OIL SPILL SIMULATION MATERIALS REVIEW

From Science to Solutions

Science Applications International Corporation
(SAIC Canada)
Environmental Program

Report presented to:
Prince William Sound
Regional Citizens' Advisory Council
Anchorage, Alaska

Contract No. 709.08.01

The opinions expressed in this PWSRCAC commissioned report are not necessarily those of PWSRCAC.

November 2008

Prince William Sound RCAC: 709.08.01
SAIC Canada Project Number: 17345
CM Number: CM002205

SAIC Canada Ottawa • Halifax
Information, Environmental and Engineering Solutions Division

QUALITY ASSURANCE AND MANAGEMENT SYSTEM	
Report Title	Oil Spill Simulation Materials Review
Report Date	November 2008
Report Number	CM002205, 17345.B.01

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(Version QM-QP-v4)

8702-QF-PRR-10

ACKNOWLEDGEMENTS

The funding for this report was provided by the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC). Mr. Roy Robertson of PWSRCAC was the scientific authority for this work.

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ABSTRACT

Evaluations of spill response equipment has benefitted from numerous standardized tests that have been developed over the past fifteen years. Quantitative evaluations under controlled conditions are now possible in a limited number of testing facilities for comparing and evaluating equipment performance. There is a need for further evaluations on a larger scale to evaluate equipment deployment and recovery techniques, as well as a need for other organizations to perform in-house testing using “safe” oils. The use of crude oil or bunker products is environmentally concerning from an environmental as well as worker-safety standpoint due to the potential risk of release and exposure. An oil simulant with similar properties could be used in such evaluations provided the simulant mimics critical oil properties it is meant to replace.

This report categorizes a range of oil spill detection, containment, and recovery equipment typically used in spill response. General background information is provided about selected oil types along with specific oil characteristics deemed critical for evaluation purposes. Oil simulants that have recently been used or considered for use by the oil spill response community are also listed. An evaluation of these simulants versus the general categories of containment and recovery equipment is made, along with recommendations for the selection of appropriate oil spill simulants.

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1 INTRODUCTION

Training of oil spill responders remains a critical issue supporting the preparedness and enhancing the abilities of a response effort. Testing and training involving actual crude or bunker oil can be problematic due to health and safety (handing), environmental and legal (permitting) concerns. The goal of this project is to identify the types of oil simulation materials that are currently available for use during training exercises and determine their effectiveness, advantages, disadvantages, and permitting requirements.

2 PROJECT OBJECTIVE AND SCOPE

The objectives of this project are as follows:

- Determine the types of oil simulation materials available where they have been used during training exercises;
- Determine the effectiveness of oil simulation materials;
- Determine the advantages and disadvantages of each of the identified oil simulant material; and
- Determine the Federal and State permitting requirements, if any, specific to Alaska, for using oil simulation materials for oil spill training and drills.

3 METHODOLOGY

The use of various types of oil simulation materials was researched through literature reviews and interviews with spill response organizations in North America, Europe and Asia. Specific instances where oil simulation materials have been used with spill response equipment were sought.

Contact was made with a range of agencies across North America and Europe with expertise and/or experience in conducting training exercises and drills. The agencies fell into one the following four categories:

1. State agencies with spill drill and training exercise programs including Alaska, Washington, California, Texas, Florida, Maine and New Jersey;
2. Federal agencies such as the United States Coast Guard, Environmental Protection Agency, and Minerals Management Service;
3. Domestic cleanup contractors, consultants and cooperatives such as Cook Inlet Spill Response Inc., Southeast Alaska Petroleum Resource Organization, Alaska Clean Seas, Marine Spill Response Corporation, National Response Corporation, and Spiltec; and
4. International agencies, cleanup contractors, companies/industry, industry representatives, consultants and cooperatives including Oil Spill Response Ltd., East Asia Response Ltd., Finnish Environment Institute (SYKE), Norwegian Oil Spill Control Association, UKSpill Association, SYCOPOL France, Environment Canada, and Canadian Coast Guard.

4 IDENTIFICATION OF TYPES OF EQUIPMENT COMMONLY USED DURING SPILL RESPONSE

A wide range of equipment is commonly used during an oil spill response. Initially detection is employed to identify areas of coverage and to try to approximate quantities discharged to the environment. Containment follows to limit the spread of oil and protect sensitive areas. Finally, recovery equipment is used to remove spilled oil from the environment. Physical and chemical properties required by oil simulants to mimic actual oils are described below.

4.1 Detection

A variety of methods have been developed for the detection of spilled oil. Perhaps the simplest relies on the visual observation of sheen on the surface of the water. Difficulties in actually detecting sheen can, however, prove problematic. Trained observers are normally used in this role due to the difficulties that can be encountered. Climactic and environmental conditions can mask or enhance the reflective properties of a slick. Even the angle of the observer to the surface of the water and the location of the sun can affect whether or not sheen is detected. The issue of positively identifying an apparent slick versus naturally occurring organic matter in the water column such as an algae bloom can also prove challenging. A range of sensors have been developed which help to detect oil under a range of environmental conditions. These sensors employ electromagnetic waves in discrete wavelengths such as active radar, side-looking airborne radar (SLAR) and synthetic aperture radar (SAR), microwave radiometers, thermal infrared cameras, mid-band infrared cameras, Ultra Violet (UV) cameras, and laser fluorosensors. (Goodman et al, 2003) These techniques rely on physical as well as chemical characteristics to detect “foreign” matter on or in the water column. Trained operators are normally required to positively identify the presence of oil in order to distinguish it from background materials.

Simulants used for detection exercises should have similar physical as well as chemical characteristics in order to be properly identified. As an example, crude and refined oil products are primarily composed of straight chain (alkanes) and aromatic hydrocarbons, resins, polycyclic aromatic hydrocarbons (PAHs) and asphaltenes. PAHs are chemical compounds that consist of fused rings. Because of the structural arrangement of PAHs they tend to fluoresce in response to light energy in the UV range (Brown, 2007).

4.2 Containment

Containment refers to the action of slowing the migration of an oil slick, inhibiting its spreading. This helps concentrate the liquid into a defined area, which facilitates recovery with devices such as skimmers, pumps and sorbents. Containment can also be deployed in a defensive mode to protect sensitive areas by diverting oil away from an area.

Many commonly available containment booms are constrained by operational conditions that limit their ability to control oil. Responders and researchers have identified a number of parameters that have an impact on performance but these parameters have not been well documented in scientific tests. Booms can be towed in the catenary mode without losing oil at speeds of up to 0.9 knots in calm water, but this limit is restricted to approximately 0.7 knots when short regular waves or harbour chop is present. When operated in a diversionary mode or Vee-Sweep, this limit raises to 1.2 knots and possibly more (Schulze and Lane, 2001).

Physical parameters such as buoyancy to weight ratio, boom draft, oil viscosity and oil density seem to have the most impact on performance and have been scrutinized over the past few years. In spite of this, questions remain as to their direct influence on containment. As a general rule of thumb, entrainment losses from a boom positioned perpendicular to flow will start at flows under 1 knot. Simulant properties such as density, viscosity, and possibly surface tension may play important roles when reaching one of the critical stages of containment – the onset of entrainment losses.

Sorbent Booms are used in containment as well as recovery modes. Recent testing in containment configurations showed losses past a single sorbent boom at velocities around the 0.5 knot range in calm conditions (see Figure 1 below). Multiple rows of sorbent booms were evaluated and although oil migrated past the first row, it was contained within the quiescent area between rows at speeds up to 0.75 knots (Cooper et al, 2005). Secondary performance testing using standard sorbent protocols would be useful in determining retention within the body of the sorbent materials. Simulant properties of density would be critical for this type of product, with viscosity and surface tension becoming important as entrainment starts to occur.

Figure 1 - Containment Attempt at 0.5 knots

4.3 Recovery

Skimmers are mechanical devices designed to separate oil from the water interface using gravity, oleophilic adhesion, mechanical adhesion, or a combination of these. There are eleven main skimmer types, consisting of the boom skimmer, brush skimmer, disc skimmer, drum skimmer, paddle belt skimmer, rope mop skimmer, sorbent belt skimmer, submersion plane skimmer, suction skimmer, weir skimmer, and advancing weir skimmer (ASTM F1778, 2008).

There are three main areas of interest that must be identified when evaluating skimmers. These areas of interest include the operating environment, slick conditions, and skimmer performance criteria. Oil type and viscosity, and slick thickness are the pertinent criteria when selecting and evaluating a skimmer. Oil density will also have a role, albeit to a lesser extent depending upon the mechanical function of the skimmer head. Some performance testing has shown that oil with a density approaching that of the water body may prove more difficult to recover from the surface depending upon the nature of the mechanical feeding device. Oil may be driven underwater due to the mechanical action of the recovery device where it is no longer accessible to the collection mechanism.

Skimmers that perform successfully on lighter to medium oils may be rendered ineffective when attempting to collect heavy oils that tend to float low in the water. Even skimmers that rely on oleophilic properties such as drum, disk, and belt skimmers may have difficulty with heavy oils depending upon their design and the viscosity of the product being recovered. High density oils may tend to collect under a stationary skimmer and may result in a large quantity of oil that will resurface once skimming operations are halted.

Pumps used for oil spill recovery typically include centrifugal pumps, positive displacement pumps, and vacuum pumps. They are used as a means of transferring oil, oil and water mixtures, and emulsions. Centrifugal pumps and vacuum pumps may be used for lower viscosity oils while positive displacement pumps are normally used to transfer higher viscosity oils and emulsions, although there may be considerable overlap in the operating regime for all pumps depending upon how they are configured and operated.

There is one primary characteristic that affects the performance of a pumping system, specifically the viscosity of the fluid being pumped. Simulants would ideally fall into defined ranges of viscosity as indicated by standardized tests, such as the ASTM F1607 Standard Guide for Reporting of Test Performance Data for Oil Spill Response Pumps.

Oil spill sorbents are normally used to remediate smaller spills (up to a few hundred gallons), to remediate spills where access for equipment mobilization is restricted or as a polishing step for larger spills when continued operation of skimming devices is no longer effective. Sorbents are categorized by their material of construction into three groups: organic, inorganic, and synthetic. Standardized testing of sorbents further differentiates sorbents by type of construction, i.e., a pad / mat, pillow or particulate material configuration. The viscosity and to a lesser extent the density of the oil simulant would be the important characteristics in evaluating the performance of sorbent materials according to standardized testing (ASTM F726, 2008).

5 PROPERTIES OF OILS

A variety of oil types are commonly transported around the world on a regular basis. Products from crude oils through refined products cover a great range of product density, viscosity, and chemical composition that will affect how they will behave if released into the environment. General classifications of the oil can fall under the following categories:

- Gasoline or similar products: consisting of blends of motor vehicle gasoline, kerosene, and Jet A1 fuel,
- Light oil: consisting of diesel and similar products such as light marine diesel, fuel oil, and fuel residue,
- Medium to Heavy oil: consisting of heavy fuel oil (bunker) intermediate fuel oil, and heavy, medium, and light crude oil, and lubricating oil.

Oils in each of these classifications will behave differently if released into the environment and will pose unique challenges to mimic behavior. When oils are spilled into the marine or aquatic environment they will immediately spread across the surface and begin a number of processes. These processes include evaporation, oxidation, dispersion, dissolution, biodegradation, sedimentation, and emulsification. Chemical composition, viscosity, and density of the oil will have a large impact on the resultant behavior of the spilled oil.

Volatile portions of the oil will begin to evaporate while natural physical processes within the water column, such as surface waves and tidal current, will lead to changes in the properties of the oil as it starts to weather. Losses due to sinking are usually low in the initial phases of spills of lighter-than-water oil but may increase due to weathering and adsorption onto suspended particles in the water column. Degradation of the oil also occurs, albeit at a slower rate than the previous physical processes. Oxidation and biodegradation will occur over longer periods of time and will also be dependant upon the composition of the parent oil and the environmental conditions.

Extremely light fuels such as gasoline are considered, for this report, as a special case due to the inherent risk of fire and explosion during response operations and are not considered for simulation purposes.

5.1 Light Oil Behaviour

Light oil such as diesel and related fuel oils have low density (typically between 0.81 and 0.87 g/cm^3) and will spread out over a spilled surface quickly. They are composed of high proportions of volatile compounds with low molecular weight including benzene, toluene, ethylbenzene, and xylenes (BTEX). They also contain a mixture of low molecular weight straight chain alkanes plus lower concentrations of more complex hydrocarbon molecules. The chemical composition of the oil affects its physical properties and results in a low viscosity liquid. When spilled they have a tendency to spread out quickly. Uninhibited thin films may be formed ranging from tens of microns down to a few microns. Wind will affect the behavior of a spill by influencing the direction of travel of the slick and will also enhance the weathering of the oil as well as increasing mixing with water. The ambient temperature will also impact the spill, but mainly as a driving force of viscosity change (low) and evaporation. Losses due to evaporation may exceed 50% within the first few days (CEDRE, 2007). Agitation combined with weathering processes described above may also lead to the formation of an emulsion. Changes to surface tension resulting from emulsion formation can impact the ability of oleophilic spill response equipment such as sorbents or skimmers from operating effectively.

As light oils emulsify their viscosity will increase. This increase will be dependant upon a number of parameters but may result in a product that is several orders of magnitude as viscous as the starting product. It is for this reason that many evaluations of spill response equipment are geared for oils of medium to high viscosity ranges.

5.2 Heavy Oil Behaviour

Heavy oils are defined as asphaltic, dense (low API gravity), and viscous oils that are typically composed of relatively low proportions of volatile compounds with low molecular weight such as BTEX. They may also typically contain some two ring napthalenes and high proportions of high molecular weight compounds. The high molecular weight compounds can be paraffins (straight chain alkanes), asphaltenes (aromatic-type hydrocarbons), resins and other compounds with high melting points and high pour points (Chevron, 2006 and Hollebone, 2006). Paraffins tend to act as solvent molecules for a variety of high molecular weight compounds and actually help improve the overall flow characteristics of the oil (viscosity). Some, but not all, heavy oils contain moderate to high levels of asphaltenes (Chevron 2006). These asphaltenes can become problematic if they precipitate out and build-up on equipment. The density of the oil is the result of a large proportion of a mixture of complex, high molecular weight, non-paraffinic compounds and a low proportion of low molecular weight, volatile compounds. Heavy oils typically contain very little paraffin and the quantity of asphaltenes can vary greatly (Chevron, 2006 and Hollebone, 2006).

High density oils typically have higher pour points, which is a measurement indicated by the temperature below which the oil becomes a semi-solid and will not flow. Because of this, high density oils are typically shipped in a heated state to allow loading and off-loading of the product. This phenomenon can help recovery efforts because the oil will have a tendency to form large mats of varying thicknesses provided the sea is calm and personnel have access to the oil before wind and waves break-up the mats into tar balls of varying sizes. The resulting tar balls present a unique set of recovery problems.

Heavy oils also tend to have high viscosities when compared with lighter oils. The actual viscosity range is quite wide as indicated in Table 1 and Table 2 below, with dynamic viscosity (cP) typically starting in the thousands, ranging up to over one million, depending upon the actual starting oil, temperature, weathering, and emulsification. This will be more pronounced in colder waters and during winter months. Higher viscosities will have an impact on pumping as higher viscosity fluids will resist flow.

Heavy oils with high pour points and high viscosities will have less of a tendency to spread which will aid recovery efforts when containing and controlling a spill. It may be possible to recover semi-solid product in calm seas, although spill incidents rarely happen during ideal weather conditions. Heavy oils also tend to be sticky in nature, which can prolong the clean-up operation by adding to the decontamination process. Clean-up may be difficult once the oil impacts shorelines, although emulsified oil may tend to adhere less than non-emulsified oils.

Identifying and assessing the location of the oil slick can be difficult from the air or even from craft on the water if over-washing or partial sinking occurs. Movement may be difficult to predict as wave action may carry the oil below the surface. After the oil is submerged very little weathering will take place. The most important process that affects the density of the spilled product is the uptake of particulate matter which will impact the ability of the oil to resurface (Fingas *et al*., 2006). Due to the density of heavy oil and its low buoyancy, an assessment of the thickness of oil patches will be difficult to calculate resulting in a poor estimate of the quantity of the spill.

Heavy fuel oils tend to be less toxic to animals than their crude oil counterparts due to the chemical make-up of the oil. One problem with this product, however, is its adhesive properties and persistence. Heavy oils do not disperse naturally in any significant manner and oil spill dispersants have not proven effective against heavy oils. The result may be a larger impact on mammals and seabirds than previously assumed.

Table 1 - Selected Oil Properties

Heavy Oil Properties	Emulsion Formation				Chemical Dispersibility		Hydrocarbon Groups		
	Visual Stability	Viscosity (mPa·s)	Complex modulus (Pa)	Water content (wt%)	Corexit 9500	Corexit 9527	Saturates	Aromatics	Resins
Boscan							25	35	22
Bunker C Fuel Oil	entrained	110,000	720	26	7	0			
Bunker C Fuel Oil (Alaska) (fresh)	entrained	28,000	130	35	14		25	47	17
Bunker C Fuel Oil (Alaska) (%Ev=8)	unstable			6	6		23	42	20
Bunker C Fuel Oil (Irving Whale)							32	32	17
California (API 11)	entrained			35	0	0			
California (API 15)	entrained			39	0	0	19	35	23
Coal Oil Point Seep Oil	entrained	280,000	1,200	32			21	35	24
Cold Lake Bitumen	entrained		2,800	17			46	24	13
FCC Light Cycle Oil							17	58	4
FCC Medium Cycle Oil						60	30	62	7
Fuel Oil No. 5 (2000) (fresh)	stable		1,540	78	15		44	40	8
Fuel Oil No. 5 (2000) (%Ev=7)	stable		2,490	73	7		40	39	8
Heavy Fuel Oil 6303 (fresh)	entrained		752	58	9		43	29	16
Heavy Fuel Oil 6303 (%Ev=2)	entrained		984	24	6		39	27	17
High Viscosity Fuel Oil	entrained	74,000	310	48	0		18	43	13
Intermediate Fuel Oil 300 (fresh)	entrained	97,000	390	52	0		26	52	12
Intermediate Fuel Oil 300 (%Ev=5)	unstable				0		24	28	30
Marine Intermediate Fuel Oil									
Orimulsion 400 (2001) (wet)	unstable				100		32	20	10
Orimulsion 400 (2001) (dry)							45	27	13
Orimulsion-100 (fresh)									
Orimulsion-100 (%Ev=26)							17	47	16
Orinoco Bitumen	entrained		36,000	8			41	21	17
Platform Irene	entrained	390,000	1,400	62			26	29	22

(Jokuty *et al*., 1999; Wang *et al*., 2002; and Wang *et al*., 2004)

Table 2 - Selected Properties of Heavy Oils

		Cold Lake Bitumen	Orinoco Bitumen	Orimulsion-400	Fuel Oil #5		HFO 6303	
					0.00%	7.20%	0.00%	2.50%
Density (g/mL) @	0°C	1.0096	1.018	1.0155	1.0034	1.016	1.0015	1.0101
	15°C	1.0016	1.0166	1.0093	0.9883	1.0032	0.9888	0.9988
	20°C	0.9987	1.0141	1.0073	0.9884	0.9993	0.9853	0.9955
	30°C	0.9927	1.0083	1.0021	0.9818	0.9919	0.9783	0.9887
	40°C	0.9868	1.0024	0.9969	0.9752	0.9853	0.9722	0.9822
API Gravity		9.68	7.65	8.63	11.55		11.47	
Dynamic Viscosity (mPa•s)	0°C	1.08E+07	2.66E+08	3.30E+02	1.86E+04	7.20E+04	2.41E+05	3.60E+06
	15°C	8.25E+05	1.02E+07	2.56E+02	1.41E+03	4.53E+03	2.28E+04	1.49E+05
Flash Point (°C)		N.M.	146	N.M.	94	136	111	133
Pour Point (°C)		18	30	1	-19	-3	-1	11
Adhesion (g/m2)		570	1800	90	34	47	100	240
Hydrocarbon Groups (*w/w*)	Saturates	45.7	40.7	32.1	44.2	39.9	42.5	38.8
	Aromatics	24.1	21.5	19.7	39.5	39.1	29	26.9
	Resins	13.2	17	9.6	8	8.3	15.5	16.6
	Asphaltenes	16.9	20.8	10.6	8.4	12.8	13	17.7
Wax Content (*w/w*)		0.00%	0.00%	N.M.	2.30%	2.50%	2.50%	2.70%
Sulphur Content (*w/w*)		4.44%	3.86%	2.00%	1.00%	1.08%	1.48%	1.50%
Water Content (*w/w*)		11.80%	<0.1%	28.00%	3.10%	<0.1%	0.10%	<0.1%
Emulsion Formation	Visual Stability	Entrained	Entrained	Unstable	Stable	Stable	Entrained	Entrained
	Complex Modulus (Pa)	2800	36000		1590	2490	752	984
	Water Content (*w/w*)	17	8		78.3	72.8	57.7	24.1

(Hollebone, 2006)

6 SIMULANTS USED IN EXERCISES

The desirable properties of an oil spill simulant vary depending upon the goals of the oil spill exercise. If the oil spill simulant is to be used to test the logistics of a spill response group, then the oil spill simulant should possess the macro properties of oil. That is to say it should float and migrate (travel) similar to oil. If the technical containment and recovery aspects of oil spill response are to be tested, then the simulant must posses the micro properties of oil, such as viscosity, density, interfacial tension and emulsion formation properties. As can be gleaned from the preceding, it is much easier to develop an environmentally friendly oil spill simulant that mimics the macro properties of oil than to develop an environmentally friendly oil spill simulant that displays the micro properties of oil. In other words, it is the micro properties that define the oil and how the oil behaves. Even these properties can vary between different types of crude oils therefore the development of a single oil simulant is difficult, let alone an environmentally friendly simulant.

An oil spill simulant should behave in the following manner:

- Dispersion behavior on water similar to oil;
- Emulsion formation / degradation properties similar to oil;
- Behaves like oil in containment/recovery equipment (flow)
- Highly visible/detectable; and,
- Proven not harmful to the environment.

6.1 Properties of Liquid Based Simulants

A number of simulants have been identified based upon a literature review and interviews with members of the spill response community in North America and Europe. Simulants can be categorized into three main groups, according to their composition. The first group consists of a range of processed oils based upon mineral or vegetable origins that are used in lab-scale controlled conditions, up through large-scale evaluations. CEDRE (France) uses real oil in their test basins and other areas (with support from the French Navy) Vegetable oils are used to evaluate equipment and logistics. One type of edible oil, palm oil, is to be avoided due to its tendency to precipitate and solidify at relatively high temperatures (15°C). Environment Canada led several studies between 2000 – 2008 that employed canola oil and biodiesel for test tank use.

Table 3 - Test Oil Characteristics - Environment Canada

Oil Type	Specific Gravity	Interfacial Tension (dynes/cm2)	Surface Tension (dynes/cm2)	Viscosity @ 25°C (cPs)
Canola	0.913	~30*	~30*	65
Biodiesel (B100)	0.885			7
Biodiesel (B20)	0.831			4

*approximation (Gunstone, 2004)

These liquids were noted for diminished toxicity and volatility concerns versus their hydrocarbon counterparts while having similar physical properties and behavior for spill response purposes.

Other organizations have continued to evaluate possible liquid oil simulants for research and evaluation purposes. As examples, Professor V. Hornof from the University of Ottawa led investigations pertaining to water-in-oil emulsion research but could not resolve some of the more difficult challenges of adhesion. More recent work at the University of Utah led to the development of simulant liquids that showed promise as possible surrogates for evaluation purposes. The goal of developing an environmentally benign and biodegradable crude has been ongoing over the past few years but ecotoxicity issues related to smothering concerns have stalled its use.

Other organizations able to operate in controlled environments have selected alternative test liquids with a range of properties that closely match those of petroleum crude oil. The Ohmsett facility, as an example, uses three manufactured oils in their spill response testing and evaluations. The first product, Calsol 8240, is described as a highly refined naphthenic oil. It has minimal volatility and high temperature resistance. The second product, Sundex 8600T, is described as an aromatic oil and is used as a heavier crude oil simulant. The third product, Hydrocal 300, is described as a naphthenic base oil manufactured by selectively saturating aromatic oil molecules and converting them to naphthenes or paraffins. These hydrotreated oils may not require labeling as carcinogenic under OSHA Hazard Communication Standard.

Table 4 - Test Oil Characteristics - Ohmsett

Oil Type	Specific Gravity	Interfacial Tension (dynes/cm2)	Surface Tension (dynes/cm^2)	Viscosity @ 25°C (cPs)
Calsol 8240	0.932	32.5	36.5	1,375
Sundex 8600T	0.95	27-32	30-36	10,000
Hydrocal 300	0.88	26-28	29-32	150

6.2 Properties of Particle/Foam Based Simulants

A range of materials have been identified as being used in simulated spill exercises. Due to the physical properties of this category, the main parameter being mimicked is the apparent density of oil. Selected exercises are identified below:

- In 1999 the State of Rhode Island Department of Environmental Management issued a News Release describing a planned training exercise using oil spill recovery boats. A small number of oranges, which “float and act the same way as oil” are identified as being used to simulate spilled oil.
- The October 2000 Newsletter Issue No. 14 from Elastec Inc. (American Marine Inc.) highlights an oil spill exercise with the United States Coast Guard. During the exercise, simulated oil was collected inside Elastec fire boom. Oranges were used to simulate oil because “their behavior and drift patterns in water are much like crude oil”.
- In 2003 the Piscataqua River Cooperative reported on a spill exercise they usually hold twice a year. Three energy companies operating terminals on the river get involved along with other agencies such as 19 Navy Shipyard, Coast Guard, Maine DEP, and the Newington Fire Department. While simulants considered for use include popcorn and rice hulls, oranges and peat moss were used in 2003 due to the peat moss spreading like oil across the surface and oranges bobbing up and down on the waves like tarballs.
- In 2005 the Northern Territory Government, Australia, announced a simulated oil spill training exercise organized by the Darwin Port Corporation in conjunction with the Marine Safety Branch and the Australian Maritime Safety Authority. This exercise involved the release of oranges which “have a similar buoyancy and rate of travel across water to that of oil”.
- An exercise in Norway funded by the Norwegian Clean Seas Association held in 2005 used popcorn as an oil simulant. The exercise planned on using 175 cubic feet of popcorn to “create a slick roughly 330 by 660 feet”
- During the BALEX DELTA 2006 exercise a volume of approximately 12 cubic meters of perlite were used. The substance was “spilled” in two portions to cover the exercise area. Response crews were then left to track and follow the slick and “respond”. Heavy wind unfortunately caused the simulant to drift too fast and it left the exercise area.

Additional simulants were identified by spill responders and researchers as having been used or considered for use in spill exercises. The complete list includes:

- Oranges (density approximates that of oil)
- Popcorn (forms paste as it takes on water “very similar to spilled oil”, and mimics the effect of ocean currents on oil)
- Peat Moss and Oranges combined (peat moss spreads like oil, oranges bob up and down like tar balls)
- Perlite (low density material to evaluate wind effects)
- Cork (low density material)
- Sunflower seeds (low density material)
- Painted wood (trajectory modeling – mimics path of oil)
- Wood chips (inexpensive)
- Hay (inexpensive)
- Dog food (density approximates that of oil)

- Peanut shells (low density, inexpensive)
- Rice hulls (low density, inexpensive)
- Pine needles (inexpensive)
- Coir (low density, inexpensive)
- Coffee Beans
- Protein based Fire Fighting Foam

Each of the particulate or foam based simulants has typically been used for testing under two conditions: as a means of exercising booming strategies and as a means of providing a simulant for tracking purposes. Each of the described particle based simulants will be affected by both wind and current in a mode similar to oil, but the interaction of particles with each other will differ. Some of these particulates will interact with one another and the water to form an agglomeration. This will help further the simulation of oil under specific operating conditions.

6.3 Advantages and Disadvantages

Each of the liquid simulants identified above will mimic spills of crude oil in a number of characteristics including spreading properties, water buoyancy, and persistence on the surface. Some will offer emulsification properties, but their main benefit is to mimic an oil with a specific characteristic profile that is relatively stable for moderate periods of time, such as the hours needed to perform containment and recovery testing. Their visibility when being used as simulants and reasonable cost make them appropriate choices for use in controlled conditions. However, their toxicity and potential to cause suffocation to both plant life and aquatic or terrestrial creatures would remain a disadvantage limiting their use.

The particulate and foam based simulants are generally inert or organic in nature and are not as much a cause for concern with respect to toxicity or suffocation issues. Their ability to mimic the behavior of oil would be limited to specific scenarios of tracking and booming or logistics exercises. Some concern has been raised over their use with respect to the consumption of food based particulate simulants by local wildlife which, while not necessarily posing a serious health risk, does remove the simulant from the evaluation area which potentially invalidates any ongoing evaluation.

Table 5 - Simulant Properties

SIMULANT	*CHARACTERISTIC*
Oranges	Spreading properties: Oranges will travel in a manner similar to oil. It will have a tendency to spread to form a monolayer on the water surface, and bob up and down like tar balls. Water buoyancy: Good buoyancy (density of 0.87 – 0.91 g/cm^3) which closely matches oil. Persistence of material: Material will persist in the aquatic environment for weeks. Emulsification properties: Will not emulsify. Visibility: Very good visibility due to color. Availability: Available year round from a number of suppliers in different countries (seasonal crop). Cost: High (estimate $1.00/lb) Will vary depending upon source country and time of year. Toxicity: Overall low, but some pesticide residue may remain on peel. Method of application: Manual unloading/dumping by crate or bag.
Popcorn	Spreading properties: Popcorn will spread but the driving force to spread will be countered by the low initial bulk density. Water buoyancy: Popcorn is relatively light and does not match oil density (initial density approximately 0.024 g/cm^3). It would initially be affected by wind to a greater extent than oil. Once popcorn takes on water, it will float lower in the water but still have a tendency to remain floating. Persistence of material: Material should degrade relatively quickly (days). Emulsification properties: Will not emulsify – but as popcorn takes on water it will form a lumpy "paste". Visibility: Good initial visibility. Availability: Readily available from a number of food distributors. Cost: Moderate ($7/kg, unpopped, must be processed), price recently being affected (increased) by shift to ethanol production for biofuel use. Toxicity: Non-toxic. Method of application: May be blown.

SIMULANT	CHARACTERISTIC
Peat Moss	Spreading properties: Peat Moss will spread to some extent but driving force to spread will be countered by low density. Particles may clump together. Water buoyancy: Peat moss is lighter than oil (density variable, approximately 0.10 – 0.12 g/cm^3) and would be affected by wind to a greater extent than oil. May depend upon the extent of drying and/or heat treatment for long term floatation. Persistence of material: It will persist in the aquatic environment. Emulsification properties: Will not emulsify. Visibility: Fair visibility - Dark color will limit distance of detection compared with other identified simulants. Availability: Available from limited sources (such as Canada), but multiple suppliers exist in North America. Cost: Low (estimate $.08 per pound, 75 lb bag - $6). Toxicity: None/no data available. Method of application: May be blown, or manually unloaded by bulk dumping / bag discharge.
Perlite	Spreading properties: Perlite will spread to some extent but driving force to spread would be countered by its low density. Particles may clump together. Water buoyancy: Perlite is lighter than oil (density variable, approximately 0.11 – 0.14 g/cm^3) and would be affected by wind to a greater extent than oil. Relatively small particle size. Persistence of material: Will persist in the aquatic environment – resists microbial breakdown. Emulsification properties: Will not emulsify. Visibility: Good initial visibility due to light color. Availability: Good – Produced in U.S. and Mexico. Other sources include Greece and China. Cost: Low (estimate $40 per ton bulk) Toxicity: None/no data available, considered inert. Method of application: May be blown, or manually unloaded by bulk dumping / bag discharge.

SIMULANT	*CHARACTERISTIC*
Cork	Spreading properties: Cork will spread to some extent but the driving force to spread will be countered by its low density. Particles may clump together or move as discrete units, depending upon particle size. Water buoyancy: Cork is lighter than water (density approximately 0.34 g/cm^3) and would be affected by wind to a greater extent than oil. May be acquired in different sized pieces/particles which would affect the bulk behaviour. Persistence of material: Will persist in the aquatic environment. Emulsification properties: Will not emulsify. Visibility: Good initial visibility. Availability: May be limited. Recent shortages have affected availability and price. Cost: High (estimate $5 per pound) Toxicity: None/ not indicated. Method of application: Manually unloaded by bulk dumping / bag discharge.
Sunflower Seeds	Spreading properties: Sunflower Seeds will spread to some extent. Particles may clump together or move as discrete units. Water buoyancy: Sunflower seeds will float on water (density approximately 0.75 g/ cm^3). Issues with evolution of sheen from sunflower oil may develop. Persistence of material: Will persist in the aquatic environment. Emulsification properties: Will not emulsify. Visibility: Fair visibility due to mix of dark and light color will limit distance of detection compared with other identified simulants. Availability: Moderate availability – source from food and pet food suppliers. Cost: High (estimate $1 per pound) Toxicity: Parts of sunflower plant identified as slightly toxic (if large quantities are ingested). Method of application: Manually unloaded by bulk dumping / bag discharge.

SIMULANT	CHARACTERISTIC
Painted Wood (fluorescent drift cards)	Spreading properties: Painted Wood (drift cards) will move as discrete units as opposed to spreading like a liquid. Water buoyancy: Painted Wood will float in water, density relatively close to oil to enable determination of modelling accuracies. Persistence of material: Will persist in the aquatic environment. Unit is a 4"x 6"x 1/8" wooden card painted with non-toxic paint. Emulsification properties: Will not emulsify. Visibility: Very good – item specifically painted for visibility. Availability: Limited supplier (NOAA project). Cost: High (estimate) – not applicable for spill response equipment evaluations other than tracking devices. Toxicity: Non-toxic paint used in manufacture. Method of application: Manually unloaded.
Wood Chips	Spreading properties: Wood Chips will spread to some extent but particles may clump together or move as discrete units, depending upon particle size. Water buoyancy: Wood Chips will generally float on water but long term buoyancy may depend upon the extent of drying and/or heat treatment. Persistence of material: Will persist in the aquatic environment. Emulsification properties: Will not emulsify. Visibility: Good initial visibility. Availability: Good availability – readily available from multiple sources. Cost: Low (by-product of milling operations). Toxicity: Generally non-toxic. Method of application: Manually unloaded by bulk dumping / manual discharge.

SIMULANT	*CHARACTERISTIC*
Hay	Spreading properties: Hay will have a tendency not to spread. Water buoyancy: Hay will float on water (density approximately 0.22 g/cm^3). May depend upon the extent of drying and/or heat treatment for long term floatation. Persistence of material: Will persist in the aquatic environment. Emulsification properties: Will not emulsify. Visibility: Moderate visibility to due inconsistent color. Availability: Good availability – widespread use for livestock. Cost: Low ($0.06/lb) Toxicity: Non-toxic Method of application: Manually unloaded by bulk dumping / manual discharge.
Dog Food (dried)	Spreading properties: Dog Food will have a tendency to spread initially into a monolayer. Water buoyancy: Dog Food will float on water (density approximately 0.8 g/cm^3) initially. Persistence of material: Will take on water and degrade (days). Emulsification properties: Will not emulsify but may clump as it degrades. Visibility: Moderate visibility due to color. Availability: Good availability from pet food suppliers. Cost: Moderate ($0.50/lb) Toxicity: Non-toxic (may contain preservatives of concern to the environment). Method of application: Manually unloaded by bulk dumping / bag discharge.

SIMULANT	*CHARACTERISTIC*
Peanut Shells	Spreading properties: Peanut Shells will have an initial tendency to spread but the driving force to spread will be countered by its low density. Particles may clump together or move as discrete units. Water buoyancy: Peanut Shells will float freely on water. Persistence of material: Will persist in the environment if initially heat treated. Emulsification properties: Will not form emulsions. Visibility: Moderate visibility due to light brown color compared with other. Availability: Limited direct from food suppliers. Cost: Low – considered waste product from food production. Toxicity: Non-toxic Method of application: Manually unloaded by bulk dumping / bag discharge.
Rice Hulls	Spreading properties: Rice Hulls will have an initial tendency to spread but the driving force to spread will be countered by its low density. Particles may clump together or move as discrete units. Water buoyancy: Rice Hulls will float freely on water. Persistence of material: Rice Hulls will persist in the environment if initially heat treated. Emulsification properties: Will not form emulsions. Visibility: Moderate visibility due to variable brown color. Availability: Limited direct from food suppliers. Cost: Low – considered waste product from food production. Toxicity: Non-toxic Method of application: Manually unloaded by bulk dumping / bag discharge.

SIMULANT	*CHARACTERISTIC*
Pine Needles	Spreading properties: Pine Needles will have an initial tendency to spread. May clump together depending upon moisture content. Water buoyancy: Pine Needles will initially float on water, may sink after taking on water. Persistence of material: Will persist in the environment. Emulsification properties: Will not form emulsions. Visibility: Low visibility due to dark green color. Availability: Limited from forestry sources. Cost: Low – considered waste product from harvest operations. Toxicity: Some pines are toxic (possible mycotoxin). Method of application: Manually unloaded by bulk dumping / bag discharge.
Coir (coconut fibers)	Spreading properties: Coir will have an initial tendency to spread but the driving force to spread will be countered by its low density. Particles may clump together or move as discrete units. Water buoyancy: Coir will float on water (bulk density 0.02 g/cm^3). Persistence of material: Will persist in the environment. Emulsification properties: Will not emulsify. Visibility: Moderate visibility due to variable brown color. Availability: Limited direct from horticultural supply stores. Cost: High (estimate $1.25 / kg) Toxicity: Possible phytotoxin. Method of application: Manually unloaded by bulk dumping / bag discharge.

SIMULANT	CHARACTERISTIC
Coffee Beans	Spreading properties: Coffee beans will spread to some extent. Particles may clump together or move as discrete units. Water buoyancy: Coffee beans will float. Persistence of material: Will persist in the environment. Emulsification properties: Will not emulsify. Visibility: Low visibility due to dark color. Availability: Available from numerous food supply sources. Cost: High (estimate $4/kg) Toxicity: May cause caffeine toxicity. Method of application: Manually unloaded by bulk dumping / bag discharge.
Protein based Fire Fighting Foam	Spreading properties: Protein based Fire Fighting Foam will have a tendency to spread. The low density of the foam, which will negatively affect spreading, will be offset by the ability of the foam to affect surface tension of water. Water buoyancy: Protein based Fire Fighting Foam will float. Persistence of material: Will degrade in the environment. Emulsification properties: Will foam when applied. Visibility: Good visibility. Availability: Available from limited sources. Cost: Low (mixed with water in a 3% - 6% ratio then foamed – increasing volume). Toxicity: Low (source material may include animal protein – derived from pig or ox blood). Method of application: Mixed then ejected using specialized equipment.

SIMULANT	CHARACTERISTIC
Canola	Spreading properties: Canola will spread like light oil due to similar viscosities. Water buoyancy: Canola will float on water (density approximately 0.92 g/cm^3). Persistence of material: Will begin to break down and degrade within days/weeks exposure to the environment. Emulsification properties: Will not readily emulsify. Visibility: Initially moderate visibility, but will darken as it becomes contaminated in the environment. Availability: Available from numerous food supply sources. Cost: High $1/kg plus Toxicity: Non-toxic (consumption), ecotoxicity is a concern. May harm wildlife by affecting natural thermal barrier of fur/feathers or through suffocation of plant life by preventing oxygen transfer. Method of application: Unloaded by pumping or manually dumping containers.
Biodiesel B100	Spreading properties: Biodiesel B100 will spread like light oil due to similar viscosities. Water buoyancy: Biodiesel B100 ill float on water (density approximately 0.85 g/cm^3). Persistence of material: Will persist in the environment. Emulsification properties: May emulsify under proper conditions. Visibility: Initially moderate visibility, but will darken as it becomes contaminated in the environment. Availability: Available from limited fuel supply sources. Cost: High $1.5/kg plus. Toxicity: Yes. Ecotoxicity is a concern. May harm wildlife by affecting natural thermal barrier of fur/feathers or through suffocation of plant life by preventing oxygen transfer. Method of application: Unloaded by pumping or manually dumping containers.

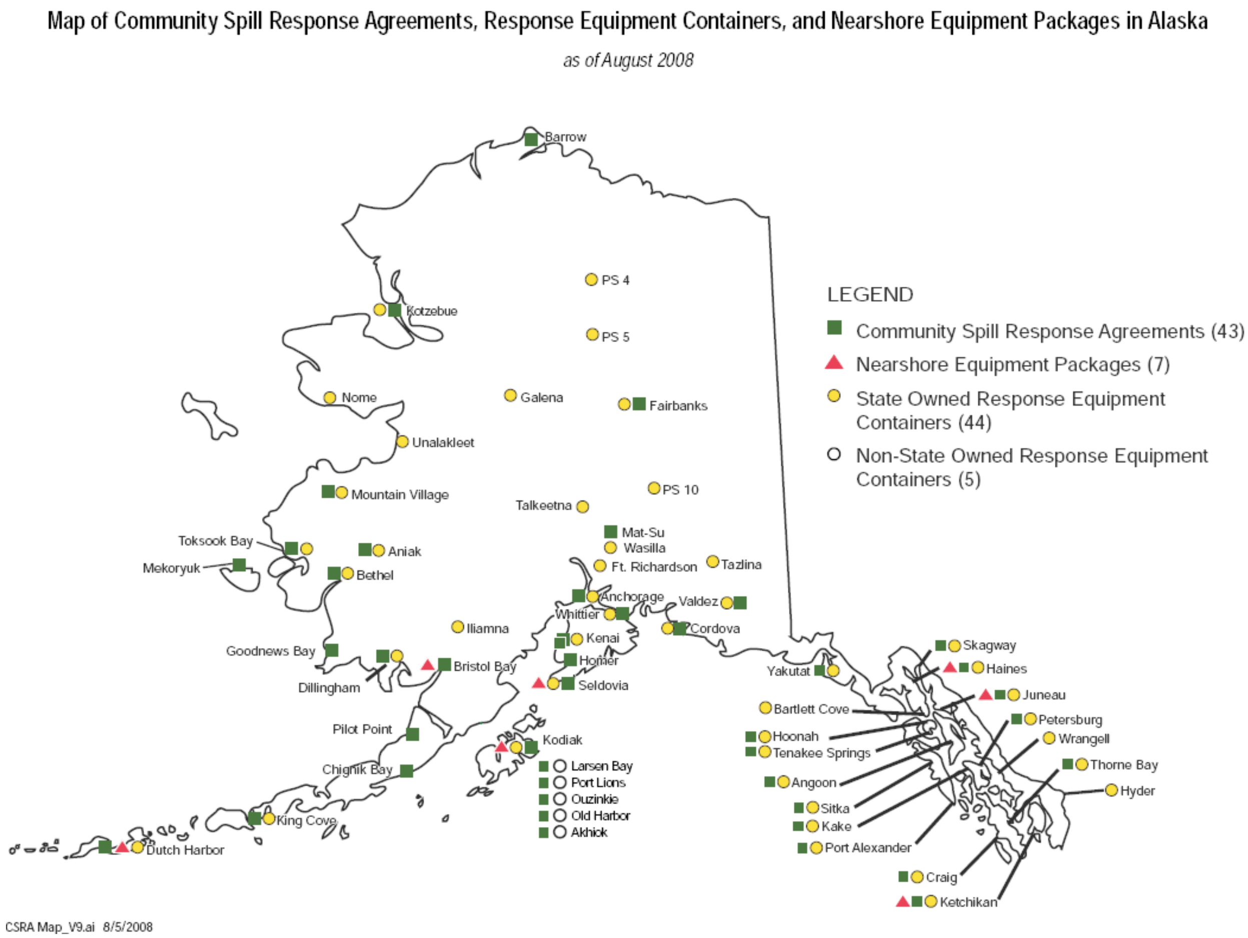
SIMULANT	CHARACTERISTIC
Calsol 8240	Spreading properties: Calsol 8240 will spread like light to medium oil due to similar viscosities. Water buoyancy: Calsol 8240 will float on water (density approximately 0.93 g/cm^3). Persistence of material: Will persist in the environment. Emulsification properties: Will emulsify. Visibility: Moderate visibility - will darken as it becomes contaminated in the environment. Availability: Low – Limited suppliers. Cost: High Toxicity: Yes. Ecotoxicity is a concern. May harm wildlife by affecting natural thermal barrier of fur/feathers or through suffocation of plant life by preventing oxygen transfer. Method of application: Unloaded by pumping or manually dumping containers.
Sundex 8600T	Spreading properties: Sundex 8600T will spread like heavy oil due to similar viscosities. Water buoyancy: Sundex 8600T will float on water (density approximately 0.95 g/cm^3). Persistence of material: Will persist in the environment. Emulsification properties: Will emulsify. Visibility: Moderate visibility - Will darken as it becomes contaminated in the environment. Availability: Low – Limited suppliers. Cost: High Toxicity: Yes. Ecotoxicity is a concern. May harm wildlife by affecting natural thermal barrier of fur/feathers or through suffocation of plant life by preventing oxygen transfer. Method of application: Unloaded by pumping or manually dumping containers.

SIMULANT	*CHARACTERISTIC*
Hydrocal 300	Spreading properties: Hydrocal 300 will spread like light oil due to similar viscosities. Water buoyancy: Hydrocal 300 will float on water (density approximately 0.88 g/cm^3). Persistence of material: Will persist in the environment. Emulsification properties: Will emulsify. Visibility: Moderate visibility - Will darken as it becomes contaminated in the environment. Availability: Low – Limited suppliers. Cost: High. Toxicity: Yes. Ecotoxicity is a concern. May harm wildlife by affecting natural thermal barrier of fur/feathers or through suffocation of plant life by preventing oxygen transfer. Method of application: Unloaded by pumping or manually dumping containers.

Table 6 - Simulant Recommendations

CRITERIA	COMMENT / RECOMMENDED SIMULANT
Spreading	Liquid simulants identified in this report will spread in a manner similar to oils. Particulate/foam simulants will also spread dependant upon interactions of the individual particles that make up the simulant. Based upon use in actual spill simulations and researcher suggestions the following particulate/foam simulants are recommended for consideration: • Peat moss • Oranges • Popcorn • Wood chips
Entrainment	Liquid simulants identified in this report will be entrained in a manner similar to oils. Particulate/foam simulants with a density closely matching oil will tend to be entrained in a similar manner. Based upon use in actual spill simulations and researcher suggestions the following particulat/foam simulants are recommended for consideration: • Oranges • Popcorn (as it takes on water and forms a paste) • Peat moss
Recovery	Liquid simulants identified in this report will work with mechanical recovery equipment including oleophilic skimming devices. Particulate/foam simulants will work with mechanical recovery devices such as weir skimmers but the range of influence may be dramatically smaller than the behavior expected with liquid simulants. Based upon use in actual spill simulations and researcher suggestions the following particulate/foam simulants are recommended for consideration: • Peat moss • Popcorn • Protein based fire fighting foam

Simulants are needed to operate under a range of climatic conditions addressing possible spill scenarios on both land and water in the Alaska environment. As an example of the geographic range of staging points, a map of response equipment containers and nearshore equipment packages in Alaska is pictured below.



http://www.dec.state.ak.us/spar/perp/hazmat/posters/CSRA%20Map%202008.pdf

7 PERMITTING REQUIREMENTS

As part of the initial steps in developing and/or selecting practical oil spill simulants, legislative and permitting requirements must be taken under consideration. The use of materials to simulate oil spills must not contravene any regulations and permitting issues must be addressed before they are employed.

The International Maritime Organization (IMO) is the international governing body with respect to ocean activities. The international legislation that covers the release of materials into the ocean falls under the London Protocol. The official title of the London convention is the “Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972.” (IMO, 2008) The objective of this convention is to control and prevent all forms of marine pollution by regulating wastes and other matter that are dumped into the sea. In 1996 the London convention was updated and was renamed the London Protocol. The current version came into force on May 24, 2006. Simply stated, the London Protocol prohibits the dumping of any material, except those materials itemized in the "reverse list". This "reverse list" allows for the dumping of the following 8 items:

- Dredged material;
- Sewage sludge;
- Fish wastes;
- Vessels and platforms;
- Inert, inorganic geologic material;
- Organic material of natural origin;
- Bulky items primarily comprising of iron, steel and concrete; and
- Carbon dioxide streams from carbon dioxide capture processes for sequestration.

As of September 13, 2006 eighty-one Governments have ratified or acceded to the Convention, including the United States and Canada.

Materials released into United States seas must also conform to U.S. Code of Federal Regulations (CFR) Title 40: Protection of the Environment. For research purposes, particular attention must be made to section 227, "Criteria for the Evaluation of Permit Applications for Ocean Dumping of Materials."

Section 227.5 goes into detail about the specific types of materials that cannot be dumped, most of which would be considered obvious hazards such as high-level radioactive waste and chemical warfare agents. However, attention should be given to paragraphs c) and d). These state that:

c) Materials *insufficiently described* by the applicant in terms of their compositions and properties to permit application of the environmental impact criteria; and

d) Persistent inert synthetic *or* natural materials which may float or remain in suspension in the ocean in such a manner that they may interfere materially with fishing navigation, or other legitimate uses of the ocean.

The above two section describe the gross material. Trace quantities of materials listed in section 227.6 are allowed, but quantities greater than trace are not allowed. "Trace" is not defined in this section. In general, materials should not be known or suspected carcinogens, mutagens or teratogens, nor shall the material be capable of bioaccumulation in marine organisms. The materials shall not allow for the formation of suspended particles that would cause significant mortality or adverse sub lethal effects.

The types of materials under consideration for use as oil spill simulants would fall under either item 5 or 6 of the "reverse list" of the London protocol. However part 227 of CFR 40 is more restrictive to the type of materials that can be dumped. It is stated that materials to be dumped "will not unduly degrade or endanger the marine environment" and that the disposal will present:

- No unacceptable adverse effects on human health and no significant damage to the resources of the marine environment;
- No unacceptable adverse effect on the marine ecosystem;
- No unacceptable adverse persistent or permanent effects due to dumping of the particular volumes or concentrations of these materials; and

- No unacceptable adverse effect on the ocean for other uses as a result of direct environmental impact.

In other words, the materials chosen should be inert to the environment and to humans and to marine life.

The National Oceanic and Atmospheric Administration (NOAA) has performed experiments using drift cards to tract ocean currents. These experiments involved releasing drift cards from a ship. The drift cards are made of wood and painted with environmentally safe paint. Part of the exercise was to ensure that the experiments met with all the relevant laws and regulations. One piece of legislation that guided selection of materials for the tests was the “International Convention for the Prevention of Pollution From Ships, 1973 as modified by the Protocol of 1978,” otherwise referred to as MARPOL 73/78, specifically Annex V which relates to the protection of oceans and costs from solid waste, such as trash and garbage. (NOAA, 2008)

NOAA has compiled a table of International and Federal regulations that apply to NOAA vessels. This table can be used as a general guideline for all materials, and all are applicable to all types of oil simulants. The regulations that pertain to the disposal of garbage at sea would most likely pertain to solid (particle) simulants.

Table 7 - Summary Matrix of International Protocols, Federal Statutes and Regulations, and NOAA Guidelines Applicable to NOAA Vessels

COMPLIANCE TOPIC	INTERNATIONAL PROTOCOL	FEDERAL LAWS AND REGS.	NOAA INSTRUCTIONS
GENERAL AIR EMISSIONS	None at present	Clean Air Act (CAA) Clean Air Act Amendments (CAAA) as implemented by State AQCR regulations	No specific instruction
OZONE DEPLETING SUBSTANCES	Montreal Protocol	CAA Section 608 CAAA of 1990 40 CFR 82	NC Instruction 9516
ASBESTOS ABATEMENT	None at present	Toxic Substances Control Act (TSCA)	NC Instruction 5100.1B Section 9-6, NOAA Fleet HM/HW Manual
SEWAGE AND GRAYWATER DISCHARGE AT SEA	None at present MARPOL 73/78, Annex IV pending adoption	Clean Water Act (CWA) 33 CFR 159 40 CFR 140	NC Instruction 5100.1B Section 9-3
DISCHARGES TO SHORE SIDE TREATMENT FACILITIES	No international guidelines, specific guidelines may apply for foreign ports	Clean Water Act (CWA) as amended. 40 CFR 503	No specific instruction.
BALLAST WATER MANAGEMENT	IMO Resolution A.774(18)	Non-Indigenous Species Control Act National Invasive Species Control Act 33 CFR 1500	No specific instruction. Coast Guard and Navy practice ballast water exchange beyond 12 nm.

DISPOSAL OF GARBAGE AT SEA	MARPOL 73/78, Annex V	Clean water Act Refuse Act 33 CFR 151	NC Instruction 5100.1B Section 9-4
DISPOSAL OF USDA REGULATED FOOD WASTE	None	7 CFR 330	No specific instruction
WASTE CONTAINING HAZARDOUS MATERIALS	None	RCRA provisions as per NOAA Instructions	NC Instruction 6280B NOAA Fleet HM/HW Manual
OIL AND OILY WASTE HANDLING AND DISCHARGE	MARPOL 73/78, Annex I Regs. 9, 10, 16 and 20	Clean Water Act 33 CFR 152	NC Instruction 5100.1B Section 9-2
PREVENTION OF OIL DISCHARGE DURING OIL TRANSFER OPERATIONS	None	Clean Water Act 33 CFR 156	NC Instruction 5100.1B Section 9-2
SPILL CONTINGENCY PLANNING AND RESPONSE	MARPOL 73/78, Annex I Regulation 26	33 CFR 151.26	NC Instruction 9540 NOAA Fleet Shipboard Oil Pollution Emergency Plan.
ENVIRONMENTAL IMPACT MITIGATION	Madrid Protocol for Antarctic	ESA of 1973 MMPA MPRSA of 1972	No specific instruction
HAZARDOUS MATERIALS MANAGEMENT	None	OSHA as applicable through E.O. 12196 Hazardous Materials Transportation Act 29 CFR 1910 40 CFR 171-172	NC Instruction 6280B NOAA Fleet HM/HW Manual
SHIPBOARD DRINKING WATER SUPPLY	None	Safe Drinking Water Act 40 CFR 140	NC Instruction 5100.1B Section 8-6 NOAA Fleet Medical Policy Manual, Appendix D
PCB MANAGEMENT	None	TSCA 40 CFR 761	No specific instructions
PESTICIDE MANAGEMENT	None	FIFRA 40 CFR 151 40 CFR 165-166 40 CFR 171	

The suggested oil spill simulant materials must be verified against both CFR 40 and the London Protocol to ensure that the permitting process for the materials will not be unduly hindered. The actual jurisdiction of State Agencies over Federal and Maritime law should be investigated further, especially with respect to marine oil spill simulations. The exact list of state agencies that would be required to be consulted before a simulant is released would vary from state to state. At the minimum, the state environmental and transportation agencies should be consulted.

As an example of state legislation pertaining to liquid simulants, the state of Alaska's department of Environmental Conservation has a section in the Oil and Other Hazardous Substances Pollution Control Act, Section 8 that pertains to the discharge of oil for scientific purposes. It is not anticipated that the oil simulant will fall under this clause since it is anticipated that the selected simulant will not be toxic [Register 180, January 2007 ENVIRONMENTAL CONSERVATION – 18 AAC 75 Oil and Other Hazardous Substances Pollution Control as amended through December 30, 2006]

Another example of state regulations that may apply to oil spill simulants is the Alaska Essential Fish Habitat Environmental Impact Statement. This statement was adapted from a document developed jointly by the National Marine Fisheries Service Alaska Region, which covers regulatory aspects with respect to fish habitats. The most pertinent section with respect to oil spill simulants is in appendix G, section 3.2. This section deals with organic and inorganic debris.

If an oil spill simulant makes land-fall, then other regulations come into effect. Depending on where the land-fall is established, even municipal regulations may come into play.

From this brief legislative review, the selected oil spill simulant materials should display certain properties. These properties are listed below. Regardless of how inert and environmentally friendly the simulant material is, permits will always be required before anything is discharged into waters. The goal of this list is not to circumvent the permitting process, but to make the permitting process easier and also to increase the chance for approval. The oil spill simulants must meet with the following requirements:

- Inert organic material or;
- Organic material of natural origin; and
- Not harmful to human health or the marine environment
- Not harmful to the marine ecosystem
- Is not persistent or exhibits permanent effects;
- Does not interfere with the use of ocean resources, such as fishing, etc.; and
- Can be proven to meet these requirements

Permitting Procedure for the Use of Oil Simulants

This section will discuss the permitting requirements for discharging oil simulants. The organisation and permitting process for an oil spill exercise is beyond the scope of this report. It is assumed that all the proper permits and advisories have been, or are in the process of being obtained for the exercise. A list of the points of contact for obtaining these permits is attached for reference.

The State of Alaska does not have a formal permitting process for oil simulant use in spill response deployment exercises. The Division of Spill Prevention and Response (SPAR) looks at each exercise individually and handles the proposed simulant conditions for use during the exercise planning process. Depending on the material being proposed, SPAR will either make the decision for use by itself or consult with our Division of Water. The Alaska Department of Environmental Conservation's (SPAR) is responsible for protecting Alaska's land, waters, and air from oil and hazardous substance spills.

If an organization wished to use oil stimulants for trials for non-spill response exercise purposes SPAR would consult with Division of Water and make the determination with them as to the need for a permit and proceed from that point based on the decision.

Table 8 - Alaska Department of Environmental Conservation Contacts

Department	**Point of Contact**
Prevention and Emergency Response	Bob Mattson Program Manager Prevention & Emergency Response Alaska Dept. of Environmental Conservation PO Box 111800 Juneau, Alaska 99811 Telephone: (907) 465-5349 Fax Number: (907) 465-2237 Email: bob.mattson@alaska.gov
SPAR	Larry Dietrick Division of Spill Prevention and Response Department of Environmental Conservation 410 Willoughby Ave., Ste 303 P.O. Box 111800 Juneau, AK 99811-1800 Telephone: (907) 465-5250 Fax Number: (907) 465-5262 Email: Larry.Dietrick@alaska.gov
Division of Water	Sharmon Stambaugh, Program Manager Division of Water Department of Environmental Conservation 555 Cordova Street Anchorage, AK 99501-2617 Telephone: 907-269-7565 Fax Number: 907-269-7600 Email Address: sharmon.stambaugh@alaska.gov

There is a provision in Chapter 75 of the Oil and Other Hazardous Substances Pollution Control under Article 8, Oil Discharge for Scientific Purposes (18 AAC 75.800 - 18 AAC 75.830), which addresses the permitting requirements for releasing oil into the environment for research. However, the use of oils is not allowed for spill response exercises. According to the Program

Manager for Prevention and Emergency Response, the State has not issued a permit for an oil discharge for scientific purposes in at least 15 years if not more.

State rules and regulations usually take precedence over federal rules and regulations. When obtaining permits where there is no State regulation, then the federal legislation applies. On occasion State and federal agencies will cooperate in defining the regulation for unique situations. Permitting for oil simulants is not a standard permit, and as such, the federal jurisdiction may apply. The two contacts indicated below can assist in the acquisition of permits. It should be mentioned again that the granting of a permit to discharge an oil simulant will only be one of numerous permits required when planning an oil spill exercise.

Table 9 - Federal Contacts

Department	Point of Contact
Oil Pollution Act (OPA), Spill Prevention, Control and Countermeasures (SPCC) plans, and Facility Response Plans (FRPs)	Matt Carr carr.matthew@epa.gov 222 West 7th Ave. #19 Anchorage, AK 99513-7588 907-271-3616
Emergency Response Planning, Training and Preparedness, or Tribal Emergency Response	Goolie, Mary goolie.mary@epa.gov EPA Region 10 222 West 7th Ave. #19 Anchorage, AK 99513-7588 907-271-3414

8 CONCLUSIONS AND RECOMMENDATIONS

A review of the simulants identified by spill responders was performed and the following conclusions as to their applicability for future development and user have been made:

A comprehensive replacement of crude oils has not yet been developed that would address all of the environmental and ecotoxicity concerns of regulators in North America. Work on the development of such a simulant has progressed and managed to address most technical concerns but the issue of ecotoxicity remains a stumbling block.

Simulants that mimic the characteristics of oils but have toxicity and/or ecotoxicity characteristics continue to be used in controlled environments where the risk of exposure can be controlled and the risk of spills into the environment can be negated. Using this type of simulant all types of oil spill equipment may be evaluated for during performance and, on a smaller scale, deployment and retrieval capabilities.

The use of particulate simulants, typically organic or cellulose based materials such as oranges, peat moss or popcorn, remain the limited choice for evaluations in the exposed environment. Simulants that come close have specific disadvantages that will severely limit or prohibit their use. No single simulant meets the criteria that have been identified.

Further research into the development of liquid simulants is recommended as they are the only simulants to properly mimic the physical interactions used by spill response and recovery equipment. Characteristics such as viscosity and surface tension simply cannot adequately be mimicked by particulate based simulants.

9 REFERENCES

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ASTM, Designation F1778-97, "Standard Guide for Selection of Skimmer for Oil-Spill Response", 2008, 7p.

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APPENDIX A: ALASKA STATE PERMITTING POINTS OF CONTACT:

http://www.dec.state.ak.us/spar/perp/permits/pdf/Permits_POC.pdf

Agency	Permit name	Point of Contact	email	Phone	Fax	Street	City	State	Zip
ADEC	Oil and Hazardous Materials Incident Final Report	Mala Kalyan	mala.kalyan@alaska.gov	269-7435	269-7648	555 Cordova St.	Anchorage	AK	99501
ADEC	Food Service Permit for >10 people	Mala Kalyan	mala.kalyan@alaska.gov	269-7435	269-7648	555 Cordova St.	Anchorage	AK	99501
ADEC	Food Service Permit for <10 People	Mala Kalyan	mala.kalyan@alaska.gov	269-7435	269-7648	555 Cordova St.	Anchorage	AK	99501
ADEC	In-Situ Burn Guidelines	Mala Kalyan	mala.kalyan@alaska.gov	269-7435	269-7648	556 Cordova St.	Anchorage	AK	99502
ADEC	Open Burn Application	Mala Kalyan	mala.kalyan@alaska.gov	269-7435	269-7648	555 Cordova St.	Anchorage	AK	99501
ADEC	Oil and Hazardous Substance Spill Notification Form	Mala Kalyan	mala.kalyan@alaska.gov	269-7435	269-7648	555 Cordova St.	Anchorage	AK	99501
ADFG	Scientific and Educational Permit (Birds & Mammals)	Mark Fink	mark.fink@alaska.gov	267-2338	267-2464	333 Raspberry Road	Anchorage	AK	99518
ADFG	Scientific and Educational Permit (Fish)	Mark Fink	mark.fink@alaska.gov	267-2338	267-2464	334 Raspberry Road	Anchorage	AK	99519
ADFG	Title 16 Special Area Permit	Mark Fink	mark.fink@alaska.gov	267-2338	267-2464	333 Raspberry Road	Anchorage	AK	99518
ADNR	Land Use Permit (Upland & Tidelands)	Clark Cox	clark.cox@alaska.gov	269-8565	269-8913	550 W 7th	Anchorage	AK	99501
ADNR	Alaska Coastal Management Program, Coast Project Questionnaire	Kim Kruse	kim.kruse@alaska.gov	269-8704	269-8907	550 W 7th, Ste. 1380	Anchorage	AK	99501
ADNR	Burning Permit (Forestry)	Arlene Weber-Sword	arlene.weber-sword@alaska.gov	269-8471	269-8931	550 W 7th, Ste. 1450	Anchorage	AK	99501
ADNR	Consultation on Historical and Cultural Sites (SHPO)	Dave McMahan	dave.mcmahan@alaska.gov	269-8721	269-8908	550 W 7th, Ste. 1310	Anchorage	AK	99501
ADNR	Title 41 Fish Habitat Permit	Cindy Anderson	cindy.anderson@alaska.gov	269-6995	269-5673	550 W 7th; Ste 1420	Anchorage	AK	99501
ADNR	Special Park Use Permit	Chris Degernes	chris.degernes@alaska.gov	269-8700	269-8907	550 W 7th, Ste. 1380	Anchorage	AK	99501
ADNR	Temporary Water Use Permit (fresh water only)	Kellie Westphal	kellie.westphal@alaska.gov	269-8646	269-8913	550 W 7th	Anchorage	AK	99501
ADOT	Permit for Oversize Vehicle - Bridge Condition Attachment	Betty Arthur	betty.arthur@alaska.gov	365-1200	365-1221	11900 Industry Way	Anchorage	AK	99515
ADOT	Driveway/Approach Road Permit	Paula Brault	paula.brault@alaska.gov	269-0696	269-0092	P.O. Box 196900	Anchorage	AK	99519
ADOT	Lane Closure Permit	Paula Brault	paula.brault@alaska.gov	269-0696	269-0093	P.O. Box 196900	Anchorage	AK	99519
ADOT	Permit for Oversize Vehicle	Betty Arthur	betty.arthur@alaska.gov	365-1200	365-1221	11900 Industry Way	Anchorage	AK	99515
ADOT	Permit for Oversize/Overweight Vehicles	Betty Arthur	betty.arthur@alaska.gov	365-1200	365-1221	11900 Industry Way	Anchorage	AK	99515
ARRT	In-situ Burn Application	Rick Rodriguez, USCG	Ricardo.Rodriguez@uscg.mil	463-2804	271-4102	1689 C Street	Anchorage	AK	99501
		Leslie Pearson, ADEC	leslie.pearson@alaska.gov	269-7543	269-7648	555 Cordova St.	Anchorage	AK	99501
		Matt Carr, EPA	carr.matthew@epa.gov	271-3616	271-3424	222 West 7th #19	Anchorage	AK	99513
ARRT	Oil Spill Response Checklist: Wildlife Capture, Transportation, Stabilization & Treatment	Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501
		Mark Fink	mark.fink@alaska.gov	267-2338	267-2464	333 Raspberry Road	Anchorage	AK	99518
ARRT	Oil Spill Response Checklist: Wildlife Hazing	Mark Fink	mark.fink@alaska.gov	267-2338	267-2464	333 Raspberry Road	Anchorage	AK	99518
		Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501
ARRT	Dispersant Use Application - General Information	Rick Rodriguez, USCG	Ricardo.Rodriguez@uscg.mil	463-2804	271-4102	1689 C Street	Anchorage	AK	99501
		Leslie Pearson, ADEC	leslie.pearson@alaska.gov	269-7543	269-7648	555 Cordova St.	Anchorage	AK	99501
		Matt Carr, EPA	carr.matthew@epa.gov	271-3616	271-3424	222 West 7th #19	Anchorage	AK	99513
ARRT	Dispersant Use Application - Zone 1	Rick Rodriguez, USCG	Ricardo.Rodriguez@uscg.mil	463-2804	271-4102	1689 C Street	Anchorage	AK	99501
		Leslie Pearson, ADEC	leslie.pearson@alaska.gov	269-7543	269-7648	555 Cordova St.	Anchorage	AK	99501
		Matt Carr, EPA	carr.matthew@epa.gov	271-3616	271-3424	222 West 7th #19	Anchorage	AK	99513
ARRT	Dispersant Use Application - Zone 2/3	Rick Rodriguez, USCG	Ricardo.Rodriguez@uscg.mil	463-2804	271-4102	1689 C Street	Anchorage	AK	99501
		Leslie Pearson, ADEC	leslie.pearson@alaska.gov	269-7543	269-7648	555 Cordova St.	Anchorage	AK	99501
		Matt Carr, EPA	carr.matthew@epa.gov	271-3616	271-3424	222 West 7th #19	Anchorage	AK	99513
ARRT	PPOR guidelines	John Bauer	john.bauer@alaska.gov	269-7522	269-7648	555 Cordova St.	Anchorage	AK	99501
NOAA -NMFS	Marine Mammal Protection Act Permits	Brad Smith	brad.smith@noaa.gov	271-6354	271-3030	222 West 7th #45	Anchorage	AK	99513
NOAA -NMFS	NMFS Endangered Species Act Permits	Brad Smith	brad.smith@noaa.gov	271-6354	271-3030	222 West 7th #45	Anchorage	AK	99513
UC	Decanting Plan	Mala Kalyan	mala.kalyan@alaska.gov	269-7683	269-7648	554 Cordova St.	Anchorage	AK	99500
UC	Decontamination Plan	Mala Kalyan	mala.kalyan@alaska.gov	269-7683	269-7648	555 Cordova St.	Anchorage	AK	99501
UC	Health and Safety Plan	Mala Kalyan	mala.kalyan@alaska.gov	269-7683	269-7648	555 Cordova St.	Anchorage	AK	99501

Alaska Oil Spill Permits Tool--Contacts
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Agency	Permit name	Point of Contact	email	Phone	Fax	Street	City	State	Zip
UC	Recovered Oil and Water Management Plan	Mala Kalyan	mala.kalyan@alaska.gov	269-7435	269-7648	555 Cordova St.	Anchorage	AK	99501
UC	Waste Management Plan	Mala Kalyan	mala.kalyan@alaska.gov	269-7435	269-7648	555 Cordova St.	Anchorage	AK	99501
USACE	Department of Army Permit Application	Glen Justis	Glen.E.Justis@poa02.usace.army.mil	753-2712	753-5567	2204, 3rd Street	Anchorage	AK	99506
USCG	Report of Marine Accident, Injury, or Death	Lt. Timothy Callister	timothy.f.callister@uscg.mil	271-6709	271-6751	510 L St. #100	Anchorage	AK	99501
USDOT	Notice to Airman	Keith Lindsey	keith.lindsey@faa.gov	269-1103	NA	700 N. Boniface Pkwy	Anchorage	AK	99506
DOI	Consultation on Historic Properties	Pamela Bergmann	pamela_bergmann@ios.doi.gov	271-5011	271-4102	1689 C Street, Room 119	Anchorage	AK	99501
DOI	Access to Lands Managed by DOI	Pamela Bergmann	pamela_bergmann@ios.doi.gov	271-5011	271-4102	1689 C Street, Room 119	Anchorage	AK	99501
DOI-FWS	Export/Import- Interstate and Foreign Commerce/Take of Animals (CITES-ESA)	Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501
DOI-FWS	Marine Mammal Protection Act Permit -Take/Import/Export/Transport	Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501
DOI-FWS	Scientific Collecting/ Research of Eagles Permit	Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501
DOI-FWS	Migratory Bird Treaty Act (MBTA) Collection Permit	Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501
DOI-FWS	Migratory Bird Treaty Act (MBTA) Rehabilitation Permit	Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501
DOI-FWS	Migratory Bird Treaty Act (MBTA) Special Purpose Salvage	Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501
DOI-NPS	National Park Special Use Permit	Bud Rice	bud_rice@nps.gov	644-3530	644-3814	240 W. 5th Ave.	Anchorage	AK	99501
DOI-FWS	Special Use Permit National Wildlife Refuge	Catherine Berg	catherine_berg@fws.gov	271-1630	271-2786	605 W. 4th Ave., Suite G-61	Anchorage	AK	99501