SOLID & HAZARDOUS WASTE DIVISION
STORAGE TANK PROGRAM
GUIDANCE DOCUMENT #7

SUBJECT: SAMPLING AND LABORATORY ANALYTICAL REQUIREMENTS AND REMEDIATION STANDARDS

SCOPE: This document provides sampling and laboratory analytical requirements to insure that analyses conducted for Storage Tank Program (STP) projects are consistent throughout the program. This document also provides remediation standards for STP contaminants of concern (CoCs). As referenced in this document, "Chapter 17" refers to Water Quality Rules and Regulations, Chapter 17, Part J. If there are any conflicts between this document and any rule or regulation, the rule or regulation will prevail.

INTRODUCTION: This document provides laboratory analytical requirements for all work phases (i.e., subsurface investigation, additional site assessment completed as part of design, operation and maintenance, and closeout confirmation sampling) associated with STP remediation projects. The requirements in this document should be included in any Sampling and Analysis Plan (SAP) or minimum site assessment (MSA) work plan submitted to the STP.

Site owners completing MSAs should use this document to increase the likelihood of an MSA being approved by the STP, allowing a site to enter the program. This guidance may also be used for environmental audits where properties may have been impacted by an STP-eligible tank release.

1. STP Contaminants of Concern

STP CoCs in <u>both soil and groundwater</u> are benzene, ethylbenzene, toluene, and xylenes (BETX); total petroleum hydrocarbons (TPH) as gasoline range organics (GRO) and as diesel range organics (DRO); and naphthalene.

Additional CoCs in <u>groundwater</u> may include (see Table 3 for applicability) methyl *tert*-butyl ether (MTBE); *tert*-butyl alcohol (TBA); ethyl *tert*-butyl ether (ETBE); diisopropyl ether (DIPE); *tert*-amyl methyl ether (TAME); 1,2-dibromoethane or ethylene dibromide (EDB); 1,2-dichloroethane (1,2-DCA); dissolved lead (Pb); dissolved cadmium (Cd); and dissolved chromium (Cr). Sampling and analyses for EDB and 1,2-DCA are not necessary if it can be shown that no tanks were installed prior to 1996 and the site never contained a tank that stored racing fuel or aviation gasoline. Additional CoCs in <u>soil</u> are total Pb, total Cd, and Cr.

The majority of STP remediation projects involve petroleum products. When regulated hazardous substances are encountered in an STP remediation project, contact the STP Project Manager for assistance with monitoring and analytical requirements.

Minimum Site Assessment Contaminants of Concern. During an MSA, at all tank sites, soil and groundwater must be analyzed for BETX, TPH-DRO, and naphthalene. At fuel tank sites, soil and groundwater must also be analyzed for TPH-GRO. Groundwater must be analyzed for EDB and 1,2-DCA unless it can be shown that no tanks were installed prior to 1996 and the site never contained a tank that stored racing fuel or aviation gasoline. At used oil tank sites, soil samples must be analyzed for Total TOX. Laboratory methods for these CoCs are provided in this document. Analyses of soil and groundwater for other CoCs discussed in this document are not required during an MSA.

2. Remediation Standards

Contaminants must be decreased to acceptable levels for protection of human health and the environment before a contaminated site can be closed.

Groundwater. Remediation standards for CoCs in groundwater include U.S. Environmental Protection Agency (EPA) maximum contaminant levels (MCLs) for drinking water. Where an MCL does not exist for a CoC found in groundwater, a state drinking water equivalent level (DWEL) has been calculated using Chapter 17. Action levels have also been established for TPH-GRO and TPH-DRO. MCLs, DWELs, and action levels for CoCs in groundwater are provided in this guidance document. If a contaminant other than a CoC is found in groundwater, and an MCL does not exist for the contaminant, a DWEL must be calculated using Chapter 17.

Soil. With the exception of TPH-DRO, soil restoration levels are site specific. A risk assessment must be completed to determine contaminant remediation levels in soil that are protective of human health. Chapter 17 provides requirements for calculating site-specific remediation levels in soil.

Chapter 17 Calculations. When a DWEL or soil restoration level must be calculated, the equations in Chapter 17 will be used. A spreadsheet has been developed in Microsoft Excel based on Chapter 17 equations that can be used to calculate acceptable contaminant levels. The spreadsheet can be found on the STP website at http://deq.state.wy.us/shwd/stp and clicking on the Guidance Document link. The spreadsheet is in the Guidance Document #7 link. Attachment B of this document provides constants to be used in the Chapter 17 equations. Attachment B also contains DWELs and default soil remediation standards for select contaminants that may be found at STP sites.

GUIDELINES:

1. Laboratory General Requirements

All laboratories analyzing samples and providing data that will be submitted to the STP must be accredited by the American Association of Laboratory Accreditation (A2LA) for the Wyoming Program. A list of laboratories currently accredited by A2LA for the Wyoming Program can be found on the STP website: http://deq.state.wy.us/shwd/stp and clicking on the "Prequalified Contractors" link.

Laboratory data and quality assurance/quality control (QA/QC) reports for STP remediation projects shall be uploaded to the STP GIS database using the Electronic Data Submittals (EDS) template found on the STP website: http://deq.state.wy.us/shwd/stp and clicking on the "Electronic Data Submittal" link. Data must be uploaded within 30 days of receipt of the sample for analyses.

New sample containers, coolers, and all equipment necessary for sampling and shipping samples shall be supplied by the party collecting the samples or the laboratory.

2. Sampling General Requirements

When the STP is paying for laboratory work through consultant or contractor remediation contracts, analyses shall be completed only for those contaminants listed in this document. The STP will not pay for additional analyses completed, unless specifically requested

and approved by the STP. The STP will not pay costs associated with broken sample containers, missed hold times, or other mishandling of samples.

Additional soil or groundwater analyses may be required to allow evaluation of soil remediation or disposal options. The consultant or contractor under contract with the STP for remediation projects shall determine additional soil or groundwater analyses required and present those to the STP during cost negotiations.

The STP does not pay for analyses when performed as part of an MSA completed by a site owner.

3. QA/QC

SAPs and work plans shall include sample preservation and handling protocol, chain-of-custody control, analytical procedures, field and laboratory QA/QC protocol. The STP Quality Assurance Project Plan shall be followed. QA/QC protocol shall include:

A. Samples must be collected and contained such that they are never in contact with any material incompatible with QA/QC procedures.

B. Handling procedures must be carefully established and followed. Proper chain-of-custody procedures must be followed. All chain-of-custody forms shall be submitted with the applicable report (e.g., remedial action plan, MSA report, closure report, etc.).

C. Trip Blank. Fill one of each type of sample bottle with an organic or aqueous solution free of any analytes of interest, transport to the site, handle like a sample, and return to the laboratory for the same analyses as the environmental samples. This sample set remains sealed until analysis. One trip blank shall be collected per sampling event or with each analytical batch, with a minimum of 1 per 20 samples.

D. Equipment Blank (Rinsate Blank). To ensure decontamination is properly completed, an aqueous or organic solution free of any analytes of interest is poured through the sampling equipment, transferred to sample bottle, and sent to the laboratory for analysis. One equipment blank is collected for each 10 percent or fraction thereof of daily non-disposable bailer use and/or one equipment blank for each type of disposable bailer used (one time only).

E. Blind Duplicate. To ensure laboratory accuracy, two separate samples are collected in the field from the same source at the same time. The sets are labeled with different nomenclature. One blind duplicate shall be collected for every day or with each analytical batch, with a minimum of 1 per 20 samples.

F. Field Duplicate. To document the precision of the sampling process, independent samples are collected as close as possible to the same point in space and time. They are two separate samples taken from the same source, stored in separate containers, and analyzed independently. These duplicates are useful in documenting the precision of the sampling process. One sample shall be collected for each day of groundwater sampling.

G. Field Blank. To ensure reagent integrity and check environmental contamination, an aqueous or organic solution free of any analytes of interest is transported to the field, transferred to the sample containers, and preserved. One field blank shall be collected per analytical batch with a minimum of 1 per 20 samples.

H. Field blanks, trip blanks, and equipment blanks are not required for non-VOC analyses.

I. Surrogate recovery shall be reported as part of the QA/QC.

4. Soil Sampling and Analyses

A. Former fuel tank sites

The most heavily contaminated soil sample collected (based on field instrument readings) from **all borings** at former fuel tank sites shall be properly preserved and submitted for laboratory analyses of total petroleum hydrocarbon gasoline range organics (TPH-GRO); total petroleum hydrocarbon diesel range organics (TPH-DRO); benzene, ethylbenzene, toluene, xylenes (BETX) (report constituents separately); and naphthalene.

The most heavily contaminated soil sample collected (based on field instrument readings) from **all borings within the tank excavation** at former fuel tank sites shall also be analyzed for total lead.

At least one soil sample shall be collected and analyzed for total organic carbon (TOC) from each storage tank site. This sample must be collected from an uncontaminated borehole, preferably upgradient of the tank basin.

B. Former used oil tank sites

The most heavily contaminated soil sample collected (based on field instrument readings) from **all borings** at former used oil tank sites shall be properly preserved and submitted for laboratory analyses of TPH-DRO, BETX (report constituents separately), and naphthalene.

The most heavily contaminated soil sample collected (based on field instrument readings) from **all borings within the tank excavation** at former used oil tank sites shall also be analyzed for total lead, total cadmium, chromium (total, hexavalent, and trivalent concentrations) and Total TOX.

At least one soil sample shall be collected and analyzed for total organic carbon (TOC) from each storage tank site. This sample must be collected from an uncontaminated borehole, preferably upgradient of the tank basin

C. The required analytical methods for soil samples are specified in Table 1 on the following page.

TABLE 1
ANALYTICAL METHODS FOR SOIL SAMPLES

Product	Constituent	EPA Method
Fuel Tanks	BETX	5035/8021B or 5035/8260B or 8260C
	Total Organic Carbon	415 for soil
	Total Lead	3020A/7421 or 6010C
	TPH-DRO (see note 2)	8015C or 8270D; C_{10} - C_{32}
	TPH-GRO	8015C or 5035/8260B or 8260C; C_6 - C_{10}
	Naphthalene	5035/8021B or 5035/8260B or 8260C
Used Oil Tanks	BETX	5035/8021B or 5035/8260B or 8260C
	Total Organic Carbon	415 for soil
	TPH-DRO (see note 2)	8015C or 8270D; C_{10} - C_{32}
	Naphthalene	5035/8021B or 5035/8260B or 8260C
	Total Lead	3020A/7421 or 6010C
	Total Cadmium	3020A/7131A or 6010C
	Total Chromium – total, hexavalent, trivalent	6010C for total; 3060A/7196A for hexavalent; trivalent as difference between total and hexavalent
	TOX	9023

Table 1 Notes:

BETX = benzene, ethylbenzene, toluene, xylenes (report constituents separately)
C_6 - C_{32} = carbon atom range
DRO = diesel range organics
EPA = Environmental Protection Agency
GRO = gasoline range organics
TPH = total petroleum hydrocarbons

1. Detection levels are EPA-method specific. Notification is required for all constituents detected above the detection level.
2. Silica gel cleanup is not required for soil samples; however, the STP Project Manager may request silica gel cleanup for any sample at any time.
3. Laboratory procedure must have a detection limit of 0.1 mg/L. If the TOX analytical concentration is above the detection limit, further analysis is required using EPA method 8260 or 8260C.

5. Soil Remediation Standards

Sections 38, 40, and 41 of Chapter 17 provide rules for remediation of contaminated soil at storage tank sites. Site-specific data should be obtained, and the procedures in Chapter 17 should be followed to calculate cleanup levels at the site. See Attachment B to this document for CoC chemical properties that should be used in Chapter 17 calculations. When using Chapter 17 to calculate soil cleanup levels, physical, chemical, and toxicological data needed for the equations must be taken from one of the following sources in the order indicated:

1. EPA, Region IX, Preliminary Remediation Goals Database (www.epa.gov/region9/waste/sfund/prg/index.html

2. EPA Integrated Risk Information System (IRIS) (www.epa.gov/iris/subst/index.html)

3. EPA Health Effects Assessment Summary Tables (HEAST)

4. EPA/State environmental agency final written guidance documents, reports, or databases

Soil remediation standards for STP CoCs are provided in Table 2.

TABLE 2
SOIL REMEDIATION STANDARDS

Product	Constituent	Remediation Standard
Fuel Tanks	BETX	Site Specific
	Total Organic Carbon	Site Specific
	Total Lead	Site Specific
	TPH-DRO	>2300 mg/kg
	TPH-GRO	Site Specific
	Naphthalene	Site Specific
Used Oil Tanks	BETX	Site Specific
	Total Organic Carbon	Site Specific
	TPH-DRO	>2300 mg/kg
	Naphthalene	Site Specific
	Total Lead	Site Specific
	Total Cadmium	Site Specific
	Chromium – total, hexavalent, trivalent	Site Specific for total only; report hexavalent and trivalent concentrations
	TOX Constituents	Site Specific (See Note 3)

Table 2 Notes:

BETX = benzene, ethylbenzene, toluene, xylenes (report constituents separately)
C_6 - C_{32} = carbon atom range
DRO = diesel range organics
EPA = Environmental Protection Agency
GRO = gasoline range organics
mg/kg = milligrams per kilogram
TPH = total petroleum hydrocarbons

1. Site-specific soil clean-up levels for organic compounds (except TPH-GRO) and metals are determined from an environmental fate and transport risk assessment model contained in the Wyoming Water

Quality Rules and Regulations, Chapter 17, Storage Tanks, Sections 40 and 41.

2. Site-specific soil clean-up levels for TPH-GRO are determined from graphs (Attachment A) using average thickness of the contaminated zone and average distance between the bottom of the contaminated zone and the top of the seasonally high groundwater table.
3. If the Total TOX exceeds the detection limit, further analysis is required to determine the presence of individual halogenated organic constituents. A site-specific remediation standard shall be calculated for all individual halogenated organic constituents detected.

6. Groundwater Sampling and Analyses

All wells without free product on the water table shall be sampled and analyzed. All wells with free product shall not be sampled; however, the free product thickness (to within 0.1 feet) and water levels (to within 0.01 feet) shall be measured and recorded. The analytical detection limit for each EPA analysis method for each constituent analyzed must be reported.

To remove polar nonhydrocarbon compounds (compounds from sources other than petroleum), the STP requires that the laboratory include a silica gel cleanup step when analyzing groundwater samples for TPH-DRO. If TPH-DRO is the only constituent found in groundwater, the STP project manager may have the well(s) resampled using a peristaltic pump or other low-flow sampling method. Low-flow sampling may reduce influence by nondissolved particle entrainment on the TPH-DRO analyses.

During STP remediation projects, the consultant shall sample existing private water wells, as requested by the STP Project Manager. The private water well sample(s) shall be analyzed for TPH-DRO, TPH-GRO, BETX, naphthalene, and initially methyl *tert*-butyl ether (MTBE), EDB, and 1,2-DCA. Analytical methods to be used shall be those shown in Table 3.

A. Former fuel tank sites

All groundwater samples collected from wells at former fuel tank sites shall be properly preserved and submitted for laboratory analyses of TPH-GRO, TPH-DRO, BETX (report constituents separately), naphthalene, MTBE, tert-butyl alcohol (TBA), ethyl tert-butyl ether (ETBE), diisopropyl ether (DIPE), and tert-amyl methyl ether (TAME).

All groundwater samples collected from wells **within tank excavations** at former fuel tank sites shall also be analyzed for dissolved lead.

During an MSA or subsurface investigation, all groundwater samples collected from wells within tank excavations and the three wells downgradient of the tank excavation with the highest concentrations of BETX shall be analyzed for EDB and 1,2-DCA. If EDB or 1,2-DCA is not found during initial site assessment, sampling for the constituent during future phases of the work is not necessary.

B. Former used oil tank sites

All groundwater samples collected from wells at former used oil tank sites shall be properly preserved and submitted for laboratory analyses of TPH-DRO, BETX (report constituents separately), and naphthalene.

All groundwater samples collected from wells **within tank excavations** at former used oil tank sites shall also be analyzed for dissolved lead, dissolved cadmium, and dissolved chromium (total, hexavalent, and trivalent concentrations).

C. The required analytical methods for groundwater samples are specified in Table 3.

TABLE 3 (SEE TABLE NOTES NEXT PAGE)
ANALYTICAL METHODS FOR GROUNDWATER SAMPLES

Product	Constituent	EPA Method
Fuel Tanks	Benzene	5030B/8021B or 5030B/8260B or 8260C
	Ethylbenzene	5030B/8021B or 5030B/8260B or 8260C
	Toluene	5030B/8021B or 5030B/8260B or 8260C
	Xylenes	5030B/8021B or 5030B/8260B or 8260C
	Methyl *tert*-Butyl Ether (MTBE)	5030B/8021B or 5030B/8260B or 8260C
	tert-Butyl Alcohol (TBA)	5030B/8021B or 5030B/8260B or 8260C
	Ethyl *tert*-Butyl Ether (ETBE)	5030B/8021B or 5030B/8260B or 8260C
	Diisopropyl Ether (DIPE)	5030B/8021B or 5030B/8260B or 8260C
	tert-Amyl Methyl Ether (TAME)	5030B/8021B or 5030B/8260B or 8260C
	TPH-GRO	8015C or 5030B/8260B or 8260C; C_6 - C_{10}
	TPH-DRO (see notes 4 and 5)	8015C with silica gel cleanup or 8270D with silica gel cleanup; C_{10} - C_{32}
	Naphthalene	5030B/8021B or 5030B/8260B or 8260C
	Dissolved Lead	3020A/7421 or 6010C
	1,2-dibromoethane or ethylene dibromide (EDB)	8011 (see note 6)
	1,2-dichloroethane (1,2-DCA)	8260B or 8260C
Used Oil Tanks	Benzene	5030B/8021B or 5030B/8260B or 8260C
	Ethylbenzene	5030B/8021B or 5030B/8260B or 8260C
	Toluene	5030B/8021B or 5030B/8260B or 8260C

	Xylenes	5030B/8021B or 5030B/8260B or 8260C
	TPH-DRO (see notes 4 and 5)	8015C, with silica gel cleanup or 8270D with silica gel cleanup; C_{10} - C_{32}
	Naphthalene	5030B/8021B or 5030B/8260B or 8260C
	Dissolved Lead	3020A/7421 or 6010C
	Dissolved Cadmium	3020A/7131A or 6010C
	Dissolved Chromium; total, hexavalent, and trivalent	6010C for total; 7196A for hexavalent; trivalent as the difference between total and hexavalent concentrations

Table 3 Notes:

C_6 - C_{32} = carbon atom range
DRO = diesel range organics
GRO = gasoline range organics
TPH = total petroleum hydrocarbons

1. Benzene, ethylbenzene, toluene, and xylenes analyses by 8260B or 8260C are required for all subsurface investigation work, additional site assessment, and confirmation sampling for project closure. Analyses by 8021B may only be used during routine monitoring events.
2. Samples collected for metal analyses, with the exception of hexavalent chromium, must be filtered on site with a 45 micron filter unless the samples can be delivered to the laboratory within 48 hours. Add nitric acid on site to lower the sample pH to <2 **after** the samples have been filtered. Samples collected for hexavalent chromium analysis must be unfiltered, not acidified and delivered to the laboratory within 24 hours of collection.
3. Detection levels are EPA-method specific. Notification is required for all constituents detected above the detection level.
4. Silica gel cleanup for TPH-DRO analyses must be specified on the chain-of-custody. The lab may choose the silica gel cleanup method to use. Silica gel cleanup is only required when TPH-DRO is the only constituent above the cleanup level or when closing a site. The STP project manager may request the silica gel cleanup for any sample at any time.
5. Microextraction method 3511 should be used by the lab when possible. The method requires 40 ml VOA bottles, which saves time and money over using the 1 liter amber jars. The method also results in less lab waste.
6. Method 8011 protocol does not specify preservation (acidification) of groundwater samples. Preservation of samples may be necessary to prevent biodegradation if the samples are not continuously refrigerated after collection or if the samples are not analyzed within the 14-day holding time. Not all laboratories routinely conduct analyses using 8011, so laboratory capability and capacity should be confirmed during the planning stages. At sites where benzene is the primary risk driver, Method 8260B or 8260C may be appropriate to monitor the quality of groundwater during active remediation. Once the concentration of benzene is reduced to below the MCL, it is necessary to switch to Method 8011 (or 504.2 drinking water method) for monitoring the concentration of EDB to determine if additional remediation is required in order to reach the MCL for EDB. (Methods 8260B or 8260C do not detect EDB to the MCL).

7. Groundwater Remediation Standards

Chapter 17, Section 39, states that STP remediation actions will protect groundwater to the most stringent of federal primacy MCLs, DWELs, or the standards found in Wyoming Water Quality Rules and Regulations, Chapters 1 and 8. For STP CoCs, the most stringent level will be MCLs or DWELs because, with the exception of lead, Chapters 1 and 8 do not contain standards for STP CoCs.

There is no MCL for TPH, nor is it appropriate to calculate a DWEL for TPH, as TPH is not a specific chemical substance but rather a series of separate organic compounds. However, TPH as a large group of organic compounds has been found to exhibit some degree of toxicity. Therefore, TPH action levels (Table 4 on the following page) are tools that may assist in the determination of when a site is nearing cleanup or if a site is clean during a tank removal.

In the STP, TPH is based on fraction-specific petroleum hydrocarbons:

Gasoline Range Organics (GRO): C_6 through C_{10}
Diesel Range Organics (DRO): C_{10} through C_{32}

The action level for TPH-GRO concentration in groundwater is 7.3 milligrams/liter (mg/L). If naphthalene is detected above the DWEL (0.7 mg/L), the TPH-DRO action level is 1.1 mg/L. However, if naphthalene and BETX concentrations are below the respective DWEL and MCLs and free product is not present on the groundwater table, the TPH-DRO plus TPH-GRO concentration must be equal to or less than 10 mg/L (sheen criteria). These values for TPH have been calculated based on protection of groundwater to drinking water standards.

STP remediation standards (MCLs, DWELs, EPA advisory levels, and action levels) as of the date of this document are provided in Table 4 (see next page). Current MCLs can be found on the EPA's website at www.epa.gov.

TABLE 4
GROUNDWATER REMEDIATION STANDARDS

PRODUCT	CONSTITUENT	MCL	DWEL	ACTION LEVEL
Fuel Tanks	Benzene	0.005	--	--
	Ethylbenzene	0.7	--	--
	Toluene	1.0	--	--
	Xylenes	10	--	--
	Naphthalene	--	0.7*	--
	Methyl *tert*-Butyl Ether (MTBE)	--	0.04	--
	tert-Butyl Alcohol (TBA)	--	0.22	--
	Ethyl *tert*-Butyl Ether (ETBE)	--	0.19	--
	Diisopropyl Ether (DIPE)	--	1.2	--
	tert-Amyl Methyl Ether (TAME)	--	0.128	--
	TPH-GRO (C_6 - C_{10})	--	--	7.3**
	TPH-DRO (C_{10} – C_{32})	--	--	1.1**
	Dissolved Lead	0.015	--	--
	1,2-dibromoethane or ethylene dibromide (EDB)	0.00005	--	--
	1,2-dichloroethane (1,2-DCA)	0.005	--	--
Used Oil Tanks	Benzene	0.005	--	--
	Ethylbenzene	0.7	--	--
	Toluene	1.0	--	--
	Xylenes	10	--	--
	Naphthalene	--	0.7*	--
	TPH-GRO (C_6 - C_{10})	--	--	7.3**
	TPH-DRO (C_{10} – C_{32})	--	--	1.1**
	Dissolved Lead	0.015	--	--
	Dissolved Cadmium	0.005	--	--
	Dissolved Chromium; total, hexavalent, and trivalent	>0.1 for total; report hexavalent and trivalent concentrations	--	--

Table 4 Notes:

All values are in milligrams per liter (mg/L)
TPH-GRO – Total petroleum hydrocarbon as gasoline range organics
TPH-DRO – Total petroleum hydrocarbon as diesel range organic
C_6 - C_{32} = carbon atom range
* EPA Health Advisory Level (2006)
** If naphthalene is detected above the DWEL (0.7 mg/L), the TPH-DRO action level is 1.1 mg/L. However, if naphthalene and BETX concentrations are below the respective DWEL and MCLs and free product is not present on the groundwater table, the TPH-DRO **plus** TPH-GRO concentration must be equal to or less than 10 mg/L (sheen criteria).

8. Vapor Hazards Evaluation

Chapter 17, Section 42, requires an evaluation of explosive atmospheres caused by leaking storage tanks. The STP action levels shown in Table 5 are 25 percent of the lower explosive level for the contaminant.

TABLE 5
EXPLOSIVE ATMOSPHERE ACTION LEVELS

CONTAMINANT	LOWER EXPLOSIVE LEVEL (%)	UPPER EXPLOSIVE LEVEL (%)	STP ACTION LEVEL (%)
Benzene	1.3	7.9	0.32 (3200 ppmv)
Diesel Fuel	1.3	7.5	0.32 (3200 ppmv)
Ethylbenzene	1	6.7	0.25 (2500 ppmv)
Fuel Oils	0.6	7.5	0.15 (1500 ppmv)
Gasoline	1.2	7.6	0.30 (3000 ppmv)
Jet Fuel (JP-4)	1.3	8	0.32 (3200 ppmv)
Toluene	1.2	7.1	0.30 (3000 ppmv)
Xylenes	1	7	0.25 (2500 ppmv)

Table 5 Notes:
% percent
ppmv – parts per million by volume

If assessment reveals that an acute or chronic vapor intrusion exposure may be a concern (e.g., plume has migrated or is suspected to have migrated under or near buildings or along preferential pathways) at the site or adjacent properties, the possibility of vapor intrusion to buildings, sewer lines, etc. shall be assessed. There are two main concerns with vapor intrusion. The first is the potential for vapors to accumulate and become a volatile explosion hazard. This is most common in sewer lines, sumps, and other confined subsurface places. The second concern is for affects to human health from vapors in homes, schools, and work places. At a minimum the following tasks shall be performed to evaluate the potential for vapor intrusion impacts:

A. Survey the immediate area at each site and interview residents and workers to determine if vapors have been detected.

B. Use an instrument capable of detecting hazardous vapors to assess potentially hazardous (explosive) spaces such as sewer lines, sumps, utility corridors, etc. Indoor air monitoring shall be performed as necessary to quantify reports of odors or potential vapor exposures.

C. The potential for vapors to affect human health from dissolved phase plumes or LNAPL plumes must be evaluated. Several guidance documents (e.g., ITRC Vapor

Intrusion Guide, 2007; EPA OSWER Draft Guidance for Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils, 2002) exist that provide steps for evaluating this pathway.

An indoor air monitoring sampling schedule shall be determined if appropriate.

Following the construction of any active subsurface remediation system that has the potential to liberate or move petroleum vapors from source areas (e.g., air sparge), a follow up vapor intrusion evaluation shall be required using the same procedures as the initial evaluation. This is intended to ensure the active system has not caused a vapor intrusion problem.

9. Indoor Air Quality

Indoor air quality must be considered at STP sites in accordance with Chapter 17, Section 42(b). Table 6 provides indoor air quality standards and action levels calculated in accordance with Chapter 17.

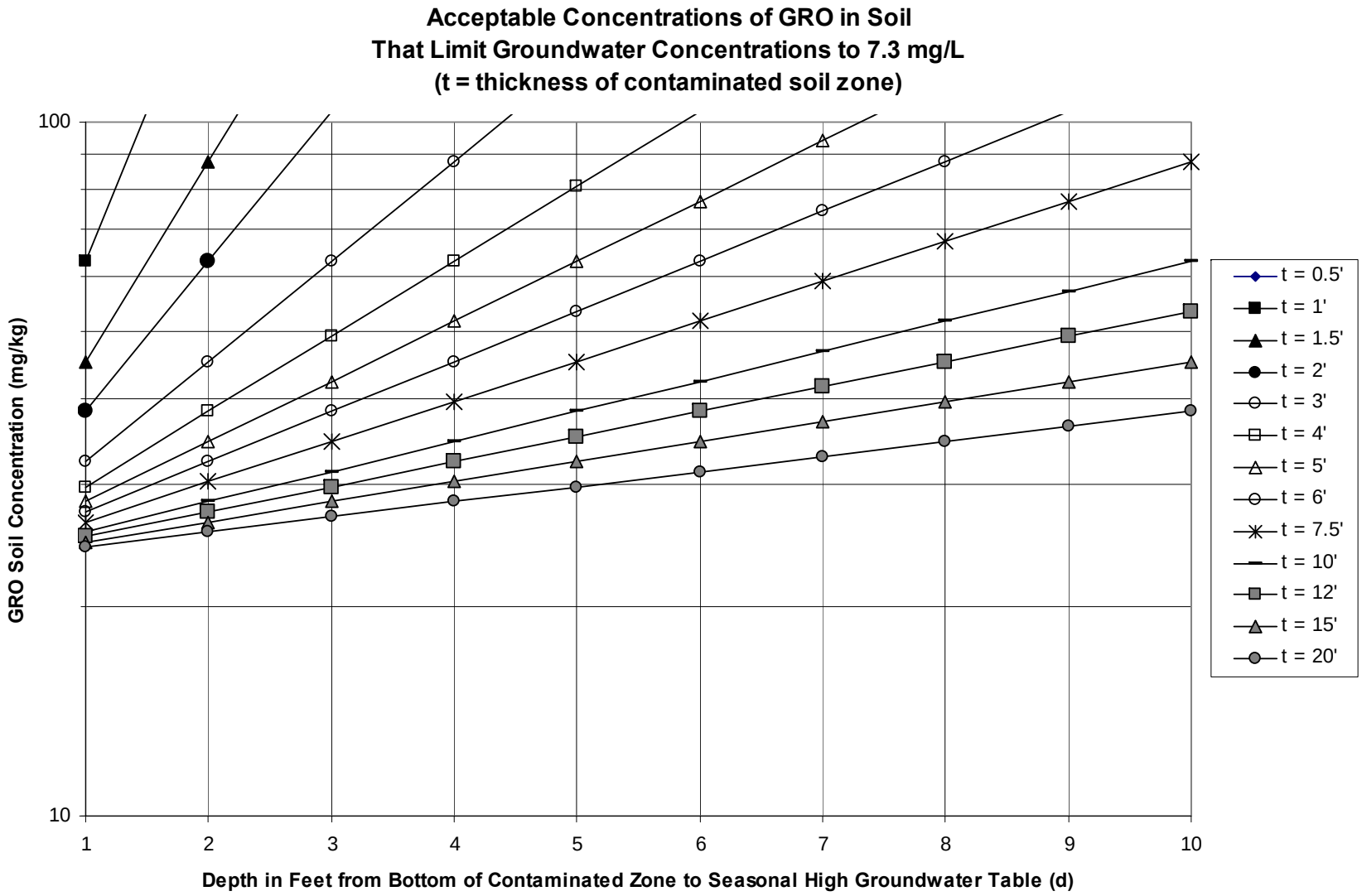
TABLE 6
INDOOR AIR QUALITY STANDARDS AND ACTION LEVELS

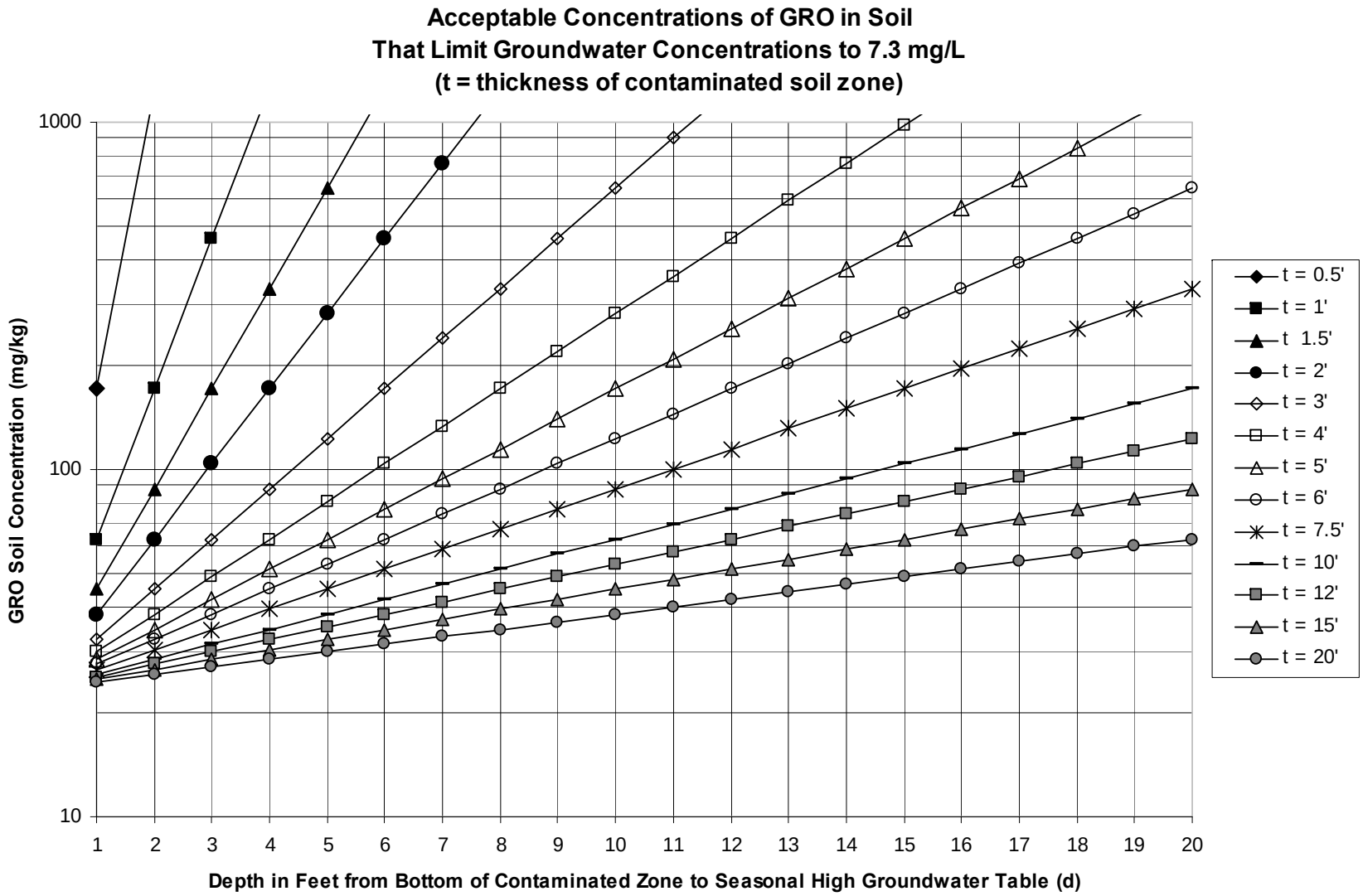
COMPOUND	WY OSHA OCCUPATIONAL STANDARD	ACTION LEVEL
Benzene	3,200	0.38
Ethylbenzene	435,000	1400
Hexane	1,800,000	270
Methyl *tert*-butyl ether (MTBE)	N/A	0.01
Toluene	377,000	530

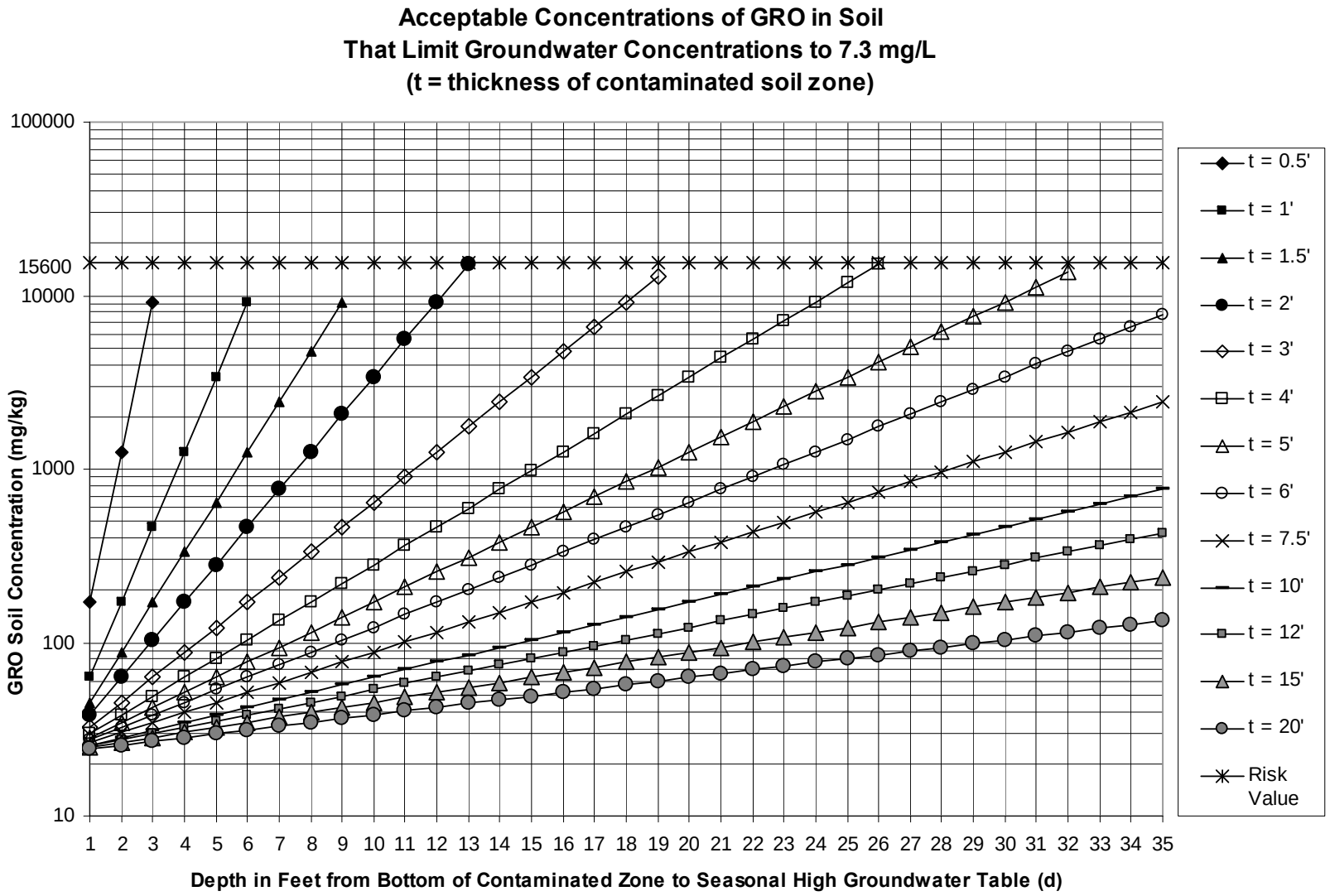
Table 6 Notes:
WY OSHA – Wyoming Occupational Safety and Health Administration
All values are in micrograms per cubic meter at 25°Celcius and 760 millimeters mercury.

ATTACHMENT A

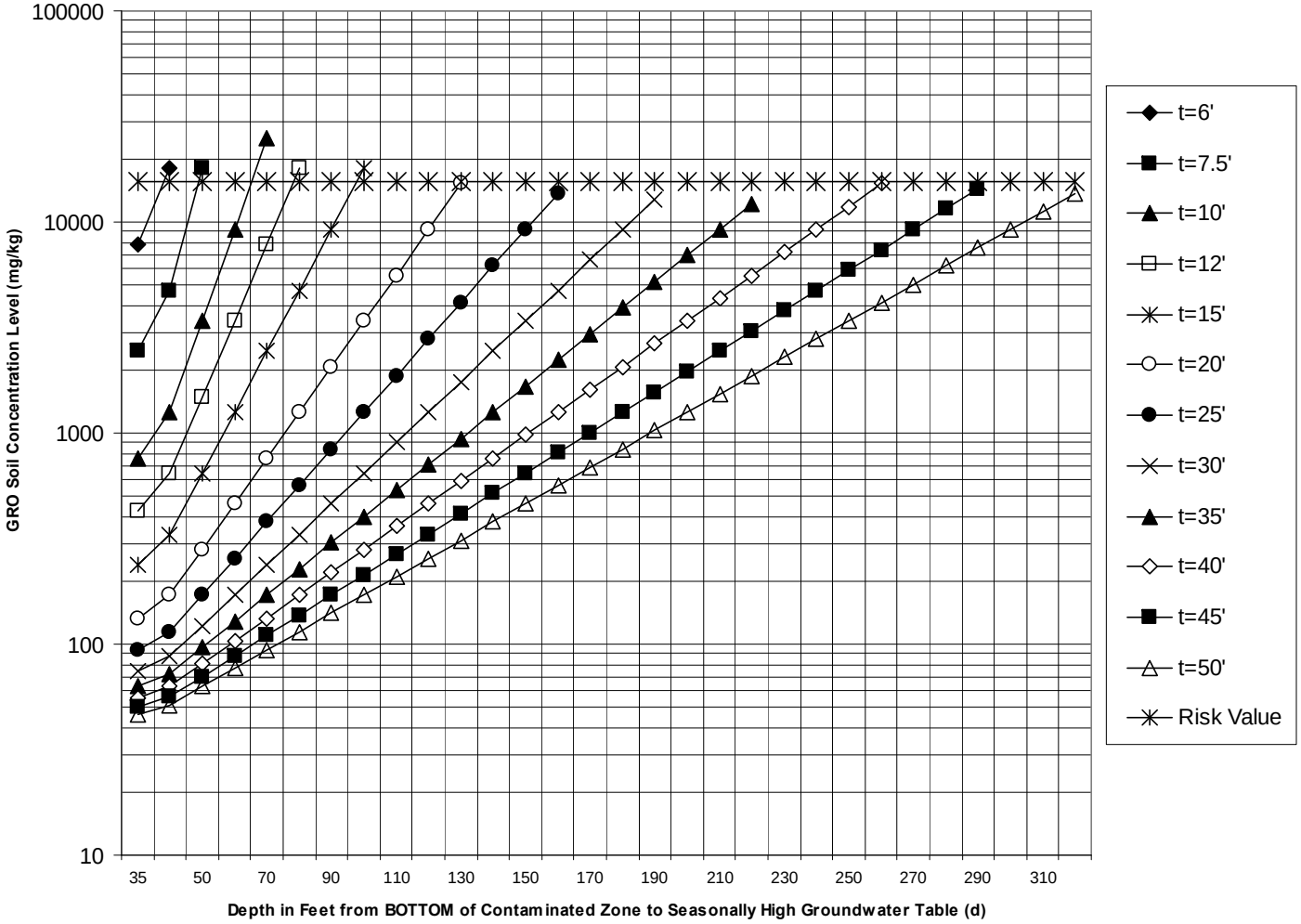
TPH-GRO GRAPHS


Acceptable Concentrations of GRO in Soil
That Limit Groundwater Concentrations to 7.3 mg/L
(t = thickness of contaminated soil zone)
GRO Soil Concentration (mg/kg)
100
10
1
2
3
4
5
6
7
8
9
10
Depth in Feet from Bottom of Contaminated Zone to Seasonal High Groundwater Table (d)
t = 0.5'
t = 1'
t = 1.5'
t = 2'
t = 3'
t = 4'
t = 5'
t = 6'
t = 7.5'
t = 10'
t = 12'
t = 15'
t = 20'


Acceptable Concentrations of GRO in Soil
That Limit Groundwater Concentrations to 7.3 mg/L
(t = thickness of contaminated soil zone)
GRO Soil Concentration (mg/kg)
1000
100
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Depth in Feet from Bottom of Contaminated Zone to Seasonal High Groundwater Table (d)
t = 0.5'
t = 1'
t 1.5'
t = 2'
t = 3'
t = 4'
t = 5'
t = 6'
t = 7.5'
t = 10'
t = 12'
t = 15'
t = 20'


Acceptable Concentrations of GRO in Soil
That Limit Groundwater Concentrations to 7.3 mg/L
(t = thickness of contaminated soil zone)
GRO Soil Concentration (mg/kg)
100000
15600
10000
1000
100
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Depth in Feet from Bottom of Contaminated Zone to Seasonal High Groundwater Table (d)
t = 0.5'
t = 1'
t = 1.5'
t = 2'
t = 3'
t = 4'
t = 5'
t = 6'
t = 7.5'
t = 10'
t = 12'
t = 15'
t = 20'
Risk Value

Acceptable Concentrations of GRO in Soil That Limit Groundwater Concentrations to 7.3 mg/L
(t= thickness of contaminated soil zone)



ATTACHMENT B

CHAPTER 17 CALCULATIONS

INTRODUCTION: Attachment B provides constants used in Chapter 17 calculations for select constituents. Attachment B also provides DWELs for select constituents and default soil remediation standards when site-specific information cannot be attained. **Prior to using default soil remediation standards, consult the STP district office.**

1. Precipitation

Average annual precipitation data can be obtained from the National Weather Service or a published precipitation map of Wyoming.

2. Drinking Water Equivalent Levels

Drinking water equivalent levels (DWELs) for STP CoCs are provided in this guidance document. Table B-1 provides DWELs for select constituents (not CoCs) that may have been stored in a storage tank. DWELs shown in Table B-1 were calculated using the equations in Chapter 17.

TABLE B-1
DWELS FOR SELECTED CONSTITUENTS

COMPOUND	DWEL (mg/L)	COMPOUND	DWEL (mg/L)
Acenaphthene	2.2	Ethylene glycol	73
Anthracene	73	Fluoranthene	1.5
Bis(2-ethylhexyl)phthalate	0.0061	Fluorene	1.5
Butylbenzylphthalate	7.3	Hexane	401
Chrysene	0.012	Methanol	18
Dibutylphthalate	3.7	Propylene glycol	18
Diethylphthalate	29	1,2,4-Trimethylbenzene	1.8
Dioctylphthalate	1.5	1,3,5-Trimethylbenzene	1.8

DWEL – Drinking Water Equivalent Level
mg/L – milligrams per liter

3. Default Soil Remediation Standards

If site-specific soil data are not available, default soil remediation standards in Table B-2 for STP CoCs may be used only after consultation with the STP district office. Table B-3 contains default soil remediation standards for other contaminants that may be found at storage tank sites. The values in Tables B-2 and B-3 were calculated using the methods in Chapter 17.

TABLE B-2
DEFAULT SOIL REMEDIATION STANDARDS
FOR STP CONTAMINANTS OF CONCERN

CONTAMINANT	HUMAN EXPOSURE	SOIL SATURATION	MIGRATION POTENTIAL TO GROUNDWATER
Benzene	5.7E-01	3.8E+02	1.8E+01
Cadmium	3.9E+01	nc	1.2E+01
Chromium (hexavalent)*	3.0E+01	nc	1.7E+00
Chromium (trivalent)*	1.2E+05	nc	5.2E+05
Chromium (total)*	2.1E+02	nc	nc
Ethylbenzene	1.3E+03	9.0E+01	nc
Lead*	4.0E+02	nc	1.8E+00
Naphthalene	nc	6.5E+01	nc
Toluene	4.8E+02	1.8E+02	1.9E+04
TPH-DRO	2.3E+03	nc	nc
TPH-GRO	1.6E+04	nc	See Section 11
Xylenes	1.8E+02	9.2E+01	5.8E+06

Notes:

All values in milligrams per kilogram.
nc – not calculated due to insufficient physiochemical parameter data, or the calculated concentration was greater than pure product in soil.
* EPA non-standard method applied.
If laboratory cannot analyze to the levels in Table B-2, the laboratory detection limit shall be the cleanup concentration.

TABLE B-3 DEFAULT SOIL CLEANUP LEVELS FOR SELECT COMPOUNDS			
CHEMICAL COMPOUND	DEFAULT SOIL CLEANUP CONCENTRATIONS		
	HUMAN EXPOSURE mg/kg	SOIL SATURATION mg/kg	MIGRATION POTENTIAL TO GROUNDWATER mg/kg
Acenaphthene	1.1E+03	4.4E+01	nc
Anthracene	2.1E+04	1.0E+00	nc
Benzo(a)pyrene	8.7E-02	1.6E+00	nc
Bis (2-ethylhexyl) phthalate	4.6E+01	5.1E+03	nc
Chrysene	8.2E+01	6.4E-01	nc
Dibutylphthalate	7.7E+03	3.9E+01	nc
Diethylphthalate	5.6E+04	4.3E+02	3.0E+03
Diisopropyl ether (DIPE)	2.7E+03	3.3E+02	nc
Dioctylphthalate	3.1E+03	1.7E+03	nc
Ethyl *tert*-butyl ether (ETBE)	4.2E+03	1.7E+04	nc
Ethylene dibromide (EDB)	2.0E-02	6.4E+02	5.5E-06
Ethylene glycol	1.6E+05	nc	6.0E+01
Fluoranthene	3.0E+03	2.3E+01	nc
Fluorene	2.5E+03	2.7E+01	nc
Hexane	9.6E+01	3.7E+01	nc
Methyl *tert*-butyl ether (MTBE)	3.8E+01	1.7E+04	4.9E-02
Propylene glycol	3.9E+04	nc	Nc
1,2,4-Trimethylbenzene	3.0E+01	1.00E+00	nc
1,3,5-Trimethylbenzene	1.3E+01	5.00E+01	nc

Notes:

- mg/kg – milligrams per kilogram
- nc – Not calculated due to insufficient physiochemical parameter data, or because the calculated concentration was greater than pure product in soil.
- If laboratory cannot analyze to the levels in Table B-3, the detection limit shall become the cleanup level.

4. Chemical Properties

Table B-4 contains chemical properties for STP CoCs that should be used in the calculations required by Chapter 17. Table B-5 contains chemical properties for other contaminants that may be found at STP site.

TABLE B-4
CHEMICAL PROPERTIES FOR
STP CONTAMINANTS OF CONCERN

CONTAMINANT	K_{oc} (mL/gm)	D_i (cm^2/s)	D_w (cm^2/s)	S (mg/L)	H´ (no units)
Benzene	5.9E+01	8.8E-02	9.8E-06	1.8E+03	2.3E-01
Diisopropyl ether (DIPE)	1.9E+01	7.4E-02	8.0E-06	2.0E+03	2.0E-01
Ethylbenzene	3.6E+02	7.5E-02	7.8E-06	1.7E+02	3.2E-01
Ethyl *tert*-butyl ether (ETBE)	4.0E+01	7.4E-02	8.0E-06	1.0E+05	1.1E-01
Methyl *tert*-butyl ether (MTBE)	6.0E+00	8.0E-02	1.0E-05	1.5E+05	2.4E-02
Naphthalene	2.0E+03	5.9E-02	7.5E-06	3.1E+01	2.0E-02
tert-Amyl methyl ether (TAME)	4.0E+01	7.4E-02	8.0E-06	2.6E+03	8.1E-02
tert-Butyl alcohol (TBA or Butanol)	2.3E+00	9.0E-02	1.0E-05	1.0E+06	5.0E-04
Toluene	1.8E+02	8.7E-02	8.6E-06	5.3E+02	2.7E-01
Xylenes	4.1E+02	7.8E-02	7.8E-06	1.6E+02	3.0E-01

Notes:

K_{oc} = Organic carbon partition coefficient. Note: When K_{oc} values cannot be located in a technical source, the following equations may be used to calculate K_{oc} using published K_{ow}, or solubility values, for a particular chemical contaminant.

$$\log K_{oc} = 1.06(\log K_{ow}) - 0.68$$

$$\log K_{oc} = -0.55(\log S) + 3.64 \text{ (Solubility, S, in mg/L)}$$

D_i = Diffusivity in air (25°C)
D_w = Diffusivity in water (25°C)
S = Solubility in water (20-25°C)
H´ = Dimensionless Henry's Law Constant (Henry's Law Constant*41) @ 25°C
mL/gm – milliliters per gram
cm^2/s – centimeters squared per second
mg/L – milligrams per liter
C – degrees Celsius

TABLE B-5 CHEMICAL PROPERTIES FOR CONTAMINANTS (OTHER THAN CoCs) THAT MAY BE FOUND AT STP SITES					
COMPOUND	**K_{oc} (mL/gm)**	**D_i (cm^2/s)**	**D_w (cm^2/s)**	**S (mg/L)**	**H´ (unit less)**
Acenaphthene	4.9E+03	4.2E-02	7.7E-06	4.2E+00	6.4E-03
Anthracene	2.4E+04	3.2E-02	7.7E-06	4.3E-02	2.7E-03
Benzo(*a*)pyrene	1.0E+06	4.3E-02	9.0E-06	1.6E-03	4.6E-05
Bis(2-ethylhexyl) phthalate	1.5E+07	3.5E-02	3.7E-06	3.4E-01	4.2E-06
Chrysene	4.0E+05	2.5E-02	6.2E-06	1.6E-03	3.9E-03
Dibutylphthalate	3.4E+04	4.4E-02	7.9E-06	1.1E+01	3.9E-08
Diethylphthalate	2.9E+02	2.6E-02	6.4E-06	1.1E+03	1.9E-05
Dioctylphthalate	8.3E+07	1.5E-02	3.6E-06	2.0E-02	2.7E-03
Ethylene dibromide	4.4E+01	7.3E-02	8.1E-06	4.2E+03	2.7E-02
Ethylene glycol	7.6E-03	unavailable	unavailable	miscible	2.5E-06
Fluoranthene	1.1E+05	3.0E-02	6.4E-06	2.1E-01	6.6E-04
Fluorene	1.4E+04	3.6E-02	7.9E-06	2.0E+00	2.6E-03
Hexane	8.9E+02	2.0E-01	7.8E-06	1.8E+01	5.0E+00
1,2,4-Trimethylbenzene	3.7E+03	7.5E-02	7.1E-06	2.6E-01	2.3E-01
1,3,5-Trimethylbenzene	8.2E+02	7.5E-02	7.1E-06	5.0E+01	3.2E-01

Notes:

K_{oc} = Organic carbon partition coefficient. Note: When K_{oc} values cannot be located in a technical source, the following equations may be used to calculate K_{oc} using published K_{ow}, or solubility values, for a particular chemical contaminant.

$\log K_{oc} = 1.06(\log K_{ow}) - 0.68$

$\log K_{oc} = -0.55(\log S) + 3.64$ (Solubility, S, in mg/L)

D_i = Diffusivity in air (25°C)

D_w = Diffusivity in water (25°C)

S = Solubility in water (20-25°C)

H´ = Dimensionless Henry's Law Constant (Henry's Law Constant*41) @ 25°C

mL/gm – milliliters per gram

cm^2/s – centimeters squared per second

mg/L – milligrams per liter

C – degrees Celsius

5. Metals

Remediation standards for metals in soil are directly affected by soil pH. The average pH in Wyoming soils is 7.8. Table B-6 presents soil metal adsorption coefficients for metals commonly found at STP sites.

TABLE B-6
STP METALS OF CONCERN
K_d VALUES, SOIL pH 7.8

Metal	K_d (mL/gm)
Cadmium	1,900
Chromium (trivalent)	4,300,000
Chromium (hexavalent)	14
Lead	100

Notes:
Source: EPA Soil Screening Guidance, OSWER 9355.4-23
K_d – Soil metal adsorption coefficient
mL/gm – milliliters per gram

6. Default Soil Properties

Table B-7 provides default bulk soil densities and volumetric moisture values that should be used when site-specific field data are not available. Site-specific data should be determined by laboratory analyses where possible.

TABLE B-7
STP DEFAULT SOIL PROPERTIES

SOIL TEXTURE	BULK SOIL DENSITY (ρ_b), gm/cm^3	VOLUMETRIC MOISTURE (Θ) AT FIELD CAPACITY, mL/cm^3
Sand	1.65	0.062
Sandy loam	1.55	0.19
Loam	1.4	0.232
Sandy clay loam	1.5	0.244
Clay loam	1.35	0.31
Sandy clay	1.45	0.321
Silty loam	1.35	0.284
Silty clay loam	1.3	0.342
Silty clay	1.25	0.371
Clay	1.25	0.378

Notes:

Source: USDA, Natural Resources Conservation Service
gm/cm^3 – grams per cubic meter
mL/cm^3 – milliliters per cubic meter

7. Half-Life Values

Table B-8 provides half-life values for select STP CoCs in soil and must be used when calculating the biodegradation rate constant, k. Table B-9 provides half-life values for other contaminants that may be present in soil at STP sites.

TABLE B-8
HALF-LIFE FOR SELECT STP CONTAMINANTS OF CONCERN IN SOIL

CONTAMINANT	SOIL HALF-LIFE ($T_{½}$) (YEARS)
Benzene	0.04
Ethylbenzene	0.03
Methyl *tert*-butyl ether (MTBE)	0.5
Naphthalene	0.13
tert-Butyl alcohol (TBA or Butanol)	0.6
Toluene	0.06
Xylenes	0.08

Source: Handbook of Environmental Degradation Fates

TABLE B-9
HALF-LIFE FOR SELECTED CONTAMINANTS IN SOIL

CONTAMINANT	SOIL HALF-LIFE ($T_{½}$) YEARS	CONTAMINANT	SOIL HALF-LIFE ($T_{½}$) YEARS
Acenaphthene	0.28	Ethylene dibromide	0.5
Anthracene	1.3	Ethylene glycol	0.03
Benzo(*a*)pyrene	1.4	Fluoranthene	1.2
Bis(2-ethylhexyl)phthalate	0.06	Fluorene	0.2
Chrysene	2.7	Methanol	0.02
Dibutyl phthalate	0.06	*tert*-Butyl alcohol (TBA or Butanol)	0.6
Diethylphthalate	0.15	1,2,4-Trimethylbenzene	0.08
Dioctyl phthalate	0.08		

Source: Handbook of Environmental Degradation Fates