

# **Appendix A**

## **Supplemental Information for a Corrective Action Plan for Monitored Natural Attenuation**

# Appendix A

## Supplemental Information for a Corrective Action Plan for Monitored Natural Attenuation

When Monitored Natural Attenuation (MNA) is the proposed corrective action option in a Corrective Action Plan (CAP), supplemental information needs to be evaluated. This Appendix outlines the information and calculations that need to be included in a CAP, in addition to the other standard CAP requirements. This information will enable the Executive Secretary (UST) of the Utah Solid and Hazardous Waste Control Board to determine if MNA is expected to meet the cleanup criteria outlined in Utah Admin. Code R311-211.

The following criteria must be met before considering MNA as a corrective action strategy:

- The source (including contaminated soil and free product) has been removed or controlled to the maximum extent practicable.
- Unacceptable risks to human health and the environment do not exist for current or potential receptors.
- The groundwater contamination plume is stable or shrinking.
- MNA will achieve the cleanup goals for the site.

### A.1. Minimum Data Requirements and Reporting

Adequate site characterization is essential to determine the ability of natural attenuation processes to control and remediate contamination. When natural attenuation is considered as a partial or sole remedy for a site, site investigation needs are generally greater than if other remedies are applied. This is due to the fact that other remedies impose an external control on contaminant migration and/or reduction. In addition, the effectiveness of other remedies to achieve site cleanup goals can usually be assessed within a relatively short time. When natural attenuation processes are relied upon as a cleanup mechanism, a thorough understanding of the processes controlling contaminant movement and degradation is required because no active intervention is controlling the movement of environmental contaminants. Consequently, the time frame for achieving site cleanup goals using natural attenuation may be considerably longer than if another remedy is implemented.

#### Data Requirements

Prior to preparing a CAP for MNA, the following data requirements must be met in order to provide sufficient data to characterize a site and evaluate MNA. Additional and/or refined data may be necessary if existing data is inadequate or yields inconclusive results.

- **Define the horizontal and vertical extent and degree of the contamination in the unsaturated and saturated soils and dissolved in the groundwater, including any free product remaining at the site.**
- The monitoring well network must be comprised of a minimum of 6 sampling locations to define the extent and degree of dissolved phase contamination. A

minimum of 3 sampling points must be located along the plume centerline. Wells outside the plume's perimeter (point of compliance wells) should never be impacted.

- Complete a minimum of 2 consecutive years of quarterly groundwater sampling, or a minimum of 8 groundwater sampling events. Sampling data must include depth to water, groundwater elevation, free product thickness, and contaminant concentrations.

### **Submittals**

The reporting requirements include, but are not limited to, the following submittals that will be used to identify receptors and assess natural attenuation processes:

- Describe the current land use for the release site and surrounding areas. Site maps and site vicinity maps should be presented with a brief discussion that details the presence of current or potential receptors located at and in the vicinity of the contaminated site and should:
  - Indicate the distance and estimated depth (in feet) below grade from the source area of petroleum contamination to the following buried utilities: water line, sanitary sewer, natural gas, storm drain, telephone, electrical, other (specify). Also describe the material of construction for the water line, storm drain and sewer utilities.
  - Indicate the distance (in feet) from the source area of petroleum contamination to property lines and building(s). Indicate type and use of property, such as residential, commercial or industrial. Indicate relevant construction details of all buildings, such as slab-on grade, basement, French drains, and other features.
  - Document the water well survey or Points of Diversion information conducted for the release site. The well survey should include well location maps, well construction details, borehole logs, current use, and wellhead protection plans for municipal wells.
- Demonstrate that the extent and degree of the contamination are defined, and estimate the contaminant mass in the source area by providing the following figures along with a brief discussion of the implications:
  - Contaminant iso-concentration contour maps showing the estimated extent of soil contamination. Maps of the initial soil concentrations and final soil concentrations should be prepared, if available (see Figure 1).
  - Geologic cross-sections detailing locations and concentrations of Contaminants of Concern (COCs) in soil, including all relevant surface and subsurface features.
  - Contaminant iso-concentration contour maps showing the extent of dissolved contaminant concentrations (see Figures 2 and 3).
  - Data tables showing all soil and groundwater sample data collected at the site, including sample location and identification, date collected, depth to

- groundwater, depth of sample, and contaminant concentrations (see Tables 1 and 2).
- Hydrographs that plot depth to groundwater and corresponding contaminant concentrations over time for a minimum of all centerline wells (see Figures 4 and 5). Show the zone and constituent concentrations of soil contamination on the hydrograph.

## **A.2. Receptor Evaluation**

Once receptors are identified, it is important to determine whether the COCs pose a threat to receptors. Consider likely pathways and site-specific factors, such as: screened intervals of pumping wells, field screening data (such as soil vapor surveys or sub-slab vapor surveys near building foundations), indoor air complaints, and other relevant exposure scenarios. The following should be included in a receptor evaluation:

- A completed Site Conceptual Exposure Model (SCEM). (See Figure 6).
- A discussion of why exposure pathways marked incomplete on the SCEM are considered incomplete.
- A discussion of any current or potential exposures to human health and the environment.
- Identification and explanation of interim abatement measures and response actions that were implemented or are planned.
- Document institutional controls used to mitigate the risk posed to the public health, safety, welfare, or the environment that:
  - Limit the use of the real property, groundwater, or surface water.
  - Limit activities that may be performed on or at the property.
  - Require maintenance of any engineering or other control.

## **A.3. Lines of Evidence**

### **Primary Lines of Evidence**

This section describes how site-specific data can be compiled and analyzed to evaluate contaminant behavior and trends in groundwater. A minimum of 2 consecutive years of quarterly groundwater sampling, or a minimum of 8 groundwater sampling events approved by the DERR project manager are required in order to determine plume trends. In some cases, additional monitoring data will be necessary. Contaminant trends will indicate whether the dissolved phase plume is expanding, stable, or shrinking. For each well, the COCs that exceed established DERR cleanup levels generally will be used in the trend analysis. Aquifer conditions should be consistent for the data points used in the analysis. For example, the water table should be at comparable elevations for time points used in trend analyses. The following two trend analyses must be completed and clearly indicate that natural attenuation is occurring and that the plume is stable or shrinking. Example figures and calculations for primary lines for evidence are provided in Figures 7 and 8.

- Groundwater Contaminant Mass Reduction Calculations:
  - Use contaminant iso-concentration contour maps to demonstrate a reduction in dissolved phase contaminant mass. Quantify this mass reduction by calculating the dissolved contaminant mass based on the contour maps for two or more separate sampling events and submit the calculations. The mass calculated for the most recent event must be lower than the mass of any earlier events to demonstrate mass reduction and effective natural attenuation.
  - In addition to commercially available software, the DERR has prepared spreadsheets that may be used to complete mass calculations. These spreadsheets are located in the LUST Program section of the DERR website for MNA.
  
- Empirical Data Trend Extrapolation: Concentration vs. Time
  - For each contaminated well, create a concentration vs. time plot in order to calculate a first-order contaminant decay rate (k) for each COC that exceeds the DERR cleanup levels. This decay rate is most easily calculated using a linear or logarithmic regression. A negative decay rate indicates a decreasing concentration trend.
  - Provide data tables, plots, and calculations to verify and support results. In addition, report statistical correlation coefficients (R<sup>2</sup>) for each regression conducted.
  - If the calculated decay rate confirms a decreasing contaminant concentration trend, use the following equation to determine a predicted time to achieve cleanup levels:

$$t = -\frac{\ln\left(\frac{C_{CL}}{C_o}\right)}{k}$$

where;

- $t$  = Time to reach cleanup level
- $C_{CL}$  = DERR established cleanup level
- $C_o$  = Initial contaminant concentration
- $k$  = First order decay rate constant.

- Report the predicted time to achieve cleanup goals for each well. This will be the time required for the most recalcitrant compound in each well to reach its associated cleanup goal.

### Secondary Lines of Evidence

Common secondary lines of evidence include measuring and evaluating electron acceptors and geochemical parameters, calculating assimilative capacity of an aquifer, and estimating contaminant source lifetime through a mass-based approach. After extensive analysis of the

secondary lines of evidence and the respective methodologies used to calculate source lifetimes, the DERR has determined that due to the high level of uncertainty used to evaluate plume lifetimes and the ongoing national debate on the proper use of secondary lines of evidence to calculate plume lifetimes, no clearly appropriate method exists.

Secondary lines of evidence can be useful at investigative phases associated with determining corrective action alternatives at sites. The DERR may revise this guidance document if future information indicates that secondary lines of evidence can accurately calculate plume lifetime.

## **A.4. Conclusion**

The conclusion should contain a discussion of the attenuation of the plume and evidence that COCs are naturally degrading. Provide a summary of the data collected and analysis of that data supporting the technical feasibility of MNA for remediation. The conclusion must also demonstrate that MNA will comply with the Corrective Action Clean-up Standards Policy (Utah Admin. Code R311-211) by considering:

- The impact or potential impact of contamination on the public health;
- The impact or potential impact of contamination on the environment; and
- Economic considerations, technological feasibility, and cost-effectiveness of cleanup options.

A sampling proposal complete with justification for the sampling schedule must be included in accordance with Section 7 of this CAP Guide. A comparison of MNA and other remedial alternatives must also be included in accordance with Section 2 of this CAP guide.

The conclusion should also include any contingencies to be implemented in the event site conditions change or additional corrective actions become necessary. Changes in site conditions may include changes in land use, new receptors, evidence of impact to existing receptors, evidence that MNA is ineffective, changes in groundwater conditions, or any other condition that would have prevented the approval of MNA as the appropriate Corrective Action alternative. If the Executive Secretary (UST) determines that the data is incomplete or inconclusive, or if the time frame for cleanup is unacceptable, additional data collection and evaluation may be required prior to CAP approval.

**EXAMPLE FIGURES AND TABLES  
FOR MONITORED NATURAL ATTENUATION**

**Table 1: Example Soil Analytical Data**

Sample	Depth		Benzene	Toluene	Ethyl- benzene	Xylenes	Naphthalene	TPH (8015)
Location	(ft)	Date	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
SB-1		4/5/1993	0.018	<0.005	<0.005	0.037	na	<1
			0.015	<0.005	<0.005	0.017	na	<1
			0.008	<0.005	0.007	0.04	na	<1
SB-2		4/7/1993	0.47	0.69	3.4	11	na	61
			20	29	71	140	na	1500
			0.15	0.035	0.23	0.25	na	<1
MW-1		4/6/1993	0.009	<0.005	<0.005	<0.015	na	<1
			27	20	93	230	na	1800
MW-2	2-5	4/8/1993	0.008	0.27	0.29	3	na	21
	16		2	0.3	4	3	na	15
	40		<0.005	<0.005	<0.005	<0.015	na	14
MW-3	16	4/9/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	40		<0.005	<0.005	<0.005	<0.015	na	<1
MW-4	15	11/30/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	25		<0.005	0.007	0.009	0.034	na	<1
	41		<0.005	<0.005	<0.005	<0.015	na	<1
MW-5	17	12/2/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	31		<0.005	<0.005	<0.005	<0.015	na	<1
	41		<0.005	<0.005	<0.005	<0.015	na	<1
MW-6	15	12/2/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	40		<0.005	<0.005	<0.005	<0.015	na	<1
MW-7	15	12/2/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	40		<0.005	<0.005	<0.005	<0.015	na	<1
MW-8	15	12/2/1993	0.3	0.5	0.62	4	na	22
	25		0.015	0.2	0.03	<0.015	na	<1
	40		<0.005	<0.005	<0.005	<0.015	na	<1
MW-9	15	12/2/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	25		<0.005	<0.005	<0.005	<0.015	na	<1
	40		0.11	0.5	0.4	2	na	65



**Table 2: Example Historical Groundwater Data, mg/L**

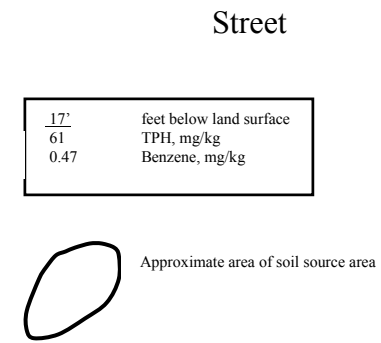
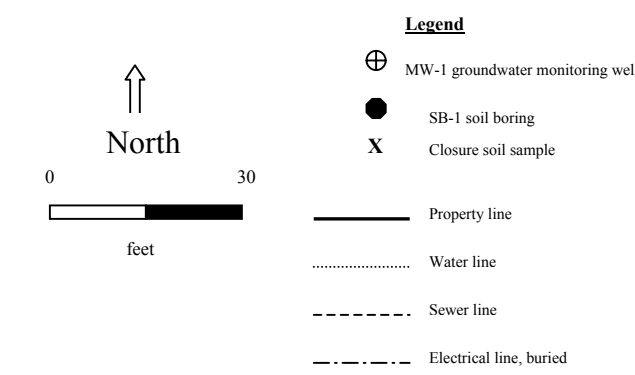
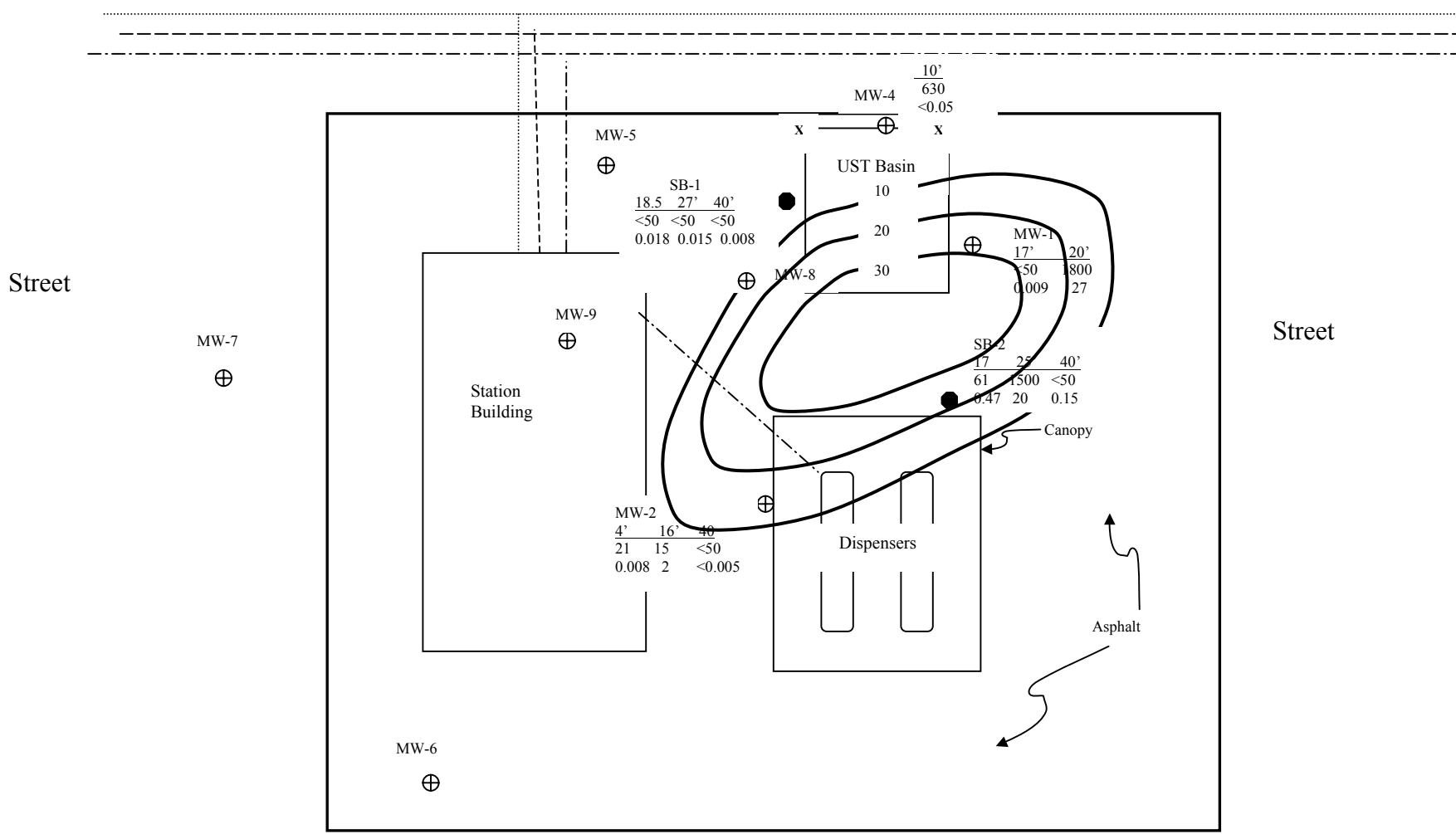
Facility Name:

Facility and Release ID:

Location:

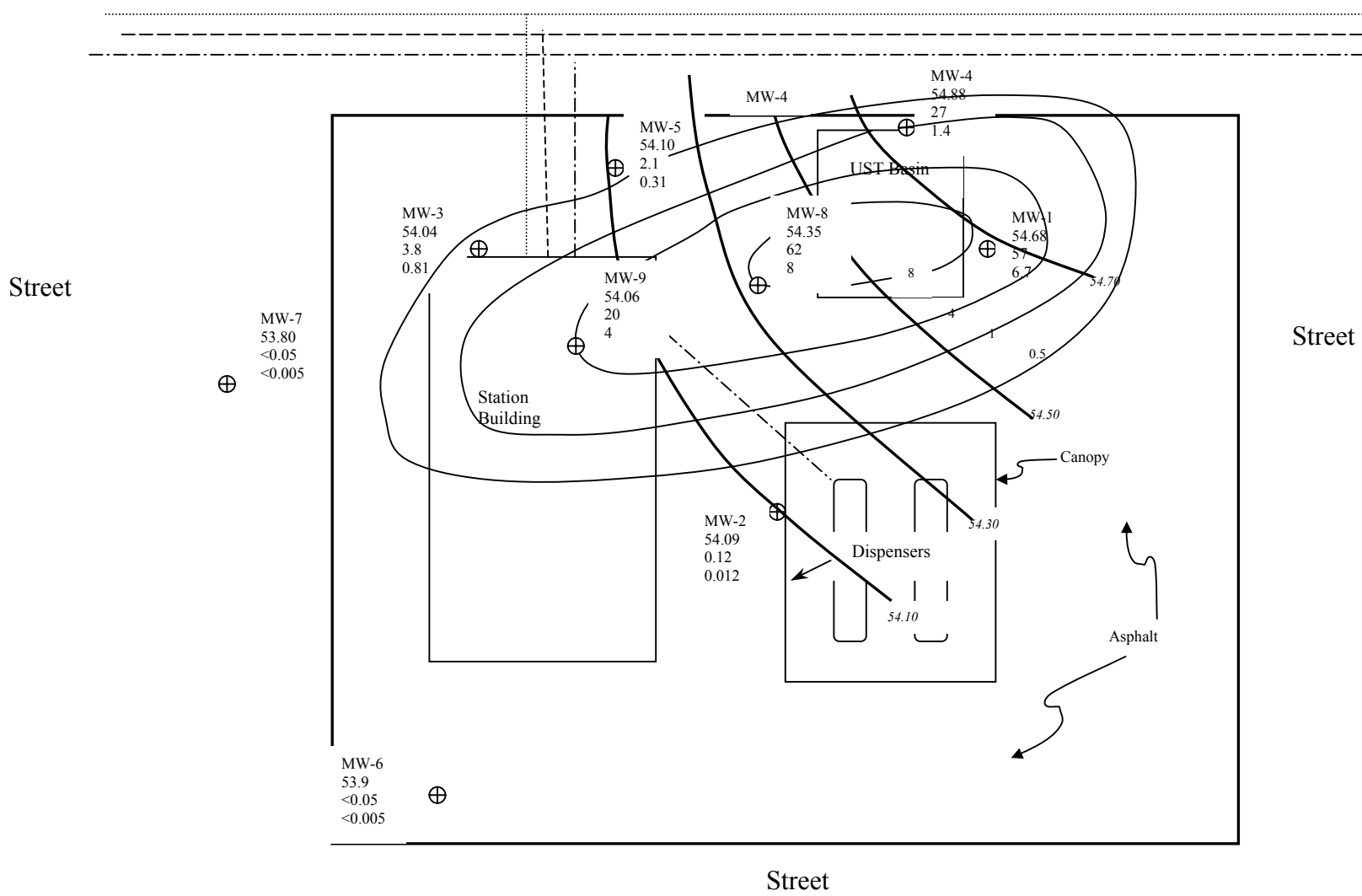
Sample Location and top of casing	Date	DTW	FP (feet)	GW Elev	Benzene	Toluene	Ethyl-benzene	Xylenes	Naphthalene	MTBE	TPH
MW-1	4/9/93	42.10	0.00	55.47	1.8	2.5	0.28	2.8	na	na	22
97.57	11/4/93	41.26	0.00	56.31	0.2	17	2	19	na	na	57
	2/22/94	41.46	0.00	56.11	7.2	16	1.5	19	na	na	89
	5/17/94	41.85	0.00	55.72	7.1	15	1.4	13	na	na	66
	8/5/94	42.38	0.00	55.19	5.8	12	1.3	10	na	na	54
	11/10/94	42.89	0.00	54.68	6.7	14	1.6	12	na	na	57
	2/7/95	42.66	0.00	54.91	7.9	16	1.8	13	na	na	61
	5/9/95	42.15	0.00	55.42	6.0	13	1.5	11	na	na	83
	8/7/95	39.65	0.00	57.92	5.5	14	1.7	13	na	na	56
	11/16/95	39.80	0.00	57.77	4.5	12	1.3	12	na	na	76
	2/13/96	40.58	0.00	56.99	5.0	16	2	15	na	na	79
	5/14/96	40.74	0.00	56.83	4.6	14	1.7	13	na	na	55
	8/19/96	41.19	0.00	56.38	5.6	14	1.9	14	na	na	66
	11/18/96	41.64	0.00	55.93	4.5	11	1.1	9.4	na	na	70
	2/17/97	41.26	0.00	56.31	3.6	7.9	0.82	6.9	na	<0.002	52
	5/19/97	40.87	0.00	56.70	2.3	8.2	1.2	10	<0.002	<0.002	59
	8/29/97	39.23	0.00	58.34	3.5	8.9	1.1	8.1	0.068	<0.002	61
	11/6/97	39.08	0.00	58.49	3.8	9.4	1.6	15	0.58	<0.002	56
	2/9/98	40.05	0.00	57.52	0.058	4.2	0.9	5.9	0.48	0.84	32
	8/13/99	38.42	0.00	59.15	5.0	3.9	1.2	5.9	<1400	<0.002	40
	11/11/99	39.51	0.00	58.06	5.72	5.39	1.77	10.7	<350	<0.002	58.2
	2/4/00	40.60	0.00	56.97	5.43	5.18	1.65	12.7	<35.0	<0.002	52.9
	5/18/00	40.97	0.00	56.60	3.82	2.94	1.44	8.61	0.485	<0.002	89.8
	11/9/00	42.47	0.00	55.10	5.08	2.74	1.42	8.11	0.282	<0.002	63.6
	2/8/01	42.06	0.00	55.51	3.76	1.93	1.02	5.78	0.18	<0.002	47.6
	5/2/01	41.95	0.00	55.62	5.23	1.51	1.17	6.85	0.255	<0.002	59.4
	8/23/01	41.05	0.09	56.52							
	8/30/01	41.08	0.13	56.49							
	11/16/01	41.55	0.23	56.02							
	2/24/02	42.34	0.00	55.23	2.4	1.3	0.82	3.7	0.29	<0.002	31
	5/24/02	42.79	0.00	54.78	4.8	0.88	1.3	3.7	0.3	<0.002	39
	8/21/02	44.16	0.00	53.41	4.4	0.71	0.97	1.8	0.24	<0.002	30
MW-3	4/12/93	43.99	0.00	54.85	0.11	0.003	<0.002	0.15			0.54
98.84	11/4/93	43.25	0.00	55.59	0.54	0.033	0.005	0.51			3.5
	2/22/94	43.30	0.00	55.54	0.76	0.11	0.015	0.6			4.5
	5/17/94	43.50	0.00	55.34	0.87	0.059	0.015	0.58			4.6
	8/5/94	44.26	0.00	54.58	1.2	0.45	0.067	0.63			6.1
	11/10/94	44.80	0.00	54.04	0.81	0.082	0.031	0.16			3.8
	2/7/95	44.49	0.00	54.35	0.76	0.058	0.022	0.15			4.1
	5/9/95	44.04	0.00	54.80	0.85	0.076	0.043	0.14			4.2
	8/7/95	41.82	0.00	57.02	0.55	0.031	0.0074	0.056			2.8
	11/16/95	41.88	0.00	56.96	0.61	0.022	0.011	0.049			3.7
	2/13/96	42.60	0.00	56.24	0.57	0.031	0.012	0.027			2.9
	5/14/96	42.72	0.00	56.12	0.58	0.024	0.02	0.029			2.6
	8/19/96	43.15	0.00	55.69	0.86	0.042	0.065	0.045			4.1
	11/18/96	43.63	0.00	55.21	0.7	0.024	0.063	0.018			4.8
	2/17/97	43.26	0.00	55.58	0.55	0.02	0.03	<0.002		<0.002	4.2
	5/19/97	42.88	0.00	55.96	0.62	<0.002	0.055	<0.002	<0.002	<0.002	4.7
	8/29/97	41.34	0.00	57.50	0.42	0.019	0.031	0.015	0.0035	0.013	4.8
	11/6/97	41.14	0.00	57.70	0.19	0.17	0.031	0.009	0.022	<0.002	1.6
	2/9/98	41.98	0.00	56.86	0.37	0.022	0.0079	<0.002	0.011	<0.002	1.1
	8/13/99	40.48	0.00	58.36	0.13	0.0066	0.028	0.0078	<35.0	<2.00	0.79
	11/11/99	41.35	0.00	57.49	0.188	0.0187	0.013	0.0376	<35.0	<20.0	0.997
	2/4/00	42.45	0.00	56.39	0.279	0.0057	0.0589	<0.500	<35.0	0.0747	1.5
	5/18/00	42.88	0.00	55.96	0.128	0.005	0.0373	<6	0.0053	<2	0.8
	11/9/00	43.29	0.00	55.55	0.108	0.0058	0.0414	<6	0.0039	<2	1.1
	2/8/01	43.94	0.00	54.90	0.0571	0.0043	0.0448	<6	0.0041	<2	1.2
	5/2/01	43.80	0.00	55.04	0.0194	0.0042	0.0566	<6	0.0052	<2	1.3
	8/23/01	42.91	0.00	55.93	0.059	0.006	0.05	0.008	<5.0	0.017	2.24
	11/16/01	43.26	0.00	55.58	0.033	0.0044	0.073	0.0057	0.007	<10	2.6
	2/24/02	44.24	0.00	54.60	0.036	0.0019	0.03	0.0067	<5.0	<10	1.9
	5/24/02	44.55	0.00	54.29	0.038	0.0018	0.022	0.0057	<5.0	<20	1.8
	8/21/02	45.80	0.00	53.04	0.023	0.0022	0.031	0.0056	<5.0	<10	1.6

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**Figure 1**  
**Soil Contaminant Concentration Map**  
**Benzene, mg/kg**  
*Sampling Date: April 5-8, 1993*  
**Example Gas Station**

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**Figure 2**  
**Groundwater Flow and**  
**Contaminant Iso-Concentration Map**  
**Benzene, mg/L**  
*Sampling Date: November*  
*10, 1994*

**Legend**

⊕ MW-1 groundwater monitoring well  
 54.68 groundwater elevation, feet above  
 permanent surveyed common marker  
 57 TPH, mg/L  
 6.7 Benzene, mg/L

— Property line  
 ..... Water line  
 - - - - - Sewer line  
 - . - . - . Electrical line, buried

Groundwater elevation contour  
 line with flow direction  
 $i = \text{Hydraulic gradient } 0.01 \text{ ft/ft}$

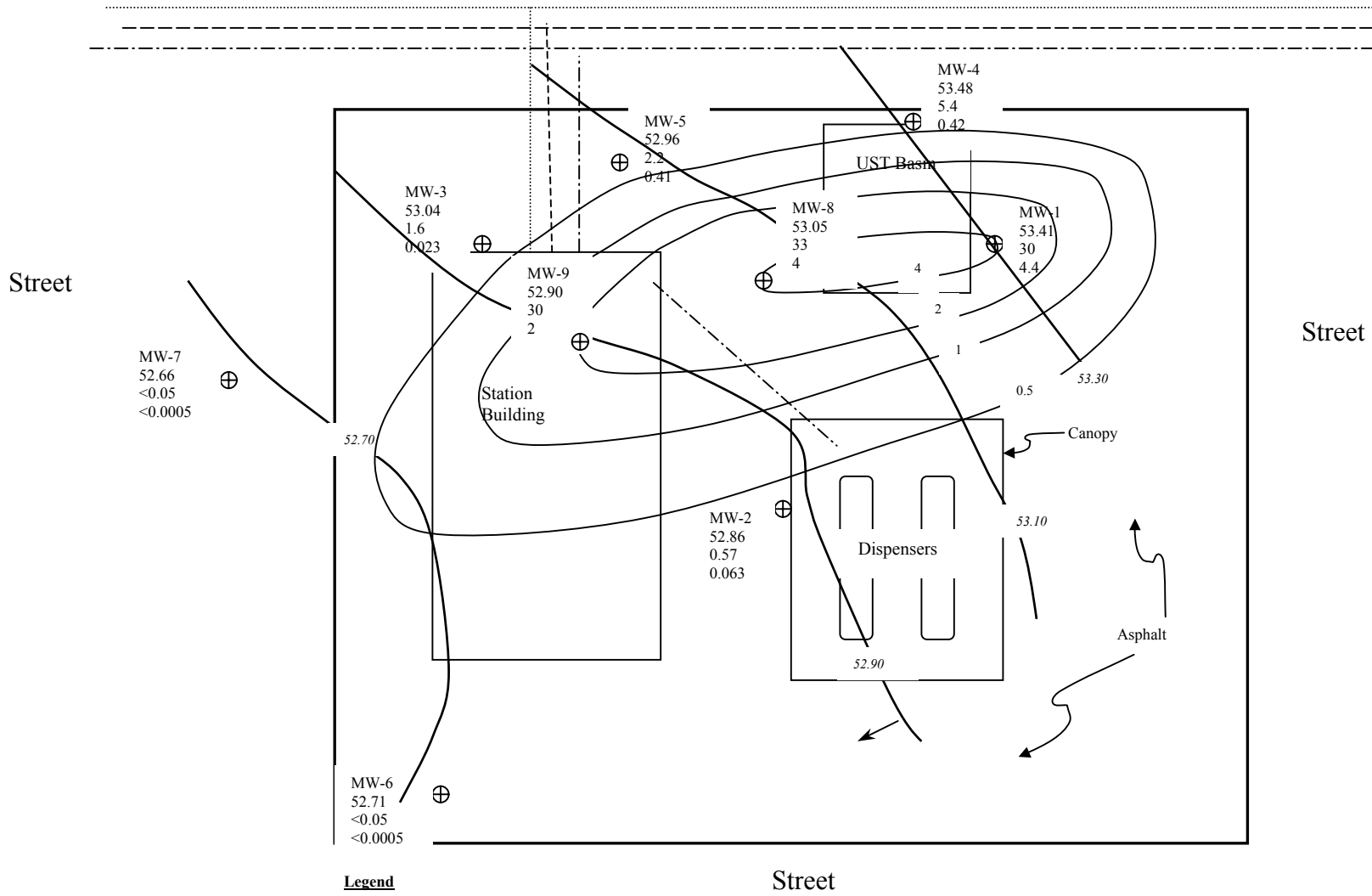
Contaminant  
 concentration contour  
 lines, estimated, mg/L

0 30  
 feet

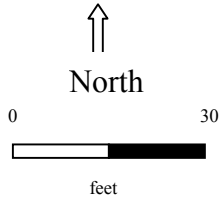
North

54.70

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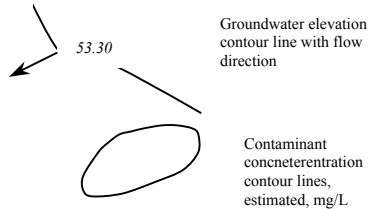


**Legend**



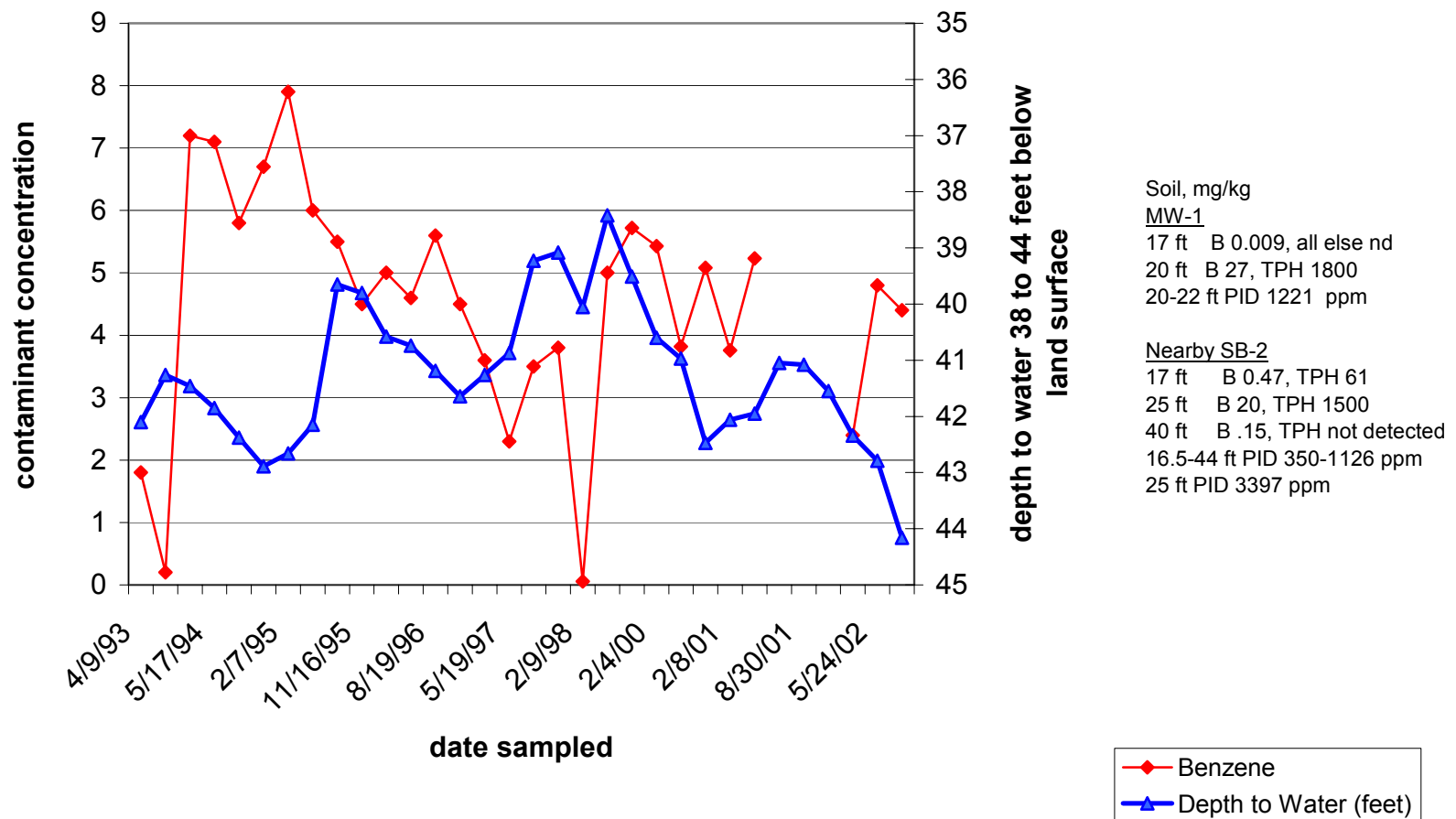
- ⊕ MW-1 groundwater monitoring well
- 53.41 groundwater elevation, feet above permanent surveyed common marker
- 30 TPH, mg/L
- 4.4 Benzene, mg/L

- Property line
- ..... Water line
- - - - Sewer line
- . - . - . Electrical line, buried

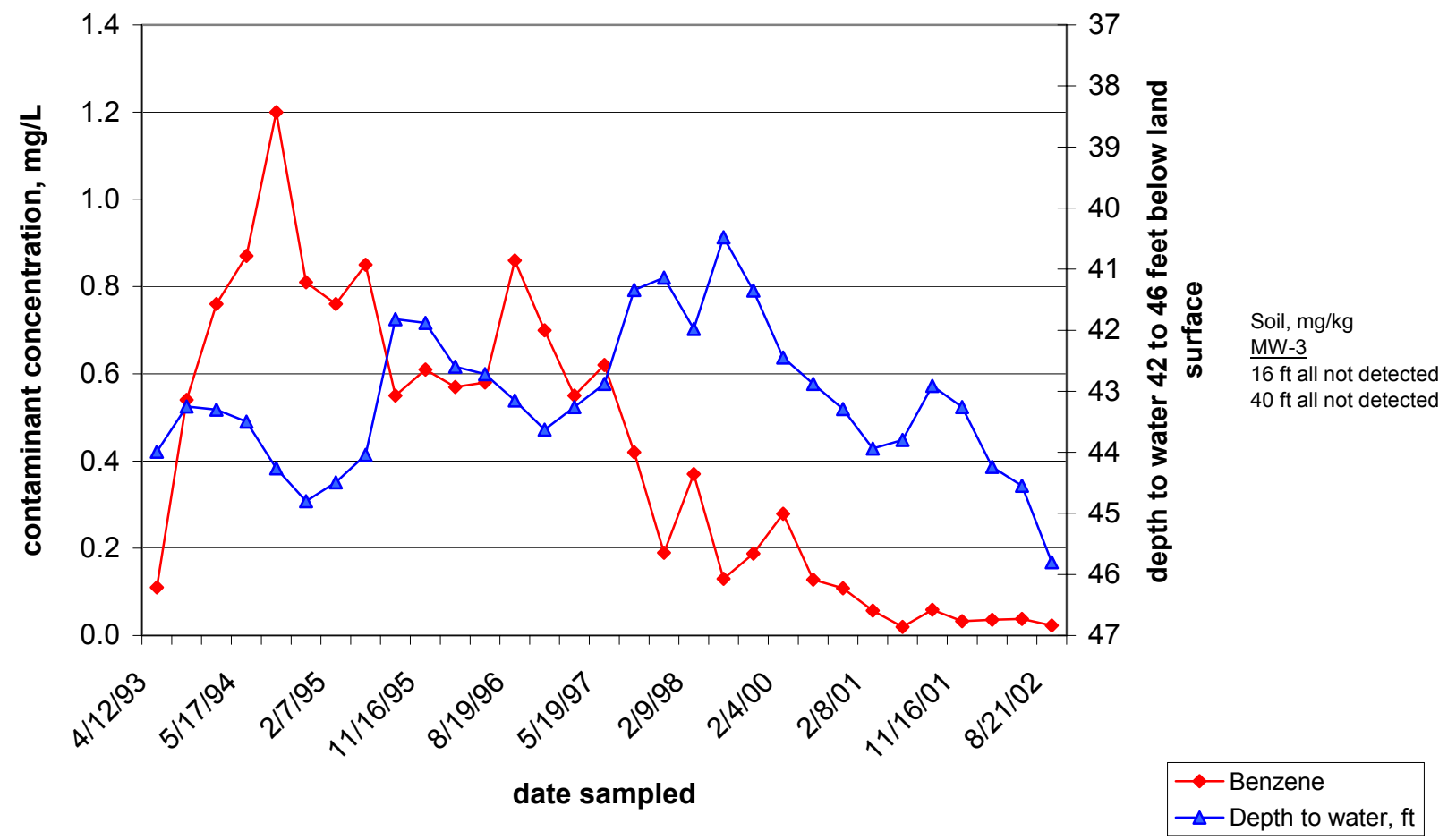


**Figure 3**  
**Groundwater Flow and**  
**Contaminant Iso-Concentration Map**  
**Benzene, mg/L**  
***Sampling Date: August 21,***  
***2002***

**Figure 4**  
**Example Facility Hydrograph**  
**MW-1, Source Area Well**  
*(note: dates not sampled = Free Product present)*



**Figure 5**  
**Example Facility Hydrograph**  
**MW-3, Perimeter Well**



Site Name: \_\_\_\_\_  
 Site Location: \_\_\_\_\_  
 Facility ID: \_\_\_\_\_

**Figure 6: Site Conceptual Exposure Model**

**INSTRUCTIONS**

1. Mark the small boxes if the specified condition is applicable
2. Fill in the shutoff valves to indicate that exposure pathway is NOT complete. Exposure pathway may not be complete due to source removal, control, and/or treatment.
3. For each complete pathway, identify the cleanup options

CAUSES of RELEASE

IMPACTED MEDIUM

TRANSPORT MECHANISM

EXPOSURE PATHWAY

POTENTIAL RECEPTORS\*

CLEANUP OPTIONS

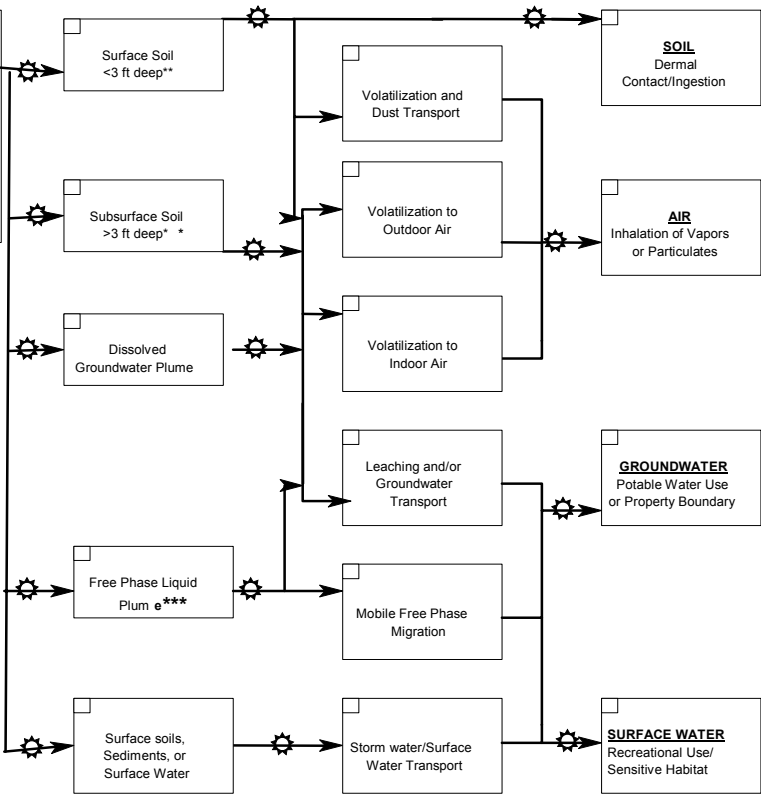
(check applicable)

\_\_\_ Product Storage (tanks/UST)

\_\_\_ Piping

\_\_\_ Dispenser

\_\_\_ Other



**Exposed Receptors**

**On-site:** Residential  nonresidential   
 Sensitive Habitat  construction worker

**Off-site:** Residential  nonresidential   
 Sensitive Habitat  construction worker

**Exposed Persons**

**On-site:** Residential  nonresidential   
 Sensitive Habitat  construction worker

**Off-site:** Residential  nonresidential   
 Sensitive Habitat  construction worker

**Groundwater Users**

**On-site:** Residential  nonresidential   
 Sensitive Habitat  construction worker

**Off-site:** Residential  nonresidential   
 Sensitive Habitat  construction worker

**Surface Water Users**

**On-site:** Residential  nonresidential   
 Sensitive Habitat  None

**Off-site:** Residential  nonresidential   
 Sensitive Habitat  construction worker

Complete \_\_\_ Current Pathway \_\_\_ Potential

Action Required? Yes \_\_\_ No \_\_\_  
 if YES, list cleanup options below:

Complete \_\_\_ Current Pathway \_\_\_ Potential

Action Required? Yes \_\_\_ No \_\_\_  
 if YES, list cleanup options below:

Complete \_\_\_ Current Pathway \_\_\_ Potential

Action Required? Yes \_\_\_ No \_\_\_  
 if YES, list cleanup options below:

Complete \_\_\_ Current Pathway \_\_\_ Potential

Action Required? Yes \_\_\_ No \_\_\_  
 if YES, list cleanup options below:

**Notes:**

- \* "Potential" refers to a projection of 5 to 10 years
- \*\* Evaluate potential for subsurface soil to be excavated and become surface soil
- \*\*\* Free Product is a source that must be eliminated or controlled. See Free Product Removal Report in Subsurface Investigation, Appendix D.

**Figure 7: Mass Calculations for Dissolved Phase**

Facility Name: Example Utah LUST Site  
 Facility & Release ID:  
 Facility Location:

Date:  
 DERR Project Manager:  
 Constituent: Benzene

**INSTRUCTIONS**

**Example of Dissolved Plume Concentration Map at TIME=INITIAL**

- The following example shows how to calculate contaminant mass in the dissolved phase for TPH.
- Construct a site-specific contaminant concentration contour map. Divide the map into discrete sections or "areas" to calculate the mass in each area for each time interval as shown. In the example, the average concentrations in Areas A, B and C at TIME = INITIAL are: A = (30 mg/L/2) = 15 mg/L; B = (30 - 10 mg/L) = 20 mg/L; C = (10 - 1 mg/L) = 9 mg/L. Use the same methodology for TIME = END.
- Calculate the total mass in each area for TIME = INITIAL and TIME = END. Identify the dates of your initial and ending times.
- The plume is stable or shrinking if the initial mass is the same or less than the ending mass. The plume is gaining mass if the initial mass is greater than the ending mass. The FINAL % REDUCTION (+) or INCREASE (-) will be displayed below.
- If you use this spreadsheet, enter your site-specific data in the unshaded cells. If you manually calculate mass, use the equations shown below:

**EQUATIONS FOR CALCULATING CONTAMINANT MASS**

The area of each plume Area is length times width  
 Mass Area(A) = Area of Area A, ft<sup>2</sup>(thickness of plume in Area A, ft)\*(average concentration in Area A, mg/L)\*(total porosity)\*(UMC)  
 Mass Area(B) = Area of Area B, ft<sup>2</sup>(thickness of plume in Area B, ft)\*(average concentration in Area B, mg/L)\*(total porosity)\*(UMC)  
 Mass Area(C) = Area of Area C, ft<sup>2</sup>(thickness of plume in Area C, ft)\*(average concentration in Area C, mg/L)\*(total porosity)\*(UMC)  
 UMC = Unit Mass Conversion = (1000 L/m<sup>3</sup>) \* (0.02832 m<sup>3</sup>/ft<sup>3</sup>) \* (1g/1000mg) \* (1kg/1000g) = kg of contaminant mass

% Mass Decrease or Increase = 1 - (Mass at Time = End/Mass at Time = Initial)

**FINAL % MASS REDUCTION (+) OR INCREASE (-) shown below**

**44%**

**TIME = INITIAL = November 10, 1994**

*GW Area "A"*

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
90	30	3	6	0.38	<b>0.523</b>

*GW Area "B"*

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet)	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
120	40	3	2.5	0.38	<b>0.169</b>

*GW Area "C"*

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
145	60	3	0.75	0.38	<b>0.094</b>

Contaminant Mass in Dissolved Phase (kg):	Contaminant Mass in Dissolved Phase (lbs)	Volume of Contaminant in Dissolved Phase (gal)	Volume of Contaminated Groundwater (gal)
<b>0.79</b>	<b>1.74</b>	<b>0.28</b>	<b>195,228</b>

**TIME = END = August 21, 2002**

*GW Area "A"*

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
90	25	3	3	0.38	<b>0.218</b>

*GW Area "B"*

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
120	40	3	1.5	0.38	<b>0.123</b>

*GW Area "C"*

Enter Plume Length below (feet)	Enter Plume Width below (feet)	Enter Plume Thickness below (feet) *	Enter Average Conc. below (mg/L)	Enter Porosity	Mass in Dissolved Phase shown below (kg)
150	60	3	0.75	0.38	<b>0.102</b>



**Figure 8**

**Facility Name:** Example Utah LUST Site  
**Facility Location and Address:**  
**State Project Manager:**

**Facility ID:**  
**Release ID:**  
**Date:**

**Instructions:** Plot contaminant concentrations over time. For the "Elapsed Time Since Sampling Began," you must adjust the formula to reflect the date since sampling began.

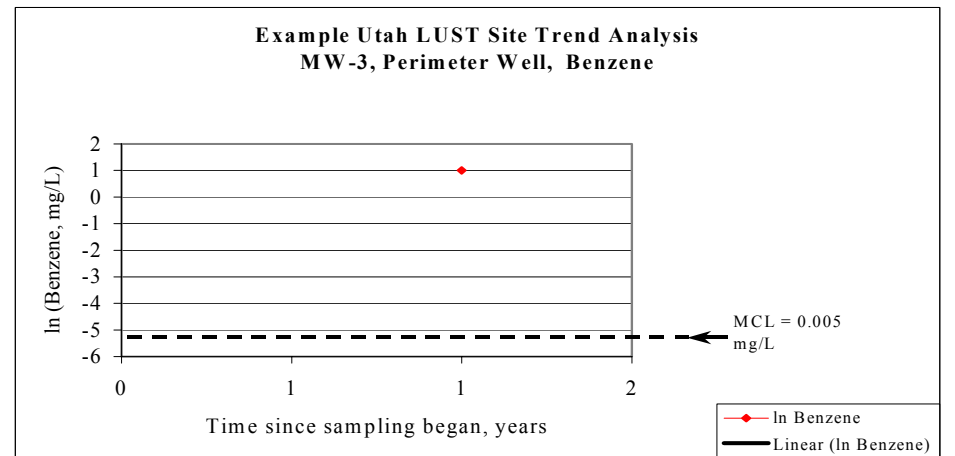
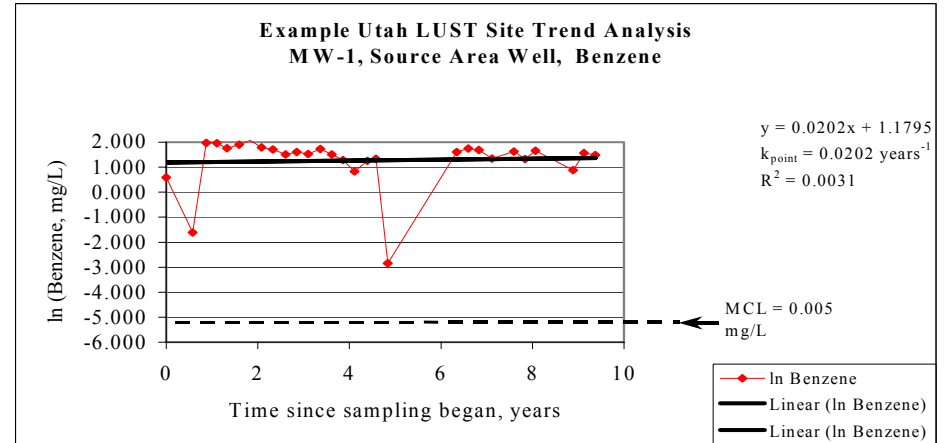
The formula for calculating Elapsed Time is: (Date - "DATE(yr,mo,dy))/365

Create a graph from the natural log of the constituent concentrations over the time elapsed since sampling began.

To plot  $y$  and  $R^2$ , click on the chart, select Chart from the menu, select Add Trendline, Select Linear Trendline, click on the adjacent Options tab, select Display Equation on Chart and Display R squared Value on Chart.

Sampling Date	Benzene MW-1 (mg/L)	In Benzene MW-1 (mg/L)	Elapsed time since 4/9/93 (years)	Sampling Date	Benzene MW-3 (mg/L)	In Benzene MW-3 (mg/L)	Elapsed time since 4/12/93 (years)
4/9/93	1.8	0.588	0.00	4/12/93	0.11	-2.207	0.00
11/4/93	0.2	-1.609	0.57	11/4/93	0.54	-0.616	0.56
2/22/94	7.2	1.974	0.87	2/22/94	0.76	-0.274	0.87
5/17/94	7.1	1.960	1.10	5/17/94	0.87	-0.139	1.10
8/5/94	5.8	1.758	1.32	8/5/94	1.2	0.182	1.32
11/10/94	6.7	1.902	1.59	11/10/94	0.81	-0.211	1.58
2/7/95	7.9	2.067	1.83	2/7/95	0.76	-0.274	1.82
5/9/95	6.0	1.792	2.08	5/9/95	0.85	-0.163	2.07
8/7/95	5.5	1.705	2.33	8/7/95	0.55	-0.598	2.32
11/16/95	4.5	1.504	2.61	11/16/95	0.61	-0.494	2.60
2/13/96	5.0	1.609	2.85	2/13/96	0.57	-0.562	2.84
5/14/96	4.6	1.526	3.10	5/14/96	0.58	-0.545	3.09
8/19/96	5.6	1.723	3.36	8/19/96	0.86	-0.151	3.36
11/18/96	4.5	1.504	3.61	11/18/96	0.7	-0.357	3.61
2/17/97	3.6	1.281	3.86	2/17/97	0.55	-0.598	3.85
5/19/97	2.3	0.833	4.11	5/19/97	0.62	-0.478	4.10
8/29/97	3.5	1.253	4.39	8/29/97	0.42	-0.868	4.38
11/6/97	3.8	1.335	4.58	11/6/97	0.19	-1.661	4.57
2/9/98	0.058	-2.847	4.84	2/9/98	0.37	-0.994	4.83
8/13/99	5.0	1.609	6.35	8/13/99	0.13	-2.040	6.34
11/11/99	5.72	1.744	6.59	11/11/99	0.188	-1.671	6.59
2/4/00	5.43	1.692	6.83	2/4/00	0.279	-1.277	6.82
5/18/00	3.82	1.340	7.11	5/18/00	0.128	-2.056	7.10
11/9/00	5.08	1.625	7.59	11/9/00	0.108	-2.226	7.58
2/8/01	3.76	1.324	7.84	2/8/01	0.0571	-2.863	7.83
5/2/01	5.23	1.654	8.07	5/2/01	0.0194	-3.942	8.06
2/24/02	2.4	0.875	8.88	8/23/01	0.059	-2.830	8.37
5/24/02	4.8	1.569	9.13	11/16/01	0.033	-3.411	8.60
8/21/02	4.4	1.482	9.37	2/24/02	0.036	-3.324	8.88
				5/24/02	0.038	-3.270	9.12
				8/21/02	0.023	-3.772	9.36

MCL 0.005 -5.298317



**Formulas**

$$t = [\ln(C_{CL}/C_o)] / -k$$

where:

t = Time to achieve cleanup levels, years

$C_{CL}$  = Cleanup level for contaminant of concern, mg/L

$C_o$  = Initial concentration of contaminant of concern, mg/L

$k_{point}$  = First-order decay rate constant, years<sup>-1</sup> = slope of the line

**Solutions**

<u>MW-1</u>		<u>MW-3</u>	
Enter $C_{CL}$	⇒ 0.005	Enter $C_{CL}$	⇒ 0.005
Enter $C_o$	⇒ 4.4	Enter $C_o$	⇒ 0.023
Enter $k_{point}$	⇒ 0.0202	Enter $k_{point}$	⇒ 0.1535
Time to reach cleanup level ⇒	336 years	Time to reach cleanup level ⇒	10 years

**Table 1: Example Soil Analytical Data, mg/kg**

Sample Location	Depth (feet bls)	Date	Benzene	Toluene	Ethyl-benzene	Xylenes	Naphthalene	TPH (8015)
SB-1	18.5	4/5/1993	0.018	<0.005	<0.005	0.037	na	<1
	27		0.015	<0.005	<0.005	0.017	na	<1
	40		0.008	<0.005	0.007	0.04	na	<1
SB-2	17	4/7/1993	0.47	0.69	3.4	11	na	61
	25		20	29	71	140	na	1500
	40		0.15	0.035	0.23	0.25	na	<1
MW-1	17	4/6/1993	0.009	<0.005	<0.005	<0.015	na	<1
	20		27	20	93	230	na	1800
MW-2	2-5	4/8/1993	0.008	0.27	0.29	3	na	21
	16		2	0.3	4	3	na	15
	40		<0.005	<0.005	<0.005	<0.015	na	14
MW-3	16	4/9/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	40		<0.005	<0.005	<0.005	<0.015	na	<1
MW-4	15	11/30/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	25		<0.005	0.007	0.009	0.034	na	<1
	41		<0.005	<0.005	<0.005	<0.015	na	<1
MW-5	17	12/2/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	31		<0.005	<0.005	<0.005	<0.015	na	<1
	41		<0.005	<0.005	<0.005	<0.015	na	<1
MW-6	15	12/2/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	40		<0.005	<0.005	<0.005	<0.015	na	<1
MW-7	15	12/2/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	40		<0.005	<0.005	<0.005	<0.015	na	<1
MW-8	15	12/2/1993	0.3	0.5	0.62	4	na	22
	25		0.015	0.2	0.03	<0.015	na	<1
	40		<0.005	<0.005	<0.005	<0.015	na	<1
MW-9	15	12/2/1993	<0.005	<0.005	<0.005	<0.015	na	<1
	25		<0.005	<0.005	<0.005	<0.015	na	<1
	40		0.11	0.5	0.4	2	na	65

Notes

bls = below land surface

na = not analyzed

**Table 2: Example Historical Groundwater Data, mg/L**

Facility Name:  
 Facility and Release ID:  
 Location:

Sample Location and TOC	Date	DTW	FP		Benzene	Toluene	Ethyl-benzene	Xylenes	Naph-thalene	MTBE	TPH
			(feet)	GWElev							
MW-1 97.57	4/9/93	42.10	0.00	55.47	1.8	2.5	0.28	2.8	na	na	22
	11/4/93	41.26	0.00	56.31	0.2	17	2	19	na	na	57
	2/22/94	41.46	0.00	56.11	7.2	16	1.5	19	na	na	89
	5/17/94	41.85	0.00	55.72	7.1	15	1.4	13	na	na	66
	8/5/94	42.38	0.00	55.19	5.8	12	1.3	10	na	na	54
	11/10/94	42.89	0.00	54.68	6.7	14	1.6	12	na	na	57
	2/7/95	42.66	0.00	54.91	7.9	16	1.8	13	na	na	61
	5/9/95	42.15	0.00	55.42	6.0	13	1.5	11	na	na	83
	8/7/95	39.65	0.00	57.92	5.5	14	1.7	13	na	na	56
	11/16/95	39.80	0.00	57.77	4.5	12	1.3	12	na	na	76
	2/13/96	40.58	0.00	56.99	5.0	16	2	15	na	na	79
	5/14/96	40.74	0.00	56.83	4.6	14	1.7	13	na	na	55
	8/19/96	41.19	0.00	56.38	5.6	14	1.9	14	na	na	66
	11/18/96	41.64	0.00	55.93	4.5	11	1.1	9.4	na	na	70
	2/17/97	41.26	0.00	56.31	3.6	7.9	0.82	6.9	na	<0.002	52
	5/19/97	40.87	0.00	56.70	2.3	8.2	1.2	10	<0.002	<0.002	59
	8/29/97	39.23	0.00	58.34	3.5	8.9	1.1	8.1	0.068	<0.002	61
	11/6/97	39.08	0.00	58.49	3.8	9.4	1.6	15	0.58	<0.002	56
	2/9/98	40.05	0.00	57.52	0.058	4.2	0.9	5.9	0.48	0.84	32
	8/13/99	38.42	0.00	59.15	5.0	3.9	1.2	5.9	<1400	<0.002	40
	11/11/99	39.51	0.00	58.06	5.72	5.39	1.77	10.7	<350	<0.002	58.2
	2/4/00	40.60	0.00	56.97	5.43	5.18	1.65	12.7	<35.0	<0.002	52.9
	5/18/00	40.97	0.00	56.60	3.82	2.94	1.44	8.61	0.485	<0.002	89.8
	11/9/00	42.47	0.00	55.10	5.08	2.74	1.42	8.11	0.282	<0.002	63.6
	2/8/01	42.06	0.00	55.51	3.76	1.93	1.02	5.78	0.18	<0.002	47.6
5/2/01	41.95	0.00	55.62	5.23	1.51	1.17	6.85	0.255	<0.002	59.4	
8/23/01	41.05	0.09	56.52					na, free product present			
8/30/01	41.08	0.13	56.49					na, free product present			
11/16/01	41.55	0.23	56.02					na, free product present			
2/24/02	42.34	0.00	55.23	2.4	1.3	0.82	3.7	0.29	<0.002	31	
5/24/02	42.79	0.00	54.78	4.8	0.88	1.3	3.7	0.3	<0.002	39	
8/21/02	44.16	0.00	53.41	4.4	0.71	0.97	1.8	0.24	<0.002	30	
MW-3 98.84	4/12/93	43.99	0.00	54.85	0.11	0.003	<0.002	0.15	na	na	0.54
	11/4/93	43.25	0.00	55.59	0.54	0.033	0.005	0.51	na	na	3.5
	2/22/94	43.30	0.00	55.54	0.76	0.11	0.015	0.6	na	na	4.5
	5/17/94	43.50	0.00	55.34	0.87	0.059	0.015	0.58	na	na	4.6
	8/5/94	44.26	0.00	54.58	1.2	0.45	0.067	0.63	na	na	6.1
	11/10/94	44.80	0.00	54.04	0.81	0.082	0.031	0.16	na	na	3.8
	2/7/95	44.49	0.00	54.35	0.76	0.058	0.022	0.15	na	na	4.1
	5/9/95	44.04	0.00	54.80	0.85	0.076	0.043	0.14	na	na	4.2
	8/7/95	41.82	0.00	57.02	0.55	0.031	0.0074	0.056	na	na	2.8
	11/16/95	41.88	0.00	56.96	0.61	0.022	0.011	0.049	na	na	3.7
	2/13/96	42.60	0.00	56.24	0.57	0.031	0.012	0.027	na	na	2.9
	5/14/96	42.72	0.00	56.12	0.58	0.024	0.02	0.029	na	na	2.6
	8/19/96	43.15	0.00	55.69	0.86	0.042	0.065	0.045	na	na	4.1
	11/18/96	43.63	0.00	55.21	0.7	0.024	0.063	0.018	na	na	4.8
	2/17/97	43.26	0.00	55.58	0.55	0.02	0.03	<0.002	na	<0.002	4.2
	5/19/97	42.88	0.00	55.96	0.62	<0.002	0.055	<0.002	<0.002	<0.002	4.7
	8/29/97	41.34	0.00	57.50	0.42	0.019	0.031	0.015	0.0035	0.013	4.8
	11/6/97	41.14	0.00	57.70	0.19	0.17	0.031	0.009	0.022	<0.002	1.6
	2/9/98	41.98	0.00	56.86	0.37	0.022	0.0079	<0.002	0.011	<0.002	1.1
	8/13/99	40.48	0.00	58.36	0.13	0.0066	0.028	0.0078	<35.0	<2.00	0.79
	11/11/99	41.35	0.00	57.49	0.188	0.0187	0.013	0.0376	<350	<20.0	0.997
	2/4/00	42.45	0.00	56.39	0.279	0.0057	0.0589	<0.500	<35.0	0.0747	1.5
	5/18/00	42.88	0.00	55.96	0.128	0.005	0.0373	<6	0.0053	<2	0.8
	11/9/00	43.29	0.00	55.55	0.108	0.0058	0.0414	<6	0.0039	<2	1.1
	2/8/01	43.94	0.00	54.90	0.0571	0.0043	0.0448	<6	0.0041	<2	1.2
5/2/01	43.80	0.00	55.04	0.0194	0.0042	0.0566	<6	0.0052	<2	1.3	
8/23/01	42.91	0.00	55.93	0.059	0.006	0.05	0.008	<5.0	0.017	2.24	
11/16/01	43.26	0.00	55.58	0.033	0.0044	0.073	0.0057	0.007	<10	2.6	
2/24/02	44.24	0.00	54.60	0.036	0.0019	0.03	0.0067	<5.0	<10	1.9	
5/24/02	44.55	0.00	54.29	0.038	0.0018	0.022	0.0057	<5.0	<20	1.8	
8/21/02	45.80	0.00	53.04	0.023	0.0022	0.031	0.0056	<5.0	<10	1.6	