed a statistically significant declining trend in TCE concentrations in monitoring well MWS-104, and no significant trend in the wells MWS-105 and MWS-110.

3.4 Support Agency Comments

The U.S. Army has worked closely with VDEQ on the remedial activities for Site C at Cameron Station. Regulatory comments received on this ESD will be reviewed and incorporated, as appropriate. A copy of the regulatory comments and the Army responses will be included in Appendix D.

3.5 Public Participation Compliance

The Army intends to allow the public the opportunity to comment during a 30-day public comment period as provided under NCP §300.825(b). The City of Alexandria and residents of the Cameron Station Community will be notified of the availability of the ESD and the public comment period by both local newspaper (*Washington Examiner*) and the Cameron Station Community Association Newsletter. The public comment period is anticipated to occur during January – February 2013. All comments will be reviewed and incorporated, as appropriate. A copy of the public comments and the Army responses will be included in Appendix E.

Public participation requirements set out in the NCP §300.435(c)(2)(i) will be met with the placement of this ESD in the Administrative Record and with the publication of a notification to the public concerning this ESD in a local newspaper (*Washington Examiner*). The ESD will be available to the public at:

Alexandria Library, Charles E. Beatley, Jr. Central Library
5005 Duke Street
Alexandria, Virginia 22304

3.6 Statutory Determination

Based on the above discussion of the proposed change to the selected remedy, the U.S. Army believes the preferred alternative, as presented in the FFS, meets the threshold criteria of protection of human health and the environment and compliance with applicable or relevant and appropriate requirements. The preferred alternative, MNA and ICs, is expected to be effective in the short-term and long-term, easily implemented, significantly less costly than other alternatives, and receive a higher degree of community acceptance. The proposed changes to the selected remedy satisfy the requirements of CERCLA Section 121. The remedy remains protective of human health and the environment and complies with Federal and State ARARs.

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APPENDIX A

Update of BIOCHLOR Modeling for TCE in Groundwater at Cameron Station Site C, May 2012

Update of BIOCHLOR Modeling for TCE in Groundwater at Cameron Station Site C

Environmental and Munitions Design Center
U.S. Army Corps of Engineers, Baltimore District
May 2012

Background

The former Dept of Defense property Cameron Station was closed under the initial round of the Base Realignment and Closure Program, and subsequently transferred out of Federal ownership. Environmental issues addressed by DoD as part of that closure and transfer included the presence of trichloroethene (TCE) in groundwater under the site. A pump and treat system was installed in 1996 to remediate the TCE, and was discontinued in 2008 after reaching an apparent asymptotic limit in TCE removal. In 2009 monitoring results were incorporated into a BIOCHLOR-based groundwater model for the site and documented in a Focused Feasibility Study (FFS) that considered further options for the site (URS, 2010). The FFS concluded that the Maximum Contaminant Level, which is the agreed site goal, would eventually be reached in an acceptable amount of time through natural attenuation, without causing the MCL to be exceeded off of the site. The FFS recommended continued quarterly groundwater monitoring and recommended that the BIOCHLOR modeling be repeated after two additional years of groundwater monitoring data was accumulated. The Department of the Army requested that the Baltimore District perform this updated groundwater modeling, which is documented in this report.

BIOCHLOR Model Summary for Cameron Station Site C

In updating the BIOCHLOR analysis described in the FFS, all of the original methodology and input assumptions were retained except as noted below, and the results are presented in the same manner as the FFS. The original model used a starting time of 2008, where the plume after that time is assumed to be defined assuming three source areas where data was available in 2008: MWS-104 at the upgradient end, DP-10 further downgradient, and DP-6 further downgradient yet. A source degradation rate had been estimated using a series of monitoring data at MWS-104, and this same degradation rate was applied in the original model for each of the three sources. The model had been run separately for each of these three sources, allowing TCE to migrate by all the mechanisms that are built into the BIOCHLOR model. This calculation generated predictions of TCE concentration caused by the action of each of these three sources operating separately. The total TCE concentration for each time and location downgradient was then calculated by summing the three predictions from the three sources at that time and location.

For the model update, only the source degradation rate and the groundwater gradient was adjusted from the original values, using information provided in the most-recent monitoring report (URS, 2012). First the source degradation was adjusted, based on a least-squares regression fit of the TCE data at MWS-104 using the additional 9 monitoring data collected after the FFS to indicate better the long-term trend of MWS-104. With that larger dataset, a slightly faster degradation rate of -0.183/yr was calculated as compared to the FFS value of -0.146/yr (see Attachment 4), and that same degradation rate was applied at all three source areas just as

the original model had done. The initialization year of 2008, using the same three source areas of MWS-104, DP-10 and DP-6 was retained because this is a valid, known measured snapshot in time for this plume. The method of running the model for these three sources, and then summing the individual sources' results, was also retained because this was an accepted methodology and the scope of this current effort was only to update what had been performed previously, while using the new data. [E1]

Another input parameter changed for this model update is the groundwater gradient, which was available from the updated groundwater elevation contours plotted in Figure 1-1 of the 1st Quarter 2012 Groundwater Monitoring Report (URS, 2012). These contours bring in information not available for the initial model run, namely a more recent set of groundwater elevations for the wells that were in place during the FFS, and also an elevation much further downgradient at newly-installed well MWS-110. This is further discussed below.

The updated reporting of results used the same array out to 1000 feet downgradient from MWS-104 as the FFS did, however an additional column at 750 feet downgradient was added to reflect the actual location of well MWS-110.

The theory and methodology are the same as in the FFS except for use of the additional data set; as a result, the description of theory and methodology listed below in paragraphs I to IV is repeated in total from the FFS, except where italicized text is added:

I. Introduction to the BIOCHLOR Model:

The BIOCHLOR model (Aziz, et. al., 2002a) was utilized to predict the behavior of the TCE plume in the groundwater at Cameron Station Site C under natural flow conditions. BIOCHLOR was developed for the Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division at Brooks Air Force Base by Groundwater Services, Inc., Houston, Texas. BIOCHLOR is a screening model that simulates natural attenuation of chlorinated solvents in groundwater. The software is based on the Domenico analytical solute transport model (Domenico, 1987) and has the ability to simulate 1-D advection, 3-D dispersion, linear adsorption, and biotransformation via reductive dechlorination under anaerobic conditions (Aziz, et. al., 2002b). However, anaerobic degradation was assumed to not occur at the site based on groundwater data, so the model was used to simulate dissolved TCE transport without decay. This mode of the model assumes that the only attenuation mechanisms are dispersion in the longitudinal, transverse, and vertical directions, and adsorption of contaminants to the soil matrix (Aziz, et. al., 2000). Volatilization and abiotic transformation of the dissolved contaminants in the plume at Cameron Station Site C are assumed to be negligible, although these attenuation mechanisms may be accounted for in the source decay model within BIOCHLOR.

II. General Approach to BIOCHLOR Model for Cameron Station Site C:

The BIOCHLOR model is designed to simulate a point-source area from the time at which the release occurred. The model also assumes that no actively engineered remedial techniques are applied to the plume. For this reason, the model cannot be used to predict the behavior of the plume prior to or during the operation of the pump-and-treat system. In addition, the historical expansion of the plume after the original release(s), followed by the operation of the pump and treat system, has resulted in a relatively large, diffuse contaminant plume. Because BIOCHLOR

models point-source releases, the model cannot be used to predict the behavior of a plume that is already established. However, the model can be used to approximate the behavior of the plume by modeling the current dissolved-phase TCE concentrations at selected locations as a series of point-source releases. The model results for each location were then aggregated into one plume model, as explained below.
Three locations were selected for BIOCHLOR modeling: MWS-104, DP-10, and DP-06 (moving from center of the plume to the downgradient edge). MWS-105 was not modeled because it is present on the upgradient edge of the plume, approximately 400 feet from MWS- 104, and the TCE concentrations in MWS-105 are lower than at MWS-104. Therefore, the TCE concentration at MWS-105 should have a minimal effect on the plume size and longevity compared to the TCE concentration at MWS-104

III. BIOCHLOR Inputs for Cameron Station Site C:

The model inputs for MW-104, DP-10, and DP-06 are shown in Attachment 1 to 3 respectively, and are described below.

1. Advection: Based on data from Section 1 of FFS. Same for each location.:

Key information from the FFS section 1.2.5 Hydrogeology is repeated and paraphrased here: The March 2009 to December 2009 groundwater elevation data indicated that groundwater at Cameron Station flows towards the southeast. The average hydraulic gradient for groundwater at Cameron Station Site C from January 2009 to December 2009 was 0.0089, or 0.89 feet of groundwater elevation change for every 100 feet of horizontal displacement.
Slug tests performed during the RI indicate hydraulic conductivity (K) values ranged from 1.2 to 13.9 feet per day (ft/day) and averaged 6.3 ft/day (Woodward-Clyde, 1993). Darcy's Law was used to calculate the groundwater velocity at Cameron Station using an assumed porosity of 0.25 (typical for silty sand in this area) and a hydraulic conductivity of 6.3 ft/day. Based on these calculations, the groundwater velocity at Cameron Station is approximately 82 feet per year (ft/year) to the east.

Update: The only updated advection information that was available was the groundwater gradient at the site. No updates were available for porosity or hydraulic conductivity, so the same porosity and hydraulic gradient values from the FFS were used for the model update.

The groundwater gradient was re-checked in the area of MWS-104 and MWS-105 using the elevation data collected in August 2011, November 2011, and February 2012 (URS, 2011; URS, 2012a; URS, 2012b). Gradients were calculated between those two wells since a line through those wells lines up fairly closely with the interpreted groundwater direction as shown on the groundwater contour figures (Figure 1-1) of the 3rd quarter 2011, 4th quarter 2011 and 1st quarter 2012 GW monitoring reports. The MWS-105 to MWS-104 gradients were 0.0083 ft/ft, 0.0091 ft/ft , and 0.0088 ft/ft, which agree fairly well with the average value of 0.0089 ft/ft used originally in the BIOCHLOR model. This indicates that the groundwater gradient has not changed appreciably in this area of the site from 2009 to 2011/2012.

The BIOCHLOR model addresses the area from MWS-104 to MWS-110, and gradient information in that section is the most useful for the model. Snce well MWS-110 was installed after the FFS in Ben Brenman Park at the down gradient end of the plume, the gradient between MWS-110 and MWS-104 was calculated. A line between these two wells approximates the GW flow direction estimated to occur from MWS-104 in the direction of MWS-110. The measured gradients in August 2011, November 2011, and February 2012 were 0.0042 ft/ft, 0.0046 ft/ft, and 0.0044ft/ft, with an average of 0.0044 ft/ft. This value could not be compared with 2009 data since well MWS-110 did not exist at that time.

This gradient was entered into BIOCHLOR, however the model found this value to create an unstable solution for the known source degradation rate of -0.183/year. The model suggested a revised degradation rate, however this was not used since the degradation rate was already fairly well known based on the available data. Instead the gradient was increased to a valuel the model would acceptt, 0.007 ft/ft,which reflects the measured gradient across the entire site, from well MWS-105 to the new well MWS-110

2. Dispersion: alpha (x) calculated in BIOCHLOR based on the plume length. Alpha (y) and alpha (z) based on default ratios to alpha (x). The dispersivities at each model location were estimated based on the total plume length because the Domenico model assumes a constant dispersivity over the length of the plume (Aziz, et. al., 2000). The "modified Xu and Eckstein" calculation for alpha (x) was used, rather than a 10% ratio of the total plume length. The use of a 10% ratio to the total plume length yielded a much higher value than the modified Xu and Eckstein method. The use of a smaller longitudinal dispersivity value appears more appropriate for Cameron Station Site C because (1) the modified Xu and Eckstein calculation appears to be more accurate for longer plumes (Figure A.3 in Aziz, et. al., 2000) and (2) the long plume length may be partly due to the release of TCE over a large area by the sewer system. Therefore, the use of the higher value may overestimate the longitudinal dispersivity.

3. Adsorption: utilizes default BIOCHLOR values. Same for each location. Typical values for the fraction organic carbon in soil (f_{oc}) can vary over orders of magnitude and may significantly affect the estimated retardation of the TCE, but no f_{oc} values were available for Cameron Station Site C. Therefore, the default value (0.001) was used.

4. Biotransformation: uses default BIOCHLOR values, but the output for the BIOCHLOR solute transport with biodegradation model was not used; anaerobic biodegradation of the TCE is not expected at Cameron Station Site C based on geochemical conditions.

5. General: uses the same values for each location: a simulation time of 30 years and a model width of 200 feet based on the fourth quarter 2009 sampling data. The model width and length do not correspond to the dimensions of the plume, but to the dimensions modeled by BIOCHLOR. The model length was set to 1,000 feet to include any potential exceedances of the MCL for TCE downgradient of each location. The compiled results demonstrate that the MCL for TCE was not exceeded at 1,000 feet from any of the three modeled locations.

6. Source data: assumes a source thickness (vertical thickness of saturated zone) of 20 feet and a width of 200 feet for each location based on the fourth quarter 2009 sampling data. The "source"

is assumed to consist of the dissolved-phase concentrations of TCE at x = 0 ft in each model location. For MWS-104, the July 2008 concentrations (the last sampling data prior to the deactivation of the pump-and-treat system) were included in the model to serve as a baseline point for the attenuation analysis. As a result, all of the BIOCHLOR results are relative to July 2008. For example, Year 3 of the analysis would be 2011. For DP-06 and DP-10, the November 2009 data were used as an approximation for 2008.

The source decay feature was used to simulate the depletion of TCE in MWS-104 over time. Source decay could not be estimated for DP-06 and DP-10 because only one sample has been collected from each of these points; MWS-105 was not included in the simulation for reasons explained above. Source decay was modeled (Aziz, et. al., 2002b) as a linear relationship between the log (TCE, mg/L) and time in Attachment 4. The linear fit for the source depletion at MWS-104 had a R_2 value of only 0.34. The poor fit for the source depletion at MWS-104 is likely the result of too few data points (only five) to obtain a reasonable fit to the data. The source decay may be better estimated in the future when additional sampling data for MWS-104 are available. The source decay estimate for MWS-104 (0.0004 $days_{-1}$, or 0.146 $years_{-1}$) was also applied to locations DP-06 and DP-10, since TCE concentrations over time at these points are not available.

Update: The revised linear fit for the source depletion at MWS-104 used the five points that were included in the original modeling, as well as nine additional points collected after the FFS, and had a R_2 value of 0.735 (see Attachment 4). Compared to the poorer fit for the source depletion at MWS-104 in the FFS (since fewer data points were available in the first modeling), this larger R2 value shows that the best-fit line represents more closely the trend of TCE concentration through the reported data. The resulting source decay estimate for MWS-104 (-0.0005 $days_{-1}$, or -0.183 $years_{-1}$) was also applied to locations DP-06 and DP-10, since TCE concentrations over time at these points are not available.

7. Field data for comparison: uses the January 2010 data for MWS-104 and the November 2009 data for DP-06 and DP-10. Therefore, the field data represent the period between Year 0 and Year 3 in the BIOCHLOR output files.

Update: Data for DP-10 and DP-6 was not used for comparison because it was used to set the initial conditions for the model, just as it was in the FFS, and also no subsequent data was available from these two sites. For MWS-104, all available data was used to initialize this model by incorporating the source degradation rate that was derived from this data; but since post-initiation data was available for MWS-104, it was included on the model results figure for comparison. Well MWS-110 (installed and monitored after the FFS) now provides data within the modeled part of the plume, and serves as an ideal source of comparison data; its results were compared to the model's results.

IV. BIOCHLOR Outputs for Cameron Station Site C:

The BIOCHLOR output files estimate the concentrations of TCE at distances down gradient from each of the three model locations, assuming that the dissolved-phase concentrations in 2008 represent a decaying point-source that spreads downgradient and attenuates over time through dispersion, dilution, and adsorption. The results were generated at three-year intervals starting with Year 3 (2011) of the simulation. In each case, only the "no degradation" results were used. Only results through Year 15 were produced for DP-06 due to negligible concentrations of TCE at that time. The output files for each of the three modeled locations (MWS-104, DP-10, and DP-06) are presented in Attachment 5 to Attachment 7.

Update: Rresults were carried out 30 years for all the locations.

Compilation of BIOCHLOR Outputs for Cameron Station Site C:

The BIOCHLOR results for each of the three model locations were assembled into a spreadsheet (Attachment 8) The predicted concentrations at each distance downgradient from the modeled source were assumed to be additive. For example, the predicted TCE concentrations at x = 400 ft in the MWS-104 model (the approximate location of DP-10) were added to the predicted TCE concentrations at x = 0 ft in the DP-10 model. Likewise, the predicted TCE concentrations at x = 650 ft in the MWS-104 model (the approximate location of DP-06) and the predicted TCE concentrations at x = 250 ft in the DP-10 model were added to the predicted concentrations of TCE at x = 0 ft in the DP-06 model. Lastly, the predicted TCE concentrations at the location of the proposed monitoring well (adjacent to Cameron Lake) were added for all three models; the initial TCE concentration at the proposed monitoring well was assumed to be zero.

Update: The new monitoring well that was proposed in the FFS was installed as well MWS-110. The predicted TCE concentrations at the location of MWS-110 (actual location 750ft from MWS-104) were added for all three models; the initial TCE concentration at MWS-110 was assumed to be zero.

V. Discussion:

Update: The combined results of the three BIOCHLOR models were graphed in Attachment 9 to demonstrate the predicted TCE concentrations at MWS-104, DP-10, DP-06, and MWS-110 through 2038 for the updated degradation rate and updated groundwater gradient. TCE concentrations at all four locations are predicted to reach the MCL (0.005 mg/L) by approximately 2029, and the TCE concentration in groundwater beyond MWS-110 (x = 750 ft in the MWS-104 model) was predicted to not exceed the MCL at any time.
In the previous modeling in the FFS, the results showed that the MCL would just be reached at 1000 feet from MWS-104, whereas the model update has it that the MCL won't be exceeded past 800 feet, and the time to reach MCL everywhere is shortened from 2035 to 2032.

Lastly, we compared theBIOCHLOR predicted concentration of TCE at MWS-110 (i..e, 750ft from the source) in 2011, with the collected data for MWS-110. The average of the 4 samples collected in 2011 is 0.004 mg/L TCE, very close to the predicted concentration of 0.003 mg/L. However, this is an average, and there is variability in the data, with individual data points both above and below the site goal of 0.005 mg/L., The BIOCHLOR model shows that in principle,

where only groundwater transport of the TCE is occurring, the TCE concentrations should be on a slight upward trend at MWS-110, peaking at 0.005 mg/L in 2029-2032, then decreasing eventually to nondetectable levels.,

VI. Sources of Uncertainty in BIOCHLOR Model for Cameron Station Site C:

The results of the BIOCHLOR model contain a large degree of uncertainty, and should be regarded as approximate. Some of the uncertainties involve:

- The extremely limited quantity of groundwater monitoring data since the pump-and-treat system was deactivated.
- The lack of f_{oc} values for the subsurface soil at Cameron Station.
- The assumption that a decaying source, rather than a continuous source, is present in the subsurface at Cameron Station Site C.
- The assumption that no biodegradation, abiotic degradation, or volatilization of the TCE contaminants occurs in the plume.

The latter source of uncertainty could decrease the time required to reach the MCL; the other sources of uncertainty could increase or decrease that time. The BIOCHLOR model should be repeated when additional groundwater monitoring data is available to refine the estimates of the remedial timeframe for natural attenuation.

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Cameron Station
MWS-104
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ◉ Ethanes ○

1. ADVECTION C

Seepage Velocity*	Vs	63.7	(ft/yr)
or			
Hydraulic Conductivity	K	2.2E-03	(cm/sec)
Hydraulic Gradient	i	0.007	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	27.167	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	5.E-02	(-)

Calc. Alpha x

3. ADSORPTION C

Retardation Factor* → R

or

Soil Bulk Density, rho		1.7	(kg/L)	
FractionOrganicCarbon, foc		1.0E-3	(-)	
Partition Coefficient	Koc			
PCE	426	(L/kg)	3.90	(-)
TCE	130	(L/kg)	1.88	(-)
DCE	125	(L/kg)	1.85	(-)
VC	30	(L/kg)	1.20	(-)
ETH	302	(L/kg)	3.05	(-)
Common R (used in model)* =			**1.88**	

4. BIOTRANSFORMATION -1st Order Decay Coefficient* C

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	2.000		0.79
TCE → DCE	1.000		0.74
DCE → VC	0.700		0.64
VC → ETH	0.400		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL C

Simulation Time*	30	(yr)
Modeled Area Width*	200	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)

L, W

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 20 (ft)

Width* (ft) Y1 200

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.001	0.183
TCE	.044	0.183
DCE	.002	0.183
VC	.0	0.183
ETH	0	0.183

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)											
TCE Conc. (mg/L)											
DCE Conc. (mg/L)											
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)											
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example | Unprotect Sheet

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Cameron Station
DP-10
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ◉ Ethanes ○

1. ADVECTION C

Seepage Velocity*	Vs	63.7	(ft/yr)
or			
Hydraulic Conductivity	K	2.2E-03	(cm/sec)
Hydraulic Gradient	i	0.007	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	27.167	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	5.E-02	(-)

Calc. Alpha x

3. ADSORPTION C

Retardation Factor* → R
or

Soil Bulk Density, rho		1.7	(kg/L)	
FractionOrganicCarbon, foc		1.0E-3	(-)	
Partition Coefficient	Koc			
PCE	426	(L/kg)	3.90	(-)
TCE	130	(L/kg)	1.88	(-)
DCE	125	(L/kg)	1.85	(-)
VC	30	(L/kg)	1.20	(-)
ETH	302	(L/kg)	3.05	(-)
Common R (used in model)* =			**1.88**	

4. BIOTRANSFORMATION -1st Order Decay Coefficient* C

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	2.000		0.79
TCE → DCE	1.000		0.74
DCE → VC	0.700		0.64
VC → ETH	0.400		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL C

Simulation Time*	30	(yr)
Modeled Area Width*	200	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 20 (ft)

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

	Y1	k_s* (1/yr)
Width* (ft)	100	
Conc. (mg/L)*	C1	
PCE	.0	0.183
TCE	.02	0.183
DCE	.002	0.183
VC	.0	0.183
ETH	0	0.183

View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)											
TCE Conc. (mg/L)											
DCE Conc. (mg/L)											
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)											
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example | Unprotect Sheet

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel 2000

Cameron Station
DP-06
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ◉ Ethanes ○

1. ADVECTION C

Seepage Velocity*	Vs	63.7	(ft/yr)
or			
Hydraulic Conductivity	K	2.2E-03	(cm/sec)
Hydraulic Gradient	i	0.007	(ft/ft)
Effective Porosity	n	0.25	(-)

2. DISPERSION

Alpha x*	27.167	(ft)
(Alpha y) / (Alpha x)*	0.1	(-)
(Alpha z) / (Alpha x)*	5.E-02	(-)

Calc. Alpha x

3. ADSORPTION C

Retardation Factor* → R
or

Soil Bulk Density, rho		1.7	(kg/L)	
FractionOrganicCarbon, foc		1.0E-3	(-)	
Partition Coefficient	Koc			
PCE	426	(L/kg)	3.90	(-)
TCE	130	(L/kg)	1.88	(-)
DCE	125	(L/kg)	1.85	(-)
VC	30	(L/kg)	1.20	(-)
ETH	302	(L/kg)	3.05	(-)
Common R (used in model)* =			**1.88**	

4. BIOTRANSFORMATION -1st Order Decay Coefficient* C

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	2.000		0.79
TCE → DCE	1.000		0.74
DCE → VC	0.700		0.64
VC → ETH	0.400		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL C

Simulation Time*	30	(yr)
Modeled Area Width*	200	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Decaying Single Planar

Source Options

Source Thickness in Sat. Zone* 20 (ft)

Width* (ft) Y1 50

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	.001	0.183
TCE	.009	0.183
DCE	.001	0.183
VC	.0	0.183
ETH	0	0.183

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

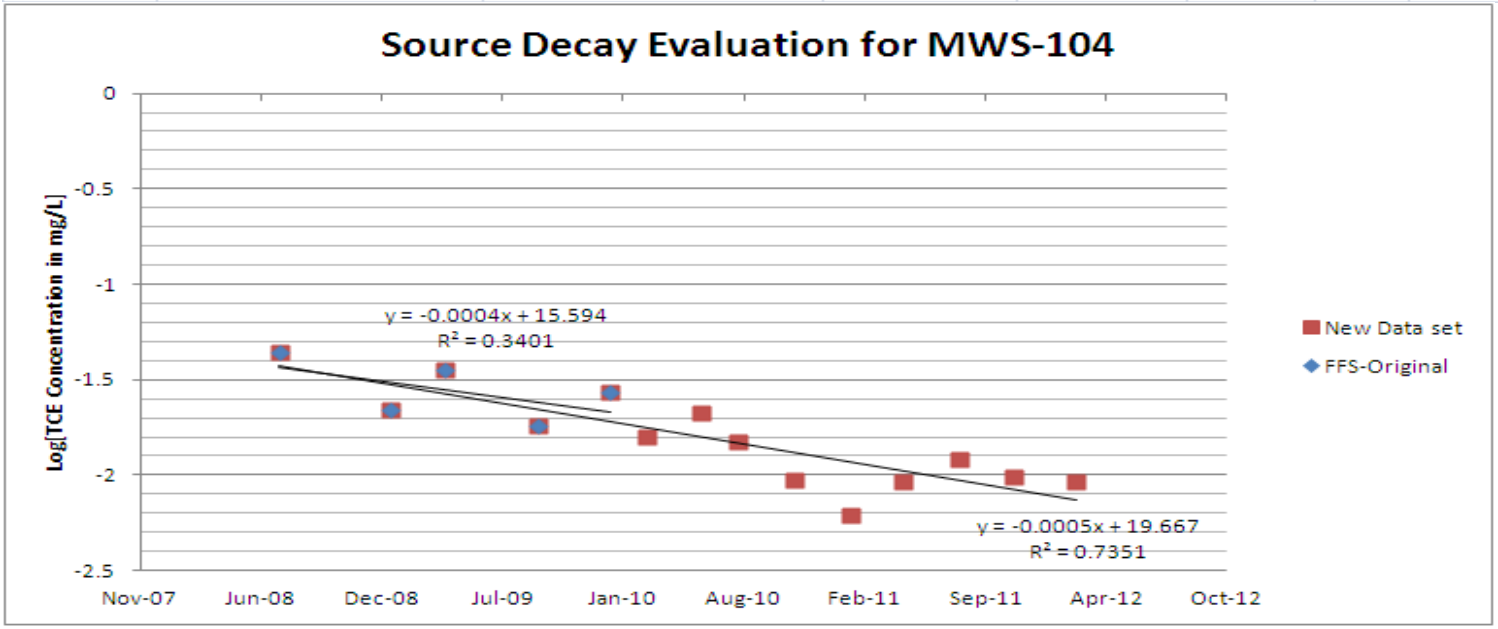
PCE Conc. (mg/L)											
TCE Conc. (mg/L)											
DCE Conc. (mg/L)											
VC Conc. (mg/L)											
ETH Conc. (mg/L)											
Distance from Source (ft)											
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example | Unprotect Sheet

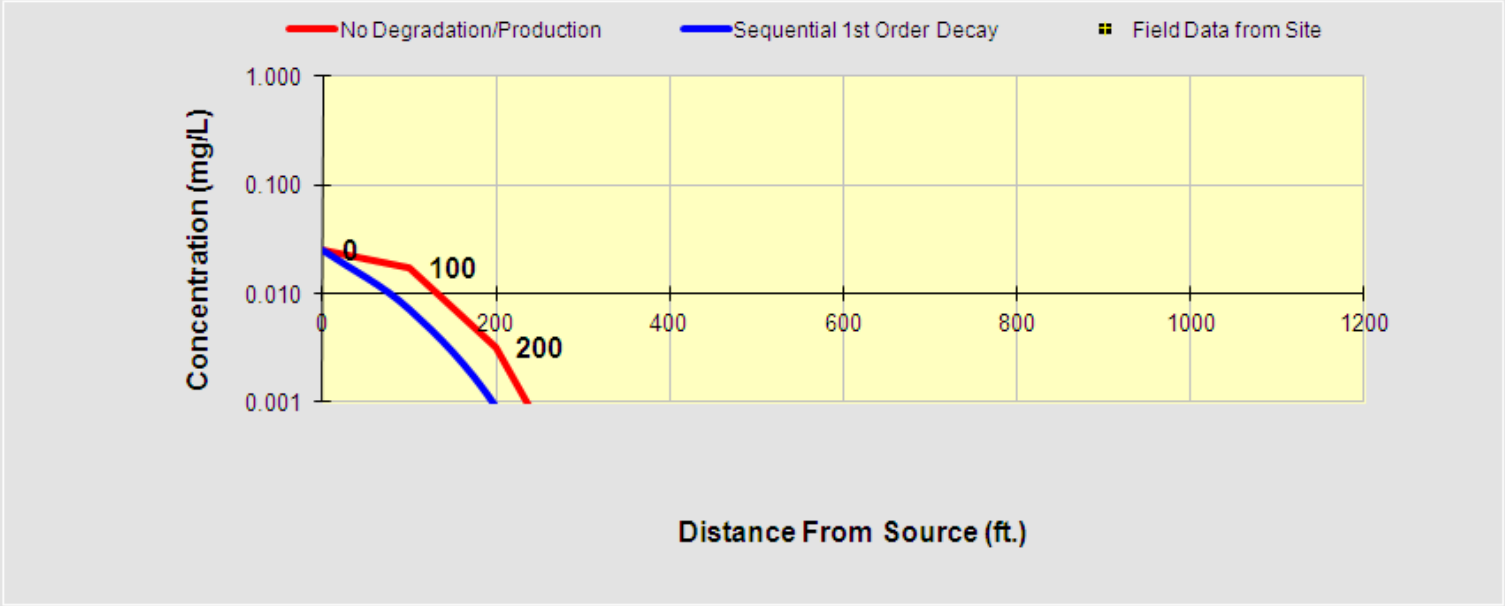
Source Decay Evaluation for MWS-104:

Date	TCE Concentration (µg/L)	TCE Concentration (mg/L)	Log (conc, mg/L)	
Jul-08	44	0.044	-1.357	
Jan-09	22	0.022	-1.658	FFS Dataset with
Apr-09	36	0.036	-1.444	slope = -0.0004/day = -0.146/yr
Sep-09	18	0.018	-1.745	
Jan-10	27	0.027	-1.569	
Mar-10	16	0.016	-1.796	
Jun-10	21	0.021	-1.678	
Aug-10	15	0.015	-1.824	New larger dataset with
Nov-10	9.5	0.0095	-2.022	slope = -0.0005 /day = -0.183/yr
Feb-11	6.2	0.0062	-2.208	
May-11	9.2	0.0092	-2.036	
Aug-11	12	0.012	-1.921	
Nov-11	9.8	0.0098	-2.009	
Feb-12	9.2	0.0092	-2.036	



DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.025	0.017	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0254	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
3.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

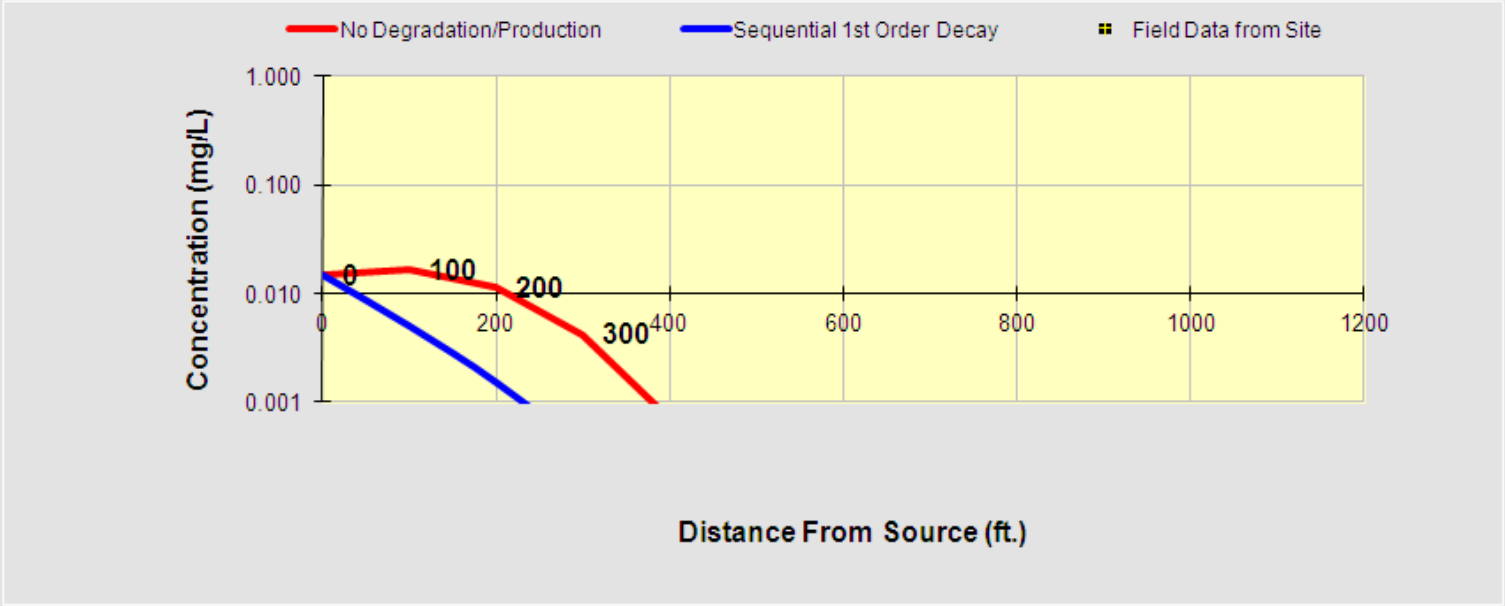
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.015	0.017	0.012	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0147	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

Field Data from Site											



See PCE

See TCE

See DCE

See VC

See ETH

Replay

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Time:

6.0 Years

Log ⟺ Linear

Unprotect Sheet

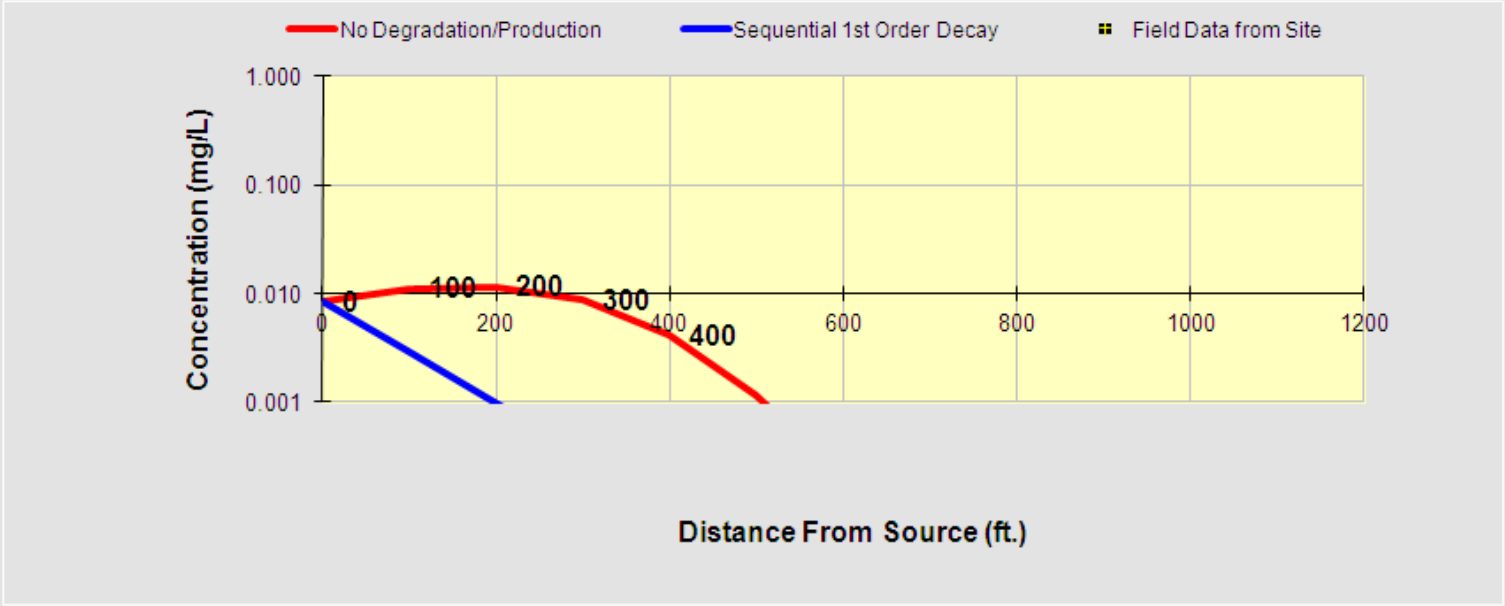
Return to Input

To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.008	0.011	0.012	0.009	0.004	0.001	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0085	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
9.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

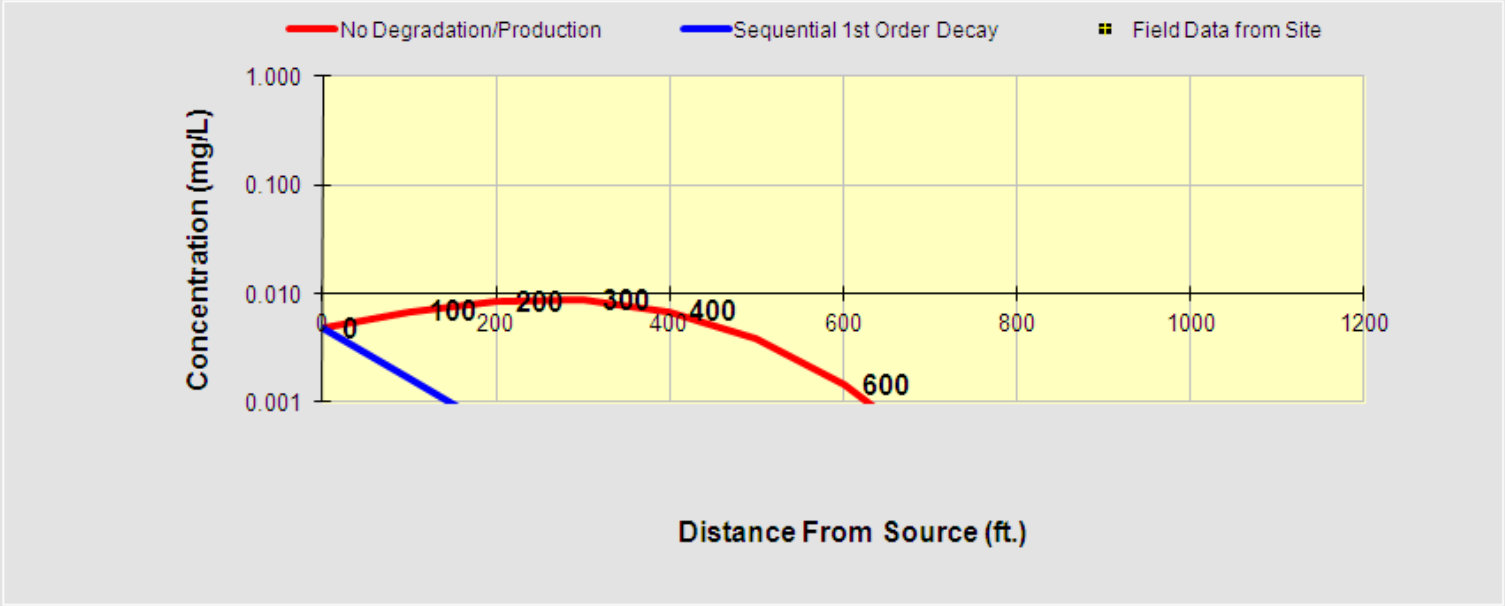
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.005	0.007	0.009	0.009	0.007	0.004	0.001	0.000	0.000	0.000	0.000
Biotransformation	0.0049	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

Field Data from Site											



See PCE

See TCE

See DCE

See VC

See ETH

Replay

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Time:

12.0 Years

Log ⟺ Linear

Unprotect Sheet

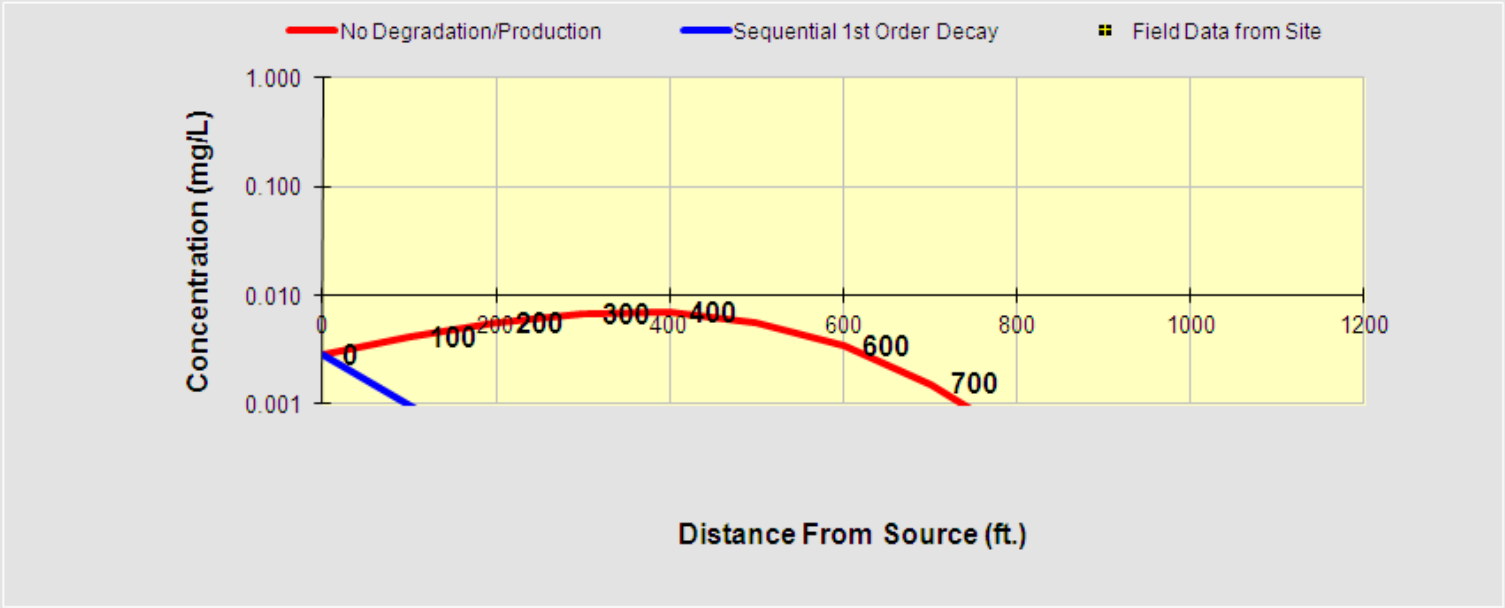
Return to Input

To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.003	0.004	0.006	0.007	0.007	0.006	0.003	0.002	0.000	0.000	0.000
Biotransformation	0.0028	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
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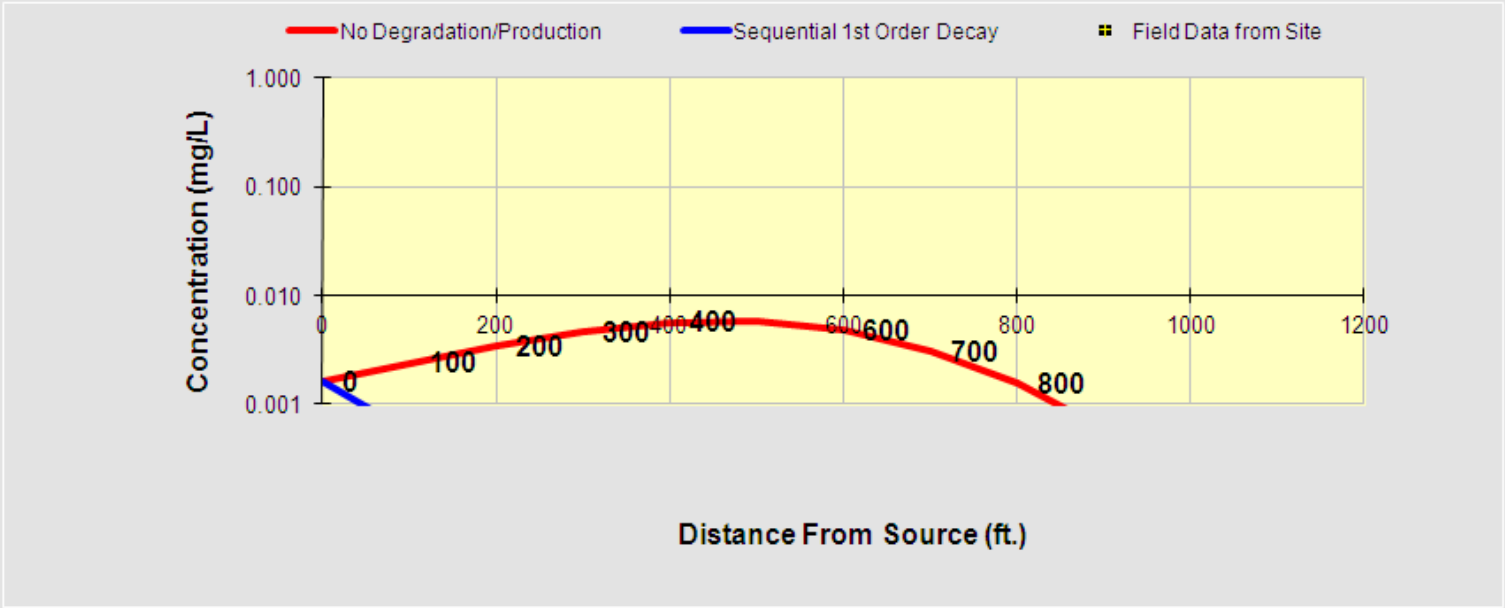
Time:
15.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.002	0.002	0.003	0.005	0.006	0.006	0.005	0.003	0.002	0.001	0.000
Biotransformation	0.0016	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											

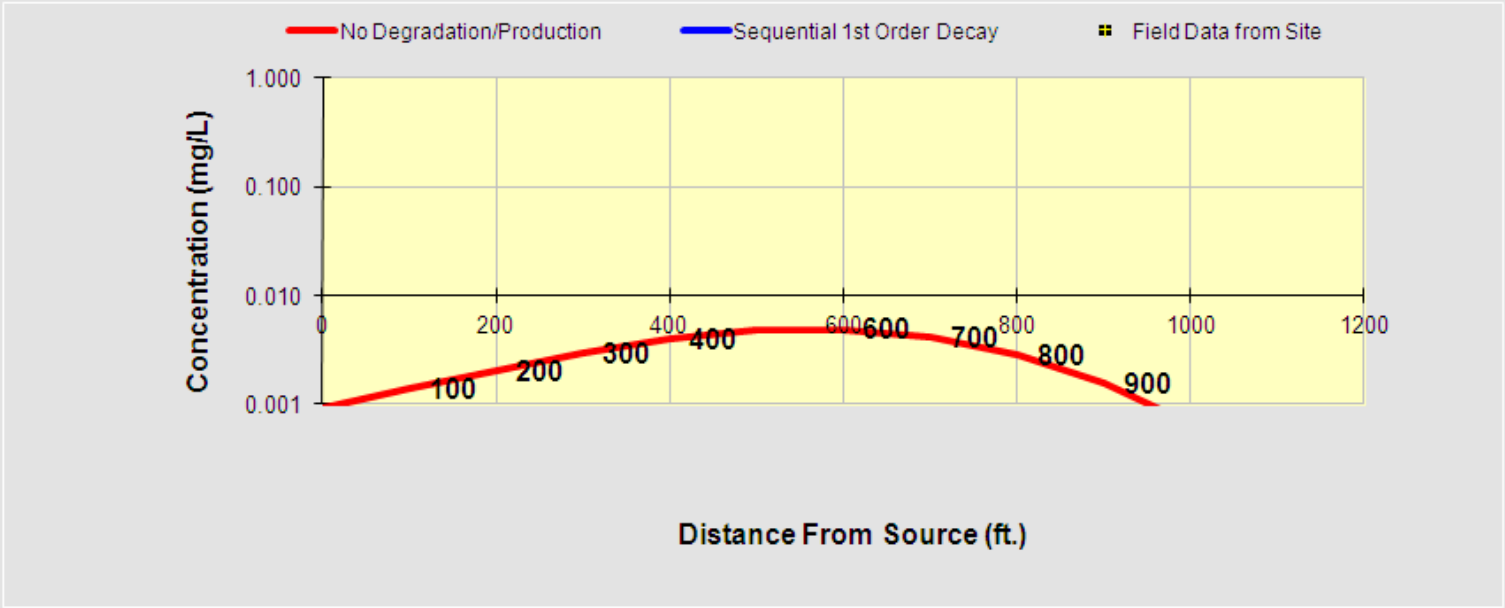


See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
18.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.001	0.001	0.002	0.003	0.004	0.005	0.005	0.004	0.003	0.002	0.001
Biotransformation	0.0009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											

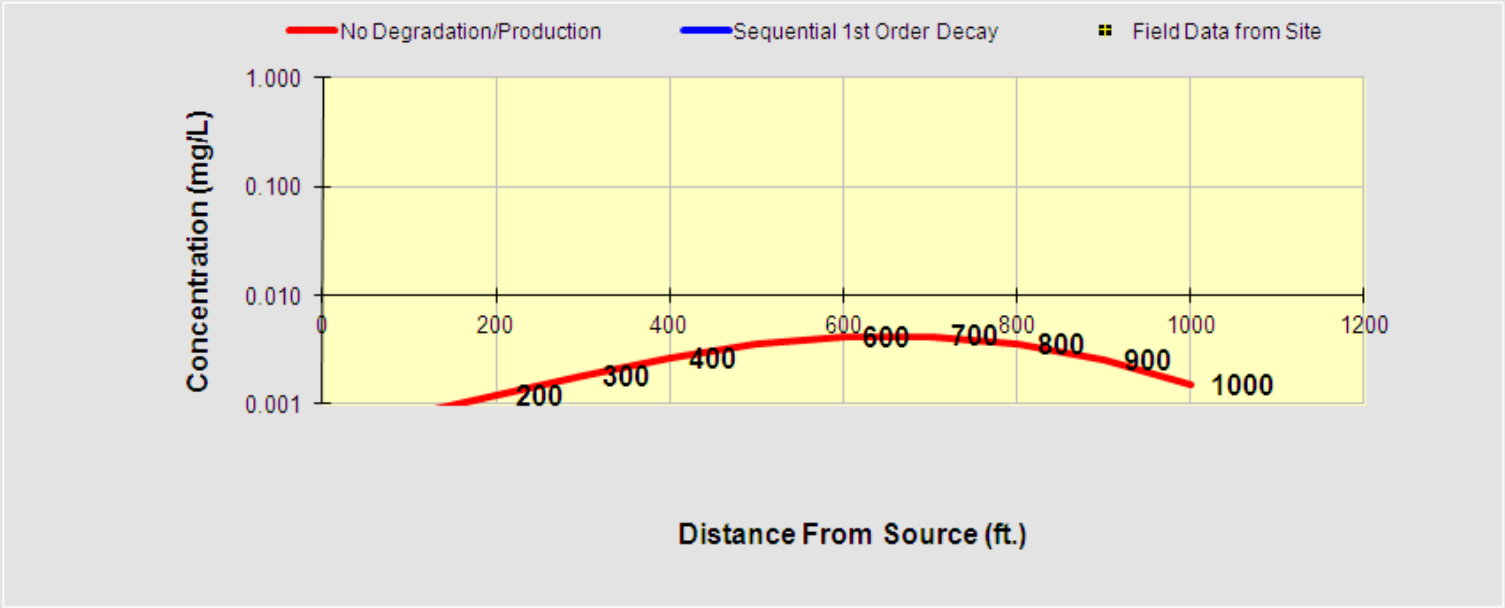


See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
21.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.001	0.001	0.001	0.002	0.003	0.004	0.004	0.004	0.004	0.003	0.001
Biotransformation	0.0005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
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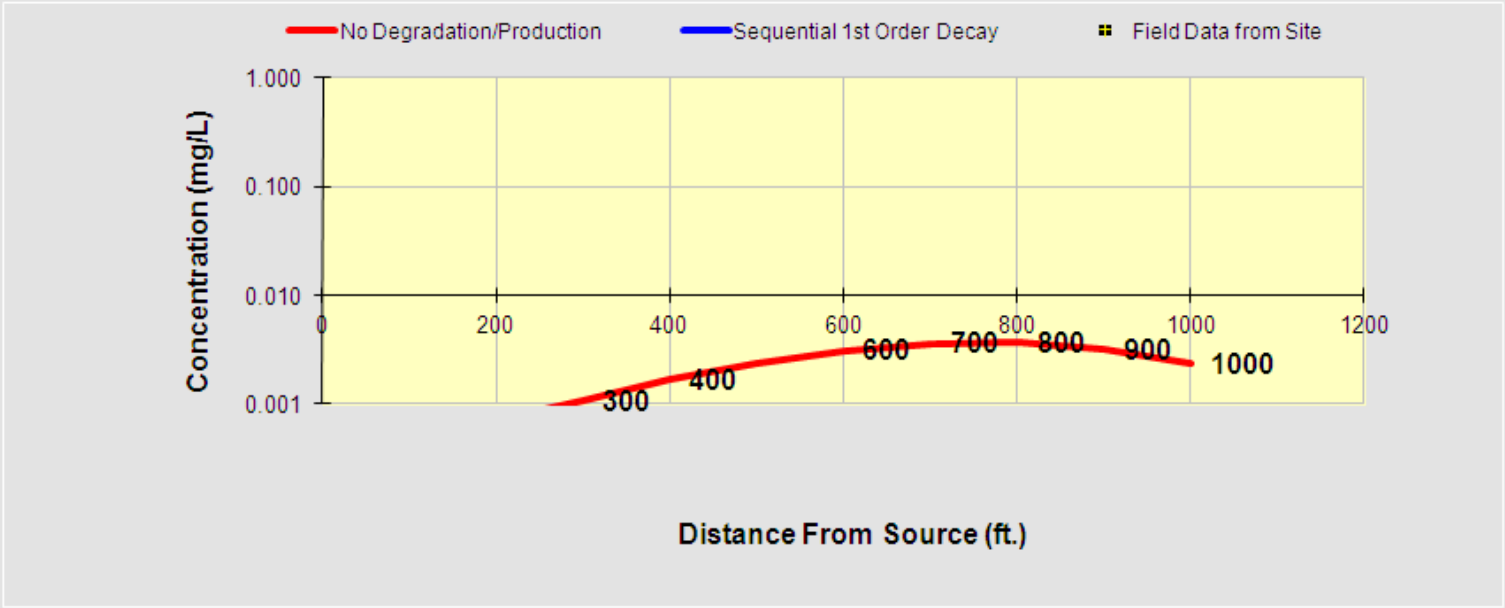
Time:
24.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.004	0.004	0.003	0.002
Biotransformation	0.0003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
27.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

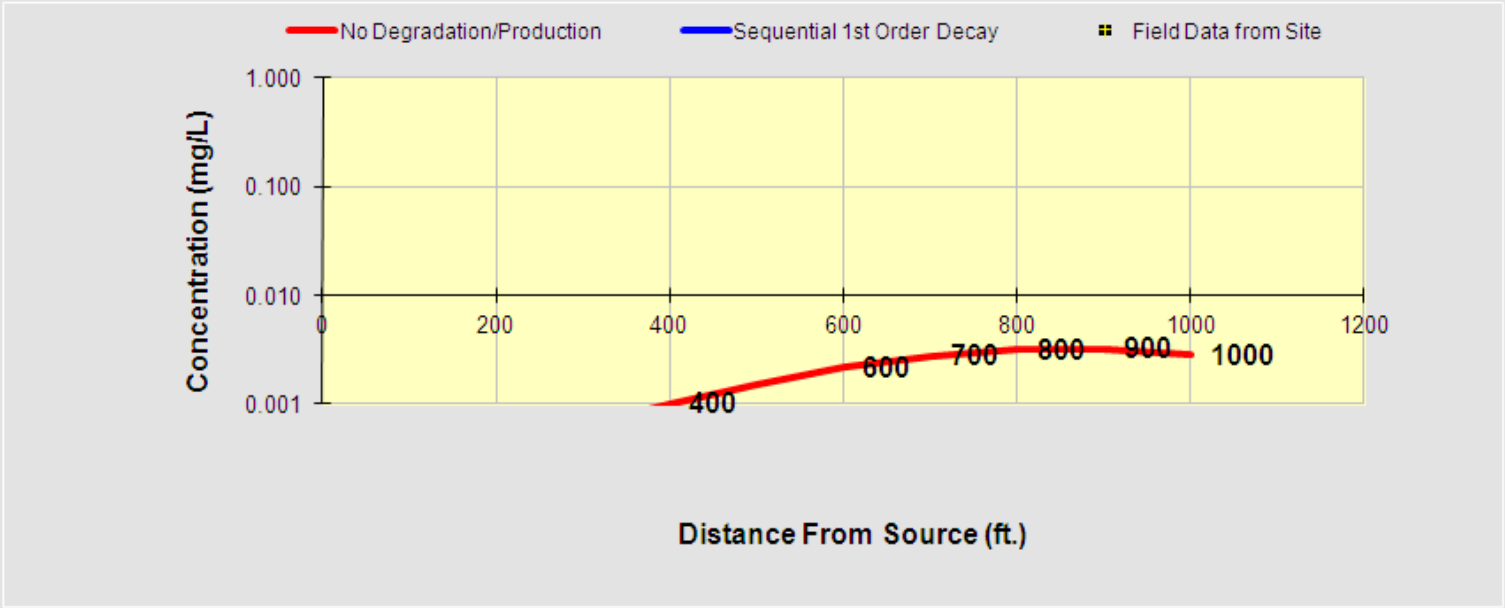
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.003	0.003
Biotransformation	0.0002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

Field Data from Site											



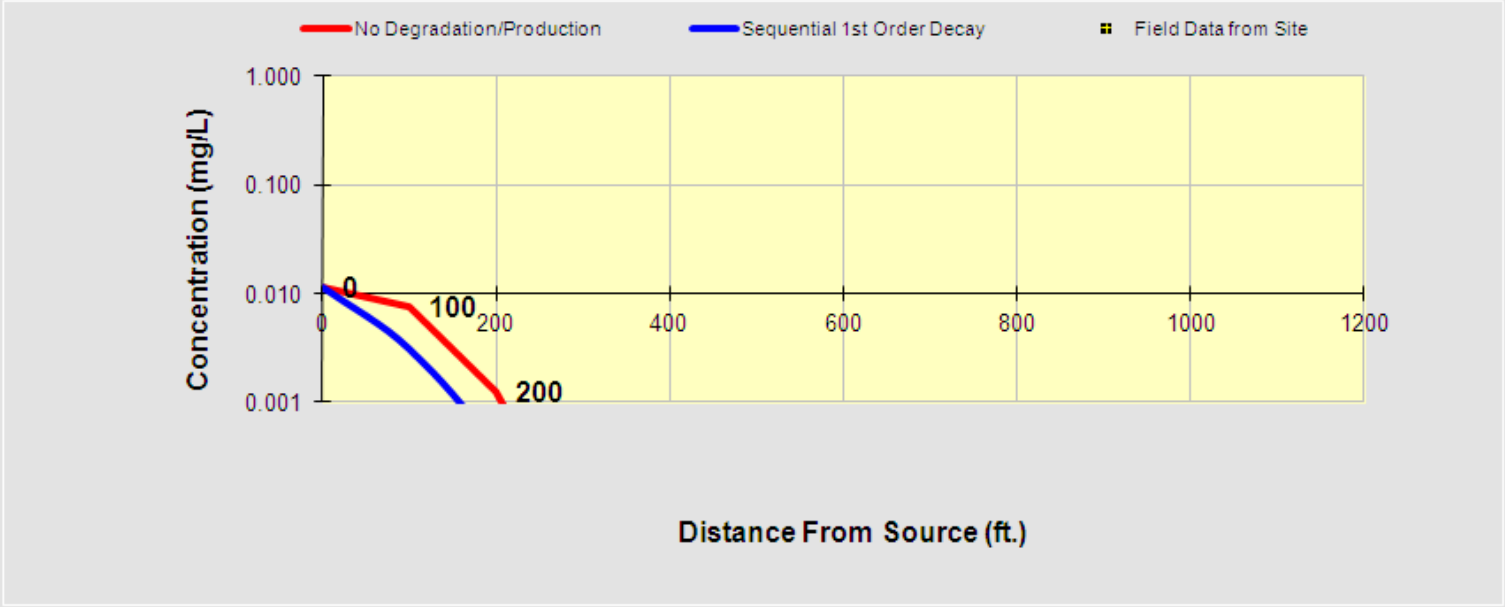
See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev

Time:
30.0 Years
Log ⟺ Linear

Unprotect Sheet
Return to Input
To All
To Array

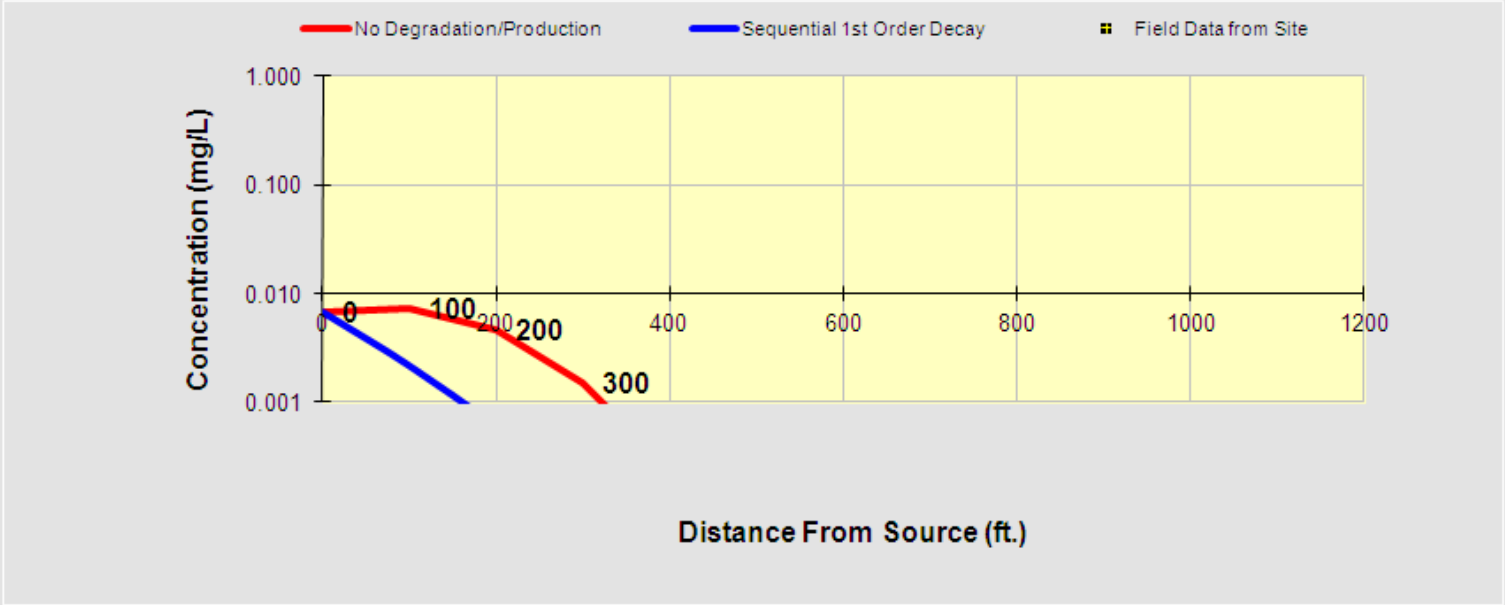
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.012	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0116	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
3.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

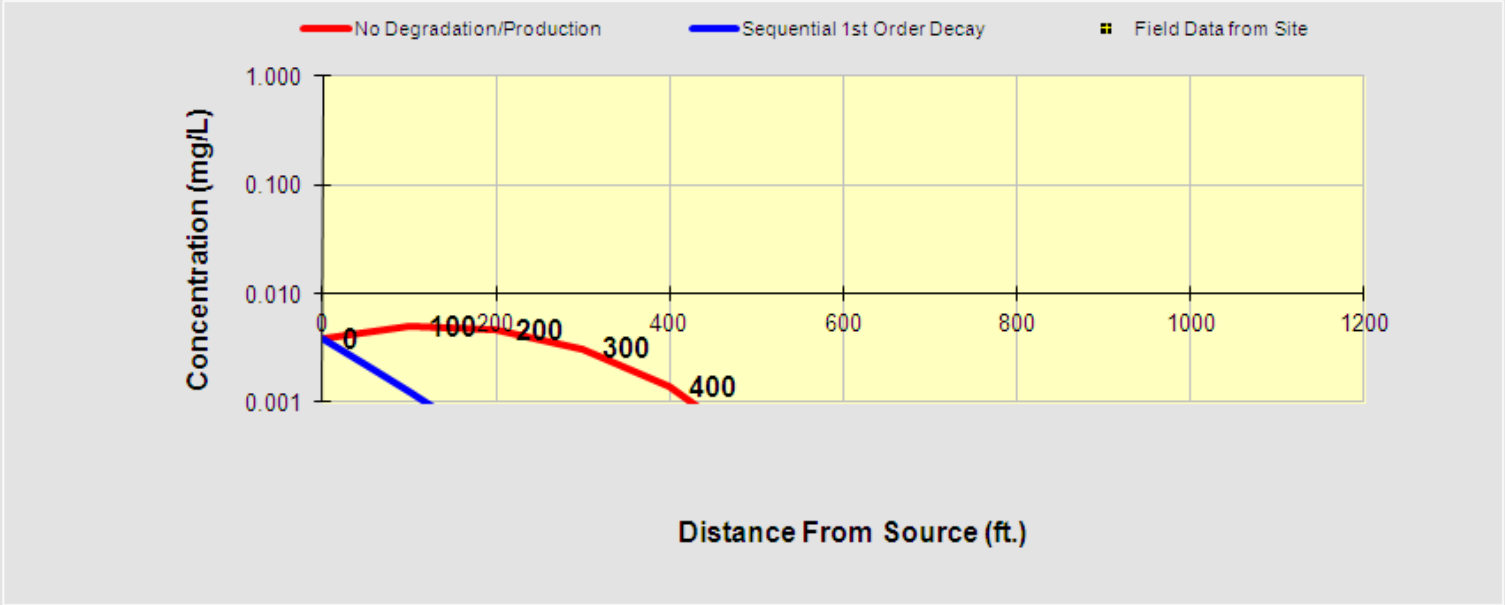
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.007	0.007	0.005	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0067	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
6.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

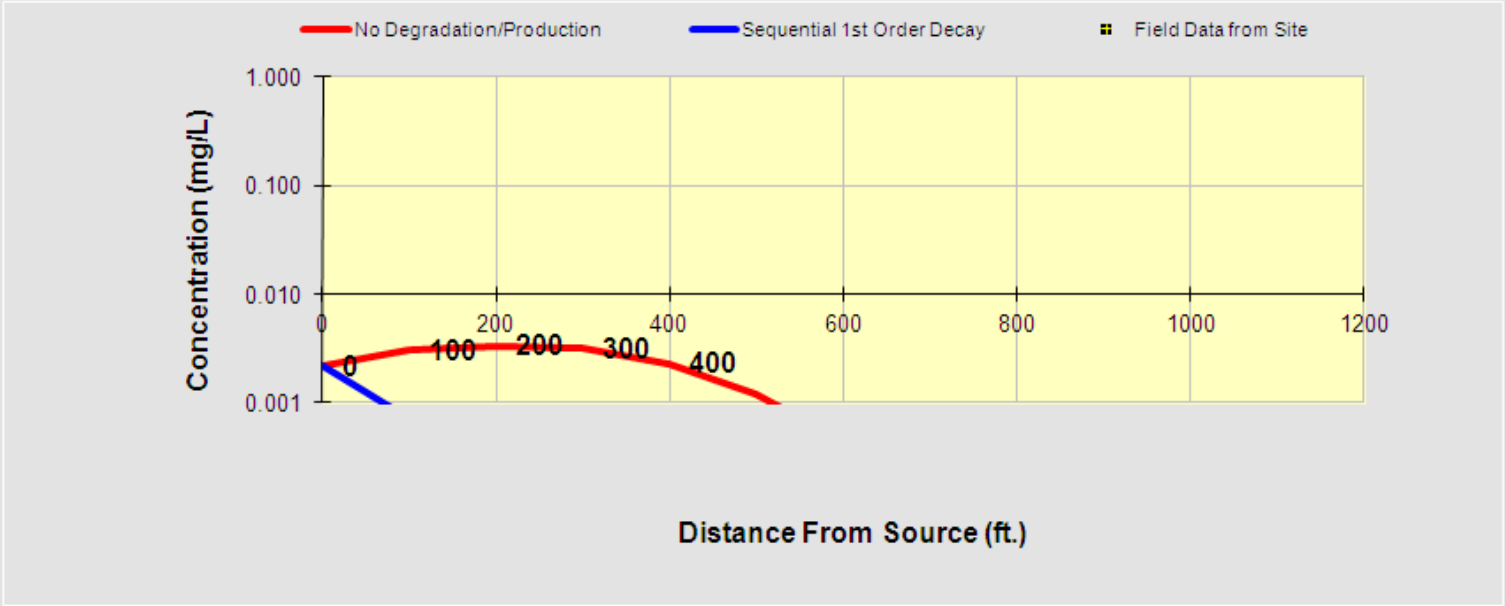
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.004	0.005	0.005	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0039	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
9.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.002	0.003	0.003	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0022	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE

See TCE

See DCE

See VC

See ETH

Replay

Next

Prev

Time:

12.0 Years

Log ⟺ Linear

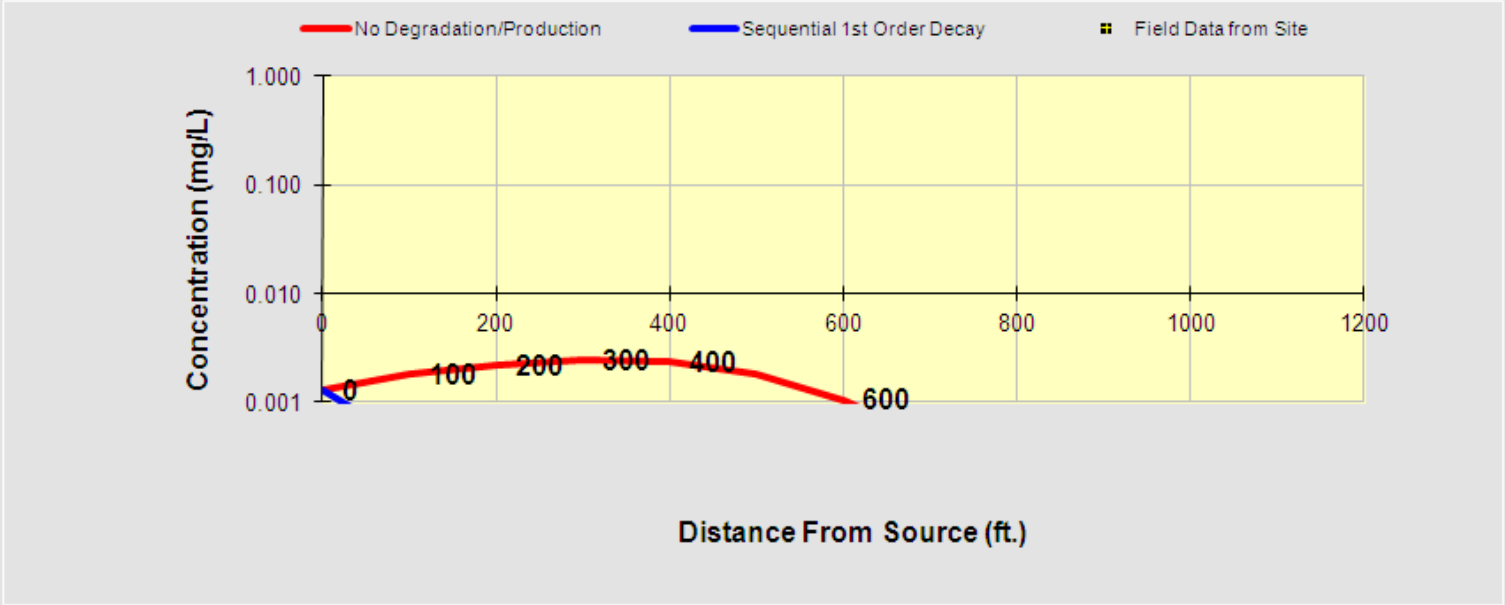
Unprotect Sheet

Return to Input

To All

To Array

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.000	0.000	0.000	0.000
Biotransformation	0.0013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE

See TCE

See DCE

See VC

See ETH

Replay

Next

Prev

Time:

15.0 Years

Log ⟺ Linear

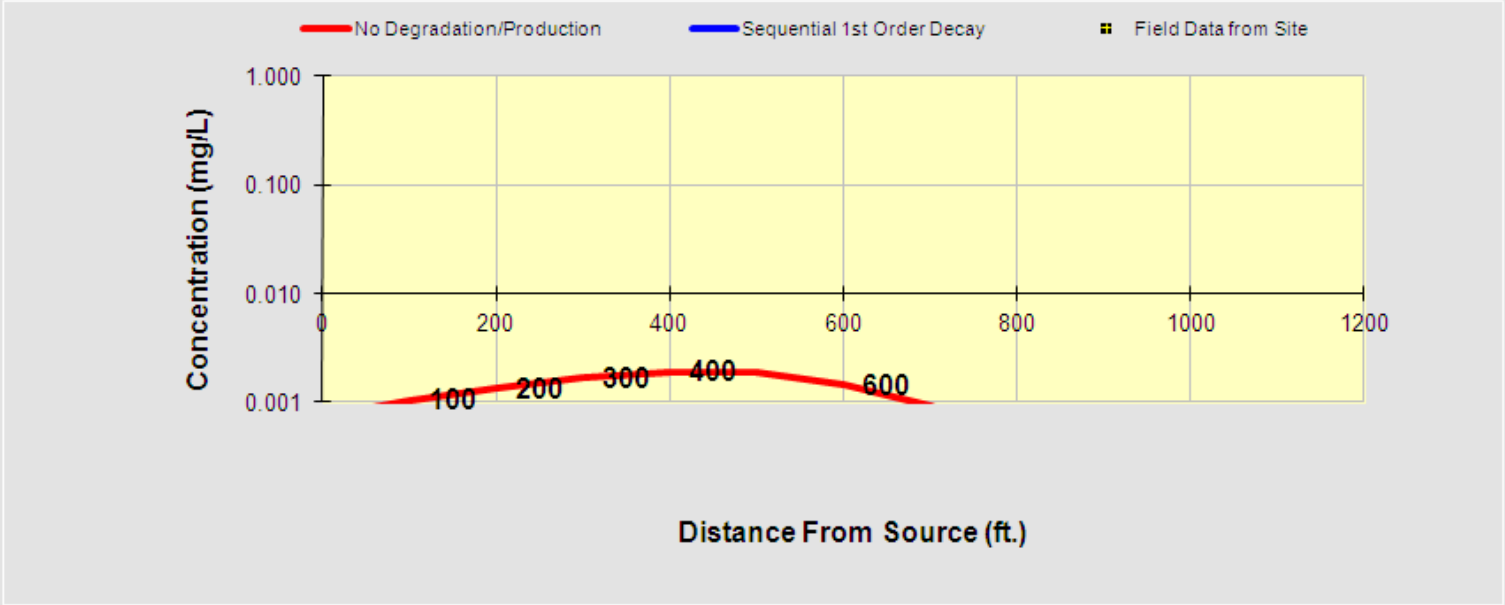
Unprotect Sheet

Return to Input

To All

To Array

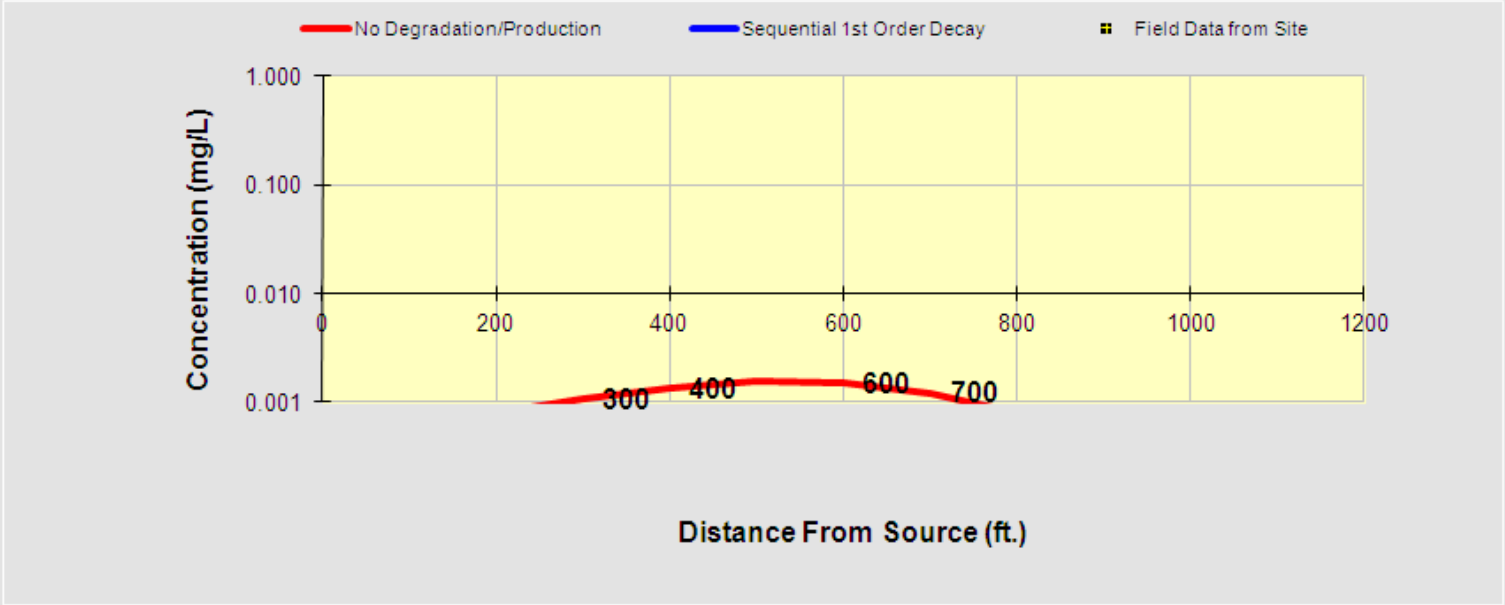
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.000	0.000	0.000
Biotransformation	0.0007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
18.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

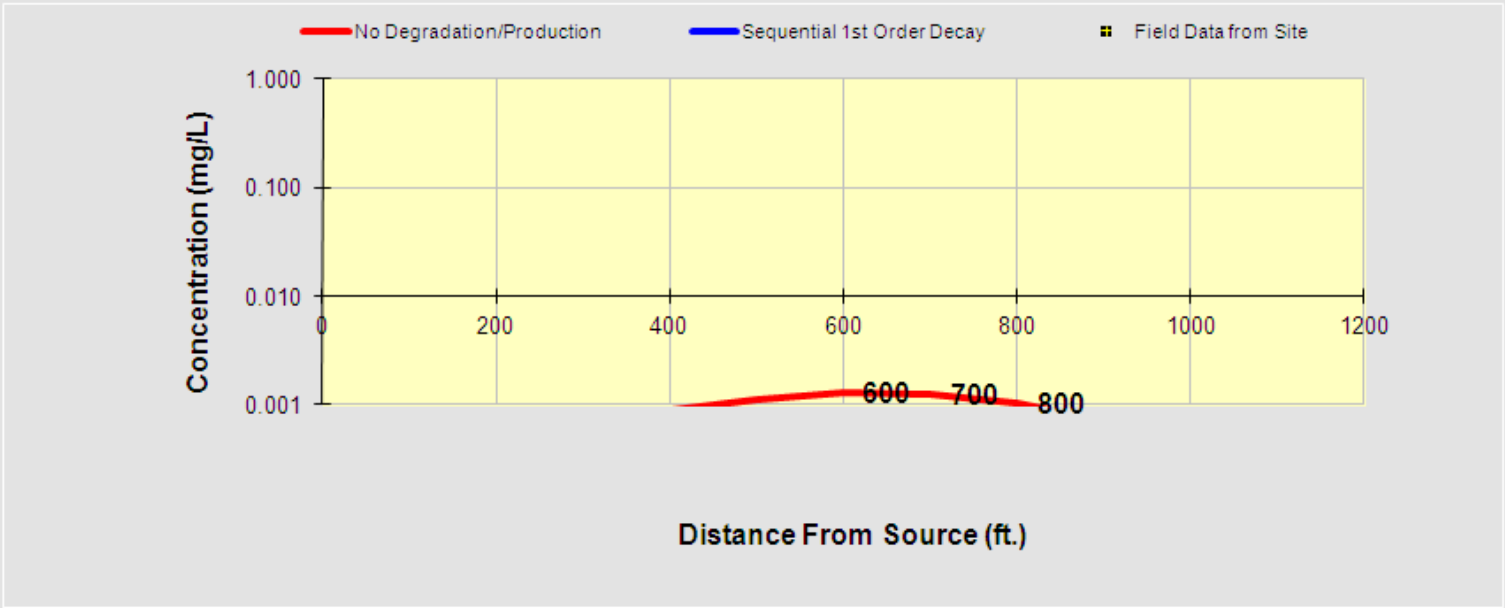
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.000	0.000
Biotransformation	0.0004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
21.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

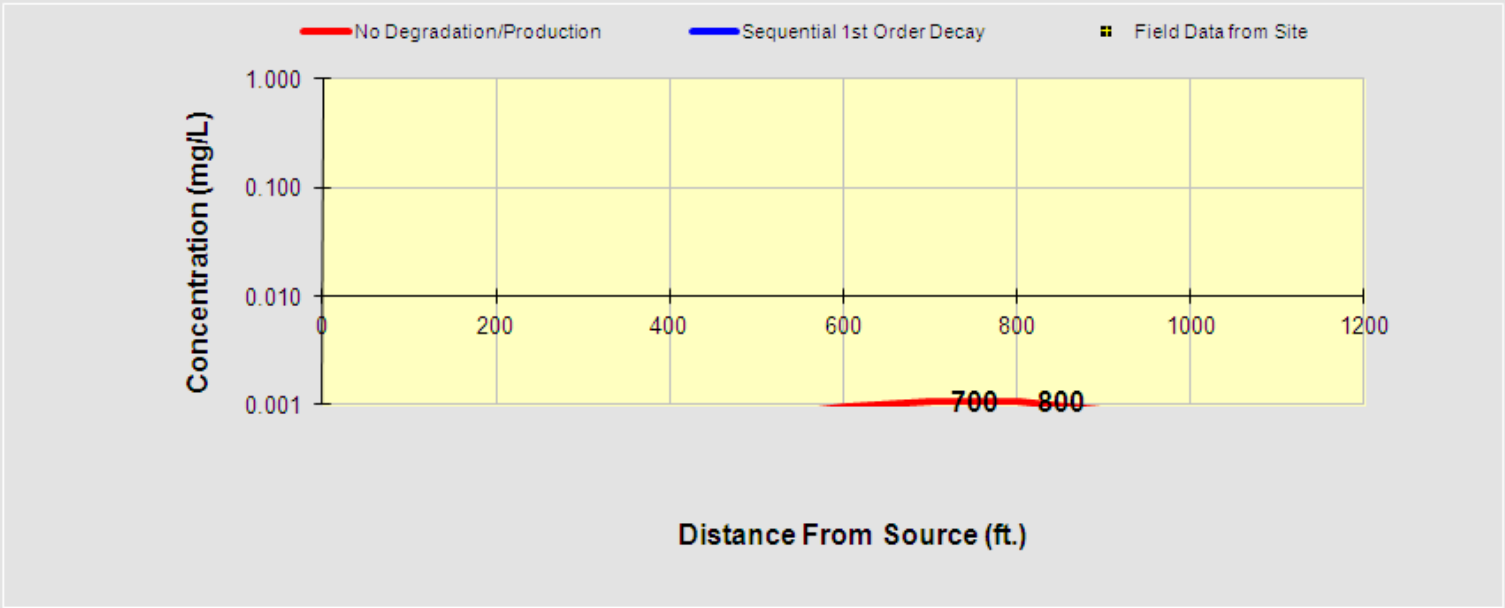
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000
Biotransformation	0.0002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
24.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

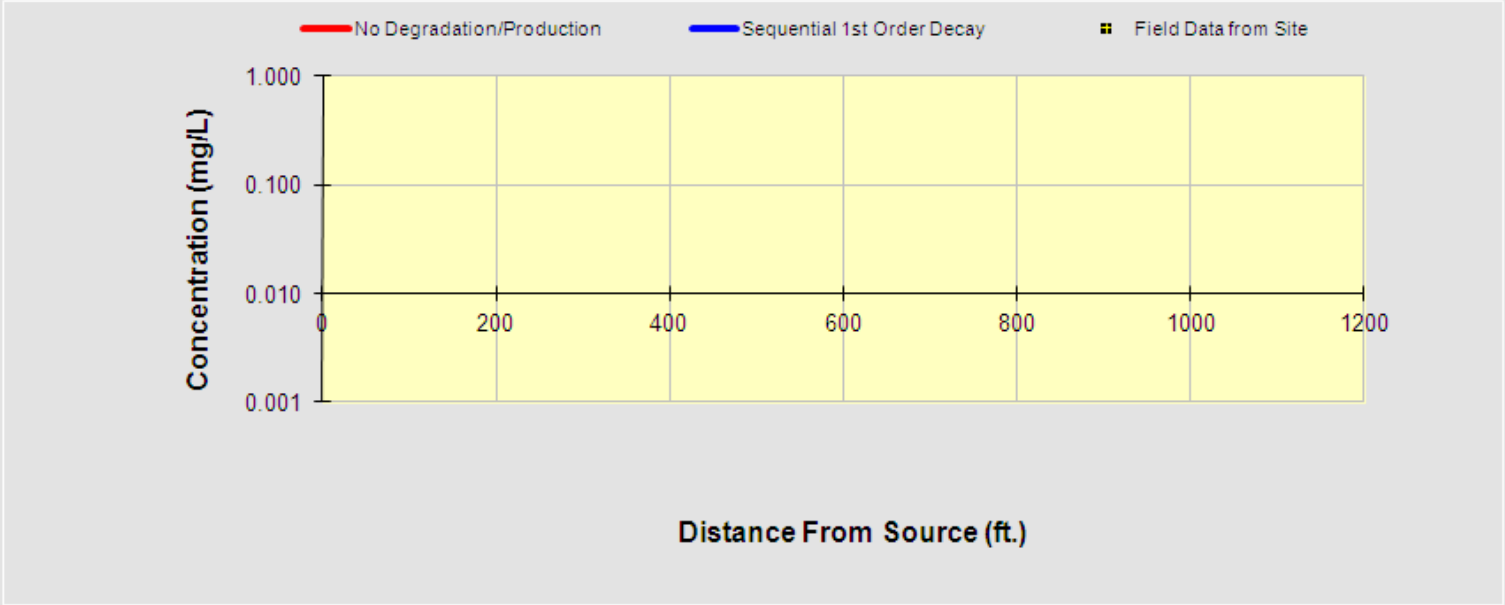
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Biotransformation	0.0001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
27.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

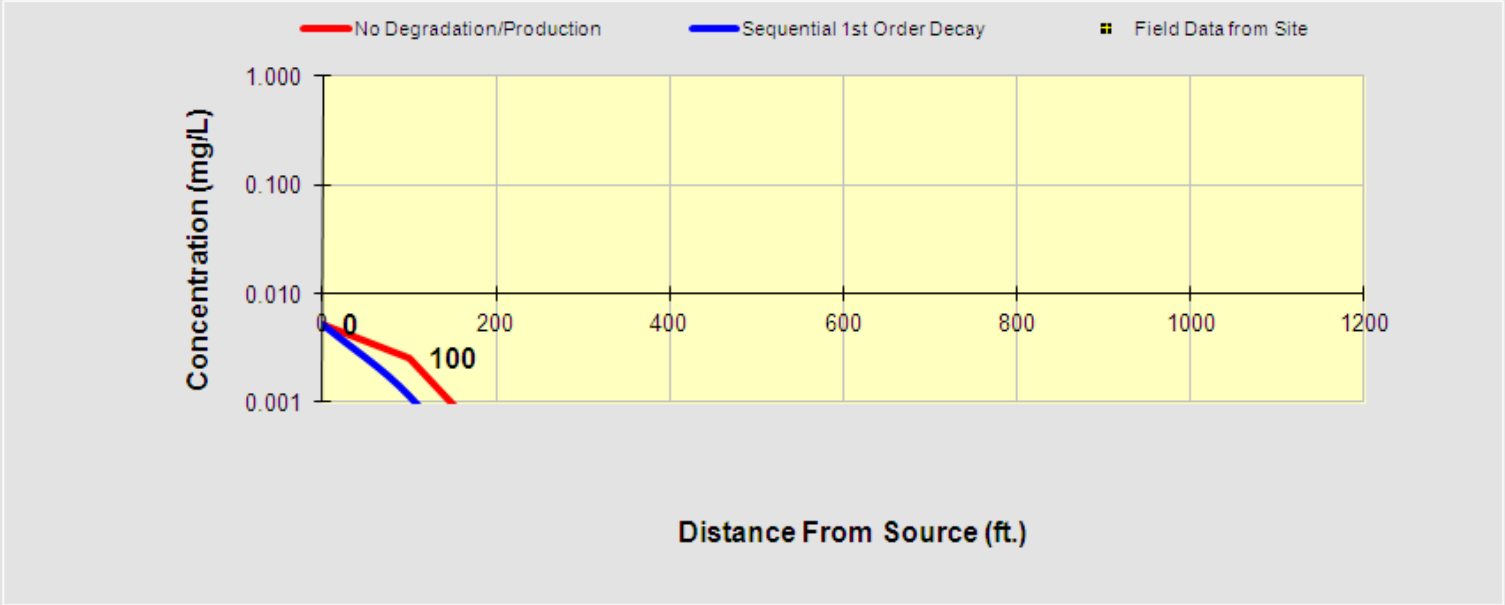
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
Biotransformation	0.0001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
30.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

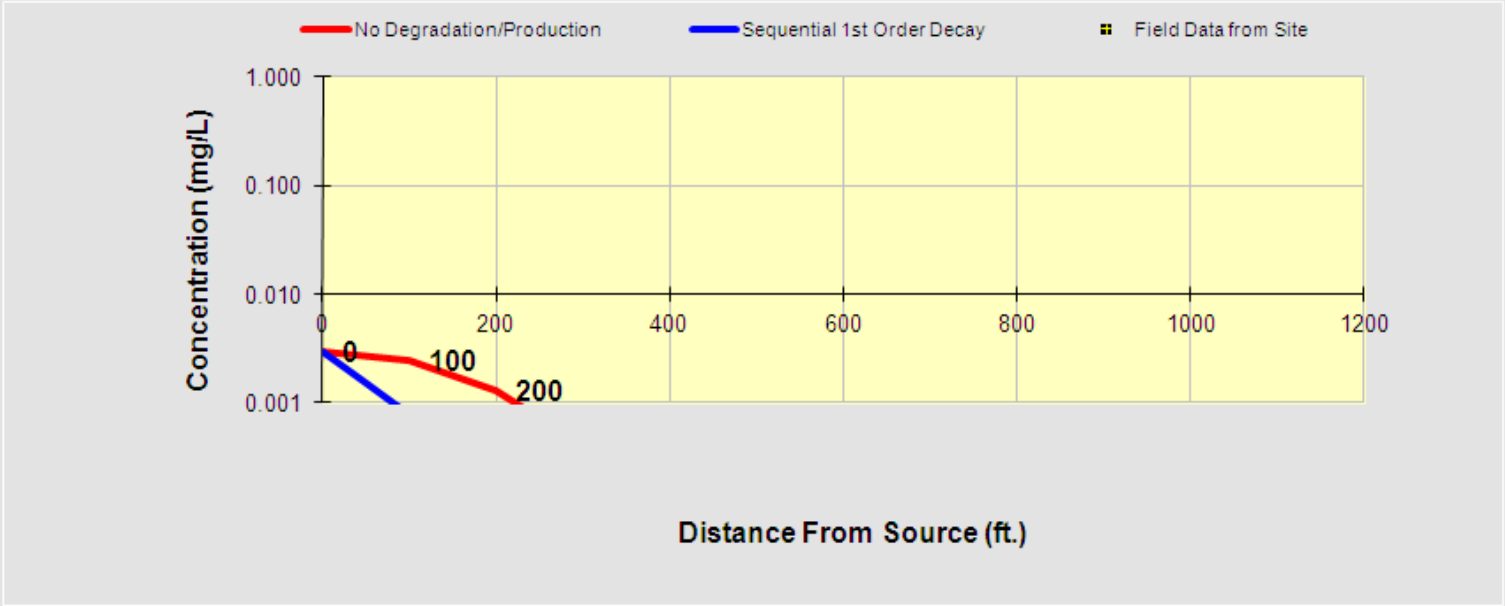
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0052	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
3.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

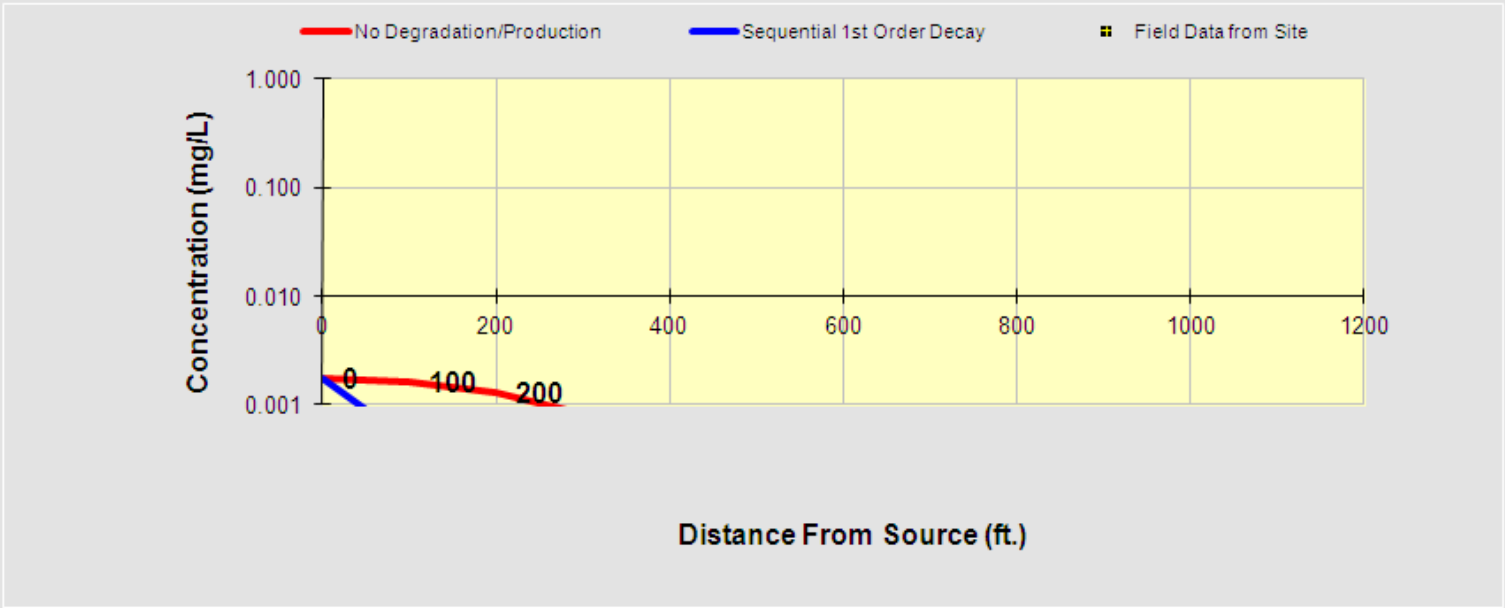
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0030	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
6.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.002	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE

See TCE

See DCE

See VC

See ETH

Replay

Next

Prev

Time:

9.0 Years

Log ⟺ Linear

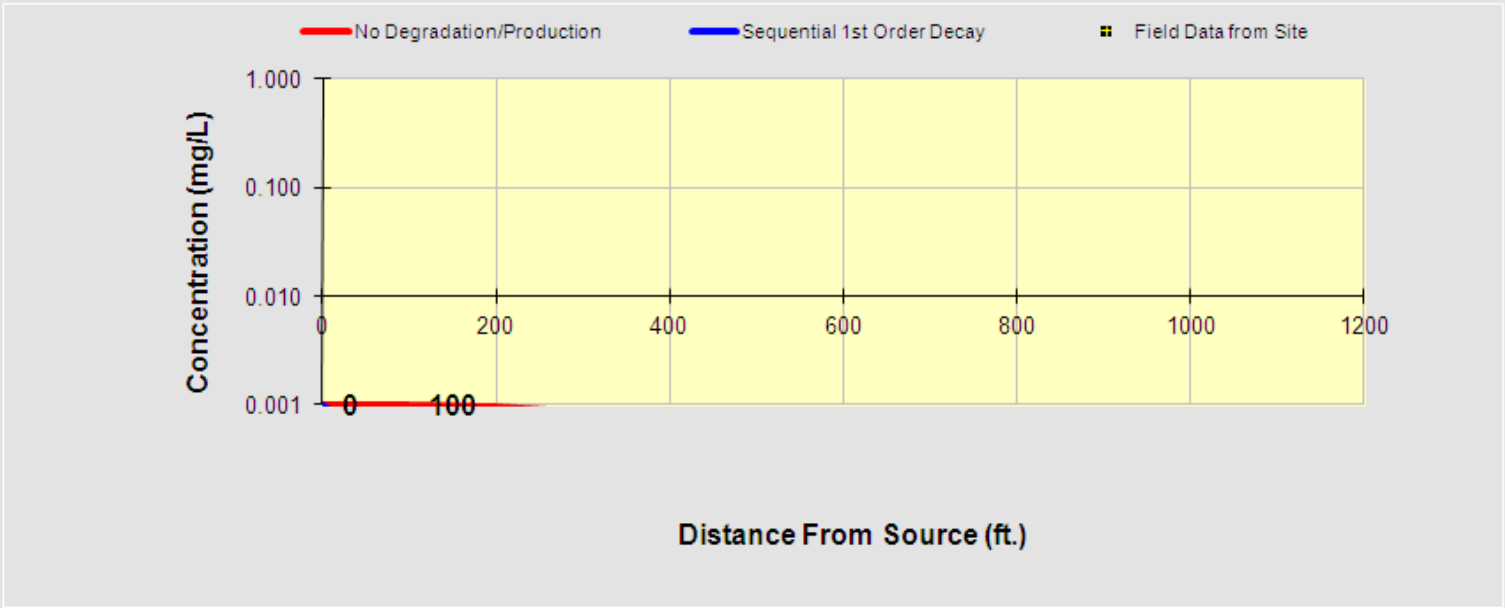
Unprotect Sheet

Return to Input

To All

To Array

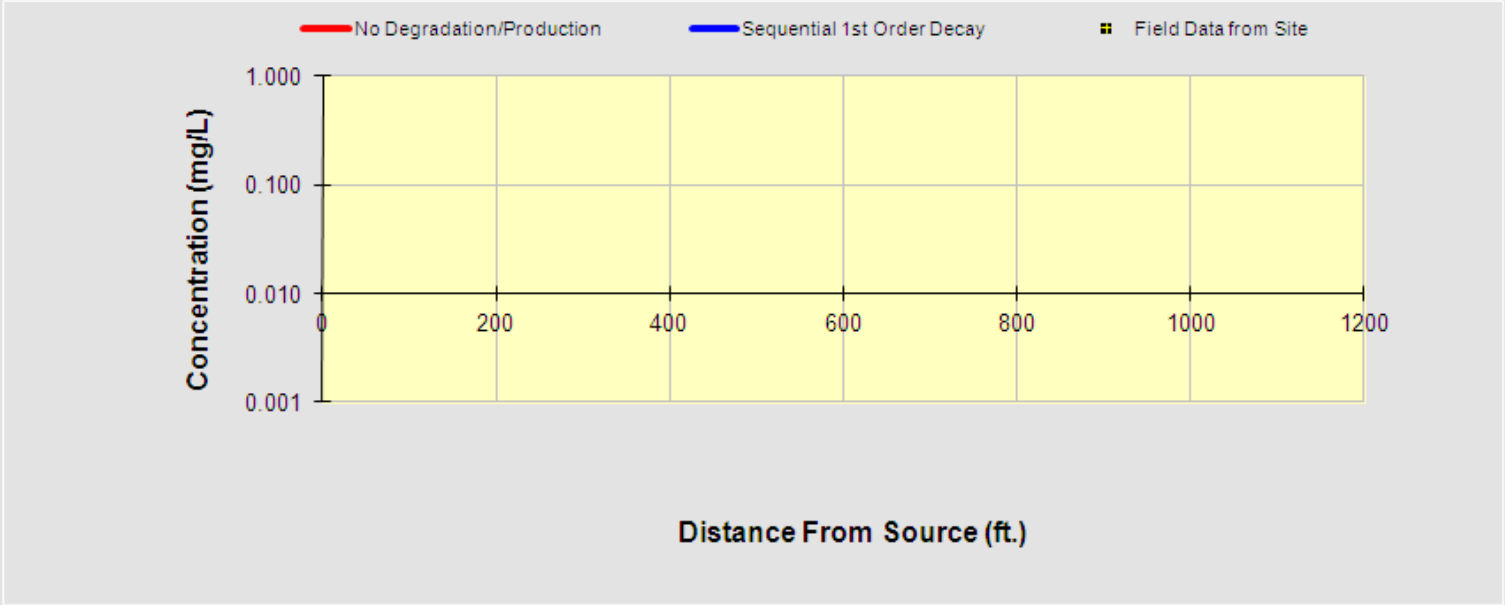
TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



See PCE
See TCE
See DCE
See VC
See ETH

Replay
Next
Prev
Time:
12.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

TCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
Field Data from Site											



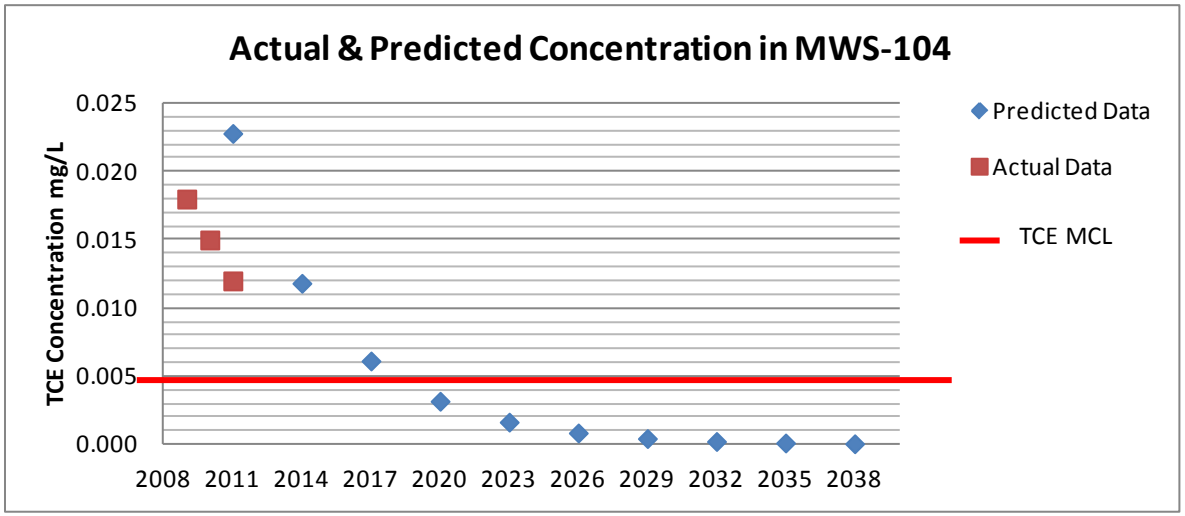
See PCE
See TCE
See DCE
See VC
See ETH

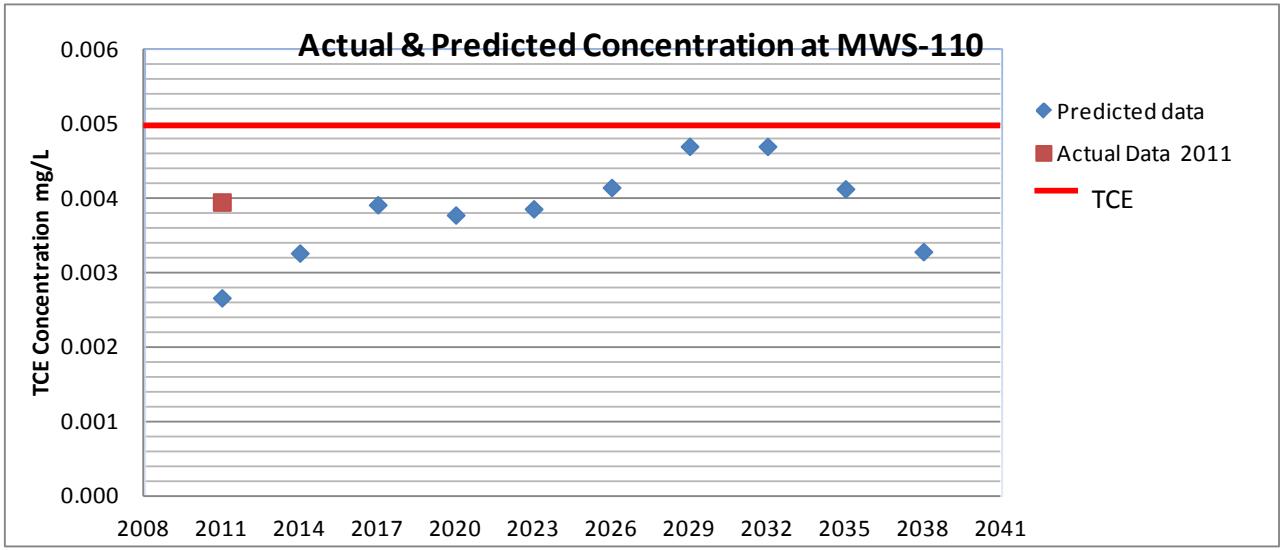
Replay
Next
Prev
Time:
15.0 Years
Log ⟺ Linear
Unprotect Sheet
Return to Input
To All
To Array

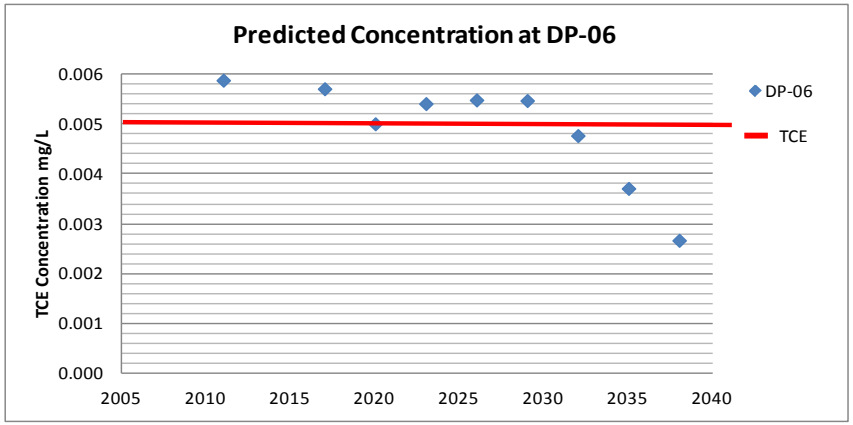
Predicted Values Downgradient of MWS-104																		
	MW-104				DP-10			DP-06		MW-110								
Feet from MWS-104	0	100	200	300	400	500	600	650	700	750	800	900	1000					
3 years	0.025	0.017	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000					
6 years	0.015	0.017	0.012	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000					
9 years	0.008	0.011	0.012	0.009	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000					
12 years	0.005	0.007	0.009	0.009	0.007	0.004	0.001	0.001	0.000	0.000	0.000	0.000	0.000					
15 years	0.003	0.004	0.006	0.007	0.007	0.006	0.003	0.002	0.002	0.001	0.000	0.000	0.000					
18 years	0.002	0.002	0.003	0.005	0.006	0.006	0.005	0.004	0.003	0.002	0.002	0.001	0.000					
21 years	0.001	0.001	0.002	0.003	0.004	0.005	0.005	0.005	0.004	0.003	0.003	0.002	0.001					
24 years	0.001	0.001	0.001	0.002	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.001					
27years	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.004	0.004	0.004	0.003	0.002					
30 years	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003					
Predicted Values Downgradient of DP-10																		
Feet from DP-10					0	100	200	250	300	350	400	500	600	700	800	900	1000	
3 years					0.012	0.008	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
6 years					0.007	0.007	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
9 years					0.004	0.005	0.005	0.004	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	
12 years					0.002	0.003	0.003	0.003	0.003	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	
15 years					0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.000	0.000	0.000	0.000	
18 years					0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.000	0.000	0.000	
21 years					0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.001	0.001	0.000	0.000	
24 years					0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	
27 years					0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
30 years					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	
Predicted Values Downgradient of DP-6																		
Feet from DP-06								0	50	100	150	250	350	450	550	650	750	850
3 years								0.005	0.004	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6 years								0.003	0.003	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
9 years								0.002	0.002	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
12 years								0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
15 years								0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Actual BioChlor Values used for interpolation																		
Feet from DP-06								0	100	200	300	400	500	600	700	800	900	1000
3 years								0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6 years								0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9 years								0.002	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12 years								0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
15 years								0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000

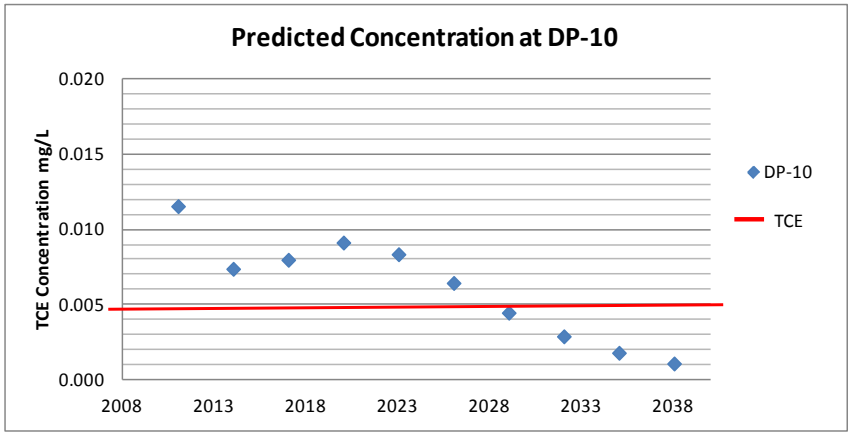
ATTACHMENT 8: COMPILATION OF BIOCHLOR OUTPUTS

Time	Year	Disance from source MWS-104													
		0(MWS104)	100	200	300	400(DP-10)	500	600	650(DP-6)	700	750(MW110)	800	900	1000	TCE MCL
3 years	2011	**0.023**	0.019	0.006	0.001	0.012	0.008	0.001	0.006	0.004	**0.003**	0.002	0.000	0.000	0.005
6 years	2014	**0.012**	0.014	0.013	0.007	0.007	0.007	0.005	0.006	0.004	**0.003**	0.002	0.001	0.000	0.005
9 years	2017	**0.006**	0.008	0.010	0.009	0.008	0.006	0.005	0.006	0.005	**0.004**	0.003	0.001	0.001	0.005
12 years	2020	**0.003**	0.004	0.006	0.007	0.009	0.007	0.005	0.005	0.004	**0.004**	0.003	0.002	0.001	0.005
15 years	2023	**0.002**	0.002	0.003	0.004	0.008	0.007	0.006	0.005	0.005	**0.004**	0.003	0.002	0.002	0.005
18 years	2026	**0.001**	0.001	0.002	0.002	0.006	0.007	0.006	0.005	0.005	**0.004**	0.003	0.002	0.001	0.005
21 years	2029	**0.000**	0.001	0.001	0.001	0.004	0.005	0.006	0.005	0.005	**0.005**	0.004	0.003	0.002	0.005
24 years	2032	**0.000**	0.000	0.000	0.001	0.003	0.004	0.005	0.005	0.005	**0.005**	0.005	0.004	0.003	0.005
27 years	2035	**0.000**	0.000	0.000	0.000	0.002	0.003	0.003	0.004	0.004	**0.004**	0.004	0.004	0.003	0.005
30 years	2038	**0.000**	0.000	0.000	0.000	0.001	0.002	0.002	0.003	0.003	**0.003**	0.004	0.004	0.004	0.005




Actual & Predicted Concentration at MWS-110
TCE Concentration mg/L
0.006
0.005
0.004
0.003
0.002
0.001
0.000
2008
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038
2041
Predicted data
Actual Data 2011
TCE


Predicted Concentration at DP-06
TCE Concentration mg/L
0.006
0.005
0.004
0.003
0.002
0.001
0.000
2005
2010
2015
2020
2025
2030
2035
2040
DP-06
TCE


Predicted Concentration at DP-10
TCE Concentration mg/L
0.020
0.015
0.010
0.005
0.000
2008
2013
2018
2023
2028
2033
2038
DP-10
TCE

APPENDIX B

Mann-Kendall Analysis for Cameron Station, June 2012

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MANN-KENDALL ANALYSIS FOR CAMERON STATION
June 2012
Environmental and Munitions Design Center
U.S. Army Corps of Engineers, Baltimore District

1. INTRODUCTION:

The Mann-Kendall test was performed to evaluate the trend of TCE concentrations at various monitoring wells located at the Cameron Station. This is an update to the Mann-Kendall analysis performed for this site as part of the Focused Feasibility Study (FFS) (URS, 2010). The FFS utilized data collected up through January 2010, and recommended that after two additional years of quarterly monitoring was completed, the Mann-Kendall analysis would be repeated with the larger dataset. This repeated analysis was performed similar to the analysis that was described in the FFS.

The analysis focused on those two wells that were included in the prior Mann-Kendall analysis, plus it added one well (MWS-110) that was installed after the FFS and was monitored 8 times. The analysis used the data that was available in the FFS, as well as the data collected after the FFS up to the present as shown in the 1st quarter 2012 Groundwater Monitoring Report (URS, 2012). TCE sampling data that was collected at MWS-104, MWS-105 and MWS-110 between 2007 and 2012 was used for the analysis. Also, field duplicates were collected from MWS105 in the sampling events after 2008, and were used as follows: the maximum concentration of the primary sample and the field duplicate samples was used in the analysis. The table below shows the TCE concentrations used in the analysis.

Trichloroethene (TCE) Concentrations (µg/L)																
Well	Mar-07	Nov-07	Jul-08	Jan-09	Apr-09	Sep-09	Jan-10	Mar-10	Jun-10	Aug-10	Nov-10	Feb-11	May-11	Aug-11	Nov-11	Feb-12
MW 104	86	53	44	22	36	18	27	16	21	15	9.5	6.2	9.2	12	9.8	9.2
MW 105	25	27	23	12	8	15	24	9.9	21	23	8.6	9.2	9.3	8.2	9.2	12
MW110									7	4.5	3.6	1.6	5.5	4	4.7	11

2. THEORY:

The following is repeated from the discussion in Appendix B-1 of the FFS:

"The Mann-Kendall technique was recommended as a tool for determining if trends are present in analytical data in the *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities,*

Unified Guidance (USEPA, 2009). The Mann-Kendall test is a non-parametric test for identifying trends in time series data. Because it is a non-parametric method, the Mann-Kendall test makes no assumption about the statistical distribution of the data. This is particularly useful because it allows for missing values and the data need not conform to any particular distribution (i.e. wells don't need to be sampled at regular intervals) (Wiedemeier, et. al., 1999; Gilbert, 1987). The test compares the relative magnitudes of sample data rather than the individual data values. The Mann-Kendall statistic, S, is computed as the number of positive differences minus the number of negative differences. If S is a large positive value, then there is evidence of an increasing trend in the data. If S is a large negative value, then there is evidence of a decreasing trend in the data (Gilbert, 1987). The S value corresponds to a probability value, which is compared to a specified significance value. A significance level of $\alpha=0.05$ was used to test the null hypothesis for the Mann-Kendall test. The null hypothesis, H_o, is no trend against the alternative hypothesis, H_a, of an upward trend. The results are reported as *p*-values: when $p < \alpha$, the null hypothesis can be rejected in favor of the alternative hypothesis. In other words, if $p < 0.05$, a trend in the data exists; if $p \geq 0.05$, a trend in the data does not exist. In those cases where the Mann-Kendall test indicated evidence for a trend, the linear slope was estimated using Sen's method (Gilbert, 1987). A positive slope indicates an increasing trend, while a negative slope indicates a decreasing trend."

Although the computer program Trend v.2.01 (Gilbert, 1987) was used to perform the Mann-Kendall test in the FFS, this test is also a part of the readily available statistical package ProUCL, offered by the U.S. Environmental Protection Agency (http://www.epa.gov/osp/hstl/tsc/software.htm).

ProUCL version 4.1.01 is recent, with a release date of 12 July 2011, and is easy to use.

It matched the conclusions generated by Trend in the FFS, and was used in this updated analysis.

3. RESULTS:

The Mann-Kendall analysis was performed for two scenarios similar to what was done in the FFS. The first scenario uses a data set from March 2007 through February 2012. This scenario uses a greater number of historical data to determine a trend. The second scenario uses data collected from January 2009 through February 2012, reflecting the period after the soil vapor extraction system was shut down in December 2008.

The Mann-Kendall test performed with data from March 2007 through February 2012 indicates that a decreasing trend exists in the concentration data in MWS-104 and MWS-105. As shown in the attached figure, a tabulated *p*-value of 0 was calculated for MWS-104, which is less than the level of significance of 0.05, thereby indicating that a statistically significant trend exists in this well. A Sen's slope of -2.92 was estimated, indicating a decreasing trend. Similarly as MWS-104, the *p*-value calculated for MWS-105 (0.013) is smaller than the significance level of 0.05, indicating that the concentration in this well exhibits a statistically significant concentration trend, and the trend is decreasing since a Sens slope of -0.73 was calculated. In the analysis included in the FFS, MWS-104 had a decreasing trend and no trend was found in MWS-105 in the interval of 2007 to 2010.

The Mann-Kendall test performed with data from January 2009 through February 2012 indicates that a decreasing trend exists in the concentration data in MWS-104, and no trend exists in the concentration data in MWS-105 and MWS-110. As shown in the attached figure, the data for MWS-104 has a tabulated p-value of 0.001, which is less than the significance level of 0.05, and the Sen's slope is -1.59, indicating a decreasing trend. The data for wells MWS-105 and MWS-110 were found to have *p*-values greater than 0.05 (0.218 and 0.36 respectively), indicating that the TCE concentrations in those wells do not exhibit a statistically significant trend. In the FFS analysis, neither MWS-104 nor MWS-105 exhibited a significant trend in the post-remediation dataset, and MWS-110 was not assessed since it had not yet been installed.

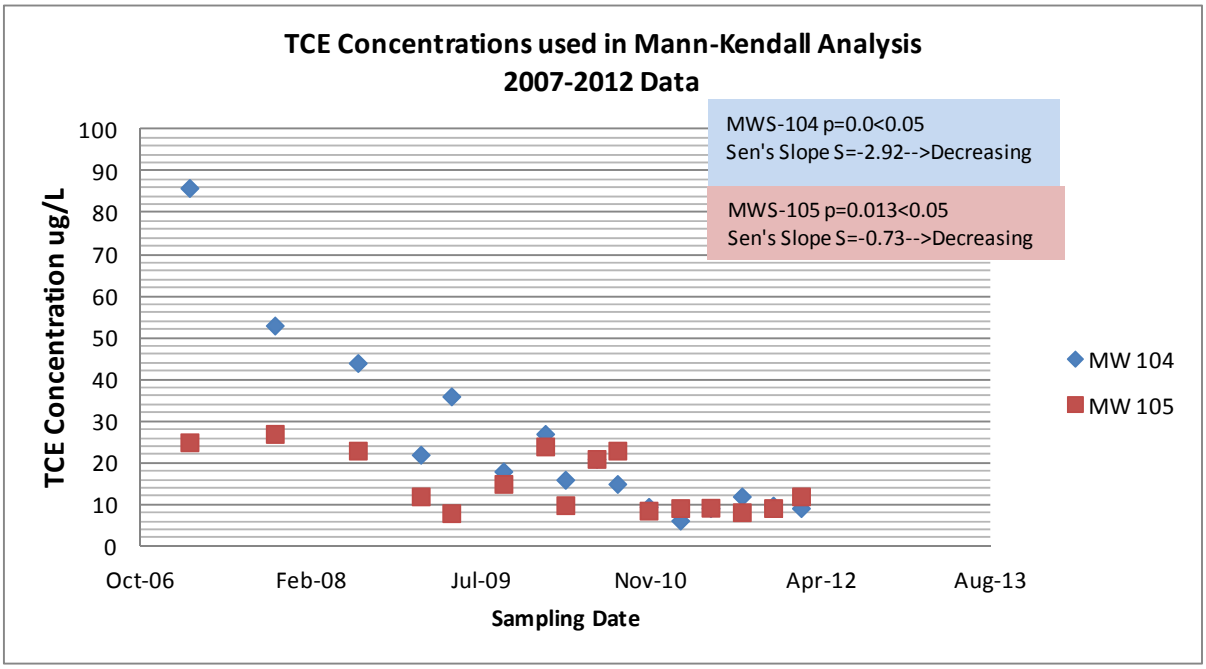
In conclusion, the TCE concentrations show a statistically significant declining trend in the monitoring well MWS-104, and no significant trend in the wells MWS-105 and MWS-110.

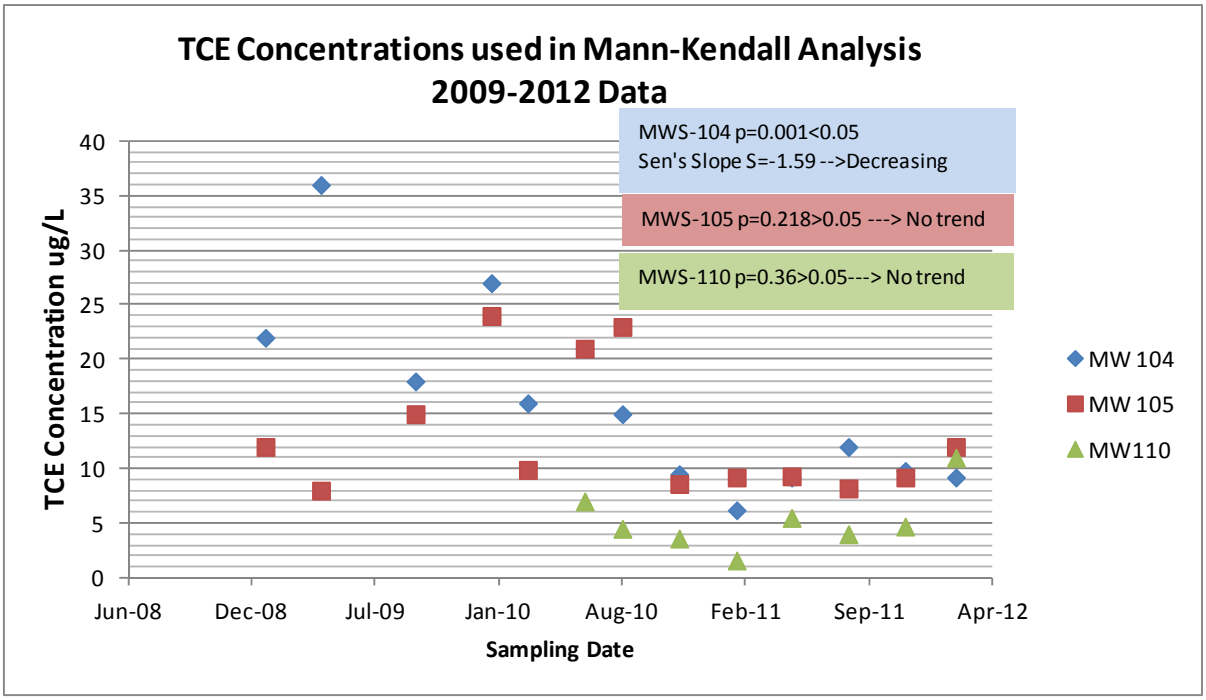
4. REFERENCES:

Gilbert, R.O., 1987. *Statistical Methods for Environmental Pollution Monitoring*. Wiley, NY.

URS, September 2010, *FINAL FOCUSED FEASIBILITY STUDY, SITE C, CAMERON STATION, ALEXANDRIA, VIRGINIA*, Prepared By URS, Herndon, Virginia, Prepared For United States Army Corps Of Engineers, Baltimore District, USACE Contract No. W912DR-09-D-0017, Delivery Order No. 0003, URS Project No. 11656350

URS, April 2012, 1st *QUARTER 2012 GROUNDWATER MONITORING REPORT, SITE C, CAMERON STATION, ALEXANDRIA, VIRGINIA*, Prepared by URS, Herndon, Virginia; Prepared for United States Army Corps of Engineers, Baltimore District, USACE CONTRACT NO. W912DR-09-D-0017, DELIVERY ORDER NO. 3, URS PROJECT NO. 15900480.



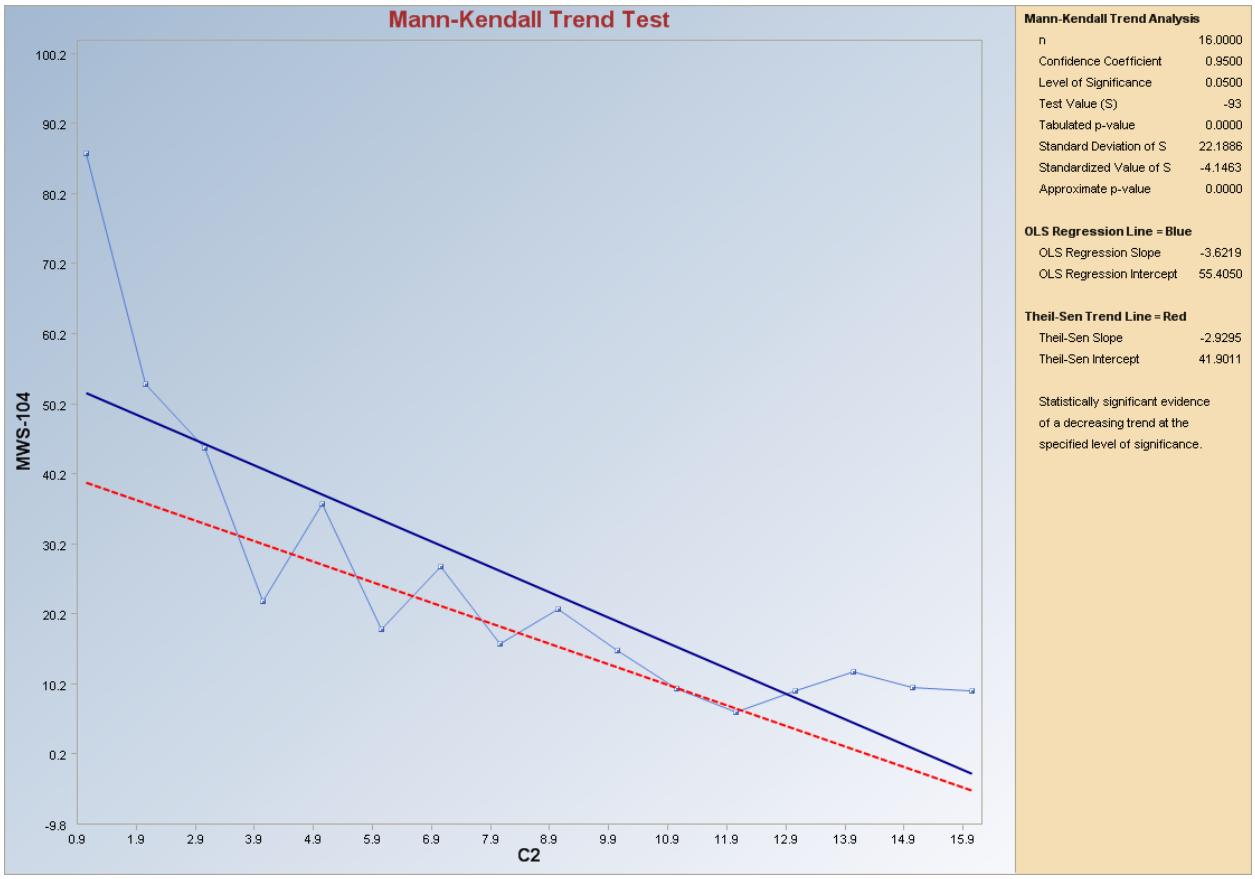


ANN-KENDALL OUTPUTS FROM PRO UCL (2007 TO 2012 DATA)

STATISTICS FOR MWS-104:

Mann-Kendall Trend Test Analysis	
General Statistics	
Number of Events	16
Number of Values	16
Minimum	6.2
Maximum	86
Mean	24.62
Geometric Mean	18.72
Median	17
Standard Deviation	21.19
SEM	5.298
Mann-Kendall Test	
Test Value (S)	-93
Tabulated p-value	0
Standard Deviation of S	22.19
Standardized Value of S	-4.146
Approximate p-value	1.689600E-005

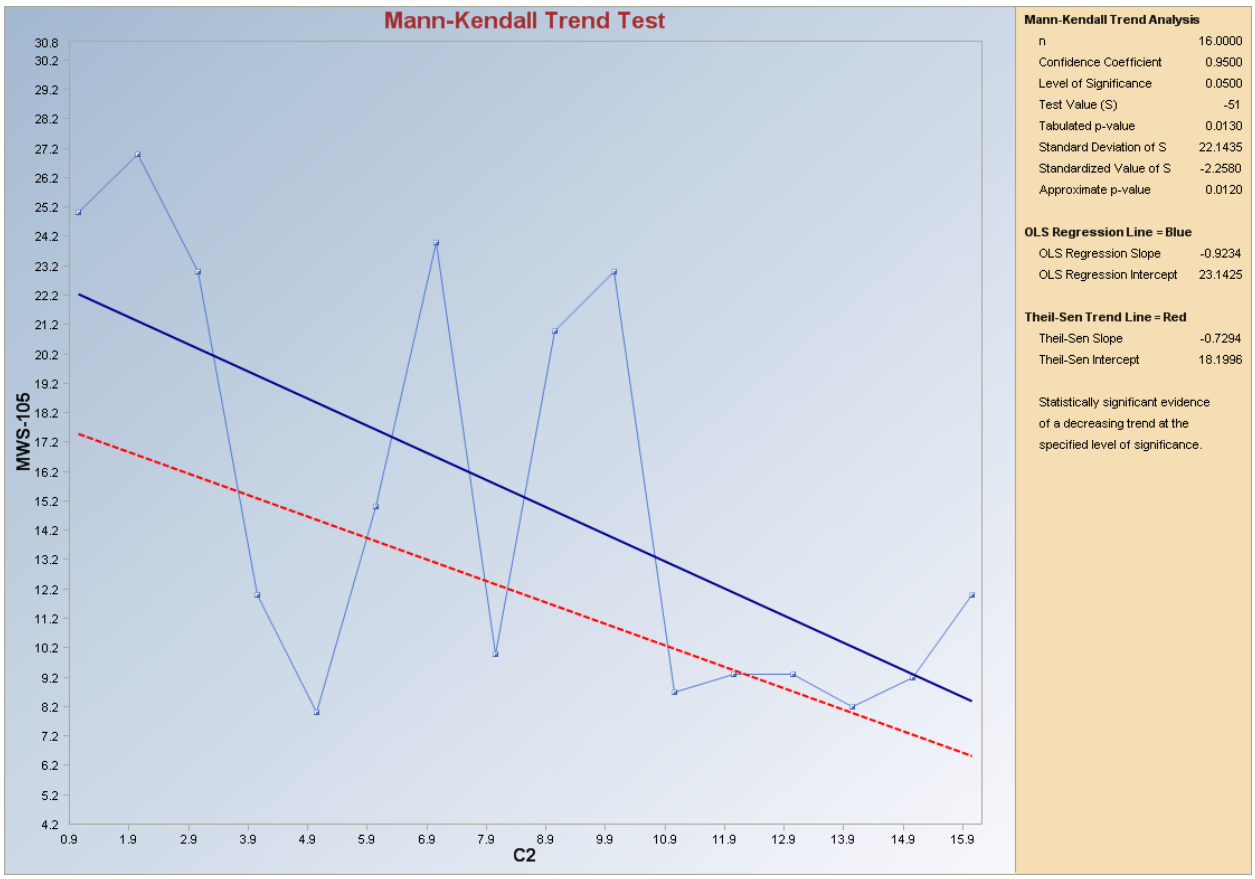
TREND CHART FOR MWS-104



STATISTICS FOR MWS-105

General Statistics	
Number of Events	16
Number of Values	16
Minimum	8
Maximum	27
Mean	15.29
Geometric Mean	13.82
Median	12
Standard Deviation	7.138
SEM	1.784
Mann-Kendall Test	
Test Value (S)	-51
Tabulated p-value	0.013
Standard Deviation of S	22.14
Standardized Value of S	-2.258
Approximate p-value	0.012

TREND CHART FOR MWS-105

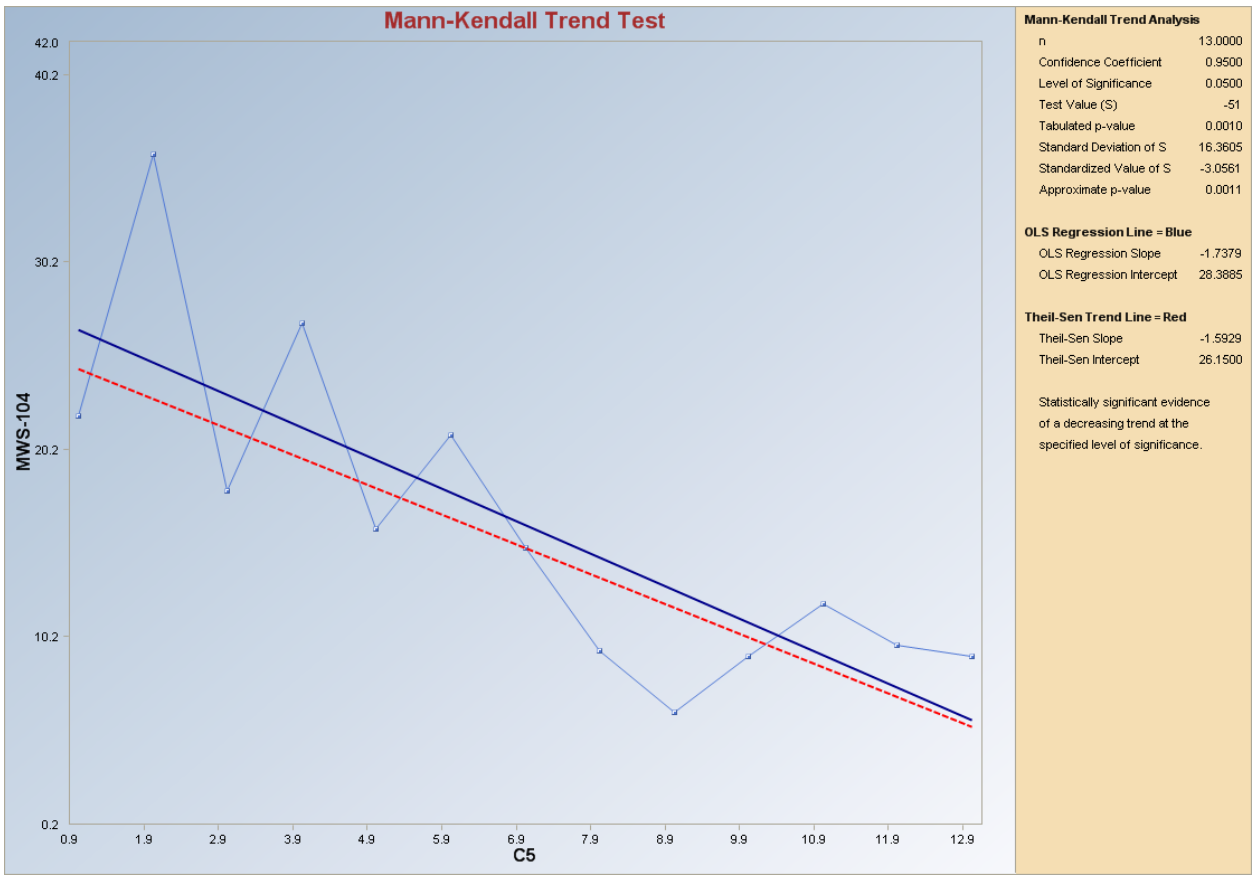


MANN-KENDALL OUTPUTS FROM PRO UCL (2009 TO 2012 DATA)

STATISTICS FOR MWS-104

General Statistics	
Number of Events	13
Number of Values	13
Minimum	6.2
Maximum	36
Mean	16.22
Geometric Mean	14.39
Median	15
Standard Deviation	8.522
SEM	2.364
Mann-Kendall Test	
Test Value (S)	-51
Tabulated p-value	0.001
Standard Deviation of S	16.36
Standardized Value of S	-3.056
Approximate p-value	0.00112

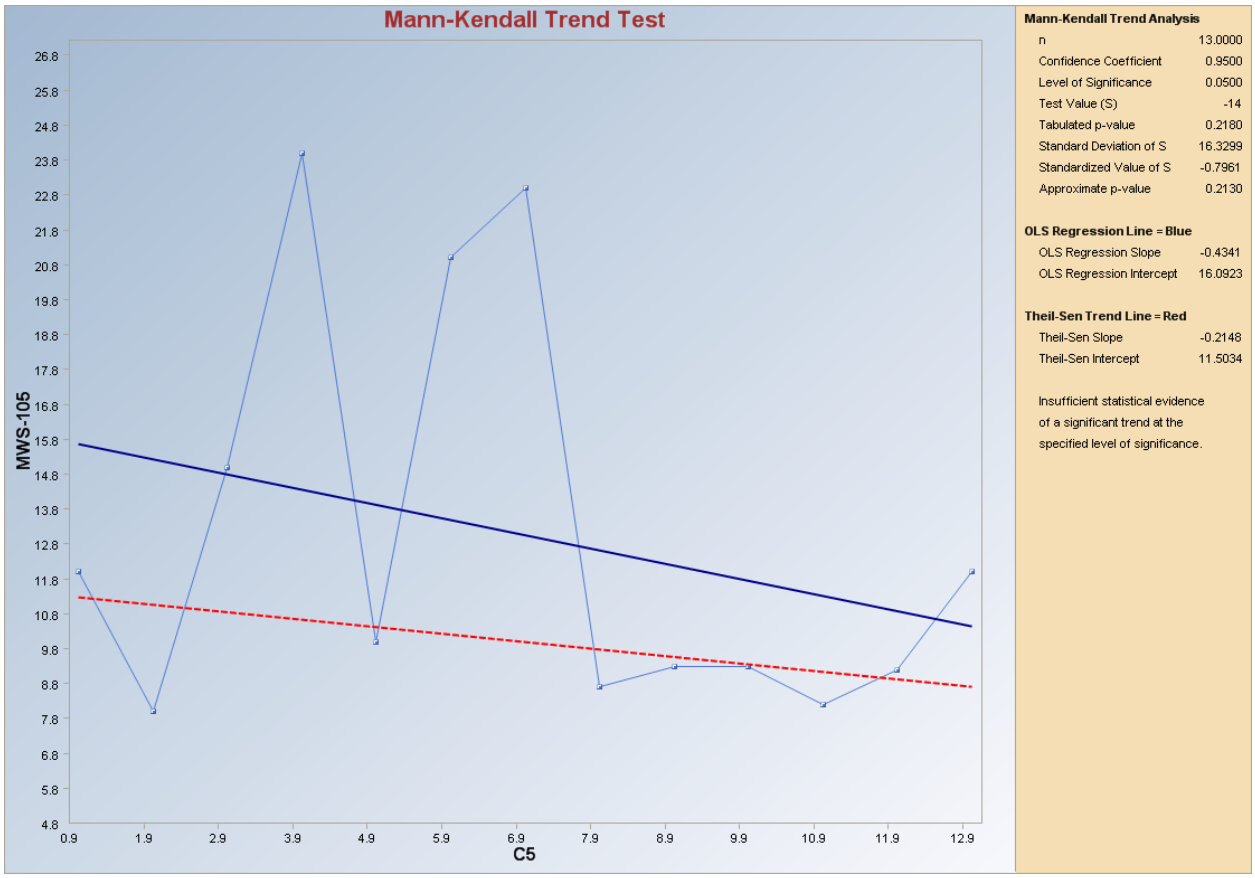
TREND CHART FOR MWS-104



STATISTICS FOR MWS-105

General Statistics	
Number of Events	**13**
Number of Values	**13**
Minimum	**8**
Maximum	**24**
Mean	**13.05**
Geometric Mean	**12.06**
Median	**50**
Standard Deviation	**5.833**
SEM	**1.618**
Mann-Kendall Test	
Test Value (S)	**-14**
Tabulated p-value	**0.218**
Standard Deviation of S	**16.33**
Standardized Value of S	**-0.796**
Approximate p-value	**0.213**

TREND CHART FOR MWS-105

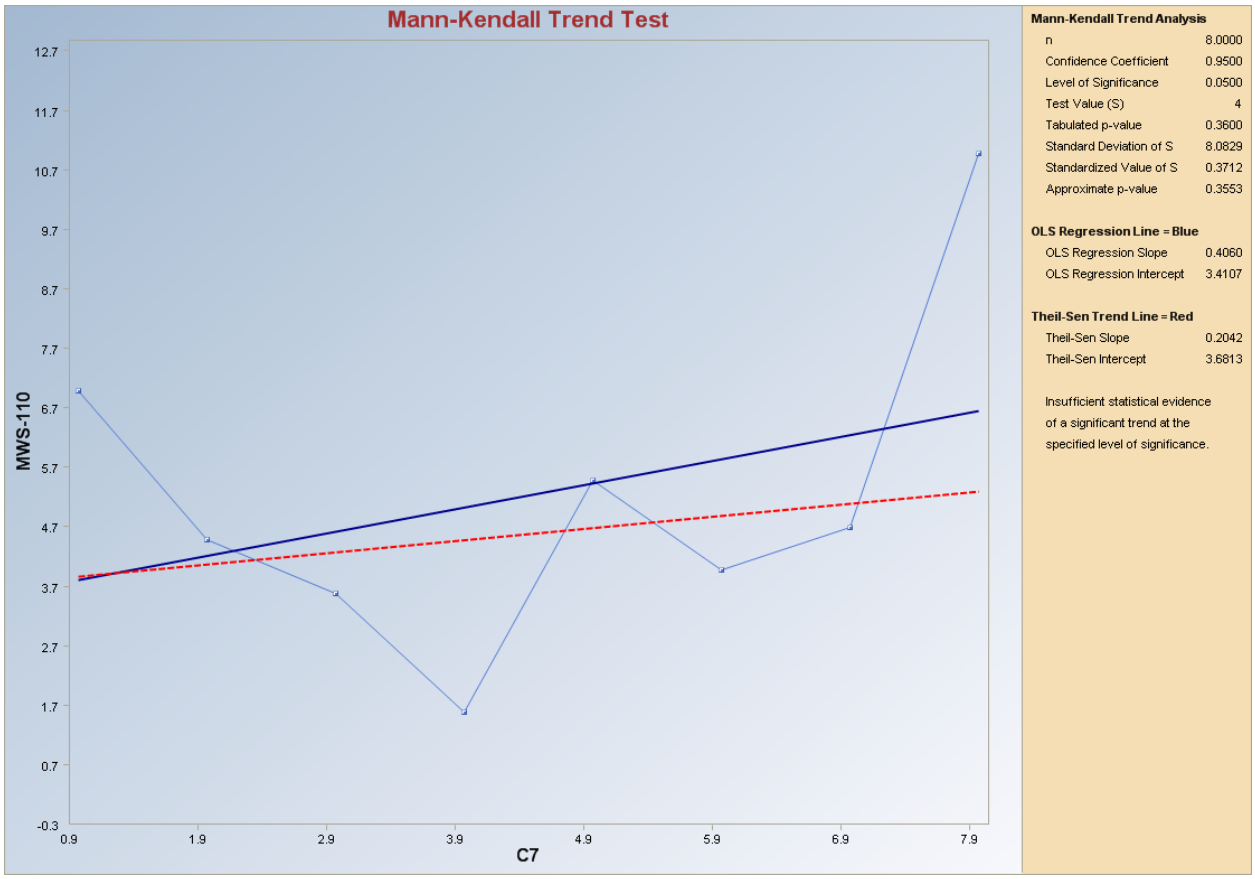


STATISTICS FOR MWS-110

General Statistics

Number of Events	**8**
Number of Values	**8**
Minimum	**1.6**
Maximum	**11**
Mean	**5.238**
Geometric Mean	**4.617**
Median	**4.6**
Standard Deviation	**2.794**
SEM	**0.988**
Mann-Kendall Test	
Test Value (S)	**4**
Tabulated p-value	**0.36**
Standard Deviation of S	**8.083**
Standardized Value of S	**-0.371**
Approximate p-value	**0.355**

TREND CHART FOR MWS-110



APPENDIX C

Revised Human Health Risk Assessment for TCE, December 2012

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REPLACEMENT TABLE 3.7a
Assumptions Used for TCE in Johnson and Ettinger Model for
Residential Scenario with Groundwater data (with Vapor Barrier): Data Entry Sheet
Cameron Station Site, Alexandria, Virginia

GW-ADV
Version 3.1; 02/04

Reset to Defaults

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial groundwater conc., C_W (µg/L)	Chemical
79016	1.31E+02	Trichloroethylene

MORE ↓

ENTER Average soil/ groundwater temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum directly above water table, (Enter A, B, or C)	ENTER SCS soil type directly above water table	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
			Totals must add up to value of L_{WT} (cell G28)							
13.88	200	477.4	210	267.4	0	B	SCL			3.00E-08

MORE ↓

ENTER Stratum A SCS soil type (Lookup Soil Parameters)	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type (Lookup Soil Parameters)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type (Lookup Soil Parameters)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
S	1.66	0.375	0.054	SCL	1.63	0.384	0.146				

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s^2)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	1219	1219	233.8	0.1	0.25	0.007429805

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-04	1
				Used to calculate risk-based groundwater concentration.	

END

REPLACEMENT TABLE 3.7B
Assumptions Used for TCE in Johnson and Ettinger Model for
Residential Scenario with Groundwater data (with Vapor Barrier): Chemical Property Sheet
Cameron Station Site, Alexandria, Virginia

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.90E-02	9.10E-06	1.03E-02	25	7,505	360.36	544.20	1.66E+02	1.47E+03	4.1E-06	2.0E-03

END

REPLACEMENT TABLE 3.7c
Assumptions Used for TCE in Johnson and Ettinger Model for
Residential Scenario with Groundwater data (with Vapor Barrier): Inter-calculation Sheet
Cameron Station Site, Alexandria, Virginia

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
9.46E+08	277.4	0.321	0.238	ERROR	#N/A	#N/A	#N/A	3.00E-08	25.86	0.384	0.051	0.333	4,876

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
2.41E+04	2.46E+06	1.98E-04	200	8,509	5.89E-03	2.50E-01	1.77E-04	1.28E-02	4.50E-03	0.00E+00	3.25E-05	3.26E-04	277.4

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
200	3.28E+04	0.10	1.24E-01	1.28E-02	4.88E+02	1.22E+00	2.30E-05	7.54E-01	4.1E-06	2.0E-03

END

REPLACEMENT TABLE 3.7d
Assumptions Used for TCE in Johnson and Ettinger Model for
Residential Scenario with Groundwater data (with Vapor Barrier): Result Sheet
Cameron Station Site, Alexandria, Virginia

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (µg/L)	Indoor exposure groundwater conc., noncarcinogen (µg/L)	Risk-based indoor exposure groundwater conc., (µg/L)	Pure component water solubility, S (µg/L)	Final indoor exposure groundwater conc., (µg/L)
NA	NA	NA	1.47E+06	NA

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.3E-06	3.6E-01

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

SCROLL DOWN TO "END"

END

REPLACEMENT TABLE 3.8
Medium-Specific Exposure Point Concentration Summary (With Vapor Barrier):
Inhalation of Groundwater Contaminants by Residents
Cameron Station Site, Alexandria, Virginia

Medium: Groundwater
Exposure Medium: Air
Receptor Populations: Currrent and Future Resident

Chemical of Potential Concern	Exposure Point Concentration (Groundwater)	Units	Exposure Medium	Exposure Medium Concentration	Units	Reference for Exposure Medium Calculation
Trichloroethene	131	ug/L	Air	0.754	ug/m^3	$C_{building}$ in Table 3.7c

REPLACEMENT TABLES 5.1, 5.3, and 5.5
2012 CALCULATION OF NON-CANCER HAZARDS AND CANCER RISKS
Cameron Station Site, Alexandria, Virginia

Medium: Groundwater
Receptor Population: Current/Future Resident
Receptor Age: Adult

Exposure Route Inhalation	Chemical of Potential Concern	Exposure Point Concentration mg/m^3	Exposure Concentration (Cancer) mg/m^3	Inhalation Unit Risk (IUR) $(mg/m^3)^{-1}$	Cancer Risk (SF x Intake)	Chemical of Potential Concern	Exposure Concentration (Noncancer) mg/m^3	Reference Concentration (RfC) mg/m^3	Hazard Quotient (Intake/Rfd) Unitless
SOIL GAS									
Table 5.1	TCE Kidney w/ADAF	1.14E-05	3.4E-06	1.0E-03	3.44E-09	TCE	5.5E-06	2.0E-03	2.73E-03
	TCE NHL and liver w/ no ADAF	1.14E-05	1.9E-06	3.1E-03	5.81E-09				
(Total)					9.24E-09				2.73E-03
GW-Without Vapor Barrier									
Table 5.3	TCE Kidney w/ADAF	3.84E-03	1.2E-03	1.0E-03	1.16E-06	TCE	1.84E-03	2.00E-03	9.21E-01
	TCE NHL and liver w/ no ADAF	3.84E-03	6.3E-04	3.1E-03	1.96E-06				
(Total)					3.11E-06				9.21E-01
GW-With Vapor Barrier									
Table 5.5	TCE Kidney w/ADAF	7.54E-04	2.3E-04	1.0E-03	2.27E-07	TCE	3.6E-04	2.00E-03	1.81E-01
	TCE NHL and liver w/ no ADAF	7.54E-04	1.2E-04	3.1E-03	3.84E-07				
(Total)					6.11E-07				1.81E-01

Notes:
ADAF = age-dependent adjustment factors; GW = groundwater; NHL = non-Hodgkin lymphoma; TCE = Trichloroethene

REPLACEMENT TABLES 5.2, 5.4, and 5.6
2012 CALCULATION OF NON-CANCER HAZARDS AND CANCER RISKS
Cameron Station Site, Alexandria, Virginia

Medium: Groundwater
Receptor Population: Current/Future Resident
Receptor Age: Child

Exposure Route Inhalation	Chemical of Potential Concern	Exposure Point Concentration mg/m^3	Exposure Concentration (Cancer) mg/m^3	Inhalation Unit Risk (IUR) $(mg/m^3)^{-1}$	Cancer Risk (SF x Intake)	Chemical of Potential Concern	Exposure Concentration (Noncancer) mg/m^3	Reference Concentration (RfC) mg/m^3	Hazard Quotient (Intake/Rfd) Unitless
SOIL GAS									
Table 5.2	TCE Kidney w/ADAF	1.14E-05	2.5E-06	1.0E-03	2.50E-09	TCE	5.5E-06	2.0E-03	2.73E-03
	TCE NHL and liver w/ no ADAF	1.14E-05	4.7E-07	3.1E-03	1.45E-09				
(Total)					3.95E-09				2.73E-03
GW-Without Vapor Barrier									
Table 5.4	TCE Kidney w/ADAF	3.84E-03	8.4E-04	1.0E-03	8.42E-07	TCE	1.84E-03	2.00E-03	9.21E-01
	TCE NHL and liver w/ no ADAF	3.84E-03	1.6E-04	3.1E-03	4.89E-07				
(Total)					1.33E-06				9.21E-01
GW-With Vapor Barrier									
Table 5.6	TCE Kidney w/ADAF	7.54E-04	1.7E-04	1.0E-03	1.65E-07	TCE	3.6E-04	2.00E-03	1.81E-01
	TCE NHL and liver w/ no ADAF	7.54E-04	3.1E-05	3.1E-03	9.61E-08				
(Total)					2.61E-07				1.81E-01

Notes:
ADAF = age-dependent adjustment factors; GW = groundwater; NHL = non-Hodgkin lymphoma; TCE = Trichloroethene

REPLACEMENT TABLES 5.7, 5.8, and 5.9
2012 CALCULATION OF NON-CANCER HAZARDS AND CANCER RISKS
Cameron Station Site, Alexandria, Virginia

Medium: Groundwater
Receptor Population: Construction/Utility Worker
Receptor Age: Adult

Exposure Route Inhalation	Chemical of Potential Concern	Exposure Point Concentration mg/m^3	Exposure Concentration (Cancer) mg/m^3	Inhalation Unit Risk (IUR) $(mg/m^3)^{-1}$	Cancer Risk (SF x Intake)	Exposure Concentration (Noncancer) mg/m^3	Reference Concentration (RfC) mg/m^3	Hazard Quotient (Intake/Rfd) Unitless
Trench ACH 2/hr Table 5.7	Trichloroethene	4.10E-04	3.3E-07	4.1E-03	1.37E-09	2.3E-05	2.0E-03	1.17E-02
(Total)					1.37E-09			1.17E-02
Trench ACH 107/hr Table 5.8	Trichloroethene	7.64E-06	6.2E-09	4.1E-03	2.55E-11	4.36E-07	2.00E-03	2.18E-04
(Total)					2.55E-11			2.18E-04
Trench ACH 113/hr Table 5.9	Trichloroethene	7.23E-03	5.9E-09	4.1E-03	2.42E-11	4.1E-07	2.00E-03	2.06E-04
(Total)					2.42E-11			2.06E-04
Total Across All Exposure Routes/Pathways					1.E-09			1.2E-02

Notes:
ACH = air changes per hour

APPENDIX D

Regulatory Comments and Responses to Comments

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Response to the Virginia Department of Environmental Quality (VDEQ), Comments on the Draft Explanation of Significant Differences for Site C, Cameron Station, Alexandria, Virginia Dated August 2012; USACE Contract No. W912DR-09-D-0017, Delivery Order No. 0031

Comment Number	Comment	Response
Ms. Karen Doran, Federal Facilities Program, VDEQ / Date Comments Received: 29 November 2012		
1	*In Section 1.4, please change the VDEQ representative to Durwood Willis, Office of Remediation Programs.*	The text was revised as suggested.
2	*In Section 2.3, the last paragraph states that the selected remedy was approved by USEPA. It is our understanding that the Decision Document selecting the remedy was signed by the Army and VDEQ. Please confirm if USEPA should be changed to VDEQ.*	We confirmed the Decision Document was signed by the Army and VDEQ. The text in section 2.3 was revised to state the following: "In 1995, a groundwater pump and treat system was selected by the U.S. Army and approved by the VDEQ as the treatment technology to remove the TCE from the groundwater."
3	*Section 3.5 described the public participation aspect of the ESD. Please indicate how the public, specifically the City of Alexandria and the current residents of Cameron Station, will be notified of the public comment period. Also, please indicate the dates of the public comment period.*	The following text was added to section 3.5: "The City of Alexandria and residents of the Cameron Station Community will be notified of the availability of the ESD and the public comment period by both local newspaper (*Washington Examiner*) and the Cameron Station Community Association Newsletter. The public comment period is anticipated to occur during January -- February 2013."
Risk Assessor, VDEQ / Date Comments Received: 31 October 2012		
1	*Section 1.3.1 of the ESD presents an overview of the 2007 Risk Assessment Update. However, it should be noted that since this update the toxicity factors for the primary constituent of concern, trichloroethylene, have changed. The ESD should also discuss whether the risks would still be acceptable under current conditions at the site using the most current toxicity information*	An assessment was performed to determine how the recent toxicological changes for TCE and USEPA's inhalation guidance affect the results of the 2006 Human Health Risk Assessment (HHRA) for Cameron Station Site C. In summary, recalculated cancer risk estimates are lower in 2012 than in 2006 and the recalculated non-cancer hazard results are higher in 2012 than in 2006, but are still below target levels. Our assessment also identified and corrected a Johnson & Ettinger indoor air modeling error from the 2006 HHRA. The attached text and tables will be incorporated into the ESD to demonstrate that current site risks remain acceptable using the most current TCE toxicity information.

APPENDIX E

Public Comments and Responses to Comments

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Placeholder for Public Comments and Responses to Comments

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