Options for Minimizing Environmental Impacts of Inland Spill Response

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Acronyms and Abbreviations

ACM	asbestos-containing materials
ADIOS	Automated Data Inquiry for Oil Spills
AFFF	aqueous film forming foam
API	American Petroleum Institute
AR-AFFF	alcohol resistant aqueous film forming foam
AR-FFFP	alcohol resistant film forming fluoroprotein foam
bbl	barrel
BLEVE	boiling liquid expanding vapor explosion
BMP	best management practice
BOD	biological oxygen demand (sometimes referred to as biochemical oxygen demand)
BTEX	benzene, toluene, ethyl benzene, and xylenes
COD	chemical oxygen demand
DOT	U.S. Department of Transportation
cSt	centistokes
EFH	Essential Fish Habitat
ESA	Endangered Species Act
FAMEs	fatty acid monoalkyl esters
FFFP	film forming fluoroprotein foam
FOSC	Federal Onscene Coordinator
g/cm^3	grams per cubic centimeter
GIS	Geographic Information System
GPS	Global Positioning System
LEL	lower explosion limit
MCL	maximum contaminant level
$\mu g/m^3$	micrograms per cubic meter
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
mmhos/cm	millimohs per centimeter
NAAQS	National Ambient Air Quality Standards
NEBA	Net Environmental Benefit Analysis
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act
NFT	No Further Treatment
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OSHA	Occupational Safety and Health Administration
P&M	patrol and maintenance
PPE	personal protection equipment
ppm	parts per million
psia	pounds per square inch absolute
RRT	Regional Response Team
SCAT	Shoreline Cleanup Assessment Technique
SDS	Safety Data Sheet
SIMA	Spill Impact Mitigation Assessment
SPCC	Spill Prevention, Control, and Countermeasures
STEL	short-term exposure limit
TDS	total dissolved solids
T&E	threatened and endangered
TWA	time-weighted average
USCG	U.S. Coast Guard
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UTV	utility vehicle
VOC	volatile organic compounds

Preface

This guide incorporates lessons learned from spill responses that can minimize the environmental impacts of inland oil spills. In addition, it provides new information on the changing risk profiles of inland spills in North America. There are eight sections and four appendices as follows:

Section 1 Purpose and Background: Describes the purpose of this guide and differences since the 1994 inland guide.

Section 2 Inland Spills: Sources and Risks: Provides brief summaries of available data and information on inland spill sources (pipelines, rail, tanker truck, tank barge/towing vessel, oil exploration and production facilities, and other regulated facilities), spill types and volumes, and recent trends.

Section 3 Comparisons between Inland and Marine Oil Spills: Highlights oil behavior and environmental and human concerns for inland spills that are different from marine spills. It also describes the different types of sensitive resources of inland environments and outlines consultation requirements.

Section 4 Oil Properties, Toxicity, and Behavior: Defines the oil types by groups 1–5, which are used throughout the guide. Summaries are provided on the properties, typical behaviors, toxicity, and changes in properties as oil weathers.

Section 5 Inland Oil Spill Detection, Delineation, and Characterization: Discusses current accepted methods for oil spill detection, delineation, and characterization for inland spills.

Section 6 Best Practices for Inland Oil Spill Response: Includes descriptions of the response techniques and inland environments that are the backbone of the guide. Guidance is provided for options to minimize environmental impacts while achieving response goals, and a "stoplight" matrix is used to indicate the relative impact of each response technique on each inland environment for each oil group.

Section 7 Cleanup Endpoints: Provides guidance on selecting appropriate cleanup endpoints for inland spills.

Section 8 Special Considerations: Provides guidance on some issues of special concern for inland spills, including protection of water intakes, response to spills of ethanol-blended fuels, air quality, release of oil field–produced waters, treatment of oiled debris, intermittent sheens, and fast-water booming strategies.

Section 9 References and Additional Reading: Includes references cited in the report and suggested further readings.

Appendix A Properties of Nonconventional Oils: Provides summaries on the categories and environmental behavior and effects for light shale oils, diluted bitumen products, biodiesel, and non-petroleum oils.

Appendix B Best Management Practices: Includes current best management practices for different response actions to minimize collateral impacts during implementation of approved response operations.

Appendix C Firefighting Foam: Describes the current types of firefighting foam, how they can be used to combat oil fires, and guidelines for management of firefighting foam wastewater.

Appendix D Responding to Spills of Very Light Crude Oils That Ignite: Provides guidance to responders for spills of these volatile oils.

NOTE Both English and metric units are used independently in this guide, based standard practice in the U.S. In general, metric units are used for chemical and physical properties, whereas English units are used for lengths, area, volume, velocity, and temperature.

Options for Minimizing Environmental Impacts of Inland Spill Response

1 Purpose and Background

The purpose of this guide is to support contingency planners and emergency responders in evaluating response techniques and selecting those techniques that will most effectively prevent or minimize adverse environmental impacts from inland spills. In this guide, inland spills are defined as those that affect terrestrial and freshwater habitats, whereas coastal and marine spills affect water bodies and habitats that are under the influence of tides and marine waters. Inland spills have unique characteristics and behavior, may have the potential to pose greater risks to the public, and often necessitate more intensive removal methods, compared to coastal and marine spills. Therefore, choosing the best response options and implementing these in the most environmentally appropriate manner can minimize adverse impacts of a response.

This guide addresses only the oil spill emergency phase of a response—that relatively short-term set of activities conducted immediately following a release. The response during this first phase focuses on control and containment of mobile oil, then active cleanup of the oil to established cleanup endpoints. This guide does not address the remediation or restoration phases that occur after the emergency phase of a response is completed.

In 1994, the American Petroleum Institute (API) and the National Oceanic and Atmospheric Administration (NOAA) published a guide entitled "Options for Minimizing Environmental Impacts of Freshwater Spill Response" (API and NOAA, 1994). The 1994 guide identified response methods for twelve primary freshwater habitats: four of which are water environments and eight are shoreline habitats. For each habitat, response methods were given a relative impact score for each of four general oil types. This current (2016) guide differs in several ways.

— Information on spill sources and risks is included, to reflect increases in oil transportation by rail, the risks of fire and air quality concerns from spills of very light crude oils from tight shale production areas, behavior of diluted bitumen products when spilled to fresh water, and special considerations for inland spill response.

— Five oil groups are used and the guide is organized based on these groups as, in most cases, responders are dealing with a specific oil type that often has a unique set of response options and impacts to various habitats. Thus, this approach helps responders evaluate and select the most appropriate spill containment and recovery, and consequently impact minimization, options for each oil group. Group 5 oils that become submerged in the water column are included in this guide. Response guidance for sunken oil spill detection, containment, and recovery is included in a separate API technical report and operations guide (API, 2016a,b).

— Guidance is provided for two phases of the response: 1) The Control and Contain Phase and 2) The Cleanup Phase. "Stoplight" matrices indicate the relative impacts of different response techniques for four water environments and seven land habitats.

— Current best management practices are compiled for different types of response actions, with the goal that these can be used in the preparation of treatment recommendations, as another means by which impacts during the emergency response phase can be minimized or avoided.

Because they are adequately covered in other documents, this guide does not address the following very important inland response topics:

— Response during snow and ice conditions: Several manuals and reports are available that provide detailed information and guidance on the complexities and response options for these conditions, including EPPR (1998; 2015) and ADEC (2010).

— Groundwater contamination or extensive subsurface oil recovery: a field guide is available from the Texas Railroad Commission (2016) for spills of condensate and numerous guidance documents have been published on remediation of oil impacted groundwater.

2 Inland Spills: Sources and Risks

2.1 Introduction

In this section, major sources of in inland oil spills in the U.S. are described: pipelines, rail, tanker truck, tank barges and towing vessels, oil exploration and production sites, oil refineries and inland-regulated facilities. Spill statistics are provided where available, although there are no comprehensive recent studies for inland areas, and some studies do not separate out inland versus non-inland spills in their analysis. Available U.S. studies include analysis of nearly 52,000 oil spills that occurred in inland navigable waters over the period 1980 to 2003 (Etkin, 2006), all spills over the period 1968 to 2007 (Etkin, 2009; 2010), and crude oil spills from pipelines over the period 1968 to 2012 (Etkin, 2014). Case studies are included to demonstrate successes and challenges of inland oil response to various spill sources and oil types.

Maps for oil-related facilities are not included. The U.S. Energy Information Agency provides a website for the U.S. Energy Mapping System (https://www.eia.gov/state/maps.cfm) that can be used to map locations of a wide range of energy facilities. This site can be useful for contingency planning as well as spill response.

2.2 Pipelines

2.2.1 Liquid Petroleum Pipeline Network

Crude oil lines are subdivided into gathering lines and transmission lines defined as follows:

Gathering Lines: Pipelines that transport crude oil over relatively short distances from a production site (wellhead) to a central collection point, frequently a processing facility. Gathering lines typically operate at relatively low pressures and flow, and they are generally less than 8 inches in diameter.

Crude Oil Transmission Lines: Pipelines that transport processed crude oil from production areas to refineries. They generally operate at higher pressures and flow, and they are generally 8–36 inches in diameter. The transmission pipeline network in the U.S. extended for 72,400 miles as of 2015, an increase of 13%) over the 5-year period from 2011–2015 (AOPL and API, 2016).

Increases in oil production in the U.S. and Canada since 2010 have resulted in a steady increase in the volumes of crude oils transported by pipelines. In 2014, 9,290 million barrels of crude oil were transported by pipeline in the U.S., of which 71% was light and medium crude oil, 9% was diluted heavy crude oil, 8% was diluted bitumen, 6% was heavy crude oil, and 6% was synthetic crude (National Academies of Sciences, Engineering, and Medicine, 2016). Production and transportation of diluted bitumen are predicted to increase 2.5-fold from 2013–2030 (Canadian Association of Petroleum Producers, 2015), although these predictions might change due to declines in crude oil prices in 2015 and 2016.

Refined petroleum product pipelines transport gasoline, jet fuel, home heating oil, and diesel fuel. They vary in size from relatively 8 to 42 inches in diameter. As of 2015, there were approximately 62,600 miles of refined product pipelines nationwide, delivering products to fuel terminals with storage tanks that are then loaded into tanker trucks, barges, etc. for distribution to consumers. There has been a 3% decrease in the length of these pipelines over the last 5 years (AOPL and API, 2016). Major industries, airports, and electrical power generation plants can be supplied directly by refined petroleum product pipelines.

2.2.2 Pipeline Operations

For pipeline spills, the exact type of oil that is released might not be immediately known, but can be determined by contacting the pipeline operator's control center. Pipeline operators typically store oil from the owners in temporary holding tanks at major terminals where they: 1) consolidate oils from different sources into shipments in batches sized for main-line movement; 2) blend oils to meet quality specifications; and 3) schedule shipments according to the needs of refiners. Therefore, many oils transported by pipeline are "blends" rather than oil from a single source. They are typically sent in batches of at least 50,000 barrels (bbl), and a large pipeline could contain multiple different batches of crude at any time. To reduce undesirable mixing at interfaces, batches are separated and sequenced according to characteristics that include density, viscosity, and sulfur content. Additionally, oil flows through most pipelines at 3–6 miles per hour, (a delivery rate of 500,000 to 1,000,000 bbl of per day in a 36-inch transmission pipeline), which creates turbulent flow conditions, further reducing intermixing of batches and keeping impurities such as water and sediment in suspension (National Research Council, 2013).

A pipeline operator's control center closely tracks the location of each batch and associated interfaces in order to ensure that each batch of oil in a pipeline is delivered to the correct receiving facility and correct storage tank. This enables control room operators to instruct a receiving facility to open valves on lateral lines leading to storage tanks at the correct time to redirect an appropriate batch of oil to the target tank(s). In the event of a pipeline spill, a control center can be contacted to obtain information on the type and volume of oil that was in that segment of line at the time of the spill and the associated Safety Data Sheet (SDS). It is important to recognize the SDS for a particular oil or refined product is often generic to account for minor variations in blending or refining and might not represent the exact properties of the batch of oil that is in the pipeline.

According to the USDOT (No date), the most common threat to the safety of pipelines, particularly in and around cities and towns, arises from third-parties digging in the vicinity of buried pipelines. There is also an increased risk of pipeline failure at river crossing during floods due to erosion of banks/river bottom that can cause a pipeline to shift and rupture.

Pipeline oil spill response plans are required, under 49 CFR 194, to address spill risks and identify and prepare for worst-case discharges that are defined as:

1) the maximum release time in hours, plus the maximum shutdown response time in hours (based on historic discharge data or, in the absence of such historic data, an operator's best estimate), multiplied by the maximum flow rate expressed in barrels per hour (based on the maximum daily capacity of a pipeline), plus the largest line drainage volume after shutdown of the line section in a response zone, expressed in barrels; or

2) the largest foreseeable discharge for a line section within a response zone, expressed in barrels, based on the maximum historic discharge, if one exists, adjusted for any subsequent corrective or preventive action taken; or

3) if a response zone contains one or more breakout tanks, the capacity of the single largest tank or battery of tanks within a single secondary containment system, adjusted for capacity or size of the secondary containment system, expressed in barrels.

Buried pipelines have a risk of underground spills with delayed detection, depending on leak rate and sensitivity of the pipeline leak detection system. As an example, an underground pipeline spill of 20,000 bbl of Bakken crude oil occurred near Tioga, ND in 2013 as a result of a lightning strike and remained undetected for months. The subsequent cleanup activities took over two years and included efforts to prevent further spread of the low viscosity oil using intercept trenches and French drains, and intensive air quality monitoring because of the continuous release of volatiles from newly exposed oil as it seeped into trenches and was excavated in open pits.

Figure 1 shows two plots for crude oil spills from onshore pipelines for the period 1968 to 2012 for: (Top) Number of spills per year; and (Bottom) Volume of oil spilled per year (Etkin, 2014). The overall numbers of reported spills from crude pipelines decreased steadily from 1985 to 2001 (Figure 1, top), then increased sharply in 2002 and continued at this same rate through 2012. Etkin (2014) hypothesized that this sudden increase in spill numbers was due, in part, to a greater responsibility in voluntary reporting.

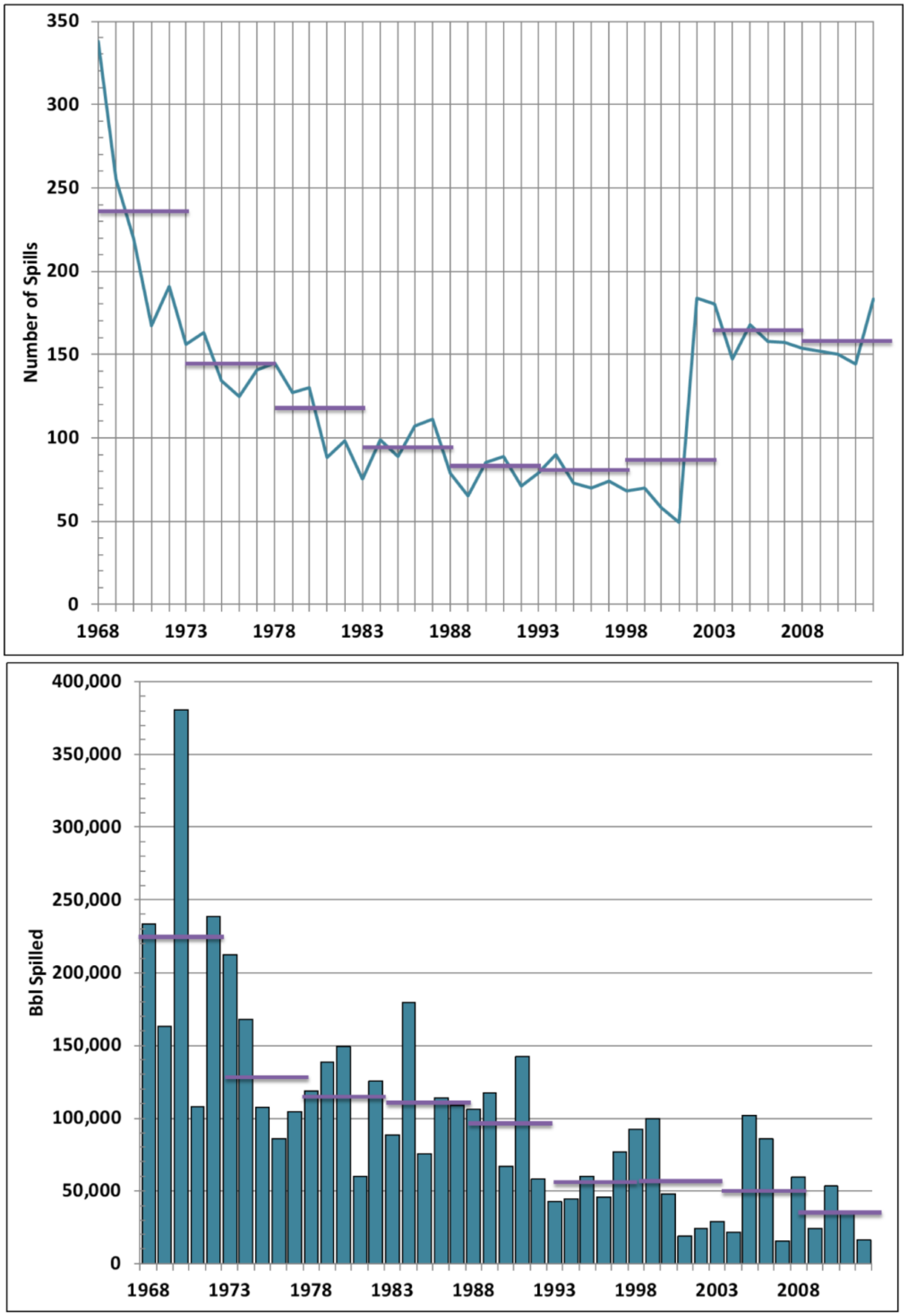


Figure 1—Annual Number (top) and Volume (bottom) of Crude Oil Spills from U.S. Pipelines for the Period 1968–2012. Bars Indicate 5-year Averages (Etkin, 2014)

The annual volume of crude oil spilled from pipelines has decreased over the 45-year period (Figure 1, bottom). Etkin (2010) noted that significant portion of the oil (about 85%) released from inland pipelines spills goes into containment areas around breakout tanks or to solid ground, rather than directly into surface waters. Recent statistics (spills >1 gallon; Etkin, 2014) for crude oil released from onshore pipelines include:

— 2003–2007: 162 spills that averaged 312 bbl per spill,

— 2008–2012: 157 spills that averaged 247 bbl per spill.

Box 1 provides a case study of a pipeline spill response.

Box 1—Pipeline Oil Spill Case Study

Name: Enbridge Line 6B Pipeline	**Date**: 22 July 2010	**Oil Type Spilled**: Diluted bitumen **Volume Spilled:** 20,071 bbl
Location: Marshall, Michigan		

Summary: The oil from a pipeline rupture flowed to a tributary of the Kalamazoo River near Marshall, Michigan, ultimately affecting 40 miles of stream and river channels. The release occurred when the river was at flood stage and had temporarily inundated the floodplain; high water levels stranded oil on vegetation and soils up to 3 feet above normal summer river levels, which then spread further as water levels fell.

Oil flowing over Cresco Dam, Kalamazoo River

Air quality concerns were very high for both public safety and occupational health during the initial weeks of the response, mainly due to high levels of benzene; an extensive air quality monitoring program lasted for several months.

Initial response operations focused on capturing, containing, and collecting floating oil using conventional techniques. The majority of oil was recovered as floating oil or deposits on land, including from the wetland at the source.

Within a week, it became apparent that some of the oil had sunk to the bottom of the river wherever the river flow slowed, particularly behind three manmade dams and in some abandoned river channels. Recovery of sunken oil increasingly became the focus of response efforts after the first autumn, although some heavily oiled islands and floodplain areas still necessitated removal of oiled sediments by excavation.

There was extensive oiling of river banks, forested floodplain, islands, and wetlands, which challenged traditional SCAT surveys and recommendations. Initial manual and passive removal methods were eventually revised to more aggressive mechanical methods because of the extent and amount of stranded oil and the stringent treatment endpoints.

Detection of sunken oil was accomplished by "poling" methods, whereby a disk on the end of a pole was inserted into the sediments and the number of oil globules and areal sheen production in a one-meter square surrounding the poling location was recorded.

Many methods were applied to contain sunken oil that was remobilized, including sediment curtains, gabion baskets, air curtains, bottom curtains, and enhancement of natural sediment accumulation areas. The gabion baskets and half-curtain bottom system were most effective, primarily where the river entered impoundments.

Sediment agitation with a hydraulic spray bar

Sunken oil removal methods included sediment agitation using manual rakes, hand-held tillers, hand-held stingers, rotating stingers, vessel-mounted water injection, vessel-mounted pipe drags, and hydraulic flushing. Studies of the effectiveness of sediment agitation in 2012 indicate that most of the oil remained mixed with sediment and resettled to the bottom. Dredging and excavation were conducted in depositional areas. Some locations were dredged multiple times over the four-year response.

More information is available in the FOSC report: https://www.epa.gov/enbridge-spill-michigan/fosc-desk-report-enbridge-oil-spill

2.3 Rail

The volume of oil transported by rail has increased significantly since 2011 (Figure 2). The number of incidents involving railroad tank cars carrying crude oil and total volume spilled per year are shown in Table 1. Clearly, not all incidents result in a spill, and often the spill volume is small; however, the sharp rise in the number of rail incidents in 2012 can be attributed to the increase in shipments of oil by rail.

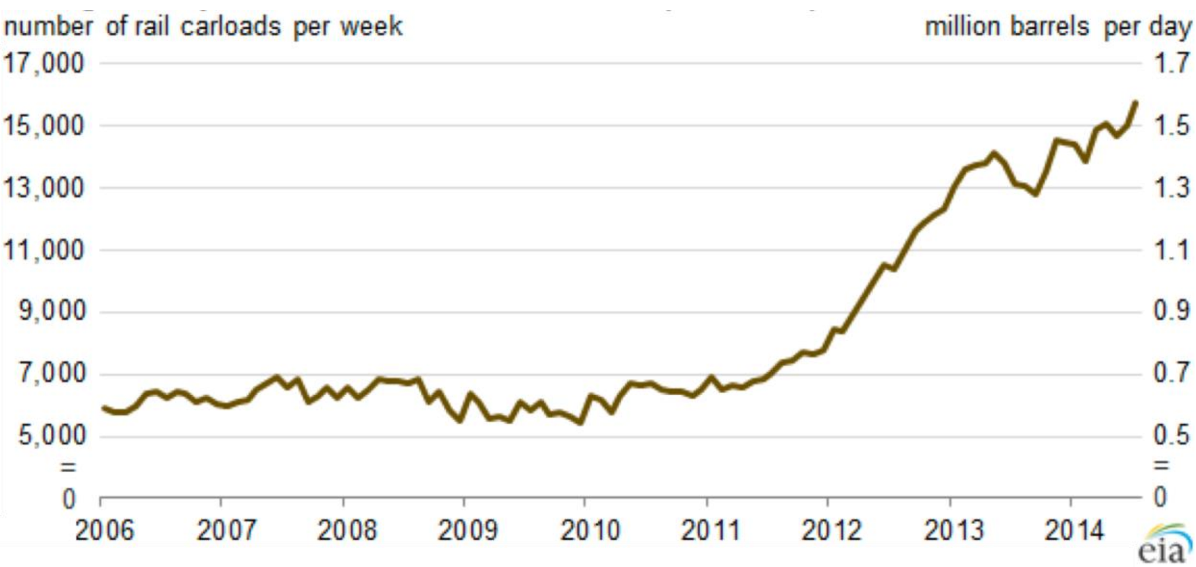


Figure 2—Average Weekly U.S. Rail Carloads and Million Barrels of Crude Oil and Petroleum Products Transported by Rail (EIA, 2015)

Table 1—Annual Incidents from Railroad Tank Cars Carrying Crude Oil in the U.S. (National Geographic, 2015)

Year	2010	2011	2012	2013	2014
Number	9	33	86	119	143
Volume (bbl)	117	93	12	22,512	1,371

Crude oil and ethanol comprise approximately 68% of the flammable liquids transported by rail. The inherent risk of flammability of these materials is compounded in the context of rail transportation because petroleum crude oil and ethanol are commonly shipped in large quantities, either as large blocks of material in a manifest (combined cargo/commodity) train or as a single commodity train (commonly referred to as a "unit train"). Box 2 provides a case study of a rail car spill response.

Box 2—Rail Car Oil Spill Case Study

Name: Aliceville, Alabama Rail Cars	**Date**: 8 November 2013	**Oil Type Spilled**: Light crude oil **Volume Spilled:** 17,857 bbl

Location: Freshwater wetland, 1 hour southwest of Tuscaloosa, Alabama

Summary: A 90-car crude oil unit train was heading to a pipeline injection terminal in Walnut Hill, FL when 26 rail cars derailed and caught fire. The derailment occurred in an isolated wetland. Due to fire danger and difficulty accessing the tank cars, first responders decided to allow the railcars to burn out. An estimated 12,800 bbl of oil discharged into a wetland.

Aerial photo of the spill site on 10 November 2015

Responding crews had to create access roads to transport equipment to the spill site. Road construction and rail wrecking operations required personnel to be working in close proximity to heavy equipment. With multiple contractors conducting different activities in the same congested area, there were risks of personnel being struck by heavy equipment. The use of spotters helped reduce those risks.

Community air monitoring was conducted throughout the response for VOCs, benzene, toluene, xylene, NO_2, SO_2, H_2S, CO, and particulates. At the derailment site, particulates were as high as 2 mg/m^3, and benzene was up to 0.3 ppm. Peak concentrations downwind of the derailment were 385.1 $\mu g/m^3$ particulate and of 2.6 ppm total VOCs. Work place air monitoring was conducted during the entire response. A benzene worker exposure program was initiated, of a representative population of workers by work task and potential exposure to petroleum vapors. Selected workers wore benzene dosimeter badges that were sent offsite for analysis. No benzene exceedances were detected.

Sorbents/filter fences for passive oil recovery

On Day 3, the Unified Command decided to extinguish the burning rail cars using aqueous film forming foam using industrial fire fighters. While moving a rail car, after the final fire watch, a pressure relief device on a ruptured rail car activated and a flash fire ignited. A second flash fire occurred 20 minutes later. All operations were ceased. Industrial fire fighters continued to cool rail cars and the rail bed for the remainder of the night. The source of ignition was never determined, but it was thought to be due to oil coming into contact with hot metal or ballast material. Due to possible re-ignition of the oil, industrial fire fighters remained on-scene until all oil was transferred from impacted rail cars.

Oil trapped within the wetland and in rail bed ballast continued to release after initial cleanup; crews returned and flushed the sediments and ballast in June 2014. Source: https://www.epaosc.org/site/site_profile.aspx?site_id=8939

2.4 Tanker Truck

Spills from tanker trucks are, for the most part, light, refined petroleum products (gasoline, diesel, home heating oil, No. 2 fuel oil) or heated asphalt products and tar (Etkin, 2006). In oil production areas, tanker trucks often transport crude oil from wells to processing plants, transmission pipelines, rail car loading facilities, and occasionally refineries, often involving hundreds of round trips per day.

Tanker truck capacity ranges between 5,500 and 11,600 gallons (130–276 bbl) per tanker. A truck could have a tank on the chassis and/or could pull a trailer with a similar volume. Etkin (2010) reported that the average annual volume of the total oil releases from tanker trucks over the period 1998–2007 was about 9,000 bbl, noting that most spills from tanker trucks go to pavements and do not directly impact waterways. The greatest environmental concern is when a light, refined product or light crude oil enters creeks or other small water bodies. Box 3 provides a case study of a tanker truck spill response.

2.5 Tank Barges and Towing Vessels

Barge traffic transits have increased in nearly all directions since 2010 with the exponential increase of oil production throughout the U.S. For example, in 2008, about 3.9 million barrels of crude were transported by barge from the Midwest to the Gulf Coast; in 2013, that volume increased 12-fold to 46.7 million barrels (Vieira, 2015).

Tank barges that operate on inland waters and the Great Lakes and transport the majority of this oil have capacities that average between 10,000 and 30,000 bbl. Most tank barges consist of three cargo tanks with 3,333 to 10,000 bbl in each tank. It is important to note that barge sizes vary within the inland waters, the Great Lakes, and intracoastal waterways. Thus, responders should always confer with the barge owner and/or operator's Qualified Individual and reference the barges' USCG-approved vessel response plan. Towing vessels that operate on inland waters and the Great Lakes have fuel capacities of between 1,000 and 3,000 bbl, with individual tank capacities ranging from 500 bbl to 1,500 bbl.

The average tow has approximately 15 barges, but tows (flotillas) can involve between 1 and 40 barges, consisting of open hopper, covered dry cargo, deck, and tank barges. Typically, tank barges are operated in tows of no more than 3 or 4 barges. Smaller tributaries can support only limited size tows because of the meandering nature of a river and varying width of a river and its locks.

Different petroleum products can be loaded in separate tanks within the same barge. Even a single product can vary among tanks, especially for blended products.

Multiple factors cause oil spill incidents within the inland waterways and the Great Lakes, but a majority of the incidents can be characterized as due to either collisions, allisions (collision of a moving vessel with a fixed object), groundings, and transfers. Collisions and allisions typically increase during high-flow conditions, whereas groundings increase during low-flow conditions.

According to the USCG Marine Information for Safety and Law Enforcement database, an estimated 200,363 gallons of oil were spilled as a result of 85 tank barge incidents in 2014. The single largest oil spill of 168,000 gallons represents 84% of the total volume spilled and the second largest spill 15% of the total volume spilled. Those two spills accounted for 99% of the total volume of oil spilled from tank barges for 2014. The oil spill rate for 2014 projects to be 2.68 gallons of oil spilled per million gallons transported. For 2013, the Army Corps of Engineers reported 273.1 million short tons, or approximately 74.9 billion gallons of oil transported by barge on U.S. waterways. That amount represents 83% of all oil carried on domestic waterways. The amount of oil transported by barge in 2013 increased by 20.7 million short tons or 5.7 billion gallons, representing a 7.6% increase over 2012. Box 4 provides a case study of a barge spill response.

Box 3—Tanker Truck Oil Spill Case Study

Name: Provo River Spill	**Date**: 28 November 2015	**Oil Type Spilled**: waxy crude oil **Volume Spilled:** 107 bbl
Location: Provo River Canyon, Utah		

Summary: A crude oil tanker truck overturned in Provo Canyon releasing a load of 107 bbl. The truck was carrying a waxy crude from the Uinta Basin, and most of the oil solidified along the roadway drainage while an estimated 25–35 bbl of crude oil flowed overland and via a storm drain into the Provo River.

Collection boom just upstream of the diversion dam

The spill occurred approximately 1 mile upstream from the Olmstead Diversion Dam that drinking water supplies for three communities: Orem, Provo, and Salt Lake City. The Central Utah Water District was promptly notified by the local sheriff and fire departments, and they closed the intake approximately 30 minutes before the first observation of oil. The water district switched to an alternative source. The water district also deployed boom, which successfully captured much of the oil. Water sample results indicated dissolved hydrocarbons were low or below detection limits. The water intake was reopened on 4 December, after the majority of oil had been collected. With the quick thinking and actions of first responders and the Central Water District, the impacts from the spill were substantially reduced.

Due to the cold weather and water temperature, along with the waxy nature of Uinta crude, the oil largely congealed into soft solid chunks. This greatly slowed the spread of the oil, yet it did eliminate the use of vacuum trucks in oil recovery.

Crews raked and lifted congealed oil by hand from behind collection booms. On Day 2, they started removing oiled soil from the crash site. During a brief warming period on December 10–11, crews were able to collect oil that had been stranded in ice.

Collecting the congealed oil along the bank by hand

The Provo River is valued as a “blue ribbon” fishery and is a highly used recreational area. In this section of the river, there were numerous families of beaver and muskrat. No impacts to wildlife or fish were observed. This was not surprising, given the waxy nature of this crude oil, which solidified in cold water into “flakes” and “chunks.”

Boom was left in place at the bridge by the diversion dam and monitored for oil accumulation for several weeks.

Source: USEPA OSC website: https://www.epaosc.org/provorivercrudeoil

Box 4—Barge Oil Spill Case Study

Name: T/B *E2MS 303*	**Date**: 22 February 2014	**Oil Type Spilled**: Light crude oil **Volume Spilled:** 750-800 bbl
Location: Mississippi River Marker 154, 50 miles above New Orleans		

Summary: The spill resulted from a collision between two barge tows. The initial oil release was a dark color, but quickly transitioned to yellowish emulsion and silvery sheen. Recoverable oil was present only within the boom around the barge, or was trapped in a fleet of 216 barges at anchor within 1–2 miles from the release, and in a few pockets within 4 miles downstream. Silver sheens were observed as far as 60 miles downriver for two days. River traffic was closed along 65 miles for 2 days.

Light crude oil in the lee of the barge on Day 1

The first USCG presence on scene typically respond in Level D personal protection equipment (PPE) and equipped with a very limited air monitoring instrument. The standard issue instrument only measures O_2, CO, H_2S, and lower explosive limit (LEL) of flammable gases. These devices lack the capability to measure the presence of VOCs at levels of concern, and are unable to "see" VOCs in a work environment, so cannot quantify the concentration of individual compounds.

When the Gulf Strike Team began air monitoring, high readings for VOCs (consistently >200 ppm) were cause for all responders to egress from the vessel and back away until the VOCs could be better quantified. When a benzene-specific detection instrument was used to quantify the level of benzene within the VOCs, the shore side concentration of benzene was >40 ppm. As this was above all recognized exposure limits for benzene, all USCG members executed acute exposure protocols for benzene, to include blood tests at a local hospital. All operations were stopped until the response contractor provided their own air monitoring suite with benzene detection capability and provided Level B PPE to responders working immediately adjacent to the damaged portion of the barge (the primary emission source of toxic vapors). Responders in the vicinity of the barge, who were not immediately adjacent to the site of the damage nor the pooled product on the water's surface, remained in Level D PPE with instructions to egress if air monitoring indicated detection of benzene above 1 ppm (OSHA permissible exposure limit, applicable to contractors) or 0.5 ppm (applicable to USCG responders). These atmospheric hazards were detected by the Gulf Strike Team upon arrival approximately 12 hours after the incident occurred, and elevated levels of benzene persisted for several days into the response.

Standard precautions for lightering/transfer operations were taken, including proper grounding/bonding of transfer pumps/equipment, elimination of external ignition sources (mechanical, electrical, smoking prohibited, etc.), and active monitoring of flammable vapors to ensure concentrations were maintained below 10% of the LEL.

No exposure concerns to the public were detected through air monitoring throughout communities along the river, and air monitoring was terminated on Day 3.

Water intakes were protected with exclusion booming as a precaution. The nearest intake was 4 miles downriver at 10 feet below the surface. Water samples from intakes showed no evidence of contamination. No fish kills were observed. The only shoreline cleanup operations were in the immediate vicinity of the spill, where flushing was conducted to clean oiled riprap adjacent to the T/B *E2MS 303* and within the barge fleet. Total amount of oil recovered was 2.3 bbl, which was about 0.3% of the amount released.

More information is available at: https://incidentnews.noaa.gov/incident/8729

2.6 Oil Exploration and Production Sites

Spills at oil exploration and production sites that spread off-site can occur during flood events, when storage tanks and/or piping are damaged, or when tanks float or move off their foundations. Oilfield storage tanks can range widely in size (210–1,000 bbl), and there could be multiple tanks per location, depending on daily oil production rates. The U.S. Environmental Protection Agency (USEPA) Spill Prevention, Control, and Countermeasures (SPCC) program requires secondary containment; however, failure of the secondary containment can occur during unusually high rainfall events, floods that damage or overtop containment, or other failure causes. Etkin (2010) reported average annual volume of oil released from inland oil production wells over the period 1998-2007 totaled about 5,600 bbl per year. Box 5 provides a case study of an oil production storage site spill response.

Box 5—Oil Production Storage Site Spill Case Study

Name: Poudre Tank Spill	**Date**: 20 June 2014	**Oil Type Spilled**: Crude oil **Volume Spilled:** 178 bbl
Location: Weld County, Colorado		

Summary: The spill resulted when flood waters along Cache la Poudre River slightly dislodged one of the storage tanks at an oil production site, which resulted in failure of a fitting on a valve at the base of the tank. Most of the oil that was reported lost appeared to have discharged to the river during the flood. When floodwaters receded, oil was found at the site and along a path to the river.

Sorbents where placed at the point of discharge as a precaution. The remaining product in the tank and observable free product between the tanks and on the river were removed using a vacuum truck. Sorbent pads were aggressively applied to collect any remaining liquid oil and a surface washing agent was used to remediate impacted soils.

Affected soils and vegetation that were left to recover naturally

The production tanks were removed and the most highly impacted soil from around the tanks was excavated. Due to damage that excavation would cause to vegetation between the tanks and the river, the impacted locations in that area were left to recover naturally. Source: https://www.epaosc.org/site/site_profile.aspx?site_id=9335

Excavating oiled soils beneath the tanks

Sorbents used to recover free product

2.7 Oil Refineries

There were 142 operable refineries in the U.S. in January 2104 with a total crude distillation capacity of about 17.9 million bbl per calendar day (American Fuel & Petrochemical Manufacturers, 2014). Spill statistics for inland refineries are not available. Etkin (2010) reported average annual volume of spills from all refineries totaled 11,271 bbl per year for the period 1998–2007, and that this volume represented 6% of the total annual U.S. spills from all land, coastal, and offshore sources for that period. Box 6 provides a case study of as oil refinery spill response.

Box 6—Oil Refinery Spill Case Study

Name: Coffeyville Refinery	**Date**: 1 July 2007	**Oil Type Spilled**: Crude oil **Volume Spilled:** 2,145 bbl
Location: Coffeyville, Kansas		

Summary: Severe flooding in southeast Kansas caused the Verdigris River to overtop a levee surrounding Coffeyville, Kansas on July 1, 2007. Flood waters carried approximately 2,145 bbl of crude oil from Coffeyville Resources Refinery through the town of Coffeyville and southward into Oklahoma. Initial on-water containment and recovery operations quickly gave way to shoreline, wetland, and land cleanup as receding flood waters left oil stranded. Agency responders were USEPA Regions 6 and 7 and Kansas and Oklahoma environmental and health agencies. A comprehensive air, water, and soil sampling plan was implemented, and a “boil order” issued for water users in Coffeyville and down river.


Flood waters carrying crude oil from the refinery


Crude oil carried by flood waters through town

Approximately 400 buildings were impacted by oil. Coffeyville Resources implemented a voluntary purchase program for the majority of residential properties that were impacted by oil, for demolition and disposal. Buildings not demolished had to be cleaned and inspected to assure that no oil remained.

A Shoreline Cleanup Assessment Technique (SCAT) program was implemented to identify appropriate cleanup techniques and end points for shoreline, wetlands and rural land. Consistent representation was used on sign off teams once cleanup endpoint criteria had been met. Oil-stained vegetation in rural areas was left to naturally attenuate. Leaves stained with oil that died and dropped off were recovered as part of the cleanup. The SCAT process also documented the cleaning of storm drains, buildings, and structures. A combination of visual inspections consistent with the SCAT process and soil sample results were used to verify soil standards in rural areas and as part of the residential demolition. Many residential lots had to have the first several inches of soil removed due to high levels of VOCs.

The response was complicated due to multijurisdictional issues associated with two USEPA regions and two states. Demolition of structures fell under National Emissions Standards for Hazardous Air Pollutants, which regulates the management of asbestos-containing materials (ACM). Structures had to be inspected and an accredited ACM contractor had to be used to remove and dispose of ACM prior to demolition. Handling and disposal of household hazardous waste, electronic waste, and putrescible waste associated with dwellings, restaurants, grocery stores, liquor stores, automobiles, and tires all required additional oversight. The majority of the cleanup operations were complete within 6 months, with the completion of demolition and land restoration program taking one year.

2.8 Inland Regulated Facilities

Inland facilities regulated under the SPCC program, other than refineries and production wells, include a wide range of oil storage volumes and types. Etkin (2006) reported that, for the period 1980–2003, SPCC facilities had a total average annual spill volume of 155,000 bbl per year, accounting for 51% of the number of spills and 55% of the volume of oil spilled to inland waters. The most frequent spills from SPCC facilities were light fuel (26%), followed by crude oil (21%), and volatile distillates (19%). Oils that accounted for the largest volume of spills were crude oil (28%), volatile distillates (26%), and light fuel (21%).

3 Comparisons between Inland and Marine Spills

3.1 Spilled Oil Properties and Behavior Comparisons

Inland oil spills typically have the following behavior characteristics and concerns that are different when compared to marine spills:

— Nearby shorelines on small water bodies can limit spreading, and consequently evaporation, which can prolong air quality concerns for workers and the public, leading to higher air monitoring and safety measure requirements.

— Increased oil:particle aggregate formation in turbulent waters with high suspended solids, which can change the density of spilled oil to potentially result in oil submergence or sinking.

— Some oils can lose the light fractions and more readily reach the lower density of fresh water, which can result in submergence or sinking.

— Stranded oil can persistent longer because of lower energy environments on lake shores or river banks (smaller waves, lack of tidal water motion and currents).

— Less dilution in shallow water bodies and with lower currents.

Table 2 presents some relative potential levels of concern for different oil properties and behavior for inland versus marine spills. For many oil properties and behaviors, inland spills have a potential higher level of concern. For example, during an inland spill, responders could have a higher level of concern about fire affecting populated areas, but a lower level of concern about the effectiveness of burning oil because it generally is thicker.

Table 2—Potential Level of Concern for Inland Compared to Marine Oil Spills

Oil Property/Behavior	Potential Outcome	Level of Concern for Inland Compared to Marine Spills
Flammability	— Fire (where it poses risks to populated areas)	More
Density	— Possible submergence or sinking	More
Percent Light Fractions	— Public exposure (if near a populated area)	More
BTEX Concentration	— Worker/public safety — Contamination of water supplies	More
Spreading	— Ability to contain and recover oil on water and floodplains	Less
Solubility	— Contamination of water supplies — Aquatic toxicity	More
Natural Dispersion	— Contamination of water supplies — Aquatic toxicity	Less

Table 2—Potential Level of Concern for Inland Compared to Marine Oil Spills (Continued)

Oil Property/Behavior	Potential Outcome	Level of Concern for Inland Compared to Marine Spills
Oil:particle Aggregate Formation	— Possible submergence — Possible sinking	More
Effectiveness of ISB	— Thicker, less weathered oil	Less
Impacts of ISB	— Damage to fauna, vegetation, soils, cultural resources — Exposure of public and wildlife to air emissions	More
Burn Residue	— Burn residue sinking	More
Oiling of Debris	— Large volumes for removal/replacement	More
Persistence of Oil Residues	— More aggressive removal — Residual soil toxicity	More

3.2 Sensitive Resources in Inland Areas

The resources at risk for inland spills include a wide variety of human, biological, and cultural resources:

— The public could be at risk in populated areas if a spill occurs in close proximity to residential and urban areas. Air quality concerns can become particularly important.

— There could be a strong concern about water quality because of high use of water for drinking, cooling, industrial, agricultural, and recreational uses.

— There are more threatened and endangered (T&E) species listed under the federal Endangered Species Act (ESA) and by similar state legislation that could be affected by both spilled oil and response actions. Table 3 lists the number of federally protected species in the U.S. by group. Note the large number of listed plants, which accounts for 54% of all listed species. Most of these listed species occur in inland areas.

— There are more locations and types of historic and cultural resources that could be affected by response in inland areas.

— Access may be limited so the response team might need to build roads, launches, staging areas, temporary storage, etc., potentially increasing the area of impact during a response.

Levels of concern about damage to these resources during an inland response could result in more stringent criteria for surveys of site operations (e.g., staging areas, transportation corridors, waste storage and disposal locations) and monitoring of operations to document compliance with BMPs.

Table 3—U.S. Species Listed under the Endangered Species Act

Group	Total	Mostly Coastal or Marine
Corals	6	6
Snails	50	2
Fishes	162	20
Amphibians	35	0
Reptiles	42	6
Mammals	102	21
Clams	88	0

Table 3—U.S. Species Listed under the Endangered Species Act (Continued)

Group	Total	Mostly Coastal or Marine
Arachnids (spiders, scorpions)	12	0
Insects	78	2
Crustaceans	25	0
Birds	100	19
Animal totals	**719**	**76**
Conifers and Cycads	4	0
Flowering Plants	860	1
Lichens	2	0
Ferns and Allies	31	0
Plant totals	**897**	**1**
Totals	**1616**	**77**

3.2.1 Consultation Requirements under the Endangered Species Act (ESA)

During a response by the USEPA or USCG to an oil spill emergency, the Federal On-Scene Coordinator (FOSC) is required to consult with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) to meet the requirements of Section 7 of the Endangered Species Act. The Section 7 consultation required for federal undertakings of an emergency spill response includes all activities related to the response, not the spilled material itself. Key guidance for consultation during emergencies is provided by the 2001 Inter-agency Memorandum of Agreement Regarding Oil Spill Planning and Response Activities Under the Federal Water Pollution Control Act's National Oil and Hazardous Substances Pollution Contingency Plan and the Endangered Species Act (https://www.uscg.mil/npfc/docs/PDFs/urg/App/ESA_MOA_AppA_04.pdf). This 2001 Memorandum of Agreement outlines the process for Emergency Consultation during a spill response under Section 7 of the ESA between the FOSC and the federal agencies as follows:

— Notification will occur as agreed in the Area Contingency Plan.

— Spill response activities that could affect listed species or their critical habitat require emergency consultation.

— Emergency consultation will be accomplished by including USFWS and/or NMFS in the Incident Command System organization established by the FOSC. These representatives will provide timely recommendations as conservation measures to eliminate/minimize impacts to listed species/critical habitat. Often, the agencies will prepare BMPs to be followed during response actions.

— The emergency will continue until removal operations are complete in accordance with 40 CFR 300.320(b). The FOSC will continue emergency consultation until the case is closed.

3.2.2 Consultation Requirements under the Magnuson-Stevens Fishery Conservation and Management Act

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act require that federal agencies consult with NMFS when their actions or activities could adversely affect habitat identified by federal regional fishery management councils or NMFS as essential fish habitat (EFH), which means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. Through this consultation process, measures are identified to avoid, reduce, or compensate for adverse impacts to EFH.

50 CFR Section 600.920(a)(1) addresses EFH consultation during emergencies:

> Consultation is required for emergency Federal actions that may adversely affect EFH, such as hazardous material clean-up, response to natural disasters, or actions to protect public safety. To this end, Federal agencies should contact NMFS early in emergency response planning, but may consult after-the-fact if consultation on an expedited basis is not practicable before taking the action.

Response activities have the potential to adversely affect riverine habitats identified as EFH and therefore trigger the consultation requirement. EFH consultation consists of a federal agency providing NMFS with an EFH Assessment, NMFS responding with EFH Conservation Recommendations followed by the federal agency's response to NMFS recommendations**.**

The mostly likely EFH in inland areas are for salmonid species that utilize rivers in Idaho, Washington, Oregon, and California that drain into the Pacific Ocean, and Atlantic salmon in rivers in Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. EFH can be identified using the EFH Mapper at: http://www.habitat.noaa.gov/protection/efh/habitatmapper.html.

In 2013, the USCG issued a policy letter on the process for consultation under Section 7 of the ESA and under the EFH requirements to ensure compliance with these environmental statues during oil spill planning and response activities (USCG, 2013).

3.2.3 Consultation Requirements under the National Historic Preservation Act (NHPA)

During a response by the USEPA or USCG to an oil or hazardous material spill emergency, the FOSC is required to consider historic properties during emergency response planning and operations. The federal undertaking for an emergency spill response includes all activities related to the response, not the spilled material itself. Historic properties are properties that are included in the National Register of Historic Places or that meet the criteria for the National Register. Section 106 of the NHPA requires consultation with affected tribes and trustees on assessing potential effects of proposed response activities and determining acceptable methods of minimizing negative impact of those actions. Key guidance for historical and cultural resource protection is provided in the 1997 Programmatic Agreement on Protection of Historic Properties during Emergency Response under the National Contingency Plan (http://www.achp.gov/pa14.pdf). This document is a national guideline for providing protection to historic properties in an emergency. Most Regional Response Teams (RRTs) have developed implementing guidelines, which should be reviewed.

When a spill response has the potential to affect cultural resources, an FOSC can appoint an Historic Properties Specialist to provide advice on historic preservation matters, including compliance with historic preservation laws. Highest levels of concern are for National Historic Landmarks, sites listed under the National Register of Historic Places, sites determined to be National Register eligible, Traditional Cultural Property, human remains and funerary objects, and areas of special concern to tribes. The Historic Properties Specialist reviews proposed response work plans and develops strategies to avoid or minimize potential adverse effects of response activities on historic properties. The Historic Properties Specialist advises and may represent the FOSC in NHPA compliance communications and assists with Section 106 consultation with affected tribes and trustees on potential effects of proposed response activities and acceptable methods to minimize negative impacts. The Historic Properties Specialist works with the FOSC, as directed, to generate pertinent directives regarding cultural resources and historic properties; these directives apply to all emergency response personnel and activities. The Historic Properties Specialist may, with an FOSC's concurrence, assemble a Technical Working Group (or advisory group) and/or liaisons with consulting parties to facilitate consultation and develop and review strategies for protecting historic properties. Inland spills are more likely to affect tribal lands or Traditional Cultural Property, thus triggering the need to consult with potentially affected tribes.

4 Oil Properties, Toxicity, and Behavior

The oil type (and thus likely properties and behavior when spilled) and amount spilled are key pieces of information during the initial stage of a response. However, oil type information is not always immediately known or appreciated, as discussed in Section 2. Obtaining a SDS for the **exact product** as early as possible is essential in determining the spilled oil's type and properties and its predicted behavior. In addition, early collection and analysis of a sample of the oil can also provide this information. Simple observations or "tailgate" tests can help determine if an oil will float and the relative viscosity and inform predictions on how it might weather (changes in physical and chemical properties) over time.

The type of oil spilled determines, to a large extent, its behavior and the range of appropriate response actions and potential environmental impacts. The oil type also largely determines its persistence in the environment which is an essential prerequisite to identifying environmental risks during an oil discharge. The USCG and USEPA use oil persistence levels within their oil spill response regulatory frameworks to calculate potential impact areas, determine response capability requirements, and influence other planning aspects. The USEPA Facility Response Plan rule (40 CFR 112.20 and 112.21) defines oil as either "persistent" or "non-persistent."

<u>Non-persistent</u> or Group 1 oils include:

A petroleum-based oil that, at the time of shipment, and consists of hydrocarbon fractions:

- at least 50% of which by volume, distill at a temperature of 340°C (645°F);
- at least 95% of which by volume, distill at a temperature of 370°C (700°F).

The volatility and flammability of non-persistent oil typically preclude an active response due to safety. The response could be one of simple evacuation and monitoring.

<u>Persistent oils</u> include petroleum-based oils that do not meet the distillation criteria listed above. These oils are further classified based on specific gravity as follows:

- Group 2: specific gravity less than 0.85;
- Group 3: specific gravity equal to or greater than 0.85 and less than 0.95;
- Group 4: specific gravity equal to or greater than 0.95 and less than 1.0;
- Group 5: specific gravity equal to or greater than 1.0.

The USCG definition of persistence is consistent with that of the USEPA. However, the USCG does require that distillation characteristics are determined using the American Standards and Testing of Materials Method D 86/78, "or any subsequent revision thereof." Despite the existence of persistent and non-persistent oils with respect to USEPA and USCG regulations, neither agency has an official list of persistent and non-persistent oils. This is in part because different batches of a particular oil type can have different characteristics, and any oil type can have different degrees of persistence at different times in a spill due to weathering and other environmental factors.

Table 4 lists the properties and typical behaviors of the 5 oil groups and Figure 3 discusses the potential toxicity and long-term effects of each group. Many response guides refer to these oil groups.

Table 4—Oil Groups: Properties and Typical Behaviors

Group	Properties and Typical Behaviors
Group 1: Gasoline Products	— Specific gravity is less than 0.80; API gravity >45 — Very volatile; National Fire Protection Association (NFPA) class is "flammable liquid" — Very volatile and evaporates quickly with no residue (in a matter of hours for spills to water) — Relatively soluble, but dissolved components often rapidly partition into the air — Low viscosity; spread rapidly into thin sheens — Readily penetrate into porous substrates, but are not sticky — High acute toxicity but short-term exposure due to rapid evaporation — High risk of ignition and air quality concerns for responders and the public
Group 2: Diesel-like Products, Jet Fuels, Kerosene, Light Crude Oils, and Very Light Crude Oils	— Specific gravity is 0.80–0.85; API gravity 35–45 — NFPA class is "combustible liquid" — Volatile, with refined products leaving little to no residue. Crude oils can have residue after evaporation is complete — Moderately soluble and toxic with dissolved components somewhat persistent as partitioning into air is slower — Low to moderate viscosity; spread rapidly into thin slicks on water — Do not readily emulsify except in cold temperatures — Readily penetrate porous substrates — Are more bioavailable/toxic than lighter oils (in part because they persist longer), so that animals in water and sediments are more likely to be exposed
Group 3: Medium Crude Oils and Intermediate Products	— Specific gravity of 0.85–0.95; API gravity 17.5–35 — Moderately volatile — For crude oils, up to one-third can evaporate in the first 24 hours — Moderate to high viscosity; spread into relatively thick slicks — Can form stable emulsions which increases viscosity — Many have limited solubility — Are more bioavailable/toxic than lighter oils (because they persist longer), so that animals in water and sediments are more likely to be exposed — Can penetrate porous substrates — Persistent residues can have long-term toxicity
Group 4: Heavy Crude Oils and Residual Products (includes Diluted Bitumen products)	— Specific gravity of 0.95–1.00; API gravity of 10–17.5 — Very little product loss by evaporation or dissolution (with exception of diluted bitumen products where the diluent component may evaporate over time) — Very viscous to semi-solid; can be heated during transport — Can form stable emulsions which increases viscosity but tends to break into tar balls quickly — Low acute toxicity to water-column biota — Penetration into substrates can be limited at first, but can increase over time — Can cause long-term effects via smothering or coating, or as residues in a water column and sediments, though generally less bioavailable than lighter oils
Group 5: Nonfloating Oil Products: Slurry Oils, Coal Tar Oils, Carbon Black Feedstock, Very Heavy Crude Oils, and Asphalt	— Specific gravity of >1.00; API gravity <10 — Limited product loss by evaporation or dissolution — Very viscous to semi-solid; can be heated or blended with a light product (which can evaporate once spilled) to facilitate pumping/transport — Low acute toxicity to water-column biota (though can have some toxicity if blended with a lighter, more-toxic diluent) and less bioavailable than lighter oils — Penetration into substrates may be limited at first, but can increase over time — Can cause long-term effects via smothering or coating, and as residues in soils

<table>
<tr><th>Oil Type</th><th>Group 1:
Very Light</th><th>Group 2
Light</th><th>Group 3
Medium</th><th>Group 4
Heavy</th><th>Group 5
Non-floating</th></tr>
<tr><td>Acute toxicity to aquatic organisms</td><td>High toxicity from soluble compounds</td><td>Moderate toxicity from soluble compounds</td><td>Moderate to low toxicity</td><td>Low toxicity, but high risk of smothering</td><td>Low toxicity, but high risk of smothering</td></tr>
<tr><td rowspan="2">Long-term environmental effects</td><td rowspan="2">Likely not severe</td><td rowspan="2">Can cause long-term sediment contamination</td><td>Can cause long-term impacts</td><td>Possible long-term sediment contamination</td><td>Can cause long-term sediment contamination</td></tr>
<tr><td colspan="2">Can impact bird, fur-bearing mammals, and shoreline habitats</td><td>Can smoother benthic habitats and organisms</td></tr>
</table>

Figure 3—Toxicity and Long-term Environmental Effects of Oil Groups 1–5

Four types of "non-conventional" oils are transported in inland environments and have somewhat different properties and potential behaviors compared to the five oil groups described in Table 4. These types are described briefly in the following paragraphs and more detailed data are provided in Appendix A.

— Light shale oils: These oils are very light and contain a higher percent of dissolved gases than most crude oils, which poses a higher risk of ignition as well as inhalation hazards to responders and the public shortly after a release, compared to other crude oils. When released to water, they can lose about 50% of their mass by evaporation and are readily dispersed under turbulent conditions. Spills on land that penetrate into soil lose the volatile fractions more slowly, and there can be secondary releases of volatiles during excavation and trenching in oiled areas.

— Diluted bitumen products: These products initially behave like a medium crude oil. However, as the light ends evaporate, their density can approach and occasionally exceed 1 gram per cubic centimeter (g/cm^3), and their viscosity can reach over 1,000,000 centiStokes (cSt) under real-world conditions. After evaporative loss of light ends, diluted bitumen spills have a greater potential to submerge and sink in freshwater, compared to seawater, particularly in freshwater environments with turbulent flow and moderate to high volumes of suspended particulate matter. Because bitumen is so highly weathered initially in its natural state, spilled residues can undergo little additional weathering when stranded on a shoreline or accumulated in bottom sediments and can be highly persistent.

— Biodiesel (unblended): Spills of biodiesel to water are expected to behave similarly to petrodiesel at first, but they can have a higher rate of natural dispersion and a slower rate of droplet resurfacing. Over time, biodiesels are likely to become more viscous, thus can have higher recovery of any remaining floating product using skimmers and sorbents. Aquatic life could suffocate because of the depletion of oxygen caused by releases to shallow or isolated water bodies. The high biodegradation rates of biodiesels in water (both fresh and salt) and soils of days to weeks under aerobic conditions and weeks to months under anaerobic conditions might support a decision to allow natural attenuation of residues after gross oil removal, if supplemental oxygen is supplied or naturally occurring oxygen is sufficient to support microbial degradation.

— Non-petroleum oils: These oils include animal fats (e.g., beef tallow oil) and vegetable oils (e.g., soybean oil, palm oil, rapeseed oil, sunflower oil). Spills can affect aquatic resources due to rapid depletion of oxygen levels in sediments and isolated water bodies because of high biological oxygen demand (BOD). They can polymerize (components cross-link), thus harden into concrete-like lumps in sandy sediments that can persist for years. However, these lumps can be readily removed during cleanup operations.

Because most oils start to weather once released to the environment, understanding how key properties change because of weathering (Table 5) is important in the response decision process and in understanding the habitats that may be impacted and how. Weathered oil tends to be denser, stickier, and more viscous but generally less toxic. Figure 4 shows how viscosity of different petroleum oils (fresh and weathered) compares with common materials whereas Table 5 provides a comparison of selected properties for fresh and weathered oils in each oil group.

Table 5—Comparison of Different Oil Properties as Oil Weathers[a]

Crude Oil	Adhesion (g/m^2)	Density (g/cm^3)	Viscosity (cSt @ 20 °C)	Flash point (ºC)
Light Crude[b]	0	0.77	1	−30
Weathered Light Crude (60% mass loss)	9	0.84	5	95
Medium Crude[c]	12	0.85	8	−10
Weathered Medium Crude (32% mass loss)	33	0.90	110	110
Heavy Crude[d]	75	0.94	820	−3
Weathered Heavy Crude (19% mass loss)	600	0.98	5,000	110
Diluted Bitumen[e]	98	0.925	285	<−5
Weathered Diluted Bitumen[f] (25% mass loss)	1,580	1.008	50,000	169
Bakken[g]	N/A	0.8	13	–36 (–59 to 50)
Weathered Bakken (45% mass loss)[g]	N/A	0.865	24	N/A

[a] Modified from NAS (2016); N/A = not available
[b] Scotia Light; [c] West Texas Intermediate; [d] Sockeye Sour; [e] Cold Lake Winter Blend; [f] Cold Lake Winter Blend that was artificially weathered to a high degree; [g] USEPA (2015b)

The oil fate plots for representative oils in each oil group in Section 6 was generated using the NOAA oil weathering model called ADIOS2 (Automated Data Inquiry for Oil Spills). The model was run on representative oils for each oil group and with the following input parameters:

— an instantaneous release of 50 bbl of oil into a confined area of 80,000 square feet (such as spreading in downstream for 800 feet in a river that is 100 feet wide), thus oil would spread out to a thickness of 0.03 inches or 0.8 millimeters;

— wind speed of 0 knots, to be representative of inland conditions where wind can be blocked by vegetation in smaller water bodies, thus there is no natural dispersion;

— sediment load of 50 g/cm^3, which is the average for rivers, and water temperature of 60°F.

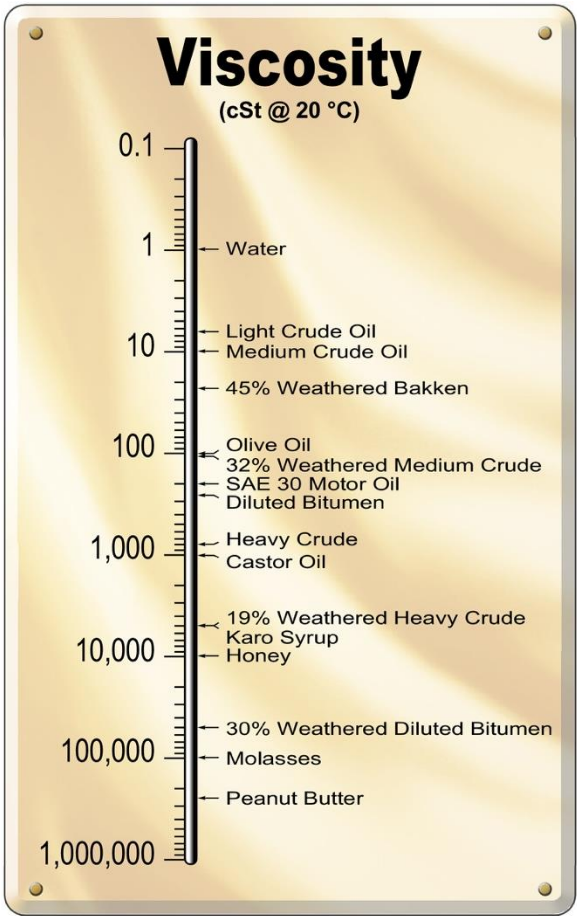


Figure 4—Viscosity of Different Oils (Fresh and Weathered) Compared to Common Materials

The model was run for five-day periods for all oils except for gasoline, which was run for 8 hours because it evaporates quickly. In the model, natural dispersion is only a function of wind speed, which is 0 knots, so no wave-generated turbulence was input that typically would naturally disperse oil; turbulence from riverine processes is not included in ADIOS2. Thus, the plots are conservative in terms of the volume of oil that might remain on a water surface.

Models that can predict the spread and weathering of oil on land are valuable for oil spill planning at specific release locations. However, oil spreading processes are driven by soil type, topography, vegetation, surface roughness, etc. so that results only reflect a specific scenario being modeled, making it difficult to generate useful comparisons among oils groups. Therefore, no modeling was undertaken for spills on land.

5 Spilled Oil Detection, Delineation, and Characterization

Timely detection and delineation is the key to effective containment and recovery and, thus minimization of environmental impacts. Inland spills that occur on land can spread, penetrate porous substrates, migrate downslope, and potentially reach a water body. Surveys to map the location of the oil and identify the affected habitats might be required to evaluate the appropriate response actions. Although facility, pipeline, and vessel response plans include general response approaches, spill-specific response actions should integrate field data on oil behavior, current physical processes, affected habitats, access points, and ecological and cultural resource issues. Repeated surveys may be appropriate to monitor the effectiveness and effects of ongoing response methods, so that benefits from possible changes in tactics, additional treatment, or constraints can be evaluated throughout the different phases of a response. This section describes current approaches and surveys for detection, delineation, and characterization of spilled oil on land and water habitats.

Managing essential response data in spatial databases using Geographic Information Systems (GIS) from the very beginning of a response should be standard practice for spills that last for more than several days or affect many different areas. Whenever practical, field data should have Global Positioning System (GPS) coordinates and all photographs should be georeferenced. A GIS is an extremely valuable tool for maintaining a common operating picture throughout a response, and it can help to track/visualize temporal patterns in oil distribution and cleanup operations.

5.1 Oil On Land/Wetlands/Shorelines

5.1.1 Surface Oil

The Shoreline Cleanup Assessment Technique (SCAT) is commonly used to survey the affected area and detect, delineate, and characterize the oil and recommend appropriate response options. SCAT teams use standard terminology to collect data on oiling conditions to support decision making on where to conduct removal actions and the preferred options to remove or treat the oil, considering the site constraints and resource sensitivities. The NOAA (2013) Shoreline Assessment Manual and the Environmental Canada SCAT manual (2016) provide detailed guidance for a SCAT program. The NOAA manual includes forms for SCAT teams to use for spills on shorelines, wetlands, river banks, and stream banks, as do many other agencies and organizations. Safety concerns should be paramount when searching for highly volatile oils as the light fractions can evaporate and present a SCAT team with inhalation hazard and pits and be a potential ignition risk.

River bank zonation for is often based on water levels (Sergy and Owens, 2011), for example:

— Over-bank area: where flood plain is inundated only by over-bank flow during flood conditions.

— Upper bank: portion which is under water only during bank-full river stage.

— Lower ban: portion is exposed only during low flow conditions.

— Exposed mid-stream: areas consisting of a shoal or bar separated by water from a river bank.

Inland oil spills can pose challenges to a SCAT program because:

— Oil can spread over wide areas and in three dimensions, for example, in floodplains during high water events where oil coats vegetation as water levels drop.

— Oil that stranded during low water can be difficult to map and characterize when water levels rise and flood oiled zones.

— Oil distribution within an “oil zone” as recorded on the SCAT forms can be highly variable, with Thick Oil in depressions adjacent to a Coat or Stain on vegetation.

— Surveys, and therefore good documentation, may be difficult in thick vegetation. Teams might need local field guides to correctly identify both sensitive and invasive species of plants and animals.

— Natural hazards (poisonous snake and plants, dangerous animals, debris piles, and soft substrates) can be a safety issue.

— The subsurface extent of substrate oiling and groundwater impacts might be difficult to document.

These complications challenge SCAT survey and data documentation methods. Under these conditions, SCAT teams might have to rely on several approaches, including aerial, boat, and ground surveys. Aerial surveys can generate data to develop general oiling categories and target areas for more detailed ground and boat surveys. The use of Unmanned Aerial Vehicles to collect aerial video and photographs in areas of difficult access is an option, assuming that operations are in compliance with current Federal Aviation Administration regulations.

GPS track lines document a survey team's locations and waypoints at observation points during ground and water surveys and can be used to generate survey maps that a team uses to delineate oiled areas for treatment. Timely delineation of areas of thick oil or oil that can be potentially remobilized is essential so that removal actions can be quickly recommended and implemented. Timeliness is particularly important when forecasted rain or increasing water levels are likely to remobilize and spread oil over larger areas, when new snow may cover oil deposits, or when snow or ice that are providing natural containment could start to melt. Close attention to changing weather conditions and water levels, typically using real-time field observations and on-line monitoring data, is particularly important for inland spills.

Ground or boat-based surveys for detection and delineation of oil on land can, in certain cases, be supported by a canine oil detection (K9-SCAT) team (API, 2016c). A canine detection team consists of:

— a trained detection canine that has been imprinted with the target odor;

— a trained and experienced handler to control the search pattern and reward the canine;

— an experienced SCAT observer to manage and direct the survey;

— an animal health and welfare protocol implemented by the handler and supported by a canine veterinarian.

K9-SCAT can be an integral part of a traditional SCAT program and has the potential to:

— rapidly clear large shoreline/inland areas or pipeline corridors with a high-confidence, low-risk survey to ensure that oil is not present in those areas that otherwise would be time consuming for a traditional ground observation team;

— be effective in areas that would be difficult or hazardous for a ground team, including large sediment (boulder and riprap), bedrock, vegetated terrain, thick debris, and deep snow;

— find oil that is hidden from visual assessment, under snow or ice, or trapped under debris.

Many of these situations, where K9-SCAT can be useful in addition to traditional SCAT surveys, are of particular value during inland oil spill response. Refer to API Technical Report 1149-4 (2016c) for additional technical information, results of field trials, and implementation plans using a K-9 SCAT program.

5.1.2 Subsurface Oil

Survey techniques are different for spills where an oil leak begins below ground (e.g., from buried pipelines or underground storage tanks) or penetrates into the subsurface from a surface release (API 2013). Pits and trenches (dug manually or mechanically), push cores, or auger drilling rigs can detect and delineate the oil's extent (both horizontally and vertically) and can provide information on soil profiles to determine risks for downward migration of oil to the water table or penetration into bedrock fractures. K9-SCAT teams can be effective in detecting subsurface oil to depths of several feet with 100% coverage, versus spot sampling by manual or mechanical excavation or coring. Groundwater wells might be appropriate to determine groundwater flow directions, measure of the thickness of oil on the water table, and to collect samples for chemical analysis. The light oils that are produced from shale areas can migrate readily through permeable subsurface sediments, similar to light refined products such as gasoline and diesel. Similar to surface oil SCAT surveys, significant safety concerns are also associated with subsurface assessments of highly volatile oils as vapors can collect in trenches and pits and be a potential health or ignition risk.

5.2 Oil On Water

5.2.1 Floating Oil

Standard terminology to describe floating oil is an important element of documentation and the NOAA (2012) Open Water Oil Identification Job Aid for Aerial Observation provides guidance on terminology and definitions. Observations in vegetated areas can be difficult due to vegetation that can create canopies over the water: boat-based K9 teams may be able to support a SCAT survey in these situations.

Spills on rivers and streams can move downstream quickly with the currents, spreading bank-to-bank in some areas, or being pushed by wind to one side. Water currents will also tend to move oil to the outside of bends in rivers or streams although the current speeds often preclude oil from accumulating in these areas. It is important to identify areas of low flow or eddies where oil can concentrate, including downstream of point bars and islands, and in side channels, oxbow lakes, and natural or man-made impoundments. Oil may also be trapped by, or accumulate in, floating debris within a waterway or along a shoreline or where vegetation or woody debris extends from a shoreline into the adjoining water. Areas with accumulations of floating oil should be prioritized for recovery as changes in water levels, current speeds or wind direction can easily remobilize the oil and impact additional areas downstream.

There are many natural materials that could be mistaken for oil (e.g., algal blooms, suspended sediments, bacterial sheens), thus ground truthing of aerial observations is essential. A nonpetroleum sheen can usually be distinguished from a petroleum sheen by disturbing the sheen, which must be done from the ground. When disturbed, a bacterial sheen typically breaks into small platelets or fractures like broken glass. In contrast, a petroleum sheen swirls and quickly reforms after a disturbance. Other techniques to differentiate nonpetroleum sheens include:

1. Hexane test, where a sample of a sheen is collected using a small piece of sheen net. The net is inserted into a glass vial containing hexane, shaken, and allowed to stabilize. A petroleum sheen dissolves in hexane, causing the hexane to discolor. Biogenic sheens do not dissolve in hexane, thus there is no change in color.

2. Ultraviolet test, where hexane vials are viewed under ultraviolet light. Petroleum oils fluoresce, whereas biogenic sheens do not (USEPA, 2016).

5.2.2 Submerged and Sunken Oil

Most oil spill response techniques and equipment are based on the simple principle that oil floats. However, oil does not always float. It can float on a water surface, suspend in a water column, or sink to the bottom of a water body; and it could do all three on the same incident: float, suspend, and sink. Furthermore, oil that has sunk to the bottom can become re-suspended by an increase in turbulence or temperature (which reduces the oil’s viscosity, allowing it to separate from the sediment) and spread by currents over time. Terminology to describe these various behaviors can be confusing; thus, the following terminology is used in this guide:

— Floating oil: Spilled oil that is on the surface of a water body.

— Submerged oil: Spilled oil that is in the water column, below the water surface, including oil that is in temporary suspension due to turbulence and will refloat or sink in absence of that turbulence.

— Sunken oil: Spilled oil that is on the bottom of a water body.

API published two documents in 2016 that addressed sunken oil spill response:

— *Sunken Oil Detection and Recovery*: Technical Report (API, 2016a: Technical Report 1154-1)—This report identifies and documents current best practices and alternative technologies to more effectively detect, delineate, characterize, contain, and recover sunken oil.

— The report identifies and describes the following sunken oil detection technologies: 1) sonar systems; 2) underwater visualization systems; 3) diver observations; 4) sorbents; 5) laser fluorosensors; 6) visual observations by trained observers; 7) bottom sampling; and 8) water-column sampling.

— Additionally, the report includes descriptions of seven sunken oil recovery technologies: 1) suction dredge; 2) diver-directed pumping and vacuuming; 3) mechanical removal; 4) sorbent/V-SORs; 5) trawls and nets; 6) manual removal; and 7) agitation/refloat.

— For each technology, a detailed description of the method is provided with advantages and disadvantages and summary tables-the types of information that are used to select the most effective options for sunken oil detection and recovery.

— *Sunken Oil Detection and Recovery: Operational Guide* (API 2016b: Technical Report 1154-2)—This guide includes decision support tools to assist responders in selection of the most appropriate techniques for sunken oil detection, delineation, and characterization, and then recovery, depending on spill conditions.

— These two documents present current best practices for spill incidents where oil has sunk to the bottom of a water body. Therefore, this topic is not discussed in this report. However, Section 5.7 includes response techniques for detection when the oil is submerged in the water column.

6 Best Practices for Inland Oil Spill Response

6.1 Introduction

This section provides guidance on best practices for inland oil spill response. Response techniques appropriate for inland habitat types are described briefly. Colored “stoplight” matrices identify the potential relative impacts of different response techniques, in the absence of oil and for each oil group.

6.2 Response Phases

Guidance to help minimize the environmental impact during implementation of treatment techniques is provided for each oil group for two different operational phases of response:

Control and Contain Phase: Represents the first hours to days of a response, when the focus is on controlling the source and containing the active spread of spilled oil on land and/or water. This phase includes efforts to protect sensitive resources at risk through construction of barriers and trenches on land, placement of underflow dams, overflow dams, weirs, and filter fences on streams, and deployment of containment, deflection, and exclusion booms on larger water bodies. This phase also includes the initial gross oil removal from active containment and natural accumulation areas. The timeliness and effectiveness of this phase of a response are two keys to environmental impact minimization and a successful response. The decision process should be keenly aware of near-term changes in meteorological conditions, water levels and flow rates, and pending rainfall events that can result in loss of containment whereby oil can spread and affect much larger areas, as well as be more difficult and expensive to remove.

Cleanup Phase: Represents the days to months following the Control and Contain phase of an emergency response, when the focus is on active and timely removal of residual oil to levels that meet spill-specific cleanup endpoints. The objective is to expedite the removal of the oil to prevent or minimize any ongoing environmental impacts. For this phase of a response, changes in water levels or rainfall events can increase the rate of natural removal of residual oil or remobilize oil that had been inaccessible.

There is often a third phase of a response, often referred to as the Project Management phase, when the initial cleanup endpoints have been reached, but some residual oil remains in the environment. In this phase the oil is generally no longer mobile, acute environmental impacts have been mitigated and only a limited amount of residual oil remains to be remediated and/or monitored. In this phase, active response operations have also been terminated but may have transitioned from active oil removal to passive techniques, such deployment of sorbents to remove intermittent sheening or maintenance of booms to contain residual oil that may be remobilized by weather or water level change events and prevent it from impacting sensitive resources. This phase often consists of patrol and maintenance (P&M) activities, when SCAT teams periodically document oiling conditions and Operations crews inspect, maintain, and replace sorbents, booms, or other passive measures. The key challenge of this phase is the process by which the response effort gradually is decreased and by which agreement is reached on when to complete and terminate this phase and the overall response; this topic is covered in Section 6 on cleanup endpoints.

6.3 Response Techniques and Relative Potential Impacts on Inland Habitats

Awareness of the response techniques that are generally applicable to inland spills, their general effectiveness on the different oil groups/types and the relative collateral environmental impacts to various habitat types often associated with their implementation are paramount in selecting the response technique(s) that will minimize the overall impacts of the spill and the response. To that end, Table 6 provides a brief description of response techniques applicable to inland spills of Group 1–4 oils and Table 7 describes the general habitats associate with inland areas. Table 8, described later in this section, identifies the relative impacts of the response techniques. The techniques described and habitats noted in this report complement those described in ASTM International F2204 and F2464, respectively. These techniques and habitats are the basis for the relative effectiveness and impact guidance provided for Oil Groups 1–4 in Sections 6.4 to 6.7. Section 6.8 includes techniques and guidance for response to Group 5 oils that are submerged in a water column or have sunk to the bottom and become resuspended.

Table 6—Response Techniques Included in This Guide for Oil Groups 1–4

Response Technique	Description
Natural Attenuation	No attempt to remove spilled oil from the land or water to minimize environmental impacts or due to infeasibility or impracticality of applicable response options or insignificant predicted potential impacts. Can be an option after gross oil removal. Can include monitoring to confirm assumptions and expectations.
Containment/Recovery	
Booming	Deployment of barriers on water to deflect, divert, exclude, or contain floating oil. Often involves vessels or anchors for deployment and/or to attach to anchor points on land. Can include use of barges as barriers.
Skimming	Mechanical equipment placed at the oil/water interface to recover floating oil. Needs containers for interim storage of recovered liquids and appropriate treatment of liquids prior to discharge. Large amounts of debris can be challenging.
Barriers	Earthen berms and other manmade or ad hoc materials, such as sand bags, used to physically contain the movement of oil on land and small creeks; underflow dams, overflow dams, air bubble curtains and silt curtains to prevent further spread of oil on water.
Trenching	Excavation of a trench (either manually or mechanically) to intercept oil flow on the surface or in the subsurface. Can include French drains in the subsurface.
Removal	
Manual Removal	Hands and hand tools (rakes, shovels, sieves) to remove oil and oiled sediments. Often includes involves utility vehicles (UTVs) or boats for worker and waste transport, and on site and/or adjacent staging areas for waste storage and handling.
Vacuum/Pumping	Vacuum or pumping system to recover bulk oil on land, on water, and under water; Range from small, portable units to large, truck- or barge-mounted systems, typically manually directed.

Table 6—Response Techniques Included in This Guide for Oil Groups 1–4 (Continued)

Response Technique	Description
Sorbents	Sorbent materials (e.g., sausage boom, rolls, sweeps, pads, snare) deployed to recover oil on the surface of the water or ground. Sorbents can be installed in filter fences in streams. Includes loose organic sorbents applied to riverbanks or shorelines/land surfaces to sorb oil or act as a contact barrier.
Excavation	Mechanical excavator to remove oiled soil and materials; can be deployed on barges to create depressions for submerged oil containment and to recover oil/oiled sediments from a waterbody. Includes extensive waste management support.
Dredging	Suction dredge, hydraulic dredge, or clamshell dredge to recover oil/oiled sediments from a water body. Includes extensive waste management support.
Debris Removal	Removal of oiled debris, both natural and manmade, by manual and mechanical methods. Removal of large woody debris is of particular concern because of its habitat value.
Vegetation Removal	Cutting of rooted grassy or woody vegetation with hand tools or floating aquatic weed cutters to remove oiled vegetation. Can include cutting of unoiled vegetation to provide access to oiled areas.
Washing/Recovery	
Flooding	Pumping of ambient water on the surface at low pressure through a perforated header hose or pipe to float oil off a substrate and carry oil down slope for collection. Can be conducted in flat terrain by isolating the oiled area with a barrier and flooding the area with water to lift oil from the substrate. Can include agitation of oil with rakes or low-pressure water streams to mobilize and liberate oil for collection.
Low Pressure/ Ambient Water Flushing	Spraying of ambient-temperature water at low pressures (<50 pounds per square inch [psi]), usually from hand-held hoses, to lift oil off substrates for collection.
High Pressure/ Heated Water Flushing	Spraying of heated water (typically 90–170°F) at high pressures (>50 psi), usually from hand-held wands, to lift oil off substrates for collection. Primarily for man-made substrates.
In Situ Treatment	
Sediment Reworking	Mechanical mixing of oiled sediments *on land* to break up and oxygenate oil residues to enhance natural attenuation. Can include sediment relocation to lower elevations on a shoreline to enhance reworking by wave action on large lakes.
Sediment Agitation/Mixing	Pressurized water or air injected into sediments, or mechanical agitation using backhoes, large rakes or chain drags under water *in a water body* to liberate sunken oil attached to sediments to mobilize oil to float to the surface for recovery with sorbents or skimmers; can include manual agitation using hand-held stingers, rakes, etc. in very shallow water.
In Situ Burning	Intentional ignition of oil that is contained on a water surface or pooled on the ground or on ice. Might necessitate construction of fire breaks on land and fire-resistant containment boom on water. Can also include burning of oiled vegetation. Typically requires government approval(s).
Biological Treatment	
Nutrient Addition	Application of nutrients (nitrogen and phosphorous) as slow-release solids, dissolved in water, or sprayed as a neat liquid (oleophilic formulations) to accelerate oil biodegradation rates. May require government approval(s).
Microbe Seeding	Application of formulations containing hydrocarbon-degrading microbes (often also with nutrients) to accelerate oil biodegradation rates. May require government approval(s).
Phytoremediation	Planting of oil-tolerant vegetation to increase the rate of degradation of oil in soils.
Chemical Treatment	
Solidifier	Chemical agent (polymers) applied at rates of 10–45% and mixed into oil to form a solid mass that can be recovered manually or with nets. Can be used in boom, socks, or pillows. May require government approval(s).

Table 6—Response Techniques Included in This Guide for Oil Groups 1–4 (Continued)

Response Technique	Description
Surface Washing Agent	Chemical agent (surfactants) sprayed neat or diluted on surface oil, allowed to soak, then flushed with water to increase removal rates at lower temperatures and pressures. May require government approval(s).
Herding Agent	Chemical agent that has a high spreading pressure applied adjacent to an oil slick or sheen at very low rates to push oil towards recovery devices or away from sensitive areas. May require government approval(s).
Dry Ice Blasting	Dry ice (frozen CO_2) pellets applied at high pressure to physically remove oil from impermeable substrates, including rock and man-made structures. The benefit is that there is no water to contain or additional chemical product to recover. Also appropriate where water is limited.

Table 7—Habitat Descriptions Used in This Guide

Habitat	Description	Potentially Sensitive Resources
Lake	Large water body with wind-generated waves and generally weak currents. Suspended sediment loads can be highly variable. Potential thermal stratification in summer and ice cover in winter.	Water intakes, important habitats for migratory and nesting birds, fish, fisheries, recreational use, navigation, and residential shorelines. Often the inlet and outlet have high sensitivity. Can be important for subsistence hunting and fishing.
Pond	Small, static, water body that is sufficiently shallow to support plant growth on the bottom. Typically have low waves and weak currents. Water exchange rates are highly variable, and some ponds have no surface water outlet. Can freeze over completely during winter.	Important habitats for nesting and migratory birds, aquatic mammals, fish, reptiles, and amphibians. Submerged and emergent vegetation can include T&E species. Can have high recreational use. Subsistence hunting, fishing, harvesting and trapping.
Large River	Large linear, flowing water body with typically year-round steady flow, strong currents and deep channels. Suspended sediment load can be high. Include backwater areas and other habitats with extensive vegetation and debris. Water can flow into adjacent floodplains during high water level events. Banks have to be surveyed and operationally treated separately.	Water intakes, local concentration areas for migratory birds, fish, and T&E mussels and fish. In high use recreational areas can be numerous access points. Important for navigation and commercial fishing and fur-bearing mammals.
Stream	Smaller linear, flowing water body with shallow water, narrow channels, and highly variable flow. Streams includes falls, cascades, riffles, and slides, which can mix oil into the water column. Can be choked with logjams and debris. Mid-channel islands and bars can divide flow into multiple channels. Both banks can be surveyed and cleaned at the same time.	Important habitat for spawning fish, reptiles, amphibians, T&E shellfish and fish, aquatic mammals, and birds. High-quality streams support valuable fisheries.
Developed Land	Residential, industrial, and urban, areas with extensive manmade surfaces and modified drainage.	People; cultural and historic structures.
Forested Upland	Woody vegetation (trees and scrubs) where drainage is sufficient that the soils are not saturated. Highly variable in density and type of understory.	Important for terrestrial mammals, birds, and reptiles. Can be important recreational areas.

Table 7—Habitat Descriptions Used in This Guide (Continued)

Habitat	Description	Potentially Sensitive Resources
Grassland/ Cropland	Natural areas composed primarily of herbaceous grasses. Cropland includes any area cultivated for agriculture production, including livestock grazing.	Native grasslands can have many T&E species and support nesting birds.
Forested Wetland	Woody vegetation with standing water or saturated soils at a frequency and duration that supports plants adapted to those conditions. Includes bottomland hardwoods and swamps.	Supports high variety of fish, wildlife, and plants, including many T&E species. Important as migratory and travel corridors. Hunting, trapping, and harvesting wild foods
Grassy Wetland	Areas of emergent vegetation with standing water and saturated soils at a frequency and duration that supports plants adapted to those conditions. Includes marshes, bogs, prairie potholes, wet meadows, and vernal pools.	Supports high variety of fish, wildlife, and plants, including many T&E species. Important habitat for bird nesting, fish spawning and rearing, reptiles, and amphibians. High recreational use areas. Wild rice beds are culturally and environmentally significant and provide subsistence harvesting and income.
Permeable Substrate	Land surfaces, shorelines, and river/stream bars composed of sand and/or gravel, or riprap structures.	Shorelines and bars can have high use by birds and mammals using this transition area between land and water. Can have high recreational use.
Impermeable Substrate	Land surfaces, shorelines, and bars composed of bedrock, muddy sediments, solid bulkheads, and pavement.	Bedrock areas can have unique faunal and floral communities.

Several recent manuals describe inland spill response techniques, including Alaska Clean Seas (2010), USEPA Region 5 (2010), Oil Spill Response Ltd. (2013), and ExxonMobil (2014). These manuals provide operational guidance, typically in graphical format, on methods to implement containment and recovery techniques. These graphics and the detailed guidance on types of equipment, mobilization times, and manpower for implementation are not repeated in this manual. These guides provide valuable material when planning for or executing an inland oil spill response.

Table 8 lists the relative potential environmental impact of utilizing the response techniques listed in Table 6, in the absence of oil, for the habitats listed in Table 7. The types of potential impacts considered include physical changes to the water column (e.g., turbidity), sediment (e.g., disturbance of listed species and critical habitats, benthic communities, change in sediment quality), or vegetation/natural debris disturbance. The impact scores reflect potential changes assuming that standard best practices are followed. Appendix B describes best management practices for different techniques and habitats. The environmental impacts primarily are due to physical disturbances from both manual methods in sensitive habitats and mechanical methods in all habitats, as well as the application of chemical agents in all habitats. The relative impact levels are described as:

— Least Impact: Disturbance is minimal in terms of the potential affected resources at risk and is short term (days to weeks).

— Some Impact: Some disturbance or removal could occur, though environmental recovery is expected to take place over a relatively short period (weeks to months).

— Greatest Impact: Significant environmental disturbance or plant/substrate removal are likely and can result in a prolonged recovery period (months to years).

Table 8—Relative Impact of Response Techniques in the Absence of Oil by Habitat

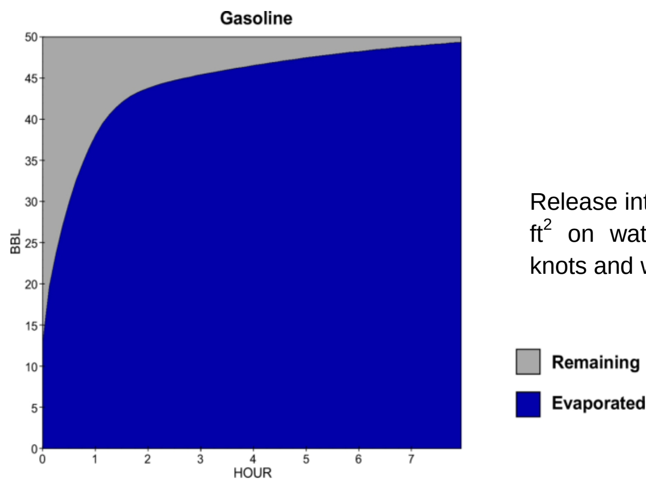
Green = Least Impact; Yellow = Some Impact; Red = Greatest Impact. - = Not Applicable for That Habitat

Response Technique	Water Habitats				Land Habitats						
	Lake	Pond	Large River	Stream	Developed Land	Forested Upland	Forested Wetland	Grassland/ Cropland	Grassy Wetland	Permeable Substrate	Impermeable Substrate
Natural Attenuation	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Containment/Recovery											
Booming	Green	Green	Green	Green	-	-	-	-	Green	-	-
Skimming	Green	Green	Green	Green	-	-	-	-	Green	-	-
Barriers	Green	Green	Green	Green	Green	Green	Yellow	Green	Yellow	Yellow	Green
Trenching	-	-	-	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	-
Removal											
Manual Removal	Green	Green	Green	Green	Green	Green	Yellow	Green	Yellow	Green	Green
Vacuum/Pumping	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Sorbents	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Excavation	Yellow	Yellow	Yellow	Red	Green	Yellow	Red	Yellow	Red	Yellow	-
Dredging	Yellow	Yellow	Yellow	Red	-	-	Red	-	Red	-	-
Debris Removal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Washing/Recovery											
Flooding	-	Green	Green	Green	Green	Green	Green	Green	Yellow	Green	Green
Low Pressure/Ambient Water Flushing	-	-	-	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Green
High Pressure/Hot Water Flushing	-	-	-	Red	-	Red	Red	Red	Red	Red	Green
In Situ Treatment											
Sediment Reworking/Mixing On Land	-	-	-	-	Green	Yellow	Yellow	Yellow	Yellow	Yellow	-
Sediment Agitation in Water	Yellow	Yellow	Yellow	Yellow	-	-	Red	-	Red	-	-
Vegetation Removal	-	Yellow	-	Yellow	Green	Yellow	Yellow	Yellow	Yellow	-	Yellow
In Situ Burning	Green	Green	Green	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Yellow
Biological Treatment											
Nutrient Addition	-	Yellow	-	-	Green	Green	Green	Green	Green	Green	-
Microbe Seeding	-	-	-	-	Green	Green	Green	Green	Green	Green	-
Phytoremediation	-	-	-	-	Green	Green	Green	Green	Green	Green	-
Chemical Treatment											
Solidifier	Yellow	Yellow	Yellow	Yellow	-	-	-	-	Yellow	-	Green
Surface Washing Agent	-	-	-	-	-	-	-	-	Yellow	-	Yellow
Herding Agent	Green	Green	Green	Green	-	-	-	-	-	-	-
Dry Ice Blasting	-	-	-	-	-	-	-	-	-	-	Green

6.4 Response Techniques for Spills of Group 1 Oils: Gasoline Type Products

6.4.1 Group 1 Oil Behaviors Affecting Response Techniques

This section addresses response techniques for Group 1 oils, which include gasoline products. Figure 5 is an example of the loss by evaporation over an 8-hour period of a 50-bbl spill of gasoline on water using the NOAA ADIOS2 oil-weathering model as described in Section 4. Gasoline has a very low viscosity, so readily penetrates porous substrates on land. Gasoline spills pose serious risks of ignition, as well as creating air quality concerns for both volatile organic compounds (VOCs) and benzene. Though gasoline has a high water solubility (50–225 milligrams per liter [mg/L], depending on water temperature), soluble fractions are also highly volatile and usually evaporate from water surfaces within a few hours. Exceptions include highly turbulent conditions where gasoline components are mixed into the water column and spills to ground where gasoline enters the vadose zone and/or the water table.



Release into a confined area of 80,000 ft^2 on water, with wind speed of 0 knots and water temperature of 60°F.

Figure 5—Evaporation over an 8-hour Period for a 50-bbl Spill of Gasoline

6.4.2 Response Techniques for Group 1 Oils: Gasoline Products

Due to the extreme fire, explosion, and inhalation hazards presented by gasoline spills, initial response techniques typically involve evacuation to a safe distance and allowing the product to spread to enhance evaporation. Defensive techniques (exclusion or deflection booming, trenching) can be implemented at a safe distance downstream or downslope of a spill, Table 9 presents response techniques with the relative potential impacts for spills of gasoline on land and water habitats. Table 10 and 11 provide guidance for the emergency phases of a response (Control and Contain; Cleanup) for spills on land and on water.

A case study of successful implementation of these cleanup techniques is the gasoline spill and fire that affected 3 miles of Whatcom Creek, WA in June 1999 (Owens et al., 2001; Mauseth et al., 2003) where the following techniques were used to remove residual product in streambed and streambank sediments:

- Manual agitation in accessible shallow water reaches with rakes, shovels, and pry bars;
- Mechanical agitation in shallow water to sediment depths of 1–2 feet using a standard tracked excavator in the lower reaches and a Spider excavator in canyon sections;
- High-pressure stingers from flat boat in deeper water in lower reaches
- Manual low-pressure washing of the stream bank slightly above the water line;
- Hydraulic flushing at night from upstream water-control structures.

Debris was removed in places to allow access.

Table 9—Gasoline Products: Relative Impact of Response Techniques by Habitat

Green = Least Impact; Yellow = Some Impact; Red = Greatest Impact; - = Not Applicable for That Habitat and/or Oil Type

Response Technique	Water Habitats				Land Habitats						
	Lake	Pond	Large River	Stream	Developed Land	Wooded Upland	Forested Wetland	Grassland/ Cropland	Grassy Wetland	Permeable Substrate	Impermeable Substrate
Natural Attenuation	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Containment/Recovery											
Booming - Contain	Yellow	Yellow	Yellow	Yellow	-	-	-	-	-	-	-
Booming - Exclude/Deflect	Green	Green	Green	Green	-	-	-	-	-	-	-
Skimming	-	-	-	-	-	-	-	-	-	-	-
Barriers	-	-	-	Yellow	Green	Green	Yellow	Green	Yellow	Yellow	Green
Trenching	-	-	-	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	-
Removal											
Manual Removal	-	-	-	-	-	-	-	-	-	-	-
Vacuum/Pumping	Yellow	Yellow	Yellow	Yellow	-	-	-	-	-	-	-
Sorbents	-	-	-	-	Green	Green	Green	Green	Green	Green	Green
Excavation	-	-	-	Red	Green	Yellow	Red	Yellow	Red	Yellow	-
Dredging	-	-	-	-	-	-	-	-	-	-	-
Debris Removal	-	-	-	Yellow	Green	Green	Green	Green	Yellow	Green	Green
Washing/Recovery											
Flooding	-	-	-	Green	-	-	Green	-	Green	-	-
Low Pressure/Ambient Water Flushing	-	-	-	Green	-	-	Yellow	-	Yellow	-	-
High Pressure/Hot Water Flushing	-	-	-	-	-	-	-	-	-	-	-
In Situ Treatment											
Sediment Reworking/Mixing On Land	-	-	-	-	Green	Yellow	Yellow	Yellow	Yellow	Yellow	-
Sediment Agitation in Water	-	-	-	Yellow	-	-	-	-	Yellow	-	-
Vegetation Removal	-		-	-	-			-	-	-	-
In Situ Burning	-	-	-	-	-	-	-	Yellow	Yellow	Yellow	-
Biological Treatment											
Nutrient Addition	-	-	-	-	-	-	-	-	-	-	-
Microbe Seeding	-	-	-	-	-	-	-	-	-	-	-
Phytoremediation	-	-	-	-	-	-	-	-	-	-	-
Chemical Treatment											
Solidifier	-	-	-	-	-	-	-	-	-	-	-
Surface Washing Agent	-	-	-	-	-	-	-	-	-	-	-
Herding Agent	-	-	-	-	-	-	-	-	-	-	-
Dry Ice Blasting	-	-	-	-	-	-	-	-	-	-	-

Table 10—Technique Considerations for Spills of Group 1 Oils (Gasoline Products) On Land

Phase	For spills of *Gasoline* on LAND:
Control and Contain Phase	— Immediately establish an air monitoring program to determine site safety, warm/hot zones, PPE specifications for workers, and community health concerns. Table 29 provides monitoring parameters and thresholds requiring specific actions for worker safety. — Air monitoring data and/or air quality models can assist in determining the need for and extent of community evacuation zones. These zones would be updated as appropriate. — If the LEL is >10%, do not attempt containment but continue monitoring; once levels are below 10% LEL, proceed with containment and recovery and continue monitoring. — Quickly identify where gasoline could reach a water body and install intercept barriers. Appendix B provides BMPs for ground disturbing activities — Prevent oil from entering storm water drains with temporary intercept dams/diversions. — For large spills that have soaked into the ground, intercept trenches may be appropriate to recover product flowing subsurface, but not in sensitive wetlands. — Line the upstream side of intercept barriers with plastic sheeting to control erosion and prevent or minimize product penetration into porous substrates. — Deploy sorbents to contain any free liquid and allow the residues to evaporate. Sand, clay, sawdust, vermiculite, etc. can be used to stop migration and suppress vapors. — Flooding or flushing on land are not recommended because of risks of generating large amounts of contaminated water for collection and disposal, or that can flow into and affect adjacent water bodies.

Phase	For spills of *Gasoline* on LAND:
Cleanup Phase	— Depending on state regulations, gasoline-contaminated soils might have to be excavated for off-site treatment or disposal, to prevent impacts to groundwater or subsurface flow to discharge into surface waters. — Soil vapor extraction methods can be used for treating contaminated sediments in situ. — If sediments are lightly contaminated with gasoline, sediment reworking to the depth of contamination can accelerate natural removal by evaporation. — In situ burning can be effective on gasoline spills that have been trapped in sediments or vegetation, where patches of liquid gasoline persist in surface sediments, or when fuel has soaked into snow or been contained by ice. — All waste materials (sorbents, soils, soaked debris) must be placed in appropriate containers and characterized for proper disposal.

Table 11—Technique Considerations for Spills of Group 1 Oils (Gasoline Products) On Water

Phase	For spills of *Gasoline* on WATER:
Control and Contain Phase	— Immediately establish an air monitoring program to determine site safety, warm/hot zones, PPE specifications for workers, and community health concerns. Table 29 provides monitoring parameters and thresholds requiring specific actions for worker safety. — Air monitoring data and/or air quality models can assist in determining the need for and extent of community evacuation zones. These zones would be updated as appropriate. — If the LEL is >10%, do not attempt containment but continue monitoring; once levels are below 10% LEL, proceed with containment and recovery and continue monitoring. — Monitor for VOCs and benzene adjacent to gasoline contained in booms. In addition, monitor for LEL in smaller water bodies (streams and ponds), where vapors could concentrate in low areas and not be dispersed by air turbulence. — Spilled gasoline quickly spreads into thin sheens in water that evaporate in minutes/hours and are highly flammable, thus natural attenuation is usually the preferred response. — Where safe and appropriate, boom spilled gasoline, using firefighting foam to suppress vapors, and vacuum fuel beneath the foam. This technique could increase risks of aquatic toxicity directly under boomed gasoline, but prevent spreading to other areas. — A layer of firefighting foam on top of liquids in vacuum trucks can also limit ignition hazard of vapors during storage and transport. — Deploy deflection or exclusion booms at a safe distance down current to protect sensitive areas. Section 7.1 provides guidance on protection of water intakes. — Monitor wind direction to aid in deflection and containment efforts and for personnel safety. — In small streams, construct barriers or trenches downstream to prevent further spread of gasoline to sensitive areas, for example, salmon spawning or juvenile fish habitat and to minimize the oiled area. However, maintain water flow downstream by using underflow dams, siphon dams, or filter fences. — Intentional burning is not recommended due to high flammability risks. Appendix C provides information on firefighting foam to extinguish burning oil or prevent ignition of a spill. — Monitor weather forecasts. Rain could aid in flushing gasoline from shorelines and debris, and proper containment preparations can take advantage of this condition.

Phase	For spills of *Gasoline* on WATER:

Cleanup Phase	— Natural attenuation is often the preferred response.
	— For gasoline that has penetrated into sediments and/or debris along a stream consider:
	    — Flooding and low-pressure flushing (<50 psi) to free gasoline from these materials and allow it to evaporate.
	    — Agitation of the stream bed to free gasoline and allow it to evaporate.
	    — Reworking of stream bank sediments or extensive woody debris removal should be evaluated for net benefits, because such methods could cause bank destabilization and erosion. Consider low-pressure flushing (<20 psi) at the water line and for oiled debris, which should be very effective on gasoline.
	— Heavily saturated debris in high public use areas can be removed for disposal; however, natural attenuation or flushing could be preferred because of habitat value of debris.

6.5 Response Techniques for Spills of Group 2 Oils: Diesel-like Refined Products and Light/Very Light Crude Oils

6.5.1 Group 2 Oil Behaviors Affecting Response Techniques

This section addresses response techniques for Group 2 oils, including: diesel-like refined products (diesel, #2 fuel oil, home heating oil, kerosene, jet fuels, biodiesel, biodiesel blends); light crude oils (West Texas Light); and very light crude oils (light shale oils). Figure 6 provides examples of the loss by evaporation of a 50-bbl spill over a 5-day period on water using the NOAA ADIOS2 oil weathering model as described in Section 4 for three oil types in this group: diesel (API = 37.2), Bakken crude oil (API = 41.8), and West Texas Light crude oil (API = 42) on. Note that there is no dispersion by natural processes such as waves and currents. All these oil types have low viscosity and can readily penetrate porous substrates on land.

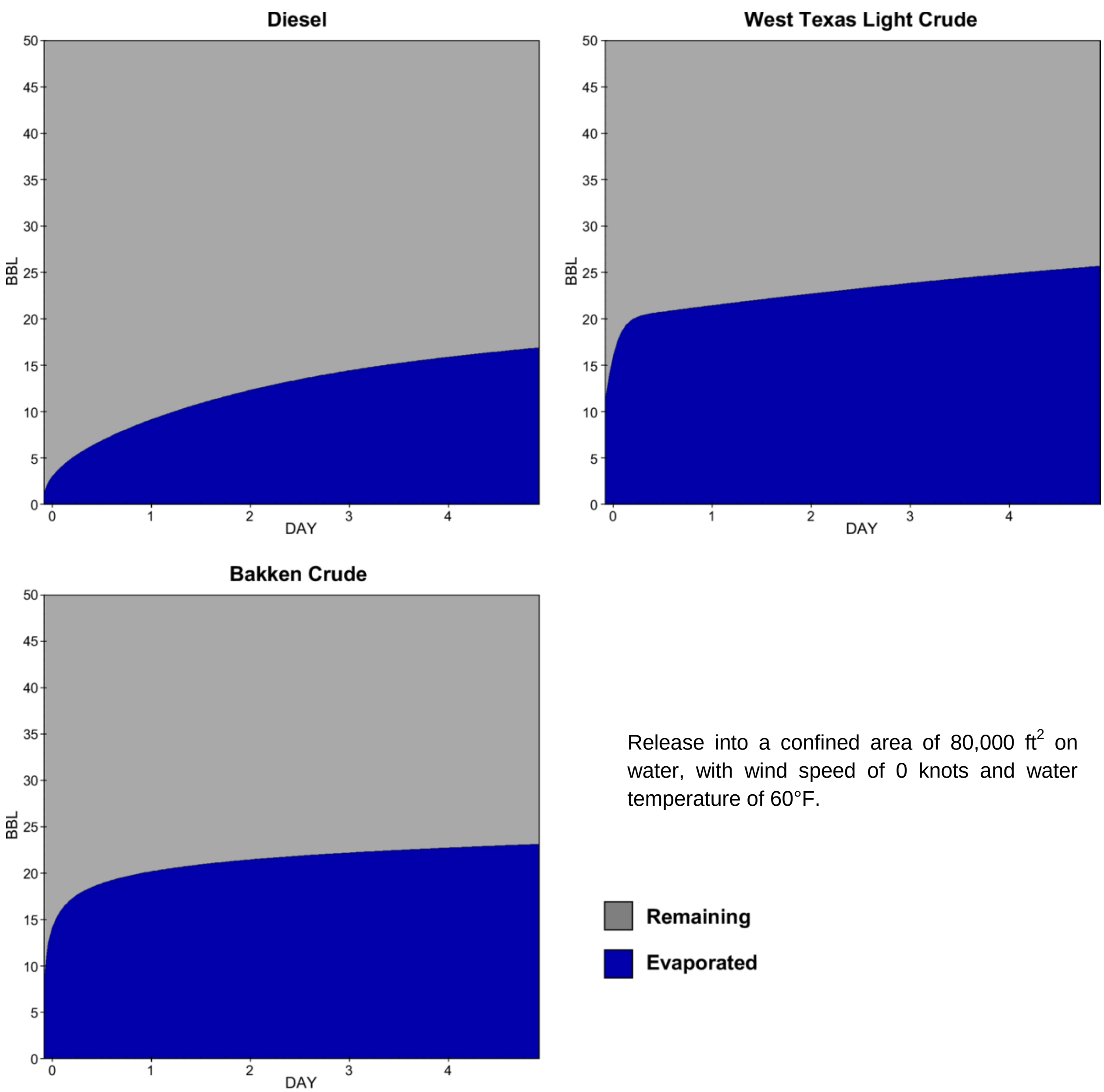


Figure 6—Evaporation over a 5-day Period for a 50-bbl Spill of Different Group 2 Oils

These three types of oil within this group have different initial behaviors after a release to water:

- Diesel-like refined products have very low viscosity and relatively low vapor pressures. They tend to spread on water into thin sheens (when uncontained), lose only about 25% of their mass by evaporation, and are readily dispersed when winds reach 5–7 knots or sea conditions are 2–4 feet. They are not very sticky, so they can be easily removed from sediments by flushing or agitation.

- Light crudes have a larger fraction of light ends, compared to narrow cut refined products, so they can lose 40–50% of their mass by evaporation. However, because they also have heavier components, as they weather they can become sticky and form unstable emulsions.

- Very light crude oils have a high vapor pressure, low viscosity, and low amounts of heavier components, thus they can lose about 50% of their mass by evaporation and will readily undergo natural dispersion when winds reach 5–7 knots or waves are 2–4 feet. As they weather, they become sticky and form unstable emulsions.

Spills of some light crude oils pose higher risks of ignition (as has occurred during rail car derailments. Note that the evaporation rate for light crude oil is not *faster* than other crude oils under the same conditions; evaporation is driven by the vapor pressure of individual hydrocarbons and proceeds at the same rate regardless of oil type. However, because these light crude oils have very low viscosity, they can spread quickly into thin slicks and sheens that cover large areas, releasing more volatile components compared to other crude oils over the same period of time.

There could be secondary releases of volatiles (and additional concerns for ignition and worker safety) when:

- pooled oil on land spreads to on water;

- oil seeps into trenches dug to intercept subsurface flow, for example, from a spill from a buried pipeline;

- as temperatures increase during the day;

- when oil enters storm drains, which can act as a confined space and concentrate vapors;

- when damaged rail cars are being moved: for example, during the Aliceville, AL spill, a pressure relief device on a ruptured rail car activated and a flash fire ignited while moving a rail car after the final fire watch.

Appendix D provides guidance for response to a spill of very light crude oil when oil ignites.

6.5.2 Response Techniques for Group 2 Oils

Table 12 shows the relative potential impacts of response techniques for spills of Group 2 oils on different water and land habitats. Tables 13 and 14 provide guidance for the emergency phases of a response (Control and Contain; Cleanup) for: 1) Group 2 oil spills on water and land in general, and 2) diesel-like oils and light/very light crude oil separately, to reflect oil-specific issues.

Table 12—Diesel-like Oils and Light/Very Light Crude Oils: Relative Impact of Response Techniques by Habitat

Green = Least Impact; Yellow = Some Impact; Red = Greatest Impact; - = Not Applicable for That Habitat and/or Oil Type

Response Technique	Water Habitats				Land Habitats						
	Lake	Pond	Large River	Stream	Developed Land	Forested Upland	Forested Wetland	Grassland/ Cropland	Grassy Wetland	Permeable Substrate	Impermeable Substrate
Natural Attenuation	Green	Yellow	Green	Yellow	Green	Green	Green	Green	Green	Green	Green
Containment/Recovery											
Booming	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Skimming	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Barriers	Green	Green	-	Green	Green	Green	Yellow	Green	Red	Yellow	Green
Trenching	-	-	-	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	-
Removal											
Manual Removal	-	Yellow	-	Yellow	Green	Green	Yellow	Green	Red	Green	Green
Vacuum/Pumping	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	-	Green
Sorbents	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Excavation	-	Red	-	Red	Green	Green	Green	Green	Red	Yellow	-
Dredging	-	Red	-	Red	-	-	Red	-	Red	-	-
Debris Removal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Washing/Recovery											
Flooding	-	-	-	Green	Green	Green	Green	Green	Green	Green	Green
Low Pressure/Ambient Water Flushing	-	-	-	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green
High Pressure/Hot Water Flushing	-	-	-	-	-	-	Red	-	Red	Yellow	Yellow
In Situ Treatment											
Sediment Reworking/Mixing On Land	-	-	-	-	Green	Yellow	Red	Yellow	Red	Yellow	-
Sediment Agitation in Water	-	Yellow	-	Yellow	-	-	Red	-	Red	-	-
Vegetation Removal	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	-	-
In Situ Burning	Green	Green	Green	Yellow	Yellow	Red	Red	Green	Green	-	-
Biological Treatment											
Nutrient Addition	-	-	-	-	Green	Green	-	Green	-	Green	-
Microbe Seeding	-	-	-	-	Green	Green	-	Green	-	-	-
Phytoremediation	-	-	-	-	Green	Green	Green	Green	Yellow	-	-
Chemical Treatment											
Solidifier	Green	Green	Green	Green	-	-	Yellow	-	-	-	Green
Surface Washing Agent	-	-	-	-	-	-	-	-	-	-	-
Herding Agent	Green	Green	Green	Green	-	-	-	-	Yellow	-	-
Dry Ice Blasting	-	-	-	-	-	-	-	-	-	-	Green

Table 13—Technique Considerations for Spills of Group 2 Oils On Land

Control and Contain Phase	**For spills of *Group 2 oils* on LAND in general:**
	— Quickly identify where oil could reach a water body and install intercept barriers. Appendix B provides BMPs for ground disturbing activities. — Block drains to underground systems using sand bags, water-filled plastic bags, or sorbents to prevent oil from reaching surface water or groundwater. — Construct berms, trenches, and other tactics to prevent further spread of oil. — Deploy plastic sheeting to line the sides of sediment berms to prevent or minimize oil penetration. — Add water and maintain a water layer for oil that is contained behind barriers or in trenches to reduce penetration into porous substrates. — Flooding and low-pressure flush can lift oil from substrates and direct towards recovery devices, being careful to avoid mixing oil with sediment or eroding sediment with too high water pressures. — Light and very light crude oils typically are not sticky when fresh; thus, flooding and flushing techniques can be very effective, particularly if conducted soon after the release before oil weathers. — Reworking of stream bank sediments or extensive woody debris removal should be evaluated for net benefits, because such methods could cause bank destabilization and erosion. Consider low-pressure flushing (<20 psi) at the water line and for oiled debris, which should be very effective on light refined oils. — Recover collected free oil as quickly as possible. — Monitor weather to predict when rainfall could cause containment measures to fail. Be prepared to contain remobilized oil under these conditions. Consider more aggressive removal actions to prevent loss of containment during heavy rainfall events. — Reduce spreading and increase the sorption capacity of surface layers by adding sorbents, including organic sorbents. RRT approval may be needed to leave organic sorbents in place. — Consider in situ burning for oil at least 1–2 millimeters thick that is trapped in wetlands, grassland, open fields, ice, or snow. Light refined oils can burn with very little residue, even weeks after release. Guidance on burning for inland oil spills is provided in API (2015) and for wetlands in Michel and Rutherford (2013).
	For spills of *light and very light crude oils* on LAND:
	— Immediately establish an air monitoring program to determine site safety, warm/hot zones, PPE specifications for workers, and community health concerns. Table 29 provides monitoring parameters and thresholds requiring specific actions for worker safety. — Air monitoring data and/or air quality models can assist in determining the need for and extent of community evacuation zones. These zones would be updated as appropriate. — If the LEL is >10%, do not attempt containment but continue monitoring; once levels are below 10% LEL, proceed with containment and recovery and continue monitoring. — Be aware of vapor ignition hazards in areas where oil has pooled on the ground, been contained by berms or in trenches, or entered sewers and other confined space. — Construct berms, dig trenches, install barriers but only at safe distances as determined by continuous air quality monitoring. Appendix B provides BMPs for ground disturbing activities. — Appendix D provides guidance on response to a spill of very light crude oil in event of a fire.

Table 13—Technique Considerations for Spills of Group 2 Oils On Land (Continued)

Cleanup Phase	**For spills of *Group 2 oils* on LAND in general:**
	— Appendix B provides BMPs for all cleanup activities on land. — Install walking boards, geotextile "sand mats" or other materials in access areas with soft substrates to prevent mixing oil into sediments and damaging vegetation. — Remove live oiled vegetation only to prevent contact with sensitive species or in high public-use areas. Consider rate of weathering to a non-sticky coat and timing of the use of an area. — Consider adding organic sorbents (e.g., peat, kenaf, bagasse), that can be left in place, to reduce contact hazards for wildlife, particularly in sensitive areas where removal actions could cause additional damage, or when removal cannot be conducted sufficiently quickly to reduce wildlife impacts. Sorbents can be lightly applied after gross oil removal. RRT approval may be required for leaving organic sorbents in place. — Monitor weather to be aware of changes that could increase rainfall, which then could remobilize stranded oil, to take advantage of natural flushing. Be prepared to contain remobilized oil under these conditions. — Natural attenuation after gross oil removal is the preferred option for sensitive wetland habitats. — Depending on state regulations, oil-contaminated soils might have to be excavated for off-site treatment or disposal, to prevent contamination of groundwater or subsurface flow to discharge into surface water. — Soil vapor extraction methods can be used for treating oiled sediments in situ. — Sediment reworking can accelerate removal by evaporation and microbial degradation for lightly oiled sediments. — In situ burning can be effective on these oil types that have been trapped in sediments or vegetation, where patches of liquid oil persist in surface sediments, or when oil has soaked into snow or been contained by ice. — All waste materials (sorbents, soils, soaked debris) must be placed in appropriate containers and characterized for proper disposal.
	For spills of *diesel-like refined oils* on LAND:
	— Light refined oils are readily biodegraded, often within weeks under optimal conditions, so consider in situ treatment options (sediment reworking and addition of nutrients and/or phytoremediation) for lightly oiled sediments. — Heavily oiled sediments can be excavated and treated by land farming off site.
	For spills of *light and very light crude oils* on LAND:
	— Conduct air quality monitoring during any ground disturbance activities in oiled sediments, as newly exposed oil can release VOCs even days and weeks after release. Table 29 provides information regarding monitoring parameters and thresholds for worker safety. — Air quality and ignition hazards during ground disturbance activities are of particular concern for subsurface releases from pipelines.

Table 14—Technique Considerations for Spills of Group 2 Oils On Water

Control and Contain Phase	**For spills of *Group 2 oils* on WATER in general**:
	— These types of oils quickly spread into thin sheens on rivers and lakes and are readily dispersed into the water column by turbulence, decreasing the effectiveness of booming/containment and skimming/recovery operations. — In rivers and large streams, booms can deflect and contain oil or divert to low-flow areas and natural collection areas (side channels, downstream of point bars, and away from cut banks), ensuring that here is appropriate on-water or on-land access for recovery operations. — Deploy deflection or exclusion booms to protect sensitive areas. Section 7.1 provides additional information on techniques specifically for protection of water intakes. — Monitor wind direction to aid in deflection and containment efforts and for personnel safety. — Monitor weather forecasts as potential increases in water flow and higher water levels could result in failure of containment and spread oil over larger areas. Containment of remobilized oil should be factored into operations planning for this eventuality. More aggressive removal actions might be appropriate prior to a heavy rainfall event to prevent loss of containment. — Oleophilic skimmers (disc, drum, and rope mop) are efficient at recovering refined oils with little associated water. Recent advancements in coated and grooved disc and drum skimmers have increased recovery rates. — In small streams, barriers or trenches constructed downstream can prevent further spread of oil to sensitive areas, for example, into salmon spawning or juvenile fish habitat. Downstream water flow is maintained with underflow dams, siphon dams, or filter fences. Pumps may be appropriate to increase the rate of water passage following rainfall events. — Where the water depth behind the underflow dam is so shallow that oil is entrained into the water and passes through the pipes, consider placing deflection booms at the head of the dam where current is slowed and oil could be diverted to collection areas. — In areas with periods of heavy rainfall, consider construction of at least two dams per location, to provide system redundancy to reduce the risk of dam failure during high runoff events. Appendix B provides BMPs for ground disturbing activities on streams. — Consider lining the upstream side of barriers with plastic sheeting to control erosion and oil penetration. — Loose, particulate sorbents should not be used on flowing water, but could be used on isolated water bodies to increase oil removal rates. — Herders can increase the thickness and thus recovery of oil sheens, or can move oil from under docks in ports and marinas and other shoreline structures. — Flooding and low-pressure flushing can remobilize and herd oil that is trapped in log jams, beaver dams, and vegetation or soaked into sediments at the water edge into open water for recovery. This can be accomplished with pumps, prop washing with vessels, or directed air flow from airboats or leaf blowers. Water pressures should be <20 psi to minimize bank erosion. — Chicken wire fences, hardware cloth, or other screen material can prevent debris from entering recovery devices. — Consider in situ burning for thicker oil (at least 2–5 millimeters on water is needed for ignition, and thicker oil burns more efficiently) contained in booms or trapped in floating debris, snow, or ice. Light oils can leave very little burn residue. Consider near-term changes in water levels that can either strand oil during lower levels or remobilize oil during higher levels. API (2015) provides for guidelines on burning inland oil spills.

Table 14—Technique Considerations for Spills of Group 2 Oils On Water (Continued)

Phase	Considerations
Control and Contain Phase	**For spills of *diesel-like refined oils* on WATER:**
	— Absorbents (both synthetic and natural) can be effective for heavier oil accumulations because oil can penetrate into these materials. — Solidifiers can effectively recover sheens and thin slicks. — Consider methods to allow recycling of recovered oil, as this can be a cost saving, reduces wastes, and works well with refined oils.
	For spills of *light and very light crude oils* on WATER:
	— Immediately establish an air monitoring program to determine site safety, warm/hot zones, PPE specifications for workers, and community health concerns. Table 29 provides guidance for monitoring parameters and presents thresholds requiring specific actions for worker safety. — If levels are below thresholds, proceed with oil containment and recovery. If levels are above thresholds, provide appropriate PPE for responders. — Air monitoring data and/or air quality models can determine the need for and extent of community evacuation zones. These zones should be updated as appropriate. — If the LEL is >10%, do not attempt containment but continue monitoring; once levels are below 10% LEL, proceed with containment and recovery and continue monitoring. — Light and very light oils may pose a risk of fire, requiring safety precautions to prevent ignition and continuous air monitoring as long as necessary. Include low-lying areas where vapors could accumulate and not be dispersed by air turbulence in a monitoring plan. — Monitor for VOCs and benzene adjacent to floating oil contained in booms. In addition, monitor for LEL around floating oil in smaller water bodies (streams and ponds), where vapors could concentrate in low areas and not be dispersed by air turbulence. — Under even moderate turbulence, expect natural dispersion of very light crude oils. Between evaporation and dispersion, there could be little oil remaining on the water surface for recovery after several hours to a day.

Phase	Considerations
Cleanup Phase	**For spills of *Group 2 oils* on WATER in general:**
	— These oils float under most conditions and do not strongly adhere to sediments under water. They also readily degrade under aerobic conditions so that dredging or excavation of water bodies would not be necessary. Natural attenuation, passive recovery of sheens, or in situ methods are preferred options. — Absorbent booms and pads can be effective for heavier oil concentrations because oil can penetrate into these materials. — Solidifiers in socks, booms, or pillows can recover heavy sheens when standard sorbents are not effective. — Apply loose solidifiers only on oil that is physically contained so the resultant solidified mixture can be recovered. — Consider live vegetation removal only where needed to access oil trapped in floating and fringing vegetation on waterbodies. — Conduct low-pressure flushing of oil coating on vegetation along stream banks quickly, before oil weathers and can no longer be effectively flushed.

Table 14—Technique Considerations for Spills of Group 2 Oils On Water (Continued)

Cleanup Phase	— Heavily saturated debris can be removed for disposal; however, natural attenuation or in situ treatment by flushing or addition of natural sorbents to reduce wildlife contact hazards might be preferred because of habitat value of debris, particularly large woody debris, or in areas of difficult access. In some instances, replacement with clean debris might be appropriate if excessive debris removal is conducted. See additional guidance in Section 7.5. — Where oil as penetrated into coarse-grained stream sediments during lower water levels, agitation of the stream bed when flooded could free oil for recovery with sorbents. Consider diversion of stream flow to these areas to provide a water layer during agitation. — For light crude oil spills, manual removal of shoreline sediments that release bulk oil into the water could be beneficial, because crude oils weather more slowly than light refined products. — Monitor weather to be aware of conditions under which water levels can rise and remobilize stranded oil, to take advantage of natural flushing. Be prepared to contain oil remobilized under these conditions.

6.6 Response Techniques for Spills of Group 3 Oils: Medium Crude Oils and Intermediate Refined Products

6.6.1 Group 3 Oil Behaviors Affecting Response Techniques

This section addresses response techniques for Group 3 oils including: medium crude oils and intermediate refined products. Figure 7 is an example of the loss by evaporation of a 50-bbl spill over a 5-day period in a confined area of 80,000 square feet on water using the NOAA ADIOS2 oil weathering model as described in Section 4 for three oil types in this Group: West Texas sour crude oil (API = 30.2), Robberson (Oklahoma) crude oil (API = 25.5), and lube oil (API = 30.4). At no wind speed, there is no emulsification and little natural dispersion of these two crude oils. When uncontained, most evaporation occurs within the first 24 hours for medium crude oils. In contrast, intermediate refined products do not have much loss by evaporation but can be dispersed into the water column by turbulence, depending on the oil's viscosity. They are a "middle cut" of crude oil, usually having relatively lower proportions of both lighter and heavier components, so that these are more biodegradable than crude oils of similar density.

6.6.2 Response Techniques for Group 3 Oils

Table 15 shows the relative potential impacts of response techniques for spills of Group 3 oils on different water and land habitats. Tables 16 and 17 provide guidance for the emergency phases of a response (Control and Contain; Cleanup) are provided for spills on land and water habitats.

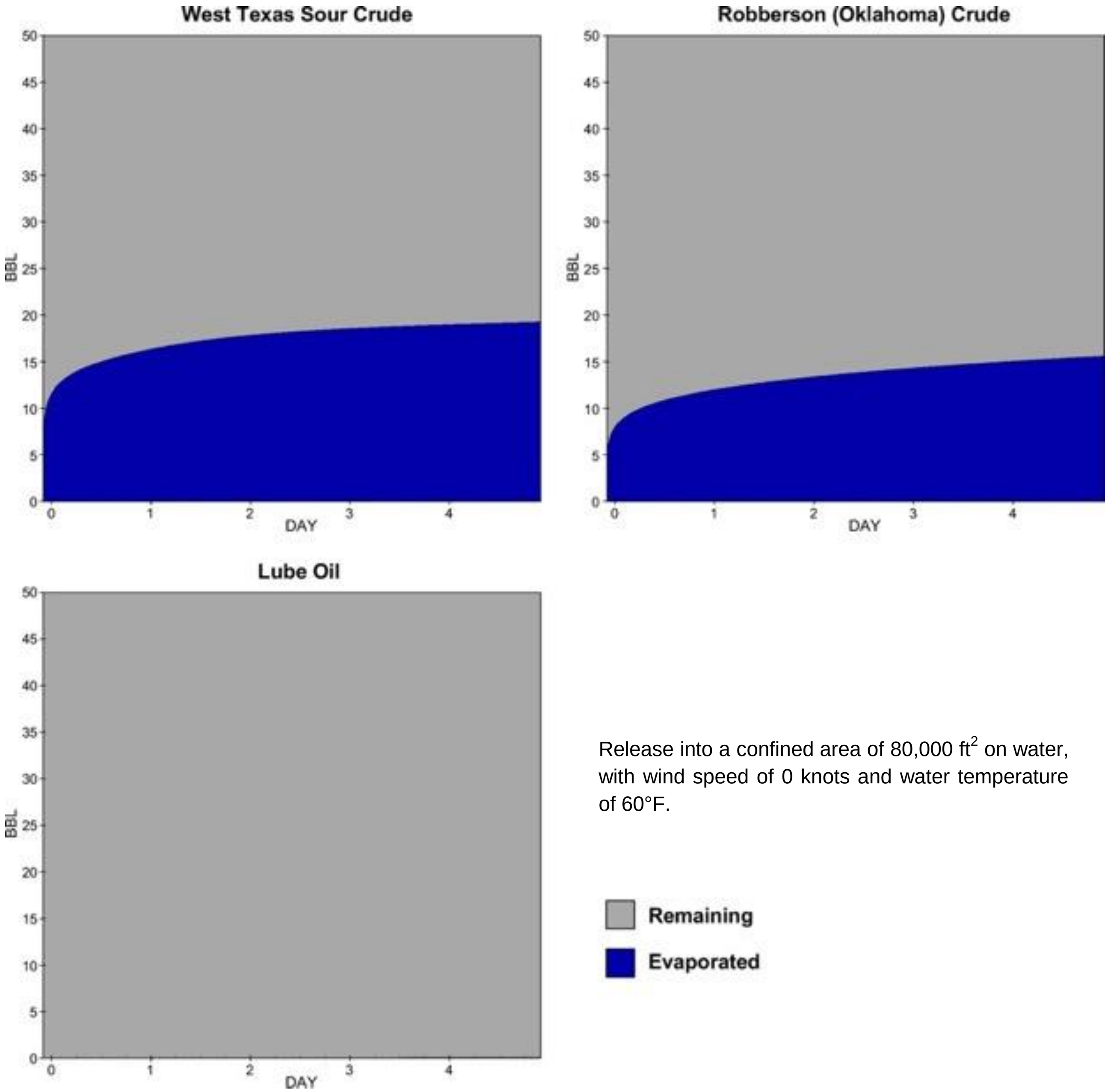


Figure 7—Evaporation over a 5-day Period for a 50-bbl Spill of Group 3 Oils

Table 15—Medium Crude Oils and Intermediate Refined Products: Relative Impact of Response Techniques by Habitat

Green = Least Impact; Yellow = Some Impact; Red = Greatest Impact; - = Not Applicable for That Habitat and/or Oil Type

Response Technique	Water Habitats				Land Habitats						
	Lake	Pond	Large River	Stream	Developed Land	Forested Upland	Forested Wetland	Grassland/ Cropland	Grassy Wetland	Permeable Substrate	Impermeable Substrate
Natural Attenuation	Green	Yellow	Green	Yellow	Yellow	Yellow	Green	Green	Yellow	Green	Green
Containment/Recovery											
Booming	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Skimming	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Barriers	Green	Green	Green	Green	Green	Green	Yellow	Green	Red	Green	Green
Trenching	-	-	-	Yellow	Green	Yellow	Red	Yellow	Red	Green	-
Removal											
Manual Removal	-	Yellow	-	Yellow	Green	Green	Yellow	Green	Yellow	Green	Green
Vacuum/Pumping	Green	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green
Sorbents	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Excavation	Yellow	Red	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	-
Dredging	Yellow	Red	Yellow	Red	-	-	Red	-	Red	-	-
Debris Removal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Washing/Recovery											
Flooding	-	-	-	Green	Green	Green	Green	Green	Green	Green	Green
Low Pressure/Ambient Water Flushing	-	-	-	Green	Green	Yellow	Yellow	Yellow	Green	Green	Green
High Pressure/Hot Water Flushing	-	-	-	-	Green	Yellow	Red	-	Red	Yellow	Yellow
In Situ Treatment											
Sediment Reworking/Mixing On Land	-	-	-	-	Green	Yellow	Red	Yellow	Red	Yellow	-
Sediment Agitation in Water	Yellow	Yellow	Yellow	Yellow	-	-	Red	-	Red	-	-
Vegetation Removal	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	-	-
In Situ Burning	Green	Yellow	Green	Yellow	Green	Red	Red	Green	Yellow	Yellow	Yellow
Biological Treatment											
Nutrient Addition	-	-	-	-	Green	Green	Yellow	Green	Yellow	Green	-
Microbe Seeding	-	-	-	-	Green	Green	Yellow	Green	-	Green	-
Phytoremediation	-	-	-	-	Green	Green	Green	Green	Yellow	Green	-
Chemical Treatment											
Solidifier	Green	Green	Green	Green	Green	Green	Yellow	-	Red	Green	Green
Surface Washing Agent	-	-	-	-	Green	Yellow	Yellow	-	Yellow	Yellow	Yellow
Herding Agent	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Dry Ice Blasting	-	-	-	-	Green	-	-	-	-	-	Green

Table 16—Technique Considerations for Spills of Group 3 Oils On Land

Phase	For spills of ***medium crude oils and intermediate refined products*** **on LAND:**
Control and Contain Phase	— Quickly identify where oil could reach a water body and install intercept barriers. Appendix B provides BMPs for ground disturbing activities. — Block drains to underground systems using sand bags, water-filled plastic bags, or sorbents to prevent oil from reaching surface or ground waters. — Increase the sorption capacity of surface layers by adding sorbents, including organic sorbents. RRT approval may be required to leave organic sorbents in place. — Construct berms, trenches, and other methods to prevent further spread of oil. Plastic sheeting to line the sides of sediment berms can prevent or reduce oil penetration. — Add water and maintain a water layer for oil that is contained behind barriers or in trenches to reduce penetration into porous substrates. — Flooding and low-pressure flushing can remobilize oil from substrates and redirect oil towards recovery devices, being careful to avoid mixing oil with sediment or eroding sediment with too high water pressures. — Recover collected free oil as quickly as possible. — Monitor weather to predict when rainfall could cause containment measures to fail. Consider more aggressive actions to prevent loss of containment and be prepared to contain remobilized oil under these conditions. — Consider in situ burning for thicker (1–2 mm) oil trapped in wetlands, fields, snow, or ice. Guidelines for burning oil in wetlands are described in Michel and Rutherford (2013). Many medium oils leave very little burn residue if burned before much weathering takes place.

Phase	For spills of ***medium crude oils and intermediate refined products*** **on LAND:**
Cleanup Phase	— Appendix B provides BMPs for all cleanup activities on land. — Install walking boards, geotextile "sand mats" or other materials in access areas with soft substrates to prevent mixing oil into sediments and damaging vegetation. — Remove oiled sediments manually and/or mechanically depending on equipment access. Consider sediment reworking as a final method to break up residues in unvegetated habitats. — Anticipate large amounts of oiled debris, leaves, sticks, and twigs mixed into oil pooled on the ground, requiring positive displacement pumps with cutter knives. Minimize removal of unoiled or lightly oiled debris, particularly large woody debris. See guidance in Section 7.5. — Remove live oiled vegetation only to prevent contact with sensitive species or in high public-use areas. Consider anticipated rate of weathering to a non-sticky coat and timing of use. — Monitor weather to be prepared for rainfall and higher water flow rates or elevated water levels, which could remobilize stranded oil, to take advantage of natural flushing, and to be prepared to contain remobilized oil under these conditions. — Consider adding organic sorbents (e.g., peat, kenaf, bagasse), that can be left in place, to reduce contact hazards for wildlife, particularly in sensitive areas where removal actions could cause additional damage, or when removal cannot be conducted sufficiently quickly to reduce wildlife impacts. Sorbents can be lightly applied after gross oil removal. RRT approval may be required for leaving organic sorbents in place. — Consider in situ burning of oil residues after bulk oil removal, particularly on crop lands where soils can be tilled and fertilized post-burn. This method has been successful at past spills.

Table 17—Technique Considerations for Spills of Group 3 Oils On Water

	For spills of ***medium crude oils and intermediate refined products*** **on WATER:**
Control and Contain Phase	— Immediately establish an air monitoring program to determine site safety, warm/hot zones, PPE requirements for workers, and community health concerns. Table 29 provides information regarding monitoring parameters and thresholds for worker safety. — In rivers and large streams, booms can contain and deflect oil or divert to low-flow areas and natural collection areas (side channels, downstream of point bars, and away from cut banks), ensuring that there is appropriate on-water or on-land access for recovery operations. — If there are no accessible natural collection points, consider excavating a side pit or ditch at the river bank and divert oil into it for recovery. — Deploy deflection or exclusion booms to protect sensitive areas. Section 7.1 provides additional information on techniques for the protection of water intakes. — If there is a dam or water control structure upstream, consider asking the operators to (a) temporarily reduce discharge rates to the river, to reduce river currents and improve boom performance, and/or (b) release a deluge after the operational day to flush oil through the work area towards a control area for recovery. — Monitor wind direction to aid in deflection and containment efforts and for personnel safety. — Monitor weather forecasts as potential increases in water flow and higher water levels could result in failure of containment and spread oil over larger areas. Be prepared to contain remobilized oil under these conditions and consider more aggressive removal actions to prevent loss of containment. — In small streams, barriers or trenches constructed downstream can prevent further spread of oil to sensitive areas, for example, into salmon spawning or juvenile fish habitat. Downstream water flow is maintained with underflow dams, siphon dams, or filter fences. In areas with periods of heavy rainfall, consider construction of at least two dams per location, to provide system redundancy to reduce risks of dam failure during high runoff events. Appendix B provides BMPs for ground disturbing activities on streams. — Where the water depth behind the underflow dam is so shallow that oil is entrained into the water and passes through the pipes, consider placing deflection booms at the head of the dam where current is slowed and oil could be diverted to collection areas. — Flooding and low-pressure flushing can remobilize bulk oil that is trapped in log jams, beaver dams, and vegetation or soaked into sediments at the water edge into open water for recovery. This can be accomplished with pumps, prop washing with vessels, or the directed air flow from airboats or leaf blowers. As these types of oil weather, increased viscosity and adhesion can reduce the effectiveness of this technique over time. — Chicken wire fences, hardware cloth, or other screen material could prevent debris from entering recovery devices. — Sorbents can recover small amounts of oil escaping from containment booms or below in-stream barriers. Use skimming and vacuum to recover larger amounts of oil to minimize waste generation. — Loose, particulate sorbents should not be used on flowing water, but could be used on isolated water bodies to increase oil removal rates. — In situ burning for thicker oil (need at least 2–5 millimeters on water for ignition) contained in booms or floating debris, snow, or ice. Medium oils can have some burn residue. API (2015) provides guidance for burning inland oil spills.

Table 17—Technique Considerations for Spills of Group 3 Oils On Water (Continued)

	For spills of *medium crude oils and intermediate refined products* on WATER:
Cleanup Phase	— These oils float under most conditions and do not strongly adhere to sediments under water so that dredging and excavation of water bodies would not be necessary. Natural attenuation, passive recovery of sheens, or in situ methods are preferred options. — Flushing of oil trapped in vegetation and debris along river and stream banks and manual removal of oiled shoreline sediments that release bulk oil into the water might be appropriate, as crude oils weather more slowly than light refined products. — Consider live vegetation removal only where needed to access gross oil trapped in floating and fringing vegetation. — Absorbent booms can be effective for heavier sheens because oil can penetrate into this material. — Herders can increase the thickness and thus recovery of oil sheens, or can move oil from under docks in ports and marinas and other shoreline structures. — Solidifiers in socks, booms, or pillows could recover light sheens when standard sorbents are not effective. — Loose solidifiers should be applied only on oil that is physically contained so that the resultant mixture can be recovered. — Where oil has penetrated into coarse-grained stream sediments, flooding and in situ agitation of the stream bed could free oil for recovery with sorbents or could flush oil downstream to recovery areas. — For streams with intermittent and fluctuating flows, consider pumps to divert water flow around heavily oiled work areas, or divert the water to adjacent land areas. — Extensive reworking of stream bank sediments or extensive woody debris removal are not recommended because such methods could cause bank destabilization and erosion. Instead, consider low-pressure flushing at the water line. — Heavily saturated debris can be removed for disposal; however, natural attenuation or in situ treatment could be preferred for lightly and moderately oiled debris because of habitat value of debris, particularly large woody debris, or where access is limited. In some instances, replacement with clean debris might be appropriate if excessive debris removal is conducted. See additional guidance in Section 7.5. — Monitor weather forecasts as rain could increase water flow rates and create higher water levels, which could aid in flushing oil from substrates and debris, and appropriate containment preparations can take advantage of this natural removal process.

6.7 Response Techniques for Spills of Group 4 Oils: Heavy Crude Oils and Heavy Refined Products

6.7.1 Group 4 Oil Behaviors Affecting Response Techniques

This section addresses response techniques for Group 4 oils including: heavy crude oils (San Joaquin Valley crude, Canadian heavy crude oils, diluted bitumen products) and heavy refined products (heavy fuel oil, No. 6 fuel oil, IFO 380). Figure 8 is an example of loss by evaporation of a spill of 50-bbl over a 5-day period on water using the NOAA ADIOS2 oil weathering model as described in Section 4 for three oil types in this Group: of Belridge Heavy (California) crude oil (API = 13.6), Cold Lake Blend diluted bitumen (API = 22.6), and IFO 380 (API = 11.5).

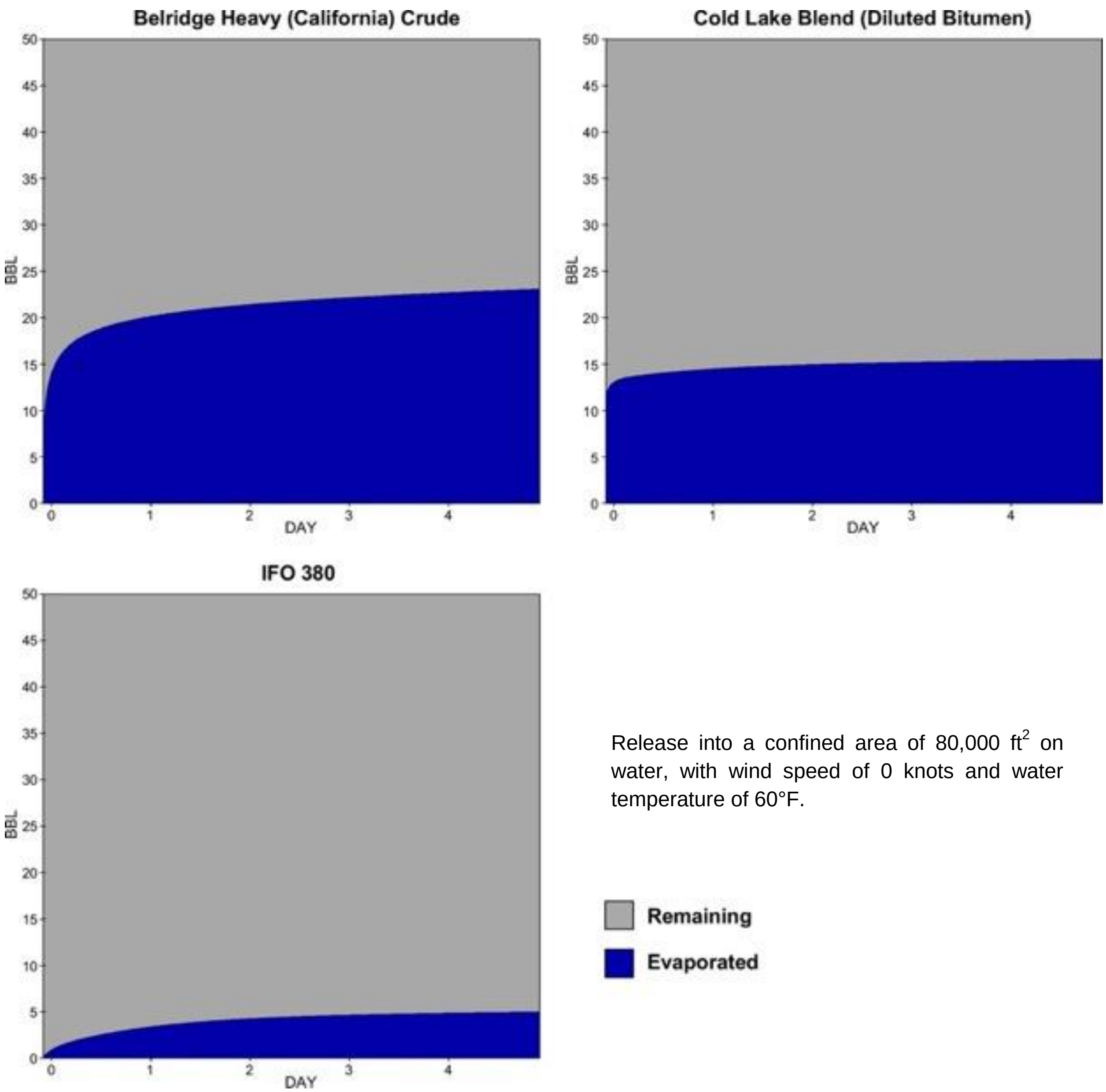


Figure 8—Evaporation over a 5-day Period for a 50-bbl Spill of Group 4 Oils On Water

Heavy oils have the following properties that affect response decisions:

— Lose the volatile fractions at rates similar to other oils, though the volatile fraction content is proportionately low so that greater amounts of the heavy components of these oils remain after the initial weathering phase (Figure 8).

— Form relatively thick slicks, particularly where spreading is constrained in smaller water bodies, which can enhance the rate of recovery on water.

— Have little tendency for natural dispersion in the water column under low-turbulence conditions, because of the initial viscosity and subsequent very high viscosity of weathered oil (Table 5).

— Are unlikely to form stable emulsions on inland waters because sufficient mixing energy often is not available. Exceptions could occur when oil passes through rapids or riffles or over cascades and weirs.

— Are less likely to penetrate deeply into porous substrates; instead, they are likely to form pools on the surface or create a continuous layer of thick oil on riverbanks or lake shorelines.

— Tend to be very adhesive; oil is typically not remobilized once stranded on banks or shorelines.

— Can move vertically in a water column during periods of large day-night temperature variations, as the weathered oil can become very viscous and dense, causing it to become neutrally buoyant or sink to the bottom at night, then rise to the surface during the day as temperatures increase.

— Have a large amount of more persistent components (asphaltenes and resins) that can weather more slowly and could require more aggressive removal to meet cleanup endpoints.

Diluted bitumen spills can have the following properties that affect inland spill response decisions:

— Initially behave like a medium crude oil but as the light diluent fraction evaporates or dissolves, the density increases and can result in the oil becoming neutrally buoyant or potentially sinking.

— Can break into droplets under turbulent conditions which could then interact with suspended sediments and organic matter to form oil:particle aggregates that can sink to the bottom in low-turbulence areas.

— Sunken oil droplets can be released from the river or lakebed by various mechanisms; thus, chronic sheening is a potential concern in low-flow areas where oil has accumulated.

— Sunken oil:particle aggregates on river beds could become resuspended during higher flow conditions, migrate downstream, and subsequently accumulate in low-flow areas.

— The bitumen component is already highly weathered and could undergo little additional weathering when stranded on the shoreline or if accumulated in bottom sediments. More aggressive removal may be appropriate under certain conditions as this residual oil may be very persistent.

6.7.2 Response Techniques for Group 4 Oils

Table 18 shows the relative potential impacts of response techniques for spills of Group 4 oils on different water and land habitats. Tables 19 and 20 provide guidance for the emergency phases of a response (Control and Contain; Cleanup) are provided for spills on land and water habitats.

Table 18—Heavy Crude Oils and Heavy Refined Products: Relative Impact of Response Techniques by Habitat

Green = Least Impact; Yellow = Some Impact; Red = Greatest Impact; - = Not Applicable for That Habitat and/or Oil Type

Response Technique	Water Habitats				Land Habitats						
	Lake	Pond	Large River	Stream	Developed Land	Forested Upland	Forested Wetland	Grassland/ Cropland	Grassy Wetland	Permeable Substrate	Impermeable Substrate
Natural Attenuation	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Containment/Recovery											
Booming	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Skimming	Green	Green	Green	Green	-	-	Yellow	-	Yellow	-	-
Barriers	Green	Green	Green	Green	Green	Green	Yellow	Green	Red	Yellow	Green
Trenching	-	-	-	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	-
Removal											
Manual Removal	Green	Yellow	Green	Yellow	Green	Green	Yellow	Green	Yellow	Green	Green
Vacuum	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Sorbents	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Excavation	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	-
Dredging	Yellow	Yellow	Yellow	Yellow	-	-	Red	-	Red	-	-
Debris Removal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Washing/Recovery											
Flooding	-	-	-	Green	Green	Yellow	Yellow	Green	Green	Yellow	Yellow
Low Pressure/Ambient Water Flushing	-	-	-	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
High Pressure/Hot Water Flushing	-	-	-	-	Green	Yellow	Red	-	Red	Yellow	Yellow
In Situ Treatment											
Sediment Reworking/Mixing On Land	-	-	-	-	Green	Yellow	Red	Yellow	Red	Yellow	-
Sediment Agitation in Water	Yellow	Yellow	Yellow	Yellow	-	-	Red	-	Red	-	-
Vegetation Removal	-	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	-	-
In Situ Burning	Green	Yellow	Green	Yellow	Green	Red	Red	Green	Yellow	Yellow	Yellow
Biological Treatment											
Nutrient Addition	-	-	-	-	-	Green	Yellow	Green	Yellow	Green	-
Microbe Seeding	-	-	-	-	-	Green	Yellow	Green	-	Green	-
Phytoremediation	-	-	-	-	-	Green	Green	Green	Yellow	Green	-
Chemical Treatment											
Solidifier	-	-	-	-	Green	-	-	-	Red	-	-
Surface Washing Agent	-	-	-	-	Green	Yellow	Yellow	-	Yellow	Yellow	Yellow
Herding Agent	-	-	-	-	-	-	-	-	-	-	-
Dry Ice Blasting	-	-	-	-	Green	-	-	-	-	-	Yellow

Table 19—Technique Considerations for Spills of Group 4 Oils On Land

Phase	For spills of ***heavy crude oils and heavy refined products*** on LAND:
Control and Contain Phase	— Quickly identify where oil could reach a water body and install intercept barriers. Appendix B provides BMPs for ground disturbing activities. — Block drains to underground systems using sand bags, water-filled plastic bags, sand bags, or sorbents to prevent oil from reaching surface water or groundwater. — Berms, trenches, and other methods can prevent further spread of oil. — Plastic sheeting to line the sides of sediment berms can prevent or minimize oil penetration in permeable substrates, such as coarse sediment or debris. — Add water and maintain a water layer for oil that is contained behind barriers to reduce penetration into porous substrates. — Flooding and low-pressure flushing can remobilize oil from substrates and redirect towards recovery devices, being careful to avoid mixing oil with sediment or eroding sediment with too high water pressures. — Recover collected free oil as quickly as possible, which, depending on the volume of oil, could involve portable vacuum systems or sorbents. — Anticipate large amounts of oiled debris, leaves, sticks, and twigs mixed in with oil pooled on the surface, requiring positive displacement pumps with cutter knives. — Consider in situ burning for thicker oil trapped in wetlands, grassland, cropland, snow, or ice. Guidelines for burning oil in wetlands are described in Michel and Rutherford (2013). Heavy oils can leave a residue that might necessitate removal post-burning.

Phase	For spills of ***heavy crude oils and heavy refined products*** on LAND:
Cleanup Phase	— Oil-saturated soils can be removed manually where practical and safe; use mechanical excavation where manual is not practical. — Expect to use more aggressive removal methods (excavation and trenching) because of the slow rate of weathering of heavy oil residues and the potential for chronic release of oil during rainfall and high-water events. — In situ burning can be effective on oil spills that have been trapped in sediments or vegetation, where patches of liquid oil persist in surface sediments, or when oil has soaked into snow or been contained by ice. — Install walking boards, geotextile “sand mats,” or other materials in access areas with soft substrates to prevent mixing oil into sediments and damaging vegetation. — Anticipate large amounts of oiled debris, leaves, sticks, and twigs mixed into oil pooled on the ground, requiring positive displacement pumps with cutter knives. Minimize removal of unoiled or lightly oiled debris, particularly large woody debris. See guidance in Section 7.5. — Can use manual and/or mechanical techniques to remove oiled sediments depending on equipment access and logistics. Sediment reworking can be a final treatment to break up residues in unvegetated habitats. — Consider adding organic sorbents (e.g., peat, kenaf, bagasse) after gross oil removal, that can be left in place (may need RRT approval), to reduce contact hazards for wildlife, particularly in sensitive areas where removal actions could cause additional damage. — Where necessary, remove only the above-ground portion of oiled vegetation, limiting disturbance to root systems, particularly along stream banks to prevent erosion.

Table 19—Technique Considerations for Spills of Group 4 Oils On Land (Continued)

Cleanup Phase	For spills of *diluted bitumen products* on LAND:
	— Residues can be very adhesive so that low-pressure flushing (<50 psi) may not be effective at removing weathered diluted bitumen products from substrates composed of man-made structures or vegetation. — Surface washing agents can increase removal rates; however, diluted bitumen products that have been exposed to the sun for days can only be scrapped off or removed with high-pressure and high-temperature flushing or dry ice blasting. — In forested wetlands, with large amounts of organic debris, diluted bitumen can adhere to the debris and sediments, and might necessitate aggressive removal or even capping to control chronic sheening.

Table 20—Technique Considerations for Spills of Group 4 Oils On Water

Control and Contain Phase	For spills of *heavy crude oils and heavy refined products* on WATER:
	— In rivers and large streams, booms can contain oil or to deflect to low-flow areas and natural collection areas (side channels, downstream of point bars, and away from cut banks), making sure there is access for on-water or on-land recovery operations. — If there are no accessible natural collection points, consider excavation of a pit or ditch at the river bank and diverting oil for recovery. — Deploy deflection or exclusion booms to protect sensitive areas. Section 7.1 provides additional information techniques specifically for protection of water intakes. — If there is a dam or water control structure upstream, consider asking the operators to (a) temporarily reduce discharge rates to the river, to reduce river currents and improve boom performance, and/or (b) release a deluge after the operational day to flush oil through the work area towards a control area for recovery. — Monitor wind direction to aid in deflection and containment efforts. — Monitor weather forecasts as potential increases in water flow rates and higher water levels could result in failure of containment and spread oil over larger areas. Be prepared to contain remobilized oil under these conditions and consider more aggressive removal actions to prevent loss of containment. — In small streams, construct barriers or trenches downstream to prevent further spread of oil, for example into salmon spawning or juvenile fish habitat. Downstream water flow is maintained with underflow dams, siphon dams, or filter fences. In areas with periods of heavy rainfall, consider construction of at least two dams per location, to provide system redundancy to reduce risks of dam failure during high runoff events. Appendix B provides BMPs for ground disturbing activities on streams. — Flooding and low-pressure flushing can remobilize bulk oil that is trapped in log jams, beaver dams, and vegetation or soaked into sediments at the water edge to water for recovery. This can be accomplished with pumps, prop washing with vessels, or directed air flow from airboats or leaf blowers. As these types of oil weather, increased viscosity and adhesion could reduce the effectiveness of this option. — Chicken wire fences, hardware cloth, or other screen material could prevent debris from entering recovery devices. — Sorbents can recover small amounts of oil escaping from containment booms or below in-stream barriers.

Table 20—Technique Considerations for Spills of Group 4 Oils On Water (Continued)

Phase	Considerations
Control and Contain Phase	**For spills of *heavy crude oils and heavy refined products* on WATER:**
	— Loose, particulate sorbents should not be used on flowing water, but could be used on isolated water bodies to increase oil removal rates. Recover all loose sorbent material.
	— Consider in situ burning for thicker oil (at least 5–10 millimeters on water is needed for ignition) contained in booms or trapped in floating debris, snow, or ice. Heavier oils can have more residue that might need removal post-burning. Consider near-term changes in water levels that could either strand oil during lower levels or remobilize oil during higher levels. API (2015) provides guidelines on burning inland oil spills.
	For spills of *diluted bitumen products* on WATER:
	— The initial behavior of diluted bitumen products may be similar to a conventional medium crude oil, thus booming and recovery techniques could be the same as for those crude oils.
	— Whenever feasible, rapid containment and recovery are essential, as rapid evaporation of the light diluent fraction may create a heavy oil that could be near, or in some cases greater than, freshwater density.
	— In most cases, in situ burning of diluted bitumen spill to water could be effective only for the first 24 hours after release due to evaporative loss of the lighter diluent fractions.

Phase	Considerations
Cleanup Phase	**For spills of *heavy crude oils and heavy refined products* on WATER:**
	— API Technical Report 1154 provides guidance for recovery of heavy oil that has sunk to the bottom of a water body.
	— Flushing may be able to remobilize oil trapped in vegetation and debris along river and stream banks for recovery using sorbents.
	— Sorbents are available that are specially designed for heavy, viscous oils to maximize oil uptake while minimizing waste generation.
	— Sorbents typically require maintenance for long periods, because of the persistence of heavier oils, particularly in low-energy settings.
	— For streams with intermittent and fluctuating flows, consider pumps to divert water flow around heavily oiled works areas, or divert the water to adjacent land areas.
	— Where oil as penetrated into coarse-grained stream sediments, flooding and agitation of the stream bed could be conducted to free oil for recovery with sorbents or to flush oil downstream to recovery areas.
	— Heavily oiled vegetation and debris might have to be removed because oil can remain sticky for weeks or longer, posing exposure contact hazards to wildlife.
	— For lightly to moderately oiled debris, consider the anticipated length of time before the oil dries and no longer poses contact hazards to wildlife and the timing of wildlife use, particularly for large woody debris which has important habitat value. Consider applying organic sorbents or dry fine-grained sediments to reduce contact hazards.
	— Reworking of stream bank sediments is not recommended because such methods could cause bank destabilization and erosion. Instead, consider low-pressure flushing at the water line.
	— Manual removal of oiled shoreline sediments that release bulk oil into surface water might be appropriate as heavy oils typically weather more slowly.

Table 20—Technique Considerations for Spills of Group 4 Oils On Water (Continued)

	For spills of *heavy crude oils and heavy refined products* on WATER:
	— Monitor weather forecasts as rain and increased water flow rates and create higher water levels, which could aid in flushing oil from substrates and debris, and appropriate containment preparations can take advantage of this natural removal process.
	For spills of *diluted bitumen products* on WATER:
	— For floating diluted bitumen, see above techniques for heavy crude oil. — If some of the diluted bitumen mixes with sediment or organic particles and sinks, oil can separate from the particulates as the water warms and then refloat, creating oil droplets and sheens on the water surface. — Sediment agitation is a response option for oil removal in fine-grained sediments. Evaluation of this option considers the risk that some of the liberated oil can remain suspended in the water column and settle back to the bottom down current: This technique could be a viable option if the mobilized oil can be contained and removed. Agitation could mix oil deeper into the sediments below the depth or normal reworking. Field tests can evaluate the efficacy of this method prior to full-scale application.

6.8 Response Techniques for Spills of Group 5 Oils: Submerged Oil in the Water Column

6.8.1 Group 5 Oil Behaviors Affecting Response Techniques

API Technical Report 1154 (API 2016a,b) covers the topic of sunken oil detection, containment, and recovery techniques. Therefore, this section addresses only oils that either immediately submerge in the water column after release or become submerged after weathering and/or uptake of sediment and/or organic matter. These oils can be heavier or become heavier than the receiving water, but do not sink at or near the release site because of strong currents or turbulence in the water body. In April 2016, the USCG updated the Oil Spill Removal Organization Guidelines to include a classification for nonfloating oils. The Nonfloating Oil Classification meets regulatory requirements of Group 5 oils in accordance with criteria set forth by 33 CFR§154.1047 and 33 CFR§155.1052 and the inherent risk of other heavy oil types that can submerge or sink.

6.8.2 Response Techniques for Submerged Oil

Potential techniques for submerged oil detection, containment, and recovery are summarized in Table 21. Experimental detection techniques are included as there are currently few proven, effective methods for the detection of submerged oil. The USCG Research and Development Center has tested experimental sonar and optical scattering systems for detection of oil in the water column in the large tank at Ohmsett with promising results (Fitzpatrick and Tebeau, 2013; Fitzpatrick et al., 2014). However, further refinement and field testing were recommended.

Table 21—Response Techniques for Submerged Oil Detection, Quantification, Containment, and Recovery

Response Technique	Description
Detection and Quantification	
Sonar System	Multibeam sonars can generate 2D and 3D images of an oil plume, as demonstrated in lab and field tests. Mostly developed for subsea leak detection; currently (2016) has not been tested on an oil spill.

Table 21—Response Techniques for Submerged Oil Detection, Quantification, Containment, and Recovery (Continued)

Response Technique	Description
Detection and Quantification	
Acoustic Camera	Very high-frequency and high-resolution imaging sonar can detect oil particles in the water column, generating a 3D optical-like image, even in low visibility settings. Potentially may best be deployed at a site to document submerged oil movement over time. Currently (2016) has not been tested on an oil spill.
Fluorometry	Fluorometers can detect the presence of aromatic hydrocarbons, as an increase above background intensity. Can differentiate between oil and natural materials that fluoresce. Many models are available for different applications, often to monitor water quality at fixed locations. Some models include optical scattering for measurement of turbidity, which can be useful for submerged oil detection.
Optical Scattering	Optical system that uses reflection and refraction of light by suspended oil droplets to determine mass and volume concentration, droplet size, and density of entrained oil. Ohmsett tank tests showed promise. Currently (2016) has not been tested on an oil spill.
Mass Spectrometer	Real-time mass spectrometer is mounted on an underwater vehicle with a navigation system and flown at appropriate depths. Most effective for dissolved oil fractions. Limited availability as of 2016.
Induced Polarization	An electric current is induced into the water column through towed electrodes, and voltage is monitored through other towed electrodes. Oil in water is detected as a phase shift between transmit and receive signals in a vertical cross section of the water.
Sorbents	Sorbents (mostly oil snare) are attached to a rope or enclosed in containers and suspended from the surface to the bottom. Regular inspection indicates presence of oil adhered to sorbents and allows sampling.
Nets	Nets of various mesh size are towed at appropriate depths and pulled to the surface for visual inspection and sampling.
Underwater Still or Video Camera	Cameras can be mounted on an underwater vehicle with navigation software to generate geo-referenced images. Water visibility should be 1–3 feet minimum. Fouling of the lens can occur.
Diver Observation	Divers with appropriate contaminated water training and gear, usually with diver comms and video, can make accurate and immediate observations. Limited by poor visibility, strong currents, bottom obstructions, and bottom time.
Containment	
Top Curtain	Water-permeable or -impermeable material is suspended from floating booms and held in place by chains, anchors, piping, etc. Submerged oil just below the surface can be directed out of the flow to areas for deposition if heavier than water or floating to the surface for recovery if lighter than water. Curtain material can quickly become fouled by oil, suspended sediment, or algal growth. Need high-angle deployment in moderate flow.
Bottom Curtain/Half Curtain	Water-permeable or -impermeable material is placed on the bottom and held in place by chains, anchors, piping, etc. By slowing water flow, suspended oil and oil:particle aggregates settle out and accumulate on both sides of the curtain. Curtain material can quickly become fouled by oil, suspended sediment, or algal growth. Need high-angle deployment in moderate flow.
Sediment Curtain/Screen	Water-permeable or -impermeable material is suspended from buoyancy floats to a specified water depth (usually 1–2 feet above the bottom) and held in place by lines, anchors, and ballast chain along the bottom. Designed for turbidity control and are most effective in low currents and start to fail when currents exceed 1 knot. Could be used in combination with agitation to contain the spread of oil and suspended sediments.
Air Curtain	Air bubbles are injected into the water column from the bottom of a water body to create an upward water flow that acts as an oil barrier on the water surface. Tank tests show failure occurs at about 0.7 knots. Used at harbor or port locations as fixed containment barriers around vessels or as an exclusion method in narrow canals to water intakes.

Table 21—Response Techniques for Submerged Oil Detection, Quantification, Containment, and Recovery (Continued)

Response Technique	Description
Containment	
Other Bottom Barrier	Natural materials (coir logs or woody vegetation) are placed on the bottom as semi-permeable barriers to oil moving along the bottom. Benefits are no surface expression and possibility no need for removal of the barrier materials.
Enhance Natural Collection Areas	A hydro-geomorphic analysis is conducted of the water body to identify natural collection areas. Then structures (coir logs, trees) are placed to either direct flow into these areas or to slow currents so oil suspended in the water column settles out. Sediment sampling devices are deployed in these areas to monitor for sediment accumulation and need for removal by dredging or excavation.
Excavate/Dredge Side Pools or Bottom Depressions	Pits or trenches are excavated in a waterbody to create a depression where oil could settle out of the water column. A hydro-geomorphic analysis could be used to identify potentially effective sites. Could necessitate removal, handling, and disposal of large volumes of sediment. Could be a long-term containment strategy.
Recovery	
Sorbents	Sorbents (often oil snare) are enclosed in mesh containers or filter fences and placed in the water column at the appropriate depth (at which oil is moving). Oil droplets suspended in the water column adhere to the sorbent. Closed loop snare might be more effective.
Pneumatic System	Microbubble generators that generate air bubbles of differing sizes are placed under an oil plume. The air bubbles adhere to oil droplets in the water column and lift them to the water surface for recovery with sorbents, skimmers, etc.
Nets	Nets of various mesh size (1–5 millimeters) are towed at low speed (up to 0.6 knots) in an oil plume or placed across the water body. Only effective for very viscous oils. Use at spills has shown some effectiveness for oil just below the surface. Not possible to clean the net once it starts to leak or otherwise fails. Sorbents can be added to increase oil retention. A liner can be added to the cod end of shrimp nets to serve as a quick-release storage bag. USCG currently (2016) is testing absorbent foam that can be wrung out and re-used multiple times, which would make use of nets feasible for recovering less viscous oils.

Submerged Oil Detection and Quantification: Techniques that have been used for submerged oil detection in a water column during actual spills are fluorometry (used often to monitor for dispersed oil), sorbents, nets, video cameras, and diver observations, all with very limited success. There are no proven methods to map the spatial extent of a submerged oil plume in a water column, particularly when there are oil:particle aggregates present. However, sonar systems are the most promising because they have wide areal coverage. Induced polarization is another promising technology, but with no current (2016) demonstrated field tests. Most of the other methods collect data at a single location, thus have to be towed in tight vertical and horizontal transects to detect a plume location and areal extent, which can be difficult when a submerged oil plume is in motion. It is important to be able to map both the vertical and horizontal extents of a submerged oil plume, which determines possible containment and recovery techniques.

For submerged and sunken oil spills in rivers, it is very important to understand the fluvial geomorphology of the river components, to be able to anticipate where suspended oil is likely to accumulate on the bottom, and the conditions under which it is likely to become remobilized. During the 2010 spill of diluted bitumen in the Kalamazoo River, Michigan, mapping of the geomorphic characteristics of the river (e.g., backwater, channel deposits, oxbows, depositional bars, impoundments, islands) enabled response planners to identify depositional areas of the river where submerged oil could accumulate under different flow conditions (USEPA, 2016; Fitzpatrick et al., 2013, 2015). This fluvial geomorphic framework became the backbone of the submerged and sunken oil assessment, monitoring, and recovery.

Table 22 lists the advantages and considerations of techniques for detection and quantification for submerged oil.

Table 22—Advantages and Considerations for Submerged Oil Detection and Quantification

Advantages	Considerations
Acoustic Sensor	
— Based on well-developed, commercially available technology that has been used in various aquatic applications. — Can survey a wide area of a water column and generate 3D plume maps. — Showed promise during testing at Ohmsett. — Works in currents or tow speed up to 5 knots. — No depth limitations; very compact and easily deployed on underwater vehicles.	— Not able to conclusively discriminate petroleum hydrocarbons from other materials that can have a similar acoustic signature. — Acoustic profiling at multiple frequencies generates a large amount of data that must be stored and processed. — Real-time interpretation currently entails subjective analysis by a trained operator.
Fluorometry	
— Based on well-developed, commercially available technology that has been used in various aquatic applications, including dispersed oil monitoring. — Can provide geo-referenced oil locations in real time and at high spatial resolution. — With real-time results, can modify a survey area to locate oil boundaries and concentration areas. — Other sensors can be added (e.g., temperature, dissolved oxygen).	— Uncertain how larger oil droplets or oil:particle aggregates affect detection and quantification. — Horizontal or vertical line transects only sample a small part of a water body. — Potential for fouling of the flow cell. — Collects data at single points along vertical and horizontal transects that have to be interpolated to generate 3D concentration maps, which can be difficult for plume that is constantly changing.
Optical Scattering	
— Compact, inexpensive instruments are available. — Showed promise during testing at Ohmsett; however, needs further testing under field conditions. — Works in currents or tow speed up to 5 knots.	— Collects data at single points along vertical and horizontal transects that have to be interpolated to generate 3D concentration maps, which can be difficult for plume that is constantly changing. — Algorithms to determine particle size and density can be challenged by oil:particle aggregates of widely varying size and shape. — Entails a specially trained team of operators and interpreters.
Mass Spectrometer	
— Use and availability has expanded, particularly for oil and gas exploration and water quality monitoring. — Can provide geo-referenced oil locations in real time and at high spatial resolution.	— Only works if there are soluble components in water. — Collects data at single points along vertical and horizontal transects that have to be interpolated to generate 3D concentration

Table 22—Advantages and Considerations for Submerged Oil Detection and Quantification (Continued)

Advantages	Considerations
Mass Spectrometer	
	maps, which is difficult for plume that is constantly changing. — Horizontal or vertical line transects only sample a small part of a water body. — Entails a specially trained team of operators and interpreters.
Induced Polarization	
— Laboratory studies show ability to detect oil in water at concentrations of a few ppm. — Collects data in 2D transects can be assembled quickly to generate a 3D map of an oil plume.	— Only laboratory studies show effectiveness at detection of oil in the water column; no spill testing. — Entails a specially trained team of operators and interpreters.
Sorbents	
— Can be placed at different depths in the water column. — Integrates oil presence over deployment time; time-series data can be used to track trends, although numerous data points are needed to be meaningful. — Low-tech but uses readily available materials, so possible for rapid deployment without special teams.	— Time and labor intensive for deployment, inspection, and replacement. — Not feasible for deployment in strong currents, likely no greater than 2–3 knots. — No calibration on efficacy of oil adsorption and how it might change over time. — Low temporal information on when oil was present during the period of deployment.
Nets	
— Low-tech but uses readily available materials, so possible for rapid deployment without special teams. — Could be installed at different positions and/or depths across a water body to cover a larger area than sorbents.	— Time and labor intensive for deployment, inspection, and replacement. — For towed nets, might not know on where along the tow oil was encountered. — Can have issues with fouling by debris or snagging on bottom obstructions (if towed). — For stationary nets, low temporal information on when oil was present during the period of deployment. — No calibration of efficacy of oil adsorption, particularly using local net materials and in currents >1–2 knots. — More waste material for disposal once contaminated, even if part of the net is oiled.

Table 22—Advantages and Considerations for Submerged Oil Detection and Quantification (Continued)

Advantages	Considerations
Underwater Still or Video Camera	
— Can generate high-resolution, geo-referenced imagery of characteristics of any visible oil. — Images can be transmitted to the Unified Command in real time. — Video camera deployed at a fixed location can capture oil behavior in currents over time.	— Not effective in low- to no-visibility conditions. — Fouling of the camera lens can occur quickly if a large amount of oil is encountered. — Horizontal or vertical line transects only image a small part of a water body.
Diver Observation	
— Can be quick data turnaround; divers can provide real-time imagery and observations to the surface, which in turn can be transmitted to the Unified Command. — Experienced river divers can conduct surveys in high-current environments that restrict ROV operations or other towed systems due to bottom obstructions.	— Contaminated water diving necessitates special equipment, training, and decontamination procedures. — Not effective in low- to no-visibility conditions. — Many environmental limitations including weather, strong current, water depth, ice/cold water, and debris. — Low coverage rate; length umbilical limits movement away from the dive support vessel.

Submerged Oil Containment and Recovery: As noted in Table 21, feasible and practical options to contain submerged oil in the water column are very limited. Containment is very difficult if current speeds and/or turbulence are sufficient to keep oil suspended in the water column. Techniques are available that can: 1) divert some of the submerged oil into low-flow areas where oil can refloat or sink depending on the relative density compared to the local water, such as where rivers enter impoundments; 2) enhance natural collection areas or excavate low-flow, slough-type side channels; and 3) contain submerged oil in small areas of low flow that are encircled by sediment curtains or air curtains around dredging activities, or where streams or culverts enter a lake or slow moving river.

Figure 9 illustrates a design for conifer tree sediment traps used during the response to the 2010 Enbridge Pipeline spill of diluted bitumen in the Kalamazoo River, Michigan (USEPA, 2016). These systems were deployed in 2012 and 2013 to slow the downstream migration of submerged oil in the river channel. Hydrodynamic modeling identified specific sites where a bottom obstruction could enhance trapping and the settling capabilities of an existing depositional area. Sediment trap sampling devices (two 32-ounce mason jars, mounted to a wooden box, and weighted with a concrete block) were placed in each location and monitored to determine the type, amount, and oil content of sediment accumulations. Oiled sediment accumulated in the traps and was removed by dredging or excavation after dewatering.

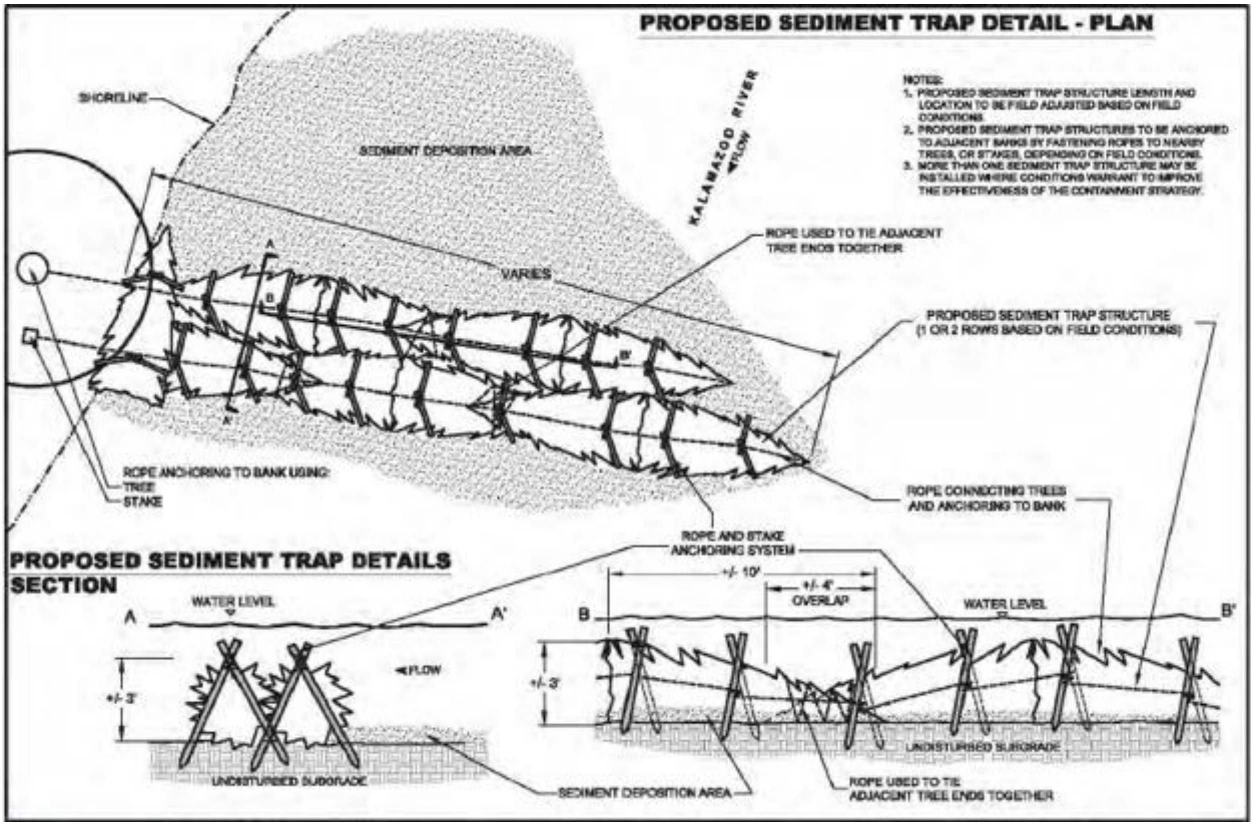


Figure 9—Design for the Sediment Trap Using Conifer Trees That Was Deployed Successfully in the Kalamazoo River, Michigan (USEPA, 2016)

Options for techniques to contain or recover submerged oil first necessitate knowledge of the exact location of the oil, in particular, whether it is moving in the upper water column, along the bottom, or throughout the water column. The flow conditions are measured in the water where oil is located and where containment or recovery methods are to be implemented; this can be achieved using acoustic Doppler current profiler meters that have the advantage that they measure flow rates throughout the water column. With these data, appropriate options for containment or recovery can be evaluated. Similar to the concept of deploying surface booms at angles in the current to prevent entrainments, any kind of curtain or barrier would perform better if deployed in the water column or on the bottom at an angle to the water flow. Multiple systems, in sequence, such as a chevron configuration, and/or on either side of the water body, would be required as the entire water body could not be covered by a single curtain or barrier, except in very narrow channels.

Figure 10 shows the design of a bottom curtain system used during the diluted bitumen spill into the Kalamazoo River and the 2013 deployment configuration. The spill occurred in July 2010, and these systems were deployed in 2012, 2013, and 2014; they were removed over the winter due the presence of ice. These systems were large, up to 700 feet long, and needed extensive logistics to deploy, maintain, and remove. Hydrodynamic models helped to design the angle of deployment and the deployment locations; the systems were deployed in tandem and chevron configurations, similar to surface booms.

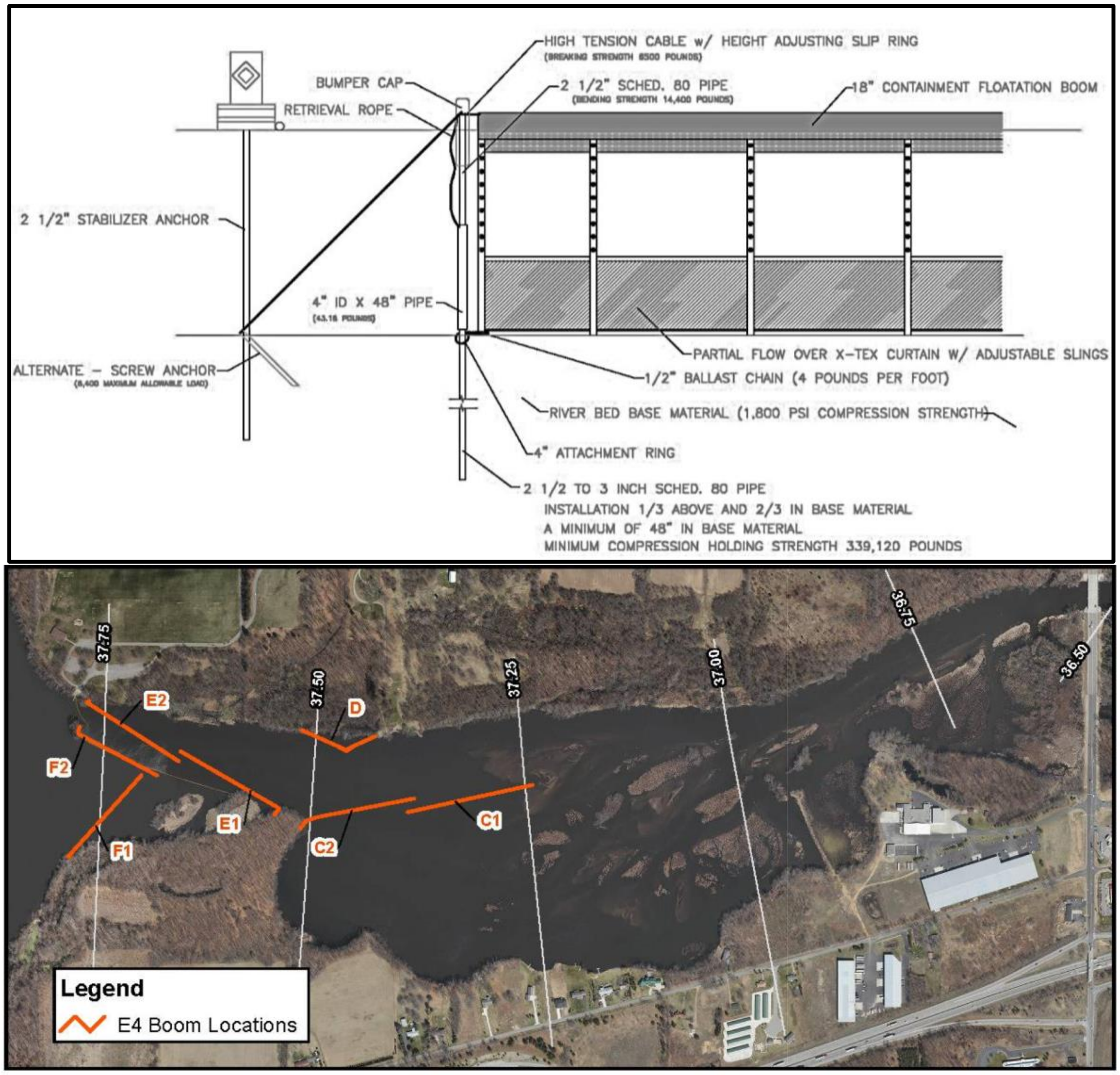


Figure 10—Bottom Current System Design (top) and Deployed in 2013 during the Kalamazoo River Spill Response (bottom) (USEPA, 2016)

Table 23 lists the advantages and considerations of techniques for containment for submerged oil.

Table 23—Advantages and Considerations for Submerged Oil Containment

Advantages	Considerations
Top Curtain	
— Deployment similar to floating booms, at appropriate angle to the currents, to direct oil to low-flow areas for recovery. — Can be deployed in ways to allow navigation. — If oil is mostly moving in the upper water column, that zone is targeted.	— Not effective at high currents, similar to surface booms. — Only addresses oil just below the surface. — Entails extensive logistics support and resources to deploy, maintain, and remove. — The skirt material can rapidly be fouled by oil and algal growth, rendering it less effective.

Table 23—Advantages and Considerations for Submerged Oil Containment (Continued)

Advantages	Considerations
Top Curtain	
	— Entails frequent maintenance to remove snags. — Has to be removed during freeze-up periods or periods of sustained higher flows (e.g., spring runoff).
Bottom Curtain	
— Deployment similar to floating booms, at appropriate angle to the currents, to direct oil to low-flow areas for recovery. — If oil is moving along the bottom, that zone is targeted.	— Not effective at even moderate currents, which can scour the bottom sediments in front/behind the structure. — Entails extensive resources to deploy, maintain, and remove. — Affects only oil moving on and just above the bottom.
Sediment Curtain/Screen	
— Curtains constructed of hydrophilic materials can sorb oil as well as slow the flow and increase sedimentation. — Half-curtains or partial curtains can be deployed at angles to the flow in moderate-flow areas to slow currents and increase deposition of oil and oiled sediments.	— Full curtains are only effective in low-flow areas, so the curtain can maintain contact with the bottom; however, these areas are where risk of oil mobilization is low. — Requires measurement of current speeds at surface and/or bottom and knowledge of hydraulics for proper design. — Can interfere with navigation.
Air Curtain	
— Does not interfere with navigation. — Could be used to protect sensitive areas/water intakes. — Can be scaled up as needed, but with increasing complexity. — Could help bring oil in the water column to the surface. — Not likely to affect fish and wildlife, and can help to reduce risk of hypoxia.	— Only effective in very low-flow areas, where risk of oil mobilization is also low. — Likely less effective with larger oil particles or viscous oil. — Requires extensive logistics support. — Logistics at the deployment site (air generators, power supplies) can limit where they can be deployed.
Other Bottom Barrier	
— If constructed of natural, degradable materials, might not have to be removed. — Less logistics for deployment, assuming a simpler anchoring system.	— Not effective at even moderate currents, which can scour the area in front/behind the structure. — Affects only oil moving on and just above the bottom. — Probably only feasible for smaller rivers.

Table 23—Advantages and Considerations for Submerged Oil Containment (Continued)

Advantages	Considerations
Enhance Natural Collection Areas	
— Builds on natural processes and uses natural materials that can be left in place. — Oil that refloats can be recovered by standard response techniques. — Does not interfere with navigation if placed below the water surface.	— Restricted to areas of natural accumulation, which can be sensitive or high-public use areas. — Mixes oil with co-accumulated clean sediment. — Could require dredging to remove the accumulated oil and sediment, which disturbs benthic habitats and can affect water quality. — Need a good understanding of seasonal flow patterns so sudden floods do not flush out oiled sediments.
Excavate/Dredge Depression	
— Takes advantage of natural processes for oil deposition. — Might be effective in combination with top or bottom curtains that direct oil to low-flow areas.	— Requires removal and storage/disposal of potentially large amounts of clean sediment to create a depression. — Requires periodic dredging or excavation of accumulated oiled sediments. — Mixes oil with co-accumulated clean sediment. — Disturbs benthic habitat and could affect water quality during dredging or excavation. — Need a good understanding of sediment transport along the bottom under different current and wind conditions.

Techniques for successful recovery of submerged oil are limited. Sorbents can be placed in mesh containers (e.g., gabion baskets) and placed at appropriate locations in the water column, or in filter fences in smaller streams. Experience during the Kalamazoo River spill showed that weighted gabion baskets on the bottom were most effective where currents were less than 1 foot per second, otherwise scouring upstream of their placement occurred; closed-loop snares were more effective (USEPA, 2016).

Pneumatic systems could be most effective in low-flow conditions (<1 foot per second). Air curtains are more effective in deeper water provide that there is sufficient air volume and pressure. The longer the distance that air is allowed to expand and rise to the surface, the greater the current flow in both directions at the surface. Air curtains are used to protect water intakes and to surround vessels in ports; they could be deployed along the bottom where rivers enter impoundments, to lift submerged oil to the surface for recovery. The USCG Research and Development Center is evaluating this approach (2016).

There have been several tank tests to determine the effectiveness of nets to recover viscous oils that might apply to submerged oils. Delvigne (1987) tested nets of varying sized openings in a flume and developed equations to predict leakage rates based on oil viscosity, water velocity, and net type. Brown and Goodman (1989) conducted 60 tests in a tank to evaluate the ability of towed nylon nets with mesh sizes of 1.0, 1.9, and 5 millimeters to collect neutrally buoyant Cold Lake diluted bitumen, concluding that there was no leakage with the smallest mesh size at tow speeds up to 0.6 knots. At this speed, the medium mesh size leaked, at what they considered, to be an “acceptable rate.” In addition, this study found that it was not possible to clean the nets, so that the net would have to be replaced each time the net was full or started to fail. Meshes with 0.25–1 square inch openings tested by Cooper et al. (2007) did not contain heavy oil with a viscosity of 1,000 cSt at current speeds of 0.8–0.9 knots. Nets can have issues with fouling by debris and snagging on bottom obstructions.

Table 24 lists the advantages and considerations of techniques for recovery of submerged oil.

Table 24—Advantages and Considerations for Submerged Oil Recovery

Advantages	Considerations
Sorbents	
— Constructed of readily available materials. — Can be deployed at and just below the surface or on the bottom, depending on water depth and where oil is moving in a water column or along the bottom. — Effective at removal of oil droplets from a water column. — Can filter an entire water flow in small streams.	— If placed on the bottom in currents >1 foot/second, there can be scouring of bottom sediments in front of the baskets and less effective oil recovery. Might be able to reduce scouring by placement of other materials upstream of the sorbents to slow flows. — Not feasible to deploy in high-flow areas or across larger water bodies. — Can completely fail and be swept downstream if flows suddenly increase. — Can entangle fish or interfere with fish movement.
Pneumatic Systems	
— Do not interfere with navigation. — Can be scaled up as needed, but with increasing complexity. — Not likely to affect fish and wildlife, and can help to reduce risk of hypoxia.	— No commercially available or proven system; limited results are available for small lab tests. — Requires extensive logistics support at the deployment site (air generators, power supplies, booms and skimmers for oil recovery) that can limit use depending on site conditions.
Nets	
— Constructed of readily available materials. — Could be placed where small streams enter a lake or impoundment. — Works best with very viscous oils that form larger particles and with less tendency to leak through the net. — Can be towed at an appropriate depth.	— Not feasible to deploy in high-flow areas or across larger water bodies. — Can completely fail and be swept downstream if flows suddenly increase. — Leakage of oil through net can occur and is hard to monitor; would need special-order nets to obtain specific mesh sizes. — Can snag on bottom obstructions. — Nets cannot be cleaned and re-used. — Can entangle fish or interfere with fish movement.

Table 25 shows the relative effectiveness of response techniques for detection and quantification, containment, and recovery of submerged oil in the water column for different water habitats. Effectiveness is a function of the following considerations:

Detection and Quantification:

— Minimum depth and width of a water body for deployment of the system. For example, induced polarization systems require water depths of at least 5 feet and the unit has two strings of electrodes that have to be towed in the water column.

— Ability to quantify amount of oil present. All of the sensors have the potential to quantify the extent and relative concentration of submerged oil plumes. Sorbents, nets, and visual methods have the potential to detect submerged oil presence but lack the ability to synoptically quantify the extent and amount of submerged oil present.

— Ability to detect oiled area, rather than at point locations that have to be interpolated to generate maps. Streams are likely to have rapidly changing submerged oil locations and be more difficult to survey, so acoustic systems are expected to be most effective.

Table 25—Submerged Oil: Relative Effectiveness of Response Techniques by Water Habitat

Green = Most Effective; Yellow = Could Be Effective; Red = Least Effective; ? = Not Proven Yet

Response Technique	Water Habitats			
	Lake	Pond	Large River	Stream
Detection and Quantification				
Acoustic Sensor	Green	Green	Green	Green
Fluorometry	Green	Green	Green	Yellow
Optical Scattering	Green ?	Green ?	Green ?	Yellow ?
Mass Spectrometer	Green	Green	Green	Yellow
Induced Polarization	Green ?	Yellow ?	Green ?	Red ?
Sorbents	Yellow	Yellow	Yellow	Yellow
Nets	Yellow	Yellow	Yellow	Yellow
Underwater Still or Video Camera	Yellow	Yellow	Yellow	Yellow
Diver Observation	Green	Yellow	Green	Yellow
Containment				
Top Curtain	Green	Green	Yellow	Yellow
Bottom Curtain	Green	Green	Yellow	Yellow
Sediment Curtain/Screen	Green	Green	Yellow	Yellow
Air Curtain	Green	Green	Yellow	Yellow
Other Bottom Barrier	Green	Yellow	Yellow	Yellow
Enhance Natural Collection Areas	Yellow	Yellow	Yellow	Yellow
Excavate/Dredge Depression	Yellow	Red	Yellow	Red
Recovery				
Sorbents	Yellow	Yellow	Yellow	Yellow
Pneumatic System	Yellow	Yellow	Yellow	Red
Nets	Yellow	Yellow	Yellow	Yellow

Containment:

— Effects of water currents on performance. Most types of curtains or barriers that extend to any appropriate depth or height can fail in large rivers because currents are too strong. Air curtains might be effective for containment or for protection of sensitive resources in areas of lower flow. Curtains and barriers in streams might be effective because they are shallower and smaller, meaning more of the water column could be affected, and oil could be diverted to low-flow areas for containment and recovery.

— Presence/absence of natural depositional areas in the habitat. For lakes and impoundments, these areas would include where rivers or streams enter them. For rivers, these areas would include side channels or man-made diversion dikes. Ponds and streams are not likely to have such natural depositional areas of any significant size.

Recovery:

— Expected efficiency of oil removal. No current option is likely to remove a significant amount of the submerged oil from the water column; most efforts focus on removal from accumulation areas.

— Effective depth of the water body for deployment. Pneumatic barriers are likely to be even less effective in small streams because of shallow water depth and stronger currents.

7 Cleanup Endpoints

The goal of any spill response is to select the appropriate treatment methods and cleanup endpoints that would minimize the overall impacts to, and result in the most rapid recovery of, the environment. For inland spills, an agreement with all stakeholders may be problematic if a scientific assessment indicates that it would be appropriate to leave some oil for natural attenuation where continued treatment or cleanup will exacerbate potential habitat or natural resource damage. Often, there are two perspectives that have to be resolved:

1) remove all of the spilled oil from the environment,

2) remove as much oil as possible without damaging or slowing overall habitat/resource recovery.

Stakeholders and the public often are unfamiliar with cleanup methods and how those methods, and associated operational activities, can result in potential damage due to trampling, road building, vegetation removal, excavation, etc. Stakeholders often also are unaware that natural attenuation can be very effective in the final phase of a spill response. It is important to develop cleanup endpoints early in a response and at the same time realize that they can be different for different phases of a response operation over time, particularly as oil weathers and becomes more difficult to remove.

Cleanup endpoints are needed in a response to:

— provide the Planning Section with the standards for which appropriate treatment options are then selected;

— provide the Operations Section with clear treatment targets for each phase of the response; for example, initial, short-term bulk oil removal endpoints, followed by sometimes different types of treatment actions to achieve long-term endpoints;

— define the conditions beyond which further active treatment is likely to provide no net environmental benefit and can delay, rather than accelerate, recovery of impacted habitats and natural resources;

— define the target conditions that enable the active treatment phase to transition into a monitoring and maintenance phase, as resources and equipment are demobilized or re-tasked once the end point criteria are achieved;

— provide SCAT teams with criteria with which to recommend the most appropriate treatment techniques and evaluate the results of treatment activities.

There are generally four types of cleanup endpoints (Sergy and Owens, 2008; NOAA, 2013):

1) quantitative endpoints that build on the terminology from the SCAT process and use metrics related to the percent oil distribution, oil thicknesses, oil type, etc. (e.g., no more than 10% Stain);

2) qualitative endpoints that describe the presence and character of oil (e.g., does not rub off on contact);

3) analytical criteria for sediment and water quality (e.g., less than x parts per million [ppm] total petroleum hydrocarbons);

4) interpretive impact endpoints (e.g., removal to the point when further treatment can result in excessive habitat disruption). At this point, no further treatment is recommended due to a net environmental benefit consideration.

This last endpoint is applied mostly to sensitive habitats when meeting one of the first three endpoints could cause greater harm than leaving oil to weather naturally. SCAT teams make this recommendation in the field based on guidelines established by the Environmental Unit for the spill.

Table 26 lists key drivers for development of cleanup endpoints for inland oil spills and illustrates why they tend to be stringent, particularly when compared to marine or coastal spills (modified from Whelan et al., 2014). These concerns and drivers are common in populated areas and this can lead to creation of one set of end points for remote areas, with potential low effects, and a separate set for populated areas or areas with ecological, recreational or other resources at risk.

Table 26—Key Drivers for Inland Spill Cleanup Endpoints

Key Driver	Cleanup Endpoints Issues
Water is a precious resource	Can require meeting water quality standards for drinking, subsistence fishing or trapping, cooling for major industries, and/or irrigation, with less tolerance for even low levels of sheening. Livestock and game use water for life cycle purposes, drinking, and eating.
Public concern, often by a community with little oil spill experience	Intense demands by the public in the affected area can drive politicians to request a more aggressive cleanup than science and experience would otherwise recommend.
Human uses of impacted water body and riparian zone, with pressure for aggressive removal and quick re-opening of closed areas	Can require meeting water quality standards for recreational use, including swimming, fishing, and boating in water bodies where oil persistence is an issue. Remobilization of oil in riparian zones can pose chronic exposures to people and pets, affecting uses such as walks along riparian zones and parks along a waterway. Prolonged closures in areas of chronic oiling can have socioeconomic effects, including refusal to consume fish, agricultural, and livestock products, and loss of tourism.
Proximity to human habitation	Can necessitate stringent treatment to reduce exposure for people who live nearby.
Persistence of spilled oil in freshwater	Can lead to more intensive removal efforts in areas with lower rates of natural physical and biological attenuation in areas with low waves and weak currents. Spills on land penetrate soils deeply and can contaminate groundwater, requiring deeper and more complete excavation. Groundwater can release oil to surface water at a delayed time.
Size of impacted water body and scope of oiling	Even small spills can affect an entire pond, stream, or wetland. Spills can cover relatively large areas per volume of oil. Can affect an entire local population of plants, insects, and other crucial habitat components as well as directly affecting animals that are dependent on those habitats.

Table 26—Key Drivers for Inland Spill Cleanup Endpoints (Continued)

Key Driver	Cleanup Endpoints Issues
Increased sensitivity of environment to cleanup methods	Inland habitats can be more susceptible to damage from response activities that include: foot traffic, construction of access corridors, topographic changes from sediment removal, habitat disturbance from vegetation removal, and increased erosion. Animals can be at greater risk to oiling, particularly those with small home ranges. Sediment/vegetation removal can increase risks of bank erosion.
Logistical challenges for Operations in gaining access	Spread of oil into areas with difficult access requires construction of access corridors and staging areas for oiled material handling. Access to or across private property can be difficult to negotiate.
State cleanup guidelines and Federal response authorities	States typically have sediment and water quality standards that must be met, often after the emergency response is completed. USEPA typically issues cleanup orders using their regulatory authority, which comes from the Clean Water Act and are contingent on sheens or threats of sheen on navigable water.
Need for coordination with multiple entities and landowners	Large spills can spread over multiple local and state jurisdictions, requiring more complex coordination. Private landowners might not allow responder access through or on their properties. Spills can affect many private landowners; third-party claims can slow a response.
Presence of cultural and historic resources	There are greater numbers of sites, which are often naturalized and difficult to recognize in the field. Historic and cultural resources can be delicate and not easily cleaned, while at the same time be the focus of high concern with high public involvement in restoration.
Presence or use by wildlife resources and important plant habitat	Inland sites especially when adjacent to water bodies and water ways are often important to a variety of wildlife species and birds. Could be important areas used by migratory birds or other protected species. Shorelines of inland water ways and water bodies can be habitat for protected plant species.
Frequent water-level changes; changes in directional flow; can be very large seasonally	Spreads oil over larger areas and to downstream reaches quickly. Could cause failure in containment strategies. Could lead to a push for aggressive removal of bulk oil before predicted high water events. Pushes oil into more sensitive floodplains where removal is more difficult.

Table 27 provides guidelines for selecting cleanup methods and endpoints for different inland habitats (Whelan et al., 2014). More aggressive removal actions tend to increase the potential for environmental damage to habitats. The goal of a response is to protect public health and maximize recovery of oiled habitats and resources, while minimizing potential injury resulting from cleanup efforts. Achieving this goal requires careful analysis of the net environmental benefit of different treatment methods, cleanup endpoints, and when it is appropriate to terminate treatment (i.e., No Further Treatment [NFT]). There are many studies that support this kind of evaluation and analysis for coastal spills; however, there are few studies of the long-term environmental impacts of response actions for inland spills.

Table 27—Guidelines for Selecting Cleanup Methods and Endpoints for Inland Habitats

Basis for Treatment	Applicable Habitats	Treatment Methods	Example Primary[a] Cleanup Endpoints	Guidelines for NFT Determination
Protection of Public Health and Safety	High public use areas Residential areas	Whatever appropriate to remove risks: excavate, cut, flush, remove/replace	No visible oil No detectable oil (sight or smell)	When oil residues are no longer a threat to human health and safety Falls below threshold odor or exposure limits

Table 27—Guidelines for Selecting Cleanup Methods and Endpoints for Inland Habitats (Continued)

Basis for Treatment	Applicable Habitats	Treatment Methods	Example Primary[a] Cleanup Endpoints	Guidelines for NFT Determination
Protection of Sensitive Resources and Habitats	Wetlands, bird-nesting areas, T&E species habitat, wildlife refuges, other protected areas	Bulk oil removal using vacuum, skimming, manual removal using walking boards in soft substrates Passive recovery of sheens	No free-floating black oil or emulsion on the water surface No accessible oiled debris No oil in sediments that are used for nesting, hibernating, grubbing for food	Usually determined by resource manager or land manager experts Case studies that show habitat damage from aggressive treatment Particular sensitivity of a species or habitat Inability to replace habitat
Removing Aesthetic Impacts in High-use Areas	Hard substrates: bedrock, gravel, seawalls, riprap Beaches Vegetation Debris	Wipe, high-pressure, higher-pressure and/or temperature flush, cut, remove/replace	No visible oil No more than 20% Stain or Coat	Less aggressive removal during seasonal low-use periods could allow natural processes to work Estimate how long before oil degrades naturally Could involve a Public Information campaign concerning remaining Staining
Removing Contact Hazard (both humans and wildlife)	Hard substrates: seawalls, riprap, bedrock Vegetation Debris Soil	Wipe, flush, cut, sorbent barriers, remove/replace	No longer rubs off on contact No oil that rubs off on sorbents	Estimate how long before the oil would weather to a non-sticky Stain or Coat Excessive vegetation removal Falls below known limits (ppm for PAHs) for hazards Could involve a Public Information campaign concerning remaining Stain or Coat
Mitigating Persistent Sheens	Rivers, streams, other flowing water bodies Lakes, ponds, other standing water bodies Seasonally flooded wetlands	Actively mitigate major sources of sheens (excavate, dredge, flush, cut, remove/replace, cap) Passively contain/recover sheens with booms and sorbents	No longer generates sheens that affect sensitive resources No longer releases black oil or emulsion during flushing operations No longer generates black oil or emulsion during high-water events	In low-use areas: Consider seasonal use and processes (e.g., flooding) that can accelerate natural removal In high-use areas: Education on considerations between aggressive treatment and chronic sheens Site-specific studies to assess receptor risk

Table 27—Guidelines for Selecting Cleanup Methods and Endpoints for Inland Habitats (Continued)

Basis for Treatment	Applicable Habitats	Treatment Methods	Example Primary[a] Cleanup Endpoints	Guidelines for NFT Determination
Mitigating Intermittent Sheens (triggered by rainfall, temperature changes, etc.)	Rivers, streams, other flowing water bodies Lakes, ponds, other standing water bodies Seasonally flooded wetlands	Actively mitigate major sources of sheens (excavate, dredge, flush, cut, remove/replace, cap) Passively contain/recover sheens with booms and sorbents	No longer generates sheens that could threaten resources at risk	In low-use areas: Education on considerations between aggressive treatment and chronic sheens In high-use areas: Education on considerations between aggressive treatment and chronic sheens Site-specific studies to assess receptor risk
Mitigating Sediment/Soil Contamination	Upland soils River/lake bed sediments Wetland sediments	Actively remove bulk oiled sediments/soil (excavate, dredge, remove /replace). Passively contain/recover remobilized oil with booms and sorbents, in situ techniques-mixing, sediment reworking, phytoremediation, nutrient addition	No visual oil greater than Stain or Coat Does not release black oil when disturbed Agriculture or pasture for human use could involve a target ppm level	High risk of erosion or excessive sedimentation Potential unacceptable changes in surface topography Excessive change in soil/ sediment quality, e.g., organic matter content, grain size Potential permanent change to a habitat type e.g., wetland to open water

[a] Secondary Cleanup Endpoints include "Or, as low as reasonably practicable considering net environmental benefit."

Cleanup endpoints for spills in coastal settings seldom have endpoints as rigorous as "No oil observed." In most coastal response operations, cleanup endpoints are developed based on the acknowledgement that any residual oil weathers or degrades over time, accelerated by natural removal processes in areas exposed to waves and currents. Thus endpoints such as "no longer rubs off on contact" or "no longer generates sheens that affect sensitive resources" can be acceptable. The U.S. authority to prohibit oil discharges is granted under the Clean Water Act and is triggered by any oil discharge that USEPA determines "may be harmful." Such discharges include those that: (a) Violate applicable water quality standards; or (b) Cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines. This authority is often translated into the cleanup endpoint of "no sheen."

For spills where consensus is not reached on cleanup endpoints, a Technical Advisory Group might be established to develop spill-specific treatment methods and cleanup endpoints, as well as guidelines for treatment completion. A Technical Advisory Group typically is composed of appropriate stakeholders, including an FOSC, State OSC, federal, state, and local resource agency representatives, land managers, land owners, tribal government representatives, and the responsible party. This Technical Advisory Group typically utilizes a process often referred to as a Net Environmental Benefit Analysis (NEBA) or Spill Impact Mitigation Assessment (SIMA) to establish cleanup endpoints. This NEBA/SIMA process provides a structured approach used by the response community and stakeholders during oil spill preparedness planning and response, to compare the environmental benefits of potential response tools and develop a response strategy that can reduce potential impacts of an oil spill and response activities on the environment and expedite recovery. During a spill response, the NEBA/SIMA process comprises four stages (API, 2016d):

1) Compile and evaluate data: Assess the specific oil spill conditions including fate and trajectory predictions, and identification of resources at risk and determination of feasible response techniques.

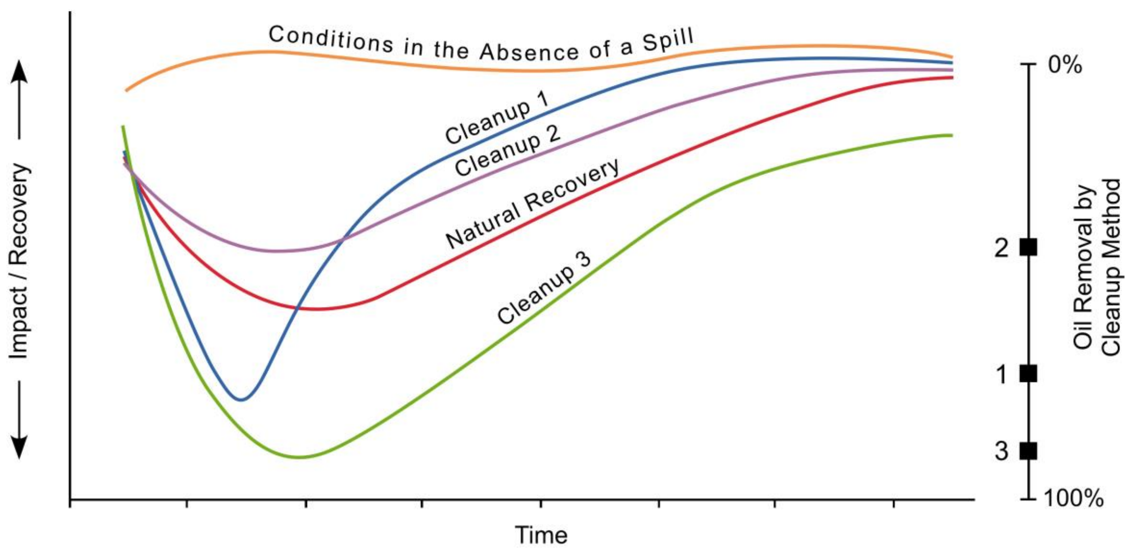
2) Predict the outcomes/impacts: Predict environmental, socio-economic and cultural impacts of the spill if no response actions are taken (natural attenuation/recovery) and the effectiveness (i.e., relative impact mitigation potential) for each feasible technique.

3) Balance trade-offs: Weigh and compare the range of benefits and drawbacks of each response technique or option, including natural attenuation.

4) Select the best response options: Selection is based on which technique(s) will minimize overall impacts and promote rapid recovery.

Figure 11 shows conceptual trajectories of the generalized impact and recovery of different cleanup methods. Method 3 removes the most oil, but has the greatest potential impact and the slowest habitat recovery. Method 2 removes less oil but habitat recovery is still slow. Method 1 is the preferred option as this removes most of the oil and has the best habitat recovery. Once approved by the Unified Command, the written guidelines generated by the Technical Advisory Group are incorporated into work orders issued to Operations and used by SCAT teams during inspection and sign-off. The on-going application of the NEBA/SIMA process allows cleanup endpoints to be developed early in a systematic manner, and to be revised as appropriate throughout a response as new data are made available.

Once a Federal emergency response has ended, the site can be turned over to the state, which then could use endpoints based on state regulations that specify water and sediment quality thresholds for contaminant levels. Removing oil to the extent that soil, sediment, and water meet state regulatory limits could necessitate additional restoration or remediation efforts.



Note that Cleanup method 3 removes the most oil but involves the longest habitat recovery. Cleanup method 1 is the preferred option as this removes more oil and has the fastest habitat recovery.

Figure 11—Conceptual Trajectories of the Impact and Recovery of Different Cleanup Methods

8 Special Considerations

This section describes risks and responses for topics of special consideration for inland oil spills:

1) protection of water intakes;

2) response considerations for spills of ethanol-blended fuels;

3) air quality concerns;

4) spills of oil-field produced water;

5) treatment of oiled debris;

6) intermittent sheening;

7) successful fast-water booming strategies.

8.1 Protection of Water Intakes

Spills to rivers, lakes, and impoundments that are sources of water for drinking, industrial, cooling, and agricultural purposes pose specific threats. Timely notification of a spill that could affect water intakes is essential in determining if or when the intake should be shut down and implementing applicable protection measures. Multi-agency Regional Response Plans often include water intake notification requirements. Lighter oils that have more soluble fractions and are more readily dispersed into the water column present a greater threat compared to heavier oils.

When drinking water intakes are at risk, samples could be collected at the raw water intake and typically analyzed for the chemicals listed in Table 28. The plant operator generally decides whether or not to shut down an intake based on these analytical results, proximity of the spill to the intake, intake depth, oil type and other factors. Another key factor is the availability of an adequate, alternative source of water that is sufficient to meet the **consumptive, hygiene, and firefighting requirements** of the water supply system. Without such an alternative, the operator can choose raw-water treatment options, including for example, use of activated carbon to reduce the risk of contamination by organic compounds in a system.

Table 28—USEPA Drinking Maximum Contaminant Levels (MCL) for Selected Oil Spill Components

Intake Type	Chemical	MCL	Odor Threshold
Drinking water	Benzene	0.005 mg/L	2.0 mg/L
	Toluene	1 mg/L	0.04–1.0 mg/L
	Ethylbenzene	0.7 mg/l	0.029–0.24 mg/l
	Xylenes (m, p, o)	10 mg/L	Likely in the range of toluene

At power plant intakes, oil in cooling water can interfere with the heat transfer process at the condensers and reduce the efficiency of power generation. If a highly viscous oil enters the condenser, the effects are likely to be more critical, eventually leading to blockage of tubing and complete loss of heat exchange. In the event of a spill that threatens a cooling water intake, it is important to check all filters prior to oil exposure to document “normal” conditions as there could be oil residues present unrelated to the spill.

Cooling water intakes often use screens to remove debris and other solids. There could be two screening systems: the first can be a coarse mesh that can be clogged, particularly if there is a high concentration of tar balls and oiled debris. Oil/debris on this first screen can be manually or mechanically removed with a rake. The second screen can be a fine-mesh mechanical band or drum screen that can be blocked by oil adhering to the surface. In addition, the weight of oil on the screen can overload the drive mechanism, causing a shut down. These fine screens are normally cleaned by water jets, which might not effectively remove sticky oil.

Industrial facility operators have guidelines for how to respond when notified of an oil spill upriver of water intakes, depending on the raw water treatment systems and how the water is used.

There are multiple lines of defense that might be implemented to protect water intakes of all kinds:

- Operators of downstream water intakes can be notified and provided information on the spread of oil, both on the surface and mixed into the water column, over time. The response should coordinate with the operators to determine how much water is in storage and the options for alternative sources for obtaining water, depending on how long the water intake may need to be shut down.
- Boom can be placed around the intake to prevent entrainment of surface oil.
- Air curtains can be installed at the entrance to intake canals on still water bodies, such as lakes or impoundments.

8.2 Response Options for Spills of Denatured Ethanol

Ethanol is a flammable colorless liquid that is blended into gasoline as an oxygenate to reduce emissions or as an octane enhancer. Even though it has a specific gravity of 0.79, as a polar solvent, it completely mixes with water. Its vapors are heavier than air and have a wider flammable range than gasoline, with a Lower Explosive Limit of 3.3% and an Upper Explosive Limit of 19%. Due to its affinity for absorbing water, ethanol is generally blended into gasoline at fuel distribution facilities immediately prior to loading into tanker trucks for transport to local service stations. Prior to shipment to fuel distribution facilities, the ethanol must be denatured by the addition of a small quantity of material (usually 5% unleaded gasoline) to make it unsuitable as a beverage, but still suitable for use as a motor fuel.

Key considerations for spills of denatured ethanol include:

- These fuels are highly flammable. However, under fire conditions where foam or water have been applied to the burning fuel, the gasoline tends to burn off first, leaving the less volatile ethanol/water solution, which might have no visible flame or smoke. Only alcohol-resistant foams are effective, and foam must be applied in a gentle-style application and often at higher flow rates to accomplish extinguishment. Thus, sufficient stocks of alcohol-resistant foams are required. Refer to Appendix C for more information on firefighting foam selection and use.
- Ethanol can conduct electricity, so that electrocution hazards and possible ignition hazards can be present during transferring operations.
- Often, the decision is made to allow the fire to burn and attempt to prevent the fire from spreading to adjacent rail cars, tanks, or structures by application of cooling water. Contain and recover runoff firefighting water, because ethanol mixes into the water.
- Ethanol has a greater affinity for water than it does for gasoline. If there is no water present, sorbents can be effective. However, in the presence of even small amounts of water, ethanol mixes into the water under the fuel. If a spill is dammed to prevent discharge to a stream and mixed with water or foam (some of which will break down), over time the gasoline would float on a layer of an ethanol/water solution.

— Ethanol is considered to be slightly toxic, based on acute toxicity tests (24-hr LC_{50} of 181 mg/L, with a range of 110–430 mg/L for fish and crustaceans). However, releases to water can cause fish kills as a result of the high BOD, which can lower dissolved oxygen levels leading to hypoxia. For large spills, the hypoxic plume can travel downstream and kill fish for tens of miles and days after the release.

— Responders could construct berms or other barriers to prevent denatured ethanol from entering surface waters. Rapid removal prevents penetration into soils and potential subsequent groundwater contamination.

— Air sparging can be used to inject oxygen to speed degradation of ethanol in water bodies. However, because ethanol has very low volatility, aeration or mixing could have limited effectiveness in accelerating the rate of removal by evaporation.

— Ethanol has low affinity for sorption on to carbon, so removal by filtering with granulated activated carbon is not very effective.

— Ethanol biodegradation rates in soil, groundwater, and surface water have predicted half-lives ranging from 0.1 to 10 days at temperatures less than 50°F. In colder temperatures, elevated ethanol concentrations can persist for several months (Shaw, 2011). Gasoline constituents tend to be more persistent.

— When ethanol-contaminated water or fuel has penetrated into sediments on land, treatment options include: natural attenuation, excavation (with appropriate precautions), controlled burning, and sediment mixing.

— The presence of ethanol in blended fuels can slow the rate of degradation of benzene, toluene, ethyl benzene, and xylenes (BTEX) compounds in the gasoline fraction (the ethanol is preferentially degraded first), which can extend the transport of BTEX in groundwater plumes.

The International Fire Chiefs Association (2008) manual and Shaw (2011) provide information on responding to spills of ethanol and ethanol-blended fuels.

8.3 Air Quality Considerations

For spills of light crude oils and refined products, it is important to set up an air quality monitoring program at the spill site that addresses the following concerns, as appropriate:

— worker safety and Personal Protection Equipment selection;

— potential exposures to the community near the incident;

— compliance with regulatory standards and guidelines;

— data for potential third-party exposure claims.

Air quality parameters that are often included in monitoring programs and action levels are listed in Table 29, for oil spills with and without fire.

For spills where the public is at risk of exposure to airborne contaminants, it might be necessary to establish a Public Health Unit within the Planning Section to set criteria for evacuations and re-occupation. When in situ burning is being considered as a response option, the burn plan should include an air monitoring program. Air monitoring can be at fixed locations based on the source location, wind direction, and receptors of concern and should include low areas where vapors could accumulate. Workers can also wear air monitors that provide real-time concentration date or are analyzed off site.

Table 29—Guidance on Air Monitoring at Spill Sites for Worker Safety

LEL and H_2S pose acute risks of ignition and death, and are highest in the order

Parameter	Measurement/Action
NO FIRE	
LEL	<10%—proceed to measure other parameters >10%—stand back until measurement is <10% LEL
H_2S	<1 ppm—proceed to measure other parameters >1 ppm—select appropriate respiratory protection for responders
VOCs	<100 ppm—proceed to measure other parameters >100 ppm—select appropriate respiratory protection and PPE for responders
Benzene	<0.5 ppm—proceed with operations >0.5 ppm—select appropriate respiratory protection and PPE for responders
FIRE (parameters in addition to those above)	
Particulates	<150 µg of $PM_{2.5}$ per m^3, averaged over 1 hr—proceed with operations >150 µg of $PM_{2.5}$ per m^3, averaged over 1 hr—select appropriate respiratory protection and PPE for responders
SO_2	<75 ppb averaged over 1 hr; <0.5 ppm averaged over 3 hr—meets NAAQS
NO_2	<100 ppb averaged over 1 hr—meets NAAQS
CO	<9 ppm averaged over 8 hr; <35 ppm averaged over 1 hr—meets NAAQS

LEL, lower explosive limit: varies by gas type—for example, Bakken crude oil has an LEL estimated to be 0.4–0.8%, Jet fuel (JP-4) = 1.3%; H_2S, hydrogen sulfide; VOCs, volatile organic compounds; SO_2, sulfur dioxide; NO_2, nitrogen dioxide; CO, carbon monoxide; NAAQS, National Ambient Air Quality Standards.

Benzene is a known carcinogen and often is included in air monitoring programs. The Occupational Safety and Health Administration (OSHA) time-weighted average limit (TWA) limit for benzene is 1 ppm over an 8-hour period; the short-term exposure limit (STEL) is 5 ppm for a 15-minute period. The National Institute for Occupational Safety and Health TWA is 0.1 ppm whereas the American Conference of Governmental Industrial Hygienists TWA is 0.5 ppm. Some organizations or companies have more stringent limits.

8.4 Spills of Oil Field–Produced Water

Water is typically co-produced during hydrocarbon production from the geologic formations along with the oil and gas. Produced water spills can affect surface and ground water quality, soils, and vegetation because they generally have very high levels (over 100,000 mg/L) of total dissolved solids (TDS) and can contain limited amounts of dissolved and free-floating oil. In clayey soils, the potential exists for the high sodium levels in produced water to replace the non-sodium ions in the clays, which can result in dispersion of the soils, which then leads to lower permeability (creation of a hard pan) and increased risk of soil erosion. Excess salinity creates an osmotic imbalance that reduces water uptake by plant roots. Plants can go into drought stress even though there is an adequate water supply in the soil. API Publication 4758 (API, 2006) on “Strategies for Addressing Salt Impacts of Produced Water Releases to Plants, Soil, and Groundwater” includes rules of thumb and guidelines for determining when a response action would be needed and selecting appropriate response options.

First response options can include controlling the source of the discharge and recovering any free liquid. The next steps may be to: 1) delineate the affected area; 2) estimate the volume of produced water discharged and its chloride content; 3) collect soil core samples in the affected area to determine the lateral and vertical extent of subsurface impacts by measuring the electrical conductivity, cation exchange capacity, exchangeable sodium percentage, and the sodium adsorption ratio of soils at selected depths; and 4) collect surface and/or groundwater samples to assess the presence and degree of produced water contamination by analysis for TDS and chloride concentrations. The rules of thumb in API 4768 for assessing soil impacts are shown in Table 30.

Table 30—Rules of Thumb for Soil Impact from Produced Water Spills (API, 2006)

Parameter	Action Most Likely Not Needed	More Analysis May Be Needed	May Need Corrective Action
Soil exchangeable sodium percentage	<5%	>5% and <22%	>22%
Soil electrical conductivity	<4 mmhos/cm	>4 mmhos/cm and <16 mmhos/cm	>16 mmhos/cm
mmhos/cm, millimohs per centimeter.			

Corrective action for impacted soils can include monitored natural attenuation by observing the rate of natural revegetation or planting of salt-tolerant vegetation (including addition of mulch and fertilizers) to speed revegetation as the soil salinity is reduced by natural water flushing. This approach works best for sandy soils, in areas with sufficient rainfall (rule of thumb is precipitation minus evaporation is greater than 4 inches per year), or where more aggressive remediation methods can cause additional damage, particularly in wetlands. Supplemental water could be required if there is insufficient rainfall. Soluble salts are transported by water; no water equals no movement. The salinity in the soils must be reduced well beyond the root zone for revegetation to occur.

Where natural leaching of salts from the soils is likely to be slow, addition of in-situ chemical amendments could be considered. Often, this approach consists of addition of a calcium-containing compound, e.g., gypsum, to replace sodium. The affected soils can be plowed to improve drainage, then the amendments are mixed to the depth needed for treatment. Fertilizer and mulch can speed restoration. A top dressing of mulch can retain moisture. Again, supplemental water could be needed. API (2006) provides guidance on estimating the amounts of amendments needed. Where soil impacts are great, it could be necessary to conduct mechanical excavation of the affected soils for off-site treatment or disposal.

Produced water spills can be transported to groundwater, which can affect its use (as a source of drinking water, industrial process water, or for irrigation) and also provide a pathway for eventual discharge to surface water. Table 31 lists various water quality guidelines for TDS and chloride. TDS and chloride are considered by USEPA not to pose a risk to human health and thus only have Secondary Maximum Contaminant Levels as “nuisance” chemicals. Several states have developed freshwater aquatic life criteria for TDS that range from 250 mg/L to 2,500 mg/L (Iowa, 2003).

Table 31—Water Quality Guidelines for TDS and Chloride (API, 2006)

Parameter	Secondary Maximum Contaminant Level	Freshwater Aquatic Life Criteria-Acute	Freshwater Aquatic Life Criteria-Chronic	Salinity Hazard for Irrigation	Livestock
TDS	500 mg/L			1,000 mg/L	>1,000–3,200 mg/L; useable, can cause temporary diarrhea
Chloride	250 mg/L	860 mg/L	230 mg/L		

API (2006) provides guidance on use of simple models to evaluate the potential impacts to groundwater resources from produced water releases. The steps include estimates of the mass of chloride released, the chloride loading rate to the groundwater, the increase in chloride concentrations in groundwater at the release site, and the increase in chloride concentrations in groundwater at a down-gradient point. They also discuss use of models to provide more accurate estimated of chloride migration in groundwater.

8.5 Oiled Debris

Oiled debris can become a major issue during inland spills for the following reasons:

— The volume of debris can be very large, requiring extensive logistics for removal, storage, and disposal.

— Segregating oiled from unoiled debris can be difficult, increasing the volume of material requiring handling and treatment or disposal.

— Large pieces of oiled debris pose particular handling issues and safety concerns if the debris has to be cut with chain saws prior to removal.

— Oiled debris can be located in areas with very limited or unsafe access by workers.

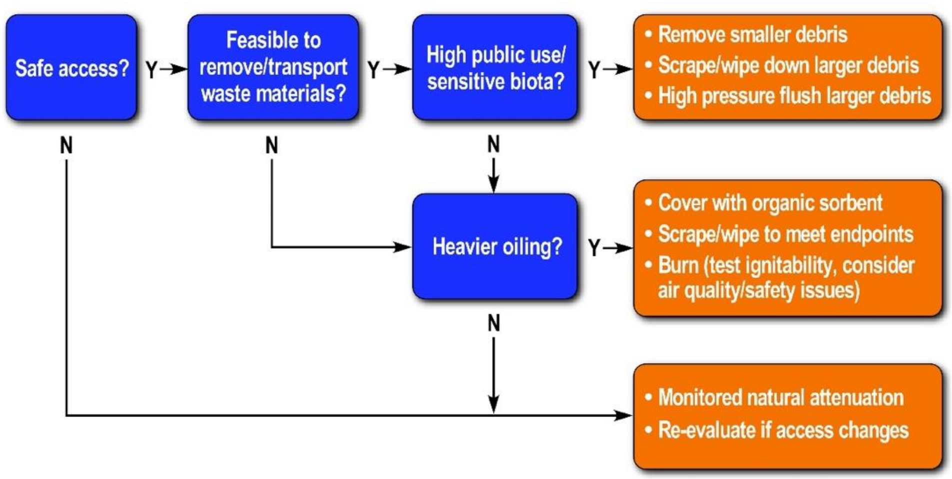
— Debris piles can be important habitat for terrestrial and aquatic species, as well as provide bank stabilization. Excessive removal can degrade habitat quality, or increase the risk of stream erosion. Large woody debris is of particular habitat value.

— Burning oiled debris might be restricted because of air quality concerns.

A factor in the evaluation of oiled debris is that oil a Coat or Stain on woody debris eventually dries to the point where it no longer poses a contact hazard to people or wildlife (usually within weeks after the spill).

Figure 12 is a flow chart to guide selection of treatment techniques for oiled debris, including removal of smaller debris, scraping/wiping down of large debris, high-pressure flushing of larger debris, covering with an organic sorbent, burning, and monitored natural attenuation. This chart includes example cleanup endpoints and BMPs during treatment activities.

Oiled Debris: Treatment Techniques



Oiled Debris: Cleanup Endpoints

- No oil on surfaces that rubs off on contact (wipe standard area with sorbent)
- No accessible oiled debris in high-use areas/sensitive habitats
- No more than 20% coat/stain on surfaces

Oiled Debris Treatment: BMPs

- Do not remove unoiled debris, which has important habitat value
- Minimize removal of lightly oiled debris, particularly in areas of low public use and low environmental sensitivity
- Minimize foot traffic in soft substrates; use walking boards where needed
- May need to replace with clean debris in streams if excessive removal affects stream stability and habitat value

Figure 12—Flow Chart for Selection of Treatment Techniques for Oiled Debris

8.6 Intermittent Sheening

Addressing intermittent sheening can be a challenge during the final stages of the emergency response for a spill. Sheens typically are very difficult to contain and recover. When sheens are released intermittently (such as triggered by rainfall or temperature changes), recovery becomes even more difficult. Long-term deployment of booms and sorbents can interfere with normal uses of a water body. In the low-energy environments common to inland waters, there is little natural energy to break up sheens. A cleanup endpoint of "No longer generates sheens that affect sensitive resources" requires the Unified Command to make a determination that sheens no longer pose public health or ecological risks. Sheens represent very small amounts of oil; Table 32 shows that continuous silver sheen contains no more than 7.8×10^{-3} bbl of oil per acre. Many times, intermittent sheens are very patchy further reducing the risk of exposure. Additionally, according to French et al. (1999) and French McCay (2009), floating oil thicknesses of < 10 microns (metallic sheens) pose minimal risks to birds and mammals.

If sheens are affecting sensitive biological or human resources, the source(s) of the sheens can be identified and actively mitigated, and/or the sheens can be passively contained and recovered with booms and sorbents or physically dispersed with water streams. However, at some point, the amount and frequency of sheening decreases to the point where potential ecological impacts are minimal, and it might be necessary to conduct a net environmental benefit analysis/spill impact mitigation assessment (NEBA/SIMA) to determine the appropriate next course of action. This kind of analysis can be simple, with all stakeholders agreeing with the decision to terminate the response. For example, a decision can be made to terminate response options when birds migrate out of an area for the season, or when water flows increase to the point where the sheens are quickly dissipated. Alternatively, it can be a more formal process, as for the 2010 Enbridge Pipeline spill into the Kalamazoo River in Michigan, where a NEBA/SIMA was conducted in Spring 2012 using risk matrices that evaluated eight different recovery actions (including monitored natural attenuation) for six ecological resource categories and eight habitat types along the river (Fitzpatrick et al., 2013).

Table 32—Sheen Description, Thickness, and Concentration (NOAA, 2012)

Code	Description	Layer-Thickness Interval		Concentration	
		microns (µm)	inches (in.)	m^3 per Km^2	bbl/acre
S	Sheen (silver/gray)	0.04 – 0.30	1.6×10^{-6} – 1.2×10^{-5}	0.04 – 0.30	1×10^{-3} – 7.8×10^{-3}
R	Rainbow	0.30 – 5.0	1.2×10^{-5} – 2.0×10^{-4}	0.30 – 5.0	7.8×10^{-3} – 1.28×10^{-1}
M	Metallic	5.0 – 50	2.0×10^{-4} – 2.0×10^{-3}	5.0 – 50	1.28×10^{-1} – 1.28
T	Transitional Dark (or True) Color	50 – 200	2.0×10^{-3} – 8×10^{-3}	50 – 200	1.28 – 5.1
D	Dark (or True) Color	>200	$> 8 \times 10^{-3}$	>200	> 5.1
E	Emulsified	Thickness range is very similar to dark oil.			

Even when sheens no longer pose an ecological threat, they could have a potential aesthetic effect to human use of a water body. In areas of high human use, it might be beneficial to involve local communities in the discussion of the options and considerations between further and possibly aggressive treatment and monitored natural attenuation. Again, a NEBA might be used to compare the ecological effects of the different response options. To support the decision, a sheen monitoring and analysis plan might be implemented to document the type, volume, frequency, and temporal patterns of sheens. A sheen monitoring plan provides data to identify the sources of sheens and whether the amount of sheening decreases over time.

In a sheen monitoring plan, field teams use standard terminology to characterize and describe sheen attributes in the designated monitoring area, such as:

- Location of sheen in the monitoring area.
- Estimated orientation and dimensions of sheen area.
- Sheen structure
  - Brittle: Sheen that breaks apart into pieces with sharp edges, like broken glass when disturbed. Brittle sheens often are of natural biogenic origin.
  - Non-brittle: Sheen that swirl and recoalesce when disturbed. Non-brittle sheens often are of petrogenic origin.
- Color and appearance (Table 32). Refer to the NOAA (2012) Open Water Oil Identification Job Aid for representative photographs of each type.
  - Silver/grey sheen: Near transparent for thinnest to silver/gray for slightly thicker layers.
  - Rainbow sheen: Rainbow colors are visible.
  - Metallic sheen: The sheen reflects/mirrors the color of the sky with some element of oil color, often between light gray and dull brown.
  - Dark: The sheen is a continuous true oil color.
  - Oil droplet: A droplet of oil on the water surface.
  - Sheen blossom: A new sheen generated when a droplet of oil floats to the surface and spreads into a sheen.
- Sheen structure and distribution.
- Potential sheen sources, if apparent.
- Frequency of sheen blossoms, if present.
- Environmental conditions such as air temperature, cloud cover, wind speed, and wind direction.

It may be appropriate to collect sheen samples to determine if they match the spill source oil, particularly in locations where there could be other sources of petrogenic sheen.

8.7 Successful Fast-Water Booming Strategies

The containment, diversion, or deflection of oil in fast flowing water presents challenges for responders. Drag force on containment boom increases dramatically in fast currents, requiring responders to understand these forces and plan accordingly. Anchor systems commonly used for securing boom in calm water can fail in fast-moving water. Containment boom entrainment failure typically occurs at 0.7 knots. If the current in a stream or river exceeds 0.7 knots (0.4 meters per second, 1.3 feet per second), containment boom should be deployed at an angle to the current to reduce or eliminate entrainment of oil under the boom. Figure 13 illustrates the required boom angle relative to current speed for effective booming.

CURRENT (knots)	CURRENT (ft/second)	BOOM ANGLE RELATIVE TO CURRENT REQUIRED TO KEEP COMPONENT OF CURRENT <3/4 KNOT
1.5	2.5	30° to 42°
1.75	2.9	25° to 35°
2.0	3.4	22° to 30°
2.25	3.8	19° to 26°
2.5	4.2	17° to 24°
2.75	4.6	16° to 21°
3.0	5.0	15° to 19°

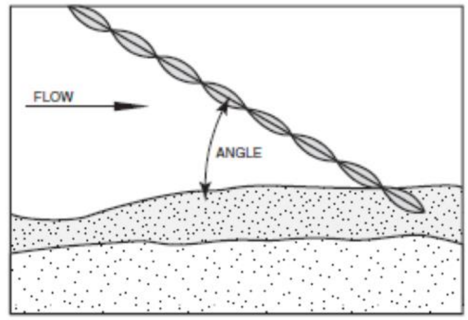


Figure 13—Boom Angle to Current (Alaska Clean Seas, 2010)

In fast-moving water, boom can be used to deflect oil away from sensitive areas such as wetlands and water intakes or to divert oil into lower-flow, calm, or back eddy areas for recovery. Conventional inland response containment boom found in most response contractor inventories is 6 inches of floatation and 12 inches of skirt/draft, with or without top tension cable. Although this boom type is adequate for inland waters with no or low flow, it may not be appropriate for fast water conditions. Containment boom with less draft and/or a shorter skirt reduces the drag force and a top tension cable/member should be used to distribute the load. Containment boom specifically designed for fast water applications are available with sections of netting built into the skirt to allow water to pass through, but in limited quantities.

Typical boom sizes that have proven to be effective at deflecting/collecting oil in fast-moving water are 6 inches x 4 inches, 6 inches x 6 inches, and 8 inches x 6 inches with top tension member/cable. Larger 8-inch diameter floatation containment booms offer improved protection against splash over associated with higher wind and wave conditions. Boom section lengths of 50 feet are recommended over the standard 100-feet section lengths of solid floatation containment boom for fast water, especially in smaller waterways. The shorter section lengths are easier to handle and transport, and offer additional end connector locations for attaching tag lines for anchoring and or tying back to the bank to hold the boom at the correct angle.

A range of manuals provide guidance for inland spill containment and recovery and which address fast-water booming strategies: Alaska Clean Seas Techniques Manual (2010), USCG Oil Spill Response in Fast Currents: A Field Guide (Hansen and Coe, 2001), USCG Oil Response in Fast Water Currents: A Decision Tool (USCG, 2002), USEPA Region 5 Inland Response Techniques Manual (UMRBA, 2010), ExxonMobil (2014) Oil Spill Response Field Manual, the International Maritime Organization (2013) Guide for Oil Spill Response in Fast Currents, and Cook (2014).

Techniques have been developed to deploy boom in fast-flowing current in single legs, by cascading multiple boom sets, or with a “Chevron” or “Open Chevron” formation. These deployments typically are accomplished with multiple lines and anchor/secure points. Although effective once in place, these deployments typically are complicated and time consuming, often requiring trained personnel. Specific techniques and equipment have been developed and tested to aid in effective booming in fast water. Boom deflectors/rudders can be attached to containment boom, between end connectors, with an adjustable wing that deflects water helping to hold containment boom in a straight line; this reduces the potential of entrainment and reduces the number of anchors or tag lines required (Figure 14). Boom Vanes can deploy boom in either containment or a deflection arrangement from the shore without the aid of vessels in currents up to 5 knots. Responders can adjust the location of the containment boom by adjusting the length of the mooring line and or the length of boom from the shoreline (Figure 14).

Figure 14—Boom Vane. Top: Boom Deployed with Deflectors/Rudders. Note the Boom Vane on the Shoreline. Bottom: Leading Edge Controlled by a Mooring Line Secured to Anchor Plate

Large trees and bridge pilings work well as anchors to secure containment boom in fast currents. Often, these are not available at the deployment site. Responders can bury anchors, drive posts and lash them together, use dead heads, or other innovative methods to anchor and secure boom. Anchor plates are flat or curved aluminum or steel plates, with holes drilled so that they can be staked in place with large tent spikes or rebar. Anchor plates can be shackled or bridled together to increase the holding force. These plates have proven to be very effective in sand, mud, and gravel (Figure 15).

"Current Busters" are oil containment and recovery devices developed to collect, contain, and decant water from recovered oil. They are designed to work in currents up to 5 knots and can be towed or deployed stationary in a current. Surface oil is funneled into the separator chamber where gravity separation occurs allowing oil to accumulate and water released from the storage area through a bottom opening. There are currently five different sizes of the Current Buster available with the most recent version designed for shallow water conditions (Figure 16).

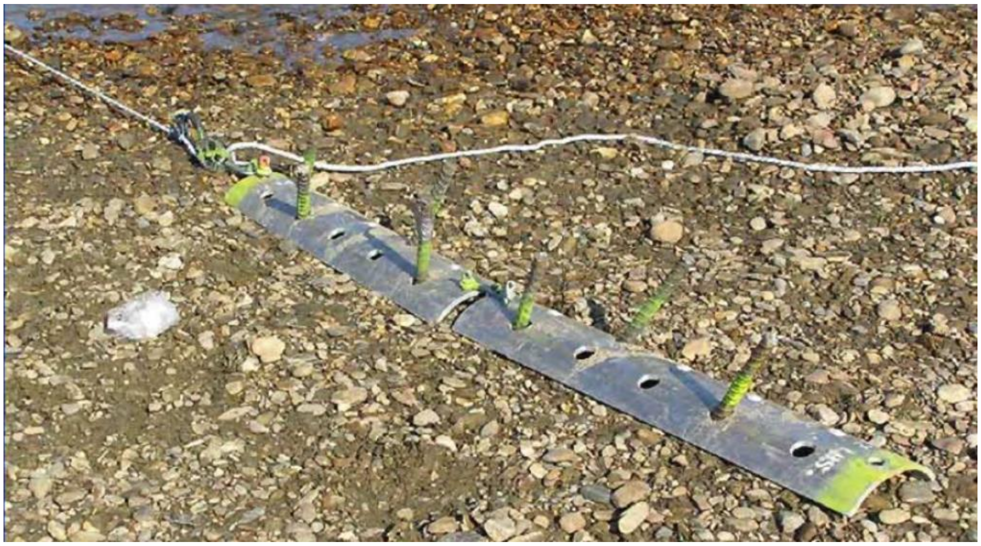


Figure 15—Two Anchor Plates Shackled Together and Fixed with Rebar

Figure 16—Current Buster 2 Deployed with Boom Vane in a River

Rivers and streams are very dynamic. Currents can vary throughout the channel with increased velocity on the outside of bends or meanders and lower velocities on the inside of the channel. Water levels can rise and flow velocity can change quickly due to snowmelt and rain. Responders should be familiar with river conditions and trained in fast-water operations. Every deployment location is different and techniques appropriate for each site should be developed, exercised and tested before adopting as a safe, effective technique for that site. Part of this preparedness involves the identification of suitable recovery sites with low current or back eddy conditions and of the evaluation of transit and deployment times, during all seasons, to assure that techniques can be deployed down current of a spill site with sufficient distance and time to effectively intercept the oil.

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Appendix A

Properties of Nonconventional Oils

Table A-1—Light Shale Oils

Oil Categories:

Shale oils or light tight oils are very light crude oils from oil reservoirs with very low permeability that are produced by horizontal drilling and fracking methods. Often, the production sites do not have a local or central processing facility, and the crude that is shipped off site contains all the volatile fractions. This characteristic may create added fire risks and air quality concerns during spills oil because of the high volatility due to the presence of dissolved gases. Examples of this type of oil include those produced from the following fields:

- Bakken, North Dakota and Montana, U.S.; Saskatchewan and Manitoba, Canada. U.S. production in 2015 was about 1,200,000 barrels (bbl) per day.
- Eagle Ford, Texas. U.S. production in 2015 was about 1,300,000 bbl per day.
- Niobrara, Colorado. U.S. production in 2015 was about 400,000 bbl per day.
- Barnett: Texas. U.S. production in 2015 was about 2,000 bbl per day.

Environmental Behavior and Effects (Sandia, 2015; USEPA, 2015a; TRANSCAER et al., 2015):

- Specific Gravity: 0.7–0.8 (API 36–44); considered to be a very light Group 2 oil, because, as a crude oil, it contains persistent compounds, and always floats on water.
- Vapor Density: 2.5–5.0, which is heavier than air; vapors may not dissipate quickly.
- Pour Point: –32.8°F; always a liquid.
- Reid Vapor Pressure at 100°F: range of 8–12.2 pounds per square inch absolute (psia); highly volatile (by comparison, gasoline is 8–15 psia, and ethanol is 2.3 psia).
- Concentration of light ends: 7–8% dissolved gases from methane to butane (compared to 3% for South Louisiana crude oil, 5.9% for West Texas Intermediate crude oil, and 8.3% for Eagle Ford crude); the light shale oils have higher amount of volatile components.
- Sulfur Content: Low (<0.2%); therefore, considered a “sweet” oil (defined as <0.5% sulfur); minimal H_2S health hazard (generally <10 ppm in the oil).
- There may be secondary releases of volatiles, and concerns for ignition and worker safety, when:
    - Pooled oil on land migrates to water and quickly spreads;
    - Oil seeps into trenches dug to intercept subsurface flow from a subsurface spill from a buried pipeline;
    - As temperatures increase during the day;
    - Where oil enters storm drains, creating a hazardous confined space; and
    - Damaged rail cars are being moved.

Summary:

Light shale oils are volatile and may contain a higher percent of dissolved gases than most crude oils, which poses a high risk of ignition as well as inhalation hazards to responders and the public shortly after a release. When released to water, these oils can lose about 50% of the volume by evaporation and are readily dispersed under turbulent conditions. Spills on land that penetrate into the soil lose the volatile fractions more slowly, and there can be secondary releases of volatiles during excavation and trenching.

Table A-2—Diluted Bitumen Products

Oil Categories:

Diluted bitumen products are oils created from bitumen, which is a highly weathered and viscous form of petroleum produced from the tar sands or oil sands in Canada. Production of bitumen is expected to increase 2.5-fold from 2013 to 2030. Bitumen has a density that is very close to 1 gram per cubic centimeter (g/cm^3) and a viscosity of ~50,000 centistokes (cSt). Diluted bitumen is an engineered product that is blended with a lighter hydrocarbon(s) to meet the minimum requirements for transport in pipelines (viscosity <350 cSt and density <0.94 g/cm^3). The lighter hydrocarbons do not separate from the blend as a liquid, though are lost by normal volatilization processes. Although this would be categorized as a Group 3 oil based on the initial density, when released to the environment the rapid weathering creates an oil that has the properties of a Group 4 oil, and is therefore assigned to that group. Table A-3 describes the different character of some of the bitumen products.

Environmental Behavior and Effects:

— Spilled diluted bitumen products initially behave like a medium crude oil. However, upon loss of the light hydrocarbon diluent fractions, the density can approach and occasionally exceed 1 g/cm^3, and the viscosity can reach over 1,000,000 cSt.

— Studies have shown that diluted bitumen spills would be expected to pose air quality concerns, similar to those associated with medium crude oil spills, which can be of significant concern for responders and when the spill occurs in proximity to residents. BTEX concentrations (average of 0.84% by volume) and H_2S concentrations (<25 ppm) may be lower than other crude oils.

— A key objective for a response for spills to water is to contain and recover the spilled oil very quickly before loss of the diluent.

— In most cases, in situ burning of diluted bitumen spills to water can be effective only for the first 24 hours after release due to evaporative loss of the diluent.

— Weathered diluted bitumen is very adhesive and adheres strongly to solid substrates, sediments, and vegetation.

— Under turbulent conditions, diluted bitumen can break into small droplets that interact with suspended sediments and organic matter and form oil:particle aggregates. If heavier than the surround water, these aggregates can sink to the bottom in low-turbulence settings in impoundments and side channels, and under high-water conditions, in oxbow lakes and floodplains.

— Oil droplets that sink can be spontaneously released from the bottom of a water body by a process known as ebullition, where anaerobic degradation of organic-rich sediments generates bubbles of methane that carry oil with them as they rise to the surface (Fitzpatrick et al., 2015). This process can increase during warmer water temperatures. Thus, chronic sheening can be a concern in low-flow areas where oil has accumulated on the bottom.

— For spills in rivers, sunken oil:particle aggregates can become resuspended during higher flow conditions, migrate downstream, and again accumulate in low-flow areas.

— Spilled residues undergo little additional weathering and may be persistent when stranded on the shoreline or accumulated in bottom sediments as the bitumen component is initially highly weathered.

Summary:

According to the report by the National Academies on diluted bitumen behavior (National Academies of Sciences, Engineering, and Medicine, 2016):

> Immediately following a spill, the environmental process, behavior, and toxicity of diluted bitumen are similar to those of other commonly transported crudes. Beginning immediately after a spill, however, exposure to the environment begins to change spilled diluted bitumen through various weathering processes. The net effect is a reversion toward properties of the initial bitumen. An important factor is the amount of time necessary for oil to weather into an adhesive, dense, viscous material. For any crude oil spill, lighter, volatile compounds begin to evaporate promptly; in the case of diluted bitumen, a dense, viscous material with a strong tendency to adhere to surfaces begins to form as a residue. For this reason, spills of diluted bitumen pose particular challenges when the reach water bodies. In some cases, the residues can submerge or sink to the bottom of the waterbody. Importantly, the density of the residual oil does not necessarily need to reach or exceed the density of the surrounding water for this to occur. The crude oil may combine with particles present in the water column to submerged, and then remain in suspension or sink.

Table A-3—Characteristics of Some Different Bitumen Products

Product	Description
Bitumen, Neatbit	Undiluted, extremely heavy oil extracted from oil sands. Must be heated to be shipped.
Diluent	Any light petroleum components used to dilute bitumen for transportation by pipeline or rail; traditionally a condensate or ultralight crude oil but can be a refinery cut, such as naphtha.
Synthetic crude	A liquid product made by partial upgrading or refining of bitumen; used as a diluent in synbit.
Dilbit	Bitumen diluted with ~30% diluent, such as condensate or naphtha, for transportation
Railbit	Bitumen diluted with ~15% diluent (i.e., half as much diluent as dilbit), typically for transport by rail car.
Synbit	Bitumen diluted ~50% with synthetic crude.
Dilsynbit	Bitumen diluted with synthetic crude plus another diluent, usually a condensate; currently (2015) Albian Heavy Synthetic is the only dilsynbit transported.
Lightened Dilbit or C_4/C_5 enhanced Dilbit	Bitumen blended with a diluent supplemented with low molecular weight alkanes such as C_4 (butane) and C_5 (pentane).

Table A-4—Biodiesels

Oil Categories:

Biodiesel can be defined as fatty acid monoalkyl esters (FAMEs), which are transesterified oils derived from vegetable oils or animal fats and blended with or used in place of conventional diesel fuels. In the U.S., most biodiesel is derived from soybean oil. Pure biodiesel (B100) is transported by rail and truck to facilities where they are blended with diesel at 5 to 20% (B5/B20) and then transported by truck to retailers who store them in both above- and below-ground tanks.

Environmental Behavior and Effects:

- Pure biodiesel properties are (Hollebone, 2009):
  - Not very soluble in water, with a water-soluble fraction of pure biodiesel typically 20–60 milligrams per liter (mg/L), but as high as 110 mg/L, whereas B5 and B20 have a water-soluble fraction of 20–30 mg/L. Petrodiesels have water-soluble fraction of 20–40 mg/L.
  - 100% soluble in diesel.
  - Less dense than water, with densities of 0.84–0.90 g/cm^{3}.
  - More viscous than water or diesel; higher recovery rates with skimmers compared to petrodiesel.
  - Can gel at low temperatures.
  - Have a very low vapor pressure, thus have a low fire risk.
  - Are mildly corrosive to metals, plastics, and other synthetic materials.
  - Are expected to behave similarly to petrodiesel at surface water release sites.
  - Naturally disperse much more easily than petrodiesel.
  - Biodiesels are mild surfactants; form a white, milky emulsion.
  - Can cause dispersion of diesel into the water column in blends as low as B10 to B20.
  - Biodegrade 2–2.5 times faster than petrodiesels in typical conditions.
  - Are at least 5 times less acutely toxic than petroleum diesels.
- Biodiesel/petrodiesel blends up to 20% have a toxicity that is similar to petrodiesel, though toxicity varies widely by biodiesels, possibly due to feedstock or additives.
- These oils can be difficult to detect visually.
- For most sorbent types, the recovery rate is very similar to that of fuels of same viscosity.

Summary:

Spills of biodiesel blends to water typically behave similar to petrodiesel at first, the rate of natural dispersion can increase and slow the rate of droplet resurfacing. Over time, biodiesels become more viscous and the recovery of any remaining floating product can be high using skimmers and sorbents. Aquatic life can suffocate because of the depletion of oxygen caused by releases to shallow or isolated water bodies. The high biodegradation rates of biodiesels in water (both fresh and salt) and soils is days to weeks under aerobic conditions and weeks to months under anaerobic conditions. This rapid weathering rate can support the decision to allow natural attenuation of residues after gross oil removal, if supplemental oxygen is supplied or naturally occurring oxygen is sufficient to support microbial degradation.

Table A-5—Non-petroleum Oils

Oil Categories:

Include animal fats (e.g., beef tallow oil) and vegetable oils (e.g., soybean oil, palm oil, rapeseed oil, sunflower oil). These oils are regulated under 40 CFR 112 and have similar spill-planning requirements for petroleum and non-petroleum oils. Vegetable oils are liquids, lighter than water (specific gravity of 0.90–0.96), and float initially. Vegetable oils can be used as lubricants in dredges and other equipment.

Environmental Behavior and Effects:

- Penetrate into porous sediments; most have viscosities less than 100 cSt at 20°C.
- Rapidly deplete the oxygen levels in the sediments and isolated water bodies because of the high biological oxygen demand (BOD).
- Sorb onto suspended particulates and sink to the bottom depending on the amount and density of the particulates.
- Can cause physical effects by coating animals and plants with oil and fouling of gills.
- Can be toxic and form toxic intermediate products during oxidation and microbial degradation.
- Produce rancid odors, thus could become an attractant to certain animals, such as bear.
- Foul shorelines, clog water treatment plants, and catch fire when ignition sources are present.
- Polymerize (components cross link) thus harden into concrete-like lumps in sandy sediments that can persist for years; however, these lumps can be effectively removed during cleanup operations.
- Be biodegradable, even under anoxic conditions.

Summary:

Little is known about the properties and behavior of animal fats, which tend to be more solid at ambient temperatures. A spill of 15,000 gallons of beef tallow into the Houston Ship Channel in 2011 formed thick patties that were corralled using fish nets and removed using pitchforks. Animal fats would likely pose fouling risks to animals and plants, have a high BOD, produce rancid odors, and slowly biodegrade.

Spills of animal fats and vegetable oils can kill or injure wildlife and produce other undesirable effects. Wildlife that becomes coated with animal fats or vegetable oils could die of hypothermia, dehydration and diarrhea, or starvation. Aquatic life can suffocate because of the depletion of oxygen caused by spilled animal fats and vegetable oils in shallow or isolated water bodies.

Appendix B
Best Management Practices

These best management practices (BMPs) can be used to guide the planning and implementation of response operations and included in Treatment Recommendations issued by the Environmental Unit. This is a partial list and other BMPs may be appropriate to take into account local environmental conditions or site-specific features.

General

— Remove anything (e.g., trash, food items) that would attract wildlife from work areas daily.

— Avoid disturbing and harassing wildlife and habitat.

— When the project is within 250 feet of sensitive cultural resources as indicated on resource maps, a qualified historic preservation professional must be present to monitor operations activities.

Staging and Waste Collection Areas

— Evaluate proposed staging areas with a qualified biologist survey to determine if there are sensitive species present and identify site-specific areas to avoid and best practices.

— In soft sediments, use sand mats, mud mats or similar materials to prevent rutting and erosion.

Foot Traffic

— Restrict foot traffic in sensitive areas, particularly wetlands.

— When foot traffic in sensitive areas is required, use walking boards, sand mats, etc. to minimize disturbance and trampling of the soils and vegetation.

Vehicle Traffic

— Follow existing or designated access/egress areas and roadways.

— UTVs should remain within established travel paths when possible or follow marked, designated traffic routes.

— Limit machinery fording of a stream to a one-time event (i.e., over and back), and only if no alternative crossing method is available. If repeated stream crossings are required, construct a temporary crossing structure. In remote areas, use stream bank and bed protection methods (e.g., swamp mats, pads).

Vessel Operations

— Avoid scouring and prop-scarring of submerged aquatic vegetation.

— Land or stage boats to avoid crushing the vegetation along the shoreline.

Vacuum/Pumping

- Use proper nozzle selection and operator supervision to optimize oil removal and minimize co-collected water or sediment.
- Treat all co-collected water prior to discharge. If on-site treatment is not feasible, store the water and transport for off-site treatment.
- In wetlands, monitor vacuum operations closely to minimize impact to plant root system, which could lead to plant mortality and erosion.

Sorbent Boom

- Do not deploy sorbents in a manner that could endanger or trap wildlife.
- Monitor sorbents daily to ensure that they are effective, replaced when needed, and not crushing or smothering vegetation or endangering wildlife.

Underflow Dams on Smaller Streams

- Not likely to be effective on streams greater than 6 feet wide, or if the banks of the creek are very low, which could cause the dammed water and oil to spread into the floodplain.
- Locate the dam where there is sufficient access for equipment and workers to recover contained oil.
- If unoiled natural woody debris is removed from the stream during installation of the dam, set aside and return it to the original location once the response activities are completed.
- Consider rainfall patterns in the design of the dam (height of the dam and volume of water that is able to flow through the dam) to avoid overtopping of the dam during rainfall events.
- Maintain the water flow through the dam to avoid impacts to downstream resources, where appropriate.
- Ensure a good seal with the bank at all times; repair any washouts immediately.
- In difficult to access sites, use small, portable vacuum systems or oleophilic skimmers to recover the contained oil, to minimize waste generation.
- If weather forecasts indicate very high flow conditions, be prepared to remove the dam.

Filter Fences on Streams

- Consider use for small amounts of floating oil, oil suspended in the water, or oil moving along the bottom.
- Can be composed of wire mesh fences or baskets stuffed with snare or hay bales staked into the ground, depending on flow volume.
- Weighted gabion-type baskets filled with snare can be placed on the bottom to recover suspended oil in deeper streams where the flow is less than ~1 foot per second; higher flows can cause scouring and reduce oil sorption.

Trenching

— Approval or archaeological monitors may be needed to dig or excavate in areas with known or suspected cultural resources.

— Locate trenches and recovery wells in un-vegetated areas.

— Segregate clean topsoil where practical.

— Line trenches that do not reach the water table with plastic to prevent the collected oil from penetrating deeper into the substrate.

— Install temporary erosion controls immediately after initial disturbance of the soil.

— If trench dewatering is utilized, filter removed water through a trench dewatering structure.

— Collapse or fill in trenches when response actions are completed; ensure sides and bottom of trenches are clean before collapsing.

— Replace topsoil where practical.

— Return the surface to its original contour and replant with native vegetation.

Flushing in Streams

— Prop intake hoses off the bottom of the source water body by at least 1 foot to minimize the amount of sediment, debris, and organisms taken into the hose and pump.

— Fit intake hoses with screens to minimize the extraction of debris, flora, and fauna.

— Adjust nozzle for the lowest “point of contact” pressure appropriate to remobilize oil without over-disturbing or eroding sediments.

— If sediment erosion occurs, lower the outlet pressure and/or increase the elevation of the nozzle and/or the angle of the flow.

— Locate containment areas where there is sufficient on-land or on-water access for equipment and workers to recover the mobilized oil.

— Where stream banks have been disturbed or damaged, use soil blankets and coir logs to stabilize the banks and prevent erosion.

Debris Removal

— Do not remove unoiled debris, as this typically has important habitat value.

— Minimize removal of lightly oiled debris, particularly in areas of low public use and low environmental sensitivity.

— Minimize foot traffic in soft substrates; use walking boards where needed during debris removal operations.

— Replace with clean debris in streams if excessive removal affects stream stability and habitat value.

Appendix C
Firefighting Foam

Many fire departments have added firefighting foam equipment to their response capabilities to address the risk of ignitions associated with the transport of light shale oils by rail. There are two types of fires according to U.S. classification applicable to oil spills:

Class A fires: involve combustible products such as vegetation, wood, cloth, paper, rubber, and plastics.

Class B fires: involve flammable liquid fuels. There are two liquid fuel categories:

— hydrocarbon fuels, such as gasoline, crude oils, ethylene, propylene, and butylene;

— alcohol fuels or polar solvents (liquids with molecules that have a slight electrical charge due to their shape) that mix easily with water, such as acetone, ethanol, and isoproponal.

Foams are used for extinguishing flammable and combustible liquids as well as non-liquids. Unlike other extinguishing agents (water, dry chemicals, and carbon dioxide), a stable, aqueous foam can extinguish a flammable or combustible liquid fire by one or more of following mechanisms:

— cooling fuels and any adjacent metal surfaces;

— separating flame/ignition source from the fuel surface;

— suppressing the release of flammable or toxic vapors that can mix with air;

— smothering the fuel surface fire;

— preventing re-flash or re-ignition of the fuel.

Foams are a stable mass of small, air-filled bubbles that have a lower density than oil or water. Foams are composed of three ingredients: water, foam concentrate, and air. When mixed in correct proportions, these three ingredients form a homogenous blanket that smothers flames and induces vapor suppression. Current types of foams can be used in fresh, brackish, and high salinity waters.

When addressing a flammable fuel fire, a responder must determine if the product involved is a standard hydrocarbon fuel or polar solvent fuel. Some foam concentrates are designed specifically for hydrocarbon fuels and do not work with polar solvents and vice versa.

There are seven general types of foams for Class B fires that are available in application rates of 1, 3, or 6%, depending on a fire source or fuel type:

1) Protein foams are used in 3% and 6% concentrations.

    — Consist of protein hydrolysate, foam stabilizers, and preservatives.

    — Must be applied gently or indirectly to a fuel source.

2) Fluoroprotein foams are used in 3% and 6% concentrations.

    — Consist of same ingredients as protein foams with addition of fluorocarbon surfactants.

- More resistant to fuel contamination/pickup and more mobile than protein foam.
- Can be applied directly and from a distance.

3) Aqueous Film Forming Foams (AFFF) are used in 1%, 3%, and 6% concentrations.

   - Ingredients consist of synthetic foaming agents, solvents, fluoro-chemical surfactants, salts, and foam stabilizers.
   - Form an aqueous film on the surface of a fuel.

Prior to 2002, formations of AFFF contained perfluorooctanesulphonate, for which degradation products are toxic and persistent in the environment, bioaccumulate, and can cause long-term groundwater contamination, particularly at firefighting training sites (Seow, 2013). All modern AFFF agents produced in the U.S. contain telomer-based fluorosurfactants and are not made with any chemicals that are currently considered by USEPA to be persistent, bioaccumulative, and toxic. The C6-based fluorosurfactants that are the predominant fluorochemicals used in telomer-based AFFF are low in toxicity and not considered to be bioaccumulative or biopersistent. Foam manufacturers are in the process of transitioning to the use of pure C6-based fluorosurfactants (http://www.fffc.org/images/AFFFfactsheet14.pdf).

4) Film Forming Fluoroprotein foams (FFFP) are used in 3% and 6% concentrations.

   - FFFP is a combination of AFFF and fluoroprotein foam.
   - Contain the quick knockdown of AFFF along with burnback resistance of fluoroprotein foam.

5) Alcohol Resistant Aqueous Film Forming Foams (AR-AFFF) are used in 3% and 6% concentrations.

   - Consist of AFFF as a base with an added high-molecular-weight polymer.
   - When used on a polar solvent fuel, protects foam from being destroyed or absorbed by the fuel.
   - Can be used as 3% concentrate on hydrocarbon fuel and 6% on polar solvent fuel.

6) Alcohol Resistant Film Forming Fluoroprotein foams (AR-FFFP) are used in 3% and 6% concentrations.

   - Consist of FFFP as a base with an added high molecular weight polymer.
   - When used on a polar solvent fuel, protects foam from being destroyed or absorbed by the fuel.

7) Synthetic foam concentrates (S) are used in 1–3% concentrations.

   - Consist of mixtures of hydrocarbon surface active agents and can contain fluorinated surface agents with additional stabilizers.
   - Contain very little water and are suitable for rapid smothering and cooling.

Guidelines for discharge to wastewater treatment facilities:

- Foam solutions cause copious foaming in aeration ponds, even at very low concentrations, which can interfere with wastewater treatment.

- Review the safety data sheet for information on aquatic toxicity, degradation rate, and biological oxygen demand/chemical oxygen demand (BOD/COD).

- High BOD/COD in foam can cause shock loading and upset of wastewater treatment plants.

- Foam concentration in influent water should not exceed 1,700 ppm. De-foamers can reduce, but not eliminate, foaming. There are no other known pretreatment options.

- Foam solutions have tendency to emulsify fuels, which can interfere with operation of oil/water separators as part of stormwater treatment or pre-treatment prior to discharge to wastewater facilities.

Guidelines for discharge to water bodies without treatment:

- The best environmental practice is to use a firefighting foam that does not contain any flurorochemicals.

- Firefighting foams that contain fluorochemicals should not be released to the environment; the firefighting runoff must be fully contained and disposed of at approved treatment facilities. Plan for large volumes of firefighting water.

- The surfactants are the primary cause of environmental concerns for toxicity and persistence. There are limited aquatic toxicity data available for a wide range of foam products, and toxicity can vary widely depending on product composition. Available data show LC_{50s} for fathead minnow and water flea in the range of 20–2,000 ppm and for rainbow trout and bluegill in the range of 10–1,500 ppm, indicating that toxicity varies by product. LC_{50s} for algae were lower, in the range of 140–180 ppm.

- Releases can cause foaming in rivers and streams at very low concentrations.

- In the absence of existing containment (e.g., stormwater sewer in a facility), use manual containment, including:

  - Blocking sewer drains and diverting fire-fighting runoff to a collection area.

  - Building portable dikes on land.

  - Deploying booms in water to contain foam for recovery.

- Do not allow foam to drift into areas where it could come into contact with wildlife (birds and aquatic mammals), because surfactants could interfere with waterproofing of fur and feathers. Heavy foam can smother birds. Foam of a certain bubble size creates an occlusion in the trachea of birds, causing a rapid onset of suffocation with a heavy layer of foam.

- Foam can emulsify light fuels, increasing the potential for fuel dispersion into water.

- Surfactants in foam solutions have a tendency to emulsify fuels, and used foam solutions can be heavily contaminated with the fuel.

Appendix D

Responding to Spills of Very Light Crude Oils That Ignite

Disclaimer: Users of this guide should not rely exclusively on the information contained in this Appendix D. Sound scientific and safety judgment should be used in employing the information contained herein. Where applicable, authorities having jurisdiction should be consulted. API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations to comply with authorities having jurisdiction.

This appendix is in two parts: On Land and On Water.

In the event of a release of a very light crude oil **On Land with FIRE**:

Secure the perimeter
— Establish and secure a safety zone. Refer to the Emergency Response Guidebook (ERG 128).
— Evacuate non-essential personnel or public evacuation based on area affected (ERG 128).
— Park first responder vehicles away from manholes and storm sewers.
— Conduct air monitoring to identify hazards and assist in establishing hot, warm, and cold zones and appropriate PPE for responder safety (Table 29).
Stop the source
— Close valves, plug holes, etc. if this can be done safely and using non-sparking tools. However, only pipeline staff should attempt to open or close pipeline valves.
Determine fire-fighting strategy (this may change over time)
Intervention
— Apply Class B firefighting foam. Foam is most effective on static fires that are contained in some manner. Firefighting foam is not effective on hydrocarbon fuels in motion (i.e., three dimensional fires) that include product leaking or spraying from manways, valves, fractures in a tank shell (e.g., rips, tears, etc.), or spills on sloping terrain.
— Key Issue: An adequate supply of foam and other equipment available for post-fire operations that may last for several hours or days.
— Apply cooling water to any exposures including adjacent tank cars or trucks containing ignition or BLEVE (boiling liquid expanding vapor explosion) hazards.
— Do not apply water directly inside a rail car or tank. Apply water from the sides and from a safe distance to keep fire-exposed containers cool. Use unmanned fire monitors for cooling rail cars when available. Withdraw immediately in case of rising sound from venting pressure relief devices or tank discoloration. If available, dry chemical extinguishing agents, such as potassium bicarbonate (i.e., Purple K), may also be used in conjunction with Class B foams.
— Improper application of fire streams may create a dangerous phenomenon known as a “slopover”, increasing risks to emergency responders. A slopover results when a water stream is applied to a hot surface of burning oil. The water is converted into steam causing agitation of the liquid and burning oil to slop over the sides of a tank or rail car. This can occur within 10 minutes of the product becoming involved in fire. Note: Slopover does not occur in a pool of crude oil on the ground. However, a water stream can spread the fire.
— Application of foam, even if done properly many cause “frothover” if the fire cannot be immediately extinguished. Frothover can occur as foam breaks down on the water surface and drains into burning oil prior to extinguishment causing conditions similar to slopover.

— Dry chemical extinguishing agents must be compatible with foam.

Non-intervention

— Allow currently burning oil to continue to burn.

— Move non-affected rail cars/containers from fire area if this can be done safely.

— Consider the need for additional fire breaks.

— Apply cooling water to adjacent rail cars, tanks, or other vehicles containing oil. Use unmanned hose holders or monitor nozzles to reduce fire fighter risk.

— Monitor the progress of a fire. Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.

Control firefighting water runoff

— Prevent runoff from entering storm or sewer systems and sensitive areas, as this may create a serious hazard and environmental problems. Appendix C provides more information on use of firefighting foam.

— Notify proper authorities, downstream sewer and water treatment operations, and other downstream users of potentially contaminated water.

— Runoff may be flammable and/or toxic and should be contained, treated, and disposed of in accordance with applicable federal, state, and local environmental regulations.

Minimize spread of unburned oil on land

— Construct berms, trenches, etc. but only at safe distances as determined by continuous air quality monitoring.

— Be aware of vapor ignition hazards in areas where oil has been contained, or in sewers and other confined space where oil has spread.

Minimize spread of unburned oil into a water body

— Construct dams, dikes, diversions, etc., but only at safe distances as determined by continuous air quality monitoring.

— Be aware of vapor ignition hazards in areas where oil has been contained, or in sewers and other confined space where oil has spread.

— Be aware that there can be renewed release of VOCs, benzene, etc. when oil that was thick on land reaches a water body and spreads into a thinner slick.

Determine if booms should be used to contain oil on water for recovery

— Monitor VOCs and benzene adjacent to floating oil on water. If VOCs and benzene levels are above thresholds, provide appropriate PPE for responders.

— In addition, monitor for LEL near floating oil in smaller water bodies (streams and ponds), where vapors could concentrate in low areas and not be dispersed by air turbulence.

— If levels are below thresholds, proceed with oil containment and recovery.

— If LEL is >10%, do not attempt containment but continue monitoring. Once levels are below 25% LEL, proceed with containment and recovery and continue monitoring.

Implement protection strategies at sensitive areas

— If oil is present, monitor for VOCs and benzene to determine responder PPE before implementing the protection strategy. Refer to OSHAs Respiratory Protection Standard 29 CFR 1910.134 for more information (https://www.osha.gov/dte/library/respirators/major_requirements.pdf).

— If no oil is present, proceed with implementing the protection strategy.

In the event of a release of a very light crude oil **on water with FIRE**:

Secure the perimeter
— Establish and secure a safety zone around a release site. Refer to the Emergency Response Guidebook (ERG 128). — Evacuate non-essential personnel or public based on area affected. — Utilize Thermal Imaging camera or Forward Looking Infrared camera to determine extent of fire impact on shoreline structures. — Conduct air monitoring to identify hazards and assist in establishing hot, warm and cold zones and offsite impacts and required PPE for responder safety (Table 29).
Stop the source
— Close valves, plug holes if this can be done safely and using non-sparking tools.
Determine fire-fighting strategy (can change over time)
Intervention — Apply cooling water externally to any structures including adjacent docks, piers, tanks, vessel hull and deck. Avoid putting water into interior of vessel to prevent destabilization. Water streams may be needed to cool fire before application of firefighting foam. — Apply Class B firefighting foam. Foam is most effective on static fires that are contained in some manner. Foam is ineffective on free-floating fuel fires and must be contained in some manner to be extinguished. — If available, dry chemical extinguishing agents, such as potassium bicarbonate (i.e., Purple K) may also be used in conjunction with Class B foams. — <u>Key Issue</u>: An adequate supply of foam and other equipment available for post-fire operations that may last for several hours or days. **Non-intervention** — Allow currently burning oil to continue to burn. — Apply cooling water to any shoreline structures at risk.
Minimize spread of burning oil
— Booming may be used to reduce the impact and spread of floating fuel fires. Fire boom can be used if available, but normal boom may be used if it is protected by Class B foam to keep fire from affecting a boom. — Fire streams may be set up on shoreline structures that could be impacted by floating fuel fires to deflect fuel and/or protect exposures.
Determine if additional protective measures should be used to limit the impact of flammable vapors
— If flammable vapors are detected in areas of concern, consider the need for vapor dispersion utilizing fog streams from fixed or portable fire monitors — If vapors cannot be suppressed utilizing Class B foams, consider using fire monitors to agitate oil on water to more rapidly increase vaporization to facilitate mechanical oil removal from water.

Additional Resources

Emergency Response Guidebook. USDOT. 2016. Available at: http://www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/Hazmat/ERG2016.pdf

Region III LEPC Fact Sheet: Bakken Crude Oil: Available at: https://crrc.unh.edu/sites/crrc.unh.edu/files/lepc_update_2015_february_regioniii_rev3_0.pdf

Sandia Report on Literature Survey of Crude Oil Properties Relevant to Handling and Fire Safety in Transport. DOE/DOT Tight Crude Oil Flammability and Transportation Spill Safety Project. March 2015. Available at: http://prod.sandia.gov/techlib/access-control.cgi/2015/151823.pdf

TRANSCAER API AAR Crude Oil by Rail Safety Course. March 2015. Available at: http://www.api.org/~/media/files/oil-and-natural-gas/rail-transportation/transcaer-api-aar-crude-oil-by-rail-safety-course.pdf

Consensus Ecological Risk Assessment of Potential Transportation-related Bakken and Dilbit Crude Oil Spills in the Delaware Bay Area: Comparative Evaluation of Response Actions. 2015. Available at: https://www.uscg.mil/d5/sectDelawareBay/Planning/Final_ERA_report_093015%20REV.pdf

National Response Team Webinar. Available at: http://www.nrt.org/production/NRT/NRTWeb.nsf/AllPagesByTitle/SP-EmergingRisksResponderAwarenessTrainingBakkenCrudeOil(2015)?Opendocument

Transportation Rail Incident Preparedness & Response: Flammable Liquid Unit Trains Resource Fact Sheet. Available at: https://www.iafc.org/files/1HAZ/TRIPRFlammableLiquidUnitTrainsFactSheet.pdf

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