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March 17, 2023

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Re: GE-Pittsfield/Housatonic River Site/Rest of River
Adjudicatory Hearing of the Town of Lee Board of Health

Dear Attorney Bonifaz:

Thank you for the opportunity to provide information to the Town of Lee Board of Health (BOH) and the extension of time to submit this material. This letter responds to certain Exhibits contained in the record maintained by the BOH regarding the Upland Disposal Facility (UDF) to be constructed in the Town of Lee. The EPA is submitting this information for the BOH's consideration in its deliberations regarding whether the UDF presents a health threat to Town of Lee residents.

In particular, EPA is responding to an affidavit from Dr. David Carpenter (Exhibit 23), a letter submitted by Charles McCreery (Exhibit 17), and information submitted by attorney Judith Knight (Exhibits 22 and 25). As a general matter on the safety of the UDF, EPA refers the Board to the Administrative Record for the 2020 Final Revised Cleanup Permit for the Rest of River, including EPA's December 2020 Response to Comments document, especially Section II.A on the safety of the UDF (referred to as the 2020 RTC). The 2020 RTC can be found at https://semspub.epa.gov/src/document/01/650441. The complete Administrative Record for the Permit is available on-line (except for records that are privileged or otherwise controlled) at https://semspub.epa.gov/src/collection/01/AR66478.

Introduction

EPA first notes that PCBs are currently uncontrolled in the Housatonic River sediment and floodplain soil, posing unacceptable risks to human health, mainly through fish consumption and, in certain reaches, direct contact with floodplain soil. Within the Town of Lee, uncontrolled PCBs are currently in the stretch of the river above Woods Pond, in Woods Pond, and migrating downstream. There are also three impoundments in Lee downstream of Woods Pond that require sediment removal and several properties in Lee that may require floodplain remediation. The cleanup set forth in the Final Revised Cleanup Permit will permanently address these unacceptable risks by safely removing, capping, transporting, and disposing of contaminated material in the secure and protective UDF and at off-site facilities for the most highly contaminated material.

In his testimony to the BOH, Dr. Carpenter testified that he is "very much in favor" of removing PCB-contaminated sediments and soils. 11/19/22 BOH Transcript, Page 85, lines 5-7. Dr. Carpenter's article attached to his Affidavit states that "it is imperative to find ways of removing these contaminants from the environment." See page 10. He also stated that he was not opposed to landfills that are secure and "secured for the duration, not just the two years." Transcript, Page 85, lines 14-17. We agree with Dr. Carpenter on the need to address PCBs in the River and floodplain.

As EPA understands it, the purpose of the BOH's hearing and deliberations is to determine "whether or not the UDF presents or does not present a risk to the health of residents of Lee and adjacent communities, based **solely** on expert testimony." BOH Exhibit 1 (emphasis original). To impact human health, there has to be a viable pathway for PCBs to enter the body. The human health exposure pathways of concern to the BOH inferred from the hearing and Exhibits are inhalation of PCBs and ingestion of PCBs from drinking water. Therefore, the Board's focus should be on the realistic impact to health from the planned consolidation at the UDF from inhalation of PCBs and consumption of PCB-contaminated drinking water.

As detailed below, EPA's Administrative Record for the Final Revised Cleanup Permit shows that volatilization of PCBs in the River does not currently pose a threat to human health. During cleanup, engineering controls will mitigate potential volatilization threats as demonstrated by air monitoring data from over 15 years of remediation in Pittsfield where material containing PCBs at orders of

magnitude greater than those in Rest of River were safely excavated and disposed of.[1] Furthermore, air monitoring data from the two On-Plant Consolidation Area (OPCA) landfills constructed in Pittsfield for the non-Rest of River phases of the GE cleanup, and other information, show that there will be no unacceptable human health risk posed by the air pathway from the UDF, both during consolidation of material and post-closure.

EPA's record also shows that the UDF does not pose a threat to drinking water sources. There are no residential or municipal supply wells downgradient of the UDF, and there is no potential pathway for contamination from the UDF to migrate upgradient to the Town of Lee surface drinking water reservoirs. Moreover, the record demonstrates that it is extremely unlikely that PCBs will leach out of the contaminated material in the UDF into the groundwater beneath the UDF, and even if they did, the levels would be extremely low, would be observed in monitoring wells, and the groundwater will not discharge to a drinking water source.

Uncontrolled PCBs can pose unacceptable health risks. But risk requires exposure, and the UDF will prevent that human exposure to PCBs. As explained below, Dr. Carpenter's Affidavit and testimony incorrectly describe the risk potentially posed by the UDF. Dr. Carpenter's conclusions regarding the risk posed by the UDF do not address in a significant manner the design of the UDF, data specific to the UDF area, data and monitoring specific to the other remediation activities at the non-Rest of River phases of the site and are not supported by data or by science as described below.[2]

[1] For example, soil was excavated with PCBs as high as 43,000 ppm at the Newell Street II area (Final Completion Report (FCR) for Newell II, October 2009, including Section 4.7; Appendix A, Tables A-3 and A-7; and Appendix F). PCBs were excavated in sediment as high as 9,410 ppm and in soil as high as 17,000 ppm at the Upper ½-Mile Reach Removal Action. (Section 4.7 and Appendix F, and Upper ½-Mile Reach FCR, January 2011, including Section 8.1.2, and Upper 1/2-Mile Work Plan, August 1999, Appendix C and D.) As documented in the Upper ½-Mile FCR and the Newell Street II FCR, there were no exceedances of the PCB airborne action level, and there was only one exceedance of the PCB air notification level.

[2] Also, based on his Curriculum Vitae, Dr. Carpenter has not demonstrated that he has expertise in landfill design and operation, geology, or groundwater fate and transport. Exhibit 23.

EPA Response to Dr. Carpenter's claims regarding volatilization of PCBs.

In his Affidavit, Dr. Carpenter makes claims about the health threat posed by the volatilization of PCBs as they are transported to and placed into the UDF and then after the UDF is closed. These claims are unfounded and alarmist.

Volatilization of PCBs currently in the Housatonic River.

An EPA human health risk assessment of air monitoring it performed or required GE to perform shows there is no current human health threat from the volatilization of PCBs in the Housatonic River or floodplain. This indicates that even in an uncontrolled state, PCBs in sediment and floodplain soil are not volatilizing enough to pose an unacceptable human health risk. See Section 5.1 (Air Pathway Screening Risk Assessment) in EPA's peer-reviewed Human Health Risk Assessment, and Appendix C.7 (Analysis of PCB Congener Composition).

Volatilization of PCBs during excavation, transportation, and consolidation into the UDF.

Site data indicate that it is extremely unlikely that there will be harmful volatilization of PCBs during the excavation and transportation of Rest of River materials and during the placement of the materials into the UDF. In the four years of excavation that occurred in the 1½-Mile Reach of the River in Pittsfield, EPA conducted air monitoring, and there were no exceedances of the health-based action level and only one exceedance of the notification level, which is a level more stringent than the action level that requires the evaluation of measures to control the emission of particulates and dust. 2020 RTC, page 33. Placement of PCB contaminated soils in the OPCAs did not exceed protective levels for PCBs in air, even though the PCB levels of such material was much higher than the material that will be placed in the UDF. 2020 RTC, pages 15-16. For example, at least 4,100 cubic yards of soil from one parcel (J9-23-8) that was sent to the Building 71 OPCA contained an approximate average of 3,500 ppm PCBs with a maximum of 43,000 ppm PCBs. Final Completion Report for Newell II, October 2009, and Conceptual Removal Design/Removal Action Work Plan, Newell II, July 2004, Appendix D; also see Footnote 1. For comparison, the UDF is limited to accepting an average of no greater than 50 ppm, and, based upon existing data and Permit disposal criteria, the average to be disposed of in the UDF is estimated to be between 20 and 25 ppm PCBs. 2020 RTC, pages 60-61.

The Rest of River excavation will primarily involve wet sediment not susceptible to airborne transmission, and all excavation will nevertheless require dust suppression and air monitoring. After dewatering of wet material, EPA expects GE to use sealed trucks and tarps to minimize the potential for releases of liquids or air emissions. 2020 RTC, pages 13-14 and 31-33; Permit Attachment D, page D-2.

A remedy consisting of all off-site disposal would still require the excavation and transportation of the same amount of PCB-contaminated material. Even if off-site disposal or treatment was used for the cleanup, the area designated for the UDF would likely be a soil/sediment staging area for at least the material coming from Woods Pond and the stretch of the river upstream of Woods Pond. Thus, elimination of the UDF would not eliminate the need to dredge/excavate, stage, dewater, and transport contaminated Rest of River material.

Further, compared to off-site disposal, use of the UDF will likely result in the reduction of 50,000 truck trips for material removed from and immediately upstream of Woods Pond, both of which straddle the Lee/Lenox town line. EPA 2020 RTC, page 38. A remedy consisting of all off-site disposal (compared to use of the UDF) would have had greater greenhouse gas and other air emissions, more fugitive dust, and more adverse community impacts (due to increased truck traffic and risks of injuries and fatalities to transport workers). 2020 RTC, page 9.

In Paragraph 9 of his Affidavit, Dr. Carpenter states that lower-chlorinated PCBs will volatize at four steps of transport. But Dr. Carpenter does not mention that his first three steps (Items a. through c.) will occur even with off-site disposal or treatment. He also does not mention that use of the UDF will result in many fewer truck trips and much less handling of contaminated sediment in the Town of Lee. Dr. Carpenter also states that lower-chlorinated PCBs will volatize more quickly when wet (Item e), but to the extent that is correct, wet sediments will require handling even for off-site disposal. Finally, Affidavit Paragraph 9 appears to contradict his testimony that he was very much in favor of getting the contaminated material out of the River, even though there may be a "transient increase in exposure to people." Transcript, page 85, lines 4-13.

Volatilization of PCBs after completion and capping of the UDF.

In his Affidavit, Dr. Carpenter makes certain claims regarding the volatilization of PCBs from the UDF after it is closed and capped. Dr. Carpenter, however, provides no support for his conclusory, counter-intuitive claim that the

lower level of PCBs contained in the dewatered sediment and floodplain soil from the River will volatilize into the air through the proposed UDF's 2.5 foot thick covering cap, which contains soil, a geosynthetic clay layer, and a 60 mil-thick geomembrane liner. (See PDF page 57, Figure 9 of the UDF Conceptual Design Plan for a figure showing the cap design.) Dr. Carpenter presents no analysis, evaluation, or data regarding the mechanism for how PCBs will volatilize and then migrate through the UDF's cap. As stated above, Dr. Carpenter has not demonstrated and is not claiming to be an expert on landfill design or operation.

In fact, Dr. Carpenter's past writings appear to support the cover system proposed for the UDF – a tightly covered landfill with both a plastic cap and soil cover. In Dr. Carpenter's article attached as his Exhibit B, titled *Exposure to and Health Effects of Volatile PCBs*, he states that "PCBs can also volatilize from landfills, depending upon how tightly they are covered (10)." Page 2 (emphasis added). The article Dr. Carpenter cites in his footnote 10 to support this sentence states that after closure of the studied landfill only background levels of PCBs were detected in air. See page 1018 of Attachment 1: Bremle G, Larsson P. *PCB in the air during landfilling of a contaminated lake sediment*. Atmos Environ 1998; 32:1011– 9.

It is also unclear whether the "waste sites" referenced in the Affidavit that are the basis for Dr. Carpenter's conclusions are at all comparable to the UDF. Are these "waste sites" uncontrolled PCB disposal sites, as opposed to capped and lined landfills? Dr. Carpenter gives no description or data regarding these "waste sites." For example, the Anniston Alabama facility Dr. Carpenter mentions in his testimony (Page 80, Line 7) did not involve a capped and lined landfill, and thus is irrelevant to proposed UDF in Lee. (For a description of the Anniston facility, see Page 196 of Carpenter, D.O., Morris, D.L. and Legator, M. *Initial attempts to profile health effects with types of exposure in Anniston, Alabama*. FEB, 12: 196-200, 2003.) In his testimony Dr. Carpenter does not indicate that the General Motors facility he describes had or has a cap. See Transcript, page 77, lines 1-10, and page 80, lines 15-17. Dr. Carpenter cites no data regarding the volatilization of PCBs from capped landfills. He cites no data to support his claim that the capped UDF will threaten the health of residents who live up to a four-mile radius of the UDF, other than the data regarding PCB waste sites, which appear to be uncontrolled sites as opposed to capped landfills. Affidavit Paragraph 5.

Actual data from the Non-rest of River phases of the GE-Pittsfield/Housatonic River Site indicate that it is extremely unlikely that the closed UDF will have harmful volatilization of PCBs into the air. In Pittsfield, since 1999 robust air monitoring has been conducted of the OPCAs, which contain higher levels of PCBs than will be placed in the UDF. See 2020 RTC, pages 15-16. During and after placement of waste in the OPCAs there were no exceedances of either the health-based notification or action levels for PCBs in air. Id at 16. There were also no such exceedances of air monitoring conducted at a nearby elementary school. Id. Also see *Graphical Representation of Polychlorinated Biphenyl (PCB) Air Sampling Data at Allendale School Playground and General Electric On-Plan Consolidation Areas (OPCA)*. https://semspub.epa.gov/src/document/01/661268. The mixtures of PCBs that were excavated and placed into the OPCAs are the same as the PCBs mixtures contained in the Rest of River sediment (that is, the predominantly higher chlorinated mixtures Aroclors 1254 and 1260). Dr. Carpenter does not address the data or information contained in EPA's 2020 RTC showing no harmful volatilization from the OPCAs or comment on EPA's air monitoring data at the OPCAs and Allendale School.

Scientific papers support the conclusion that volatilization will not occur in harmful amounts from the UDF. Bremle G, Larsson P. *PCB in the air during landfilling of a contaminated lake sediment*. Atmos Environ 1998; 32:1011– 9 (see page 1018). Lewis, R. G., Martin, B. E., Sgontz, D. L., and Howes, J. E. Jr. (1985) *Measurement of fugitive atmospheric emissions of polychlorinated biphenyls from hazardous waste landfills*. Environmental Science and Technology 19, 986-991 (see pages 987-988). Studies also indicate that the PCB concentration in air decreases exponentially with the distance from industrial sources. Bremle G, (1998) (see page 1017). These articles are Attachments 1 and 2 to this submission.

As a protective measure, like the OPCAs, during consolidation and after closure and capping of the UDF, GE will be required to conduct air monitoring for PCBs to ensure harmful levels are not detected.

Even if lower-chlorinated PCBs are more volatile than more highly chlorinated PCBs, the materials to be consolidated in the UDF will contain very low percentages of the lower chlorinated PCBs. Numerous technical resources

generally document the congener makeup of different Aroclors.[3] (The Rest of River materials contain Aroclors 1254 and 1260, which are more highly chlorinated.) Site documents in the Rest of River Administrative Record document the congener distribution that will be prevalent in the materials to be consolidated in the UDF. See Section 5.1 (Air Pathway Screening Risk Assessment) in EPA's peer-reviewed Human Health Risk Assessment, and Appendix C.7 (Analysis of PCB Congener Composition) in EPA's peer-reviewed Ecological Risk Assessment. Highly chlorinated PCBs also tend to bind to soils, which significantly reduces volatilization.[4]

Finally, EPA notes that Dr. Carpenter's Affidavit differs in significant aspects from the testimony that he gave to the BOH on November 19, 2022. In his testimony, Dr. Carpenter clearly supported removal of PCBs from the Housatonic River. Transcript, page 77, lines 16-19 and page 85, lines 4-17. Dr. Carpenter's Affidavit does not mention his support for PCB removal. Further Dr. Carpenter's testimony appears related to unlined sites, and he did not discuss any capped sites, whereas these distinctions are not mentioned in this Affidavit. See Transcript, page 78, lines 22-24, and page 80, lines 13-17.

In sum, Dr. Carpenter presents no expert evidence to support his claim that the UDF will pose a threat to health of Lee residents via the air inhalation pathway.

Dr. Carpenter's claims regarding potential groundwater contamination.

The Board has stated that its charge is to determine whether the UDF poses a health threat to the residents of Town of Lee, not if the UDF represents a threat to the Housatonic River, the groundwater, or a risk to ecological receptors. Drs. Carpenter and DeSimone did not show any pathway for PCBs, even if they leaked though the bottom of the UDF, to realistically affect the health of Lee residents. No one is drinking from wells downgradient of the UDF; the groundwater beneath the UDF site is not now or reasonably foreseeably to be used as a municipal

[3] For example, see https://cluin.org/contaminantfocus/default.focus/sec/Polychlorinated_Biphenyls_(PCBs)/cat/Chemistry_and_Behavior and the linked table of PCB properties.

[4] See, ATSDR, 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs), Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service. https://www.atsdr.cdc.gov/toxprofiles/tp17.pdf.

drinking water source; and it is not possible for the groundwater to migrate to the Town of Lee water supply, which is from surface reservoirs that are located over one mile away and upgradient from the UDF. See 2020 RTC, pages 20-21 and HDR Groundwater Memo, Attachment 3.

In his Affidavit, Dr. Carpenter presents no evidence or support for his conclusory statements about potential groundwater contamination from the UDF.[5] To the extent his testimony is relevant, it is duplicative of the report from Dr. DeSimone.

Although Dr. Carpenter states that "all of the known data" on the life of liners in toxic landfills support the conclusion that they will eventually leak, he presents no such data and does not address EPA's 2020 Response to Comments regarding the safety of the UDF. The only data he cites for his conclusion that when the UDF liners leak they will eventually contaminate the groundwater and water table for the Town of Lee is the report of Dr. David DeSimone. EPA has addressed this report in letter to the Board dated November 8, 2022. Further, Attachment 3, a report from an expert from HDR APTIM on groundwater and contaminant fate and transport, concludes that the UDF does not present a threat to the Town Lee's drinking water supplies.

Many site-specific factors and redundant safeguards led to EPA's determination that the UDF will be protective of human health. These are detailed in EPA's Administrative Record, and in particular in the 2020 Response to Comments, but the following is a summary of some of the protective factors.

- The fact that PCBs do not readily migrate in groundwater. 2020 RTC, pages 21-22; Attachment 3, page 11.

- Only lower level of PCBs will be disposed of in the UDF. 2020 RTC, pages 12-13 and 60-61. Because of restrictions mandated by EPA in the cleanup Permit, the material to be disposed of in the UDF is estimated to have an average concentration of about 20 to 25 ppm PCBs. 2020 RTC, pages 60-61. For comparison, PCB levels below 50 ppm can be disposed of in a municipal solid waste landfill. 2020 RTC, page 12.

[5] Dr. Carpenter has not demonstrated that he is an expert in cap design, liner safety and durability, geology, groundwater flow, and PCB fate and transport in groundwater. Exhibit 23. Dr. Carpenter's opinions on groundwater are therefore not expert testimony.

- EPA is requiring that the UDF will be built with a low-permeability cover to prevent the infiltration of rainwater though the material in the UDF. Permit at p. 55, subsection (e); 2020 RTC, page 12.

- To prevent leaks into groundwater, the UDF will have two low-permeability bottom liner systems, each including drainage layers and two separate low-permeability layers (a plastic membrane (HDPE) and a geocomposite clay liner (GCL)). The bottom of the UDF will be sloped so that any leachate (water) migrating down to the primary (uppermost) bottom liner will drain via a drainage layer into pipes that collect and safely dispose of any leachate. (These drainage layers are also designed to prevent water pressure from building up on top of the liners.) A second sloping drainage layer will be placed below the first liner system to collect and safely dispose of leachate in the unlikely event that the first liner leaks. The presence of leachate in this second drainage layer will be monitored to detect any leaks from the first liner. The second liner system, also comprised of two separate low-permeability layers, is a backup in case the first liner fails. As additional protection, GE has proposed a one-foot thick compacted, low-permeability clay liner beneath the two bottom liner collection systems. This results in a total of five low-permeability layers interspersed with two drainage layers that will direct any leachate to a leachate collection system and reduce water pressure on the low-permeability layers. GE also increased the thickness of the HDPE liners from the Permit minimum of 30 mil to 60 mil. For further depiction of these elements, see Figures, Attachments 4 and 5.

- The permeability of the HDPE liners is typically 1×10^{-13} cm/sec, which is up to one million times less permeable than the permeability requirements under the Permit and under the federal standard for lined and unlined PCB chemical waste landfills, both of which are 1×10^{-7} cm/sec. See Permit Paragraph II.B.5.a.(2).(f) and 40 CFR 761.75.

- EPA is requiring that prior to material being placed in the UDF, the cover and bottom liners will be tested to ensure that they are compatible with PCBs and that there are not any leaks in the liners. 2020 RTC, page 18.

- Studies show that low-permeability caps and liners are durable and long-lasting. 2020 RTC, pages 12 and 18.

- EPA has had a positive experience with capping, 2020 RTC, pages 12 and 18, including two other PCB landfills (the OPCAs) safely isolating and containing PCBs at the GE site in Pittsfield. 2020 RTC, pages 14-18. One of these landfills, Building 71, contains much higher levels of PCBs than will be placed in the UDF. Based upon sampling conducted since at least 1999, these two Pittsfield landfills have not leaked into or contaminated groundwater. 2020 RTC, pages 16-17.

- EPA is requiring that the UDF will be built to the same or similar design standards used by commercial landfills permitted to accept much higher levels of PCB waste. 2020 RTC, page 13.

- EPA is requiring GE to maintain the UDF and to install groundwater monitoring wells abutting the UDF. 2020 RTC, pages 21-22. In the unlikely event of a leak, these monitoring wells will be able to detect leaks from the UDF.

- Under GE's Cleanup Permit that EPA issued, GE is required to operate, monitor, and maintain the UDF for as long as waste is present. Under the Consent Decree for the Site, GE is subject to significant stipulated and statutory penalties for noncompliance.

Even in the unlikely event of a leak from the UDF, such a leak would not impact the Town's drinking water supply. The natural features of the area around the UDF and the associated groundwater flows will restrict the extent of any contamination resulting from such a leak.

- In the area of the UDF, groundwater moves upward (is upwelling), therefore any leaks are unlikely to reach bedrock. See Attachment 3, pages 1 and 10.

- The Town of Lee's drinking water supply does not come from groundwater supply wells from the groundwater beneath the UDF aquifer or from the Housatonic River. Nor is the Housatonic River a source of drinking water

for any towns in Massachusetts. Attachment 3, page 1. The Town of Lee's drinking water comes from surface reservoirs located uphill from the UDF and over one mile from the UDF. Id. and 2020 RTC, pages 20-21. It is not possible for potentially contaminated groundwater or stormwater surface runoff to migrate from the UDF and contaminate the upgradient drinking water supplies. 2020 RTC, pages 20-21; Attachment 3, page 11.

- Future use of groundwater beneath and near the UDF is unlikely due to existing groundwater contamination, which is unrelated to the UDF or the GE-Housatonic River site. 2020 RTC, page 65.

- In the unlikely event of an undetected leak from the UDF, because of groundwater flows such a leak would flow directly towards the River and away from the Town's water supply. Attachment 3, pages 1 and 10-11. Also, PCBs tend to bind to organic material, so any uncontrolled PCBs will tend to bind to organic matter in the soils and sediments located outside of the UDF. Attachment 3, page 11. EPA's groundwater expert has opined that "detectable concentrations of PCBs would not be expected to migrate a significant distance from the UDF or arrive at the Housatonic River or any know current nearby water supply." Id.

- There are currently uncontrolled PCBs in Woods Pond, which have been there for decades. The surface water in Woods Pond is hydraulically connected to the underground aquifer that is located beneath the UDF. Attachment 3, page 11. PCBs have not been detected in current groundwater monitoring conducted for the UDF near Woods Pond. Id. The fact that the uncontrolled PCBs in Woods Pond have not contaminated the valley aquifer supports EPA's conclusion that is it not possible for the PCBs in the UDF to contaminate the aquifer and then migrate upgradient to Lee's surface water drinking reservoirs. Attachment 3, pages 1, and 10-11.

In sum, the redundant protective features of the UDF, combined with the groundwater flows in the area of the UDF, combined with the fact that the Town's drinking water source is from surface water reservoirs located away and upgradient of the UDF, show that there is not a realistic pathway for residential exposure to contaminated drinking water from the UDF.

Correspondence from Charles McCreery (Exhibit 17).

Comment: *In Exhibit 17, Mr. McCreery states that EPA dropped dioxins as a contaminant of concern without a technical justification in the administrative record (thus understating risk), and that Rest of River materials are not suitable for disposal in the UDF because of the risks from dioxins/furans when combined with dioxin-like PCB congeners. Mr. McCreery also states that the Rest of River materials may be subject to federal Land Disposal Restrictions (40 CFR 268) or qualify for disposal in a Toxic Substances Control Act (TSCA) landfill.*

EPA Response:

First, dioxin and furans (also referred to as PCDDs/PCDFs) were extensively sampled and evaluated during the Rest of River remedy selection process. EPA conducted the investigation of the Rest of River, and GE incorporated EPA's investigation results into a RCRA Facility Investigation (RFI) report (*Housatonic River – Rest of River RCRA Facility Investigation Report,* prepared for General Electric Company, by Blasland, Bouck & Lee, Inc., and Quantitative Environmental Analysis, LLC 2003). EPA analyzed more than 300 sediment, riverbank, and floodplain soil samples for dioxin and furans in the Primary Study Area (PSA), which consists of River Reaches 5 and 6. In addition, EPA analyzed more than 225 sediment, riverbank, and floodplain soil samples for PCB congeners in the PSA. The majority of biota samples were analyzed for PCB congeners. See RFI, Sections 4.9, 5.7, and Appendix C (Table C-2).

Second, EPA then conducted a peer-reviewed human health risk assessment (HHRA) of all contaminants of potential concern (COPCs), including dioxins and furans. Section 4 of EPA's HHRA provides an in-depth discussion of the toxicity assessment for the COPCs considered for the Rest of River, including dioxin and furans. The risk assessment for dioxin-like congeners (including dioxins and furans) by media is discussed in HHRA Sections 5 through 9. The analysis in the HHRA indicates that the dioxin-like PCB congeners in floodplain soil contribute the majority of cancer risk, followed by furans, and then dioxins. HHRA Attachment 3, Table 3. Accordingly, based upon the lower levels of cancer risk presented by dioxins and furans found in the HHRA risk assessment, EPA determined that, for the purpose of evaluating cleanup alternatives in the Corrective Measures Study, it was appropriate to limit the evaluation of remedies to the impact of the remedies on total PCB concentrations. Also, dioxins and

furans are generally found in the same types of areas within the Housatonic River (for example, in banks, floodplain soil, and depositional sediment) as PCBs, as noted in RFI Sections 8.6.2 and 9.6.[6]

Third, as for the protectiveness of the UDF relating to dioxins and furans, these compounds share many of the general physical and chemical properties of PCBs. Section 8.9 of the RFI. Similar to PCBs, dioxins and furans are organic compounds characterized by low aqueous solubilities, low vapor pressures, high octonal-water partition coefficients (RFI Table 8-5), and do not readily degrade in the environment. Dioxins and furans are more hydrophobic than PCBs (RFI Table 8-5) and, therefore, have similar or greater affinity to bind to particles than the PCBs.[7] Thus, because dioxins and furans are even less likely than PCBs to be transported by groundwater, the UDF, which is protective for PCBs, is also protective for dioxins and furans.

The dioxin and furans present in the Rest of River media are not a hazardous waste as defined by the federal Resource Conservation and Recovery Act (RCRA). For contaminated soil or sediment to be such a waste, the material must contain a waste listed under RCRA or exhibit a characteristic of a hazardous waste, as set forth in RCRA regulations. The contaminated sediment, which came from the GE plant in Pittsfield, does not contain a listed RCRA waste. It also does not qualify as a characteristic waste as defined by 40 CFR Part 261 Subpart C, see 40 CFR 261.24 in particular. Accordingly, the provisions of RCRA's Land Disposal Restrictions do not apply. As for TSCA, EPA is disposing of the material in the UDF pursuant to TSCA's risk-based approval provisions of 40 CFR 761.61(c). See Appendix D to the 2020 Permit for further details. EPA notes that the UDF is built to the same or similar design standards of landfills permitted to accept much higher levels of PCB contaminated materials that what will be found in the material consolidated in the UDF. 2020 RTC, page 12.

[6] With the exception of Rising Pond, where the concentrations and composition of dioxins and furans suggest that there may have been an additional source of dioxins and furans, possibly from paper mills located downstream of Woods Pond (Reach 6).

[7] PCB partitioning coefficients were derived from analyses of site-specific data for the Housatonic River. Housatonic River PCB log Koc = 6.5. Literature values for dioxins and furans range from log Koc 5.61 (estimated) for 2,3,7,8 TetraCDF to log Koc 8.57 estimated for 1,2,3,4,6,7,8,9 OctaCDF.

Opinions and Correspondence from Judith Knight (Exhibits 22, 23, and 25).

Comment: *In Exhibit 22, Attorney Judith Knight submits the Settlement Agreement between EPA, GE, and other parties (including the municipalities) and opines that it is too vague to be enforceable and contains insufficient details regarding the UDF. In Exhibit 25, Ms. Knight submits GE's UDF Conceptual Design document and opines that it lacks sufficient detail; she also attaches newspaper articles regarding GE's corporate reorganization.*

EPA Response: First, EPA notes that Attorney Knight is not an environmental or scientific expert and did not provide expert testimony or any technical reports relevant to the safety of the UDF (besides Dr. Carpenter's affidavit). As to Ms. Knight's claims regarding the lack of enforceability, GE's obligations regarding the UDF are fully enforceable by EPA under the Consent Decree for the Site, the Revised Final Cleanup Permit EPA issued to GE in 2020, and the submittals that are required under the Permit and approved by EPA.

Second, as to Ms. Knight's claims regarding the lack of detail for the UDF, further details regarding the UDF are and will be contained in the submittals that are required under the Permit. GE's Conceptual Design document is just that, a conceptual design of the UDF that is not intended to address all the details regarding the UDF and future inspections and maintenance. EPA will be issuing a response letter regarding the Conceptual Design, and then GE must submit a final design document that will have many more details regarding the UDF. That document must respond to EPA's response letter on the Conceptual Design document.

Even though this next document will be titled a "final" design, the public will be able to provide input on the document before the EPA responds to that document. That is, the public and EPA will have the ability to provide input to EPA on the final design before it becomes a final document that forms the basis for construction of the UDF. When it submits the final design document, GE is also required to submit a separate operations, monitoring, and maintenance plan for the UDF that will also be subject to public input and EPA approval. Details regarding the transportation of materials to the UDF will be contained in separate submittals that require EPA approval and will be available for public input prior to that approval. Although there are further details to be worked out, there were, at the time the Permit was issued, sufficient details for EPA to have made the determination that the UDF will be protective of human health.

Regarding GE's corporate reorganization, EPA has addressed that issue in a letter to the BOH, which attaches a letter that EPA sent to GE regarding the reorganization. See Exhibit 13 (EPA letter to the BOH dated November 15, 2022).

In Exhibit 23, Attorney Knight attaches the affidavit of Dr. Carpenter, which we respond to above.

****

In summary, the testimony at the BOH hearing and the submitted exhibits do not demonstrate that the UDF poses a health risk to Lee residents. In fact, the BOH's record, EPA's Administrative Record for the Permit, and this and other responses provided by EPA to the BOH show the opposite—that the UDF is safe and protective of the health of Town of Lee residents.

This document is not intended to contain all information relevant to the Board's inquiry. For more information and details, EPA refers the Board to the Administrative Record for the Final Revised Cleanup Permit, including EPA's 2020 Response to Comments document (especially Section II.A on the safety of the UDF), and EPA's letters to the Board dated October 5, 2022 (Exhibit 9) and November 8 (Exhibit 9), November 15 (Exhibit 13), and November 18, 2022 (Exhibit 14).

Although the Board of Health has limited its evaluation to the health effect of the UDF to the residents of the Town of Lee, EPA's considerations are not so limited. By submitting this response that is focused on the UDF, EPA notes that it seeks to protect human health and the environment as a whole and that EPA's remedy decision involved a balancing of many different factors.

By submitting our response, we are not conceding that a potential order from the BOH preempts CERCLA, the federal Superfund law.

Please let us know if you have any further questions or need help locating documents from EPA's Administrative Record.

Sincerely,

DEAN TAGLIAFERRO

Digitally signed by DEAN TAGLIAFERRO
Date: 2023.03.17 14:05:37 -04'00'

Dean Tagliaferro,
EPA Project Coordinator for the GE-Pittsfield/Housatonic River Site and for the Rest of River Permit
Chief, Operations Branch,
Superfund and Emergency Management Division, EPA New England

Attachment 1: Bremle G, Larsson P. *PCB in the air during landfilling of a contaminated lake sediment*. Atmos Environ 1998; 32:1011– 9.

Attachment 2: Lewis, R. G., Martin, B. E., Sgontz, D. L., and Howes, J. E. Jr. (1985) *Measurement of fugitive atmospheric emissions of polychlorinated biphenyls from hazardous waste landfills*. Environmental Science and Technology 19, 986-991.

Attachment 3: Technical Memorandum from Shane McDonald, HDR APTIM, dated March 16, 2023.

Attachment 4: Figure of Floor Base Liner System.

Attachment 5: UDF Configuration Figure

Cc: Town of Lee, Selectboard
Town of Lee, Town Manager
Bryan Olson, EPA
Anni Loughlin, EPA
Bob Cianciarulo, EPA
Rich Fisher, EPA
John Kilborn, EPA
Tim Conway, EPA
Kelsey Dumville, EPA
Chris Ferry, Superfund Records Center

Pergamon

Atmospheric Environment Vol. 32, No. 6, pp. 1011–1019, 1998
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1352–2310/98 $19.00 + 0.00

PII: S1352–2310(97)00343–9

PCB IN THE AIR DURING LANDFILLING OF A CONTAMINATED LAKE SEDIMENT

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(*First received* 3 *February* 1997 *and in final form* 8 *July* 1997. *Published March* 1998)

Abstract — We studied PCB concentration in the air during the build-up of a landfill of PCB-contaminated sediment. A small lake was remediated and the sediment (150 000 m^3 containing about 400 kg PCB) deposited in a nearby landfill. PCB concentration in the air was elevated during landfilling and the extent was determined by the amount of sediment handled and the temperature. The air was enriched in more volatile PCB congeners compared to the deposited sediment, suggesting volatilization as the major transport process in addition to particle transport. The PCB concentration in air showed an exponential decline with distance from the centre of the landfill, with a one order of magnitude decrease 350 m from the centre. At a distance of 850 m from the centre about 5% of the elevated PCB level remained, which was significantly higher when compared to the reference concentration (15 km from the landfill). The PCB congener pattern changed gradually from the landfill centre to the reference. After the landfill was closed and the contaminated, dewatered sediment covered by uncontaminated soil, PCB levels and pattern were similar to that of the reference. © 1998 Elsevier Science Ltd. All rights reserved.

Key word index: Polychlorinated biphenyls, remediation, sediment, landfill, volatilization.

INTRODUCTION

The atmosphere serves as an important pathway for the transport of PCB. Sources of pollutant transport to the atmosphere include city dumps, landfills, incinerators, accidental spills or diffuse sources such as emission from buildings and revolatilization from soils. Harrad *et al*. (1994) calculated the PCB burden in the British environment and estimated the relative significance of different sources. They found that soil held the largest amount of PCB compared to other compartments (air, freshwater, biota, etc.) and was the greatest source (90%) to the atmosphere by recirculation today. The PCB deposited from the atmosphere to the ground in the 1960- and 1970-ies now revolatilize to the air as a result of equilibrium partitioning. The release from landfills was considered negligible. Harner *et al*. (1995) modelled the long-term exchange of PCBs between soil and atmosphere in the southern United Kingdom from 1942 to 1992 and found that from once being a sink, soil nowadays functioned as a source to the atmosphere.

Will air, water, soil, biota, etc., act as sources or sinks of PCBs in the environment? The PCBs in the environment that cycle between these compartments are driven by fugacity (Mackay, 1979) and influenced by concentration gradients and temperature. The PCBs will volatilize from a contaminated soil and be dispersed into the air, the rate will rise as the temperature increases. When air concentrations are high and temperature is low PCBs may be deposited on uncontaminated soil. Since concentration in the air is positively temperature dependent, there will be seasonal variations in the atmosphere (Manchester-Neesvig and Andren, 1989).

The processes described above are dependent on the contaminants vapour pressure, the Henry law constant and the water solubility. As these properties vary from low-to high-chlorinated congeners, the composition of PCB congeners change between different matrices, with distance from the emission areas and in time. The PCBs with higher volatility, lower adsorption on surfaces, higher ortho chlorine substitution, and higher air–water partitioning coefficients would be expected to have a preferential emission to the air phase (Bidleman, 1988).

Lake Järnsjön, a small lake in the Emån river system of southern Sweden, has been contaminated with PCB. About 400 kg of the compounds was estimated to have been deposited in the sediment (Gullbring and Hammar, 1993). The PCB was released from the sediment, and affected the PCB concentrations in the water from the lake to the river mouth in the Baltic Sea (Bremle *et al*., 1995). About 3.4 kg reached the Baltic Sea yearly, and the lake was also shown to function as a source of PCB to the atmosphere

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(Larsson *et al*., 1990). Remediation of the sediment in the lake was performed in 1993 and 1994.

The aim of this study was to follow the concentration and composition of PCBs in the air during the remediation of a PCB-contaminated lake and during the further build-up of a landfill containing the dredged sediment. The study was ended after the landfill had been covered by uncontaminated soil. The task also included a comparison of the influence of the PCB-containing sediment when present in the lake (including effects on concentration in the river system) with the influence when deposited in the landfill.

MATERIAL AND METHODS

Remediation

The lake was remediated in the summers of 1993 and 1994. About 400 kg PCB in 150 000 m^3 sediment was dredged, dewatered and deposited in a landfill in close vicinity to the lake. The contaminated sediments (containing Aroclor 1242) had been mixed with fibers from a upstream situated paper-mill. A brief summary of the project is presented in Gullbring and Hammar (1993). The landfill (about 5 ha, diameter of 150–200 m, circumference of about 700 m) was placed on an excavated piece of land about 400 m NW of the lake and river (Fig 1). It was built with a sealing layer but no sealing liner or filter was used in the bottom of the landfill due to the low permeability of the material itself. The dewatered, dry (approximately 30% moisture content) sediment was bulldozed in the landfill. In October 1994 the landfill was covered with 2 m of uncontaminated material from the site and sown and restored to pastureland.

Pcb sampling

Stations ($n = 11$) for PCB sampling in air were set up in the area (Fig. 1). One sampling unit was placed on an anchored raft in the middle of the lake, one in the centre of the working area by the sludge basin and one in the central part of the landfill. The rest were spread around the edges of the landfill and in a gradient of the prevailing wind direction up to about 750 m in a NE-direction from the landfill. A reference station was also established 15 km NE from the landfill. Sampling was performed about 1 m above ground. The sampling method is described earlier (Larsson *et al*., 1990). One sample represents two weeks of continuous measure. For each sample about 1000 m^3 of air was pumped through polyurethane columns (PUC) at a flow rate of 40 $\ell\ min^{-1}$. Both volatilized and particle-bound PCBs were collected in the columns. Samples were stored in a freezer until analysis. The PUC were precleaned in hexane : acetone Soxhlet for 20 h and fieldblanks were found to be uncontaminated through handling and transport.

The remediation began in April 1993 and after a winter standstill (November to April, due to ice formation in the lake), was continued in April 94 and completed in October with the covering of the landfill. The PCB measurements in air proceeded over the whole remediation period, followed by two measurements after the landfill was covered. The measurements ended in August 1995, when the landfill had been covered and overgrown by grass. In all, 120 samples from 14 occasions were sampled (Table 1).

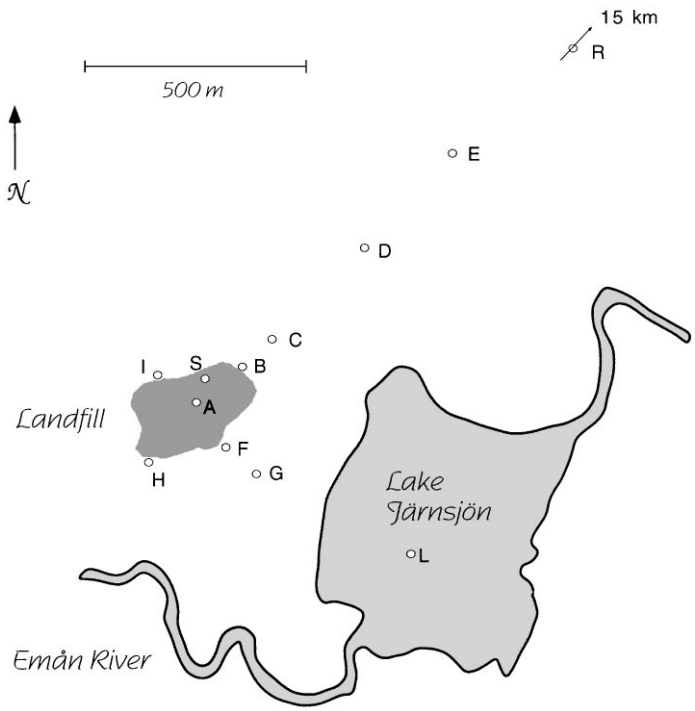

Fig. 1. Map of Emån River with Lake Järnsjön and the landfill showing the positions of air-samplers scattered around the landfill. A, at the centre of the landfill, B, at the NE edge of the landfill, C, D and E stations at NE out to 850 m. The reference R, is situated 15 km NE. Samples were also taken from above the middle of the lake, L and at the sludge basin S. Some samples were also taken around the landfill in other directions, I, H, F and G.

Table 1. Concentration of PCB (ng m^{-3}) in the air in the vicinity of the landfill during remediation and landfilling of a PCB contaminated lake sediment. PCB was sampled at 14 occasions from June 1993 to August 1995. Station code is according to Fig. 1

Start	Stop	Sludgebasin	Centre					Reference						
		S	A	B	C	D	E	R	F	G	H	I	L	
June 16 1993	June 30 1993		3.74	1.28			0.19	0.15						
June 30 1993	July 14 1993	10.26	7.20	2.08			0.15	0.14						
July 14 1993	July 28 1993	22.24	8.66	3.58	0.74	0.30	0.33	0.20	6.22	1.23	1.48	2.75	2.07	
August 4 1993	August 18 1993	10.63	4.49	1.17	0.46	0.18	0.17	0.15	2.02	0.40	1.06		1.80	
September 2 1993	September 16 1993	5.25	3.74	0.41	0.33	0.29	0.23	0.05	1.75	1.01	3.63	1.18	1.41	
September 23 1993	October 7 1993	11.16	2.38	0.98	0.46	0.27	0.27	0.07	0.72		2.65	2.75		
October 14 1993	October 28 1993	2.52	3.91	0.87	0.22	0.12	0.15	0.08	2.84		1.18	0.62		
November 25 1993	December 9 1993	1.85	0.13	0.89	0.56	0.22	0.18	0.13						
December 16 1993	December 30 1993		0.44				0.13	0.14	0.38		0.15	0.37		
June 13 1994	June 27 1994	3.64	1.14	0.85	0.20	0.07	0.07	0.08						
July 5 1994	July 19 1994	6.59	2.55	1.34	0.24	0.24	0.19	0.19						
August 23 1994	September 6 1994	4.00	0.69	0.62	0.22	0.14	0.13	0.11						
October 25 1994	November 8 1994		0.09	0.35	0.10	0.22	0.11	0.12						
August 17 1995	August 30 1995		0.15	0.12	0.04	0.10	0.10	0.13						

Analysis of PCB

Detailed methods for sample preparation and analysis are described in Bremle *et al.* (1995). The PUC were Soxhlet extracted in hexane : acetone and evaporated in a vacuum centrifuge. Concentrated extracts were purified on acid/basic double-layer silicagel columns. Eluates were evaporated in a vacuum centrifuge and redissolved in iso-octane. Samples were then analysed for PCBs by capillary-gas chromatography/ECD (Shimadzu GC-14A) with split/splitless injector, 20 m DB 5 quarts capillary column (i.d. 0.18 mm).

The PCB components were identified and quantified according to Mullin *et al.* (1984) and Schulz *et al.* (1989). Pentachlorobenzene was used as a chromatographic standard (to check retention and response). The analytical performance was regularly controlled with PCB standards such as Aroclor 1242 and Clophen A60. Concentration of the total PCB was calculated from the sum of concentrations of 46 identified peaks (IUPAC no. 10/4, 7/9, 6, 18/17/15, 24/27, 16/32, 29, 26, 25, 31/28, 20/33/53, 51/22, 45, 46, 52, 49, 44, 37/59/42, 41/64, 40, 74, 70, 66/95, 91, 90/101, 99, 97, 87/115, 77/110, 82/151, 135, 123/149/118, 132/153/105, 141/179, 160/138/158, 129/126/178, 187, 128, 185, 174, 177, 202/171/156, 172, 180, 170/190, 199, 194). The extraction recovery of the PUCs was based on octachloronaphthalene added prior to the extraction and calculated to be, for air, $94 \pm 22\%$ (in Agrell *et al.*, 1997). Samples were not corrected for extraction efficiencies.

Sediment samples

Five samples of the sediment prepared for landfilling were analyzed for PCB. The Sediment was dried overnight at 60°C and dry-weight determined. 1–2 g of the sediment was extracted with 4 ml acetone and 8 ml *n*-hexane in an ultrasound bath. The liquid was siphoned to a vial and the acetone was separated with a water equilibrium. After phase-separation with the aid of sulphuric acid, the hexane phase was transferred and treated as the air sample extracts.

Data handling and statistical analysis

The statistical analysis were performed on 10-log transformed values due to nonconstant variation of the concentration data (Berthouex and Brown, 1994). Statistics were carried out using StatView 4.02 and SYSTAT 5.2 (1996) computer package. Pearson correlations with pairwise deletion was used and paired *t*-test for comparisons. Similarities and differences in PCB congener composition of the samples were analysed by Principal Component Analysis (PCA). Congener data was normalized to unit concentration, based on the sums of the congeners. The Pearson correlation matrix was factored and components were rotated (Varimax). The first PCA evaluated the congener pattern differences in the gradient from the central part of the landfill to the reference. Data from the stations in the gradient was available for three periods (October 1993, June 1994, August to September 1994). The second PCA was carried out with data from three stations; above landfill (A), the sludge-treatment basin (S) and the reference (R), for different periods over the two years.

Vapour pressure plot

The pattern of PCB from the sediment samples was compared to the pattern in the air above the landfill (five samples during build-up of the land-fill and a consistent pattern according to the PCA). The congener air/sediment ratio was calculated from the geometrical mean concentration in ng m^{-3} of individual PCB congeners in the air as the numerator, and the geometric mean concentration of that congener in sediment ng/g dry weight as the denominator. The ratio for each individual congener was plotted against the negative logarithm of the congener vapour pressure. Data of vapour pressures (Vp) was taken from Foreman and Bidleman

(1985), for peaks including more than one congener, the average Vp was calculated.

Meteorological data were provided by the Swedish Metoerological and Hydrological Institute and were collected at a station 15 km East of the landfill. The amount of PCB handled in the remediation for each 14 d period was calculated based on the knowledge of the PCB concentration in sediment of the lake (measured in an earlier investigation), the position of the dredger during that time and the amount of deposited sediment.

RESULTS

The PCB concentration in the air at the reference site (R) over the two years was 0.13 ng m^{-3} (median, $n = 14$, 25 and 75 percentiles: 0.08 and 0.15). There seemed to be a seasonal trend with high concentration in summer and low in the autumn, but no significant correlation between temperature and PCB concentration was found at the reference site.

The PCB concentration in the air above Lake Järnsjön water during the remedial action was about 2 ng m^{-3} ($n = 3$) which was 15 times higher than background levels in the area. At the sludge basin, in the area where the PCB contaminated sediment was dewatered and subsequently landfilled, the concentration of PCB in the air was elevated. The median for the PCB concentration in the air above the sludge basin (S) was 5.9 ng m^{-3} ($n = 10$, 25 and 75 percentiles: 3.6 and 10.6) which was 45 times higher than the background level. PCB concentration in the air above the sludge basin varied largely and was correlated to the amount of dredged PCB in the period ($r = 0.65$, $p < 0.05$) and to air temperature ($r = 0.70$, $p < 0.05$).

The stations from the central part of the landfill to the NW showed a decreasing gradient in PCB concentration with distance for all periods during remediation, but the levels differed (Fig. 2). The higher the level at the central station (A), which in turn depended on the amount of handled PCB and the temperature just as station S, the steeper the gradient. In the autumn, when landfilling had stopped, the curve flattened and the highest value was not detected in the central part (A) but at the edge of the landfill (B), which was close to the sludge basin (S). After the landfill was covered with 2 m of uncontaminated soil in October 1994, the PCB concentration in air at the centre of the landfill decreased to 0.09 ng m^{-3}. In August 1995 the concentration at this site, now covered with grass, was 0.15 ng m^{-3}.

There was an exponential decrease in PCB concentration from the central landfill toward the reference, as shown by boxplots for the periods with active landfilling (10 periods, Fig. 3). The PCB concentration in the air at the last station (station E, 850 m from the landfill centre) was significantly higher than the reference (station R, paired t-test for all 14 measured periods, $T = 2.26$, $p < 0.05$). On a relative scale with the PCB concentration in the air at the centre of the landfill (A) set at 100%, the PCB concentration in

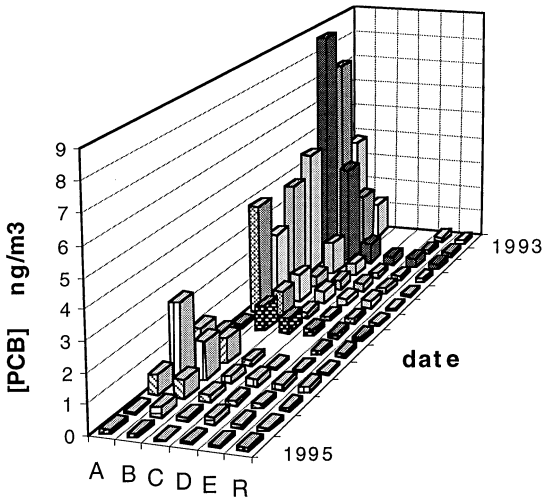

Fig. 2. PCB concentration in the air from the centre of the landfill (A) out to the reference (R) during all 14 sampling periods from 1993 to 1995 (according to Table 1).

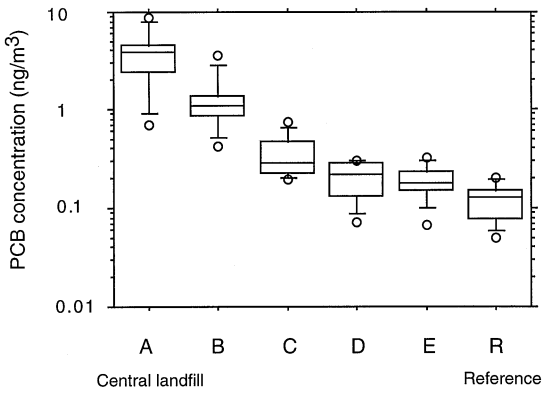

Fig. 3. Box plot of the PCB concentrations in a distance-gradient covering 10 periods of active remediation. Each box displays the 25th to75th percentile, the line in the middle is the 50th percentile or median. The verticle lines from the boxes show the 10th and 90th percentiles and values outside his range are plotted as circles.

C (250 m from the centre, about 150 m from the edge of the landfill) had decreased to 10% of that at the centre (calculated for 8 periods with clear exponential decrease). The concentration in the outermost station (E) was down to 5%. Background concentration at the reference (R) was 3% of the concentration in A.

The pattern of the different PCB congeners in the air above the landfill under construction, resembled that of the contaminated sediment. There was, however, a discrimination against more high-chlorinated PCBs in the air relative to the composition of the landfilled sediment. The ratio of congener concentration in air to sediment was correlated to the negative logarithm of the congener vapour pressure ($r = -0.75$, $p < 0.001$, Fig. 4).

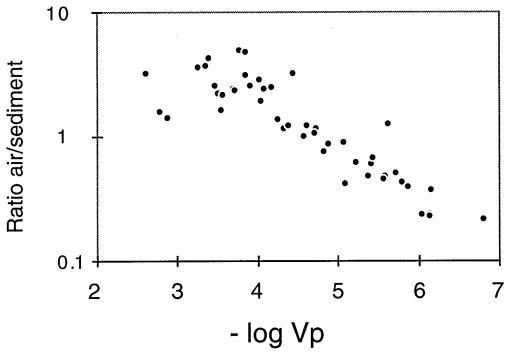

Fig. 4. Ratio of PCB congener concentration between air and deposited sediment vs. the negative logarithm of the vapour pressure of that congener.

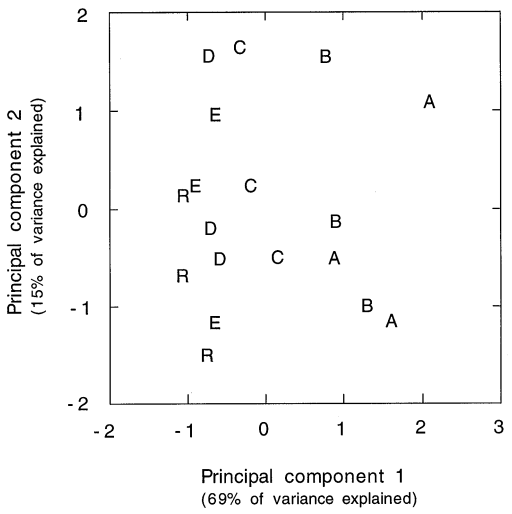

Fig. 5. Principal-component analysis score plot of the PCB congener pattern in the air from the centre of the landfill (A) to the reference (R). Samples from three periods are included. The first principal component explained 69% of variation and the second explained 15%.

The PCB fingerprint at the reference site showed a more evenly distributed pattern over the range of PCB congeners. From the landfill and outward, the pattern of PCB congeners gradually changed from a pattern similar to the remediated sediment, to a "background" pattern similar to the reference. The PCA score plot, including 3 periods of active landfilling, showed the separation of the PCB congener patterns in the air for the stations on the first principal component (explaining 69% of the variation, Fig. 5).

The PCA-including samples from the sludge basin (S) and the central part of the landfill (A) clustered in one group, samples from the reference (R) into another, in PC1 (explaining 69% of the variation) in the score plot (Fig. 6). After closing the landfill in October 1994, two samples from the central part of landfill (A) were clustered in the same group in the PCA as the reference (R), showing the similar PCB congener patterns. The bar-charts of weight percent of the individual PCBs exemplified the pattern in the selected samples (Fig. 6), stressing that patterns in the air above the sludge basin (S) and above the centre of the landfill (A) were similar in October 1993 during active landfilling, whereas after landfill closure the pattern in the air over the landfill resembled that of the reference (R).

DISCUSSION

The concentration of PCB in the air at the reference site (0.13 ng m^{-3}) agreed with the results from other investigations from Sweden. Backe *et al.* (1994) investigated 11 stations scattered over a 15 000 km^2 area, including both rural and urban sites, continuously with fortnightly samples for one year and found the geometric mean $\sum$PCB concentration to be 0.9 ng m^{-3}. Agrell *et al.* (1997) reported 0.6 ng m^{-3} as a median concentration over one year from 16 stations scattered along the Baltic sea coast. Investigations at a rural site near Lake Michigan showed a geometrical mean of 0.13 ng m^{-3} (Cotham and Bidleman, 1995).

A somewhat higher levels of PCB in air were found during summer at the reference site in this investigation. In air above the contaminated area near the sludge basin and the central part of the landfill, on the other hand, the PCB concentration was correlated to the mean air temperature during the sampling period. Seasonal variations of PCB concentration in air have been shown earlier, and the major cause of this variation is temperature (Manchester-Neesvig and Andren, 1989). The PCB concentration in the air in the vicinity of superfund dumps was investigated by Hermanson and Hites (1989), it varied positively with temperature, so that vapour-phase PCB concentrations showed a seasonal dependence with 1.7–3.8 ng m^{-3} in summer and 0.27–0.58 ng m^{-3} in winter.

The concentrations of PCB in air above the central landfill and sludge basin were also positively correlated to the amount of processed PCB during that period. The dredged lake sediment varied in PCB content depending on location in the lake and sediment depth. In the first year the most contaminated part was remediated and about 325 kg of PCB was deposited in the landfill compared to 70 kg in the second year and, consequently, higher PCB concentrations in air over the landfill were detected during the first year.

The PCB concentrations in the air above the working area and landfill were elevated compared to the background values. The median PCB concentration above the sludge basin was 5.9 ng m^{-3} and over the landfill 2.5 ng m^{-3} (all 14 periods). However, the PCB concentrations in air during the build-up of the landfill were within the range of concentrations recently found in some urban areas. Halsall *et al.* (1995)

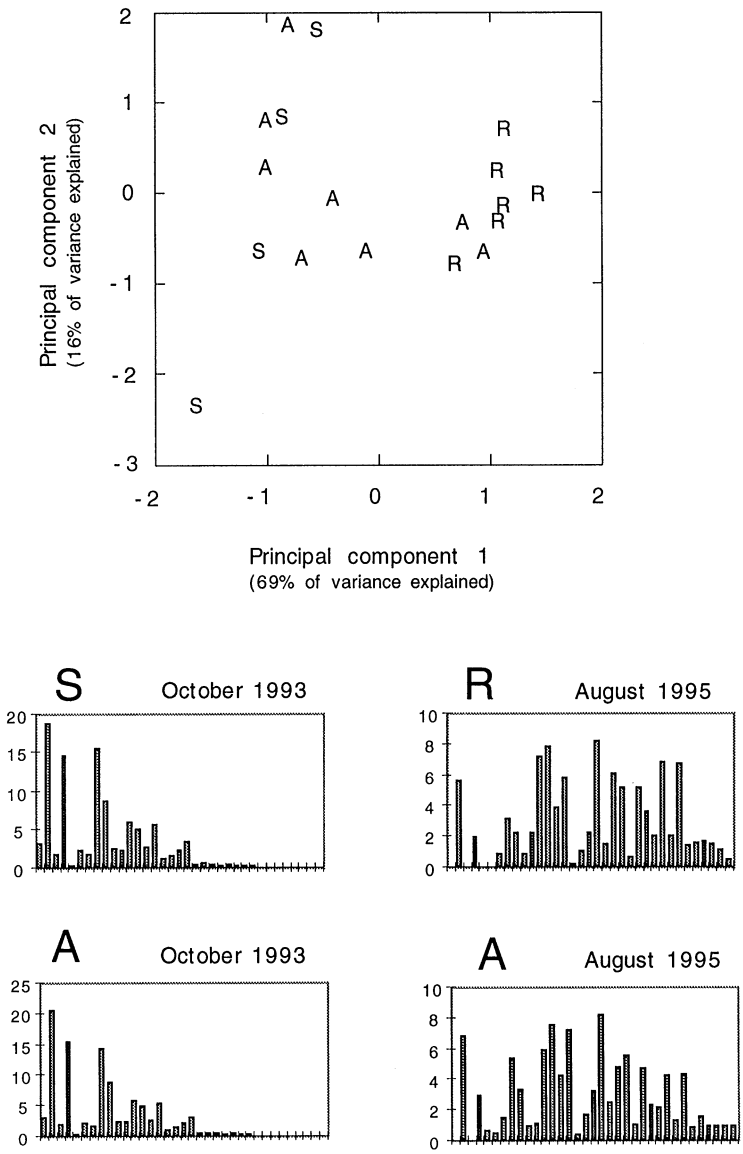

Fig. 6. The PCB congener pattern for air samples above the landfill illustrated with PCA-score-plot and bar-charts. During remediation the PCB pattern in air over the centre of the landfill (A) resembles the pattern above the sludge basin. After closing the landfill, PCB pattern in A, measured on two occasions, clustered together with PCB patterns in the air at the reference (R). Bar-charts with PCB congeners from low- to high-chlorinated illustrate further the similarity between A and S in October 1993 and A and R in August 1995.

measured PCB concentrations every two weeks for two years (1991–1992) in United Kingdom urban air (including sites such as London and Manchester) and found levels ranging from 0.1 to 3.8 ng m^{-3}. In Chicago in February 1988 the geometric mean $\sum$PCB was 1.3 ng m^{-3} (Cotham and Bidleman, 1995). The PCB concentration in the air in the Paris area in 1992 and 1993 was in the range 0.3 to 4.9 ng m^{-3} (Chevreuil *et al.*, 1996).

High concentration of PCB (on average 820 ng m^{-3} in air) was monitored around a site of stored used capacitors in a suburb of Bangkok, Thailand (Watanabe *et al.*, 1996). In the vicinity of three uncontrolled landfills in USA, known to contain large quantities of PCB, the atmospheric PCB concentrations ranged from 0.04 to 193 μg m^{-3} (Lewis *et al.*, 1985). At a specially designed closed landfill with PCB-containing transformer-oil contaminated soil, however, PCB levels at or near background levels were measured. Murphy *et al.* (1985) suggest that municipal sanitary landfills will be a continued source of PCB in contrast to industrial and hazardous-waste landfills. The large amount of organic waste present in sanitary landfills will by anaerobic decomposition

continuously generate large amounts of gases which will escape from the landfill together with other compounds present such as PCBs. The average PCB concentration measured in air above sanitary landfills was 190 ng m^{-3}. The landfill in our study contains dried sediment with a large amount of cellulose fibers, PCB and mercury. This is probably not an optimal environment for microbial activity and decomposition of organic matter and subsequent gas production. No ventilating system was considered necessary on construction.

Several studies show that the concentration of $\sum$PCB in air decreases exponentially with the distance from industrial sources (e.g. Harvey and Steinhauer, 1974). Similarly, our investigation showed an exponential decrease in PCB concentration from the central part of the landfill during build-up, which was valid for all sampling periods except during winter when work was temporarily stopped. During winter, the concentration of PCB in the air at the edge of the landfill, near the sludge basin, was higher than above the central part. An enhanced PCB concentration in air could be traced out to station C (250 m from the central part, 150 m from the edge), but also the station situated 750 m from the edge had significantly higher levels than the reference. No significant effect of wind speed or direction on PCB concentration in the air was found. This was probably due to the different resolution in data with a two-weeks intergrated sampling of PCB with changing wind speed and direction over that period.

Hosein *et al.* (1987) measured airborne PCB during a soil clean-up operation. Levels decreased rapidly with distance from the excavation site. The vapour-phase PCB level was 123 ng m^{-3} at the work site and 100 m from the source, the mean vapour-phase concentration decreased to 4%. An increase in wind speed resulted in decrease in the airborne concentrations, whereas an increase in air temperature resulted in an increase. The particle-bound PCBs in the air were in the same order as the vapour-phase PCB. Hermanson and Hites (1989) monitored the atmospheric PCB concentration in Bloomington within 14 km of three landfills contaminated with PCBs. They concluded that since the PCB concentration only differed with a factor of 2–3 compared to other areas in the Great Lakes, PCB dispersed in the atmosphere within short distances of the source. Lewis *et al.* (1985) studied the vertical emission profiles in the air at hot spots over landfills and found that PCB concentration decreased with distance above the contaminated surface. The PCB concentration at 2 cm above ground level were 40–100 times higher than that at an elevation of 180 cm.

Our sampling technique traps both vapour-phase PCB as well as particle-bound PCB. When the landfill was built up, earth-moving equipment transported and drove over contaminated dried sediment, so contaminated particles were likely to whirl up into the air. This was supported by the fact that the PCB congener distribution in the centre of the landfill was similar to the pattern in the contaminated sediment. However, the relative enrichment of low-chlorinated PCB congeners in the air at the centre of the landfill compared to the sediment, correlate to vapour pressure and suggest that volatilization of PCB from the deposited sediment occurred. The dispersion of PCB was, thus, not only occurring by dusting of PCB contaminated particles. Furthermore, if the transport of PCB from the landfill was mediated solely by particles, the decline in PCB concentration in air should have been in close vicinity of the landfill as particle sediment. Any further transport should then be goverened mainly within the vapour-phase. The absolute relation between dusting and vapourization remains unknown, but the results indicate that volatilization was an important pathway. The vapour-to-particle ratio probably differed from time to time since the ratio depends on temperature (Hermanson and Hites, 1989), and the extent of the volatilization process also on the composition of the sediment (type, organic content, PCB concentration, etc.), as well as the intensity and handling of the deposited sediments on the landfill.

In the vicinity of a superfund dump Hermanson and Hites (1989) found low concentration of particle-bound PCBs compared to vapour-phase bound. The particle-bound concentration showed no seasonal trend as for vapour-phase PCB. The vapour to particle ratios of PCB was positively dependent on temperature and varied between congeners according to Henry's law. This resulted in higher vapour to particle ratios for low-chlorinated congeners. In a dry and barren area in the Canadian Arctic, the rate loss of PCB congeners from soil was shown to be positively correlated to vapour pressure (Grundy *et al.*, 1996). A better criterion than vapour pressure to describe a compounds partitioning to the terrestrial environment and the air–soil equilibrium is the K_{OA} (octanol-air partitioning coefficient, Wania and Mackay, 1996). The K_{OA} was not used for the correlation with ratio of congeners in air to sediment, due to lack of complete congener specific K_{OA} -data.

The composition of PCB congeners showed to be very useful in studying the airborne loss at the landfill. In addition to understanding the volatilization process, the congener-specific data visualizes the influence from the landfill on the surrounding environment. The pattern of PCB congeners gradually changed in the air above the central landfill to that of the reference. From station C (250 m from the centre and 150 m from the edge of the landfill) and further out, the pattern was more similar to the one in the reference station according to the PCA. The PCB pattern clustered on the first-principal component which explained 69% of the variation. The second-principal component, which accounted for 15% of the variation, separated the two years. The variation on this axis could arise as a result of several processes, e.g. that various areas of the lake were remediated

containing varied quality of sediment and PCB amounts, various amounts of particle-induced transport, natural seasonal or yearly differences in PCB pattern, etc.

The two measurements of PCB in air at the central landfill after closing and covering showed background PCB levels. The one in summer 1995 is somewhat higher than in October 1994, probably due to higher air temperatures. The pattern of PCB congeners at these two occasions were similar to that at the reference, as shown by the same clustering in the PCA. The PCA showed the grouping of patterns on the first principal component explaining 69% of the variance. Also in this PCA, the two years clustered out on principal component 2.

The PCB exposure on the surrounding environment from the landfill during build-up was low in comparison to the exposure of the aquatic ecosystem downstream during and before remediation of the lake. Before remediation, elevated PCB concentrations in the water was detected a long distance downstream. At 110 km downstream, the concentration of PCB in the river water was 15% of that in the contaminated Lake Järnsjön (calculated from Bremle *et al*., 1995). In contrast, the PCB concentrations in the air decreased close to the landfill. After the landfill had been covered, no influence on PCB concentration in the air was detected. This is to be compared with the far downstream effect in the river before remediation, with possible water-to-air transport in addition to exposure of the aquatic ecosystem. However, landfills are by no means a complete solution to the problem, effects on groundwater and terrestrial biota still are to be evaluated.

Acknowledgements—Thanks to all involved in the Lake Järnsjön project, especially A. Helgée, B. Troedsson and T. Hammar. In the laboratory, Marie Svensson, Marco Tidén and Lennart Okla have been most helpful. Funding was recieved from the Swedish Environmental Protection Agency (lake Järnsjön Project).

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Measurement of Fugitive Atmospheric Emissions of Polychlorinated Biphenyls from Hazardous Waste Landfills

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■ Four landfills known to contain large quantities of polychlorinated biphenyls (PCBs) were monitored for atmospheric emissions: Three of these were uncontrolled and contained large numbers of electrical capacitors, many of which were scattered on the surface and leaking PCB askarel fluids. The other is a state-of-the-art PCB waste landfill designed to exceed the requirements of the Toxic Substances Control Act of 1978 (ToSCA) for PCB disposal. Both high-volume and low-volume air sampling equipment were utilized at each landfill to monitor air levels of PCBs on site, upwind and downwind. In addition, vent ports were monitored at the controlled site. Simultaneous, collocated sampling was performed for quality assurance purposes and to obtain information on sampling performance and comparability. High atmospheric PCB concentrations were measured at the uncontrolled sites, while air levels were at or near background at the ToSCA-designed landfill. PCBs were detected at low levels in gas vents at the latter site.

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Introduction

The disposal of polychlorinated biphenyls (PCBs) is strictly regulated under the Toxic Substance Control Act (ToSCA). Specifically designed chemical waste landfills with impermeable liners are required and are subject to approval by the U.S. Environmental Protection Agency. The only access to the external environment in the case of ToSCA landfills is through open vents and ports required for leachate monitoring and for relief for gases generated within the landfill from decaying organic matter. Prior to 1978, however, many PCB-containing articles were disposed of in municipal landfills or at uncontrolled chemical waste disposal sites.

PCBs possess sufficiently high vapor pressures (10^{-4}–10^{-5} kPa) to be emitted directly into the air surrounding hazardous waste disposal sites through volatilization from contaminated surfaces (*1*, *2*). They also may be released from controlled landfills through vents along with more volatile gases (*3*). To test this premise, four PCB landfills were monitored in this study. One was a ToSCA-designed facility in North Carolina which was studied to determine if PCBs were being emitted into the surrounding atmospheric environment from gas vents and leachate access ports. The other three consisted of two uncontrolled private landfills and one municipal landfill in Indiana, each of which contained large numbers of PCB-containing capacitors.

Materials and Methods

Air sampling was performed with low-volume (LV) and/or high-volume (HV) sampling systems previously described (*4–6*). The components of the LV sampling system consisted of a battery-operated, constant flow sampling pump (Du Pont Model P-4000A) and a glass cartridge containing a 22-mm diameter × 7.6-cm long cylinder of polyurethane foam (PUF). The HV sampler consisted of a conventional Hi-Vol shelter and pump modified by addition of an inlet head to accommodate a PUF sampling cartridge. The sampling head was comprised of an aluminum housing which held a 10-cm diameter particulate filter (Pallflex 2500 QAST quartz) followed by a glass sampling cartridge containing a 62 mm diameter × 7.6 cm cylindrical PUF plug. The General Metal Works (Village of Cleves, OH) Model PS-1 sampler is essentially identical with the HV sampler used in these studies.

The Du Pont sampling pumps were calibrated with a Du Pont calibrator pack (catalog no. 66-242-f-l) before and after each sampling period. The HV samplers were calibrated once each week by means of a calibrated venturi tube which was attached to the inlet. Flow audits were conducted in the field prior to and at the termination of monitoring activities by an independent team using two laminar flow elements calibrated by the National Bureau of Standards (NBS). Clean filters and PUF plugs were used to simulate actual initial operating conditions.

The PUF plugs were precleaned by Soxhlet extraction with acetone as previously described (*4*), vacuum dried, and loaded into the appropriate glass sampling cartridges under clean laboratory conditions. The cartridges were wrapped in hexane-rinsed aluminum foil and stored in carefully cleaned glass jars padded with clean PUF for transport to and from the sampling sites. Exposed filters from the HV samplers were completely wrapped in prerinsed foil and placed in the jars with the PUF cartridge. Disposable latex surgical gloves and prerinsed tongs were used for handling the sampling cartridges when PUF plugs were loaded and unloaded in the laboratory and for attaching them to the sampling systems in the field.

Exposed PUF plugs and filters were Soxhlet extracted together with 5% diethyl ether in hexane following the procedure of Lewis et al. (*4*, *6*), the extracts reduced to 10 or 1 mL in Kuderna-Danish concentrators according to analytical needs, and the PCBs determined by electron capture gas chromatography following EPA Method 608 (*7*). Identification and quantification of Aroclors 1242 and 1260 in the samples were performed by the technique originally described by Webb and McCall (*8*). All solvents were pesticide quality or analytical reagent grade. NBS Standard Reference Material 1581 (Aroclors 1242 and 1260 in motor oil and transformer oil) were used for calibration purposes. Recovery of Aroclors 1242 and 1260 from PUF plugs fortified with SRM 1581 at three levels (0.06, 0.6, and 6 μg/plug) averaged 93%. One laboratory blank and one laboratory "spiked" PUF plug were analyzed with each 20 samples. In addition, ca. 10% of all samples analyzed were field blanks which had been transported to and from the monitoring sites.

Continuous measurements of wind speed, wind direction, ambient air temperature, and relative humidity were obtained with Meteorology Research, Inc., portable weather stations. Since the landfill sites were subject to

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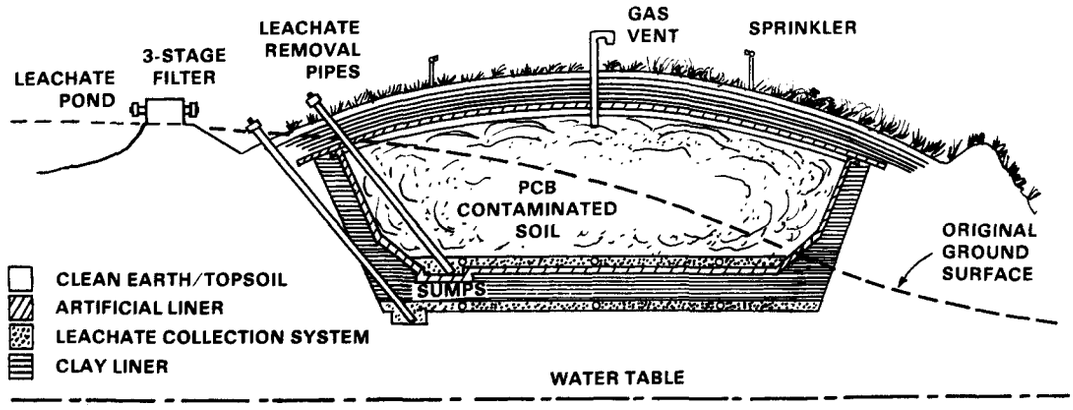

Figure 1. Cross-sectional drawing of controlled PCB landfill in North Carolina.

the Comprehensive Environmental Response, Compensation and Liability Act ("Superfund"), all samples were collected, handled, and transported under standard chain-of-custody procedures.

Results and Discussion

Controlled Landfill. In 1978, an unprecedented spill of PCBs along 387 km of roadway occurred in central North Carolina. Some 40 000–120 000 L of transformer fluid consisting of Aroclors 1260 and 1242 in chlorobenzenes were illegally and surreptitiously dumped along the shoulders of the roads. Over 4 years of litigation were required before a disposal site for the 30 000 m^3 of contaminated soil could be located in a sparsely populated area of the state. Because of the great amount of public concern over the safety of the disposal site, a state-of-the-art landfill designed to exceed the requirements of ToSCA was constructed in late 1982. The EPA-approved (Superfund) site, located on a 4 ha of land in a rural area, measures 75 m × 145 m and has a maximum depth of about 7 m. The contaminated soil is encapsulated within 0.6-m (top) to 1.5-m (bottom and sides) thick layers of highly impervious, compacted clay, augmented with 10-mil (0.25-mm) and 30-mil (0.75-mm) plastic liners on the top and bottom, respectively. The landfill is properly sloped and equipped with sump pumps and a leachate collection system for monitoring purposes. It is also provided with a gas vent which protrudes 1.5 m into the landfill for relief of methane and other gases generated by bacterial decay of organic matter contained in the soil. A cross-sectioned drawing of the landfill is shown in Figure 1.

Several months after closure of the landfill, local residents voiced concerns that gases emanating from the vent pipe and (as yet uncapped) leachate collection pipes may have been introducing PCBs into the surrounding atmosphere. In response, a study was undertaken in Jan and Feb 1983 to monitor these emissions and the ambient air at the site.

Only the LV samplers were used in this study. The vents and leachate access ports were sampled by placing the PUF cartridge inlets into the pipes or ports and sealing the openings with plastic bags to assure maintenance of positive pressures. Sampling was performed for 8 h at reduced flow rates of 1.2–1.4 L/min so as not to exceed the volumetric flow rates of the vent pipes. The sampling efficiency of the LV sampler employing PUF cartridges had been previously shown to be essentially quantitative for collection of Aroclor 1242 in natural gas, which is 97–98% methane (*9*). Soil temperatures within the landfill were presumed to be nearly constant at 4–5 °C (thermic temperature regime); therefore, emission rates were essentially independent of ambient air temperatures.

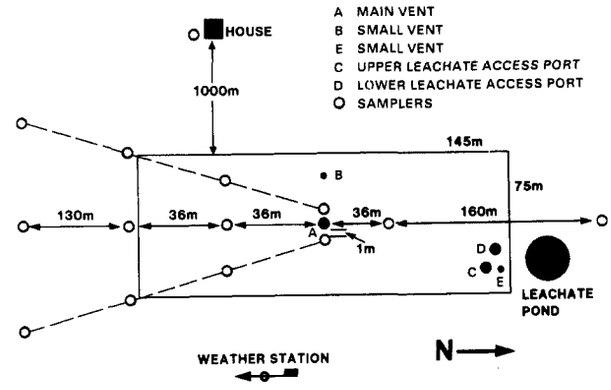

Figure 2. Sampling arrangement for monitoring at the controlled landfill when winds were from the north. Array was rotated with wind direction so as to monitor at the perimeter of the landfill and at half the distance for the main vent to the perimeter.

Ambient air sampling was performed with an array of samplers operating at 3.8 L/min and located from 1 to 200 m upwind and downwind of the main vent as shown by the example presented in Figure 2. Air samples were collected at 1.2 m aboveground at each of the 13 locations designated by open circles. Simultaneous samples were also collected at 4.6 m above ground at the perimeter of the mounded landfill (72 m downwind of the main vent in the arrangement shown in Figure 2) so as to be on line-of-sight with the opening of the main vent. The spatial arrangement of the samplers was alternated as necessary at the start of each sampling period to reflect average wind direction. That is, downwind samplers were placed in a fanned-out array at half the distance from the main vent to the perimeter, at the perimeter, and at the tree line (100–130 m downwind). Upwind samplers were placed accordingly. One sample was taken at the same location in the yard of the nearest house (1 km away) during each sampling period. Sampling was performed from 0900 to 1700 Eastern Standard Time on 3 days and from 2100 to 0500 on the fourth day. Ambient air temperatures ranged from −1 to +14 °C, wind speed from 0.04 to 6.6 m/s, and relative humidity from 46 to 95%. No vent sampling was performed on these days, and all vents were left open.

Analytical results from the gas samples collected from five vents are presented in Table I. It should be noted that the lower leachate removal pipe extends below the landfill. The two small pipes were installed temporarily to release gas bubbles in the upper plastic liner. PCB concentrations in the gases (principally methane) emanating from the main vent ranged from 105 to 141 $\mu g/m^3$ measured as Aroclor 1242 and from 1.8 to 2.1 $\mu g/m^3$ measured as Aroclor 1260. A typical gas chromatogram of the PCB mixture found in the main gas vent is shown

Table I. Controlled PCB Landfill Vent Monitoring Results

location	PCB concentration, $\mu g/m^3$			
	Aroclor 1242		Aroclor 1260	
	range	av	range	av
main vent (A)	105.7–141.5	120.2	1.8–2.1	2.0
upper leachate access port (C)	0.8–2.8	2.6	0.3–0.6	0.5
lower leachate access port (D)	ND–0.09	0.04	ND–0.08	0.05
small vent (B)	ND–0.07	0.05	<0.02–<0.3	<0.02
small vent (E)	<0.02–0.67	0.24	<0.02–1.3	0.4

[a] Letters in parentheses refer to position identification in Figure 2. [b] Average of three to four measurements; 7–8-h samples.

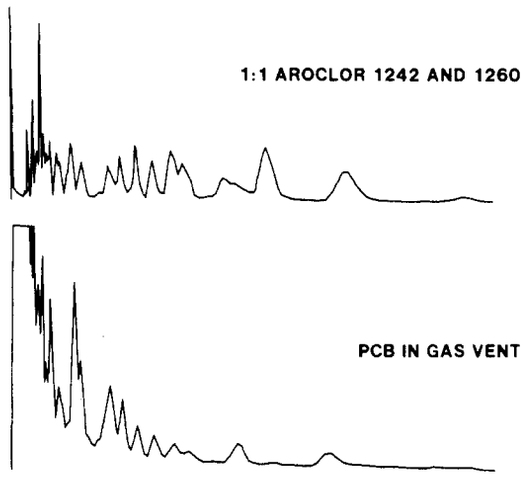

Figure 3. Gas chromatograms of standard mixture and sample from main gas vent at controlled landfill.

in Figure 3 along with the 1:1 Aroclor 1242–Aroclor 1260 standard used for quantification. Collocated samples collected in the main vent agreed within 6–9%. Concentrations found in the leachate collection ports were much lower, ranging from nondetectable (ND) to 2.8 $\mu g/m^3$ Aroclor 1242 and from ND to 0.5 $\mu g/m^3$ Aroclor 1260. Detection limits were 0.01–0.02 $\mu g/m^3$. Analyses of transformer oil and soil samples prior to interment showed a 4:1 ratio of Aroclor 1260 to Aroclor 1242. The greater volatility of the latter mixture apparently accounted for the relatively higher concentrations found.

Ambient air data are given in Table II. Only four of the 39 ambient air samples analyzed contained detectable quantities of PCB (MDL = 6 ng/m^3). Three samples were positive for Aroclor 1260 only (at 11, 12, 50, and 71 ng/m^3) and did not appear correlate with proximity to the vents. The two maximum levels were found 98 m downwind of the main vent.

Gas flow measurements made at three different times showed flow rates of 4.8–6.4 (average 5.7) L/min from the main vent. No flow was measurable from the leachate ports or small vents. The average gaseous PCB emission rate from the landfill, therefore, was estimated to be 12.1 ng/s. By use of these emission parameters and meteorological conditions that prevailed during the study, standard dispersion models were applied to calculate downwind PCB concentrations for comparison with field measurements. Two EPA models (*10*, *11*) were employed to calculate estimates of maximum hourly concentrations under a full spectrum of meteorological conditions and estimates of the range of hourly ambient concentrations that would occur at downwind distances of 50, 100, and 150 m under the meteorological conditions that probably controlled

Table II. Ambient Air Monitoring at Controlled Landfill

location	air concentration, $\mu g/m^3$	
	Aroclor 1242	Aroclor 1260
beside main vent	<0.006	<0.01–0.01[a]
on site, downwind	<0.006	<0.01
on site, upwind	<0.006	<0.01
fence line, downwind	<0.006	<0.01–0.07[b]
off site, downwind	<0.006	<0.01
off site, upwind	<0.006	<0.01
nearby house	<0.006	<0.01–0.01[c]

[a] One of six measurements above detection limit. [b] Two of 13 measurements above detection limit (0.05 and 0.07 $\mu g/m^3$). [c] One of six measurements above detection limit.

dispersion during the field monitoring. The predicted maximum 1-h concentrations downwind of the vent under prevailing and worst case conditions ranged from 4×10^{-6} ng/m^3 at 14 m to 1×10^{-7} ng/m^3 at 50 to 150 m. The 8-h concentrations would be expected to be about 10^{-8} ng/m^3. These values are far below the detection capability of the sampler employed (or that of any known sampler).

Uncontrolled Landfills. Three disposal sites in the vicinity of one city in Indiana have been the subject of recent concern because they contain large numbers of PCB-containining transformers which were dumped there prior to 1972. One of the sites, designated here as site 1, is about 8 ha in size and located on an abandoned farm. Site 2 is a small, rural site of about 0.2 ha, surrounded by mobile homes. Site 3 was a municipal landfill, some 3 ha in area, located in a suburban area. At each of these sites capacitors were strewn across the ground surface (sometimes in mounds) and were visibly leaking askarels containing Aroclor 1242 into the soil and nearby streams. The total quantity and depth of burial of the capacitors is unknown.

Both LV and HV samplers were employed to monitor PCB atmospheric emissions at the three uncontrolled landfills. The air measurements at the sites were performed at localized areas (hot spots) where leaking capacitors were evident and at other locations to determine upwind (background) and downwind levels. Three different sampling approaches each using PUF cartridges for collection of PCBs were used. The LV samplers were set up at hot spots to sample during 8-h daytime periods at 3.8 L/min with intakes positioned 120 cm above ground. The HV systems were set to sample at 226 L/min for 8–24-h periods at hot spots and at upwind and downwind points. The intakes at the HV sampler were 180 cm above ground. Where line power was unavailable, gasoline-powered generators placed downwind of the HV samplers were used. Arrays of five LV sampling systems placed from 2 to 180 cm above ground were used to determine the vertical concentration profiles at hot spots. Detection limits were ca. 10 ng/m^3 for the LV sampler and ca. 50 pg/m^3 for the HV sampler.

Three or four days of monitoring was performed at each site during June and July 1983. Results from single-level (120 or 180 cm above ground) monitoring are presented in Table III. The following summarizes these results:

At capacitor disposal site 1, airborne PCB concentrations measured at 120–180 cm above five hot spots during the day (0900–1700 central daylight savings time) ranged from 0.4 to 18 $\mu g/m^3$. Levels along the downwind perimeter of the site ranged from 0.2 to 1.8 $\mu g/m^3$. Upwind PCB concentrations ranged from <0.05 to 0.09 $\mu g/m^3$.

Ambient air PCB concentrations measured at 120–180 cm above two hot spots at site 2 ranged from

Table III. Range of PCB Concentrations ($\mu g/m^3$) in Air at Uncontrolled Sites, June–July 1983

location	site 1		site 2		site 3	
	daytime	24 h	daytime	24 h	daytime	24 h
hot spots	0.4–18.0	8.3–13.0	0.6–33.8		6.3–193	21.5–77.4
downwind	0.3–0.5	0.60–1.3		0.08–0.20		0.3–0.8
upwind	<0.05–0.10	0.08–0.09	<0.04–0.07	0.08–0.20	<0.04–0.05	0.08–0.09
meteorology						
temperature range, °C		19–42		19–38		22–42
wind velocity range, m/s		0–2.3		0.1–2.7		0–2.2
relative humidity range, %		62–83		37–83		24–70

Table IV. Vertical Profile Air Measurements at Uncontrolled Landfills

distance above ground, cm	air concentration,[a] $\mu g/m^3$			
	site 1a		site 1b	site 3
	October	July	July	July
2	271–520	577–1053	602–1108	367–955
30	27–33	56–120	111–157	53–159
60	8.6–18	30–58	40–62	28–69
120	2.9–5.7	17–30	15–21	16–33
180	1.3–2.3	6.4–1.3	8.6–10	6.8–21

[a] Average daytime levels over a 4-day period.

0.6 to 19 $\mu g/m^3$ during the day. Near residences adjacent to the site, levels ranged from <0.04 to 0.2 $\mu g/m^3$.

At the municipal landfill (site 3), daytime PCB air levels measured at 120–180 cm above three hot spots ranged from to 193 $\mu g/m^3$. Upwind concentrations were fairly constant at ca. 0.05 $\mu g/m^3$, and levels measured downwind of the landfill ranged from 0.3 to 0.8 $\mu g/m^3$. There were a number of residences around the perimeter of this site.

Generally, the airborne PCB levels measured at hot spots correlated with the quantity of exposed capacitors.

Vertical emission profiles at hot spots are given in Table IV. Air concentrations decreased with distance above contaminated surfaces. Levels at 2 cm above ground level were from 40 to 100 times higher than the levels at an elevation of 180 cm, while those at 120 cm were twice as high. PCB emission rates during July 1983 were probably maximized by the unseasonbly warm (19–42 °C), dry weather which prevailed throughout the study period. Sampling data from site 1 during Oct 1982, when temperatures ranged from 13 to 30 °C, showed PCB levels about half of those obtained during the summer.

Typical gas chromatograms of downwind and upwind samples from site 1 are shown in Figure 4. Chromatograms of hot spot air samples taken at several heights are presented in Figure 5.

Both the LV and HV samplers (including one commercial version of the latter) performed well throughout the study. Sampler pumps were calibrated before and after each sampling period. Flow calibrations ranged from +1.9 to −7.9% for the LV samplers and from +8 to −7% for the HV samplers. Pre- and postflow readings agreed within ±5% in over 90% of the cases. Independent flow audits indicated average flow accuracies of −2.8% for 20 LV pumps and +5.2% for seven HV samplers. Field blanks analyzed with ambient air samples collected at each landfill site showed no PCB (measured at Aroclor 1242) above the minimum detectable level of 0.02 μg per plug. The blank sampling cartridges were carried through all field handling operations except attachment to the sampling devices.

During the field study, pairs of LV and HV samplers were operated for the same time period at the same sampling location to estimate the reproducibility of the measurement methods. Measurements were also made with collocated LV and HV samplers to compare results obtained by the two methods. As can be seen from the data in Table V, good agreement between pairs was obtained. The average difference calculated from all the paired LV sampler measurements was 7.2% while that for the HV

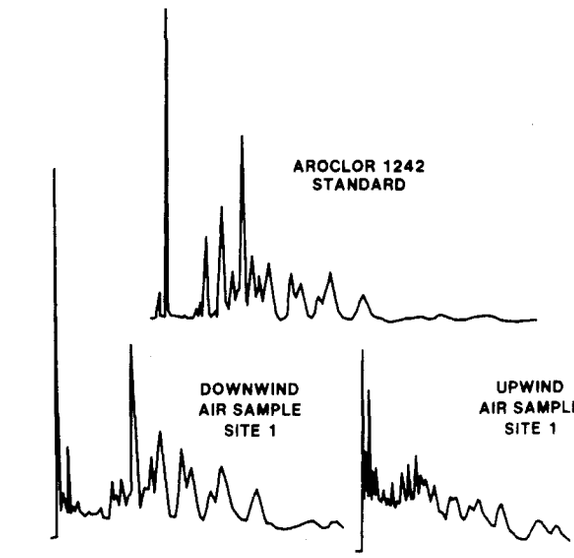

Figure 4. Gas chromatograms of standard and ambient air samples at uncontrolled landfill.

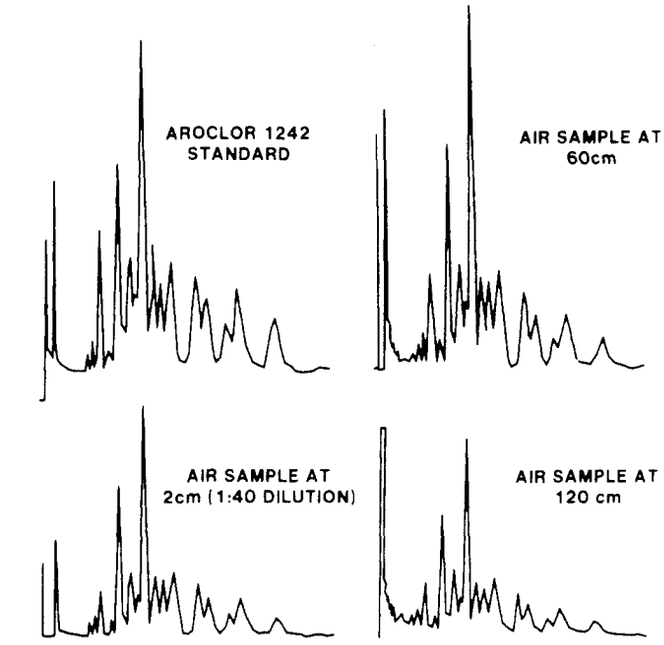

Figure 5. Gas chromatograms of standard and air samples at several heights above hot spots at uncontrolled landfill.

Table V. Collocated Sampler Comparisons

paired LV samplers,[a] $\mu g/m^3$			paired HV samplers,[b] $\mu g/m^3$			paired LV and HV samplers,[b,c] $\mu g/m^3$		
sampler A	sampler B	% difference in pair	sampler A	sampler B	% difference in pairs	sampler A	sampler B	% difference in pairs
9.4	11	15.7	12	14	15	8.7	7.1	+20.3
8.8	8.6	2.3	11	12	8	7.0	6.5	+7.4
11	6.8	47.2	37	61	49	8.5	11.6	-30.8
11	12	8.7	98	89	9	5.2	9.9	-62.3
5.1	5.3	3.8	30	47	44	11.0	12.3	-11.2
7.9	9.1	14.1	20	23	14	8.5	13.5	-45.5
18	19	5.4	45	45	0	18.5	28.0	-40.9
77	72	6.7				11.0	21.0	-62.5
6.2	6.0	3.3				40.0	49.0	-20.2
85	89	4.6						
		11.2[d]			20[d]			-27.3[d]

[a] Located 30 cm apart. [b] Located 1 m apart. [c] Data corrected to account for difference in height of intake above ground. [d] Average.

Table VI. Comparison of Active and Passive Sampling Data

distance above ground, cm	air concentration, $\mu g/m^3$						
	site 1a		site 1b		average		
	active	passive	active	passive	active	passive	% difference P/A
2	1060	980	670	340	865	660	-24
30	120	53	90	125	105	89	-16
60			37	55/100	37	77	+48/108
120	19	14	17		18	14	-22
180			5.1/5.2	5/16	5	10	+100
							+16.8[a]

[a] Average.

samplers was 20%. Since the inlets of the HV and LV samplers were not located at the same heights above ground, it was necessary to apply a correction factor in order to achieve reasonably accurate comparisons between values obtained from collocated pairs of HV and LV samplers. For this purpose, corrected HV values (C_{180}) were calculated by

$$C_{180} = C_{120}(V_{180}/V_{120})$$

where C_{180} and C_{120} were the PCB air concentrations measured by the collocated HV and LV samplers, respectively, and V_{180} and V_{120} were concentration values obtained from vertical profile measurements with the LV samplers at 120 and 180 cm above ground, respectively. After these adjustments, the LV/HV sampler comparison averaged -27.3%, with the LV sampler generally giving lower results.

A limited numer of experimental passive devices (*12*) were also exposed at hot spots on site 1 on 2 of the 4 days of sampling. The passive sampling devices (PSDs) were 3.8 cm diameter × 1.3 cm stainless-steel cylinders containing a series of diffusion screens and plates on each end. Tenax GC (0.4 g) was used to collect PCB gases diffusing into the devices. The sampling rate for PCBs was estimated at 30 cm^3/min on the basis of trichlorobiphenyl. The devices were transported to and from the exposure sites in sealed cans, which were placed in a larger can containing activated charcoal. Cyclohexane was used for extraction of the PCBs from the PSDs. Collocated exposures with the LV samplers showed reasonably good agreement, as can be seen from the data presented in Table VI. The detection limit for the PSDs was only ca. 5 $\mu g/m^3$ for 8-h exposures, however. Efforts are currently under way to improve sensitivity by means of supercritical fluid extraction and concentration.

Temporary remedial actions were taken during 1983–1984 at sites 1 and 2 to remove all exposed capacitors and obviously contaminated surface soil. Following this cleanup, limited additional air monitoring was performed during a 4-day period in Aug 1984. The results of HV sampling at both sites are presented in Table VII. Vertical profile measurements (using the LV samplers) at two previously monitored hot spots on site 1 are given in Table VIII. Significant reductions (by an order of magnitude) of PCB air levels at the hot spots were noted postcleanup. However, downwind levels at both sites 1 and 2 appeared unchanged, suggesting that the landfill proper is still

Table VII. Range of PCB Concentrations[a] ($\mu g/m^3$) in Air at Uncontrolled Sites after Temporary Cleanup, Aug 1984

location	site 1	site 2
hot spots	3.1–4.6	2.7–3.1
downwind	0.4–1.4	0.1–0.2
upwind	0.2–0.3	0.1–0.1
meteorology		
temperature range, °C	14–32	
wind velocity range, m/s	0–1.3	
relative humidity range, %	48–92	

[a] 24-h samples.

Table VIII. Vertical Profile Air Measurements at Uncontrolled Landfills after Temporary Cleanup, April 1984

distance above ground, cm	air concentration,[a] $\mu g/m^3$	
	site 1	site 1b
2	2.3–3.2	11.5–21.3
30	1.1–1.8	4.1–5.8
60	0.9–1.4	1.7–3.1
120	0.7–1.4	1.7–3.1
180	0.4–0.6	1.5–2.5

[a] Average daytime levels over a 4-day period.

contributing PCBs to the surrounding atmosphere.

Conclusions

The results of these studies demonstrate that fugitive emissions of PCBs into the atmosphere can occur at uncontrolled landfills. At the three sites, PCB air levels measured at hot spots on the landfills greatly exceeded ambient background levels, thus indicating that PCBs from the leaking capacitors were being emitted into the air. Concentrations that exceeded background levels were also observed at sampling locations downwind of the landfills, even after removal of exposed capacitors and obviously contaminated surface soil. By contrast, air emissions of PCB from a well-designed chemical waste landfill were found to be negligible.

All PCB sampling systems were found to perform well. The LV samplers offered an advantage over the HV samplers when electrical power was not available (as was the case at most of the sites monitored). However, limited battery life would not permit 24-h sampling with the LV pumps. The experimental passive sampler, which can readily operate unattended for 24 h, shows much promise if its sensitivity can be increased by 100-fold through improved extraction and analysis methods.

Acknowledgments

We than Donald E. Johnson of Southwest Research Institute, San Antonio, TX, for valuable laboratory support in preparation and analysis of PUF cartridges, Jack C. Suggs of the U.S. Environmental Protection Agency, Research Triangle Park, NC, for modeling assistance, William F. Barnard and Jack A. Bowen of the U.S. Environmental Protection Agency, Research Triangle Park, NC, for performing field audits, James Gray of EPA Region IV, Athens, GA, for field support at the controlled landfill, and Ralph Riggin of Battelle for analysis of the passive sampling devices.

Registry No. Aroclor 1242, 53469-21-9; Aroclor 1260, 11096-82-5.

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Received for review December 19, 1984. Accepted April 5, 1985. Although the research described in this article was funded wholly or in part by the U.S. Environmental Protection Agency through Contract 68-02-3745, it has not necessarily reflect the views of the Agency, and no official endorsement should be inferred. Mention of trade names for commercial products does not constitute endorsement or recommendation for use.

Technical Memorandum

HDR APTIM
a Joint Venture

To: Rich Fisher (EPA)

From: Shane McDonald (Senior Technical Leader, Hydrogeology and Modeling, HDR APTIM)

Date: March 16, 2023

Subject: Groundwater movement at the planned Housatonic River UDF based on water level measurements in onsite and nearby monitoring wells

An Upland Disposal Facility (UDF) is planned to store non-TSCA PCB contaminated sediment dredged from the Housatonic River as part of the Rest of River remediation. There is concern that PCBs inadvertently released in water from the planned UDF[1] could be transported by groundwater to the Housatonic River and current and potential future local water supplies creating a risk for human health. The current water supply for the Town of Lee is from surface water reservoirs located about a mile and a quarter to the east southeast on the bedrock valley wall (Leahey Reservoir) and a lower reservoir at the bottom edge of the valley wall (Vanetti Reservoir, which is an emergency reservoir). In addition, there are no known drinking water uses of the Housatonic River in Massachusetts (Weston, 2011; MassMapper, 2023). Evaluation of historical groundwater levels collected at nearby existing landfills and measured in newly installed wells at the UDF site show that groundwater near the UDF flows westerly towards the Housatonic River which is west of the UDF site. In addition, vertical hydraulic gradients in well couplets both at the UDF site and at the Lee sanitary landfill immediately south of the UDF site show that groundwater movement at the planned UDF is upward from the underlying bedrock toward the river. Unless there are unusual circumstances (such as nearby pumping), all rivers in the northeast United States receive groundwater discharge in this way. These water level measurements show that in the unlikely event that PCBs were released from the landfill to the groundwater, their transport would be towards the river, away from the underlying bedrock, and away from the Town's water supply reservoirs. Figure 1 is a map of the area around the UDF site showing its relationship to the Housatonic River and the Reservoirs.

Geologic and Hydrogeologic Setting of the UDF Area

The UDF is planned at a former gravel pit adjacent to the Housatonic River and Woods Pond. The sand and gravel at the gravel pit is Pleistocene aged glacial valley fill outwash from the retreat of the Wisconsinan glacier and in places is underlain by glacial till.[2] Adjacent to the Housatonic River and at undifferentiated places on the UDF property it is likely that more recent alluvium from the river also exists. Much of the UDF property has been modified for the removal of sand and gravel. As evidenced by the geology encountered as part of General Electric's Pre-Design Investigation (Arcadis 2022), there is a thickness of up to 110 feet of unconsolidated overburden[3] on the site. This overburden includes glacial outwash deposits of silt, sand, and gravel in undifferentiated layers and lenses, with occasional dense silty sand and gravel deposits just above the bedrock that could be till above the bedrock.

[1] The UDF design, including double lining and other water control mechanisms, will make the release of PCB contaminated water from the facility very unlikely. See Arcadis 2022 for descriptions of the facility design and water control measures that will be undertaken.

[2] Glacial till is unconsolidated material that was placed by the movement of ice age glaciers and is typically composed of over-compacted heterogenous material (sand, silt, clay, and gravel).

[3] Overburden is a term used to describe unconsolidated geologic material that exists above consolidated bedrock.

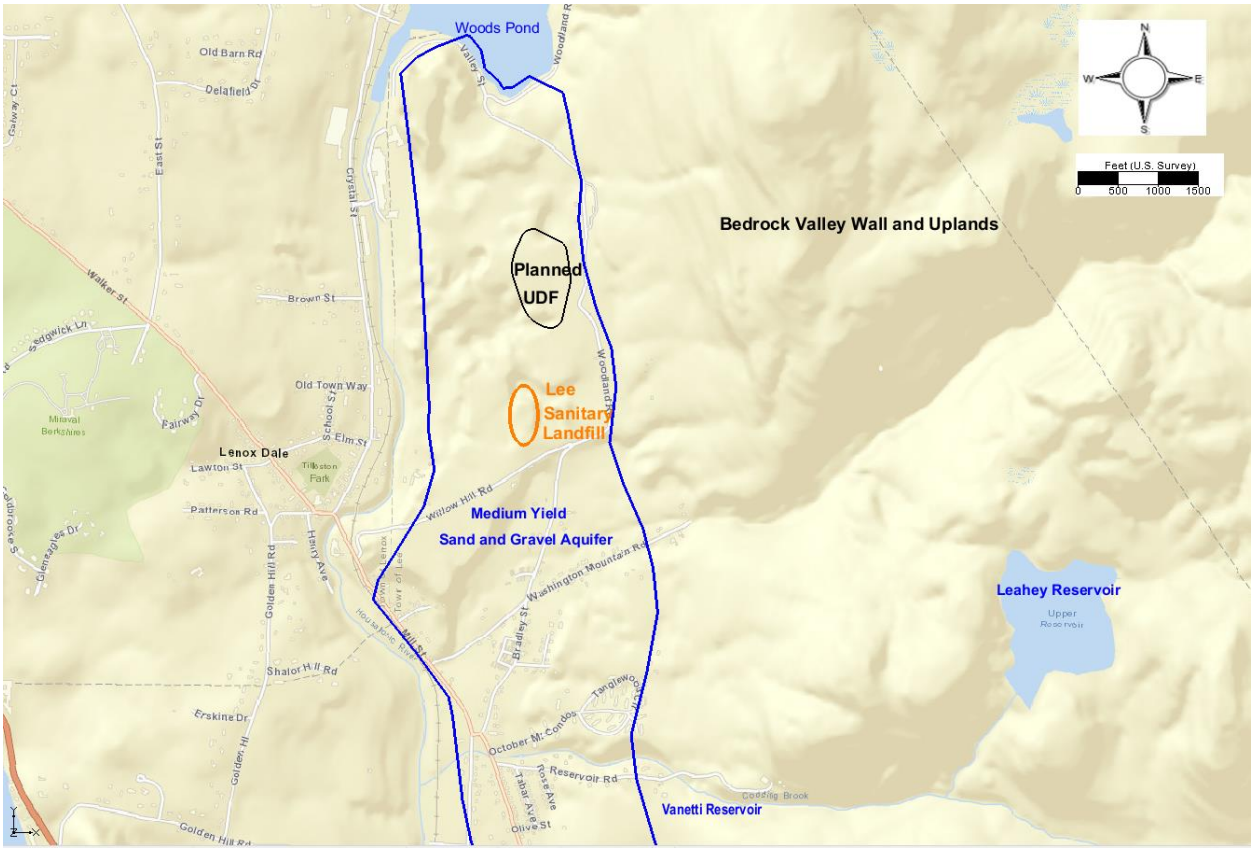

Figure 1 - Site Map (aquifer area from Mass Mapper 2023 MassGIS Data: Aquifers)

The overburden is a valley fill sand and gravel aquifer that thins at the valley walls exposing the underlying bedrock to the east of the site. Beneath this overburden and making up the valley walls are metamorphic rocks of the Taconic-Berkshire Zone. Immediately beneath the UDF site is the Early Cambrian aged Stockbridge Formation, a dolostone or dolomitic marble (Horton, San Juan, and Stoeser, 2017; Zen et. al., 1983). Note that bedrock cores collected during the PDI indicated that the bedrock at the UDF site was marble[4] (Arcadis, 2022a). The valley walls are comprised of the Precambrian (Neoproterozoic) Dalton Formation metasedimentary quartzite and other rock types and (Mesoproterozoic) aged Tyringham Gneiss, Washington Gneiss, and Lee Gneiss (Horton, San Juan, and Stoeser, 2017; Zen et. al., 1983). Figure 2 is a surficial geology map of area around the UDF showing the relationship between the valley fill and the bedrock and topographic information for the land surface (Stone and DiGiacomo-Cohen, 2018). In the figure, yellow represents recent alluvium, pink is swamp deposits, olive green is alluvial fan deposits, gold is coarse glacial deposits, dark green is valley till, light green is thick till, and red horizontal striping indicates bedrock is close to the surface or outcropping (Stone et. al, 2018). Note the Housatonic River crosses the coarse deposits near the UDF site.

[4] The two locations where bedrock cores were collected on site had rock quality designations (RQD) of 79 percent and 92 percent, indicating that the cores had few fractures.

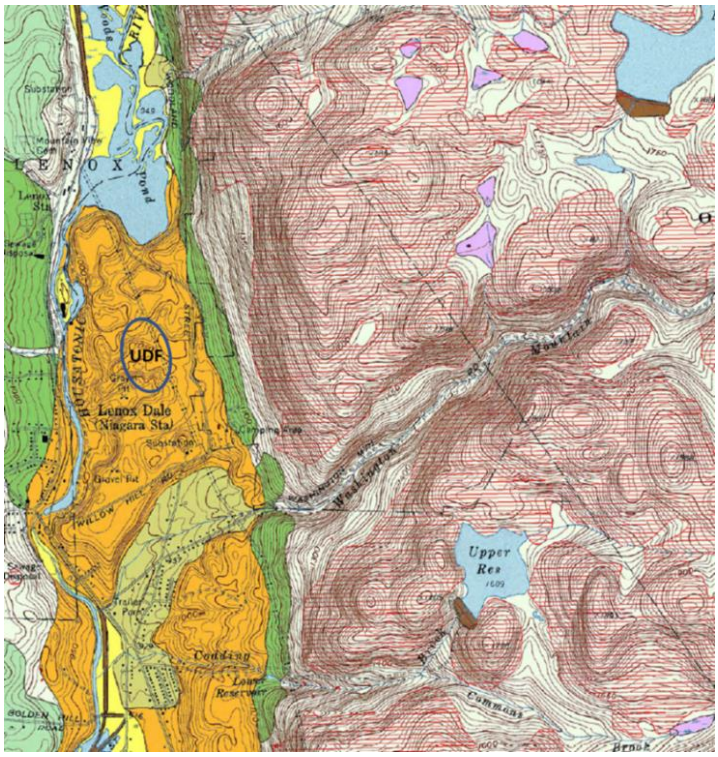

Figure 2 - Surficial Geology Map of UDF Area (from Stone and DiGiacomo-Cohen, 2018)

Typically, in the Northeastern United States, a portion of the precipitation that falls on the ground surface infiltrates as groundwater recharge. The recharge percolates into the subsurface either through fractures in the bedrock in the uplands or through the pore spaces between sand and gravel grains on the valley floor.[5] Groundwater accumulates where the fractures and pore spaces become fully saturated. The groundwater flows from higher elevation recharge areas to lower elevation discharge areas such as streams and rivers. Figure 3 is a groundwater contour map of shallow overburden water levels measured at the UDF site on October 8, 2022, and Figure 4 is a conceptual cross section through the UDF site that shows the relationship between overburden and bedrock groundwater. The Figure 4 inset box includes groundwater levels measured at the UDF site on October 8, 2022.

As the groundwater moves through the subsurface it flows both horizontally and vertically from higher hydraulic pressure (head) towards lower head: groundwater recharged at hill tops will pass below groundwater recharged lower in the valley to ultimately discharge at the lowest head at the river or stream. So, in general as groundwater approaches a stream or other discharge point, groundwater that is at greater depths has higher head than shallower groundwater near the discharge point at the river. The difference in head divided by the intervening distance between measurement points is called the hydraulic gradient (which can be either vertical or horizontal). Hydraulic gradients can be used to determine the direction of groundwater movement. While dominant flow is usually laterally from higher head to lower head, a positive vertical hydraulic gradient between a coupled deep and shallow well pair (that is, the water level measured in the deep well is higher than in the shallow well) indicates the groundwater has the potential to or is upwelling (that is, migrating upward from deeper to shallower in addition to its lateral migration).

[5] Following installation of the base liner system and cap, recharge through the UDF consolidation footprint will be eliminated.

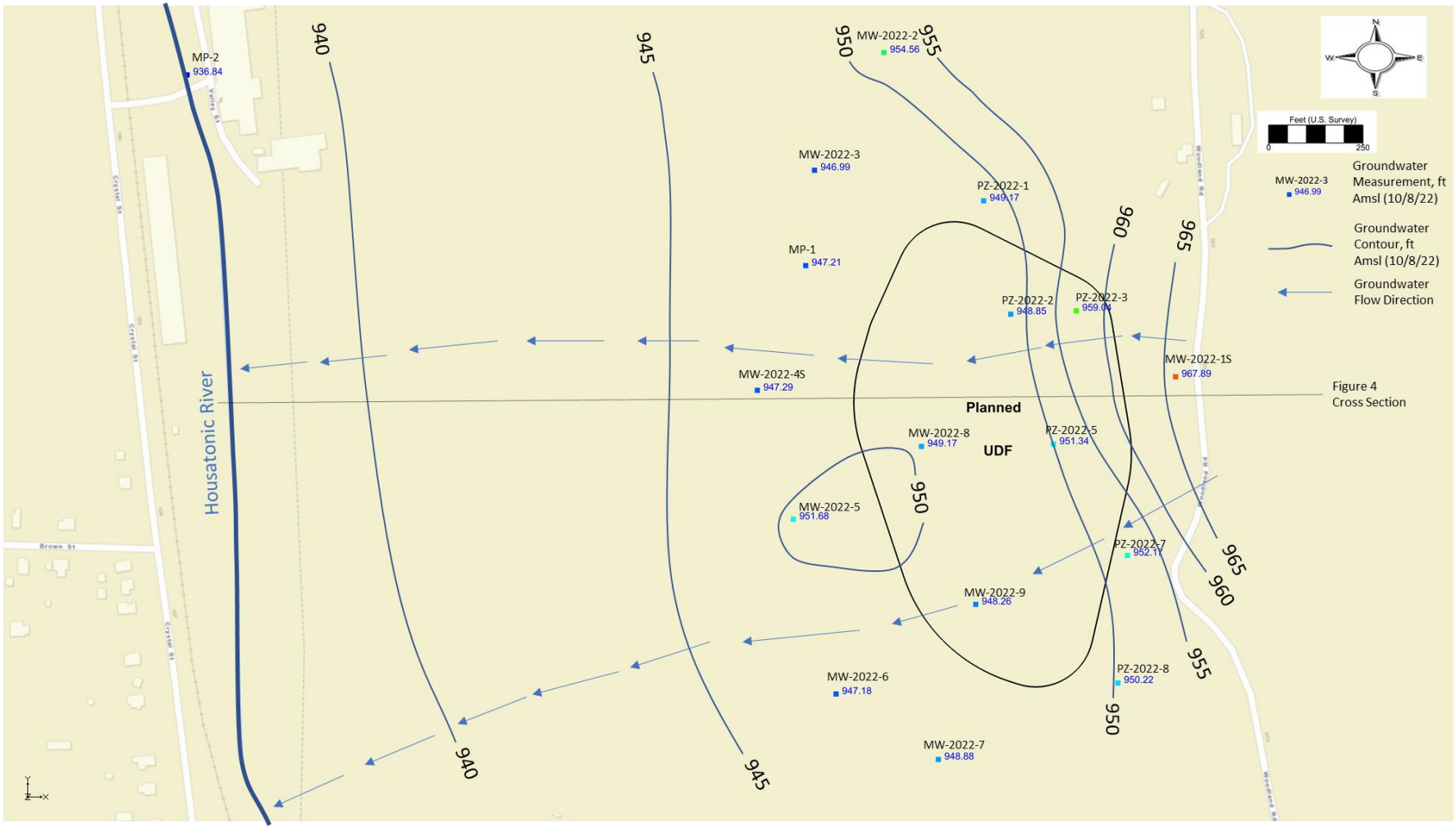

Figure 3 - Shallow Groundwater Contour Map (10/8/22)

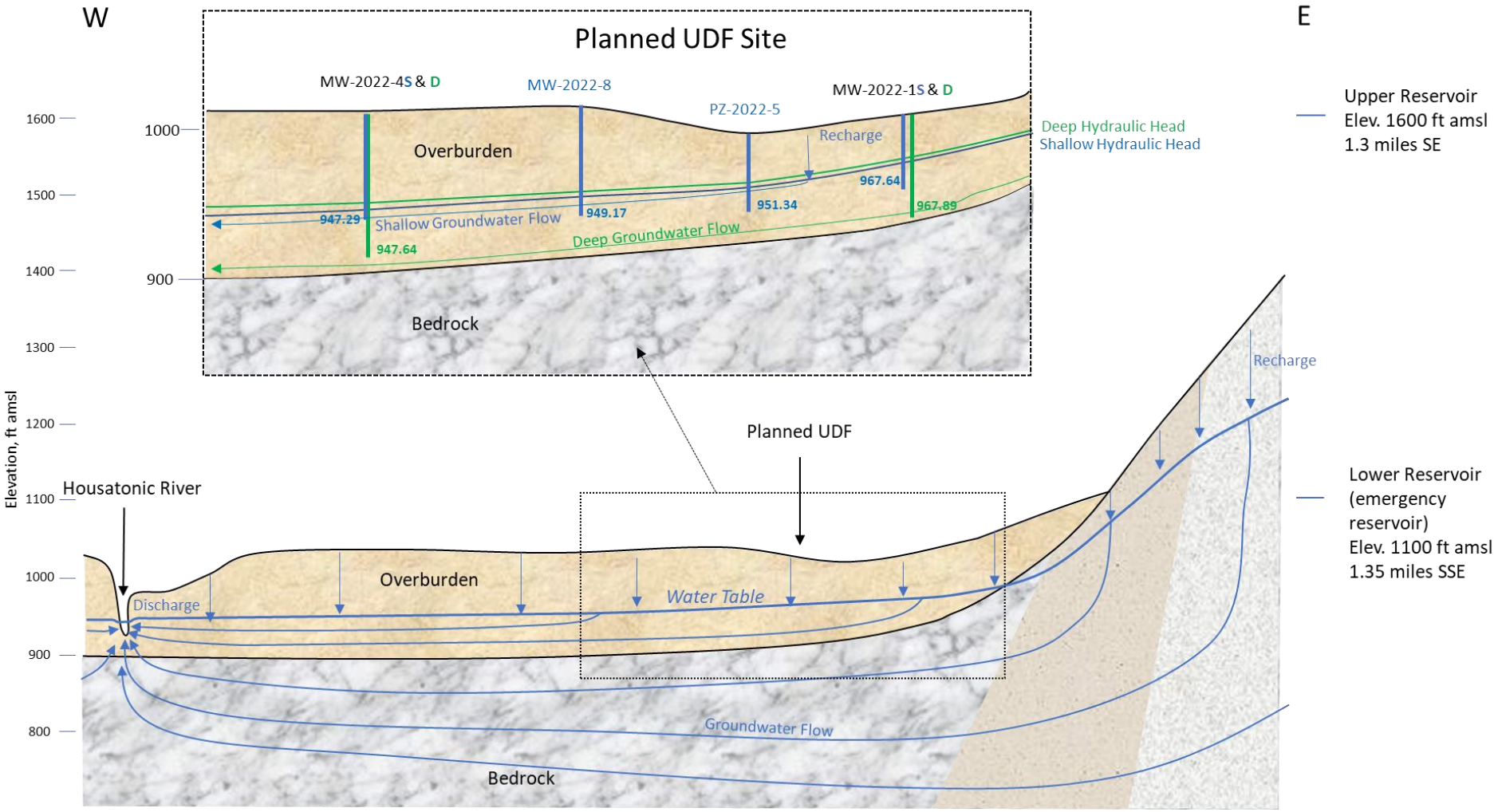

Figure 4 - Conceptual Cross Section Through the UDF Site

Historical Groundwater Levels at Lee Landfill

The Lee Landfill is a former capped sanitary landfill that is located near the UDF property. Groundwater monitoring occurred at Lee Landfill in the 1980s and 1990s. Records have been located from a monitoring event that occurred in 1995 which shows lateral, westerly groundwater flow towards the Housatonic River and a strong upward gradient at well couplets (bedrock and overburden monitoring wells) beneath the site as the regional groundwater approaches the river (CDM, 1995). The report documents the overburden (84 series) and bedrock (94 series) wells on the site. Figure 5 is the groundwater contour map prepared by CDM showing the groundwater elevations in the bedrock and in the overburden as measured in 1995. Measured water level elevations on the eastern side of the map both in the bedrock and the overburden wells (that is, MW84-1, 960.16 feet above mean sea level [ft amsl], and MW-94-1, 960.58 ft amsl) are higher than water levels on the western side of the map closer to the Housatonic River (for example, MW84-3, 950.15 ft amsl and MW94-3, 950.36 ft. amsl). The groundwater levels and contours show the lateral component of groundwater movement was from east towards the west and the Housatonic River both in the bedrock and the overburden. Also seen in the figure, the measured water level elevations in the bedrock well at each location was at a higher elevation than in the coupled overburden well (for example, the monitoring pair MW84-2, overburden, 949.94 ft amsl and MW94-2, bedrock, 950.41 ft amsl) indicating an upward component to the movement of groundwater.

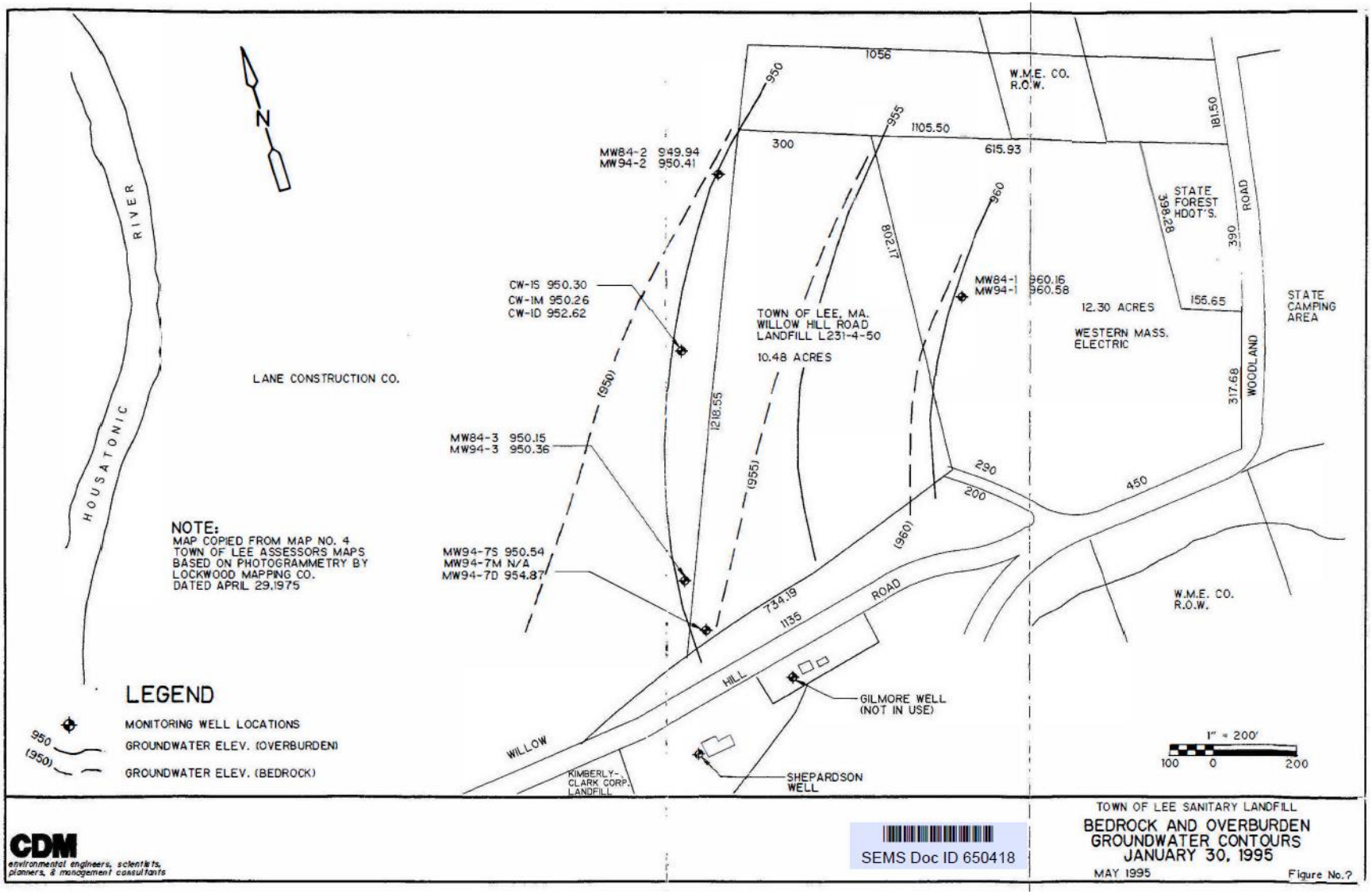

Figure 5 - Groundwater Contours and Elevations from January 1995

Recent Groundwater Levels Measured in Newly Installed Monitoring Wells

GE installed a combination of 17 monitoring wells and piezometers, including two deep and shallow well pairs (MW-2022-1S and D and MW-2022-4S and D) in 2022, and measured water levels in these wells and piezometers between June and November 2022 (Arcadis, 2022a). Two surface water locations, one on the Housatonic River (MP-2) and one in a gravel pond on the property (MP-1), were monitored at the same time. To measure groundwater levels, GE's contractor, Arcadis, used both transducers residing in the wells which record water levels multiple times a day as well as periodic (monthly) manual water level measurements. Table 1 presents the water levels measured manually by GE which demonstrate both horizontal flow between well locations and vertical gradients between wells in deep and shallow pairs.

Table 1 - Groundwater Elevations (ft amsl) Measured at the UDF Site

	Groundwater Level Elevation by Date					
Well/Piezometer ID	**6/6/2022**	**7/8/2022**	**8/10/2022**	**9/8/2022**	**10/7/2022**	**11/8/2022**
MW 2022-1S	NA	971.08	969.51	968.52	967.64	966.80
MW 2022-1D	972.75	971.16	969.80	968.73	967.89	967.04
MW 2022-2	956.25	954.55	951.41	953.10	954.56	954.82
MW 2022-3	949.58	948.57	947.70	947.34	946.99	946.90
MW 2022-4S	950.55	949.46	948.42	947.77	947.29	947.22
MW 2022-4D	951.78	950.47	949.04	948.19	947.64	947.73
MW 2022-5	955.29	954.60	953.69	952.74	951.68	950.97
MW 2022-6	951.54	950.13	948.74	947.89	947.18	947.26
MW 2022-7	954.55	952.70	950.91	949.67	948.88	949.16
MW 2022-8	954.39	952.29	950.94	949.92	949.17	948.87
MW 2022-9	953.40	951.57	949.96	948.84	948.26	948.44
Lee LF MW-84-1	959.77	957.47	955.35	953.97	953.36	954.97
Lee LF MW-84-2	954.46	953.24	951.80	950.75	950.10	949.52
PZ 2022-1	951.54	950.85	950.06	949.58	949.17	949.28
PZ 2022-2	952.61	951.35	950.28	949.47	948.85	948.70
PZ 2022-3	963.79	962.71	961.38	960.13	959.04	958.40
PZ 2022-5	954.13	952.30	951.37	951.38	951.34	951.30
PZ 2022-7	957.62	955.49	953.59	952.37	952.17	952.86
PZ 2022-8	956.90	954.52	952.52	952.18	Dry	Dry
Gravel Pond (MP-1)	949.58	948.54	NA	947.56	947.21	947.16
Housatonic (MP-2)	936.52	936.34	936.10	936.93	936.84	936.80

Notes:
1. Elevations are referenced to NGVD 29.
2. MW 2022-1S and MW 2022-1D are a shallow and deep well couplet
3. MW 2022-4S and MW 2022-4D are a shallow and deep well couplet
4. "Dry" indicates no water was detected in well.
5. "Gravel Pond" represents on-site pond at location identified as MP-1. "Housatonic" represents Housatonic River measured from bridge at location identified as MP-2
6. Taken from Arcadis 2022a

Abbreviations
ft = feet
NA = Not Applicable (measurement not available).

Water levels in the monitoring wells and piezometers trended overall east to west and were at least 11 feet higher than water levels in adjacent Housatonic River (MP-2). Figure 6 shows the water levels manually measured in the monitoring wells, piezometers, and the two surface water measurement points. The X axis of the graph (horizontal axis) is the surveyed easting coordinates of the measurement points (in ft MA State Plane NAD83), and the vertical Y axis is the water level elevation in feet. The graph shows that groundwater flow is consistently towards the river. Note that the Upper Reservoir water supply is at 1600 ft amsl, and the Lower Reservoir is at 1100 ft amsl (see Figures 2 and 4).

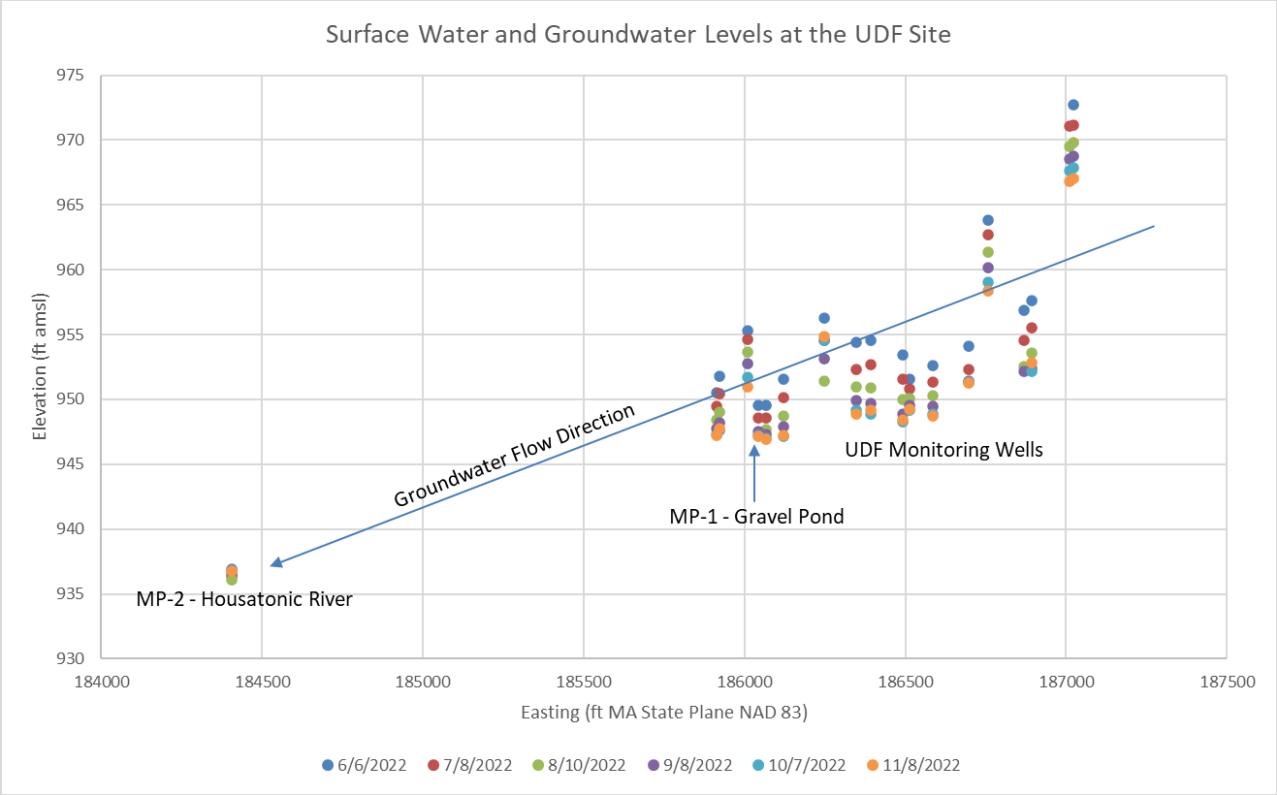

Figure 6 - Surface Water and Groundwater Levels at the UDF Site

In addition, water levels in the two well pairs consistently showed upward vertical gradients both in the manual measurements and the transducer measurements (measured water levels in the deep wells were consistently higher than the shallow wells - See Table 1). Figures 7 and 8 shows a comparison of the plotted measurements in the two well pairs after adjusting the graphs from Arcadis' Interim PDI report to the same scale. The plotted lines represent the logged transducer readings while the solid squares represent the manual measurements from Table 1.

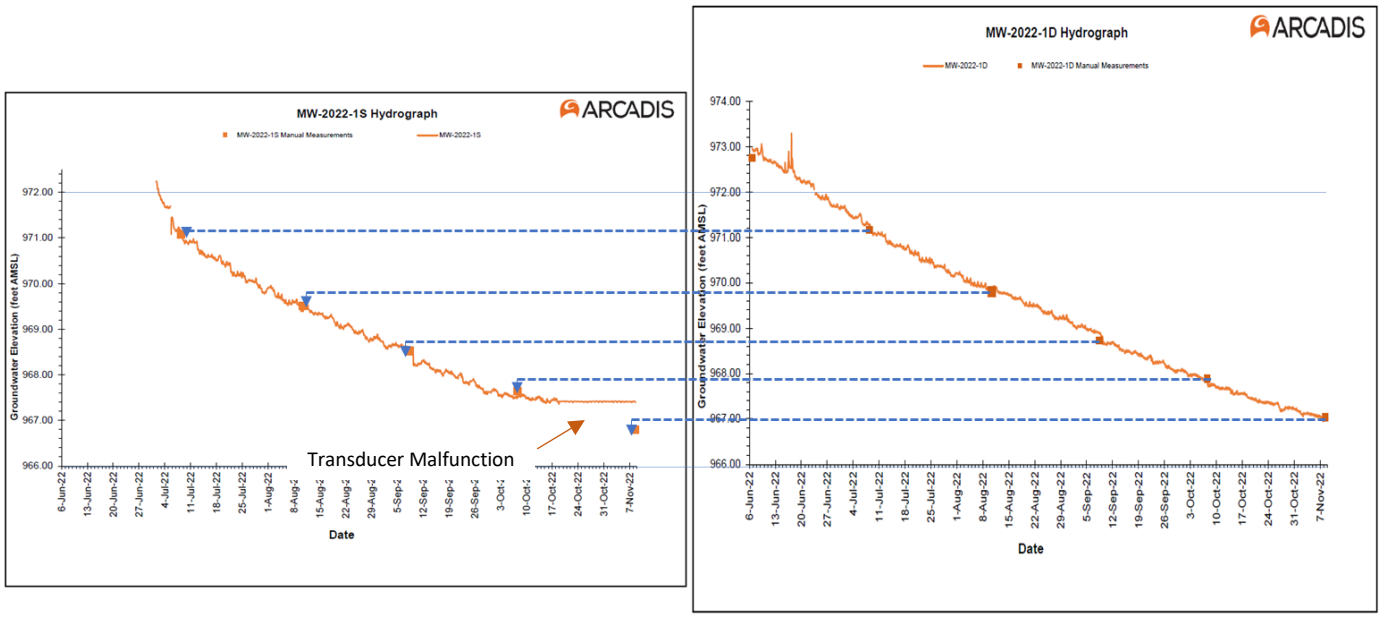

Figure 7 - Water Level Comparison MW2022-1S and -1D

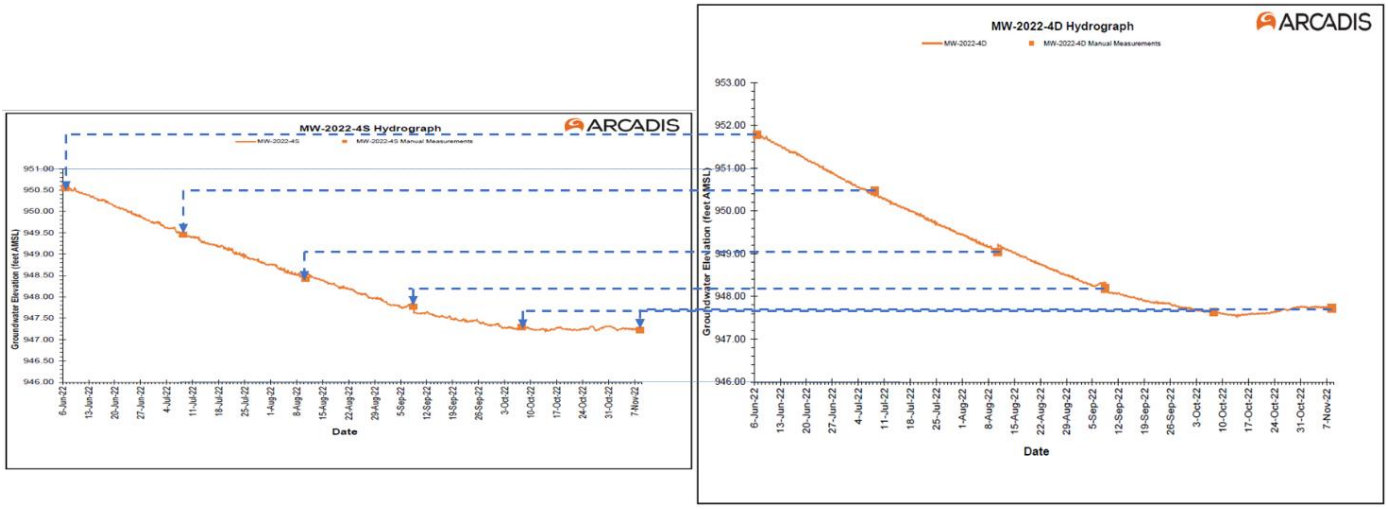

Figure 8 - Water Level Comparison MW2022-4S and -4D

Conclusions

Groundwater measurements at the planned UDF site and surrounding area show that groundwater at the UDF site moves westerly towards discharge at the Housatonic River and moves upwards from the bedrock to the overburden and then to the river. These relationships in turn show that if an unlikely release of PCB-contaminated water occurred from the planned UDF, any PCB migration would be directly towards the river and not eastward toward the Lee water supply reservoirs or downward into the bedrock. There is only a small portion of the aquifer between the planned UDF and the river, and this area would be unlikely for future public drinking water development due to the property use

(Eurovia asphalt plant) and the two nearby unlined former landfills. Because the Town of Lee's main water supply reservoir (Leahey) is 100s of feet higher in elevation than the UDF site, and the emergency reservoir (Vanetti) is 10s of feet higher in elevation, and both reservoirs are more than a mile cross and up-gradient of the planned UDF, they are isolated from the UDF and would not be impacted by a release from the UDF. There are also no known drinking water intakes on the Housatonic River. In addition, PCBs are extremely hydrophobic (low solubility) with high organic sorption rates and are thus not easily transported by groundwater without a co-solubilizing solvent[6]. Thus, any release of water from the UDF would have at most low concentrations of dissolved PCBs that would be further attenuated by sorption to any organic carbon in the overburden as well as mechanical dispersion and diffusion into finer grained materials. For these reasons, in the unlikely event of a release from the UDF, detectable concentrations of PCBs would not be expected to migrate a significant distance from the UDF or to arrive at the Housatonic River or any known current nearby water supply.

It is worth noting that as shown on Figure 1 and Figure 2, Woods Pond, where PCB impacted sediments have existed for over 50 years, is hydraulically connected to the valley fill sand and gravel aquifer that is beneath the planned UDF site. While the depicted boundary of the aquifer is based upon shallow surficial geology mapping (see Figure 2), which accounts for the presence of Woods Pond, the glacial valley fill outwash certainly extends beneath Woods Pond and is contiguous and interacts with the medium yield overburden aquifer beneath the UDF. These impacted Woods Pond sediments are uncontrolled and are freely in connection with the water of the aquifer (as it discharges to Woods Pond). Groundwater in overburden monitoring wells (both shallow and deep) installed at the UDF site, which is between Woods Pond and Town of Lee's reservoirs, has been analyzed for PCBs. No PCBs were detected, and no PCBs have arrived at the reservoirs. That PCBs have not migrated in the groundwater from Woods Pond to the UDF site or the reservoirs in the last 50 years supports the conclusion that low-level PCB impacted soils and sediments placed in the double lined and capped UDF will also not result in PCB migration through the groundwater to the reservoirs.

[6] In addition, as for the protectiveness of the UDF relating to dioxins and furans, EPA approved site documents summarize how these compounds share many of the general physical and chemical properties of PCBs. Similar to PCBs, dioxins and furans are organic compounds characterized by low aqueous solubilities, low vapor pressures, high octonal-water partition coefficients, and do not readily degrade in the environment. Dioxins and furans are considerably more hydrophobic than PCBs and have similar or greater affinity to bind to particles than the PCBs (BB&L, 2003). Thus, because dioxins and furans are even less likely than PCBs to be transported by groundwater, if the UDF is protective for PCBs, then it is also protective for dioxins and furans.

References

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Stone, J.R., Stone, B.D., DiGiacomo-Cohen, M.L., and Mabee, S.B., comps., 2018 Surficial materials of Massachusetts—A 1:24,000-scale geologic map database: U.S. Geological Survey Scientific Investigations Map 3402, 1 sheet, scale 1:24,000, https://doi.org/10.3133/sim3402.

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Zen, E-An, Goldsmith, G.R., Ratcliffe, N.L., Robinson, Peter, and Stanley, R.S., 1983, Bedrock geologic map of Massachusetts: U.S. Geological Survey Monograph series, 3 sheets, scale 1:250,000.

Shane McDonald, PG

Senior Technical Leader Hydrogeology and Modeling
Senior Professional Associate

Shane's experience includes in-depth involvement in environmental, water supply, and geotechnical projects in the United States and abroad. He is expert in evaluating geologic and hydrogeologic data and computer models. He has extensive experience in evaluating groundwater under a wide range of hydrogeologic conditions and for a wide range of purposes. He has been responsible for the development of innovative approaches to complex geologic problems and is expert in conceptualizing complex geologic and hydrogeologic settings.

Shane is experienced in dealing with clients, regulatory agencies, legal entities, and stakeholders and has been an expert witness in support of litigation. He also has extensive practical experience in geologic and hydrogeologic field investigations and techniques. Shane was awarded Louis Berger's 2015 Grand Global Values Award for Client Focus for his role as project manager and lead hydrogeologist for expert professional and litigation support on behalf of the Republic of Ecuador. In 2021, Mr. McDonald was award an HDR Fellowship to research and develop wicking wells, a novel method to remediate dissolved solids contminated groundwater which he invented. The method is now patent pending, and additional development is underway.

EDUCATION
MEng Systems Engineering, Pennsylvania State University 2010

BS Geology, Kent State University 1984

REGISTRATIONS & CERTIFICATIONS
Professional Geologist (PA, PG-000272, 1994)

Professional Geologist (NY, PG-000101, 2017)

Certified Professional Geologist (American Institute of Professional Geologists, CPG-9485, 1995)

40 Hour Hazardous Waste Operations

8 Hour OSHA Supervisor Training for Hazardous Waste Site Operations

AWARDS
HDR Fellowship 2021, 2022

Louis Berger Grand Global Values Award for Client Focus 2015

NGWA Outstanding Project in Ground Water Protection: Lead Scientist – US Marine Head Quarters Range Environmental Vulnerability Assessment, 2009

NGWA Outstanding Project in Ground Water Supply: Project Manager - Sanctuary Springs Development for Nestle Waters North America,

SELECT RELEVANT EXPERIENCE

6/15/2022 – Ongoing, CADWR – California Aqueduct Subsidence Program (CASP)
As Task Leader, lead efforts for both the Subsidence and Groundwater Monitoring and the Subsidence and Groundwater Modeling Tasks of the multi-year evaluation of impacts to the California Aqueduct from land subsidence caused by overdrafts of groundwater in the Central Valley of California. Lead multiple organization and multi-disciplinary teams to plan and implement monitoring and modeling of groundwater levels and land subsidence and relate those efforts to the overall evaluation of impacts to and performance of the aqueduct.

11/9/2017 – Ongoing, NYCDEP – Newtown Creek Superfund Site / New York, NY
As hydrogeology technical lead, representing NYCDEP, with focus on groundwater issues and groundwater surface water interaction at the large and complex superfund site. Contamination sources are from oil handling facilities (Greenpoint Oil Spill, largest in US history until BP Deepwater Horizon), manufactured gas plant, copper smelter, and other potential sources. Designed and implemented groundwater-surface water interface investigations over the 3-mile long estuary and its tributaries. Lead investigations of the occurrence of NAPL (both tar and oil) using laser induced fluorescence (LIF). Lead investigations of ebullition facilitated NAPL migration. Review technical documents and approach being put forth by the common consultant and give comments and guidance on best approaches for evaluating groundwater and

2002

YEARS OF EXPERIENCE
37

SELECT PUBLICATIONS
Chapman, S.D., Parker, B., Cherry, J., McDonald, S.D., Goldstein, K., Frederick, J., St. Germain, D., Cutt, D., Williams, C.; "Combined MODFLOW-FRACTRAN Application to Assess Chlorinated Solvent Transport and Remediation in Fractured Sedimentary Rock"; *Remediation Journal* Summer 2013

McDonald, S.D., Goldstein, KJ., Chapman, S., Parker, B., Cherry, J., St. Germain, D., Frederick, J., Cutt, D., Williams, C., 2012, "Combined use of MODFLOW groundwater flow model and FRACTRAN discrete fracture network model to assess the fate and transport of chlorinated solvents in fractured sedimentary rock", Eighth International Conference on Remediation of Chlorinated and Recalcitrant Compounds. Monterey, CA 2012

McDonald, S.D., Goldstein, K., Chapman, S., Parker, B., Cherry, J., Frederick, J., St. Germain, D., Cutt, D., Williams, C.; "MODFLOW and FRACTRAN Discrete Fracture Network Model Estimates Fate and Transport of Contaminants in Fractured Rock"; Eighth International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, California; May 21-24, 2012

McDonald, S.D., Gbondo-Tugbawa, S., Garvey, E., Atmadja, J., Conetta, B., "Scow Unavailability and Its Impact on Dredging Productivity in the Hudson River: An Assessment of Scow

other technical issues.

8/1/2019 – 5/1/2022, LOTT Clean Water Alliance – Reclaimed Water Infiltration Study, Olympia, WA
As lead groundwater modeler led a team developing a 3-dimensional model to simulate recharging reclaimed water to a regional aquifer system to evaluate the fate and transport of residual chemicals for a risk assessment. The project included detailed hydrogeologic investigations in support of the groundwater modeling, including a year-long tracer test at the active recharge facility. The modeling and engineering team interacts with both a science advisory team and a peer-review panel.

3/10/2022 – Ongoing, Confidential Client – Assessment of Dewatering and Operation of Pump and Storage Facility
As lead modeler, assessed potential impacts of construction dewatering and operations of a reservoir at a planned pump and storage facility being constructed near a groundwater contamination as well as a nearby wetland and spring. Reviewed historic record of groundwater investigation from the brownfield site and presence of the spring and wetland. Developed a groundwater model to assess the impacts of dewatering and reservoir operations on the plume, spring, and wetland.

1/14/2021 – 8/1/20-22, Confidential Client – Water Use Permit, FL
As lead groundwater modeler, develop a site-specific groundwater model based on a regional model to assess the impacts of a 7-well, 43 MGD groundwater use on adjacent water resources and the effects of alternative pumping strategies and moving the discharge point on an adjacent river. The modeling was done in support of the water use permit renewal. The permit was issued without exception.

9/1/2020 – 1/1/22, Confidential Client – MFL Impact Assessment, FL
As lead modeler, modified and used a regional model to assess the impacts of a 7 MGD water use on two karst lakes that are covered under Florida's Minimum Flows and Level (MFL) program. Conducted research into the conditions at the lakes as well as the development of the regional groundwater model used by the water management districts to assess impacts. Determined the wells would have minimal impacts on the lake levels.

10/26/2021 – 8/1/22, City of Cedar Rapids – Flood Control System, Cedar Lake Levee, IA
As lead modeler and hydrogeologist, developed a model to assess construction dewatering's impact on groundwater contamination plumes adjacent to the levee construction. The planned dewatering will be between 20,000 and 30,000 GPM and water quality in the dewatering system's discharge is a limiting factor. The model was used to estimate discharge water quality based on a sampling program conducted for the dewatering and identify alternative methods to reduce potential levels of iron and ammonia in the discharge. Ongoing.

8/6/2019 – 2/1/22, Confidential Client – Groundwater Model of Coal Combustion Residual Storage Facility
As lead modeler, developed groundwater flow model and constituent fate and transport model and geochemical evaluation of a coal ash storage facility in Nebraska. The model was used to evaluate the occurrence of the constituents in the groundwater, their impact on the adjacent river and the effectiveness of

Queuing Effects", presented at the 6th International Conference on Remediation of Contaminated Sediment, New Orleans LA, 2011

McDonald, S.D., Howe, P., "Evaluating the Effects of Open-Pit Iron Ore Mining on South Australia's Eyre Peninsula's Regional Water Resources", Proceedings American Institute of Professional Geologists 2009 Geology and Resources Conference, Grand Junction CO, 2009

McDonald, S.D., Jablokow, K.W., "Understanding Ourselves and the Role of 'Innovation' in Science," written at the invitation of the editor of Learned Discourses: Timely Scientific Opinions in *Integrated Environmental Assessment and Management*, Vol. 5, No. 3, pp. 483-491, Summer 2009.

McDonald, S.D., Atmadja, J., "Groundwater Evaluation Process for the USMC's REVA Program," presented at the Environment, Energy Security & Sustainability (E2S2) Symposium & Exhibition Colorado Convention Center, Denver, CO, May 4–7, 2009.

McDonald, S.D., Weiland, E.F., Bell, C.F., Lang, D.C., "Using One and Two-Dimensional Models as Screening Tools: Are They Useful for Decision Making?," presented at the 2009 Ground Water Summit and 2009 Ground Water Protection Council Spring Meeting of the National Ground Water Association (NGWA), Tucson AZ, April 19-23, 2009.

McDonald, S.D., "Fate of Persistent Chemicals in Tidal Passaic River Sediments," invited speaker at Workshop on

potential corrective measure.

7/11/2019 – Ongoing, Confidential Client - Brickhaven Mine Tract "A" Structural Fill Hydrogeologic Investigation and Compliance Monitoring, Brickhaven, NC
As lead groundwater modeler, developing a site conceptual model of the structural fill and potential releases of contaminants. The structural fill is a mono-fill of coal ash contained in a double lined and capped landfill with redundant leachate collection systems. The conceptual model lead to hydrogeologic investigations and groundwater modeling to assess any releases that may have occurred and determine long-term corrective actions if necessary.

08/13/2018 – 7/14/2020, Confidential Client – Groundwater Model of Coal Combustion Residual Storage Facility
As lead modeler, developed groundwater flow model and constituent fate and transport model of a coal ash storage facility in Nebraska. The model simulates the complex hydrologic history of the site over a 40-year period and then the fate and transport of constituents that have statistically significant increases (SSI's) associated with the facility.

10/26/2018 – 8-15-2019, Confidential Client – Evaluation of CCR Facilities' Hydrogeologic Settings and Development of Groundwater Modeling Process
As lead modeler, developed preliminary conceptual models of groundwater conditions at six fossil fuel power plants with respect to the storage of CCR. Included site visits to all six plants, review of historic investigation and documents, and interactions with plant personnel. Developed a phased approach to evaluate the CCR facilities at these plants using groundwater models in an iterative process.

4/23/2019 – 3/9/2022, City of Clinton, Iowa – Pumping Station Upgrade Dewatering
As lead modeler, developed a groundwater model to simulate construction dewatering needed to upgrade the subsurface structures of a pumping station adjacent to the Mississippi River. The modeling was used to assess if the dewatering would inadvertently capture contaminated groundwater from a nearby Superfund Site.

1/24/2019 – Ongoing, Piedmont Lithium Mine, North Carolina
Developed a groundwater model to simulate pit dewatering at a planned lithium mine in North Carolina to estimate dewatering rates and evaluate impacts on local water resources. The transient groundwater flow model was used to simulate 20 years of planned mining.

1/10/2018 – 8/23/2018, United States Environmental Protection Agency - TuTu Wells Superfund Site, U. S. Virgin Islands
As lead modeler developed a model to simulate the interactions between chlorinated solvents in groundwater and rock matrix (matrix diffusion) to evaluate the effects of remedial alternatives on long term concentrations in groundwater arriving at the point of compliance.

12/20/2017 – Ongoing, Confidential Client – Simulation of MTBE and Benzene in a Karst Aquifer, PA
As lead modeler, developed a groundwater model to simulate groundwater flow

Contaminated Soils sponsored by the Australian Society of Soil Science Inc. (ASSSI), South Australia Branch, University of South Australia, Mawson Lakes Campus, March 24, 2009.

McDonald, S.D., Jablokow, K.W., "Embracing Cognitive Diversity in the Progression of Science," poster presentation at the 29th Annual Meeting of the Society of Environmental Toxicology and Chemistry (SETAC North America 2008),Tampa FL, November 16-20, 2008.

McDonald, S.D., "The Geologist and Cognitive Diversity as a Key to Problem Solving," Proceedings, Joint 45th Annual Meeting of the American Institute of Professional Geologists (AIPG), 21st Annual Symposium of the Arizona Hydrological Society (AHS), and 3rd International Professional Geology Conference IPGC), Flagstaff AZ, September 21-23,2008.

McDonald, S., Accardi-Dey, A., Atmadja, J., Garvey, E., and Fidler, B., "Fate of Persistent Chemicals in Tidal Passaic River Sediments," Presented at The International Conference on Remediation of Contaminated Chlorinated and Recalcitrant Compounds, Monterey, CA, May 19-22, 2008

McDonald, S., Fidler, B., Garvey, E., and Talley, J., "Underwater Dirt: Empirical Approaches to Understanding Contaminant Fate in Sediments" Presented at the Joint Services Environmental Management Training Conference and Exposition,

and the fate and transport of MTBE and benzene in a complex karst aquifer. The model was based on the folded and faulted local structural geology and was used to predict where these constituents may ultimately be transported.

NON-HDR EXPERIENCE (Pre-November 9, 2017)

NYCDEP – Newtown Creek Wastewater Treatment Plant Upgrade Construction Dewatering
As lead modeler, developed a groundwater model to simulate construction dewatering needed during the 8-year, multi-billion-dollar upgrade of the Newtown Creek Waste Water Treatment Plant which receives waste water from large portions of Manhattan, Brooklyn and Queens. The simulations were used to assess the need for water-tight sheet piling during subsurface structure construction and to estimate dewatering volumes for the water withdrawal permitting needed for the project. The modeling was conducted prior to construction and then updated as construction proceeded for each phase of the construction.

The Republic of Ecuador – Assessment of Oil Field Remediation and Environmental conditions for International Arbitration
As project manager and consulting expert, lead an expert team in a multi-year assessment of the environmental conditions and effectiveness of previous remediation in a large oil field concession area in a South American country. Including investigations of conditions at multiple well sites and productions stations with emphasis on closure of reserve pits and contamination in adjacent water resources. Resulted in preparation of 4 expert reports and three experts from the team testifying in the arbitration before an international tribunal and an in-country well-site visit by the international arbitrators.

NYCDEP – Gowanas Canal / New York, NY
As lead hydrogeologist, developed a groundwater model to estimate the amount of contaminants loaded from a large dense non-aqueous phase liquid (DNAPL) body and dissolved in the groundwater to the canal sediments and surface water. The model used MODFLOW to simulate groundwater flow and SEAM3D to simulate dissolution of the DNAPL as well as contaminant transport. The DNAPL was a coal tar, composed of several different constituents. Four prominent constituents, which represented different classes of contaminants, were simulated simultaneously in the transport model. Designed and implemented a study to assess groundwater impacts on surface water. The study was published as a peer-reviewed paper in *Remediation Journal* in Autumn 2016, with Mr. McDonald as lead author.

OFA - Kansas City District: Cornell Dublier Superfund Site / Bound Brook, NJ.
As lead modeler, developed a groundwater model to evaluate the fate and transport of chlorinated solvents in a multiple media aquifer system. The model domain included both porous media and fractured rock aquifers and the effects of several well fields tapping both materials and interactions with surface water features. The effort was supported by Dr. John Cherry and Dr. Beth Parker from the University of Guelph, Ontario and resulted in a peer-reviewed paper regarding innovative modeling approach in *Remediation Journal* (Mr. McDonald was corresponding author). The unique approach to the modeling included using the USGS's finite difference model, MODFLOW, to simulate the groundwater flow and the discrete fracture network model, FRACTRAN, to evaluate the

Denver, CO, May 5-8, 2008

McDonald, S., Hansen C., Accardi-Dey, A., Atmadja, J., Garvey, E., and Fidler, B., “Advances in the Conceptual Site Model of the Lower Passaic River’s Contamination History,” Presented at The Fourth International Conference on Remediation of Contaminated Sediment, Savannah, GA, January 25-26, 2007

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contaminants transport and interaction with the bedrock aquifer, including matrix diffusion. Included collecting and evaluating hydrogeologic data from the field to support the modeling effort.

U.S. Marine Corps (HQMC), USMC FY06/07/08/09 Range Environmental Vulnerability Assessment (REVA), Mobile, Alabama
As program technical leader, develop process for evaluating operational military range's potential to impact adjacent environment through munitions constituent transport in groundwater and surface water. Provided technical guidance to use of the process on all of the Marine's operational ranges. Interact with HQMC and installation environmental staff to assure that investigations of operational ranges are being completed accurately, efficiently, and in accordance with DoD directives including responding to third-party review of all documents. Responsible for technical content of documents produced in this far-reaching program. This program received the National Ground Water Association’s 2009 Award for Outstanding Project in Ground Water Protection.

Nestle Waters North America: Sanctuary Springs Investigation / Mecosta MI.
As Project Manager, evaluated Sanctuary Springs as a potential source for a spring water bottling plant, including extensive field investigations, groundwater modeling and well and well-field design, installation, testing and commissioning. Ultimately four production wells were designed, installed and brought into production. The effects of withdrawals from the wellfield were evaluated with multiple pumping tests and extensive detailed groundwater and surface water monitoring. The project involved working closely with legal teams, lobbyists, local and state governments, as well as with public relation firms and community stakeholders. The project resulted in the successful permitting of four Type II water supply wells to supply a new spring water bottling plant. Once the plant was established there was a legal challenge to the supply, where Mr. McDonald provided litigation support and expert testimony. The Sanctuary Springs project was awarded the National Ground Water Association's 2002 Outstanding Project in Water Supply.

OFA - Kansas City District: Hudson River PCB Superfund Site / New York
As senior team member, evaluated the results of the first season of dredging in the Hudson River and prepared a report for a peer review panel review of the dredging and the Engineering Performance Standards (EPS). Prepared analyses of the program’s ability to achieve the goals of the Record of Decision and the EPS. Created a model of the scow unloading to assess the efficiency of the scow management during the project and the impacts of scow queues on the project’s productivity. Was lead author in the final Engineering Performance Standards, which were accepted by both the USEPA and the potentially responsible party, General Electric.

OFA - Kansas City District: Passaic River / Newark NJ
Lead scientist on Conceptual Site Model development and geochemical evaluations conducted for the highly contaminated 17-mile tidal portions of the Passaic River. This high-profile project involves interaction with several state and federal agencies and with a large multi-entity cooperating parties group. The assessments involve evaluating the multiple persistent contaminants that are found in the river's water column and sediments and pore-water. Assisted in the evaluation of multiple years of bathymetric data to assess the dynamic nature of the river bottom sediments. Tasks also included developing the project work plan

and field sampling plans, overseeing highly technical subcontractors including modelers and risk assessors, working with the Technical Advisory Committee and simulating pore water flux with computer models.

Michigan Department of Environmental Quality, AAR Cadillac
As project manager oversaw investigation of chlorinated solvents in groundwater. Included well drilling, groundwater sampling, interfacing with client and potentially responsible party. Ultimately provided expert testimony on the groundwater contamination, including depositions and in-court testimony.

Malcolm Pirnie – Crane Arbitration, Phoenix AZ
As technical lead, supported Malcolm Pirnie, Inc. during arbitration with a former client regarding a discharge from a defective treatment system of partially treated groundwater containing chlorinated solvents and perchlorate back into the aquifer. Evaluated the occurrence of the defect and the timing of groundwater contamination using a groundwater model. Worked closely with outside experts, including Dr. C. W. Fetter, the author of hydrogeology textbook, Applied Hydrogeology, and Jim Rumbaugh, author of the groundwater modeling software Groundwater Vistas.

Confidential Client: Groundwater modeling / New York
Created a groundwater model based on more than 30 years of pumping records from an urbanized sole-source aquifer on Long Island, New York. The model was used to evaluate the effects of pumping from approximately 30 municipal and industrial wells on the fate of chlorinated solvents in groundwater emanating from a hazardous waste site and the potential for that contamination to impact the water supply. Also used advanced geostatistical techniques to separate and distinguish contaminant plumes with sources on adjacent properties.

New York City Department of Environmental Protection: Brooklyn-Queens Aquifer Restoration Project / New York, New York.
Developed a groundwater model of Western Long Island, including the New York City Burroughs of Brooklyn and Queens designed to evaluate the restoration of underlying aquifers for municipal water supply. The aquifer beneath Brooklyn and Queens has been rising since the Jamaica Water Supply company shut down in the mid-1900's. The model was used to evaluate optimizing water use from dewatering of subsurface structures such as subway stations for alternative water supplies while providing a benefit of lowering the aquifer levels at strategic locations.

Confidential Client - Evaluation of Oil Sands Tailings Storage Facility
As lead modeler, oversaw the development of a groundwater model to evaluate control of process water impacted groundwater at a tailings pond for an oil sand mine in Alberta, Canada.

Tybout's Corner Landfill Trust, Remedial Design, New Castle County, Delaware
Located eight interceptor wells for the Tybouts Corner Landfill Superfund Site remediation using three-dimensional groundwater model and site data. Designed the interceptor well screens. Conducted and evaluated 72-hour pumping tests on the interceptor wells. Developed operation and maintenance program for interceptor well system as well as groundwater monitoring program to evaluate the system's effectiveness. Once the system was in operation, developed methods to reduce iron bacteria fouling of the interceptor wells and conveyance

system.

U.S. Army Corps of Engineers, Baltimore District, RCRA Corrective Action at Watervliet Arsenal, Watervliet, New York
Conducted groundwater modeling to design a reactive-wall remediation of TCE contaminated groundwater. Included use of MODFLOW and MODPATH. Published paper (Lang, McDonald, Goldstein) of results. Centrex Metals, Inc., Wilgerup Iron Ore Project, Regional Water Resources Study, South Australia. As lead scientist, evaluated the long-term effects of the planned open mine pit on regional water resources to assist Centrex in acquiring their Mine Lease Permit.

BHP-Billiton Olympic Dam Expansion - Yarrawerta Springs Evaluation, South Australia.
As lead scientist, evaluated the hydrogeologic setting of Yarrawerta Springs, a sensitive ecological resource at the northern end of dry Lake Torrens, with respect to the planned Olympic Dam Expansion.

Centrex Metals, Inc., Wilgerup Iron Ore Project - Regional water resources study, South Australia.
As lead scientist, evaluated and modeled the long-term effects of the planned open mine pit on regional water resources. Included evaluation of extensive hydrogeologic data base from on-site testing as well as historic records from the region. This study developed a comprehensive and quantitative hydroegologic conceptual model to evaluate the effects of evaporation at the open pit mine on regional ground water resources, in particular sensitive freshwater lenses that were the main water supply for agriculture and municipalities.

In-situ Uranium Leaching hydrogeochemical evaluations, Confidential Client South Australia.

As technical lead, evaluate water resource and disposal options for planned in-situ leachate uranium mining facility. Evaluated geochemical implications of various aspects of the planned operation as well as hydraulic effects of water supply, mining and wastewater disposal.

Bruckunga Mine South Australia Dept. of Ind. & Resource Adelaide SA Australia
Evaluated Acid Rock Drainage at a former pyrite mine in the Adelaide Hills east of Adelaide. As technical lead and in conjunction with a technical advisory group, helped design and implement a course of investigation that included geologic mapping, oriented rock coring, rotosonic drilling through waste rock piles, installation of monitoring wells, aquifer testing by packer tests and slug tests, collecting soil, water and groundwater samples for chemical analyses.

Salt Mining Facility: Evaluation of Areas of Environmental Concern / Monterey Mexico
Evaluation of areas of environmental concern at a large salt mining facility; included field mapping, development of stratigraphic section and cross-section. Prepared report on findings and recommendations for further studies and remedial measures.

Fort Drum: BTEX Plume / Fort Drum NY
Conducted groundwater modeling for the United States Army Corp of Engineers, including MODFLOW, MODPATH, and MT3D of remediation efforts, designed to clean up a BTEX plume in groundwater at a military base in New York.

Beverage Bottler: Production Well Rehabilitation / Guadalajara, Mexico
Investigated the source of microbes occurring in a groundwater source at a beverage bottling plant in Mexico. Determined that the plant's production well was not satisfactorily sealed from surface water infiltration. Oversaw the rehabilitation of the plant's well.

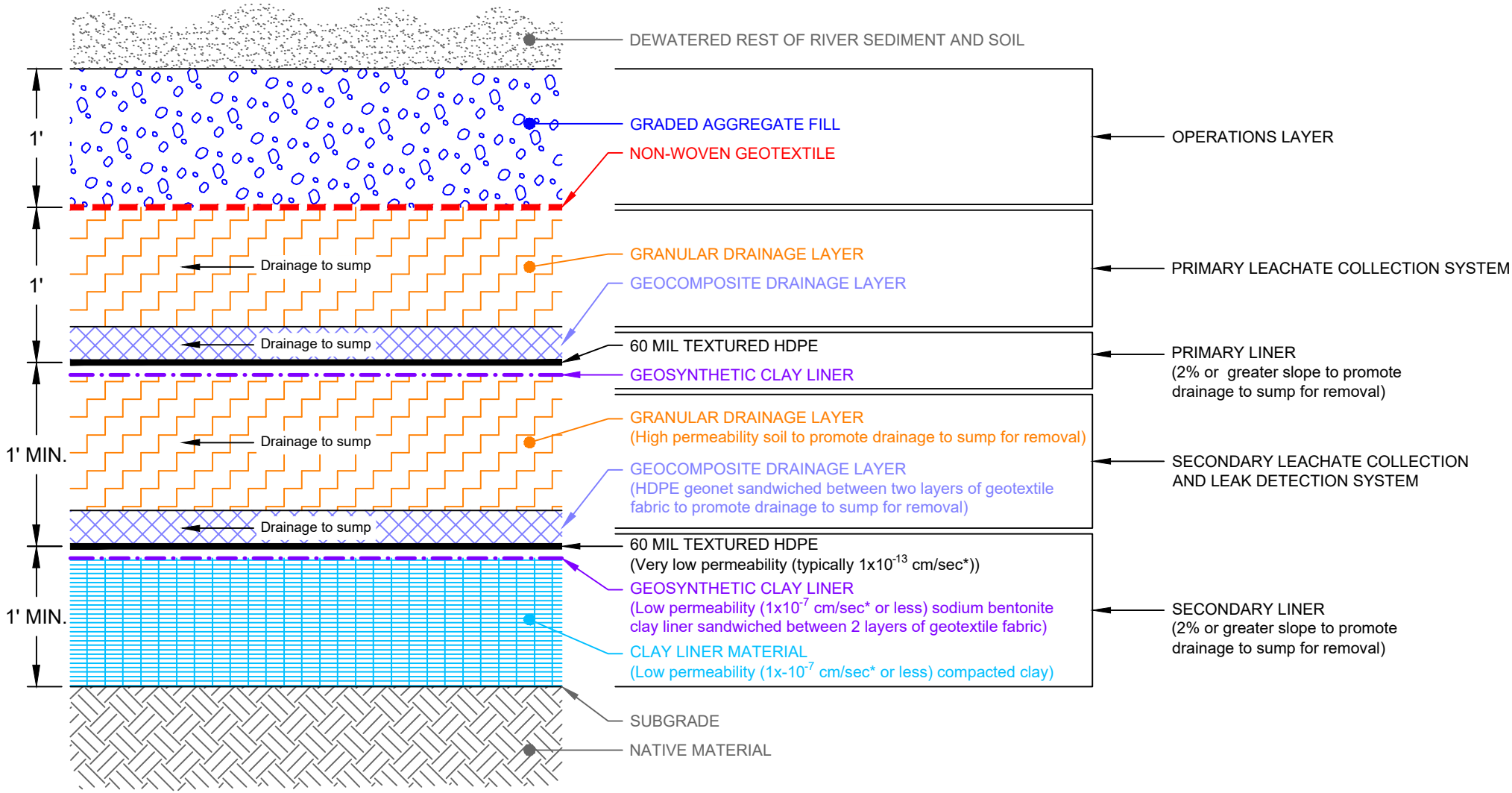
Cape Coral Groundwater Model – Cape Coral, Florida
As technical quality consultant, reviewed and guided the development of a regional groundwater model. The model was used to evaluate the effects of municipal withdrawals on the aquifers and the potential for saltwater intrusion. This information guided optimization of well field usage and drilling of new supply wells.

Michigan Department of Environmental Quality, Easton Tar/Methane Remediation, Kingsford, Michigan
As project manager, assisted the MDEQ in evaluating PRP submittals concerning a highly complex groundwater contamination and methane migration occurrence at a large wood tar site in northern Michigan. Included review of RI documents as well as confirmatory investigations.

FLOOR BASE LINER SYSTEM

NOT TO SCALE

Adapted from GE's UDF Conceptual Design Plan dated December 6, 2022



*$1x10^{-13}$ cm/sec = 0.0000000000001 centimeters per second permeability
*$1x10^{-7}$ cm/sec = 0.0000001 centimeters per second permeability

Applicable Revised Permit Performance Standards

II.B.5.a.2.(c) - The Upland Disposal Facility shall consist of a double bottom liner, separated by a drainage layer, and shall incorporate primary and secondary leachate collection systems.

II.B.5.a.2.(f) - Liners (bottom liners and cap liners) shall have a permeability equal to less than 1 x 10^{-7} cm/sec*, a minimum thickness of 30 mils and be chemically compatible with PCBs.

UDF Configuration

Figure not to scale

grass
top soil
soil fill material
low-permeability liners
dewatered soil/sediment

leachate treatment

dewatered soil/sediment

slope

leachate pipes from sumps to treatment

sumps

monitoring well network

15 foot minimum depth to groundwater

drainage layer / leachate collection to sump
low permeability liners
drainage layer / leachate collection to sump
low permeability liners
clay liner material