



**Revitalizing Auto Communities
Environmental Response Trust**

December 6, 2011

Ms. Michelle Kaysen
USEPA Region 5
77 West Jackson Blvd
Mail Code DE-9J
Chicago, IL 60604-3507

RE: Corrective Measures Proposal
RCRA Corrective Action
Former GM Delco Plant 5 Kokomo, Indiana
USEPA ID No. IND000806844

Dear Ms. Kaysen:

Enclosed please find one paper copy and one "pdf" copy on a CD of the finalized Corrective Measures Proposal (CMP) for the captioned site. If you have any questions, or would like to discuss this submittal, please call me at the number below.

Sincerely,

Robert W. Hare, P.E. CHMM
Cleanup Manager (IL, IN, KS, MO, NJ, WI)
RACER Trust

C: Glynda Oakes, IDEM Office of Land Quality (on CD)
Howard County Health Department (on CD)
Carey Stranahan, City of Kokomo (on CD)
Glen Boise, Kokomo Howard County Plan Commission (on CD)
Kokomo Public Library (Public Information Repository) (on CD)
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RCRA Corrective Action
Corrective Measures Proposal

Former GM Delco Plant 5, Kokomo, IN

USEPA ID IND000806844

Prepared for:

RACER Trust

December 6, 2011



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RCRA Corrective Action

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Prepared for:
RACER Trust

Prepared by:

ARCADIS U.S., Inc.

Date:
December 6, 2011

Acronyms	iv
1 Introduction	1
1.1 General	1
1.2 Report Organization	2
2 Proposed Final Corrective Measures	2
3 Facility Background	3
3.1 Facility Location	3
3.2 Climate	4
3.3 Surface Water Hydrology	4
3.4 Geology and Hydrogeology	5
3.4.1 Unconsolidated Deposits	5
3.4.2 Bedrock Geology	6
3.4.3 Facility Hydrogeology	7
3.5 Water Supply	10
3.6 Groundwater Modeling	14
3.6.1 Model Code and Model Domain	14
3.6.2 Model Calibration	15
3.6.3 Model Simulations	16
3.6.4 Model Results	17
3.7 Land Use	18
3.7.1 Zoning and Land Use Patterns	18
3.7.2 Population and Housing Trends	20
3.8 Ecology	20
3.9 Summary of RFI	20
3.9.1 Pre-RFI	20
3.9.2 RFI	21
3.9.3 Summary of Risk Assessment	26

4	Summary of Corrective Measures Alternatives	26
4.1	Soil	27
4.2	Groundwater	30
4.3	Facility-Wide Management Controls	33
5	Evaluation of Corrective Measures Alternatives	34
5.1	Criteria for Evaluation of Corrective Measures Technologies	35
5.2	Sustainability Criteria	41
6	Proposed Corrective Measures	42
7	Schedule	43
8	References	44

Tables

1	Areas of Interest
2	Summary of Documents Located in Public Repository
3	Overview of Corrective Measures Alternatives
4a	Evaluation of Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor
4b	Evaluation of Soil Corrective Measure Alternatives
4c	Evaluation of Groundwater Corrective Measure Alternatives
5	Proposed Corrective Measures Endpoints Summary
6a	Summary of Costs, Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor
6b	Summary of Costs, Soil Corrective Measure Alternatives
6c	Summary of Costs, Groundwater Corrective Measure Alternatives

Drawings

1	Site Location
2	Aerial Photograph
3	Investigation Locations

4	Boundary of Proposed Well Restriction – Overlay District
5	Boundary of Area Identified for Soil Corrective Measures
6	Boundary of Area Identified for Groundwater Corrective Measures

Appendices

A	Groundwater Modeling Evaluation
B	Supplemental Information for Vapor Intrusion Criteria
C	Vapor and Groundwater Monitoring Program
D	Corrective Measures Detailed Cost Backup
E	Green Remediation Qualitative Assessment

Acronyms

AOI	Area of Interest
ASML	Above Mean Sea Level
AWC	American Water Company
bgs	below ground surface
cfs	cubic feet per second
cm/sec	centimeter/second
CMP	Corrective Measures Proposal
DOCC	Document of Current Conditions Report
ERH	Electrical Resistivity Heating
FLUTe	Flexible Liner Underground Technologies
F	Fahrenheit
ft	Feet
ft/day	feet per day
GM	General Motors Corporation
HI	Hazard Index
IAWC-NWF	Indiana American Water Company – Northwest Well Field
IAWC-SWF	Indiana American Water Company – South Well Field
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
MCL	Maximum Contaminant Level
MLC	Motors Liquidation Company
RACER	Revitalizing Auto Communities Environmental Response
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RME	Reasonable Maximum Exposure
SAA	Satellite Accumulation Area

SWWF	Significant Water Withdrawal Facility
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WH-OL	Wellhead Overlay
WR-OL	Well Restriction Overlay

1 Introduction

1.1 General

ARCADIS U.S., Inc. (ARCADIS) has prepared this Resource Conservation and Recovery Act (RCRA) Corrective Measures Proposal (CMP) on behalf of RACER Trust (RACER) for the former GM Delco Plant 5 facility located at 1723 North Washington Street, Kokomo, Indiana (Drawing 1).

The United States Environmental Protection Agency (USEPA) and General Motors Corporation (GM) entered into a performance-based RCRA Corrective Action Agreement (Agreement) in March 2006. Pursuant to the Agreement, GM had worked in cooperation with USEPA to investigate releases of hazardous wastes or hazardous constituents at or from the Former GM Delco Plant 5 (the Facility) located in Kokomo, Indiana (USEPA ID IND000806844). As a result of GM's June 2009 bankruptcy, existing, non-continuing assets remain the property of "old" GM, which changed its name to Motors Liquidation Company in its capacity as a debtor-in-possession in the bankruptcy case. On March 31, 2011 the Revitalizing Auto Communities Environmental Response (RACER) Trust became effective. On that date, all assets and cleanup funding that had been the responsibility of MLC were transferred to RACER Trust. RACER Trust has responsibility for completing the Corrective Action activities at this Facility in accordance with the Cost Estimate and Settlement Agreement that are the basis for the Trust.

GM conducted a RCRA Facility Investigation (RFI) to investigate the areas of interest (AOIs) identified in the Facility's Description of Current Conditions (DOCC) (ARCADIS, 2005a) for the presence of releases of hazardous waste or hazardous constituents that could pose an unacceptable risk to human health and/or the environment. A table presenting the AOIs investigated is presented as Table 1. The RFI was conducted in accordance with an RFI Work Plan (ARCADIS, 2005b). Supplemental data work plans for additional phases of field investigation were submitted to the USEPA (see Section 7.0 – References). The final RFI Report (ARCADIS, 2010), which incorporated comments from USEPA, was submitted by MLC on March 31, 2010. An aerial photograph of the site and surrounding area is presented as Drawing 2. A drawing showing the AOIs and the sample locations is presented as Drawing 3. Documents submitted to USEPA during the Corrective Action activities have also been provided to the public repository, Kokomo-Howard County Public Library, located at 220 N. Union Street, Kokomo, Indiana. A listing of the documents submitted to the public repository as of the date of this report is presented in Table 2.

This CMP describes the proposed Corrective Measures for the Facility. The details on the selection of the proposed Corrective Measures are provided in Section 5. USEPA will select the final Corrective Measures for the Facility after a public comment period. This CMP references information that can be found in the RFI Report (ARCADIS, 2010) and in other documents submitted to the USEPA during the RCRA Corrective Action process and are cited herein. A public repository of documents prepared as part of the RCRA Corrective Action has been maintained at the Kokomo Public Library located at 220 North Union Street, Kokomo, Indiana.

1.2 Report Organization

The remainder of this Report is organized as follows:

- Section 2 provides a summary of the proposed Corrective Measures.
- Section 3 provides a summary of the Site background information, a summary of groundwater modeling, an overview of the RFI including a summary of the areas investigated during the RFI, and a summary of the risk assessment.
- Section 4 provides a summary of the Corrective Measures alternatives.
- Section 5 provides an evaluation of the Corrective Measures against the nine corrective measures criteria and includes a sustainability evaluation.
- Section 6 presents the proposed Corrective Measures.
- Section 7 lists references identified in this report.
- Tables, figures, and appendices follow the text.

2 Proposed Final Corrective Measures

The proposed Final Corrective Measures for this Facility are discussed in detail in Section 4.1 (Soil), 4.2 (Groundwater) and 4.3 (Facility-wide) and include:

1. Implementation of land use restrictions for the entire Facility to ensure that the human health risk assessment assumptions regarding future on-site land use remain valid. Specifically, the Facility will be limited to commercial/industrial uses and groundwater use will be prohibited.

2. Implementation of a Well Restriction Overlay District to ensure that no new groundwater use wells will be installed in a designated area around the Facility.
3. Implementation of corrective measures to address soil contamination at or above a threshold treatment concentration of 400 milligrams per kilogram (mg/kg) of trichloroethene (TCE). The threshold treatment concentration was selected to 1) address areas (at and around soil borings SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775) which indicated the potential for significant future exposure via vapor intrusion, and 2) address soil that could continue to leach TCE to groundwater at a rate that would create a TCE groundwater concentration of 1,000 micrograms per liter (µg/L) or higher. Corrective measures will consist of soil treatment with calcium oxide. A Work Plan will be submitted to USEPA prior to implementation.
4. Implementation of corrective measures to address groundwater contamination at or above a threshold treatment concentration of 4,000 µg/L of TCE. Corrective measures will consist of groundwater treatment using in-situ chemical oxidation. A Work Plan will be submitted to USEPA prior to implementation.
5. Implementation of groundwater and soil gas monitoring. Selected monitoring wells and soil gas ports at and in the vicinity of the Facility will be sampled semi-annually for two years to evaluate concentration trends in groundwater and evaluate the soil gas to confirm the conclusions of the RFI that potentially significant exposure is not occurring. The number of wells/soil gas ports included and frequency of monitoring will be evaluated after two years and may be terminated or extended considering need and available funding. RACER Trust will coordinate modifications to the monitoring plan with USEPA.

3 Facility Background

3.1 Facility Location

The Facility is bounded by Butler Street to the north, beyond which are residential and industrial properties; by an abandoned industrial property to the south (former Midwest Plating Corporation); a railroad to the west, beyond which are residential and

commercial properties; and North Washington Street to the east, beyond which are residential properties.

The majority of the Facility is a vacant grass field with the exception of a 4.31-acre parking lot and abandoned road in the northern portion of the property. Figure 5 of the DOCC shows an overview of the land cover at the Facility. The abandoned road (Spraker Street) separates the parking lot on the north side of the property from the vacant grass field comprising the remainder of the property.

3.2 Climate

The Howard County climate is influenced by the Great Lakes and has a continental climate. Cool air from Canada collides with warmer air to from the south to bring changes in the climate within days and creates a variability of the seasons.

Frequent weather changes come from the passing of weather fronts and associated low and high centers of air pressure across the region. Winds are typically from the southwest, but during the winter months are dominantly from the northwest. The average daily temperature is 53.1° Fahrenheit (F). The average annual daily low temperature is 20.7° F in January. The average annual daily high temperature is 89.3° F in July.

The total annual precipitation for the county is 37.18 inches. Average annual snowfall is 23.7 inches. Average annual lake evaporation for the area is about 33 inches (United States Department of Agriculture 1971).

3.3 Surface Water Hydrology

There are no surface water bodies in the immediate vicinity of the Facility. The nearest major surface water body is Wildcat Creek, which is located approximately 1.5 miles south of the Facility and flows in a west-southwest direction.

The Wildcat Creek is a major tributary of the Wabash River in north central Indiana. Wildcat Creek consists of three main forks: North, South, and Middle, with two major tributaries: the Little Wildcat Creek and the Kokomo Creek. All forks flow in a general east-west direction through flat to gently rolling glacial plains which have been slightly modified by stream erosion (Smith 1985). Land uses of drainage basin include, cropland, pasture, forest and residential and industrial developed areas.

The Wildcat Creek is one of the principal streams flowing through the outwash aquifer in Howard County. Wildcat Creek is a gaining stream. The surface water flow in the creek is influenced by groundwater infiltration, as well as by treated sewage discharge, diversion of surface water, lowhead dams, and two reservoirs located east of Kokomo (Smith 1985). The arithmetic mean annual discharge of Wildcat Creek (USGS Station 03333700, located on Wildcat Creek near the intersection of W. Markland Ave and S. Berkley Rd) as calculated by the United States Geological Survey from 1956 to 1982 is 230 cubic feet per second (cfs), and the seven day, ten year low flow (7Q10) of the creek is 12 cfs. (<http://waterdata.usgs.gov/nwis/uv?03333600>).

3.4 Geology and Hydrogeology

The Facility is located in Howard County, Indiana and the generalized elevation is approximately 826 feet above mean sea level, with the land surface being relatively flat. The Facility is located in the Upper Wabash Basin. The Facility lies within the Bluffton/Tipton Till Aquifer System physiographic unit (Scott 2008). The topography of this unit resulted from Pleistocene time Wisconsinan glacial advances (Wayne 1996). The regional geology of the area around the Facility consists of approximately 80 feet of alluvial and glacial deposits overlying sedimentary carbonate bedrock (Fenelon 1994). The Pleistocene glacial drift is characterized by clay tills and stream deposits consisting largely of sand and gravel. The discontinuous sand and gravel deposits are interspersed within the clay tills (Smith 1985).

3.4.1 Unconsolidated Deposits

According to the United States Department of Agriculture (USDA) *Soil Survey of Howard County*, the soil type at the Facility is classified as the Crosby Series and specifically the Crosby silt loam. The Crosby Series is described as poorly drained soils that formed in thin deposits of loess and in underlying glacial till. Runoff is very slow with a 0 to 2 percent slope. Typically, this soil has a high water capacity and a low permeability.

Geologic cross-sections and a cross-section reference drawing are presented as Drawings 3 through 6 of the RFI Report. Three sand units separated by clay layers have been identified at the Facility and have been designated units S1 through S3, with unit S1 being the shallowest and unit S3 being the deepest.

Sand unit S1 is the uppermost continuous water-bearing unit, and consists primarily of sand and gravel. Groundwater within the S1 unit is under confined conditions. The S1

unit is generally encountered between approximately 10 to 25 ft below ground surface (bgs) (816 to 801 ft AMSL), and ranges in thickness from 1 ft near the southeastern margins of the investigated area and 35 ft near the center of the former operations area. Refer to cross sections provided on Drawings 4 and 6 of the RFI Report, and the isopach map of the S1 unit provided on Drawing 7 of the RFI Report.

Underlying the S1 unit is a hard clay (till), which has an approximate range in thickness of 10 to 40 ft. Underlying this hard clay (till) is the S2 unit, which is comprised of poorly sorted sands and gravels, and is generally encountered at 50 ft to 55 ft bgs. The S2 unit is fully saturated, and under confined conditions. The S2 unit ranges in thickness from 20 ft near the center of the Facility to 1.5 ft near the southeastern margins of the investigated area. The S2 unit ultimately pinches out, and is not present south of the Facility. Refer to cross sections provided on Drawings 4, 5, and 6 of the RFI Report and the isopach map of the S2 unit provided on Drawing 7 of the RFI Report.

The S3 unit is a deeper water-bearing unit that sits directly on top of the carbonate bedrock and is found exclusively in the northern portion of the investigated area at MW-0501-S3U. The S3 unit is separated from the S2 unit by 9 ft of a hard gray clayey silt, and is encountered at a depth of approximately 85 ft, with a thickness of 7 ft.

The potentiometric surface at the Facility is located at approximately 812 ft AMSL in the S1 unit and 808 ft AMSL in the S2 and S3 units (Refer to Drawings 9 through 11 of the RFI Report).

In addition to the sand units discussed above, several discontinuous pockets of sand were identified at various depths at the Facility. In general, these discontinuous sands were present either above the S1 unit (monitoring wells set within this upper discontinuous sand have a suffix "P1" assigned to the monitoring well identification) or between the S1 and S2 units (monitoring wells set within this intermediate discontinuous sand have a suffix "I2" assigned to the monitoring well identification). Examples of these discontinuous sand units can be seen on cross-sections provided on Drawing 4 of the RFI Report.

3.4.2 Bedrock Geology

Bedrock is encountered at a depth of approximately 85 ft bgs (741 ft AMSL) on the northern part of the Facility and approximately 60 ft bgs (766 ft AMSL) immediately south of the Facility. The bedrock surface continues to rise closer to the ground surface as you move south towards Wildcat Creek (see Drawing 8 of the RFI Report).

Based on a review of available literature, the regional bedrock at the Facility is limestone and dolomite in the Wabash Formation of the Silurian System (Drawing 8 of the RFI Report). The thickness of the limestone and dolomite is approximately 375 feet thick (Fenelon 1994). Regionally, the Wabash limestone and dolomite has a sharp basal contact with underlying limestone and interbedded shale of the Ordovician System. Site-specifically, the presence of a weathered bedrock zone consisting of mechanically fractured parent limestone angular clasts imbedded and cemented within a lime mud matrix is encountered at the interface between the unconsolidated deposits and the bedrock. Throughout the Facility, the weathered bedrock zone ranges from 3 ft to 49 ft in thickness and is encountered at an elevation varying between 754 and 768 ft above mean sea level (AMSL). Based on boring logs from the Facility, water supply well records, and available literature, the local bedrock beneath the Facility is the Kokomo Limestone Member of the Wabash Formation. Characteristically, this dolomitic limestone is micritic with alternating thin bands of light gray and tan laminations. Across the Facility, interformational breccias have been observed that consist of vuggy limestone with increased fossilization that includes coral and sponge relicts and clasts. These features are associated with shallow subtidal to intertidal depositional environments (Tollefson 1979). These features can be readily identified in the rock core obtained and documented in the bedrock boring log from MW-0616-B1A. In general, it has been observed that the weathered bedrock zone exhibits increased fractures, crevices, and dissolution weathering features along joints and bedding planes, but the dolomitic limestone becomes increasingly competent (massive) and less vuggy with increased depth. These observations indicate that the majority of the hydrologic transmissivity is associated with the weathered, upper bedrock zone. This observation was confirmed by a series of hydrogeologic investigations that were performed, from August 2007 to November 2008, in order to identify major hydraulic pathways within the upper bedrock unit (discussed in more detail in Section 3.4.3).

3.4.3 Facility Hydrogeology

Regional groundwater flow in the unconsolidated saturated sand units is generally southeast towards Wildcat Creek in S1, and is divided and flows both south and northwest in S2. The divided nature of groundwater flow in the S2 unit represents a change in condition since the RFI, when groundwater flow in the S2 unit was southeast. A public water supply well field known as the northwest well field (IAWC-NWF) is located approximately 1.5 miles northwest (upgradient) of the Facility. The IAWC-NWF, which began operating in 2007, and has wells screened in the S2 and S3 sand units, appears to have an influence on groundwater flow at the Facility. Within

the S1 and S2 sand units, the groundwater is under confined conditions due to the overlying clay till deposits.

The local potentiometric surface in the S1 unit is presented on Drawing 9 of the RFI Report. These groundwater elevation contour maps are based on depth to water measurements collected on March 8, 2007, November 11, 2008, February 17, 2009 and July 12, 2009, and illustrates the potentiometric surface of the first encountered saturated confined sand and gravel unit (unit S1). These potentiometric surface maps suggest that groundwater within the S1 unit flows toward the southeast. The S1 potentiometric surface at the Facility ranges from approximately 812 ft AMSL (November 11, 2008) and 817 ft AMSL (December 5, 2006). The local potentiometric surface in the S2 unit is presented on Drawing 10 of the RFI Report and is based on groundwater level measurements collected on March 8, 2007, November 11, 2008, February 17, 2009 and July 12, 2009. Sand unit S2, the second encountered saturated confined sand and gravel unit, has a shallow gradient, and has historically demonstrated a groundwater flow direction toward the southeast, as is illustrated in March 8, 2007. However, since November 11, 2008, the potentiometric surface suggests that groundwater flow within the S2 unit is divided and flows both south and northwest. The S2 unit potentiometric surface at the Facility ranges from 808 ft AMSL (November 11, 2008) to 816 ft AMSL (March 8, 2007). Regional groundwater flow within the bedrock unit is generally southeast towards Wildcat Creek. Potentiometric surface maps for the bedrock unit are provided as Drawing 11 of the RFI Report and are based on groundwater level measurements collected on March 8, 2007, November 11, 2008, February 17, 2009 and July 12, 2009.

An evaluation of groundwater uses at and in the vicinity of the Facility was performed and submitted to USEPA in April 2009 (Appendix F of the RFI Report). The evaluation included discussions of significant water withdrawal facilities relative to contaminant delineation and flow characteristics.

Based on the variable hydraulic gradient observed in sand unit S2, a groundwater potentiometric surface study was conducted at the Facility using pressure transducers placed within three monitoring well nests. Based on the results of the study (Appendix E of the RFI Report), groundwater flow direction in the S2 sand unit at the Facility flows from a divide in the central portion of the Facility toward the south and varying from the northeast to northwest. The northern flow components that were observed between the March 2007 and November 2008 monitoring events is believed to result from pumping activities at the municipal well field located to the northwest of the Facility that began pumping in April 2007.

The hydrogeologic characteristics beneath the Facility have been assessed using data collected from a variety of field investigation techniques coupled with available published literature. From 1979 through 1982, the United States Geological Survey (USGS) completed a study of the availability of water from the confined sand and gravel units beneath Howard County (Smith 1985). The USGS averaged a total of 54 hydraulic conductivities in Howard County for an average hydraulic conductivity of 200 feet per day (ft/day), based on lithologic data (Smith 1985).

In November 2006, ARCADIS conducted slug tests on select monitoring wells to evaluate the saturated hydraulic conductivity of the S1, S2 and B1 units. The data collected was analyzed using AQTESOLV® aquifer test analysis software. The Bower and Rice and Butler 1998 methods were used to estimate hydraulic conductivity of the tested units. The estimated hydraulic conductivity for the S1 unit ranged from 4.91×10^{-3} centimeters per second (cm/sec) (13.9 ft/day) to 4.70×10^{-2} cm/sec (133 ft/day). The average hydraulic conductivity of the S1 unit was 2.97×10^{-2} cm/sec (84.1 ft/day) and was generated by calculating the average of all test results (see Table 3.4.1 of the RFI Report). This hydraulic conductivity suggests well sorted sands and glacial outwash (Fetter 1994).

The estimated hydraulic conductivity for the S2 unit ranged from 6.09×10^{-4} cm/sec (1.73 ft/day) to 1.01×10^{-1} cm/sec (288 ft/day). The average hydraulic conductivity of the S2 unit was 4.84×10^{-2} cm/sec (137 ft/day) and was generated by calculating the average of all test results (Table 3.4.1 of the RFI Report). This hydraulic conductivity suggests well sorted sands and glacial outwash to silt, sandy silts and clayey sands (Fetter 1994).

The estimated hydraulic conductivity for the B1 unit ranged from 1.53×10^{-3} cm/sec (4.35 ft/day) to 4.85×10^{-2} cm/sec (138 ft/day). The average hydraulic conductivity of the B1 unit was 1.95×10^{-2} cm/sec (55.3 ft/day) and was generated by calculating the average of all test results (Table 3.4.1 of the RFI Report). This hydraulic conductivity is consistent with that of carbonate rocks.

Using historic groundwater elevation data, the hydraulic gradient beneath the Facility has been estimated and is provided in Table 3.4.1 of the RFI Report. Estimated total volume discharge (per unit width of saturated unit) and groundwater flow velocity is calculated and provided in Table 3.4.1 of the RFI Report for each of the abovementioned hydraulic conductivities.

In order to identify major hydraulic pathways within the limestone bedrock, an additional series of aquifer tests were designed and performed from August of 2007 through August of 2008 on the following open bedrock boreholes: MW-0503-B1a, MW-0615-B1a, MW-0616-B1a and MW-0701-B1a. These tests involved the use of packer interval testing and Flexible Liner Underground Technologies (FLUTe) hydraulic profiling techniques. Details of both the packer interval testing and FLUTe hydraulic profiling, along with the results obtained, were presented in a series of technical memorandums sent to the USEPA (*Evaluation of Packer Testing versus FLUTe Hydraulic Profiling* (ARCADIS 2007d), *Vertical Profiling of Flow Zones and Groundwater Contaminant Concentrations in Bedrock* (ARCADIS 2008a), *Open Borehole Installation and Transmissivity Testing* (ARCADIS 2008c), and *Open Borehole Installation, Transmissivity Testing, and Isolated Packer Sampling* (ARCADIS 2008d)). Based on the data collected between August 2007 and November 2008, the following zones were identified as potential groundwater flow pathways:

- MW-0503-B1A demonstrated relatively greater hydraulic conductivity in the following zones: 85.7 ft to 90 ft bgs, 122 ft to 127ft bgs, and 146 ft to 152 ft bgs,
- MW-0615-B1A demonstrated relatively greater hydraulic conductivity in the following zones: 80 ft to 90 ft bgs, 93 ft to 103 ft bgs, and 103 ft to 113 ft bgs,
- MW-0616-B1A demonstrated relatively greater hydraulic conductivity in the following zones: 110 ft to 117 ft bgs, 117 ft to 127 ft bgs, 127 ft to 137 ft bgs, and 137 ft to 150 ft bgs, and
- MW-0701-B1A demonstrated relatively greater hydraulic conductivity in the following zones: 88 ft to 98 ft bgs and 98 ft to 108 ft bgs.

A summary of hydrogeologic data at the Facility (i.e. hydraulic conductivity, gradient and calculated groundwater flow velocities) is provided as Table 3.4.1 of the RFI Report. Additionally, a table summarizing vertical gradients between selected monitoring well pairs (i.e. S1 unit to S2 unit and S2 unit to B1 unit) is provided as Tables 3.4.2 and 3.4.3 of the RFI Report.

3.5 Water Supply

Groundwater is not currently used at the Facility for potable or non-potable purposes. The expected future use of groundwater at the property is consistent with the current

use and will be maintained via a deed restriction placed on the property and the establishment of a Well Restriction Overlay (WR-OL) District for the area, if possible. The WR-OL District is established and enforced by the City of Kokomo to protect the community from groundwater contaminated with chemicals. The WR-OL District restricts the drilling of water wells that may bring contaminated groundwater to the surface. These two controls (deed restriction and WR-OL District) are components of the proposed Corrective Measures.

A review of the available water well records maintained by the Indiana Department of Natural Resources (IDNR) was conducted during the RFI to identify any wells in the area surrounding the Facility. All available well construction logs were examined. The search included both low capacity wells (<70 gallons per minute [gpm]) and high capacity wells (>70 gpm) within a 1/2-mile radius. Subsequently a separate review was conducted during preparation of a groundwater model, which included a review of significant water withdrawal facilities (SWWFs) within Cass, Howard and Miami Counties. Additional information regarding the SWWFs during the model preparation is presented in Appendix A.

A total of ten water well records were identified within a ½ mile radius of the Facility. Five of the ten were identified as low capacity wells, and the other five are classified as high capacity wells. Complete details including water well locations and current status (i.e., active, inactive, etc) of identified water wells is provided as Appendix C of the RFI Report. The following is a summary of the known status of currently identified water wells:

- All five of identified low capacity water wells are known to be abandoned, no longer utilized, or used for manufacturing purposes only.
- Two of the five identified high capacity water wells are known to be utilized for manufacturing purposes only.
- The status (i.e., active or inactive) for three of the five high capacity wells is not currently known; however, the following information is known:
 - o Based on records provided by Indiana American Water Company (AWC) (municipal water supplier for the City of Kokomo), the property where high capacity water well 168105 is located, receives a water bill. Further, the approximate location of this water well is 1,200 ft southwest of the Facility. The total depth of the well is 360 feet, with

casing installed to a depth of 65 feet and the remaining 295 feet consisting of open borehole. No information was found regarding the depth at which the pump is set, but is likely set at a depth greater than 70 feet. The identified depth of groundwater impacts identified during the RFI was approximately 40 feet. Because the casing depth is greater than the depth of impacts and the well is located over 1,000 feet from the Facility, no further investigation is warranted at this time regarding this high capacity water well.

- o High capacity water well 127486 is believed to be located approximately 1,500 to the northeast of the Facility. The total depth of the well is 160 feet, with casing installed to a depth of 85 feet and the remaining 75 feet consisting of open borehole. No information was found regarding the depth at which the pump is set, but is likely set at a depth greater than 90 feet. The identified depth of groundwater impacts identified during the RFI was approximately 40 feet. Because the casing depth is greater than the depth of impacts and the well is located over 1,000 feet from the Facility, no further investigation is warranted at this time regarding this high capacity water well.
- o High capacity water well 127556 is believed to be located approximately 1,200 ft to the east of the Facility. The total depth of the well is 523 feet, with casing installed to a depth of 83.5 feet and the remaining 439.5 feet consisting of open borehole. No information was found regarding the depth at which the pump is set, but is likely set at a depth greater than 85 feet. The identified depth of groundwater impacts identified during the RFI was approximately 40 feet. Because the casing depth is greater than the depth of impacts and the well is located over 1,000 feet from the Facility, no further investigation is warranted at this time regarding this high capacity water well.

In addition to reviewing available records maintained by the IDNR, the following additional steps were completed to determine water uses in the vicinity of the Facility:

- Visually inspected 124 properties surrounding the Facility for the presence of a water well,
- Contacted the AWC to determine whether the 124 inspected properties received water bills, and

- Completed additional visual inspections at properties identified as not receiving water bills.

The following summarizes the results of these activities:

- 123 of the 124 inspected properties were either confirmed to be receiving a water bill from AWC or were determined to be a vacant lot.
- The one remaining location (1936 North Washington Street (The Beetle Shop)) was identified as not receiving a water bill from AWC. Several attempts to contact the Beetle Shop were made, but no response to-date has been received. However, based on conversations with a neighboring property owner, it is believed that this address is rarely occupied and is used primarily as storage. Additionally a water meter was noted in front of this building. Based on this property's proximity to the Facility and known groundwater impacts, the fact that no record of a registered water well (high or low capacity) with the IDNR is associated with this property, and the additional information gathered, no further investigation is warranted at this time regarding water use at this property.

Two municipal well fields were identified at a distance greater than ½-mile from the Facility. The south well field (IAWC-SWF) is located approximately 1.2 miles southeast (downgradient) of the facility and the northwest well field (IAWC-NWF) is located approximately 1.5 miles northwest (upgradient) of the Facility. The northwest well field, which began operating in 2007 and has wells screened in the S2 and S3 sand units, appears to have an influence on groundwater flow in the S2 and S3 units at the Facility. Pre-2007 groundwater flow direction in the S2 unit in the vicinity of the Facility was to the south.

Based on communication with the IDNR, the Facility is not located within a wellhead protection area (IDNR 2009). Based on communication with the AWC, the Facility is not within the 5-year or 10-year time of travel for either of the two municipal water well fields in Kokomo (see Drawing 1 of the RFI Report for these municipal well field locations).

A water tower was previously located on-site; however, there is no evidence of a historical water supply well on-site and no construction logs are available. Most likely, water from the water tower, including potable water, was supplied by AWC. A

combined sanitary/storm sewer system is located along North Washington Street; however, the Facility does not currently generate sanitary wastewater.

3.6 Groundwater Modeling

A groundwater flow and solute transport model was developed as part of the corrective measures study for the Facility. Specific objectives of the groundwater flow and solute transport model were to:

1. Estimate the migration distance of existing site-related concentrations of trichloroethene (TCE) and its breakdown products in the groundwater at concentrations exceeding MCLs. This analysis served as the basis for refining the area that will be proposed for a WR-OL District, which is one of institutional controls proposed for groundwater management at the Facility.
2. Evaluate the potential future contribution of the Facility groundwater, if any, to the well fields.

3.6.1 Model Code and Model Domain

The code MODFLOW, a publicly available groundwater flow simulation program developed by the United States Geological Survey (USGS; McDonald and Harbaugh 1988), was selected to develop the groundwater flow model. The code MT3D (Zheng and Wang 1999) was used for the solute transport simulations. Both MODFLOW and MT3D are thoroughly documented; widely used by consultants, government agencies, and researchers; and are consistently accepted in regulatory and litigation proceedings. In addition, MODPATH (Pollock 1989) was also utilized in the modeling effort to conduct well field capture zone analysis. MODPATH is a particle tracking post-processing package that was developed for three-dimensional flow paths using output from groundwater flow simulations. It uses a semi-analytical tracking scheme that allows an analytical expression of the particle's flow path to be obtained within each finite-difference grid cell. MODPATH is one of the most widely-used particle tracking programs in delineating capture zones.

The numerical model consists of 201 rows, 272 columns, and eight layers which covers an area of approximately 9 miles by 20 miles. The model row and column widths vary throughout the model domain, with cell size being 50 ft by 50 ft in the vicinity of the city of Kokomo, and expanding to 500 ft by 500 ft towards the periphery of the model (Appendix A Figure A-11). This areal extent is considered sufficient to

evaluate the regional flow regime for the objectives of this model, based on: 1.) the significant influence of hypothetical groundwater pumping modeled by Smith et. al., where drawdown was predicted to extend up to 4 miles from a pumping well, and, 2.) the distance to available stream boundary conditions, Deer Creek and Wildcat Creek, to the north and south, respectively. Vertically, there are eight layers in the numerical model. Layer elevations are based on saturated unit (S1, S2 and S3 units) and bedrock topography and thickness from Smith et al. (1985). The layer elevations were adjusted from those in Smith et al. in the vicinity of the Facility based on site-specific information.

3.6.2 Model Calibration

A flow model calibration for steady-state conditions was conducted to quantitatively match simulated potentiometric heads within each saturated unit (S1, S2, S3 and B1) to observed values presented in Smith et al. (1985). Residual statistics for the calibrated groundwater flow model indicate an acceptable agreement between simulated and measured groundwater elevations. Further, the flow model was calibrated under transient conditions using heads and gradients within each saturated unit (S1, S2 and S3) collected during the potentiometric study completed while the IAWC-NWF was operational (ARCADIS 2009). Finally, a qualitative solute model calibration was completed by comparing the distribution of TCE and cis-1,2-dichloroethene (cis-1,2-DCE) following 30 years of simulated transport with an initialized TCE plume in S1, based on the groundwater flow velocities of steady-state flow model (which excludes the effects of pumping at the IAWC-NWF), with the current observed distribution of each constituent (June 2009 conditions). Solute transport parameters were adjusted to match observed and predicted TCE and cis-1,2-DCE plume footprints and approximate concentrations. Calibrated transport parameters are summarized in Appendix A Table A-4. The details regarding the groundwater flow and solute transport model calibration are discussed in Appendix A.

Note that vinyl chloride has been detected at concentrations exceeding its MCL in groundwater samples collected from onsite and offsite monitoring wells. The maximum detected vinyl chloride concentrations are 150 µg/L, 4.1 µg/L and 3.6 µg/L, in units S1, S2 and B1, respectively. The relatively high vinyl chloride concentrations are measured in S1 unit only, where COC plumes are expected to be relatively stable. The majority of the COC transport is expected to occur in unit S2, where the detected concentrations of vinyl chloride are low compared to those of TCE and cis-1,2-DCE in S2 unit, indicating that the degradation of cis-1,2-DCE to vinyl chloride is not significant in S2 unit. Accordingly, as a conservative approach, degradation of cis-1,2-DCE to vinyl

chloride was included using a relatively long half-life (i.e. slow degradation rate), which would not result in significant vinyl chloride concentrations. This agrees with the available data, as concentrations of vinyl chloride have not been observed in the S2 unit greater than 4.1 ug/l.

3.6.3 Model Simulations

Once the groundwater flow and solute transport models were calibrated, predictive solute fate and transport simulations were completed to evaluate the migration of both TCE and cis-1,2-DCE in response to pumping at the IAWC-NWF. Major solute transport parameters that will affect TCE and cis-1,2-DCE migration distance include: TCE source area initial concentrations, retardation factors for TCE and cis-1,2-DCE, half lives of TCE and cis-1,2-DCE, and IAWC-NWF pumping rates. To assess the sensitivity of these parameters and provide a conservative basis to estimate the WR-OL District, six model simulations were conducted for 50 years to represent six different scenarios, as summarized below (Table A-4 in Appendix A provides the major fate and transport input parameters for each scenario.):

- Scenario 1: Calibrated Solute Transport Parameters and IAWC-NWF Pumping at Average Rates
- Scenario 2: Reduced Retardation Factors and IAWC-NWF Pumping at Average Rates
- Scenario 3: Reduced Retardation Factors, No Degradation of cis-1,2-DCE, and IAWC-NWF Pumping at Average Rates
- Scenario 4: Reduced Retardation Factors, No degradation of cis-1,2-DCE, Reduced Source Concentration, and IAWC-NWF Pumping at Average Rates
- Scenario 5: Reduced Retardation Factors, No degradation of cis-1,2-DCE, Increased TCE Half-Life, and IAWC-NWF Pumping at Average Rates
- Scenario 6: Reduced Retardation Factors, No degradation of cis-1,2-DCE, and IAWC-NWF Pumping Rates Doubled

3.6.4 Model Results

The model results for each scenario are discussed in detail in Appendix A, Section 6. In general, groundwater migration distance and the potential impact of TCE and cis-1,2-DCE contaminated groundwater on the two well fields located within the migration pathway : IAWC-NWF and Syndicate Sales, Inc. well field, were discussed for each scenario. The modeling results indicate that the extents of the impacted groundwater above the MCLs do not reach the model-simulated 5-year travel time boundary for five of the six modeled scenarios, with the exception of Scenario 5. Scenario 5, which had an increased half-life of TCE (5 years versus 2 years) and used the average pumping rates for the IAWC-NWF, predicted groundwater containing TCE concentrations greater than its MCL will migrate approximately 1,700 ft past the model-simulated 5-year travel time boundary, and extend approximately 800 ft into the established Wellhead Overlay (WH-OL) District. Scenario 4, which simulates a 79 % on-site source reduction due to the proposed soil treatment and used the average pumping rates for the IAWC-NWF, is the most likely scenario to occur at the Site. It is predicted that groundwater at TCE and cis-1,2-DCE concentrations greater than their respective MCLs would migrate approximately 720 and 700 ft, respectively, past the model-simulated 10-year travel time boundary in the S2 unit. No exceedance of TCE and cis-1,2-DCE is expected at the existing WH-OL. In addition, the predicted plume extents for TCE and cis-1,2-DCE do not migrate beyond the Kokomo city limits (Figure A-43 through A-46).

Furthermore, the modeling results show that groundwater from the Facility will not reach the IAWC-NWF at concentrations above MCLs for TCE and/or cis-1,2-DCE for any of the scenarios. The modeling results also indicate that (1) TCE impacted groundwater at concentrations slightly exceeding its MCL will migrate in sand unit S2 past the Syndicate Sales, Inc. well field in 5 scenarios of the 6 scenarios evaluated; and (2) cis-1,2-DCE impacted groundwater is expected to migrate in sand unit S2 past the Syndicate Sales, Inc. at concentrations slightly greater than its MCL in 4 scenarios of the 6 scenarios evaluated. However, model simulation results for all 6 scenarios demonstrate that no exceedance of TCE and/or cis-1,2-DCE impacted groundwater is predicted in the deeper bedrock B1 aquifer at and in the vicinity of the Syndicate Sales, Inc. well field, indicating that the influence of impacted groundwater migration from the sand unit S2 to the bedrock B1 unit is not significant. Therefore, groundwater extracted at Syndicate Sales, Inc. well field is not expected to be impacted with TCE and cis-1,2-DCE, due to the fact that Syndicate Sales, Inc. well field is screened in the bedrock unit B1.

The primary objective of the numerical modeling effort was to provide the basis to delineate the WR-OL District. The proposed WR-OL District was defined as the envelope curve that encompasses the extents of model-simulated TCE and cis- 1,2 -DCE plumes in the S1 and S2 units for the most likely case, which is the 79% source reduction simulated in Scenario 4 , plus an additional 100 ft outward in all directions to provide a buffer zone. The buffer zone is less than 100 ft along the northwest extent of the WR-OL to keep it within the Kokomo city limits, which would simplify the permitting process. It is important to note that the model predicted TCE and cis-1,2-DCE plumes in the S2 unit for Scenario 4 do not extend beyond the Kokomo city limits in the northwest direction (Appendix A Figures A-43 and A-46). The proposed WR-OL District (shown on Drawing 4) is intended to prevent water supply wells from being installed within areas where TCE and/or cis -1,2 -DCE may exceed their respective MCLs based on the modeling results.

3.7 Land Use

The Facility is situated in an area zoned for medium intensity industrial use and is zoned MI (Moderate Intensity Industrial/Light Manufacturing). The Facility's future use is expected to remain consistent with the current use and will be maintained via a deed restriction placed on the property. The current zoning designation for the Facility and surrounding area is presented on Drawing 1c of the RFI Report. The deed restriction is a component of the proposed Corrective Measures.

As discussed in Section 1.2.1, the Facility occupies approximately 10.5 acres on the northern-side of Center Township in Howard County.

The land use patterns at and around the Facility; trends in population and development; the City's Comprehensive Plan for this area; and the implications of these factors for future land use at and around the Facility are discussed in the following Sections. The City of Kokomo Comprehensive Plan is depicted in Drawing 1d of the RFI Report.

3.7.1 Zoning and Land Use Patterns

Zoning in Center Township is divided into 17 districts, which include classes of industrial, commercial, dwelling, agricultural, institutional, and parks. Drawing 1c of the RFI Report shows the zoning districts for the Facility and surrounding area. The zoning districts are defined in the City of Kokomo Zoning Ordinance (City of Kokomo,

Zoning Ordinance, No. 6279). The Facility is zoned as a *Moderate Intensity Industrial/Light Manufacturing* zoning district.

The area immediately surrounding the Facility includes the following industrial, commercial, dwelling, and special use zoning districts:

North of the Facility: Small to Large Scale General Commercial, Low Intensity Industrial/Business Park, and High Density Urban Residential.

East of the Facility: Small to Medium Scale General Commercial, Medium Density Urban Residential, Low Intensity Industrial/Business Park, Moderate Intensity Industrial/Light Manufacturing.

South of the Facility: Small to Large Scale General Commercial, Moderate Intensity Industrial/ Light Manufacturing, Medium Density Residential, General Multifamily Residential, and Neighborhood Commercial.

West of the Facility: Medium to High Density Urban Residential, Mobile Home Park, Small to Large Scale General Commercial, Low Intensity to High Intensity Industrial/Heavy Manufacturing.

The diverse range of properties surrounding the Facility, discussed in Section 3.1, is consistent with the current zoning districts. The City of Kokomo Comprehensive Plan identifies different areas of the City of Kokomo, and Center Township, as having different land use goals for future development and use, (City of Kokomo, *City of Kokomo Comprehensive Plan* 2001). As shown in Drawing 1d of the RFI Report, the Facility predominantly lies within a Heavy/Medium Industrial Development Area, which designates uses that manufacture or assemble products and that typically have moderate to significant traffic, environmental, or aesthetic impact on the surrounding areas.

Within the immediate vicinity of the Facility there are a variety of major transportation corridors, which include major roadways and an active railway. North Washington Street is a four lane road which runs north-south on the eastern border of the Facility. North Davis Avenue borders the Facility to the west and runs northwest-southeast, and is a two lane road. There is an active rail line that runs parallel to North Davis Avenue and borders the Facility to the west. Although such high traffic transportation corridors are unattractive to residential development, they provide essential support to industrial use of the area at and around the Facility.

3.7.2 Population and Housing Trends

Center Township experienced its largest recorded growth period between 1900 and 1920. Center Township's population increased markedly between 1940 and 1960, while the 1990 population in Center Township saw a marked drop in comparison to the 1970 population. Between 1970 and 1990, the Township's population decreased by about 12%. However, between 1990 and 2000 the Township's population stabilized and weakly rebounded with 1% growth. Overall, the Township experienced a 25% increase in population between 1940 and 2000. The following shows the population trend in Center Township from 1940 to 2000.

Year	Population	Change	% Change
1940	36,125		
1950	42,435	6,310	15%
1960	51,393	8,958	17%
1970	53,282	1,889	4%
1980	52,504	-778	-1%
1990	47,354	-5,150	-11%
2000	47,619	265	1%

Population data obtained from: <http://www.stats.indiana.edu/topic/population.asp>

3.8 Ecology

An Ecological Habitat Characterization was conducted for the Facility and was presented in Appendix E of the DOCC. The assessment included a site visit and a review of historical analytical data. A habitat assessment decision matrix was developed to identify those areas at the Facility that may provide terrestrial and aquatic habitats. Based on the evaluation, the site does not provide potential habitat for wildlife and no further evaluation of ecological risks were conducted.

3.9 Summary of RFI

3.9.1 Pre-RFI

As described in the DOCC, a screening evaluation was performed using data collected during investigations previously performed at the Facility. The analytical results were compared to conservative screening criteria to determine the need for additional investigation or evaluation. Based on the results of the screening evaluation, further

investigation was proposed in four (4) AOIs at the Facility and no further action or investigation was proposed for three (3) AOIs

The following AOIs were identified in the DOCC as requiring no further action or investigation:

- AOI 1 - Off-Site Drums
- AOI 3 - Former South Manufacturing Building Satellite Accumulation Area (SAA)
- AOI 4 - Former East Manufacturing Building SAA

As discussed in the DOCC, investigative activities were not originally proposed/completed within AOI 3 during Phase I and Phase II RFI activities. Based on data obtained in Phase I and Phase II activities, it was determined that data were needed from within the footprint of the Former North and South Manufacturing areas. Data collected as part of characterizing the Former North and South Manufacturing area, while currently assigned to AOI 3, may not be indicative of environmental impacts associated the historic satellite accumulation area which is defined as AOI 3.

3.9.2 RFI

The following AOIs were identified in the DOCC and the RFI Work Plan as requiring further investigation:

- AOI 2 – Fill Area
- AOI 5 - Former Hazardous Waste Storage Area
- AOI 6 - Former Waste Pile
- AOI 7 - Northern Portion of Former East Manufacturing Building
- Downgradient

The rationale for further investigation was discussed in the DOCC. During the RFI field investigation, additional investigation was recommended at AOI 3 and Upgradient. The RFI field investigation; therefore, included 7 AOIs. As discussed in Section 4.9 of the RFI Report, soil and groundwater were also investigated at the Former Midwest Plating facility during the RFI. The results of the RFI investigation indicate that groundwater contamination at the Former Midwest Plating facility is not related to activities at the former Kokomo Plant 5 Facility.

The objective of the RFI field investigation was to determine whether a significant release of hazardous constituents to the environment has occurred from the AOIs being investigated. Based on the results of the initial phase of the RFI field investigation, three additional phases of field investigation were conducted to characterize the nature and extent of the releases found during the initial phase. The findings from the first three phases of investigation were provided to USEPA (ARCADIS 2006b, 2007b) and reviewed with USEPA to determine the scope of the next phase of field investigation. The findings from all four phases of the RFI field investigation (including Phase IV), are discussed in Section 4 of the RFI Report. Details of these investigations are presented in the RFI Report and summarized in the following subsections.

Upgradient Groundwater Evaluation

The Upgradient investigation activities consisted of four monitoring wells (MW-0501-P1, MW-0501-S2, and MW-0501-S3U) installed upgradient from the former Facility operations. Vinyl chloride was detected above the drinking water criteria in a groundwater sample collected during Phase II RFI activities at monitoring well MW-0501-P1. Vinyl chloride was not detected at any of the four monitoring wells at concentrations above the groundwater screening criteria during Phase III or after Phase IV of the RFI. The RFI Report concluded that the data collected meets the objectives of the RFI and adequately characterizes soil and groundwater upgradient of the former operations area. The groundwater data collected during the RFI indicated that concentrations in groundwater are stable. Detected concentrations in the monitoring wells did not exceed the drinking water criteria.

AOI 2

The scope of the RFI work completed at AOI 2 involved the sampling of an existing monitoring well (MW-0103-S1U) during Phases II and IV of the RFI to evaluate shallow groundwater quality in AOI 2. TCE, cis-1,2-DCE and vinyl chloride were detected above their respective drinking water criteria during the RFI at AOI 2. Downgradient from AOI 2, TCE, cis-1,2-DCE and vinyl chloride are bounded by monitoring wells that do not have concentrations higher than their respective drinking water criteria. The RFI Report concluded that the data collected meets the objectives of the RFI and adequately characterizes groundwater at and around AOI 2. The groundwater data collected during the RFI indicated that concentrations in groundwater are stable in this area.

AOI 3

Investigative activities were not originally proposed or completed within AOI 3 during Phase I and Phase II RFI activities; because historic information (as detailed in the DOCC) indicated no additional investigation was warranted. One soil boring (SB-0506) was advanced west of AOI 3 during Phase I to collect metals background data. Six additional soil borings (SB-0622 through SB-0627) were advanced as part of Phase II of the RFI to delineate lead and volatile organic compounds (VOC) concentrations from the original background soil boring and a pre-RFI soil boring. Additionally, three monitoring wells installed during Phase II of the RFI (MW-0605-S1, MW-0605-S2 and MW-0605-B1) and originally associated with AOI 5 were reassigned to AOI 3 for data evaluation. Based on data obtained during Phase I and Phase II activities at nearby AOIs, it was determined that data was needed from within the footprint of the Former North and South Manufacturing areas. The scope of Phase III of the RFI included the installation of nine soil borings, collection of borehole water samples from three of the nine soil borings, and the installation and sampling of six monitoring wells. The scope of Phase IV of the RFI included the advancement of 102 soil borings in and around the Former North and South Manufacturing areas. It should be noted that data collected as part of characterizing the Former North and South Manufacturing area (during Phase III and Phase IV activities) while currently assigned to AOI 3 and encroaching into AOI 2, may not be indicative of environmental impacts associated the historic satellite accumulation area which is designated as AOI 3.

Lead, TCE, PCE, cis-1,2-DCE, methylene chloride and vinyl chloride were detected in soil at concentrations above the industrial PRG, industrial volatilization to indoor air, and/or migration to groundwater criteria for soil within AOI 3 during the RFI. Soil concentrations exceeding these soil criteria are bounded by locations with lower concentrations within AOI 3 or by AOIs to the north and east of AOI 3. Cadmium, TCE, cis-1,2-DCE, and vinyl chloride were detected above the drinking water criteria in AOI 3. Downgradient from AOI 3, Cadmium, TCE, cis-1,2-DCE, and vinyl chloride are bounded by monitoring wells that do not have concentrations higher than the drinking water criteria. The RFI Report concluded that the data collected meets the objectives of the RFI and adequately characterizes soil and groundwater at and around AOI 3. The groundwater data collected during the RFI indicated that concentrations in groundwater are stable in this area.

AOI 5

The scope of the RFI at AOI 5 involved the advancement of fifteen soil borings and the installation and sampling of ten monitoring wells to characterize soil and water quality in the vicinity of and downgradient from AOI 5. TCE was detected in soil at concentrations above the Industrial PRG, industrial volatilization to indoor air, and/or migration to groundwater criteria for soil within AOI 5 during the RFI. Soil concentrations exceeding these soil criteria are bounded by locations with decreasing concentrations within AOI 5 or by AOIs to the east of AOI 5. TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride were detected at concentrations above their respective drinking water criteria in AOI 5. Downgradient from AOI 5, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride are bounded by monitoring wells that do not have concentrations higher than their respective drinking water criteria. Further, based on the vertical groundwater data obtained within AOI 5, groundwater concentrations are delineated vertically within AOI 5. The RFI Report concluded that the data collected meets the objectives of the RFI and adequately characterizes soil and groundwater at and around AOI 5.

AOI 6

The scope of the RFI at AOI 6 involved the advancement of eighteen soil borings and the installation and sampling of four monitoring wells to characterize soil and water quality in the vicinity of and downgradient from AOI 6. TCE and PCE were detected in soil at concentrations above the industrial PRG, industrial volatilization to indoor air, and/or migration to groundwater criteria for soil within AOI 6 during the RFI. Soil concentrations exceeding these soil criteria are bounded by locations within AOI 6. TCE, cis-1,2-DCE and vinyl chloride were detected above their respective drinking water criteria in AOI 6. Downgradient from AOI 6, TCE, cis-1,2-DCE and vinyl chloride are bounded by monitoring wells that do not have concentrations higher than their respective groundwater screening criteria. The RFI Report concluded that the data collected meets the objectives of the RFI and adequately characterizes soil and groundwater at and around AOI 6. The groundwater data collected during the RFI indicated that concentrations in groundwater are stable at this area.

AOI 7

The scope of the RFI at AOI 7 involved the advancement of fifteen soil borings, the installation and sampling of five monitoring wells, and sampling of an existing monitoring well to characterize soil and water quality in the vicinity of and downgradient from AOI 7. TCE was detected in soil at concentrations above the Industrial PRG, industrial volatilization to indoor air, and/or migration to groundwater criteria for soil

within AOI 7 during the RFI. Soil concentrations exceeding these soil criteria are bounded by locations within AOI 7. TCE, cis-1,2-DCE, and vinyl chloride were detected above their respective drinking water criteria in AOI 7. Downgradient from AOI 7, TCE, cis-1,2-DCE, and vinyl chloride are bounded by monitoring wells that do not have concentrations higher than their respective drinking water criteria. The RFI Report concluded that the data collected meets the objectives of the RFI and adequately characterizes soil and groundwater at and around AOI 7. The groundwater data collected during the RFI indicated that concentrations in groundwater are stable at this area.

Downgradient Investigation - Off-Site East

The Off-Site East Investigation consisted of monitoring wells, soil borings and soil gas vapor ports that are located downgradient and to the east of the former Facility. The scope of the RFI completed as part of the Off-Site East investigation included the advancement of nine soil borings, the installation and sampling of 22 monitoring wells, and the installation and sampling of eleven soil gas ports. No soil concentrations exceeded soil screening criteria. TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride were detected above their respective drinking water criteria for the Off-Site East area. TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride are bounded by monitoring wells that do not have concentrations higher than the drinking water criteria. Further, based on the vertical groundwater data obtained from MW-0701-B1a, groundwater is bound vertically. No soil gas concentrations exceeded the soil gas screening criteria. The RFI Report concluded that the data collected meets the objectives of the RFI and adequately characterizes soil and groundwater at and around the Off-Site East area. The groundwater data collected during the RFI indicated that concentrations in groundwater are stable. Detected concentrations in groundwater collected at the furthest downgradient monitoring wells did not exceed the drinking water criteria.

Downgradient Investigation – Off-Site West

The Off-Site West Investigation consisted of monitoring wells and soil borings that are located downgradient and to the west of the former Facility. The scope of the RFI completed as part of the Off-Site West investigation included the advancement of one soil boring and the installation of thirteen monitoring wells to characterize soil and groundwater quality off-site and to the west of the former Facility. No soil concentrations exceeded soil screening criteria. TCE, cis-1,2-DCE, and vinyl chloride were detected above the drinking water criteria for the Off-Site West area. Based on data collected to date it would appear that these detections are not related to historic

operations at the Facility. The RFI Report concluded that the data collected meets the objectives of the RFI and adequately characterizes soil and groundwater at and around the Off-Site West area. The groundwater data collected during the RFI indicated that concentrations in groundwater are stable. Detected concentrations in groundwater collected at the furthest downgradient monitoring wells did not exceed the drinking water criteria.

3.9.3 Summary of Risk Assessment

A baseline human health risk assessment was conducted as part of the RFI to evaluate the health significance of site-related constituent concentrations at all areas where soil, groundwater, and soil gas data were collected during the RFI field investigation. The purpose of the risk assessment is to determine whether any site-related concentrations pose a potentially significant risk based on current and reasonably expected future land use and groundwater use which would warrant corrective measures. The human health risk assessment discussed in Section 5 of the RFI Report assumed that future land and groundwater at the Facility remain consistent with the current use (commercial/industrial and no groundwater use) and that a WR-OL District would be implemented to prohibit new uses of groundwater in the vicinity of the Site.

The human health risk assessment concluded that none of the areas investigated during the RFI pose a potentially significant risk under current land use and groundwater use. The human health risk assessment also concluded that none of the areas investigated during the RFI pose a potentially significant risk under future land use and groundwater use, except via potential future vapor intrusion from soil at the sub-areas around boring locations SB-0746, SB-0749, SB-0756, SB-0757, and SB-0775. The human health risk assessment and its results are discussed in Section 5 of the RFI Report.

4 Summary of Corrective Measures Alternatives

The human health risk assessment in the RFI Report concluded that there was the potential for significant exposure to soil via vapor intrusion into future buildings at five soil boring locations (SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775). The RFI Report concluded that evaluation of potential Corrective Measures at these five soil boring locations was required. Additionally, at the request of USEPA, aquifer restoration was also considered during the evaluation of potential Corrective Measures and the scope of soil remediation.

The human health risk assessment in the RFI Report assumed no current or future uses of contaminated groundwater would occur at or in the vicinity of the site. This assumption is supported by the groundwater modeling which has predicted that while groundwater impacted with TCE and cis-1,2-DCE in the S2 unit is predicted to migrate beyond the Syndicate Sales, Inc. well field (Appendix A), the Syndicate Sales, Inc. well field is screened in the deeper bedrock B1 unit where no exceedance of the MCLs is predicted. The model-predicted concentrations of TCE and cis-1,2-DCE in the S3 unit and bedrock B1 unit are negligible. Additionally, vinyl chloride in excess of its MCL is not expected at potential groundwater supply wells because geochemical conditions are not conducive to significant generation of vinyl chloride at the site, as evidenced by the low concentrations observed (<10 ug/L) in the S2 unit. The vinyl chloride concentration in S3 unit and bedrock B1 unit is negligible as well. The alternatives evaluated for addressing contaminated groundwater are designed to meet the corrective measures objective of demonstrating no migration of groundwater at concentrations above the drinking water levels to potential groundwater users. In addition, at the request of USEPA, aquifer restoration was also considered as a goal when evaluating potential Corrective Measures.

4.1 Soil

Due to the size of the Facility, the soil information available prior to the RFI fieldwork (as summarized in the DOCC), and the need to evaluate potential source areas, the investigation of soil conditions during the RFI was conducted on an AOI-specific basis. The results of the RFI and baseline human health risk assessment found that contaminant concentrations in soil may pose a potentially significant future risk through one pathway (vapor intrusion), at only one AOI (AOI 3).

As discussed in Section 3.9.3, soil at and around locations SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 was initially identified for potential corrective measures as a result of potentially significant future vapor intrusion exposure, as discussed above. All five of these soil borings contain similar constituents, pose the same potential exposure risk (vapor intrusion), and are located in the same general area of the Facility, as shown on Drawing 5. Therefore, given their proximity and the uniformity in types of contaminants, these locations are grouped together for the evaluation of corrective measure alternatives. A proposed treatment area was developed, using Thiessen polygons. The proposed treatment area was established by first identifying the Thiessen polygons around soil borings SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775, and then extending the area 75 percent of the way from the edge of the polygon around each of these locations to the next soil sampling location where

cumulative risk estimates did not exceed the risk limits. This area initially proposed for soil remediation was approximately 10,000 square feet in aerial extent.

The proposed treatment area was discussed with USEPA during a November 17, 2010 meeting. In a letter dated January 7, 2011, USEPA requested that the treatment area be expanded to provide additional source control to foster aquifer restoration. ARCADIS reviewed the soil data from the RFI and identified several options for defining a revised treatment area:

- 1) Use of the 500 mg/kg TCE isoconcentration contour to define the treatment area. This TCE concentration represents the highest proportion of mass on site and focuses on capturing the area encompassing soil borings SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775.
- 2) Use of the 400 mg/kg TCE isoconcentration contour to define the treatment area. This TCE concentration represents the soil concentration that, based on leaching calculations, could create a TCE groundwater concentration of 1,000 µg/L.
- 3) Use of the 61 mg/kg TCE contour to define the treatment area. This TCE concentration is the industrial/commercial direct contact screening criteria used to guide the field investigation during the RFI.

These options were evaluated using the following goals to revise the initially proposed treatment area:

- Addressing the soil within the areas of soil borings SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 to manage potentially significant future vapor intrusion exposure.
- Providing sufficient mass removal to foster groundwater restoration.

Based on these goals, a revised treatment area, using the 400 mg/kg TCE isoconcentration contour, was selected. The aerial extent of the revised treatment area is illustrated in Drawing 5, and is approximately 12,300 square feet in aerial extent.

Summary of Alternatives

The following alternatives were evaluated to address the soil in the revised treatment area:

Alternative 1: Institutional Controls – Institutional controls would be adopted to limit land use in the area encompassing SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 to ensure that the human health risk assessment assumptions on future on-site land use remain valid. For example, a land use restriction could be adopted to prevent the construction of a building over the area encompassing SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775, unless vapor mitigation controls are implemented at future buildings in this area. Additional institutional controls could also be adopted to support other corrective action alternatives. For example, if an asphalt cap (an Engineering Control, see Alternative 2) is installed to facilitate site redevelopment, a companion maintenance plan (i.e., an institutional control) would be developed to outline inspection and maintenance procedures.

Alternative 2: Engineering Controls – Engineering control, in the form of an asphalt cap, was identified as a potentially feasible alternative. The asphalt cap would stabilize the ground surface in the revised treatment area to prevent soil erosion, limit construction of structures that would be affected by vapor intrusion, and reduce infiltration and subsequent leaching of contaminants from soil to groundwater. A companion deed restriction would be adopted to prohibit construction of a building over the area to eliminate the vapor intrusion pathway. The revised treatment area would be cleared, rough-graded, covered with a 6-inch layer of gravel sub-base, and overlain with a 9-inch layer of asphalt pavement. The paved area would then be fenced for security. The asphalt cap would have to be maintained.

Alternative 3: Phytoremediation – Phytoremediation was identified as a potentially feasible alternative. Under this option, trees (TreeWells[®] or similar product) would be planted within the revised treatment area. Microorganisms within the rhizosphere formed by the tree roots would facilitate the biodegradation of the organic constituents and remove dissolved constituents through transpiration; however, there is some question as to whether phytoremediation would be able to meet the corrective measures endpoint. The clay soil and depth of impacts may limit the effectiveness of this alternative. This alternative scored well during the green remediation qualitative assessment and; therefore, was retained for further review.

Alternative 4: Direct Excavation and Disposal – Excavation and off-site disposal at a licensed facility was identified as a potentially feasible alternative. The soil within the

revised treatment area would be excavated, characterized and transported off-site for proper disposal.

Alternative 5: Calcium Oxide Treatment and Reuse of Soil – On-site treatment of soil using calcium oxide was identified as a potentially feasible alternative. Under this option, soil within the revised treatment area would be treated in lifts. Calcium oxide would be placed on top of the soil lift to be treated, mixed with conventional construction equipment, and hydrated with water. The reaction between the calcium oxide and water is strongly exothermic, with the heat inducing volatilization of the organic contaminants. The calcium oxide and water will also react with soil minerals to create a binder that will reduce the permeability of the soil and immobilizes the contaminants. The treated soil is excavated to allow treatment of the next lift. Samples are collected from the stockpiled soil to verify that adequate reduction in constituent concentrations has been achieved. The treated soil is then used as backfill.

Alternative 6: Electrical Resistivity Heating (ERH) – In-situ treatment of soil using ERH was identified as a potentially feasible alternative. Under this option, a series of electrodes would be installed in the soil. An electrical current would be passed through the electrodes. The electrical resistance of the soil and soil moisture generates heat, which causes volatilization of organic constituents and water. The gases are captured by a companion vapor extraction system, which provides a pathway for the in-situ generated gases to exit the subsurface.

4.2 Groundwater

Due to the size of the Facility, the groundwater information available prior to the RFI fieldwork as summarized in the DOCC, and the potential need to evaluate downgradient groundwater quality at AOIs where a groundwater impact potential was indicated, the investigation of groundwater conditions during the RFI was initially conducted on an AOI-specific basis; however, the investigation was expanded to a facility-wide focus to monitor the CVOC plume. The groundwater analytical results were initially compared to drinking water criteria to evaluate the need for additional data collection.

As discussed in Section 3.9.3, the baseline human health risk assessment concluded that no potential significant exposures to groundwater exist under current and reasonably expected future land use at and around the Facility. The human health risk

assessment assumed no current or future uses of contaminated groundwater would occur at or in the vicinity of the Site.

Based on the groundwater modeling results discussed in Section 3.6, impacted groundwater is not expected to reach the IAWC-NWF at concentrations exceeding the MCLs. Additionally, no exceedance of TCE, cis-1,2-DCE or vinyl chloride is expected in groundwater extracted from the two well fields located between the site and the IAWC-NWF: the Moon Fabricating Corporation well field and Syndicate Sales, Inc. well field, both of which extract groundwater from the bedrock B1 unit at a relatively insignificant rate (less than 10 gpm).

Based on the results of the baseline human health risk assessment and the groundwater modeling results, active groundwater remediation was not initially proposed during the November 17, 2010 meeting with USEPA. In a letter dated January 7, 2011, USEPA requested the evaluation of active groundwater corrective measures to foster aquifer restoration. As discussed above, the baseline human health risk assessment assumed no future use of groundwater and groundwater modeling results indicated that migration to current wells (i.e., potential receptors) was unlikely, ARCADIS selected a target TCE groundwater concentration based on contaminant distribution. Such an approach would address the USEPA's goal of aquifer restoration by focusing corrective measures on the area with the highest groundwater contaminant concentration and would minimize any increase in groundwater concentrations in the S1 unit to the east.

ARCADIS reviewed the results from the RFI to identify a groundwater treatment area. The highest groundwater concentrations are located in the S1 unit, in the northern portion of the site and at one off-site monitoring well location to the east. TCE concentrations in this area range as high as 13,000 µg/L. Drawing 6 depicts the isoconcentration contours for TCE. Based on the TCE concentrations detected during the RFI and the distribution, a target concentration of 4,000 µg/L was selected to define the groundwater treatment area. This area is located within the S1 unit and is depicted in Drawing 6.

Summary of Alternatives

The following alternatives were evaluated to address groundwater in the groundwater treatment area:

Alternative 1: Groundwater Extraction – Groundwater extraction was identified as a potentially feasible alternative. Under this option, a series of groundwater extraction wells would be installed along the downgradient edge of the site, within the S1 unit. Extracted groundwater would be pumped to an above-ground treatment system, and treated water would be discharged to the storm sewer system. Groundwater extraction typically results in low rates of mass recovery, but provides hydraulic control to limit migration of the contaminants.

Alternative 2: In-Situ Chemical Oxidation (ISCO) – ISCO was identified as a potentially feasible alternative. Under this option, a series of injection wells would be installed within the 4,000 µg/L TCE isoconcentration contours located within the northern and central portions of the site, and near off-site monitoring well MW-0612-S1 to the east. The injection wells would target the areas of groundwater TCE concentrations in the S1 unit that exceed 4,000 µg/L.

A mobile system would be used to inject a solution of sodium permanganate into the S1 unit via the injection wells. The sodium permanganate would react chemically with the contaminants, oxidizing the contaminants into innocuous byproducts including carbon dioxide and water. This alternative assumes that four quarterly injection events would be conducted.

Alternative 3: Enhanced Reductive Dechlorination (ERD) – ERD was identified as a potentially feasible alternative. Similar to Alternative 2, a series of injection wells would be installed within the 4,000 µg/L TCE isoconcentration contours located within the northern and central portions of the site, and near off-site monitoring well MW-0612-S1 to the east. The injection wells would target the areas of groundwater TCE concentrations in the S1 unit that exceed 4,000 µg/L.

A mobile system would be used to inject a carbon substrate such as molasses or whey into the S1 unit via the injection wells. The carbon substrate would be used as a food source by the indigenous microbial community, reducing the concentration of dissolved oxygen and creating strongly reducing conditions in the aquifer. These conditions promote the growth of microorganisms that biodegrade chlorinated alkenes. The process removes chlorine atoms sequentially from the alkene, with TCE being biodegraded to cis-1,2-dichloroethene, to vinyl chloride, and then to ethene. This alternative assumes that eight quarterly injection events would be conducted.

Alternative 4: Bentonite Cutoff Wall – A bentonite cutoff wall was identified as a potentially feasible alternative. Under this option, a bentonite cutoff wall would be

installed along the east property boundary, extending from the ground surface to the clay unit at the base of the S1 unit. The bentonite cutoff wall would reduce the migration of contaminants off-site. To manage groundwater accumulating along the bentonite cutoff wall, groundwater extraction wells would be installed at each end of the wall and at the midpoint. Extracted groundwater would be pumped to an above-ground treatment system, and treated water would be discharged to the storm sewer system.

4.3 Facility-Wide Management Controls

Corrective measure alternatives for soil included institutional controls as an alternative, focusing on a relatively limited area and on managing potential risk associated with contaminated soil. Institutional controls can also be applied more broadly to limit land use and groundwater use on site and beyond the site. In addition, management systems may be needed to verify that the corrective measures have been effective and aquifer restoration is occurring.

The following alternatives were evaluated for use as facility-wide management controls, to be applied in conjunction with the soil and groundwater corrective measures:

Alternative 1: Groundwater Deed Restriction – Contaminants in groundwater at concentrations exceeding the drinking water standards exist on-site. If the use of contaminated groundwater for drinking water is prevented, the groundwater will not pose a risk to human health. A groundwater deed restriction could be placed on the property. This institutional control provides notification to potential future owners that the groundwater contamination is present, and that the installation of a water supply well is prohibited.

Alternative 2: Well Restriction Overlay District – Contaminants in groundwater at concentrations exceeding the drinking water standards also extend off-site, beneath multiple properties. It would be impractical to file a groundwater use restriction for each individual property. A WR-OL District is a unique and conservative tool for restricting groundwater use on a regional basis. The WR-OL District is established and enforced by the City of Kokomo to protect the community from groundwater contaminated with chemicals. The WR-OL District restricts the drilling of water wells that may bring contaminated groundwater to the surface. MLC discussed the establishment of the WR-OL District with the Director of the Kokomo Planning Commission and has received general acceptance of the proposal; however, the plan

will need to be presented to the Plan Commission and receive approval before being established.

Alternative 3: Land Use Restriction – The human health risk assessment discussed in Section 5 of the RFI Report assumed that future land at the Facility will remain consistent with the current use (commercial/industrial). To reduce the likelihood of a change in land use, a land use restriction would be entered onto the deed, limiting future land use to commercial/industrial.

Alternative 4: Monitoring Program – Once active corrective measures are completed for soil and groundwater, trends in contaminant concentrations will need to be evaluated over time to verify that assumptions made as part of the groundwater modeling and remediation effectiveness continue to be reasonable. Vapor monitoring would confirm that no significant risk to human health is present via vapor intrusion. Groundwater monitoring would demonstrate that contaminant concentrations and distribution are consistent with the model results and that the groundwater remedy was successful in fostering aquifer restoration and that no significant risk to human health is present via vapor intrusion. Analytical results will be compared to vapor intrusion screening criteria presented in Appendix B for soil vapor and groundwater data; however, an evaluation of the trends, concentrations and verification of the model will all be used to determine any adjustment in the monitoring scope or frequency. The vapor and groundwater monitoring program is generally outlined in Appendix C; however, specific details of the monitoring program will be provided in the Corrective Measures Implementation Work Plan.

5 Evaluation of Corrective Measures Alternatives

An evaluation of the Corrective Measures alternatives identified in Section 4 was performed. A summary of the Corrective Measures alternatives is presented in Table 3. The evaluation of alternatives considered the degree to which each potential corrective measure alternative satisfies the nine criteria outlined in the US EPA document entitled "RCRA Corrective Action Plan" (OSWER 9902.3-2A, May 1994). The RCRA Corrective Action evaluation criteria and the results of the evaluation for each of the potential Corrective Measures alternatives are presented in Table 4a (facility-wide controls/monitoring for soil, groundwater and vapor), Table 4b (soil corrective measure alternatives), and Table 4c (groundwater corrective measure alternatives), and summarized in Section 5.1. In addition, ARCADIS also completed a green remediation qualitative assessment (sustainability assessment) which is

summarized in Section 5.2. The assessment was completed in accordance with the USEPA document entitled “Principles for Greener Clean-up” (August 2009).

5.1 Criteria for Evaluation of Corrective Measures Technologies

The RCRA Corrective Action evaluation criteria and the results of the evaluation for each of the potential Corrective Measures alternatives are summarized below.

1. Overall Protection

The human health risk assessment completed during the RFI concluded that the groundwater and soil conditions do not present significant exposure risks under current and reasonably expected future land use at and around the Facility, except via potential future vapor intrusion from soil at certain locations of the Facility.

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: Each of the control alternatives listed in Table 4a, with the exception of the ‘no action’ alternative, would be protective of human health and the environment. The groundwater/vapor monitoring program will be used to verify the results from the RFI and groundwater modeling. The risk assessment considered existing land and groundwater use restrictions for commercial/industrial land use and existing groundwater uses as of March 2010. A WR-OL District will be requested from the City of Kokomo in order to establish an enforceable mechanism to prevent groundwater at the Facility and the nearby area from being used in the future. A deed restriction will be placed on the property to limit future use of the property to commercial/industrial uses and prohibit all groundwater uses.

Soil Corrective Measure Alternatives: Each of the Corrective Measures alternatives for soil was evaluated to assess the degree of protection the alternative provides for limiting potential future exposure to soil via vapor intrusion at the locations identified in Section 3.9.3. Each of the alternatives listed in Table 4b, with the exception of the ‘no action’ and possibly ‘phytoremediation’ alternatives would be protective of human health and the environment. As mentioned in Section 4.1, the effectiveness of phytoremediation may be limited due to clay soil and depth of impacts.

Groundwater Corrective Measure Alternatives: Each of the Corrective Measures alternatives for groundwater was evaluated to assess the degree of protection the alternative provides to human health and the environment. Each of the alternatives listed in Table 4c, with the exception of the 'no action' alternative, would be protective of human health and the environment. Since there is no significant risk associated with the use of contaminated groundwater based on current and anticipated future use, even the 'no action' alternative would be protective of human health if institutional controls were adopted to restrict the installation of drinking water wells.

2. Attainment of Media Cleanup Standards

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: The endpoints for the facility-wide controls are limiting site use to commercial and industrial uses and prohibiting the ingestion of contaminated groundwater, as summarized on Table 5. Groundwater and vapor monitoring will be used to: 1.) confirm the groundwater model (concentrations above MCLs are limited to within the boundary of the WR-OL District and 2.) vapor concentrations in soil gas ports are below the soil gas screening levels identified in the RFI. Each of the alternatives listed in Table 4a, with the exception of the 'no action' alternatives, would be capable of meeting the endpoints.

Soil Corrective Measure Alternatives: The endpoint for the soil Corrective Measures is demonstration that no significant vapor intrusion exposure exists at the soil sample locations identified in Section 3.9.3, as summarized on Table 5. Additionally, a target treatment concentration of 400 mg/kg of TCE was selected to promote aquifer restoration. Each of the Corrective Measures alternatives for soil was evaluated to assess whether the endpoints will be attained. Each of the alternatives listed in Table 4b, with the exception of the 'no action' alternative, would be capable of meeting some Corrective Measures endpoints either through reduction of the CVOC concentrations in soil or through the elimination of the future potential for vapor intrusion exposure.

Groundwater Corrective Measures Alternatives: The endpoint for the groundwater Corrective Measures is the promotion of aquifer restoration, through the reduction of TCE groundwater concentrations to 1,000 µg/L or less, as summarized in Table 5. Each of the Corrective Measures alternatives for groundwater was evaluated to assess whether the endpoint will be

attained. Each of the alternatives listed in Table 4c, with the exception of the 'no action' alternative, would be capable of meeting the endpoint either through reduction of the CVOC concentrations in groundwater or reducing off-site migration.

3. Controlling the Sources of Releases

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: Each of the Corrective Measures alternatives for facility-wide controls was evaluated to assess the degree to which source control will be attained. Of the alternatives listed in Table 4a, only the adoption of the WR-OL District would result in controlling the source of releases by eliminating the potential induced migration of impacted groundwater through groundwater pumping.

Soil Corrective Measure Alternatives: Each of the Corrective Measures alternatives for soil was evaluated to assess the degree to which source control will be attained. Each of the alternatives listed in Table 4b, with the exception of the 'no action' alternative, would be capable of providing some control of source releases.

Groundwater Corrective Measure Alternatives: Each of the Corrective Measures alternatives for groundwater was evaluated to assess the degree to which source control will be attained. Each of the alternatives listed in Table 4c, with the exception of the 'no action' alternative, would be capable of providing some control of source releases.

4. Compliance with Applicable Standards for Waste Management

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: Each of the Corrective Measures alternatives for facility-wide controls was evaluated to assess compliance with waste management standards. Of the alternatives listed in Table 4a, only the vapor/groundwater monitoring program would result in generation of waste. As part of any monitoring program, procedures would be adopted to verify management of waste in accordance with applicable standards.

Soil Corrective Measure Alternatives: Each of the Corrective Measures alternatives for soil was evaluated to assess compliance with waste management standards. Each of the alternatives listed in Table 4b, with the

exception of the 'no action' alternative, would result in the generation of some waste. For all of the alternatives where waste would be generated, procedures will be adopted to verify management of waste in accordance with applicable standards.

Groundwater Corrective Measure Alternatives: Each of the Corrective Measures alternatives for groundwater was evaluated to assess compliance with waste management standards. Each of the alternatives listed in Table 4c, with the exception of the 'no action' alternative, would result in the generation of some waste, such as soil cuttings from well installation or extraction of contaminated groundwater. For all of the alternatives where waste would be generated, procedures will be adopted to verify management of waste in accordance with applicable standards

5. Long Term Reliability and Effectiveness

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: Each of the Corrective Measures alternatives for facility-wide controls was evaluated to assess long term reliability and effectiveness. Each of the alternatives listed in Table 4a, with the exception of the 'no action' alternative, would provide long term reliability and effectiveness.

Soil Corrective Measure Alternatives: Each of the Corrective Measures alternatives for soil was evaluated to assess long term reliability and effectiveness. Each of the alternatives listed in Table 4b, with the exception of the 'no action' alternative, would provide long term reliability and effectiveness.

Groundwater Corrective Measure Alternatives: Each of the Corrective Measures alternatives for groundwater was evaluated to assess long term reliability and effectiveness. Each of the alternatives listed in Table 4c, with the exception of the 'no action' alternative, would provide long-term reliability and effectiveness.

6. Reduction of Toxicity, Mobility or Volumes of Wastes

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: Each of the Corrective Measures alternatives for facility-wide controls was evaluated to assess ability to reduce toxicity, mobility or volume of waste. None of the

alternatives listed in Table 4a would provide a reduction in the toxicity, mobility or volume of waste.

Soil Corrective Measure Alternatives: Each of the Corrective Measures alternatives for soil was evaluated to assess ability to reduce toxicity, mobility or volume of waste. As indicated in Table 4b, the 'no action', 'engineering controls', and 'institutional controls' alternatives would not provide a reduction in the toxicity, mobility or volume of waste. The remaining alternatives would provide varying reductions in the toxicity, volume, and/or mobility of waste.

Groundwater Corrective Measure Alternatives: Each of the Corrective Measures alternatives for groundwater was evaluated to assess ability to reduce toxicity, mobility or volume of waste. As indicated in Table 4c, the 'no action' would not provide a reduction in the toxicity, mobility or volume of waste. The remaining alternatives would provide varying reductions in the toxicity, volume, and/or mobility of waste. The groundwater extraction and funnel/gate alternatives would provide limited reductions in mass or toxicity, but would limit mobility. The ISCO and ERD alternatives would provide mass reduction, and would reduce mobility by reducing contaminant concentrations in the aquifer.

7. Short-Term Effectiveness

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: Each of the Corrective Measures alternatives for facility-wide controls was evaluated to assess short-term effectiveness. Each of the alternatives listed in Table 4a, with the exception of the 'no action' alternative, would provide short term effectiveness.

Soil Corrective Measure Alternatives: Each of the Corrective Measures alternatives for soil was evaluated to assess short-term effectiveness. As indicated in Table 4b, the 'no action' alternative would not provide short-term effectiveness, and the phytoremediation alternative would provide limited effectiveness in the short term.

Groundwater Corrective Measure Alternatives: Each of the Corrective Measures alternatives for groundwater was evaluated to assess short-term effectiveness. As indicated in Table 4c, the 'no action' alternative would not provide short-term effectiveness.

8. Implementation

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: Each of the Corrective Measures alternatives for facility-wide controls was evaluated to assess practicality of implementation. Each of the alternatives listed in Table 4a can be practically implemented.

Soil Corrective Measure Alternatives: Each of the Corrective Measures alternatives for soil was evaluated to assess practicality of implementation. Each of the alternatives listed in Table 4b can be practically implemented. However, the presence of clay soil may limit the degree to which the vapor extraction component of the ERH system can be implemented.

Groundwater Corrective Measure Alternatives: Each of the Corrective Measures alternatives for groundwater was evaluated to assess practicality of implementation. Each of the alternatives listed in Table 4c can be practically implemented.

9. Costs

Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor: Each of the Corrective Measures alternatives for facility-wide controls was evaluated for cost. A summary of the costs for each alternative is presented in Table 6a. A detailed breakdown of the costs is presented in Appendix D. Each of the alternatives listed in Table 4a have a relatively low cost associated with implementation.

Soil Corrective Measure Alternatives: Each of the Corrective Measures alternatives for soil was evaluated for cost. A summary of the costs for each alternative is presented in Table 6b. A detailed breakdown of the costs is presented in Appendix D. Each of the alternatives listed in Table 4b have a low to moderate cost associated with implementation.

Groundwater Corrective Measure Alternatives: Each of the Corrective Measures alternatives for groundwater was evaluated for cost. A summary of the costs for each alternative is presented in Table 6c. A detailed breakdown of the costs is presented in Appendix D. Each of the alternatives listed in Table 4c have a moderate cost associated with implementation.

5.2 Sustainability Criteria

In addition to the evaluation described above, a qualitative assessment of green remediation was completed. The assessment evaluated the potential impact each Corrective Measure alternative would have on the following five core elements:

- Energy requirements
- Air emissions
- Water requirements and impacts on water resources
- Land and ecosystem impacts
- Material consumption and waste generation

Appendix E presents the green remediation qualitative assessment. The qualitative assessment assigned numerical rankings to each element of each potential Corrective Measure alternative. The 'No Action' alternative was used as the baseline condition to which the impacts of the other six remedial alternatives were compared. A numerical ranking value was assigned to each core element to represent the relative impact. These values ranged from -3 (much less favorable to baseline conditions) to +3 (much more favorable to baseline conditions). Quantitative estimates of the predicted performance of the alternatives relative to the five core elements (e.g., life-cycle estimates for power demand, CO₂ discharge rates, water consumption, etc.) were not generated as part of this qualitative assessment. The aggregate of the rankings assigned to each core element was used to compare the overall environmental impacts of the alternatives. The results of the green remediation qualitative assessment and the scoring for each potential Corrective Measure alternative are provided in a Table in Appendix E. A summary of the green remediation qualitative assessment is provided for each alternative in Tables 4a, 4b and 4c under the heading of "sustainability".

The results of the green remediation assessment were used in conjunction with the core elements of the RCRA corrective action alternatives evaluation to identify Corrective Measures that would balance effectiveness and sustainability.

6 Proposed Corrective Measures

Tables 4a, 4b and 4c present the Corrective Measures alternatives evaluated as part of RCRA Corrective Action. The proposed Final Corrective Measures for the Facility are summarized below and listed on Table 5.

- Facility-Wide Controls/Monitoring for Groundwater and Soil

Well Restriction Overlay District (On-Site and Limited Off-Site) will restrict the installation of water wells that may bring contaminated groundwater to the surface.

Deed Restriction - Groundwater Use (On-Site) will prohibit use of groundwater on the property.

Deed Restriction - Land Use (On-Site) will limit the use of the property to commercial or industrial uses.

Monitoring - Groundwater and Soil Vapor (On-Site and Limited Off-Site) will provide data for confirmation of the groundwater model and evaluation of risks to potential receptors (via soil vapor or groundwater).

- Soil Corrective Measure Alternatives

Calcium Oxide Treatment will reduce the concentration of VOCs in soil within the revised treatment area.

- Groundwater Corrective Measure Alternatives

ISCO will reduce the concentration of VOCs in groundwater within the treatment area.

Based on information currently available, these proposed Final Corrective Measures provide the best balance of the alternatives evaluated with respect to the evaluation criteria. The proposed Final Corrective Measures, the corrective measures endpoints, and information on how the confirmation of those endpoints will be achieved are presented in Table 5. As discussed above, work plans will be prepared and submitted to USEPA for the active Corrective Measures (Calcium Oxide, ISCO, groundwater/vapor monitoring). In the event that the selected Corrective Measures do

not meet the target objectives, either through bench/pilot tests or during full-scale implementation, the corrective measures will be re-evaluated and a supplemental Corrective Measures Proposal will be submitted to USEPA.

7 Schedule

A Corrective Measures Implementation Work Plan will be submitted within 90-days after USEPA selects the final remedy. Implementation of final Corrective Measures will commence within 60-days of receiving USEPA's approval of the CMI Work Plan or within 60-days of submittal of the CMI Work Plan, if no response from USEPA is obtained. As much of the remediation work as practicable pertaining to the Corrective Measures proposed in the preceding sections of this CMP will be completed within three years after USEPA selects the final remedies, and all remedies will be completed within a reasonable period of time to protect human health. Monitoring activities may continue for up to 30 years based on need and funding; however, this timeframe can be adjusted with concurrence from USEPA. Final Remedy Construction Completion with Controls Report will be submitted within 90-days after attainment of Corrective Measures Endpoints.

RACER will provide quarterly progress reports to USEPA by the fifteenth day of the month after the end of each calendar quarter. The report will list work performed to date, data collected, problems encountered, project schedule, and percent project completed, unless otherwise agreed.

8 References

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Appendix A

Groundwater Modeling Evaluation

Appendix B

Supplemental Information for Vapor
Intrusion Criteria

Appendix C

Vapor and Groundwater Monitoring
Program

Appendix D

Corrective Measures Detailed Cost
Backup

Appendix E

Green Remediation Qualitative
Assessment

Table 1. Areas of Interest, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

AOI	Name	Location	Description
1	Off-Site Drums	North of Parking Lot	Two drums north of site
2	Fill Area	West-Central of Site	Fill area south of Spraker Street
3	Former South Manufacturing Building Satellite Accumulation Area	West-Central of Site	Satellite Accumulation Area
4	Former East Manufacturing Building Satellite Accumulation Area	East-Central of Site	Satellite Accumulation Area
5	Former Hazardous Waste Storage Area	Southwest of Site	Concrete Hazardous Waste Storage Area
		Southwest of Site	Soil Vapor Extraction System
6	Waste Pile	Southwest of Site	Waste Pile produced by Midwest Plating
7	Northern Portion of Former East Manufacturing Building	Northeast of Site	Impacted groundwater with unknown source

Table 2. Summary of Documents Located in Public Repository, Kokomo-Howard County Public Library, 220 North Union Street, Kokomo, Indiana

Date	Author	Report Title
9/23/2005	ARCADIS	Information Repository for RCRA Corrective Action Documents
10/4/2005	GM	Dear Neighbor Letter
10/10/2005	ARCADIS	Description of Current Conditions
10/14/2005	Favero Geosciences	Third Quarter 2005 Progress Report
12/15/2005	ARCADIS	RCRA Facility Investigation Work Plan
1/13/2006	Favero Geosciences	Fourth Quarter 2005 Progress Report
1/19/2006	GM/ENCORE	Dear Neighbor Letter #2
3/16/2006	USEPA	Letter transmitting fully executed Performance Based Corrective Action Agreement
4/14/2006	Favero Geosciences	First Quarter 2006 Progress Report
5/26/2006	ARCADIS	RCRA Facility Data Rport
7/6/2006	Favero Geosciences	Second Quarter 2006 Progress Report
10/5/2006	GM	Neighborhood Letter
10/5/2006	GM/ENCORE	Project Fact Sheet #2
10/13/2006	Favero Geosciences	Third Quarter 2006 Progress Report
1/12/2007	Favero Geosciences	Fourth Quarter 2006 Progress Report
4/13/2007	Favero Geosciences	First Quarter 2007 Progress Report
6/1/2007	ARCADIS	RCRA Facility Investigation Data Report Updated May 2007
7/30/2007	GM/ENCORE	Fact Sheet #3
10/12/2007	Favero Geosciences	Third Quarter 2007 Progress Report
12/21/2007	ARCADIS	Soil Gas Data Report
1/11/2008	Favero Geosciences	Fourth Quarter 2007 Progress Report
4/14/2008	Favero Geosciences	First Quarter 2008 Progress Report
6/27/2008	ARCADIS	Supplemental Data Report - June 2008
7/14/2008	Favero Geosciences	Second Quarter 2008 Progress Report
10/14/2008	Favero Geosciences	Third Quarter 2008 Progress Report
1/14/2009	Favero Geosciences	Fourth Quarter 2008 Progress Report
4/14/2009	Favero Geosciences	First Quarter 2009 Progress Report
7/14/2009	Favero Geosciences	Second Quarter 2009 Progress Report
10/14/2009	Favero Geosciences	Third Quarter 2009 Progress Report
1/14/2010	Favero Geosciences	Fourth Qtr 2009 Progress Report
4/14/2010	Favero Geosciences	First Quarter 2010 Progress Report
5/21/2010	ARCADIS	RFI Report Former GM Delco Plant 5
7/14/2010	Favero Geosciences	Second Quarter 2010 Progress Report
8/30/2010	ARCADIS	Draft Corrective Measures Proposal
10/14/2010	Favero Geosciences	Third Quarter 2010 Progress Report
1/14/2011	Favero Geosciences	Fourth Quarter 2010 Progress Report
4/14/2011	RACER Trust	First Quarter 2011 Progress Report

Table 3. Overview of Corrective Measures Alternatives, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

AOI	Name & Description	Physical Location	Potentially Significant Exposures	Constituent(s) Considered for Corrective Measures	Description of Interim Measures	Potential Corrective Measures	Proposed Corrective Measure
Facility-wide and Near-Site Groundwater - Groundwater use at the Facility and limited off-site properties will be managed through a Well Restriction Overlay District.							
Facility-wide Groundwater - Groundwater use at the facility would be restricted through adoption of a deed restriction.							
Facility-wide Land Use - A deed restriction will be adopted to limit land use to commercial and industrial uses.							
Facility-wide Groundwater and Vapor Monitoring - Selected monitoring wells at and in the vicinity of the Facility will be sampled to evaluate groundwater quality. A soil vapor monitoring program will also be implemented. The data will allow for evaluation of groundwater and soil vapor quality trends and determine what, if any, additional action will be necessary. Groundwater monitoring would be performed semi-annually during active remediation and for 2 years thereafter. Annual groundwater monitoring will be conducted for an additional 3 years. Recommendations regarding continued monitoring will be made following completion of the annual monitoring program. Vapor monitoring would be conducted quarterly for 2 years to evaluate seasonality of data and verify RFI results. Recommendations regarding continued monitoring will be made following completion of the quarterly monitoring program.							
AOI 3	Former South Manufacturing Building SAA - South of AOI 2 and north of AOI 3.	Northwest portion of grassy area.	1. Potential future soil vapor intrusion. 2. Leaching to groundwater	Soil - CVOCs	Not Applicable	1.No action 2. Institutional controls 3. Engineering controls 4. Phytoremediation 5. Direct excavation and disposal 6. Calcium oxide treatment and reuse of soil 7. Electrical resistivity heating	3. Calcium oxide treatment and reuse of soil
		Central portion of site and off-site along Lordeman Street	1. Component to vapor intrusion 2. Ingestion. 3. Off-site migration	Groundwater - CVOCs	Not Applicable	1. No action 2. Groundwater extraction 3. In situ chemical oxidation 4. Enhanced reductive dechlorination 5. Bentonite cutoff wall	3. In situ chemical oxidation

The recommended corrective measures for soil includes source removal and contaminant mass reduction in accordance with requirements presented in a letter from USEPA dated April 28, 2010.

CVOC - Chlorinated Volatile Organic Compounds

SAA - Satellite Accumulation Area

AOI - Area of Interest

Table 4a. Evaluation of Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

Evaluation Criteria	Corrective Measures Alternatives				
	No Action	Well Restriction Overlay District (On-Site and Limited Off-Site)	Deed Restriction - Groundwater Use (On-Site)	Deed Restriction - Land Use (On-Site)	Monitoring - Groundwater and Soil Vapor (On-Site and Limited Off-Site)
<i>Protect Human Health and the Environment</i>	Not effective protecting human health and the environment.	Effective protecting human health and the environment by prohibiting potable and non-potable uses.	Effective protecting human health and the environment by prohibiting potable and non-potable uses.	Effective protecting human health and the environment by limiting land use to commercial and industrial.	Does not directly protect human health and the environment, but provides data that can be used to evaluate whether human health and the environment are protected.
<i>Attain Media Cleanup Standards (Corrective Measures End Points) Set by the Implementing Agency</i>	Will not meet corrective measures end points.	Will not reduce CVOC concentrations, but will attain corrective measures end points associated with limiting exposure.	Will not reduce CVOC concentrations, but will attain corrective measures end points associated with limiting exposure.	Will not reduce CVOC concentrations, but will attain corrective measures end points associated with limiting exposure.	Will not meet corrective measures end points.
<i>Control the Sources of Releases</i>	Does not control the sources of releases.	Controls the sources of the releases by eliminating potential induced migration associated with groundwater pumping.	Does not control the sources of releases.	Does not control the sources of releases.	Does not control the sources of releases.
<i>Comply with Any Applicable Standards for Management of Waste</i>	No waste would be generated from this corrective measure.	Does not produce waste requiring management.	Does not produce waste requiring management.	Does not produce waste requiring management.	Wastes derived from monitoring will be managed in accordance with applicable standards.
<i>Long-Term Reliability and Effectiveness</i>	Not reliable or effective in the long term.	Reliable and effective in the long term by prohibiting potable and non-potable uses of groundwater.	Reliable and effective in the long term by prohibiting potable and non-potable uses of groundwater.	Reliable and effective in the long term by limiting land use to commercial and industrial.	Criteria is not directly applicable, but monitoring data will be used to assess long-term reliability and effectiveness of other corrective measures.
<i>Reduction in the Toxicity, Mobility and Volume of Wastes</i>	Does not reduce toxicity, mobility, or volume of chlorinated volatile organic compounds (CVOCs).	Does not reduce toxicity, mobility, or volume of CVOCs.	Does not reduce toxicity, mobility, or volume of CVOCs.	Does not reduce toxicity, mobility, or volume of CVOCs.	Does not reduce toxicity, mobility, or volume of CVOCs.
<i>Short-Term Effectiveness</i>	Not effective in the short term.	Effectiveness achieved in a short-term time frame.	Effectiveness achieved in a short-term time frame.	Effectiveness achieved in a short-term time frame.	Criteria is not directly applicable, but monitoring data will be used to assess short-term reliability and effectiveness of other corrective measures.

Table 4a. Evaluation of Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

Evaluation Criteria	Corrective Measures Alternatives				
	No Action	Well Restriction Overlay District (On-Site and Limited Off-Site)	Deed Restriction - Groundwater Use (On-Site)	Deed Restriction - Land Use (On-Site)	Monitoring - Groundwater and Soil Vapor (On-Site and Limited Off-Site)
<i>Implementability</i>	No action is easily implemented.	A Well Restriction Overlay District may be easily implemented in the short term, depending on response from county.	A groundwater deed restriction is easily implemented in the short term.	A land use deed restriction is easily implemented in the short term.	Groundwater monitoring is easily implementable because the monitoring well network is already in place. Vapor monitoring points can be easily installed and maintained to facilitate sampling. Implementation completed in the short term.
<i>Cost</i>	Low costs for implementation.	Low costs for implementation.	Low costs for implementation.	Low costs for implementation.	Low to moderate costs to complete periodic monitoring, data evaluation, and reporting. Maintenance costs would be low for monitoring well repairs, as required.
<i>Sustainability</i>	No energy and water requirements, air emissions, additional impacts to land, material consumption and waste generation.	No energy and water requirements, air emissions, additional impacts to land, material consumption and waste generation.	No energy and water requirements, air emissions, additional impacts to land, material consumption and waste generation.	No energy and water requirements, air emissions, additional impacts to land, material consumption and waste generation.	Limited energy requirements for sample collection, shipping and testing. Limited water usage for equipment decontamination. No air emissions or additional impacts to land. Limited material consumption and waste generation.
Conclusion	This technology was not included in the final corrective measures since more appropriate options are available.	Included in proposed final corrective measures to prohibit well installation.	Included in proposed final corrective measures to prohibit potable and non-potable uses of groundwater.	Included in proposed final corrective measures.	Included in proposed final corrective measures.

Table 4b. Evaluation of Soil Corrective Measure Alternatives, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

Evaluation Criteria	Corrective Measures Alternatives						
	No Action	Engineering Controls- Soil Cover	Institutional Controls - Cover Management Plan	Phytoremediation	Soil Excavation	Calcium Oxide Treatment	Electrical Resistivity Heating
<i>Protect Human Health and the Environment</i>	Not effective protecting human health and the environment.	Effective protecting human health and the environment by establishing a cover over the soil. Limits construction of buildings over soil, thus preventing potential exposure via vapor intrusion. Reduces infiltration through the impacted soil and subsequent leaching to groundwater.	Effective protecting human health and the environment by establishing means and methods for maintaining engineering controls.	Effective stimulating biodegradation of chlorinated volatile organic compounds (CVOCs) and limiting migration of dissolved phase constituents in shallow groundwater. However, may have limited effectiveness due to the clay soil and depth of impacts.	Effective protecting human health and the environment by eliminating potential contact with receptors.	Effective protecting human health and the environment by volatilizing CVOCs and binding contaminants to the treated soil matrix.	Effective protecting human health and the environment by removing CVOCs from the soil. The technology can also be used to treat contaminated groundwater in the S1 groundwater zone (with modification and additional cost).
<i>Attain Media Cleanup Standards (Corrective Measures End Points) Set by the Implementing Agency</i>	Will not meet corrective measures end points.	Will not reduce CVOC concentrations, but can attain some corrective measures end points associated with limiting exposure.	Will not reduce CVOC concentrations, but can attain corrective measures end points associated with limiting exposure.	Can reduce CVOC concentrations to meet corrective measures end points.	Can reduce CVOC concentrations to meet corrective measures end points.	Can reduce CVOC concentrations to meet corrective measures end points.	Can reduce CVOC concentrations to meet corrective measures end points.
<i>Control the Sources of Releases</i>	Does not control the sources of releases.	Controls the sources of releases by limiting exposure to receptors and reducing infiltration through the impacted soil and subsequent leaching to groundwater.	Controls the sources of releases by limiting exposure to receptors and reducing infiltration through the impacted soil and subsequent leaching to groundwater.	Controls the sources of releases by reducing CVOC concentrations and uptake of groundwater.	Controls the sources of releases by removing CVOCs from the soil.	Controls the sources of releases by removing CVOCs from the soil.	Controls the sources of releases by removing CVOCs from the soil.
<i>Comply with Any Applicable Standards for Management of Waste</i>	No waste would be generated from this corrective measure.	Waste derived from construction of cover would be managed in accordance with applicable standards.	Waste derived from maintenance of cover would be managed in accordance with applicable standards.	Waste derived from installation of phytoremediation system would be managed in accordance with applicable standards.	Waste removed during excavation would be managed in accordance with applicable standards.	None to limited waste generated, as soil is placed back on site and accumulated groundwater can be used to mix calcium oxide and soil.	Waste removed during system construction would be managed in accordance with applicable standards.
<i>Long-Term Reliability and Effectiveness</i>	Not reliable or effective in the long term.	Reliable and effective in the long term by limiting contact with CVOCs.	Increases the reliability and effectiveness of the cover system by establishing means and methods for maintaining engineering controls.	Reliable and effective in the long term, although treatment rate may be reduced during dormant season.	Reliable and effective in the long term as CVOCs are removed from site.	Reliable and effective in the long term as CVOCs are removed from site, and treatment residuals act as a binder to reduce CVOC mobility.	Reliable and effective in the long term as CVOCs are removed from site.
<i>Reduction in the Toxicity, Mobility and Volume of Wastes</i>	Does not reduce toxicity, mobility, or volume of contaminants.	Does not reduce toxicity, mobility, or volume of CVOCs.	Does not reduce toxicity, mobility, or volume of CVOCs.	Can reduce toxicity, mobility and volume of CVOCs. However, seasonal dormancy of vegetation limits effectiveness.	Does not reduce toxicity or mobility of CVOCs; however, removes CVOCs from Site and places it into a controlled and monitored landfill. Some CVOCs transferred from soil to air for subsequent dispersion and degradation.	Does not reduce the toxicity of CVOCs, but limits contaminant mobility. Reduces volume at site. CVOCs are transferred from the soil to air for subsequent dispersion and degradation.	Does not reduce the toxicity of CVOCs, but limits contaminant mobility. Reduces volume at site. CVOCs are transferred from the ground to air for subsequent dispersion and degradation.

Table 4b. Evaluation of Soil Corrective Measure Alternatives, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

Evaluation Criteria	Corrective Measures Alternatives						
	No Action	Engineering Controls- Soil Cover	Institutional Controls - Cover Management Plan	Phytoremediation	Soil Excavation	Calcium Oxide Treatment	Electrical Resistivity Heating
<i>Short-Term Effectiveness</i>	Not effective in the short term.	Effectiveness achieved in a short-term time frame.	Effectiveness achieved in a short-term time frame.	Limited CVOC reduction in the short term, until root systems become established.	Effectiveness achieved in a short-term time frame.	Effectiveness achieved in a short-term time frame.	Effectiveness achieved in a short-term time frame.
<i>Implementability</i>	No action is easily implemented.	A cover is easily implemented in the short term.	A cover management plan is easily implemented in the short term.	The area that would be treated consists of open ground, and planting of trees would be easily completed.	Soil excavation is easily implemented in the short-term.	Calcium oxide treatment is easily implemented in the short term.	The area that would be treated consists of open ground, and installation of equipment would be easily completed. The technology relies on use of a companion vapor extraction system to recover volatilized CVOCs. The shallow soil at the site consists of clay, which can limit the performance of vapor extraction.
<i>Cost</i>	Low costs for implementation.	Low costs for implementation.	Low costs for implementation and minimal cost for verification and/or maintenance of cover.	Moderate capital cost, based on estimates from vendor. Low O&M costs for fertilizing trees, limiting growth of competing vegetation and replacing diseased/dead trees.	Moderate capital costs and no operation and maintenance costs.	Moderate capital costs and no operation and maintenance costs.	Moderate capital costs. Moderate O&M costs for periodic repairs, equipment replacement and system monitoring.
<i>Sustainability</i>	No energy and water requirements, air emissions, additional impacts to land, material consumption, and waste generation.	Minimal amount of energy used in site clearing/grubbing and application of an asphalt cap. Minimal air emissions, water and material usage, and land/ecosystem impacts during cover construction. Air emissions generated during production of asphalt.	Limited energy use, material consumption and waste generation during maintenance activities. No water requirements, air emissions, or additional impacts to land.	Moderate amount of energy required in the tree well installation phase. Minimal energy and water resources after the 2-year tree establishment period. Renewable materials (trees) and waste are used. Positive land/ecosystem impact.	Large amount of energy required to power excavation and de-watering equipment over a two-month period. Additional energy involved in wastewater treatment. Significant air emissions are generated from the continuous use of heavy machinery. A large amount of soil waste generated will be disposed of in a landfill. Energy use and air emissions associated with transporting large amount of clean soil and equally large amount of impacted soil a long distance.	Moderate amount of energy to excavate and mix calcium oxide into the impacted soil for 3 months. Air emissions are mainly associated with the operation of heavy equipment for excavation, mixing operations, and the volatilization reaction of the treatment process. Water requirements, material consumption, waste generation, and additional land impacts are very low.	Large amount of electricity required over 6 months. Air emissions primarily from electricity generated by coal-powered plants. Soil cutting waste generated from 48 soil vapor extraction and sensor wells. Water demand is moderate, but impact to the land/ecosystem are minimal.
Conclusion	This technology was not included in the final corrective measures since more appropriate options are available.	This technology was not included in the final corrective measures since more appropriate options are available.	This technology was not included in the final corrective measures since more appropriate options are available.	This technology was not included in the final corrective measures since more appropriate options are available.	This technology was not included in the final corrective measures since more appropriate and cost-effective options are available.	Included in proposed final corrective measures to reduce source mass.	This technology was not included in the final corrective measures since more appropriate and cost-effective options are available.

Table 4c. Evaluation of Groundwater Corrective Measure Alternatives, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana.

Evaluation Criteria	Corrective Measures				
	No Action	Groundwater Extraction	In Situ Chemical Oxidation	Enhanced Reductive Dechlorination	Bentonite Cutoff Wall
<i>Protect Human Health and the Environment</i>	Not effective protecting human health and the environment.	Effective protecting human health and the environment by limiting migration to potential ingestion receptors.	Effective protecting human health and the environment by decreasing chlorinated volatile organic compound (CVOC) concentrations.	Effective protecting human health and the environment by decreasing chlorinated volatile organic compound (CVOC) concentrations.	Effective protecting human health and the environment by limiting migration to potential ingestion receptors.
<i>Attain Media Cleanup Standards Set by the Implementing Agency</i>	Will not meet remediation endpoints.	Can reduce CVOC concentrations to meet remediation endpoints.	Can reduce CVOC concentrations to meet remediation endpoints.	Can reduce CVOC concentrations to meet remediation endpoints.	Will not meet remediation endpoints.
<i>Control the Sources of Releases</i>	Does not control the sources of releases.	Controls the sources of releases by limiting migration to potential ingestion receptors.	Controls the sources of releases by treating sorbed-phase and dissolved phase CVOCs.	Controls the sources of releases by treating sorbed-phase and dissolved phase CVOCs.	Controls the sources of releases by limiting migration to potential ingestion receptors.
<i>Comply with Any Applicable Standards for Management of Waste</i>	No waste would be generated from this corrective measure.	Waste derived from construction of extraction wells and installation of piping would be managed in accordance with applicable standards.	Waste derived from injection well installations would be managed in accordance with applicable standards.	Waste derived from injection well installations would be managed in accordance with applicable standards.	Waste removed during wall installation would be managed in accordance with applicable standards.
<i>Long-Term Reliability and Effectiveness</i>	Not reliable or effective in the long term.	Reliable and effective in the long term by limiting migration of CVOCs.	Reliable and effective in the long term as CVOCs are removed from site.	Reliable and effective in the long term as CVOCs are removed from site.	Reliable and effective in the long term by limiting migration of CVOCs.
<i>Reduction in the Toxicity, Mobility and Volume of Wastes</i>	Does not reduce toxicity, mobility, or volume of contaminants.	Does not reduce toxicity of CVOCs. Can limit mobility and volume of CVOCs	Decreases the volume of CVOCs. Does not reduce toxicity or mobility of CVOCs.	Decreases the volume of CVOCs. Does not reduce toxicity or mobility of CVOCs. Process can produce vinyl chloride, which has not been present at site to date.	Does not reduce toxicity, mobility, or volume of contaminants.
<i>Short-Term Effectiveness</i>	Not effective in the short term.	Establishment of hydraulic control achieved in a short-term time frame. However, continued operation is necessary in the long term to maintain hydraulic control.	Effectiveness achieved in a short-term time frame.	Effectiveness achieved in a short-term time frame.	Establishment of hydraulic control achieved in a short-term time frame. However, continued operation is necessary in the long term to maintain hydraulic control.
<i>Implementability</i>	No action is easily implemented.	Groundwater extraction is a well-understood technology that can be easily implemented. However, effluent discharge would require permitting.	The treatment areas on-site are readily accessible.	The treatment areas on-site are readily accessible. However, process can produce methane and vinyl chloride, which may be difficult to control at off-site locations.	The cutoff wall would be placed along the downgradient edge of the property, which consists of open land, and so would be easily implemented.

Table 4c. Evaluation of Groundwater Corrective Measure Alternatives, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana.

Evaluation Criteria	Corrective Measures				
	No Action	Groundwater Extraction	In Situ Chemical Oxidation	Enhanced Reductive Dechlorination	Bentonite Cutoff Wall
<i>Cost</i>	Low costs for implementation.	Moderate cost for initial implementation. High long-term costs due to need for continued operation until CVOC concentrations decrease to levels that can be managed through natural attenuation.	Moderate capital costs and no operation and maintenance costs.	Moderate capital cost, and moderate operation costs during treatment phase. Continued post-remediation monitoring would be needed to confirm control of methane and vinyl chloride.	Moderate cost for initial implementation. High long-term costs due to need for continued operation until CVOC concentrations decrease to levels that can be managed through natural attenuation.
<i>Sustainability</i>	No energy and water requirements, air emissions, additional impacts to land, material consumption, or waste generation.	High amount of energy and materials consumed for system operation over 30 yrs. Minimal water required for well installation but large amount of water extracted from aquifer.	High amount of energy for installation of 61 injection wells. Moderate amount of water and materials consumed for injection process. Low impact of land/ecosystem due to short-term system operation.	High amount of energy for installation of 61 injection wells. Moderate amount of water and materials consumed for injection process. Low impact of land/ecosystem due to short-term system operation. Low impacts on air emissions due to methane production from remediation process	High amount of energy and materials consumed for system operation over 30 yrs. Moderate amount of waste generated from barrier wall/treatment system installation and operation. Minimal water required for well installation but large amount of water extracted from aquifer and excavation process.
Conclusion	This technology was not included in the final corrective measures since more appropriate options are available.	This technology was not included in the final corrective measures since more appropriate options are available.	This technology was selected for the final corrective measure for groundwater.	This technology was not included in the final corrective measures since more appropriate and cost-effective options are available.	This technology was not included in the final corrective measures since more appropriate and cost-effective options are available.

Table 5. Proposed Corrective Measures Endpoints Summary, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

Area	Media Requiring Corrective Measures	Proposed Corrective Measures	Corrective Measures End Point	Confirmation of Corrective Measures End Point
Facility-wide				
Facility-wide Groundwater		Groundwater use at the Facility will be restricted through a deed restriction filed with Howard County to prohibit potable uses.	Deed restriction recorded with Howard County	Copy of recorded deed restriction received by USEPA
Facility-wide and Near-Site Groundwater		A Well Restriction Overlay District will be requested from the Howard County Plan Commission that will incorporate the Facility and limited off-site properties.	Demonstrate properties within identified area are not utilizing groundwater for potable or non-potable purposes, with the exception of wells installed prior to establishing the district and wells used for monitoring or groundwater remediation, as specified in the Zoning Ordinance.	Copy of revised zoning map received by USEPA
Facility-wide Land-use		The property use at the Facility will be restricted through a deed restriction filed with Howard County to restrict use to industrial and commercial purposes.	Deed restriction recorded with Howard County	Copy of recorded deed restriction received by USEPA
Facility-wide groundwater and vapor monitoring		Groundwater monitoring of selected monitoring wells at and in the vicinity of the Facility. Soil vapor monitoring from soil gas ports in the vicinity of the Facility. The data will allow for evaluation of groundwater quality trends and determine what, if any, additional action will be necessary. The monitoring would be performed semi-annually for two years.	Demonstrate groundwater concentrations above MCL are within the boundary of the WR-OL District. Where an off-site vapor intrusion pathway is complete, demonstrate that exposure medium (soil vapor or indoor air, as appropriate) concentrations are below the cumulative target risk level of 1x10-5 and the target hazard index of 1.	Documentation of demonstration that groundwater concentrations above MCL are limited to WR-OL District boundary and exposure medium (soil vapor or indoor air, as appropriate) concentrations are below the cumulative target risk level of 1x10-5 and the target hazard index of 1.
Soil Corrective Measures				
AOI 3 - Former South Manufacturing Building SAA	Soil	Calcium Oxide Treatment of Soil within Treatment Area	Demonstrate that soil TCE concentrations 1) have been reduced such that no significant vapor intrusion risk is present and 2) soil TCE concentrations are less than 400 mg/kg. The 400 mg/kg TCE concentration threshold is the concentration of TCE in soil that would create a TCE concentration of 1,000 ug/L of TCE in groundwater, based on leaching modeling.	Documentation of demonstration that soil TCE concentrations 1) have been reduced such that no significant vapor intrusion risk is present and 2) soil TCE concentrations are less than 400 mg/kg; or implementation of engineering control (vapor mitigation) is submitted to USEPA.
Groundwater Corrective Measures				
AOI 3 - Former South Manufacturing Building SAA	Groundwater	In Situ Chemical Oxidation within Treatment Area	Demonstrate that TCE concentrations in S1 Unit have been reduced to 1,000 ug/L or less.	Implementation of a facility-wide groundwater monitoring program to 1) document that TCE concnetrations in the S1 Unit have decreased to 1,000 ug/L or less, 2) Contaminant concentrations in groundwater are stable or decreasing, and 3) the extent of contaminants in groundwater is consisent with the groundwater model and the WR-OL District.

Table 6a. Summary of Costs, Facility-Wide Controls/Monitoring for Soil, Groundwater and Vapor, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

Remedial Alternative	Remediation Design and Contracting	Construction/ Implementation	Operation and Maintenance - Annual	Duration of Operation and Maintenance (years)	Design and Construction (i.e., no O&M Cost)	Operation and Maintenance	Order of Magnitude Total Cost
No Action	\$0	\$0	\$0	0	\$0	\$0	\$0
Well Restriction Overlay District	\$29,000	\$0	\$8,000	30	\$29,000	\$240,000	\$269,000
Groundwater Deed Restriction	\$9,000	\$0	\$4,000	30	\$9,000	\$120,000	\$129,000
Land Use Deed Restriction	\$9,000	\$0	\$3,000	30	\$9,000	\$90,000	\$99,000
Facility-Wide Groundwater and Vapor Monitoring	\$21,000	\$105,300	See Notes	30	\$126,300	\$1,443,000	\$1,569,300

Notes:

Duration of operation and maintenance period has been assumed for estimating purposes. Additional operation and maintenance beyond the assumed period may be required. Annual monitoring costs for facility-wide groundwater and vapor monitoring program vary, depending on phase of monitoring program. A monitoring duration of 30 years has been assumed for estimating purposes. See Appendix D for details.

Table 6b. Summary of Costs, Soil Corrective Measure Alternatives, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

Remedial Alternative	Remediation Design and Contracting	Construction/ Implementation	Operation and Maintenance - Annual	Duration of Operation and Maintenance (years)	Design and Construction (i.e., no O&M Cost)	Operation and Maintenance	Order of Magnitude Total Cost
No Action	\$0	\$0	\$0	0	\$0	\$0	\$0
Engineering Control - Cover	\$25,000	\$104,000	\$20,000	30	\$129,000	\$600,000	\$729,000
Institutional Control - Cover	\$9,000	\$0	\$15,000	30	\$9,000	\$450,000	\$459,000
Phytoremediation	\$63,000	\$178,000	\$85,000	15	\$241,000	\$1,275,000	\$1,516,000
Soil Excavation	\$38,000	\$5,743,000	\$0	0	\$5,781,000	\$0	\$5,781,000
Calcium Oxide Treatment	\$70,000	\$1,473,000	\$0	0	\$1,543,000	\$0	\$1,543,000
Electrical Resistivity Heating	\$66,000	\$1,815,000	\$480,000	0.5	\$1,881,000	\$480,000	\$2,361,000

Notes:

Duration of operation and maintenance period has been assumed for estimating purposes. Additional operation and maintenance beyond the assumed period may be required.

Table 6c. Summary of Costs, Groundwater Corrective Measure Alternatives, Corrective Measures Proposal, Former GM Delco Plant 5, Kokomo, Indiana

Remedial Alternative	Remediation Design and Contracting	Construction/ Implementation	Operation and Maintenance - Annual	Duration of Operation and Maintenance (years)	Design and Construction (i.e., no O&M Cost)	Operation and Maintenance	Order of Magnitude Total Cost
No Action	\$0	\$0	\$0	0	\$0	\$0	\$0
Groundwater Extraction	\$88,000	\$310,000	\$104,000	30	\$398,000	\$3,120,000	\$3,518,000
In Situ Chemical oxidation	\$164,000	\$1,078,688	\$0	0	\$1,242,688	\$0	\$1,242,688
Enhanced Reductive Dechlorination	\$156,000	\$1,154,730	\$0	0	\$1,310,730	\$0	\$1,310,730
Hydraulic Barrier/Groundwater Extraction	\$146,000	\$839,900	\$104,000	30	\$985,900	\$3,120,000	\$4,105,900

Notes:

Duration of operation and maintenance period has been assumed for estimating purposes. Additional operation and maintenance beyond the assumed period may be required. Each Groundwater Corrective Measure Alternative requires groundwater monitoring to assess effectiveness. Costs associated with groundwater monitoring are captured in the facility-wide monitoring program. Remedy-specific monitoring is included in the above estimates where applicable.

XREFS:

IMAGES:

PROJECTNAME: —

ARCADIS Color Logo.JPG
galveston b.jpg
kokomo east b.jpg
kokomo west b.jpg
miami b.jpg



RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
CORRECTIVE MEASURES PROPOSAL

SITE LOCATION

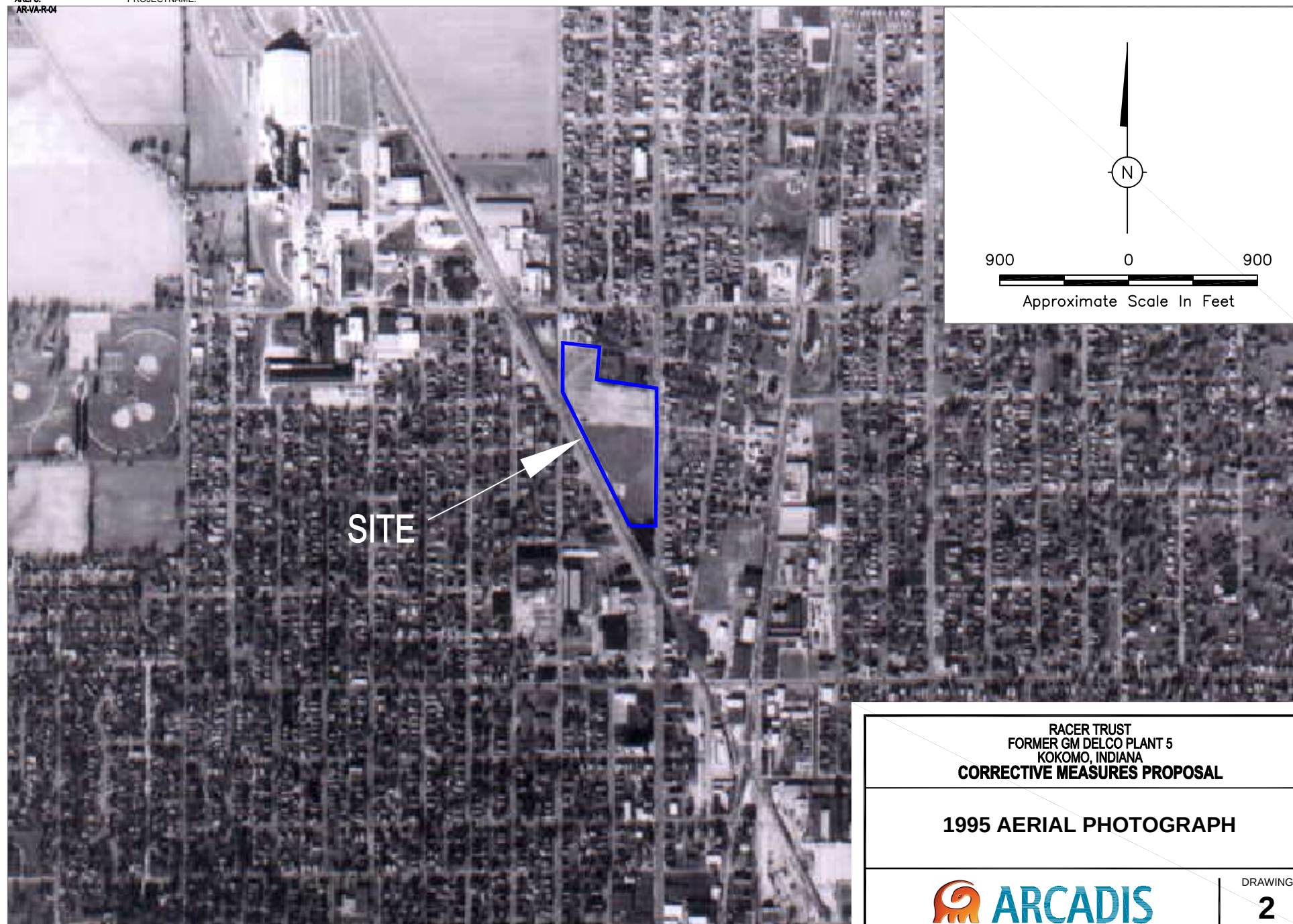


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1

XREFS:
AR-VA-R-04

PROJECTNAME: ---



RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
CORRECTIVE MEASURES PROPOSAL

1995 AERIAL PHOTOGRAPH



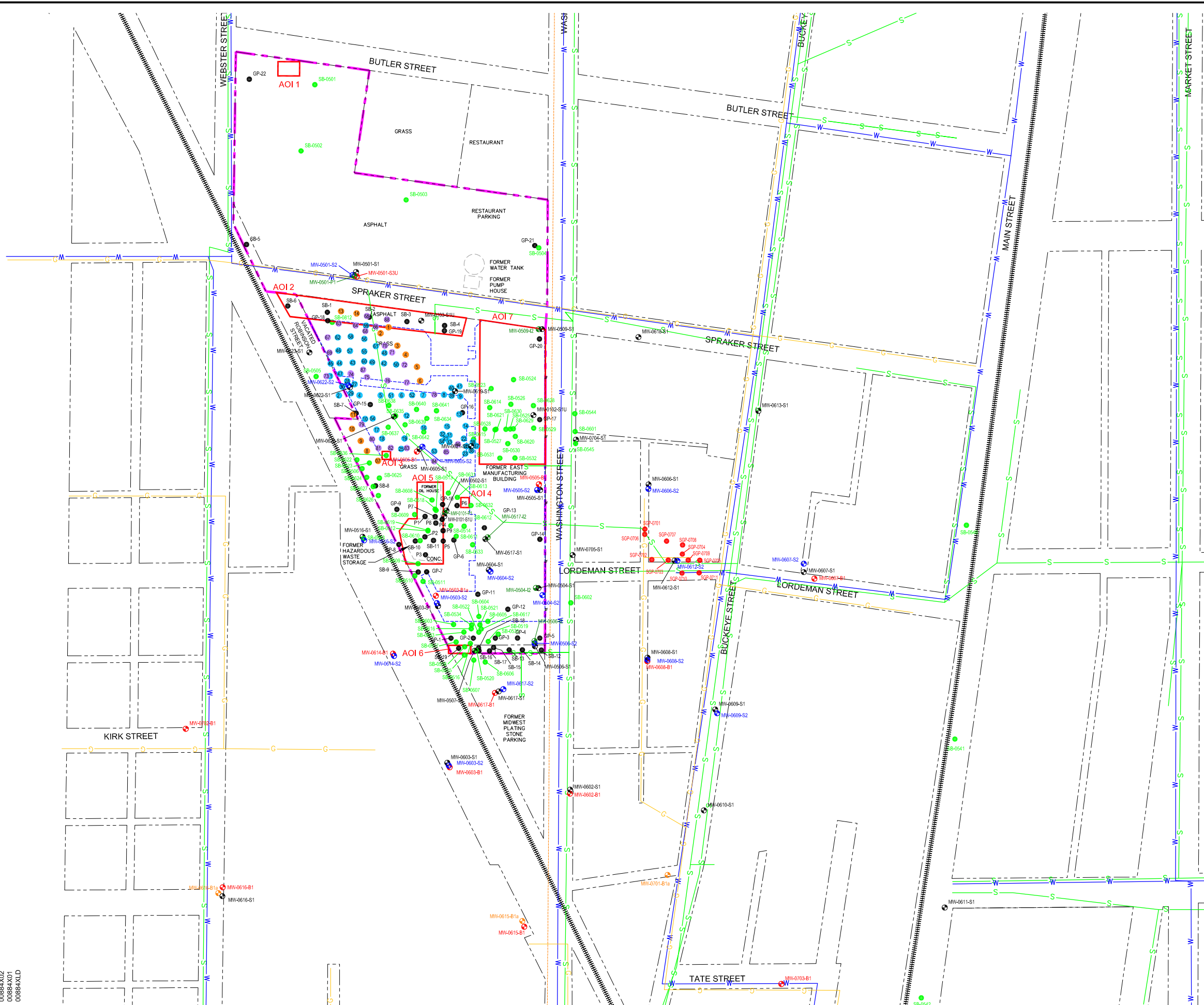
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2

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PROJECTNAME: ---

0084X02
0084X01
0084XLD



LEGEND

- MONITORING WELL SCREENED IN DISCONTINUOUS UNIT
P1 DENOTES SCREENED INTERVAL IS IN A PERCHED ZONE ABOVE UNIT S1
12 DENOTES SCREENED INTERVAL IS A SAND UNIT BETWEEN UNITS S1 AND S2
- MONITORING WELL S2 SCREENED IN UNIT S1
- MONITORING WELL SCREENED IN UNIT S2
- MONITORING WELL SCREENED IN UNIT B1. UNIT B1 REFERS TO THE UPPER-MOST TRANSMISSIVE ZONE WITHIN THE LIMESTONE BEDROCK UNIT.
- MONITORING WELL (B1A LOCATIONS ARE OPEN BEDROCK BOREHOLES TO A DEPTH OF APPROXIMATELY 150 FT BG CURRENTLY SEALED WITH FLUTE LINERS)
- PRE-RFI SOIL BORING LOCATIONS
- RFI SOIL BORING LOCATIONS
- RFI PHASE IV LOCATION (ID IS THE LAST DIGIT ASSOCIATED WITH BORING ID) E.G. 1 EQUALS SB-0701 AND 54 EQUALS SB-0754
- RFI PHASE IV NOVEMBER 2007 STEP-OUT LOCATIONS (ID IS THE LAST DIGIT ASSOCIATED WITH BORING ID) E.G. 63 EQUALS SB-0763 AND 75 EQUALS SB-0775
- RFI PHASE IV JANUARY 2008 STEP-OUT LOCATIONS (ID IS THE LAST DIGIT ASSOCIATED WITH BORING ID) E.G. 01 EQUALS SB-0801 AND 14 EQUALS SB-0814
- SOIL GAS MONITORING POINT
- SEWER UTILITY
- WATER UTILITY
- GAS UTILITY
- FIBER OPTIC UTILITY

NOTE:

UTILITY LOCATIONS ARE APPROXIMATE
BASED ON REVIEW OF AVAILABLE PRINTS
FROM EACH UTILITY.

0 100' 200'
GRAPHIC SCALE

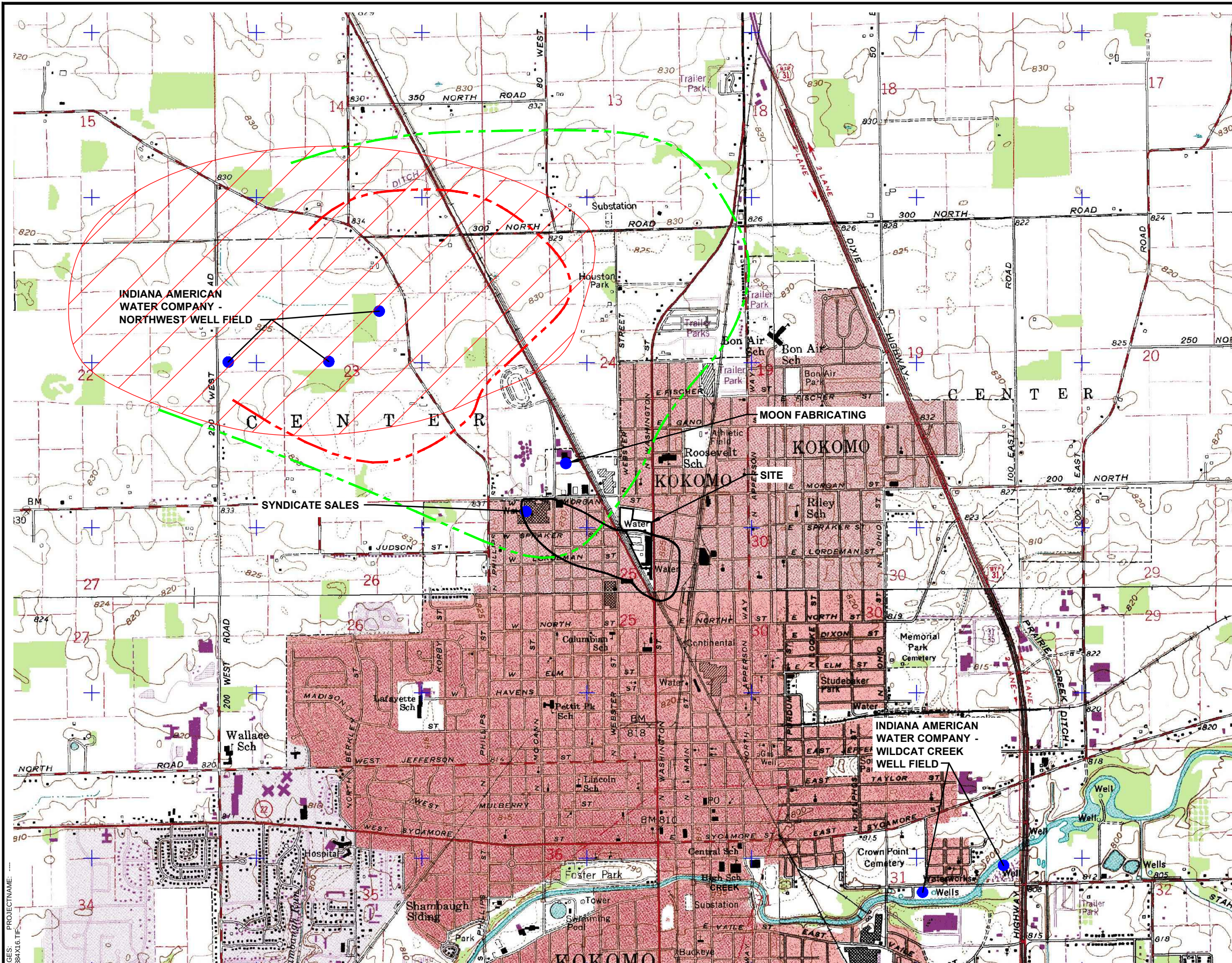
RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
CORRECTIVE MEASURES PROPOSAL

INVESTIGATION LOCATIONS



DRAWING

3

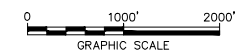


LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- PROPOSED WELL RESTRICTION OVERLAY DISTRICT EXTENT
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTE:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.



RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**BOUNDARY OF PROPOSED WELL
RESTRICTION - OVERLAY DISTRICT**



DRAWING

4

CITY: (req) DIV/GRP: (req) DB: (req) LD: (req) PIC: (req) TM: (req) LVR: (req) OFF: (req) REF: G:\PROJECTS\Racer Trust\1288 - Kokomo Corrective Measures Proposal (CMP)\soil treatment area_rev_4-28-2011.dwg LAYOUT: LAYOUT1 PLOT: 4/27/2011 2:28 PM ACADVER: 17.25 (LMS TECH) PAGESETUP: PLOTSTYLETABLE: ACAD.CTB PLOTTED: 4/27/2011 2:28 PM BY: FISHER, SARAH

PROJECT NAME: RACER TRUST
Kokomo Base Map 1_2009
arcadis_addresses

RED ROBINSON STREET

APPROXIMATE AREA = 5103/sqft

ASPHALT

GRASS

FORMER NORTH
MANUFACTURING
BUILDING

SB-0746

SB-0757

SB-0756

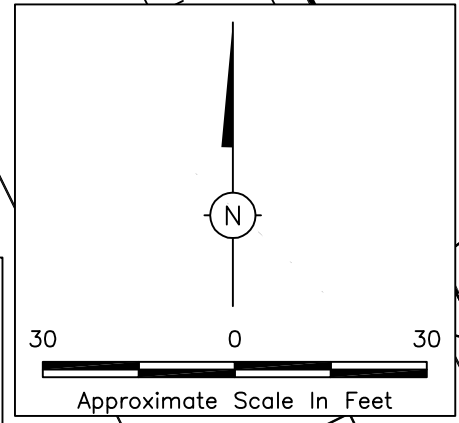
SB-0749

SB-0775

APPROXIMATE AREA = 7197 sqft

LEGEND

- BOUNDARY OF THIESSEN POLYGON
- SOIL SAMPLE LOCATION WITH POTENTIAL RISK
- 400 mg/kg TCE CONTOUR
- ESTIMATED TREATMENT AREA BOUNDARY
- ESTIMATED TREATMENT AREA
- FORMER BUILDING BOUNDARY



RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
CORRECTIVE MEASURES PROPOSAL

**BOUNDARY OF AREA IDENTIFIED FOR
SOIL CORRECTIVE MEASURES**



DRAWING
5



LEGEND

- MW-0501-P1 MONITORING WELL SCREENED IN DISCONTINUOUS UNIT
P1 DENOTES SCREENED INTERVAL IS IN A PERCHED ZONE ABOVE UNIT S1
12 DENOTES SCREENED INTERVAL IS A SAND UNIT BETWEEN UNITS S1 AND S2
- MW-0603-S1 MONITORING WELL SCREENED IN UNIT S1
- MW-0603-S2 MONITORING WELL SCREENED IN UNIT S2
- MW-0603-B1 MONITORING WELL SCREENED IN UNIT B1. UNIT B1 REFERS TO THE UPPER-MOST TRANSMISSIVE ZONE WITHIN THE LIMESTONE BEDROCK UNIT.
- MW-0615-B1a OPEN BEDROCK BOREHOLE (B1a LOCATIONS ARE OPEN BEDROCK BOREHOLES TO A DEPTH OF APPROXIMATELY 150 FT BG CURRENTLY SEALED WITH FLUTE LINERS)
- (<5 U) TCE CONCENTRATION IN µg/L (JUNE 2009)
- (<5 U) HISTORIC TCE CONCENTRATION IN µg/L (OCTOBER 2005, MARCH & NOVEMBER 2006 AND NOVEMBER & DECEMBER 2008)
- 5 ISOCONCENTRATION CONTOUR IN µg/L
- * B1a DATA IS FROM THE UPPER MOST SAMPLED UNIT
- ESTIMATED TREATMENT AREA



RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA

CORRECTIVE MEASURES PROPOSAL

**BOUNDARY OF AREA IDENTIFIED
FOR GROUNDWATER CORRECTIVE
MEASURES**

DRAWING
6

**Revitalizing Auto Communities
Environmental Response Trust**

**Appendix A: Groundwater Model
Report**

August 31, 2011



Xin Song, Ph.D., P.E.
Hydrogeologist/Engineer



Quentin R. Moore
Senior Engineer



Gastón Leone
Principal Hydrologist

**Appendix A: Groundwater
Model Report**

Prepared for:
Revitalizing Auto Communities
Environmental Response Trust

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Our Ref.:
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Date:
August 31, 2011

1. Introduction	1
1.1 Site Background and Objectives	1
2. Conceptual Site Model	3
2.1 Geology	3
2.1.1 Regional Geology	3
2.1.2 Site Geology	3
2.2 Hydrogeology	5
2.2.1 Regional Groundwater Flow	5
2.2.2 Large Well Fields	5
2.2.3 Surface Water	6
2.2.4 Site Groundwater Flow	6
2.3 Distribution of Constituents of Concern in Soil and Groundwater	7
3. Groundwater Flow Model	9
3.1 Model Code Selection	9
3.2 Model Code Description	9
3.3 Model Domain and Grid	10
3.4 Hydraulic Parameters	10
3.5 Boundary Conditions	12
3.5.1 Constant Head Boundaries	12
3.5.2 Drains	12
3.5.3 Recharge	13
3.5.4 Water Supply	13
4. Groundwater Flow Model Calibration	13
4.1 Model Steady-State Flow Calibration	13
4.1.1 Head Targets	14
4.1.2 Steady-State Calibration Results	14

4.2	Model Transient Flow Calibration	15
4.2.1	Transient Calibration Head Targets (Potentiometric Study)	15
4.2.2	Transient Calibration Results	15
5.	Solute Transport Model	16
5.1	Model Code Selection	16
5.2	Model Code Description	16
5.3	Source Areas	17
5.4	Solute Transport Calibration	17
5.5	Solute Transport Parameters	18
6.	Model Predictive Simulations	19
6.1	IAWC-NWF Travel Time Boundaries and Well Restriction Overlay District	20
6.2	Scenario 1 – Calibrated Solute Transport Parameters and IAWC-NWF Pumping at Average Rates	21
6.3	Scenario 2 – Reduced Retardation Factors and IAWC-NWF Pumping at Average Rates	22
6.4	Scenario 3 – Reduced Retardation Factors, No Degradation of cis-1,2-DCE, and IAWC-NWF Pumping at Average Rates	23
6.5	Scenario 4 – Reduced Retardation Factors, No Degradation of cis-1,2-DCE, Reduced on-site Source Concentration, and IAWC-NWF Pumping at Average Rates	24
6.6	Scenario 5 – Reduced Retardation Factors, No Degradation of cis-1,2-DCE, Increased TCE Half-Life, and IAWC-NWF Pumping at Average Rates	26
6.7	Scenario 6 – Reduced Retardation Factors, No Degradation of cis-1,2-DCE, and IAWC-NWF Pumping Rates Doubled	27
7.	Conclusions and Recommendations	28
8.	Uncertainties and Limitations	30
9.	References	31

Tables

Table A-1	Summary of Hydraulic Parameter Distributions in the Groundwater Flow Model
Table A-2	Summary of Extraction Rates of Well Fields in the Groundwater Flow Model
Table A-3	Groundwater Flow Model Calibration Results
Table A-4	Summary of Solute Transport Parameters for Predictive Scenarios

Figures

Figure A-1	Site Location
Figure A-2	Facility Layout
Figure A-3	Site Cross-Sections
Figure A-4	Regional Extent of S1, S2, and B1 Units (from Smith Report)
Figure A-5	Regional Potentiometric Surface Map (from Smith Report)
Figure A-6	Regional Large Well Fields
Figure A-7	Site Potentiometric Maps (from RCRA Corrective Action Report)
Figure A-8	Distribution of TCE in Soils (from RCRA Corrective Action Report)
Figure A-9	TCE Distribution in Groundwater (from RCRA Corrective Action Report)
Figure A-10	cis-1,2-DCE Distribution in Groundwater (from RCRA Corrective Action Report)
Figure A-11	Model Domain and Grid
Figure A-12	Hydraulic Conductivity and Model Boundary Conditions (Layer 1)
Figure A-13	Hydraulic Conductivity and Model Boundary Conditions (Layer 2)
Figure A-14	Hydraulic Conductivity and Model Boundary Conditions (Layer 3)
Figure A-15	Hydraulic Conductivity and Model Boundary Conditions (Layer 4)
Figure A-16	Hydraulic Conductivity and Model Boundary Conditions (Layer 5)
Figure A-17	Hydraulic Conductivity and Model Boundary Conditions (Layer 6)
Figure A-18	Hydraulic Conductivity and Model Boundary Conditions (Layer 7)

Figure A-19	Steady-State Calibration Residuals and Model Simulated Water Levels in Unit S1 (Model Layer 2)
Figure A-20	Steady-State Calibration Residuals and Model Simulated Water Levels in Unit S2 (Model Layer 4)
Figure A-21	Steady-State Calibration Residuals and Model Simulated Water Levels in Unit B1 (Model Layer 7)
Figure A-22	Steady-State Calibration Scatter Plot
Figure A-23	Transient Calibration Hydrographs for Well Clusters in Sand Unit S1
Figure A-24	Transient Calibration Hydrographs for Well Clusters in Sand Unit S2
Figure A-25	Transient Calibration Hydrographs for Well Clusters in Sand Unit S3/ Bedrock B1
Figure A-26A	Initial TCE Plume in the Model Domain (Predictive Simulations)
Figure A-26B	Initial DCE Plume in the Model Domain (Predictive Simulations)
Figure A-27	Indiana American Water Company-Northwest Well Field Wellhead Protection Areas
Figure A-28	Predicted TCE Distribution in Sand Unit S1 – Scenario 1
Figure A-29	Predicted cis-1,2-DCE Distribution in Sand Unit S1 – Scenario 1
Figure A-30	Predicted TCE Distribution in Sand Unit S2 – Scenario 1
Figure A-31	Predicted cis-1,2-DCE Distribution in Sand Unit S2 – Scenario 1
Figure A-32	Predicted Concentrations through Time – Scenario 1
Figure A-33	Predicted TCE Distribution in Sand Unit S1 – Scenario 2
Figure A-34	Predicted cis-1,2-DCE Distribution in Sand Unit S1 – Scenario 2
Figure A-35	Predicted TCE Distribution in Sand Unit S2 – Scenario 2
Figure A-36	Predicted cis-1,2-DCE Distribution in Sand Unit S2 – Scenario 2
Figure A-37	Predicted Concentrations through Time – Scenario 2
Figure A-38	Predicted TCE Distribution in Sand Unit S1 – Scenario 3
Figure A-39	Predicted cis-1,2-DCE Distribution in Sand Unit S1 – Scenario 3
Figure A-40	Predicted TCE Distribution in Sand Unit S2 – Scenario 3
Figure A-41	Predicted cis-1,2-DCE Distribution in Sand Unit S2 – Scenario 3
Figure A-42	Predicted Concentrations through Time – Scenario 3

Figure A-43	Predicted TCE Distribution in Sand Unit S1 – Scenario 4
Figure A-44	Predicted cis-1,2-DCE Distribution in Sand Unit S1 – Scenario 4
Figure A-45	Predicted TCE Distribution in Sand Unit S2 – Scenario 4
Figure A-46	Predicted cis-1,2-DCE Distribution in Sand Unit S2 – Scenario 4
Figure A-47	Predicted Concentrations through Time – Scenario 4
Figure A-48	Predicted TCE Distribution in Sand Unit S1 – Scenario 5
Figure A-49	Predicted cis-1,2-DCE Distribution in Sand Unit S1 – Scenario 5
Figure A-50	Predicted TCE Distribution in Sand Unit S2 – Scenario 5
Figure A-51	Predicted cis-1,2-DCE Distribution in Sand Unit S2 – Scenario 5
Figure A-52	Predicted Concentrations through Time – Scenario 5
Figure A-53	Predicted TCE Distribution in Sand Unit S1 – Scenario 6
Figure A-54	Predicted cis-1,2-DCE Distribution in Sand Unit S1 – Scenario 6
Figure A-55	Predicted TCE Distribution in Sand Unit S2 – Scenario 6
Figure A-56	Predicted cis-1,2-DCE Distribution in Sand Unit S2 – Scenario 6
Figure A-57	Predicted Concentrations through Time – Scenario 6
Figure A-58	Proposed Well Restriction Overlay District Extent

1. Introduction

The United States Environmental Protection Agency (USEPA) and General Motors Corporation (GM) entered into a performance-based Resource Conservation and Recovery Act (RCRA) Corrective Action Agreement (the Agreement) in March 2006. Pursuant to the Agreement, GM had worked in cooperation with USEPA to investigate releases of hazardous wastes or hazardous constituents at or from the Former GM Delco Plant 5 (the Facility) located in Kokomo, Howard County, Indiana (USEPA ID IND000806844) (Figure A-1). As a result of GM's June 2009 bankruptcy, the operating assets of GM were sold on July 10, 2009 to a newly formed company, which is now known as General Motors LLC. Existing, non-continuing assets remain the property of "old" GM, which changed its name to Motors Liquidation Company (MLC Trust) in its capacity as a debtor-in-possession in the bankruptcy case. On March 31, 2011 the Revitalizing Auto Communities Environmental Response (RACER) Trust became effective. On that date, all assets and cleanup funding that had been the responsibility of MLC were transferred to RACER Trust. RACER Trust has responsibility for completing the Corrective Action activities at this Facility in accordance with the Cost Estimate and Settlement Agreement that are the basis for the Trust.

A memorandum (Groundwater Flow Modeling, ARCADIS 2010a), dated 3/18/2010, was submitted to the USEPA with a proposed approach to conduct groundwater flow and solute transport model simulations at and in the vicinity of the Facility. Following the approval of the memorandum (dated 4/28/2010), a groundwater flow and solute transport model was developed to conservatively estimate the distance that site-related trichloroethene (TCE) and its breakdown product (cis-1,2-dichloroethene [cis-1,2-DCE]) could migrate at concentrations above their Maximum Contaminant Level (MCL). The numerical modeling results were used as the basis to define the extent of the proposed Well Restriction Overlay District (WR-OL), which is one of the institutional controls for groundwater management at the Facility.

1.1 Site Background and Objectives

The Facility was used to produce electronic circuit boards for automotive applications. Processes at the Facility included attaching diodes, transistors, resistors, and chips to circuit boards. A mixture of rosin flux and isopropanol was sprayed on the parts in preparation for soldering. The parts were then soldered with lead/zinc solder. As discussed in the preliminary assessment and visual site inspection (PA/VS), after soldering, the parts were degreased with freon, 1,1,1-trichloroethane (1,1,1-TCA), or

water-based washes (PRC 1992). The circuit boards were then dipped in a solvent based coating for protection.

ARCADIS submitted a Draft RCRA Facility Investigation Report (RFI Report, ARCADIS 2009) to the USEPA on October 5, 2009. The human health risk assessment included in the Draft RFI Report evaluated potential current and future exposures to site-related constituents in soil and groundwater at and in the vicinity of the Facility. The risk assessment assumed that institutional controls would be implemented to restrict groundwater uses within the area of existing groundwater contamination, which has been shown to be stable as documented in the CA750 determination prepared by RACER Trust in November 2009. The risk assessment also concluded that there is no current or potential future unacceptable risk from drinking water exposures because the area of existing groundwater contamination does not affect any current drinking water wells, and is not expected to affect any drinking water wells in the future, if institutional controls to restrict groundwater use are established for the existing and potential future areas of groundwater contamination (ARCADIS 2010b).

To establish the WR-OL, one of the institutional controls to restrict groundwater use for the existing and potential future area of groundwater contamination, a groundwater flow and solute transport model was developed to estimate the travel distance of site-related TCE and its breakdown product, cis-1,2-DCE at concentrations above their MCLs, which was used as the basis for defining the area that would be included in the WR-OL. The groundwater flow model was developed to:

1. estimate the travel distance of existing site-related concentrations of TCE and cis-1,2-DCE in groundwater at concentrations exceeding MCLs; and
2. evaluate the potential future contribution of the Facility groundwater, if any, to the well fields located in the vicinity of the Facility.

Specifically, the model objectives included the following:

- Development of an expanded hydrogeologic conceptual site model (CSM),
- Construction and calibration of a numerical groundwater flow model,
- Development of a fate and transport model, and

- Conducting predictive simulations for TCE and its breakdown product cis-1,2-DCE.

2. Conceptual Site Model

As shown in Figure A-2, the Facility is bounded by Butler Street to the north, beyond which are residential and industrial properties; by an abandoned industrial property to the south (former Midwest Plating Corporation); by a railroad to the west, beyond which are residential and commercial properties; and by North Washington Street to the east, beyond which are residential properties.

The majority of the Facility is a vacant grass field with the exception of a 4.31-acre parking lot and abandoned road in the northern portion of the property. The abandoned road (Spraker Street) separates the parking lot on the north side of the property from the vacant grass field comprising the remainder of the property (Figure A-2).

2.1 Geology

2.1.1 Regional Geology

The Facility lies within the Bluffton/Tipton Till Aquifer System physiographic unit (Scott 2008). The topography of this unit resulted from Pleistocene time Wisconsin glacial advances (Wayne 1996). The regional geology of the area around the Facility consists of approximately 80 feet (ft) of alluvial and glacial deposits overlying sedimentary carbonate bedrock (Fenelon 1994). The Pleistocene glacial drift is characterized by clay tills and stream deposits consisting largely of sand and gravel. The discontinuous sand and gravel deposits are interspersed within the clay tills (Smith et al. 1985). The regional bedrock at the Facility is limestone and dolomite in the Wabash Formation of the Silurian System. The thickness of the limestone and dolomite is approximately 375 feet thick (Fenelon 1994). Regionally, the Wabash limestone and dolomite has a sharp basal contact with underlying limestone and interbedded shale of the Ordovician System.

2.1.2 Site Geology

The generalized elevation for the facility is approximately 826 ft above mean sea level (amsl), with the land surface being relatively flat. Three continuous sand units separated by clay layers have been identified at the Facility and have been designated units S1 through S3, with unit S1 being the shallowest and unit S3 being the deepest

(Figure A-3). Sand unit S1 consists primarily of sand and gravel and ranges in thickness from 1 ft near the southeastern margins of the investigation area and 35 ft near the center of the former operations area. Underlying the S1 unit is a hard clay (till), which has an approximate thickness range of 10 to 40 ft. Underlying this hard clay (till) is the S2 unit, which is comprised of poorly sorted sands and gravels, and is generally encountered at 50 ft to 55 ft below ground surface (bgs). The S2 unit ranges in thickness from 20 ft near the center of the Facility to 1.5 ft near the southeastern margins of the investigated area. The S2 unit ultimately pinches out, and is not present south of the Facility. The S3 unit is located above the carbonate bedrock and is found exclusively in the northern portion of the investigated area at MW-0501-S3U. The S3 unit is separated from the S2 unit by 9 ft of a hard gray clayey silt, and is encountered at a depth of approximately 85 ft, with a thickness of 7 ft.

In addition to the sand units discussed above, several discontinuous pockets of sand were identified at various depths at the Facility. In general, these discontinuous sands were present either above the S1 unit (shown as P1 in Figure A-3) or between the S1 and S2 units (shown as I2 in Figure A-3).

Bedrock is encountered at a depth of approximately 85 ft bgs (741 ft amsl) on the northern part of the Facility and approximately 60 ft bgs (766 ft amsl) immediately south of the Facility (Figure A-3). The elevation of the bedrock surface becomes shallow moving south from the Facility towards Wildcat Creek. Throughout the Facility the weathered bedrock zone ranges from 3 ft to 49 ft in thickness and is encountered at an elevation varying between 754 and 768 ft amsl. The presence of a weathered bedrock zone consisting of mechanically fractured parent limestone, angular clasts imbedded and cemented within a lime mud matrix is encountered at the interface between the unconsolidated deposits and the bedrock. Based on boring logs from the Facility, water supply well records, and available literature, the local bedrock beneath the Facility is the Kokomo Limestone Member of the Wabash Formation. The upper bedrock zone beneath the weathered bedrock zone exhibits increased fractures, crevices, and dissolution weathering features along joints and bedding planes, and with increased depth the dolomitic limestone becomes increasingly competent (massive) and less vuggy. The dolomitic limestone is micritic with alternating thin band of light gray and tan laminations. The characteristics of the bedrock vary across the Facility with interformational breccias observed that consist of vuggy limestone with increased fossilization which includes coral and sponge relicts and clasts. These features are associated with shallow subtidal to intertidal depositional environments (Tollefson 1979).

2.2 Hydrogeology

2.2.1 Regional Groundwater Flow

The Facility is located in the Upper Wabash River Basin. Figures presenting the regional extent and top elevations of the Upper Sand and Gravel Saturated Sand Unit (S1 unit), Middle Sand and Gravel Saturated Sand Unit (S2 unit), and Bedrock Saturated Unit (B1 unit) from Smith et al. (1985) are presented on Figure A-4. Groundwater flow is influenced by deposits of till plain with the till acting as semi-confining layers and groundwater confined in the sand layers. Groundwater is also contained in the upper beds of limestone and dolomite that underlie the glacial deposits (Smith et al. 1985). Regional potentiometric surface maps that correspond to the S1, S2 and S3 units are presented on Figure A-5, which show that regionally groundwater flows from east to west with local flow direction influenced primarily by discharge to surface water features.

2.2.2 Large Well Fields

The large well fields identified in the study area are shown in Figure A-6. Three major municipal well fields are located near the Facility, including the Indiana-American Water Company (IAWC) Wildcat Creek Well Field (WCWF), IAWC Southeast Well Field (SWF) and the IAWC Northwest Well Field (NWF). The WCWF is located approximately 1.8 miles southeast (downgradient) of the Facility, the SWF is located approximately 3.5 miles east of the Facility and the NWF is located approximately 1.3 miles northwest (upgradient) of the Facility.

The WCWF wells are screened in the B1 aquifer and pump at an average rate of approximately 1,980 gpm. The WCWF does not appear to influence groundwater flow at the Facility because this well field draws most of its water directly from Wildcat Creek. Consequently, these wells are not included in the groundwater flow model. The SWF wells are also screened in the B1 unit and extract groundwater at an average rate of approximately 240 gpm. The SWF wells do not appear to influence groundwater flow at the Facility because the extraction rate is not substantial and the wells are sufficiently far from the Facility. The NWF wells, which began operating in 2007, are screened in the S2 sand unit, and extract groundwater at an annual average rate of approximately 1,100 gpm. The NWF appears to influence groundwater flow at the Facility.

The additional well fields active in the groundwater flow model and shown on Figure A-6 include the Town of Galveston well field, Deer Creek Estates well field, Northwestern School Corporation east and west well fields, the Moon Fabricating Corporation well, and the Syndicate Sales, Inc. well field. These well fields are not significant producers of groundwater and do not influence groundwater flow in the vicinity of the Facility. The Town of Galveston well field extracts groundwater from the B1 unit at an average rate of approximately 70 gpm. The Deer Creek Estates, Moon Fabricating Corporation and Syndicate Sales, Inc. well fields extract groundwater from the B1 unit at a relatively low rate (less than 10 gpm). The Northwestern School Corporation east and west well fields extract groundwater from the S2 sand unit at a relatively low rate (less than 10 gpm). Groundwater extraction rates for each of these facilities are based on information provided in the Indiana Department of Natural Resources (IDNR) Significant Water Withdrawal Facility (SWWF) database.

2.2.3 Surface Water

There are no major surface water bodies in the immediate vicinity of the Facility. The nearest major surface water body is Wildcat Creek, which is located approximately 1.5 miles south of the Facility and flows in a west-southwest direction. Wildcat Creek is a major tributary of the Wabash River. Wildcat Creek is one of the principal streams flowing through the outwash aquifer in Howard County and is mostly a gaining stream. The surface water flow in the creek is controlled by treated sewage discharge, diversion of surface water, lowhead dams, and two reservoirs located east of Kokomo (Smith et al. 1985). The arithmetic mean annual discharge of Wildcat Creek [United States Geological Survey (USGS) Station 03333700, located on Wildcat Creek near the intersection of W. Markland Ave and S. Berkley Rd] as calculated by the USGS from 1956 to 1982 is 230 cubic feet per second (cfs), and the seven day, ten year low flow (7Q10) of the creek is 12 cfs (<http://waterdata.usgs.gov/nwis/uv?03333600>).

2.2.4 Site Groundwater Flow

In the vicinity of the Facility, the ground surface is relatively flat and is characterized by a dense drainage pattern. The three continuous sand units separated by clay layers identified at the Facility as S1 through S3 correspond with water bearing units at the Facility. Sand unit S1 is the uppermost continuous water-bearing unit. Groundwater within the S1 unit is under confined conditions. The S1 unit is generally encountered between approximately 10 to 25 ft bgs (816 to 801 ft amsl). The underlying S2 unit is fully saturated, and under confined conditions. The S3 unit is a deeper water-bearing unit that is located above the carbonate bedrock.

Groundwater flow within S1 and S2 is strongly influenced by overlying clay till deposits and generally flows southeast towards Wildcat Creek. Groundwater elevation contour maps were prepared for S1, S2 and B1 based on measurements collected on March 8, 2007, November 11, 2008, February 17, 2009 and July 12, 2009 (RFI, ARCADIS 2009). Figures A-7 presents representative potentiometric maps for S1, S2 and B1 based on water level data collected on July 12, 2009. Panel A in Figure A-7 illustrates the potentiometric surface of the first encountered saturated confined sand and gravel unit (sand unit S1). The potentiometric surface map suggests that groundwater within the S1 unit flows toward the southeast. The local potentiometric surface in the S2 unit is presented on Figure A-7 Panel B. Sand unit S2, the second encountered saturated confined sand and gravel unit, has a relatively flat gradient, and has historically demonstrated a groundwater flow direction toward the southeast, as illustrated by the March 8, 2007 potentiometric surface (RFI, ARCADIS, 2009). However, since November 11, 2008, the potentiometric surface suggests that a groundwater divide occurs within the S2 unit, likely due to pumping from the IAWC-NWF which started in 2007 (Figure A-7 Panel B). The potentiometric surface map for the bedrock unit (B1) is provided on Figure A-7 Panel C, which also shows a groundwater divide similar to the S2 unit.

Due to the variable hydraulic gradients observed in sand unit S2, a groundwater potentiometric surface study was conducted at the Facility using pressure transducers placed within three monitoring well nests to further evaluate groundwater flow directions in sand unit S2. Results of the study (RFI, ARCADIS 2009) indicate that groundwater flow direction in the S2 sand unit at the Facility flows from a divide in the central portion of the Facility toward the southeast and varying from the northeast to northwest. The northern flow components that were observed between the March 2007 and November 2008 monitoring events was likely the result of pumping activities at the municipal well field (IAWC-NWF) located to the northwest of the Facility that began pumping in April 2007.

2.3 Distribution of Constituents of Concern in Soil and Groundwater

The primary constituents of concern (COCs) include TCE and its breakdown products cis-1,2-DCE and vinyl chloride. Soil samples were collected from borings advanced as part of the RFI (ARCADIS, 2009). TCE concentrations in soil are presented on Figure A-8. No TCE impacted soil with concentrations greater than 2 mg/kg (calculated soil migration to groundwater criteria) was observed in soils from 0-8 ft bgs. TCE impacts in soil were observed from 8 to 10 ft bgs and at depths greater than 10 ft bgs. The soil concentrations exceed 61 mg/kg (EPA Region 9 PRG) from 8 to 10 ft bgs in the central

area of the Facility and exceed 2 mg/kg in small areas in the southern area of the Facility. Soil concentrations in excess of 500 mg/kg were generally located in the northwest portion of the Facility from samples collected at depths greater than 10 ft bgs. Areas of soil concentrations exceeding 2 mg/kg at depths greater than 10 ft bgs were located in the central and southern areas of the Facility.

Groundwater samples were collected from monitoring wells during the RFI (ARCADIS, 2009). TCE and cis-1,2-DCE groundwater concentration contours are presented on Figure A-9 and Figure A-10, respectively. In the S1 unit, TCE groundwater concentrations greater than the MCL (5 µg/L) are present at the Facility and offsite to the east and southeast. In the S2 unit, TCE groundwater concentrations greater than the MCL are present at the Facility and offsite to the southeast of the Facility. TCE concentrations greater than the MCL are present in B1 unit at the southern end of the Facility and extend offsite to the south. Cis-1,2-DCE groundwater concentrations in the S1 unit are greater than the MCL (70 µg/L) at the Facility and are present east of the Facility. In the S2 unit, concentrations of cis-1,2-DCE in groundwater are greater than the MCL in the southeast corner of the Facility and offsite to the southeast. Cis-1,2-DCE groundwater concentrations greater than the MCL in the B1 unit in the southeastern corner of the Facility and are present offsite to the southeast, south and southwest of the Facility. The groundwater data collected during the RFI indicated that TCE and cis-1,2-DCE concentrations in groundwater are stable.

Vinyl chloride has also been detected at concentrations exceeding its MCL in groundwater samples collected from onsite and offsite monitoring wells. The maximum detected vinyl chloride concentrations are 150 µg/L, 4.1 µg/L and 3.6 µg/L, in units S1, S2 and B1, respectively. The relatively high vinyl chloride concentrations are measured only S1 unit, where COC plumes are expected to be relatively stable. The majority of the COC transport is expected to occur in unit S2, where the detected concentrations of vinyl chloride are below the MCL of 5 µg/L, indicating that the degradation of cis-1,2-DCE to vinyl chloride is not significant in the S2 unit. Accordingly, as a conservative approach, degradation of cis-1,2-DCE to vinyl chloride was included using a relatively long half-life (i.e. slow degradation rate) which would not result in significant vinyl chloride concentrations. This agrees with the available data, as concentrations of vinyl chloride have not been observed in the S2 unit greater than 4.1 µg/L. Additionally, based on a review of available data at the site, the low detections of vinyl chloride at the Site are likely the result of cis-1,2-DCE degradation. However, the field measurements of oxidation-reduction potential indicate that strongly reducing conditions are not observed in the S2 unit, resulting in a lack of significant vinyl chloride concentrations (ARCADIS, 2010c).

3. Groundwater Flow Model

3.1 Model Code Selection

The numerical code selected for this model is MODFLOW (McDonald and Harbaugh 1988) and the graphic user interface Groundwater Vistas (Environmental Simulations International 2004). MODFLOW was selected because it is widely used in both academia and industry, is familiar to and accepted by regulatory agencies, and has the flexibility to simulate the hydrologic and hydrogeologic stresses and boundary conditions found at the Facility.

3.2 Model Code Description

MODFLOW simulates transient, three-dimensional groundwater flow through porous media described by the following partial differential equation for a constant density fluid:

$$\frac{\partial}{\partial x} \left(K_{xx} \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(K_{yy} \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left(K_{zz} \frac{\partial h}{\partial z} \right) - W = S_s \frac{\partial h}{\partial t} \quad (3-1)$$

where:

K_{xx} , K_{yy} and K_{zz} are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity [L/T];

h is the potentiometric head [L];

W is a volumetric flux and represents sources and/or sinks of water [1/T];

S_s is the specific storage of the porous material [1/L]; and,

t is time [T];

In Equation 3-1, the hydraulic parameters (i.e., K_{xx} , K_{yy} , K_{zz} and S_s) may vary in space but not in time, while the source/sink (W) terms may vary in both space and time.

3.3 Model Domain and Grid

The numerical model domain is three-dimensional, consisting of 201 rows, 272 columns, and eight layers. The model domain covers an area of approximately 9 miles by 20 miles. The model row and column widths vary throughout the model domain. The model row and column widths are each 50 ft in the vicinity of the city of Kokomo, and expand to 500 ft towards the periphery of the model. Figure A-11 presents the model domain and grid. The active cells within the model domain encompass the area between Deer Creek to the North and Wildcat Creek to the South, which are major hydrologic boundaries where significant groundwater discharge occurs. The east-west extent of the model is bounded by groundwater elevations which were assigned based on regional potentiometric surface maps developed by the USGS (Smith et al. 1985). This extent is considered sufficient to evaluate the regional flow regime for the objectives of this model.

Layer elevations are based on units (S1, S2 and S3) and bedrock topography and thickness from Smith et al. (1985). The layer elevations were adjusted based on site-specific information in the vicinity of the Facility. The uppermost model layer (Layer 1) represents the surficial till, which acts as a semi-confining layer. Layer 2 of the numerical model represents the S1 unit, where present, and till where the S1 sand unit is absent. Layer 3 of the numerical model represents the semi-confining layer between the upper sand unit (S1) and middle sand unit (S2). Layer 4 of the numerical model represents the S2 unit, where present, and till where the S2 sand unit is absent. Layer 5 of the numerical model represents the semi-confining layer between the middle sand unit (S2) and lower sand unit (S3). Layer 6 of the numerical model represents the S3 and/or B1 units, where present, and till where the S3 sand unit or B1 unit is absent. Layers 7 and 8 of the numerical model represent the B1 unit. The total model thickness is approximately 300 ft.

3.4 Hydraulic Parameters

Hydraulic parameters, such as hydraulic conductivity and storage coefficients, were assigned using hydrogeologic zones. Hydrogeologic zones are areas where hydraulic parameters are spatially constant. Initially, a single hydrogeologic zone was assigned to each geologic unit. Additional hydrogeologic zones were added for some geologic units as model calibration progressed and hydraulic parameters were modified within sub-areas to meet calibration criteria as well as to incorporate field test data.

From 1979 through 1982, the USGS completed a study of the availability of water from the confined sand and gravel units beneath Howard County (Smith et al. 1985). Transmissivity values represented in the model completed by Smith et al. indicated a range in transmissivity for the surficial till ranging from 0.01 to 0.0005 ft²/day. The transmissivity for the sand and gravel units (S1, S2) ranged from 650 to 8,700 ft²/day and the transmissivity of the bedrock (B1) unit ranged from 1,250 to 6,250 ft²/day.

In November 2006, ARCADIS conducted slug tests on selected monitoring wells to evaluate the saturated hydraulic conductivity of the S1, S2 and B1 units. The data collected were analyzed using the AQTESOLV® aquifer test analysis software (Duffield, 2007). The Bouwer and Rice and Butler (1989) solution was used to estimate hydraulic conductivity of the tested units. The estimated hydraulic conductivity for the S1 unit ranged from 4.91×10^{-3} centimeters per second (cm/sec) (13.9 ft/day) to 4.70×10^{-2} cm/sec (133 ft/day). Based on analysis, the average hydraulic conductivity of the S1 unit was 2.97×10^{-2} cm/sec (84.1 ft/day).

The estimated hydraulic conductivity for the S2 unit ranged from 6.09×10^{-4} cm/sec (1.73 ft/day) to 1.01×10^{-1} cm/sec (288 ft/day). Based on analysis, the average hydraulic conductivity of the S2 unit was 4.84×10^{-2} cm/sec (137 ft/day). The estimated hydraulic conductivity for the B1 unit ranged from 1.53×10^{-3} cm/sec (4.35 ft/day) to 4.85×10^{-2} cm/sec (138 ft/day). Based on analysis, the average hydraulic conductivity of the B1 unit was 1.95×10^{-2} cm/sec (55.3 ft/day). Additional analysis and interpretation of bedrock cores indicate that the majority of the transmissivity is associated with the upper bedrock zone. This observation was confirmed by a series of hydrogeologic investigations that were performed from August 2007 to November 2008, in order to identify major hydraulic pathways within the upper bedrock unit.

Comparison of aquifer system extent from interpretations from RFI investigation to those presented in Smith et al. indicates there is an agreement between the findings of the RFI at the Facility and interpretations presented by Smith et al. (1985). Also, this review indicates an apparent continuity of units between the Facility and the Indiana American Water Company Northwest Well Field (IAWC-NWF). Based on boring logs, it appears that the S2 unit is thicker at the IAWC-NWF compared to that at the Facility.

Hydraulic parameters obtained from Smith et al. (1985) and site-specific data collected from field testing were mapped into the numerical model. Hydraulic conductivity (K) values for different zones were then adjusted by trial and error in the model calibration process. Calibrated values for the hydraulic conductivity used in the model are summarized in Table A-1, along with regional and the Facility vicinity K values. As

demonstrated in the table, the calibrated K values are within the range of hydraulic conductivity values estimated by slug tests conducted at the Facility. In addition, the calibrated hydraulic conductivity values for sand units S1 and S2, bedrock B1 are comparable to those used in the regional model developed by Smith et al. (1985). The horizontal hydraulic conductivity was set equal in both horizontal directions for all layers. Vertical anisotropy varied to account for the presence of discontinuous sand and till layers and heterogeneity within the sand and bedrock units. Figures A-12 to A-18 present the calibrated hydraulic conductivity distribution in model Layers 1 through 8, along with the boundary conditions for each layer, as discussed in Section 3.5.

3.5 Boundary Conditions

Boundary conditions are assigned to account for the interaction between groundwater flow within the model domain and the rest of the system. Selected boundary conditions consist of constant head cells, drain cells, extraction wells, and inactive (or no-flow) cells. The areas north of Deer Creek and south of Wildcat Creek were simulated as a no-flow boundary condition. Boundary conditions in the numerical model are shown in Figures A-12 to A-18 for model layers 1 to 8.

3.5.1 Constant Head Boundaries

Constant head cells in the eastern most model column and layers 1 through 8, at the upgradient (eastern) portion of the model, represent the flow contribution from and connection to the groundwater flow system upgradient of the model domain. Constant head cells in the western most model column and in layers 3 through 8, at the downgradient (western) portion of the model, represent the flow contribution to and connection to the groundwater flow system downgradient of the model domain. The head elevations for both east and west constant head boundaries are variable and were based on potentiometric surface maps of each unit presented in Smith et al. (1985).

3.5.2 Drains

The MODFLOW drain package was used to simulate the creeks within the model domain, including Wildcat Creek, Deer Creek and Little Deer Creek, in layers 1 through 4 of the model. The drain package was selected because the creeks are generally gaining streams, and drain cells simulate the flow of groundwater from an aquifer to a surface water body, effectively allowing the surface water body to remove water from the groundwater system without adding water. The elevations of the drains are variable

and were based on potentiometric surface maps of each unit presented in Smith et al. (1985). Drain conductance which relates the communication between the drain and the surrounding aquifer was specified at 5,000 ft²/day for all drain cells, based on the hydraulic conductivity of the streambeds presented in Smith et al. (1985).

3.5.3 Recharge

The total annual average precipitation for the county is 37.2 inches. Average annual lake evaporation for the area is about 33 inches (United States Department of Agriculture 1971). A uniform recharge of approximately 2.6 in/yr was applied over the model domain, which was the average recharge rate estimated from gain and loss of stream flow conducted by the USGS (Smith et al., 1985).

3.5.4 Water Supply

The off-site extraction wells for industrial and public supply were simulated using the MODFLOW well package. Extraction wells within the model domain were each simulated at their respective average pumping rate over the time period between 2006 and 2008 or 2009, depending on pumping record availability. Table A-2 presents the extraction rates for each well in the steady-state simulation.

The total pumping from the IAWC WCWF can exceed 2,000 gpm, most of which is drawn directly from the adjacent Wildcat Creek. Losses in stream flow of up to 10 cubic feet per second (cfs) have been measured in Wildcat Creek near the well field, which is attributed to groundwater extraction by the WCWF (Smith et al. 1985). Consequently, only wells completed in bedrock (wells IAWC-15R, IAWC-16, and IAWC-17), which comprise the IAWC SWF and are expected to draw most water from areas away from Wildcat Creek, were included in the model simulation.

4. Groundwater Flow Model Calibration

4.1 Model Steady-State Flow Calibration

Calibration of a groundwater flow model refers to the process of adjusting model parameters to obtain a reasonable match between observed and simulated water levels. In general, model calibration is an iterative procedure that involves adjustment of hydraulic properties or boundary conditions to achieve the best match between observed and simulated water levels. During model calibration, model parameters are

varied over a narrow range set by site-specific data using the conceptual model as a guide.

4.1.1 Head Targets

During calibration of a groundwater flow model, use of empirical point data (targets) eliminates the potential for interpretive bias that may result from attempting to match a contoured potentiometric surface (Konikow 1978; Anderson and Woessner 1992). The steady-state flow calibration process consisted of comparing simulated potentiometric heads within each unit (S1, S2, S3 and B1) to observed values presented in Smith et al. (1985), digitized as observation points 1 to 119 (OBS1 to OBS 119 as summarized in Table A-3). The model wells representing the IAWC-NWF were inactive (modeled with a pumping rate of zero ft³/day), because these wells were not operational at the time of the Smith et al. investigation.

4.1.2 Steady-State Calibration Results

The steady-state flow model calibration was established once the differences between the simulated head values and observed head values were minimized to a reasonable degree of accuracy, suitable for the purposes of the steady-state flow model. The quality of the model calibration can be determined by a statistical analysis of the residuals. Residuals are defined as the difference between the model-simulated heads and fluxes and the observed values. Positive residual values indicate that the model-simulated values are lower than the target values, and negative residual values indicate that the model-simulated values are higher than the target values. Figures A-19, A-20 and A-21 show the simulated head contours for units S1, S2 and B1 respectively, along with head residuals for calibration targets. The model-simulated groundwater flow direction in these units at the Facility is predominantly to the south-southeast which is consistent with the observed flow direction prior to pumping at the IAWC-NWF. The results of the calibration are presented graphically on Figure A-22 in the form of a scatter plot, which plots simulated head values against observed head values. An acceptable calibration is represented by the data points clustering near a 1:1 ratio line through the plot. This indicates that the simulated values closely match the field measured water levels. Residual statistics (Table A-3) for the calibrated groundwater flow model indicate an acceptable agreement between simulated and measured groundwater elevations. The residual mean, absolute residual mean, and residual standard deviation were calculated to be -0.98 ft, 7.75 ft, and 9.96 ft, respectively.

4.2 Model Transient Flow Calibration

In addition to developing a steady-state flow calibration, a transient flow calibration was developed, with a specific focus on calibrating to recent water levels collected in a potentiometric study conducted at the Facility.

4.2.1 Transient Calibration Head Targets (Potentiometric Study)

The transient flow calibration process consisted of comparing simulated potentiometric heads and gradients within each unit (S1, S2 and S3) to observed values collected during the potentiometric study completed while the IAWC-NWF was operational (RFI, ARCADIS 2009). The period simulated by the transient flow model was from August 6, 2009 through September 2, 2009. The onsite potentiometric heads and gradients observed during this period are based on water level measurements collected from three monitoring well clusters: MW-0501, MW-0605 and MW-0617. Each monitoring well cluster consists of three monitoring wells, each screened in the S1, S2 and S3/B1 units, respectively. The transient flow model calibration was established once the differences between the simulated and observed onsite horizontal and vertical gradients were minimized to a reasonable degree of accuracy, suitable for the purposes of the transient flow model.

4.2.2 Transient Calibration Results

Specific-storage and local hydraulic conductivity were both adjusted during the transient calibration to refine the model calibration. Several model runs were conducted iteratively between the calibrated steady-state model and the transient models to ensure that any adjustments to the transient flow model would not negatively impact the steady-state flow model calibration. The main objective of the transient flow calibration was not to minimize the difference between simulated and observed potentiometric heads. Rather, it was to minimize the difference between simulated and observed local horizontal and vertical gradients, in an effort to simulate the hydraulic fluctuations and associated gradients observed onsite in response to pumping at the IAWC-NWF. Figure A-23 through Figure A-25 present the observed potentiometric heads and simulated potentiometric heads. As shown in Figure A-23, little to no fluctuation in water levels was observed in onsite monitoring wells located in S1 unit in response to pumping at the IAWC-NWF. The calibrated transient model results also showed very little fluctuation in groundwater elevations, indicating reasonable estimates on the hydraulic parameters for sand unit S1 were obtained. The water levels observed in onsite monitoring wells indicated significant responses to pumping

at the IAWC-NWF in both S2 unit and S3/Bedrock B1 unit (Figures A-24 and A-25). The calibrated transient model was able to simulate similar responses in these units, which indicates the ability of the model to properly simulate the hydraulic responses due to pumping at the IAWC-NWF. Final calibrated specific storage values ranged from 1×10^{-7} to 1×10^{-3} , which are within the range of values previously estimated by the USGS (Smith et al. 1985).

5. Solute Transport Model

5.1 Model Code Selection

The numerical code selected for the solute transport model is MT3DMS (Zheng and Wang, 1999). This code was selected because it can be coupled with block-centered finite-difference flow model codes (such as MODFLOW) and it has the capability for simulating dual-domain transport processes (Zheng and Wang, 1999). Dual-domain systems consist of two distinct domains, a mobile domain where transport is controlled predominately by advection and an immobile domain where transport is controlled predominately by molecular diffusion. Mass transfer into and out of the less mobile porosity is generally slow because the process is controlled by diffusion. A mass transfer coefficient defines the rate of mass transfer between the two domains. The dual-domain approach was selected for this model because it is expected to provide a more accurate representation of the interaction between mobile and immobile portions of the units which can significantly affect long-term transport predictions.

5.2 Model Code Description

A dual-domain system consists of a mobile porosity and an immobile porosity. The mobile porosity represents the more mobile portion of the formation (where advection is dominant), while the immobile porosity represents the less mobile portion of the formation (where diffusion is dominant). The solute transport modeling approach utilizing the dual-domain mass transfer model of Zheng and Wang (Zheng and Wang 1999) has been introduced as represented by the following equations:

$$\theta_m \frac{\partial C_m}{\partial t} + \theta_{im} \frac{\partial C_{im}}{\partial t} = \frac{\partial}{\partial x_i} (\theta_m D_{ij} \frac{\partial C_m}{\partial x_j}) - \frac{\partial}{\partial x_i} (q_i C_m) + q_s C_s \quad (5-1)$$

$$\theta_{im} \frac{\partial C_{im}}{\partial t} = \beta (C_m - C_{im}) \quad (5-2)$$

where C_m is the solute concentration in the mobile domain, C_{im} is the solute concentration in the immobile phase, θ_m is the porosity of the mobile domain, θ_{im} is the porosity of the immobile domain, θ is the total porosity ($\theta = \theta_{im} + \theta_m$), β is the first-order mass transfer coefficient between the mobile and immobile domains, t is time, x_i is the horizontal coordinate (east-west direction), x_j is the transverse coordinate (north-south direction), D_{ij} is the dispersion coefficient tensor, q_i is the Darcy flux, q_s is the fluid source/sink, and C_s is the concentration of fluid source/sink.

5.3 Source Areas

As discussed in Section 2.3, the primary COCs simulated in the solute transport model include TCE and its breakdown daughter product cis-1,2 DCE. For the purposes of developing a solute transport model calibration, initial concentrations of TCE were specified in layer 2 (sand unit S1) (presented on Figure A-9 Panel A) using the approximate plume configuration from June 2009 (RFI, ARCADIS 2009). The solute transport model was not initialized with concentrations of cis-1,2-DCE, because the cis-1,2-DCE observed onsite was assumed to be generated from the degradation of TCE. To maintain stable groundwater concentrations of TCE and cis-1,2-DCE in the source area, a relatively high distribution coefficient (K_d) was assigned to areas where high concentrations have been observed. This approach effectively creates a large mass of source constituents sorbed to soil that will slowly dissolve into groundwater and is meant to account for additional contributions from unsaturated soils where a large mass of constituents is likely stored and may continue to act as long-term source to groundwater.

5.4 Solute Transport Calibration

The solute transport model was calibrated qualitatively by adjusting various solute transport parameters. The calibration was assessed by comparing the distribution of TCE and cis-1,2-DCE following 30 years of simulated transport, based on the groundwater flow velocities of the steady-state flow model (which excludes the effects of pumping at the IAWC-NWF), with the current observed distribution of each constituent (June 2009 conditions). A 30-year time period was estimated as a reasonable time-frame for the development of the current groundwater plumes given the historical operations at the Facility. The observed extent of TCE and cis-1,2-DCE impacts to groundwater have not changed significantly over time and are restricted to a localized area in the vicinity of the Facility. It was assumed that 30 years of simulated transport, based on an initial TCE distribution in only the S1 unit (approximated by the

current distribution in the S1 unit), and without an initial cis-1,2-DCE distribution in any unit is sufficient for the purposes of qualitatively calibrating the solute transport model.

5.5 Solute Transport Parameters

The simulation of solute transport requires specification of various parameters that control the rate, movement, mixing, absorption, and degradation of solutes in the subsurface.

Solute transport was simulated based on a dual-domain mass transport system. A dual-domain mass transfer model, combined with the effects of sorption, better accounts for the hydrogeological heterogeneity of each unit and the processes controlling solute transport. An assumed site-specific total porosity (mobile plus immobile) was 45 percent for the till and 35 percent for the sand units. The till material was assigned a mobile porosity of 10 percent and an immobile porosity of 35 percent. The sand units were assigned a mobile porosity of 15 percent and an immobile porosity of 20 percent. The mobile porosity values of 10% and 15% are comparable to effective porosity values for sands and gravels (Domenico and Schwartz, 1990). The assumed total porosity represents the upper bound for available pore space for a sand and gravel unit. The solute transport model was initialized with consistent contaminant concentrations in both the mobile and immobile domains. Literature reported mass transfer coefficients for two domains range from 0.0001 d^{-1} to 0.001 d^{-1} (Gillham et al., 1984; Molz et al. 2006; Harvey and Gorelick, 2000; Feehley et al. 2000). The qualitatively calibrated solute transport model was established with a mass transfer coefficient of 0.00001 d^{-1} for both TCE and cis-1,2-DCE in the till and a mass transfer coefficient of 0.05 d^{-1} for both TCE and cis-1,2-DCE in the sand units. The relatively high mass transfer coefficient in the sand units indicates that transport in the sand units approaches a single-domain system.

A limitation of the finite-difference scheme applied by MT3DMS is that some numerical dispersion is inherent in the simulation results. Numerical dispersion is a function of the size of the grid cell spacing and the time step size. The numerical dispersivity can be computed on a block-by-block basis in models solved using finite difference methods (Zheng and Bennett 1995). Application of the equations reported by Zheng and Bennett (1995) indicates that the numerical dispersivity is approximately one-half the modeled grid size (approximately 25 to 250 ft). Recent studies suggest that plumes are mostly dominated by advection and that dispersivity does not continue to increase with plume scale. Xu and Eckstein (1995) developed a relationship that results in more accurate dispersivity values for large scale plumes. The numerical dispersion

associated with this model is comparable to values predicted by Xu and Eckstein for a plume of this magnitude, therefore, no additional dispersivity terms were added to the simulation.

Sorption of TCE and cis-1,2 DCE was simulated in the solute transport model following a linear isotherm based on a distribution coefficient (K_d). The distribution coefficient is a function of the formation fraction of organic carbon (f_{oc}) and the contaminant distribution coefficient for organic carbon (K_{oc}). The qualitatively calibrated solute transport model was established with a K_d of 0.013 cubic feet per pound (ft^3/lb) for TCE and 0.003 ft^3/lb for cis-1,2-DCE throughout the model domain, with the exception of the source area. The K_d for each constituent is based on a f_{oc} of 0.005 for both the sand units and till, which agrees well with literature values. The K_{oc} for both TCE and cis-1,2-DCE are based on literature provided values: TCE K_{oc} = 166 liters per kilogram (L/kg), and cis-1,2-DCE K_{oc} = 35.5 L/kg (USEPA 2002).

Retardation is simulated in the solute transport model based on the distribution coefficient, total porosity and soil bulk density. The qualitatively calibrated solute transport model was established with a retardation factor of 5.0 for TCE and 1.9 for cis-1,2-DCE in the sand units and 4.1 for TCE and 1.7 for cis-1,2-DCE in the till, based on an assumed bulk density of 1.7 kilograms per liter (kg/L) for both sand and till, and each material's respective total porosity.

Degradation refers to the mass decay of a solute due to physical, chemical, and biological activity. The solute transport model simulates the degradation of TCE and the generation of its daughter product cis-1,2-DCE. The qualitatively calibrated solute transport model was established with a half-life of two years for TCE and a half-life of five year for cis-1,2-DCE, which are considered average values based on observations at other sites.

6. Model Predictive Simulations

Predictive fate and transport simulations were completed to evaluate the migration of TCE and cis-1,2-DCE in response to pumping at the IAWC-NWF. Fifty years of solute transport was simulated based on the steady-state groundwater flow field with the IAWC-NWF pumping at 2008 through 2009 average rates (approximately 1,100 gpm), unless specified otherwise in a scenario where the effect of increased pumping rate was evaluated. Fifty years of solute transport was selected to allow a sufficient period of time for the groundwater plume to stabilize under various predictive scenarios. The predictive model was initialized with, approximately, the current distribution of TCE and

cis-1,2-DCE concentrations observed at the site. Figures A-26A and A-26B present initial concentration distributions for TCE and cis-1,2-DCE, respectively, in the sand units S1 and S2, and bedrock B1.

The sensitivity of the solute transport model to various fate and transport parameters was assessed through a number of predictive scenarios. A total of six simulations were conducted in this modeling effort, as summarized below. Table A-4 provides the major fate and transport input parameters for each scenario. These scenarios are meant to provide a conservative range of predicted model results based on the qualitative model calibration. The following Sections 6.2 through 6.7 discuss the results of each scenario.

- Scenario 1: Calibrated Solute Transport Parameters and IAWC-NWF Pumping at Average Rates
- Scenario 2: Reduced Retardation Factors and IAWC-NWF Pumping at Average Rates
- Scenario 3: Reduced Retardation Factors, No Degradation of cis-1,2-DCE, and IAWC-NWF Pumping at Average Rates
- Scenario 4: Reduced Retardation Factors, No Degradation of cis-1,2-DCE, Reduced on-site Source Concentration, and IAWC-NWF Pumping at Average Rates
- Scenario 5: Reduced Retardation Factors, No Degradation of cis-1,2-DCE, Increased TCE Half-Life, and IAWC-NWF Pumping at Average Rates
- Scenario 6: Reduced Retardation Factors, No Degradation of cis-1,2-DCE, and IAWC-NWF Pumping Rates Doubled

6.1 IAWC-NWF Travel Time Boundaries and Well Restriction Overlay District

The existing Wellhead Protection Overlay District (WH-OL), prepared by Howard County Plan Commission, is shown in Figure A-27. As discussed above, impacted groundwater originated from the Facility flows northwest towards IAWC-NWF due to its operation. To delineate the wellhead protection area, approximate 5-year and 10-year travel time boundaries were estimated based on the steady-state groundwater flow field, but with the IAWC-NWF pumping at 2008 through 2009 average rates

(approximately 1,100 gpm). The 5-year and 10-year travel time boundaries correspond to locations where the times required for groundwater to travel to the well field are 5 years and 10 years, respectively. This analysis was completed using MODPATH using an estimated total porosity of 0.35 for the S2 sand unit, combined with the flow fields produced by MODFLOW. The resulting 5-year and 10-year travel time boundaries are depicted on Figure A-27. The model simulated 5-year travel time boundary appears to be similar to the existing WH-OL, with a slight difference in the extent to the east and south. The extent of model simulated 10-year travel time boundary is larger than the existing WH-OL and model simulated 5-year travel time boundary. As shown in Figure A-27, the IAWC-NWF is the only well field located within the model simulated 5-year travel time boundary.

Both the 5-year and 10-year travel time boundaries, along with the existing WH-OL will be used in the results discussion for all six scenarios, and therefore, are included in all figures presenting predicted TCE and cis-1,2-DCE distribution in sand units S1 and S2 in Sections 6.2 through 6.7. Additionally, to evaluate the potential impact to the wellhead protection area, targets are placed at the 5-year and 10-year travel boundaries downgradient of the TCE and cis-1,2-DCE plumes to obtain TCE and cis-1,2-DCE concentration profiles over model simulated period.

6.2 Scenario 1 –Calibrated Solute Transport Parameters and IAWC-NWF Pumping at Average Rates

This predictive scenario served as the base case; 50 years of solute transport were simulated based on the calibrated fate and transport parameters. Figures A-28 through A-31 present concentrations of TCE and cis-1,2-DCE in the S1 and S2 units at year 50. Figure A-32 presents the concentration profiles over time for both TCE and cis-1,2-DCE in the S2 unit.

The results of Scenario 1 indicate that the TCE and cis-1,2-DCE groundwater plumes in the S1 unit would remain relatively stable. No exceedance of TCE and cis-1,2-DCE MCLs is expected beyond the 5-year and 10-year travel time boundaries in the S1 unit. In addition, no exceedance of TCE and cis-1,2-DCE is predicted within the existing WH-OL at year 50 in the S1 unit. However, in the S2 unit, TCE and cis-1,2-DCE with concentrations exceeding their respective MCLs, are predicted to migrate past the 10-year travel time boundary by approximately 1,750 ft and 700 ft, respectively, by year 50. As shown in Figure A-32, TCE and cis-1,2-DCE migrate across the 10-year travel boundary at concentrations of 23 µg/L and 121 µg/L, respectively, at year 50. As in

sand unit S1, no exceedance of TCE and cis-1,2-DCE MCLs is expected beyond the 5-year travel time boundary and within the existing WH-OL at year 50.

Furthermore, TCE impacted groundwater, in the S2 unit, is predicted to migrate beyond the Syndicate Sales, Inc. well field (Figure A-30). However, the Syndicate Sales, Inc. well field is screened deeper, in the bedrock B1 unit, where no exceedance of the TCE MCL is predicted. The model predicted concentrations of TCE and cis-1,2-DCE in the S3 unit and bedrock B1 unit are negligible. Therefore, the TCE and cis-1,2-DCE distribution in the S3/B1 units are not presented in these figures.

6.3 Scenario 2 – Reduced Retardation Factors and IAWC-NWF Pumping at Average Rates

This predictive scenario, like Scenario 1, simulates 50 years of solute transport and is based on the calibrated fate and transport parameters, with the exception of reduced retardation factors for both TCE and cis-1,2-DCE. In Scenario 2, the retardation factors are reduced to approximately 1.0 for both constituents, which results in faster migration rates with respect to Scenario 1. Figures A-33 through A-36 present concentrations of TCE and cis-1,2-DCE in the S1 and S2 units at year 50. Figure A-37 presents the concentration profiles over time for both TCE and cis-1,2-DCE in the S2 unit.

The results of Scenario 2 indicate that the TCE and cis-1,2-DCE groundwater plumes in the S1 unit would remain relatively stable. Although the retardation factors for both constituents were reduced, no exceedance of TCE and cis-1,2-DCE MCLs is predicted beyond the 5-year and 10-year travel time boundaries in the S1 unit. In addition, no exceedance of TCE and cis-1,2-DCE is predicted within the existing WH-OL at year 50 in the S1 unit. As in Scenario 1, TCE and cis-1,2-DCE are expected to migrate past the 10-year travel time boundary at concentrations exceeding their respective MCLs in the S2 unit by year 50. The migration distances downgradient of the 10-year travel time boundary are approximately 1,850 and 750 ft, for TCE and cis-1,2-DCE, respectively. The TCE and cis-1,2-DCE concentration profiles for the S2 unit indicate that TCE and cis-1,2-DCE would migrate across the 10-year travel time boundary at approximately 21 µg/L and 123 µg/L, after 50 years of transport. Neither TCE nor cis-1,2-DCE are predicted to reach the 5-year travel time boundary and the existing WH-OL at concentrations exceeding their respective MCLs in the S2 unit by year 50.

As in Scenario 1, TCE impacted groundwater is predicted to migrate beyond the Syndicate Sales, Inc. well field in the S2 unit (Figure A-35), however no exceedance of TCE in the deeper B1 unit is predicted at these wells. The model predicted

concentrations of TCE and cis-1,2-DCE in the S3 unit and bedrock B1 unit are negligible.

A comparison between results from Scenarios 1 and 2 indicates that the model-predicted plume extents are not sensitive to the retardation factors for both TCE and cis-1,2-DCE.

6.4 Scenario 3 – Reduced Retardation Factors, No Degradation of cis-1,2-DCE, and IAWC-NWF Pumping at Average Rates

This predictive scenario is based on the calibrated fate and transport parameters, with the exception of reduced retardation factors for both TCE and cis-1,2-DCE as well as elimination of cis-1,2-degradation. As in Scenario 2, the retardation factors are reduced to approximately 1.0 for both constituents in Scenario 3. In addition, cis-1,2-DCE degradation is eliminated to evaluate the sensitivity of the cis-1,2-DCE plume migration to its degradation rate. Figures A-38 through A-41 present concentrations of TCE and cis-1,2-DCE in the S1 and S2 units at year 50. Figure A-42 presents the concentration profiles over time for both TCE and cis-1,2-DCE in the S2 unit.

The results of Scenario 3 indicate that the TCE and cis-1,2-DCE groundwater plumes in the S1 unit would remain relatively stable. As in Scenarios 1 and 2, no exceedance of TCE and cis-1,2-DCE MCLs is predicted beyond the 5-year and 10-year travel time boundaries in the S1 unit. However, much higher cis-1,2-DCE concentrations (500-1,000 µg/L) are expected to remain in S1 unit due to the elimination of cis-1,2-DCE degradation. In addition, no exceedance of TCE and cis-1,2-DCE is predicted within the existing WH-OL in the S1 unit at year 50. In the S2 unit, TCE and cis-1,2-DCE with concentrations exceeding their respective MCLs are predicted to migrate past the 10-year travel time boundary by approximately 1,850 ft and 2,550 ft, respectively. Compared to Scenarios 1 and 2, the migration distance downgradient of 10-year travel time boundary at year 50 is similar for TCE in Scenario 3. However, the migration distance is much farther downgradient for cis-1,2-DCE in Scenario 3, due to the elimination of cis-1,2-DCE degradation. Concentration profiles in Figure A-42 show that TCE and cis-1,2-DCE migrate across the 10-year travel boundary at concentrations of 21 µg/L and 356 µg/L, respectively, after 50 years of transport. Neither TCE nor cis-1,2-DCE are predicted to reach the 5-year travel time boundary and the existing WH-OL at concentrations exceeding their respective MCLs in the S2 unit by year 50.

TCE and cis-1,2-DCE impacted groundwater is predicted to migrate beyond the Syndicate Sales, Inc. well field in the S2 unit, unlike in Scenarios 1 and 2 (Figures A-40 and A-41). However no exceedance of TCE or cis-1,2-DCE in the deeper B1 unit is predicted at these wells. Therefore, no impact of TCE and/or cis-1,2-DCE is expected at the Syndicate Sales, Inc. well field. The results of Scenario 3 also indicate that the impacts of TCE and cis-1,2-DCE are minor in the S3/B1 units.

A comparison between results from Scenarios 1 and 3 indicates that elimination of cis-1,2-DCE degradation in the model simulation does not affect the TCE plume migration, as expected because the TCE half life is unchanged, but does exert a significant influence on the cis-1,2-DCE plume migration. The resulted cis-1,2-DCE migration distance downgradient of 10-year travel time boundary is farther, and cis-1,2-DCE concentration at the 10-year travel time boundary is much higher in Scenario 3 at year 50.

6.5 Scenario 4 – Reduced Retardation Factors, No Degradation of cis-1,2-DCE, Reduced on-site Source Concentration, and IAWC-NWF Pumping at Average Rates

This predictive scenario, like Scenario 3, is based on the calibrated fate and transport parameters, with the exception of reduced retardation factors for both TCE and cis-1,2-DCE and elimination of cis-1,2-DCE degradation. Similar to Scenario 3, the retardation factors are reduced to approximately 1.0 for both constituents, and the cis-1,2-DCE degradation is eliminated. In addition, the TCE and cis-1,2-DCE initial concentrations are reduced in Scenario 4. The on-site initial concentrations of TCE and cis-1,2-DCE are reduced by 79 percent to evaluate the long-term, reduced impact to groundwater by the implementation of remediation in the source area. The 79 percent reduction is based on the proposed soil treatment, which is expected to reduce the on-site mass of TCE within the S1 unit by 79%. Off-site soil impacts east of the Site will not be addressed by the proposed soil remediation and are conservatively assumed to continue to act as a source in this model simulation. Figures A-43 through A-46 present concentrations of TCE and cis-1,2-DCE in the S1 and S2 units at year 50. Figure A-47 presents the concentration profiles over time for both TCE and cis-1,2-DCE in the S2 unit.

The results of Scenario 4 indicate that the TCE and cis-1,2-DCE groundwater plumes in the S1 unit would remain relatively stable. As in Scenarios 1, 2 and 3, no exceedance of TCE and cis-1,2-DCE MCLs is predicted beyond the 5-year and 10-year travel time boundaries in the S1 unit. In addition, no exceedance of TCE and cis-1,2-DCE is predicted within the existing WH-OL in the S1 unit at year 50. However,

comparing to Scenario 3, much lower TCE concentrations are expected to remain in the S1 unit on-site due to the reduced source strength on-site. TCE concentrations at the eastern portion of plume (off-site) remain high due to the assumed continuity of off-site sources. Similarly, cis-1,2-DCE concentrations are expected to remain in S1 unit at lower concentrations on-site due to the reduced cis-1,2-DCE initial source strength. Cis-1,2-DCE concentrations at the eastern portion of the plume are similar to those in Scenario 3 since no change is made in the initial concentrations in this area. In the S2 unit, TCE and cis-1,2-DCE with concentrations exceeding their respective MCLs are predicted to migrate past the 10-year travel time boundary by approximately 720 ft and 700 ft, respectively. Compared to Scenarios 1, 2 and 3, the migration distance downgradient of 10-year travel time boundary for TCE in Scenario 4 is much shorter, due to the reduced on-site TCE source strength. Cis-1,2-DCE migration distance downgradient of 10-year travel time boundary is similar to those in Scenario 1 and 2 (by approximately 700-750 ft), but shorter than that of Scenario 3 (by approximately 2,550 ft). This is a combined effect of elimination of cis-1,2-DCE degradation and reduced on-site initial source concentrations.

The concentration profiles in Figure A-47 indicate that TCE and cis-1,2-DCE migrate across the 10-year travel boundary at concentrations of 19 µg/L and 175 µg/L, respectively, after 50 years of transport. The TCE concentration at the 10-year travel time boundary downgradient of TCE plume migration is slightly lower than those of Scenarios 1, 2 and 3 due to reduced on-site TCE source concentrations, but unchanged off-site TCE source concentrations. Cis-1,2-DCE concentration at the 10-year travel time boundary downgradient of TCE plume migration is higher than that of Scenarios 1 and 2, but lower than Scenario 3, due to the combined effect of elimination of cis-1,2-DCE degradation and reduced on-site TCE and cis-1,2-DCE source concentrations. As in the sand unit S1, TCE and cis-1,2-DCE are not expected beyond the 5-year travel time boundary and within the existing WH-OL at concentrations above their respective MCLs at year 50.

TCE and cis-1,2-DCE impacted groundwater is predicted to migrate in the S2 unit in the vicinity of the Syndicate Sales, Inc. well field (Figures A-45 and A-46), which is the combined effect of reduced on-site TCE and cis-1,2-DCE source concentrations and elimination of cis-1,2-DCE degradation. The model predicted TCE and cis-1,2-DCE plume footprints in the S3 unit and bedrock B1 unit are negligible. Therefore, as with Scenarios 1, 2 and 3, no impact of cis-1,2-DCE is expected in the vicinity of the Syndicate Sales, Inc. well field, since the well screen is in bedrock B1.

The results in Scenario 4 indicate that both TCE and cis-1,2-DCE plume migration are sensitive to the initial TCE and cis-1,2-DCE source strength. In addition, the cis-1,2-DCE plumes are sensitive to the elimination of degradation, as in Scenario 3.

6.6 Scenario 5 – Reduced Retardation Factors, No Degradation of cis-1,2-DCE, Increased TCE Half-Life, and IAWC-NWF Pumping at Average Rates

This predictive scenario, like Scenario 3, simulates 50 years of solute transport and is based on the calibrated fate and transport parameters, with the exception of reduced retardation factors for both TCE and cis-1,2-DCE and reduced cis-1,2-degradation. The retardation factors are reduced to approximately 1.0 for both constituents, and the cis-1,2-DCE degradation is eliminated. Additionally, the half-life of TCE is increased in Scenario 5. The half-life for TCE is increased from two years to five years to evaluate the sensitivity of the model to TCE biodegradation rate. The 5-year TCE half-life is within the high end of observed values on other sites (Wiedemeier, 1999), which is expected to result in conservative model predictions. The combination of these parameter values are expected to result in more conservative model predictions with respect to Scenario 3. Figures A-48 through A-51 present concentrations of TCE and cis-1,2-DCE in the S1 and S2 units at year 50. Figure A-52 presents the concentration profiles over time for both TCE and cis-1,2-DCE in the S1 and S2 units.

The results of Scenario 5 indicate that the TCE and cis-1,2-DCE groundwater plumes in the S1 unit would remain relatively stable. As in Scenario 1, 2 and 3, no exceedance of TCE and cis-1,2-DCE MCLs is predicted beyond the 5-year and 10-year travel time boundaries in sand unit S1. In addition, no exceedance of TCE and cis-1,2-DCE is predicted within the existing WH-OL in the S1 unit at year 50. However, comparing to Scenarios 1, 2 and 3, higher TCE concentrations (greater than 3,000 µg/L) are expected to remain in S1 unit due to the increased TCE half-life. In the S2 unit, TCE with concentrations exceeding their respective MCLs are predicted to migrate not only past the 10-year travel time boundary at 5,400 ft downgradient, but also past the 5-year travel time boundary at 1,700 ft downgradient. Furthermore, the TCE plume extends approximately 800 ft into the existing WH-OL by year 50. The increased TCE migration distance is due to the increased TCE half-life. Figure A-52 shows that TCE migrates across the 10-year travel boundary and 5-year travel time boundary at concentrations of 100 µg/L and 11 µg/L, respectively, after 50 years of transport. As with the farther TCE migration distance, the predicted higher TCE concentrations at the 10-year and 5-year travel boundaries are due to the increased TCE half-life. Cis-1,2-DCE with concentrations exceeding its MCL are predicted to migrate past the 10-year travel time boundary 2,000 ft, because of the combined effect of increased TCE half-life and

elimination of cis-1,2-DCE degradation. The predicted cis-1,2-DCE concentration at the 10-year travel time boundary is 254 µg/L (Figure A-52), higher than that of Scenarios 1 and 2, but lower than Scenario 3, due to the combined effect of increased TCE half-life and elimination of cis-1,2-DCE degradation. Cis-1,2-DCE is not expected at concentrations above its MCL beyond the 5-year travel time boundary and within the existing WH-OL at year 50.

TCE and cis-1,2-DCE impacted groundwater is predicted to migrate beyond the Syndicate Sales, Inc. well field in the S2 unit (Figures A-50 and A-51). However, no exceedance of TCE or cis-1,2-DCE in the deeper B1 unit is predicted at these wells. Therefore, TCE and cis-1,2-DCE impact is not expected at the Syndicate Sales, Inc. well field. The results of Scenario 5 indicate that the impacts of TCE and cis-1,2-DCE are minor in the S3/B1 units.

The modeling results of Scenario 5 indicate that both TCE and cis-1,2-DCE plume migration are sensitive to the increased TCE half-life. The increased TCE half-life results in TCE migrating farther downgradient, extending not only into the 10-year travel boundary, but also the 5-year travel boundary and the existing WH-OL.

6.7 Scenario 6 – Reduced Retardation Factors, No Degradation of cis-1,2-DCE, and IAWC-NWF Pumping Rates Doubled

This predictive scenario, like Scenario 3, simulates 50 years of solute transport and is based on the calibrated fate and transport parameters, with the exception of reduced retardation factors for both TCE and cis-1,2-DCE and reduced cis-1,2-DCE degradation. Similar to Scenario 3, the retardation factors are reduced to approximately 1.0 for both constituents, and the cis-1,2-DCE degradation is eliminated. In addition, the groundwater extraction at the IAWC-NWF is doubled in Scenario 6. The purpose of Scenario 6 is to evaluate the effects of increased groundwater extraction in the event that IAWC-NWF is required to increase pumping in response to an increase in demand. Figures A-53 through A-56 present concentrations of TCE and cis-1,2-DCE in the S1 and S2 units at year 50. Figure A-57 presents the concentration profiles over time for both TCE and cis-1,2-DCE in the S1 and S2 units.

The results of Scenario 6 indicate that the TCE and cis-1,2-DCE groundwater plumes in the S1 unit would be less stable compared with all other 5 scenarios. TCE and cis-1,2-DCE plumes are expected to migrate farther to the northwest in the S1 unit, due to the influence of increased IAWC-NWF pumping rates on the groundwater flow field. Unlike the other 5 scenarios, TCE and cis-1,2-DCE plumes are predicted to migrate

past the 10-year travel time boundary 500 ft and 800 ft, respectively, at concentrations exceeding their respective MCLS in the sand unit S1 (Figure A-53 and A-54). However, no exceedance of TCE and cis-1,2-DCE is predicted beyond the 5-year travel boundary and within the existing WH-OL at year 50 in S1 unit. In the S2 unit, TCE and cis-1,2-DCE with concentrations exceeding their respective MCLS are predicted to migrate past the 10-year travel time boundary 3,400 ft and 2,500 ft, respectively. The differences in TCE and cis-1,2-DCE plume migration distance between Scenario 3 and Scenario 6 are due to the increased pumping rates at IAWC-NWF. Figure A-57 shows that TCE and cis-1,2-DCE migrate across the 10-year travel boundary at concentrations of 37 µg/L and 298 µg/L, respectively, after 50 years of transport. As in S1 unit, no exceedance of TCE and cis-1,2-DCE is predicted beyond the 5-year travel boundary and within the existing WH-OL at year 50 in S2 unit.

TCE and cis-1,2-DCE impacted groundwater is predicted to migrate beyond the Syndicate Sales, Inc. well field in the S2 unit (Figures A-55 and A-56). However, no exceedance of TCE or cis-1,2-DCE in the deeper B1 unit is predicted at these wells. Therefore, TCE and cis-1,2-DCE impact is not expected at the Syndicate Sales, Inc. well field in Scenario 6, as with all other 5 scenarios. The results of Scenario 6 indicate that the impacts of TCE and cis-1,2-DCE are minor in the S3/B1 units.

Scenario 6 model simulation results suggest that both TCE and cis-1,2-DCE plume migrations are sensitive to the IAWC-NWF pumping rates. The doubled IAWC-NWF pumping rate results in a stronger northwest migration direction in both sand units S1 and S2.

7. Conclusions and Recommendations

ARCADIS developed a calibrated numerical groundwater flow and solute transport model to:

1. evaluate the contribution of groundwater in the vicinity of the Facility to nearby well fields, and
2. conservatively estimate the distance that site-related TCE and its breakdown product cis-1,2 DCE, would migrate above each constituent's respective MCL.

The primary objective of the numerical modeling effort was to provide the basis to delineate the proposed WR-OL. To meet this objective, ARCADIS constructed and calibrated a regional steady-state groundwater flow model, largely based on the USGS

Water-Resources Investigation Report (Smith et al 1985); developed a transient flow model calibration, based on a recent potentiometric study (ARCADIS 2009); qualitatively calibrated a solute transport model; and simulated various predictive scenarios for solute transport.

As discussed in the Section 6.2 through Section 6.7, the extent of the impacted groundwater above the MCLs does not reach the model-simulated 5-year travel time boundary for five of the six modeled scenarios, with the exception of Scenario 5. Scenario 5, which had an increased half-life of TCE (5 years versus 2 years) and used the average pumping rates for the IAWC-NWF, predicted groundwater containing TCE concentrations greater than its MCL would migrate approximately 1,700 ft past the model-simulated 5-year travel time boundary in the S2 unit, and extends approximately 800 ft into the existing WH-OL. Scenario 4, which simulates a 79 % on-site source reduction due to the proposed soil treatment and used the average pumping rates for the IAWC-NWF, is the most likely scenario to occur at the Site. It is predicted that groundwater at TCE and cis-1,2-DCE concentrations greater than their respective MCLs would migrate approximately 720 and 700 ft, respectively, past the model-simulated 10-year travel time boundary in the S2 unit. No exceedance of TCE and cis-1,2-DCE is expected at the existing WH-OL in Scenario 4. In addition, the predicted plume extents for TCE and cis-1,2-DCE do not migrate beyond the Kokomo city limits (Figure A-43 through A-46). Additionally, the modeling results indicate that groundwater from the Facility would not reach the nearby IAWC-NWF at concentrations above MCLs for TCE and/or cis-1,2-DCE for any of the scenarios. Furthermore, no exceedance of TCE and/or cis-1,2-DCE is expected at the Syndicate Sales, Inc. well field, which extracts groundwater from the bedrock B1 unit at a relatively low rate (less than 10 gpm).

The proposed WR-OL (Figure A-58) was defined as the envelope curve that encompasses the extents of model-simulated TCE and cis-1,2-DCE plumes in the S1 and S2 units for the most likely case, which is the 79% source reduction simulated in Scenario 4, plus an additional 100 ft outward in all directions to provide a buffer zone. The buffer zone is less than 100 ft along the northwest extent of the WR-OL to keep it within the Kokomo city limits which would simplify the permitting process. It is important to point out that the model predicted TCE and cis-1,2-DCE plumes in the S2 unit for Scenario 4 do not extend beyond the Kokomo city limits in the northwest direction (Figures A-45 and A-46). ARCADIS will continue to monitor groundwater quality to determine the accuracy of model simulations, and the model will be updated as needed. The proposed WR-OL is intended to prevent water supply wells from being

installed within areas where TCE and/or cis -1,2 -DCE may exceed their respective MCLs based on the modeling results.

8. Uncertainties and Limitations

Based on known site conditions and calibration results, the numerical model presented in this report can be used to estimate the groundwater concentrations of cis-1,2-DCE and TCE in the S1, S2 , S3 and B1 units. However, this model includes fundamental simplifying assumptions regarding aquifer conditions. Therefore, this model has inherent limitations and uncertainties when used to describe real systems. The amount of uncertainty associated with the model results is directly related to the degree that actual site conditions deviate from model assumptions and input parameter values, including:

- **Boundary Conditions:** The drain conductance terms were calibrated against potentiometric head targets of the steady-state calibration, while considering aquifer hydraulic conditions (i.e., aquifer hydraulic parameters, thicknesses, and depths). This limitation imposes some uncertainties in predicting water flow from the aquifers to the streams. The actual permeability of the streambed will dictate how much groundwater flow is contributed to the streams. Additionally, because natural boundary conditions were not available for the upgradient (east) and downgradient (west) extents of the model domain, the flux was estimated from the constant head boundaries specified at those upgradient and downgradient locations.
- **Hydraulic Conductivity:** The model hydraulic conductivity values were estimated based on regional data and available site data. Hydraulic conductivity can vary several orders of magnitude over short distances which significantly affect model predictions.
- **Transport Parameters:** The transport parameters were estimated from available literature sources for geologic settings similar to those observed at the Facility and based on the qualitative solute transport calibration. The transport calibration was conducted using a limited historic dataset and assumptions regarding plume development over time which may significantly affect the estimated parameter values. Additionally, solute transport parameters along predicted migration areas may differ from those estimated for the Facility.

9. References

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Table A-1 Summary of Hydraulic Parameter Distributions in the Groundwater Flow Model
Former GM Delco Plant 5, Kokomo, Indiana

Geologic Unit	Regional Hydraulic Conductivity (ft/day) (Smith et. al.)	Facility Vicinity Hydraulic Conductivity (ft/day)	Calibrated Hydraulic Conductivity in the Numerical Model (ft/day)
Till	<1	NA	0.01 - 0.05
Sand Unit S1	200	14 - 133	75 - 100
Sand Unit S2	200	2 - 288	40 - 600
Bedrock B1	NA ¹	4 - 138	2 - 40

Notes:

NA = Not available

ft/day = feet per day

Smith et. al. = Smith, Barry S., M. Hardy, and E. James, 1985. Water Resources of Wildcat Creek and Deer Creek Basins, Howard and Parts of Adjacent Counties, Indiana, 1979-82

¹ Smith et. Al. provided a transmissivity range for the Bedrock B1 unit; however the B1 unit thickness modeled is not provided. The transmissivity of the B1 unit ranges from 1,250 ft²/day to 6,250 ft²/day.

Table A-2 Summary of Extraction Rates of Well Fields in the Groundwater Flow Model
Former GM Delco Plant 5, Kokomo, Indiana

Well ID	Rate (gpm) / (ft ³ /day)	Model Layer(aquifer unit)
Northwestern School Corp. – 1	4.8 / 931	4 (S2)
Northwestern School Corp. – 2	2.1 / 410	4 (S2)
Northwestern School Corp. – 3	0.8 / 159	4 (S2)
Northwestern School Corp. – 4	1.2 / 237	4 (S2)
Northwestern School Corp. – 6	0.4 / 83	4 (S2)
Indiana American Water Company South Well Field (IAWC-SWF) – 15R	20.3 / 3,907	7 (B1)
Indiana American Water Company South Well Field (IAWC-SWF) – 16	144.7 / 27,850	7 (B1)
Indiana American Water Company South Well Field (IAWC-SWF) – 17	76.0 / 14,622	7 (B1)
Moon Fabricating Corporation	3.6 / 684	7 (B1)
Syndicate Sales, Inc – B	3.1 / 600	7 (B1)
Syndicate Sales, Inc – C	6.6 / 1,266	7 (B1)
Indiana American Water Company Northwest Well Field (IAWC-NWF) – 1	551.5 / 106,178	4 (S2)
Indiana American Water Company Northwest Well Field (IAWC-NWF) – 2	541.6 / 104,264	4 (S2)
Indiana American Water Company Northwest Well Field (IAWC-NWF) – 4	10.8 / 2,082	4 (S2)
Deer Creek Estates Homeowners Water Association – 1	1.6 / 308	7 (B1)
Town of Galveston – 1	22.8 / 4,388	7 (B1)
Town of Galveston – 2	17.6 / 3,385	7 (B1)
Town of Galveston – 3	27.0 / 5,207	7 (B1)
Indiana American Water Company - Wildcat Creek Well Field (WCWF)	1,980 / 381,150	NA

Notes:

gpm = gallons per minute

ft³/day = cubic foot or feet per day

S1 = sand unit S1

S2 = sand unit S2

B1 = bedrock B1

NA = Not Applicable. (The Wildcat Creek Well Field is not included in the groundwater flow model because these wells extract water from Wildcat Creek, primarily.)

Table A-3 Groundwater Flow Model Calibration Results
Former GM Delco Plant 5, Kokomo, Indiana

Name	Model Layer	Observed Water Level	Computed Water Level (ft amsl)	Residual (ft)
OBS1	7	705	710.9	-5.9
OBS2	7	711	718.5	-7.5
OBS3	7	737	731.5	5.5
OBS4	7	765	763.1	1.9
OBS5	7	779	762.0	17.0
OBS6	7	776	765.9	10.1
OBS7	7	779	766.9	12.1
OBS8	7	784	791.8	-7.8
OBS9	7	787	785.6	1.4
OBS10	7	789	789.7	-0.7
OBS11	7	774	780.3	-6.3
OBS12	7	776	774.1	1.9
OBS13	7	749	747.5	1.5
OBS14	7	779	767.5	11.5
OBS15	7	762	749.6	12.4
OBS16	7	787	778.1	8.9
OBS17	7	757	738.1	18.9
OBS18	7	757	725.9	31.1
OBS19	7	768	769.7	-1.7
OBS20	7	763	771.5	-8.5
OBS21	7	805	787.5	17.5
OBS22	7	808	804.9	3.1
OBS23	7	809	806.5	2.5
OBS24	7	801	803.2	-2.2
OBS25	7	791	795.0	-4.0
OBS26	7	807	804.6	2.4
OBS27	7	802	808.1	-6.1
OBS28	7	793	802.5	-9.5
OBS29	7	806	798.4	7.6
OBS30	7	810	808.4	1.6
OBS31	7	803	815.5	-12.5
OBS32	7	778	776.2	1.8
OBS33	7	740	765.3	-25.3
OBS34	7	741	762.2	-21.2
OBS35	7	743	760.5	-17.5
OBS36	7	744	745.8	-1.8
OBS37	7	789	778.1	10.9
OBS38	7	802	801.3	0.7
OBS39	7	793	813.7	-20.7
OBS40	7	812	826.7	-14.7
OBS41	7	811	817.0	-6.0
OBS42	7	819	820.0	-1.0
OBS43	7	805	800.2	4.8
OBS44	7	813	801.6	11.4
OBS45	7	813	820.9	-7.9
OBS46	7	816	809.6	6.4

Table A-3 Groundwater Flow Model Calibration Results
Former GM Delco Plant 5, Kokomo, Indiana

Name	Model Layer	Observed Water Level	Computed Water Level (ft amsl)	Residual (ft)
OBS47	7	812	811.5	0.5
OBS48	7	824	836.0	-12.0
OBS49	7	826	836.8	-10.8
OBS5	7	824	829.2	-5.2
OBS6	7	822	824.5	-2.5
OBS7	7	829	827.7	1.3
OBS8	7	824	839.8	-15.8
OBS9	7	824	825.5	-1.5
OBS5.5	7	821	818.3	2.7
OBS56	7	827	822.3	4.7
OBS57	7	824	817.8	6.2
OBS58	7	808	815.1	-7.1
OBS59	7	807	820.9	-13.9
OBS60	7	808	819.2	-11.2
OBS61	7	809	810.9	-1.9
OBS62	2	819	831.6	-12.6
OBS63	2	806	810.8	-4.8
OBS64	2	826	823.9	2.1
OBS65	2	831	838.7	-7.7
OBS66	2	822	824.7	-2.7
OBS67	2	818	820.1	-2.1
OBS68	2	802	815.4	-13.4
OBS69	2	817	806.5	10.5
OBS70	2	809	811.9	-2.9
OBS71	2	807	826.3	-19.3
OBS72	2	800	805.5	-5.5
OBS73	2	784	785.5	-1.5
OBS74	2	785	780.1	4.9
OBS75	2	799	805.0	-6.0
OBS76	2	793	789.6	3.4
OBS77	2	783	790.4	-7.4
OBS78	2	803	810.6	-7.6
OBS79	2	824	819.2	4.8
OBS80	2	783	781.3	1.7
OBS81	4	829	837.3	-8.3
OBS82	4	826	828.6	-2.6
OBS83	4	815	817.3	-2.3
OBS84	4	822	816.2	5.8
OBS85	4	811	808.3	2.7
OBS86	4	811	823.2	-12.2
OBS87	4	787	793.8	-6.8
OBS88	4	779	762.8	16.2
OBS89	4	797	791.9	5.1
OBS90	4	748	758.0	-10.0
OBS91	4	762	760.5	1.5
OBS92	4	709	727.8	-18.8

Table A-3 Groundwater Flow Model Calibration Results
Former GM Delco Plant 5, Kokomo, Indiana

Name	Model Layer	Observed Water Level	Computed Water Level (ft amsl)	Residual (ft)
OBS93	6	823	818.3	4.7
OBS94	6	813	819.3	-6.3
OBS95	6	816	819.4	-3.4
OBS96	6	800	819.7	-19.7
OBS97	6	758	767.2	-9.2
OBS98	6	775	765.3	9.7
OBS99	6	815	802.9	12.1
OBS100	6	786	790.2	-4.2
OBS101	6	813	805.2	7.8
OBS102	6	815	820.9	-5.9
OBS103	6	807	821.0	-14.0
OBS104	6	809	817.1	-8.1
OBS10.5	6	816	816.9	-0.9
OBS106	6	817	814.2	2.8
OBS107	6	813	813.1	-0.1
OBS108	6	796	794.4	1.6
OBS109	6	797	797.7	-0.7
OBS110	6	812	808.0	4.0
OBS111	6	778	761.7	16.3
OBS112	6	757	757.2	-0.2
OBS113	6	754	769.2	-15.2
OBS114	6	788	780.8	7.2
OBS115	6	767	764.1	2.9
OBS116	6	761	733.5	27.5
OBS117	6	787	776.5	10.5
OBS118	6	791	782.4	8.6
OBS119	6	795	788.1	6.9
Calibration Statistics				
Residual Mean	-0.98 ft			
Residual Standard Deviation	9.96 ft			
Sum of Squares	11,815 ft ²			
Absolute Residual Mean	7.75 ft			
Minimum Residual	-25.3 ft			
Maximum Residual	31.1 ft			
Range in Target Values	126 ft			
Standard Deviation/Range	0.08 ft			

Note:

ft = foot or feet

ft² = square foot or feet

Table A-4 Summary of Solute Transport Parameters for Predictive Scenarios
Former GM Delco Plant 5, Kokomo, Indiana

Scenario/Parameter	K _d (ft ³ /lb)	Retardation Factor (Unitless)	Half-life (year)	Source Concentrations (µg/L)	Pumping rate at IAWC-NWF (gpm)
Scenario 1	TCE: 0.013 DCE: 0.003	TCE: 5.03 DCE: 1.86	TCE: 2 DCE: 5	Based on current concentrations of TCE and cis-1,2-DCE in the S1, S2 and S3/B1 units	1,100
Scenario 2	TCE: 0.0003 DCE: 0.0001	TCE: 1.08 DCE: 1.02	TCE: 2 DCE: 5	Same as Scenario 1	1,100
Scenario 3	TCE: 0.0003 DCE: 0.0001	TCE: 1.08 DCE: 1.02	TCE: 2 DCE: NA	Same as Scenario 1	1,100
Scenario 4	TCE: 0.0003 DCE: 0.0001	TCE: 1.08 DCE: 1.02	TCE: 2 DCE: NA	Initial TCE and cis-1,2-DCE concentration applied on site in Scenario 1 reduced by 79 percent	1,100
Scenario 5	TCE: 0.0003 DCE: 0.0001	TCE: 1.08 DCE: 1.02	TCE: 5 DCE: NA	Same as Scenario 1	1,100
Scenario 6	TCE: 0.0003 DCE: 0.0001	TCE: 1.08 DCE: 1.02	TCE: 2 DCE: NA	Same as Scenario 1	2,200

Note:

TCE = trichloroethene

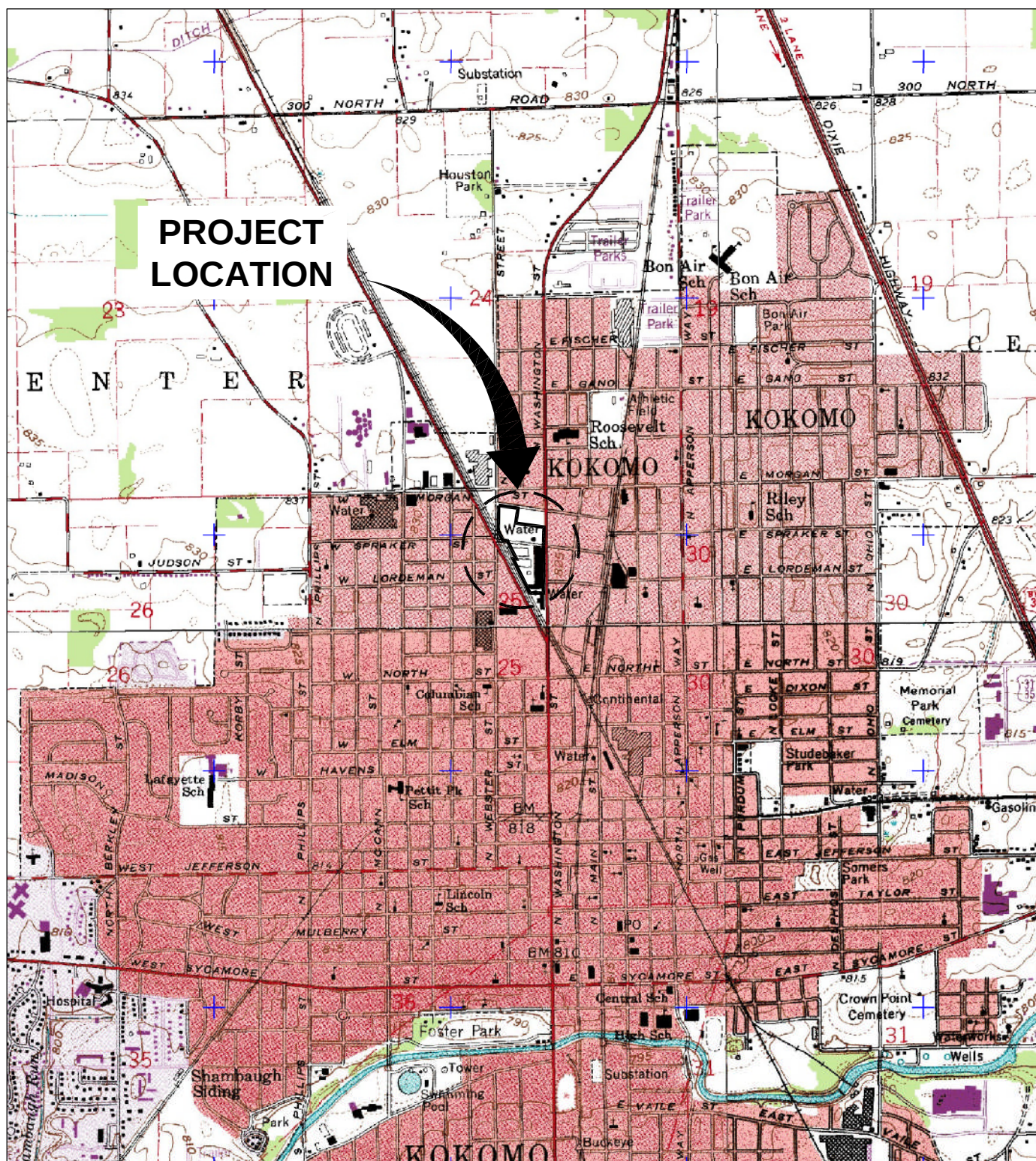
DCE = cis-1,2-Dichloroethene

NA = Not Applicable (*i.e.* , no degradation)

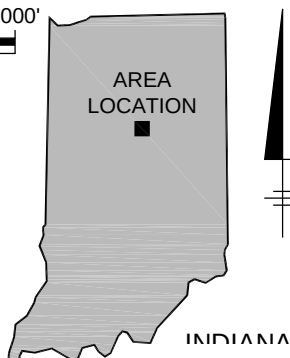
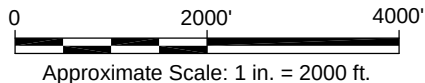
gpm = gallon per minute

ft/day = feet per day

ft³/lb = cubic feet per pound



REFERENCE: BASE MAP USGS 7.5. MIN. TOPO. QUAD., CITY, STATE, 19??, PHOTOREVISED 19??.



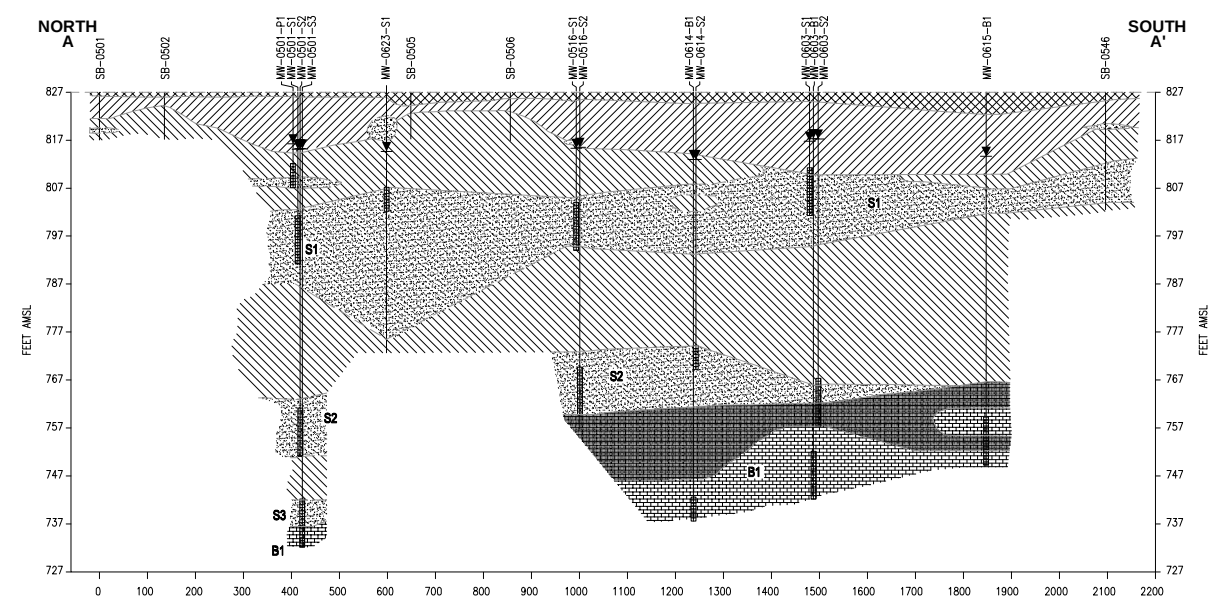
RACER TRUST
 FORMER GM DELCO PLANT 5
 KOKOMO, INDIANA
CORRECTIVE MEASURES STUDY

SITE LOCATION MAP

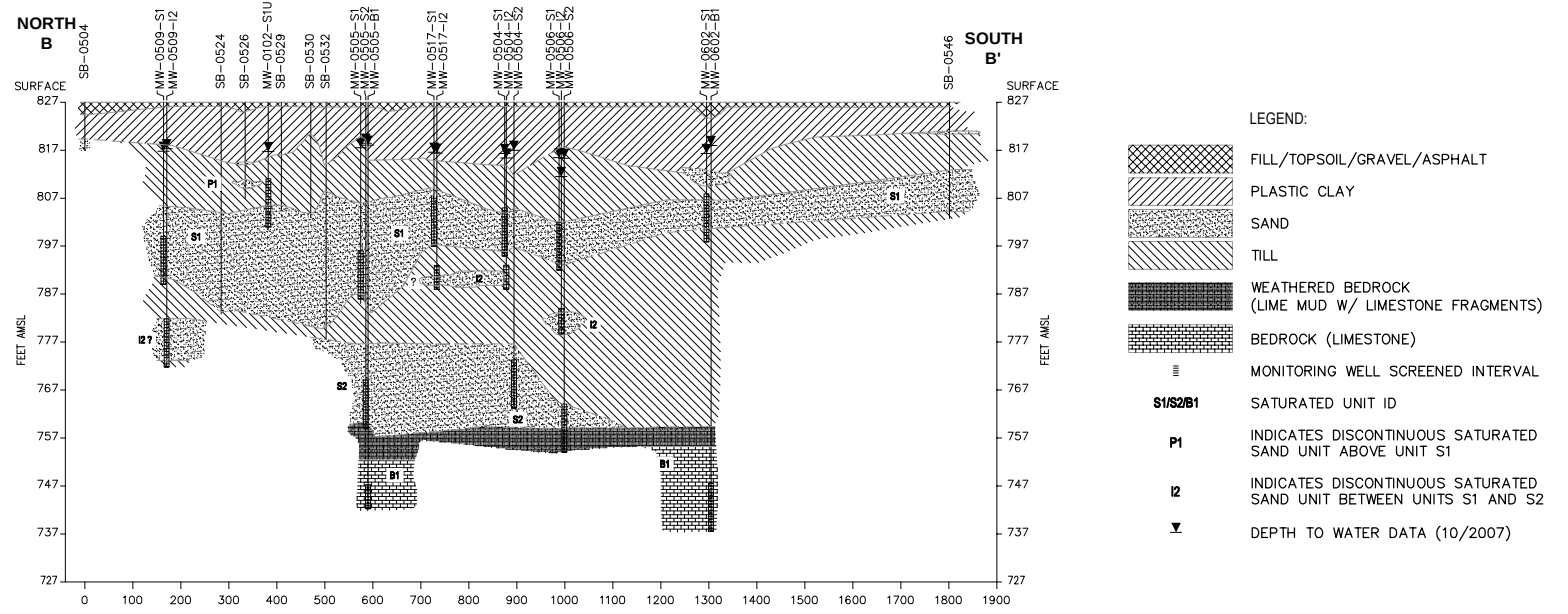


FIGURE
A-1

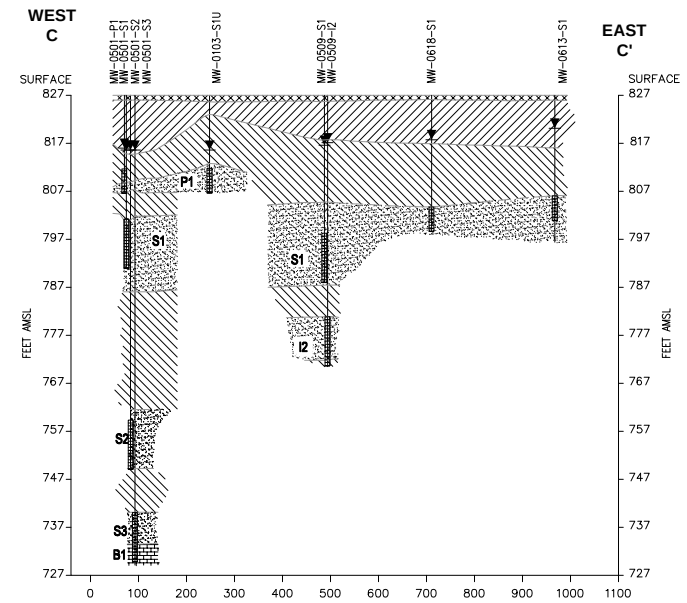
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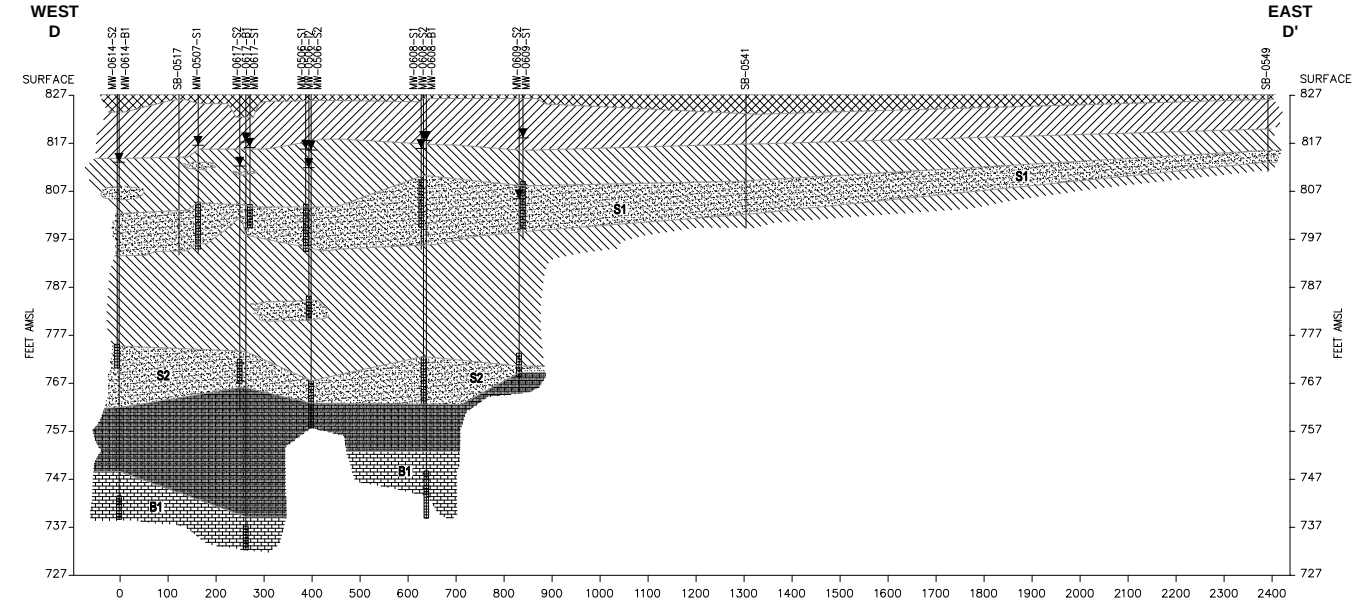
CROSS-SECTION A-A'
SEE GRAPHIC SCALES



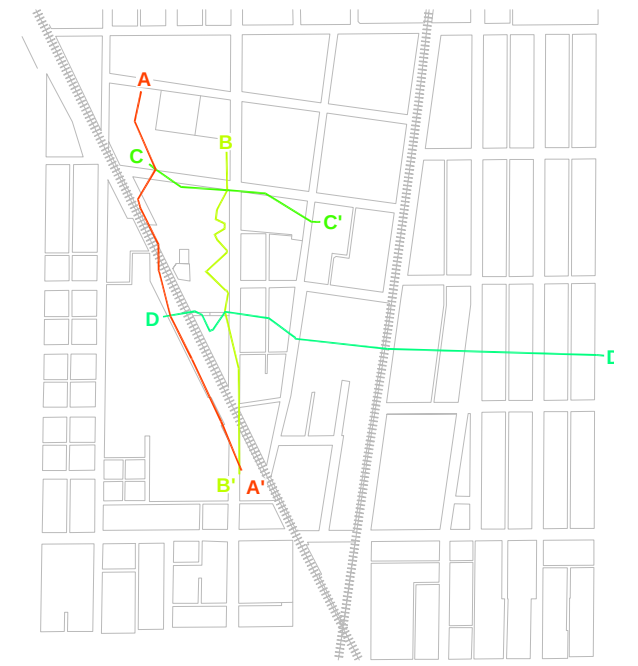
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SEE GRAPHIC SCALES



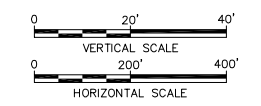
CROSS-SECTION C-C'
SEE GRAPHIC SCALES



CROSS-SECTION D-D'
SEE GRAPHIC SCALES



CROSS-SECTION LOCATIONS
NOT TO SCALE



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CROSS SECTIONS
A - A', B - B', C - C', AND D - D'

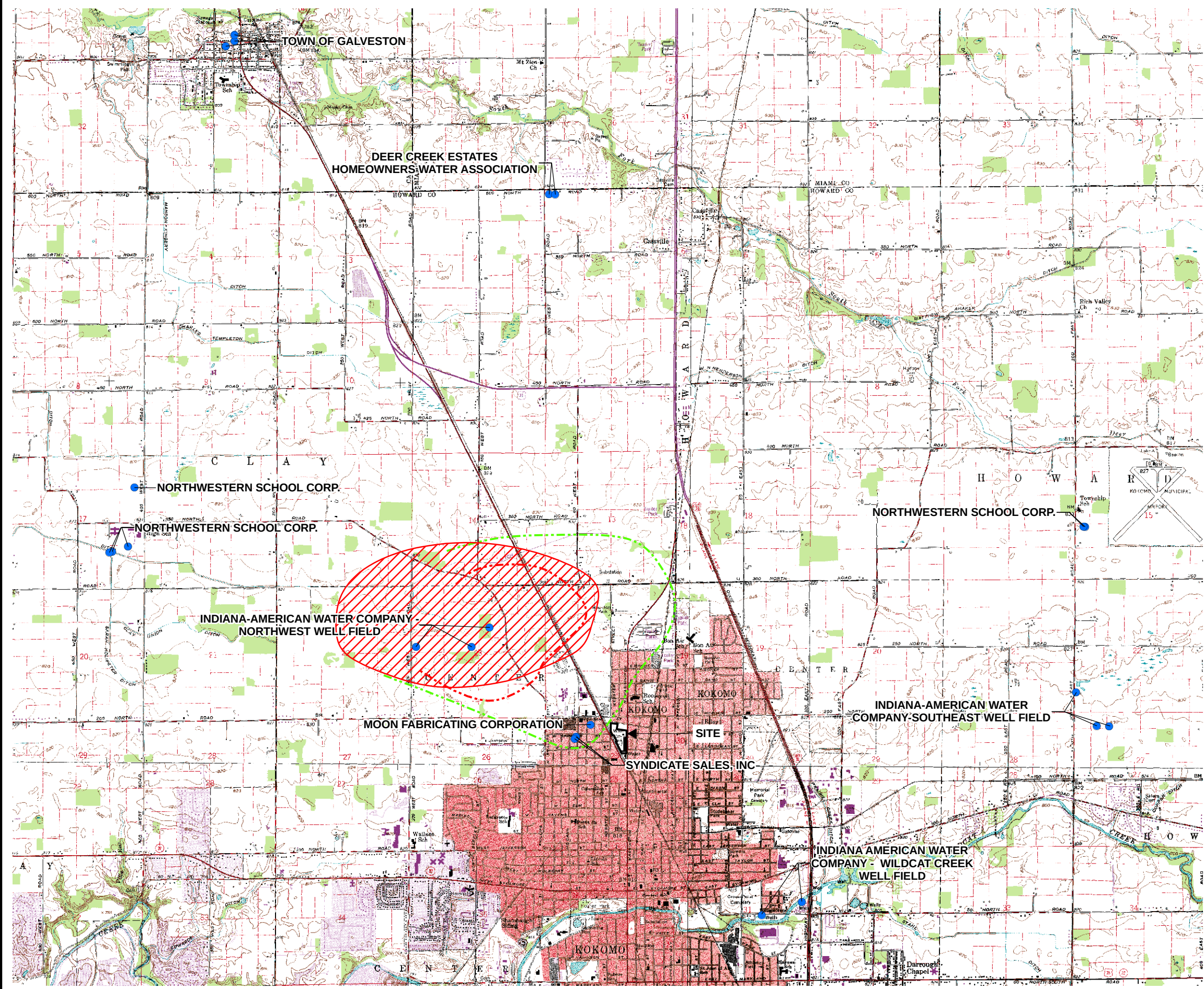


FIGURE
A-3



1. FORMER GM SITE, IAWC-WILDCAT CREEK WELL FIELD, AND IAWC-NORTHWEST WELL FIELD LOCATIONS ARE APPROXIMATE.
2. DATA REFERENCE: SMITH, BARRY S., M. HARDY, AND E. JAMES, 1985. WATER RESOURCES OF WILDCAT CREEK AND DEER CREEK BASINS, HOWARD AND PARTS OF ADJACENT COUNTIES, INDIANA, 1979-82.

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Motor's Liquidation (N000984.2011.00006)
Q:\Motor's Liquidation Company\Kokomo\IT\GW\Monitoring\Report\mxd\RegionalLargeWellFields.mxd - 4/13/2011 @ 10:36:24 AM



- LEGEND:
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
 - MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
 - LOCATION OF KNOWN SIGNIFICANT WATER USERS
 - ▨ APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTE:
1. SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.

0 4,000 8,000
Feet

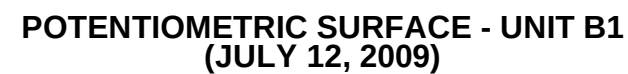
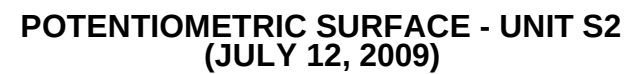
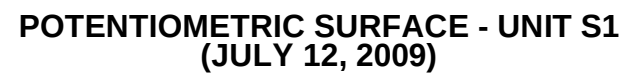
GRAPHIC SCALE

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REGIONAL LARGE WELL FIELDS



FIGURE
A-6



LEGEND

MONITORING WELL S2 SCREENED IN UNIT S1

MONITORING WELL SCREENED IN UNIT S2

MONITORING WELL SCREENED IN UNIT B1. UNIT B1 REFERS TO THE UPPER-MOST TRANSMISSIVE ZONE WITHIN THE LIMESTONE BEDROCK UNIT.

DENOTES AREA WHERE S2 UNIT IS NOT PRESENT

GROUNDWATER ELEVATION

GROUNDWATER CONTOUR (DASHED WHERE INFERRED)

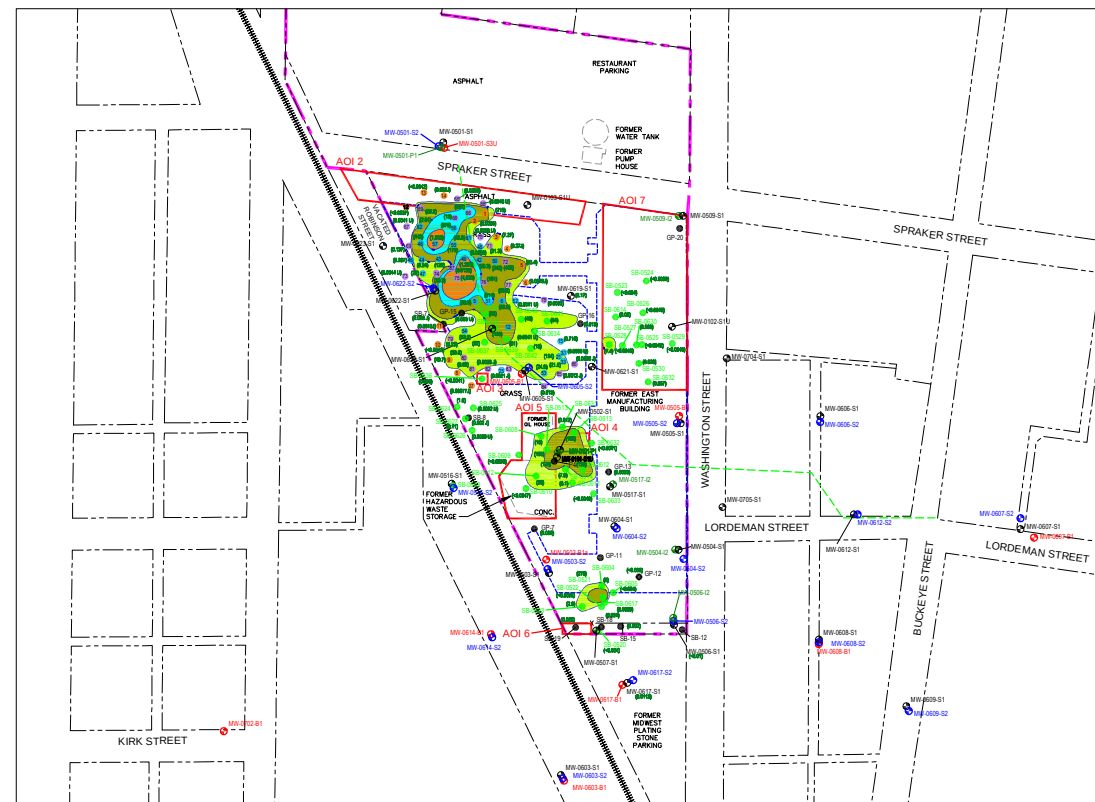
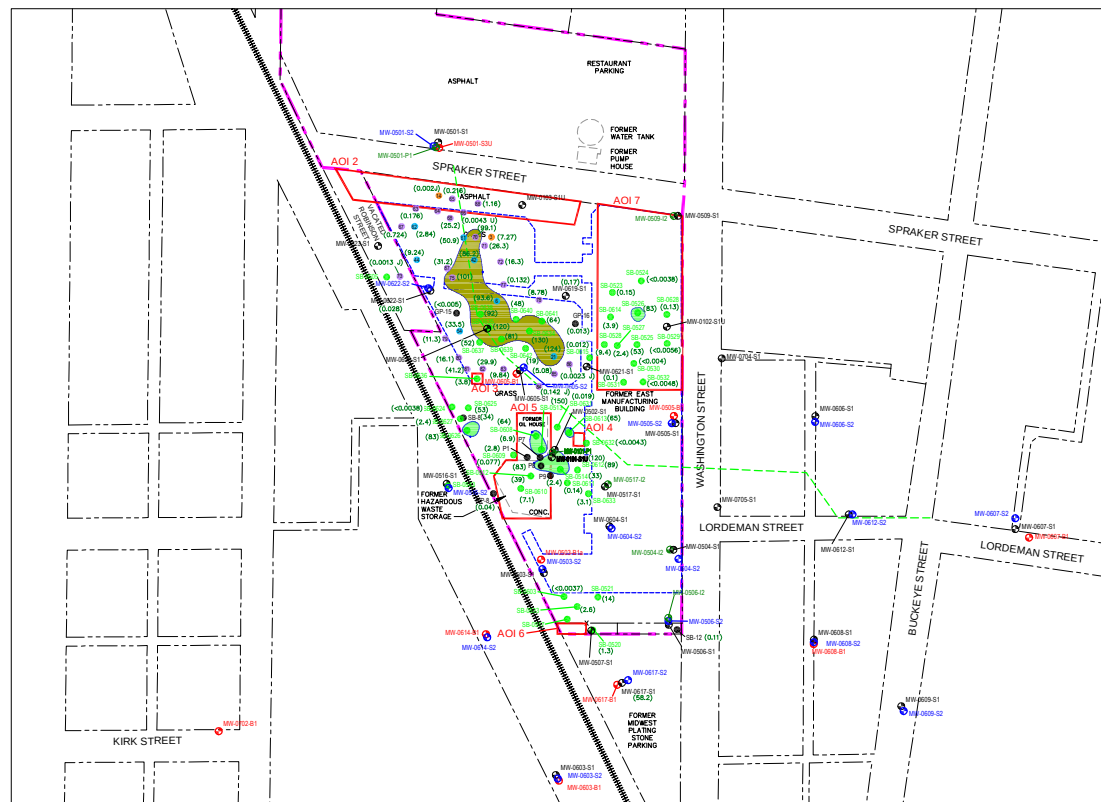
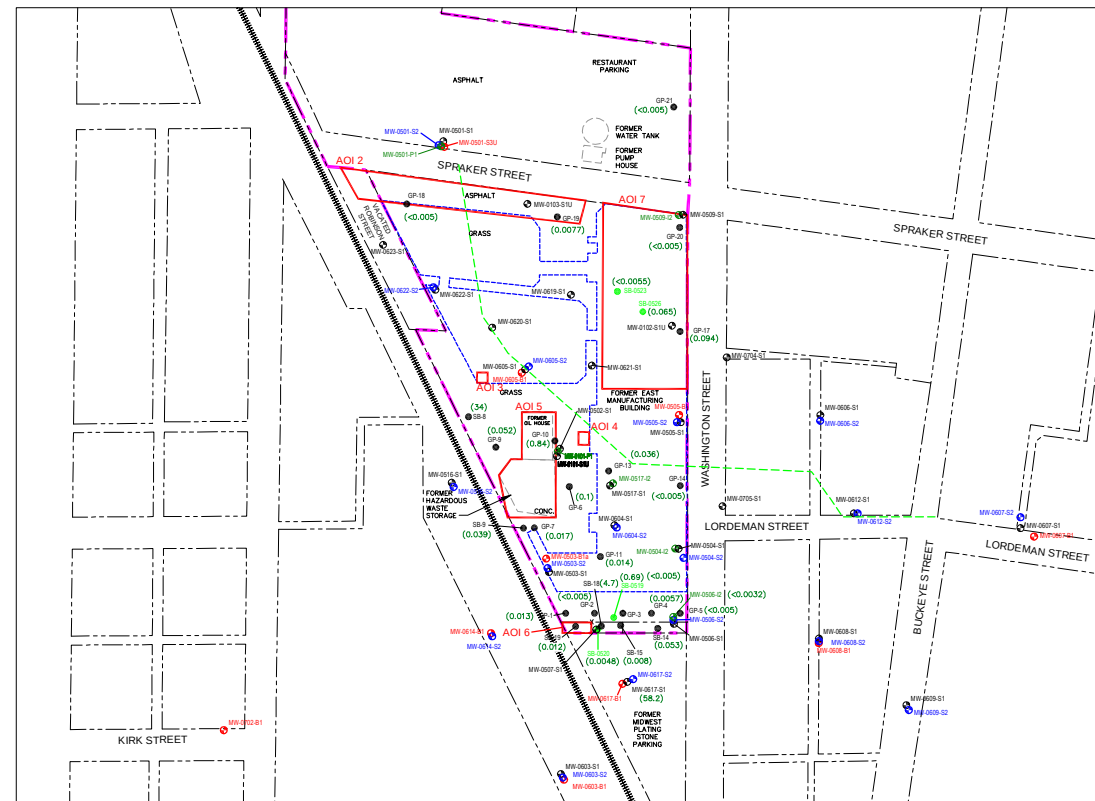
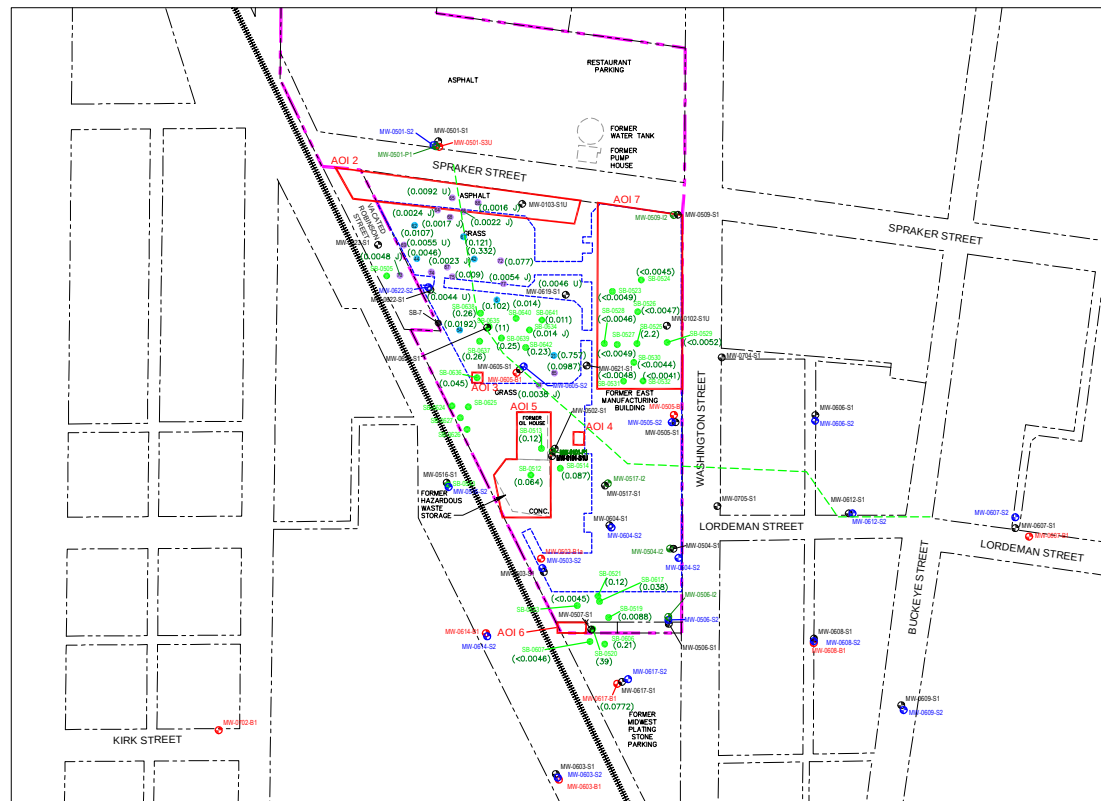


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POTENTIOMETRIC SURFACE MAPS - UNITS S1, S2, AND B1



FIGURE
A-7



LEGEND

- MW-0501-P1 ● MONITORING WELL SCREENED IN DISCONTINUOUS UNIT
P1 DENOTES SCREENED INTERVAL IS IN A PERCHED ZONE
ABOVE UNIT S1
12 DENOTES SCREENED INTERVAL IS A SAND UNIT BETWEEN
UNITS S1 AND S2
- MW-0603-S1 ● MONITORING WELL S2 SCREENED IN UNIT S1
- MW-0603-S2 ● MONITORING WELL SCREENED IN UNIT S2
- MW-0603-B1 ● MONITORING WELL SCREENED IN UNIT B1 RFI PHASE IV
- MW-0615-B1a ● MONITORING WELL (B1a LOCATIONS ARE OPEN BEDROCK
BOREHOLES TO A DEPTH OF APPROXIMATELY 150 FT BG
CURRENTLY SEALED WITH FLUTE LINERS)
PRE-RFI SOIL BORING LOCATIONS
- RFI SOIL BORING LOCATIONS
- RFI PHASE IV LOCATION (ID IS THE LAST DIGIT ASSOCIATED WITH
BORING ID) E.G. 1 EQUALS SB-0701 AND 54 EQUALS SB-0754
- 62 ● RFI PHASE IV NOVEMBER 2007 STEP-OUT LOCATIONS (ID IS THE
LAST DIGIT ASSOCIATED WITH BORING ID) E.G. 63 EQUALS
SB-0763 AND 75 EQUALS SB-0775
- 63 ● RFI PHASE IV JANUARY 2008 STEP-OUT LOCATIONS (ID IS THE
LAST DIGIT ASSOCIATED WITH BORING ID) E.G. 01 EQUALS
SB-0801 AND 14 EQUALS SB-0814
- 64 ● TCE CONCENTRATION IN $\mu\text{g/L}$ (NOVEMBER/DECEMBER 2008)
- (<5) HISTORIC TCE CONCENTRATION IN $\mu\text{g/L}$ (OCTOBER 2005, MARCH
& NOVEMBER 2006, MARCH 2007)
- WILLIAM B. MORGAN SEWER (10" CLAY TILE) (ATTEMPTS TO
LOCATE SEWER WERE UNSUCCESSFUL IN DECEMBER 2007)
- SOIL CONCENTRATIONS EXCEED 1,000 mg/kg
- SOIL CONCENTRATIONS RANGE FROM 500 TO 1,000 mg/kg
- SOIL CONCENTRATIONS EXCEED REGION 9 COMMERCIAL/INDUSTRIAL
BASED PRG FOR DIRECT CONTACT AT A TARGET CANCER RISK OF
1a-5 (61 mg/kg)
- SOIL CONCENTRATIONS EXCEED CALCULATED SOIL MIGRATION TO
GROUNDWATER CRITERIA (2 mg/kg)

NOTE:

1. SAMPLE DEPTHS REPRESENT THE DEEPEST
SAMPLE COLLECTED FROM THE BORING.

0 150' 300'

GRAPHIC SCALE

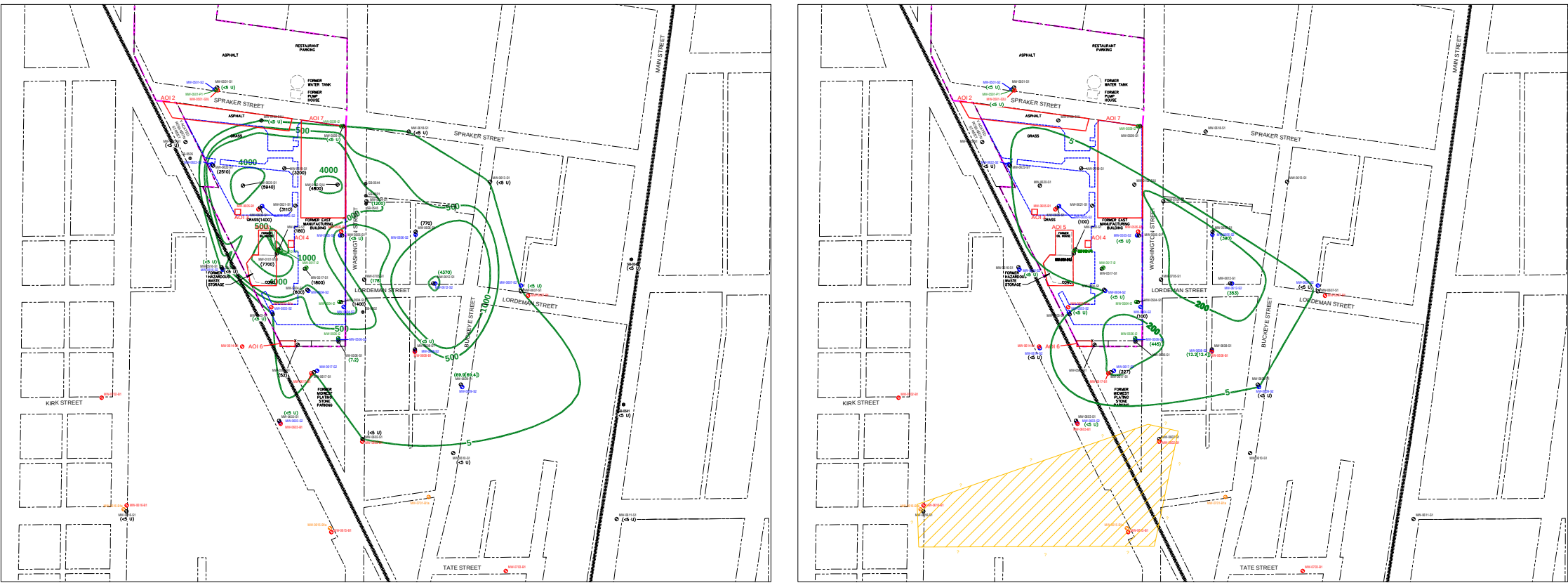
RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
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TCE CONCENTRATION CONTOURS IN SOIL



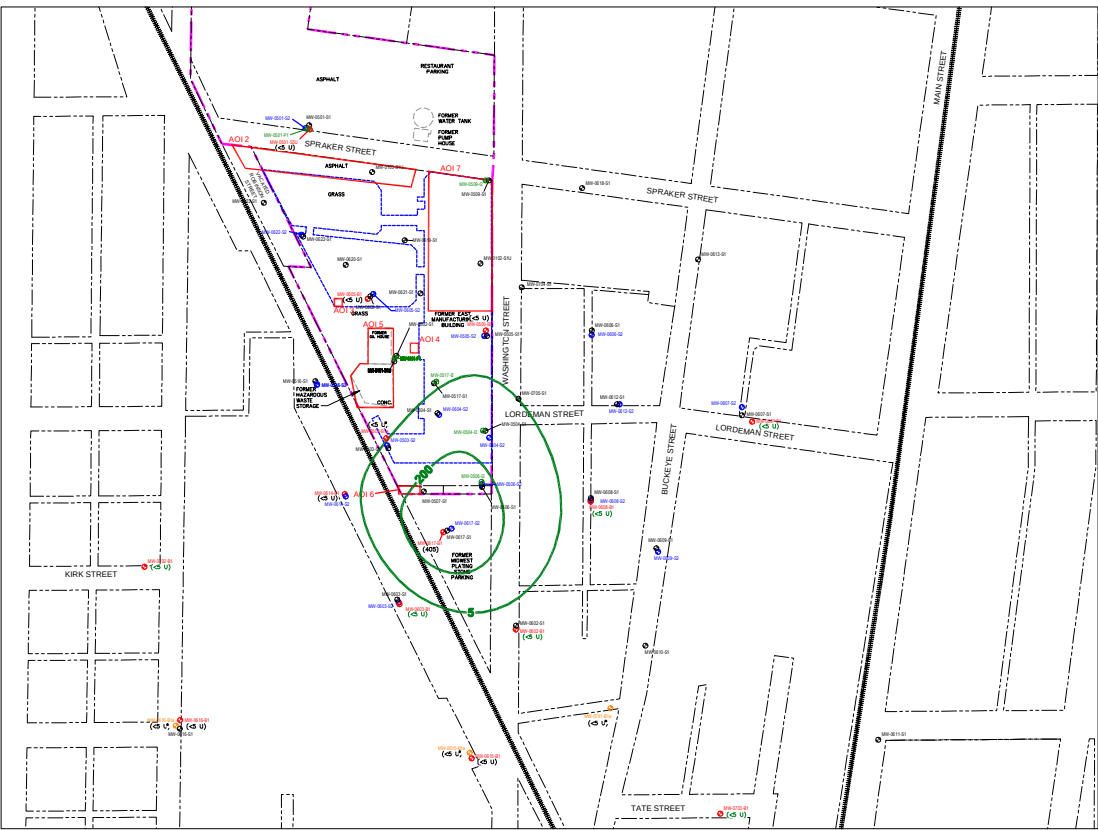
FIGURE
A-8

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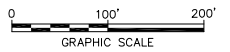
UNIT S1

UNIT S2



UNIT B1

- LEGEND
- MW-0501-P1 MONITORING WELL SCREENED IN DISCONTINUOUS UNIT
P1 DENOTES SCREENED INTERVAL IS IN A PERCHED ZONE ABOVE UNIT S1
I2 DENOTES SCREENED INTERVAL IS A SAND UNIT BETWEEN UNITS S1 AND S2
 - MW-0603-S1 MONITORING WELL SCREENED IN UNIT S1
 - MW-0603-S2 MONITORING WELL SCREENED IN UNIT S2
 - MW-0603-B1 MONITORING WELL SCREENED IN UNIT B1. UNIT B1 REFERS TO THE UPPER-MOST TRANSMISSIVE ZONE WITHIN THE LIMESTONE BEDROCK UNIT.
 - MW-0615-B1a OPEN BEDROCK BOREHOLE (B1a LOCATIONS ARE OPEN BEDROCK BOREHOLES TO A DEPTH OF APPROXIMATELY 150 FT BG CURRENTLY SEALED WITH FLUTE LINERS)
 - (<5 U) TCE CONCENTRATION IN µg/L (JUNE 2009)
 - (<5 U) HISTORIC TCE CONCENTRATION IN µg/L (OCTOBER 2005, MARCH & NOVEMBER 2006 AND NOVEMBER & DECEMBER 2008)
 - 5 ISOCONCENTRATION CONTOUR IN µg/L
 - * B1a DATA IS FROM THE UPPER MOST SAMPLED UNIT



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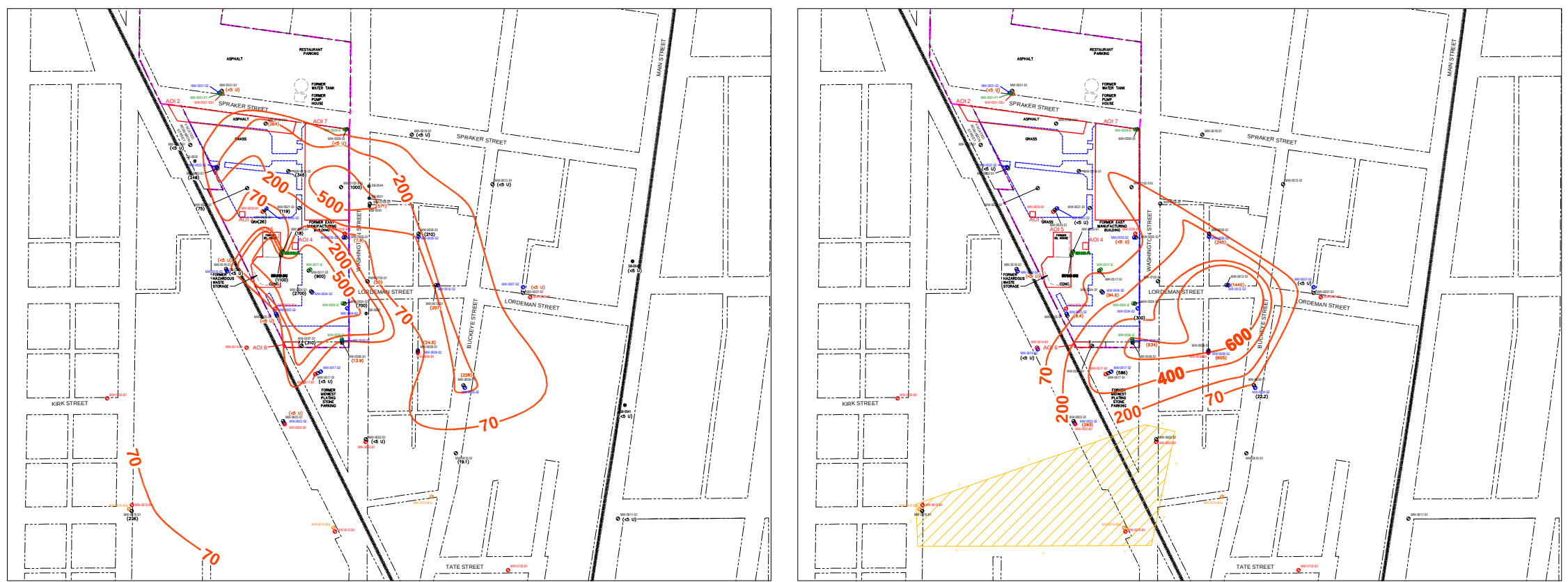
**TCE GROUNDWATER
CONCENTRATION CONTOURS**

ARCADIS

FIGURE
A-9

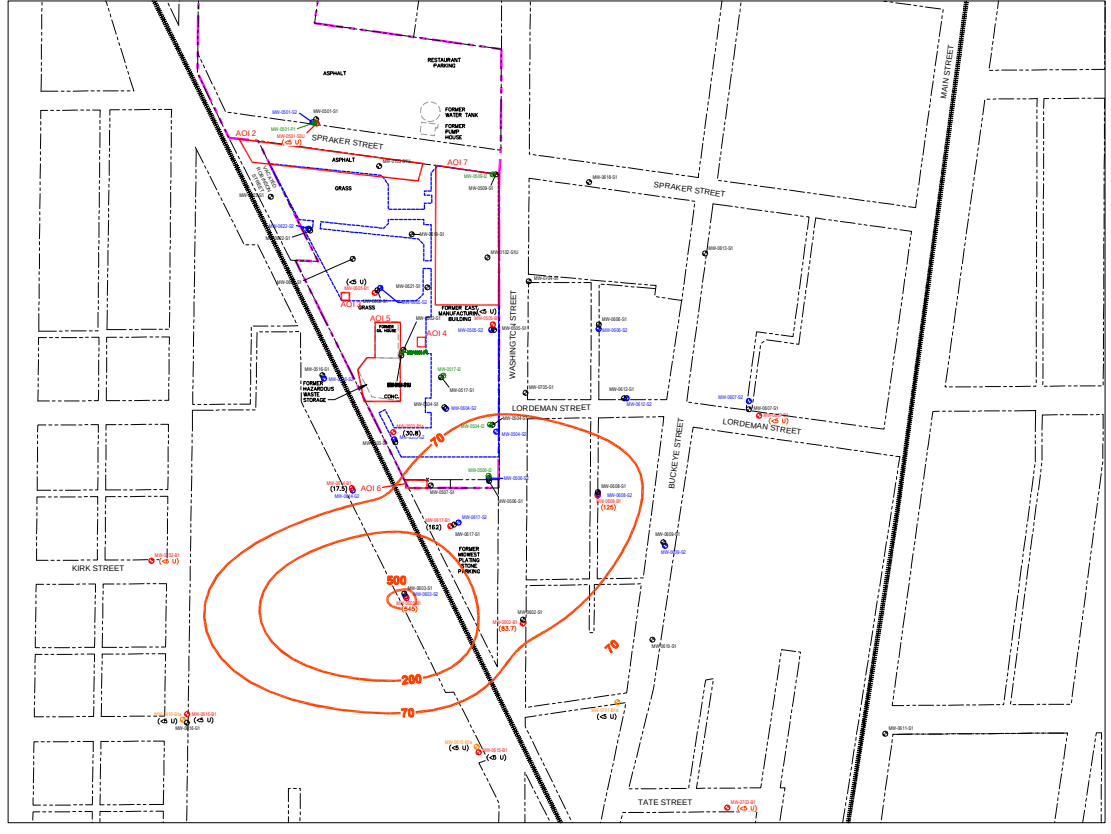
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IMAGES: PROJECTNAME: -



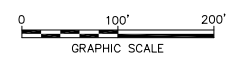
UNIT S1

UNIT S2



UNIT B1

- LEGEND
- MONITORING WELL SCREENED IN DISCONTINUOUS UNIT
P1 DENOTES SCREENED INTERVAL IS IN A PERCHED ZONE ABOVE UNIT S1
I2 DENOTES SCREENED INTERVAL IS A SAND UNIT BETWEEN UNITS S1 AND S2
 - MW-0501-P1
 - MONITORING WELL SCREENED IN UNIT S1
 - MW-0603-S1
 - MONITORING WELL SCREENED IN UNIT S2
 - MW-0603-S2
 - MONITORING WELL SCREENED IN UNIT B1. UNIT B1 REFERS TO THE UPPER-MOST TRANSMISSIVE ZONE WITHIN THE LIMESTONE BEDROCK UNIT.
 - MW-0603-B1
 - OPEN BEDROCK BOREHOLE (B1a LOCATIONS ARE OPEN BEDROCK BOREHOLES TO A DEPTH OF APPROXIMATELY 150 FT BG CURRENTLY SEALED WITH FLUTE LINERS)
 - MW-0615-B1a
 - DENOTES AREA WHERE S2 UNIT IS NOT PRESENT
 - CIS-1,2-DCE CONCENTRATION IN $\mu\text{g/L}$ (JUNE 2009)
 - HISTORIC CIS-1,2-DCE CONCENTRATION IN $\mu\text{g/L}$ (OCTOBER 2005, MARCH & NOVEMBER 2006 AND NOVEMBER & DECEMBER 2008)
 - 70 ISOCONCENTRATION CONTOUR IN $\mu\text{g/L}$
 - * B1a DATA IS FROM THE UPPER MOST SAMPLED UNIT

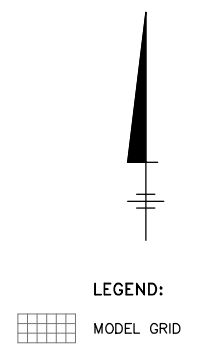
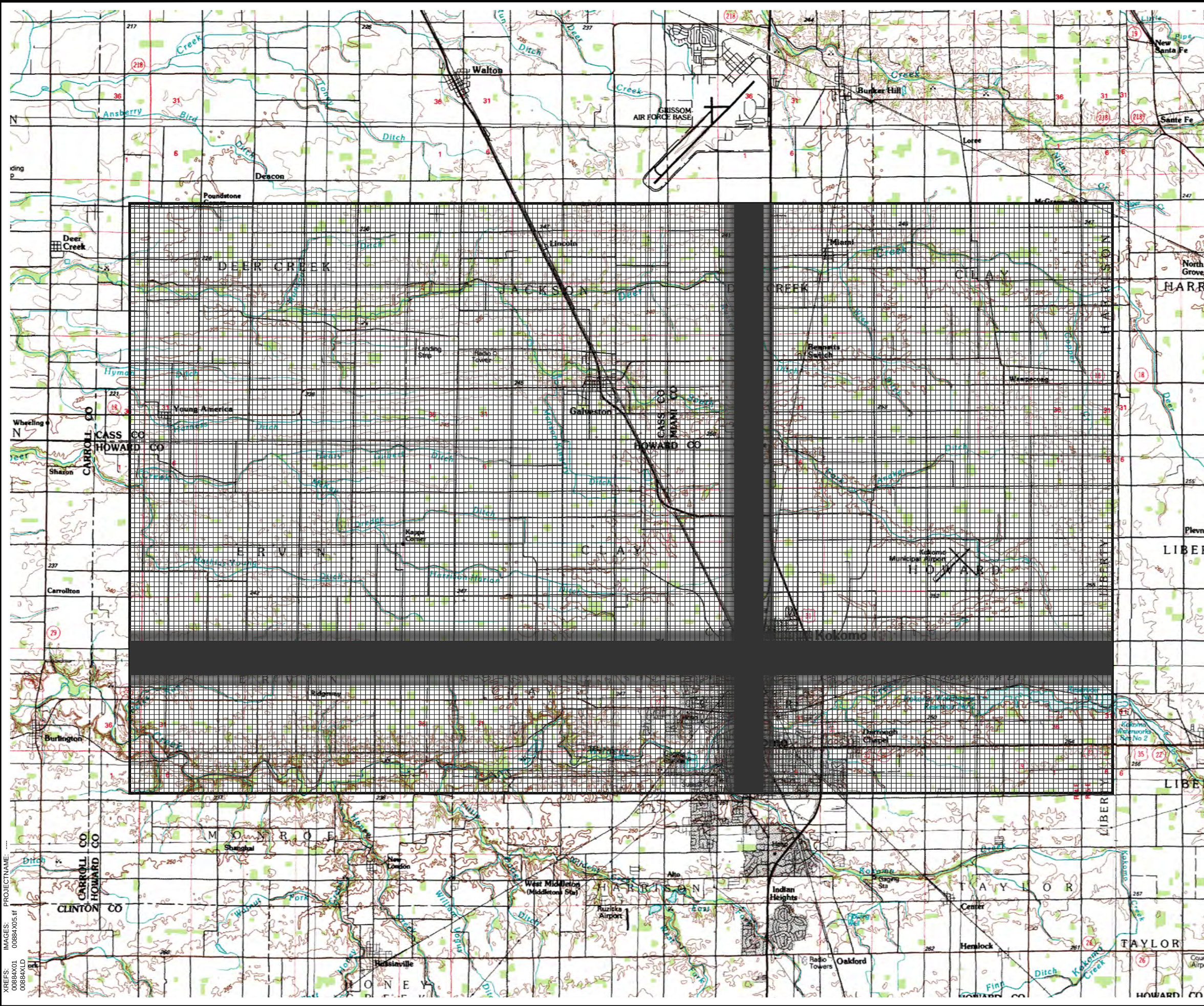


RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

CIS-1,2-DCE GROUNDWATER
CONCENTRATION CONTOURS



CITY(Refd) DIV(GROUP(Refd) DE(Refd) LD(Refd) PIC(Refd) PM(Refd) TM(Refd) LVR(Option)=OFF=REF*
G:\ENVCAD\S\TRACUSELECT\UN008842010\0020\DWG\RCFA-FR00884201.dwg LAYOUT: A-11. SAVED: 4/15/2011 5:06 PM ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOTSETUP: C:\D2B-PDF-CONV PLOTSTYLETABLE: PLTULL.CTB PLOTTED: 4/15/2011 5:18 PM BY: STOWELL, GARY



- NOTE:
1. THE MODEL DOMAIN CONSISTS OF 201 ROWS, 272 COLUMNS, AND EIGHT LAYERS.
 2. MODEL ROW AND COLUMN WIDTHS ARE EACH 50 FEET IN THE VICINITY OF THE CITY OF KOKOMO, AND EXPAND TO 500 FEET TOWARDS THE PERIPHERY OF THE MODEL.

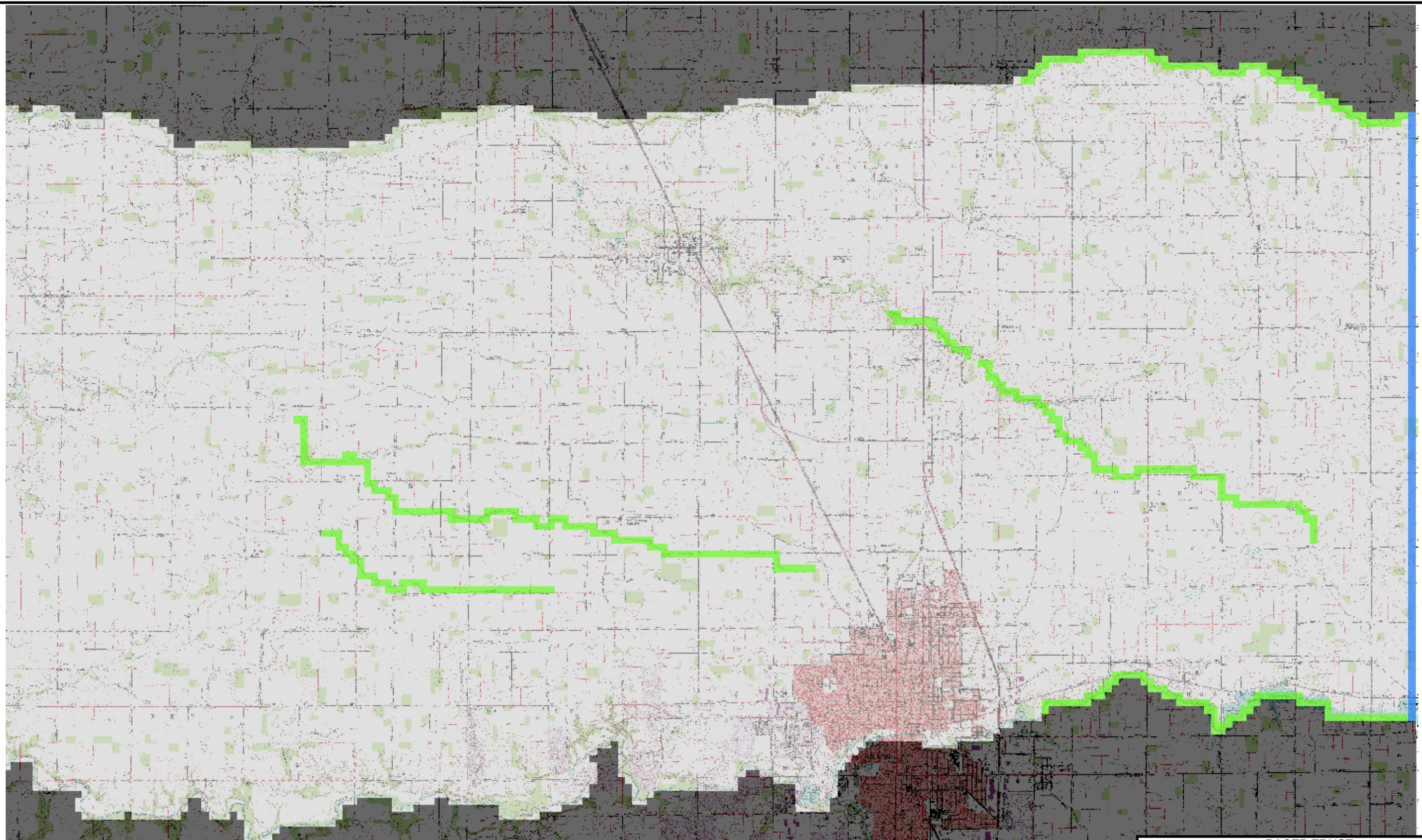


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KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

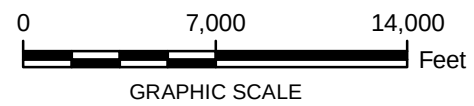
MODEL DOMAIN AND GRID



CITY: SYR DIV/GRP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\IT\GW\Monitoring\Report\mxd\HydroConductivity Model\layer1.mxd - 4/18/2011 @ 11:43:55 AM



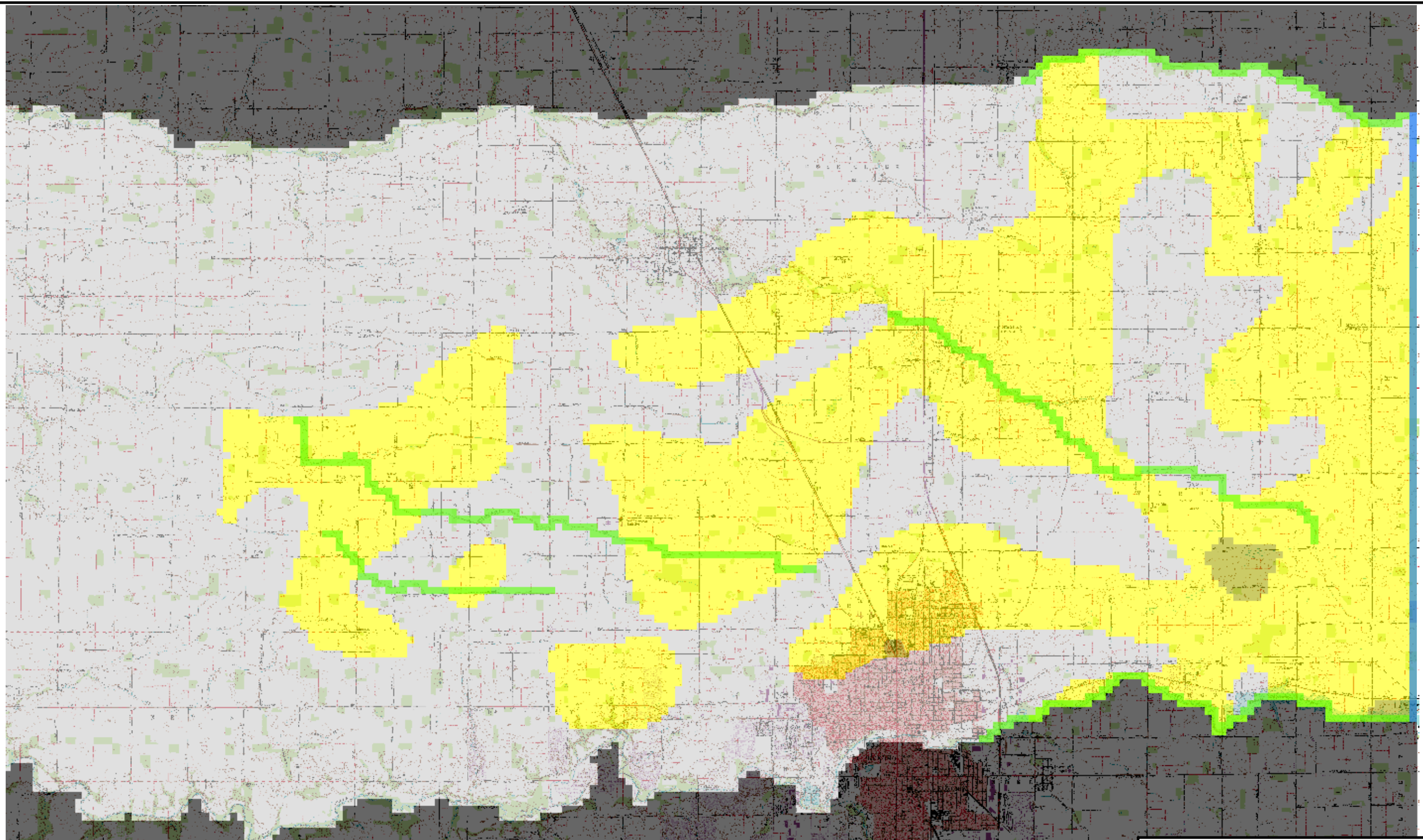
- LEGEND:
- CONSTANT HEAD CELL
 - DRAIN CELL
 - SURFICIAL TILL (K=0.05 FT/DAY WITH AN ANISOTROPY OF 10:1)
 - NO FLOW CELL



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FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
HYDRAULIC CONDUCTIVITY AND
MODEL BOUNDARY CONDITIONS
(MODEL LAYER 1)



FIGURE
A-12



LEGEND:

- TILL (K=0.05 FT/DAY WITH AN ANISOTROPY OF 10:1)
- SAND UNIT S1 (K=100 FT/DAY WITH AN ANISOTROPY OF 10:1)
- SAND UNIT S1 (K=75 FT/DAY WITH AN ANISOTROPY OF 10:1)
- CONSTANT HEAD CELL
- DRAIN CELL
- NO FLOW CELL

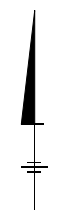
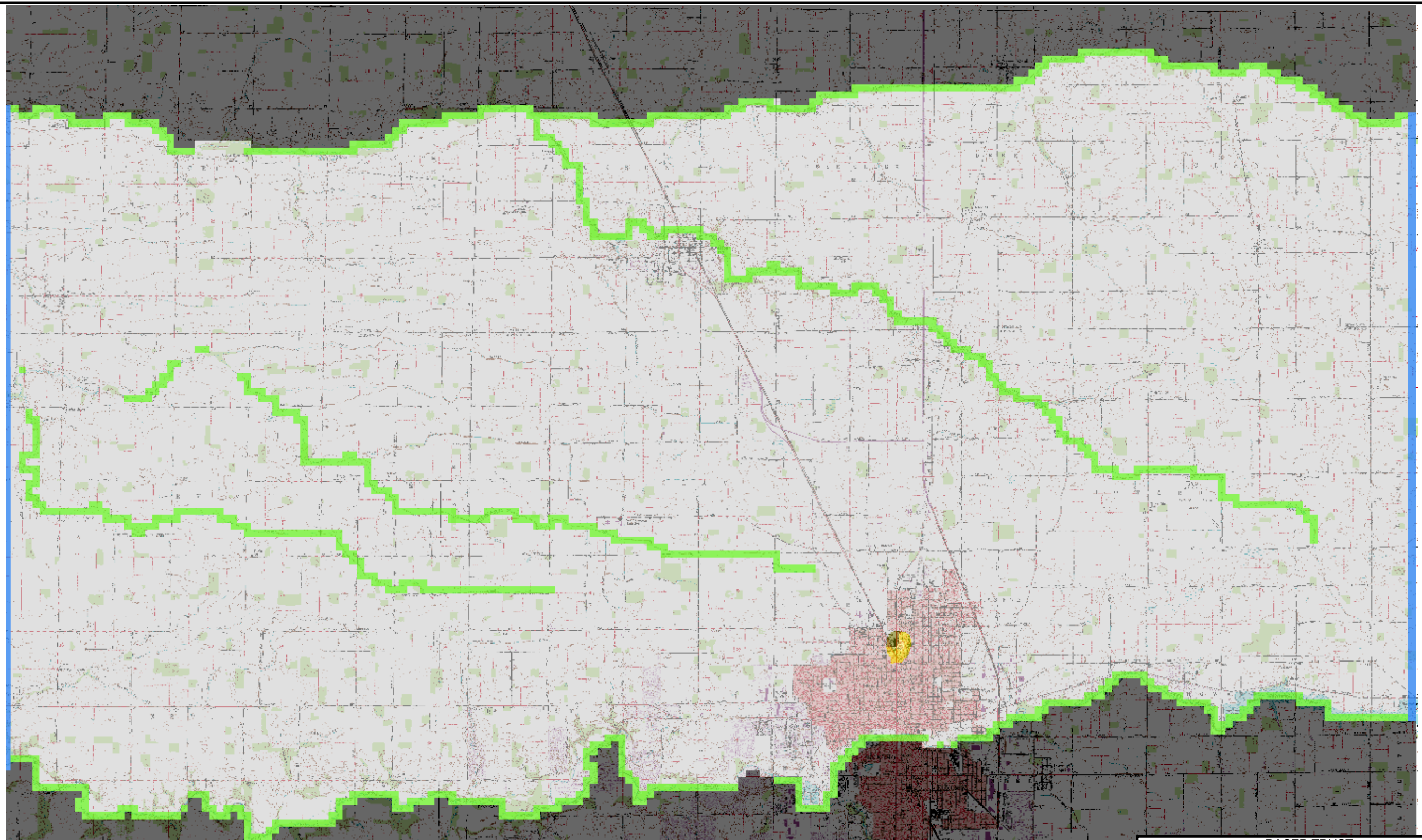
0 7,000 14,000
Feet
GRAPHIC SCALE

RACER TRUST
FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
**HYDRAULIC CONDUCTIVITY AND
MODEL BOUNDARY CONDITIONS
(MODEL LAYER 2/SAND UNIT S1)**



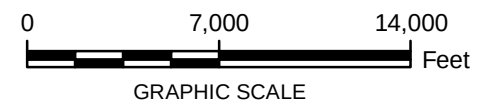
FIGURE
A-13

CITY: SYR DIV/GROUP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\IT\GWMonitoringReport.mxd HydroConductivity Model Layer3.mxd - 4/18/2011 @ 11:45:43 AM



LEGEND:

- | | |
|---|--|
|  SURFICIAL TILL (K=0.03 FT/DAY WITH AN ANISOTROPY OF 10:1) |  CONSTANT HEAD CELL |
|  TILL (K=0.03 FT/DAY WITH AN ANISOTROPY OF 1:1) |  DRAIN WELL CELL |
|  TILL (K=0.1 FT/DAY WITH AN ANISOTROPY OF 2:1) |  NO FLOW CELL |
|  TILL (K=0.03 FT/DAY WITH AN ANISOTROPY OF 10:1) | |

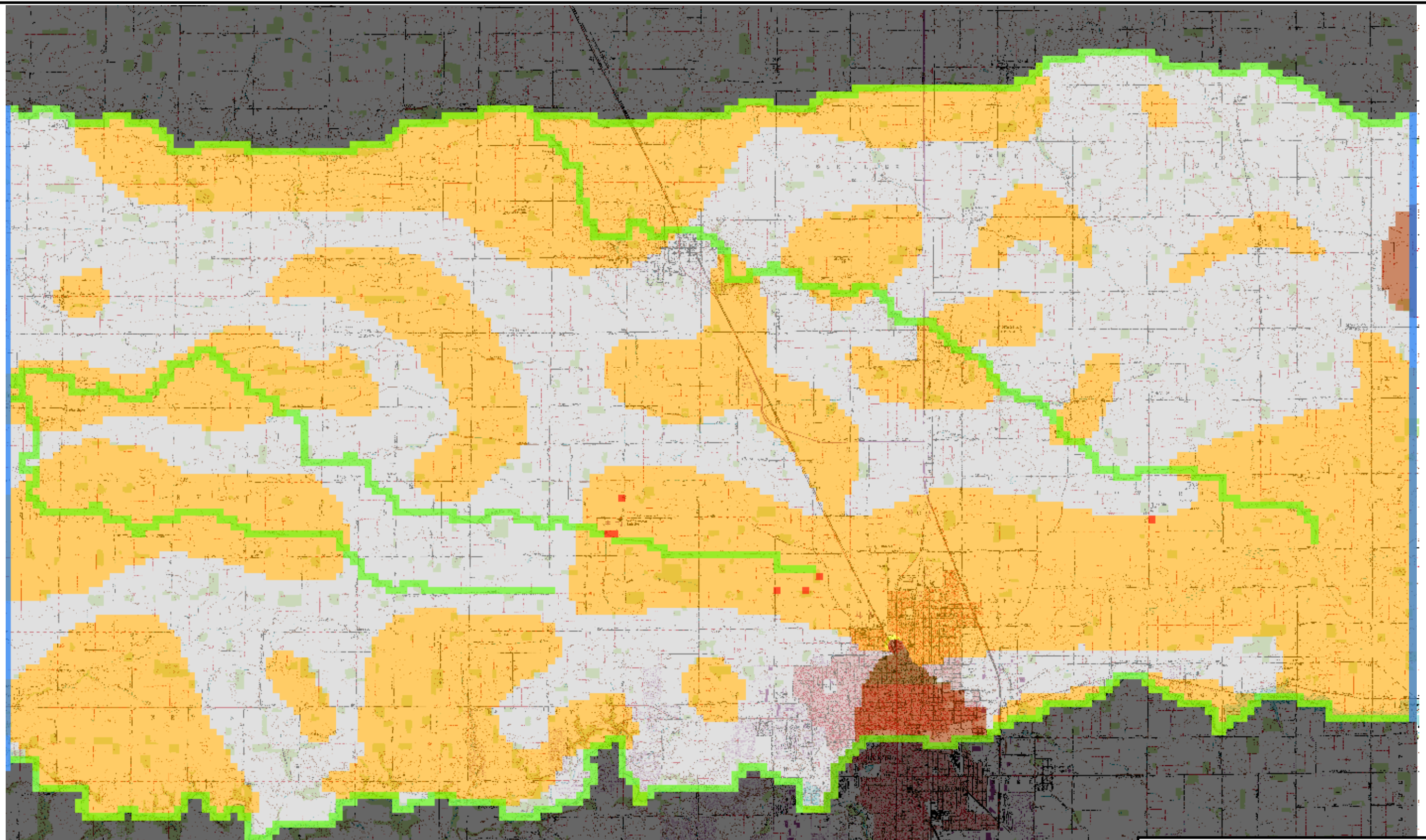


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FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
HYDRAULIC CONDUCTIVITY AND
MODEL BOUNDARY CONDITIONS
(MODEL LAYER 3)



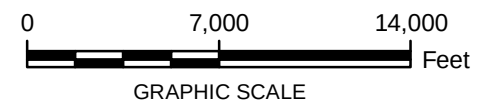
FIGURE
A-14

CITY: SYR DIV/GRP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\IT\GW\Monitoring\Report\mxd\HydroConductivity Model Layer 4.mxd - 4/18/2011 @ 11:46:35 AM



LEGEND:

- | | |
|--|--------------------|
| TILL (K=0.03 FT/DAY WITH AN ANISOTROPY OF 10:1) | CONSTANT HEAD CELL |
| SAND UNIT S2 (K=40 FT/DAY WITH AN ANISOTROPY OF 100:1) | DRAIN CELL |
| SAND UNIT S2 (K=80 FT/DAY WITH AN ANISOTROPY OF 8:1) | WELL CELL |
| SAND UNIT S2 (K=450 FT/DAY WITH AN ANISOTROPY OF 10:1) | NO FLOW CELL |
| SAND UNIT S2 (K=600 FT/DAY WITH AN ANISOTROPY OF 30:1) | |

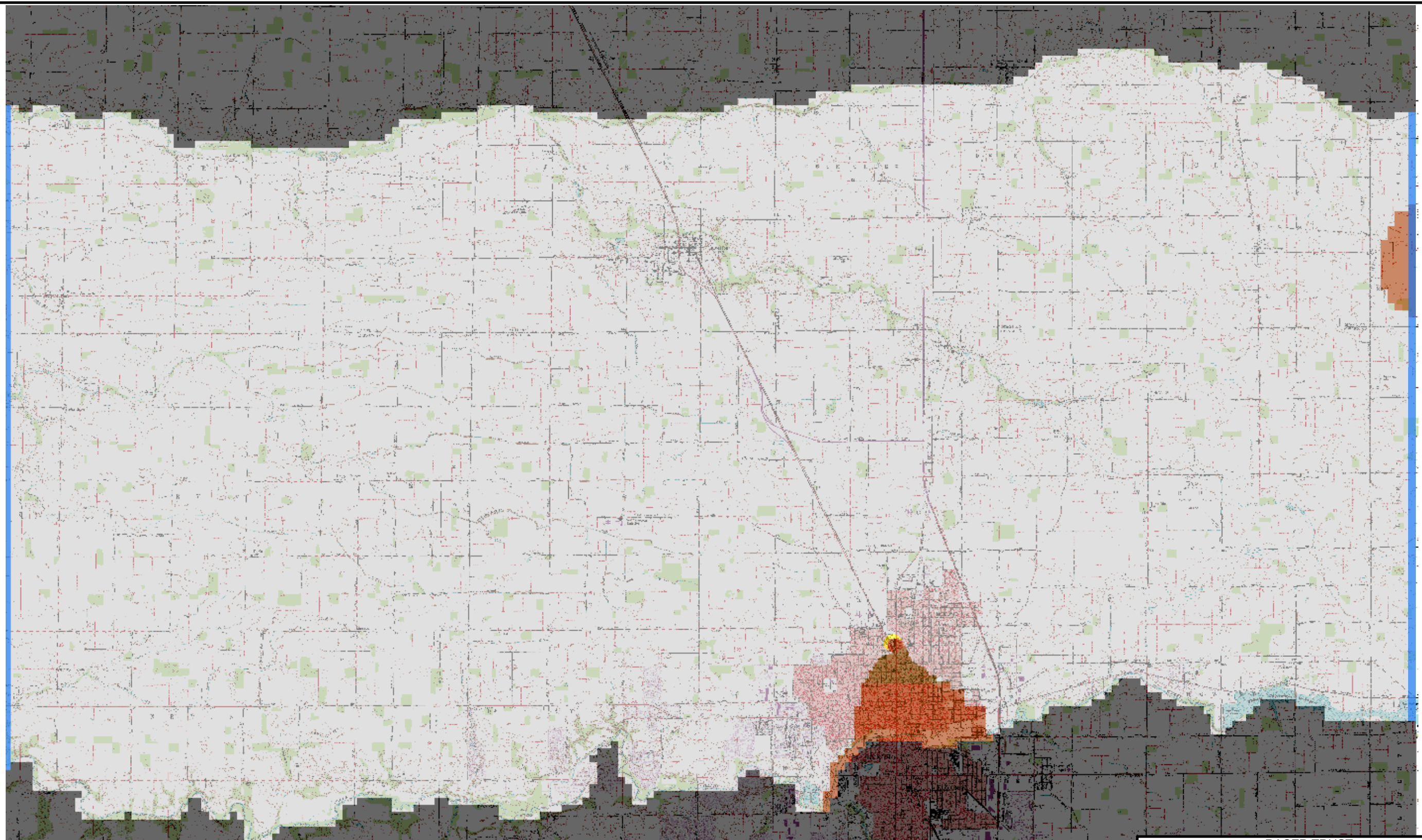


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FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
**HYDRAULIC CONDUCTIVITY AND
MODEL BOUNDARY CONDITIONS
(MODEL LAYER 4/SAND UNIT S2)**



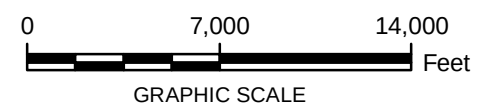
FIGURE
A-15

CITY: SYR DIV/GROUP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\IT\GWMonitoringReport\mxd\HydroConductivity ModelLayer5.mxd - 4/18/2011 @ 11:47:03 AM



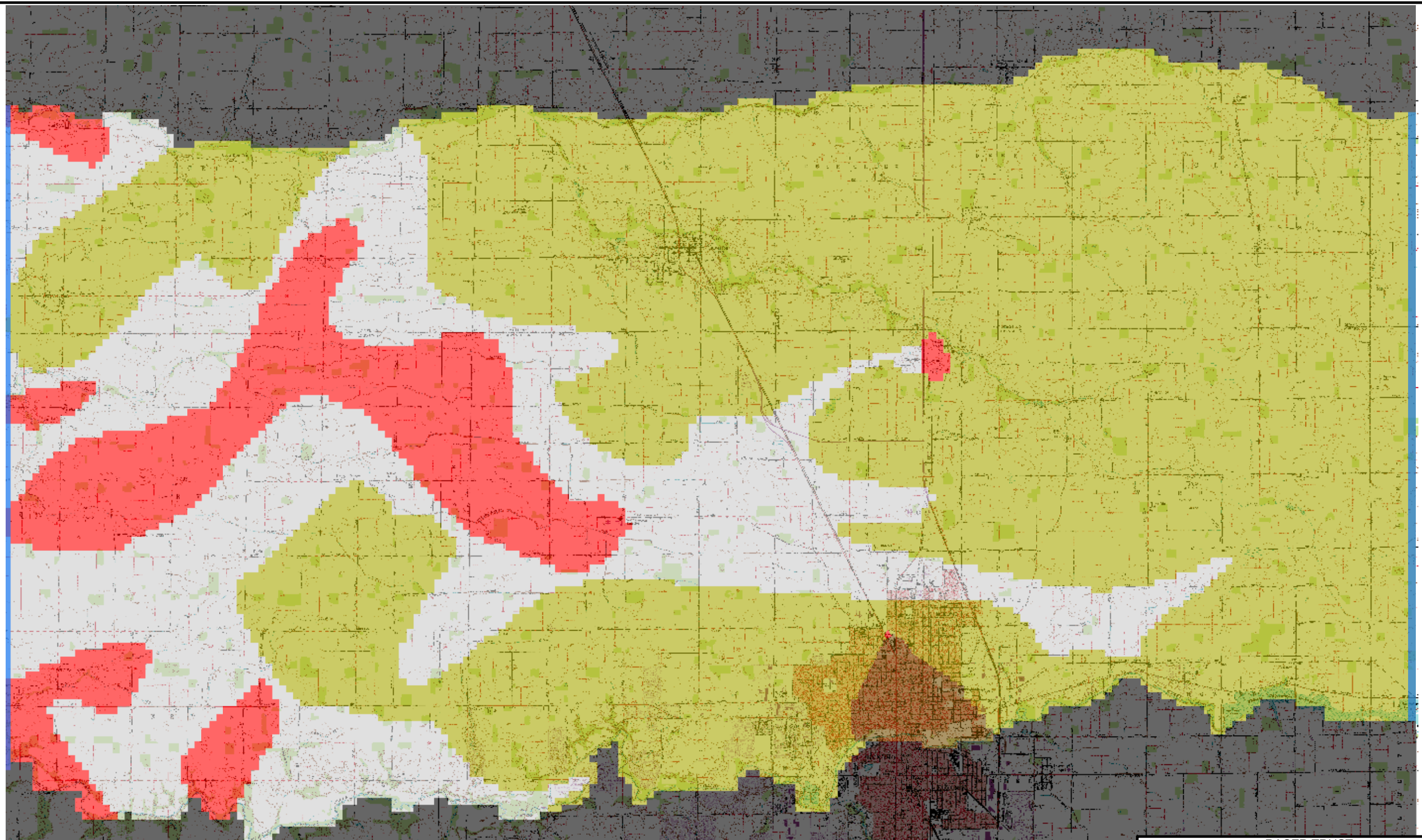
LEGEND:

- | | |
|---|--------------------|
| TILL (K=0.05 FT/DAY WITH AN ANISOTROPY OF 10:1) | CONSTANT HEAD CELL |
| SAND UNIT S2/S3 (K=40 FT/DAY WITH AN ANISOTROPY OF 100:1) | DRAIN CELL |
| SAND UNIT S2/S3 (K=80 FT/DAY WITH AN ANISOTROPY OF 8:1) | NO FLOW CELL |
| SAND UNIT S2/S3 (K=450 FT/DAY WITH AN ANISOTROPY OF 10:1) | |



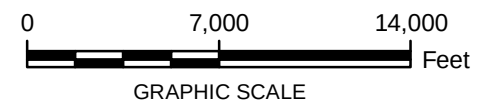
RACER TRUST FORMER DELCO PLANT 5 KOKOMO, INDIANA	
GROUNDWATER MONITORING REPORT	
HYDRAULIC CONDUCTIVITY AND MODEL BOUNDARY CONDITIONS (MODEL LAYER 5)	
	FIGURE A-16

CITY: SYR DIV/GROUP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\IT\GWMonitoringReport.mxd\HydroConductivity Model Layer6.mxd - 4/18/2011 @ 11:47:28 AM



LEGEND:

- | | |
|--|--|
|  TILL (K=0.01 FT/DAY WITH AN ANISOTROPY OF 10:1) |  CONSTANT HEAD CELL |
|  TILL (K=0.03 FT/DAY WITH AN ANISOTROPY OF 10:1) |  NO FLOW CELL |
|  BEDROCK B1 (K=40 FT/DAY WITH AN ANISOTROPY OF 10:1) | |
|  SAND UNIT S3 (K=200 FT/DAY WITH AN ANISOTROPY OF 10:1) | |

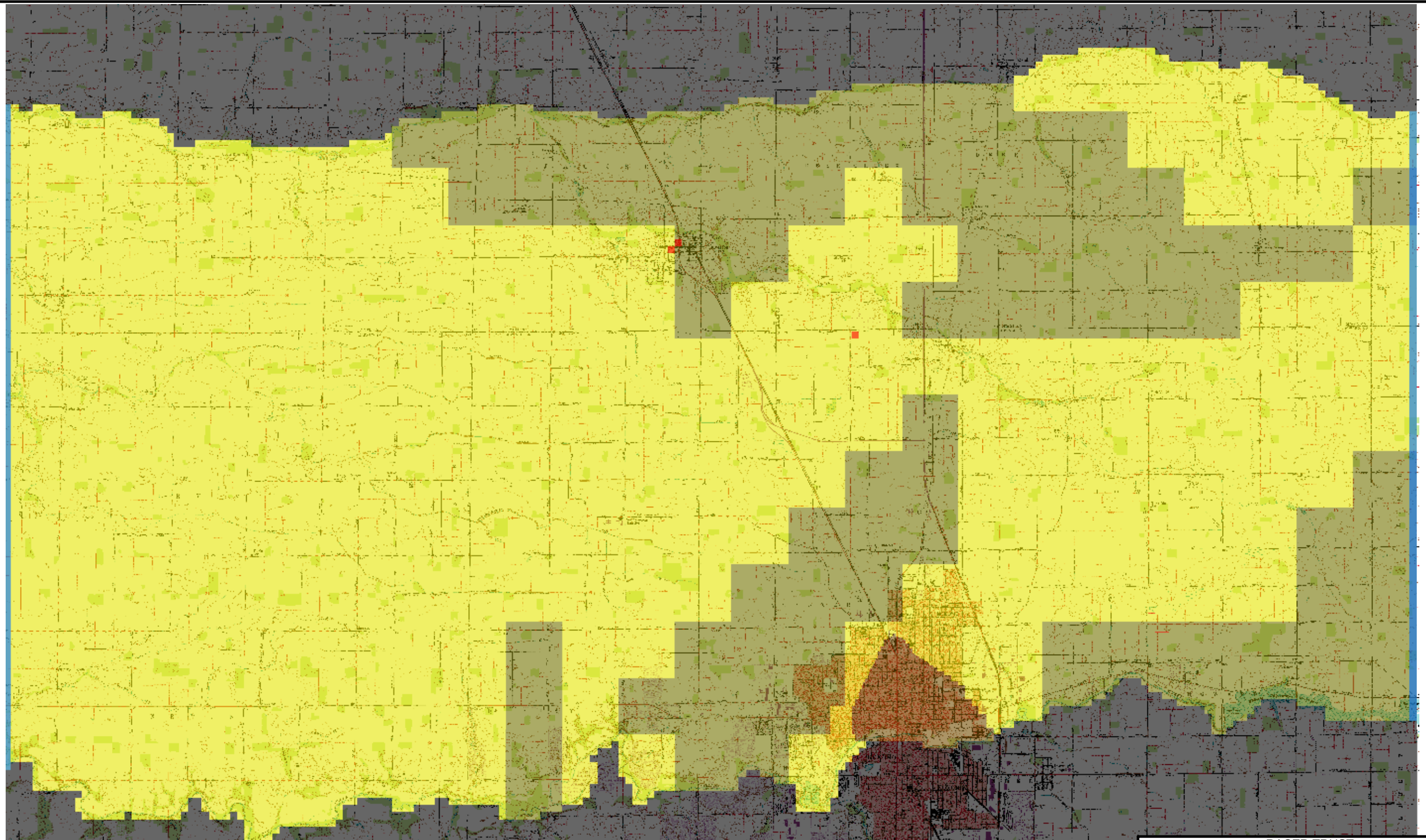


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FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
**HYDRAULIC CONDUCTIVITY AND MODEL
BOUNDARY CONDITIONS (MODEL LAYER 6/
SAND UNIT S3 AND/OR BEDROCK B1)**



FIGURE
A-17

CITY: SYR DIV/GRP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\IT\GWMonitoringReport\HydroConductivity Model\Layer7.mxd - 4/18/2011 @ 11:48:03 AM



LEGEND:

- | | |
|---|--------------------|
| TILL (K=0.01 FT/DAY WITH AN ANISOTROPY OF 10:1) | CONSTANT HEAD CELL |
| BEDROCK B1 (K=2 FT/DAY WITH AN ANISOTROPY OF 10:1) | WELL CELL |
| BEDROCK B1 (K=40 FT/DAY WITH AN ANISOTROPY OF 10:1) | NO FLOW CELL |

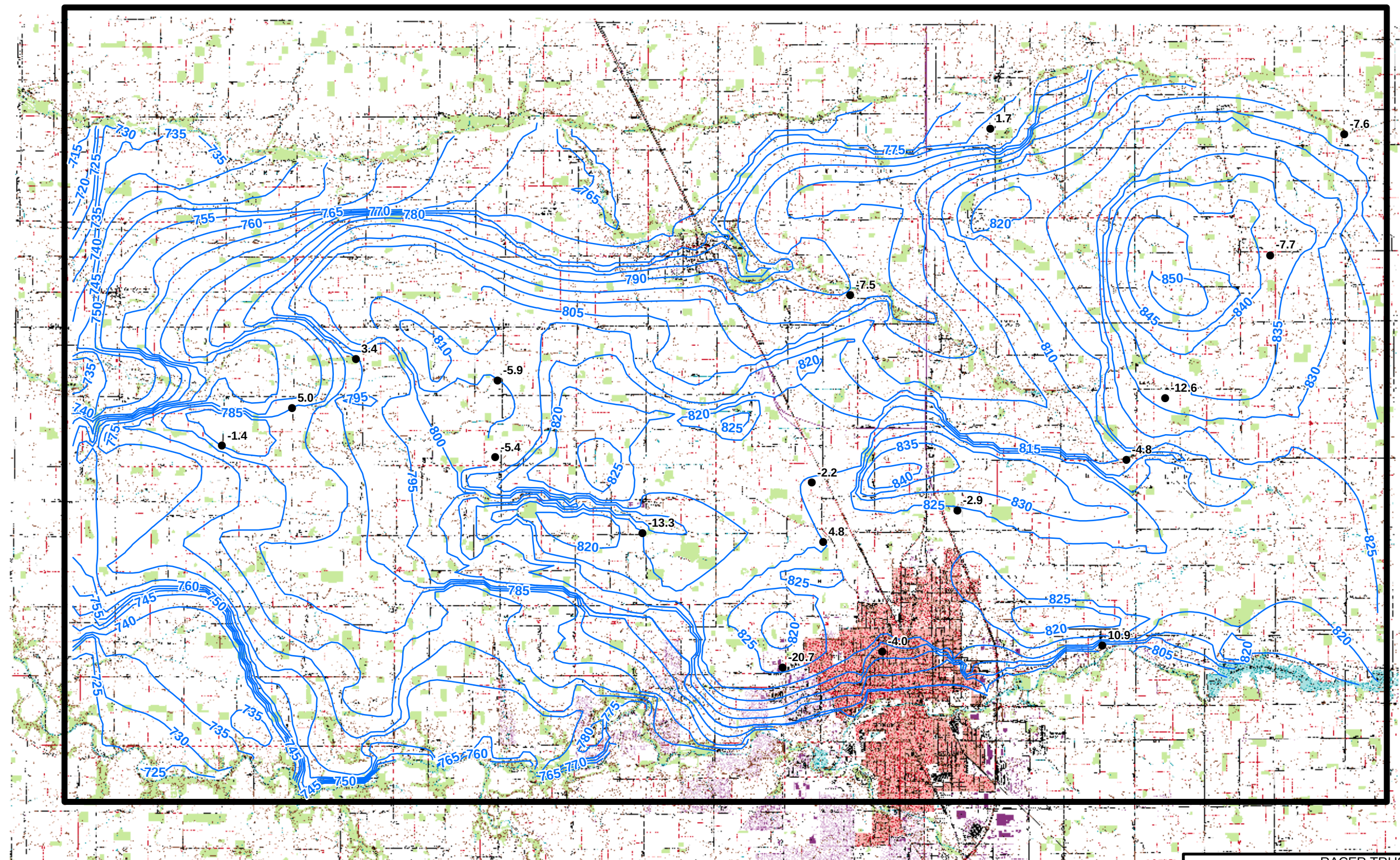
0 7,000 14,000
Feet
GRAPHIC SCALE

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FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
**HYDRAULIC CONDUCTIVITY AND
MODEL BOUNDARY CONDITIONS
(MODEL LAYER 7/8/BEDROCK B1)**



FIGURE
A-18

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Motor's Liquidation (N0000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\GIS\Monitoring\Report\mxd\CalibrationResidual L2.mxd - 4/18/2011 @ 11:48:49 AM



LEGEND:

- MODEL DOMAIN EXTENT
- MODEL SIMULATED GROUNDWATER CONTOUR LINE
- 2.2 MODEL POSITIVE VALUES INDICATE MODEL SIMULATED VALUES LOWER THAN THE OBSERVED TARGET VALUES
- -2.9 MODEL NEGATIVE VALUES INDICATE MODEL SIMULATED VALUES HIGHER THAN THE OBSERVED TARGET VALUES

0 8,000 16,000
Feet
GRAPHIC SCALE

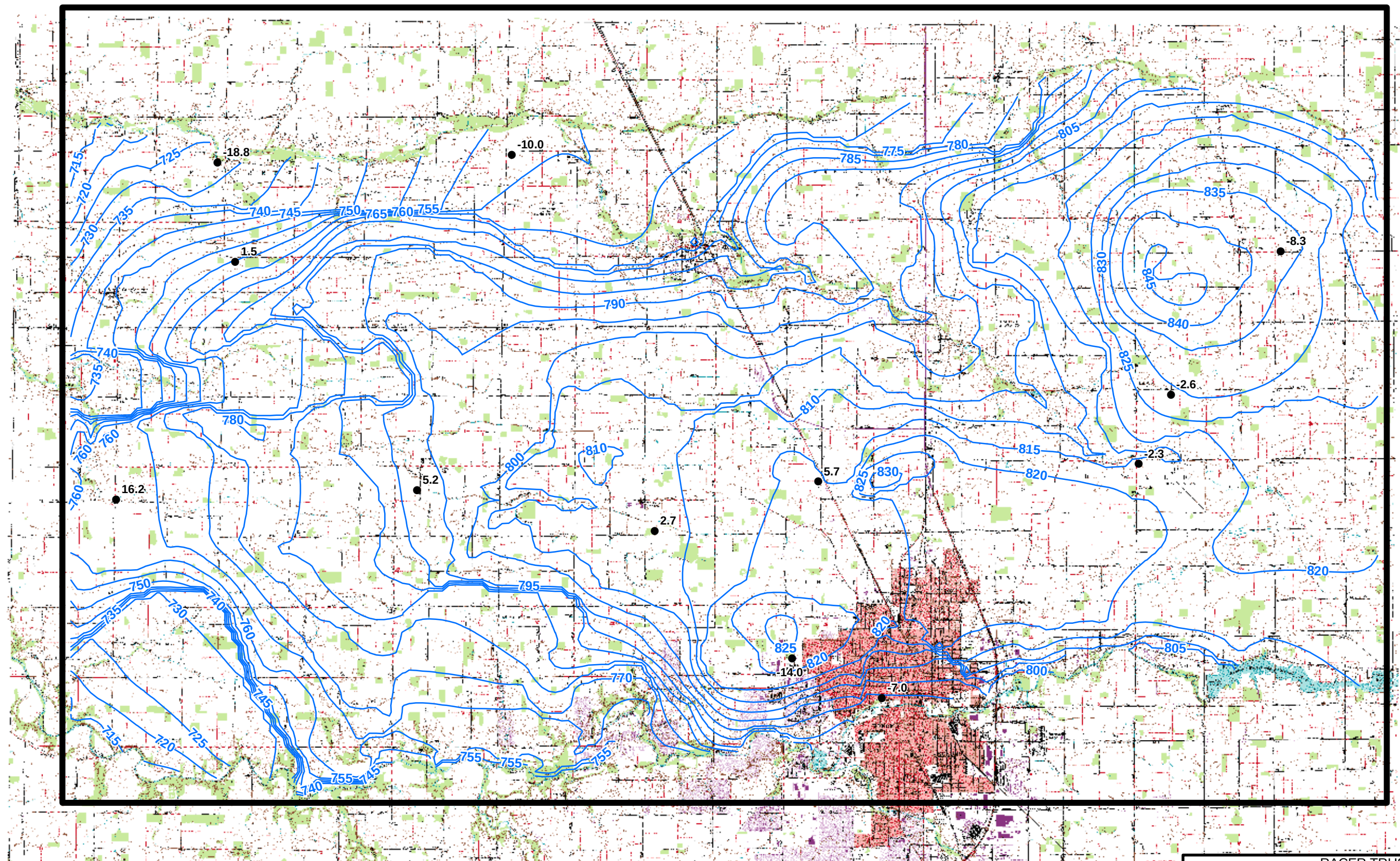
RACER TRUST
FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

STEADY-STATE CALIBRATION RESIDUALS
AND MODEL SIMULATED WATER
LEVELS IN UNIT S1 (MODEL LAYER 2)



FIGURE
A-19

CITY: SYR DIV/GRP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N0000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\GIS\Monitoring\Report\mxd\CalibrationResidual L4.mxd - 4/18/2011 @ 11:49:14 AM



- LEGEND:
- MODEL DOMAIN EXTENT
 - MODEL SIMULATED GROUNDWATER CONTOUR LINE
 - 2.2 MODEL POSITIVE VALUES INDICATE MODEL SIMULATED VALUES LOWER THAN THE OBSERVED TARGET VALUES
 - -2.9 MODEL NEGATIVE VALUES INDICATE MODEL SIMULATED VALUES HIGHER THAN THE OBSERVED TARGET VALUES

0 8,000 16,000
Feet
GRAPHIC SCALE

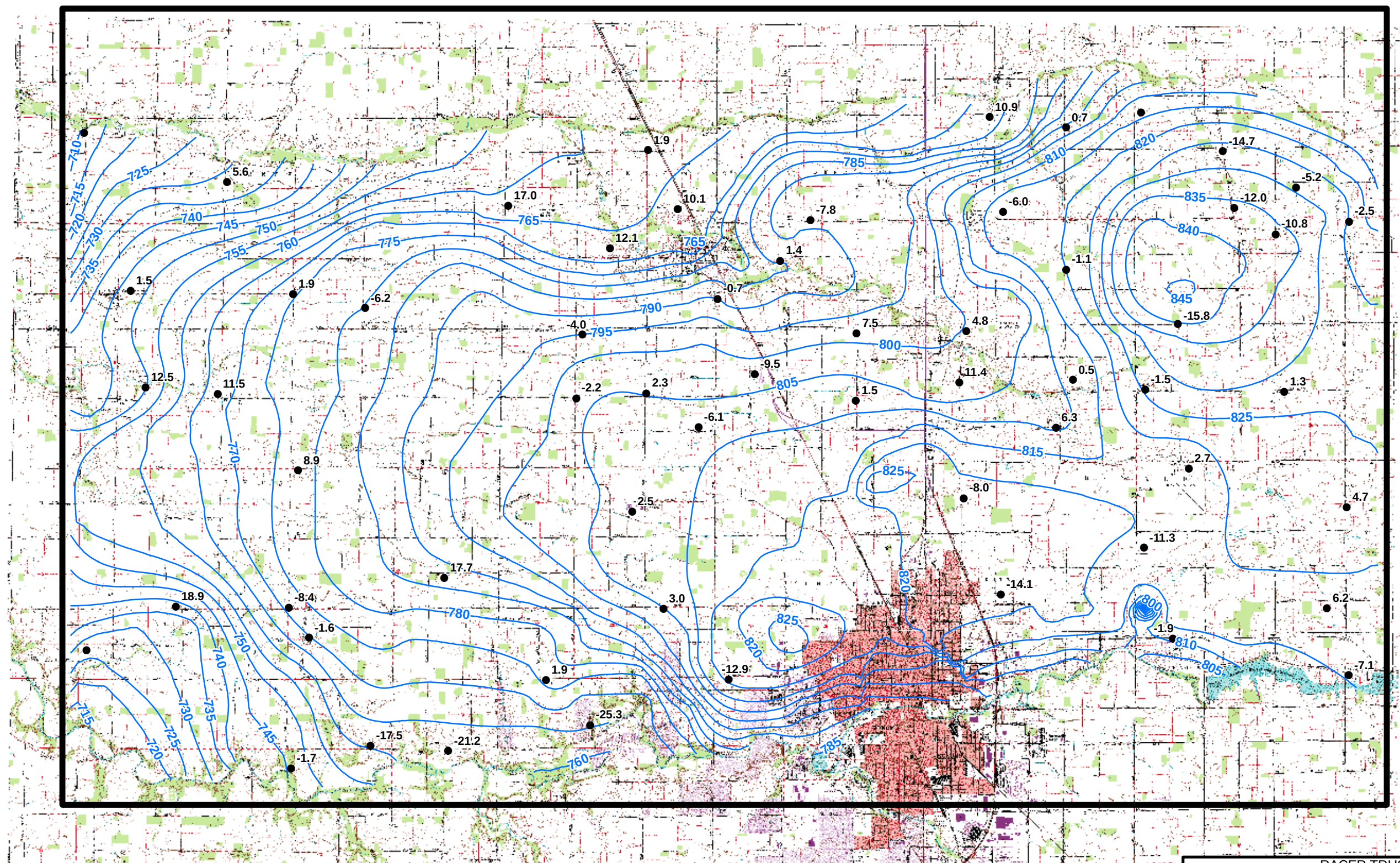
RACER TRUST
FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**STEADY-STATE CALIBRATION RESIDUALS
AND MODEL SIMULATED WATER
LEVELS IN UNIT S2 (MODEL LAYER 4)**

 **ARCADIS**

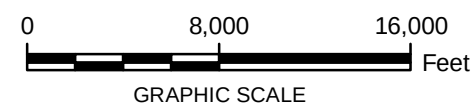
FIGURE
A-20

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Motor's Liquidation (N0000884.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\GIS\Monitoring\Report\mxd\CalibrationResidual L7.mxd - 4/18/2011 @ 11:49:30 AM



LEGEND:

- MODEL DOMAIN EXTENT
- MODEL SIMULATED GROUNDWATER CONTOUR LINE
- 2.2 MODEL POSITIVE VALUES INDICATE MODEL SIMULATED VALUES LOWER THAN THE OBSERVED TARGET VALUES
- -2.9 MODEL NEGATIVE VALUES INDICATE MODEL SIMULATED VALUES HIGHER THAN THE OBSERVED TARGET VALUES



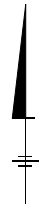
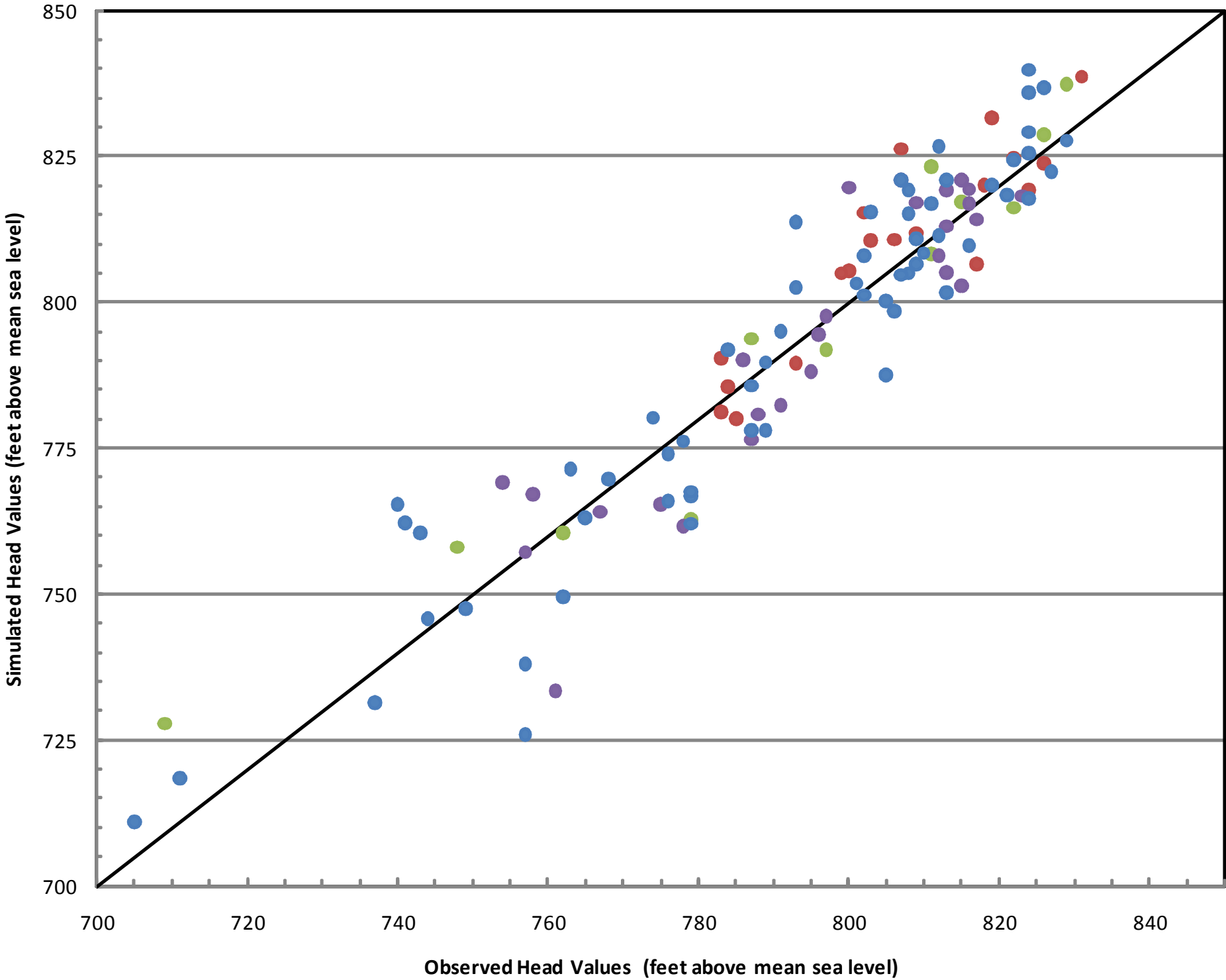
RACER TRUST
FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**STEADY-STATE CALIBRATION RESIDUALS
AND MODEL SIMULATED WATER
LEVELS IN UNIT B1 (MODEL LAYER 7)**

 **ARCADIS**

FIGURE
A-21

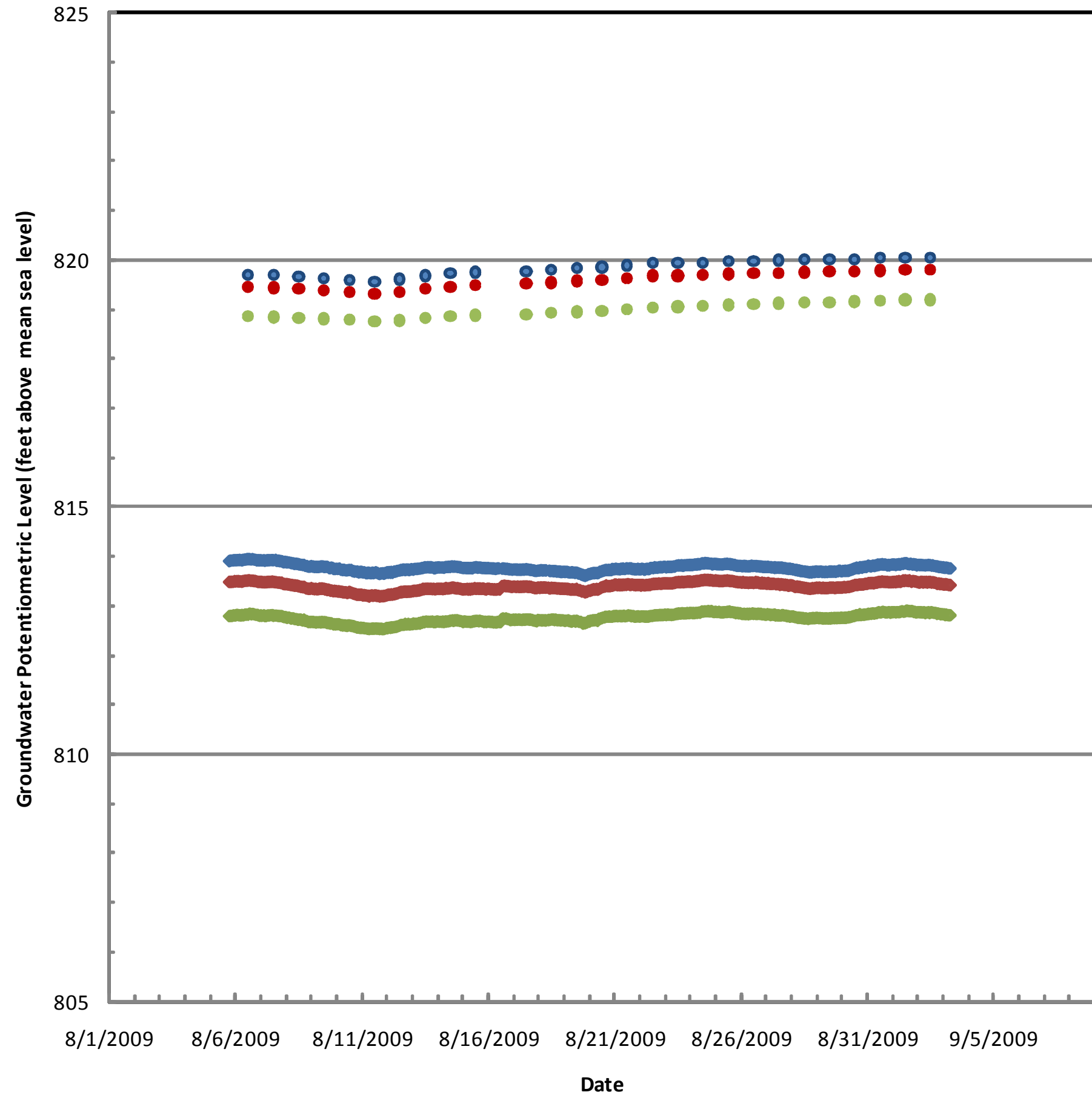
Steady State Calibration



CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR: Motors Liquidation (N000884.2010.00200) Q:\MotorLiquidationCompany\Kokomo\NIGW\MonitoringReport\mxd\A22_ScatterPlot.mxd - 4/18/2011 @ 11:50:03 AM

RACER TRUST FORMER DELCO PLANT 5 KOKOMO, INDIANA GROUNDWATER MONITORING REPORT	
STEADY-STATE CALIBRATION SCATTER PLOT	
	FIGURE A-22

CITY: SYR DIV/GRP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N000084.2010.0020)
Q:\Motor's Liquidation Company\Kokomo\NIGW\MonitoringReport\mxd\A23 TargetCalibrationS1.mxd - 4/18/2011 @ 11:50:20 AM



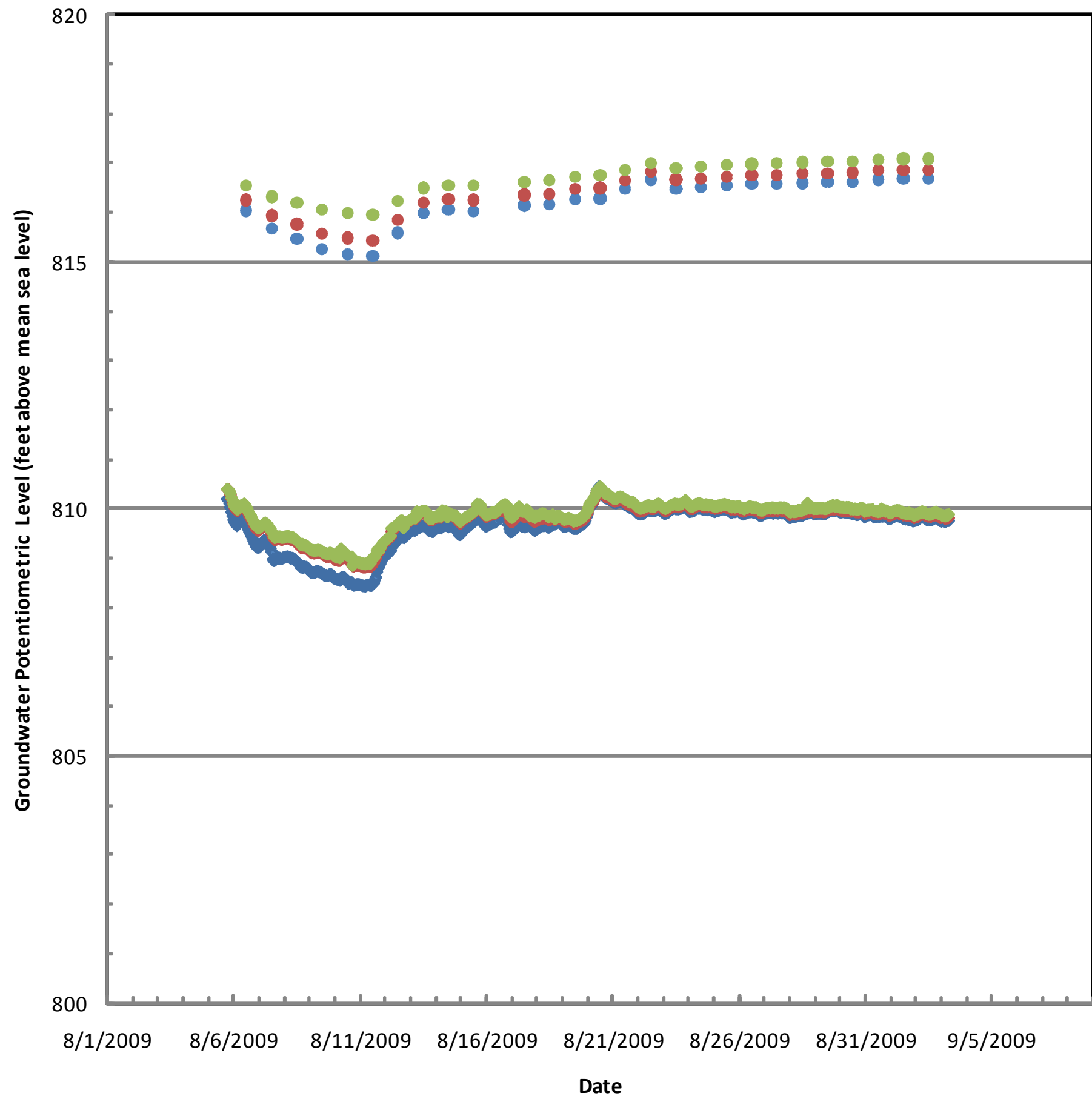
RACER TRUST
FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**TRANSIENT CALIBRATION
HYDROGRAPHS FOR WELL
CLUSTERS IN SAND UNIT S1**

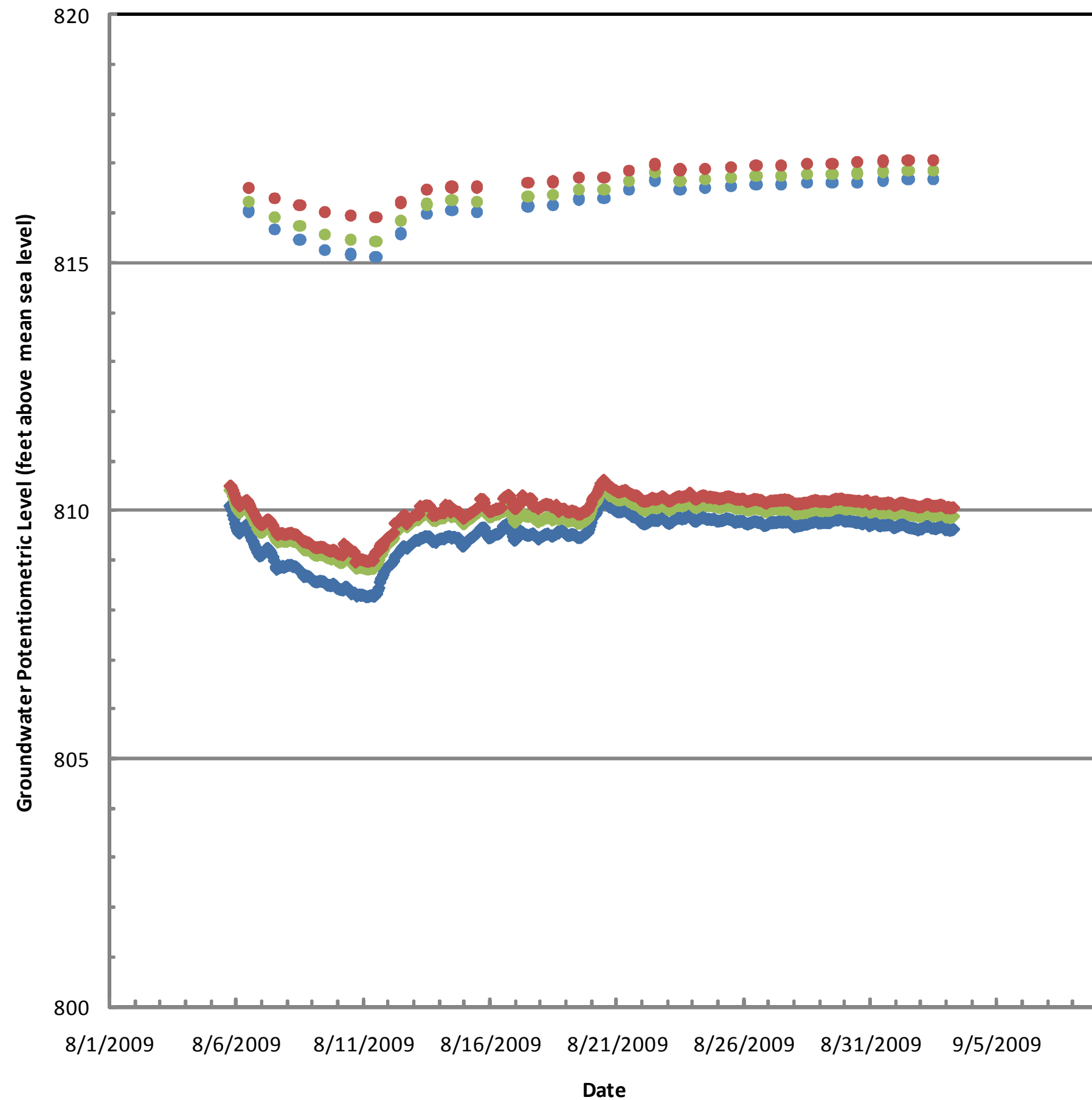


FIGURE
A-23

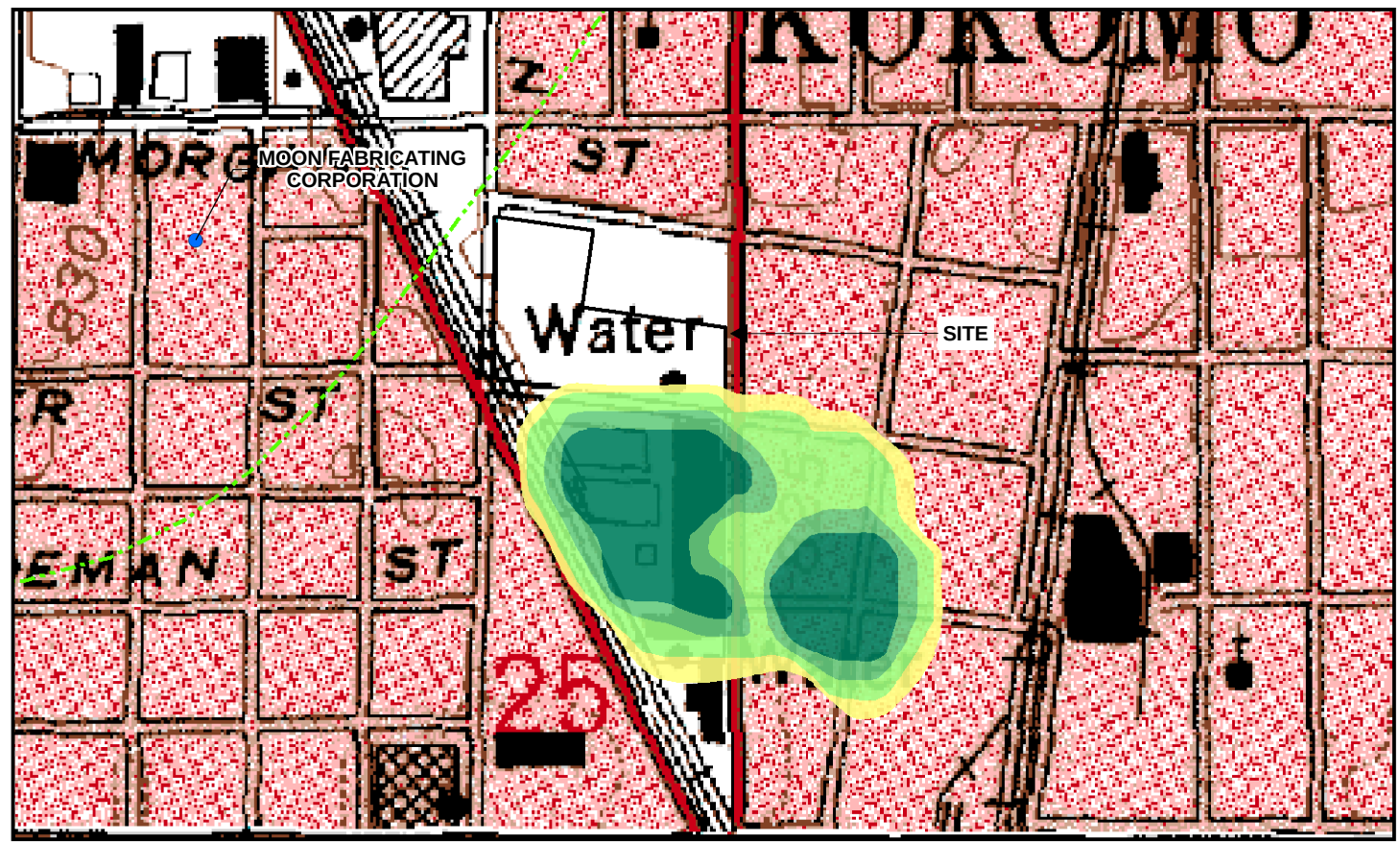
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Motor's Liquidation (N000084.2010.00200)
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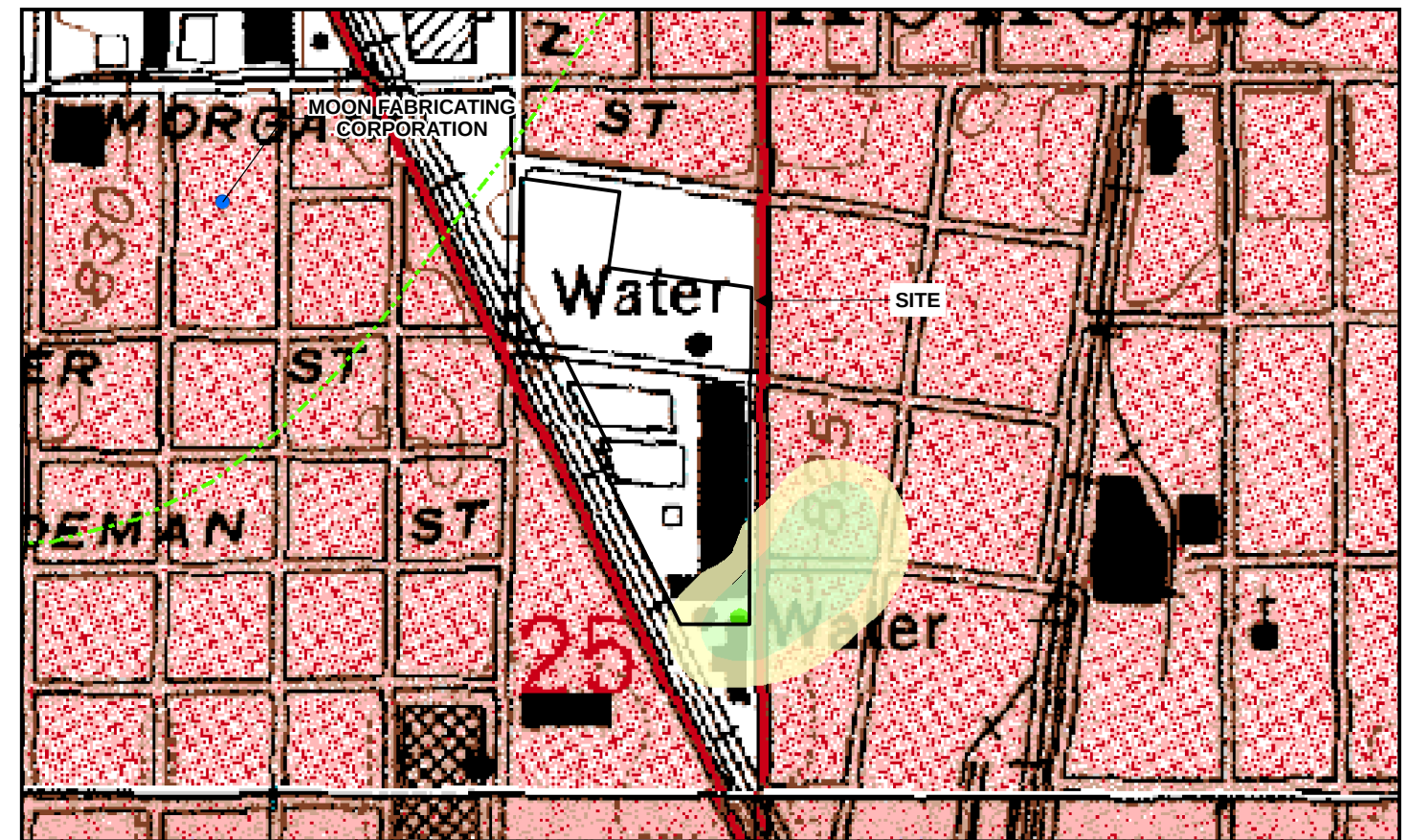
CITY: SYR DIV/GROUP: IT DB: KES ID: PIC: PM: TM: TR:
Motor's Liquidation (N000084.2010.00200)
Q:\Motor's Liquidation Company\Kokomo\NIGW\MonitoringReport\mxd\A25 Target Calibration\S3BR1.mxd - 4/18/2011 @ 11:50:53 AM



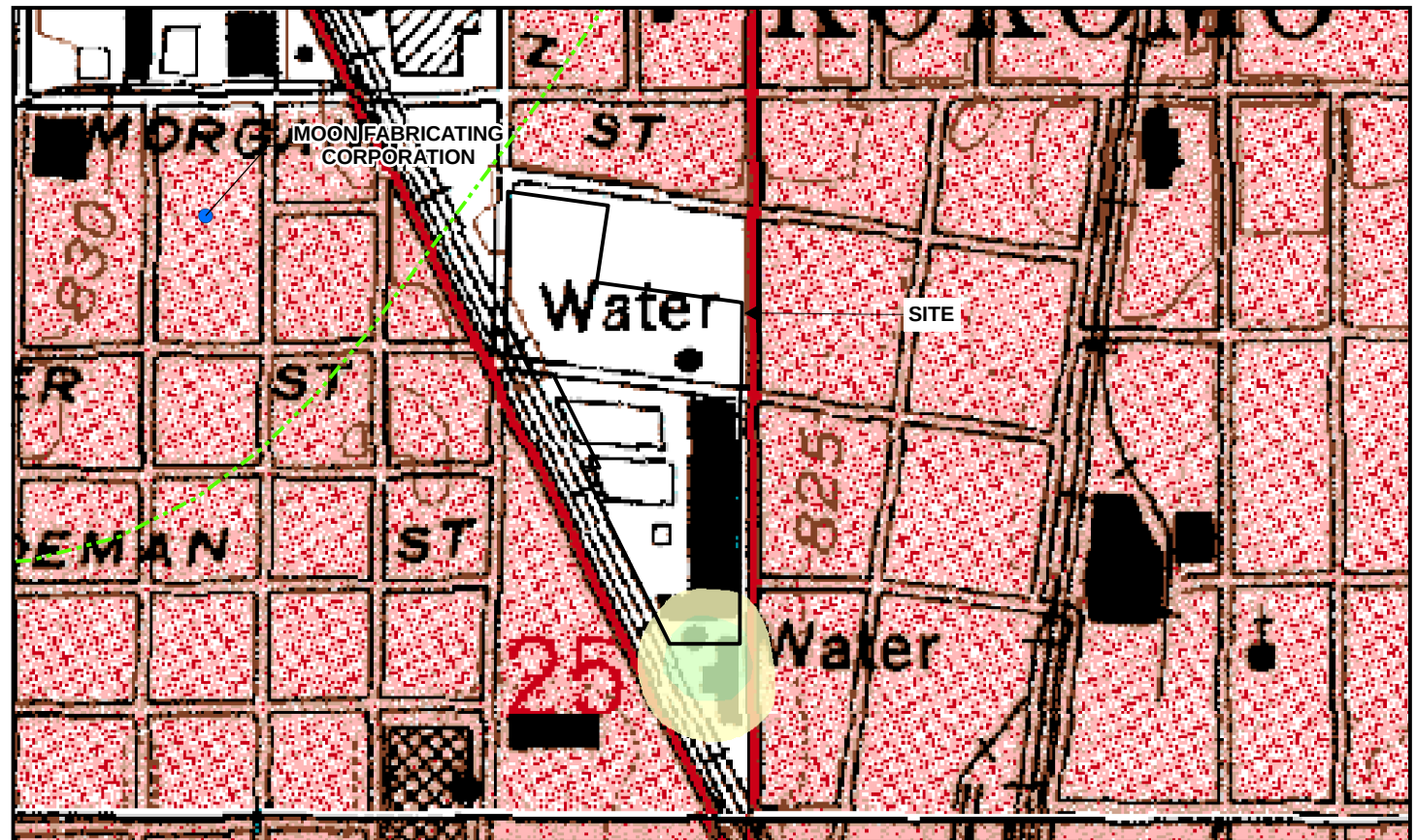
CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Motor's Liquidation (N0000884.2011.00006)
Q:\Motor's Liquidation Company\Kokomo\TCE\MonitoringReport\TCEPlume_ModelDomain.mxd - 4/13/2011 @ 10:38:02 AM



SAND UNIT S1



SAND UNIT S2



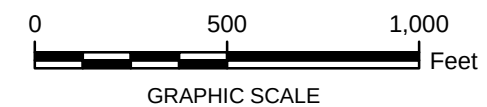
BEDROCK B1

LEGEND:

- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 5 - 100
- 100 - 500
- 500 - 1000
- > 1000
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE

NOTE:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.

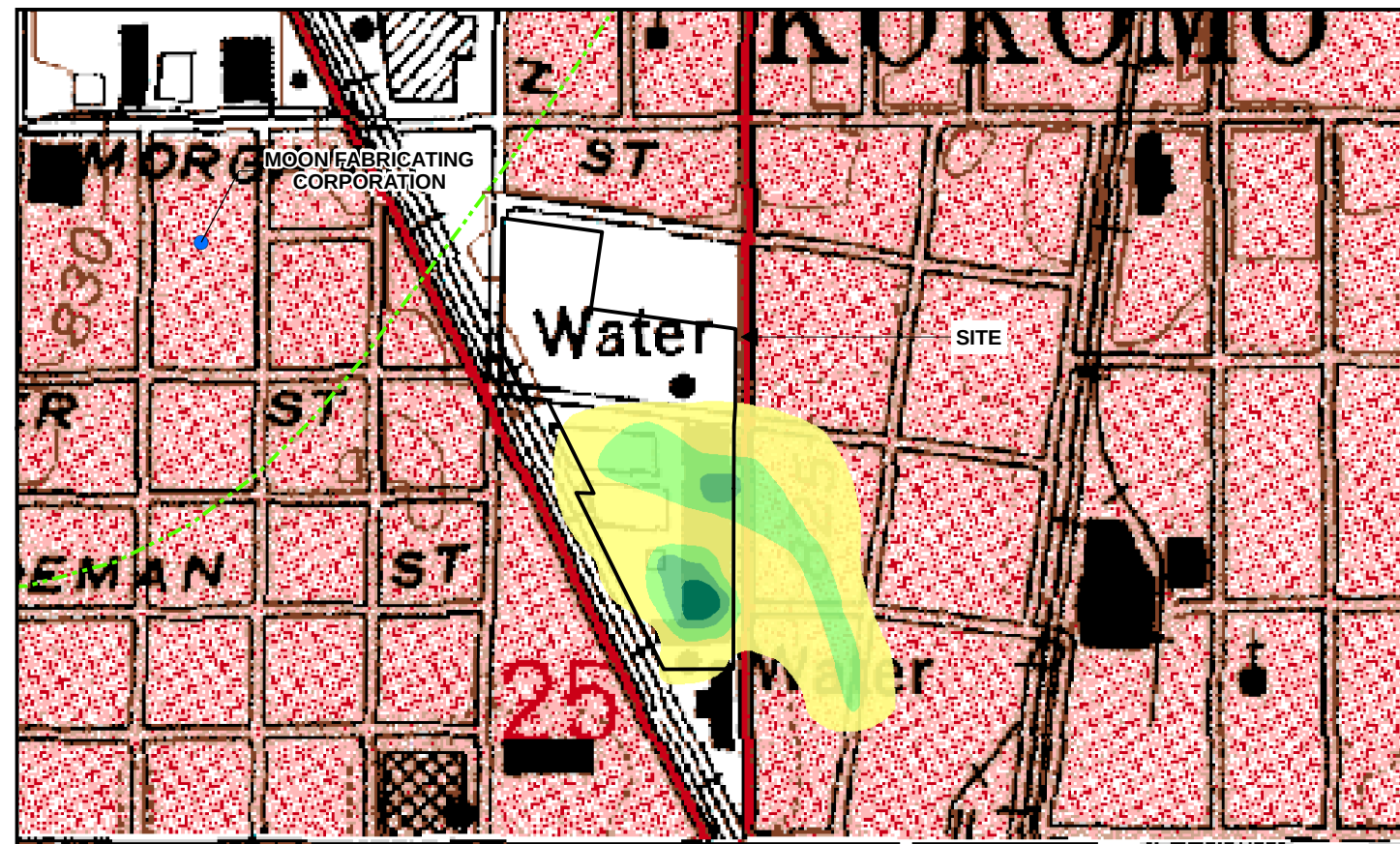


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FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
INITIAL TCE PLUME
IN THE MODEL DOMAIN
(PREDICTIVE SIMULATIONS)

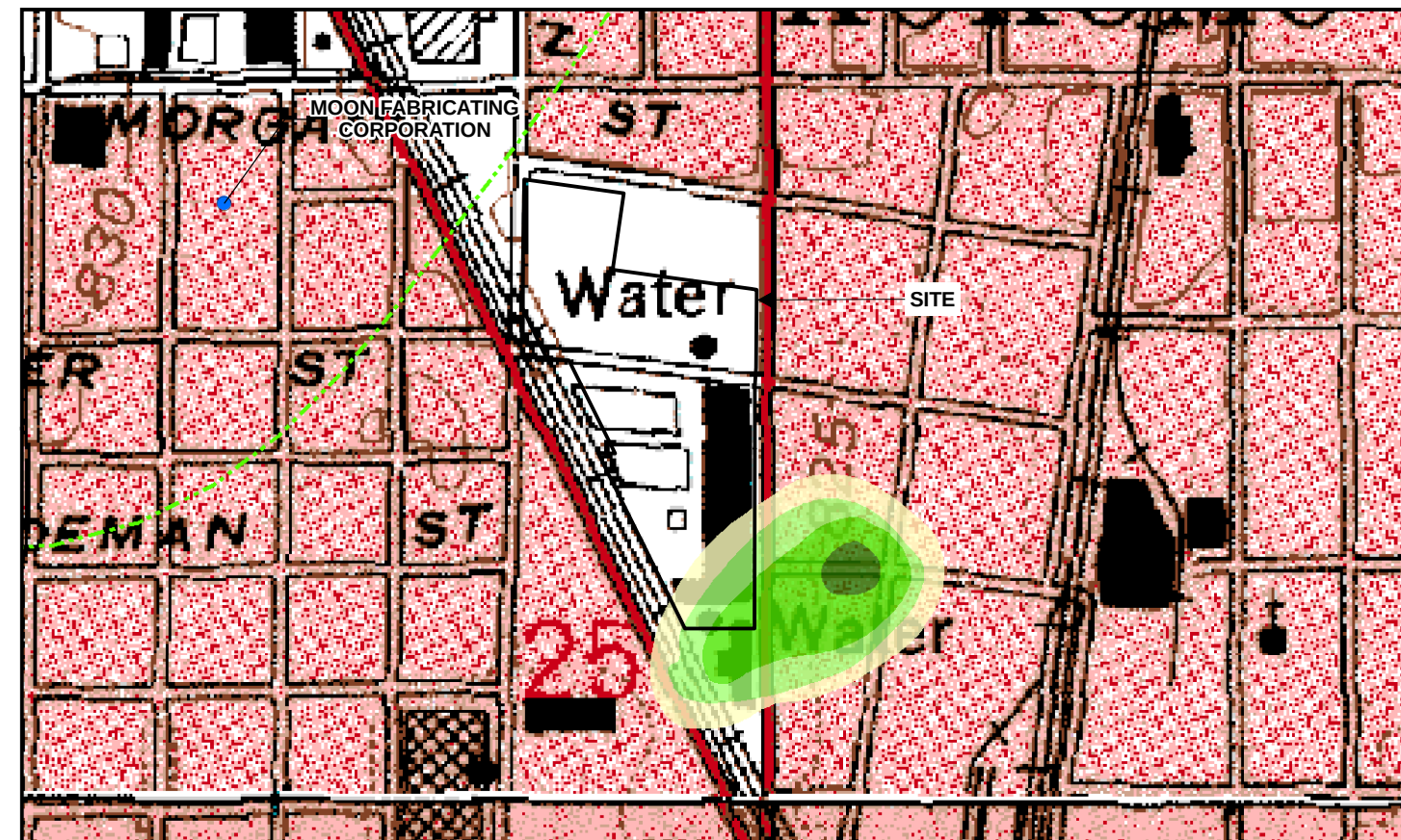


FIGURE
A-26A

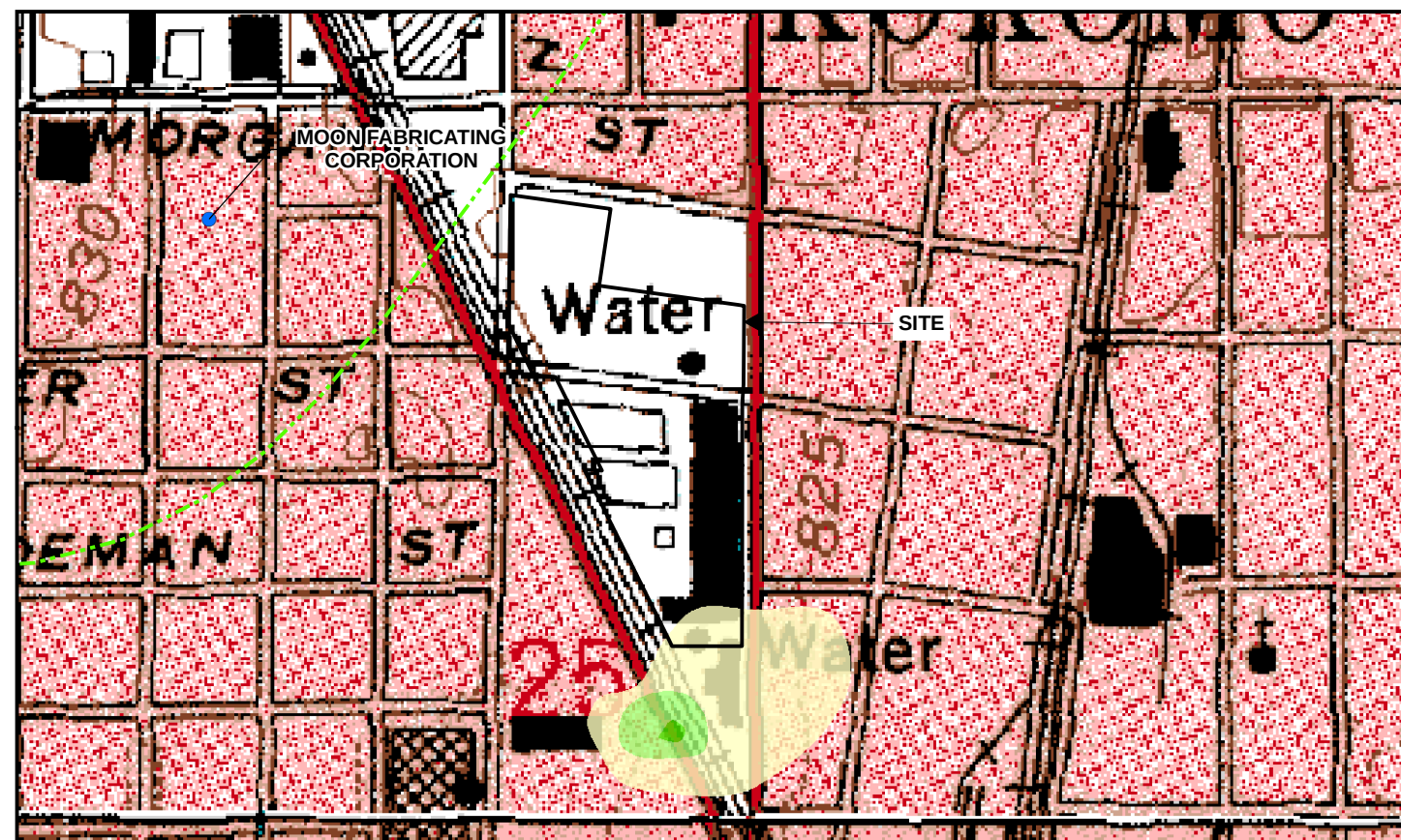
CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR:
Motors Liquidation (N000984 2011.00006)
Q:\MotorsLiquidationCompany\Kokomo\NGW\MonitoringReport\mxd\DCePlume ModelDomain.mxd - 4/13/2011 @ 10:37:30 AM



SAND UNIT S1



SAND UNIT S2



BEDROCK B1

LEGEND:

- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- 70 - 200 ug/L
- 200 - 500 ug/L
- 500 - 1000 ug/L
- > 100 ug/L

NOTE:

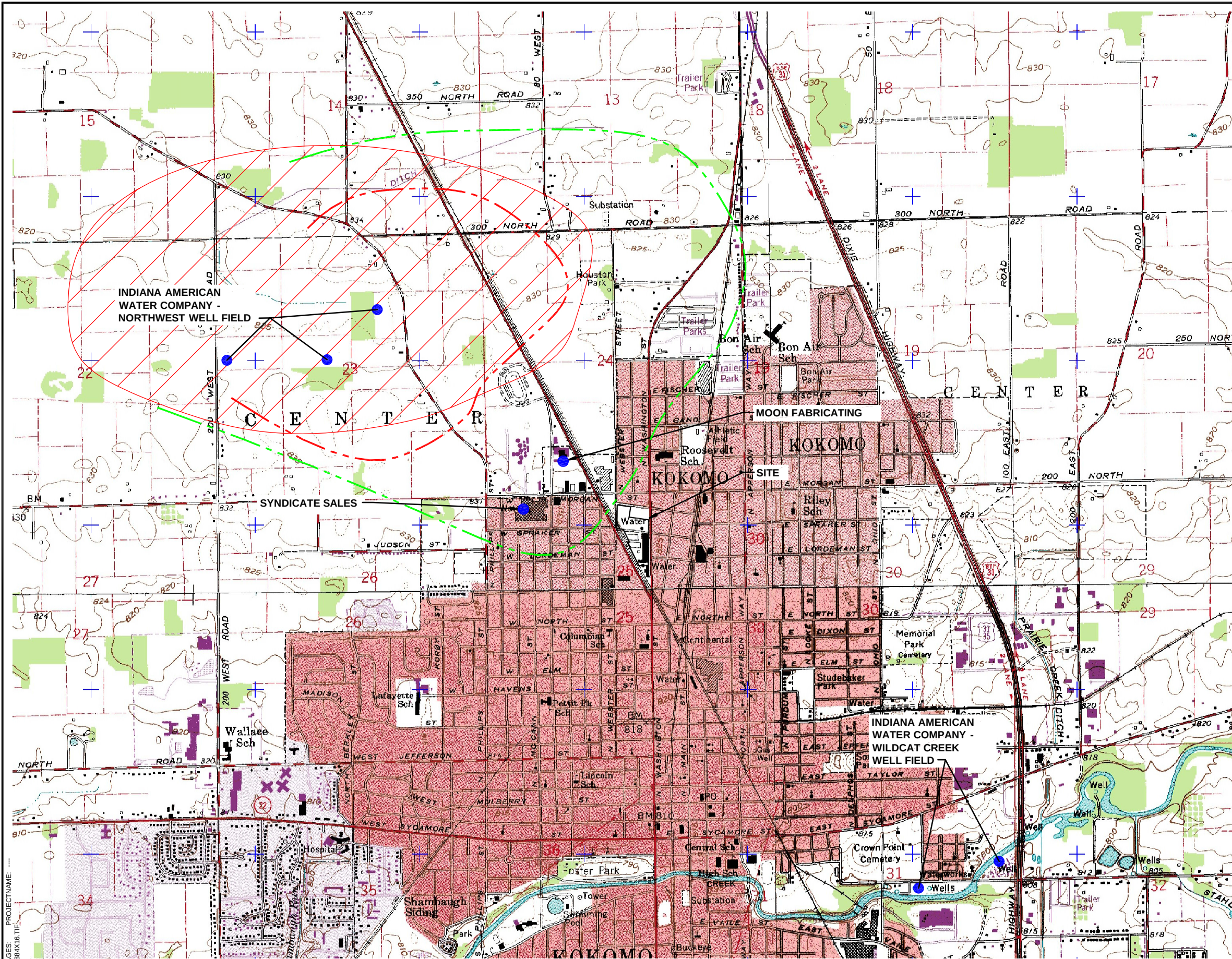
1. SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.



RACER TRUST
FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
INITIAL cis-1,2-DCE PLUME
IN THE MODEL DOMAIN
(PREDICTIVE SIMULATIONS)



FIGURE
A-26B

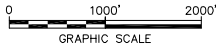


LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTE:

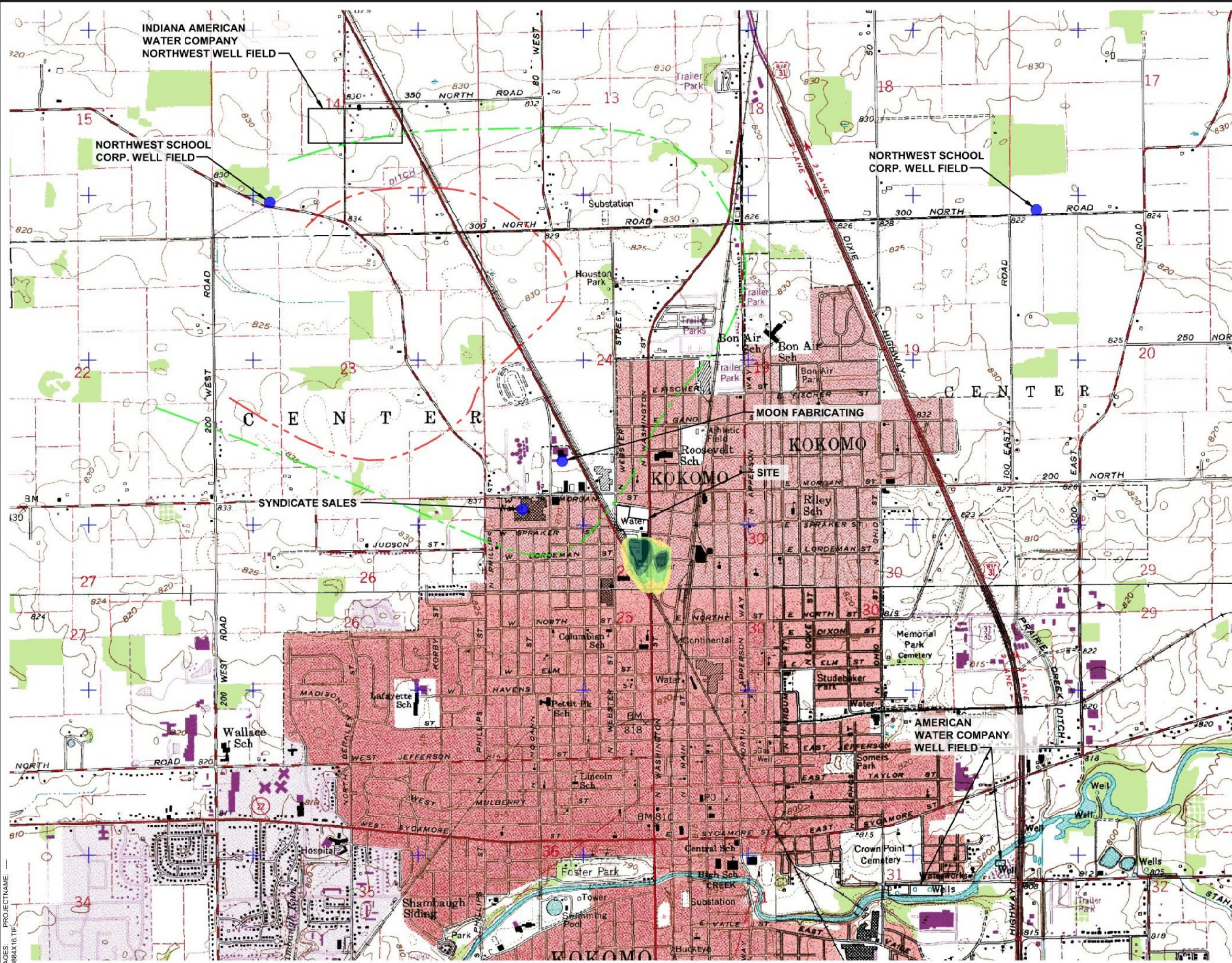
- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.



RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT
INDIANA AMERICAN WATER COMPANY
- NORTHWEST WELL FIELD WELLHEAD
PROTECTION AREAS



CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000884\2010\00200\DWG\RCRA-FR\00884110.dwg LAYOUT: A-28
XREFS: 00884X.D 00884X16.TIF
PROJECTNAME: 00884X16.TIF
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: PLT: 00884110.dwg PLOTTED: 4/14/2011 9:21 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 5-100 ug/L
- 100-500 ug/L
- 500-1000 ug/L
- >1000 ug/L

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

0 1000' 2000'
GRAPHIC SCALE

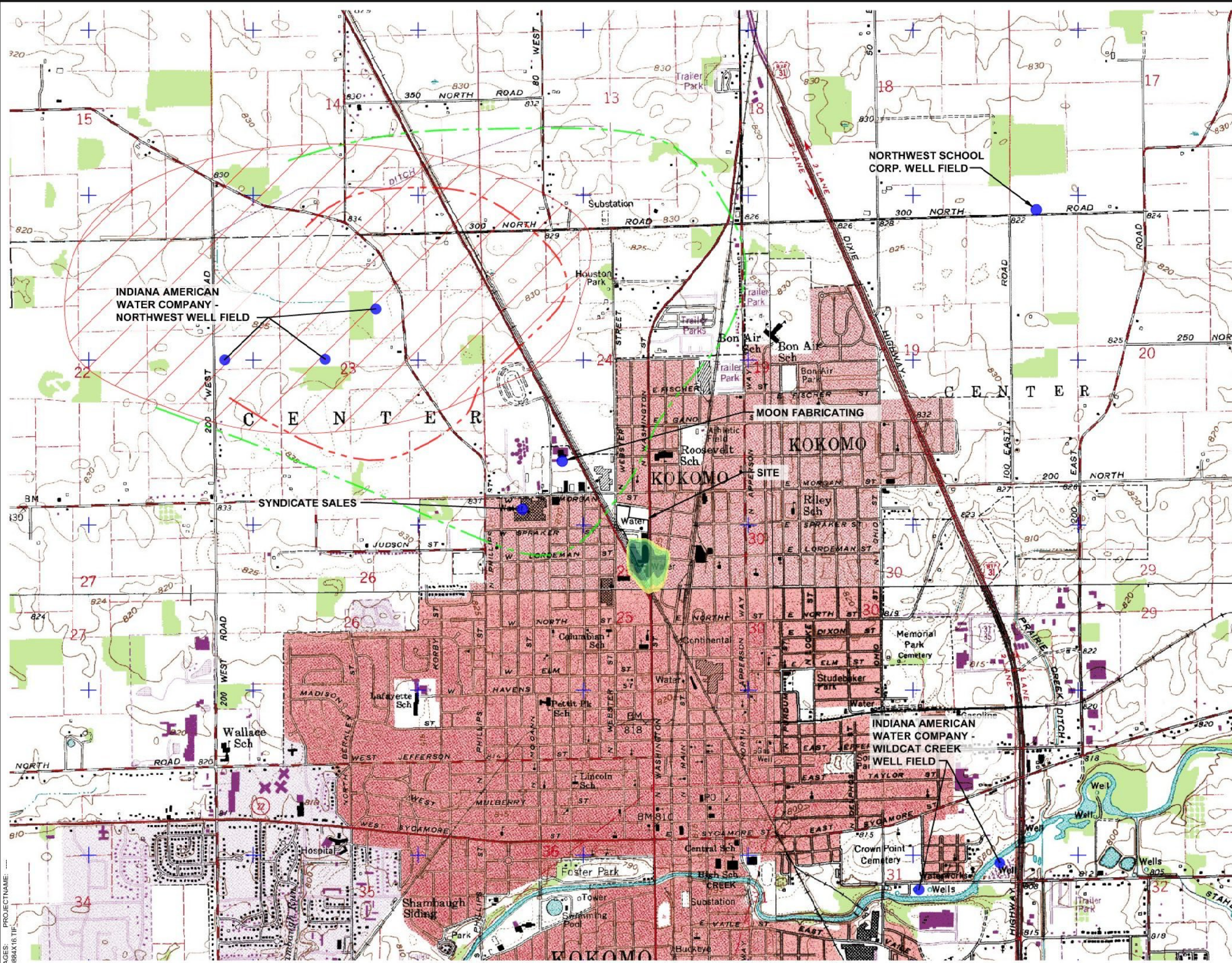
RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**PREDICTED TCE DISTRIBUTION IN
SAND UNIT S1 - SCENARIO 1**

ARCADIS

FIGURE
A-28

CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000000\DWG\RCRA-FR\008411.dwg LAYOUT: A-29
SAVED: 4/13/2011 9:32 AM ACADVER: 18.05 (LMS TECH) PAGES: 18
PLOT: 4/14/2011 9:22 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

0 1000' 2000'
GRAPHIC SCALE

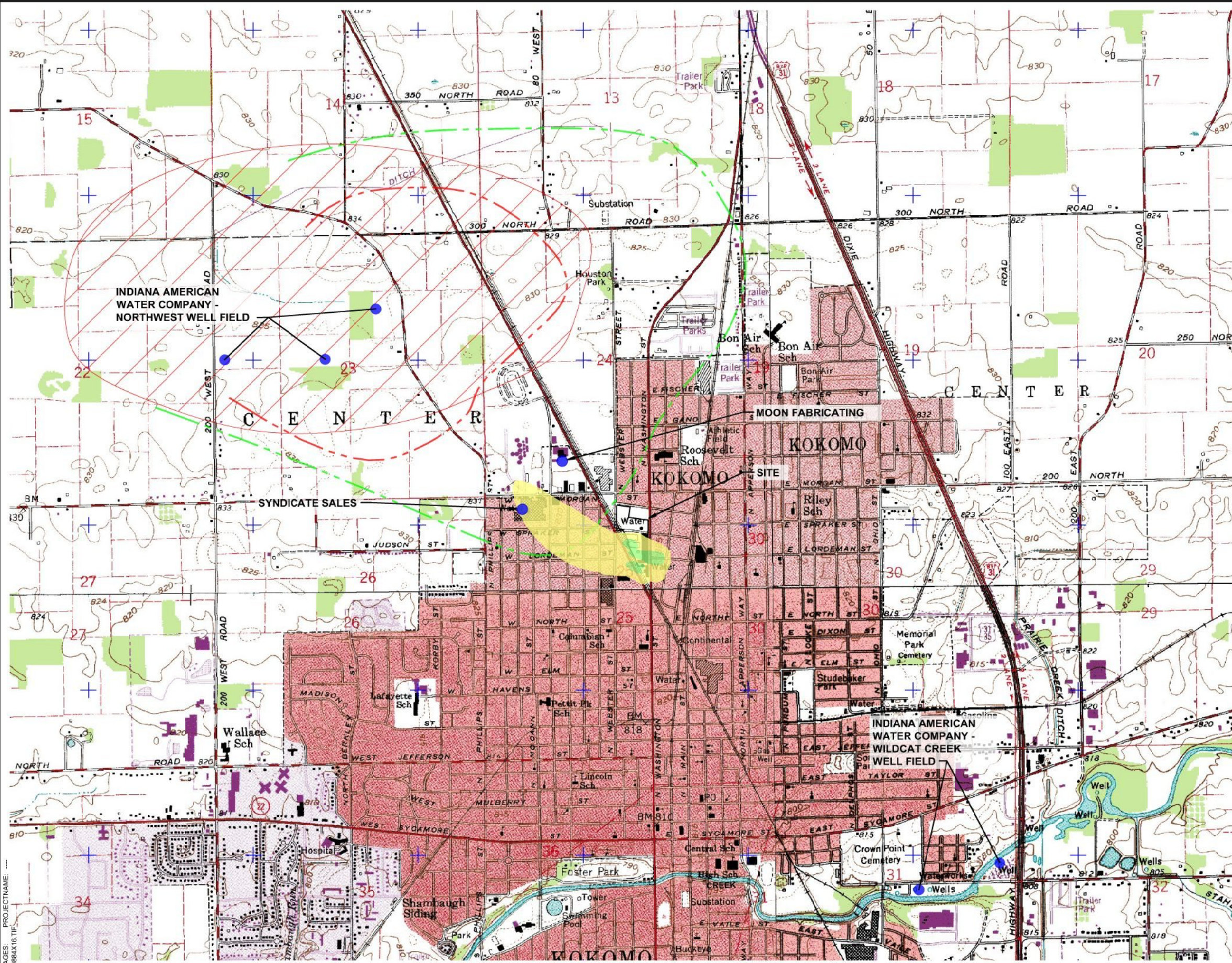
RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S1 - SCENARIO 1**

ARCADIS

FIGURE
A-29

CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000000\DWG\RCRA-FIR\0084112.dwg LAYOUT: A-30
XREFS: 0084XLD 0084X16 0084X15 0084X14 0084X13 0084X12 0084X11 0084X10 0084X09 0084X08 0084X07 0084X06 0084X05 0084X04 0084X03 0084X02 0084X01 0084X00
PROJECTNAME: 0084X16
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: PLT: 0084X16
BY: STOWELL, GARY 4/14/2011 9:24 AM



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 5-100 ug/L
- 100-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

0 1000' 2000'
GRAPHIC SCALE

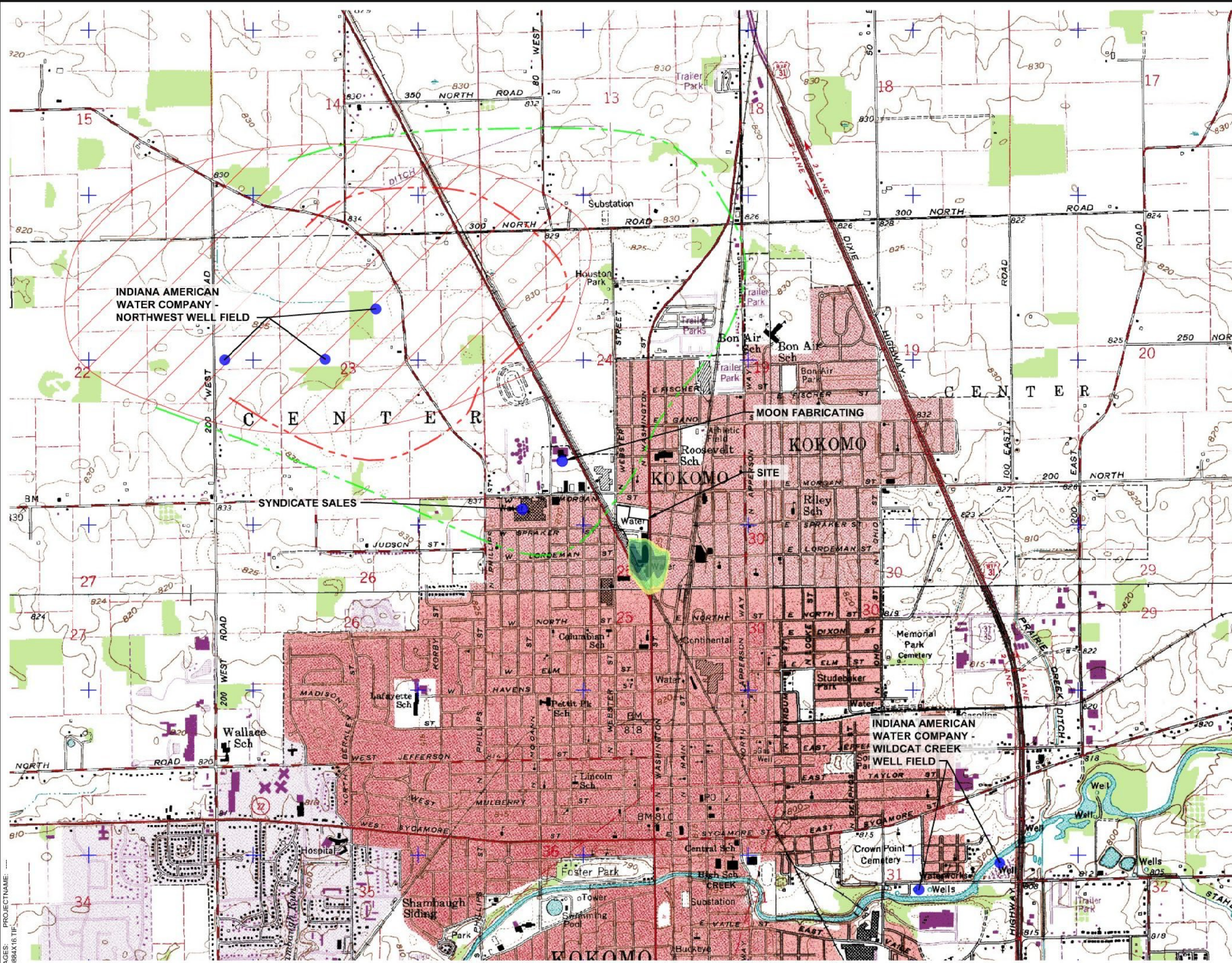
RACER TRUST
FORMER GM DELCO PLANT 5
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GROUNDWATER MONITORING REPORT

**PREDICTED TCE DISTRIBUTION IN
SAND UNIT S2 - SCENARIO 1**

ARCADIS

FIGURE
A-30

CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LYN: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\00000000\DWG\RCRA-FR\0084113.dwg LAYOUT: A-34
XREFS: 0084XLD 0084X16TIF
PROJECTNAME: 0084X16TIF
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: 4/14/2011 9:26 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

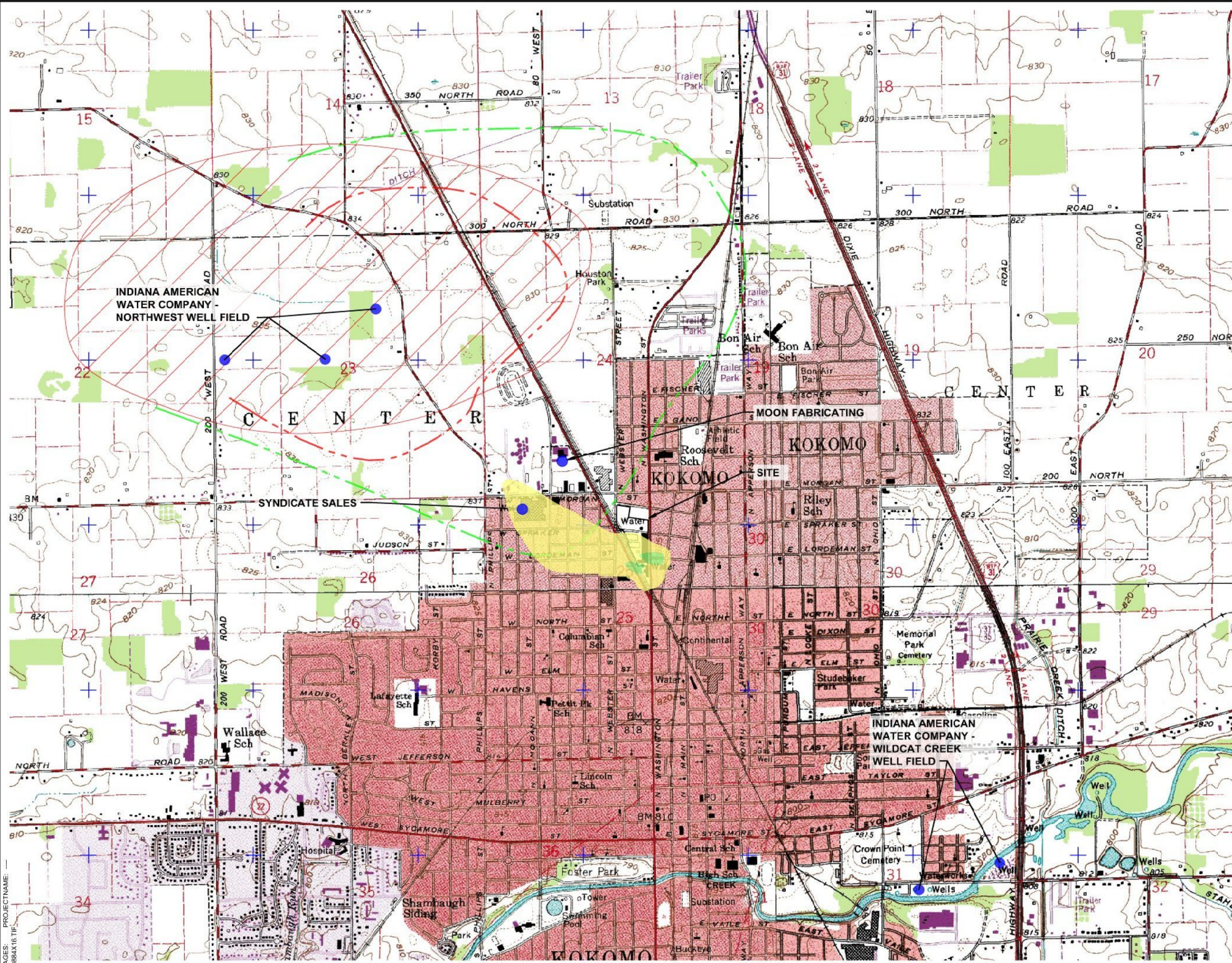


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PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S1 - SCENARIO 2



CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000000\DWG\RCRA-FR\0084116.dwg LAYOUT: A-35
XREFS: 0084XLD 0084X16.TIF
PROJECTNAME: 0084X16.TIF
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: PLT: 4/14/2011 9:40 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 5-100 ug/L
- 100-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

0 1000' 2000'
GRAPHIC SCALE

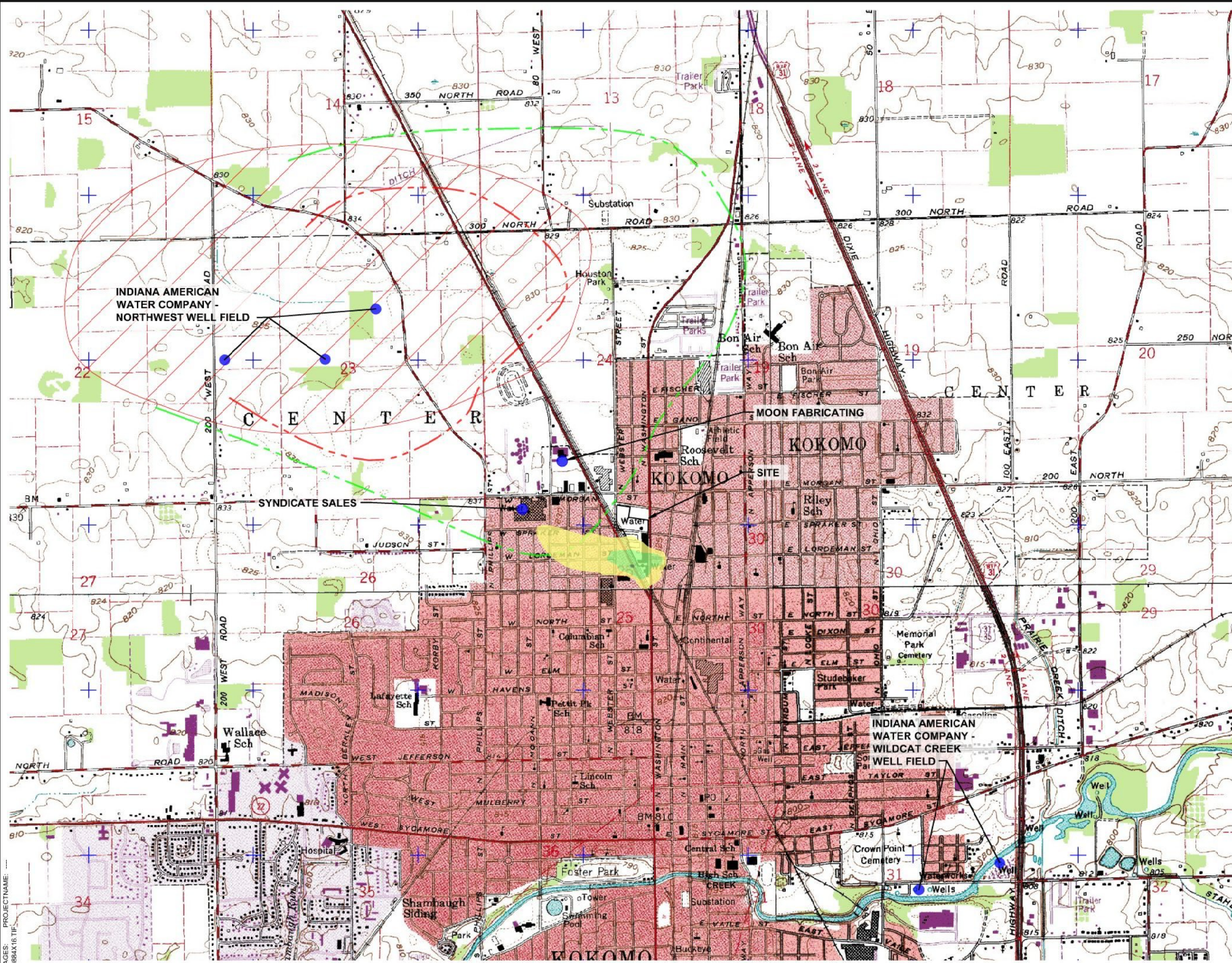
RACER TRUST
FORMER GM DELCO PLANT 5
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**PREDICTED TCE DISTRIBUTION IN
SAND UNIT S2 - SCENARIO 2**

ARCADIS

FIGURE
A-35

CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000000\DWG\RCRA-FR\0084115.dwg LAYOUT: A-36
SAVED: 4/13/2011 8:43 AM ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: PLT: 4/14/2011 9:39 AM BY: STOWELL, GARY

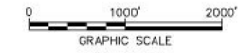


LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.



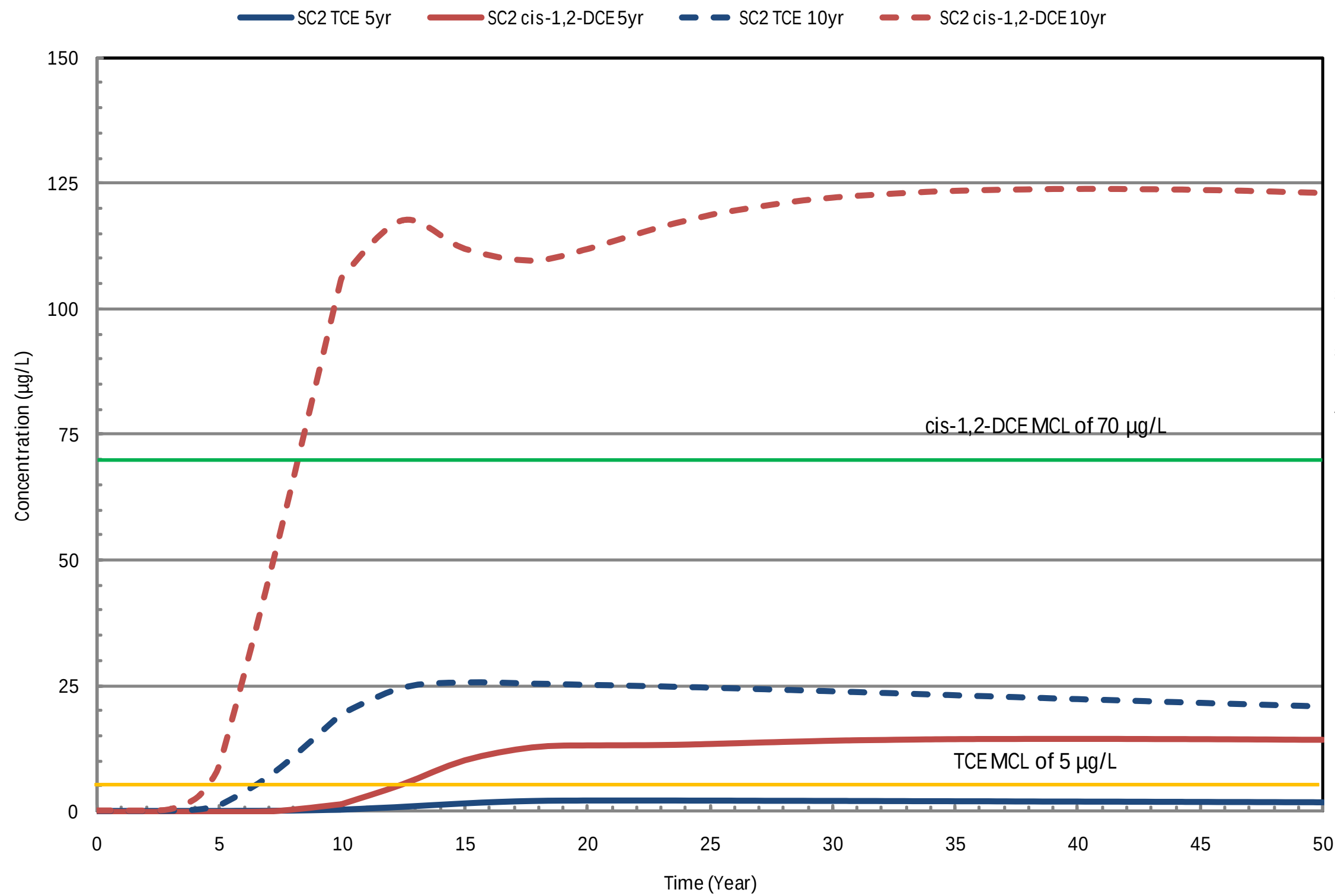
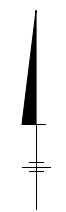
RACER TRUST
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GROUNDWATER MONITORING REPORT

**PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S2 - SCENARIO 2**

ARCADIS

FIGURE
A-36

SCENARIO 2: TCE and cis-1,2-DCE Concentrations vs. Time



- NOTES:
1. SC2 TCE 5 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 2.
 2. SC2 CIS-1,2-DCE 5 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 2.
 3. SC2 TCE 10 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 2.
 4. SC2 CIS-1,2-DCE 10 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 2.

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR: Motors Liquidation (N000884.2010.00200) Q:\MotorsLiquidationCompany\Kokomo\NIGW\MonitoringReport\mxd\Concentrations Scenario2.mxd - 4/20/2011 @ 1:33:54 PM

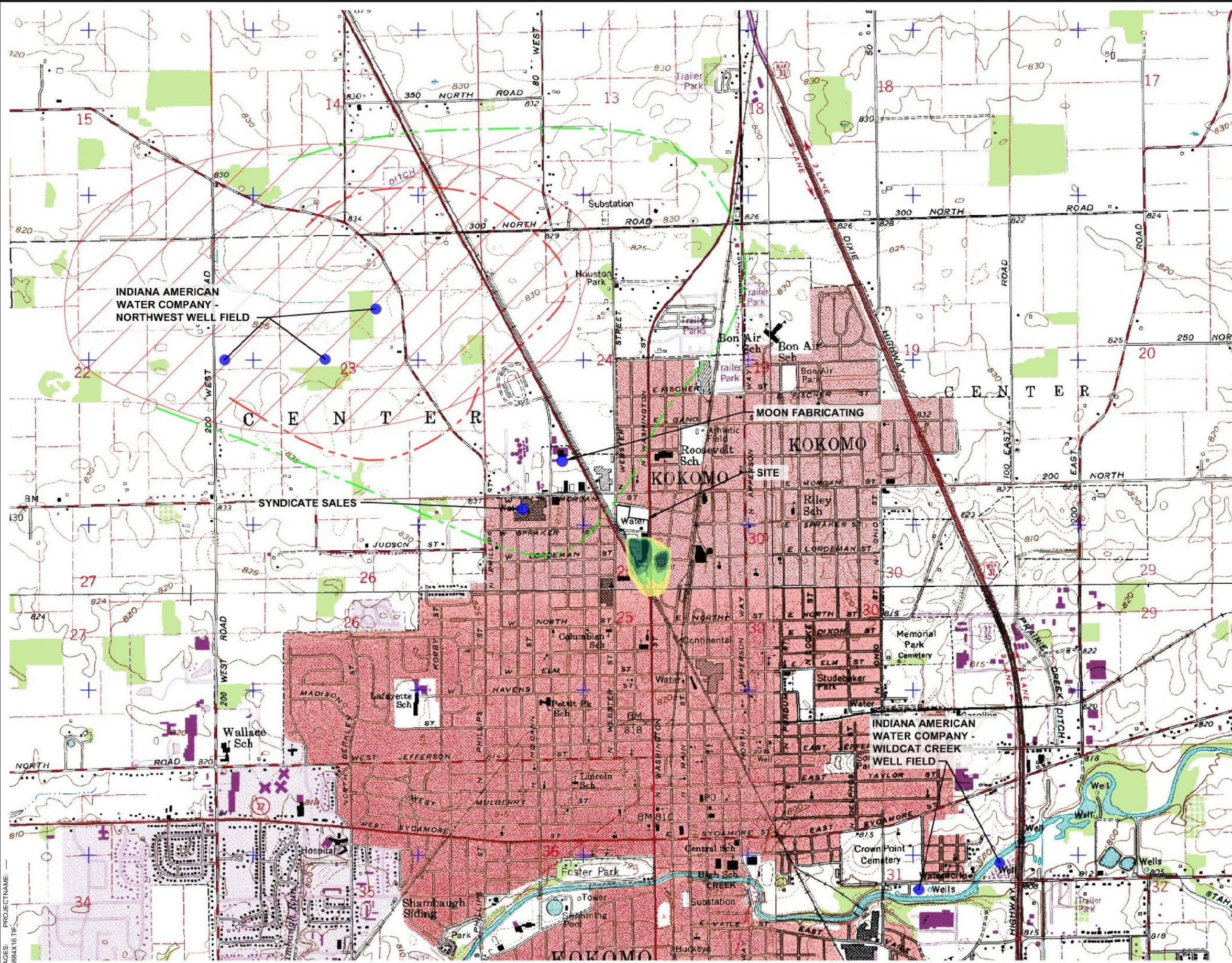
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KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**PREDICTED CONCENTRATIONS
THROUGH TIME - SCENARIO 2**



FIGURE
A-37

CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LYN: ON*OFF=REF
G:\ENVCAD\SYRACUSE\ACT\IN000884\20100200\DWG\RCRA-FIR\00884118.dwg LAYOUT: A-38
XREFS: 00884X.D 00884X16.TIF
IMAGES: 00884X16.TIF
PROJECTNAME: ---
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: PLT/CTB PLOTTED: 4/14/2011 9:15 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 5-100 ug/L
- 100-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

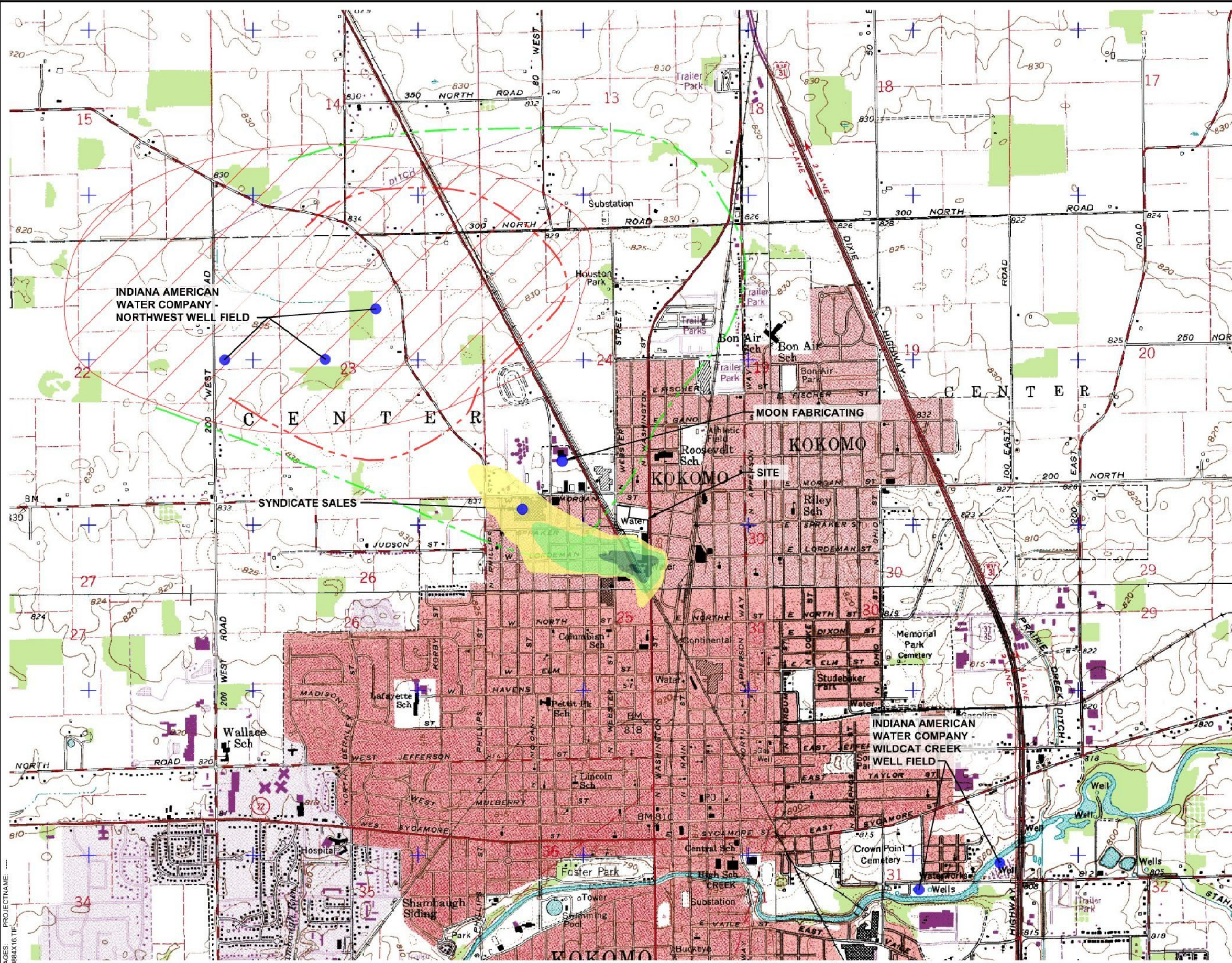


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GROUNDWATER MONITORING REPORT

PREDICTED TCE DISTRIBUTION IN
SAND UNIT S1 - SCENARIO 3



CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000000\DWG\RCRA-FIR\0084119.dwg LAYOUT: A-41
XREFS: 0084XLD 0084X16TIF
PROJECTNAME: 0084X16TIF
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: 4/14/2011 9:14 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

0 1000' 2000'
GRAPHIC SCALE

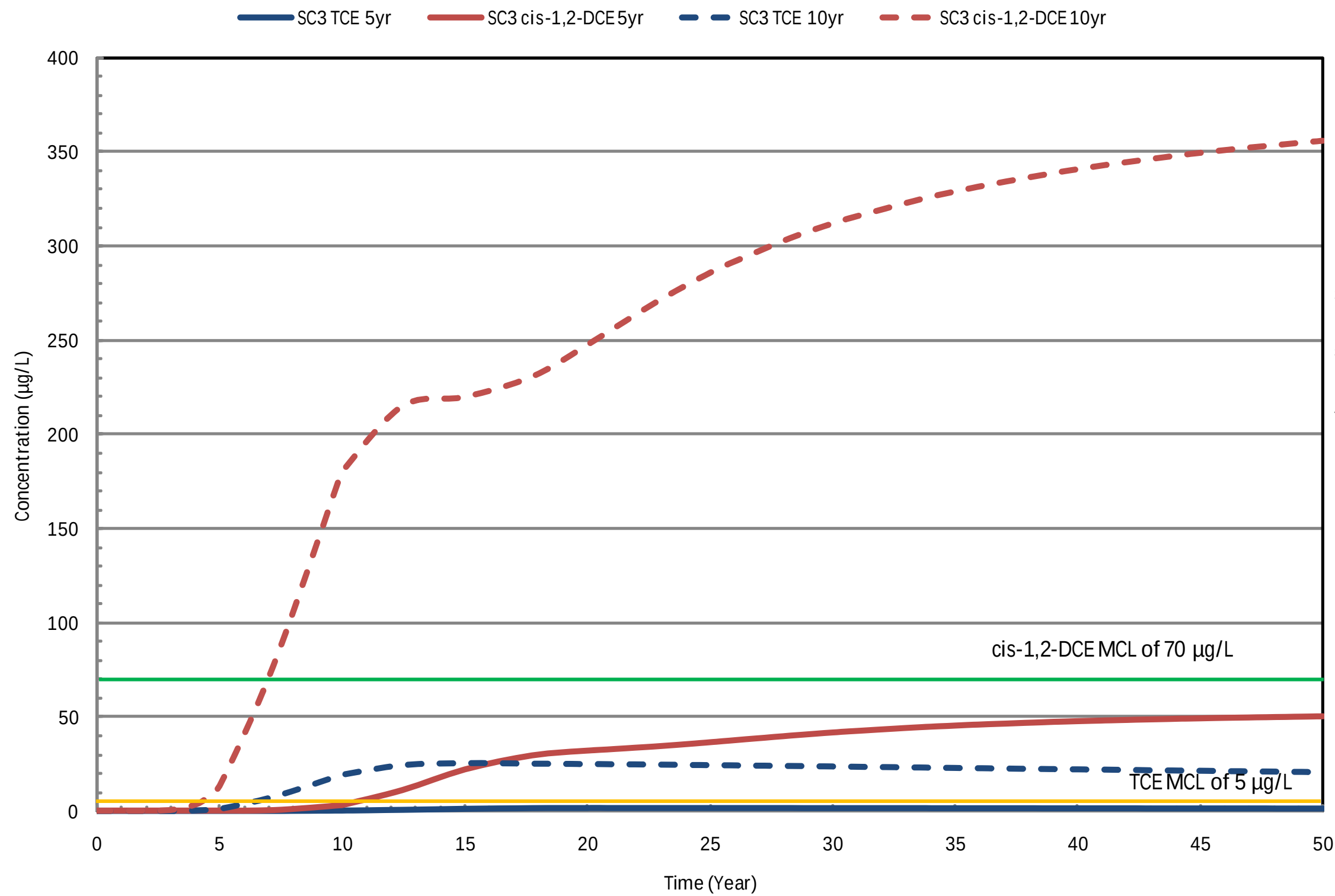
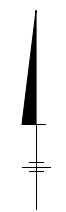
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GROUNDWATER MONITORING REPORT

**PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S2 - SCENARIO 3**

ARCADIS

FIGURE
A-41

SCENARIO 3: TCE and cis-1,2-DCE Concentrations vs. Time



- NOTES:
1. SC3 TCE 5 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 3.
 2. SC3 CIS-1,2-DCE 5 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 3.
 3. SC3 TCE 10 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 3.
 4. SC3 CIS-1,2-DCE 10 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 3.

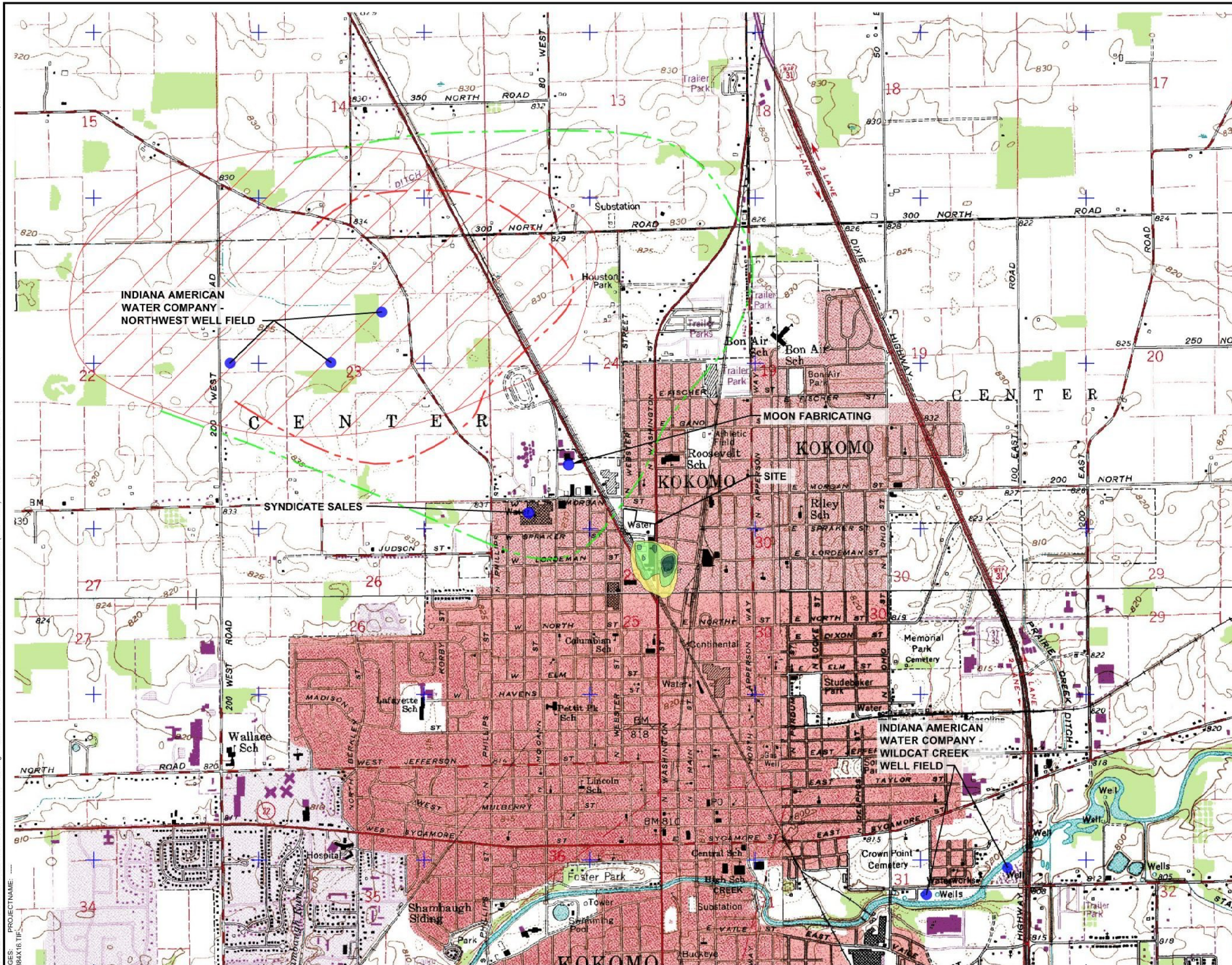
CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR: Motors Liquidation (N000884.2010.00200) Q:\MotorsLiquidationCompany\Kokomo\NIGW\MonitoringReport\mxd\Concentrations Scenario3.mxd - 4/20/2011 @ 1:34:08 PM

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**PREDICTED CONCENTRATIONS
THROUGH TIME - SCENARIO 3**



FIGURE
A-42



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 5-100 ug/L
- 100-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

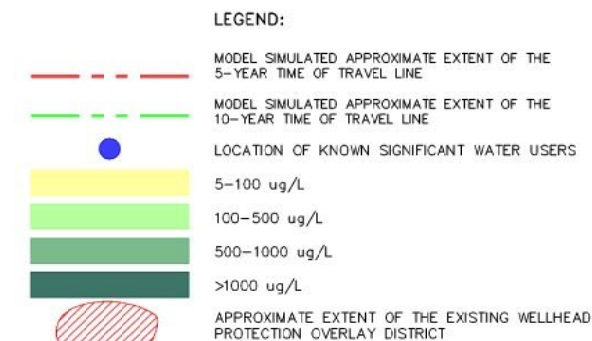
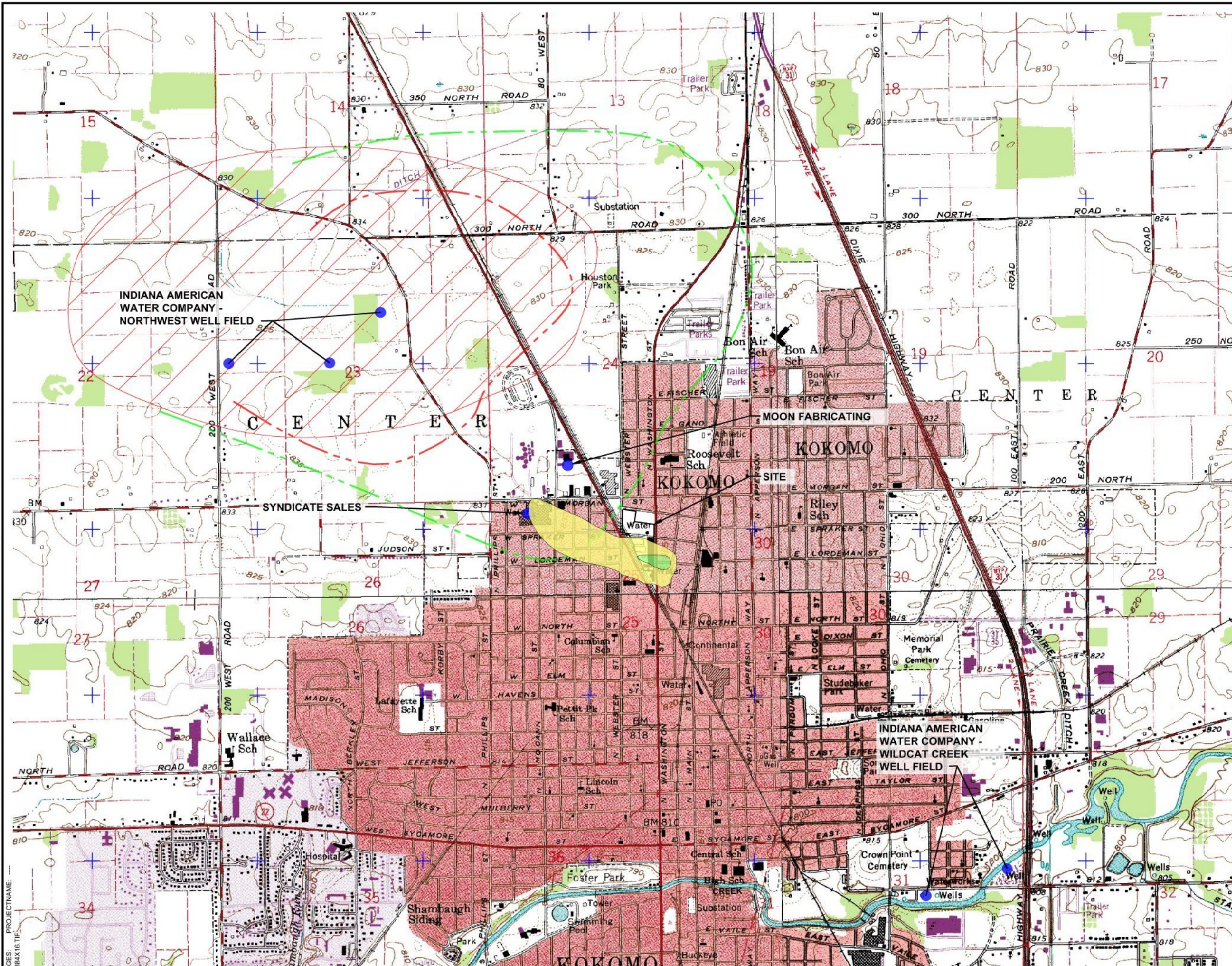
0 1000' 2000'
GRAPHIC SCALE

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GROUNDWATER MONITORING REPORT

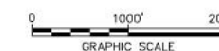
PREDICTED TCE DISTRIBUTION IN
SAND UNIT S1 - SCENARIO 4



FIGURE
A-43



- NOTES:
- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
 - THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

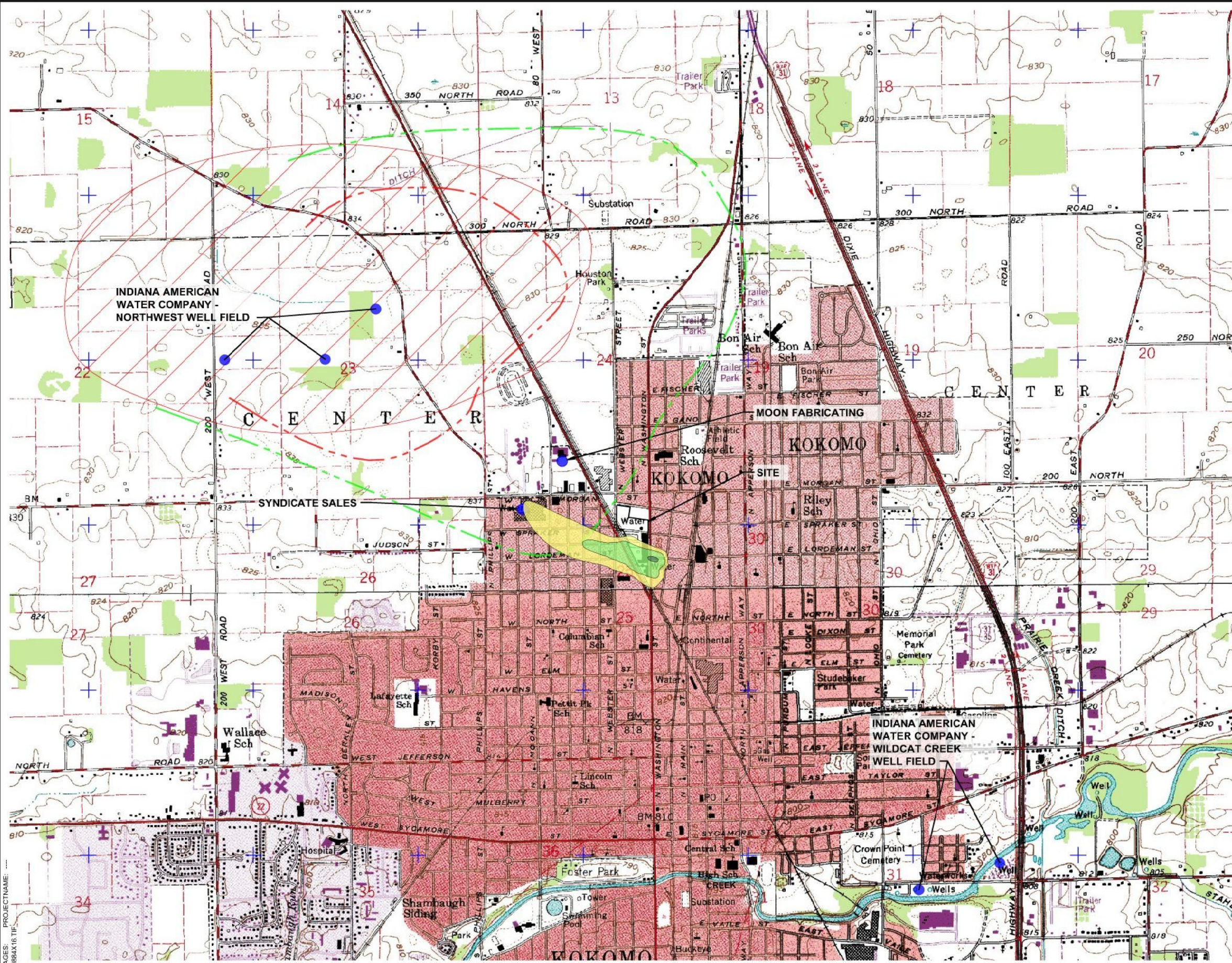


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PREDICTED TCE DISTRIBUTION IN
SAND UNIT S2 - SCENARIO 4



CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000000\DWG\RCRA-FR\0084123.dwg LAYOUT: A-46
SAVED: 4/13/2011 9:11 AM ACADVER: 18.05 (LMS TECH) PAGES: 18
PLOT: 4/14/2011 10:14 AM BY: STOWELL, GARY

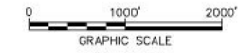


LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.



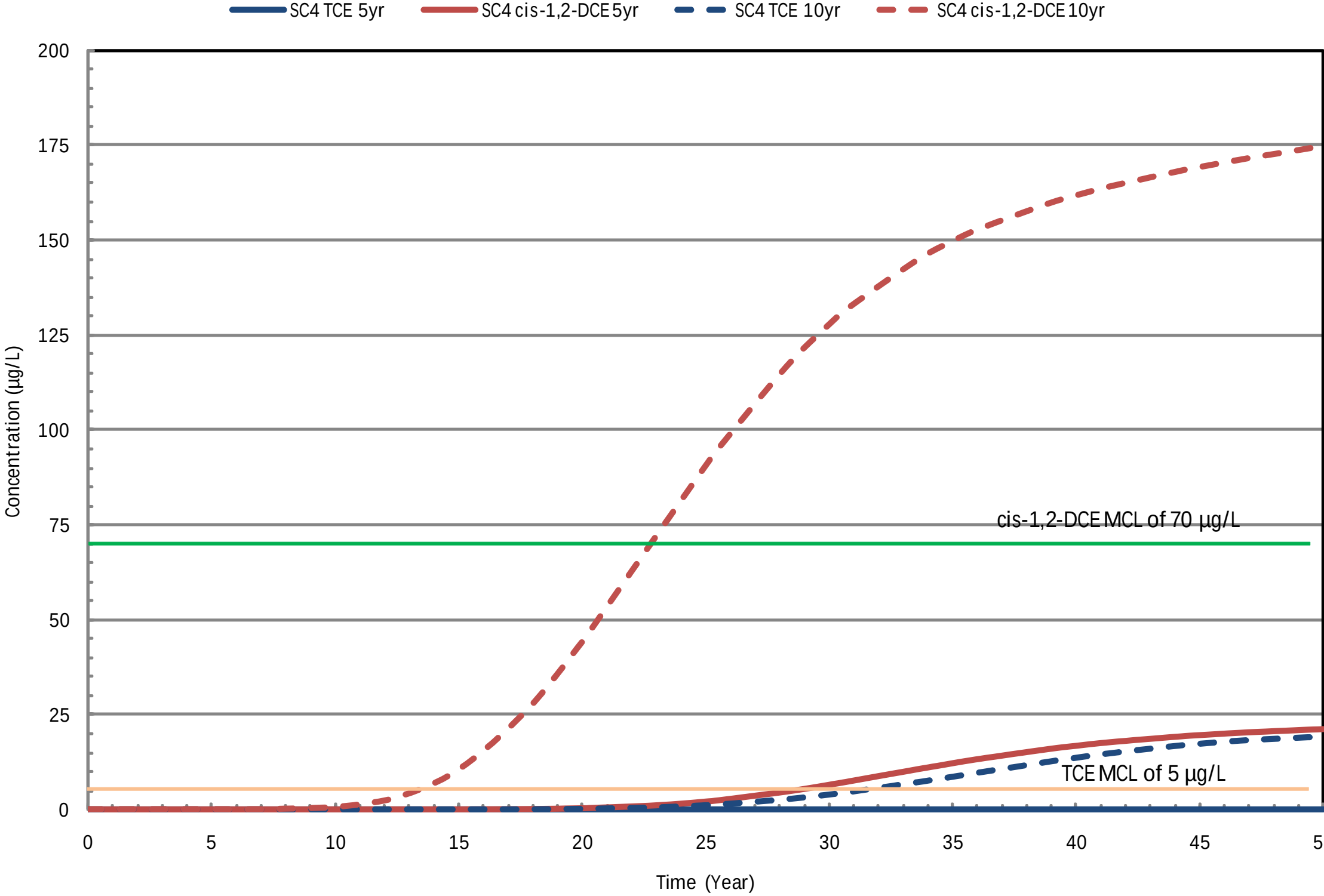
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**PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S2 - SCENARIO 4**

FIGURE
A-46

SCENARIO 4: TCE and cis-1,2-DCE Concentrations vs. Time



- NOTES:
1. SC4 TCE 5 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 4.
 2. SC4 CIS-1,2-DCE 5 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 4.
 3. SC4 TCE 10 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 4.
 4. SC4 CIS-1,2-DCE 10 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 4.

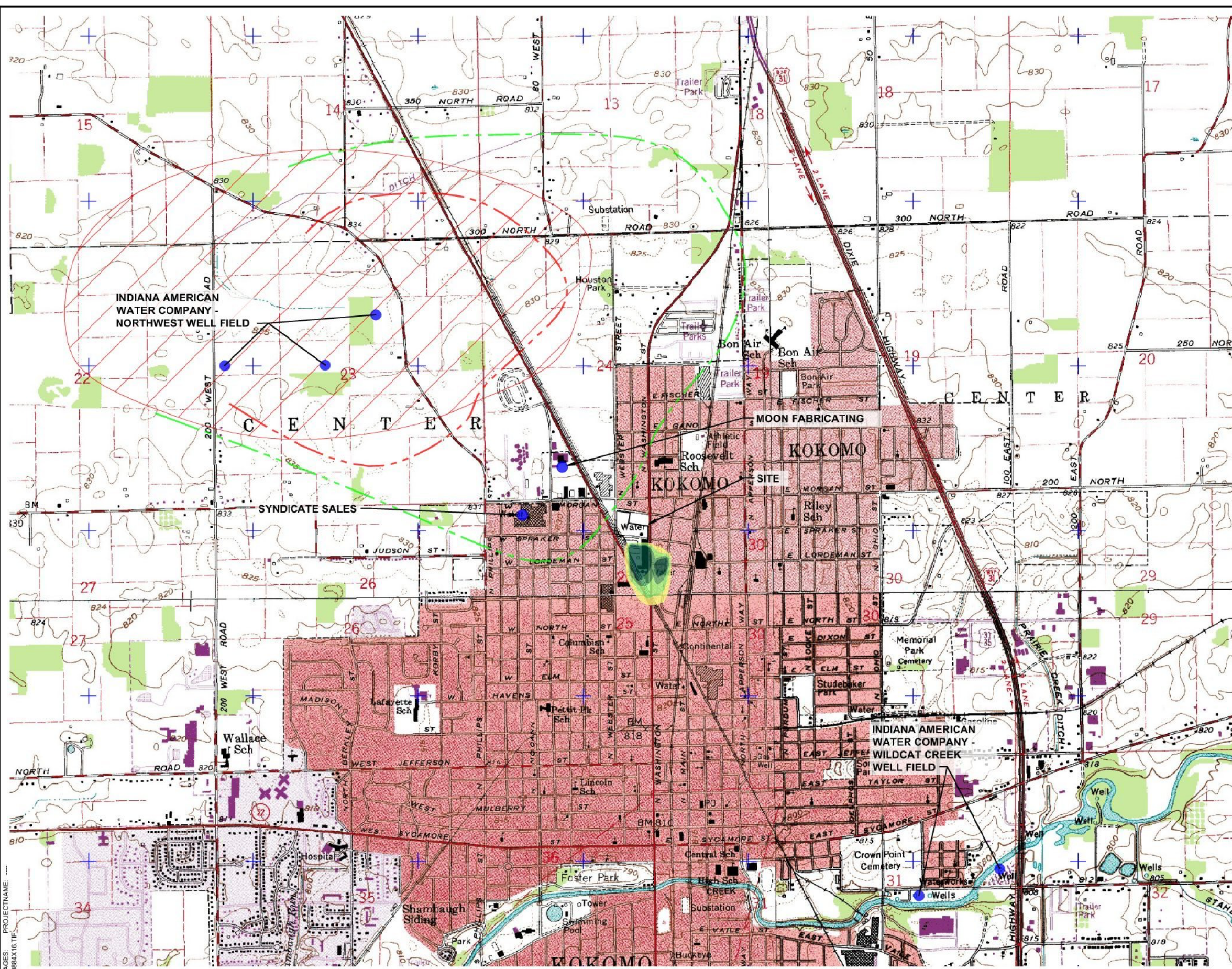
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**PREDICTED CONCENTRATIONS
THROUGH TIME - SCENARIO 4**



FIGURE
A-47

CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LYN: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000000\DWG\RCRA-FR\0084129.dwg LAYOUT: A-48
XREFS: 0084XLD 0084X16.TIF
PROJECTNAME: 0084X16.TIF
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: 4/14/2011 10:28 AM BY: STOWELL, GARY

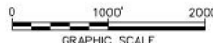


LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 5-100 ug/L
- 100-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.



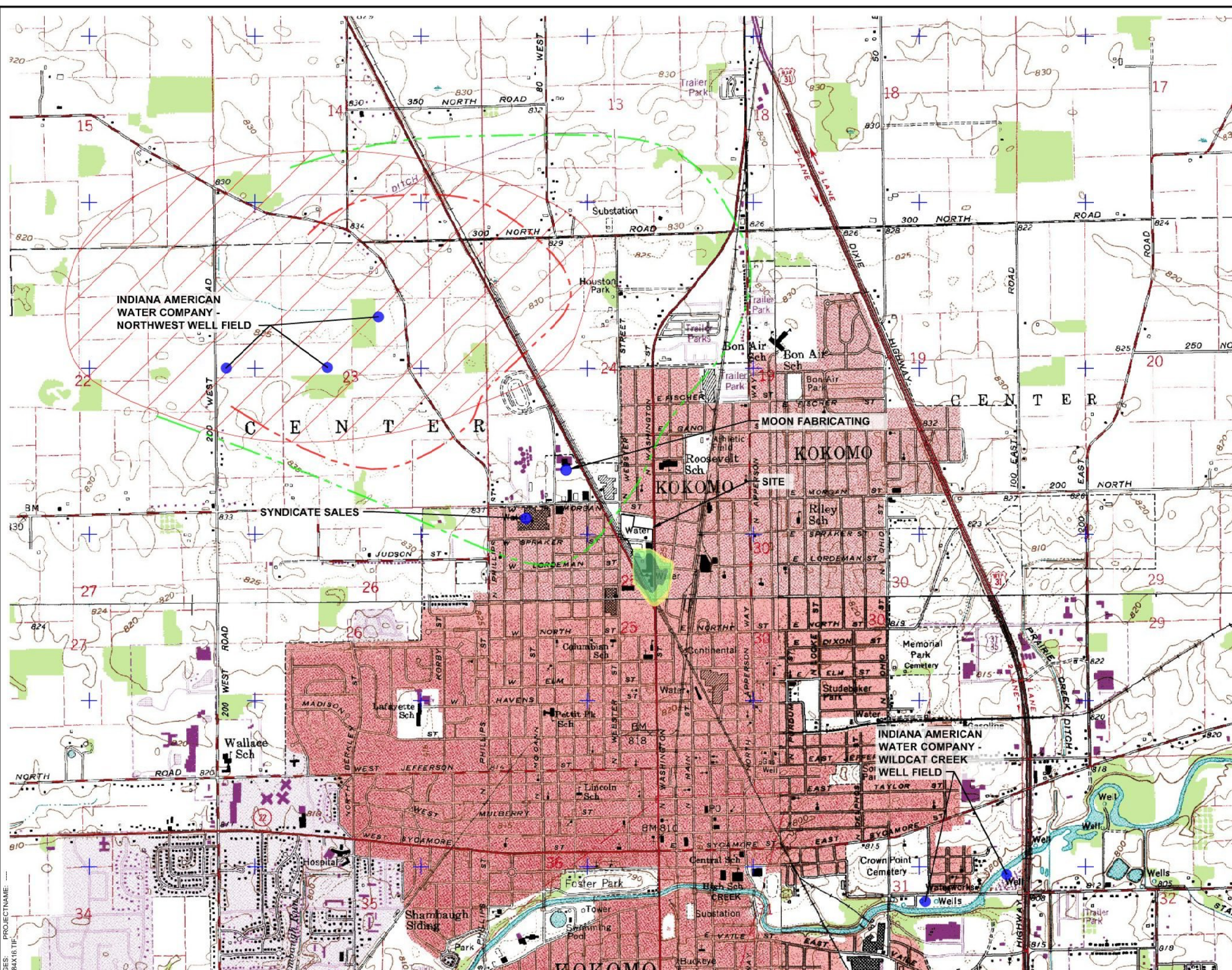
RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

PREDICTED TCE DISTRIBUTION IN
SAND UNIT S1 - SCENARIO 5



CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LYR: ON*OFF=REF
G:\ENVCAD\SYRACUSE\ACT\IN0000884\201002000\DWG\RCRA-FR\00884125.dwg LAYOUT: A-49
SAVED: 4/14/2011 10:17 AM ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: FULL C.TB
PLOT: 4/14/2011 10:17 AM BY: STOWELL, GARY

PROJECTNAME: 00884X16.TIF
XREFS: 00884X1D

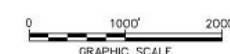


LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.



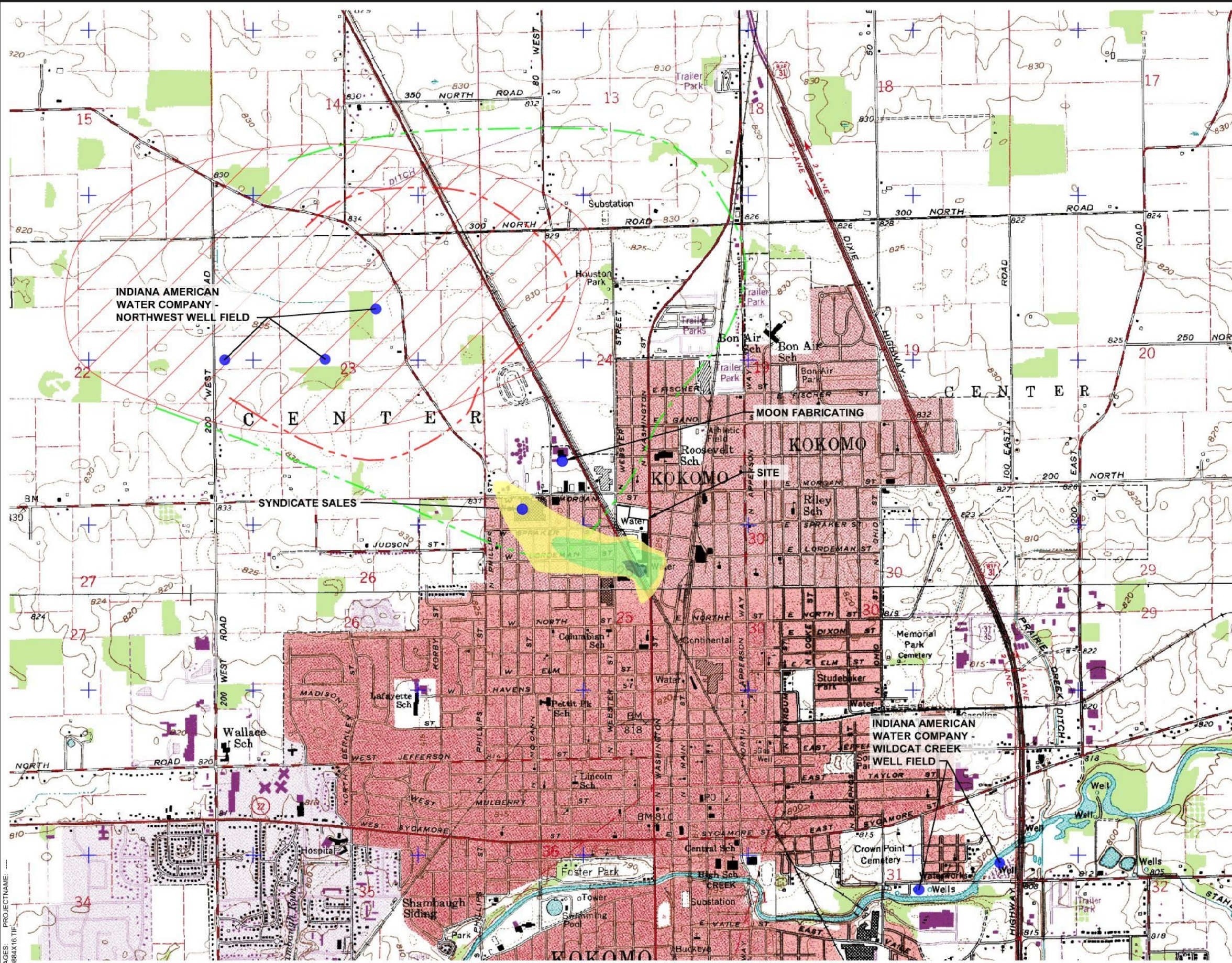
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GROUNDWATER MONITORING REPORT

**PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S1 - SCENARIO 5**

FIGURE
A-49

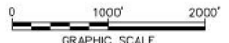
CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\000000\DWG\RCRA-FIR\0084128.dwg LAYOUT: A-51
XREFS: 0084XLD 0084X16 0084X15
PROJECTNAME: 0084X16
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: 4/14/2011 10:27 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

- NOTES:**
- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
 - THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.



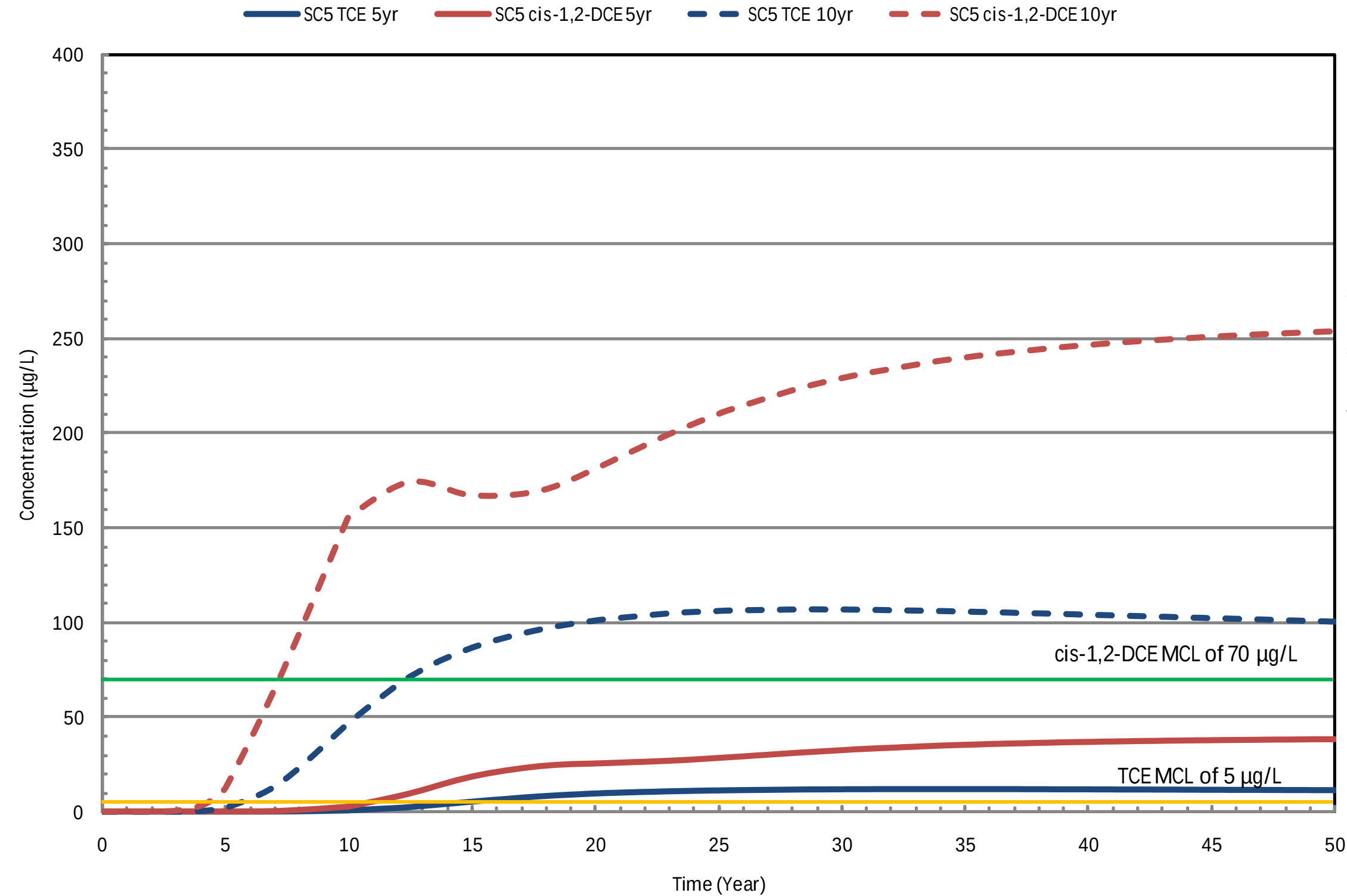
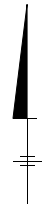
RACER TRUST
FORMER GM DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S2 - SCENARIO 5**

ARCADIS

FIGURE
A-51

SCENARIO 5: TCE and cis-1,2-DCE Concentrations vs. Time



- NOTES:
1. SC5 TCE 5 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 5.
 2. SC5 CIS-1,2-DCE 5 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 5.
 3. SC5 TCE 10 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 5.
 4. SC5 CIS-1,2-DCE 10 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 5.

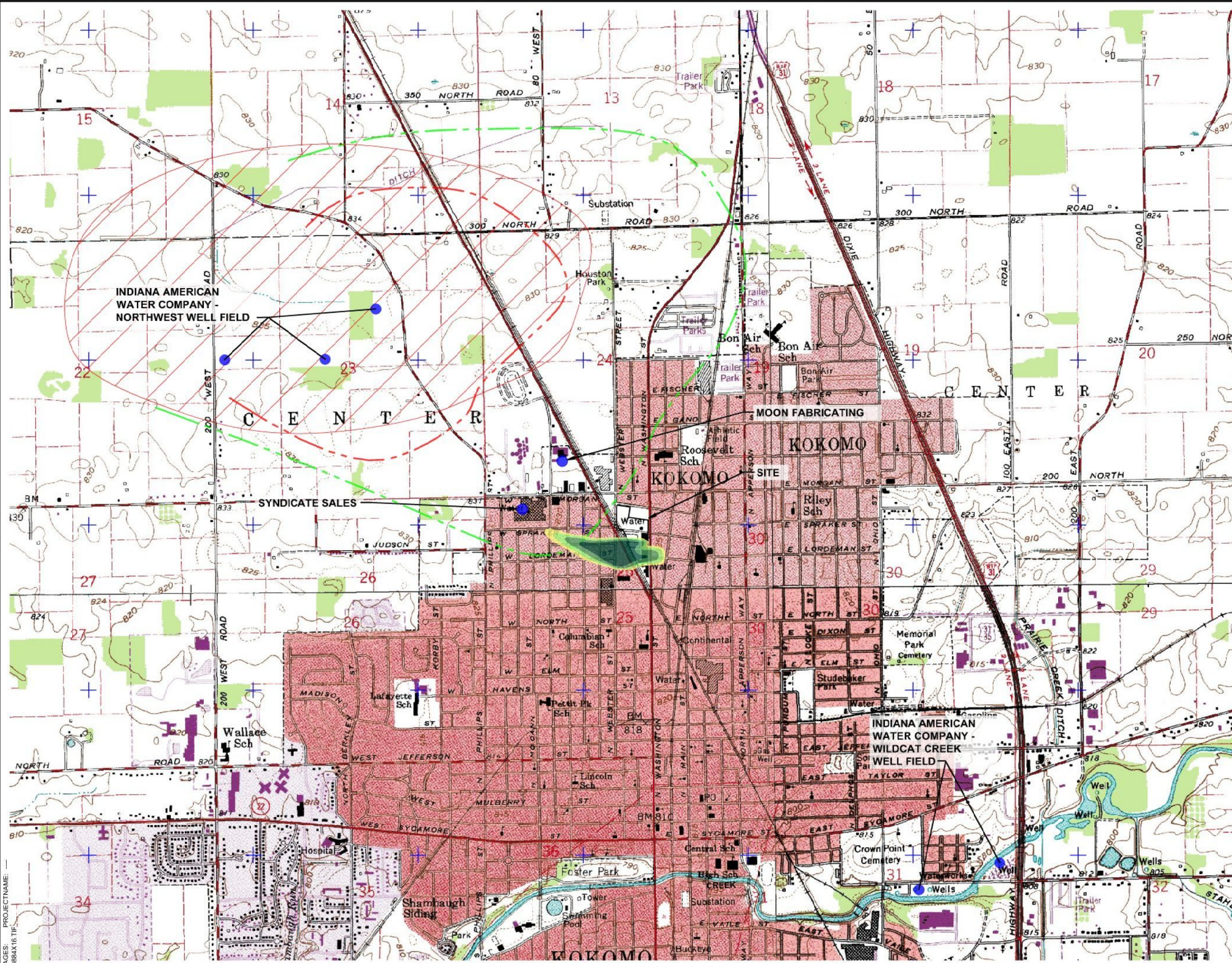
RACER TRUST
FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**PREDICTED CONCENTRATIONS
THROUGH TIME - SCENARIO 5**



FIGURE
A-52

CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LVR: ON*OFF=REF
G:\ENV\CAD\SYRACUSE\ACT\IN\00000000\DWG\RCRA-FR\0084130.dwg LAYOUT: A-54
XREFS: 0084XLD 0084X16.TIF
PROJECTNAME: 0084X16.TIF
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: 4/14/2011 10:29 AM BY: STOWELL, GARY

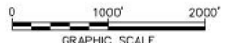


LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTES:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
- THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.

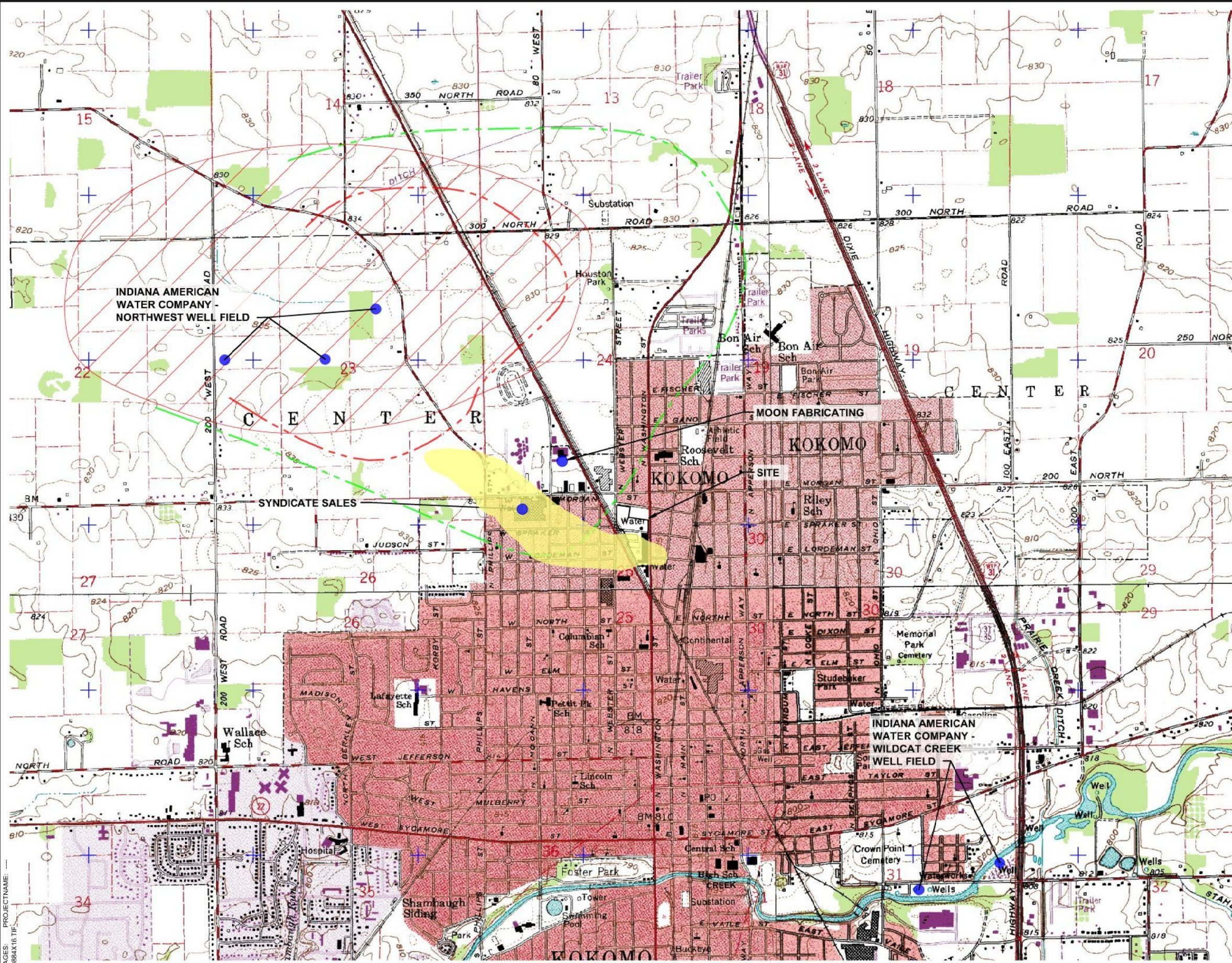


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KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S1 - SCENARIO 6**



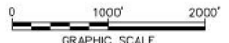
CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LYN: ON*OFF=REF
G:\ENVCAD\SYRACUSE\ACT\IN000084\201002000\DWG\RCRA-FR\0084134.dwg LAYOUT: A-55
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IMAGES: 0084X16.TIF
PROJECTNAME: ---
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: 4/14/2011 10:36 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 5-100 ug/L
- 100-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

- NOTES:
- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
 - THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.



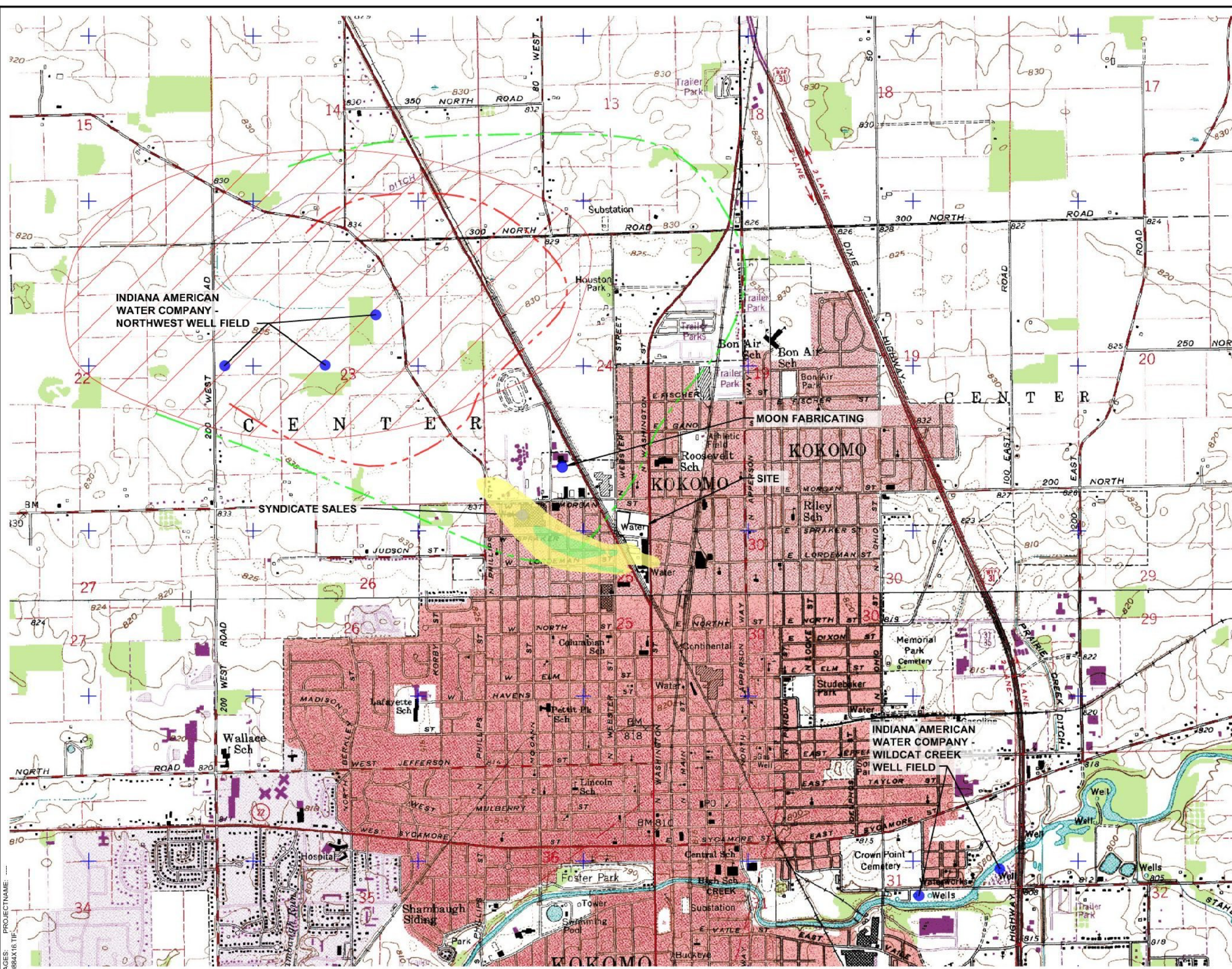
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GROUNDWATER MONITORING REPORT

**PREDICTED TCE DISTRIBUTION IN
SAND UNIT S2 - SCENARIO 6**

ARCADIS

FIGURE
A-55

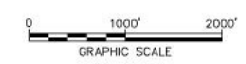
CITY: SYRACUSE DIV/GRP: 141 DB: GMS LD: GMS PM: (Red) LYR: ON*OFF=REF
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XREFS: 0084XLD 0084X16.TIF
PROJECTNAME: 0084X16.TIF
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: 4/14/2011 10:34 AM BY: STOWELL, GARY



LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- 70-200 ug/L
- 200-500 ug/L
- 500-1000 ug/L
- >1000 ug/L
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

- NOTES:
- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.
 - THE PLUME FOOTPRINT SHOWN IS THE MODEL SIMULATED RESULT AFTER 50 YEARS OF SOLUTE TRANSPORT.



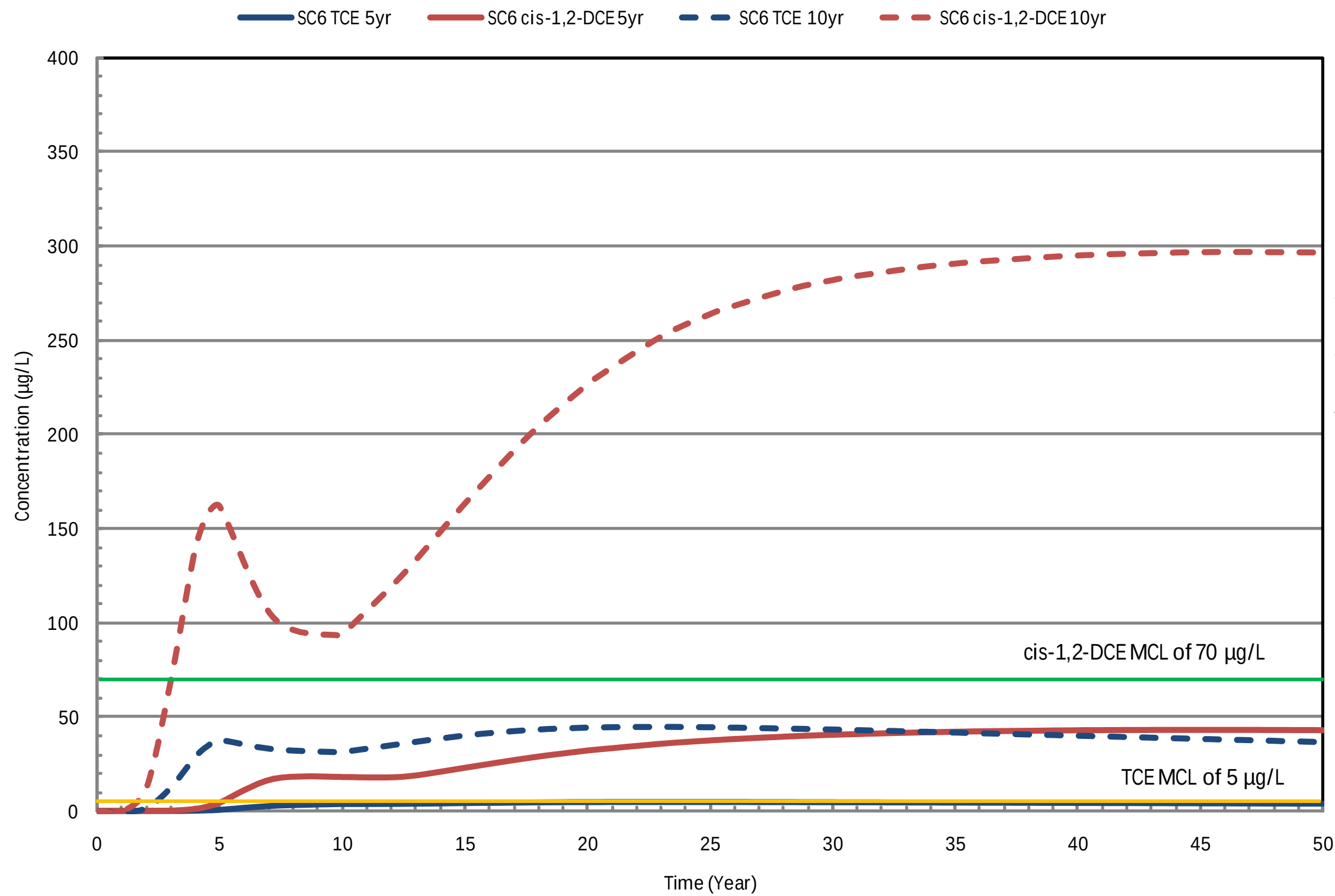
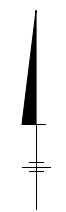
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KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**PREDICTED cis-1,2-DCE DISTRIBUTION
IN SAND UNIT S2 - SCENARIO 6**

ARCADIS

FIGURE
A-56

SCENARIO 6: TCE and cis-1,2-DCE Concentrations vs. Time



- NOTES:
1. SC6 TCE 5 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 6.
 2. SC6 CIS-1,2-DCE 5 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 5-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 6.
 3. SC6 TCE 10 YR REFERS TO THE TCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 6.
 4. SC6 CIS-1,2-DCE 10 YR REFERS TO THE CIS-1,2-DCE BREAKTHROUGH CURVE AT THE MODEL SIMULATED 10-YEAR TRAVEL TIME BOUNDARY FOR SCENARIO 6.

CITY: SYR DIV/GROUP: IT DB: KES LD: PIC: PM: TM: TR: Motors Liquidation (N000884.2010.00200) Q:\MotorsLiquidationCompany\Kokomo\NIGW\MonitoringReport\mxd\Concentrations Scenario6.mxd - 4/20/2011 @ 1:34:40 PM

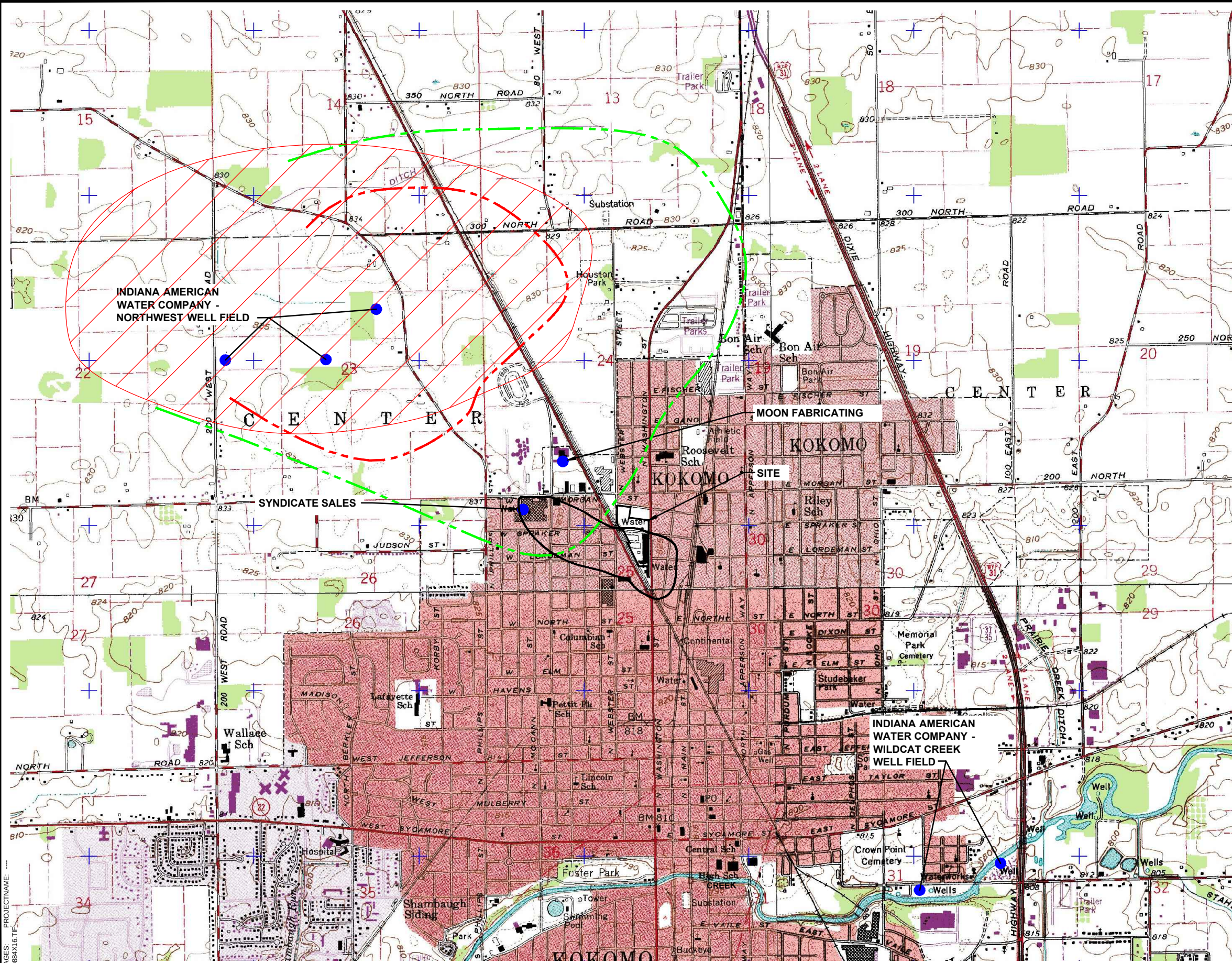
RACER TRUST
FORMER DELCO PLANT 5
KOKOMO, INDIANA
GROUNDWATER MONITORING REPORT

**PREDICTED CONCENTRATIONS
THROUGH TIME - SCENARIO 6**



FIGURE
A-57

CITY:SYRACUSE DIV:GROUP 141 DB:GMS LD:GMS PW:Rend LVR:ON=OFF=REF
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IMAGES: 00884X16.TIF
PROJECTNAME: 00884X16.TIF
ACADVER: 18.05 (LMS TECH) PAGES: 18.05 (LMS TECH) PLOT: 4/19/2011 10:03 AM BY: STOWELL, GARY

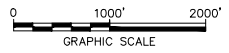


LEGEND:

- MODEL SIMULATED APPROXIMATE EXTENT OF THE 5-YEAR TIME OF TRAVEL LINE
- MODEL SIMULATED APPROXIMATE EXTENT OF THE 10-YEAR TIME OF TRAVEL LINE
- PROPOSED WELL RESTRICTION OVERLAY DISTRICT EXTENT
- LOCATION OF KNOWN SIGNIFICANT WATER USERS
- APPROXIMATE EXTENT OF THE EXISTING WELLHEAD PROTECTION OVERLAY DISTRICT

NOTE:

- SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC MAP.



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**BOUNDARY OF PROPOSED WELL
RESTRICTION - OVERLAY DISTRICT**



FIGURE
A-58

Appendix B

Supplemental Information for Vapor Intrusion Criteria

Introduction

Risk-based screening criteria for exposure to constituents in groundwater via vapor intrusion into residential or commercial/industrial buildings are included in this Appendix to the Corrective Measures Proposal (CMP) (ARCADIS 2011). Screening criteria were identified for both groundwater and soil vapor. The following sections describe the derivation of vapor intrusion (VI) screening criteria for groundwater and soil vapor.

Groundwater VI Screening Criteria

For the groundwater to indoor air VI pathway, screening criteria for groundwater were calculated using the Johnson & Ettinger (J&E) model (USEPA, 2004a) and the recommendation by USEPA (M. Kaysen, 2011) to incorporate site-specific soil strata information into this model. The model was used to estimate the vapor emissions from groundwater to soil gas concentrations beneath the foundation (i.e., “sub-slab” concentrations) and then to indoor air. The physical/chemical information, exposure factors and toxicity information used to calculate the screening criteria are the default values built into the J&E model spreadsheets as provided by USEPA (GW-ADV, Version 3.1). Soil type information was obtained from the boring logs for monitoring well MW-612; USEPA default values for these soil types were used in the model. As derived, the groundwater screening criteria are applicable to off-site locations within the groundwater contaminant plume. Soil type information for monitoring well MW-603 was used to select model default values by soil type in the J&E model to derive groundwater screening criteria applicable to off-site locations outside of the groundwater contaminant plume.

The J&E model uses a spreadsheet format to summarize the input parameters (DATAENTER tab), chemical properties (CHEMPROPS tab), interim calculations (INTERCALCS tab), toxicity and other chemical specific information (VLOOKUP tab) and a “final indoor exposure groundwater concentration” (RESULTS tab). The risk-based groundwater concentration (termed “final indoor exposure groundwater concentration”) on the RESULTS tab is the groundwater concentration (expressed in units of ug/L) that would not result in an indoor air concentration above the target cancer risk of 1×10^{-5} or a hazard index greater than 1; this value is identified as the groundwater vapor intrusion screening criterion. The modeling spreadsheets are presented in this Appendix for these chemicals: 1,1-Dichloroethene; cis-1,2-Dichloroethene; trans-1,2-Dichloroethene; Tetrachloroethene; Trichloroethene; and Vinyl Chloride. Two receptor groups were evaluated including workers in a commercial/industrial building for an exposure frequency of 250 days per year for an exposure duration of 25 years (USEPA standard default assumptions); and residents of a residential dwelling for the model default exposure frequency of 350 days per year for an exposure duration of 30 years. Conditions inside and outside the groundwater plume, represented by soil strata information

from MW-612 and MW-603, respectively, were modeled separately. Input parameters as shown on the DATAENTER tab are also model default values (USEPA, 2004b).

The vapor intrusion screening criteria for groundwater summarized in Table B-1 (in units of mg/L) are applicable to off-site locations within the groundwater contaminant plume. The vapor intrusion screening criteria for groundwater summarized in Table B-2 are applicable to off-site locations outside of the groundwater contaminant plume. The commercial/industrial groundwater vapor intrusion criteria apply to commercial/industrial buildings. The residential groundwater vapor intrusion criteria apply to residential buildings. In all cases evaluated, the individual chemical target cancer risk is 1×10^{-5} and the target hazard index is 1.

Soil Gas VI Screening Criteria

The vapor intrusion screening criteria for residential exposure to soil gas constituents that could migrate into indoor air were calculated following procedures outlined in IDEM's draft Remediation Closure Guide (RCG) dated 2011. The following equation was used:

$$C_{\text{vi-slab-SL}} = C_{\text{ia}} / \alpha_{\text{sub}} \quad \text{Equation 110 (IDEM, 2011)}$$

Where:

$C_{\text{vi-slab-SL}}$ = Vapor Intrusion Sub Slab Screening Level ($\mu\text{g}/\text{m}^3$); chemical-specific

C_{ia} = Indoor Air Health Protective Level ($\mu\text{g}/\text{m}^3$); chemical-specific

α_{sub} = Attenuation Factor – Sub Slab (unitless); IDEM default = 0.1

The vapor intrusion screening criteria for soil gas are summarized on Table B-3.

The Indoor Air Health Protective Level for each chemical is presented in the RCG; these levels were calculated by IDEM to meet a target cancer risk level of 1×10^{-5} or hazard index of 1 (See Equations 95-98, 103-104 in IDEM, 2011).

The sub-slab to indoor air attenuation factor was assumed to be 0.1 for residential buildings, which is a conservative default value recommended by IDEM. This same attenuation factor was used to develop soil gas vapor intrusion screening criteria for commercial/industrial buildings, although IDEM (2011) states that an attenuation factor of 0.01 could be used depending on these location-specific factors: building size; foundation thickness and structural integrity; ceiling height; and air exchange rate (IDEM, 2011). Use of an attenuation factor of 0.01 would increase the commercial/industrial soil gas VI screening criteria listed in Table B-3 by a factor of 10 (e.g., TCE soil gas VI screening criteria would be $870 \mu\text{g}/\text{m}^3$). These higher screening

criteria may be applied depending on an evaluation of building conditions at specific commercial/industrial buildings.

Applicability

The groundwater and soil gas screening criteria presented in this Appendix are not remedial action levels for the site. They are intended to identify situations where groundwater and soil gas concentrations should be further investigated to evaluate if a potentially complete vapor intrusion pathway exists. Exceeding the model-based groundwater VI screening criteria or the IDEM default screening levels does not indicate that there is a complete vapor intrusion pathway or that there is a significant health risk. It indicates that further evaluation and sampling including sub-slab soil vapor and/or indoor air testing may be required.

It is anticipated that changes in chemical-specific toxicity factors will result in changes to the screening criteria. For example, a change in the cancer unit risk factor for PCE from the current USEPA value listed in the Integrated Risk Information System (IRIS) would result in a change to the groundwater and soil gas risk-based screening criteria. Screening criteria will be revised as toxicity information changes. The screening criteria for TCE were calculated based on the toxicity factors finalized by USEPA (IRIS, 2011).

References

- Indiana Department of Environmental Management (IDEM). May 2, 2011 (Pending). Remediation Closure Guide (RCG) <http://www.in.gov/idem/6683.htm>.
- Johnson, P. C., and R. A. Ettinger. 1991. Heuristic model for predicting the intrusion rate of contaminant vapors into buildings. *Environ. Sci. Technol.* 25(8):1445-1452.
- Kaysen, Michelle, USEPA. May 11, 2011. Email Re: Agency's Position on CMI Monitoring Plan.
- U.S. Environmental Protection Agency (USEPA). 2011. Integrated Risk Information System Substance File for Trichloroethylene. Last updated September 28.
- U.S. Environmental Protection Agency (USEPA). 2004a. Johnson & Ettinger model spreadsheets. GW-ADV, Version 3.1.
- U.S. Environmental Protection Agency (USEPA). 2004b. User's Guide for Evaluating Subsurface Vapor Intrusion Into Buildings. February 22.

**Table B-1: Groundwater Vapor Intrusion Screening Criteria
Former Delco Plant 5, Kokomo, Indiana
Application: Off Site Within Plume**

Chemical	CASRN	Off-Site Commercial/ Industrial Groundwater VI Screening Criteria (mg/L)	Off-Site Residential Groundwater VI Screening Criteria (mg/L)
1,1-Dichloroethene	75-35-4	78.3	55.9
cis-1,2-Dichloroethene	156-59-2	59.5	42.5
trans-1,2-Dichloroethene	156-60-5	73.8	52.7
Tetrachloroethene	127-18-4	3.95	2.35
Trichloroethene	79-01-6	2.19	1.57
Vinyl Chloride	75-01-4	0.919	0.547

Note:

Vapor intrusion (VI) screening criteria for groundwater were calculated using USEPA Johnson & Ettinger Model Version 3.1 (February 2004) and a target cancer risk of 1E-5 or target HI of 1; the selected criterion value is the lower of the allowable concentrations for each chemical. Modeling spreadsheets for each chemical are provided in this Appendix. Model default values for the soil types at monitoring well MW-612 were used to derive screening criteria that will be applied to off-Site areas within the groundwater contaminant plume.

CASRN = Chemical Abstract Service Registry Number

**Table B-2: Groundwater Vapor Intrusion Screening Criteria
Former Delco Plant 5, Kokomo, Indiana
Application: Off Site Outside of Plume**

Chemical	CASRN	Off-Site Commercial/ Industrial Groundwater VI Screening Criteria (mg/L)	Off-Site Residential Groundwater VI Screening Criteria (mg/L)
1,1-Dichloroethene	75-35-4	52.4	37.5
cis-1,2-Dichloroethene	156-59-2	30.1	21.5
trans-1,2-Dichloroethene	156-60-5	41.9	29.9
Tetrachloroethene	127-18-4	2.05	1.49
Trichloroethene	79-01-6	1.3	0.93
Vinyl Chloride	75-01-4	0.623	0.371

Note:

Vapor intrusion (VI) screening criteria for groundwater were calculated using USEPA Johnson & Ettinger Model Version 3.1 (February 2004) and a target cancer risk of 1E-5 or target HI of 1; the selected criterion value is the lower of the allowable concentrations for each chemical. Modeling spreadsheets for each chemical are provided in this Appendix. Model default values for the soil types at monitoring well MW-603 were used to derive screening criteria that will be applied to off-Site areas outside of the groundwater contaminant plume.

CASRN = Chemical Abstract Service Registry Number

**Table B-3: Soil Gas Vapor Intrusion Screening Criteria Summary
Former Delco Plant 5, Kokomo, Indiana**

Chemical	CASRN	Off-Site Commercial/Industrial Soil Gas VI Screening Criteria (ug/m³)	Off-Site Residential Soil Gas VI Screening Criteria (ug/m³)
1,1-Dichloroethene	75-35-4	3500	830
cis-1,2-Dichloroethene	156-59-2	NA	NA
trans-1,2-Dichloroethene	156-60-5	2600	630
Tetrachloroethylene	127-18-4	210	41
Trichloroethene	79-01-6	87	21
Vinyl Chloride	75-01-4	280	16

Note:

Vapor intrusion (VI) screening criteria for soil gas are generic values from IDEM, 2011, *Draft Remediation Closure Guide* (RCG, Pending). These values were calculated by applying an IDEM default soil gas attenuation factor of 0.1 to lower of the IDEM Health Protective Levels (HPLs) for indoor air based on a target cancer risk of 1E-5 and a target hazard index of 1. To reflect final USEPA toxicity factors for TCE, the HPLs were recalculated for Commercial/Industrial using Equations 103 and 104 of the IDEM RCG and for Residential using Equations 95 and 96 of the IDEM RCG. The lower of the cancer and non-cancer HPLs was then divided by 0.1 to derive soil gas VI screening criteria.

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical									
75354		4.37E+03		1,1-Dichloroethylene									
MORE ↓	ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) 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)				
	10	200	308	308			A	C	C				
	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)
C		1.43	0.459	0.215									
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	1000	1000	366	0.1	0.5	5					
	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		25	25	250	1.0E-05	1							
				Used to calculate risk-based groundwater concentration.									
END													

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
9.00E-02	1.04E-05	2.60E-02	25	6,247	304.75	576.05	5.89E+01	2.25E+03	0.0E+00	2.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	6,392	1.47E-02	6.33E-01	1.75E-04	3.90E-03	0.00E+00	0.00E+00	2.04E-05	2.70E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	6.33E+02	0.10	8.33E+01	3.90E-03	4.00E+02	1.59E+232	8.80E-06	5.57E-03	NA	2.0E-01
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END

RESULTS SHEET

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	5.24E+04	5.24E+04	2.25E+06	5.24E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES

X

OR

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

YES

ENTER
Chemical
CAS No.
(numbers only,
no dashes)

75354

ENTER
Initial
groundwater
conc.,
 C_w
($\mu\text{g/L}$)

4.37E+03

Chemical

1,1-Dichloroethylene

MORE
↓

ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)
Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)								
10	200	308	308			A	C	C		

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)
C	1.43	0.459	0.215								

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	1000	1000	366	0.1	0.5	5

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-05	1

END

Used to calculate risk-based
groundwater concentration.

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
9.00E-02	1.04E-05	2.60E-02	25	6,247	304.75	576.05	5.89E+01	2.25E+03	0.0E+00	2.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	6,392	1.47E-02	6.33E-01	1.75E-04	3.90E-03	0.00E+00	0.00E+00	2.04E-05	2.70E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	6.33E+02	0.10	8.33E+01	3.90E-03	4.00E+02	1.59E+232	8.80E-06	5.57E-03	NA	2.0E-01
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END

RESULTS SHEET

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	3.75E+04	3.75E+04	2.25E+06	3.75E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																		
75354		4.37E+03		1,1-Dichloroethylene																		
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)											
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																	
			10	200	669			365	304			B	SIC	SC								
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)											
												SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216			
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	1000	1000	366	0.1	0.5	5								
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	25	25	250	1.0E-05	1											
Used to calculate risk-based groundwater concentration.																						

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
9.00E-02	1.04E-05	2.60E-02	25	6,247	304.75	576.05	5.89E+01	2.25E+03	0.0E+00	2.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	6,392	1.47E-02	6.33E-01	1.75E-04	2.32E-03	4.67E-03	0.00E+00	3.26E-05	7.84E-05	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	6.33E+02	0.10	8.33E+01	2.32E-03	4.00E+02	#NUM!	5.89E-06	3.73E-03	NA	2.0E-01
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END

RESULTS SHEET

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	7.83E+04	7.83E+04	2.25E+06	7.83E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																		
75354		4.37E+03		1,1-Dichloroethylene																		
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)											
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																	
			10	200	669			365	304			B	SIC	SC								
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)											
												SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216			
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	1000	1000	366	0.1	0.5	5								
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-05	1											
												Used to calculate risk-based groundwater concentration.										

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
9.00E-02	1.04E-05	2.60E-02	25	6,247	304.75	576.05	5.89E+01	2.25E+03	0.0E+00	2.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	6,392	1.47E-02	6.33E-01	1.75E-04	2.32E-03	4.67E-03	0.00E+00	3.26E-05	7.84E-05	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	6.33E+02	0.10	8.33E+01	2.32E-03	4.00E+02	#NUM!	5.89E-06	3.73E-03	NA	2.0E-01
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END

RESULTS SHEET

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	5.59E+04	5.59E+04	2.25E+06	5.59E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																	
156592		4.37E+03		cis-1,2-Dichloroethylene																	
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)										
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																
			308																		
10	200	308	308			A	C	C													
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)										
												C	1.43	0.459	0.215						
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	1000	1000	366	0.1	0.5	5							
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	25	25	250	1.0E-05	1										
				Used to calculate risk-based groundwater concentration.																	

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.36E-02	1.13E-05	4.07E-03	25	7,192	333.65	544.00	3.55E+01	3.50E+03	0.0E+00	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	7,734	2.04E-03	8.77E-02	1.75E-04	3.19E-03	0.00E+00	0.00E+00	4.52E-05	5.97E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	8.77E+01	0.10	8.33E+01	3.19E-03	4.00E+02	4.48E+283	1.93E-05	1.70E-03	NA	3.5E-02
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END

RESULTS SHEET

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	3.01E+04	3.01E+04	3.50E+06	3.01E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																	
156592		4.37E+03		cis-1,2-Dichloroethylene																	
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)										
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																
			10	200	308			308				A	C	C							
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)										
												C	1.43	0.459	0.215						
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	1000	1000	366	0.1	0.5	5							
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-05	1										
						Used to calculate risk-based groundwater concentration.															

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.36E-02	1.13E-05	4.07E-03	25	7,192	333.65	544.00	3.55E+01	3.50E+03	0.0E+00	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
---	--	--	---	---	--	--	---	---	---	---	---	---	---

5.08E+04	1.80E+06	2.22E-04	200	7,734	2.04E-03	8.77E-02	1.75E-04	3.19E-03	0.00E+00	0.00E+00	4.52E-05	5.97E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	8.77E+01	0.10	8.33E+01	3.19E-03	4.00E+02	4.48E+283	1.93E-05	1.70E-03	NA	3.5E-02
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END

RESULTS SHEET

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	2.15E+04	2.15E+04	3.50E+06	2.15E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																		
156592		4.37E+03		cis-1,2-Dichloroethylene																		
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)											
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																	
			10	200	669			365	304			B	SIC	SC								
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)											
												SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216			
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	1000	1000	366	0.1	0.5	5								
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	25	25	250	1.0E-05	1											
												Used to calculate risk-based groundwater concentration.										

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.36E-02	1.13E-05	4.07E-03	25	7,192	333.65	544.00	3.55E+01	3.50E+03	0.0E+00	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	7,734	2.04E-03	8.77E-02	1.75E-04	1.90E-03	3.82E-03	0.00E+00	5.53E-05	1.30E-04	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
--	---	--------------------------------------	---	---	---	--	---	--	--	---

200	8.77E+01	0.10	8.33E+01	1.90E-03	4.00E+02	#NUM!	9.79E-06	8.59E-04	NA	3.5E-02
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END

RESULTS SHEET

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	5.95E+04	5.95E+04	3.50E+06	5.95E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																		
156592		4.37E+03		cis-1,2-Dichloroethylene																		
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)											
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																	
			10	200	669			365	304			B	SIC	SC								
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)											
												SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216			
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	1000	1000	366	0.1	0.5	5								
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-05	1											
Used to calculate risk-based groundwater concentration.																						

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.36E-02	1.13E-05	4.07E-03	25	7,192	333.65	544.00	3.55E+01	3.50E+03	0.0E+00	3.5E-02

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	7,734	2.04E-03	8.77E-02	1.75E-04	1.90E-03	3.82E-03	0.00E+00	5.53E-05	1.30E-04	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	8.77E+01	0.10	8.33E+01	1.90E-03	4.00E+02	#NUM!	9.79E-06	8.59E-04	NA	3.5E-02
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END

RESULTS SHEET

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	4.25E+04	4.25E+04	3.50E+06	4.25E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																	
156605		4.37E+03		trans-1,2-Dichloroethylene																	
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)										
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																
			308																		
10	200	308	308			A	C	C													
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)										
												C	1.43	0.459	0.215						
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	1000	1000	366	0.1	0.5	5							
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	25	25	250	1.0E-05	1										
				Used to calculate risk-based groundwater concentration.																	

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.07E-02	1.19E-05	9.36E-03	25	6,717	320.85	516.50	5.25E+01	6.30E+03	0.0E+00	7.0E-02

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	7,136	4.94E-03	2.13E-01	1.75E-04	3.06E-03	0.00E+00	0.00E+00	2.67E-05	3.52E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	2.13E+02	0.10	8.33E+01	3.06E-03	4.00E+02	2.96E+295	1.15E-05	2.44E-03	NA	7.0E-02
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END

RESULTS SHEET

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	4.19E+04	4.19E+04	6.30E+06	4.19E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.
MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																	
156605		4.37E+03		trans-1,2-Dichloroethylene																	
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)										
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																
			308					A	C		C										
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)										
												C	1.43	0.459	0.215						
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	1000	1000	366	0.1	0.5	5							
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-05	1										
						Used to calculate risk-based groundwater concentration.															

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.07E-02	1.19E-05	9.36E-03	25	6,717	320.85	516.50	5.25E+01	6.30E+03	0.0E+00	7.0E-02

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	7,136	4.94E-03	2.13E-01	1.75E-04	3.06E-03	0.00E+00	0.00E+00	2.67E-05	3.52E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	2.13E+02	0.10	8.33E+01	3.06E-03	4.00E+02	2.96E+295	1.15E-05	2.44E-03	NA	7.0E-02
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END

RESULTS SHEET

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	2.99E+04	2.99E+04	6.30E+06	2.99E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																		
156605		4.37E+03		trans-1,2-Dichloroethylene																		
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)											
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																	
			10	200	669			365	304			B	SIC	SC								
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)											
												SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216			
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	1000	1000	366	0.1	0.5	5								
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	25	25	250	1.0E-05	1											
Used to calculate risk-based groundwater concentration.																						

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.07E-02	1.19E-05	9.36E-03	25	6,717	320.85	516.50	5.25E+01	6.30E+03	0.0E+00	7.0E-02

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	7,136	4.94E-03	2.13E-01	1.75E-04	1.83E-03	3.67E-03	0.00E+00	3.63E-05	8.65E-05	469
----------	----------	----------	-----	-------	----------	----------	----------	----------	----------	----------	----------	----------	-----

Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
--	---	--------------------------------------	---	---	---	--	---	--	--	---

200	2.13E+02	0.10	8.33E+01	1.83E-03	4.00E+02	#NUM!	6.51E-06	1.38E-03	NA	7.0E-02
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END

RESULTS SHEET

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	7.38E+04	7.38E+04	6.30E+06	7.38E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																		
156605		4.37E+03		trans-1,2-Dichloroethylene																		
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)											
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																	
			10	200	669			365	304			B	SIC	SC								
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)											
												SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216			
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	1000	1000	366	0.1	0.5	5								
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-05	1											
Used to calculate risk-based groundwater concentration.																						

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.07E-02	1.19E-05	9.36E-03	25	6,717	320.85	516.50	5.25E+01	6.30E+03	0.0E+00	7.0E-02

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	7,136	4.94E-03	2.13E-01	1.75E-04	1.83E-03	3.67E-03	0.00E+00	3.63E-05	8.65E-05	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	2.13E+02	0.10	8.33E+01	1.83E-03	4.00E+02	#NUM!	6.51E-06	1.38E-03	NA	7.0E-02
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END

RESULTS SHEET

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	5.27E+04	5.27E+04	6.30E+06	5.27E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

MESSAGE: Risk/HQ or risk-based groundwater concentration is based on a route-to-route extrapolation.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																	
127184		4.37E+03		Tetrachloroethylene																	
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)										
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																
			308																		
10	200	308	308			A	C	C													
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)										
												C	1.43	0.459	0.215						
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	1000	1000	366	0.1	0.5	5							
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	25	25	250	1.0E-05	1										
				Used to calculate risk-based groundwater concentration.																	

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	6.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
---	--	--	---	---	--	--	---	---	---	---	---	---	---

5.08E+04	1.80E+06	2.22E-04	200	9,553	7.81E-03	3.36E-01	1.75E-04	3.12E-03	0.00E+00	0.00E+00	1.91E-05	2.53E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	3.36E+02	0.10	8.33E+01	3.12E-03	4.00E+02	1.67E+290	8.24E-06	2.77E-03	5.9E-06	6.0E-01
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END

RESULTS SHEET

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)
2.50E+03	3.16E+05	2.50E+03	2.00E+05	2.50E+03

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																	
127184		4.37E+03		Tetrachloroethylene																	
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)										
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																
			308																		
10	200	308	308			A	C	C													
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)										
												C	1.43	0.459	0.215						
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	1000	1000	366	0.1	0.5	5							
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-05	1										
				Used to calculate risk-based groundwater concentration.																	

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	6.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
---	--	--	---	---	--	--	---	---	---	---	---	---	---

5.08E+04	1.80E+06	2.22E-04	200	9,553	7.81E-03	3.36E-01	1.75E-04	3.12E-03	0.00E+00	0.00E+00	1.91E-05	2.53E-05	108
----------	----------	----------	-----	-------	----------	----------	----------	----------	----------	----------	----------	----------	-----

Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	3.36E+02	0.10	8.33E+01	3.12E-03	4.00E+02	1.67E+290	8.24E-06	2.77E-03	5.9E-06	6.0E-01
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END

RESULTS SHEET

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)
1.49E+03	2.26E+05	1.49E+03	2.00E+05	1.49E+03

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES ☒

Reset to
Defaults

OR

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

YES ☐

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical								
127184		4.37E+03		Tetrachloroethylene								
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) 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)
10	200	669	365	304				B	SIC	SC		

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)
SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216				

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	1000	1000	366	0.1	0.5	5

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	25	25	250	1.0E-05	1

END

Used to calculate risk-based
groundwater concentration.

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	6.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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_e (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)
7.88E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000

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)
5.08E+04	1.80E+06	2.22E-04	200	9,553	7.81E-03	3.36E-01	1.75E-04	1.86E-03	3.74E-03	0.00E+00	2.89E-05	6.92E-05	469

Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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, $\exp(Pe^I)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
200	3.36E+02	0.10	8.33E+01	1.86E-03	4.00E+02	#NUM!	5.21E-06	1.75E-03	5.9E-06	6.0E-01

END

RESULTS SHEET

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)
3.95E+03	5.00E+05	3.95E+03	2.00E+05	3.95E+03

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES

X

OR

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

YES

ENTER
Chemical
CAS No.
(numbers only,
no dashes)

127184

ENTER
Initial
groundwater
conc.,
 C_w
($\mu\text{g/L}$)

4.37E+03

Chemical

Tetrachloroethylene

MORE
↓

ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) <table><tr><td>ENTER Thickness of soil stratum A, h_A (cm)</td><td>ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)</td><td>ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)</td></tr></table>			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)
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)											
10	200	669	365	304		B	SIC	SC					

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)
SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216				

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	1000	1000	366	0.1	0.5	5

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-05	1

END

Used to calculate risk-based
groundwater concentration.

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	1.55E+02	2.00E+02	5.9E-06	6.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
---	--	--	---	---	--	--	---	---	---	---	---	---	---

5.08E+04	1.80E+06	2.22E-04	200	9,553	7.81E-03	3.36E-01	1.75E-04	1.86E-03	3.74E-03	0.00E+00	2.89E-05	6.92E-05	469
----------	----------	----------	-----	-------	----------	----------	----------	----------	----------	----------	----------	----------	-----

Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
--	---	--------------------------------------	---	---	---	--	---	--	--	---

200	3.36E+02	0.10	8.33E+01	1.86E-03	4.00E+02	#NUM!	5.21E-06	1.75E-03	5.9E-06	6.0E-01
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END

RESULTS SHEET

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)
2.35E+03	3.57E+05	2.35E+03	2.00E+05	2.35E+03

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES ☒

Reset to
Defaults

OR

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

YES ☐

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical	
79016		4.37E+03		Trichloroethylene	

ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)
Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)								
10	200	308	308			A	C	C		

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)
C	1.43	0.459	0.215								

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	1000	1000	366	0.1	0.5	5

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	25	25	250	1.0E-05	1

END

Used to calculate risk-based
groundwater concentration.

DATA ENTRY SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/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	4.0E-06	2.0E-03

END

DATA ENTRY SHEET

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)
7.88E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000

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_{A}^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_{B}^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_{C}^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
5.08E+04	1.80E+06	2.22E-04	200	8,557	4.78E-03	2.06E-01	1.75E-04	3.42E-03	0.00E+00	0.00E+00	2.53E-05	3.34E-05	108

Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/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, $\exp(Pe')$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m ³)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
200	2.06E+02	0.10	8.33E+01	3.42E-03	4.00E+02	2.94E+264	1.09E-05	2.24E-03	4.0E-06	2.0E-03

END

DATA ENTRY SHEET

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS:

INCREMENTAL RISK 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)	Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
4.56E+03	1.30E+03	1.30E+03	1.47E+06	1.30E+03	NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES ☒

Reset to
Defaults

OR

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

YES ☐

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical	
79016		4.37E+03		Trichloroethylene	

ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)
Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)				A	C	C		

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)
C	1.43	0.459	0.215								

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	1000	1000	366	0.1	0.5	5

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-05	1

END

Used to calculate risk-based
groundwater concentration.

DATA ENTRY SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/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	4.0E-06	2.0E-03

END

DATA ENTRY SHEET

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_{ie} (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	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000

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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
5.08E+04	1.80E+06	2.22E-04	200	8,557	4.78E-03	2.06E-01	1.75E-04	3.42E-03	0.00E+00	0.00E+00	2.53E-05	3.34E-05	108

Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/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, $\exp(Pe')$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m ³)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
200	2.06E+02	0.10	8.33E+01	3.42E-03	4.00E+02	2.94E+264	1.09E-05	2.24E-03	4.0E-06	2.0E-03

END

DATA ENTRY SHEET

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)
2.72E+03	9.31E+02	9.31E+02	1.47E+06	9.31E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

RESULTS SHEET

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 ☐

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical								
79016		4.37E+03		Trichloroethylene								
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) 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)
10	200	669	365	304			B	SIC	SC			
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)	
SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216					
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	1000	1000	366	0.1	0.5	5					
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	25	25	250	1.0E-05	1							
				Used to calculate risk-based groundwater concentration.								

END

RESULTS SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/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	4.0E-06	2.0E-03

END

RESULTS SHEET

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_{ie} (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)
7.88E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000

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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
5.08E+04	1.80E+06	2.22E-04	200	8,557	4.78E-03	2.06E-01	1.75E-04	2.04E-03	4.10E-03	0.00E+00	3.60E-05	8.61E-05	469

Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/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., $C_{building}$ (μg/m ³)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
200	2.06E+02	0.10	8.33E+01	2.04E-03	4.00E+02	#NUM!	6.48E-06	1.33E-03	4.0E-06	2.0E-03

END

RESULTS SHEET

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)
7.67E+03	2.19E+03	2.19E+03	1.47E+06	2.19E+03

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

RESULTS SHEET

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 ☐

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical								
79016		4.37E+03		Trichloroethylene								
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28) 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)
10	200	669	365	304			B	SIC	SC			
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)	
SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216					
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	1000	1000	366	0.1	0.5	5					
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-05	1							
				Used to calculate risk-based groundwater concentration.								

END

RESULTS SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (ug/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	4.0E-06	2.0E-03

END

RESULTS SHEET

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_{ie} (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	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000

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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
5.08E+04	1.80E+06	2.22E-04	200	8,557	4.78E-03	2.06E-01	1.75E-04	2.04E-03	4.10E-03	0.00E+00	3.60E-05	8.61E-05	469

Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/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., $C_{building}$ (μg/m ³)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
200	2.06E+02	0.10	8.33E+01	2.04E-03	4.00E+02	#NUM!	6.48E-06	1.33E-03	4.0E-06	2.0E-03

END

RESULTS SHEET

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)
4.56E+03	1.57E+03	1.57E+03	1.47E+06	1.57E+03

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

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

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																	
75014		4.37E+03		Vinyl chloride (chloroethene)																	
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)										
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																
			308																		
10	200	308	308			A	C	C													
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)										
												C	1.43	0.459	0.215						
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)														
							5														
10	40	1000	1000	366	0.1	0.5															
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)																
						Used to calculate risk-based groundwater concentration.															
70	25	25	250	1.0E-05	1																

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
1.06E-01	1.23E-05	2.69E-02	25	5,250	259.25	432.00	1.86E+01	8.80E+03	8.8E-06	1.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	5,000	1.72E-02	7.41E-01	1.75E-04	4.59E-03	0.00E+00	0.00E+00	2.33E-05	3.09E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	7.41E+02	0.10	8.33E+01	4.59E-03	4.00E+02	1.43E+197	1.01E-05	7.46E-03	8.8E-06	1.0E-01
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END

RESULTS SHEET

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)
6.23E+02	1.96E+04	6.23E+02	8.80E+06	6.23E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																	
75014		4.37E+03		Vinyl chloride (chloroethene)																	
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)										
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																
			308																		
10	200	308	308			A	C	C													
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)										
												C	1.43	0.459	0.215						
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)														
							5														
10	40	1000	1000	366	0.1	0.5															
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)																
						Used to calculate risk-based groundwater concentration.															
70	30	30	350	1.0E-05	1																

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
1.06E-01	1.23E-05	2.69E-02	25	5,250	259.25	432.00	1.86E+01	8.80E+03	8.8E-06	1.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	108	0.244	ERROR	ERROR	0.324	2.26E-09	0.821	1.86E-09	81.52	0.459	0.047	0.412	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	5,000	1.72E-02	7.41E-01	1.75E-04	4.59E-03	0.00E+00	0.00E+00	2.33E-05	3.09E-05	108
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	7.41E+02	0.10	8.33E+01	4.59E-03	4.00E+02	1.43E+197	1.01E-05	7.46E-03	8.8E-06	1.0E-01
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END

RESULTS SHEET

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)
3.71E+02	1.40E+04	3.71E+02	8.80E+06	3.71E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																		
75014		4.37E+03		Vinyl chloride (chloroethene)																		
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)											
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																	
			10	200	669			365	304			B	SIC	SC								
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)											
												SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216			
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	1000	1000	366	0.1	0.5	5								
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	25	25	250	1.0E-05	1											
Used to calculate risk-based groundwater concentration.																						

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
1.06E-01	1.23E-05	2.69E-02	25	5,250	259.25	432.00	1.86E+01	8.80E+03	8.8E-06	1.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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7.88E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	5,000	1.72E-02	7.41E-01	1.75E-04	2.74E-03	5.50E-03	0.00E+00	3.78E-05	9.07E-05	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	7.41E+02	0.10	8.33E+01	2.74E-03	4.00E+02	#NUM!	6.82E-06	5.05E-03	8.8E-06	1.0E-01
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END

RESULTS SHEET

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)
9.19E+02	2.89E+04	9.19E+02	8.80E+06	9.19E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

DATA ENTRY SHEET

GW-ADV
Version 3.1; 02/04Reset to
Defaults

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

YES

X

OR

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

YES

ENTER Chemical CAS No. (numbers only, no dashes)		ENTER Initial groundwater conc., C_w ($\mu\text{g/L}$)		Chemical																		
75014		4.37E+03		Vinyl chloride (chloroethene)																		
ENTER Average soil/ groundwater temperature, T_s ($^{\circ}\text{C}$)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to water table, L_{WT} (cm)	ENTER Totals must add up to value of L_{WT} (cell G28)			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)											
			Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)																	
			10	200	669			365	304			B	SIC	SC								
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)											
												SC	1.63	0.385	0.197	SIC	1.38	0.481	0.216			
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	1000	1000	366	0.1	0.5	5								
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-05	1											
												Used to calculate risk-based groundwater concentration.										

END

CHEMICAL PROPERTIES SHEET

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 (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm ³ /g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
1.06E-01	1.23E-05	2.69E-02	25	5,250	259.25	432.00	1.86E+01	8.80E+03	8.8E-06	1.0E-01

END

INTERMEDIATE CALCULATIONS SHEET

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)
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9.46E+08	469	0.188	0.265	ERROR	0.299	1.74E-09	0.837	1.46E-09	192.31	0.481	0.057	0.424	4,000
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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_A^{eff} (cm ² /s)	Stratum B effective diffusion coefficient, D_B^{eff} (cm ² /s)	Stratum C effective diffusion coefficient, D_C^{eff} (cm ² /s)	Capillary zone effective diffusion coefficient, D_{cz}^{eff} (cm ² /s)	Total overall effective diffusion coefficient, D_T^{eff} (cm ² /s)	Diffusion path length, L_d (cm)
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5.08E+04	1.80E+06	2.22E-04	200	5,000	1.72E-02	7.41E-01	1.75E-04	2.74E-03	5.50E-03	0.00E+00	3.78E-05	9.07E-05	469
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Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/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., $C_{building}$ (µg/m ³)	Unit risk factor, URF (µg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)
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200	7.41E+02	0.10	8.33E+01	2.74E-03	4.00E+02	#NUM!	6.82E-06	5.05E-03	8.8E-06	1.0E-01
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END

RESULTS SHEET

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)
5.47E+02	2.06E+04	5.47E+02	8.80E+06	5.47E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL
DOWN
TO "END"

END

VLOOKUP TABLES

Soil Properties Lookup Table										SCS Soil Name
SCS Soil Type	K _s (cm/h)	α ₁ (1/cm)	N (unitless)	M (unitless)	n (cm ³ /cm ³)	θ _r (cm ³ /cm ³)	Mean Grain Diameter (cm)	Bulk Density (g/cm ³)	θ _w (cm ³ /cm ³)	
C	0.61	0.01496	1.253	0.2019	0.459	0.098	0.0092	1.43	0.215	Clay
CL	0.34	0.01581	1.416	0.2938	0.442	0.079	0.016	1.48	0.168	Clay Loam
L	0.50	0.01112	1.472	0.3207	0.399	0.061	0.020	1.59	0.148	Loam
LS	4.38	0.03475	1.746	0.4273	0.390	0.049	0.040	1.62	0.076	Loamy Sand
S	26.78	0.03524	3.177	0.6852	0.375	0.053	0.044	1.66	0.054	Sand
SC	0.47	0.03342	1.208	0.1722	0.385	0.117	0.025	1.63	0.197	Sandy Clay
SCL	0.55	0.02109	1.330	0.2481	0.384	0.063	0.029	1.63	0.146	Sandy Clay Loam
SI	1.82	0.00658	1.679	0.4044	0.489	0.050	0.0046	1.35	0.167	Silt
SIC	0.40	0.01622	1.321	0.2430	0.481	0.111	0.0039	1.38	0.216	Silty Clay
SICL	0.46	0.00839	1.521	0.3425	0.482	0.090	0.0056	1.37	0.198	Silty Clay Loam
SIL	0.76	0.00506	1.663	0.3987	0.439	0.065	0.011	1.49	0.180	Silt Loam
SL	1.60	0.02667	1.449	0.3099	0.387	0.039	0.030	1.62	0.103	Sandy Loam

Chemical Properties Lookup Table															
CAS No.	Chemical	Organic carbon partition coefficient, K _{oc} (cm ³ /g)	Diffusivity in air, D _a (cm ² /s)	Diffusivity in water, D _w (cm ² /s)	Pure component water solubility, S (mg/L)	Henry's law constant H' (unitless)	Henry's law constant at reference temperature, H (atm·m ³ /mol)	Henry's law constant reference temperature, T _R (°C)	Normal boiling point, T _B (°K)	Critical temperature, T _C (°K)	Enthalpy of vaporization at the normal boiling point, ΔH _{v,b} (cal/mol)	Unit risk factor, URF (μg/m ³) ⁻¹	Reference conc., RfC (mg/m ³)	URF extrapolated (X)	RfC extrapolated (X)
		(cm ³ /g)	(cm ² /s)	(cm ² /s)	(mg/L)	(unitless)	(atm·m ³ /mol)	(°C)	(°K)	(°K)	(cal/mol)	(μg/m ³) ⁻¹	(mg/m ³)	(X)	(X)
56235	Carbon tetrachloride	1.74E+02	7.80E-02	8.80E-06	7.93E+02	1.24E+00	3.03E-02	25	349.90	556.60	7,127	1.5E-05	0.0E+00		
57749	Chlordane	1.20E+05	1.18E-02	4.37E-06	5.60E-02	1.99E-03	4.85E-05	25	624.24	885.73	14,000	1.0E-04	7.0E-04		
58899	gamma-HCH (Lindane)	1.07E+03	1.42E-02	7.34E-06	7.30E+00	5.73E-04	1.40E-05	25	596.55	839.36	15,000	3.7E-04	1.1E-03	X	X
60297	Ethyl ether	5.73E+00	7.82E-02	8.61E-06	5.68E+04	1.35E+00	3.29E-02	25	307.50	466.74	6,338	0.0E+00	7.0E-01		X
60571	Dieldrin	2.14E+04	1.25E-02	4.74E-06	1.95E-01	6.18E-04	1.51E-05	25	613.32	842.25	17,000	4.6E-03	1.8E-04		X
67641	Acetone	5.75E-01	1.24E-01	1.14E-05	1.00E+06	1.59E-03	3.87E-05	25	329.20	508.10	6,955	0.0E+00	3.5E-01		X
67663	Chloroform	3.98E+01	1.04E-01	1.00E-05	7.92E+03	1.50E-01	3.66E-03	25	334.32	536.40	6,988	2.3E-05	0.0E+00		
67721	Hexachloroethane	1.78E+03	2.50E-03	6.80E-06	5.00E+01	1.59E-01	3.88E-03	25	458.00	695.00	9,510	4.0E-06	3.5E-03		X
71432	Benzene	5.89E+01	8.80E-02	9.80E-06	1.79E+03	2.27E-01	5.54E-03	25	353.24	562.16	7,342	7.8E-06	3.0E-02		
71556	1,1,1-Trichloroethane	1.10E+02	7.80E-02	8.80E-06	1.33E+03	7.03E-01	1.72E-02	25	347.24	545.00	7,136	0.0E+00	2.2E+00		
72435	Methoxychlor	9.77E+04	1.56E-02	4.46E-06	1.00E-01	6.46E-04	1.58E-05	25	651.02	848.49	16,000	0.0E+00	1.8E-02		X
72559	DDE	4.47E+06	1.44E-02	5.87E-06	1.20E-01	8.59E-04	2.09E-05	25	636.44	860.38	15,000	9.7E-05	0.0E+00	X	
74839	Methyl bromide	1.05E+01	7.28E-02	1.21E-05	1.52E+04	2.55E-01	6.22E-03	25	276.71	467.00	5,714	0.0E+00	5.0E-03		
74873	Methyl chloride (chloromethane)	2.12E+00	1.26E-01	6.50E-06	5.33E+03	3.61E-01	8.80E-03	25	249.00	416.25	5,115	1.0E-06	9.0E-02		
74908	Hydrogen cyanide	3.80E+00	1.93E-01	2.10E-05	1.00E+06	5.44E-03	1.33E-04	25	299.00	456.70	6,676	0.0E+00	3.0E-03		
74953	Methylene bromide	1.26E+01	4.30E-02	8.44E-06	1.19E+04	3.52E-02	8.59E-04	25	370.00	583.00	7,868	0.0E+00	3.5E-02		X
75003	Chloroethane (ethyl chloride)	4.40E+00	2.71E-01	1.15E-05	5.68E+03	3.61E-01	8.80E-03	25	285.30	460.40	5,879	8.3E-07	1.0E+01	X	
75014	Vinyl chloride (chloroethene)	1.86E+01	1.06E-01	1.23E-05	8.80E+03	1.10E+00	2.69E-02	25	259.25	432.00	5,250	8.8E-06	1.0E-01		
75058	Acetonitrile	4.20E+00	1.28E-01	1.66E-05	1.00E+06	1.42E-03	3.45E-05	25	354.60	545.50	7,110	0.0E+00	6.0E-02		
75070	Acetaldehyde	1.06E+00	1.24E-01	1.41E-05	1.00E+06	3.23E-03	7.87E-05	25	293.10	466.00	6,157	2.2E-06	9.0E-03		
75092	Methylene chloride	1.17E+01	1.01E-01	1.17E-05	1.30E+04	8.96E-02	2.18E-03	25	313.00	510.00	6,706	4.7E-07	3.0E+00		
75150	Carbon disulfide	4.57E+01	1.04E-01	1.00E-05	1.19E+03	1.24E+00	3.02E-02	25	319.00	552.00	6,391	0.0E+00	7.0E-01		
75218	Ethylene oxide	1.33E+00	1.04E-01	1.45E-05	3.04E+05	2.27E-02	5.54E-04	25	283.60	469.00	6,104	1.0E-04	0.0E+00		
75252	Bromoform	8.71E+01	1.49E-02	1.03E-05	3.10E+03	2.41E-02	5.88E-04	25	422.35	696.00	9,479	1.1E-06	7.0E-02		X
75274	Bromodichloromethane	5.50E+01	2.98E-02	1.06E-05	6.74E+03	6.54E-02	1.60E-03	25	363.15	585.85	7,800	1.8E-05	7.0E-02	X	X
75296	2-Chloropropane	9.14E+00	8.88E-02	1.01E-05	3.73E+03	5.93E-01	1.45E-02	25	308.70	485.00	6,286	0.0E+00	1.0E-01		
75343	1,1-Dichloroethane	3.16E+01	7.42E-02	1.05E-05	5.06E+03	2.30E-01	5.61E-03	25	330.55	523.00	6,895	0.0E+00	5.0E-01		
75354	1,1-Dichloroethylene	5.89E+01	9.00E-02	1.04E-05	2.25E+03	1.07E+00	2.60E-02	25	304.75	576.05	6,247	0.0E+00	2.0E-01		
75456	Chlorodifluoromethane	4.79E+01	1.01E-01	1.28E-05	2.00E+00	1.10E+00	2.70E-02	25	232.40	369.30	4,836	0.0E+00	5.0E+01		
75694	Trichlorofluoromethane	4.97E+02	8.70E-02	9.70E-06	1.10E+03	3.97E+00	9.68E-02	25	296.70	471.00	5,999	0.0E+00	7.0E-01		
75718	Dichlorodifluoromethane	4.57E+02	6.65E-02	9.92E-06	2.80E+02	1.40E+01	3.42E-01	25	243.20	384.95	9,421	0.0E+00	2.0E-01		
76131	1,1,2-Trichloro-1,2,2-trifluoroethane	1.11E+04	7.80E-02	8.20E-06	1.70E+02	1.97E+01	4.80E-01	25	320.70	487.30	6,463	0.0E+00	3.0E+01		
76448	Heptachlor	1.41E+06	1.12E-02	5.69E-06	1.80E-01	6.05E+01	1.48E+00	25	603.69	846.31	13,000	1.3E-03	1.8E-03		X
77474	Hexachlorocyclopentadiene	2.00E+05	1.61E-02	7.21E-06	1.80E+00	1.10E+00	2.69E-02	25	512.15	746.00	10,931	0.0E+00	2.0E-04		
78831	Isobutanol	2.59E+00	8.60E-02	9.30E-06	8.50E+04	4.83E-04	1.18E-05	25	381.04	547.78	10,936	0.0E+00	1.1E+00		X
78875	1,2-Dichloropropane	4.37E+01	7.82E-02	8.73E-06	2.80E+03	1.15E-01	2.79E-03	25	369.52	572.00	7,590	1.9E-05	4.0E-03	X	
78933	Methylethylketone (2-butanone)	2.30E+00	8.08E-02	9.80E-06	2.23E+05	2.29E-03	5.58E-05	25	352.50	536.78	7,481	0.0E+00	5.0E+00		
79005	1,1,2-Trichloroethane	5.01E+01	7.80E-02	8.80E-06	4.42E+03	3.73E-02	9.11E-04	25	386.15	602.00	8,322	1.6E-05	1.4E-02		X
79016	Trichloroethylene	1.66E+02	7.90E-02	9.10E-06	1.47E+03	4.21E-01	1.03E-02	25	360.36	544.20	7,505	1.1E-04	4.0E-02	X	
79209	Methyl acetate	3.26E+00	1.04E-01	1.00E-05	2.00E+03	4.84E-03	1.18E-04	25	329.80	506.70	7,260	0.0E+00	3.5E+00		X
79345	1,1,2,2-Tetrachloroethane	9.33E+01	7.10E-02	7.90E-06	2.96E+03	1.41E-02	3.44E-04	25	419.60	661.15	8,996	5.8E-05	2.1E-01		X
79469	2-Nitropropane	1.17E+01	9.23E-02	1.01E-05	1.70E+04	5.03E-03	1.23E-04	25	393.20	594.00	8,383	2.7E-03	2.0E-02		
80626	Methylmethacrylate	6.98E+00	7.70E-02	8.60E-06	1.50E+04	1.38E-02	3.36E-04	25	373.50	567.00	8,975	0.0E+00	7.0E-01		
83329	Acenaphthene	7.08E+03	4.21E-02	7.69E-06	3.57E+00	6.34E-03	1.55E-04	25	550.54	803.15	12,155	0.0E+00	2.1E-01		X
86737	Fluorene	1.38E+04	3.63E-02	7.88E-06	1.98E+00	2.60E-03	6.34E-05	25	570.44	870.00	12,666	0.0E+00	1.4E-01		X
87683	Hexachloro-1,3-butadiene	5.37E+04	5.61E-02	6.16E-06	3.20E+00	3.33E-01	8.13E-03	25	486.15	738.00	10,206	2.2E-05	7.0E-04		X
88722	o-Nitrotoluene	3.24E+02	5.87E-02	8.67E-06	6.50E+02	5.11E-04	1.25E-05	25	495.00	720.00	12,239	0.0E+00	3.5E-02		X
91203	Naphthalene	2.00E+03	5.90E-02	7.50E-06	3.10E+01	1.98E-02	4.82E-04	25	491.14	748.40	10,373	0.0E+00	3.0E-03		
91576	2-Methylnaphthalene	2.81E+03	5.22E-02	7.75E-06	2.46E+01	2.12E-02	5.17E-04	25	514.26	761.00	12,600	0.0E+00	7.0E-02		X

VLOOKUP TABLES

92524 Biphenyl	4.38E+03	4.04E-02	8.15E-06	7.45E+00	1.23E-02	2.99E-04	25	529.10	789.00	10,890	0.0E+00	1.8E-01		X
95476 o-Xylene	3.63E+02	8.70E-02	1.00E-05	1.78E+02	2.12E-01	5.18E-03	25	417.60	630.30	8,661	0.0E+00	1.0E-01		
95501 1,2-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	1.56E+02	7.77E-02	1.90E-03	25	453.57	705.00	9,700	0.0E+00	2.0E-01		
95578 2-Chlorophenol	3.88E+02	5.01E-02	9.46E-06	2.20E+04	1.60E-02	3.90E-04	25	447.53	675.00	9,572	0.0E+00	1.8E-02		X
95636 1,2,4-Trimethylbenzene	1.35E+03	6.06E-02	7.92E-06	5.70E+01	2.52E-01	6.14E-03	25	442.30	649.17	9,369	0.0E+00	6.0E-03		
96184 1,2,3-Trichloropropane	2.20E+01	7.10E-02	7.90E-06	1.75E+03	1.67E-02	4.08E-04	25	430.00	652.00	9,171	5.7E-04	4.9E-03	X	
96333 Methyl acrylate	4.53E+00	9.76E-02	1.02E-05	6.00E+04	7.68E-03	1.87E-04	25	353.70	536.00	7,749	0.0E+00	1.1E-01		X
97632 Ethylmethacrylate	2.95E+01	6.53E-02	8.37E-06	3.67E+03	3.44E-02	8.40E-04	25	390.00	571.00	10,957	0.0E+00	3.2E-01		X
98066 tert-Butylbenzene	7.71E+02	5.65E-02	8.02E-06	2.95E+01	4.87E-01	1.19E-02	25	442.10	1220.00	8,980	0.0E+00	1.4E-01		X
98828 Cumene	4.89E+02	6.50E-02	7.10E-06	6.13E+01	4.74E+01	1.46E-02	25	425.56	631.10	10,335	0.0E+00	4.0E-01		
98862 Acetophenone	5.77E+01	6.00E-02	8.73E-06	6.13E+03	4.38E-04	1.07E-05	25	475.00	709.50	11,732	0.0E+00	3.5E-01		X
98953 Nitrobenzene	6.46E+01	7.60E-02	8.60E-06	2.09E+03	9.82E-04	2.39E-05	25	483.95	719.00	10,566	0.0E+00	2.0E-03		
100414 Ethylbenzene	3.63E+02	7.50E-02	7.80E-06	1.69E+02	3.22E-01	7.86E-03	25	409.34	617.20	8,501	0.0E+00	1.0E+00		
100425 Styrene	7.76E+02	7.10E-02	8.00E-06	3.10E+02	1.12E-01	2.74E-03	25	418.31	636.00	8,737	0.0E+00	1.0E+00		
100447 Benzylchloride	6.14E+01	7.50E-02	7.80E-06	5.25E+02	1.70E-02	4.14E-04	25	452.00	685.00	8,773	4.9E-05	0.0E+00	X	
100527 Benzaldehyde	4.59E+01	7.21E-02	9.07E-06	3.30E+03	9.73E-04	2.37E-05	25	452.00	695.00	11,658	0.0E+00	3.5E-01		X
103651 n-Propylbenzene	5.62E+02	6.01E-02	7.83E-06	6.00E+01	4.37E-01	1.07E-02	25	432.20	630.00	9,123	0.0E+00	1.4E-01		X
104518 n-Butylbenzene	1.11E+03	5.70E-02	8.12E-06	2.00E+00	5.38E-01	1.31E-02	25	456.46	660.50	9,290	0.0E+00	1.4E-01		X
106423 p-Xylene	3.89E+02	7.69E-02	8.44E-06	1.85E+02	3.13E-01	7.64E-03	25	411.52	616.20	8,525	0.0E+00	1.0E-01		
106467 1,4-Dichlorobenzene	6.17E+02	6.90E-02	7.90E-06	7.90E+01	9.82E-02	2.39E-03	25	447.21	684.75	9,271	0.0E+00	8.0E-01		
106934 1,2-Dibromoethane (ethylene dibr	2.50E+01	2.17E-02	1.19E-05	4.18E+03	3.04E-02	7.41E-04	25	404.60	583.00	8,310	2.2E-04	2.0E-04		
106990 1,3-Butadiene	1.91E+01	2.49E-01	1.08E-05	7.35E+02	3.01E+00	7.34E-02	25	268.60	425.00	5,370	3.0E-02	2.0E-03		
107028 Acrolein	2.76E+00	1.05E-01	1.22E-05	2.13E+05	4.99E-03	1.22E-04	25	325.60	506.00	6,731	0.0E+00	2.0E-05		
107062 1,2-Dichloroethane	1.74E+01	1.04E-01	9.90E-06	8.52E+03	4.00E-02	9.77E-04	25	356.65	561.00	7,643	2.6E-05	0.0E+00		
107131 Acrylonitrile	5.90E+00	1.22E-01	1.34E-05	7.40E+04	4.21E-03	1.03E-04	25	350.30	519.00	7,786	6.8E-05	2.0E-03		
108054 Vinyl acetate	5.25E+00	8.50E-02	9.20E-06	2.00E+04	2.09E-02	5.10E-04	25	345.65	519.13	7,800	0.0E+00	2.0E-01		
108101 Methylisobutylketone (4-methyl-2-	9.06E+00	7.50E-02	7.80E-06	1.90E+04	5.64E-03	1.38E-04	25	389.50	571.00	8,243	0.0E+00	3.0E+00		
108383 m-Xylene	4.07E+02	7.00E-02	7.80E-06	1.61E+02	3.00E-01	7.32E-03	25	412.27	617.05	8,523	0.0E+00	1.0E-01		
108678 1,3,5-Trimethylbenzene	1.35E+03	6.02E-02	8.67E-06	2.00E+00	2.41E-01	5.87E-03	25	437.89	637.25	9,321	0.0E+00	6.0E-03		
108872 Methylcyclohexane	7.85E+01	7.35E-02	8.52E-06	1.40E+01	4.22E+00	1.03E-01	25	373.90	572.20	7,474	0.0E+00	3.0E+00		
108883 Toluene	1.82E+02	8.70E-02	8.60E-06	5.26E+02	2.72E-01	6.62E-03	25	383.78	591.79	7,930	0.0E+00	4.0E-01		
108907 Chlorobenzene	2.19E+02	7.30E-02	8.70E-06	4.72E+02	1.51E-01	3.69E-03	25	404.87	632.40	8,410	0.0E+00	6.0E-02		
109693 1-Chlorobutane	1.72E+01	8.26E-02	1.00E-05	1.10E+03	6.93E-01	1.69E-02	25	351.60	542.00	7,263	0.0E+00	1.4E+00		X
110009 Furan	1.86E+01	1.04E-01	1.22E-05	1.00E+04	2.21E-01	5.39E-03	25	304.60	490.20	6,477	0.0E+00	3.5E-03		X
110543 Hexane	4.34E+01	2.00E-01	7.77E-06	1.24E+01	6.82E+01	1.66E+00	25	341.70	508.00	6,895	0.0E+00	2.0E-01		
111444 Bis(2-chloroethyl)ether	1.55E+01	6.92E-02	7.53E-06	1.72E+04	7.36E-04	1.80E-05	25	451.15	659.79	10,803	3.3E-04	0.0E+00		
115297 Endosulfan	2.14E+03	1.15E-02	4.55E-06	5.10E-01	4.58E-04	1.12E-05	25	674.43	942.94	14,000	0.0E+00	2.1E-02		X
118741 Hexachlorobenzene	5.50E+04	5.42E-02	5.91E-06	5.00E-03	5.40E-02	1.32E-03	25	582.55	825.00	14,447	4.6E-04	2.8E-03		X
120821 1,2,4-Trichlorobenzene	1.78E+03	3.00E-02	8.23E-06	4.88E+01	5.81E-02	1.42E-03	25	486.15	725.00	10,471	0.0E+00	4.0E-03		
123739 Crotonaldehyde (2-butenal)	4.82E+00	9.56E-02	1.07E-05	3.69E+04	7.99E-04	1.95E-05	25	375.20	568.00	9	5.4E-04	0.0E+00	X	
124481 Chlorodibromomethane	6.31E+01	1.96E-02	1.05E-05	2.60E+03	3.20E-02	7.81E-04	25	416.14	678.20	5,900	2.4E-05	7.0E-02	X	X
126987 Methacrylonitrile	3.58E+01	1.12E-01	1.32E-05	2.54E+04	1.01E-02	2.46E-04	25	363.30	554.00	7,600	0.0E+00	7.0E-04		
126998 2-Chloro-1,3-butadiene (chloropre	6.73E+01	8.58E-02	1.03E-05	2.12E+03	4.91E-01	1.20E-02	25	332.40	525.00	8,075	0.0E+00	7.0E-03		
127184 Tetrachloroethylene	1.55E+02	7.20E-02	8.20E-06	2.00E+02	7.53E-01	1.84E-02	25	394.40	620.20	8,288	5.9E-06	6.0E-01		
129000 Pyrene	1.05E+05	2.72E-02	7.24E-06	1.35E+00	4.50E-04	1.10E-05	25	667.95	936	14370	0.0E+00	1.1E-01		X
132649 Dibenzofuran	5.15E+03	2.38E-02	6.00E-06	3.10E+00	5.15E-04	1.26E-05	25	560	824	66400	0.0E+00	1.4E-02		X
135988 sec-Butylbenzene	9.66E+02	5.70E-02	8.12E-06	3.94E+00	5.68E-01	1.39E-02	25	446.5	679	88730	0.0E+00	1.4E-01		X
141786 Ethylacetate	6.44E+00	7.32E-02	9.70E-06	8.03E+04	5.64E-03	1.38E-04	25	350.26	523.3	7633.66	0.0E+00	3.2E+00		X
156592 cis-1,2-Dichloroethylene	3.55E+01	7.36E-02	1.13E-05	3.50E+03	1.67E-01	4.07E-03	25	333.65	544	7192	0.0E+00	3.5E-02		X
156605 trans-1,2-Dichloroethylene	5.25E+01	7.07E-02	1.19E-05	6.30E+03	3.84E-01	9.36E-03	25	320.85	516.5	6717	0.0E+00	7.0E-02		X
205992 Benzo(b)fluoranthene	1.23E+06	2.26E-02	5.56E-06	1.50E-03	4.54E-03	1.11E-04	25	715.9	969.27	17000	2.1E-04	0.0E+00	X	
218019 Chrysene	3.98E+05	2.48E-02	6.21E-06	6.30E-03	3.87E-03	9.44E-05	25	714.15	979	16455	2.1E-06	0.0E+00	X	
309002 Aldrin	2.45E+06	1.32E-02	4.86E-06	1.70E-02	6.95E-03	1.70E-04	25	603.01	839.37	15000	4.9E-03	1.1E-04		X
319846 alpha-HCH (alpha-BHC)	1.23E+03	1.42E-02	7.34E-06	2.00E+00	4.34E-04	1.06E-05	25	596.55	839.36	15000	1.8E-03	0.0E+00		
541731 1,3-Dichlorobenzene	1.98E+03	6.92E-02	7.86E-06	1.34E+02	1.27E-01	3.09E-03	25	446	684	9230.18	0.0E+00	1.1E-01		X
542756 1,3-Dichloropropene	4.57E+01	6.26E-02	1.00E-05	2.80E+03	7.24E-01	1.77E-02	25	381.15	587.38	7900	4.0E-06	2.0E-02		
630206 1,1,1,2-Tetrachloroethane	1.16E+02	7.10E-02	7.90E-06	1.10E+03	9.90E-02	2.41E-03	25	403.5	624	9768.282525	7.4E-06	1.1E-01		X
1634044 MTBE	7.26E+00	1.02E-01	1.05E-05	5.10E+04	2.56E-02	6.23E-04	25	328.3	497.1	6677.66	0.0E+00	3.0E+00		
7439976 Mercury (elemental)	5.20E+01	3.07E-02	6.30E-06	2.00E+01	4.40E-01	1.07E-02	25	629.88	1750	14127	0.0E+00	3.0E-04		

Vapor and Groundwater Monitoring Program

Former GM Delco Plant 5

Kokomo, Indiana

Sampling Program:

A formal Corrective Measures Implementation Work Plan will be prepared and presented in the Corrective Measures Implementation Work Plan and will include details for groundwater and vapor monitoring. Below is a summary of the monitoring program for the purposes of evaluation in the CMP. The expected post-Corrective Measures monitoring schedule, frequency and analysis is presented below:

- 11 soil vapor ports during each quarterly event (2-yrs) (VOCs)
- 60 monitoring wells during each semi-annual event (2-yrs) (depth to water, VOCs)
- 50 monitoring wells during each annual event (3-yrs) (depth to water VOCs)
- 40 monitoring wells during each annual event (25-yrs) (depth to water VOCs)

The number and location of monitoring wells to be sampled and the frequency may be evaluated prior to and during the course of the monitoring period. These changes will be communicated to and approved by USEPA prior to initiating. Additionally, monitoring to evaluate progress of the selected Corrective Measures during implementation will be detailed in the Corrective Measures Implementation Work Plan.

Data Evaluation:

Soil vapor ports are located within the most impacted portion of the off-site plume east of the Site. Soil vapor concentrations will be evaluated via comparison to soil gas vapor intrusion screening criteria that are calculated consistent with the IDEM draft Remediation Closure Guide (2011). Screening criteria for residential and commercial/industrial buildings are presented in Appendix B of the CMP. These criteria will be used to identify the potential need for additional data evaluation to ensure that cumulative risk estimates meet the corrective action endpoints in Table 5 of the CMP.

Groundwater concentrations will be compared to drinking water criteria that are protective of the exposure routes and calculated consistent with the approach used in the RFI Report and CMP. Additionally, off-site groundwater will also be compared to groundwater vapor intrusion screening criteria (presented in Appendix B of the CMP) based on where the monitoring well is located with respect to the existing impacted groundwater plume. Specifically, groundwater concentrations off-site to the east but within the boundary of the existing impacted groundwater plume will be compared to the screening levels in Table B-1; while groundwater concentrations off-site to the west and/or past the eastern boundary of the existing impacted groundwater plume will be compared to the screening levels in Table B-2.

These screening criteria will be used to identify the potential need for additional data evaluation to ensure that cumulative risk estimates meet the corrective action endpoints in Table 5 of the CMP. The evaluation of groundwater or soil gas concentrations to the different screening criteria will be completed after each sampling event. If a concentration in groundwater or soil gas exceeds the screening criteria, RACER Trust will perform additional evaluation. The evaluation may include, but not necessarily be limited to, additional sampling including sub-slab soil vapor and/or indoor air testing.

Additionally, an evaluation of groundwater flow relative to the groundwater flow predictions will be completed as a part of model verification. An evaluation of concentration trends (qualitative or quantitative depending on the circumstances at the time), and comparison to the groundwater contaminant transport predictions will also be completed as part of model verification. The model verification will be completed three years after the initiation of the monitoring program, then at five year

intervals after remediation is complete until concentrations are stable, reducing or become asymptotic, at which point verification will be completed every 10 years, or at a timeframe that is mutually agreeable between USEPA and RACER Trust, The evaluation of groundwater data to the model predictions should provide advance warning should additional measures need to be considered before impacted groundwater associated with the Site reach the edge of the WR-OL District at concentrations exceeding the MCLs.

Table D-1. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Facility-Wide,
Former GM Delco Plant 5, Kokomo, Indiana
Well Restriction Overlay District

Description: Work with county to establish a well restriction overlay district for facility and limited off-site properties. The well restriction overlay district would prohibit installation of additional water supply wells within bounds of district.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Discussions with Government Representatives	1	lump sum	\$8,000	\$8,000
Survey for Existing Wells	1	lump sum	\$5,000	\$5,000
Overlay District Proposal	1	lump sum	\$8,000	\$8,000
Response to Regulator Comments	1	lump sum	\$2,000	\$2,000
<i>Subtotal, Remediation Design and Contracting</i>				\$23,000
25% contingency				\$5,800
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$29,000
<i>Construction/Implementation</i>				
				\$0
<i>Subtotal, Construction/Implementation</i>				\$0
25% contingency				\$0
<i>Subtotal, Construction/Implementation and Contingency</i>				\$0
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$29,000
<i>Operation and Maintenance - Annual</i>				
Survey for Installed Wells	1	year	\$5,000	\$5,000
Reporting	1	year	\$3,000	\$3,000
Utilities	1	year	\$0	\$0
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$8,000
Estimated Total Cost Excluding Operation and Maintenance				\$29,000
Estimated Total Cost Including 30 years of Operation and Maintenance				\$269,000

Assumptions:

Extent of Overlay District to be based on groundwater modeling results and groundwater monitoring data
County agrees to allow creation of overlay district

Table D-2. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Facility-Wide,
Former GM Delco Plant 5, Kokomo, Indiana
Groundwater Deed Restriction

Description: Adopt a groundwater deed restriction for the facility. Restriction would prohibit the installation of potable and non-potable water supply wells within the bounds of the facility.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Draft Groundwater Deed Restriction	1	lump sum	\$3,000	\$3,000
Response to Regulator Comments	1	lump sum	\$2,000	\$2,000
Filing of Deed Restriction	1	lump sum	\$2,000	\$2,000
<i>Subtotal, Remediation Design and Contracting</i>				\$7,000
25% contingency				\$2,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$9,000
<i>Construction/Implementation</i>				\$0
<i>Subtotal, Construction/Implementation</i>				\$0
25% contingency				\$0
<i>Subtotal, Construction/Implementation and Contingency</i>				\$0
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$9,000
<i>Operation and Maintenance - Annual</i>				
Reporting	1	year	\$4,000	\$4,000
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$4,000
Estimated Total Cost Excluding Operation and Maintenance				\$9,000
Estimated Total Cost Including 30 years of Operation and Maintenance				\$129,000

Assumptions:

Groundwater deed restriction only covers bounds of plant property

Table D-3. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Facility-Wide,
Former GM Delco Plant 5, Kokomo, Indiana
Land Use Restriction

Description: Adopt a land deed restriction for the facility. Restriction would limit land use to commercial and industrial.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Draft Land Use Deed Restriction	1	lump sum	\$3,000	\$3,000
Response to Regulator Comments	1	lump sum	\$2,000	\$2,000
Filing of Deed Restriction	1	lump sum	\$2,000	\$2,000
<i>Subtotal, Remediation Design and Contracting</i>				\$7,000
25% contingency				\$2,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$9,000
<i>Construction/Implementation</i>				
				\$0
<i>Subtotal, Construction/Implementation</i>				\$0
25% contingency				\$0
<i>Subtotal, Construction/Implementation and Contingency</i>				\$0
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$9,000
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$0	\$0
Reporting	1	year	\$3,000	\$3,000
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$3,000
Estimated Total Cost Excluding Operation and Maintenance				\$9,000
Estimated Total Cost Including 30 years of Operation and Maintenance				\$99,000

Assumptions:

Land use restriction only covers bounds of plant property

Table D-4. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Facility-Wide,
Former GM Delco Plant 5, Kokomo, Indiana
Facility-Wide Groundwater Monitoring and Vapor Monitoring

Description: Selected monitoring wells at and in the vicinity of the Facility will be sampled to evaluate groundwater quality. An off-site soil vapor monitoring program will also be implemented. The data will allow for evaluation of groundwater and soil vapor quality trends and determine what, if any, additional action will be necessary. Vapor monitoring would be conducted using eleven existing vapor probes on a quarterly basis for 2 years. Groundwater monitoring would be performed semi-annually during active remediation and for 2 years thereafter. Annual monitoring will be conducted for an additional 3 years, followed by a 25-year post-closure monitoring program. The number and location of monitoring wells to be sampled and the frequency may be evaluated prior to and during the course of the monitoring period.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Design Report	1	lump sum	\$8,000	\$8,000
Permitting	1	lump sum	\$5,000	\$5,000
Response to Regulator Comments	1	lump sum	\$4,000	\$4,000
<i>Subtotal, Remediation Design and Contracting</i>				\$17,000
25% contingency				\$4,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$21,000
<i>Construction/Implementation</i>				
Vapor Probe Abandonment	11	well	\$300	\$3,300
Well Abandonment	65	well	\$1,000	\$65,000
Abandonment Oversight	10	day	\$1,000	\$10,000
Reporting	1	lump sum	\$6,000	\$6,000
<i>Subtotal, Construction/Implementation</i>				\$84,300
25% contingency				\$21,000
<i>Subtotal, Construction/Implementation and Contingency</i>				\$105,300
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$126,300
<i>Vapor Monitoring Program, Quarterly Monitoring (2 years)</i>				
Sample Collection	8	event	\$10,000	\$80,000
Vapor Laboratory Analysis - VOCs	8	event	\$3,000	\$24,000
Well Maintenance	2	year	\$5,000	\$10,000
Reporting	8	event	\$10,000	\$80,000
<i>Subtotal, Semi-Annual Monitoring (2 years)</i>				\$194,000
<i>Groundwater Monitoring Program, Semi-Annual Monitoring Phase (2 years)</i>				
Sample Collection	4	event	\$18,000	\$72,000
Groundwater Laboratory Analysis - VOCs	4	event	\$6,600	\$26,000
Groundwater Laboratory Analysis - Metals	4	event	\$1,350	\$5,000
Well Maintenance	2	year	\$10,000	\$20,000
Reporting	4	event	\$10,000	\$40,000
<i>Subtotal, Semi-Annual Monitoring (2 years)</i>				\$163,000

Table D-4. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Facility-Wide,
Former GM Delco Plant 5, Kokomo, Indiana
Facility-Wide Groundwater Monitoring and Vapor Monitoring

Description: Selected monitoring wells at and in the vicinity of the Facility will be sampled to evaluate groundwater quality. An off-site soil vapor monitoring program will also be implemented. The data will allow for evaluation of groundwater and soil vapor quality trends and determine what, if any, additional action will be necessary. Vapor monitoring would be conducted using eleven existing vapor probes on a quarterly basis for 2 years. Groundwater monitoring would be performed semi-annually during active remediation and for 2 years thereafter. Annual monitoring will be conducted for an additional 3 years, followed by a 25-year post-closure monitoring program. The number and location of monitoring wells to be sampled and the frequency may be evaluated prior to and during the course of the monitoring period.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Groundwater Monitoring Program, Annual Monitoring Phase (3 years)</i>				
Sample Collection	3	event	\$15,000	\$45,000
Groundwater Laboratory Analysis - VOCs	3	event	\$5,500	\$17,000
Groundwater Laboratory Analysis - Metals	3	event	\$1,350	\$4,000
Well Maintenance	3	year	\$10,000	\$30,000
Reporting	3	event	\$10,000	\$30,000
Subtotal, Annual Monitoring (3 years)				\$126,000
<i>Groundwater Monitoring Program, Post-Closure Care Phase (25 years)</i>				
Sample Collection	25	event	\$14,000	\$350,000
Groundwater Laboratory Analysis - VOCs	25	event	\$4,400	\$110,000
Well Maintenance	25	year	\$10,000	\$250,000
Reporting	25	event	\$10,000	\$250,000
Subtotal, Post-Closure Care Monitoring (25 years)				\$960,000
Estimated Total Cost				\$1,569,300

Assumptions:

Permitting costs are associated with reviewing and maintaining access agreements for off-site wells

Existing monitoring well network will be sufficient to evaluate trends in groundwater

Existing soil probes will be sufficient to evaluate off-site vapor migration

Sixty groundwater monitoring wells will be sampled during each semi-annual event and analyzed for VOCs. Samples from a subset of nine wells will be analyzed for metals.

Fifty groundwater monitoring wells will be sampled during each annual event and analyzed for VOCs. Samples from a subset of nine wells will be analyzed for metals.

Forty monitoring wells will be sampled during each annual post-closure care event and analyzed for VOCs.

Table D-5. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Engineering Control - Cover Option

Description: Construction of an asphalt cover over the area within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater (approximately 12,000 square feet) to prevent exposure to underlying soils.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Design Report	1	lump sum	\$8,000	\$8,000
Permitting	1	lump sum	\$3,000	\$3,000
Response to Regulator Comments	1	lump sum	\$2,000	\$2,000
Construction Specifications	1	lump sum	\$4,000	\$4,000
Bid Procurement and Contractor Selection	1	lump sum	\$3,000	\$3,000
<i>Subtotal, Remediation Design and Contracting</i>				\$20,000
25% contingency				\$5,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$25,000
<i>Construction/Implementation</i>				
Mobilization	1	lump sum	\$18,000	\$18,000
Clearing/grubbing/rough grading of area	1	lump sum	\$4,200	\$4,200
Surveying	1	lump sum	\$9,000	\$9,000
Supply, Spread, and Compact 6" of Gravel Subbase	276	CY	\$18	\$5,000
Asphalt Pavement 9"	420	CY	\$35	\$14,700
Perimeter Chain Link Fence	600	LF	\$14	\$8,400
Site Restoration	1	lump sum	\$6,000	\$6,000
Construction Oversight - 1 week	1	lump sum	\$8,400	\$8,400
Preparation of Summary/As-Built Report	1	lump sum	\$9,600	\$9,600
<i>Subtotal, Construction/Implementation</i>				\$83,300
25% contingency				\$20,800
<i>Subtotal, Construction/Implementation and Contingency</i>				\$104,000
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$129,000
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$15,000	\$15,000
Reporting	1	year	\$5,000	\$5,000
Utilities	1	year	\$0	\$0
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$20,000
Estimated Total Cost Excluding Operation and Maintenance				\$129,000
Estimated Total Cost Including 30 years of Operation and Maintenance				\$729,000

Assumptions:

Demolition of surface or subsurface structures not required

Replacement or improvements to existing curbs and storm sewers in the public right-of-way not required

Improvements to onsite drainage structures not required

Annual maintenance will extend cover life and reduce potential for total replacement

Table D-6. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Institutional Control - Cover Option

Description: An engineered cover would need inspection and maintenance to be effective. This option includes the development of a cover maintenance plan.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Design Report	1	lump sum	\$5,000	\$5,000
Permitting	1	lump sum	\$0	\$0
Response to Regulator Comments	1	lump sum	\$2,000	\$2,000
Construction Specifications	1	lump sum	\$0	\$0
Bid Procurement and Contractor Selection	1	lump sum	\$0	\$0
<i>Subtotal, Remediation Design and Contracting</i>				\$7,000
25% contingency				\$2,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$9,000
<i>Construction/Implementation</i>				
Construction	0	lump sum	\$15,000	\$0
<i>Subtotal, Construction/Implementation</i>				\$0
25% contingency				\$0
<i>Subtotal, Construction/Implementation and Contingency</i>				\$0
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$9,000
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$10,000	\$10,000
Reporting	1	year	\$5,000	\$5,000
Utilities	1	year	\$0	\$0
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$15,000
Estimated Total Cost Excluding Operation and Maintenance				\$9,000
Estimated Total Cost Including 30 years of Operation and Maintenance				\$459,000

Assumptions:

This option would be implemented in conjunction with the engineering control cover option

Table D-7. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Phytoremediation Option

Description: Construction of a phytoremediation treatment unit over the area within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater (approximately 12,000 square feet). Plantings, consisting of hybrid poplars, would be established in the treatment area. Trees would be planted on 10-foot center, alternating as follows, a tree planted in a hole augered to a depth of 2 feet, next to a tree planted in a root sleeve liner placed in a hole augered to 10 feet. Planting at two depths would be conducted to target the 0 to 20 foot depth interval. As the trees mature, the rhizosphere of the trees would encourage microbial growth to stimulate biodegradation. In addition, transpiration would remove contaminants.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Design Report	1	lump sum	\$15,000	\$15,000
Permitting	1	lump sum	\$7,000	\$7,000
Response to Regulator Comments	1	lump sum	\$6,000	\$6,000
Construction Specifications	1	lump sum	\$15,000	\$15,000
Bid Procurement and Contractor Selection	1	lump sum	\$7,000	\$7,000
<i>Subtotal, Remediation Design and Contracting</i>				\$50,000
25% contingency				\$13,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$63,000
<i>Construction/Implementation</i>				
Mobilization	1	lump sum	\$18,000	\$18,000
Clearing/grubbing of planting area	1	lump sum	\$4,000	\$4,000
Installation of trees - shallow	75	planting	\$100	\$8,000
Installation of trees - deep	75	planting	\$500	\$38,000
Installation of temporary irrigation system	1	lump sum	\$7,000	\$7,000
Perimeter Chain Link Fence	600	LF	\$14	\$8,000
Collection/Containerizing of soil cuttings	1	lump sum	\$6,000	\$6,000
Transportation of soil for disposal	12	tons	\$85	\$1,000
Disposal and Chemical Oxidation at EQ, soil	12	tons	\$190	\$2,000
Site Restoration	1	lump sum	\$7,000	\$7,000
Construction Oversight - 1 month	1	lump sum	\$29,000	\$29,000
Preparation of Summary/As-Built Report	1	lump sum	\$14,000	\$14,000
<i>Subtotal, Construction/Implementation</i>				\$142,000
25% contingency				\$36,000
<i>Subtotal, Construction/Implementation and Contingency</i>				\$178,000
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$241,000

Table D-7. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Phytoremediation Option

Description: Construction of a phytoremediation treatment unit over the area within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater (approximately 12,000 square feet). Plantings, consisting of hybrid poplars, would be established in the treatment area. Trees would be planted on 10-foot center, alternating as follows, a tree planted in a hole augered to a depth of 2 feet, next to a tree planted in a root sleeve liner placed in a hole augered to 10 feet. Planting at two depths would be conducted to target the 0 to 20 foot depth interval. As the trees mature, the rhizosphere of the trees would encourage microbial growth to stimulate biodegradation. In addition, transpiration would remove contaminants.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$72,000	\$72,000
Reporting	1	year	\$10,000	\$10,000
Utilities	1	year	\$3,000	\$3,000
Subtotal, Inspection and Maintenance (1 year)				\$85,000
Estimated Total Cost Excluding Operation and Maintenance				\$241,000
Estimated Total Cost Including 15 years of Operation and Maintenance				\$1,516,000

Assumptions:

Soil disposal at EQ facility, located in Belleville, Michigan

Soil tonnage based upon a 1.5 tons to 1 cubic yard in-place soil volume conversion factor

Table D-8. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Excavation Option

Description: Soil would be excavated from within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater. The excavation would extend to a depth of 20 feet.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Design Report	1	lump sum	\$12,000	\$12,000
Permitting	1	lump sum	\$3,000	\$3,000
Response to Regulator Comments	1	lump sum	\$5,000	\$5,000
Construction Specifications	1	lump sum	\$6,000	\$6,000
Bid Procurement and Contractor Selection	1	lump sum	\$4,000	\$4,000
<i>Subtotal, Remediation Design and Contracting</i>				\$30,000
25% contingency				\$8,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$38,000
<i>Construction/Implementation</i>				
Mobilization	1	lump sum	\$18,000	\$18,000
Clearing/grubbing of excavation area	1	lump sum	\$4,000	\$4,000
Temporary Chain Link Fence	600	LF	\$8	\$5,000
Soil characterization sampling	1	lump sum	\$22,000	\$22,000
Excavation	9065	CY	\$5	\$45,000
Air Monitoring and Reporting	1	lump sum	\$60,000	\$60,000
Dewatering - equipment and 2 months O&M	1	lump sum	\$78,000	\$78,000
Dewatering - sanitary fees	329554	gallons	\$0.01	\$3,000
Disposal and Chemical Oxidation at EQ, soil	13598	tons	\$190	\$2,584,000
Transportation of soil for disposal	13598	tons	\$85	\$1,156,000
Backfill, purchase and transport	13598	tons	\$30	\$408,000
Backfill, placement and compaction	13598	tons	\$8	\$109,000
Site Utility Survey	1	lump sum	\$18,000	\$18,000
Site Restoration	1	lump sum	\$12,000	\$12,000
Construction Oversight - 2 months	1	lump sum	\$58,000	\$58,000
Preparation of Summary/As-Built Report	1	lump sum	\$14,000	\$14,000
<i>Subtotal, Construction/Implementation</i>				\$4,594,000
25% contingency				\$1,149,000
<i>Subtotal, Construction/Implementation and Contingency</i>				\$5,743,000
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$5,781,000

Table D-8. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Excavation Option

Description: Soil would be excavated from within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater. The excavation would extend to a depth of 20 feet.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$0	\$0
Reporting	1	year	\$0	\$0
Utilities	1	year	\$0	\$0
Subtotal, Inspection and Maintenance (1 year)				\$0

Estimated Total Cost \$5,781,000

Assumptions:

Excavation can be completed within 2 months. Beyond 2 months estimated water management cost is \$25K/month.

Soil disposal at EQ facility, located in Belleville, Michigan

Soil tonnage based upon a 1.5 tons to 1 cubic yard in-place soil volume conversion factor

No operation and maintenance is required for this corrective action option.

Table D-9. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Calcium Oxide Treatment Option

Description: Soil would be treated within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater. Treatment would be completed in 18 to 24-inch lifts, beginning at ground surface and working to the desired depth of excavation (20 feet). As each lift is treated in the excavation area with calcium oxide, it is excavated and temporarily stockpiled adjacent to the treatment area for additional reaction time and treatment verification sampling. Upon receipt of soil treatment verification data, the treated soil is then backfilled into the excavation.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Design Report	1	lump sum	\$17,000	\$17,000
Permitting	1	lump sum	\$6,000	\$6,000
Response to Regulator Comments	1	lump sum	\$10,000	\$10,000
Construction Specifications	1	lump sum	\$15,000	\$15,000
Bid Procurement and Contractor Selection	1	lump sum	\$8,000	\$8,000
<i>Subtotal, Remediation Design and Contracting</i>				\$56,000
25% contingency				\$14,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$70,000
<i>Construction/Implementation</i>				
Mobilization and Site Preparation	1	lump sum	\$84,000	\$84,000
Site Management/Coordination	1	lump sum	\$96,000	\$96,000
In-Situ Treatment	9065	CY	\$60	\$544,000
Perimeter Chain Link Fence, Dust Screen	600	LF	\$20	\$12,000
Dewatering - equipment and 3 months O&M	1	lump sum	\$108,000	\$108,000
Dewatering - sanitary fees	327000	gallons	\$0.01	\$3,000
Air Monitoring and Reporting	1	lump sum	\$75,000	\$90,000
QA/QC Sampling & Analysis	1	lump sum	\$12,000	\$14,000
Site Utility Survey	1	lump sum	\$18,000	\$18,000
Site Restoration and Demobilization	1	lump sum	\$36,000	\$36,000
Construction Oversight - 3 months	1	lump sum	\$86,000	\$86,000
Vapor Probe Installation	10	probe	\$1,000	\$10,000
Vapor Probe Installation Oversight	1	day	\$2,000	\$2,000
Vapor Monitoring	4	quarter	\$10,000	\$40,000
Vapor Laboratory Analysis - VOCs	4	quarter	\$2,750	\$11,000
Vapor Probe Abandonment	10	probe	\$400	\$4,000
Vapor Probe Abandonment Oversight	1	day	\$2,000	\$2,000
Preparation of Summary/As-Built Report	1	lump sum	\$18,000	\$18,000
<i>Subtotal, Construction/Implementation</i>				\$1,178,000
25% contingency				\$295,000
<i>Subtotal, Construction/Implementation and Contingency</i>				\$1,473,000
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$1,543,000

Table D-9. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Calcium Oxide Treatment Option

Description: Soil would be treated within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater. Treatment would be completed in 18 to 24-inch lifts, beginning at ground surface and working to the desired depth of excavation (20 feet). As each lift is treated in the excavation area with calcium oxide, it is excavated and temporarily stockpiled adjacent to the treatment area for additional reaction time and treatment verification sampling. Upon receipt of soil treatment verification data, the treated soil is then backfilled into the excavation.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$0	\$0
Reporting	1	year	\$0	\$0
Utilities	1	year	\$0	\$0
Subtotal, Inspection and Maintenance (1 year)				\$0

Estimated Total Cost \$1,543,000

Assumptions:

Treatment can be completed within 3 months.

Water treatment and disposal is not necessary. Water will be used for hydration of calcium oxide.

Soil tonnage based upon a 1.5 tons to 1 cubic yard in-place soil volume conversion factor

No air emissions treatment required

No RCRA permitting required

No operation and maintenance is required for this corrective action option.

Table D-10. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Electrical Resistivity Heating Treatment Option

Description: Soil would be treated within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater via resistive heating of soil and groundwater through buried electrodes. ERH increases subsurface temperatures beyond the boiling point of most VOCs, causing mass transfer to the vapor phase. A vacuum is then induced to recover the vapor phase through conventional vapor recovery wells.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Design Report	1	lump sum	\$10,000	\$10,000
Permitting	1	lump sum	\$10,000	\$10,000
Response to Regulator Comments	1	lump sum	\$10,000	\$10,000
Construction Specifications	1	lump sum	\$15,000	\$15,000
Bid Procurement and Contractor Selection	1	lump sum	\$8,000	\$8,000
<i>Subtotal, Remediation Design and Contracting</i>				\$53,000
25% contingency				\$13,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$66,000
<i>Construction/Implementation</i>				
Pilot Test	1	lump sum	\$75,000	\$75,000
Perimeter Chain Link Fence	600	LF	\$14	\$8,000
Electrical Profiling	1	lump sum	\$4,000	\$4,000
Modeling and Remedial Design	1	lump sum	\$20,000	\$20,000
System Installation	1	lump sum	\$636,000	\$636,000
Acceptance Testing	1	lump sum	\$14,000	\$14,000
Mobilization and Demobilization	1	lump sum	\$41,000	\$41,000
Electrode Borehole Drilling	1105	LF	\$40	\$44,000
Extraction Well Drilling	607	LF	\$50	\$30,000
Sensor Well Drilling	317	LF	\$35	\$11,000
Well Abandonment	1.0	lump sum	\$20,000	\$20,000
Construction	1.0	lump sum	\$110,000	\$110,000
Dual Phase Extraction System	1.0	lump sum	\$150,000	\$150,000
Water Connection	1.0	lump sum	\$30,000	\$30,000
Confirmation Sampling and Reporting	1.0	lump sum	\$18,000	\$18,000
3-phase Electrical Power Drop	1.0	lump sum	\$20,000	\$20,000
Waste Disposal	1.0	lump sum	\$12,000	\$12,000
Site Utility Survey	1	lump sum	\$18,000	\$18,000
Site Restoration	1	lump sum	\$12,000	\$12,000
Drilling and Construction Oversight - 3 months	1	lump sum	\$86,000	\$86,000
Vapor Probe Installation	10	probe	\$1,000	\$10,000
Vapor Probe Installation Oversight	1	day	\$2,000	\$2,000
Vapor Monitoring	4	quarter	\$10,000	\$40,000
Vapor Laboratory Analysis - VOCs	4	quarter	\$2,750	\$11,000
Vapor Probe Abandonment	10	probe	\$400	\$4,000

Table D-10. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Soil,
Former GM Delco Plant 5, Kokomo, Indiana
Electrical Resistivity Heating Treatment Option

Description: Soil would be treated within the 400 mg/kg TCE isoconcentration contour, addressing soil in the area of SB-0746, SB-0749, SB-0756, SB-0757 and SB-0775 and soil that could leach TCE to groundwater at concentrations of 1,000 ug/L or greater via resistive heating of soil and groundwater through buried electrodes. ERH increases subsurface temperatures beyond the boiling point of most VOCs, causing mass transfer to the vapor phase. A vacuum is then induced to recover the vapor phase through conventional vapor recovery wells.

Task	Quantity	Units	Unit Rate	Estimated Cost
Vapor Probe Abandonment Oversight	1	day	\$2,000	\$2,000
Preparation of Summary/As-Built Report	1	lump sum	\$24,000	\$24,000
<i>Subtotal, Construction/Implementation</i>				\$1,452,000
25% contingency				\$363,000
<i>Subtotal, Construction/Implementation and Contingency</i>				\$1,815,000
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$1,881,000
<i>Operation and Maintenance - 6 Months</i>				
Labor/Travel/Rental Equipment	6	months	\$15,000	\$90,000
Operations	6	months	\$19,200	\$115,000
Energy/Utilities	2745600	kWHr	\$0.10	\$275,000
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$480,000
Estimated Total Cost				\$2,361,000

Assumptions:

Preliminary system design consists of 46 electrode locations, 23 soil vapor extraction wells and 25 sensor wells.

Detailed technical summary of assumed operation parameters available upon request

No operation and maintenance is required for this corrective action option, once system operation is terminated.

Table D-11. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Groundwater,
Former GM Delco Plant 5, Kokomo, Indiana
Groundwater Extraction Option

Description: Install five groundwater extraction wells in the S1 unit. Four wells would be installed along east side of property to intercept groundwater plume, and one would be installed in southern portion of site to address southern component of groundwater flow. Assumed spacing is 100 feet. S1 unit is variable in thickness, with a depth ranging from 10 to 50 feet. 40 feet was selected as a well depth for costing purposes. Extracted water would be treated using a shallow tray stripper and discharged to the storm sewer system. Operating costs were developed for 30 year lifecycle. Groundwater monitoring costs would be captured under the facilitywide monitoring program.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Pump Test	1	lump sum	\$20,000	\$20,000
Design Report	1	lump sum	\$15,000	\$15,000
Permitting	1	lump sum	\$10,000	\$10,000
Response to Regulator Comments	1	lump sum	\$7,000	\$7,000
Construction Specifications	1	lump sum	\$12,000	\$12,000
Bid Procurement and Contractor Selection	1	lump sum	\$6,000	\$6,000
<i>Subtotal, Remediation Design and Contracting</i>				\$70,000
25% contingency				\$17,500
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$88,000
<i>Construction/Implementation</i>				
Mobilization	1	lump sum	\$15,000	\$15,000
Extraction Well Drilling	200	LF	\$50	\$10,000
Trenching/Conveyance Line Installation	450	LF	\$40	\$18,000
Wellhead Construction	5	ea	\$300	\$1,500
Soil Spoils Disposal	20	CY	\$30	\$600
Soil Spoils Transportation	20	CY	\$10	\$200
Submersible Pumps	5	ea	\$2,000	\$10,000
Pump Controls	5	ea	\$3,000	\$15,000
Treatment Building Construction	1	lump sum	\$10,000	\$10,000
Effluent Discharge Sewer Connection	1	lump sum	\$8,000	\$8,000
Canister Filter	1	lump sum	\$5,000	\$5,000
Tray Stripper	1	lump sum	\$15,000	\$15,000
Equalization Tank	1	ea	\$3,000	\$3,000
Transfer Pump	1	ea	\$2,000	\$2,000
Building Heater	1	ea	\$4,000	\$4,000
Piping and Valves	1	lump sum	\$6,000	\$6,000
Instrumentation and Controls	1	lump sum	\$20,000	\$20,000
Equipment Installation	1	lump sum	\$20,000	\$20,000
Electrical Drop	1	lump sum	\$20,000	\$20,000
Surveying	1	lump sum	\$3,000	\$3,000
Site Restoration	1	lump sum	\$5,000	\$5,000
Construction Oversight	4	week	\$7,000	\$28,000

Table D-11. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Groundwater,
Former GM Delco Plant 5, Kokomo, Indiana
Groundwater Extraction Option

Description: Install five groundwater extraction wells in the S1 unit. Four wells would be installed along east side of property to intercept groundwater plume, and one would be installed in southern portion of site to address southern component of groundwater flow. Assumed spacing is 100 feet. S1 unit is variable in thickness, with a depth ranging from 10 to 50 feet. 40 feet was selected as a well depth for costing purposes. Extracted water would be treated using a shallow tray stripper and discharged to the storm sewer system. Operating costs were developed for 30 year lifecycle. Groundwater monitoring costs would be captured under the facilitywide monitoring program.

Task	Quantity	Units	Unit Rate	Estimated Cost
Start-Up/System Shakedown	2	week	\$7,000	\$14,000
Preparation of Summary/As-Built Report	1	lump sum	\$15,000	\$15,000
<i>Subtotal, Construction/Implementation</i>				\$248,300
25% contingency				\$62,100
<i>Subtotal, Construction/Implementation and Contingency</i>				\$310,000
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$398,000
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$60,000	\$60,000
Effluent Monitoring and Reporting	1	year	\$12,000	\$12,000
Equipment Replacement	1	year	\$5,000	\$5,000
Reporting	1	year	\$12,000	\$12,000
Utilities	1	year	\$15,000	\$15,000
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$104,000
Estimated Total Cost Excluding Operation and Maintenance				\$398,000
Estimated Total Cost Including 30 years of Operation and Maintenance				\$3,518,000

Table D-12. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Groundwater,
Former GM Delco Plant 5, Kokomo, Indiana
In-Situ Chemical Oxidation, with Off-site Treatment Option

Description: Following completion of soil corrective action activities, a series of injection wells would be installed to address on-site impacted groundwater via application of an oxidant. Injections would target the S1 unit, at four injection areas: TCE impacts in the vicinity of MW-0620-S1, TCE impacts off-site in the vicinity of MW-0612-S1, TCE and cis-1,2-DCE impacts in the vicinity of MW-0102-S1U, and TCE and cis-1,2-DCE impacts in the vicinity of MW-0101-S1U and MW-0504-S1. Assume well spacing is 25 feet, to a depth of 40 feet. Total number of wells estimated to be 65 wells. Assume four rounds of quarterly injections for 1 year, using sodium permanganate. Assume

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Pilot Test/Tracer Test	1	lump sum	\$80,000	\$80,000
Design Report	1	lump sum	\$15,000	\$15,000
Permitting	1	lump sum	\$12,000	\$12,000
Access Agreement - Off-Site Wells	1	lump sum	\$6,000	\$6,000
Response to Regulator Comments	1	lump sum	\$7,000	\$7,000
Construction Specifications	1	lump sum	\$7,000	\$7,000
Bid Procurement and Contractor Selection	1	lump sum	\$4,000	\$4,000
<i>Subtotal, Remediation Design and Contracting</i>				<i>\$131,000</i>
25% contingency				\$33,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				<i>\$164,000</i>
<i>Construction/Implementation</i>				
Mobilization	1	lump sum	\$15,000	\$15,000
Injection Well Drilling	2600	LF	\$30	\$78,000
Wellhead Construction	65	ea	\$150	\$9,750
Soil Spoils Disposal	30	CY	\$250	\$7,500
Soil Spoils Transportation	30	CY	\$100	\$3,000
Drilling Oversight	4.2	week	\$7,000	\$29,400
Surveying	1	lump sum	\$7,000	\$7,000
Injection Equipment Procurement	1	lump sum	\$10,000	\$10,000
Injection System Fabrication	1	lump sum	\$8,000	\$8,000
Injection Event	4	Event	\$23,000	\$92,000
Sodium Permanganate Solution Purchase	85600	lb	\$3	\$256,800
Sodium Permanganate Delivery	4	Event	\$3,000	\$12,000
Remediation Groundwater Monitoring	5	Event	\$9,700	\$48,500
Vapor Probe Installation	40	probe	\$1,000	\$40,000
Vapor Probe Installation Oversight	4	day	\$2,000	\$8,000
Vapor Monitoring	6	quarter	\$15,000	\$90,000
Vapor Laboratory Analysis - VOCs	6	quarter	\$10,250	\$61,500
Vapor Probe Abandonment	40	probe	\$400	\$16,000
Vapor Probe Abandonment Oversight	3	day	\$2,000	\$6,000
Well Abandonment	65	ea	\$500	\$32,500
Well Abandonment Oversight	1	week	\$7,000	\$7,000

Table D-12. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Groundwater,
Former GM Delco Plant 5, Kokomo, Indiana
In-Situ Chemical Oxidation, with Off-site Treatment Option

Description: Following completion of soil corrective action activities, a series of injection wells would be installed to address on-site impacted groundwater via application of an oxidant. Injections would target the S1 unit, at four injection areas: TCE impacts in the vicinity of MW-0620-S1, TCE impacts off-site in the vicinity of MW-0612-S1, TCE and cis-1,2-DCE impacts in the vicinity of MW-0102-S1U, and TCE and cis-1,2-DCE impacts in the vicinity of MW-0101-S1U and MW-0504-S1. Assume well spacing is 25 feet, to a depth of 40 feet. Total number of wells estimated to be 65 wells. Assume four rounds of quarterly injections for 1 year, using sodium permanganate. Assume

Task	Quantity	Units	Unit Rate	Estimated Cost
Site Restoration	1	lump sum	\$5,000	\$5,000
Preparation of Summary/As-Built Report	1	lump sum	\$20,000	\$20,000
<i>Subtotal, Construction/Implementation</i>				\$862,950
25% contingency				\$215,738
<i>Subtotal, Construction/Implementation and Contingency</i>				\$1,078,688
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$1,242,688
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$0	\$0
Reporting	1	year	\$0	\$0
Utilities	1	year	\$0	\$0
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$0
Estimated Total Cost Excluding Operation and Maintenance				\$1,242,688
Estimated Total Cost Including 30 years of Operation and Maintenance				\$1,242,688

Table D-13. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Groundwater,
Former GM Delco Plant 5, Kokomo, Indiana
Enhanced Reductive Dechlorination Option

Description: Following completion of soil corrective action activities, a series of injection wells would be installed to address on-site impacted groundwater via application of a carbon substrate. Injections would target the S1 unit, at three injection areas: TCE impacts in the vicinity of MW-0620-S1, TCE and cis-1,2-DCE impacts in the vicinity of MW-0102-S1U, and TCE and cis-1,2-DCE impacts in the vicinity of MW-0101-S1U and MW-0504-S1. Assume well spacing is 25 feet, to a depth of 40 feet. Total number of wells estimated to be 61 wells. Assume eight rounds of quarterly injections for 2 years, using Emulsified Oil Substrate (EOS). Assume 500 gallons of EOS solution per well per event. EOS is diluted to a 10 gallon EOS/500 gallon water solution. Groundwater monitoring costs would be captured under the facilitywide monitoring program. Methane monitoring would be conducted along the property boundary and is included herein. However, assume sampling of a subset of 13 wells on a quarterly basis (and one baseline event) to monitoring progress of remediation (9 monitoring events).

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Pilot Test/Tracer Test	1	lump sum	\$80,000	\$80,000
Design Report	1	lump sum	\$15,000	\$15,000
Permitting	1	lump sum	\$12,000	\$12,000
Response to Regulator Comments	1	lump sum	\$7,000	\$7,000
Construction Specifications	1	lump sum	\$7,000	\$7,000
Bid Procurement and Contractor Selection	1	lump sum	\$4,000	\$4,000
<i>Subtotal, Remediation Design and Contracting</i>				\$125,000
25% contingency				\$31,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$156,000
<i>Construction/Implementation</i>				
Mobilization	1	lump sum	\$15,000	\$15,000
Injection Well Drilling	2440	LF	\$30	\$73,200
Wellhead Construction	43	ea	\$150	\$6,450
Methane Probes	10	ea	\$500	\$5,000
Soil Spoils Disposal	30	CY	\$250	\$7,500
Soil Spoils Transportation	30	CY	\$100	\$3,000
Drilling Oversight	4	week	\$7,000	\$28,000
Surveying	1	lump sum	\$6,000	\$6,000
Injection Equipment Procurement	1	lump sum	\$10,000	\$10,000
Injection System Fabrication	1	lump sum	\$8,000	\$8,000
Injection Event	8	Event	\$21,000	\$168,000
EOS Solution Purchase	39040	lb	\$2	\$78,080
EOS Delivery	8	Event	\$5,000	\$40,000
Methane Monitoring	12	Event	\$3,000	\$36,000
Remediation Groundwater Monitoring	9	Event	\$9,000	\$81,000
Vapor Probe Installation	30	probe	\$1,000	\$30,000
Vapor Probe Installation Oversight	3	day	\$2,000	\$6,000
Vapor Monitoring	10	quarter	\$10,000	\$100,000
Vapor Laboratory Analysis - VOCs and methane	10	quarter	\$12,400	\$124,000
Vapor Probe Abandonment	30	probe	\$400	\$12,000
Vapor Probe Abandonment Oversight	2	day	\$2,000	\$4,000

Table D-13. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Groundwater,
Former GM Delco Plant 5, Kokomo, Indiana
Enhanced Reductive Dechlorination Option

Description: Following completion of soil corrective action activities, a series of injection wells would be installed to address on-site impacted groundwater via application of a carbon substrate. Injections would target the S1 unit, at three injection areas: TCE impacts in the vicinity of MW-0620-S1, TCE and cis-1,2-DCE impacts in the vicinity of MW-0102-S1U, and TCE and cis-1,2-DCE impacts in the vicinity of MW-0101-S1U and MW-0504-S1. Assume well spacing is 25 feet, to a depth of 40 feet. Total number of wells estimated to be 61 wells. Assume eight rounds of quarterly injections for 2 years, using Emulsified Oil Substrate (EOS). Assume 500 gallons of EOS solution per well per event. EOS is diluted to a 10 gallon EOS/500 gallon water solution. Groundwater monitoring costs would be captured under the facilitywide monitoring program. Methane monitoring would be conducted along the property boundary and is included herein. However, assume sampling of a subset of 13 wells on a quarterly basis (and one baseline event) to monitoring progress of remediation (9 monitoring events).

Task	Quantity	Units	Unit Rate	Estimated Cost
Well Abandonment	61	ea	\$500	\$30,500
Well Abandonment Oversight	1	week	\$7,000	\$7,000
Site Restoration	1	lump sum	\$5,000	\$5,000
Preparation of As-Built Report	1	lump sum	\$20,000	\$20,000
Preparation of Remediation Summary Report	1	lump sum	\$20,000	\$20,000
<i>Subtotal, Construction/Implementation</i>				\$923,730
25% contingency				\$231,000
<i>Subtotal, Construction/Implementation and Contingency</i>				\$1,154,730
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$1,310,730
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$0	\$0
Reporting	1	year	\$0	\$0
Utilities	1	year	\$0	\$0
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$0
Estimated Total Cost Excluding Operation and Maintenance				\$1,310,730
Estimated Total Cost Including 30 years of Operation and Maintenance				\$1,310,730

Table D-14. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Groundwater,
Former GM Delco Plant 5, Kokomo, Indiana
Hydraulic Barrier and Groundwater Extraction Option

Description: Install a bentonite cutoff wall along the east property boundary to reduce off-site migration. The wall would be keyed into the clay unit between the S1 and S2 units. Install one extraction well along midpoint of wall and one well at each end to capture groundwater flowing around the wall. S1 unit is variable in thickness, with a depth ranging from 10 to 50 feet. 40 feet was selected as a well depth for costing purposes, and for the depth of the cutoff wall. Extracted water would be treated using a shallow tray stripper and discharged to the storm sewer system. Operating costs were developed for 30 year lifecycle. Groundwater monitoring costs would be captured under the facilitywide monitoring program.

Task	Quantity	Units	Unit Rate	Estimated Cost
<i>Remediation Design and Contracting</i>				
Pump Test	1	lump sum	\$20,000	\$20,000
Drilling Program - Establish Key Unit Depth	1	lump sum	\$20,000	\$20,000
Design Report	1	lump sum	\$25,000	\$25,000
Permitting	1	lump sum	\$10,000	\$10,000
Response to Regulator Comments	1	lump sum	\$10,000	\$10,000
Construction Specifications	1	lump sum	\$20,000	\$20,000
Bid Procurement and Contractor Selection	1	lump sum	\$12,000	\$12,000
<i>Subtotal, Remediation Design and Contracting</i>				\$117,000
25% contingency				\$29,000
<i>Subtotal, Remediation Design and Contracting and Contingency</i>				\$146,000
<i>Construction/Implementation</i>				
Mobilization	1	lump sum	\$30,000	\$30,000
Clearing/Grubbing of Barrier Path	1	lump sum	\$3,000	\$3,000
Barrier - Material	14400	SF	\$10	\$144,000
Barrier - Installation	14400	SF	\$10	\$144,000
Soil Spoils Disposal	1600	CY	\$30	\$48,000
Soil Spoils Transportation	1600	CY	\$10	\$16,000
Extraction Well Drilling	120	LF	\$50	\$6,000
Trenching/Conveyance Line Installation	400	LF	\$40	\$16,000
Wellhead Construction	3	ea	\$300	\$900
Submersible Pumps	3	ea	\$2,000	\$6,000
Pump Controls	3	ea	\$3,000	\$9,000
Treatment Building Construction	1	lump sum	\$10,000	\$10,000
Effluent Discharge Sewer Connection	1	lump sum	\$8,000	\$8,000
Canister Filter	1	lump sum	\$5,000	\$5,000
Tray Stripper	1	lump sum	\$15,000	\$15,000
Equalization Tank	1	ea	\$3,000	\$3,000
Transfer Pump	1	ea	\$2,000	\$2,000
Building Heater	1	ea	\$4,000	\$4,000
Piping and Valves	1	lump sum	\$6,000	\$6,000
Instrumentation and Controls	1	lump sum	\$20,000	\$20,000
Equipment Installation	1	lump sum	\$20,000	\$20,000
Electrical Drop	1	lump sum	\$20,000	\$20,000
Surveying	1	lump sum	\$6,000	\$6,000
Site Restoration	1	lump sum	\$12,000	\$12,000
Construction Oversight	12	week	\$7,000	\$84,000

Table D-14. Order-of-Magnitude Cost Estimate for Corrective Measures Alternative, Groundwater,
Former GM Delco Plant 5, Kokomo, Indiana
Hydraulic Barrier and Groundwater Extraction Option

Description: Install a bentonite cutoff wall along the east property boundary to reduce off-site migration. The wall would be keyed into the clay unit between the S1 and S2 units. Install one extraction well along midpoint of wall and one well at each end to capture groundwater flowing around the wall. S1 unit is variable in thickness, with a depth ranging from 10 to 50 feet. 40 feet was selected as a well depth for costing purposes, and for the depth of the cutoff wall. Extracted water would be treated using a shallow tray stripper and discharged to the storm sewer system. Operating costs were developed for 30 year lifecycle. Groundwater monitoring costs would be captured under the facilitywide monitoring program.

Task	Quantity	Units	Unit Rate	Estimated Cost
Start-Up/System Shakedown	2	week	\$7,000	\$14,000
Preparation of Summary/As-Built Report	1	lump sum	\$20,000	\$20,000
<i>Subtotal, Construction/Implementation</i>				\$671,900
25% contingency				\$168,000
<i>Subtotal, Construction/Implementation and Contingency</i>				\$839,900
<i>Subtotal, Remediation Design/Contracting and Construction/Implementation</i>				\$985,900
<i>Operation and Maintenance - Annual</i>				
Maintenance Activities	1	year	\$60,000	\$60,000
Effluent Monitoring and Reporting	1	year	\$12,000	\$12,000
Equipment Replacement	1	year	\$5,000	\$5,000
Reporting	1	year	\$12,000	\$12,000
Utilities	1	year	\$15,000	\$15,000
<i>Subtotal, Inspection and Maintenance (1 year)</i>				\$104,000
Estimated Total Cost				\$985,900
Estimated Total Cost				\$4,105,900
Including 30 years of Operation and Maintenance				

APPENDIX E –GREEN REMEDIATION QUALITATIVE ASSESSMENT

Green (or Sustainable) Remediation is the practice of considering environmental impacts through every stage of remediation activities in order to maximize the net environmental benefit of a cleanup, thereby limiting the stress on the environment during cleanup actions. This approach aims to reduce the overall “footprint” of remediation. The remediation industry is striving for a definition that collectively captures the net environmental benefit, economic viability, and social responsibility and stewardship, as shown on Figure 1.

A green remediation qualitative assessment was conducted on each of the five groundwater and seven soil remedial alternatives identified for the Former GM Delco Plant 5 relative to the five core elements of green remediation that have been developed by the U.S. Environmental Protection Agency (USEPA). As defined in their “Principles for Greener Clean-up” issued in August 2009, the five core elements are listed below:

- Energy requirements
- Air emissions
- Water requirements and impacts on water resources
- Land and ecosystem impacts
- Material consumption and waste generation

The activities performed during investigation, pilot study, installation/construction, and operation and maintenance (O&M) of a remedial system must be considered when evaluating the above five elements. The energy requirement and air emission elements can include mobile and stationary forms of energy and sources of pollution. Air emissions may also include off-gassing from the remedial technology itself. Water requirements can include the consideration of water use from potable sources, reused water, or water generated onsite from an extraction well. Impacts on water resources can include the discharge of process water to wetlands and surface waters, how stormwater is handled on site, how the remedial alternative affects groundwater supply and quality, and whether or not water is permanently removed from the watershed. The land and ecosystem impacts element considers the change in impervious cover and how that affects stormwater generation, as well as whether or not the installation and operation of a system will impact flora and fauna habitat. Material consumption and waste generation considers all material throughput of the system during every stage of the project, including temporary and permanent materials. The USEPA technology primer titled “Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites” (EPA 542-R-08-002, April 2008) was referenced in developing these understandings of the five core elements.

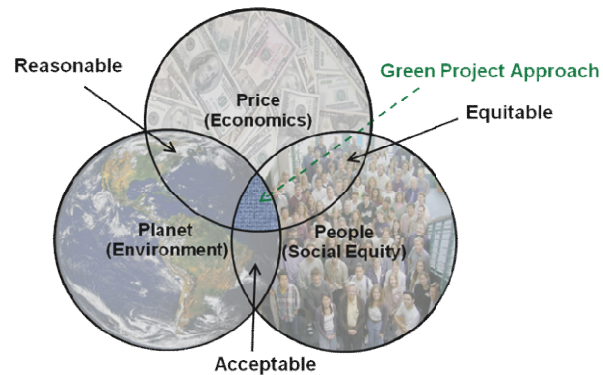


Figure 1 Confluence of the three major factors - Price, Planet & People - that makes green remediation itself a “sustainable” economic, environmental, and social concept. Three different examples are given where only two of the three factors are considered for each individual example. However, the green remediation approach considers all three factors.

This assessment was based on detailed information generated in the main body of the Corrective Measures Proposal (CMP) to identify the relative impact that each remedial alternative may have on the five core elements of sustainability. Using the information presented in the CMP, a short written summary of impact on each of the five core elements for each of the five groundwater and seven soil remedial alternatives was prepared.

From the qualitative assessment, numerical rankings were assigned to each element of each remedial alternative. The remedial alternative No Action was used as the baseline condition to which the impacts of the other four remedial alternatives were compared. A numerical ranking value was assigned to each core element to represent the relative impact. These values ranged from -3 (much less favorable to baseline conditions) to +3 (much more favorable to baseline conditions). Quantitative estimates of the predicted performance of the alternatives relative to the five green remediation factors (e.g., life-cycle estimates for power demand, CO₂ discharge rates, water consumption, etc.) were not generated as part of this qualitative assessment. The aggregate of the rankings assigned to each core element was used to compare the overall environmental impacts between remediation alternatives.

The table in this appendix presents the detailed findings of the green remediation qualitative assessment and the associated numerical rankings for each remedial alternative identified for the Former GM Delco Plant 5. A summary of findings for each groundwater and soil remedial alternative follows.

Groundwater

No Action

The No Action alternative served as the baseline for the green remediation evaluation to which all other alternatives are compared. Under this alternative, there are no site activities. Therefore, there will be no energy or water requirements, air emissions, impact to land, material consumption, or waste generation. However, this alternative is not protective of human health and the environment.

Groundwater Extraction

The installation and construction of a groundwater extraction system that includes the use of five extraction wells and a treatment building requires a small amount of energy and water. It also would produce little air impacts and would consume and generate a small amount of materials and waste, respectively. Energy would be consumed in the transportation of 20 cubic yards of impacted soil 250 miles to a landfill. However, to operate this system for the lifetime of 30 continuous years weighs negatively with respect to energy requirements, air emissions, material consumption, and waste generation and would require a large amount of energy and generate waste. Depending on the flow rate of the five extraction wells, the treatment equipment associated with a shallow tray stripper would require regular media change-outs resulting in high material use and waste generation. In addition, a large amount of groundwater would be discharged to the local sewer system which weighs negatively on the impact to water resources.

In Situ Chemical Oxidation

Within the initial construction phase and implementation of this remedy, the energy requirements, material consumption, and waste generation is significantly higher than any other alternative proposed due to a network of 61 injection wells proposed for the In Situ Chemical Oxidation (ISCO) alternative. Water requirements during O&M are also high because of the number of wells and the delivery of the oxidant as an aqueous solution. However, due to the effective one-year treatment timeframe compared to the 30-year operational time frame of the remedies involving extraction, the environmental impact is far less.

Enhanced Reductive Dechlorination

The implementation of enhanced reductive dechlorination has a similar impact to that of ISCO, however, the lifetime of this remedy requires two years. A large amount of energy is required and materials consumed for the installation of 61 injection wells. The consumption of 40,000 pounds of the organic carbon source (emulsified oil substrate) and 240,000 gallons of water weighs negatively on the net footprint of this remedy.

Bentonite Cutoff Wall

The installation and construction of a bentonite wall and a groundwater extraction system that includes the use of three extraction wells and a treatment building requires a moderate amount of energy and materials. Although there are fewer wells proposed for this alternative as compared to the groundwater extraction alternative, energy would be consumed in the transportation of 1,600 cubic yards of impacted soil 250 miles to a landfill. It also would produce moderate air impacts and would generate a moderate amount of waste.

To operate this system for the lifetime of 30 continuous years weighs negatively with respect to energy requirements, air emissions, material consumption, and waste generation and would require a large amount of energy and generate waste. Depending on the flow rate of the five extraction wells, the treatment equipment associated with a shallow tray stripper would require regular media change-outs resulting in high material use and waste generation. In addition, a large amount of groundwater would be discharged to the local sewer system which weighs negatively on the impact to water resources.

Results and Conclusions

Based on the numerical rankings from the green remediation qualitative assessment, the order of remedial alternatives, from more favorable to less favorable from a sustainability perspective is as follows:

- In Situ Chemical Oxidation
- Enhanced Reductive Dechlorination
- Groundwater Extraction
- Bentonite Cutoff Wall

This ranking only considers the five core elements of green remediation. Additional criteria were also considered in selecting corrective measures for the Former GM Delco Plant 5, and are presented in the CMP.

Soil

No Action

The No Action alternative served as the baseline for the green remediation evaluation to which all other alternatives are compared. Under this alternative, there are no site activities. Therefore, there will be no energy or water requirements, air emissions, impact to land, material consumption, or waste generation. However, this alternative is not protective of human health and the environment.

Engineering Control Cover

The installation of an asphalt cap over approximately 10,000 square feet as an engineering control generates little waste and requires a moderate amount of energy and no water to implement. Minimal impacts on water resources would occur, associated with a decrease in infiltration through the ground and

increased runoff from the asphalt cap as a result of the asphalt replacing the natural grassy surface that currently covers most of the site. The replacement of a natural surface (grass) with an asphalt cap also increases the impact to the land and ecosystem. There are minimal air emissions, mainly originating from the construction activities involved in applying the gravel and asphalt and the off-gassing associated with the asphalt itself. The amount of consumed materials is moderate to low compared to the other soil remedial alternatives.

Institutional Control

The institutional control is a complement to an engineered asphalt cover to verify effectiveness through inspection and maintenance. This option includes the development of a cover maintenance plan. Therefore, there will be no energy or water requirements, air emissions, impact to land, material consumption, or waste generation.

Phytoremediation

The implementation of phytoremediation requires a moderate amount of energy to install the estimated 122 trees and to supply nutrients to the root system. The air emissions associated with this remedy are mainly coupled with the excavation activities. Compared to the other proposed remediation strategies, this method requires minimal energy and water resources once the 2-year tree establishment period has passed. Material consumption and waste generation are minimal in that the majority of materials consumed are renewable resources (trees) and a limited volume of soil cuttings will be generated as waste during planting.

Soil Excavation

A large amount of energy is required to power excavation and de-watering equipment over a 2-month period. In addition, energy is also involved in the transportation of 11,000 tons of clean soil onsite, the transportation of 11,000 tons of impacted soil 250 miles to a landfill, and treatment an estimated 300,000 gallons of waste water generated. Significant air emissions are generated from the continuous use of heavy machinery and transportation. There is also a potential contribution of air emissions from chlorinated volatile organic compounds (CVOCs) that may be released during excavation activities. Although minimal water is required, there is a large amount of soil waste generated.

Calcium Oxide Treatment

This method requires a moderate amount of energy to excavate/mix the impacted soil and to operate the water pumps needed to activate the calcium oxide. Air emissions are associated with the mixing operations and volatilization of CVOCs from the soil/calcium oxide mixture. Water requirements, material consumption, and waste generation are relatively low due to this remedy's in-situ nature and reuse of excavated soil. In the event excess groundwater is generated during excavation activities there would be energy requirements, air emissions, and waste generation associated with the transport and treatment of impacted water offsite.

Electrical Resistivity Heating

Compared to the other remedial alternatives, this method requires a large amount of electricity and water need to create an electric field strong enough to heat the ground and volatilize the CVOCs. With 48 proposed soil vapor extraction (SVE) and sensor wells and 46 electrode boreholes, this remedial alternative has high energy requirements, and therefore, high air emissions associated with energy production sourced from non-renewable resources (largely coal). The transportation of the equipment and

soil cuttings to and from the site also contributes to higher energy requirements and air emissions. This remedial option also has high material consumption and waste generation during the construction phase. The CVOC emission treatment equipment will require regular media change-outs and regeneration resulting in high material use and waste generation, as well as associated impacts from transportation of the media on and off site.

Results and Conclusions

Based on the numerical rankings from the green remediation qualitative assessment, the order of remedial alternatives, from more favorable to less favorable from a sustainability perspective is as follows:

- Phytoremediation
- Engineering Control, with companion Institutional Control
- Calcium Oxide Treatment
- Electrical Resistivity Heating
- Soil Excavation

This ranking only considers the five core elements of green remediation. Additional criteria were also considered in selecting corrective measures for the Former GM Delco Plant 5, and are presented in the CMP.

GREEN REMEDIATION QUALITATIVE ASSESSMENT OF POTENTIAL SOIL CORRECTIVE MEASURE ALTERNATIVES
FORMER GM DELCO PLANT 5 – KOKOMO, IN

Potential Soil Corrective Measure Alternative	GREEN REMEDIATION ELEMENTS					Rank Summary
	Energy Requirements	Air Emissions	Water Requirements and Impacts on Water Resources	Land and Ecosystem Impacts	Material Consumption and Waste Generation	
No Action	No energy requirements	No air emissions from corrective measure energy requirements or CVOCs off-gas	Less certainty on the rate and extent of natural CVOC degradation in groundwater	No impacts to land and ecosystems	No material consumption and waste generation	Baseline
Engineering Control – Soil Cover	-1 Moderate amount of energy to: - Operate equipment for site clearing activities - Operate equipment for gravel and asphalt application - Transportation of 230 cubic yards of gravel, 350 cubic yards of asphalt, and 2,130 linear feet of fencing	-1 Mobile emissions associated with: - Construction activities - Transportation of 230 cubic yards of gravel, 350 cubic yards of asphalt, and 2,130 linear feet of fencing Negligible off-gassing of asphalt constituents	-1 Water not required for application of asphalt cap Increased runoff from the asphalt cap Decreased rainwater infiltration Less certainty on the rate and extent of natural CVOC degradation in groundwater	-1 10,000 sq ft of grassy area covered with asphalt	-2 Material consumption: - 230 cubic yards of gravel - 350 cubic yards of asphalt - 2,130 linear feet of fencing Minimal waste generation	-6
Institutional Control – Cover Management Plan	0 No energy requirements	0 No air emissions from corrective measure energy requirements or CVOCs off-gas Negligible emissions associated with support work (i.e., reporting)	0 No water use requirements Less certainty on the rate and extent of natural CVOC degradation in groundwater	0 No further impacts to land and ecosystems	0 No material consumption and waste generation	0
Phytoremediation	-1 Moderate amount of energy to: - Operate equipment for augering 122 tree locations - Supply oxygen and nutrients to root systems - Transportation of 122 trees, 10 tons of clean soil onsite, and 10 tons of impacted soil offsite	-1 Mobile emissions associated with transportation of 122 trees, 10 tons of clean soil onsite, and 10 tons of impacted soil offsite Mobile emissions from tree site preparation and planting Consumption of CO2 by 122 trees	+1 Negligible water usage during 2-year tree establishment period No additional water inputs needed following 2-year tree establishment period Land cover converted to trees reduces stormwater runoff by rainfall interception Reduces source mass thereby limiting future impacts to groundwater	+3 Creation of natural habitat	-2 Material consumption: - Oxygen consumption for root aeration - 122 trees, as a renewable resource - 10 tons soil - Limited water and fertilizer for irrigation Material consumption and waste generation: - Minimal impacts from monitoring and laboratory analysis Waste Generation: - Minimal soil waste (10 tons) disposed in landfill - Negligible impact from tree maintenance waste	0
Soil Excavation	-2 Large amount energy to: - Operate dewatering equipment for 300,000 gallons of groundwater - Transportation of 11,000 tons of impacted soil to landfill 250 miles away - Transportation of 11,000 tons of clean soil onto site	-2 Mobile emissions associated with: -Construction activities -250-mile transport of impacted soil - Transporting clean fill to site Moderate amount of dust created from excavation activities Stationary emissions associated with use of	-2 Collected groundwater from dewatering activities is treated offsite Minimal water used for decontamination of heavy machinery Reduces source mass	-2 Large amount of excavated soil waste (11,000 tons) stored in landfill No further impacts to land and ecosystems	-3 Material consumption: - 11,000 tons soil required for backfill Material consumption and waste generation: - Minimal impacts from monitoring and laboratory analysis Waste Generation: - Minimal clearing/grubbing waste	-11

Potential Soil Corrective Measure Alternative	GREEN REMEDIATION ELEMENTS					Rank Summary
	Energy Requirements	Air Emissions	Water Requirements and Impacts on Water Resources	Land and Ecosystem Impacts	Material Consumption and Waste Generation	
	Energy required for construction activities over a 2-month period Energy required offsite for treatment of 300,000 gallons of waste water	electricity generated with non-renewable fuel (coal) Potential emissions of CVOCs during excavation activities	thereby limiting future impacts to groundwater		- 11,000 tons of soil waste disposed in landfill	
Calcium Oxide Treatment	-2 Moderate amount of energy to: - Operate soil mixing equipment for 3 months - Transport calcium oxide to the site - Operate water pumps to activate oxidant - Treat/dispose of excess water	-2 Mobile emissions associated with use of heavy machinery over a 3-month excavation period Emissions associated with vehicular transportation of calcium oxide Emissions associated with the volatilization reaction due to treatment process Mobile emissions of potential offsite treatment/disposal of groundwater	0 Minimal amount of water required to activate oxidant Minimal water required for decontamination of heavy machinery Reduces source mass thereby limiting future impacts to groundwater Potential removal of excess groundwater from de-watering activities	0 No further impacts to land and ecosystems	-1 Material consumption: - Calcium oxide, a non-renewable resource Material consumption and waste generation: - Minimal impacts from monitoring and laboratory analysis Waste Generation: - Waste associated with potential water disposal Other Considerations: - Treated soil used as backfill (no offsite soil disposal required)	-5
Electrical Resistivity Heating	-3 Large amount of energy to: - Install system (including 23 soil vapor extraction (SVE) wells and 25 sensor wells) and 46 electrode boreholes - Operate system for 6 months (2,300,000 kWhr) - Operate SVE system Moderate amount of energy for: - Post treatment soil sampling - Transportation of equipment to site - Transportation of impacted soil cuttings off-site - Regeneration of activated carbon from emission control system	-3 Stationary emissions associated with use of electricity generated with non-renewable fuel (coal) ERH-generated vapor extracted by SVE system treated using activated carbon Mobile emissions associated with transportation of impacted soil cuttings offsite	-2 Moderate water demand over 6-month operation period Water used in system operation volatilizes and is treated in SVE system Reduces source mass thereby limiting future impacts to groundwater	0 No further impacts to land and ecosystems	-2 Material consumption: - Construction and equipment for 770 linear feet of SVE and sensor wells - Electrodes Material consumption and waste generation: - Activated carbon regeneration/replacement - Minimal impacts from monitoring and laboratory analysis - Minimal waste from well abandonment Waste Generation: - Soil cuttings from 23 soil vapor extraction wells and 25 sensor wells, and 46 electrode boreholes and 25 post-treatment soil sampling locations	-10

Notes:
CVOCs – Chlorinated Volatile Organic Compounds
Rankings were assigned to each technology based on the relative impact, as compared to the baseline technology, which in this case was No Action. Rankings ranged from -3 (much less favorable when compared to the baseline) to +3 (much more favorable when compared to the baseline).
Energy Requirement ranking influenced by air emissions associated with electricity and contribution to climate change via gas emissions through energy use.
The USEPA technology primer titled “Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites” (EPA 542-R-08-002, April 2008) was referenced in developing rankings for the five core elements.

GREEN REMEDIATION QUALITATIVE ASSESSMENT OF POTENTIAL GROUNDWATER CORRECTIVE MEASURE ALTERNATIVES
FORMER GM DELCO PLANT 5 – KOKOMO, IN

Potential Groundwater Corrective Measure Alternative	GREEN REMEDIATION ELEMENTS					Rank Summary
	Energy Requirements	Air Emissions	Water Requirements and Impacts on Water Resources	Land and Ecosystem Impacts	Material Consumption and Waste Generation	
No Action	No energy requirements	No air emissions from corrective measure energy requirements or CVOCs off-gas	Less certainty on the rate and extent of natural CVOC degradation in groundwater	No impacts to land and ecosystems	No material consumption or waste generation for remedy construction, operation, maintenance, monitoring, or laboratory analyses	Baseline
Groundwater Extraction	-3 High amount of energy to: - Install 5 extraction wells - Operate 5 extraction pumps - Overcome pressure drop in filtration and LGAC units - Construct treatment building - Operate treatment building for 30 years	-3 Mobile emissions associated with construction activities of treatment building and well installation/operation Stationary emissions associated with use of electricity generated with non-renewable fuel (coal) Air stripper gas effluent treated prior to discharging to atmosphere	+1 Minimal amount of water required for installation of 5 extraction wells. Extracted water treated to MCLs Plume is hydraulically-contained	-2 Low amount of impermeable surface area added from treatment building Moderate impact to ecosystem for construction and O&M activities	-2 Material consumption: - 450 linear feet of piping for conveyance system - Construction and equipment of 200 linear feet for 5 new extraction wells - Construction of treatment building - Treatment units: air stripper, filtration, LGAC Material consumption and waste generation: - Potentially caustic de-scaling cleansers for periodic air stripper cleaning - Use and disposal of bag filters (or other filtration media) for pre-air stripper treatment - Adsorption media used in treating gas effluent will become spent and need to be recharged or landfilled Waste Generation: - 20 cubic yards of soil cuttings from installation of 5 extraction wells and trenching/conveyance line installation	-9
In Situ Chemical Oxidation	-2 Low amount of energy to operate: - Injection well pumps (at a low pressure and quarterly for 1 year) - Pump for water source during injection process High amount of energy to: - Install 61 injection wells Shorter-term system operation due to effectiveness of treating source areas results in low life-time energy use	-1 Shorter-term system operation due to effectiveness of treating source areas results in low life-time emissions Mobile emissions associated with: - Well installation activities - Transportation of oxidant - 250-mile transport of impacted soil from well installation	0 98,000 gals of water required to mix with oxidant Moderate amount of water required for installation of 61 injection wells Treatment of groundwater at source areas	-2 Temporary but high impact to ecosystem for construction and O&M activities of 61 injection wells No impermeable surface area added	-3 Material consumption: - Construction and equipment for 2,440 linear feet of injection wells - Manifold, storage tank, and other injection equipment - 80,000 pounds of potassium permanganate oxidant Material consumption and waste generation: - Minimal impacts from monitoring and laboratory analysis Waste Generation routed to landfills: - 30 cubic yards of soil cuttings from installation of 61 injection wells	-8
Enhanced Reductive Dechlorination	-2 Low amount of energy to operate: - Injection well pumps (at a low pressure and only periodically) - Pumps for water source during injection process High amount of energy to:	-2 Mobile emissions associated with: - Well installation activities - Transportation of organic carbon solution - 250-mile transport of impacted soil Stationary emissions associated with use of electricity generated with non-renewable fuel	0 240,000 gals of water required to mix with organic carbon source Moderate amount of water required for installation of 61 injection wells	-2 Temporary but high impact to ecosystem for construction and O&M activities of 61 injection wells	-3 Material consumption: - Construction and equipment for 2,440 linear feet of injection wells - Manifold, storage tank, and other injection equipment - 39,000 pounds of organic carbon source	-9

Potential Groundwater Corrective Measure Alternative	GREEN REMEDIATION ELEMENTS					Rank Summary
	Energy Requirements	Air Emissions	Water Requirements and Impacts on Water Resources	Land and Ecosystem Impacts	Material Consumption and Waste Generation	
	- Install 61 injection wells Shorter-term system operation due to effectiveness of treating source areas results in low life-time energy use	(coal) Methane generation from ERD treatment	Treatment of groundwater at source areas	No impermeable surface area added	Material consumption and waste generation: - Minimal impacts from monitoring and laboratory analysis Waste Generation routed to landfills: - 30 cyd of soil cuttings from installation of 61 injection wells	
Bentonite Cutoff Wall	-3 High amount of energy to: - Construct bentonite wall - Install 3 extraction wells - Operate 3 extraction pumps - Overcome pressure drop in filtration and LGAC units - Construct treatment building - Operate treatment building for 30 years - Transportation of 1,600 cubic yards of impacted soil to landfill 250 miles away	-3 Mobile emissions associated with: - Construction activities of treatment building and well installation/operation - Construction activities of extraction wells and bentonite wall - 250-mile transport of impacted soil Stationary emissions associated with use of electricity generated with non-renewable fuel (coal) Air stripper gas effluent treated prior to discharging to atmosphere Potential emissions of CVOCs during excavation activities	-1 Collected groundwater from dewatering activities is treated offsite Minimal water used for decontamination of heavy machinery Minimal amount of water required for installation of 3 extraction wells. Extracted water treated to MCLs Plume is hydraulically-contained	-3 Moderate amount of excavated soil waste (1,600 cubic yards) stored in landfill Low amount of impermeable surface area added from treatment building Moderate impact to ecosystem for construction and O&M activities	-3 Material consumption: - 14,400 square feet of bentonite barrier material - 400 linear ft of piping for conveyance system - Construction and equipment of 150 linear feet for 3 new extraction wells - Construction of treatment building - Treatment units: air stripper, filtration Material consumption and waste generation: - Minimal impacts from monitoring and laboratory analysis - Potentially caustic de-scaling cleansers for periodic air stripper cleaning - Use and disposal of bag filters (or other filtration media) for pre-air stripper treatment - Adsorption media used in treating gas effluent will become spent and need to be recharged or landfilled Waste Generation: - Minimal clearing/grubbing waste - 1,600 cubic yards of soil waste disposed in landfill	-13

Notes:

CVOCs – Chlorinated Volatile Organic Compounds

LGAC – Liquid Granular Activated Carbon

Rankings were assigned to each technology based on the relative impact, as compared to the baseline technology, which in this case was No Action. Rankings ranged from -3 (much less favorable when compared to the baseline) to +3 (much more favorable when compared to the baseline).

Energy Requirement ranking influenced by air emissions associated with electricity and contribution to climate change via gas emissions through energy use.

The USEPA technology primer titled “Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites” (EPA 542-R-08-002, April 2008) was referenced in developing rankings for the five core elements.