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OCCURRENCE OF RELEASES WITH THE POTENTIAL TO IMPACT SOURCES OF DRINKING WATER

Office of Water (MC-140) EPA 817-R-21-001 February 2021

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Disclaimer

The Water Security Division of the Office of Ground Water and Drinking Water has reviewed and approved the report "Occurrence of Releases with the Potential to Impact Sources of Drinking Water" for publication in February 2021. This document is intended for use by the drinking water sector to better understand the risk of potential releases into sources of drinking water. It may provide information useful for conducting *Risk and Resilience Assessments*, as required under America's Water Infrastructure Act (AWIA) of 2018.

AWIA, Section 2013 requires community water systems to conduct *Risk and Resilience Assessments*, which must consider important system assets, including source water. This report demonstrates that releases to sources of drinking water occurred at an average rate of 393 releases per year over the 10-year study period. Furthermore, the report demonstrates this risk is not equally distributed across the water sector – some community water systems are at substantially greater risk of releases to their source water. To address this risk, this report recommends that community water systems conduct an inventory of facilities that could release a harmful substance into their source water as part of their AWIA *Risk and Resilience Assessments*. An important resource for developing contamination threat inventories is Tier II chemical inventory data collected under the Emergency Planning and Community Right to Know Act (EPCRA). AWIA, Section 2018 amended EPCRA to provide community water systems with access to Tier II chemical inventory data.

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Table of Contents

List of Figures

List of Tables

Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
CWA-HS	Clean Water Act Hazardous Substances
CWS	Community Water System
GW	Groundwater
HSEES	Hazardous Substance Emergency Events Surveillance
HUC	Hydrologic Unit Code
kgal	One thousand gallons
lat/long	Latitude and Longitude coordinates
NHD	National Hydrography Dataset
NRC	National Response Center
NTSIP	National Toxic Substances Incidents Program
ORSANCO	Ohio River Valley Water Sanitation Commission
PCBs	Polychlorinated biphenyls
PHMSA	Pipeline and Hazardous Materials Safety Administration
SDWIS	Safe Drinking Water Information System
SW	Surface water
TRI	Toxics Release Inventory
U.S. CG	United States Coast Guard
U.S. CSB	United States Chemical Safety and Hazard Investigation Board
U.S. EIA	United States Energy Information Administration
U.S. EPA	United States Environmental Protection Agency
ZOC	Zone of Concern

Section 1: Introduction

1.1 Background

Releases of harmful chemicals through accidents or unpermitted discharges into sources of drinking water can cause significant problems for public water systems and the communities they serve. Potential consequences can include adverse impacts on public health, interruptions in water service, loss of public confidence, increased treatment costs, damage to water system infrastructure, and cost to mitigate the impacts of the release. Congress recognized the importance of this risk to source water by including Section 2018 in America's Water Infrastructure Act which authorizes community water systems to access hazardous chemical inventory data and requires that these systems receive prompt notification of spills contaminating their source water (U.S. Congress, 2018).

1.1.1 Notable Releases to Source Waters

Several source water contamination incidents have been reported in the media, and a few notable contamination incidents are summarized in **Table 1**. The amount of material released in these examples ranged from 10,000 gallons to more than 11 million gallons. Materials released include coal ash, mine waste, wastewater, and uncommon industrial chemicals like crude methylcyclohexane methanol. The causes of the releases shown in Table 1 include equipment failure, operator error, and natural disasters. Regardless of their specific conditions, all of the releases share one thing in common – they significantly degraded the quality of a source of drinking water.

Table 1. Examples of Significant Source Water Contamination Incidents (2010 to 2019)

Year	Waterbody	Description
2011	Mulberry Fork, AL (NRC# 975693)	On May 8, 2011, approximately 1.6 million gallons of untreated wastewater was released from American Proteins into the Mulberry Fork, a source of drinking water for the City of Birmingham. The release resulted from tornado damage to a wastewater treatment basin. Subsequent releases from this same facility include a release of 80,000 gallons of wastewater in May/June 2015 and a release of 900 gallons of sulfuric acid in August 2016 (Sack, 2016).
2014	Elk River, WV (NRC#: 1070627)	On January 9, 2014, approximately 10,000 gallons of a mixture containing methylcyclohexane methanol (MCHM) was released to the Elk River, due to corrosion in an above ground storage tank. The Elk River is the drinking water source for Charleston, WV. The contamination incident resulted in a "do not use" order for approximately 300,000 residents for 4 to 9 days (U.S. CSB, 2016; Rosen et al, 2014).
2014	Dan River, NC (NRC#: 1073040)	On February 2, 2014, approximately 39,000 tons (11 million gallons) of coal ash (containing arsenic, cadmium, lead, mercury, and other metals) was released into the Dan River from the Duke Energy Dan River Steam Station near Eden, NC. The release resulted from failure of a stormwater pipe that allowed the contents of the coal ash impoundment to leak into the river for several days. The release impacted water quality at several drinking water intakes in North Carolina and Virginia. Testing of treated water at the downstream community water systems indicated that National Primary Drinking Water Standards were met (U.S. EPA, 2014). However, elevated concentrations in the source water may have exceeded these standards, and no information was available for contaminants not regulated under the Safe Drinking Water Act.
2015	Yellowstone River, MT (NRC#: 1105969)	On January 17, 2015, a ruptured oil pipeline leaked approximately 40,000 gallons of crude oil into the Yellowstone River in Montana. The release impacted the drinking water source for the nearby town of Glendive (Beker, 2015). Testing of treated water in Glendive showed no contamination, however, residents reported odors of diesel fuel prompting the system to issue a "do not use" notice (National Park Trips Media, 2017).

Year	Waterbody	Description
2015	Cement Creek & Animas River, CO (NRC#: 1124824)	On August 5, 2015, approximately 3 million gallons of mine waste (containing arsenic, lead, and other metals) was released from the Gold King mine complex to Cement Creek near Silverton, CO. The release was due to a breach in the containment structure that occurred during an inspection. Cement Creek is a tributary of the Animas River which flows into the San Juan River near Farmington, NM. The contaminant plume reached Lake Powell on August 12. Five drinking water systems draw water from the Animas River, and these systems closed their intakes and/or issued “do not use” notices. Advisories were issued for private domestic wells along the Animas River (U.S. EPA, 2015a).
2017	Ohio River, KY / OH (NRC#: 1200030)	On December 19, 2017, an estimated 467,000 gallons of urea ammonium nitrate was released when a barge suffered catastrophic failure. The release threatened the drinking water supply for downstream utilities in Louisville, KY, Evansville, IN, and Henderson, KY (ORSANCO, 2018). Staff from Louisville Water Co. and ORSANCO monitored the river conditions daily and then hourly as the spill flowed to Louisville. Strategic management of the intake rate helped the system avoid pulling in water at peak contaminant concentration (Louisville Water Company, 2017).

NRC#: National Response Center report number

1.1.2 Previous Research

The examples listed in **Table 1** were reported in widely distributed media, but such reporting is the exception. Most releases into sources of drinking water receive scant attention outside of notification to the responsible parties, responders, and ideally to affected community water systems. Because releases to the environment are under-reported, there is no definitive assessment of the number or impact of releases to water. However, several research efforts have attempted to characterize the occurrences of releases that impacted sources of drinking water.

A research group at the University of Mississippi developed a database of releases into sources of drinking water that occurred between 1990 and 2006. Two sources of information were used to populate this database, the *National Response Center* (NRC) and *Hazardous Substance Emergency Events Surveillance* (HSEES), both of which are described later in this section. A stated objective of the project was to capture releases that impacted drinking water infrastructure; however, the project report did not provide the methodology for making this determination (Zhu et al, 2009). The database is no longer available from the project website.

During the development of the *Clean Water Act Hazardous Substances Spill Prevention Proposed Rule*, U.S. EPA analyzed NRC records to identify releases involving Clean Water Act Hazardous Substances (CWA-HS) over a 10-year period between 2007 and 2016. Over this period, a total of 285,867 incidents were reported to the NRC, of which 9,416 (3.3%) involved the release of a CWA-HS with 3,140 (1.1%) of these releases reaching water. This analysis reported that polychlorinated biphenyls (PCBs) were the most commonly released CWA-HS, involved in 59% of CWA-HS releases that reached water. The next four most frequently released CWA-HS were: sulfuric acid, sodium hydroxide, ammonia, and benzene (U.S. EPA, 2018).

Several studies have focused on the release of oil and related materials to water. One such study analyzed 6,622 spills from 21,300 unconventional oil and gas extraction wells in four states (Pennsylvania, North Dakota, Colorado, and New Mexico) from 2005 to 2014. The U.S. Forest Service’s *Forest to Faucets* “index of importance as a source of drinking water” was used to evaluate the risk to drinking water supplies. Releases were characterized with respect to location (state), material released, and volume released. The most commonly released materials were: production waste streams (brine, flowback, and produced water), crude oil, hydraulic fracturing solution, drilling waste (drilling mud, cuttings, and drilling fluid), and production chemicals (hydrochloric acid, antifreeze, surfactants, and glycol). The volume of material released ranged from 0.0001 to 991 kgal (Maloney et al, 2017).

U.S. EPA conducted a study to evaluate the potential impact of releases associated with hydraulic fracturing on surface and ground waters. State databases were used to identify releases that occurred between January 2006 and April 2012 in ten states with the most hydraulic fracturing activity reported at the time of the study: Arkansas, Colorado, Louisiana, New Mexico, North Dakota, Oklahoma, Pennsylvania, Texas, Utah, and Wyoming. Data sources were searched separately using a combination of filters, keywords, and line-by-line reviews, with additional details provided by the state, service company, and well operator where applicable. Of the approximately 36,000 release records identified, 24,000 (66%) were determined to be unrelated to hydraulic fracturing, and most of the remaining 12,000 (33%) records had insufficient data to make the determination. 457 release records could be linked to hydraulic fracturing, of which 370 (81% of hydraulic fracturing-related spills) reported the volume released, which ranged from fewer than 5 gallons to more than 1.3 million gallons. Fifty-six percent of these 370 records involved a release volume less than 1,000 gallons, and accounted for only 3% of the total volume released by the 370 incidents. The majority (57%) of volume released came from a single spill of 1.3 million gallons of flowback and produced water. Storage units were the most common source of a release and failure of container integrity (e.g. holes, seal failures) were generally associated with larger release volumes (U.S. EPA, 2015b).

A study evaluating oil releases over a 20-year period from 1980 to 2000 determined that crude oil accounted for the greatest volume released while light fuels accounted for the greatest number of releases (Etkin, 2004). In a later study, U.S. EPA Region 5 analyzed NRC records to characterize the vulnerability of sub-watersheds in its states (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin) to releases of crude oil (Brody et al, 2012).

1.1.3 Release Tracking Databases

In addition to snapshot studies, some state and federal programs track source water spills over time. The NRC, for example, is an emergency call center that fields initial reports of releases and forwards that information to the appropriate federal or state agencies. The NRC posts release reports to their website for every calendar year starting in 1990. These reports contain initial information about the incident, and in most cases this information has not been validated or investigated by a response agency (U.S. CG, 2020). A number of studies have used the NRC as a primary source of information about releases, including: Balasubramanian and Louvar, 2004; Etkin, 2004; Howard et al, 2008; Zhu et al, 2009; Brody et al, 2012; and U.S. EPA, 2018.

The *National Toxic Substances Incidents Program* (NTSIP), managed by the Department of Health and Human Services, Agency for Toxic Substances and Disease Registry (ATSDR) was active between 2010 and 2018. Release of toxic substances from seven states (Louisiana, New York, North Carolina, Oregon, Tennessee, Wisconsin, and Utah) were captured in NTSIP. This program replaced a similar program, *Hazardous Substance Emergency Events Surveillance* (HSEES), which was active from 1990 through 2009. The HSEES monitored for incidents in 14 partner states (ATSDR, 2018).

The *Toxic Release Inventory* (TRI) is a program created under the Emergency Planning and Community Right to Know Act. TRI requires industries that meet specific criteria to file an annual report documenting releases of certain toxic chemicals to air, land, and water that may pose a threat to human health and to the environment. TRI reporting is limited to a list of approximately 755 individual chemicals and 33 chemical categories. TRI reporting limits change over time, complicating temporal analysis of releases. Facilities must submit annual reporting forms for each chemical if they manufacture, process, or otherwise use the chemical in amounts above established levels (U.S. EPA, 2020).

The Pipeline and Hazardous Materials Safety Administration (PHMSA) is managed by the U.S. Department of Transportation and maintains a Hazmat Incident Database that contains information from the Hazardous Materials Incident Report Form 5800.1. This database includes information on the quantity of material released, mode of transportation, packaging information, and impacts of hazardous materials released during transportation (PHMSA, 2020).

Collectively, these studies and data collection efforts provide valuable insight into the occurrence of releases that impact sources of drinking water. However, the efforts described are either limited in scope (i.e., a limited number of substances or a limited geographic region), or they do not differentiate between releases to any media and releases specifically to sources of drinking water. A review of published studies failed to yield a comprehensive, national study of releases into sources of drinking water in the U.S.

1.2 Objectives

The objective of the study described in this report was to characterize the occurrence of releases into sources of drinking water used by community water systems in the U.S.

Specifically, the study evaluated:

- Temporal occurrence of releases between 2010 and 2019 (full calendar years)
- Geographic occurrence of releases
- Type and amount of material released
- Responsible party and cause of releases
- Distribution of the number of releases impacting individual community water systems

Furthermore, the results of this study are intended to inform *Risk and Resilience Assessments*, as required under AWIA, Section 2013. One of the assets that must be considered in these assessments is source water, and as shown by the results presented in this report, some community water systems face a risk of spills and releases into their source of drinking water. Systems that have experienced source water contamination incidents previously, or determine that they are at risk, should consider developing an inventory of facilities that could release a harmful substance into their source water. An important resource for developing contamination threat inventories is Tier II chemical inventory data collected under the Emergency Planning and Community Right to Know Act (EPCRA). AWIA, Section 2018 amended EPCRA to provide community water systems with access to Tier II chemical inventory data.

1.3 Scope

The scope of this analysis was limited to the following:

- Releases reported to the NRC. The NRC is a national call center that receives initial reports of releases of any material into any medium. While the NRC is the most comprehensive source of information about releases in the U.S., releases do occur that are not reported to the NRC.

- Community water systems. This analysis was limited to releases into source water zones of concern (described in Section 2.3) for community water systems, as defined in Section 1401(15) of the Safe Drinking Water Act. Community water systems were considered in this analysis, rather than all public water systems, because the former are required to conduct risk and resilience assessments, and one asset that must be considered in these assessments is source water.

Section 2: Methodology

2.1 Data Sources

Safe Drinking Water Information System (SDWIS) was used to identify community water systems from among the larger universe of public water systems and provided information such as the source water type (e.g., surface water, ground water) and location of intakes and wells for community water systems.

National Hydrography Dataset (NHD) served as the primary source of information about location of surface waterbodies. The high-resolution NHD waterbody areas and flowlines were used when available, otherwise medium-resolution NHD flowlines and waterbody boundaries were used. **Figure 1** provides an example of NHD waterbody and flowline representations.

Media reports were used to investigate, validate, and in some cases correct initial NRC reports for significant releases (i.e., large volume releases). Media reports from reputable outlets were considered more reliable than the NRC reports because the latter are preliminary and often incomplete, while the former use sources such as representatives from state and federal response agencies and drinking water systems to obtain details about the incident.

National Response Center (NRC) served as the primary source of information about releases. The NRC annual release reports for 2010 through 2019 were downloaded from the NRC website (nrc.uscg.mil). A list of the fields extracted from the NRC reports to support this analysis is provided in Appendix A.

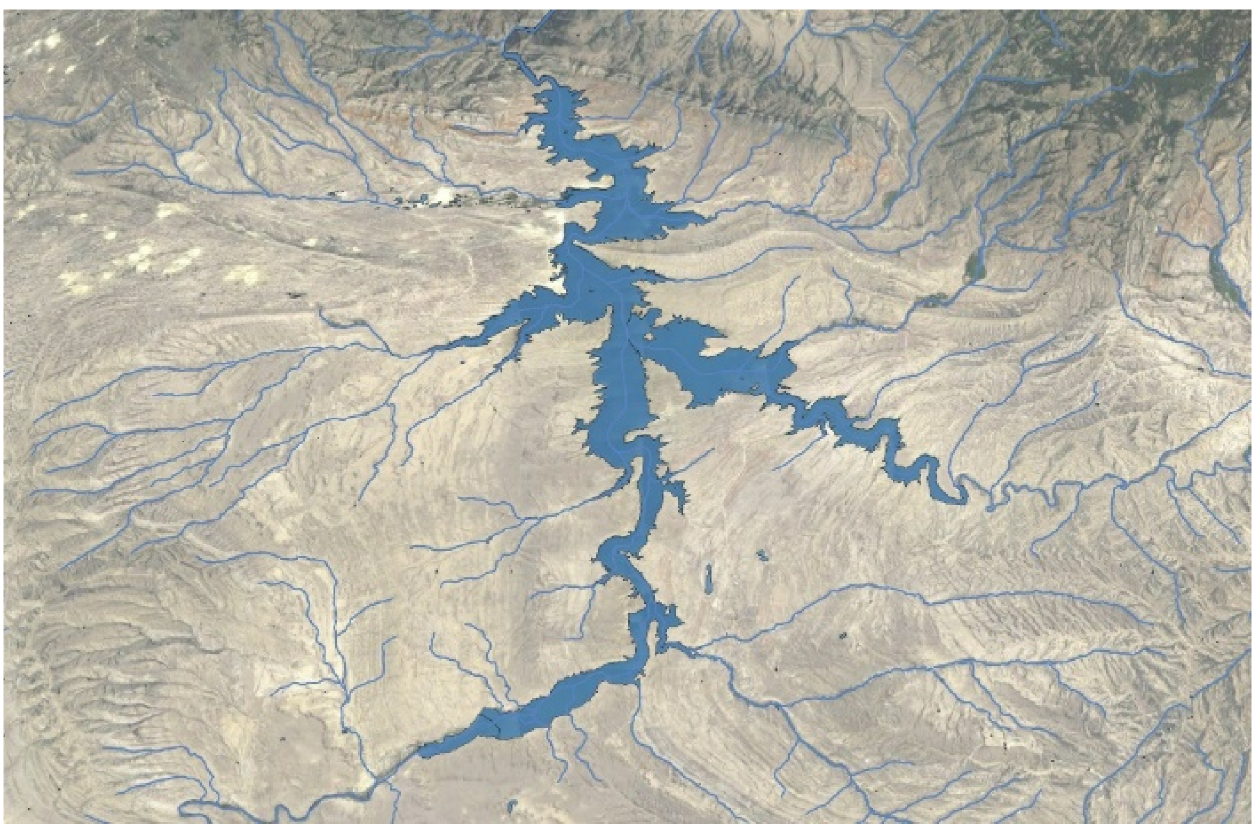


Figure 1. Example of NHD Flowline and Waterbody Representations

2.2 Data Processing

While the data fields in the NRC record are standardized, data entry errors occurred. Most errors involve incorrect spelling and inconsistent naming of record attributes such as the names of waterbodies and materials released. Additionally, details such as the name of the material released and the units for the volume of material released are not standardized, which results in the use of synonyms or ambiguous identifiers and several different volumetric or weight units. In some cases, important details about the spill such as additional materials released and volumes of the materials released were included in the free-text *Incident Details* field but not carried over into the appropriate, specific data fields. Finally, a significant number of records were missing information important to the analysis, such as the precise location of the release, the name of the material released, and volume of material released.

The following data processing was performed prior to analysis.

- **Populate missing information** for the name and volume of material released by parsing and searching the *Incident Details* field, which is a free-text field used to capture non-standard information provided by the individual reporting the release.
- **Amount of material in water** was assumed to be equal to the volume of material released if the *Incident Details* field provided information to indicate the release likely occurred directly into a waterbody and if the *Amount of Material Released* field was populated while the *Amount in Water* field was empty. As an example, if a record reported that 1,000 gallons of diesel fuel was released, and the *Incident Details* stated that the release was from a rail car that derailed into a stream, it would be assumed that the *Amount in Water* was 1,000 gallons if this field was left blank.
- **Names of bodies of water** were corrected for spelling errors and standardized to a common name for each waterbody. Rules used to standardize the names of bodies of water are provided in Appendix B.
- **Names of materials released** were corrected for spelling errors.
- **Material categories** were developed to group similar materials together to support an aggregate analysis for trends in the types of material released (see **Table 2**). Note that these material categories are limited with respect to understanding potential consequences. Each specific material has unique properties that will impact fate and transport, treatability, and public health concerns.
- **Units for the amount of material released and amount in water** were normalized to gallons where possible. The conversion factors used are listed in Appendix C.
- **Location data** was standardized by removing extraneous characters and applying algorithms to identify a best address for the location of each release (when address information was provided in the NRC record). The best address was then geocoded to support spatial analysis. The methods used to prepare location data are described in Appendix D.

Table 2. Material Categories

Category	Materials Most Commonly Released that Fall within the Category
Acid	Sulfuric Acid, Hydrochloric Acid, Phosphoric Acid
Alcohol	Denatured Alcohol, Bourbon
Antifreeze	Ethylene Glycol, Propylene Glycol
Caustic Material	Sodium Hydroxide, Caustic Soda Solution
Chlorine	Sodium Hypochlorite, Chlorine
Coal Combustion By-Products	Coal Ash, Creosote, Fly Ash
Crude Petroleum	Crude Oil
Cyanide Compounds	Sodium Cyanide Solution
Drilling Fluid	Drilling Brine, Produced Water, Drilling Mud
Fertilizer	Fertilizer, Anhydrous Ammonia, Urea, Ammonium Nitrate Urea Solution
Firefighting Foam	Fire Fighting Foam, Fire Fighting Water, AFFF (Aqueous Film Forming Foam)
Food Products	Milk, Vegetable Oil, Palm Oil
Metals and Metalloids	Arsenic, Lead
Mine Waste	Mine Waste, Mine Water
Organic Solvents	Toluene, Ethyl Alcohol, Ethanol, Acetone
Paint	Paint, Oil Based Paint
Pesticides/Herbicides	Dieldrin, Paraquat Dichloride, Diphenylamine, Insecticide
Radiological Materials	Radioactive Material, Uranium, Radium
Refined Oil	Automotive Gasoline, Fuel Oil, Diesel Oil, Hydraulic Oil
Salt Water	Saltwater
Transformer Oil	Transformer Oil, Mineral Oil, Polychlorinated Biphenyls
Unknown Material	Unknown Chemicals, Unknown Material
Wastewater	Sewage, Wastewater

2.3 Defining Zones of Concern

Zones of concern (ZOC) were developed using the locations of surface water intakes and groundwater wells. Releases with adequate location data were analyzed to determine whether they occurred within a ZOC for a community water system. The criteria for establishing surface water (SW) ZOCs are shown in the callout box and are consistent with criteria for establishing source water area delineations for conducting a source water contamination threat inventory (U.S. EPA, 2006).

Surface Water (SW) ZOCs: The ZOC for each surface water intake extends 50 miles upstream, ¼ mile downstream, includes all major tributaries, and includes a ¼ mile buffer inland from the waterbody area boundary (see **Figure 2** for an example).

The confidential version of SDWIS was used to identify 5,119 surface water intakes for community water systems serving a population greater than 1,000 customers. SW ZOCs were delineated for 4,899 of these surface water intakes, while ZOCs could not be delineated for 220 intakes because intakes were located too far away from the NHD flowlines, on the shores of lakes or reservoirs, or in areas with highly complex NHD flowlines. Three of the 220 surface water intakes for which a ZOC was not delineated belong to community water systems serving more than 500,000 people. The intakes for these three large systems are located in highly protected source water areas that contain no industry, chemical storage (other than that maintained by the community water system), transportation routes, or pipelines, and thus are unlikely to have experienced a release. The 220 SW ZOCs that did not delineate properly were reviewed and 30 were selected for manual processing: 26 were selected because the associated community water system has a population served greater than or equal to 100,000 or a number of service connections greater than or equal to 30,000. An additional four SW ZOCs were selected because the intakes are located in a watershed that experienced releases in other SW ZOCs. Applying these adjustments, the total number of SW ZOCs considered in this analysis is 4,929 (4,899 that automatically delineated plus 30 that were manually delineated).

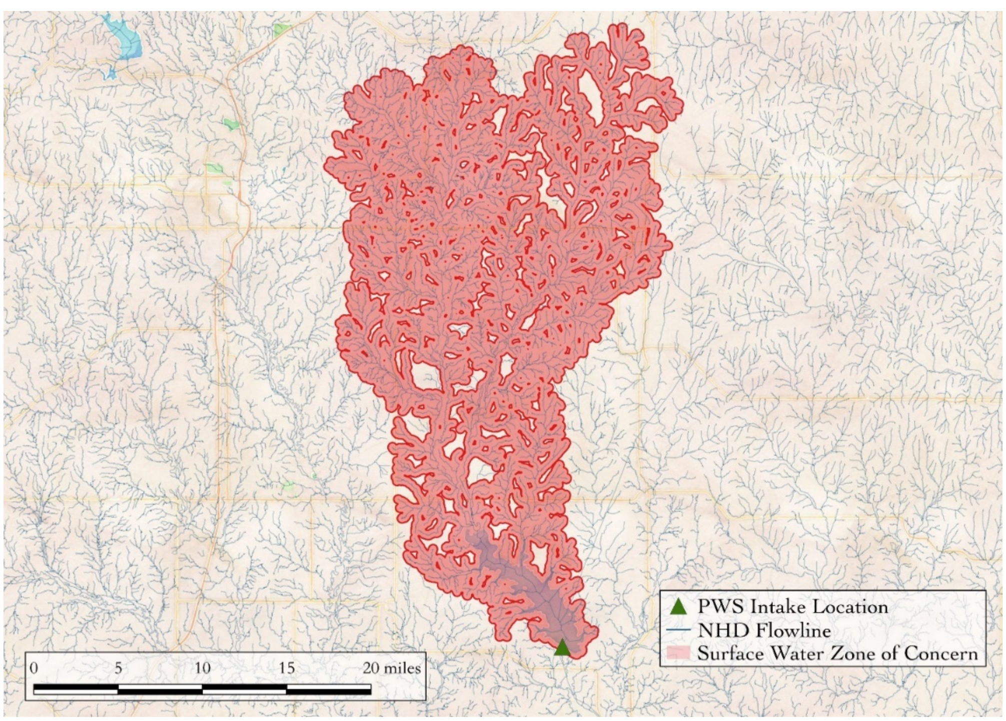


Figure 2. Example of a Surface Water Zone of Concern

Guidance from U.S. EPA states that an “arbitrary fixed radius” can be used as a first approximation for a source water area delineation (U.S. EPA, 2006). Using this method, 106,816 GW ZOCs were delineated.

Groundwater (GW) ZOCs: The ZOC for each groundwater well is defined by a ½ mile radius around the well location (see **Figure 3** for an example).

The SW ZOCs and GW ZOCs used in this study were defined to be conservative, meaning that they cover a large area in order to capture most releases that could have impacted water quality at the intake or wellhead. However, whether a specific release would impact water quality at the point of withdrawal depends on several factors, such as volume of material released, characteristics of the material released, size and flow of waterbody, etc. There have been large releases that have impacted utilities more than 50 miles downstream of the point of release. Conversely, small releases of certain contaminants may have no appreciable impact on water quality within one mile from the point of release.

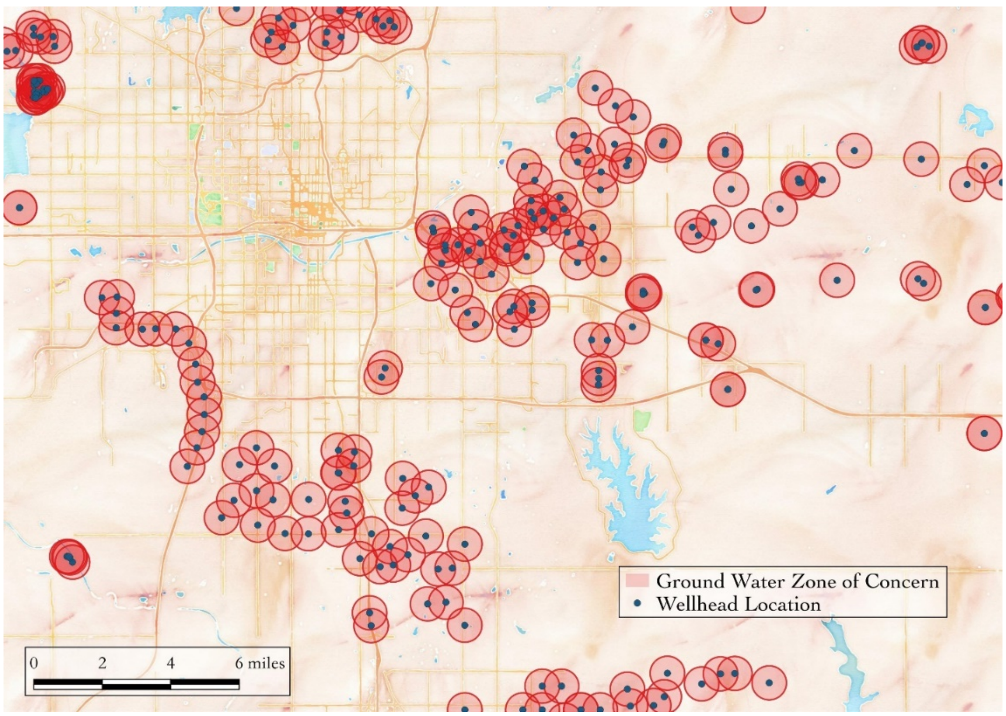


Figure 3. Example of Groundwater Zones of Concern

2.4 Identifying Significant Releases

In calendar years 2010 through 2019, a total of 281,141 releases were reported to the NRC. The following criteria were used to identify releases with the potential to significantly contaminate a source of drinking water.

- Releases in which fewer than 100 gallons of material were released were excluded from the analysis, with the exception of highly toxic materials as described in the third bullet.
- Records for which the volume of material released was not reported were evaluated for indicators that they had the potential to release a volume greater than 100 gallons. Specifically, releases with records that did not report a volume, but which met any of the following criteria, were included in this analysis:
    - Release resulting in contamination of the water supply
    - Release from a storage tank with a capacity greater than or equal to 1,000 gallons

  - Release involving a freight train or freight car
  - Release involving a barge or a tanker
  - Release resulting in a closed rail track or waterway
  - Release resulting in property damages
- Releases of a highly toxic material were included in the analysis regardless of the amount of material released (including records for which the volume released was not reported). The materials identified in the NRC record were screened based on relative acute toxicity, and those with the lowest toxicity threshold were categorized as highly toxic materials for this analysis. The four classes of highly toxic materials identified in the NRC record include:
  - Arsenic compounds
  - Cyanide compounds
  - Pesticides, insecticides, and herbicides
  - Radionuclides
- Releases with location information sufficient to geocode the record were analyzed to determine if they fell within a ZOC for a community water system. Releases that occurred outside of a ZOC were excluded from the analysis, with the exception of 14 unique incidents that were reported to have impacted drinking water systems further than 50 miles downstream of the release location.
- Releases without location information were retained in the analysis if the volume released exceeded 100 gallons, had the potential to release more than 100 gallons for records in which the volume released was not recorded, or released a highly toxic material. However, other filters were still applied to these records, as described in the following bullet.
- Remaining records were screened to remove those with the following attributes:
  - Reports generated during drills
  - Releases that occurred outside of the U.S.
  - Releases to air
  - Releases that occurred offshore or in specific bodies of water that were verified to be unconnected to a source of drinking water
  - Releases involving materials unlikely to change water quality (e.g., sand, aggregate, steel). A complete list of materials excluded can be found in Appendix E.
  - Duplicate records
- One release not captured in the NRC record, but reported in the media, was added to the dataset for this analysis: a release of 794 kgal of oil and produced water in McKittrick, CA in 2019.

2.5 Record Review

Following the data processing steps and removal of records of releases unlikely to significantly impact a source of drinking water, the quality of the remaining records was further assessed. Due to the volume of records it was infeasible to review them all. Instead, the following methods were used to screen and identify records for further review:

- Records for releases of 2,000 gallons of material or more were reviewed. While most of these releases were confirmed, a small number were not credible and thus removed from the analysis. Reports deemed not credible generally involved volumes released greater than 1 million gallons of material that could not be verified through another source, or releases of large volumes of material rarely stored in large quantities (e.g., release of 100,000 gallons of radioactive waste).
- Records for releases in which the *Incident Description* contained words such as “neighbor” or “parked car” were reviewed. In most cases, records that contained these words or phrases

pertained to releases that were unlikely to significantly impact sources of drinking water (e.g., a "neighbor" dumping used motor oil in a sewer or a "parked car" leaking fluids).
- Records that updated information about an incident reported under another record identifier were reviewed. If multiple NRC records pertaining to the same incident were identified, information from the multiple records was consolidated into a single NRC record.

If information in an NRC record was deemed questionable or incomplete, research was conducted to investigate the details of the incident. Information from the NRC record such as location, date, material released, and responsible party was used to search media reports for corroborating information and additional details. When available, reports from established media outlets were used to populate missing fields or correct information provided in the initial NRC report. The details of more than 200 records were corrected using information identified in the *Incident Description* field or obtained from media reports.

2.6 Limitations of the Methodology

- The analysis considers only releases reported to the NRC, with the exception of one release that was identified through media reports, as noted in Section 2.4.
- NRC reports are preliminary and in most cases the information is not reviewed or corrected by response agencies.
- The NRC record likely underrepresents the total number of releases that occur. Anecdotal information suggests that releases that are first reported to a 911 call center may not be reported to the NRC. Additionally, less obvious releases, such as combined sewer overflows, may not be reliably reported to the NRC.
- NRC reports are often incomplete and missing important information such as the location of the release, the material released, or the volume of material released.
- Assumptions were made to identify releases that had the potential to significantly impact a source of drinking water. Notably, NRC records for releases in which the reported amount of material released was less than 100 gallons were removed from the analysis, except for releases of highly toxic chemicals. In cases where the reported amount underestimated the actual amount of material released, a significant release could have been incorrectly removed from the analysis.
- The criteria used to develop ZOCs were by necessity generic. It is possible that releases significantly impacting a source of drinking water occurred outside a zone of concern. Conversely, it is also possible that releases within a zone of concern did not significantly impact the source water.

Section 3: Results and Discussion

Results from the analysis of releases that potentially impacted a source of drinking water are presented in the following subsections:

3.1	Provides a summary of the number and volume of releases potentially impacting source water
3.2	Presents the temporal occurrence of releases to water over the 10-year study period
3.3	Presents the geographic occurrence of releases to water
3.4	Presents the occurrence of releases to water involving different material categories
3.5	Presents the reported causes and parties responsible for releases to water
3.6	Presents distribution of release occurrences within SW and GW ZOCs

3.1 Occurrence of Significant Releases

The total number of releases reported to the NRC between January 1, 2010 and December 31, 2019, plus one release identified outside of the NRC record, was 281,142. After the records were processed according to the methodology described in Section 2, there were 5,806 records remaining in this analysis. The impact of the various filters in reducing the number of records is shown in **Table 3**. The filter resulting in the greatest reduction in the number of records was the "significant release" filter, which consisted of the following criteria:

- Records involving an unknown amount of material released during an incident that did not involve large volume transportation (e.g., barge or rail transport) nor result in significant impacts (e.g., closure of a waterway, contamination of the water supply). 144,497 records were removed based on this criterion.
- Records involving a known amount of material released but below the threshold of 100 gallons. 95,354 records were removed based on this criterion.
- Records reporting the release of a highly toxic material, as described in Section 2.4, were retained regardless of the amount of material released. There were 880 records involving the release of a highly toxic material that were retained even though the amount released was less than 100 gallons.

As shown in **Table 3**, the net number of records removed under the significant release criteria was 238,971 (85%).

Table 3. Filters Applied to Identify Records for Inclusion in the Analysis

Filter Criterion	# Records Removed
Records that did not meet criteria for a significant release or involve the release of a highly toxic material	238,971 (85%)
Records of releases into bodies of water not used for drinking water	20,552 (7.3%)
Records of releases that occurred offshore	11,056 (3.9%)
Duplicate records	2,845 (1.0%)
Records that were generated during drills	993 (0.4%)
Records of releases involving materials that would not degrade water quality	549 (0.2%)
Records of releases that occurred outside of the U.S.	377 (0.1%)

Throughout this report, the term ***incident*** refers to a specific event that resulted in the release of at least one material, while the term ***release*** refers to the release of a specific material. Each ***NRC record*** relates to a unique ***release*** of a specific material. A single incident can result in multiple releases and thus generate multiple NRC records. For example, an accident involving a tanker truck that spilled fuel oil from its cargo tank, diesel fuel from its saddle tanks, and coolant from its radiator would generate three NRC records relating to this single incident. The 5,806 NRC records identified in this analysis correspond to 3,931 unique incidents, many of which resulted in multiple releases.

Over the 10-year study period 3,931 incidents were identified with the potential to impact a source of drinking water.

Of these 3,931 incidents:

- 1,111 reported precise location information
- 3,907 reported the name(s) of material(s) released
- 3,114 reported the volume(s) of material(s) released, with a total of 38,940,397 gallons
- 1,884 reported the volume of material that reached water, with a total of 36,010,550 gallons
- 3,860 reported water as the medium affected by the incident, 4 reported ballast, 31 reported land, 22 reported other, 10 reported soil, 1 reported subsurface, and 3 reported unknown
- All 3,931 incidents reported a nearby body of water that was affected

3.2 Temporal Occurrence

Figure 4 shows the occurrence of releases with the potential to impact sources of drinking water during the 10-year timeframe considered in this study. The average number of incidents per year over this period was 393 with a standard deviation of 81. The number of incidents per year ranged from 481 in 2011 to 229 in 2019 and shows a decreasing trend over the 10-year period. This same trend was observed in the complete NRC dataset (i.e., before applying the filters described in Section 2). Specifically, for the complete NRC dataset, the number of releases decreased from 27,809 in 2010 to 23,587 in 2019, and the number of releases from 2015 through 2019 was always less than 25,000.

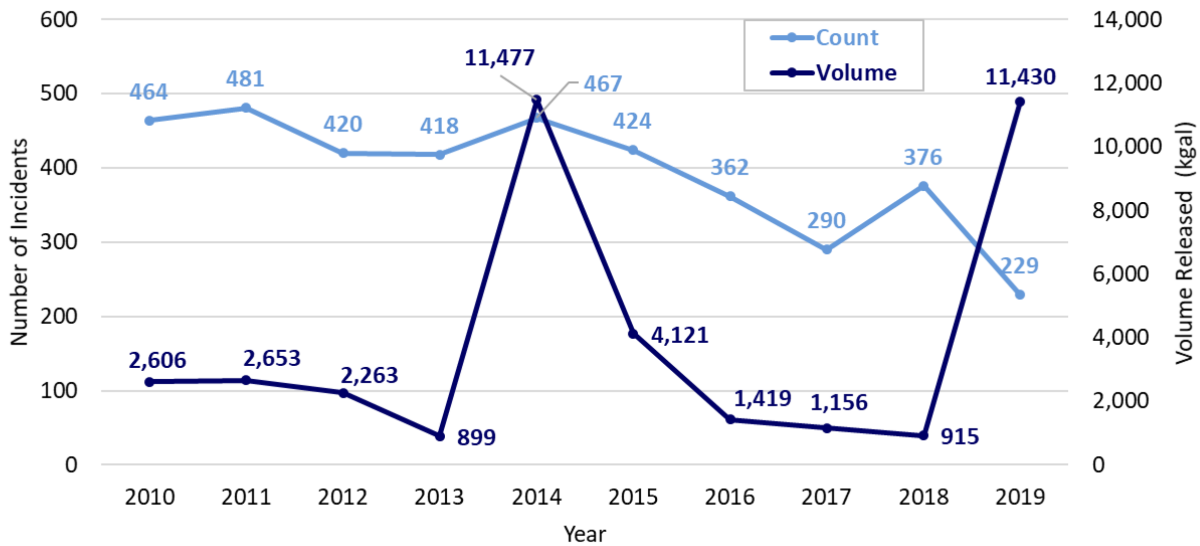


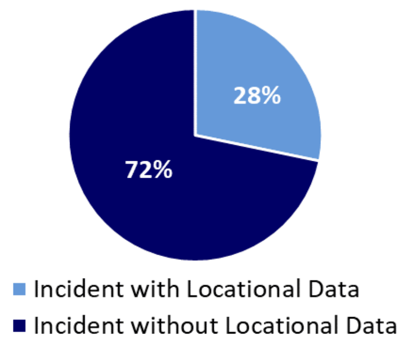
Figure 4. Annual Occurrence of Incidents Potentially Impacting Sources of Drinking Water

Figure 4 also shows the cumulative volume of material released per year over this same time period (note that 3,114 of the 3,931 incidents reported the volume released). The average cumulative volume released per year over this period is 3,894 kgal with a standard deviation of 4,105 kgal. The cumulative volume released per year ranged from 899 kgal in 2013 to 11,477 kgal in 2014. Notably, the year 2019 had the smallest number of incidents but the second largest cumulative volume released. The high cumulative volume reported in 2019 was driven by two large releases: (1) a release of 7,593 kgal of wastewater into Sugar Creek and the Withlacoochee River in Georgia (WTXL, 2019) and (2) a release of 1,418 kgal of bourbon into Glenns Creek and the Kentucky River in Kentucky (Grinberg, 2019). Similarly, there was a spike in the cumulative volume released in 2014, when 11,477 kgal was released over the course of the year. The large cumulative volume released in 2014 was primarily due to a single release of 10,491 kgal of coal ash into the Dan River in North Carolina.

Large cumulative volumes released in any given year were due to one or two very large releases.

3.3 Occurrence by Geographic Location

Of the 3,931 unique incidents considered in this analysis, 1,111 (28%) included precise latitude and longitude (lat/long) coordinates. Lat/long coordinates were estimated for an additional 2,820 incidents, using the centroid of the smallest region identified in the NRC report, most often a city or town. The precise or estimated lat/long coordinates for these incidents are mapped in **Figure 5**, which shows geographic clustering around urban areas, industrial hubs, resource extraction hubs, and transportation corridors.



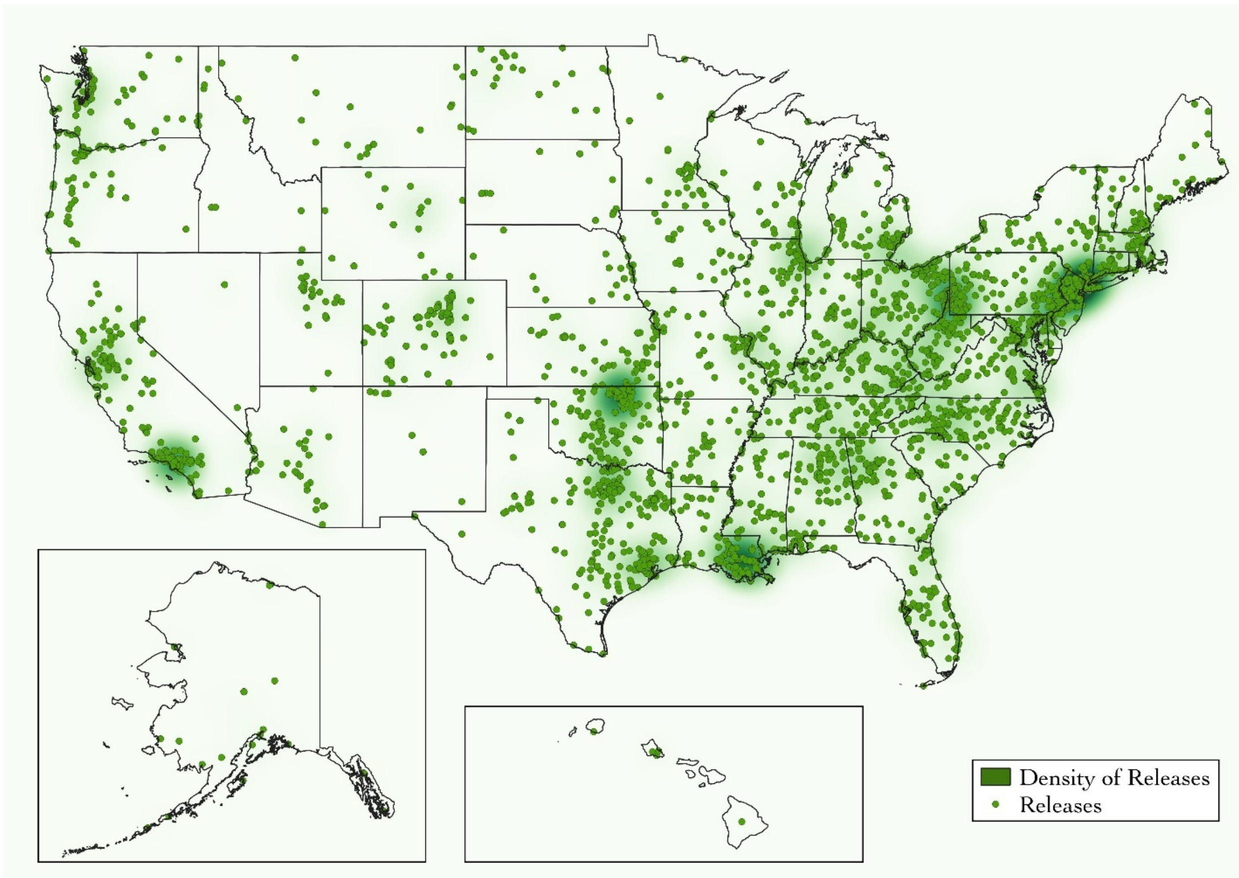


Figure 5. Geographic Distribution of Incidents Potentially Impacting Sources of Drinking Water between January 1, 2010 and December 31, 2019 *(Map shows the location of 1,111 incidents with precise lat/long coordinates and 2,820 incidents with estimated lat/long coordinates)*

Figure 6 shows the number of incidents (black circles) and cumulative volume released in kgal (blue shading and number within state boundary) to water in each state over the 10-year study period. States with the greatest number of incidents include: Texas (303), California (244), Oklahoma (236), Louisiana (205), and Pennsylvania (169).

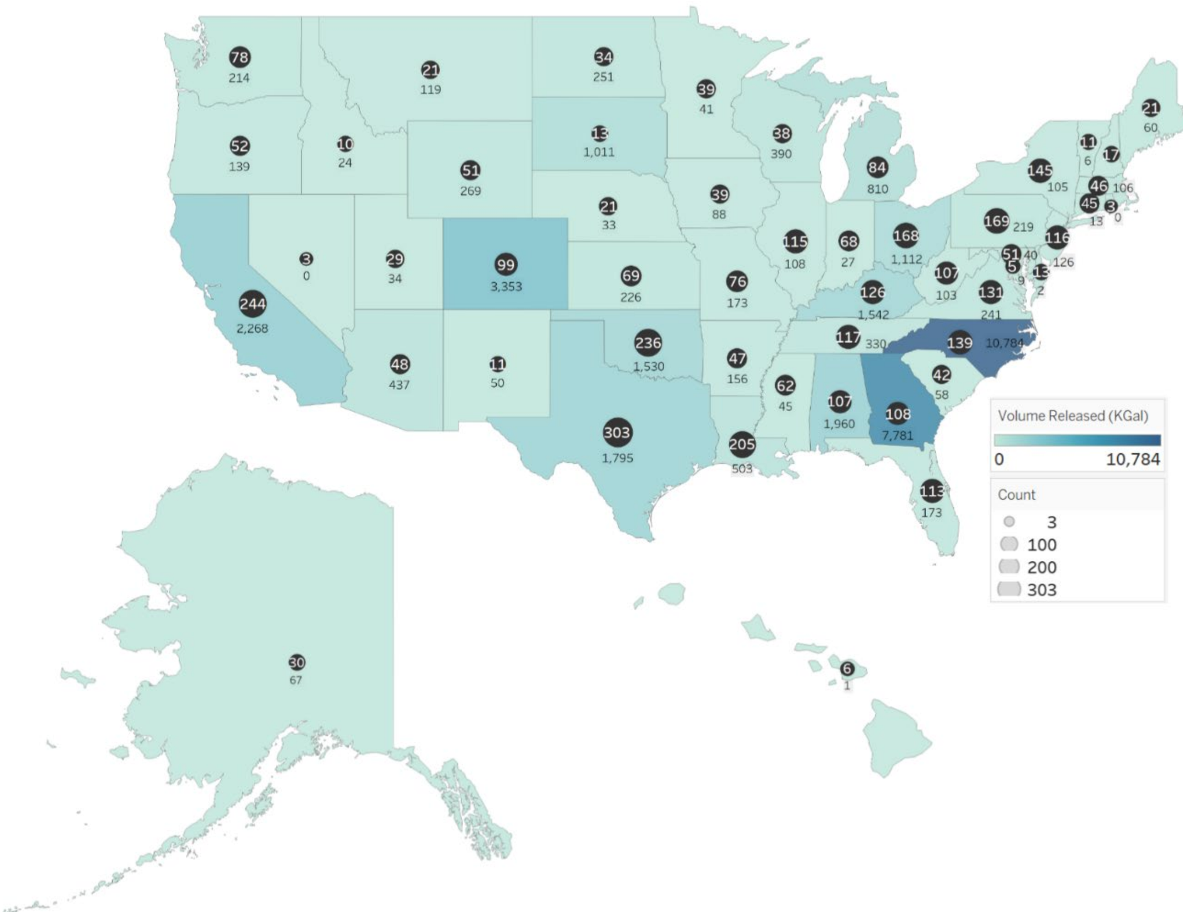


Figure 6. Total Number of Incidents and Cumulative Volume Released per State between January 1, 2010 and December 31, 2019

Figure 6 also shows the cumulative volume released in each state over the 10-year period considered in this analysis. Four states experienced a total volume released greater than 2,000 kgal: North Carolina (10,784 kgal), Georgia (7,781 kgal), Colorado (3,353 kgal), and California (2,268 kgal). The large total volumes released in these four states were driven by a single, large-volume incident in each state:

- In North Carolina, a single incident involving the release of 10,491 kgal of coal ash into the Dan River accounts for 97% of the total volume released during the study period.
- In Georgia, a single incident involving the release of 7,593 kgal of wastewater into Sugar Creek and the Withlacoochee River accounts for 98% of the total volume released during the study period.
- In Colorado, a single incident involving the release of 3,000 kgal of mine waste into Cement Creek and the Animas River accounts for 89% of the total volume released during the study period.

- In California, a single incident involving the release of 794 kgal of oil and produced water into an unnamed body of water accounts for 35% of the total volume released during the study period.

Figure 7 shows the number of incidents released in each hydrologic unit code region (HUC-2) over the 10-year study period. A numeric ID is shown for each HUC-2 region in the white hexagon, and the number of incidents occurring in each HUC-2 region is shown in the black circle. HUC codes with the greatest number of incidents include: [3] South Atlantic-Gulf Region (542), [5] Ohio Region (531), and [2] Mid-Atlantic Region (480). As shown in **Figure 7**, eight of the HUC-2 regions extend into neighboring countries ([17], [10], [9], [4], [1], [18], [15], and [13]), however, the analysis considered only releases that occurred within the borders of the U.S. (i.e., releases occurring in Canada and Mexico were not considered in this analysis).

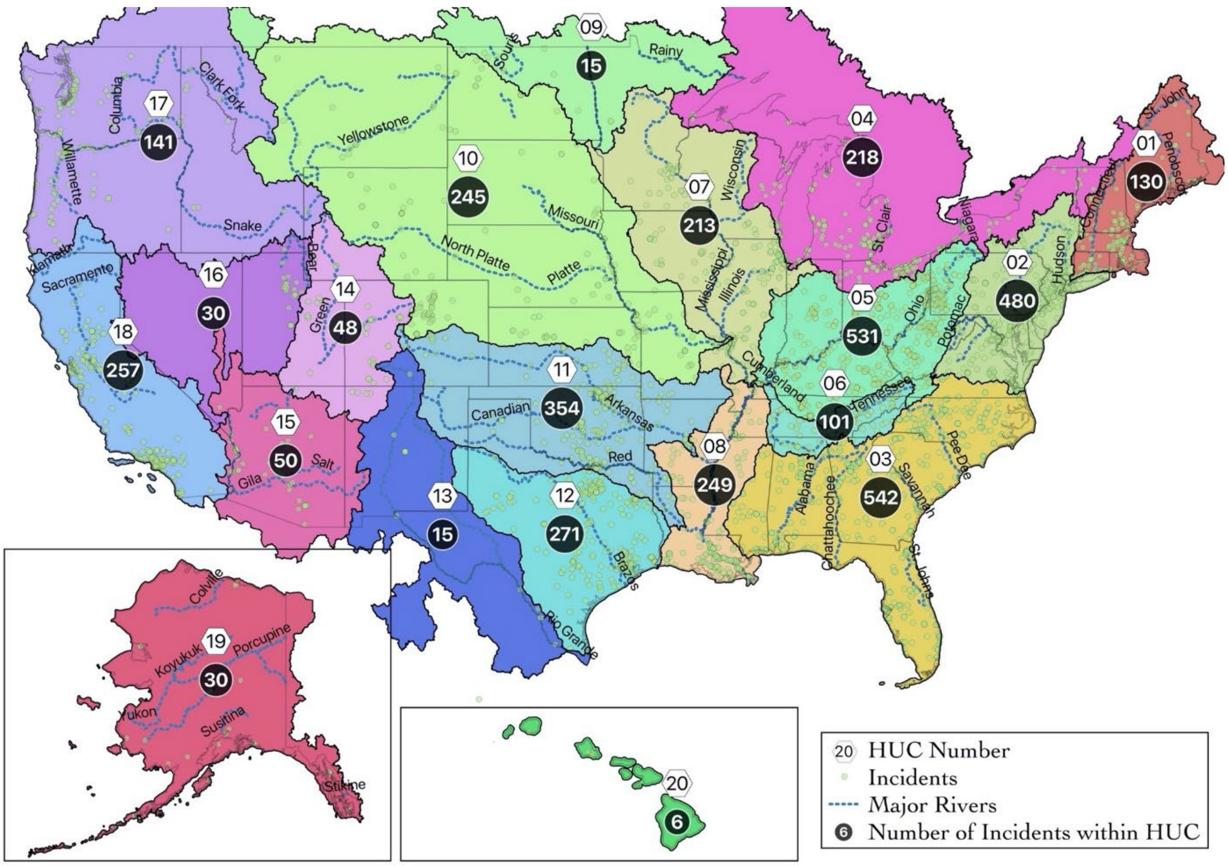


Figure 7. Total Number of Incidents per HUC-2 Region between January 1, 2010 and December 31, 2019

Table 4 shows the 25 counties across the U.S with the greatest number of incidents. The states with the most counties on this list are Louisiana with 4 counties, Texas with 3 counties, and Oklahoma with 2 counties. The four Louisiana counties are located close together in the southern metropolitan region of the state, which contains oil and gas extraction operations. The Mississippi River flows through each county and two of these counties border the Gulf of Mexico. The three Texas counties are in eastern Texas, with the adjacent counties of Tarrant and Dallas in the northeastern region and Harris County in the southeast region. These counties contain large urban areas with extensive resource extraction and industrial development. The Oklahoma counties are Osage and Carter. Osage County in northern

Oklahoma, is bounded by the Arkansas River, and contains resource extraction mines and oil and gas wells. Carter County is located in southern Oklahoma and contains extensive oil, gas, and mineral extraction operations.

Table 4. Twenty-five Counties with the Greatest Number of Incidents across the U.S.
(*Top Material Categories Released* includes counts for any unique material released during the incident.)

County	State	No. of Incidents	County Characteristics	Top Material Categories Released (Count)
Osage	OK	117	Population 49,000 (21/mi^2) Resource Extraction – Oil & Gas/Mines Borders the Arkansas River	Drilling Fluid (55) Crude Petroleum (40) Salt Water (40)
Los Angeles	CA	91	Population 9,818,000 (2,100/mi^2) Resource Extraction – Oil & Gas/Mines Bisected by the Los Angeles River	Refined Oil (40) Wastewater (28)
Harris	TX	37	Population 4,713,000 (2,730/mi^2) Resource Extraction – Oil & Gas/Mines San Jacinto & Buffalo Bayou Rivers	Refined Oil (25)
Cook	IL	36	Population 5,150,000 (5,450/mi^2) Des Plaines & Calumet, Rivers Borders Lake Michigan	Refined Oil (24)
Queens	NY	30	Population 2,254,000 (20,900/mi^2) JFK International Airport Borders the East River	Refined Oil (14) Anti-Freeze (6)
Natrona	WY	28	Population 80,000 (14/mi^2) Resource Extraction – Oil & Gas/Mines North Platte River	Drilling Fluid (24)
Duval	FL	24	Population 958,000 (1,200/mi^2) St. Johns River	Refined Oil (14)
Weld	CO	20	Population 324,000 (76/mi^2) Resource Extraction – Oil & Gas/Mines South Platte River	Drilling Fluid (11) Refined Oil (5) Crude Petroleum (5)
King	WA	20	Population 2,253,000 (1,000/mi^2) Resource Extraction – Mines SEA-TAC International Airport Duwamish River, Green River Borders the Puget Sound	Refined Oil (14)
Orleans	LA	19	Population 390,000 (2,000/mi^2) Resource Extraction – Oil & Gas Borders the Mississippi River, Lake Pontchartrain, and Lake Borgne	Refined Oil (15)
Carter	OK	19	Population 48,000 (58/mi^2) Resource Extraction – Oil & Gas/ Mines Washita River & Caddo Creek	Crude Petroleum (13) Drilling Fluid (11)
Mobile	AL	18	Population 413,000 (337/mi^2) Resource Extraction – Mines Mobile River & Gulf of Mexico	Refined Oil (11)
Plaquemines	LA	18	Population 23,000 (9/mi^2) Resource Extraction – Oil & Gas Mississippi River & Gulf of Mexico	Refined Oil (13)
Wayne	MI	18	Population 1,749,000 (3,000/mi^2) Borders Detroit River & Lake St. Clair	Refined Oil (14)
Dallas	TX	18	Population 2,636,000 (3,000/mi^2) Resource Extraction – Oil & Gas/ Mines Trinity River	Refined Oil (11) Wastewater (4)
New Haven	CT	17	Population 855,000 (1,000/mi^2) Resource Extraction – Mines Quinnipiac & Housatonic Rivers	Refined Oil (12)

County	State	No. of Incidents	County Characteristics	Top Material Categories Released (Count)
St. James	LA	17	Population 21,000 (86/mi^2) Resource Extraction – Oil & Gas Mississippi River	Refined Oil (10) Crude Petroleum (4)
Westchester	NY	17	Population 968,000 (2,000/mi^2) Borders the Hudson River and Long Island Sound	Refined Oil (10) Transformer Oil (4)
Allegheny	PA	17	Population 1,216,000 (1,700/mi^2) Major Industrial Hub Commerce transport along Ohio, Allegheny, and Monongahela Rivers	Refined Oil (13)
Tarrant	TX	17	Population 2,103,000 (2,100/mi^2) Resource Extraction – Oil & Gas W. Fork Trinity River & Clear Fork Trinity River	Refined Oil (11)
St. Louis	MO	16	Population 994,000 (1,900/mi^2) Resource Extraction – Mines St. Louis Lambert International Airport Borders the Missouri, Mississippi, & Meramec Rivers	Refined Oil (13)
Cuyahoga	OH	16	Population 1,235,000 (2,800/mi^2) Resource Extraction – Oil & Gas Cuyahoga & Rocky Rivers Borders Lake Erie	Refined Oil (13)
Shelby	TN	16	Population 937,000 (1,200/mi^2) Resource Extraction – Mines Mississippi, Wolf, and Loosahatchie Rivers	Refined Oil (14)
E. Baton Rouge	LA	15	Population 440,000 (940/mi^2) Resource Extraction – Oil & Gas Mississippi River	Refined Oil (8)
Harrison	WV	15	Population 68,000 (170/mi^2) Resource Extraction – Oil & Gas West Fork River	Refined Oil (5) Drilling Fluid (4)

Figure 8 shows the number of incidents and total volume released into "unknown or unnamed" bodies of water or into "named" bodies of water. The majority (61%) of incidents occur into an unknown or unnamed waterbody, however, most of the volume released (85%) occurs into named bodies of water. This discrepancy may be due to more complete reporting of releases involving large volumes (i.e., more information, including the name of the body of water, is reported for large releases).

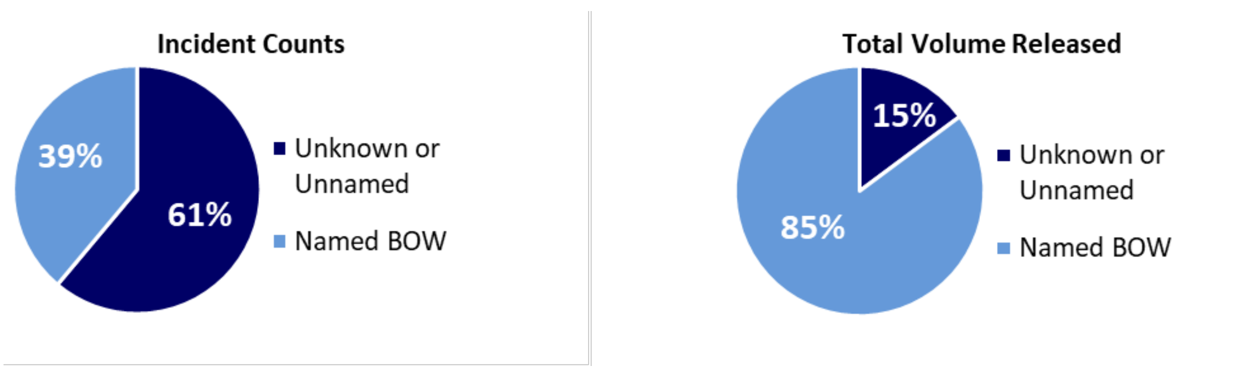


Figure 8. Incident Counts and Total Volume Released into Named Bodies of Water (BOW) and Unknown or Unnamed Bodies of Water

The thirty-one named waterbodies with the greatest number of incidents or largest total volume released are shown in **Figure 9**. The waterbodies with the greatest number of incidents include the Mississippi River (139 incidents), Ohio River (77 incidents), and Hudson River (29 incidents). Figure 8 also shows the waterbodies into which the largest cumulative volumes were released: the Dan River (10,491 kgal), Withlacoochee River (7,593 kgal), and Cement Creek/Animas River (3,002 kgal). Notably, these three bodies of water were impacted by a small number of incidents: one, one, and two, respectively. Similar to the analysis of release by state, this analysis shows that a relatively small number of very large releases dominate the distribution of cumulative volumes released across waterbodies.

Regardless of the geographic boundaries used in the analysis, three characteristics are common to regions with a high occurrence of releases: (1) urban areas, (2) transportation corridors, or (3) resource extraction activity.

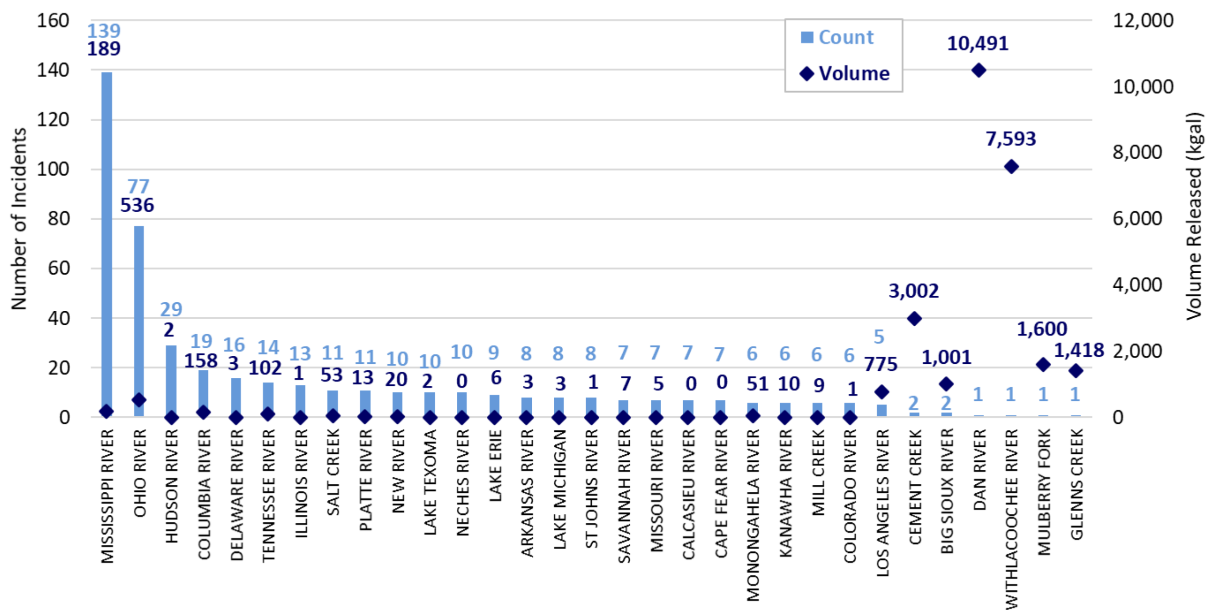
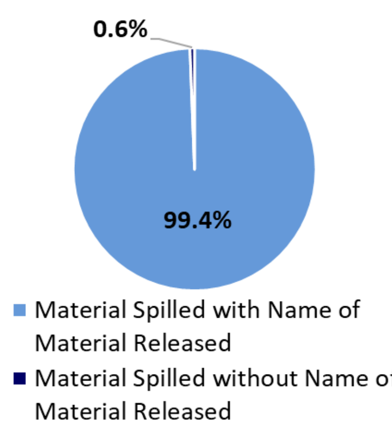


Figure 9. Thirty-one Waterbodies with the Greatest Number of Incidents or Largest Cumulative Volume Released to Water across the U.S. *(A volume less than 0.5 kgal is displayed as 0 in the figure: Neches River (0.13 kgal), Cape Fear River (0.40 kgal), and Calcasieu River (0.45 kgal))*

3.4 Materials Released

Of the 3,931 unique incidents considered in this analysis, 3,907 (99.4%) incidents included the name of the material(s) released. These incidents involved 840 different materials, which were grouped into the categories listed in **Table 2**. Incidents involving the release of multiple materials are counted under multiple material categories resulting in a total of 4,226 unique material releases, of which 3,250 reported the volume released and 1,954 reported the amount in water.



The frequency of releases and total volume released involving each of these material categories is shown in **Figure 10.** Materials in the Refined Oil category are the most frequently released materials by a significant margin.

There were 2,401 (56.8%) releases of Refined Oil over the 10-year study period. Within the Refined Oil category, the most commonly released material is diesel, accounting for 45.7% of releases of Refined Oil, followed by unknown oil (10.5%), and gasoline (8.4%). Releases of gasoline accounted for the largest total volume released, 588 kgal (29.7%), within the Refined Oil category.

The next most frequently released material category was Crude Petroleum, with 398 (9.4%) releases, followed by Wastewater with 285 (6.7%) releases, Drilling Fluid 231 (5.5%), Transformer Oil 164 (3.9%), and Other Materials 116 (2.7%). The Other Materials category includes a wide range of materials, most of which are poorly characterized and were involved in three or fewer incidents. The largest volume of a named material captured under the Other Materials category was a release of 44 kgal of stearic acid into an unnamed body of water in Massachusetts in 2011.

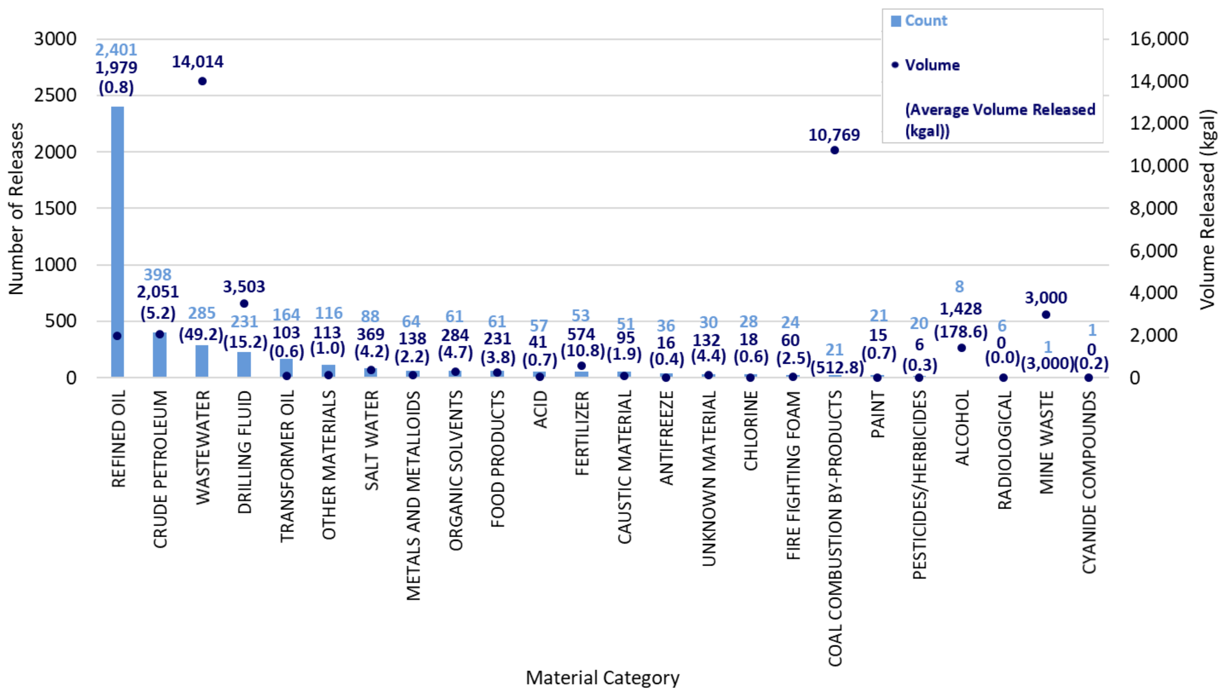


Figure 10. Total Number of Incidents and Cumulative Volume Released for each Material Category *(A volume less than 0.5 kgal is displayed as 0 in the figure: Cyanide Compounds (0.21 kgal) and Radiological (no volumes reported))*

There were 164 (3.9%) releases of transformer oil over the 10-year period. Transformer oil is most often released from pole mounted transformers that can contain 50 to 100 gallons of transformer oil; however, transformers can be much larger, requiring significantly larger volumes of oil (Power Partners Inc., 2009). Of the 164 releases involving transformer oil, twenty-two released volumes between 1 kgal and 1.4 kgal. These releases included discharges from vehicles carrying transformer oil, large transformers damaged during flooding, sub-station transformer discharges, and releases from storage tanks. The NRC records for releases of transformer oil were not always clear whether the oil contained PCBs. Through the 1970s, transformer oil often contained PCBs. However, the Toxic Substances Control Act banned the production of new PCBs in 1979, thus it is hypothesized that very few releases of transformer oil during the study period involved oils containing PCBs.

Figure 10 also shows the cumulative volume released for each material category over the study period. Wastewater releases accounted for 14,014 kgal (36%) of the total volume released over the 10-year study period (38,940 kgal), an average volume per incident of 49.2 kgal. There were 3 releases of wastewater of 1,000 kgal or more. The largest release occurred in 2019 where 7,592 kgal of wastewater were released into the Withlacoochee River in Georgia. The second largest release of wastewater occurred in 2011 when 1,600 kgal were released into Mulberry Fork in Alabama.

While refined oils are involved in the largest number of releases, wastewater accounts for the largest cumulative volume released.

Coal Combustion By-Products, which include fly ash, bottom ash, and boiler slag among other material, had the second highest cumulative volume released. Coal Combustion By-Products accounted for 10,769 kgal (27.7%) of the total volume released, an average volume per incident of 512.8 kgal. This total volume is dominated by a single release of 10,491 kgal of coal ash (specifically, fly ash) into the Dan River in North Carolina in 2014. Coal combustion by-products can present a serious threat to water quality since they contain toxic metals and metalloids including arsenic, cadmium, lead, and mercury.

Drilling Fluid had the third highest cumulative volume released at 3,503 kgal (9%), an average volume per incident of 15.2 kgal. Drilling fluids often contain brine that can increase the bromide concentration in the source water. Some community water systems have attributed increases in the concentration of brominated disinfection by-products to contamination from drilling fluids (States et al, 2013).

Mine Waste had the fourth highest total volume released at 3,000 kgal (7.7%). Because there was only one incident involving the release of mine wasted in this analysis, the average volume per incident is also 3,000 kgal. Similar to coal-combustion by-products, mine waste may contain high concentrations of toxic metals.

Table 5 shows the number of releases that occurred within a specified range of volumes for each of the material categories. Four volume ranges were considered: less than 1 kgal; between 1 and 10 kgal; between 10 and 100 kgal; and greater than 100 kgal. With only one exception, Alcohol, most releases for each material category were less than 1 kgal, and the number of releases in each volume range decreases as volume increases. This table also illustrates that occurrence of large volume releases varies across material categories. The following material categories were involved in releases larger than 10 kgal, but less than 100 kgal (shaded yellow in the table): Caustic Material, Fire Fighting Foam, Metals and Metalloids, Other Materials, Refined Oil, Salt Water, and Transformer Oil. The following material categories were involved in releases larger than 100 kgal (shaded orange in the table): Alcohol, Coal Combustion By-products, Crude Petroleum, Drilling Fluid, Fertilizer, Food Products, Mine Waste, Organic Solvents, Unknown Material, and Wastewater.

Table 5. Count of Releases Involving a Volume within the Indicated Range for Each Material Category *(A volume released less than 0.5 kgal is displayed as 0 in the table: Cyanide Compounds (0.21 kgal) and Radiological (no volumes reported))*

Material Category	No. of Releases	Total Volume Released (kgal)	Number of Releases in Volume Range					Largest Volume Released (kgal)
			Not Reported	< 1 (kgal)	1 - 10 (kgal)	10 - 100 (kgal)	> 100 (kgal)	
TOTAL	**4,226**	**38,940**	**976**	**2,301**	**786**	**134**	**29**	**N/A**
Acid	57	41	12	33	12	0	0	7
Alcohol	8	1,428	4	0	3	0	1	1,418
Antifreeze	36	16	14	17	5	0	0	4
Caustic Material	51	95	8	26	15	2	0	24
Chlorine	28	18	7	13	8	0	0	5
Coal Combustion By-Products	21	10,769	7	6	4	2	2	10,491
Crude Petroleum	398	1,257	36	260	91	9	2	794
Cyanide Compounds	1	0	0	1	0	0	0	0.21
Drilling Fluid	231	3,503	6	85	106	28	6	977
Fertilizer	53	574	13	24	13	2	1	467
Fire Fighting Foam	24	60	3	13	5	3	0	20
Food Products	61	231	13	22	22	3	1	100
Metals and Metalloids	64	138	44	13	4	3	0	80
Mine Waste	1	3,000	0	0	0	0	1	3,000
Organic Solvents	61	284	28	11	19	2	1	178
Other Materials	116	113	44	53	18	1	0	44
Paint	21	15	7	9	5	0	0	4
Pesticides/ Herbicides	20	6	8	11	1	0	0	4
Radiological	6	0	6	0	0	0	0	N/A
Refined Oil	2,401	2,773	605	1,461	308	27	0	88
Salt Water	88	369	5	31	41	11	0	33
Transformer Oil	164	103	13	129	20	2	0	14
Unknown Material	30	132	23	4	1	1	1	100
Wastewater	285	14,014	70	79	85	38	13	7,592

The results in **Table 5** show that the following material categories account for 79% of the number of releases and 83% of the total volume released: Refined Oil, Crude Petroleum, Wastewater, Drilling Fluids, and Coal Combustion By-Products. To investigate the geographic distribution of releases in these categories, they were mapped in **Figures 11 - 15**. These maps show the precise and estimated lat/long coordinates as points, while the shading shows the density of release occurrence, with darker shading indicating a higher occurrence of releases.

Figure 11 shows the geographic distribution of releases of Refined Oil, indicating a widespread distribution of releases in urban areas. Regions with a high density of Petroleum Product releases include Western New Jersey/Eastern Pennsylvania; Western Pennsylvania/West Virginia/Eastern Ohio; Southeastern Louisiana, and Central Oklahoma/Northcentral Texas. The states with the most releases of Refined Oil include: Texas with 146 (6%), Ohio with 122 (5%), Pennsylvania with 120 (5%), and Louisiana with 120 (5%). The majority of releases in Texas occurred into drainage and collection areas (69), followed by unnamed creeks, streams, or tributaries (16). The remaining releases of Refined Oil in Texas occurred into various named creeks or rivers, with the Neches River experiencing the most (6). The majority of releases in Ohio also occurred into drainage and collection areas (48), followed by the Ohio River (22), and unnamed creeks, streams, or tributaries (16). The bodies of water impacted by the most releases of Refined Oil include: drainage and collection (932), unnamed creeks, streams, or tributaries (256), the Mississippi River (102), and the Ohio River (73). Releases occurring on the Mississippi River and Ohio River can impact adjacent and downstream states. Releases of Refined Oil into the Mississippi River occurred in Louisiana (67), Missouri (10), Illinois (5), Minnesota (5), Mississippi (5), Kentucky (3), Tennessee (3), Iowa (2), Arizona (1), and Wisconsin (1). Releases of Refined Oil into the Ohio River occurred in Ohio (22), Kentucky (16), West Virginia (14), Indiana (10), Pennsylvania (6), and Illinois (5).

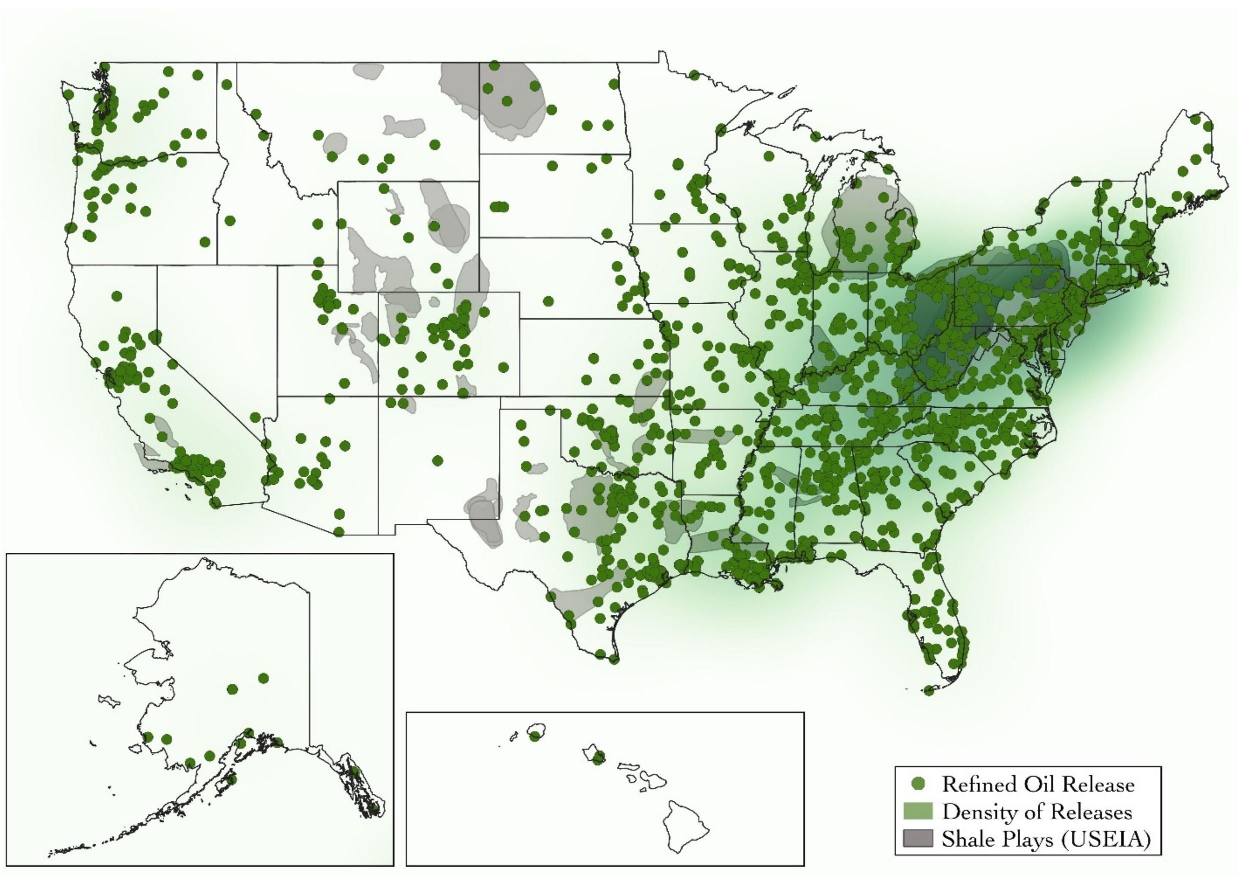


Figure 11. Geographic Distribution of Releases of Refined Oil that Occurred between January 1, 2010 and December 31, 2019

Figure 12 shows the geographic distribution of releases of Crude Petroleum with hot spots in Central Oklahoma/Southeast Kansas, Southeast Texas/Southern Louisiana, and West Virginia/Eastern Kentucky. There is significant overlap between these hot spots and the major shale plays that are sources of oil and natural gas. The states with the most releases of Crude Petroleum include: Oklahoma with 98 (25%), Texas with 62 (16%), Louisiana with 41 (10%), and Kansas with 28 (7%). The majority of releases in Oklahoma occurred into unnamed creeks, streams, and tributaries (33), followed by drainage and collection areas (18). The remaining releases of Crude Petroleum in Oklahoma occurred into various named creeks or rivers, with the Little Chief Creek experiencing the most (4). The majority of releases in Texas occurred into unnamed creeks, streams, or tributaries (13), followed by drainage and collection areas (6). The remaining releases of Crude Petroleum in Texas occurred into various named creeks or rivers, with Neches River and Sabine River experiencing the most (4 each). The bodies of water impacted by the most releases of Crude Petroleum include: unnamed creeks, streams, or tributaries (90), drainage and collection areas (69), unnamed reservoirs, lakes, or ponds (30), unnamed wetland area (18), and the Mississippi River (10). Releases of Crude Petroleum into the Mississippi River occurred in Louisiana (7), Illinois (2), and Mississippi (1).

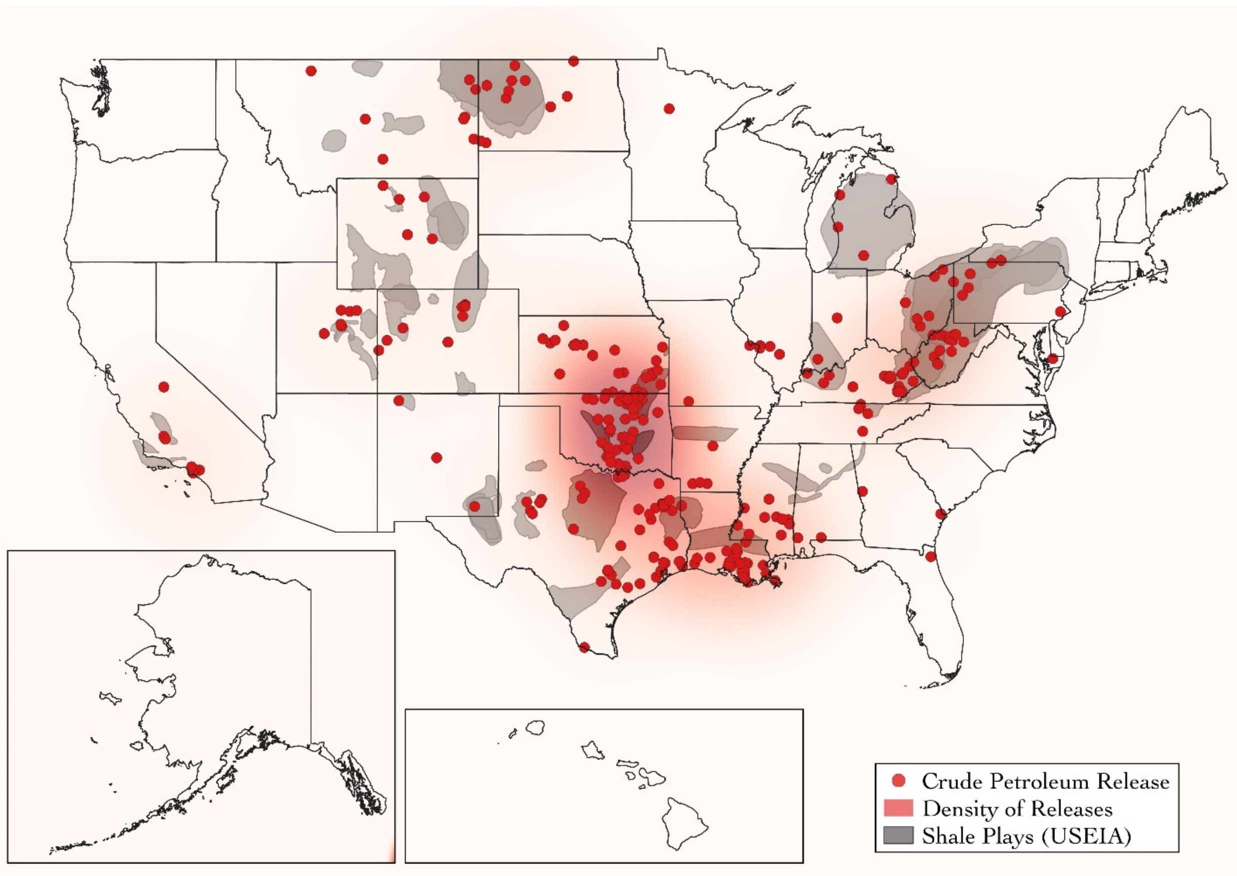


Figure 12. Geographic Distribution of Releases of Crude Petroleum that Occurred between January 1, 2010 and December 31, 2019

Figure 13 shows the geographic distribution of releases of Wastewater in urban areas across the U.S., similar to the distribution of releases of Refined Oil. This result is expected given that refined oils and wastewater are prevalent in urban areas. Regions with a high density of Wastewater releases include Southern California and Southwestern Pennsylvania. The states with the most releases of Wastewater include: California with 54 (19%), Virginia with 25 (9%), and Texas with 21 (7%). The majority of releases in California occurred into drainage and collection areas (36), followed by the Los Angeles River (4), the San Joaquin River (2), and Hutchinson Creek (2). The remaining releases of Wastewater in California occurred in various named creeks or rivers. The majority of releases in Virginia occurred into drainage and collection areas (14), followed by drinking water (3), Skiffes Creek (3), and the Elizabeth River (2). The bodies of water impacted by the most releases of Wastewater releases include: drainage and collection areas (101), unnamed creeks, streams, or tributaries (22), drinking water (20), and unnamed reservoirs, lakes, or ponds (8).

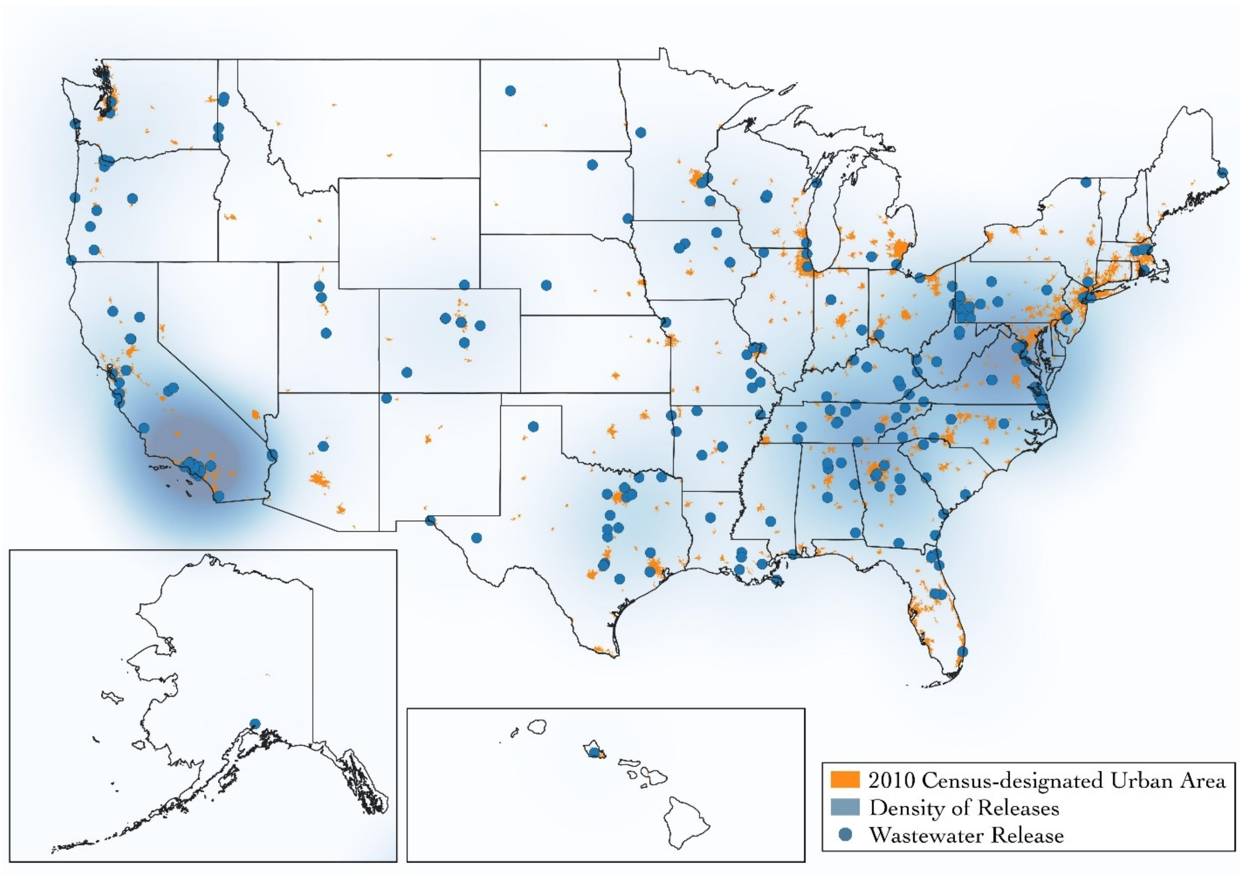


Figure 13. Geographic Distribution of Releases of Wastewater that Occurred between January 1, 2010 and December 31, 2019

Figure 14 shows the geographic distribution of releases of Drilling Fluid, with regions experiencing a large number of releases in Northern Oklahoma/Southern Kansas, Northeastern Texas/Southcentral Oklahoma, Central Wyoming, Northeastern North Dakota, and Northern West Virginia/Eastern Ohio/Southwestern Pennsylvania. All of these regions contain large shale plays and associated oil and gas extraction operations that use large quantities of drilling fluids. The states with the most releases of Drilling Fluid include: Oklahoma with 81 (35%), followed by Wyoming with 31 (13%), and Texas with 24 (10%). The majority of releases in Oklahoma occurred into unnamed creeks, streams, or tributaries (23), followed by a drainage or collection area (22), and unnamed reservoirs, lakes, or ponds (12). The remaining releases of Drilling Fluid in Oklahoma occurred into various named creeks or rivers, with Hay Creek experiencing the most (3). The majority of releases in Wyoming also occurred into drainage and collection areas (15), followed by Castle Creek (4). The bodies of water impacted by the most releases of Drilling Fluid include: drainage and collection areas (61), unnamed creeks, streams, or tributaries (51), unnamed reservoirs, lakes, or ponds (18), and South Platte River in Colorado (6).

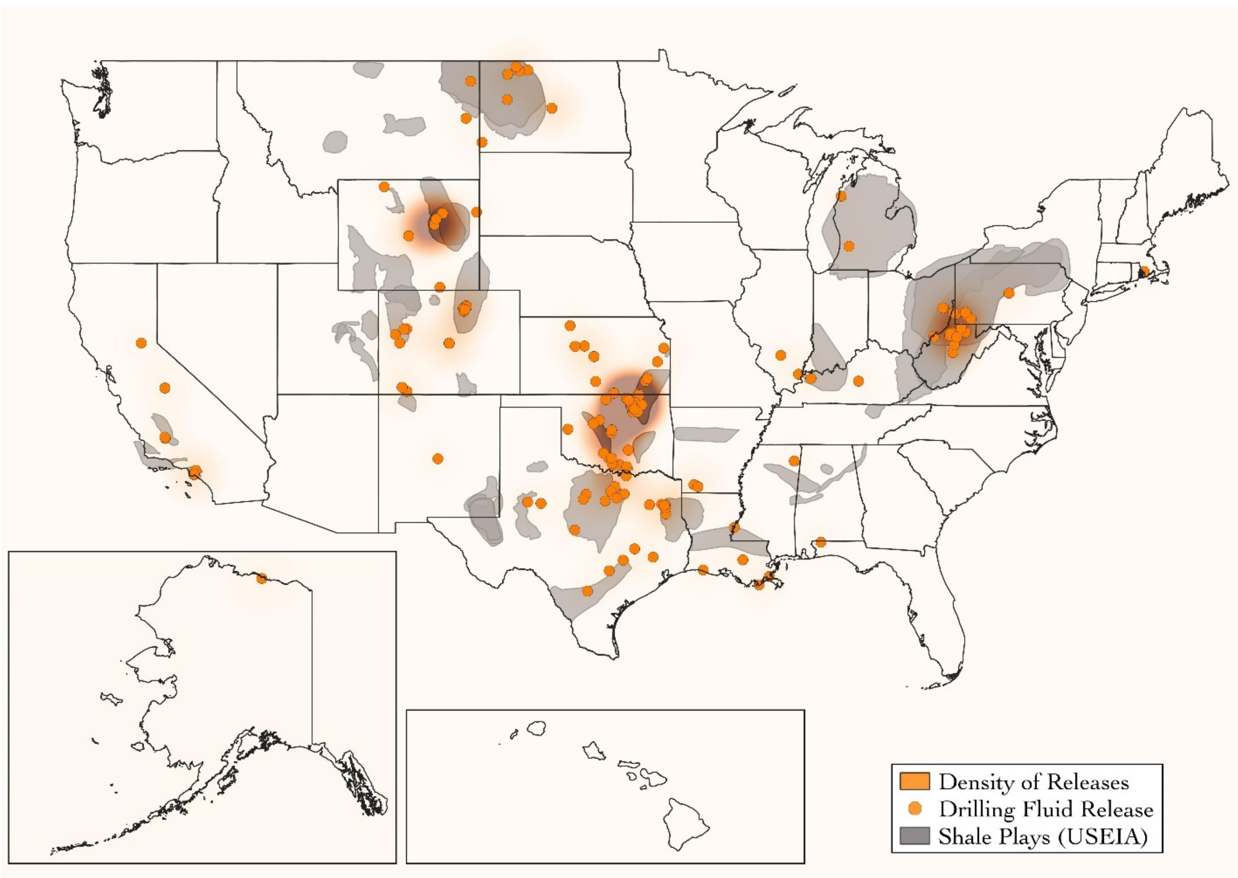


Figure 14. Geographic Distribution of Releases of Drilling Fluids that Occurred between January 1, 2010 and December 31, 2019

Figure 15 shows the geographic distribution of releases of Coal Combustion By-Products, with a concentration of releases occurring in Western Pennsylvania/Eastern Ohio/Northern West Virginia. The states with the most releases of Coal Combustion By-Products include: Ohio with 3 (14%) and North Carolina with 2 (10%). The high number of releases in these regions is likely a result of the large number of active and closed coal-fired power plants in these same regions. The three releases in Ohio occurred into Block House Hollow, the Ohio River, and Riddles Run while the two releases in North Carolina occurred into the Dan River and the Neuse River. The bodies of water impacted by the most releases of Coal Combustion By-Products include: drainage and collection areas (2), drinking water (2), Hudson River (2) which only impacted New York, and the Dan River (1) which impacted only North Carolina.

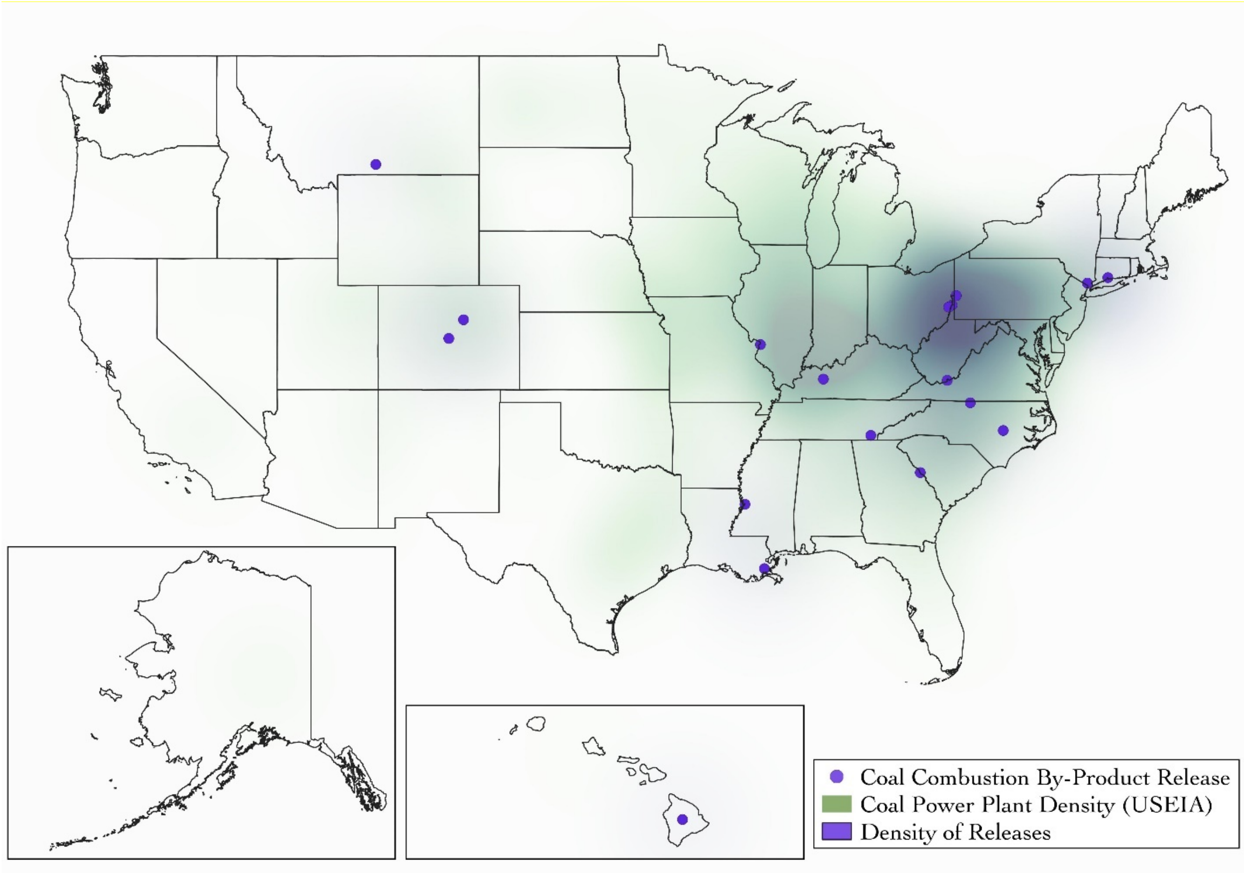


Figure 15. Geographic Distribution of Releases of Coal Combustion By-Products that Occurred between January 1, 2010 and December 31, 2019

3.5 Cause of Incidents and Responsible Parties

The NRC record includes standardized fields for recording the reported cause and responsible party of a release. The causes of releases reported to the NRC and considered in this analysis include:

- Equipment Failure: including ruptures in storage vessels and pipelines, over pressurization, and explosions
- Transportation Accident: including accidents occurring on roadways, railways, and waterbodies that involve a vehicle or vessel
- Operator Error: including failure to follow procedures for transport and transfer of materials
- Natural Phenomena: including hurricanes, flooding, and tornados

- Dumping: including unpermitted discharges as well as illegal dumping by private companies and citizens
- Other: cause known but other than the standard causes listed above.
- Unknown: cause of the release unknown or not reported

All 3,931 incidents included in this analysis have information about the cause. The number of incidents and cumulative volume of releases attributed to each cause are shown in **Figure 16**. Equipment Failure was reported as the leading cause of an incident 27% (1,078), was responsible for the 49% (19,260 kgal) of the cumulative volume released, and had an average volume released per incident of 17.9 kgal. Transportation Accidents caused 13% (505) of the incidents but only 2% (820 kgal) of the cumulative volume released, and thus had a much lower average volume per incident of 1.6 kgal. Natural Phenomena caused only 5% (212) of the incidents but accounted for 5% (1,807 kgal) of the cumulative volume released, with an average volume released of 8.5 kgal.

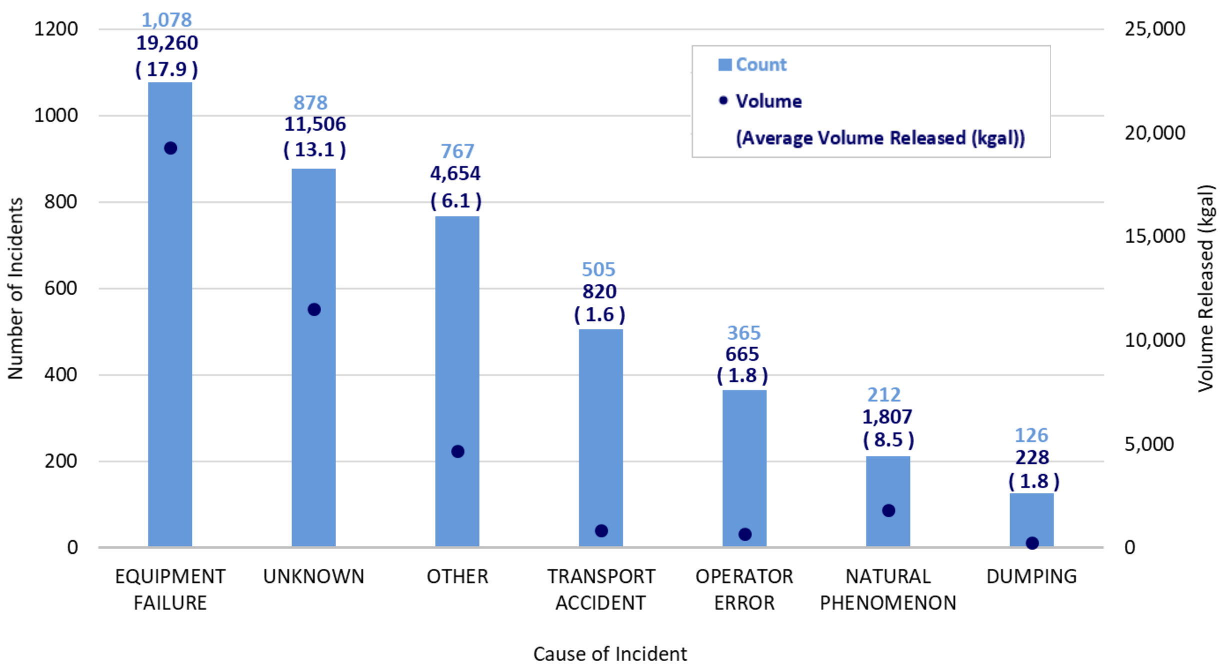


Figure 16. Total Number of Incidents and Cumulative Volume of Material Released for each Cause between January 1, 2010 and December 31, 2019

Because wastewater accounts for most of the cumulative volume released, the causes of wastewater releases were investigated. The majority of wastewater releases were caused by equipment failure (100), other causes (57), unknown causes (52), and illegal dumping of materials (29). Pipeline breaks and pump failures were the two most common types of equipment failures leading to wastewater releases.

All 3,931 incidents included in this analysis listed the responsible party using the following designations:

- Private Enterprise
- Private Citizen
- Federal Government

- State Government
- Local Government / Public Utility (two unique NRC designations that were combined for this analysis)
- Military
- Tribe
- Other
- Unknown

Private industry is the most often reported responsible party. The most common cause of a release is equipment failure.

Figure 17 shows the number of incidents and total volume released attributed to the above categories of responsible party. Private Enterprises was listed as the responsible party for 69% (2,712) of the total number of incidents, 87% (34,308 kgal) of the total volume released, and an average volume per incident of 12.7 kgal. Within this category Chaparral Energy, an oil and natural gas producing company in Oklahoma, was responsible for the largest number of incidents (53), which involved petroleum products and drilling fluids. Local Government / Public Utilities were responsible for 6% (236) of the incidents, 8% (3,329 kgal) of the total volume released, and an average volume per incident of 14.1 kgal. Most incidents caused by Local Government / Public Utility involved the release of wastewater from municipal wastewater systems. Private Citizens were responsible for 4% (140) of the total number of incidents, 0.15% (59 kgal) of the total volume released, and an average volume per incident of 0.4 kgal.

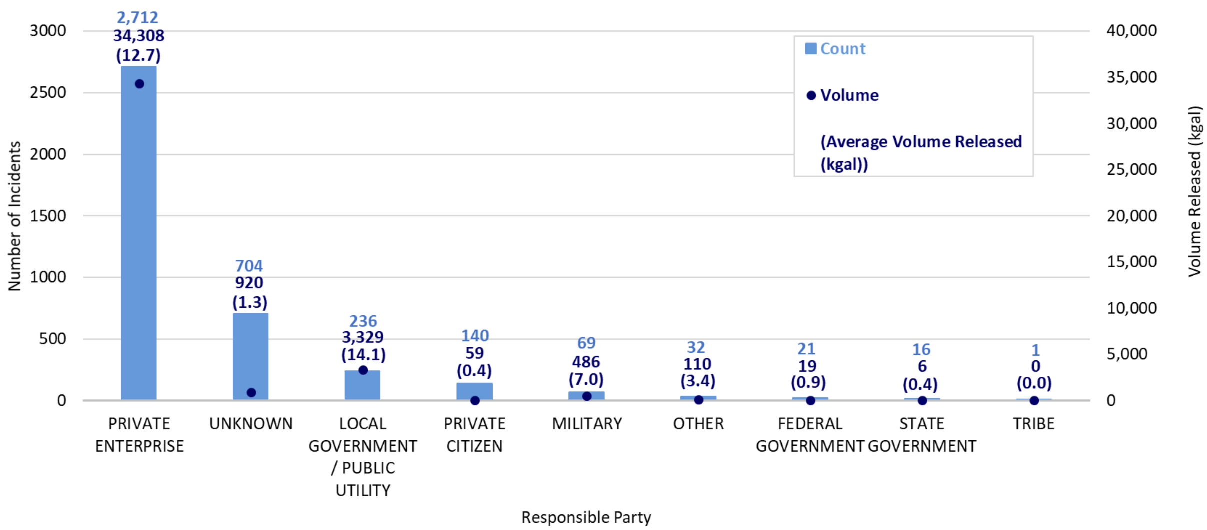


Figure 17. Total Number of Incidents and Cumulative Volume of Material Released by each Responsible Party Category between January 1, 2010 and December 31, 2019

Table 6 shows the materials most commonly released by each of the responsible party categories. Refined Oil and Crude Petroleum are the most commonly released materials for all responsible party categories except Tribes. Wastewater was a commonly released material by Local Government / Public Utilities, Military, and Tribes.

Table 6. Most Commonly Released Materials for each Responsible Party Category

Responsible Party Category	Most Commonly Released Materials
Private Enterprise	Diesel Oil, Crude Oil, Unleaded Automotive Gasoline
Unknown	Diesel Oil, Unknown Oil, Fuel Oil, Unleaded Automotive Gasoline
Local Government / Public Utility	Wastewater, Hydraulic Oil, Transformer Oil
Military	Wastewater, Diesel Oil, Jet Fuel
Other	Diesel Oil, Crude Oil, Other Oil
Federal Government	Hydraulic Oil, Diesel Oil, Gasoline
State Government	Diesel Oil, Hydraulic Oil, Fuel Oil
Tribe	Wastewater

Figure 18 shows the number of incidents and total volume released for various types of incidents. The most common type of incident involved Other Transportation, not including Watercraft and Railroads, which are captured under separate categories. While Other Transportation accounted for a large number of incidents, 1,257 (32%), they only accounted for 1,475 kgal (4%) of the cumulative volume released, and thus had an average volume released per incident of only 1.2 kgal. The second most common type of incident were those at Fixed Facilities, which were involved in 1,081 (27%) incidents, accounted for 29,272 kgal (75%) of the cumulative volume released, and had the largest average volume released per incident of 27.1 kgal. While Pipeline breaks account for only 354 (9%) incidents, they account for the second largest total volume released 4,500 kgal (12%). The average size of a release from a pipeline break is 12.7 kgal. The NRC allows releases to be assigned to both Fixed Facilities and Storage Tanks (which are also fixed facilities). It is unclear how these two categories are differentiated, and it’s likely that there is some overlap – specifically, some releases from Fixed Facilities likely came from storage tanks at those facilities.

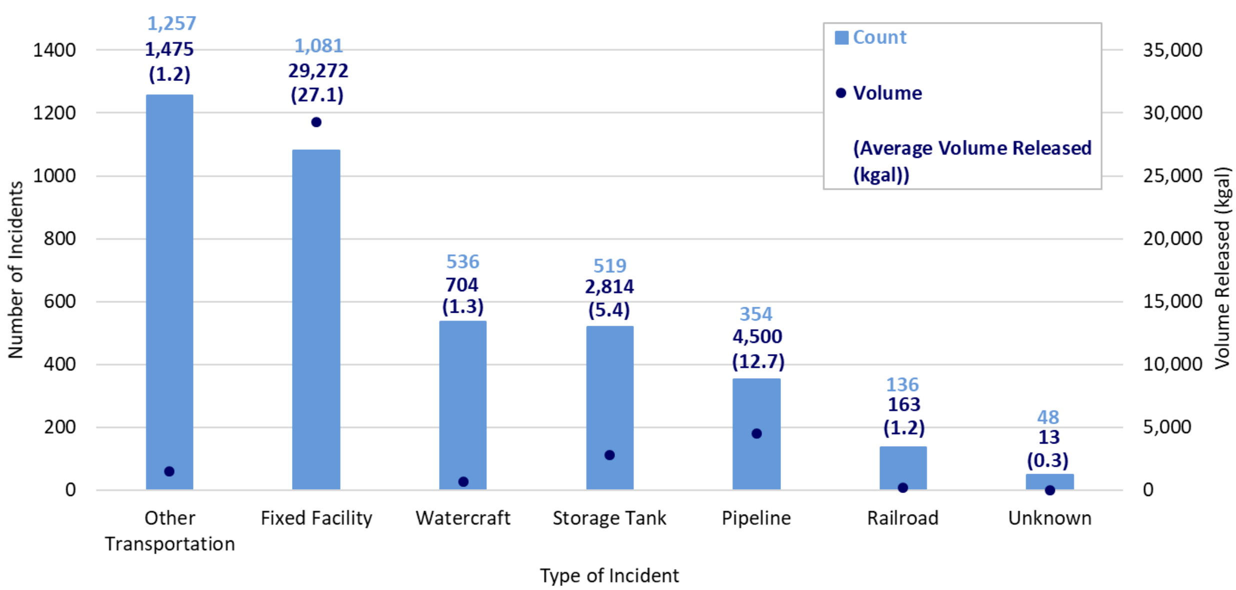


Figure 18. Total Number of Incidents and Cumulative Volume of Material Released by Type of Incident between January 1, 2010 and December 31, 2019

3.6 Occurrence of Releases by Source Water Zone of Concern

In Sections 3.1 through 3.5, the analysis considered the occurrence and attributes of releases, treating each incident as a unique data point. This section considers the occurrence of unique incidents within a source water ZOC for all community water system intakes and wells included in the analysis. In cases where ZOCs for multiple intakes or wells overlap, the same incident can impact multiple ZOCs. Furthermore, this analysis includes only the 1,111 incidents for which there is precise location data (i.e., lat/Long coordinates). Of these, 1,097 fell within a ZOC, as defined in Section 2.3. While the remaining 14 incidents did not fall within a ZOC, it was confirmed that the contaminant plume from the incident reached one or more downstream intakes that were more than 50 miles from the release location and prompted a response (e.g., closing an intake, deploying booms, collecting and analyzing samples). These incidents were manually reviewed and assigned to SW and/or GW ZOCs by tracing the closest NHD flowline and identifying the closest downstream ZOC(s) that may have been affected by the incident.

Figure 19 shows the number of community water systems whose source water ZOC experienced at least "n" incidents, where "n" is the number indicated on the y-axis. The figure shows a significant difference in the occurrence of incidents for SW ZOCs and GW ZOCs. Of the 4,929 SW intakes considered in this analysis, 85% (4,204) did not have an incident occur within their ZOC under the assumptions of this analysis. The remaining 725 SW intakes experienced at least one incident that potentially impacted their source of drinking water. While the distribution of incidents in SW ZOCs drops off rapidly, there were a small number of ZOCs that experienced a significantly larger number of incidents. Twenty-five SW ZOCs experienced at least 10 incidents (on average, one release per year) and three SW ZOCs experienced 22 incidents over the 10-year study period.

SW ZOCs are more likely to experience a release than are GW ZOCs: 15% for SW ZOCs vs. 0.7% for GW ZOCs.

Of the 106,816 GW wells considered in this analysis, 0.7% (700) experienced at least one incident within its ZOC under the assumptions of this analysis. The distribution of incidents in GW ZOCs drops off much more quickly compared with the distribution for SW ZOCs. The maximum number of incidents in a GW ZOC was four, experienced within only four GW ZOCs.

The data in **Figure 19** suggest that SW ZOCs are more likely to experience a release than are GW ZOCs: 15% for SW ZOCs vs. 0.7% for GW ZOCs. Also, SW ZOCs are more likely to experience a greater number of releases compared with GW ZOCs. However, this analysis does not consider the prevalence of long-term or chronic contamination of ground water aquifers.

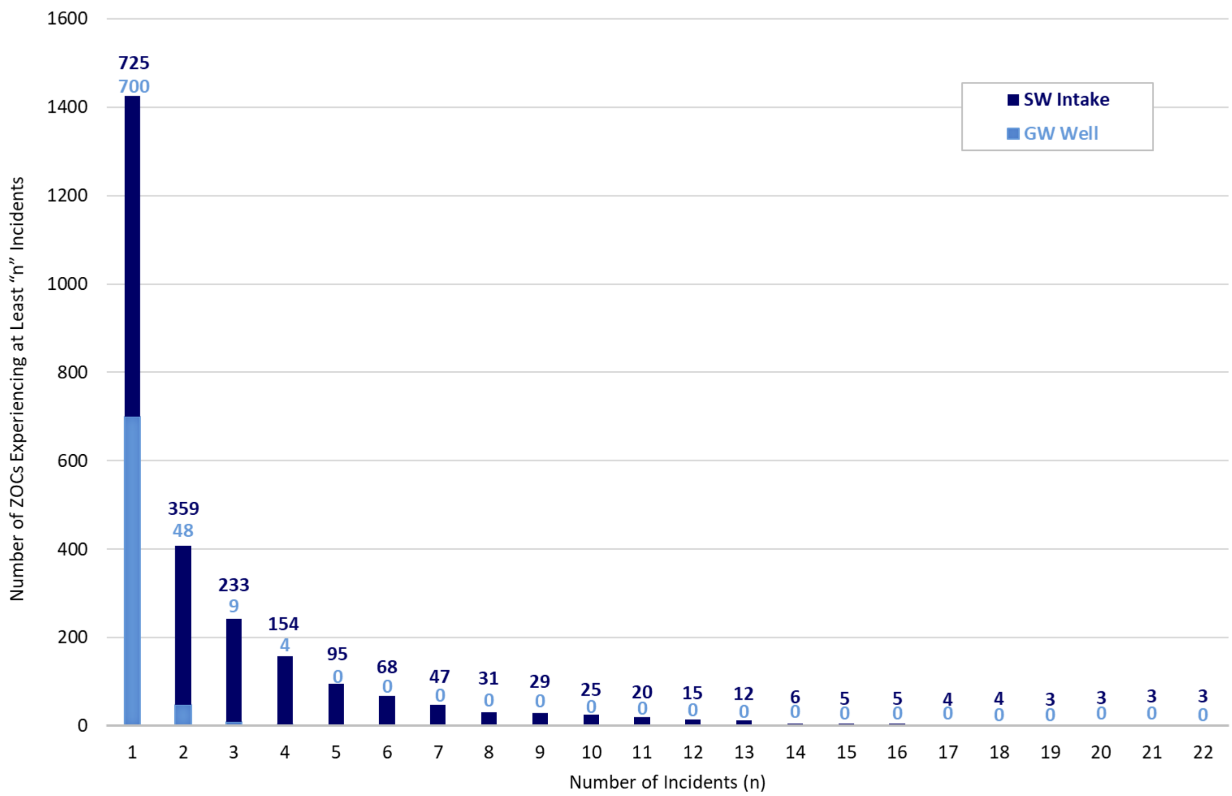


Figure 19. Frequency of Releases to Source Water ZOCs between January 1, 2010 and December 31, 2019 *(total number of SW ZOCs = 4,929, total number of GW ZOCs = 106,816)*

Table 7 presents attributes of the six SW ZOCs with the greatest number of releases. The three ZOCs with the greatest number of incidents are in Osage County, Oklahoma and overlap almost completely and thus experienced the same 22 incidents. Osage county has a significant oil, gas, and mineral extraction industry. The Pennsylvania ZOC with the second largest number of incidents (18) contains a large urban area with major river commerce routes. The majority of incidents in this ZOC involved Refined Oil products.

The area of the ZOCs varied by more than three orders of magnitude, which could be a factor in the number of incidents experienced in a ZOC. The areas of the SW ZOCs ranged from 0.42 square miles to 1,518 square miles, with an average area of 345 square miles. GW ZOCs used a standard 0.5-mile radius, and thus had a uniform area of 0.78 square miles. To account for the impact of area on incident occurrence, the incident count was normalized by the area of the ZOC. The normalized incident count ranged from 0.0008 to 2.36 incidents per square mile. However, large normalized incident counts can result from ZOCs with small areas. Because GW ZOCs have a small uniform area of 0.78 square miles, they have an artificially large normalized count. GW ZOCs with one incident have a normalized count of 1.28 per square mile and those with four releases have a normalized count of 5.13 per square mile.

Table 7. Surface Water Zones of Concern that Experienced the Most Releases

ID	State	Counties within ZOC	Zone Area (Sq. Miles)	Number of Incidents	Incidents per Sq. Mile	Top Material Categories Spilled (Count)
A	OK	Osage	303	22	0.072	Drilling Brine (16)
B	OK	Osage	303	22	0.072	Drilling Brine (16)
C	OK	Osage	303	22	0.072	Drilling Brine (16)
D	PA	Allegheny Armstrong Washington	1,066	18	0.017	Refined Oil (8) Transformer Oil (4)
E	PA	Allegheny Washington	935	16	0.017	Refined Oil (8)
F	CT/ NY	Fairfield New Haven New London Westchester	193	14	0.073	Refined Oil (7)

Table 8 presents the five SW ZOCs that experienced more than one incident, and which had the largest number of incidents per square mile. Two ZOCs from Louisiana (I and J) that experienced a large number of incidents (12 and 13, respectively) also have a large number of releases per square mile (0.40 and 0.32 incidents per square mile, respectively). However, the other three zones experienced a modest number of releases (4 or 5). A commonality among the five ZOCs with the largest number of incidents per square mile is that they all have relatively small areas (3 to 41 square miles) – much smaller than the average zonal area of 345 square miles. Thus, in all five zones, it is the small zonal area that is largely responsible for the high normalized count.

Table 8. Source Water Zones of Concern that Experienced more than One Release and which have the Greatest Number of Releases per Square Mile

ID	State	Counties Impacted	Zone Area (Sq. Miles)	Number of Incidents	Incidents/sq. mile	Top Material Categories Spilled (Count)
G	PA / NJ	Warren	3	4	1.34	Refined Oil (4)
H	CA	San Mateo	12	5	0.41	Refined Oil (5)
I	LA	Jefferson Orleans Plaquemines St. Bernard	30	12	0.40	Refined Oil (7)
J	LA	Jefferson Orleans Plaquemines St. Bernard	41	13	0.32	Refined Oil (7)
K	IL	Cook	14	4	0.28	Refined Oil (2)

Figure 20 shows the geographic distribution of all incidents that impacted a ZOC. Similar to **Figure 5**, the distribution of releases within ZOCs shows a concentration of releases near major urban areas or regions with significant oil and gas extraction operations. Two areas that experienced a large number of releases are Southern Louisiana and Western Pennsylvania/Eastern Ohio. The states with the most releases impacting a ZOC are: Ohio with 207 (8%), Texas with 204 (8%), Pennsylvania with 193 (7%), and Louisiana with 162 (6%). Notably, this is a different ranking from the broader analysis of incidents by state presented in **Figure 6** in which the states with the most releases were: Texas (303), California (244), Oklahoma (236), Louisiana (205), and Pennsylvania (169). The different trends depicted in Figures

6 and 20 indicates that there may not always be a correlation between the occurrences of releases to water and the occurrence of releases in a ZOC.

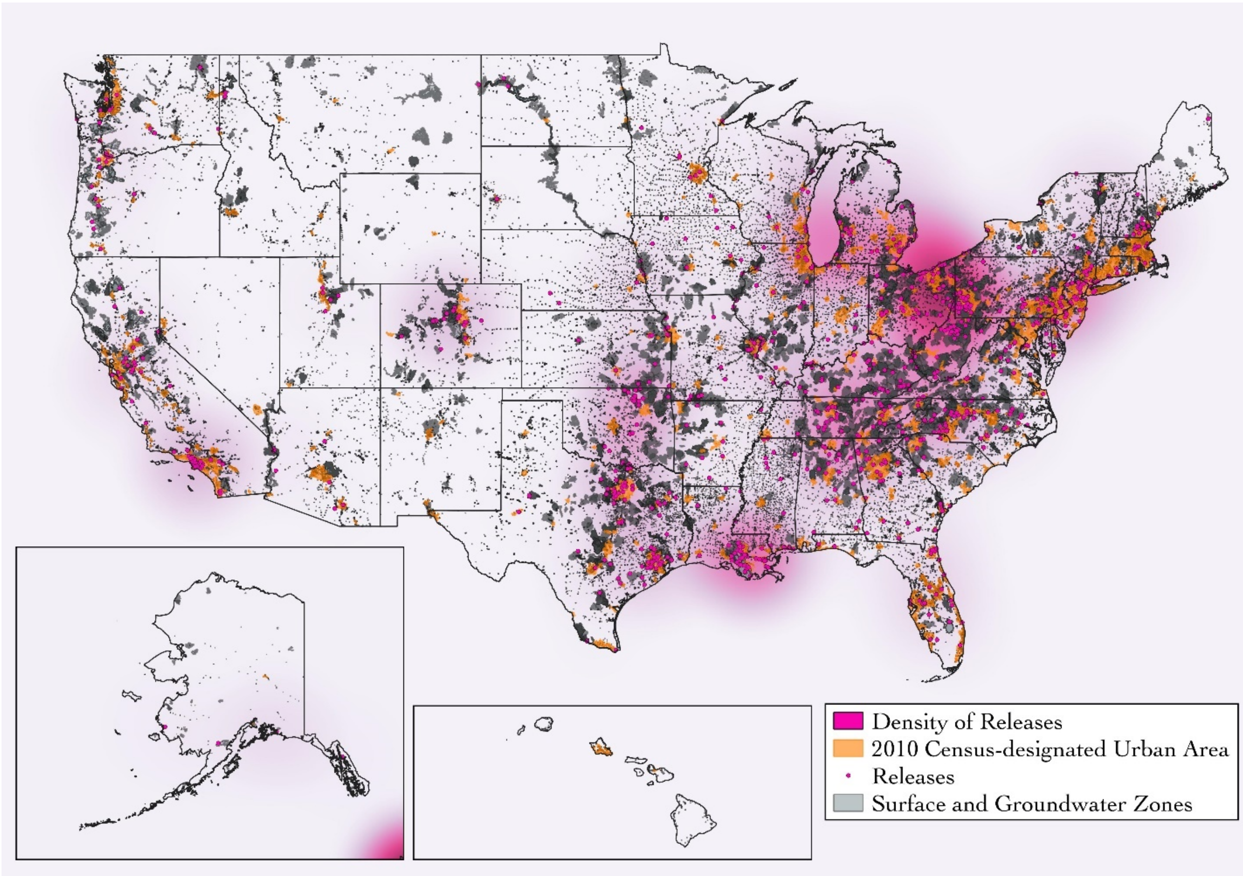


Figure 20. Geographic Distribution of Releases in SW and GW ZOCs between January 1, 2010 and December 31, 2019

Section 4: Summary and Conclusions

2.1% of releases reported to the NRC over a 10-year period had the potential to impact source water.

An analysis of releases reported to the NRC from January 1, 2010 through December 31, 2019 showed that 5,806 out of 281,142 records, or 2.1%, had the potential to impact sources of drinking water. The criteria used to identify these releases include: volume released greater than 100 gallons (or an indicator of a high volume release when the volume was not recorded), releases of highly toxic materials, and releases with location data and which fell within a ZOC or affected a nearby ZOC. There were also criteria for excluding records, such as those that were generated during drills, occurred outside of the U.S., were released to air, occurred offshore, or included materials that were unlikely to change the water quality (e.g., sand, steel, aggregate). A downward trend in the number of releases potentially impacting source water was observed between 2010 and 2019.

The 5,806 records were related to 3,931 unique incidents. Of the 3,931 unique incidents, 3,114 reported the volume released and 1,884 reported the volume released to water. The total volume released over this 10-year period was over 38,940 kgal. The volume released varied significantly from year to year, from a low of 899 kgal in 2013 to a high of 11,477 kgal in 2014. Notably the year 2019 had both the lowest number of unique incidents and the second largest cumulative volume released, which was driven by two large releases: (1) a release of 7,593 kgal of wastewater into Sugar Creek and the Withlacoochee River in Georgia and (2) a release of 1,418 kgal of bourbon into Glenns Creek and the Kentucky River in Kentucky. This reflects the general trend that most releases are relatively small; 54.4% were less than 1 kgal, while a small number of very large releases are responsible for the majority of material released (0.7% released more than 100 kgal).

54.4% of releases were smaller than 1 kgal, however, 0.7% released more than 100 kgal.

Releases occurred in all 50 states and D.C. with the highest density of releases near urban areas, industrial hubs, resource extraction hubs, and transportation corridors (including rivers used for cargo transport). States with the greatest number of unique incidents include: Texas (303), California (244), Oklahoma (236), Louisiana (205), and Pennsylvania (169). There was a large range in the total volume released in each state, ranging from < 1 kgal in Rhode Island and Nevada to 10,784 kgal in North Carolina. Four states experienced a total volume released to water greater than 2,000 kgal: North Carolina (10,784 kgal), Georgia (7,781 kgal), Colorado (3,353 kgal), and California (2,268 kgal). The large total volumes released to water in these five states were the result of one or two significant incidents in each state. The Mississippi and Ohio Rivers were the two named bodies of water impacted by the greatest number of releases.

There were 840 different materials released over the study period, but the most commonly released materials by a significant margin were Refined Oil products, which were involved in 56.8% (2,402) of releases. However, the material categories responsible for the largest total volume released were: Wastewater with 14,014 kgal (36%), Coal Combustion By-products with 10,769 kgal (27.7%), Drilling Fluid with 3,503 kgal (9%), and Mine Waste with 3,000 kgal (7.7%).

The highest occurrence of releases occurs near urban areas, industrial hubs, resource extraction hubs, and transportation corridors.

Equipment Failure was reported as the leading cause of incidents, 27% (1,078), and was responsible for 49% (19,260 kgal) of the total volume released. Transportation Accidents were another significant cause of incidents accounting for 13% (505) of the incidents but only 2% (820 kgal) of the total volume released – an average release volume of 1.62 kgal. By comparison, Natural Phenomena caused only 5% (212) of the releases but accounted for 5% (1,807 kgal) of the total volume released – a significantly larger average release volume of 8.52 kgal.

The number and volumes released within individual SW or GW ZOCs varied widely. Most SW ZOCs (85%) and GW ZOCs (99.3%) considered in this study did not experience any incidents over the 10-year study period. There were 725 SW ZOCs and 700 GW ZOCs that experienced at least one incident. Of the ZOCs that experienced more than one incident, twenty-five SW ZOCs experienced at least 10 incidents, four SW ZOCs experienced 22 unique incidents, and four GW ZOCs experienced four incidents.

The results of this analysis indicate regional trends in the risk of source water contamination. However, the absence of a release in a particular area or ZOC should not be inferred to mean that the ZOC is free from risk. Ultimately what matters is where the next significant release into water occurs and whether it impacts a water system's source water. The following section provides recommendations to help water systems understand and prepare for their unique risk profile.

Section 5: Recommendations

The findings from this study demonstrate there is a significant risk of releases into sources of drinking water at a national scale. However, the risk to a community water system will depend on their unique circumstances. To understand the relative risk of source water contamination to a community water system, it is recommended that releases into source water be considered in an all-hazards risk assessment, such as that required under America's Water Infrastructure Act (U.S. EPA, 2019a). Factors to consider when assessing the risk of releases to source water include:

Assessing the risk

- ✓ History of releases into a community water system's source water protection area (or a smaller zone of concern near the intake or wellhead)
- ✓ Land use and population in the source water protection area
- ✓ The number and capacity of resource extraction and refining operations (oil, gas, minerals, etc.) in the source water protection area
- ✓ Volume and type of industrial activity in the source water protection area
- ✓ Use of waterbody for commodity transport
- ✓ Prevalence of hazmat transport on roads, rail lines, and waterways in the source water protection area
- ✓ Prevalence of wastewater and stormwater outfalls in the source water protection area
- ✓ Prevalence of power generation facilities in the source water protection area

If the results of the all-hazards risk assessment indicate that the risk of releases to source water is significant, consider actions to prepare for and mitigate that risk, such as:

Actions to prepare

- ✓ Conduct a thorough inventory of source water contamination threats and prioritize those threats to focus attention on those that present the greatest risk to a community water system
    - o Take advantage of the source water provisions of Section 2018 of America's Water Infrastructure Act, which give community water systems access to Tier II chemical inventory data collected under the Emergency Planning and Community Right to Know Act (U.S. EPA, 2019b) for facilities in a source water protection area
- ✓ Share contact information with facility owners and arrange for direct notification in the event of a release from that facility
    - o Ensure that notifications of releases that are reported under the Emergency Planning and Community Right to Know Act are promptly reported to community water systems that could be impacted (U.S. EPA, 2019b)
- ✓ Develop relationships with Local Emergency Planning Committees and local first responders and arrange for timely notification of releases, particularly those resulting from transportation accidents, that could impact a source water
- ✓ Identify the materials stored, used, or discharged at facilities that pose the greatest acute risk to source water
- ✓ Identify methods and laboratories that can analyze for these materials
- ✓ Evaluate the ability of treatment processes to remove or neutralize these materials
- ✓ Update emergency response plans to include procedures to respond to releases to source water
- ✓ Plan for controls such as booms or curtains that could protect a water intake from a contaminant plume

References

ATSDR, 2018. National Toxic Substances Incidents Program. Retrieved from https://www.atsdr.cdc.gov/ntsip/index.html

ATSDR, 2009. Hazardous Substance Emergency Events Surveillance. Retrieved from https://www.atsdr.cdc.gov/hs/hsees/index.html

Balasubramanian, S.G. and Louvar. J.F., 2004. Study of major accidents and lessons learned. AlChE Process Safety Progress.

Becker, R. A., 2015. Massive Oil Spill in Yellowstone River Contaminates Drinking Water. PBS. Retrieved from https://www.pbs.org/wgbh/nova/article/massive-oil-spill-yellowstone-river-contaminates-drinking-water/

Biesecker, M and Suderman, A, 2018. Dam breach at N.C. power plant causes coal ash spill into Cape Fear River. Insurance Journal. Retrieved from https://www.insurancejournal.com/news/southeast/2018/09/24/502096.htm

Brody, T.M., Bianca, P.D., and Krysa, J., 2012. Analysis of inland crude oil spill threats, vulnerabilities, and emergency response in the Midwest United States. Risk Analysis, Vol. 32, No. 10.

Etkin D.S., 2004. Twenty-year trend analysis of oil spills in EPA oil jurisdiction. Freshwater Spills Symposia. Retrieved from https://archive.epa.gov/emergencies/content/fss/web/pdf/etkin_04.pdf

Grinberg, Emanuella, 2019. The Kentucky River is Brimming with Dead Fish After a Fire at a Bourbon Warehouse. CNN. Retrieved from https://www.cnn.com/2019/07/07/us/jim-beam-warehouse-fire-kentucky-environmental-impact-trnd/index.html

Howard, M., Morin, I., and Watts, K., 2008. Review of oil spill incidents reported to the National Response Center from onshore oil production facilities. International Oil Spill Conference Proceedings. Vol. 2008, No. 1, pp. 561-569. Retrieved from https://doi.org/10.7901/2169-3358-2008-1-561

Louisville Water Company, 2017. Update on Ohio River Spill. Retrieved from https://www.louisvillewater.com/newsroom/update-ohio-river-spill

Maloney, K.O., Baruch-Mordo, S., Patterson, L.A., Nicot, J.P., Entrekin, S.A., Fargione, J.E. Kiesecker, J.M., Konschnik, K.E., Ryan, J.N., Trainor, A.M., Saiers, J.E., Wiseman H.J., 2017. Unconventional oil and gas spills: materials, volumes, and risks to surface waters in four states of the U.S. Science of the Total Environment, 581-582 (2017) 369-377.

Murawski, J., 2018. Duke Energy Says Coal Ash Isn’t Contaminating Cape Fear River; State Awaits Its Own Tests. The News & Observer. Retrieved from https://www.newsobserver.com/news/local/article218893790.html

National Park Trips Media, 2017. Pipeline Spills Oil into Yellowstone River Again. Retrieved from https://www.yellowstonepark.com/news/pipeline-oil-spill-yellowstone-river#:~:text=January%2017%2C%202015%2C%20an%20oil,River%20on%20near%20Glendive%2C%20Montana.&text=The%20Bridger%20Pipeline%20Company%20reported,of%2042%2C000%20gallons%20of%20oil.

ORSANCO, 2018. Ohio River Valley Water Sanitation Commission Annual Report 2018. Retrieved from http://www.orsanco.org/wp-content/uploads/2018/10/2018_Annual_Report.pdf

PHMSA, 2020. U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration. Retrieved from https://www.phmsa.dot.gov/hazmat-program-management-data-and-statistics/data-operations/incident-statistics

Power Partners Inc., 2009. Single Phase Overhead Distribution Transformers, PDL 46-200, Athens, GA. Retrieved from http://www.powerpartners-usa.com/wp-content/uploads/2016/01/single-phase_product_spec_sheet.pdf?x30412

Rosen, J.S., Whelton, A.J., McGuire, M.J., Clancy, J.L., Bartrand, T., Eaton, A, Patterson, J., Dourson, M., Nance, P., and Adams, C., 2014. The crude MCHM chemical spill in Charleston, W.Va. JAWWA, 106:9

Sack, W, 2016. American Proteins to pay $50,000 fine for violations including Mulberry Fork acid spill. The Cullman Tribune. Retrieved from https://www.cullmantribune.com/2016/12/01/updated-american-proteins-to-pay-50000-fine-for-violations-including-mulberry-fork-acid-spill/

Sangul, H., Santella, N., Steinberg, L.J., and Cruz. A.M., 2012. Analysis of hazardous material releases due to natural hazards in the United States. Disasters. Retrieved from https://doi.org/10.1111/j.1467-7717.2012.01272.x

States, S., Cyprych, G., Stoner, M., Wydra, F., Kuchta, J., Monnel, J. and Casson, L., 2013. Marcellus shale drilling and brominated THMs in Pittsburgh, PA Drinking Water. JAWWA, 105:5

U.S. Congress, 2018. America's Water Infrastructure Act. Retrieved from https://www.congress.gov/bill/115th-congress/senate-bill/3021/text

U.S. CSB, 2016. Chemical Spill Contaminates Public Water Supply in Charleston, West Virginia, Report No. 2014-01-I-WV.

U.S. EPA, 2006. How-to Manual: Update and Enhance Your Local Source Water Protection Assessment. EPA 816-K-06-004. Office of Water, Washington, D.C. Retrieved from https://www.epa.gov/sourcewaterprotection/how-manual-how-update-and-enhance-your-local-source-water-protection

U.S. EPA, 2014. Duke Energy Coal Ash Spill in Eden, NC. Washington, D.C. Retrieved from https://www.epa.gov/dukeenergy-coalash/history-and-response-timeline

U.S. EPA, 2015a. Emergency Response to August 2015 Release from Gold King Mine. Washington, D.C. Retrieved from https://www.epa.gov/goldkingmine

U.S. EPA, 2015b. Review of State and Industry Spill Data: Characteristics of Hydraulic Fracturing-Related Spills, EPA/601/R-14/001. Retrieved from https://www.epa.gov/sites/production/files/2015-05/documents/hf_spills_report_final_5-12-15_508_km_sb.pdf

U.S. EPA, 2018. Clean Water Act Hazardous Substances Spill Prevention Proposed Rule. Retrieved from https://www.epa.gov/rulemaking-preventing-hazardous-substance-spills/proposed-rulemaking-clean-water-act-hazardous

U.S. EPA, 2019a. Overview of New Risk Assessment and Emergency Response Plan Requirements for Community Water Systems. Retrieved from https://www.epa.gov/waterresilience/overview-new-risk-assessment-and-emergency-response-plan-requirements-community

U.S. EPA, 2019b. America's Water Infrastructure Act, Section 2018: Amendments to the Emergency Planning and Community Right to Know Act. Retrieved from https://www.epa.gov/sites/production/files/2019-05/documents/awia_sec_2018_factsheet_for_water_sector_final.pdf

U.S. EPA, 2020. Toxic Release Inventory. Retrieved from https://www.epa.gov/toxics-release-inventory-tri-program

WTXL, 2019. More than 7 million Gallons of Sewage May Have Contaminated Withlacoochee River. WTXL ABC 27. Retrieved from https://www.wtxl.com/news/local-news/sewage-spill-in-valdosta-results-in-over-7-000-gallons-of-contamination-in-withlacoochee-river

Zhu, T., Jia, Y., Chao, X., Frihi, M., and Hammouri, M., 2009. Development of NCCHE chemical spill incident database. Published by the National Center for Computational Hydroscience and Engineering, School of Engineering, University of Mississippi. Retrieved from https://www.ncche.olemiss.edu/

Glossary

Clean Water Act Hazardous Substances. A list of substances defined under authorities of Section 311(b)(2) of the Clean Water Act (Title 40 of the CFR, Part 116).

Community Water System. A system that provides water for human consumption through pipes or other constructed conveyances and has at least fifteen service connections or regularly serves at least twenty-five individuals, and which serves the same population year-round (as defined in SDWA section 1401(15)).

Hazardous Substance Emergency Events Surveillance. An environmental surveillance system established by ATSDR to collect and analyze information about acute releases of hazardous substances and threatened releases that result in a public health action such as an evacuation. The system was active from 1990 through 2009.

National Hydrography Dataset. A dataset maintained by the USGS that represents the water drainage network of the United States with features such as rivers, streams, canals, lakes, ponds, coastline, dams, and stream gages.

National Response Center. The designated federal point of contact for reporting all oil, chemical, radiological, biological and etiological discharges into the environment, anywhere in the United States and its territories. The National Response Center is part of the federally established National Response System and staffed 24 hours a day by the U.S. Coast Guard.

National Toxic Substances Incidents Program. A surveillance program established by ATSDR to track the release of toxic substances, which was active between 2010 and 2018.

Toxic Release Inventory. A program created under the Emergency Planning and Community Right to Know Act that requires certain industries to file an annual report documenting releases of certain toxic chemicals that may pose a threat to human health and to the environment. Reporting is limited to a list of approximately 755 individual chemicals and 33 chemical categories.

Zone of Concern. For surface water intakes, an area that extends 50 miles upstream, ¼ mile downstream, includes all major tributaries, and includes a ¼ mile buffer inland from the waterbody area boundary. For ground water wells, an area defined by a ½ mile radius around the well location. This definition was used solely for the purposes of the study presented in this report.

Appendices

Appendix A: Fields Extracted from the NRC Reports and Used in Analysis

CALLS - Contains Report receipt and Suspected Responsible Party information	
FIELD NAME	FIELD DESCRIPTION
NRC Report Number	Unique Identifier assigned to each report (known as SEQNOS)
Call Type	Categorized Type of Call: INC = Incident; DRL = Drill
Responsible Company	Name of Suspected Responsible Company
Responsible Org Type	Organization Type of the Suspected Responsible party
INCIDENT COMMONS - Contains general information which is common to all types of Incident Reports such as location, type of incident, cause, etc.	
FIELD NAME	FIELD DESCRIPTION
Description of Incident	Detailed explanation of the incident
Type of Incident	Specific type of incident being reported
Incident Cause	Cause of the incident
Incident Date Time	Date and time incident occurred, was discovered or planned
Incident Location	Additional details about the location of the spill (e.g., river mile marker)
Location Address	Street address or intersection nearest to the incident location
Location Nearest City	City or town nearest to the incident location
Location State	State where incident occurred
Location County	County where incident occurred
Location Zip	Postal zip code where incident occurred
Lat (Deg, Min, Sec, Quad)	Degrees of Latitude for incident location
Long (Deg, Min, Sec, Quad)	Degrees of Longitude for incident location
INCIDENT DETAILS - Contains information which further describes the situation and impact of the Incident.	
FIELD NAME	FIELD DESCRIPTION
Damages	Indicates if there were any damages that occurred during the release
Waterway Corridor Closed	Indicates if any waterway traffic corridors were closed
Track Closed	Indicates if any rail tracks were closed
Medium Description	Medium affected as a result of the incident
Body of Water	Immediate body of water impacted by the incident if applicable
Water Supply Contaminated	Indicates if a drinking water source was contaminated by the release
Nearest River Mile Marker	The nearest river mile marker of the incident location if applicable
Offshore	Indicates if the incident location is offshore
INCIDENTS - Contains information specific to each type of Incident	
FIELD NAME	FIELD DESCRIPTION
Type of Fixed Object	Categorized object type
Capacity of Tank	Capacity of the storage tank
Capacity of Tank Units	Unit of measure for the storage tank capacity
MATERIAL INVOLVED - Contains information specific to each material spilled	
FIELD NAME	FIELD DESCRIPTION
CHRIS Code	Chemical Hazards Response Information System Code
CAS Number	Chemical Abstracts Service Registry Number
Amount Of Material	Amount of material released
Unit Of Measure	Unit of measure for amount released
Name of Material	Name of material released
Amount In Water	Amount of material that reached water
Unit of Measure Reach Water	Unit of measure for amount in water
TRAINS DETAIL - Contains information about the train(s) involved	
FIELD NAME	FIELD DESCRIPTION
Train Type	Type of train involved
VESSELS DETAIL - Contains information about sea going vessels involved with an incident	
FIELD NAME	FIELD DESCRIPTION
Vessel Type	Type of vessel involved
MOBILE DETAILS - Contains information about mobile vehicles involved with an incident	
FIELD NAME	FIELD DESCRIPTION
Hazmat Carrier	Indicates if a transport for hazardous materials

Appendix B: Rules to Standardize Names of Bodies of Water

Standardized Name	If the Body of Water name contains the following:
Mississippi River	"Mississ"
Unnamed Creek, Stream, or Tributary	"Unnamed Creek," "Unknown Creek," "Local creek," or "Unknown Tributary"
Genesee River	"Genes"
Monongahela River	"Monog," "Monon," "Mong," or "Monoag"
Schuylkill River	"Schuykill," "Schyukill," or "Schulkill"
Vermilion River	"Vermi"
Willamette River	"Wilam" or "Willam"
Passaic River	"Passaic"or "Passiac"
Tennessee River	"TN River" or "Tenn"
Allegheny River	"Alleg"
Androscoggin River	"Scog"
Delaware River	"Delaware"
Colorado River	"Colorado River"
Cuyahoga River	"Cuyahoga"
Elizabeth River	"Elizabeth River"
Acushnet River	"Acu"
Anacostia River	"Anac"
Anclote River	"Ancl"
Arkansas River	"Arka"
Brazos River	"Braz"
Withlacoochee River	"Withl"
Arthur Kill	"Arthur Kill"
Kill Van Kull	"Kill V"
Canal	"Canal"
Unnamed Groundwater Source	"Water Well", "Well Water", "Well", "Groundwater", or "Aquifer"
Unnamed Reservoir, Lake, or Pond	"Unknown Pond", "Reservoir", or "Unknown Lake"
Drainage and Collection	"Storm," "Drain," "Sewer," "Ditch", "Basin", "Runoff", or "Culvert"
Drinking Water	"City Water", "Tap Water", "Drinking Water", "Drinking Water Wells", or "Potable Water"
Unnamed Wetland Area	"Wetland," "Marsh," or "Swamp"

Appendix C: Unit Conversion Multipliers

For each unit of measure below, multiply the value reported in those units by the multiplier to convert to gallons (U.S., liquid).

- Barrels (petroleum) = 42.0
- Barrels (not petroleum) = 31.5
- Cubic Meters = 264.172
- Cubic Yards = 201.974
- Cups = 0.0625
- Drops = 0.0000132086
- Gallons = 1.0
- Liters = 0.264
- Ounces = 0.0078125
- Pints = 0.125
- Pounds = 0.12 (assuming a density of 8.345 pounds/gallon, which is the density of water)
- Quarts = 0.25
- Tablespoons = 0.00390625
- Tons = 269.0 (assuming a density of 8.345 pounds/gallon, which is the density of water)

Appendix D: Process for Preparing Spatial Data

- Generating a "best address" for records lacking latitude/longitude information:
    - Removing leading and trailing white space
    - Correcting format of address record by applying a script that matches one or more numbers, followed by a space, and followed by one or more characters
    - Reviewing the NRC fields: "Location Address", "Location Street 1", and "Location Street 2" for valid addresses
    - Removing any value after a decimal in zip codes and adding a leading 0 to the zip code in states whose zip codes are verified to contain leading zeros
    - Addresses were run through the 2012-2013 version of the Max Rice/Juice Analytics Excel geocoding tool and latitude & longitudes for each record with a validated "best address" were provided
- Geocoding records with latitude/longitude degrees, minutes, and seconds:
    - Deleting duplicate rows
    - Records with any missing information in the latitude/longitude degrees, minutes, or seconds were omitted from the geocoding process
    - Records with latitude degrees <18 or >72 were omitted from the geocoding process (outside of the U.S.)
    - Records with longitude degrees <66.5 or >180 were omitted from the geocoding process (outside of the U.S.)
    - Records with latitude/longitude minutes or seconds outside the range of 0-60 range were omitted from the geocoding process
    - Formulas were applied & latitude/longitude generated:
        - Latitude: degrees + (minutes/60) + (seconds/3600)
        - Longitude: (degrees + (minutes/60) + (seconds/3600))*-1
- Latitudes & longitudes for each record were added to QGIS and clipped to the appropriate delineated zone

Appendix E: Materials Excluded from Analysis

Releases of the following materials were excluded from the analysis, however, not all examples and variations of the contaminant name are listed below.

- AMMUNITION/EXPLOSIVES
- BATTERIES AND RELATED PRODUCTS
- BENTONITE/CLAY
- COAL
- CONSTRUCTION MATERIALS
    - ROOFING SHINGLES
    - STEEL COIL
    - CEMENT/CONCRETE
    - FLORESCENT LIGHTS
    - WOOD STEPS
- DYES
- EARTH/MINERAL PRODUCTS
    - GRAVEL
    - GYPSUM
    - LIMESTONE
    - LEAVES
    - DIRT
    - ROCKS
- FOAM PRODUCTS
    - BROWN FOAM
    - FOAM BLANKET
    - BLUE DYE- FOAM MARKER
    - STYRAFOAM
- METAL AND SCRAP
    - METAL SCRAPS
    - METAL SHAVINGS
    - JUNK AND SCRAP METAL
    - OLD TIRES
    - RUST AND METALLIC SUBSTANCE
- MISCELLANEOUS WASTE
    - BAG OF TRASH
    - BURNING TIRES
    - GARBAGE/DEBRIS
    - TOILETS
- VOLATILE CHEMICALS
    - BUTANE
    - METHANE
    - CNG
    - LNG
    - NATURAL GAS
- WATER
    - CHILL WATER

- CHLORINATED WATER
- DRINKING WATER
- CITY WATER
- GROUNDWATER
- FIRE WATER
- RAIN WATER