United States
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Superfund Remedy Report

16th Edition

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Top left: Bird resting on boom at New Bedford Harbor Site in Massachusetts. Photo courtesy of EPA Region 1, https://www.flickr.com/photos/usepagov/sets/72157625453872678/

Top middle left: Soil sampling at Smokey Mountain Smelters in Tennessee. Photo courtesy of EPA, https://response.epa.gov/site/image_zoom.aspx?site_id=4643&counter=133144&category=&ReturnURL=image_listview.aspx

Top middle right: Mechanical dredging at New Bedford Harbor Site in Massachusetts. Photo courtesy of EPA Region 1, https://www.flickr.com/photos/usepagov/31537773908/in/album-72157625453872678/

Top right: Filter press at New Bedford Harbor Site in Massachusetts. Photo courtesy of EPA Region 1, https://www.flickr.com/photos/usepagov/sets/72157625453872678/

Middle left: Treatment vessels at Fairfax St. Wood Treaters in Florida. Photo courtesy of EPA, https://response.epa.gov/site/image_zoom.aspx?site_id=6253&counter=120810&category=&ReturnURL=image_listview.aspx

Middle center: Structure demolition at Savannah River Site in South Carolina. Photo courtesy of EPA Region 4, https://www.epa.gov/superfund/superfund-success-stories-epa-region-4

Middle right: Treatment plant at Bunker Hill Mining and Metallurgical Complex in Idaho. Photo courtesy of EPA Region 10, https://www.epa.gov/superfund/superfund-success-stories-epa-region-10

Bottom left and right: Before and after photographs of the Milltown Reservoir Sediments Site in Montana. Photos courtesy of EPA Region 8, https://www.flickr.com/photos/usepagov/14625061943/in/album-72157645621495463/

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Notice and Disclaimer

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A portable document format version of *Superfund Remedy Report (SRR) 16th Edition* is available for viewing or downloading from www.epa.gov/remedytech/superfund-remedy-report. The data that forms the basis of the analyses contained in *SRR 16th Edition* can be found at https://www.epa.gov/superfund/superfund-data-and-reports by downloading *Contaminant of Concern Data for Decision Documents by Media, FY 1982-2017* and *Remedy Component Data for Decision Documents by Media, FY 1982-2017*.

Acronyms and Abbreviations

ASR	Annual Status Report
BTEX	Benzene, toluene, ethylbenzene, xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Contaminant of concern
DNAPL	Dense non-aqueous phase liquid
EK	Electrokinetics
EMNR	Enhanced monitored natural recovery
EPA	U.S. Environmental Protection Agency
ESD	Explanation of significant differences
FY	Fiscal year
IC	Institutional control
ISCO	In situ chemical oxidation
ISCR	In situ chemical reduction
ISTT	In situ thermal treatment
LNAPL	Light non-aqueous phase liquid
MNA	Monitored natural attenuation
MNR	Monitored natural recovery
NAPL	Non-aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
OU	Operable unit
P&T	Pump and treat
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PRB	Permeable reactive barrier
ROD	Record of Decision
S/S	Solidification/stabilization
SRR	Superfund Remedy Report
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
TCE	Trichloroethene
TI	Technical impracticability
VOC	Volatile organic compound

Executive Summary

The U.S. Environmental Protection Agency (EPA) prepared the *Superfund Remedy Report (SRR) 16th Edition* to provide information and analyses on remedies selected to address contamination at Superfund sites. The statute authorizing EPA to clean up uncontrolled hazardous waste sites and spills established a preference for remedial actions in which treatment permanently and significantly reduces the volume, toxicity or mobility of the hazardous substances, pollutants, and contaminants. Hence, EPA is particularly interested in documenting and disseminating information on treatment technologies that advance its mission of protecting human health and the environment at contaminated sites. This report is the latest in a series, prepared since 1991, on Superfund remedy selection.

The *SRR* series provides historical trends of remedies selected in Superfund decision documents and more detailed analyses of recent remedies. The previous edition, *SRR 15th Edition*, included remedies selected in fiscal years (FYs) 1981 through 2014. The *SRR 16th Edition* updates remedy trends and includes detailed analyses of remedies selected in FYs 2015, 2016, and 2017. Decision documents include Records of Decision (RODs), ROD amendments, and explanations of significant differences (ESDs) for National Priorities List (NPL) and Superfund Alternative approach sites. From the inception of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) through FY 2017, EPA has signed 5,601 decision documents, including 3,867 RODs, 472 ROD amendments, and 1,262 ESDs, for 1,603 Superfund sites[1]. Data from these documents form the basis for the SRR remedy analysis. The SRR compiles data on remedies and presents separate analyses for contaminants overall and contaminants in select media (soil, sediment, and groundwater). This edition also provides a discussion of groundwater technical impracticability (TI) waivers included in decision documents.

For the majority (78 percent) of the 1,595 Superfund sites with decision documents available, treatment has been selected, often in combination with other remedies. Most of these sites have more than one contaminated medium, most frequently groundwater and soil. Most sites also have different types of contaminants of concern (COCs): more than half of sites address volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs) and metals, while a quarter of sites address two of these groups.

For FYs 2015 to 2017, remedies were selected in 272 decision documents, including 174 RODs, 39 ROD amendments, and 59 ESDs with remedial components (out of a total of 140 ESDs). Of the 272 decision documents, 175 (64 percent) include a remedy for source materials (such as soil and sediment) and 110 (40 percent) for groundwater. Remedies were also selected for soil gas and air related to vapor intrusion.

For this three-year period, more than 40 percent of decision documents with source remedies include treatment. One-fifth of all source decision documents include in situ treatment. In situ solidification/stabilization (S/S), soil vapor extraction, and in situ thermal treatment are the most frequently selected in situ treatment technologies for sources with soil being the most common source medium addressed. Physical separation is the most common ex situ treatment method.

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[1] There are eight sites with no documents available, leaving 1,595 sites with documents available for analysis.

Metals, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) are the COCs most commonly addressed.

Of the 175 recent source decision documents, 40 include a remedy for sediments. Most of the sediment decision documents (88 percent) include dredging, excavation, off-site disposal, or on-site containment as part of the selected remedy. Some treatment was also selected — for example, physical separation, amendments, and in situ amended caps. Examples of other sediment remedies include wetlands restoration and enhanced or monitored natural recovery. Nearly two-thirds of the sediment decision documents include institutional controls (ICs). Metals, PCBs, and PAHs are the COCs most frequently addressed.

For the 110 groundwater decision documents signed in FYs 2015 to 2017, the groundwater remedies continue to be primarily a mix of in situ treatment, pump and treat (P&T), and monitored natural attenuation (MNA); most also include ICs. The use of in situ groundwater treatment is selected in over half of groundwater decision documents. Of these, bioremediation and chemical treatment remain the most frequently selected. The majority of in situ bioremediation remedies specify anaerobic bioremediation, and most chemical treatment remedies specify in situ chemical oxidation. The selection of P&T in groundwater decision documents has decreased significantly since the early 1990s and continues to decline, averaging approximately 20 percent for FYs 2015 to 2017. Groundwater MNA also decreased to 20 percent. Containment technologies (vertical engineered barriers such as slurry walls) were selected at one site. By far, halogenated VOCs (primarily chlorinated VOCs) are the most common type of groundwater COC, addressed in 74 percent of recent groundwater decision documents.

This edition includes a new section summarizing groundwater TI waivers. From FYs 1988 to 2017, 105 decision documents have included TI waivers for groundwater at 96 sites.

In this report, EPA also discusses optimization reviews. The optimization highlights provide examples of how optimization efforts have informed remedy selection in recent decision documents.

In addition, vapor intrusion mitigation was selected for existing structures in 8 recent decision documents, and ICs for either existing structures or future construction in 40. Some ICs restrict the future use of structures to avoid vapor intrusion exposure and others require the installation of mitigation systems as part of future construction. Active depressurization is the most common mitigation method specified.

The remedy and site information provided in this report informs stakeholders in Superfund communities about the program's remedy decisions and helps federal, state, and tribal remediation professionals select future remedies. Analyzing the trends in remedy decisions provides an indication of the future demand for remedial technologies, which helps technology developers and consulting and engineering firms evaluate cleanup markets. The trends also indicate program needs for expanded technical information and support related to specific technologies or site cleanup challenges. For example, continued selection of in situ groundwater technologies suggests an ongoing need for additional knowledge and support associated with those technologies.

I. Purpose and Introduction

The U.S. Environmental Protection Agency's (EPA) Office of Superfund Remediation and Technology Innovation prepared this *Superfund Remedy Report (SRR) 16th Edition* to share analysis of remediation technologies selected to address contamination at Superfund sites. EPA is particularly interested in documenting and disseminating information on treatment technologies to advance its mission of protecting human health and the environment at contaminated sites. The report focuses on treatment because the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) has a statutory preference for treatment.[2]

The *SRR 16th Edition* adds remedy information from decision documents issued during fiscal years (FYs) 2015, 2016, and 2017. The data in this report build on the evaluations in the 12 editions of *Treatment Technologies for Site Cleanup: Annual Status Report* (ASR), which covered the timeframe from FY 1982 through a portion of FY 2005; *SRR 13th Edition* (FYs 2005 to 2008); *SRR 14th Edition* (FYs 2009 to 2011); and *SRR 15th Edition* (FYs 2012 to 2014).

Selected remedial actions for Superfund sites, including National Priorities List (NPL) and Superfund Alterative approach sites are recorded in a decision document, such as a Record of Decision (ROD), ROD amendment, or explanation of significant differences (ESD). The information in this report was extracted from these Superfund decision documents. This report inventories all remedies selected, however, not all selected remedies are ultimately implemented. Sometimes changes are made prior to implementation. For example, a different remedy may be required when a treatment technology that was selected in a ROD based on bench-scale treatability testing proves ineffective in pilot-scale tests conducted during the design phase. In addition, a remedial technology may be added to the original remedy if additional contamination is discovered during remedy implementation or a different approach can more efficiently address residual contamination. Furthermore, a particular remedy may have been included in a ROD as a contingent remedy, but subsequent site investigations reveal that implementation is not necessary. Fundamental changes to remedies selected in a ROD are documented in a ROD amendment, and significant changes are documented in an ESD.

A site can be divided into a number of operable units (OUs), which can result in multiple decision documents. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) defines an OU as "a discrete action that comprises an incremental step toward comprehensively addressing site problems. This discrete portion of a remedial response manages migration, or eliminates or mitigates a release, threat of a release, or pathway of exposure. The cleanup of a site can be divided into a number of OUs, depending on the complexity of the problems associated with the site. OUs may address geographical portions of a site, specific site problems, or initial phases of an action, or may consist of any set of actions performed over time or any actions that are concurrent but located in different parts of a site."[3] Figure 1 illustrates an example of a

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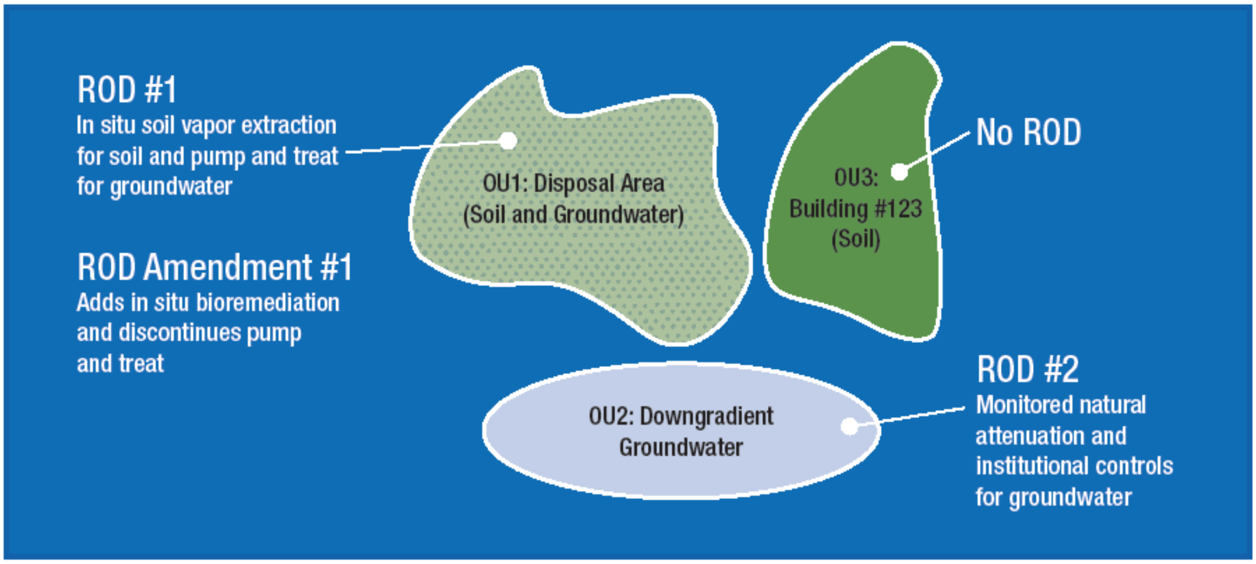
[2] Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the amendments made by subsequent enactments (42 U.S.C. 9601-9675).

[3] Code of Federal Regulations (CFR), title 40, sec 300.5. www.gpo.gov/fdsys/pkg/CFR-2001-title40-vol24/pdf/CFR-2001-title40-vol24-sec300-5.pdf

remedial approach at a site with multiple OUs, decision documents, and remedies. In the example, the site has been divided into three OUs, with two addressing separate sources and two addressing groundwater. In the example, EPA has issued a ROD and ROD amendment for the OU1 source area. The OU1 ROD amendment made a fundamental change to the application of the selected soil vapor extraction (SVE) technology by adding in situ bioremediation and discontinuing pump and treat (P&T). OU2 has a ROD that addresses groundwater downgradient from OU1 and OU3. OU3 addresses a separate source area that is still under investigation and does not yet have a decision document.

Figure 1: Example Remedial Approach at a Site



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The *SRR 16th Edition* includes 10 sections and 3 appendices.

- Section I discusses the purpose and introduces the report.
- Section II describes the approach used to collect and analyze data.
- Section III describes the scope of the report.
- Section IV analyzes types of remedies and media addressed at Superfund sites.
- Section V analyzes contaminants of concern (COC) included in decision documents.
- Section VI discusses source remedies, including a breakout of sediment remedies.
- Section VII discusses groundwater remedies, including technical impracticability (TI) waivers and optimization highlights.
- Section VIII discusses vapor intrusion remedies.
- Section IX presents conclusions.
- Section X lists the data sources and provides information on how to access the electronic version of this and previous editions of SRR.
- Appendix A provides the definitions of selected remedies.
- Appendix B lists treatment technologies by fiscal year.
- Appendix C lists individual contaminants and their assigned contaminant groups and provides an analysis of detailed contaminant groups by media.

II. Approach

EPA used data from decision documents available as of November 2019 to compile information about remedy selection for all years with a focus on the most recent three years (FYs 2015, 2016 and 2017).[4] The data used include remedies selected in decision documents (RODs, ROD amendments, and select ESDs). Only ESDs with additions or changes to remedy components were included in the remedy analyses. ESDs were not included if they did not change a remedy component but instead addressed another aspect of the remedy, such as quantity of material to be addressed, COCs, cost information, or monitoring requirements.

The SRR remedy analysis distinguishes between remediation of contaminated source materials and non-source materials such as groundwater. EPA defines "source material" as "material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contamination to ground water to surface water, to air, or acts as a source for direct exposure." This includes contaminated soil, sludge, sediment, solid waste, debris, drummed waste, leachate, and any non-aqueous phase liquid both light (LNAPL) and dense (DNAPL) (EPA, 1991a). Groundwater is considered "non-source material" (EPA, 1991a).

The report groups remedies into major categories, indicated by the green bars in Table 1. It discusses remedies as related to source, groundwater, or vapor intrusion based on the media addressed. Appendix A provides definitions of all categories and corresponding remedy types under each category.

Table 1: Summary of Remedy Categories

Source Control
Treatment
· Alters the composition of a hazardous substance or pollutant or contaminant through chemical, biological, or physical means to reduce toxicity, mobility, or volume of contaminated source media · Can be either in situ or ex situ · Examples include chemical treatment and in situ thermal treatment
On-site Containment
· Examples include the use of caps, liners, covers, and landfilling on site
Off-site Disposal
· Includes excavation and disposal at an off-site facility
Monitored Natural Attenuation (MNA)
· Reliance on natural processes[5] · Natural recovery processes may include physical, chemical, and biological processes
Monitored Natural Recovery (MNR)
· Reliance on natural processes to reduce risk from sediments · Natural recovery processes may include physical, chemical, and biological processes

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[4] The data that forms the basis for the analyses contained in *SRR 16th Edition* is available for download at https://www.epa.gov/superfund/superfund-data-and-reports.

[5] For further information about MNA, refer to Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Office of Solid Waste and Emergency Response. April 21, 1999. OSWER Directive No. 9200.4-17P. https://semspub.epa.gov/src/document/HQ/159152.pdf

Source Control (continued)
Enhanced Monitored Natural Recovery (EMNR)
· Combines natural recovery with an engineered approach for sediments · Typically includes placing a thin layer of clean sediment to accelerate the recovery process
Institutional Controls
· Non-engineered instruments, such as administrative and legal controls, that help minimize the potential for human exposure to contamination and protect the integrity of the remedy · Examples for source media include land use restrictions and access agreements
Other
· Source control remedies that do not fall into the categories of source control treatment, on-site containment, off-site disposal, MNA, MNR, EMNR, or institutional controls · Examples include wetlands replacement and shoreline stabilization
Groundwater
In Situ Treatment
· Treatment of groundwater in place without extraction from an aquifer · Examples include in situ chemical oxidation and in situ bioremediation
Pump and Treat (P&T)
· Pumping of groundwater from a well or trench, followed by aboveground treatment · Examples of aboveground treatment include air stripping and granular activated carbon
Monitored Natural Attenuation (MNA)
· Reliance on natural attenuation processes[6] · Natural attenuation processes may include physical, chemical, and biological processes
Containment
· Containment of groundwater using a vertical, engineered, subsurface, impermeable barrier
Institutional Controls
· Examples for groundwater include drilling restrictions and water supply use restrictions
Alternative Water Supply
· Examples include installing new water supply wells, providing bottled water or extending a municipal water supply
Other
· Groundwater remedies that do not fall into the categories of in situ treatment, P&T, MNA, containment, institutional controls, or alternative water supply · Examples include drainage/erosion control and wetlands restoration
Vapor Intrusion
Mitigation
· Mitigation of soil gas or indoor air to reduce exposure to vapor contamination in buildings · Examples include active depressurization technologies and passive barriers
Institutional Controls
· Examples for vapor intrusion include land use restrictions and requirements for vapor intrusion mitigation for new buildings

This report includes remedies selected in the Superfund remedial program, including treatment, containment, and remedial components such as institutional controls (ICs); treatment technologies are discussed in more detail. "*Treatment technology* means any unit operation or series of unit operations that alters the composition of a hazardous substance or pollutant or

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[6] Ibid.

contaminant through chemical, biological or physical means so as to reduce toxicity, mobility or volume of the contaminated materials being treated."[7]

In the analysis conducted for the SRR, monitoring is not included separately as a remedy. According to EPA guidance, "[a]n alternative may include monitoring only and still be considered 'no action.'" (EPA, 1999a). Thus, monitoring is not considered itself a remedy. However, the Superfund program recognizes the importance of effective monitoring and has implemented a long-term monitoring optimization strategy.[8]

The report presents data in figures at the decision document-level or at the site-level, depending on the objective of the figure. For some figures, decision documents that selected multiple remedies are counted in each remedy category, as appropriate. For example, a single decision document that selected both in situ treatment and a cap is listed in both remedy categories. For other figures, a hierarchy is used to classify a decision document into a single category of remedy types. This hierarchy has been established to represent the data consistent with the CERCLA statutory preference for treatment. Notes on individual figures and tables indicate whether a hierarchy was used. Additionally, some figures present historical or cumulative data, and others focus on recent remedy selection.

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[7] CFR, title 40, sec 300.5. www.gpo.gov/fdsys/pkg/CFR-2001-title40-vol24/pdf/CFR-2001-title40-vol24-sec300-5.pdf

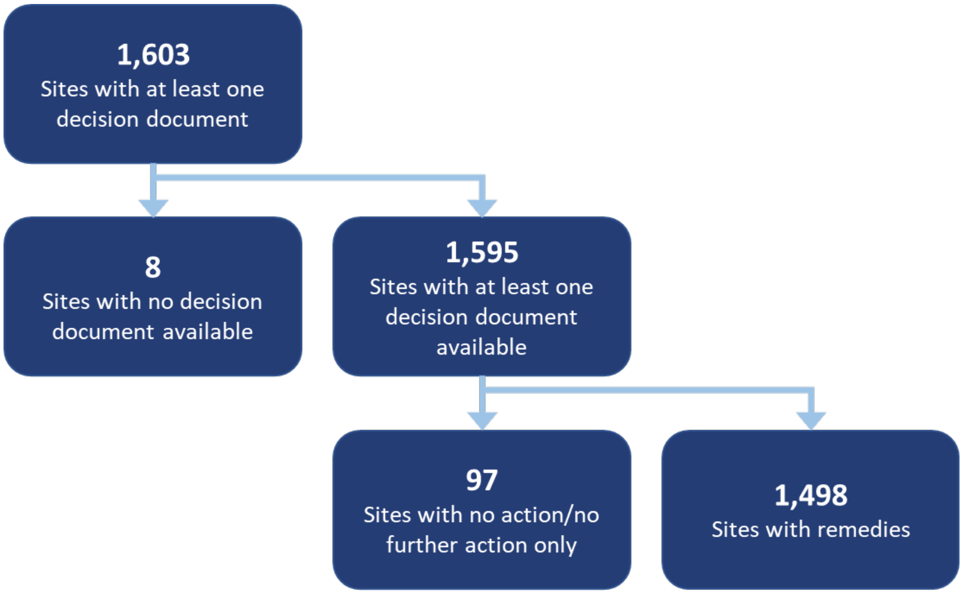
[8] For further information, please visit the Cleanup Optimization at Superfund Sites web page at www.epa.gov/superfund/cleanup-optimization-superfund-sites

III. Scope of this Report

This report discusses decision documents for current and deleted NPL sites that had at least one decision document as of the end of FY 2017. In addition, the SRR analysis includes 56 decision documents for 52 Superfund Alternative approach sites (as of April 2019).[9] The current analysis does not include decision documents for other non-NPL sites or sites that were proposed for the NPL but not yet on the final NPL. For the first time, the report includes information on TI waivers at groundwater sites.

There are 1,603 sites that have at least one decision document. Of the 1,603 sites, 8 sites had no electronic decision documents available, leaving 1,595 sites represented in this report. Further, 97 sites have selected only a no action or no further action decision for the site, leaving 1,498 sites with remedies (Figure 2).

Figure 2: Total Number of Superfund Sites



The decision documents issued for these sites form the basis for the SRR and its analyses. A total of 5,601 decision documents, including 3,867 RODs, 472 ROD amendments, and 1,262 ESDs have been signed at the 1,603 sites. As discussed previously, most sites have multiple decision documents. Figure 3 depicts the total number of RODs, ROD amendments and ESDs issued each year through FY 2017. Only ESDs with a remedy component were included in the remedy analysis (682). The first ESD was signed in 1988.

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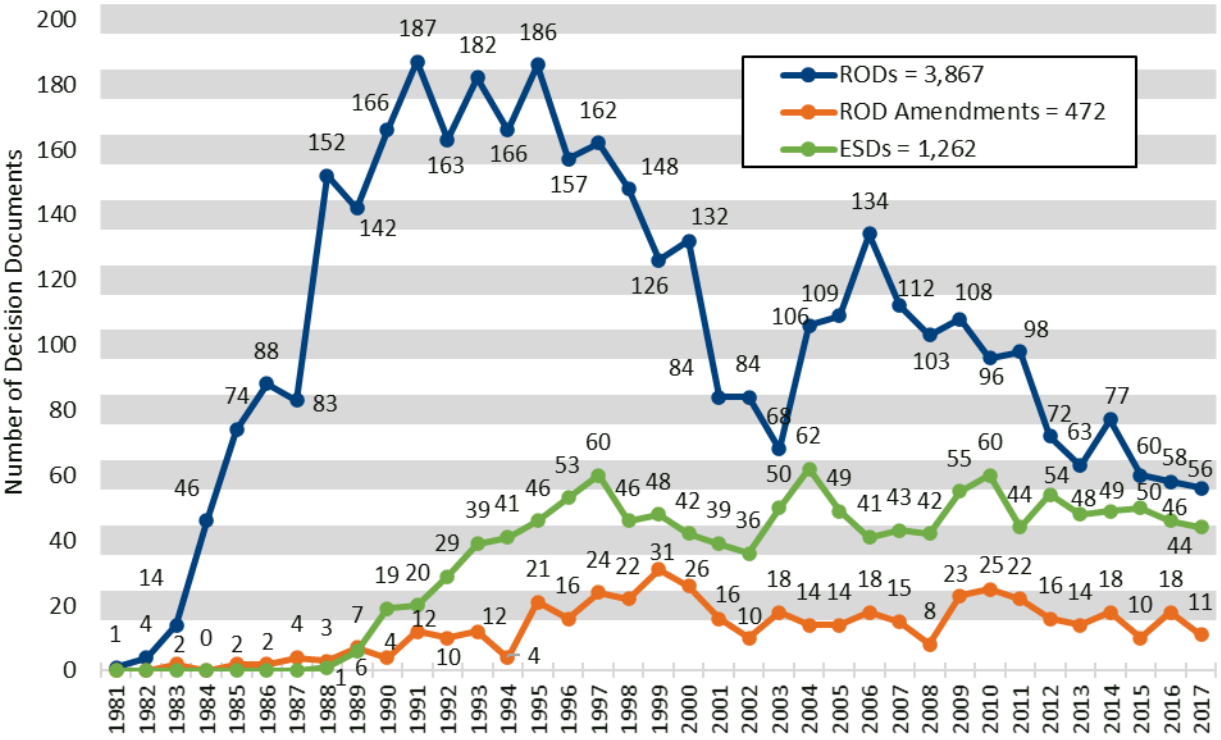
[9] "One of EPA's non-NPL Superfund pathways is referred to as the Superfund Alternative (SA) approach. The SA approach uses the same process and standards for investigation and cleanup as sites on the NPL. Sites using the SA approach are not eligible for federal remedial cleanup funds. Cleanup funding for sites with SA agreements is provided by the potentially responsible parties (PRPs)." (EPA, 2008b). To be considered an official Superfund Alternative approach site, there needs to be a Superfund Alternative approach agreement per OECA policy (see: www.epa.gov/enforcement/superfund-alternative-approach). The list of sites with a Superfund Alternative approach agreement is as of April 1, 2019.

Figure 3: Decision Documents per Fiscal Year (FY 1981-2017)[10]



- Of the 1,262 ESDs, only ESDs with a remedy component (682) included in remedy analyses for this report.
- No ESDs signed before FY 1988.
- Decision documents tracked as actions in Superfund Enterprise Management System. Sometimes a document tracks multiple actions (i.e., remedy decisions for more than one OU at the site). Data in this report counts each action separately, and those documents count once for each action.

This report evaluates remedy selection trends historically and cumulatively through FY 2017. It also provides a more detailed analysis of the 272 decision documents signed at 189 sites in FYs 2015 to 2017. These documents include 174 RODs, 39 ROD amendments, and 59 ESDs with changes to remedy components. Approximately 40 percent of the decision documents from FYs 2015 to 2017 are for federal facilities.

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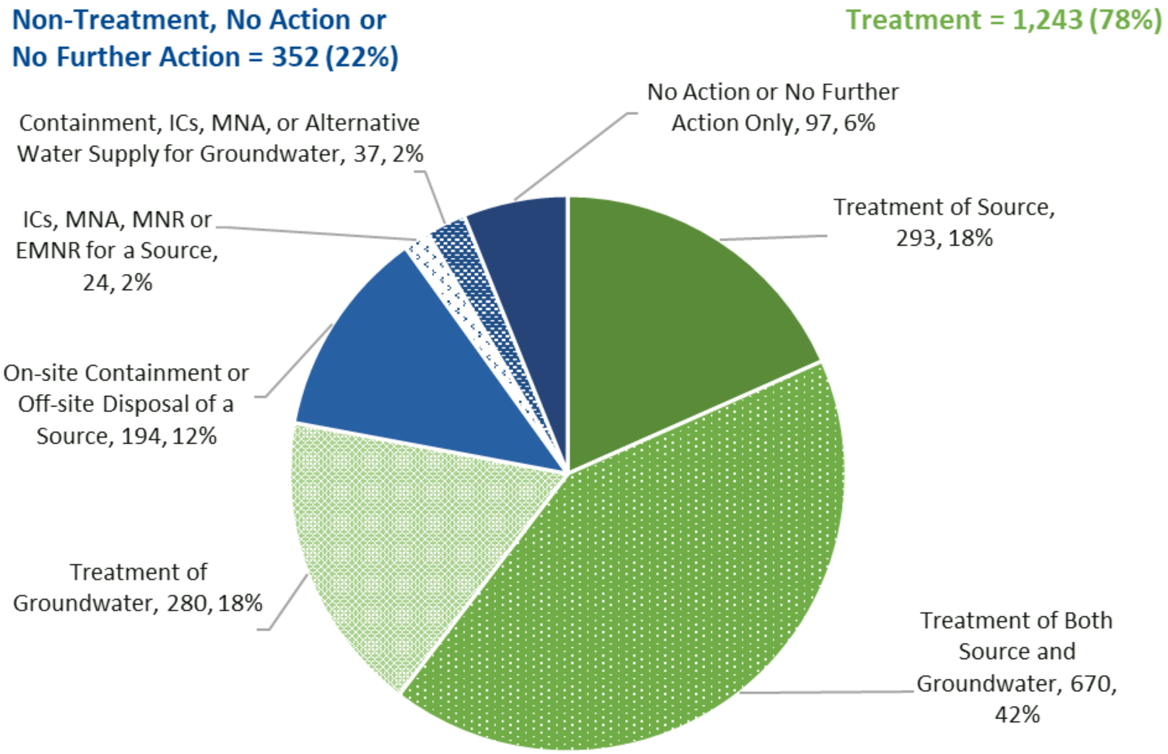
[10] In FYs 2018 and 2019, a total of 121 RODs, 20 ROD Amendments, and 96 ESDs were issued (Superfund Enterprise Management System, 5/12/2020). These decision documents are currently being analyzed.

IV. Overview of Remedies

Of the 1,595 sites with decision documents available as of the end of FY 2017, remedies were selected at 1,498 sites and no action or no further action was specified at 97 sites. Figure 4 focuses on treatment remedies and shows the proportion of Superfund remedies by remedy category (including source and groundwater remedies). Sites are included once using the following hierarchy: treatment, on-site containment or off-site disposal, other non-treatment remedies (including ICs, monitored natural attenuation [MNA], enhanced or monitored natural recovery [EMNR or MNR], and alternative water supply), and no action or no further action. At 78 percent of Superfund sites, at least one treatment remedy was selected for source, groundwater, or both. Appendix B lists the type and number of source and groundwater treatment technologies selected by fiscal year.

Figure 4: Treatment at Superfund Sites (FY 1981-2017)



- Sites with remedies, no action or no further action, and available decision documents = 1,595.
- Sites counted in this figure using following hierarchy: (1) treatment, (2) on-site containment or off-site disposal of a source, (3) other non-treatment remedies of a source, (4) containment or non-treatment remedies for groundwater, and (5) no action or no further action only.
- Sites with treatment remedies include in situ or ex situ treatment, and may also include non-treatment remedies.
- Sites with only non-treatment remedies do not include treatment remedies in any decision document.
- Sites with only no action or no further action (97) do not have treatment or non-treatment remedies selected in any decision document.

Hill Air Force Base[11] **in Utah** is an example of a site that has selected treatment remedies for both source and groundwater. Dating back to World War II, Hill Air Force Base has been the site for maintenance and repair activities for numerous types of aircraft. Activities at Hill Air Force Base generate various wastes including chlorinated and non-chlorinated solvents and degreasers, fuels, other hydrocarbons, acids, bases, and metals. The site contains many contaminated source areas such as landfills, chemical and waste pits, fire training areas, sludge drying beds, dumps, spill areas, and groundwater contaminant plumes. Several recent documents (three FY 2015 RODs and one FY 2017 ROD amendment) selected treatment remedies, including in situ bioremediation for both soil and groundwater, P&T of groundwater, and free-product recovery of non-aqueous phase liquid (NAPL). Numerous other remedies have been selected and implemented at the site since its first ROD in 1991. Those remedies include excavation and disposal of soil, SVE, engineered caps and soil covers for source media; ICs for both source and groundwater; and permeable reactive barriers (PRBs) and MNA for groundwater.

EPA analyzed which types of media remedies target at Superfund sites (Figure 5). Groundwater is addressed most frequently, followed by soil. Remedies also frequently target sediments and solid waste. In this analysis, all media addressed within decision documents for the site are counted once for each medium even if it was targeted at multiple OUs or in multiple decision documents.

Of the 1,498 sites with selected remedies, 85 percent have remedies for more than one medium. A total of 1,093 sites have remedies for both source media and groundwater.

American Creosote Works Inc. (Pensacola Plant)[12] **in Florida** illustrates a site that is addressing several media. For example, in FY 2017 alone, remedies were selected for groundwater, NAPL, and soil at this former wood-treating facility. Earlier decision documents addressed debris, sediment, and sludge.

NAPL is considered a source medium when it contributes to groundwater contamination. However, EPA does not have complete data on its presence at Superfund sites. NAPL is often difficult to locate during a site investigation, and there may not be direct evidence of its presence at the time EPA signs a decision document. In addition, EPA has only recently tracked NAPL as a separate medium when reviewing remedy decisions. For these reasons, NAPL is not included in Figure 5.

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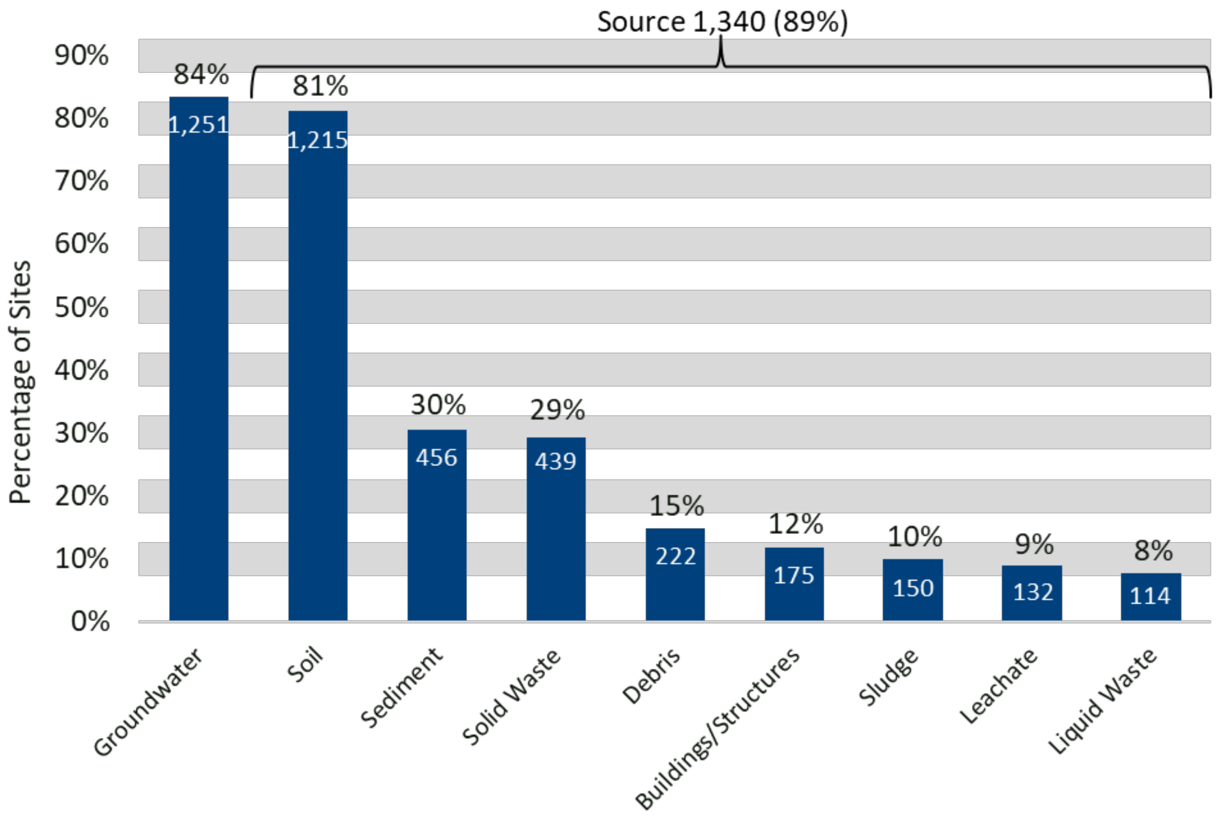
[11] Hill Air Force Base: (1) ROD, OU4, 9/25/17, https://semspub.epa.gov/src/document/08/100005817; (2) ROD, OU9, 9/23/15, https://semspub.epa.gov/src/document/08/1574521; (3) ROD, OU10, 9/23/15, https://semspub.epa.gov/src/document/08/1574523; (4) ROD, OU11, 7/21/15, https://semspub.epa.gov/src/document/08/1574587; and (5) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0800753.

[12] American Creosote Works (Pensacola Plant): (1) ROD, 9/7/17, https://semspub.epa.gov/src/document/04/11070338; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0400572.

Figure 5: Media Addressed at Superfund Sites with Remedies (FY 1981-2017)



- Number of sites with remedies: 1,498.
- Number of sites with remedies for source media and groundwater: 1,093.
- Does not include NAPL, or soil gas and air media addressed by vapor intrusion technologies.

V. Overview of Contaminants

Decision documents typically identify COCs addressed by selected remedies. EPA evaluated the types of COCs at Superfund sites based on decision documents with remedies and identified COCs (1,494 sites). COC data were unavailable for 4 sites with remedies, less than one percent. The contaminants may be in the same or different media and may be addressed by the same or different remedies.

For this report, contaminants are categorized in three major groups based on general treatability: metals, volatile organic compounds (VOCs), and semivolatile organic compounds (SVOCs). Any contaminant that does not fit into one of those groups is categorized as “other.”

The contaminant groups are defined below:

- **Metals** – Metals; metalloids; explosive metals; radioactive metals; and organometallic pesticides and herbicides.
- **VOCs** – Halogenated VOCs (primarily chlorinated VOCs); benzene, toluene, ethylbenzene, xylene (BTEX); and other nonhalogenated VOCs.
- **SVOCs** – Polychlorinated biphenyls (PCBs); polycyclic aromatic hydrocarbons (PAHs); organic pesticides and herbicides; phenols; most fuels and distillates; most explosives; dioxins and furans; and other halogenated and nonhalogenated SVOCs.
- **Other** – nonmetallic inorganics; asbestos; and unspecified organics or inorganics.

Contaminants are further grouped into more detailed categories. Appendix C lists contaminants and their associated categories and provides an analysis of contaminants in detailed categories for groundwater, soil, and sediment.

Over half of sites have COCs in all three groups: VOCs, SVOCs, and metals (Figure 6). Another 23 percent of sites have two types of contaminants, and 24 percent have one type. In Figure 6, any of the groups shown may include “other” contaminants.

An example of a site that has all three types of contaminants groups is **Barstow Marine Corps Logistics Base**[13] **in California**. The base has two major functions: providing equipment maintenance, repair, overhaul, and rebuilding; and receiving, storing, maintaining, and shipping materials. Consequently, most of the contamination at this site resulted from vehicle-related activities and war surplus materials. In the FY 2015 ROD, remedies addressed trichloroethene (TCE), tetrachloroethene (PCE), aroclor 1016, aroclor 1254, dibenzo(a,h)anthracene, and benzo[a]pyrene in soil and groundwater, and lead in soil.

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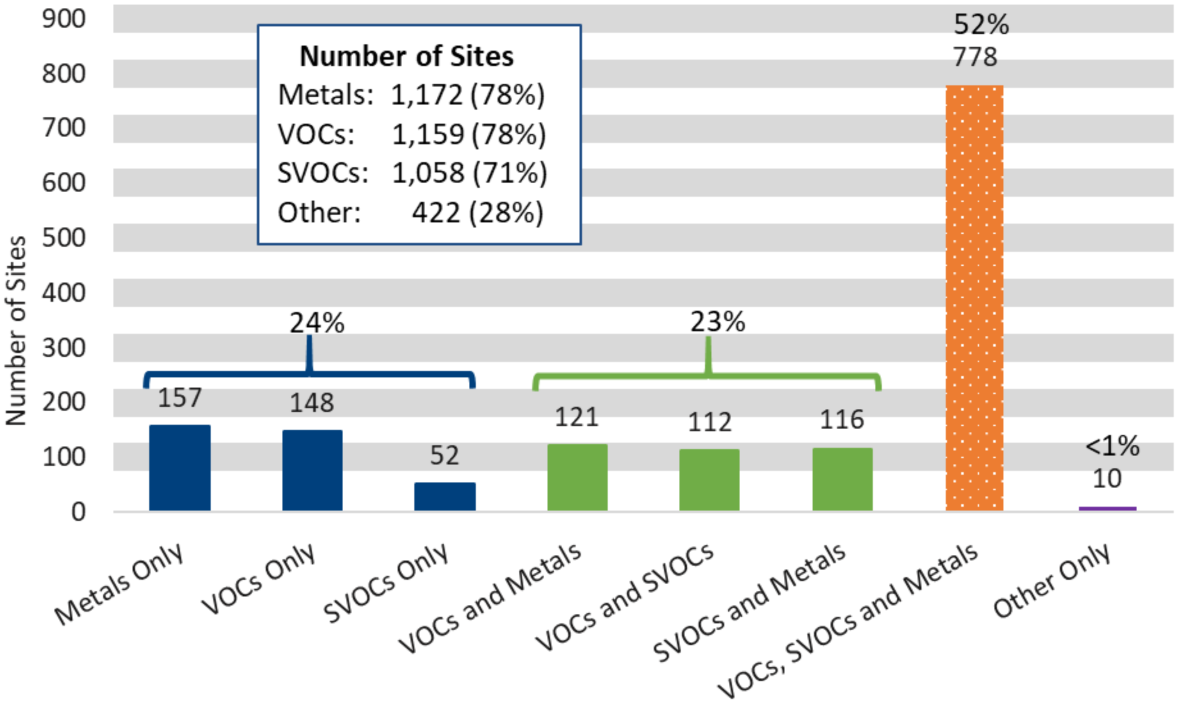
[13] Barstow Marine Corps Logistics Base: (1) ROD, OU7, 11/18/14, https://semspub.epa.gov/src/document/09/1149112; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0902790.

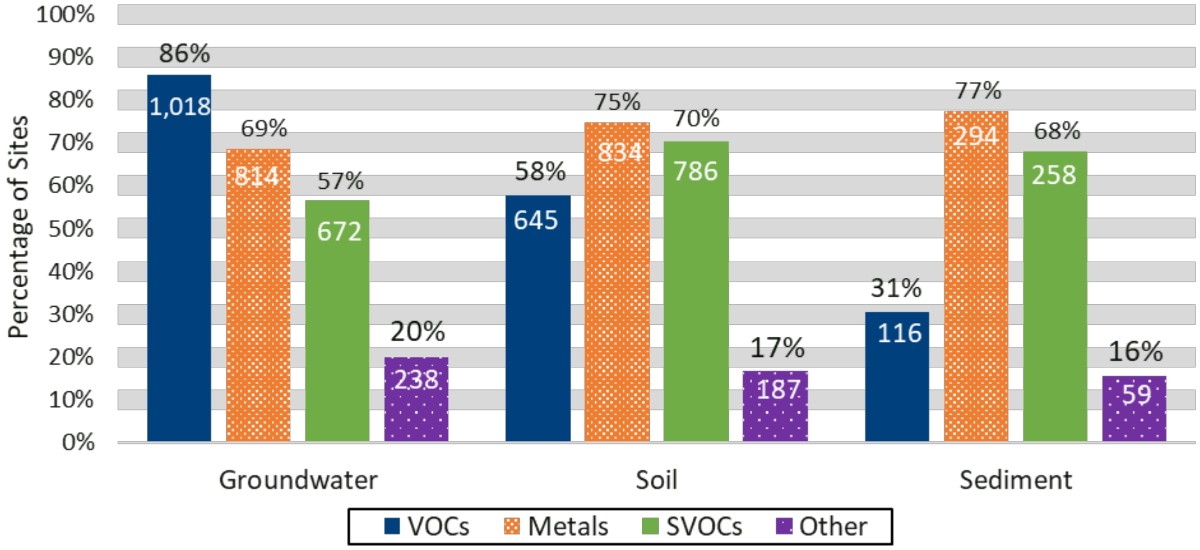
Figure 6: COCs at Superfund Sites (FY 1981-2017)



- Number of sites with identified COCs and a remedy = 1,494.

EPA analyzed COCs by the three media most frequently targeted (groundwater, soil, and sediment) (Figure 7). On a site-wide basis, VOCs, metals, and SVOCs are all common in groundwater and soil at Superfund sites with remedies. Metals and SVOCs are the most common COCs in sediment.

Figure 7: COCs by Media at Superfund Sites (FY 1981-2017)



- Number of groundwater sites with identified COCs and a remedy = 1,187.
- Number of soil sites with identified COCs and a remedy = 1,117.
- Number of sediment sites with identified COCs and a remedy = 380.

VI. Source Remedies

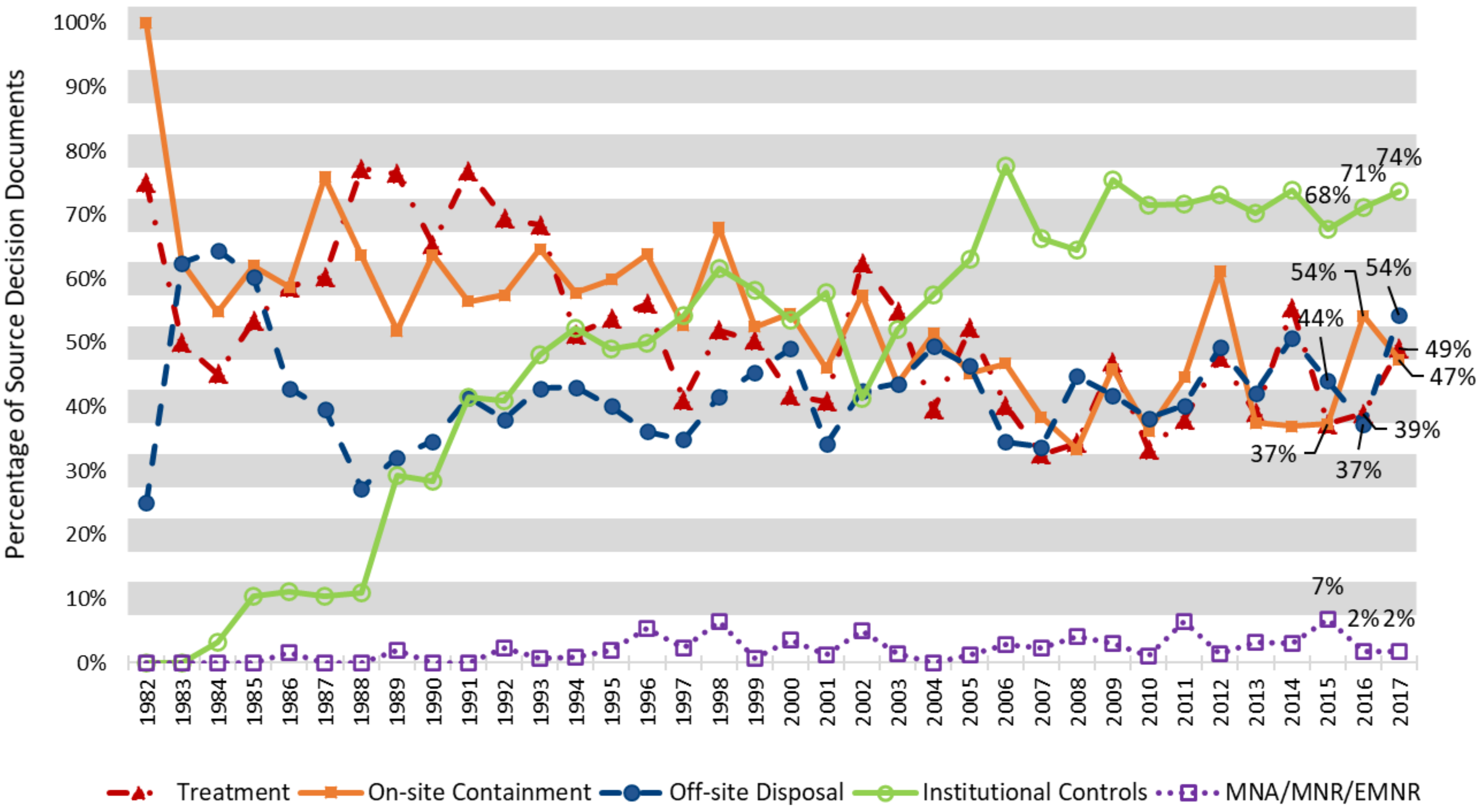
Source media include soil, sediment, solid waste, debris, buildings and structures, sludge, leachate, liquid waste, and NAPL. The first figure in this section shows historical trends in source remedies. Subsequent figures and tables provide additional information on remedies used to address sources in recent decision documents. Descriptions of source remedies are included in Appendix A. Sediments are included in the analysis of source remedies and are discussed in more detail in the Sediment Remedies subsection.

To better understand the nature of the source remedies being selected in the Superfund program, the source remedies are grouped into the following categories. See Table 1 for more detail on each category:

- Treatment.
- On-site containment.
- Off-site disposal.
- MNA, EMNR, or MNR.
- ICs.

EPA has tracked use of these source remedies since EPA began issuing remedy decision documents (FY 1981). EPA evaluated remedy selection trends from FY 1981 to 2017 for 3,235 source decision documents with remedies (Figure 8). In the first few years of the program, the number of decision documents issued was very low. After those early years, the selection of treatment, on-site containment, and off-site disposal has remained relatively stable on average for source remedies over the last 20 years. IC remedies increased somewhat in the early 2000s before leveling off.

Figure 8: Selection Trends for Decision Documents with Source Remedies (FY 1982-2017)



- Number of source decision documents with remedies: FY 1982-2017 = 3,234.
- One decision document from FY 1981 not included.
- Decision documents may be included in more than one category.

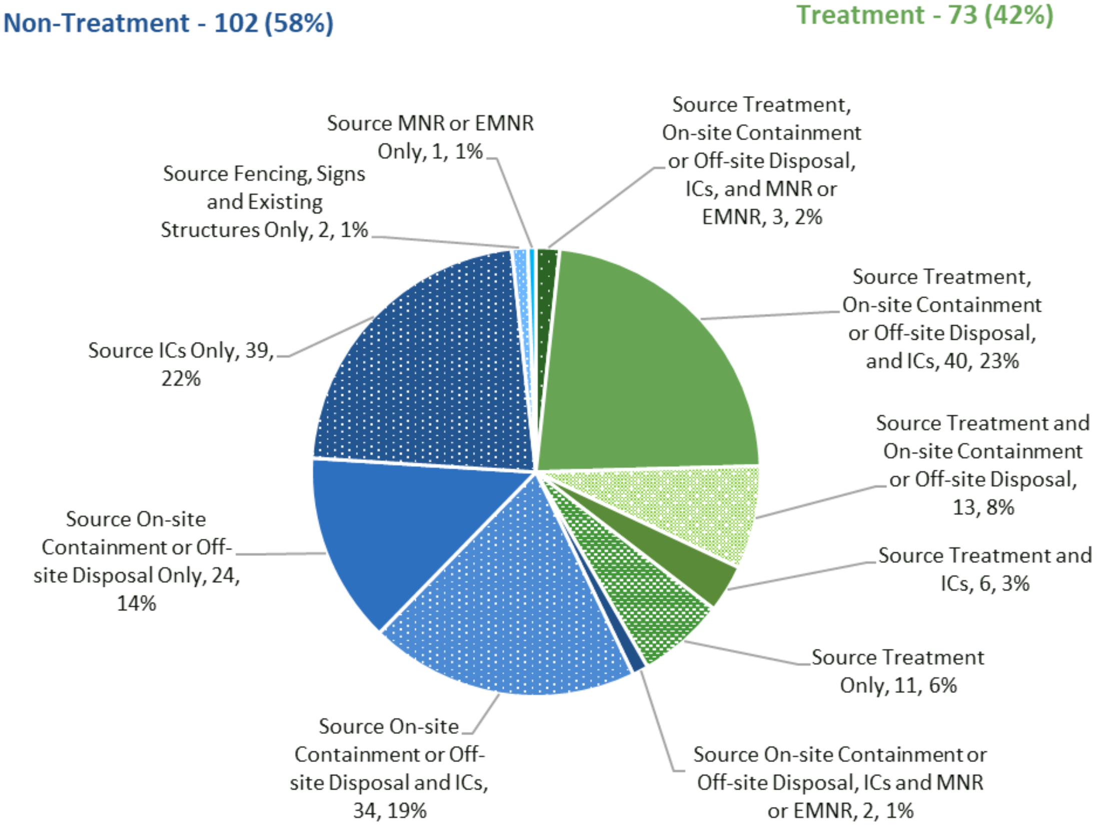
EPA evaluated remedies in more detail for the 272 FY 2015 to 2017 decision documents. Of these documents, 175 (or 64 percent) address source contamination at 131 sites. The percentage of decision documents addressing sources is consistent with the previous period evaluated (FYs 2012 to 2014).

Of the FY 2015 to 2017 source decision documents, 42 percent select source treatment, either by itself or in combination with non-treatment remedies for sources (Figure 9). Overall, 56 percent of decision documents with source remedies select multiple remedial approaches, including various combinations of treatment, on-site containment or off-site disposal, MNR or EMNR (for sediments), and ICs. An examination of the recent decision documents selecting ICs as the only source remedy found that all were for sites with previous remedial or removal actions. This finding is consistent with the NCP, which includes the expectation that ICs should be used to supplement engineering controls to prevent or limit exposure (EPA, 2012n).

Of the 131 sites with a source remedy from FY 2015 to 2017, 44 percent (57) also include a groundwater remedy for that same timeframe. However, for all years, 73 percent of sites have a remedy for both source and groundwater.

On-site source containment primarily includes caps and cover systems. Although some waste sent for off-site disposal is treated prior to disposal in accordance with waste disposal regulations, if the treatment is not specified in the decision document, it is not included as treatment in this analysis.

Figure 9: Combinations of Recent Source Remedies (FY 2015-2017)



- Number of source decision documents = 175.

Table 2 summarizes the specific types of remedies selected in source decision documents for FYs 2015 to 2017. In situ treatment was selected in one-fifth of these documents. Of the 73 decision documents with source treatment, 35 (or 48 percent) specified in situ treatment. The most frequently selected in situ methods for sources are solidification/stabilization (S/S), SVE, in situ thermal treatment (ISTT), bioremediation, and chemical treatment (including in situ chemical oxidation [ISCO] and in situ chemical reduction [ISCR]).

Note that the number of decision documents selecting each type of technology within a category is not additive to the total number of documents for the category. Frequently more than one type of technology is selected to address source. For example, ISTT followed by flushing, ISCO and enhanced in situ bioremediation, as necessary, was selected in the FY 2015 ROD amendment to address NAPL contamination in the source area of **Escambia Wood – Pensacola**[14] **in Florida**. Treatment technologies will be finalized during the design phase. The selections of ISTT, flushing, ISCO, and bioremediation at Escambia Wood – Pensacola are included in the number of documents for each of those technologies, but the FY 2015 Escambia Wood – Pensacola document is only counted once in the number of documents selecting in situ treatment.

Table 2: Source Remedies Selected in Recent Decision Documents (FY 2015-2017)

Remedy	Number of Decision Documents (FY15-17)	Percent Source Decision Documents
In Situ Treatment	**35**	**20%**
Solidification/Stabilization	9	5%
Soil Vapor Extraction	9	5%
Thermal Treatment	8	5%
Bioremediation	6	3%
Chemical Treatment	5	3%
Cap (amended, in situ sediment)	2	1%
Amendments (sediment)	2	1%
Multi-phase Extraction	2	1%
Electrokinetics	1	1%
Flushing	1	1%
Soil Amendments	1	1%
Ex Situ Treatment	**50**	**29%**
Physical Separation	22	13%
Source P&T	7	4%
Recycling	5	3%
Thermal Treatment	4	2%
Solidification/Stabilization	3	2%
Incineration (off-site)	2	1%
Soil Vapor Extraction	2	1%
Aeration	1	1%

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[14] Escambia Wood – Pensacola: (1) ROD Amendment, OU2, 9/25/15, https://semspub.epa.gov/src/document/04/11014642; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0400573.

Remedy	Number of Decision Documents (FY15-17)	Percent Source Decision Documents
Ex Situ Treatment (continued)		
Bioremediation	1	1%
Chemical Treatment	1	1%
Constructed Treatment Wetland	1	1%
Open Burn/Open Detonation	1	1%
Thermal Desorption	1	1%
Unspecified Ex Situ Treatment (off-site)	9	5%
Unspecified Ex Situ Treatment (on-site)	1	1%
Containment/Disposal	**117**	**67%**
Containment (on-site)	81	46%
Cap (engineered cap)	43	25%
Drainage/Erosion Control	37	21%
Cover (soil)	24	14%
Containment (other, onsite)	12	7%
Vertical Engineered Barrier	7	4%
Repair (pipe/sewer/tank/structure)	4	2%
Bottom Liner	2	1%
Building Sealant	2	1%
Leachate Control	2	1%
Containment (encapsulation)	1	1%
Disposal (off-site)	79	45%
MNR/EMNR	**6**	**3%**
Sediment EMNR	4	2%
Sediment MNR	4	2%
Institutional Controls	**124**	**71%**
Other	**43**	**25%**
Fencing, Signs, and Existing Structures	17	10%
Wetlands Restoration	13	7%
Revegetation	6	3%
Habitat Restoration	5	3%
Population Relocation	5	3%
Stream Realignment	3	2%
Shoreline Stabilization	2	1%
Wetlands Replacement	1	1%

- Number of source decision documents = 175.
- Number of source decision documents with treatment = 73.
- Decision documents with multiple remedies within a category counted once per category, documents may be included in more than one remedy category.
- For unspecified on-site or off-site treatment, decision document indicates on- or off-site treatment but does not specify a particular treatment technology.

Physical separation is the most commonly selected ex situ treatment. Consistent with CERCLA, all types of physical separation are classified as treatment because they reduce the volume of contaminated material. Physical separation processes include sifting, sieving, and sorting solid media to separate components; dewatering; and decontamination (for example, cleaning contaminated building surfaces). Of the 22 recent decision documents that selected physical separation; 13 selected dewatering; 5 decontamination; and 8, other physical separation processes, such as oil/water separation, sieving, and mechanical sorting. Four documents included more than one type of physical separation.

Source P&T refers to extraction and ex situ treatment of leachate or liquid waste media. Ex situ treatment technologies typically include carbon adsorption, neutralization, aeration, evaporation, or bioremediation. Of the seven documents selecting source P&T in FYs 2015 to 2017, five are for mining waste while two are for leachate.

Figure 10 shows the top COCs targeted by source remedies in FY 2015 to 2017 decision documents. Sixty-four percent of these documents address metals; 40 percent, PAHs; and 32 percent, PCBs. More than half of recent documents with source remedies address more than one contaminant group (72 of 137). For example, an FY 2015 ROD for **Aerojet General Corp.**[15] **in California** addresses a variety of contaminants resulting from the manufacture of various chemicals and rocket propellants. Contaminants include chlorinated VOCs (TCE, PCE, and 1,1,2,2-tetrachloroethane), metals (such as lead, cadmium, and chromium), nonhalogenated SVOCs (such as bis(2-ethylhexyl)phthalate and n-nitrosodimethylamine), pesticides (such as dieldrin and pendimethalin), PAHs (such as benzo(a)pyrene, naphthalene and phenanthrene), PCBs (aroclor 1248, aroclor 1254, and aroclor 1260), BTEX (toluene), halogenated SVOCs (phenol), other organics (petroleum hydrocarbons), and other inorganics (perchlorate).

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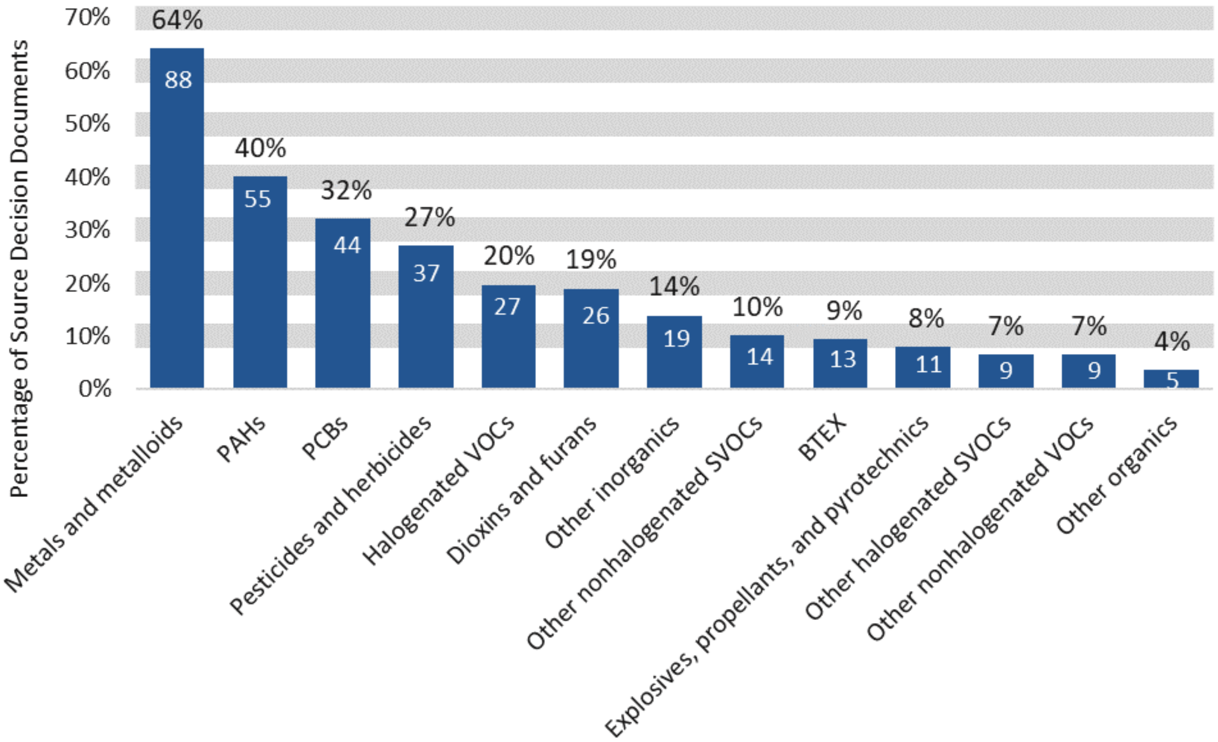
[15] Aerojet General Corp.: (1) ROD, OU6, 7/22/15 https://semspub.epa.gov/src/document/09/1153972; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0901718.

Figure 10: Detailed COCs in Decision Documents with Source Remedies (FY 2015-2017)



- Number of source decision documents with identified COCs and a remedy = 137.

Sediment Remedies

Fifty-three source decision documents for FYs 2015 to 2017 address sediment (Table 3). Of those, 40 selected a remedy for sediments (at 37 sites) and 13 specified only no action or no further action. Appendix A includes descriptions of sediment remedies. Most (88 percent) include dredging, containment, or disposal, while 35 percent include treatment. The most common treatment method is physical separation; as discussed previously, consistent with CERCLA, any technology that reduces toxicity, mobility, or volume is classified as treatment. Other sediment treatment selected includes amended caps and sediment amendments. Sixty-three percent of recent decision documents for sediments also include ICs.

The **Portland Harbor**[16] **site in Oregon** includes an in-river and an upland portion of the lower Willamette River, contaminated from decades of industrial use along the Willamette River. Water and sediment at the site are contaminated with many hazardous substances, including PCBs, PAHs, dioxins and furans, pesticides, and heavy metals. To address the contamination, the FY 2017 ROD includes selection of in situ treatment using amendments, such as activated carbon or organoclay, a cap with possible amendment addition, dredging with off-site disposal, EMNR, ICs, habitat restoration, and wetlands restoration. The type and quantity of amendments to be used for

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[16] Portland Harbor: (1) ROD, OU2, 1/6/17 - https://semspub.epa.gov/src/document/10/100036257; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=1002155.

treatment, as well as the need for adding amendments to the cap, will be determined during remedial design.

Each individual technology selected in the decision documents are counted in Table 3, however, the decision document is only counted once in the category total. For example, the Portland Harbor decision document is counted in the number of decision documents selecting dredging/excavation and cap (in situ), but it is only counted once in the category total for dredging, disposal, and containment. Therefore, the individual technology numbers are not additive to the category total.

Table 3: Sediment Remedies Selected in Recent Decision Documents (FY 2015-2017)

Remedy	Number of Decision Documents (FY15-17)	Percent Sediment Decision Documents
Treatment	**14**	**35%**
Physical Separation	11	28%
Cap (amended, in situ sediment)	2	5%
Amendments (sediment)	2	5%
Aeration	1	3%
Incineration (off-site)	1	3%
Unspecified Ex Situ Treatment (off-site)	2	5%
Unspecified Ex Situ Treatment (on-site)	1	3%
Dredging, Disposal, and Containment	**35**	**88%**
Dredging/Excavation	29	73%
Disposal (off-site)	21	53%
Cap (in situ)	13	33%
Cap (ex situ)	5	13%
Drainage/Erosion Control	2	5%
Vertical Engineered Barrier	2	5%
Bottom Liner	1	3%
Containment (other, onsite)	1	3%
Repair (pipe/sewer/tank/structure)	1	3%
Enhanced Monitored Natural Recovery	**4**	**10%**
Monitored Natural Recovery	**4**	**10%**
Institutional Controls	**25**	**63%**
Other	**19**	**48%**
Wetlands Restoration	8	20%
Revegetation	6	15%
Habitat Restoration	5	13%
Stream Realignment	3	8%

Remedy	Number of Decision Documents (FY15-17)	Percent Sediment Decision Documents
Other (continued)		
Fencing, Signs, and Existing Structures	2	5%
Shoreline Stabilization	2	5%
Wetlands Replacement	1	3%

- Number of decision documents with a sediment remedy = 40. (Does not include 13 decision documents specifying no action or no further action only.)
- Decision documents with multiple remedies within a category counted once per category, and documents may be included in more than one remedy category.

EPA analyzed COCs addressed by sediment remedies in recent decision documents (Figure 11). Over 70 percent of these documents include metals. PCBs and PAHs are the next most frequent categories of COCs with 55 percent and 32 percent, respectively. More than half of recent sediment documents address multiple contaminant groups (17 of 31). For example, the FY 2015 ROD for **Lower Duwamish Waterway**[17] **in Washington** selected capping and EMNR (both with the option for addition of amendments, if appropriate), dredging with off-site disposal, MNR, and ICs to address chlorinated dioxins and furans, halogenated SVOCs (such as phenol and 1,2,4-trichlorobenzene), halogenated VOCs (1,2-dichlorobenzene and 1,4-dichlorobenzene), metals (such as arsenic and lead), nonhalogenated SVOCs (such as bis(2-ethylhexyl)phthalate and phenylmethanol), pesticides (pentachlorophenol and hexachlorobenzene), PCBs, and PAHs (such as benzo(a)pyrene and phenanthrene).

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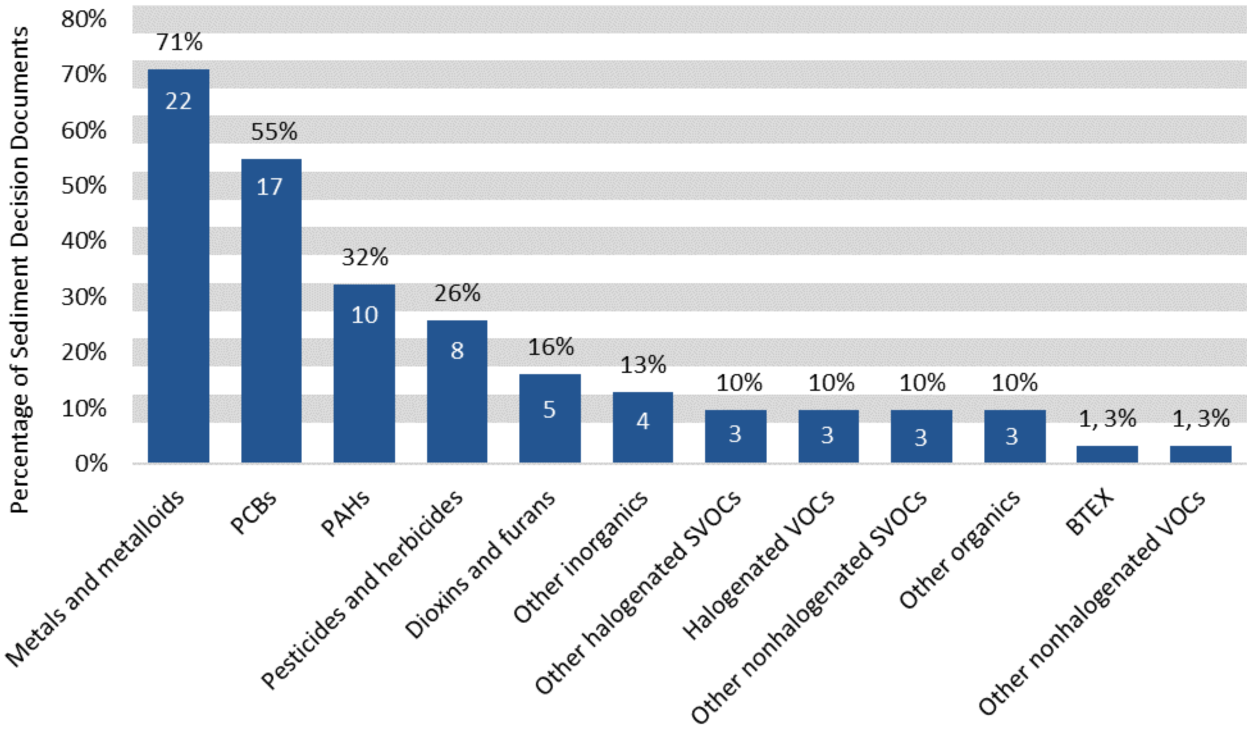
[17] Lower Duwamish Waterway: (1) ROD, OU1, 11/21/14, https://semspub.epa.gov/src/document/10/715975; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=1002020.

Figure 11: Detailed COCs in Decision Documents with Sediment Remedies (FY 2015-2017)

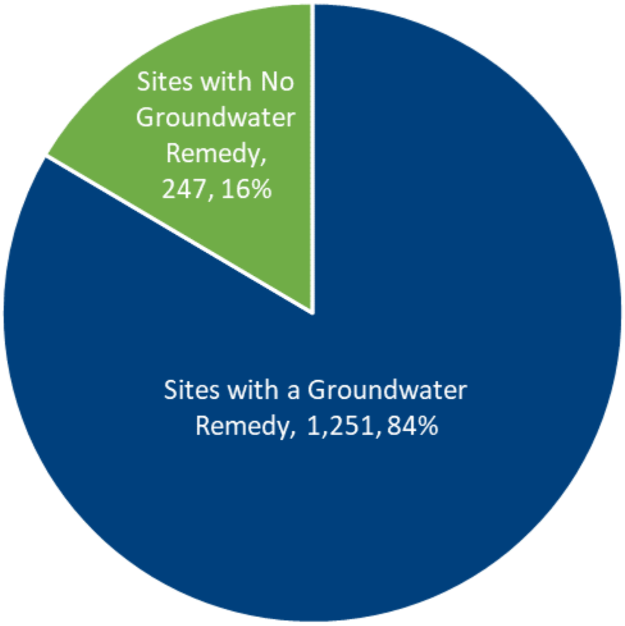


- Number of sediment decision documents with identified COCs and a remedy = 31.

VII. Groundwater Remedies

Groundwater contamination occurs at most Superfund sites. Of the 1,498 Superfund sites with remedies, 84 percent (1,251 sites) have groundwater remedies (Figure 12), which are documented in 2,542 decision documents. The figures and tables in this section present additional information on groundwater remedies and trends. Appendix A includes descriptions of groundwater remedies.

Figure 12: Superfund Sites with Groundwater Remedies (FY 1981-2017)



- Number of Superfund sites with a remedy = 1,498.
- Does not include 97 sites with only no action or no further action.

Figure 13 shows the selection trends for groundwater remedies in 2,541 decision documents from FY 1982 to 2017. The selection of in situ groundwater treatment and the selection of P&T remain consistent with the previous three years (FYs 2012 to 2014). In situ treatment has remained at an average of 51 percent of groundwater decision documents in the most recent three years. The percentage selecting P&T remains low, at an average of 20 percent, down from 23 percent in the previous three years. Almost all recent groundwater decision documents include ICs[18] with percentages currently ranging from 64 to 78 percent. EPA determined that sites with groundwater decision documents that did not include ICs had selected ICs for the groundwater in a previous decision document or the decision was an interim remedy and ICs will likely be selected with the final remedy in a later decision document.

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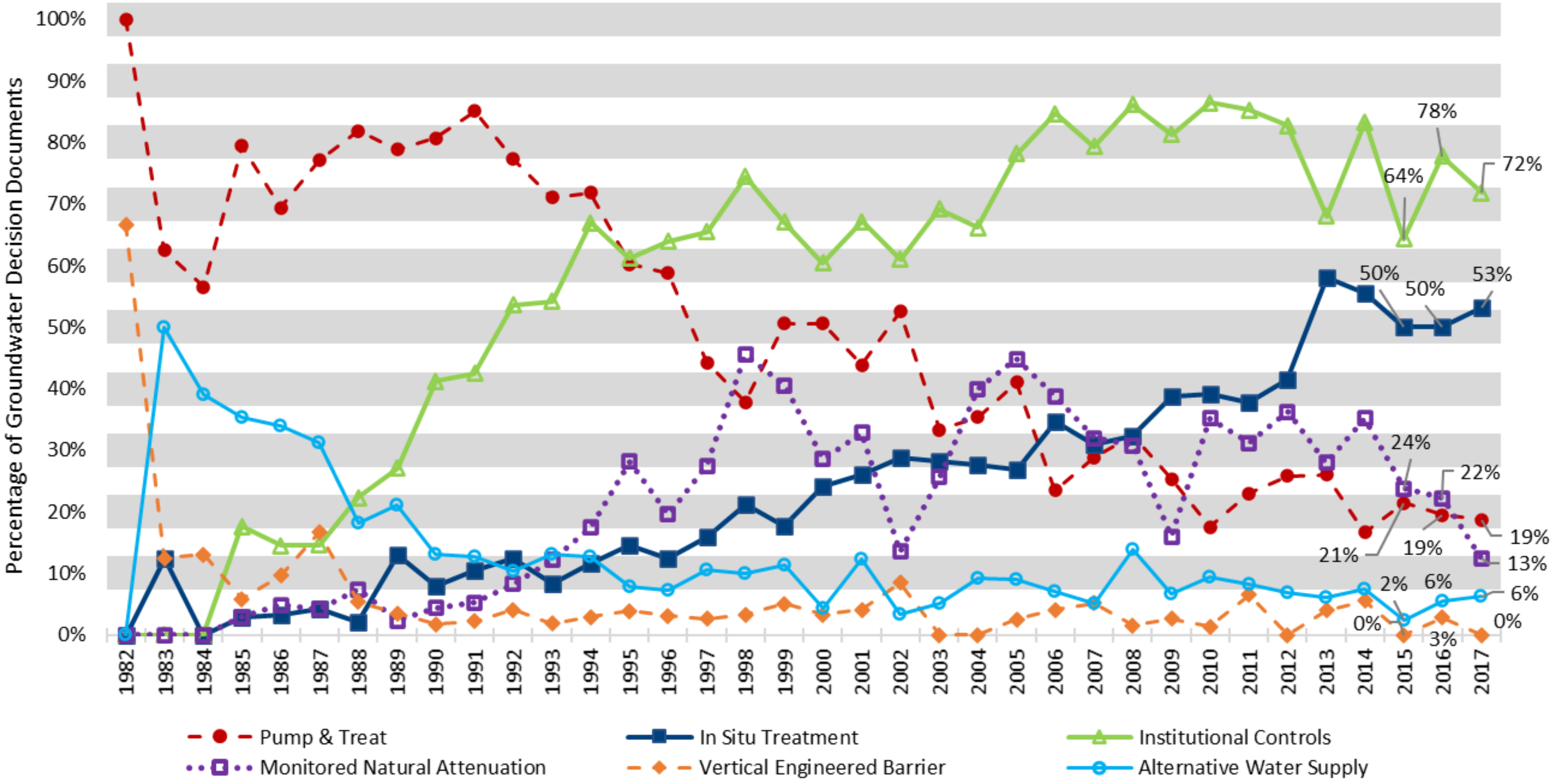
[18] Refer to Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites. OSWER. December 2012. EPA 540-R-09-001. http://semspub.epa.gov/src/document/11/175446

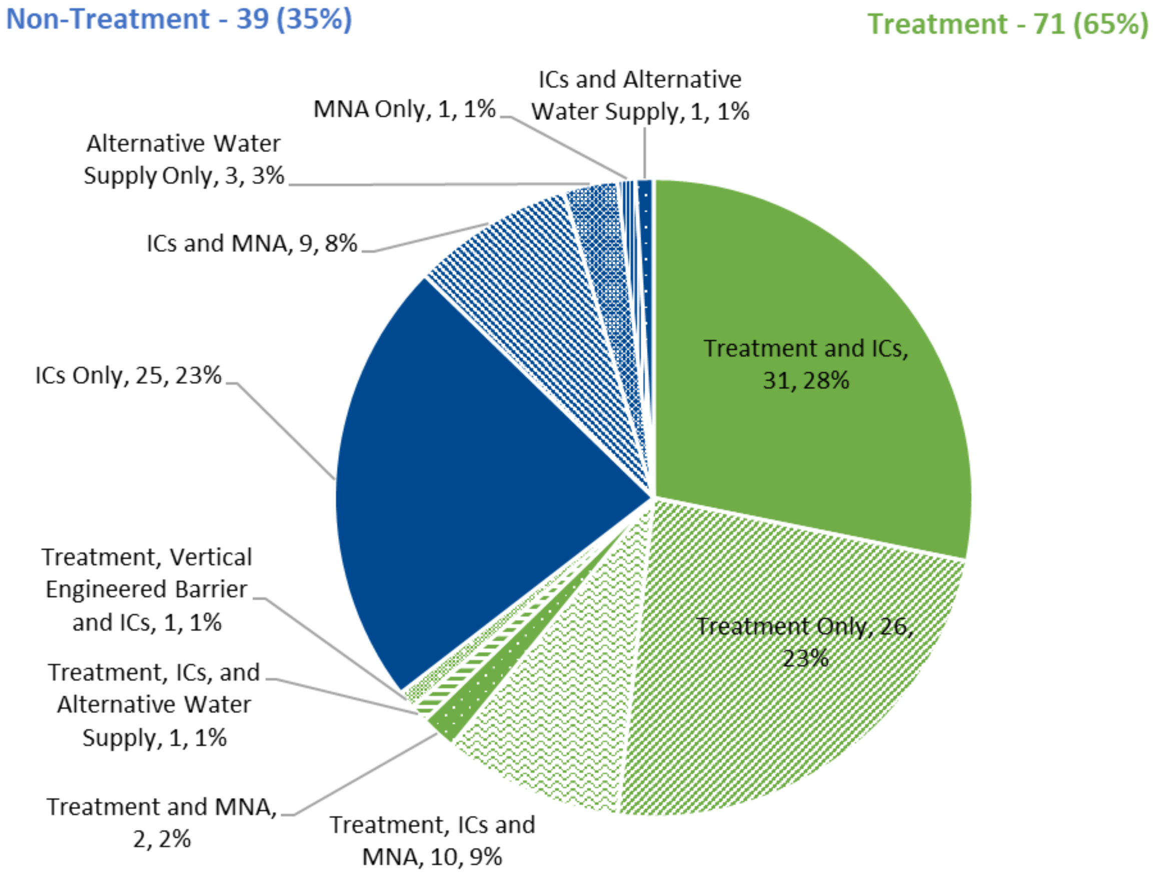
Figure 13: Selection Trends for Decision Documents with Groundwater Remedies (FY 1982-2017)



- Number of groundwater decision documents with remedies: FY 1982-2017 = 2,541.
- One decision document from FY 1981 not included.
- Decision documents may be included in more than one category.

EPA evaluated remedies selected in 272 FY 2015 to 2017 decision documents. Of these, 40 percent (110 documents) address groundwater contamination, and 71 (65 percent) of the 110 documents included treatment, which consists of P&T or in situ treatment, selected by itself or in combination with non-treatment remedies for groundwater (Figure 14). Overall, 52 percent of decision documents with groundwater remedies select multiple remedial approaches, including various combinations of treatment, vertical engineered barriers, MNA, and ICs.

Figure 14: Combinations of Recent Groundwater Remedies (FY 2015-2017)



- Number of groundwater decision documents = 110.
- Treatment includes P&T or in situ treatment for groundwater.
- Percentage totals for treatment and non-treatment from chart off by 1 percent due to rounding.

In situ treatment was selected in over 50 percent (56) of the 110 groundwater decision documents (Table 4). Of these 56 documents, bioremediation was selected in more than half (30) and nearly half include chemical treatment (26). One-fifth of recent decision documents for groundwater selected MNA.

One example of a combined remedy approach is at the **Cristex Drum**[19] **site in North Carolina.** Cristex Drum is a former fabric mill engaged in knitting, dyeing and finishing that operated from 1966 until 1986. During operations, the plant used an above-ground storage tank, oil-water separator, a drum storage pad, and a small wastewater storage and treatment lagoon. Primary sources of soil, sediment, surface water, and groundwater contamination include spills, leaks, and facility operations. COCs in the groundwater include 1,4-dichlorobenzene, benzene, benzo(a)pyrene, chloroethene, TCE, PCE, and cis-1,2-dichloroethene. The FY 2017 ROD selected a combination of ISCO and electrokinetics (EK). A direct current applied to the subsurface (electrokinetics) will enhance the transport of oxidant through the area to enhance contact of the oxidant with COCs. The EK-ISCO approach will target the suspected source area and the most contaminated portion of the saturated source zone where residual DNAPL and adsorbed phase chlorinated VOCs may be present. Enhanced in situ bioremediation bio-barriers will be installed down-gradient of the ISCO array to accelerate degradation of dissolved contamination in the northern half of the saturated source zone, which has lower contaminant concentrations primarily in the dissolved phase.

Each individual technology selected in the decision documents are counted in Table 4. As in previous remedy tables, the decision document is only counted once in the total number of decision documents for each category. For example, the Cristex Drum decision document is counted in chemical oxidation (in situ), bioremediation (anaerobic, in situ), bioremediation (bioaugmentation, in situ), and electrokinetics but is only counted once in the category total for in situ treatment. Therefore, the individual technology numbers are not additive to the category total.

Table 4: Groundwater Remedies Selected in Recent Decision Documents (FY 2015-2017)

Remedy	Number of Decision Documents (FY15-17)	Percent Groundwater Decision Documents
Ex Situ Treatment (P&T)	**22**	**20%**
In Situ Treatment	**56**	**51%**
Bioremediation	30	27%
Bioremediation (anaerobic, in situ)	21	19%
Bioremediation (bioaugmentation, in situ)	11	10%
Bioremediation (aerobic, in situ)	5	5%
Bioremediation (unspecified, in situ)	4	4%
Chemical Treatment	26	24%
Chemical Oxidation (in situ)	19	17%
Chemical Reduction (in situ)	8	7%
Neutralization (in situ)	1	1%
Thermal Treatment	6	5%

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[19] Cristex Drum: (1) ROD, OU1, 9/29/17, https://semspub.epa.gov/src/document/04/11070129; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0406597.

Remedy	Number of Decision Documents (FY15-17)	Percent Groundwater Decision Documents
In Situ Treatment (continued)		
Permeable Reactive Barrier	5	5%
Multi-phase Extraction	4	4%
Air Sparging	3	3%
Solidification/Stabilization	2	2%
Electrokinetics	1	1%
Flushing	1	1%
Phytoremediation	1	1%
Vapor Extraction	1	1%
Unspecified In Situ Treatment	3	3%
Monitored Natural Attenuation	**22**	**20%**
Containment (Vertical Engineered Barrier)	**1**	**1%**
Institutional Controls	**78**	**71%**
Alternative Water Supply	**5**	**5%**

- Number of groundwater decision documents = 110.
- Number of groundwater decision documents with treatment = 71.
- Decision documents with multiple remedies within a category counted once per category, and documents may be included in more than one remedy category.

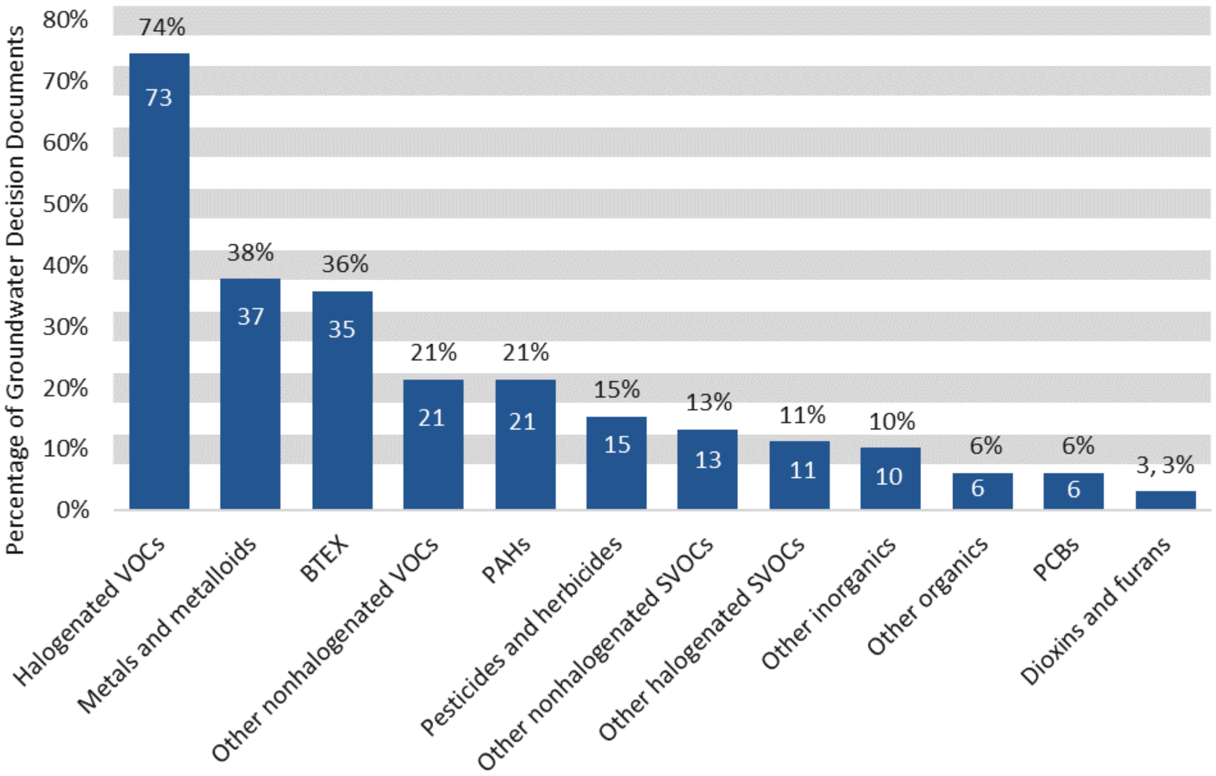
For decision documents that selected bioremediation, 70 percent specify anaerobic bioremediation (Table 4). Some bioremediation remedies also specify aerobic bioremediation or bioaugmentation (addition of bacteria capable of degrading specific chemicals). About three-quarters of decision documents that selected chemical treatment specify ISCO, while more than a quarter select ISCR. Two documents selected both ISCO and ISCR. Appendix A includes descriptions of bioremediation and chemical treatment remedies.

Figure 15 shows the COCs most frequently addressed in recent groundwater decision documents. Nearly 75 percent of groundwater decision documents have remedies that target halogenated (primarily chlorinated) VOCs. Metals and BTEX are the next most common contaminant categories at 38 and 36 percent, respectively. Nearly 60 percent of recent groundwater decision documents with COCs have more than one contaminant group (57 of 98).

At **Standard Chlorine**[20] **in New Jersey,** various manufacturing activities conducted between 1916 and 1993, including the production, storage and packaging of moth balls and flakes; the manufacture of lead-acid batteries; formulation of drain cleaners; production of dye carriers; and distillation and purification of chlorinated benzenes, resulted in a variety of contaminants at the site. In the FY 2016 ROD, groundwater remedies have been selected to address halogentated VOCs (such as 1,2-dichlorobenzene and 1,1'-biphenyl), halogenated SVOCs (1,2,4-trichlorobenzene), BTEX (benzene, ethylbenzene and xylene), PAHs (such as benzo(a)pyrene and naphthalene), and metals (such as lead and chromium).

Of the 21 decision documents with anaerobic bioremediation, 19 had COCs indicated and 17 included chlorinated VOCs. Of the 8 ISCR projects, 6 indicated COCs, as follows: organic COCs only (2), metals and organic COCs (3), and metals only (1).

Figure 15: Detailed COCs in Decision Documents with Groundwater Remedies (FY 2015-2017)



- Number of groundwater decision documents with identified COCs and a remedy = 98.

Technical Impracticability Waivers

While EPA is committed to restoring groundwater at Superfund sites, there are circumstances that may warrant waiving the requirement for groundwater restoration. "ARARs [applicable or relevant and appropriate requirements] may be waived by EPA for any of the six reasons specified by

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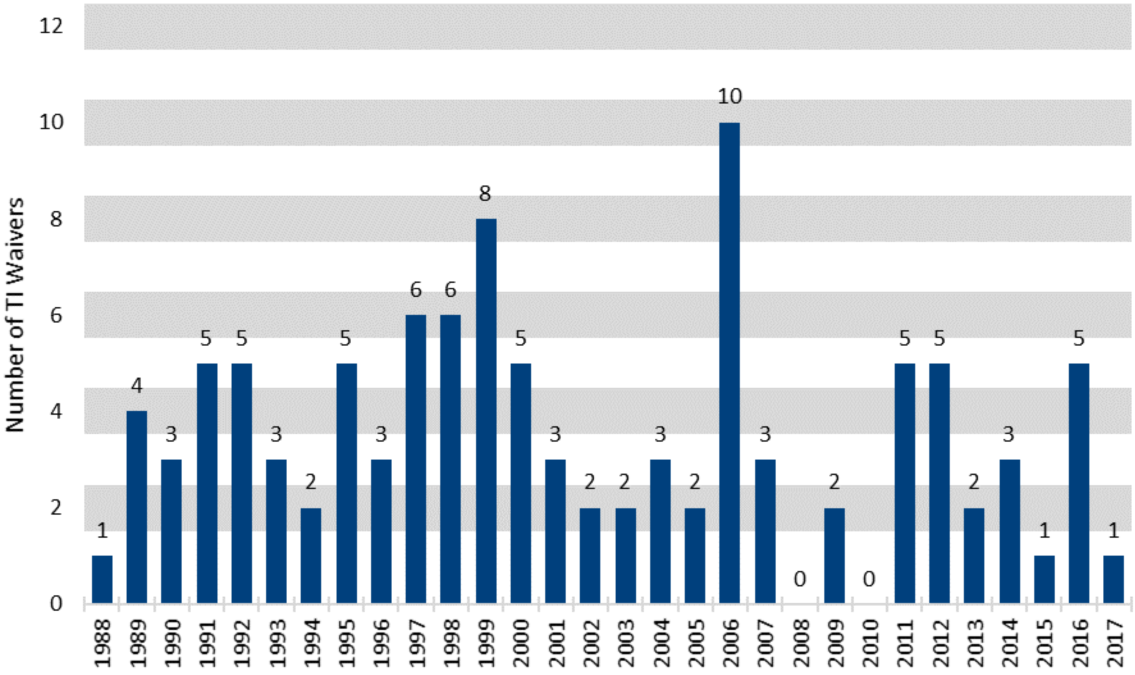
[20] Standard Chlorine: (1) ROD, OU1, 9/30/16, https://semspub.epa.gov/src/document/02/393188; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0200146.

CERCLA and the NCP…, including technical impracticability from an engineering perspective. TI waivers generally will be applicable only for ARARs that are used to establish cleanup performance standards or levels, such as chemical-specific MCLs [maximum contaminant levels] or State ground-water quality criteria." (EPA, 1993).

When determined that groundwater restoration is technically impracticable from an engineering perspective, a TI waiver may be included in a decision document. One hundred and five (105) decision documents from FYs 1988 through 2017 specify TI waivers for groundwater (Figure 16). These 105 documents are for 96 sites; sites may issue multiple TI waivers to address different plumes or areas of the site.

Figure 16: Groundwater TI Waivers per Fiscal Year (FY 1988-2017)



- Number of groundwater TI waivers = 105.
- Does not include surface water only TI waivers.
- Only includes TI waivers at Superfund Alternative approach sites and final or deleted NPL sites.

Optimization

EPA has been conducting optimization reviews and providing technical support to specific projects since 1997. Early in the program, optimization reviews focused on Fund-lead groundwater P&T remedies and primarily addressed the remedy and long-term monitoring stages. EPA has since issued the *National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion* that expands and formalizes optimization practices from site assessment to site completion for the Superfund program. The Strategy institutes changes to Superfund remedial program business processes to take advantage of newer tools and strategies that promote more effective and efficient cleanups. The Strategy identifies several objectives to achieve verifiably protective site cleanups faster, cleaner, greener, and cheaper. Many of these approaches have been applied for years at a subset of sites under the EPA's management as well as sites managed by other federal and state programs. The body of knowledge on applied optimization techniques and their use throughout the cleanup life cycle is substantial and growing rapidly (EPA, 2012o).

Two examples of recent decision documents informed by site optimization are summarized below.

Jones Road Ground Water Plume

OU01, Optimization Review in August 2014, ROD Amendment issued September 29, 2017.

The Jones Road site is contaminated with chlorinated VOCs, including PCE, in soil and groundwater. In 2013 during the design of two groundwater P&T systems, there were concerns about their future implementation and effectiveness. The project was referred for an independent optimization review of the preliminary remedy design. The review team found that addressing the continuing sources for contaminants to the groundwater would be a more cost-effective approach than first implementing P&T. The review focused on addressing the VOCs in soil contributing to the contamination of both the shallow water-bearing zone and the Deep Chicot Aquifer. Recommendations included using a phased remedial approach. To reduce VOC discharge to the Lower Chicot water-bearing zone, the team recommended installing an SVE system in the deep unsaturated Chicot sand unit. To address the shallow water-bearing zone, the recommendation was to pilot test an SVE system and install a full system if successful. The need and possible design for a P&T remedy to contain the migration of groundwater contaminants and restore the aquifer could be better evaluated after the effectiveness of source treatment was known through continued groundwater monitoring. Source mitigation of the two soil vapor sources in the Shallow Source Area Soil and the Deep Unsaturated Chicot Sand is the focus of the 2017 ROD amendment.

Benfield Industries, Inc.

OU01, Optimization Review in September 2007, ROD Amendment issued September 16, 2015.

The Benfield Industries site is contaminated with PAHs, SVOCs, VOCs, and metals in soil and groundwater. A 2007 optimization review recommended, in part, assessment of in situ treatment, particularly ISCO, of remaining soil hot spots. Additional characterization of the residual soil contamination and groundwater confirmed that continuing elevated levels of PAHs in the groundwater is the result of the PAHs dissolving into the groundwater from the smear zone. A focused feasibility study conducted in 2014 resulted in the selection of ISCO followed by enhanced in situ bioremediation, as needed, to address this source contamination. The selection was documented in the 2015 ROD amendment.

VIII. Vapor Intrusion

Data for remedies that target air and soil gas media to address vapor intrusion have been tracked since the *SRR 14th Edition*. Vapor intrusion mitigation technologies and ICs selected in FY 2015 to 2017 decision documents are included in Table 5. Descriptions of the mitigation technologies are found in Appendix A.

Vapor intrusion is the term given to the migration of vapor-forming chemicals from any underground source into a structure (for example, homes, businesses, schools). Contaminated groundwater or soil is the most common subsurface vapor source, although contamination in sewers, drain lines, and other conduits can also present a vapor intrusion threat in some settings. Vapor-forming chemicals may include VOCs, select SVOCs, some pesticides, some PCBs, and some inorganic contaminants, such as elemental mercury. Concentrations of vapor-forming chemicals in indoor air may pose an unacceptable health risk to building occupants. EPA issued two technical guides for assessing and mitigating vapor intrusion (EPA, 2015a and 2015b).

Forty FY 2015 to 2017 decision documents address vapor intrusion (Table 5). Eight of these documents select vapor intrusion mitigation for existing structures. Six specify active depressurization or positive building pressurization. Fourteen decision documents select ICs for vapor intrusion at existing structures. Thirty-eight recent decision documents include ICs related to building design and construction of future structures in areas with subsurface contamination that does not allow unlimited land use and unrestricted exposure.

A total of 100 decision documents from FYs 2009 to 2017 have addressed vapor intrusion since the data began being tracked for *SRR 14th Edition*. Of these documents, 31 documents select vapor intrusion mitigation for existing structures, with 17 decision documents selecting active depressurization. Thirty-seven decision documents select ICs for vapor intrusion at existing structures, while seventy-nine decision documents include ICs related to building design and construction of future structures.

At the **Raymark Industries, Inc.**[21] **site in Connecticut,** liquid manufacturing wastes were discharged to the facility's drainage system, which led to extensive VOC contamination in the groundwater**.** Groundwater in the source area also contains DNAPL. To address vapor intrusion resulting from volatile contaminants in the groundwater, the FY 2016 ROD includes the continued operation and maintenance of active depressurization technologies (sub-slab depressurization systems) at 106 homes, in addition to installing and operating similar systems at 20 additional buildings.

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[21] Raymark Industries, Inc.: (1) ROD, OU2, 9/9/16, https://semspub.epa.gov/src/document/01/592492; and (2) Site profile, https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0100094.

Table 5: Vapor Intrusion Remedies Selected in Recent Decision Documents (FY 2015-2017)

Remedy	2015	2016	2017	Total
Vapor Intrusion Mitigation at Existing Structures	**3**	**4**	**1**	**8**
Active Depressurization Technology	0	4	1	5
Positive Building Pressurization (commercial/industrial)	1	0	0	1
Vapor Intrusion Mitigation (unspecified)	3	0	0	3
Institutional Controls	**13**	**12**	**15**	**40**
ICs for Future Construction	13	10	15	38
ICs for Existing Buildings	5	6	3	14

- Number of decision documents selecting vapor intrusion remedies = 40.
- Existing buildings may continue to require ICs for future use changes or modifications.
- Decision documents with multiple remedies within a category are counted once per category, and documents may be included in more than one remedy category.

The *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* (EPA, 2015a) states that "the preferred long-term response to the intrusion of vapors into buildings is to eliminate or substantially reduce the level of contamination in the subsurface vapor source (e.g., groundwater, subsurface soil, sewer lines) by vapor-forming chemicals to acceptable-risk levels, thereby achieving a permanent remedy." For sites with vapor intrusion remedies, source or groundwater remedies may have been selected to address subsurface contamination or such remedies may be planned. Selected remedies are included in the source and groundwater sections (Section VI and Section VII, respectively). Building mitigation for vapor intrusion should "be regarded as an interim action that can provide effective human health protection, which may become part of a final cleanup plan" (EPA, 2015a).

IX. Conclusions

Based on EPA's analysis of recently selected remedies (FYs 2015 to 2017) and trends over the life of the Superfund program, treatment continues to be selected frequently and remains selected at 78 percent of Superfund sites with decision documents. Superfund also continues to address complex sites involving multiple media and contaminants. In addition, optimization studies have led to remedy changes in recent decision documents.

With respect to recent source remedies:

- The Superfund remedial program continued to select treatment for a large number of source remedies.
- Source remedies continued to include a combination of treatment, on-site containment, off-site disposal, and ICs.
- One-fifth of recent source decision documents selected in situ treatment.
- S/S, SVE, and ISTT were the most frequently selected remedies for in situ treatment.
- Physical separation and recycling were recently selected most often for ex situ treatment.
- Remedies in more than 60 percent of recent source decision documents addressed metals.
- Almost all sediment decision documents included excavation or dredging. One-third of sediment decision documents included either in situ or ex situ treatment (primarily dewatering).

Pertaining to recent groundwater remedies:

- The selection of in situ treatment for groundwater remains at over 50 percent of recent groundwater decision documents.
- The selection of P&T in groundwater decision documents has decreased significantly since the early 1990s and is hovering near 20 percent. By comparison, P&T selection was above 80% as late as 1992.
- Seventy percent of recent groundwater decision documents included ICs.
- The selection of alternative water supply remedies and vertical engineered barriers are both down slightly.
- Bioremediation and chemical treatment were the most frequently selected in situ remedies for groundwater.
- The majority of in situ bioremediation remedies specified anaerobic bioremediation. Most of the chemical treatment remedies specified ISCO.
- The most common COCs addressed by groundwater remedies were halogenated VOCs, primarily chlorinated VOCs.
- One hundred and five (105) decision documents from FYs 1988 through 2017 have TI waivers for groundwater.
- Since FY 2007, five or fewer TI waivers have been approved annually.

Regarding vapor intrusion remedies:

- Active depressurization was the most frequently selected technology for vapor intrusion mitigation.
- ICs were frequently selected to reduce the risk of exposure to vapor intrusion in current buildings and to require mitigation for future structures constructed in areas with subsurface contamination that does not support unlimited land use and unrestricted exposure.

The remedy and site information provided in this report informs stakeholders in Superfund communities about the program's remedy decisions, and helps federal, state, and tribal remediation professionals select future remedies. Analyzing the trends in remedy decisions provides an indication of the future demand for remedial technologies, which helps technology developers, and consulting and engineering firms, evaluate cleanup markets. The trends also indicate program needs for expanded technical information and support related to specific technologies or site cleanup challenges. For example, continued selection of in situ groundwater technologies suggests an ongoing need for additional knowledge and support associated with those technologies.

X. Sources and Electronic Versions

This section lists the sources of information used in this report and provides information on how to access the electronic version of this report and previous versions of the ASR and SRR.

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Electronic Versions

SRR 16th Edition is available electronically at https://www.epa.gov/remedytech/superfund-remedy-report.The body of the report and its appendices can be downloaded from the website. The list below describes the appendices for the *SRR 16th Edition*.

Appendix A: Definitions of Selected Remedies. This appendix defines the specific remedies selected as part of remedial actions.

Appendix B: Treatment Technologies by Fiscal Year. This appendix lists the ex situ and in situ source treatment technologies, groundwater in situ treatment technologies, and groundwater pump and treat remedies by FY from 1982 to 2017.

Appendix C: Individual Contaminants and Assigned Contaminant Groups. This appendix lists the individual contaminants from decision documents and identifies which contaminant groups the individual contaminants were assigned.

The data that forms the basis of the analyses contained in *SRR 16th Edition* can be found at https://www.epa.gov/superfund/superfund-data-and-reports by downloading *Contaminant of Concern Data for Decision Documents by Media, FY 1982-2017* and *Remedy Component Data for Decision Documents by Media, FY 1982-2017*.

In addition, previous editions of ASR and SRR can be downloaded from https://www.epa.gov/remedytech/superfund-remedy-report.

APPENDIX A

DEFINITIONS OF SELECTED REMEDIES

Appendix A: Definitions of Selected Remedies

Table of Contents

A.1 Treatment Technologies

Most treatment technologies were grouped into one of the four main treatment categories: biological, chemical, physical or thermal treatment. Ex situ treatment technologies associated with pump and treat (P&T) systems are included separately as its own treatment category.

A.1.1 Biological Treatment

Biological treatment involves adding or stimulating the growth of microorganisms, which metabolize contaminants or create conditions under which contaminants will chemically convert to non-hazardous or less toxic compounds or compounds that are more stable, less mobile, and/or inert. **Phytoremediation,** the use of plants to remove, stabilize, or destroy contaminants, is included in the definition of biological treatment.

Bioaugmentation is "[the] addition of microbes to the subsurface where organisms able to degrade specific contaminants are deficient. Microbes may be 'seeded' from populations already present at a site and grown in aboveground reactors or from specially cultivated strains of bacteria having known capabilities to degrade specific contaminants" (EPA, 2000).

Bioremediation "is a technology that uses microorganisms to treat contaminants through natural biodegradation mechanisms (intrinsic bioremediation) or by enhancing natural biodegradation mechanisms through the addition of microbes, nutrients, electron donors, and/or electron acceptors (enhanced bioremediation). This technology, performed *in situ* (below ground or in place) or *ex situ* (above ground), is capable of degrading organic compounds to less toxic materials such as carbon dioxide (CO2), methane, and water through aerobic or anaerobic processes" (EPA, 2001).

Constructed Treatment Wetlands are "manmade wetlands built to remove various types of pollutants that may be present in water that flows through them. They are constructed to recreate, to the extent possible, the structure and function of natural wetlands…They possess a rich microbial community in the sediment to effect the biochemical transformation of pollutants, they are biologically productive, and…they are self-sustaining….[Constructed wetlands] utilize many of the mechanisms of phytoremediation" (ITRC, 2003). Note that the term "constructed wetlands" is used to refer only to wetlands constructed for the purposes of treatment, and not to wetlands constructed to compensate for wetlands destroyed by a remedy (such as placement of a cap in a marsh). Such "compensatory wetlands" are considered as "**Wetlands Replacement**."

Phytoremediation "uses [macroscopic] plants to extract, degrade, contain, or immobilize contaminants in soil, groundwater, and other contaminated media. The phytoremediation mechanisms used to treat contaminated [media]…are phytoextraction, rhizodegradation, phytodegradation, phytovolatilization, and phytostabilization" (EPA, 2006). Phytoremediation may be applied in situ or ex situ.

Note that while phytoremediation may include the use of microorganisms in conjunction with plants, it is distinguished from bioremediation in that bioremediation does not use macroscopic plants or trees. For purposes of this report, the use of plants to control surface water drainage, to influence groundwater movement, or to adjust the water table are not considered phytoremediation since the purpose is not to extract the contaminants from the media. Such remedies are classified as engineering controls.

A.1.2 Chemical Treatment

Chemical treatment chemically converts hazardous contaminants to non-hazardous or less toxic compounds or compounds that are more stable, less mobile, inert, or all three. Even though a chemical reaction is not always involved in chemical precipitation, chemical precipitation is typically included in this category.

Amendments are "specialized materials used to reduce risk through in situ sequestering or destruction of contaminants in sediment" (EPA, 2013a). Examples include activated carbon, organoclay, and phosphate additives. "Direct amendment of surficial sediment with sorbents can reduce pollutant bioavailability to the food chain and flux of pollutants into the water column. Amendments can be spread on the surface of the contaminated sediment as a thin layer, intended to be mixed with the sediments through natural processes, or mixed into the surface using equipment similar to a rototiller" (EPA, 2013b).

Cap (amended, in situ) for sediment refers to a subaqueous cover in which "[specialized] materials [are] used to enhance the chemical isolation capacity…compared to sand caps. Examples include…reactive/adsorptive materials such as activated carbon, apatite, coke, organoclay, zero-valent iron and zeolite. Composite geotextile mats containing one or more of these materials (i.e., reactive core mats) are becoming available commercially" (EPA, 2005).

Chemical Fixation or **Chemical Stabilization**– See **Solidification and Stabilization**.

Chemical Oxidation "typically involves reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, or inert. Redox reactions involve the transfer of electrons from one chemical to another. Specifically, one reactant is oxidized (loses electrons) and one is reduced (gains electrons). There are several oxidants capable of degrading contaminants. Commonly used oxidants include potassium or sodium permanganate, Fenton's catalyzed hydrogen peroxide, hydrogen peroxide, ozone, and sodium persulfate. Each oxidant has advantages and limitations, and while applicable to soil contamination and some source zone contamination, they have been applied primarily toward remediating groundwater" (EPA, 2006). Chemical oxidation can be conducted either in situ or ex situ.

Chemical Reduction "uses chemicals called 'reducing agents' to help change contaminants into less toxic or less mobile forms….[Chemical reduction] can clean up several types of contaminants dissolved in groundwater. It can also be used to clean up contaminants known as 'dense non-aqueous phase liquids' or 'DNAPLs,' which do not dissolve easily in groundwater and can be a source of contamination for a long time. [Chemical reduction] is most often used to clean up the metal chromium and the industrial solvent trichloroethene, or 'TCE,' which is a DNAPL.

"Common reducing agents include zero valent metals, which are metals in their pure form. The most common metal used in [**in situ chemical reduction** (ISCR)] is zero valent iron, or 'ZVI.' ZVI must be ground up into small granules for use in ISCR. In some cases, micro- or nano-scale (extremely small) particles are used. The smaller particle size increases the amount of iron available to react with contaminants. Other common reducing agents include polysulfides, sodium dithionite, ferrous iron, and bimetallic materials, which are made up of two different metals. The most common bimetallic material used in ISCR is iron coated with a thin layer of palladium or silver" (EPA, 2012e).

In Situ Chemical Oxidation (ISCO) – See **Chemical Oxidation**.

In Situ Chemical Reduction (ISCR) – See **Chemical Reduction**.

Nanoremediation "methods entail the application of reactive nanomaterials for transformation and detoxification of pollutants. These nanomaterials have properties that enable both chemical reduction and catalysis to mitigate the pollutants of concern....Because of their minute size and innovative surface coatings, nanoparticles may be able to pervade very small spaces in the subsurface and remain suspended in groundwater, allowing the particles to travel farther than larger, macro-sized particles and achieve wider distribution....

"Many different nanoscale materials have been explored for remediation...Of these, nanoscale zero-valent iron (nZVI) is currently the most widely used....nZVI particles range from 10 to 100 [nanometers (nm)] in diameter....The high reactivity of nZVI particles is in part a direct result of their high specific surface area....nZVI's small particle size also allows more of the material to penetrate into soil pores, and it can be more easily injected into shallow and deep aquifers, a property that is particularly beneficial when contamination lies underneath a building" (Karn, Kuiken, & Otto, 2009).

Neutralization is a chemical reaction between an acid and a base. The reaction involves acidic or caustic wastes that are neutralized (pH is adjusted toward 7.0) using caustic or acid additives.

Permeable Reactive Barriers (PRB) are "in situ, permeable treatment zone[s] designed to intercept and remediate a contaminant plume. The term 'barrier' is intended to convey the idea that contaminant migration is impeded; however, the PRB is designed to be more permeable than the surrounding aquifer media so that groundwater can easily flow through the structure without significantly altering groundwater hydrology. The treatment zone may be created directly using reactive materials such as ZVI, or indirectly using materials designed to stimulate secondary processes (e.g., adding carbon substrate and nutrients to enhance microbial activity). In this way, contaminant treatment may occur through physical, chemical, or biological processes" (ITRC, 2011).

A.1.3 Physical Treatment

Physical treatment uses the physical properties of the contaminants or the contaminated medium to separate or immobilize the contamination.

Air Sparging "involves drilling one or more injection wells into the soil below the water table. An air compressor at the surface pumps air underground through the wells. As air bubbles flow through the groundwater, it carries contaminant vapors upward into the soil above the water table. The mixture of air and vapors is then pulled out of the ground for treatment using [soil vapor extraction (SVE)]" (EPA, 2012i). Oxygen added to the contaminated groundwater and vadose-zone soils also can enhance biodegradation of contaminants below and above the water table. The injection of ozone into the aquifer is referred to as ozone sparging and is a form of chemical treatment.

Electrokinetic Separation is "an emerging technology that relies on the application of a low-intensity, direct current through the soil to separate and extract heavy metals, radionuclides, and organic contaminants from unsaturated soil, sludge, and sediment. The current is applied across electrode pairs that have been implanted in the ground on each side of the contaminated soil mass. During electromigration, positively charged chemical species, such as metals, ammonium ions, and some organic compounds, move toward the cathode, and negatively charged chemicals, such as chloride, cyanide, fluoride, nitrate, and negatively-charged organic species, migrate toward the anode....The target compounds are either extracted to a recovery system or deposited at the electrode" (EPA, 2006).

Flushing "involves flooding a zone of contamination with an appropriate solution to remove the contaminant from the soil. Water or liquid solution is injected or infiltrated into the area of contamination. The contaminants are mobilized by solubilization, formation of emulsions, or a chemical reaction with the flushing solutions. After passing through the contamination zone, the contaminant-bearing fluid is collected and brought to the surface for disposal, recirculation, or on-site treatment and reinjection....Flushing solutions may be water, acidic aqueous solutions, basic solutions, chelating or complexing agents, reducing agents, cosolvents, or surfactants" (EPA, 2006).

In Situ Geochemical Stabilization – See **Solidification and Stabilization**.

In-Well Air Stripping systems "create a circulation pattern in the aquifer by drawing water into and pumping it through the wells, and then reintroducing the water into the aquifer without bringing it above ground....The well is double-cased with hydraulically separated upper and lower screened intervals within the aquifer....The system can be configured with an upward in-well flow or a downward in-well flow. The most common configurations involve the injection of air into the inner casing, decreasing the density of the groundwater and allowing it to rise....Through this system, volatile contaminants in the ground water are transferred from the dissolved phase to the vapor phase by the rising air bubbles. Contaminated vapors can be drawn off and treated above ground or discharged into the vadose zone" (EPA, 1998).

Mechanical Soil Aeration agitates contaminated soil, using tilling or other means to volatilize contaminants.

Multi-Phase Extraction (MPE) "is an enhancement of the traditional SVE system. Unlike SVE, MPE simultaneously extracts both groundwater and soil vapor. The groundwater table is lowered in order to dewater the saturated zone so that the SVE process can be applied to the newly exposed soil. This allows the volatile compounds sorbed on the previously saturated soil to be stripped by the induced vapor flow and extracted. In addition, soluble VOCs present in the extracted groundwater are also removed" (EPA, 1997b). "[MPE] systems can be implemented to target all phases of contamination associated with a typical NAPL spill site. These systems remove residual vadose zone soil contamination residing in soil gas, dissolved in soil pore-space moisture, and adsorbed to soil particles. [MPE] also effectively removes dissolved and free-phase (both light and dense NAPL [LNAPL and DNAPL]) contamination in groundwater" (EPA, 1997a). **Dual-phase extraction** and **bioslurping** are types of MPE.

Physical Separation processes use physical properties to separate contaminated and uncontaminated media, or separate different types of media. For example, different-sized sieves and screens can be used to separate contaminated soil from relatively uncontaminated debris. Another application of physical separation is the dewatering of sediments or sludge. Physical separation is included as treatment because it reduces the volume of contaminated material.

Recycling is the process of collecting and processing materials that would otherwise require disposal and turning them into new products. Examples include recycling recovered oil and solvents.

Soil Vapor Extraction (SVE) "extracts vapors from the soil above the water table by applying a vacuum to pull the vapors out…SVE involves drilling one or more extraction wells into the contaminated soil to a depth above the water table, which must be deeper than 3 feet below the ground surface. Attached to the wells is equipment (such as a blower or vacuum pump) that creates a vacuum. The vacuum pulls air and vapors through the soil and up the well to the ground surface for treatment" (EPA, 2012i). SVE usually is performed in situ; however, in some cases, it can be used as an ex situ technology.

Soil Washing "is a process that uses physical and/or chemical techniques to separate contaminants from soil and sediments. Contaminants are concentrated into a much smaller volume of contaminated residue, which is either recycled or disposed. Washwater can consist of water only or can include additives such as acids, bases, surfactants, solvents, chelating or sequestering agents which are utilized to enhance the separation of contaminants from soils or sediments" (ITRC, 1997). "Hazardous contaminants tend to bind, chemically or physically, to silt and clay. Silt and clay, in turn, bind to sand and gravel particles. The soil washing process separates the contaminated fine soil (silt and clay) from the coarse soil (sand and gravel). When completed, the smaller volume of soil, which contains the majority of the fine silt and clay particles, can be further treated by other methods (such as incineration or bioremediation) or disposed of according to state and federal regulations" (EPA, 1996).

Solidification and Stabilization (S/S) "refer[s] to a group of cleanup methods that prevent or slow the release of harmful chemicals from wastes, such as contaminated soil, sediment, and sludge. These methods usually do not destroy the contaminants. Instead, they keep them from 'leaching' above safe levels into the surrounding environment…[Solidification and stabilization] are often used together to prevent people and wildlife from being exposed to contaminants, particularly metals and radioactive contaminants….

"Solidification involves mixing a waste with a binding agent, which is a substance that makes loose materials stick together. Common binding agents include cement, asphalt, fly ash, and clay. Water must be added to most mixtures for binding to occur; then the mixture is allowed to dry and harden to form a solid block.

"Similar to solidification, stabilization also involves mixing wastes with binding agents. However, the binding agents also cause a chemical reaction with contaminants to make them less likely to be released into the environment. For example, when soil contaminated with metals is mixed with water and lime — a white powder produced from limestone — a reaction changes the metals into a form that will not dissolve in water" (EPA, 2012j). Stabilization remedies are classified as S/S whether or not they ultimately involve solidification.

S/S may be performed either ex situ or in situ. Note that chemical agents added in situ for the purpose of binding with contaminants in groundwater is classified as in situ S/S.

Solvent Extraction uses an organic solvent as an extractant to separate contaminants from soil. The organic solvent is mixed with contaminated soil in an extraction unit. The extracted solution then is passed through a separator, where the contaminants and extractant are separated from the soil.

A.1.4 Thermal Treatment

Thermal treatment uses heat to separate contaminants from contaminated media by increasing their mobility. Thermal treatment includes volatility; destroying contaminants or contaminated media by burning, decomposing, or detonating the contaminants or the contaminated media; or immobilizing contaminants by melting and solidifying the contaminated media.

Electrical Resistance Heating (ERH) "delivers an electrical current between metal rods called 'electrodes' installed underground. The heat generated as movement of the current meets resistance from soil converts groundwater and water in soil into steam, vaporizing contaminants" (EPA, 2012f). A low-energy ERH approach raises the subsurface temperatures to approximately 30 to 60°C to enhance the rate of biotic and abiotic contaminant dechlorination, respectively. (ESTCP Project ER-200719, Combining Low-Energy Electrical Resistance Heating with Biotic and Abiotic Reactions for Treatment of Chlorinated Solvent DNAPL Source Areas). A type of **In Situ Thermal Treatment**.

Incineration "is the process of burning hazardous materials at temperatures high enough to destroy contaminants. Incineration is conducted in an 'incinerator,' which is a type of furnace designed for burning hazardous materials in a combustion chamber…Hazardous materials must be excavated or pumped into containers before incineration. They may require further preparation, such as grinding or removing large rocks and debris, or removing excess water. The materials are then placed in the combustion chamber of an incinerator where they are heated to an extremely high temperature for a specified period of time. The temperature and length of time depend on the types of wastes and contaminants present. Air or pure oxygen may be added to the chamber to supply the oxygen needed for burning…Depending on the contaminants present, the target temperature may range from 1,600 to 2,500°F [870 to 1,370 °C]….

"As the wastes heat up, the contaminants volatilize (change into gases) and most are destroyed. Gases that are not destroyed pass through a secondary combustion chamber for further heating and destruction. The resulting gases then pass though air pollution control equipment….

"Incinerators can be constructed for temporary use at the site. However, in recent years, it has been more common for the wastes to be loaded onto trucks for transport to a permanent offsite facility. EPA requires that an incinerator can destroy and remove at least 99.99 percent of each harmful chemical in the waste it processes. When some extremely harmful chemicals are present, EPA requires that an incinerator show it can destroy and remove at least 99.9999 percent of contaminants in the waste" (EPA, 2012g).

In Situ Thermal Treatment (ISTT) “methods heat contaminated soil, and sometimes nearby groundwater, to very high temperatures. The heat vaporizes (evaporates) the chemicals and water changing them into gases… [which] can move more easily through soil. The heating process can make it easier to remove NAPLs from both soil and groundwater. High temperatures also can destroy some chemicals in the area being heated…The chemical and water vapors are pulled to collection wells and brought to the ground surface by applying a vacuum [that is, SVE]” (EPA, 2012f). Lower energy ISTT (see ERH) can enhance biotic or abiotic contaminant destruction. Specific types of ISTT techniques include conductive heating, electrical resistive heating, radio frequency heating, hot air injection, hot water injection, and steam enhanced extraction.

In Situ Thermal Desorption – See **In Situ Thermal Treatment**.

Open Burn (OB) and Open Detonation (OD) operations “are conducted to destroy excess, obsolete, or unserviceable (EOU) munitions and energetic materials. In OB operations, energetics or munitions are destroyed by self-sustained combustion, which is ignited by an external source, such as a flame, heat, or a detonation wave…In OD operations, detonatable explosives and munitions are destroyed by detonation, which is generally initiated by the detonation of an energetic charge” (FRTR, 2007).

Steam Enhanced Extraction (SEE) “injects steam underground by pumping it through wells drilled in the contaminated area. The steam heats the area and mobilizes and evaporates contaminants” (EPA, 2012f). SEE is a type of **In Situ Thermal Treatment**.

Thermal Conduction Heating (TCH) “uses heaters placed in underground steel pipes. TCH can heat the contaminated area hot enough to destroy some chemicals” (EPA, 2012f). TCH is a type of **In Situ Thermal Treatment**.

Thermal Desorption “removes organic contaminants from soil, sludge or sediment by heating them in a machine called a ‘thermal desorber’ to evaporate the contaminants. Evaporation changes the contaminants into vapors (gases) and separates them from the solid material…. A thermal desorber is not the same as an incinerator, which heats contaminated materials to temperatures high enough to destroy the contaminants…. Thermal desorption involves excavating soil or other contaminated material for treatment in a thermal desorber. The desorber may be assembled at the site for onsite treatment, or the material may be loaded into trucks and transported to an offsite thermal desorption facility. To prepare the soil for treatment, large rocks or debris first must be removed or crushed….If the material is very wet, the water may need to be removed to improve treatment….

“The prepared soil is placed in the thermal desorber to be heated. Low-temperature thermal desorption is used to heat the solid material to 200-600°F [90 to 320°C] to treat VOCs. If SVOCs are present, then high-temperature thermal desorption is used to heat the soil to 600-1000°F [320 to 540°C].

“Gas collection equipment captures the contaminated vapors. Vapors often require further treatment, such as removing dust particles. The remaining organic vapors are usually destroyed using a thermal oxidizer, which heats the vapors to temperatures high enough to convert them to carbon dioxide and water vapor…

"Often, treated soil can be used to fill in the excavation at the site. If the treated soil contains contaminants that do not evaporate, such as most metals, they may be disposed of and capped onsite, or transported offsite to an appropriate landfill" (EPA, 2012k). Thermal desorption is an ex situ treatment process. In situ thermal desorption processes are previously discussed as In Situ Thermal Treatment.

Thermally-Enhanced SVE – See In Situ Thermal Treatment.

Vitrification is a thermal treatment process that converts contaminated soil to stable glass and crystalline solids. There are two methods for producing heat for melting the contaminated soil. The older method uses electrodes and electrical resistance to vitrify materials, while the emerging technique uses plasma arc technology.

"In the electrical resistance method, high voltage is applied to electrodes (typically four) placed in the soil. Starter frit (generally graphite) is placed on the soil surface and electrical current heats the soil from the top down to temperatures between 1,400 and 2,000°C [2,550 to 3,650°F].... If the silica content of the soil is sufficiently high, contaminated soil can be converted into glass. Heating vaporizes or pyrolyzes organic contaminants. Most inorganic contaminants are encased in the glass-like monolith that results when the soil cools after treatment" (EPA, 2006). Vitrification may be conducted in situ or ex situ.

A.1.5 Pump and Treat (P&T)

Pump and treat "is a common method for cleaning up groundwater [and other aqueous media] contaminated with dissolved chemicals, including industrial solvents, metals, and fuel oil. [Water is extracted and conveyed] to an above-ground treatment system that removes the contaminants. (P&T) systems also are used to 'contain' the contaminant plume. Containment of the plume keeps [the plume] from spreading by pumping contaminated water toward the wells. This pumping helps keep contaminants from reaching drinking water wells, wetlands, streams, and other natural resources" (EPA, 2012h). For the purpose of this report, all P&T systems are considered treatment, even if designed to only contain, rather than restore, a contaminated plume.

Activated Carbon Treatment – "Activated carbon is a material used to filter harmful chemicals from contaminated water and air. It is composed of black granules of coal, wood, nutshells or other carbon-rich materials. As contaminated water or air flows through activated carbon, the contaminants sorb (stick) to the surface of the granules and are removed from the water or air. Granular activated carbon or 'GAC' can treat a wide range of contaminant vapors including radon and contaminants dissolved in groundwater, such as fuel oil, solvents, polychlorinated biphenyls (PCBs), dioxins, and other industrial chemicals, as well as radon and other radioactive materials. It even removes low levels of some types of metals from groundwater.

"Activated carbon treatment generally consists of one or more columns or tanks filled with GAC. Contaminated water or vapors are usually pumped through a column from the top down, but upward flow is possible. As the contaminated water or air flows through the GAC, the contaminants sorb to the outer and inner surfaces of the granules. The water and air exiting the container will be cleaner. Regular testing of exiting water or air is conducted to check contaminant levels. If testing shows that some contaminants remain, the water or air may need to be treated again to meet the treatment levels.

"The GAC will need to be replaced when the available surfaces on the granules are taken up by contaminants and additional contaminants can no longer sorb to them. The 'spent' GAC may be replaced with fresh GAC or 'regenerated' to remove the sorbed contaminants. To regenerate spent GAC, it is usually sent to an offsite facility where it is heated to very high temperatures to destroy the contaminants. If a lot of GAC needs to be regenerated, equipment to heat the GAC and remove the sorbed contaminants can be brought to the site.

"Depending on the site, treated groundwater may be pumped into a nearby stream or river or back underground through injection wells or trenches. At some sites, a sprinkler system can distribute the water over the ground surface so that it seeps into soil. The water also may be discharged to the public sewer system for further treatment at a sewage treatment plant" (EPA, 2012a).

Air Stripping "is the process of moving air through contaminated groundwater or surface water in an above-ground treatment system. Air stripping removes chemicals called 'volatile organic compounds' or 'VOCs.' VOCs are chemicals that easily evaporate, which means they can change from a liquid to a vapor (a gas). The air passing through contaminated water helps evaporate VOCs faster. After treating the water, the air and chemical vapors are collected, and the vapors are either removed or vented outside if VOC levels are low enough. Air stripping is commonly used to treat groundwater as part of the 'pump and treat' cleanup method....

"Air stripping uses either an air stripper or aeration tank to force air through contaminated water and evaporate VOCs. The most common type of air stripper is a packed-column air stripper, which is a tall tank filled with pieces of plastic, steel, or ceramic packing material.

"Contaminated water is pumped above ground and into the top of the tank and sprayed over the top of the packing material. The water trickles downward through the spaces between the packing material, forming a thin film of water that increases its exposure to air blown in at the bottom of the tank. A sieve-tray air stripper is similar in design but contains several trays with small holes. As water flows across the trays, a fan at the bottom blows air upwards through the holes, increasing air exposure. Aeration tanks are another type of design that remove VOCs by bubbling air into a tank of contaminated water" (EPA, 2012b).

Filtration "is the physical process of mechanical separation based on particle size whereby particles suspended in a fluid are separated by forcing the fluid through a porous medium. As fluid passes through the medium, the suspended particles are trapped on the surface of the medium and/or within the body of the medium. Ultrafiltration/microfiltration occurs when particles are separated by forcing fluid through a semipermeable membrane. Only the particles whose size are smaller than the openings of the membrane are allowed to flow through" (FRTR, 2007). Other filtration methods include nanofiltration and reverse osmosis.

Ion Exchange "removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. They also may be inorganic and natural polymeric materials. After the resin capacity has been exhausted, resins can be regenerated for re-use" (FRTR, 2007).

Metals Precipitation "from contaminated water involves the conversion of soluble heavy metal salts to insoluble salts that will precipitate. The precipitate can then be removed from the treated water by physical methods such as clarification (settling) and/or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation. Typically, metals precipitate from the solution as hydroxides, sulfides, or carbonates. The solubilities of the specific metal contaminants and the required cleanup standards will dictate the process used. In some cases, process design will allow for the generation of sludges that can be sent to recyclers for metal recovery" (FRTR, 2007).

A.2 On-Site Containment Technologies

For the purpose of this report, containment includes several containment technologies, including caps, covers, and vertical engineered barriers (VEBs).

Building Sealant refers to "in-place sealing and covering of accessible contaminated building materials with a high performance coating to prevent release of [contaminants] into the indoor air of residential, commercial, and industrial structures…The common method of applying an encapsulant is by brush, roller, or airless sprayer."

Caps and Cover Systems – "Capping involves placing a cover over contaminated material such as landfill waste or contaminated soil…. Caps do not destroy or remove contaminants. Instead, they isolate them and keep them in place to avoid the spread of contamination….The cap design selected for a site will depend on several factors, including the types and concentrations of contaminants present, the size of the site, the amount of rainfall the area receives, and the future use of the property. Construction of a cap can be as simple as placing a single layer of a material over lightly contaminated soil to placing several layers of different materials to isolate more highly contaminated wastes. For example, an asphalt cap might be selected to cover low levels of soil contamination on a property whose future reuse requires a parking lot. A cap for a hazardous waste landfill, however, might require several layers, including a vegetative layer, drainage layer, geomembrane, and clay layer" (EPA, 2012c).

Cap (In situ) for sediment refers to "the placement of a subaqueous covering or cap of clean material over contaminated sediment that remains in place. Caps are generally constructed of granular material, such as clean sediment, sand, or gravel" (EPA, 2005).

Containment Cell (subaqueous) for sediment, also referred to as contained aquatic disposal (CAD), "is a type of subaqueous capping in which the dredged sediment is placed into a natural or excavated depression elsewhere in the water body. A related form of disposal, known as level bottom capping, places the dredged sediment on a level bottom elsewhere in the water body, where it is capped. [CAD] has been used for navigational dredging projects (e.g., Boston Harbor, Providence River), but has been rarely considered for environmental dredging projects. However, there may be instances when neither dredging with land disposal nor capping contaminated sediment in-situ is feasible, and it may be appropriate to evaluate CADs. The depression used in the case of a CAD should provide lateral containment of the contaminated material, and also should have the advantage of requiring less maintenance and being more resistant to erosion than level-bottom capping" (EPA, 2005).

Containment Cell (upland, adjacent) for sediment refers to containment in a confined disposal facility (CDF) either upland or adjacent to the water body. "CDFs are engineered structures enclosed by dikes and designed to retain dredged material. They may be located upland (above the water table), partially in the water near shore, or completely surrounded by water. A CDF may have a large cell for material disposal, and adjoining cells for retention and decantation of turbid, supernatant water. A variety of linings have been used to prevent seepage through the dike walls. The most effective are clay or bentonite-cement slurries, but sand, soil, and sediment linings have also been used… Caps are the most effective way to minimize contaminant loss from CDFs, but selection of proper liner material is also an important control in CDFs. Finally, CDFs require continuous monitoring to ensure structural integrity." (EPA, 1991b).

Evapotranspiration (ET) Covers are alternatives to conventional cap and cover systems. "ET cover systems are designed to rely on the ability of a soil layer to store the precipitation until it is naturally evaporated or is transpired by the vegetative cover. In this respect they differ from more conventional cover designs in that they rely on obtaining an appropriate water storage capacity in the soil rather than…engineered low hydraulic conductivity [barrier components]. ET cover system designs are based on using the hydrological processes (water balance components) at a site, which include the water storage capacity of the soil, precipitation, surface runoff, evapotranspiration, and infiltration. The greater the storage capacity and evapotranspirative properties are, the lower the potential for percolation through the cover system" (EPA, 2011).

Repair (pipe/sewer/tank/structure) involves the repair of subsurface structures, such as pipes, sewer lines, and tanks, to control a source of contamination.

Vertical Engineered Barriers (VEB) are "[walls] built below ground to control the flow of groundwater. VEBs may be used to divert the direction of contaminated groundwater flow to keep it from reaching drinking water wells, wetlands, or streams. They also may be used to contain and isolate contaminated soil and groundwater to keep them from mixing with clean groundwater. VEBs differ from permeable reactive barriers in that they do not clean up contaminated groundwater" (EPA, 2012m). Common types of VEBs include slurry walls and sheet pile walls.

A.3 Monitored Natural Attenuation (MNA)

MNA is "the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a timeframe that is reasonable compared to that offered by other more active methods. The 'natural attenuation processes' that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants. When relying on natural attenuation processes for site remediation, EPA prefers those processes that degrade or destroy contaminants. Also, EPA generally expects that MNA will only be appropriate for sites that have a low potential for contaminant migration" (EPA, 1999b).

A.4 Monitored Natural Recovery (MNR) for Sediment

Sediment MNR "[relies] on a wide range of naturally occurring processes to reduce risk [from contaminated sediments] to human and/or ecological receptors. These processes may include physical, biological, and chemical mechanisms that act together to reduce the risk posed by the contaminants….Natural processes that reduce toxicity through transformation or reduce bioavailability through increased sorption are usually preferable as a basis for remedy selection to mechanisms that reduce exposure through natural burial or mixing-in-place because the destructive/sorptive mechanisms generally have a higher degree of permanence. However, many contaminants that remain in sediment are not easily transformed or destroyed. For this reason, risk reduction due to natural burial through sedimentation is more common and can be an acceptable sediment management option. Dispersion is the least preferable basis for remedy selection based on MNR. While dispersion may reduce risk in the source area, it generally increases exposure to contaminants and may result in unacceptable risks to downstream areas or other receiving water bodies….

"The key difference between MNA for ground water and MNR for sediment is in the type of processes most often being relied upon to reduce risk. Transformation of contaminants is usually the major attenuating process for contaminated ground water; however, these processes are frequently too slow for the persistent contaminants of concern in sediment to provide for remediation in a reasonable timeframe. Therefore, isolation and mixing of contaminants through natural sedimentation is the process most frequently relied upon for contaminated sediment" (EPA, 2005).

A.5 Enhanced Monitored Natural Recovery (EMNR) for Sediment

Natural recovery combined with an engineering approach is called Enhanced Monitored Natural Recovery. "In some areas, natural recovery may appear to be the most appropriate remedy, yet the rate of sedimentation or other natural processes is insufficient to reduce risks within an acceptable timeframe. Where this is the case, project managers may consider accelerating the recovery process by engineering means, for example by the addition of a thin layer of clean sediment. This approach is sometimes referred to as 'thin-layer placement' or 'particle broadcasting.' Thin-layer placement normally accelerates natural recovery by adding a layer of clean sediment over contaminated sediment. The acceleration can occur through several processes, including increased dilution through bioturbation of clean sediment mixed with underlying contaminants. Thin-layer placement is typically different than…isolation caps…because it is not designed to provide long-term isolation of contaminants from benthic organisms. While thickness of an isolation cap can range up to several feet, the thickness of the material used in thin layer placement could be as little as a few inches….Clean sediment can be placed in a uniform thin layer over the contaminated area or it can be placed in berms or windrows, allowing natural sediment transport processes to distribute the clean sediment to the desired areas.

"Project managers might also consider the addition of flow control structures to enhance deposition in certain areas of a site" (EPA, 2005).

Note that a layer of clean sediment placed as backfill following dredging or excavation is not considered EMNR.

A.6 Vapor Intrusion Mitigation

Vapor intrusion is the term given to migration of vapor-forming chemicals from any underground source into a structure (e.g., homes, businesses, schools) (EPA, 2015a). For example, vapors can enter buildings as a component of soil gas by migrating through cracks, seams, interstices, and gaps in basement floors, walls, or foundations ("adventitious openings") or through intentional openings (e.g., perforations due to utility conduits, sump pits) (EPA, 2015a).

As used in this document, mitigation refers to "interim actions taken to reduce or eliminate human exposure to vapor-forming chemicals in a specific building arising from the vapor intrusion pathway" (EPA, 2015a). Functionally, mitigation methods can be categorized into two basic strategies: (i) those that seek to prevent or reduce vapor entry into a building (e.g., active depressurization technologies, positive building pressurization, sealing cracks and openings); and (ii) those that seek to reduce or eliminate vapors that have entered into a building (e.g., indoor air treatment, interior ventilation). Neither strategy entails reducing the level of vapor-forming contamination in the subsurface source, which refers to remediation.

Active Depressurization Technology "creates a driving force for air flow from the building into the subsurface by lowering the pressure below the slab, thereby reducing vapor intrusion (soil gas entry into a building)" (EPA, 2015a). This approach is the most thoroughly studied and demonstrated approach for mitigating vapor intrusion. This approach consists of a group of methods that site teams can customize to treat different construction features of a building, including sub-slab depressurization (SSD), drain tile depressurization, wall depressurization, baseboard depressurization, and sub-membrane depressurization (EPA, 2015a). Another active depressurization method involves depressurization of a sewer system. This approach may be effective when the sewer is determined to be a major intrusion pathway (Nielsen and Hvidberg, 2017).

Interior Ventilation – Increasing building ventilation (i.e., increasing the rate at which indoor air is replaced with outdoor air) can reduce the buildup of vapor-forming chemicals within a structure. "Natural ventilation may be accomplished by opening windows, doors, and vents. Forced or mechanical ventilation may be accomplished by using a fan to blow air into or out of the building" (EPA, 2015a). Exhausting air from the building will generally contribute to under-pressurization of the building, relative to the subsurface, thereby potentially resulting in an increased rate of soil gas entry (i.e., vapor intrusion), which could lead to *higher* levels of vapors in indoor air unless ambient air entry into the building is increased disproportionately.

Passive Barrier (Impermeable Membrane) Installation involves "placing sheets of 'geomembrane' or strong plastic beneath a building to prevent vapor entry. Vapor barriers are best installed during building construction, but can be installed in existing buildings that have crawl spaces" (EPA, 2012l). Spray-on vapor barriers (rubberized asphalt emulsions or epoxy) may also be used (EPA, 2008a).

Passive Soil Depressurization is designed to achieve lower sub-slab air pressure relative to indoor air pressure by use of a vent pipe routed through the conditioned space of a building and venting to the outdoor air, thereby relying solely on the convective flow of air upward in the vent to draw air from beneath the slab" (EPA, 2008a).

Positive Building Pressurization "involves adjusting the building's heating, ventilation, and air-conditioning [HVAC] system to increase the pressure indoors relative to the sub-slab area. This method is typically used for office buildings and other large structures" (EPA, 2012l).

Sealing Cracks and Openings involves filling in adventitious and intentional openings in the building foundation using products such as synthetic rubbers, acrylics, oil-based sealants, asphalt/bituminous products, swelling cement, silicon, epoxy or elastomeric polymers (EPA, 2015a). In addition, "[c]oncrete can be poured over unfinished dirt floors" (EPA, 2012l).

Soil Pressurization systems "are used to push air into the soil or venting layer below the slab instead of pulling it out. The intention is to increase the sub-slab air pressure above ambient levels, forcing soil gas from the subsurface to the sides of the building." (ITRC, 2007)

Sub-slab Ventilation refers to engineered controls that function by diluting the vapor concentrations beneath the slab and foundation (EPA, 2008a) by drawing outside air into and through the sub-slab area. When installed during building construction, sub-slab ventilation systems "typically consist of: a venting layer (e.g., filled with porous media such as sand or pea gravel; or suitably fabricated with continuous voids) below a floor slab to allow soil gas to move laterally to a collection piping system for discharge to the atmosphere; and a sub-slab liner that is installed on top of the venting layer to reduce entry points for vapor intrusion" (EPA, 2015a).

A.7 Other or Unspecified Remedies

Alternative Water Supply Remedy - "In CERCLA, section 101(34) states that '[t]he term 'alternative water supplies' includes, but is not limited to, drinking water and household water supplies.' Also, CERCLA section 118 states that in taking response actions, the President [EPA] shall 'give a high priority to facilities where the release of hazardous substances or pollutants or contaminants has resulted in the closing of drinking water wells or has contaminated a principal drinking water supply.'…Providing an alternative supply of water to affected users generally is designed to prevent residents from being exposed to contaminated groundwater…Providing an alternative water supply may involve furnishing clean, drinkable water on a permanent or temporary basis. For example, providing a permanent supply of drinking water may include installing a private well, connecting to a municipal water system, drilling of a new community water supply well, or reinstating a previously contaminated water supply well once the groundwater has been cleaned up. Examples of providing a temporary supply of water may involve installing individual treatment units or delivering bottled water. When a [Superfund] response action that provides an alternative water supply involves connecting hundreds of homes to a municipal system (i.e., a residential connection to a water purveyor), it generally means that [residents are connected] to a water supply line that is located relatively close by" (EPA, 2010).

Fracturing for Site Cleanup – "Fracturing creates or enlarges openings in bedrock or dense soil, such as clay, to help soil and groundwater cleanup methods work better. The openings, called "fractures," become pathways through which contaminants in soil and groundwater can be treated in situ (in place, underground) or removed for above-ground treatment. Although fractures can occur naturally in soil and rock, they are not always wide or long enough to easily reach underground contamination using cleanup methods. Fracturing can enlarge the cracks and create new ones to improve the speed and effectiveness of the cleanup" (EPA, 2012d).

Fracturing for site cleanup is different from fracturing to recover oil and gas. "Oil and gas hydraulic fracturing is used to stimulate the recovery of oil or natural gas from underground geologic formations. Oil and gas hydraulic fracturing works by pumping a mixture of fluids and other substances into the target formation to create and enlarge fractures. Such operations are much larger, use different equipment and chemical additives, occur at greater depths, and use higher volumes of fluid than fracturing for site cleanup. Fracturing to clean up a contaminated site rarely exceeds a depth of 100 feet, and the affected area around the fracturing well usually is less than 100 feet in any direction. However, wells to extract oil and gas often are drilled hundreds or thousands of feet downward and sometimes horizontally into the oil- or gas-bearing rock. Fractures may extend over 500 feet from these wells" (EPA, 2012d).

Institutional Controls (ICs) are defined by EPA as "non-engineered instruments, such as administrative and legal controls, that help to minimize the potential for human exposure to contamination and/or protect the integrity of a response action. ICs typically are designed to work by limiting land and/or resource use or by providing information that helps modify or guide human behavior at a site. ICs are a subset of Land Use Controls (LUCs). LUCs include engineering and physical barriers, such as fences and security guards, as well as ICs" (EPA, 2012n). Some common examples of ICs include zoning restrictions, building or excavation permits, well drilling prohibitions, easements, and covenants.

Soil Amendments – "Many soils, particularly those found in urban, industrial, mining, and other disturbed areas, suffer from a range of physical, chemical, and biological limitations. They include soil toxicity, too high or too low pH, lack of sufficient organic matter, reduced water-holding capacity, reduced microbial communities, and compaction. Appropriate soil amendments may be inorganic (e.g., liming materials), organic (e.g., composts) or mixtures (e.g., lime-stabilized biosolids). When specified and applied properly, these beneficial soil amendments may limit many of the exposure pathways and reduce soil phytotoxicity. Soil amendments also can restore appropriate soil conditions for plant growth by balancing pH, adding organic matter, restoring soil microbial activity, increasing moisture retention, and reducing compaction." (EPA, 2007).

Wetlands Replacement – "Compensatory mitigation is required to replace the loss of wetland and aquatic resource functions in [a] watershed. Compensatory mitigation refers to the restoration, establishment, enhancement, or in certain circumstances preservation of wetlands, streams or other aquatic resources for the purpose of offsetting unavoidable adverse impacts [from a specific project (EPA, 2008c). For the purposes of this report, mitigation performed at the site of the adverse impacts is excluded from the definition of wetlands replacement. For mitigation performed at the site of adverse impacts, see Wetlands Restoration. For wetlands constructed as a form of treatment, see Constructed Treatment Wetlands.

Wetlands Restoration is defined as "[r]e-establishment or rehabilitation of a wetland or other aquatic resource with a goal of returning natural or historic functions and characteristics to a former or degraded wetland" (EPA, 2008c). For the purposes of this report, restoration conducted at a location other than the impacted site is excluded from the definition of wetlands restoration and is instead considered Wetlands Replacement. For wetlands constructed as a form of treatment, see Constructed Treatment Wetlands.

APPENDIX B

TREATMENT TECHNOLOGIES BY FISCAL YEAR

Appendix B: Treatment Technologies by Fiscal Year

Type	Remedy	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	Total
Ex Situ Source Treatment	Acid Extraction	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	Aeration	0	0	0	1	2	2	2	3	1	4	0	0	0	0	0	0	2	3	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	24
	Bioremediation	0	0	1	0	3	2	6	9	4	5	9	8	6	6	6	1	4	9	3	0	3	2	3	1	0	2	0	2	1	1	0	0	1	0	1	0	99
	Chemical Treatment	0	0	0	1	0	0	1	5	0	4	2	4	0	3	2	1	2	2	1	2	1	0	1	3	1	0	0	1	0	1	0	1	1	1	0	0	41
	Constructed Treatment Wetland	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	1	1	0	0	7
	Incineration	0	0	0	2	2	1	2	4	0	0	0	5	1	2	3	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
	Incineration (off-site)	0	0	7	5	8	3	9	10	9	16	7	14	7	10	7	5	5	6	1	2	3	0	1	0	1	0	1	0	1	0	5	0	0	0	2	0	145
	Incineration (on-site)	0	0	1	2	5	8	12	12	18	6	4	5	2	4	3	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85
	Neutralization	0	1	0	0	0	0	0	0	1	0	4	0	0	1	2	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	13
	Open Burn/Open Detonation	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	7
	Physical Separation	0	1	3	11	9	7	20	19	20	33	24	20	7	17	16	11	18	14	8	8	9	12	9	9	8	4	5	14	9	10	11	6	12	6	8	8	406
	Recycling	0	1	0	0	2	2	7	4	9	9	12	12	5	4	9	3	4	5	3	1	5	2	5	6	5	2	0	4	2	3	3	5	5	2	2	1	144
	Soil Vapor Extraction	0	0	0	1	0	1	3	0	2	0	0	0	10	2	3	1	0	2	0	1	0	0	1	1	0	1	0	0	0	0	0	1	0	0	1	1	32
	Soil Washing	0	0	0	0	1	1	2	3	9	2	4	2	0	3	1	1	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33
	Solidification/Stabilization	0	0	2	0	8	10	16	17	15	26	31	23	8	11	10	9	12	10	8	1	10	8	11	4	15	5	10	9	5	5	3	1	2	1	0	2	308
	Source P&T	2	0	2	8	6	4	18	5	7	12	13	8	4	6	3	2	4	4	1	2	5	1	3	1	1	1	1	1	2	1	2	1	0	3	4	0	138
	Thermal Desorption	0	0	0	0	0	0	1	1	5	8	1	4	3	6	8	1	7	5	1	1	2	1	1	2	0	0	0	1	0	0	0	1	0	1	0	0	61
	Thermal Treatment	0	0	0	0	2	3	8	6	5	4	2	3	2	4	2	1	2	2	5	0	1	1	0	0	1	0	0	0	1	0	2	0	0	1	0	3	61
	Unspecified Ex Situ Treatment	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
	Unspecified Ex Situ Treatment (off-site)	0	1	0	3	2	1	0	5	8	4	2	2	5	4	3	3	2	4	5	1	6	1	5	3	2	1	4	3	3	6	2	1	5	1	1	7	106
	Unspecified Ex Situ Treatment (on-site)	0	0	0	2	2	2	2	4	1	1	1	6	1	3	2	2	1	2	0	0	1	1	2	2	0	1	0	0	0	0	4	0	2	0	0	1	46
	Total	**2**	**4**	**16**	**36**	**52**	**47**	**109**	**107**	**115**	**135**	**119**	**118**	**61**	**88**	**80**	**43**	**66**	**69**	**40**	**22**	**50**	**29**	**42**	**33**	**35**	**17**	**22**	**36**	**25**	**29**	**32**	**18**	**29**	**18**	**19**	**24**	**1,787**
In Situ Source Treatment	Amendments (sediment)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
	Bioremediation	0	0	0	0	0	1	4	2	2	2	7	4	6	9	11	4	12	9	3	3	3	1	1	3	5	3	1	2	2	2	1	2	4	4	1	1	115
	Cap (amended, in situ sediment)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	1	1	0	1	7
	Chemical Treatment	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	1	2	2	1	4	7	4	3	3	7	2	1	2	43
	Constructed Treatment Wetland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
	Electrokinetics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Flushing	0	0	0	1	0	2	4	6	3	6	3	3	2	0	1	1	0	2	2	1	0	0	0	0	0	0	2	0	1	0	0	0	0	1	0	0	41
	Fracturing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	3
	Multi-phase Extraction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	2	0	5
	Phytoremediation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	7
	Soil Amendments	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1	0	1	2	1	0	1	1	1	0	0	12
	Soil Vapor Extraction	0	0	0	0	0	3	9	16	15	31	18	18	7	11	22	17	12	11	7	8	11	12	8	7	7	7	7	6	7	10	2	6	6	3	2	4	310
	Solidification/Stabilization	1	0	1	2	0	3	5	5	6	7	12	9	4	6	11	10	18	5	6	4	5	3	3	5	6	2	5	3	4	3	2	3	2	2	3	4	170
	Thermal Treatment	0	0	0	0	1	2	1	5	6	5	2	11	5	6	3	6	1	5	5	1	0	0	1	4	3	2	2	3	4	0	5	3	3	2	3	3	103
	Unspecified In Situ Treatment	0	0	0	1	0	1	2	0	3	1	0	1	2	3	0	0	0	1	1	1	3	0	1	2	0	1	1	0	0	1	0	0	0	0	0	0	26
	Total	**1**	**0**	**1**	**4**	**1**	**13**	**25**	**34**	**36**	**53**	**42**	**46**	**26**	**35**	**48**	**38**	**45**	**37**	**26**	**18**	**22**	**16**	**15**	**23**	**25**	**19**	**20**	**23**	**27**	**21**	**14**	**21**	**25**	**17**	**12**	**17**	**846**
Source Treatment (Unspecified)	Unspecified Source Treatment	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
	Unspecified Treatment (on-site)	1	1	0	6	3	3	8	2	5	6	8	4	2	3	0	3	5	4	4	2	3	2	5	1	2	0	1	1	1	1	0	0	0	0	0	0	87
	Total	**1**	**1**	**0**	**6**	**3**	**3**	**9**	**2**	**5**	**6**	**9**	**4**	**2**	**3**	**0**	**3**	**5**	**4**	**4**	**2**	**3**	**2**	**5**	**2**	**2**	**0**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**90**
In Situ Groundwater Treatment	Air Sparging	0	0	0	0	0	0	0	0	0	1	0	4	3	6	6	12	8	10	7	5	6	2	2	5	2	1	1	6	3	1	1	2	2	0	0	3	99
	Bioremediation	0	0	0	1	1	1	1	6	5	5	6	4	6	5	5	2	3	4	5	9	6	3	5	11	21	14	13	22	20	10	13	17	17	10	10	10	271
	Chemical Treatment	0	0	0	0	0	1	0	1	2	2	2	0	0	3	0	0	1	0	3	0	0	0	0	7	10	13	5	6	10	10	15	9	15	11	8	7	141
	Electrokinetics	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
	Flushing	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	4
	Fracturing	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	5
	In-well Air Stripping	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	1	0	0	0	0	2	0	0	0	1	1	0	0	0	9
	Multi-phase Extraction	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	0	2	0	2	0	1	1	1	1	1	1	1	1	0	2	0	1	1	2	22
	Permeable Reactive Barrier	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	1	4	0	2	3	1	2	5	3	4	1	1	1	3	4	0	4	3	0	4	1	51
	Phytoremediation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	1	0	1	2	0	2	0	0	0	0	0	0	0	2	0	1	0	13
	Solidification/Stabilization	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
	Thermal Treatment	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	2	1	2	1	3	13
	Unspecified In Situ Treatment	0	1	0	0	0	0	0	1	2	4	1	1	1	0	1	1	2	1	4	1	5	3	6	2	1	4	0	0	0	0	0	1	2	1	1	1	48
	Vapor Extraction	0	0	0	0	0	0	0	0	0	3	1	1	1	3	2	9	4	5	1	0	0	1	0	0	0	2	2	0	1	2	0	0	0	0	0	1	39
	Total	**0**	**1**	**0**	**1**	**2**	**2**	**2**	**11**	**9**	**17**	**12**	**10**	**14**	**18**	**15**	**27**	**23**	**21**	**27**	**20**	**21**	**13**	**22**	**30**	**41**	**36**	**23**	**38**	**38**	**28**	**31**	**40**	**44**	**26**	**27**	**30**	**720**
Groundwater Pump and Treat	Pump and Treat	3	5	13	27	43	37	77	67	92	114	75	76	74	62	57	50	34	40	46	32	31	13	23	32	23	28	21	19	13	14	15	13	9	9	7	6	1,300

Data in Appendix B may vary from data presented in the SRR 15th Edition. EPA has updated the dataset to add remedy components for decision documents from the early years of the program that had not previously been recorded and has updated older data to conform more readily to recently updated media and remedy categories.

APPENDIX C

INDIVIDUAL CONTAMINANTS AND ASSIGNED CONTAMINANT GROUPS

Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
(2-METHYL-2-PROPANYL)BENZENE		X									X					
(2Z)-2-BUTENEDIOIC ACID				X									X			
(3R)-1-AZABICYCLO[2.2.2]OCTAN-3-YL HYDROXY(DIPHENYL)ACETATE				X									X			
(4-CHLORO-2-METHYLPHENOXY)ACETIC ACID		X												X		
(E)-1,3-DICHLORO-1-PROPENE			X				X									
(Z)-1,3-DICHLORO-1-PROPENE			X				X									
[(E)-PROP-1-ENYL]BENZENE				X									X			
1,1,1,2-TETRACHLOROETHANE			X				X									
1,1,1-TRICHLOROETHANE			X				X									
1,1,2,2-TETRABROMOETHANE			X				X									
1,1,2,2-TETRACHLORO-1,2-DIFLUOROETHANE			X				X									
1,1,2,2-TETRACHLOROETHANE			X				X									
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE			X				X									
1,1,2-TRICHLOROETHANE			X				X									
1,1'-BIPHENYL			X				X									
1,1-DICHLOROETHANE			X				X									
1,1-DICHLOROETHENE			X				X									
1,2,3,4,6,7,8,9-OCTACHLORODIBENZO[b,e][1,4]DIOXIN (OCDD)		X				X										
1,2,3,4,6,7,8,9-OCTACHLORODIBENZOFURAN		X				X										
1,2,3,4,6,7,8-HEPTACHLORODIBENZO[b,e][1,4]DIOXIN (HpCDD)		X				X										
1,2,3,4,7,8-HEXACHLORODIBENZO[b,e][1,4]DIOXIN (HxCDD)		X				X										
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN (HxCDF)		X				X										
1,2,3,4-TETRACHLOROBENZENE		X							X							
1,2,3,6,7,8-HEXACHLORODIBENZO[b,e][1,4]DIOXIN (HxCDD)		X				X										
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN (HxCDF)		X				X										
1,2,3,7,8-PENTACHLORODIBENZO[b,e][1,4]DIOXIN (PeCDD)		X				X										
1,2,3,7,8-PENTACHLORODIBENZOFURAN		X				X										
1,2,3-TRICHLOROBENZENE		X							X							
1,2,3-TRICHLOROPROPANE			X				X									
1,2,3-TRIMETHYLBENZENE			X									X				
1,2,4,5-TETRACHLOROBENZENE		X							X							
1,2,4-TRICHLOROBENZENE		X							X							
1,2,4-TRIMETHYLBENZENE			X									X				
1,2-DIBROMO-3-CHLOROPROPANE		X												X		
1,2-DIBROMOETHANE			X				X									
1,2-DICHLORO-1,1,2,2-TETRAFLUOROETHANE			X				X									
1,2-DICHLOROBENZENE			X				X									
1,2-DICHLOROETHANE			X				X									
1,2-DICHLOROETHENE (CIS AND TRANS MIXTURE)			X				X									
1,2-DICHLOROPROPANE			X				X									
1,2-DIHYDROACENAPHTHYLENE		X														X
1,2-DIMETHYLBENZENE (O-XYLENE)			X		X											
1,2-DIPHENYLHYDRAZINE		X									X					
1,2-ETHANEDIOL (ETHYLENE GLYCOL)		X									X					
1,2-PROPANEDIOL		X									X					
1,3 (OR 1,4)-DIMETHYLBENZENE (M (OR P)-XYLENE)			X		X											

Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
1,3,5,7-TETRANITRO-1,3,5,7-TETRAZOCANE (HMX)		X									X					
1,3,5-TRICHLOROBENZENE		X							X							
1,3,5-TRIMETHYLBENZENE			X									X				
1,3,5-TRINITROBENZENE		X									X					
1,3-BENZENEDIOL		X									X					
1,3-BUTADIENE			X									X				
1,3-DICHLOROBENZENE			X				X									
1,3-DICHLOROPROPENE (EZ MIXTURE)			X				X									
1,3-DIMETHYLBENZENE (M-XYLENE)			X		X											
1,3-DINITROBENZENE		X									X					
1,3-DIOXO-1,3-DIHYDRO-2-BENZOFURAN-5-CARBOXYLIC ACID				X									X			
1,4-BENZENEDICARBOXYLIC ACID				X									X			
1,4-DICHLOROBENZENE			X				X									
1,4-DIMETHYLBENZENE (P-XYLENE)			X		X											
1,4-DINITROBENZENE		X									X					
1,4-DIOXANE			X									X				
1,4-DITHIANE			X				X									
10-CHLORO-5H-PHENARSAZININE				X									X			
10H-PHENOTHIAZINE				X									X			
1-BROMO-4-PHENOXYBENZENE		X							X							
1-BUTANOL (N-BUTANOL)			X									X				
1-BUTOXYBUTANE			X									X				
1-CHLORO-2-[(2-CHLOROETHYL)SULFANYL]ETHANE			X				X									
1-CHLORO-2-ETHENOXYETHANE			X				X									
1-CHLORO-2-METHYLBENZENE (O-CHLOROTOLUENE)			X				X									
1-CHLORO-4-PHENOXYBENZENE		X							X							
1H-INDENE		X														X
1-METHYL-2-NITROBENZENE		X									X					
1-METHYL-3-NITROBENZENE		X									X					
1-METHYL-4-NITROBENZENE		X									X					
1-METHYL-4-PROPAN-2-YLBENZENE		X									X					
1-METHYLNAPHTHALENE		X														X
1-NITROSOPYRROLIDINE		X									X					
1-PHENYLETHANONE		X									X					
1-PROPENE			X									X				
2-(1-METHYLPROPYL)-4,6-DINITROPHENOL (DINOSEB)		X												X		
2-(2,4,5-TRICHLOROPHENOXY)PROPANOIC ACID		X												X		
2-(2,4-DICHLOROPHENOXY)PROPANOIC ACID		X												X		
2,2',2''-NITRILOTRIETHANOL			X									X				
2,2,2-TRICHLORO-1,1-BIS(4-CHLOROPHENYL)ETHANOL		X												X		
2,2,4-TRIMETHYLPENTANE			X									X				
2,2-DICHLOROETHENYL DIMETHYL PHOSPHATE		X												X		
2,2'-OXYDIETHANOL				X									X			
2,3,4,7,8-PENTACHLORODIBENZOFURAN (PeCDF)		X				X										
2,3,5,6-TETRACHLOROPHENOL		X							X							
2,3,7,8-TETRACHLORODIBENZOFURAN		X				X										

Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN (TCDD)		X				X										
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN (TCDD) TOXICITY EQUIVALENTS (TEq)		X				X										
2,4,5-TRICHLOROPHENOL		X							X							
2,4,5-TRICHLOROPHENOXYACETIC ACID		X												X		
2,4,6-TRICHLOROPHENOL		X							X							
2,4,6-TRINITROPHENOL		X									X					
2,4,6-TRINITROTOLUENE		X									X					
2,4-DICHLOROPHENOL		X							X							
2,4-DICHLOROPHENOXYACETIC ACID		X												X		
2,4-DIMETHYLPHENOL		X							X							
2,4-DINITROPHENOL		X							X							
2,4-DINITROTOLUENE		X									X					
2,6-DINITROTOLUENE		X									X					
2-[FLUORO(METHYL)PHOSPHORYL]OXYPROPANE (SARIN)			X				X									
2-AMINO-4,6-DINITROTOLUENE		X									X					
2-AMINOPYRIDINE				X									X			
2-BENZOFURAN-1,3-DIONE		X									X					
2-BUTANONE (METHYL ETHYL KETONE)			X									X				
2-BUTOXYETHANOL				X									X			
2-CHLORO-1-PHENYLETHANONE				X									X			
2-CHLOROANILINE		X							X							
2-CHLORONAPHTHALENE		X							X							
2-CHLOROPHENOL		X							X							
2-ETHOXYETHANOL			X									X				
2-FLUOROACETIC ACID		X												X		
2-HEXANONE			X									X				
2-HYDROXY-2,2-DIPHENYLACETIC ACID				X						X						
2-METHOXY-2-METHYLPROPANE (MTBE)			X									X				
2-METHYL-2-PROPANOL			X									X				
2-METHYL-4,6-DINITROPHENOL (4,6-DINITRO-O-CRESOL)		X							X							
2-METHYLANILINE		X									X					
2-METHYLNAPHTHALENE		X														X
2-METHYLOXIRANE			X									X				
2-METHYLPHENOL (O-CRESOL)		X							X							
2-METHYLPROP-2-ENENITRILE			X									X				
2-NAPHTHALENAMINE		X									X					
2-NITROANILINE		X									X					
2-NITROPHENOL		X							X							
2-PROPAN-2-YLOXYPROPANE			X									X				
2-PROPANOL			X									X				
2-PROPENENITRILE (ACRYLONITRILE)			X									X				
3-(3,4-DICHLOROPHENYL)-1,1-DIMETHYLUREA (DIURON)		X												X		
3-(4-CHLOROPHENYL)-1,1-DIMETHYLUREA		X												X		
3,5,5-TRIMETHYLCYCLOHEX-2-EN-1-ONE		X									X					
3,6-DICHLORO-2-METHOXYBENZOIC ACID		X												X		
3-CHLOROANILINE		X							X							

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3-CHLOROPROP-1-ENE			X				X									
3-METHYLPHENOL (M-CRESOL)		X							X							
3-METHYLPHENOL (MIXED MONOCHLORINATED ISOMERS)		X							X							
3-NITROANILINE		X									X					
4-(2,4-DICHLOROPHENOXY)BUTANOIC ACID		X												X		
4-(4-AMINO-3-CHLOROPHENYL)-2-CHLOROANILINE		X							X							
4-(4-AMINO-3-METHYLPHENYL)-2-METHYLANILINE		X									X					
4,4'-METHYLENEBIS(2-CHLOROANILINE)		X							X							
4-AMINO-2,6-DINITROTOLUENE		X									X					
4-CHLORO-3-METHYLPHENOL		X							X							
4-CHLOROANILINE		X							X							
4-CYANO-1,2,3,4-TETRAHYDRO-1-NAPHTHALENE-PROPIONITRILE		X									X					
4-CYANO-1,2,3,4-TETRAHYDRO-ALPHA-METHYL-1-NAPHTHALENEACETONITRILE		X									X					
4-METHOXYPHENOL		X							X							
4-METHYL-2-PENTANONE (METHYL ISOBUTYL KETONE)			X									X				
4-METHYLCHRYSENE		X														X
4-METHYLHEPTYL 2-(2,4,5-TRICHLOROPHENOXY)PROPANOATE		X												X		
4-METHYLPHENOL (P-CRESOL)		X							X							
4-NITROANILINE		X									X					
4-NITROPHENOL		X							X							
4-NITROSODIPHENYLAMINE		X									X					
4-PHENYLANILINE		X									X					
9H-CARBAZOLE		X									X					
9H-FLUORENE		X														X
ACENAPHTHYLENE		X														X
ACETONE			X									X				
ACETONITRILE			X									X				
ACROLEIN			X									X				
ACRYLAMIDE		X												X		
ACTINIUM-227	X							X								
ACTINIUM-228	X							X								
ALACHLOR		X												X		
ALDRIN		X												X		
ALPHA GROSS				X						X						
ALPHA-CHLORDANE		X												X		
ALPHA-HEXACHLOROCYCLOHEXANE		X												X		
ALUMINUM	X							X								
ALUMINUM OXIDE	X							X								
AMERICIUM	X							X								
AMERICIUM-241	X							X								
AMMONIA				X						X						
AMMONIUM HYDROXIDE				X						X						
AMMONIUM NITRATE				X						X						
AMMONIUM TETRACHLOROZINCATE				X						X						
ANILINE		X									X					
ANTHANTHRENE		X														X

Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
ANTHRACENE		X														X
ANTIMONY	X							X								
ANTIMONY COMPOUNDS	X							X								
AROCLOR 1016		X													X	
AROCLOR 1221		X													X	
AROCLOR 1232		X													X	
AROCLOR 1242		X													X	
AROCLOR 1248		X													X	
AROCLOR 1254		X													X	
AROCLOR 1260		X													X	
AROCLOR 1268		X													X	
ARSENIC	X							X								
ARSENIC COMPOUNDS	X							X								
ASBESTOS				X						X						
ATRAZINE		X												X		
AZEPAN-2-ONE				X									X			
AZOBENZENE		X									X					
AZULENE		X														X
BARIUM	X							X								
BARIUM CHLORIDE				X						X						
BARIUM COMPOUNDS	X							X								
BENZALDEHYDE			X									X				
BENZENE			X		X											
BENZIDINE		X									X					
BENZIDINE AND ITS SALTS		X									X					
BENZO(B)FLUORANTHENE		X														X
BENZO(GHI)PERYLENE		X														X
BENZO(K)FLUORANTHENE		X														X
BENZO[A]ACEANTHRYLENE		X														X
BENZO[A]ANTHRACENE		X														X
BENZO[A]PYRENE		X														X
BENZO[A]PYRENE EQUIVALENTS (BaPEq)		X														X
BENZO[E]PYRENE		X														X
BENZO[J]FLUORANTHENE		X														X
BENZOIC ACID		X									X					
BENZONITRILE			X									X				
BENZOPHENONE			X									X				
BENZOYL BENZENECARBOPEROXOATE				X									X			
BENZOYL CHLORIDE			X				X									
BERYLLIUM	X							X								
BERYLLIUM COMPOUNDS	X							X								
BETA GROSS				X						X						
BETA-HEXACHLOROCYCLOHEXANE		X												X		
BIS(2-CHLOROETHOXY) METHANE		X							X							
BIS(2-CHLOROETHYL)ETHER		X							X							
BIS(2-CHLOROISOPROPYL) ETHER		X							X							

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	High Level Group				Detailed Category											
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BIS(2-ETHYLHEXYL) ADIPATE				X									X			
BIS(2-ETHYLHEXYL)PHTHALATE		X									X					
BIS(CHLOROMETHYL) ETHER			X				X									
BISMUTH	X							X								
BISMUTH TEILLURIDE				X						X						
BORON	X							X								
BORON OXIDE				X						X						
BROMACIL		X												X		
BROMINE (BR2)				X						X						
BROMINE-CONTAINING INORGANIC COMPOUNDS				X						X						
BROMOCHLOROMETHANE			X				X									
BROMODICHLOROMETHANE			X				X									
BROMOFORM			X				X									
BROMOMETHANE			X				X									
BUTAN-2-YLBENZENE			X									X				
BUTYL ACETATE			X									X				
BUTYL BENZYL PHTHALATE		X									X					
BUTYLATE		X												X		
BUTYLBENZENE			X									X				
C.I. ACID GREEN 3				X									X			
C.I. BASIC VIOLET 1				X									X			
C11-C22 AROMATIC HYDROCARBONS		X											X			
C13-C18 ALIPHATIC HYDROCARBONS		X											X			
C19-C36 ALIPHATIC HYDROCARBONS		X											X			
C5-C8 ALIPHATIC HYDROCARBONS		X											X			
C9-C10 AROMATIC HYDROCARBONS		X											X			
C9-C12 ALIPHATIC HYDROCARBONS		X											X			
C9-C18 ALIPHATIC HYDROCARBONS		X											X			
CADMIUM	X							X								
CALCIUM	X							X								
CALCIUM CARBONATE				X						X						
CALCIUM OXIDE				X						X						
CAMPHOR				X									X			
CARBARYL		X												X		
CARBOFURAN		X												X		
CARBON DISULFIDE			X									X				
CARBON TETRACHLORIDE			X				X									
CARBON-14				X						X						
CARBONYL DICHLORIDE (PHOSGENE)				X						X						
CARBOPHENOTHION		X												X		
CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS (cPAH)		X														X
CESIUM	X							X								
CESIUM-134	X							X								
CESIUM-137	X							X								
CHLORDANE		X												X		
CHLORDECONE		X												X		

Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
CHLORENDIC ACID				X									X			
CHLORIDE				X						X						
CHLORINATED DIOXINS AND FURANS		X				X										
CHLORINE (CL2)				X						X						
CHLOROACETIC ACID		X												X		
CHLOROBENZENE			X				X									
CHLOROBENZILATE		X												X		
CHLOROBENZOIC ACID		X												X		
CHLOROETHANE			X				X									
CHLOROETHENE (VINYL CHLORIDE)			X				X									
CHLOROFORM			X				X									
CHLOROMETHANE			X				X									
CHLOROMETHYLBENZENE			X				X									
CHLOROPHENOXY HERBICIDES		X												X		
CHLORPYRIFOS		X												X		
CHROMIC ACID				X						X						
CHROMIUM	X							X								
CHROMIUM (HEXAVALENT COMPOUNDS)	X							X								
CHROMIUM (III)	X							X								
CHROMIUM COMPOUNDS	X							X								
CHROMIUM(III) CHLORIDE				X						X						
CHROMIUM(III) SULFATE				X						X						
CHROMIUM(VI)	X							X								
CHRYSENE		X														X
CIS-1,2-DICHLOROETHENE			X				X									
COBALT	X							X								
COBALT-57	X							X								
COBALT-60	X							X								
COPPER	X							X								
COPPER COMPOUNDS	X							X								
COUMAPHOS		X												X		
CREOSOTE		X														X
CRESOL (MIXED ISOMERS)		X									X					
CUMENE			X									X				
CURIUM	X							X								
CYANIDE				X						X						
CYANIDE COMPOUNDS				X						X						
CYANIDES, INORGANIC SALTS				X						X						
CYCLOHEXANE			X									X				
CYCLOHEXANOL			X									X				
CYCLOHEXANONE			X									X				
DDT AND METABOLITES		X												X		
DELTA-HEXACHLOROCYCLOHEXANE		X												X		
DEMEPHION-S		X												X		
DIAMINOTOLUENE (MIXED ISOMERS)		X									X					
DIAZINON		X												X		

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DIBENZ[A,H]ACRIDINE		X														X
DIBENZ[A,J]ANTHRACENE		X														X
DIBENZO(A,H)ANTHRACENE		X														X
DIBENZO[A,E]PYRENE		X														X
DIBENZO[A,H]PYRENE		X														X
DIBENZOFURAN		X									X					
DIBROMOCHLOROMETHANE			X				X									
DIBROMOMETHANE			X				X									
DIBUTYL PHTHALATE		X									X					
DICHLORO-[(E)-2-CHLOROETHENYL]ARSANE (LEWISITE)	X							X								
DICHLOROBENZENE (MIXED ISOMERS)			X				X									
DICHLORODIFLUOROMETHANE			X				X									
DICHLOROMETHANE (METHYLENE CHLORIDE)			X				X									
DICHLOROPROPANE (MIXED ISOMERS)			X				X									
DICYCLOPENTADIENE		X									X					
DIELDRIN		X												X		
DIESEL FUEL		X											X			
DIESEL RANGE ORGANICS		X											X			
DIETHYL ETHER			X									X				
DIETHYL PHTHALATE		X									X					
DIETHYLBENZENE (MIXED ISOMERS)		X									X					
DIMETHOXYMETHANE			X									X				
DIMETHYL PHENOL (MIXED ISOMERS)		X									X					
DIMETHYL PHTHALATE		X									X					
DIMETHYL SULFIDE				X									X			
DIMETHYLFORMAMIDE		X												X		
DIMETHYLMERCURY			X									X				
DINITROTOLUENE (MIXED ISOMERS)		X									X					
DI-N-OCTYL PHTHALATE		X									X					
DIOXINS (CHLORINATED DIBENZODIOXINS)		X				X										
DIOXINS AND DIBENZOFURANS		X				X										
DIPHENAMID		X												X		
DIPHENYLAMINE		X									X					
DISULFOTON		X												X		
ENDOSULFAN (I OR II)		X												X		
ENDOSULFAN I		X												X		
ENDOSULFAN II		X												X		
ENDOSULFAN SULFATE		X												X		
ENDRIN		X												X		
ENDRIN ALDEHYDE		X												X		
ENDRIN KETONE		X												X		
ETHANE			X									X				
ETHANE-1,2-DIAMINE		X												X		
ETHANETHIOL			X									X				
ETHANOL			X									X				
ETHION		X												X		

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ETHYL ACETATE			X									X				
ETHYL CARBONOCHLORIDATE			X				X									
ETHYL PROP-2-ENOATE			X									X				
ETHYLBENZENE			X		X											
EUROPIUM	X							X								
EUROPIUM-152	X							X								
EUROPIUM-155	X							X								
FENSULFOTHION		X												X		
FLUORANTHENE		X														X
FLUORIDE				X						X						
FLUORINE (F2)				X						X						
FONOFOS		X												X		
FORMALDEHYDE			X									X				
FORMIC ACID			X									X				
FORMOTHION		X												X		
FURAN		X				X										
GAMMA RADIOACTIVITY EMITTERS				X						X						
GAMMA-CHLORDANE		X												X		
GAMMA-HEXACHLOROCYCLOHEXANE (LINDANE)		X												X		
GASOLINE		X											X			
GUTHION		X												X		
HALOGENATED VOCs			X				X									
HEAVY METALS	X							X								
HEPTACHLOR		X												X		
HEPTACHLOR EPOXIDE		X												X		
HEPTACHLORODIBENZO[b,e][1,4]DIOXIN (HpCDD) (MIXED ISOMERS)		X				X										
HEPTANE			X									X				
HEXACHLORO-1,3-BUTADIENE		X							X							
HEXACHLOROBENZENE		X												X		
HEXACHLOROCYCLOPENTADIENE		X												X		
HEXACHLORODIBENZO[b,e][1,4]DIOXIN (HxCDD) (MIXED ISOMERS)		X				X										
HEXACHLOROETHANE		X							X							
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE (RDX)		X									X					
HEXANE			X									X				
HYDRAZINE				X						X						
HYDROCARBONS		X											X			
HYDROGEN (H2)				X						X						
HYDROGEN CARBONATE				X						X						
HYDROGEN CHLORIDE				X						X						
HYDROGEN CYANIDE				X						X						
HYDROGEN SULFIDE				X						X						
INDENO(1,2,3-CD)PYRENE		X														X
INDIUM	X							X								
INORGANICS				X						X						
IODINE (I2)				X						X						
IODINE-129				X						X						

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IRON	X							X								
ISODRIN		X												X		
KEROSENE		X											X			
LEAD	X							X								
LEAD COMPOUNDS	X							X								
LEAD COMPOUNDS (INORGANIC)	X							X								
LEAD(II) ACETATE			X									X				
LEAD-210	X							X								
LEAD-212	X							X								
LINURON		X												X		
LITHIUM	X							X								
MAGNESIUM	X							X								
MALATHION		X												X		
MANGANESE	X							X								
MANGANESE COMPOUNDS	X							X								
MANGANESE-54	X							X								
MECOPROP		X												X		
MERCURY	X							X								
MERCURY COMPOUNDS	X							X								
METALS	X							X								
METHANE			X									X				
METHANETHIOL			X									X				
METHANOL			X									X				
METHIOCARB		X												X		
METHOXYCHLOR		X												X		
METHYL 2-METHYLPROP-2-ENOATE			X									X				
METHYL ACETATE			X									X				
METHYL MERCURY	X							X								
METHYL PARATHION		X												X		
METHYL PROP-2-ENOATE			X									X				
METHYLCYCLOHEXANE			X									X				
METHYLCYCLOHEXANOL (MIXED ISOMERS)			X									X				
METHYLMERCURY DICYANDIAMIDE		X												X		
METHYLPHOSPHONIC ACID				X									X			
MEVINPHOS		X												X		
MINERAL OILS		X									X					
MIREX		X												X		
MOLINATE		X												X		
MOLYBDENUM	X							X								
MONOCROTOPHOS		X												X		
N,N-DIBUTYLNITROUS AMIDE		X									X					
N,N-DIETHYLNITROUS AMIDE		X									X					
N,N-DIMETHYLANILINE		X									X					
N,N-DIPHENYLNITROUS AMIDE		X									X					
N,N-DIPROPYLNITROUS AMIDE		X									X					
NAPHTHALENE		X														X

Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
NAPHTHENIC ACIDS				X									X			
NEODYMIUM	X							X								
NEPTUNIUM	X							X								
NICKEL	X							X								
NICKEL-63	X							X								
NITRATE				X						X						
NITRATE/NITRITE				X						X						
NITRITE				X						X						
NITROAROMATICS		X									X					
NITROBENZENE		X									X					
NITROGEN				X						X						
NITROGLYCERIN		X									X					
NITROTOLUENE (MIXED ISOMERS)		X									X					
N-METHYL-N,2,4,6-TETRANITROANILINE (TETRYL)		X									X					
N-NITROSODIMETHYLAMINE		X									X					
NONANE		X									X					
O,O,O,O-TETRAETHYL DITHIODIPHOSPHATE		X												X		
OCTANE			X									X				
O-DINITROBENZENE		X									X					
O-ETHYL O-(4-NITROPHENYL) PHENYLPHOSPHONOTHIOATE		X												X		
O-ETHYL S,S-DIPROPYL PHOSPHORODITHIOATE (ETHOPROP)		X												X		
ORGANICS				X									X			
OXAMYL		X												X		
P,P'-DDD		X												X		
P,P'-DDE		X												X		
P,P'-DDT		X												X		
PARATHION		X												X		
p-CYMENE		X									X					
PEBULATE		X												X		
PENDIMETHALIN		X												X		
PENTACHLOROBENZENE		X							X							
PENTACHLORODIBENZO[b,e][1,4]DIOXIN (PECDD) (MIXED ISOMERS)		X				X										
PENTACHLORODIBENZOFURAN (PeCDF)		X				X										
PENTACHLOROETHANE			X				X									
PENTACHLORONITROBENZENE		X							X							
PENTACHLOROPHENOL		X												X		
PENTAERYTHRITOL TETRANITRATE (PETN)		X									X					
PENTANE			X									X				
PERCHLORATE				X						X						
PERFLUOROOCTANE SULFONIC ACID		X											X			
PERFLUOROOCTANOIC ACID (PFOA)		X											X			
PESTICIDES		X												X		
PHENACETIN		X									X					
PHENANTHRENE		X														X
PHENOL		X							X							
PHENYLMETHANOL		X									X					

Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
PHORATE		X												X		
PHOSPHORIC ACID				X						X						
PHOSPHORUS				X						X						
PHOSPHORUS (P4)				X						X						
PHOTOMIREX		X												X		
PLATINUM	X							X								
PLUTONIUM	X							X								
PLUTONIUM-238	X							X								
PLUTONIUM-239	X							X								
PLUTONIUM-239/240	X							X								
PLUTONIUM-240	X							X								
PLUTONIUM-241	X							X								
PLUTONIUM-242	X							X								
PLUTONIUM-244	X							X								
POLONIUM-210	X							X								
POLYBROMINATED BIPHENYLS (FIREMASTER FF 1)				X									X			
POLYCHLORINATED BIPHENYLS (CONTAINING 60 OR MOREPERCENT CHLORINE BY MOLECULAR WEIGHT)		X													X	
POLYCHLORINATED BIPHENYLS (PCBs)		X													X	
POLYCHLORINATED TERPHENYLS		X													X	
POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)		X														X
POLYCYCLIC AROMATIC HYDROCARBONS, HIGH MOLECULAR WEIGHT (HPAHS)		X														X
POLYCYCLIC AROMATIC HYDROCARBONS, LOW MOLECULAR WEIGHT (LPAHS)		X														X
POTASSIUM	X							X								
POTASSIUM CYANIDE				X						X						
POTASSIUM HYDROXIDE				X						X						
POTASSIUM NITRATE	X							X								
POTASSIUM PERMANGANATE				X						X						
PROMETHIUM-147	X							X								
PROMETON		X												X		
PROMETRYN		X												X		
PROPANEDINITRILE			X									X				
PROPYLBENZENE		X									X					
PYRENE		X														X
PYRIDINE		X									X					
QUINOLINE		X									X					
RADIOACTIVE	X							X								
RADIONUCLIDES	X							X								
RADIUM	X							X								
RADIUM-224	X							X								
RADIUM-226	X							X								
RADIUM-228	X							X								
RADON				X						X						
RADON AND ITS DECAY PRODUCTS				X						X						
RADON-222				X						X						
RESIDUAL RANGE ORGANICS (RRO)		X											X			
RONNEL		X												X		

Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
RUTHENIUM-106	X							X								
SELENIUM	X							X								
S-ETHYL N,N-DIPROPYLCARBAMOTHIOATE (EPTC)		X												X		
SILICON	X							X								
SILICON DIOXIDE (AMORPHOUS SILICA)				X						X						
SILICONE				X						X						
SILVER	X							X								
SIMAZINE		X												X		
SODIUM	X							X								
SODIUM CYANIDE				X						X						
SODIUM HYDROXIDE				X						X						
SODIUM NITRATE				X						X						
SODIUM NITRITE				X						X						
SODIUM-22	X							X								
STODDARD SOLVENT			X									X				
STRONTIUM	X							X								
STRONTIUM-90	X							X								
STYRENE			X									X				
SULFATE				X						X						
SULFIDE			X									X				
SULFUR				X						X						
SULFUR DIOXIDE				X						X						
SULFURIC ACID				X						X						
TANTALUM	X							X								
TECHNETIUM-99	X							X								
TETRACHLORODIBENZO[b,e][1,4]DIOXIN (TCDD) (MIXED ISOMERS)		X				X										
TETRACHLORODIBENZOFURAN (TCDF)		X				X										
TETRACHLOROETHENE			X				X									
TETRAETHYL LEAD			X									X				
TETRAHYDROFURAN			X									X				
THALLIUM	X							X								
THALLIUM CHLORIDE				X						X						
THALLIUM COMPOUNDS	X							X								
THALLIUM(I) CARBONATE				X						X						
THALLIUM-204	X							X								
THORIUM-228	X							X								
THORIUM-230	X							X								
THORIUM-232	X							X								
THORIUM-234	X							X								
TIN	X							X								
TITANIUM	X							X								
TITANIUM DIOXIDE				X						X						
TOLUENE			X		X											
TOLUENE DIISOCYANATE (MIXED ISOMERS)		X									X					
TOTAL BENZOFLUORANTHENES		X														X
TOTAL EXTRACTABLE PETROLEUM HYDROCARBONS (TEPH)		X											X			

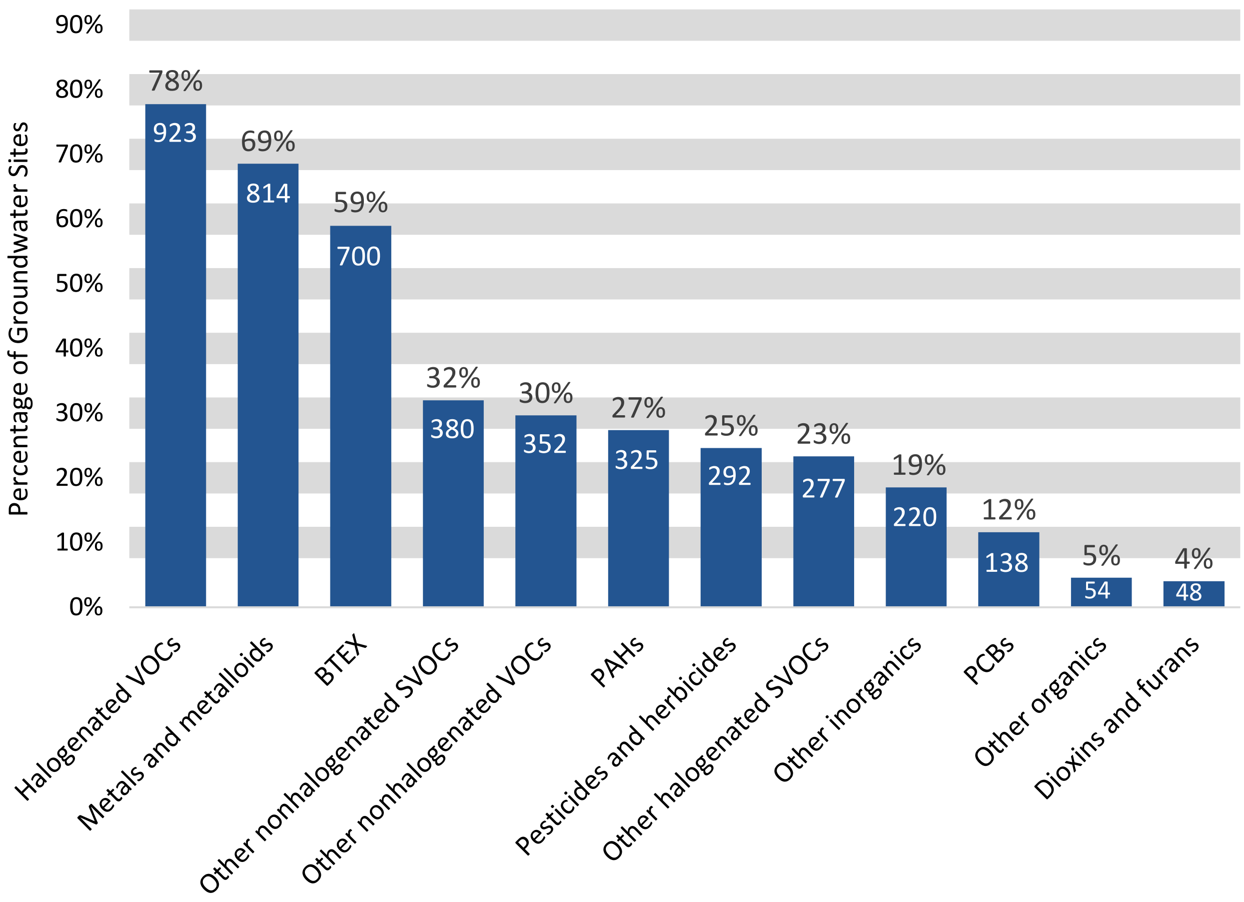
Appendix C-1: Individual Contaminants and Assigned Contaminant Groups

	High Level Group				Detailed Category											
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PAHs
TOTAL PETROLEUM HYDROCARBON -DIESEL		X											X			
TOTAL PETROLEUM HYDROCARBON -GASOLINE		X											X			
TOTAL PETROLEUM HYDROCARBONS (TPH)		X											X			
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (TRPH)		X											X			
TOTAL TRIHALOMETHANES			X				X									
TOXAPHENE		X												X		
TRANS-1,2-DICHLOROETHENE			X				X									
TRANS-NONACHLOR		X												X		
TRIBUTYL PHOSPHATE		X									X					
TRIBUTYL(CHLORO)STANNANE				X									X			
TRIBUTYLSTANNANYLIUM				X									X			
TRIBUTYLSTANNYL BENZOATE				X									X			
TRICHLORO(NITRO)METHANE		X												X		
TRICHLOROETHANE (MIXED ISOMERS)			X				X									
TRICHLOROETHENE			X				X									
TRICHLOROFLUOROMETHANE			X				X									
TRICHLOROPHENOL (MIXED ISOMERS)		X							X							
TRIFLURALIN		X												X		
TRIMETHYLBENZENE (MIXED ISOMERS)		X									X					
TRIPHENYL PHOSPHATE				X									X			
TRIS(2,3-DIBROMOPROPYL) PHOSPHATE		X							X							
TRIS(CHLOROPROPYL)PHOSPHATE		X							X							
TRITIUM				X						X						
TUNGSTEN	X							X								
URANIUM	X							X								
URANIUM-233	X							X								
URANIUM-234	X							X								
URANIUM-234/235/238	X							X								
URANIUM-235	X							X								
URANIUM-238	X							X								
VANADIUM	X							X								
VANADIUM PENTOXIDE				X						X						
VANADIUM, METAL AND/OR ALLOY	X							X								
VERNOLATE		X												X		
VINYL ACETATE			X									X				
VX				X									X			
XYLENE (MIXED ISOMERS)			X		X											
ZINC	X							X								
ZIRCONIUM	X							X								

Appendix C-2: Analysis of Detailed Contaminant Categories by Media

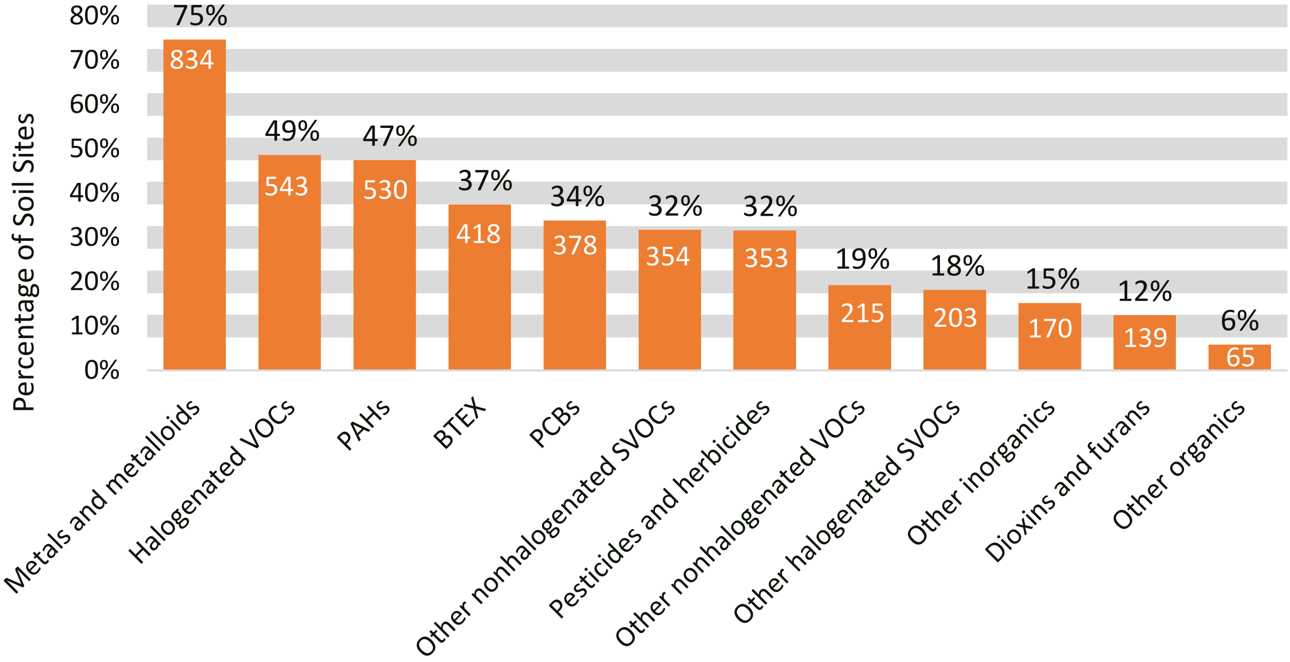
In addition to the contaminant groups discussed in Section V, EPA classified contaminants into more detailed categories and analyzed how frequently remedies target them in groundwater, soil, and sediment (Figures C-2a, C-2b, and C-2c). Remedies frequently address metals in all media. A more detailed look at organic COCs shows halogenated VOCs (primarily chlorinated VOCs) and BTEX to be the most common in groundwater (Figure C-2a); and halogenated VOCs and PAHs in soil (Figure C-2b). For sediment, PAHs and PCBs are the most frequently targeted organics (Figure C-2c).

Figure C-2a: Detailed COCs in Groundwater at Superfund Sites (FY 1981-2017)



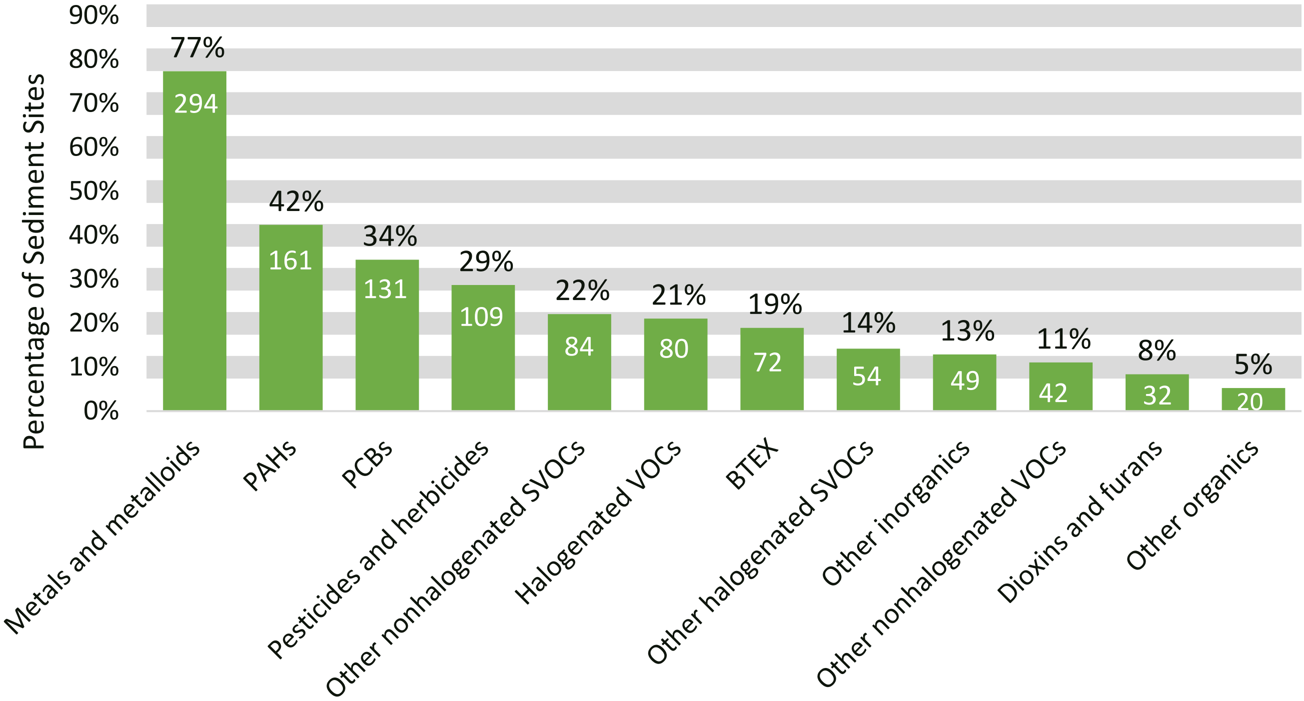
- Number of groundwater sites with identified COCs and a remedy = 1,187.

Figure C-2b: Detailed COCs in Soil at Superfund Sites (FY 1981-2017)



- Number of soil sites with identified COCs and a remedy = 1,117.

Figure C-2c: Detailed COCs in Sediment at Superfund Sites (FY 1981-2017)



- Number of sediment sites with identified COCs and a remedy = 380.