

# **In Situ Thermal Desorption (ISTD) and In-Pile Thermal Desorption (IPTD): TerraTherm's Technologies for Treatment of Semi-Volatile Organic Compounds**

**Introduction and Conceptual Approach**

**Prepared by:**



and



**September 2009**

[www.terra-therm.com](http://www.terra-therm.com)

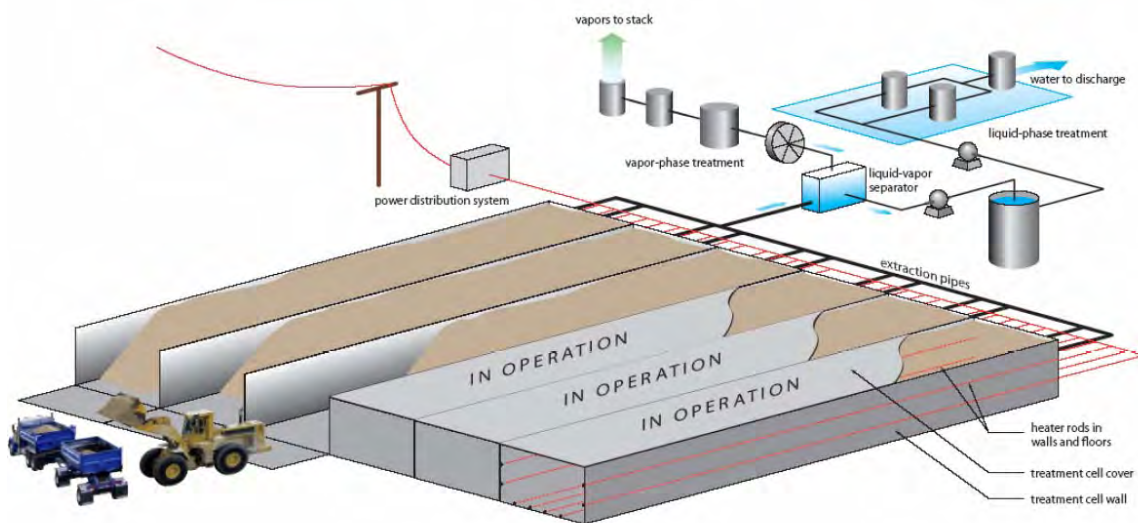
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## 1. ISTD/ IPTD Background

TerraTherm's proprietary In Situ Thermal Desorption (ISTD)/ In-Pile Thermal Desorption (IPTD) technology has been used successfully on numerous projects involving soil or sediment containing high-boiling organic contaminants including polychlorinated dibenzo-dioxins and furans (PCDD/Fs) and polychlorinated biphenyls (PCBs). Both ISTD and IPTD utilize the same technology: thermal conduction heating (TCH) coupled with vapor recovery, but in different geometries. Demonstration-scale projects include General Electric Co., Glens Falls, NY (PCBs); Missouri Electric Works Superfund Site, Cape Girardeau, MO (PCBs); and US Navy BADCAT, Vallejo, CA (PCBs). Full-scale projects include US Army Corps of Engineers, Saipan, W. Pacific (PCBs); US Navy, Ferndale, CA (PCBs); Southern California Edison, Alhambra, CA (polycyclic aromatic hydrocarbons [PAHs], pentachlorophenol and PCDD/Fs); and National Grid, N. Adams, MA (PAHs associated with manufactured gas plant wastes). Appendix B provides a Summary Table of projects where semi-volatile organic compounds (SVOCs) have been treated utilizing ISTD and/or IPTD. In addition, TerraTherm has extensive experience treating soil and sediment contaminated with chlorinated volatile organic compounds (CVOCs) and chlorobenzenes. Further information is available on the website, [www.terratherm.com](http://www.terratherm.com), and/or upon request.

## 2. IPTD Approach

A schematic of the IPTD approach is shown in Figure 1.



**Figure 1. IPTD Process Schematic**

*Note: No heaters or pipes inside soil to impede loading / unloading.*



The IPTD process utilizes conductive heating and vapor recovery to remediate soil and sediment contaminated with SVOCs, such as PCDD/Fs. Each of the rectangular treatment cells shown in Figure 1 can be readily filled using conventional soil-handling equipment – there are no heaters or pipes in the way. Once each cell is filled and covered, it is essentially a closed container with controlled air inlets and outlets. Heat and vacuum are applied simultaneously to the sediment with an array of horizontal heaters and vapor collectors situated within the rigid floor and walls of the treatment cells. Each electrically powered heating element has an operating temperature of approximately 1400 to 1500°F (~750-800°C), modulated by silicon controlled rectifiers (SCRs).

The key to the effectiveness of the IPTD process is the long residence time at target temperature. Whereas rotary kiln and incineration-type processes elevate the soil or sediment to target temperature for seconds or at most minutes, in the IPTD batch process the soil or sediment attains and remains at target temperature for a day or more depending on the contaminants being treated. This leads to very high destruction and removal efficiency (DRE), demonstrated at >99.9999%, with treatment costs that are much lower than competing technologies.

*Results of a Recent Demonstration.* In an IPTD demonstration overseen by the Ministry of Environment in Japan, TerraTherm treated 4 metric tonnes of sediment in a highly instrumented treatment cell contaminated with 1,800 pg-TEQ/g of dioxins. This sediment mass was heated in 22 days of operation. After IPTD treatment, the sediment contained dioxins at a concentration of 23 to 140 pg-TEQ/g or an average concentration of 67.75 pg-TEQ/g, well below 1,000 pg-TEQ/g, the environmental standard for soil in Japan and a typical standard in the U.S.<sup>1</sup> Emissions from the Air Quality Control system were also well below standards. These dioxin results (Table 1) replicate those obtained by.

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<sup>1</sup> Heron, G., Baker, R., Galligan, J., Tawara, K., Braatz, H., Ito, Y. and Higuchi, S. 2009. "In-Pile Thermal Desorption for Treatment of Dioxin-Contaminated Sediment in Japan". Abstract submitted to Seventh Int. Conf. on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 24-27, 2010. Battelle, Columbus, OH

**Table 1. Dioxin Results obtained from ISTD and IPTD Field Projects**

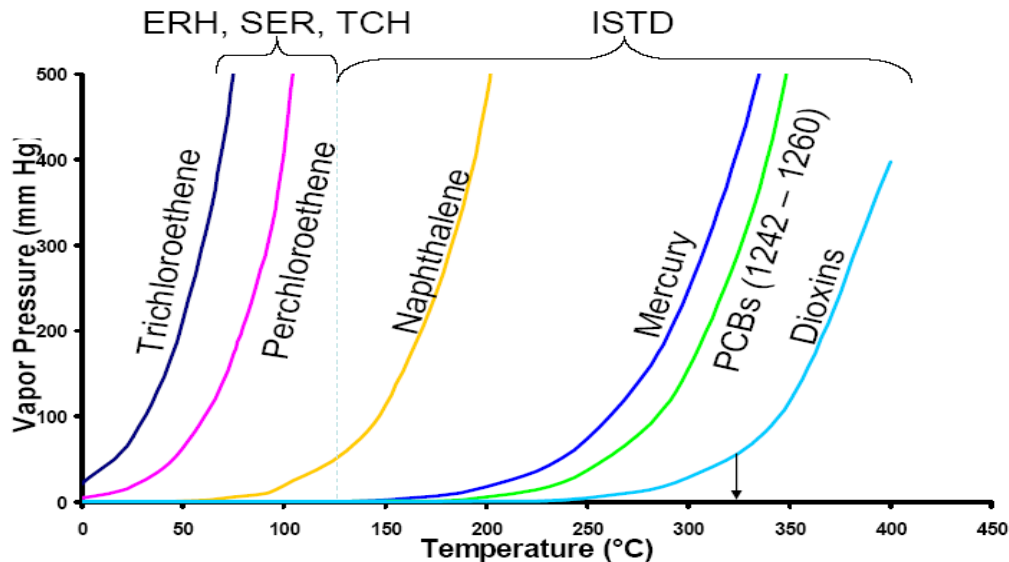
Site	Target Media	Average Pre-Treatment Concentration	Average Post-Treatment Concentration	Exhaust Gas Concentration
		[pg-TEQ/g]	[pg-TEQ/g]	[ng-TEQ/Nm <sup>3</sup> ]
Yamaguchi, Japan	Sediment	1,800	67.75	0.000018
Alhambra, California USA	Soil	18,000	110	0.0071
Cape Girardeau, Missouri USA	Soil	6,500	3.2	0.0029
Ferndale, California USA	Soil	3,200	7.3	0.0055

TerraTherm in full-scale ISTD projects such as the one at Alhambra, CA. Note that while the starting dioxin concentrations were relatively low at these projects, the technologies can also obtain similar post-treatment concentrations when starting concentrations are much higher.

*Heat Flow and Removal Mechanisms.* Heat flows from the heating elements located in the walls and floor of the treatment cells through the sediment primarily by thermal conduction. This results in uniform heat propagation, for unlike other physical properties of soil or sediment, thermal conductivity is nearly invariant over a wide range of sediment types (e.g., clay to sand). In a typical IPTD installation for sediment contaminated with high-boiling point SVOCs, such as PCDD/Fs, the coolest material in between the heaters is heated to a treatment temperature of 335°C<sup>2</sup>. Figure 2 shows vapor pressures versus temperatures for a variety of environmental contaminants and in

<sup>2</sup> Uzgiris, E.E., Edelstein, W.A., Philipp, H.R., and Iben, I.E.T. 1995. "Complex Thermal Desorption of PCBs from Sediment." *Chemosphere*, 30(2):377–387.

## Vapor Pressure vs. Temperature



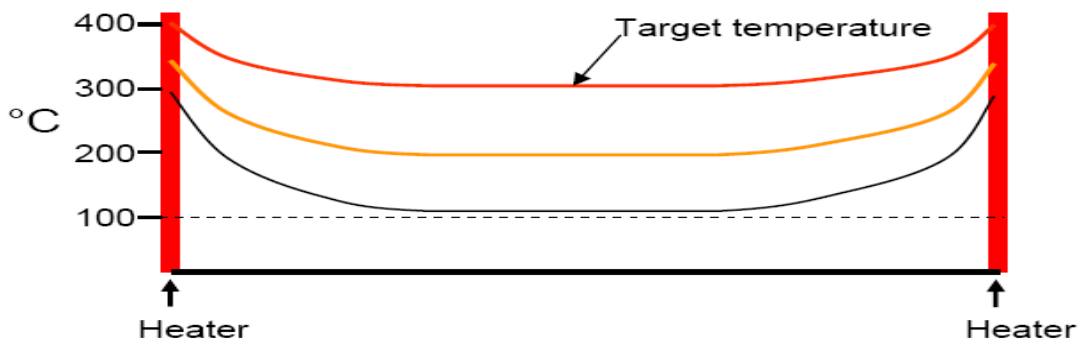
**Figure 2: Vapor pressures versus temperatures and environmental contaminants that can be treated using thermal methods.**

situ thermal remediation technologies (i.e., ERH = electrical resistance heating; SER = steam enhanced recovery; and TCH= thermal conductive heating). Because heat and vacuum are applied simultaneously, compounds with relatively low vapor pressures can be removed from soils using this technology. Please note that this treatment temperature is much lower than the 1300-2000°C temperature range typically used for melting / vitrification processes (e.g., Ecomelt®; GeoMelt®), and therefore IPTD is much more energy-efficient.

Heat and vacuum are applied simultaneously to the target media with an array of vertical or horizontal heater elements. For the ISTD technology, each heater contains a heating element (typically electrically powered resistance heaters), with an operating temperature of approximately 1400 to 1500°F (~750 to 800°C; Figure 3). As the soil is heated, volatile, semi-volatile and non-volatile organic contaminants in the soil are vaporized and/or destroyed by a number of mechanisms, including:

- 1) **evaporation,**
- 2) **steam distillation,**
- 3) **boiling,**
- 4) **oxidation, and**
- 5) **pyrolysis (chemical decomposition in the absence of oxygen).**

The vaporized water and contaminants, as well as some volatilized inorganic compounds, are drawn counter-current to the heat flow into the vacuum extraction wells (termed “heater-vacuum” wells; Figure 4)<sup>3</sup>. Perforated conduits convey gases into and out of the walls and floor of each treatment cell. The vaporized water and contaminants are drawn into the vapor recovery conduits. Contaminant vapors are then removed from the produced vapor stream at the surface with an Air Quality Control (AQC) system.



**Figure 3: Temperature distribution between heater wells.**



**Figure 4: Depiction of organic vapors being drawn into vapor recovery well while passing through heated soil.**

<sup>3</sup> Stegemeier, G.L., and Vinegar, H.J. 2001. “Thermal Conduction Heating for In-Situ Thermal Desorption of Soils.” Ch. 4.6, pp. 1-37. In: Chang H. Oh (ed.), Hazardous and Radioactive Waste Treatment Technologies Handbook, CRC Press, Boca Raton, FL.



The treated sediment is clean of contaminants, and yet still has the properties of soil or sediment. It remains a porous medium, and once cool, the treated sediment can be returned to its origin, or beneficially used for other purposes. Cooling can be accelerated by addition of water.

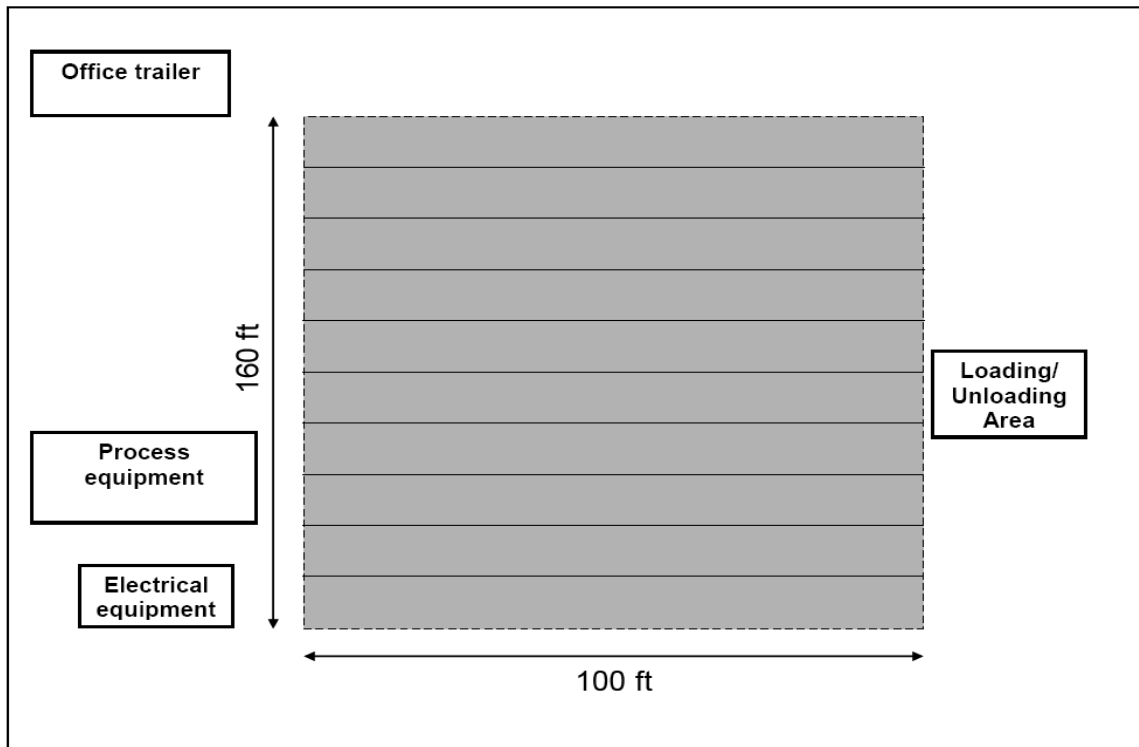
### **3. Treatment Cell Layout and Construction**

A typical IPTD layout showing ten adjoining treatment cells is shown in Figure 5:

Subject to detailed design, approximately 710 cy of sediment are placed in each approximately 16 ft wide x 100 ft long x 12 ft high treatment cell. The overall dimensions shown in Figure 2 reflect a single complex of 10 adjoining treatment cells, with a combined treatment capacity of 7,100 cubic yard. Note: that some additional space is required around the system as shown, to allow for lay-down, maintenance, and interim sampling.

Features of the IPTD system include the following:

- A leachate collection system is provided to enable containment and treatment of any leachate generated during the process of filling and heating the treatment cells.
- Horizontally-oriented heater elements are distributed within the rigid floor and walls of the treatment cells, to allow uniform heating of the sediment.



**Figure 5. In-Pile Thermal Desorption (IPTD) System Layout.** A single complex of 10 adjoining treatment cells is shown. *Not to scale.*

- The floor, exterior walls and cover over the treatment cells are insulated to reduce heat losses during treatment.
- Vapor injection and extraction conduits are distributed within the floor and walls and beneath the cover over the treatment cells.
- An insulating vapor cover is used to contain fugitive emissions and allow for application of a net vacuum to each of the treatment cells. All vapors and steam generated during heating are collected and treated.
- Thermocouple ports are provided at select locations to enable tracking of the progress of heating.

*Heating Elements.* TerraTherm utilizes its proprietary rod heating elements, which have been field-proven at numerous ISTD / IPTD sites (Figure 6). Their operating wattage is approximately 1.0 kW per linear meter of the heaters (300 Watts per foot). They are simple, durable and re-usable. TerraTherm has built and operated over 10 miles of heater elements, with over 99% up-time.



**Figure 6. Proprietary TerraTherm Heater Element used Inside the Walls and Floor of each of the Treatment Cells.** Covered by one or more of the following: U.S. Patent Nos. 5,190,405, 5,318,116, 6,485,232 and 6,632,047. International patents include EPC 1272290.

The metal rod has a diameter of approximately 1.27 cm (0.5 inches). The white beads are ceramic isolators. Electric power flows through the steel rod, causing it to heat resistively. Heat then flows by conduction to the rigid walls and floor of the treatment cells, and into the sediment.

Each of the heater elements shown in Figure 6 is installed inside a thin-walled stainless steel liner. The materials of construction are designed to withstand the temperature and chemistry to which they will be exposed.

*Air Injection, Dewatering and Vacuum Conduits.* The conduits situated beneath the cover and within the walls and/or floor of each of the treatment cells serve as vacuum recovery wells. Vacuum conduits are provided with perforations spanning the length of each cell. A vacuum is applied continuously to the vacuum conduits, to ensure that vapor and steam generated during heating are captured and treated. Several conduits are used for allowing replacement air to enter the treatment cells, which supply oxygen to fuel destruction reactions within the heated sediment. Each of the air injection conduits can, if desired be equipped with an electrical heating element, heating the replacement air to approximately 800°F as it enters the pile, thereby eliminating unwanted cooling by the supplied air.

#### **4. Estimated Treatment Cost**

Treatment costs are subject to economies scale, but expected costs typically can range \$300 to \$400 per cubic yard. Electric power cost is a significant portion of the overall cost. Normally the client pays for power directly and usually at lower industrial rates.



## 5. Health Safety and Community Acceptance

*Health and Safety.* TerraTherm places the highest priority on health and safety. In over 9 years in business (over 315,000 work hours logged), TerraTherm has maintained a perfect OSHA safety record with no recordable incidents or lost-time injuries.

*Experience Working Adjacent to Occupied Residences.* Seven ISTD projects have been carried out immediately adjacent to occupied residences and businesses, with no problems or complaints, and with excellent public reaction:

- Portland, IN
- Eugene, OR
- Confidential Site, Midwest U.S.
- Taunton, MA
- Endicott, NY
- Knullen, Denmark
- Reerslev, Denmark

While all projects have included monitoring of breathing zone air as part of the Health & Safety Plan, some of these projects also included ambient air monitoring systems.

## 5. Attachments

**Attachment 1, Page 11:** California Department of Toxic Substances Control letter to Southern California Edison approving of the ISTD cleanup of polycyclic aromatic hydrocarbon, pentachlorophenol, dioxins and furans from soils in Alhambra, CA.

**Attachment 2, Page 12:** Summary Table: ISTD / IPTD Projects Treating SVOCs.



Linda S. Adams  
Secretary for  
Environmental Protection



## Department of Toxic Substances Control

Maureen F. Gorsen, Director  
1011 North Grandview Avenue  
Glendale, California 91201



Arnold Schwarzenegger  
Governor

February 8, 2007

Ms. Jennie King  
Project Manager  
Environmental Affairs  
Southern California Edison  
2244 Walnut Grove Avenue  
Rosemead, California 91770

REMEDIAL ACTION COMPLETION REPORT APPROVAL AND AOC-2  
CERTIFICATION, SOUTHERN CALIFORNIA EDISON (SCE) ALHAMBRA COMBINED  
FACILITY, ALHAMBRA, CALIFORNIA

Dear Ms. King:

The Department of Toxic Substances Control (DTSC) has reviewed the subject Remedial Action Completion Report (Report) for AOC-2 at the SCE Alhambra Combined Facility submitted by TerraTherm. The Report documents the treatment of approximately 16,500 cubic yards of soil at AOC-2 contaminated with polycyclic aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), dioxins and furans.

DTSC approves the Report and certifies that it meets all of the conditions of the approved Remedial Action Plan developed pursuant to Health and Safety Code Section 25356.1 for the contaminated soil remediation. DTSC has determined that the AOC-2 portion at this Site has been remediated to allow for unrestricted land use and that No Further Action is required.

Thank you for your efforts in remediating this Area of Concern. If you have any questions please contact Mr. Tedd Yargeau, Project Manager, at (818) 551-2864 or myself at (818) 551-2822.

Sincerely,

A handwritten signature in blue ink that reads "Sayareh Amir".

Sayareh Amir, Chief  
Site Mitigation and Brownfields Reuse Program – Glendale Office

cc: See next page

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Site Name	Location	Date Completed	Volume	Depth Treated (Well Spacing)	Major Contaminant(s) of Concern	Type(s) of Soil (thickness, ft); Water Table	Target Temperature	Maximum and/or Mean Pretreatment Concentration	Remedial Goal	Mean Post-treatment Concentration
			cy	ft		ft	°C	mg/kg	mg/kg	mg/kg
GE Test 3B	S. Glens Falls, NY	Mar-96	16	0.5 (thermal blanket)	PCB 1248/1254	sand; vadose zone	-370	Max.: 5,212 Mean: 509	2	< 0.033
Missouri Electric Works	Cape Girardeau, MO	May-97	61	12 (5)	PCB 1260	silty clay; water table at 40 ft depth	8370	Max.: 19,900 Mean: 649	2	< 0.033
US Navy Former Mare Is. Naval Shipyard	Vallejo, CA	Dec-97	175	14 (5)	PCB 1254/1260	silt/clay; water table at ~20 ft depth	-370	Max.: 2,200 Mean: 53.5	2	< 0.033
Tanapag Village Site Remediation	Saipan, NMI	Aug-98	1000	N/A (IPTD)	PCB 1254/1260	silty sands and crushed coral vadose zone	-370	Max: 10,000 Mean: 500	10	< 10
US Navy Centerville Beach	Ferndale, CA	Dec-98	530	17 (6)	PCB 1254/1260	silty and clayey colluvium	316	Max: 860 Mean: 302	1	< 0.17
Southern California Edison AOC-2	Alhambra, CA	Jan-06	16,200	0 to 105 (7.0)	PAHs, PCP and PCDD/Fs	Silty sand; vadose zone	335	Max.: Total PAHs: 35,000 PCP: 58 PCDD/Fs: 0.194 (TEQ) Mean: Total PAHs: 2,306 PCP: 2.94 PCDD/Fs: 0.018 (TEQ)	PAHs [B(a)P-Eq]: 0.065 PCP: 2.5 PCDD/Fs: 0.001 (TEQ)	PAHs [B(a)P-Eq]: 0.059 PCP: 1.25 PCDD/Fs: 0.00011 (TEQ)
National Grid Former MGP Site	North Adams, MA	Mar-05	2,010	6 to 18 (12.5)	Benzene, PAHs, Coal Tar	Fill and debris inside gasholder; perched water initially filled gasholder; water table below bottom of gasholder	Mid-portion of gasholder: 325 Bottom of gasholder: 120	Mean: Mid-portion: Benzene: 2,068 Naphthalene: 679 Benzo(a)pyrene: 20 TPH: 4,000 Bottom of gasholder: Coal Tar DNAPL	Mid-portion: Benzene: 2,000 Naphthalene: 10,000 Benzo(a)pyrene: 100 TPH: 10,000 Bottom of gasholder: No DNAPL	Mid-portion: Benzene: 0.35 Naphthalene: 5.7 Benzo(a)pyrene: 0.33 TPH: 43.15 Bottom of gasholder: No DNAPL present
Rt. 44 Drum Site	Taunton, MA	Mar-07	5,300	0 to 14 (12)	Chlorobenzenes, Naphthalene, Toluene	Sandy fill and sand; water table at 12 to 16.5 ft depth	Unsaturated Zone: 150 Saturated Zone: 100	Max.: Total TCB: 4000 Total DCB: 450 Naphthalene: 2500 Toluene: 350 (max conc./history indicate DNAPL likely present)	No Strict Goals; Reduce COPC mass to accelerate attainment of water quality goals. For reference, the S2-GW3 Standard is: 1,2,4-TCB: 890 1,2-DCB: 290 Naphthalene: 990 Toluene: 990	Unsaturated Zone, Total TCB: 10.1 Total DCB: 0.65 Naphthalene: 19 Toluene: 0.58 Saturated Zone, Total TCB: 310 Total DCB: 4 Naphthalene: 120 Toluene: 30