Bureau of Safety and Environmental Enforcement
Oil Spill Preparedness Division

Collection and Recovery of Chemically Treated, Undispersed Oil

Final Report

June 2024

(Photo: BSEE)

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US Department of the Interior
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Contracts:

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ABOUT THE COVER

Cover image displays the Ohmsett tank with HOOP crude treated with Corexit® EC9500A that has entrained under the containment boom and has dispersed throughout the Ohmsett tank. (BSEE)

EXECUTIVE SUMMARY

It is known that an oil slick may not be fully dispersed using chemical dispersants if it is under-dosed, if sufficient surface mixing energy is not present, or if the oil has unfavorable properties. This may interfere with other oil spill response tactics, such as mechanical recovery. For example, during the Deepwater Horizon response dispersants were widely used and injected directly at the wellhead, while at the surface, reports indicated that surface oil was sometimes "slippery and not recoverable" by mechanical measures. This study conducted systematic testing to determine whether oil treated with low doses of dispersant behaved differently than untreated oil during mechanical collection and recovery operations.

Oil response booms are used to gather surface oil into a thick slick, which is then recovered using oil recovery skimmers. An advancing containment boom was tested to measure the boom's ability to contain untreated crude oil and crude oil treated with dispersant at dispersant to oil ratios (DORs) of 1:50 and 1:200. Two oleophilic skimmers, a smooth drum skimmer and a disc skimmer, were tested to measure their ability to recover untreated crude oil and crude oil treated with dispersant at DORs of 1:50 and 1:200. Performance values were measured to compare collection and recovery performance.

The presence of dispersant had a significant effect on the containment boom's ability to collect and contain surface oil, even at low DOR. The boom adequately collected the untreated oil at a tow speed that would typically be used in field operations, losing essentially no oil at 0.9 knot tow speed. However, for the oil treated with a small amount of dispersant (DOR 1:200) the boom at the same 0.9 knots lost an average of 15% of the oil. At the DOR 1:50 treatment, the full oil volume was unsuccessfully contained in the boom and was dispersed by the energy provided by the towing operation. The color and depth of the resulting dispersion indicated a relatively small median droplet size. No instrumentation was deployed in the tank to measure droplet size as that was beyond the scope of this project.

Each skimmer reacted differently when recovering oil with increasing amounts of dispersant. The disc skimmer maintained a fairly consistent fluid recovery rate, although it picked up increasing amounts of water along with the oil which did not separate out during the standard settling time of 30 minutes. The drum skimmer was more significantly impacted by the presence of dispersants, exhibiting both a decrease of 10% in fluid recovery rate and a more significant decrease of 43% in oil recovery rate (ORR) with the increasing presence of dispersant.

Skimmer type	Dispersant Dosage (DOR) Ratio	Avg. Fluid Recovery Rate (gpm)	Avg. Oil Recovery Rate (gpm)	Avg. Recovery Efficiency (%)
Disc skimmer	Control	8.0	8.0	99.5
	1:200	9.4	8.9	94.8
	1:50	9.5	7.7	81.0
Drum skimmer	Control	19.9	17.5	88.4
	1:200	17.7	12.3	69.7
	1:50	17.7	10.1	57.0

For both skimmers, the presence of dispersant caused the recovered fluid to entrain increasing amounts of water that did not separate out within a standard settling time of 30 minutes. This effect increased with the increasing DOR and affected the recovery efficiency (RE) of both skimmers. This effect was more apparent with the drum skimmer, possibly because its larger surface area in contact with the water imparted greater mixing energy in the area of recovery. RE decreased for the disc skimmer from 99.5% to 81.0% and for the drum skimmer from 88.4% to 57.0%.

It is important to note that this testing occurred with only one crude oil that is a relatively low viscosity crude oil and is readily dispersible. Testing with different crudes would likely provide different results, as other reviews have shown that oil properties have a significant impact on dispersibility (Bittler 2017.) The same factors that influence the dispersibility of an oil may also influence the ability of that oil to be mechanically contained and recovered should it be under-dosed with dispersants. In addition, the properties of oil have a significant impact on recovery and emulsification absent of treatment by dispersants. This testing should be conducted on additional types of crude, with other skimmers, and possibly in environmental conditions to apply the results to actual spill scenarios.

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1 Introduction and Background

It is known that an oil slick may not be fully dispersed using chemical dispersants if it is under-dosed, if sufficient surface mixing energy is not present, or if the oil has unfavorable properties. (Bittler, 2017). Some reports during the Deepwater Horizon response indicated that surface oil was sometimes “slippery and not recoverable” (e.g. Walker, 2010). One possible explanation of this was that the oil had reached the water’s surface containing dispersant at a concentration that was too low to effectively disperse it but that affected its ability to be successfully collected and recovered. The Bureau of Safety and Environmental Enforcement (BSEE) and Ohmsett, the National Oil Spill Response Research and Renewable Energy Test Facility, conducted systematic testing to investigate whether oil treated with low doses of dispersant behaved differently than untreated oil during collection and recovery operations. All testing for this project was conducted at Ohmsett (Figure 1), located on Naval Weapons Station Earle in Leonardo, NJ, and managed by the BSEE as part of its mandated requirements by the Oil Pollution Act of 1990 (OPA, 1990).

Figure 1 – Ohmsett Test Tank

2 Approach

This study tested multiple aspects of mechanical recovery including the performance of booms and skimmers. Booms are used to gather oil on the water surface into a thick slick, which is then recovered using skimmers. Both collecting the oil by boom and recovering the oil with skimmers are critical for successful recovery of oil by mechanical means.

An advancing containment boom was tested to measure the boom's ability to successfully collect and contain untreated crude oil and crude oil treated with dispersant during towing operations. Dispersant to oil ratios (DORs) of 1:50 and 1:200 were used for testing. These DOR ratios were selected to encompass the range that could be expected in the field, particularly for oil that has re-surfaced and may have been under treated. For example, surface dispersant application targets a ratio of 1:20 (e.g. Steffek et al 2017) and subsea dispersants were used at a DOR of 1:100 in the Deepwater Horizon response (e.g. Zhao et al 2021). The DORs selected are a conservative estimate. Surface oil is targeted to be treated at a ratio of 1:20, but in operations due to mis-estimating or missing the oil slick can be less. The speeds at which the boom began to lose oil and the amounts of oil remaining in the boom after tow operations were compared to assess the effect of the presence of dispersants.

Two oleophilic skimmers, a smooth drum skimmer and a disc skimmer, were tested in controlled conditions to measure their ability to recover untreated crude oil and crude oil treated with dispersant at DORs of 1:50 and 1:200. The skimmers' rates and efficiencies of oil recovery were compared to assess the effect of the presence of dispersants.

3 Equipment Used for Test

3.1 Containment Boom

There are many types of containment boom available including curtain, fence, and specialty booms. Additionally, booms are available in multiple sizes, materials, and designs. For this test a Lamor foam filled curtain boom was chosen that represented typical characteristics of an offshore recovery boom and that could be tested in the Ohmsett's tank with minimal sidewall and tank bottom effects (MMS, 1992.) The boom measures 22 inches high overall and contains 10 inch diameter by 6 foot long float sections. The boom's measured draft is 15 inches. The boom contains galvanized chain sewn into the skirt bottom as a tension member/ballast and is configured with ASTM style end connectors. A pair of towing bridles with mating ASTM connectors attached the boom to the Ohmsett main bridge tow points for towing of the boom down the tank. Figure 2 shows the setup of the containment boom within the Ohmsett main tank.

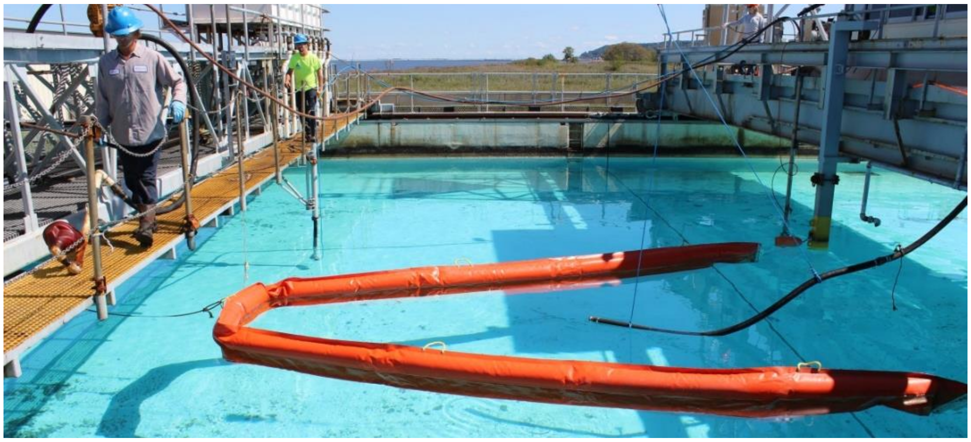

Figure 2 – Containment Boom

3.2 Skimmers

Skimming systems are typically utilized during oil recovery operations to remove surface oil. There are many types of skimming systems including suction skimmers, weir skimmers, and various types of oleophilic skimmers. Dispersants contain surfactants which act to reduce interfacial tension between the oil and water, and it was thought that oleophilic type skimmers would see the largest variance in performance when recovering oil treated with dispersant. Therefore, for this test, two hydraulically powered oleophilic skimmers, a drum and a disc, were chosen. Each type interacts with the surface slick uniquely and provides different mixing energy in the immediate vicinity of recovery. Therefore, it was beneficial to test each type of skimmer. A brief description of each skimmer follows.

3.2.1 Drum Skimmer

The drum skimmer (Elastec American Marine TDS 118) is a lightweight, shallow draft skimmer. It measures 52 inches wide x 40.5 inches long x 10 inches high and uses two 17 inch diameter x 17 inch wide polyethylene drums to recover oil. As the drums rotate through the slick, oil adheres to the drum surfaces and is lifted and scraped off by scrapers. The recovered fluid flows into a perimeter trough and continues into a sump where it is offloaded by an Elastec E150 transfer pump. An Elastec American Marine D-10 hydraulic power unit (HPU) provides the hydraulic power to the motors driving the drums and the offload pump (McKinney, 2015.) Figure 3 shows the Elastec TDS 118 skimmer.

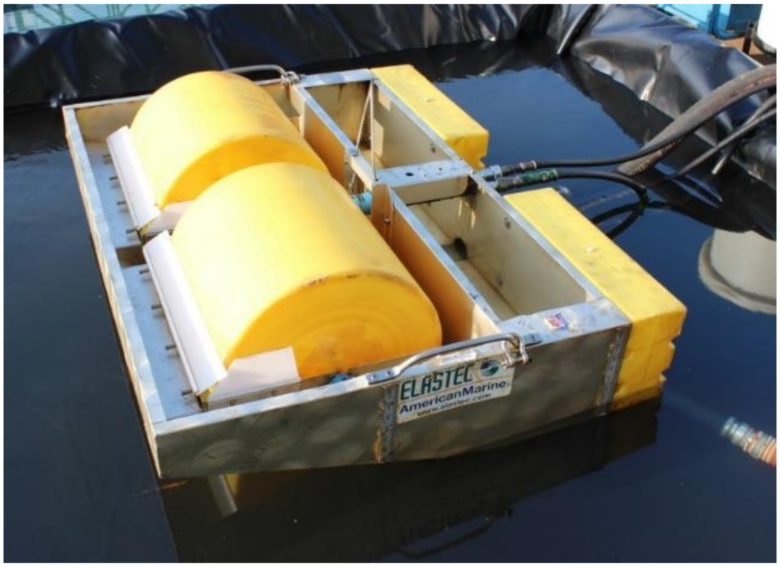

Figure 3 – Drum Skimmer

3.2.2 Disc Skimmer

The disc skimmer (Desmi-AFTI, Inc. MI-2HD) is a triangular shape skimmer that operates on the rotating disc principle. The discs rotate through the oil layer collecting oil that is removed from the discs as they rotate through a set of scrapers. Its triangular configuration allows oil to feed to the discs from all directions. The skimmer measures 26 inches wide x 10 inches high with a draft of 2.5 inches and weighs 70 pounds. The skimmer has three banks of seven discs each with a diameter of 7 inch. For this test, the factory supplied PVC discs were replaced with custom manufactured dimensionally equivalent aluminum (T6061) discs. The offload pump is a bronze gear type pump located within the sump tank. The skimmer is powered by a MI-2HD hydraulic unit which controls the rotational speed of the discs and the offload pump. Figure 4 shows a view of the Desmi-AFTI MI-2HD skimmer.

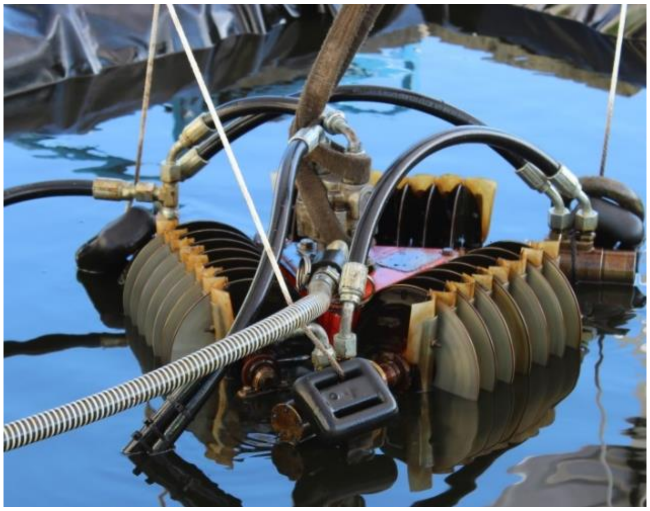

Figure 4 – Disc Skimmer

4 Test Fluids

4.1 Test Oil

Weathered HOOPS crude oil was used for all of the comparison tests. HOOPS is a low viscosity crude oil blend whose constituents come from various reservoirs that supply the Hoover Offshore Oil Pipeline System in the western Gulf of Mexico. Table 1 lists properties of the HOOPS oil. Hydrocal 300 was used for preliminary boom tests to assess the boom's operation. Hydrocal 300 is a refined oil commonly used for testing at Ohmsett.

Table 1 – Properties of HOOPS Crude Oil

Parameters	Method	HOOPS
API Gravity @ 60°	ASTM D2887	34
Flash Point, Closed Cup	ASTM D93	74°F
Pour Point	ASTM D97	-22°F
Paraffin – wt.% (percent by weight)	---	<0.01
Sulfur – wt. %	ASTM D4294	1.360
Saturates – wt. %	ASTM D2007	29.49
Aromatics – wt. %	ASTM D2007	60.36
Asphaltenes – wt. %	ASTM D2008	0.14
Polar Compounds (Resins) – wt. %	ASTM D2009	10.00

4.1.1 Weathering of the HOOPS Crude Oil

The HOOPS oil was weathered prior to testing with a target of 10-15% reduction by volume. An initial volume of approximately 7000 gallons of HOOPS was stored in a bulk container located in a secondary containment area. The weathering process was accomplished in batches of approximately 900 gallons using three 330 gallon steel totes (Figure 5). A custom air sparging system was designed and fabricated to provide air flow through the oil to accelerate the weathering process. Three sparges were fabricated with the base of each forming a loop which fit in through the tote hatch and covered a large area of the tote bottom to distribute airflow. Numerous 1/16 inch diameter orifices were drilled into the loop creating small diameter bubbles when air pressure was applied. Air flow through each manifold was controlled using a pressure regulator and individual flow meter configured as a manifold to provide a controlled uniform flow rate. At the beginning of the weathering process a curve was developed correlating the percent weathered by volume to change in density. The volume of fresh HOOPS oil was measured using soundings in the tote as corresponding density samples were taken and analyzed in the laboratory at several time intervals throughout the weathering process. Density of subsequent batches was monitored, and the degree of weathering determined from the established curve. All batches were consolidated into a second bulk container and agitated with air to ensure the oil was uniformly mixed.

Figure 5 – Weathering Totes, Bulk Storage Tank, and Sparger Outside and Inside Tote

4.2 Dispersant

Corexit® EC9500A was used for all tests. This dispersant represents a large portion of the global dispersant stockpile, has been used in spill response events, and has been studied extensively. Oil was pretreated (blended) with dispersant to the proper dosage prior to testing.

5 Test Setup

5.1 Boom Tests

The boom tests were conducted in Ohmsett’s main tank. The 50 foot long boom was rigged using a 1:3 gap to length ratio which resulted in the boom’s tow points spaced at 16.7 feet. Forces generated during the tow operations were recorded using load cells inline at the tow point connections. The load cells measured an average tow force of 38 lb. at 0.9 knots and 62 lb. at 1.2

knots. The main and auxiliary bridges were maintained at a fixed distance of 22.5 feet apart during the boom testing. Oil or dispersant treated oil was dispensed from the main bridge storage tank directly into the boom's apex using a custom distribution bar designed to provide a slow exit velocity and to minimize mixing energy during release. Preload and post-test containment of the oil within the boom's apex was accomplished using a gentle water spray imposed on the surface from a pair of nozzles located in front of the boom mouth. Figure 6 shows a view of the boom with the oil distribution bar.

Figure 6 – Containment Boom and Oil Distribution Bar

After each test was completed, the oil remaining in the boom was recovered using a J-trap vacuum skimmer positioned from the auxiliary bridge. Fluid recovered from the J-trap skimmer was directed to collection tanks for measurement and sampling. Figure 7 shows Ohmsett staff colling fluid with the J-trap vacuum skimmer.

Figure 7 – J-trap Vacuum Skimmer

5.2 Skimmer Tests

The skimmers were tested in portable tanks located on Ohmsett's north deck. The drum skimmer was tested in a 10 foot x 10 foot tank whose surface area equated to 62 gallons of fluid per inch of thickness. The disc skimmer was tested in a 6 foot 2 inch x 6 foot 2 inch tank whose surface area equated to 24 gallons per inch of thickness. Ohmsett test basin water (salinity at 29.6 ppt) was used for this series of tests, and a layer of oil or dispersant treated oil was dispensed on the water's surface prior to each skimmer test. Portable tents with side curtains were placed over the test areas to eliminate the effects of solar heating and maintain consistent oil slick properties. Figure 8 shows a view of the skimmer test area.

Figure 8 – Skimmer Test Area

The preload volume of oil was dispensed into the test area from a portable tote raised above the tank water elevation. Volumes were dispensed accurately using a fluid level sight tube with 1/16 inch calibrated markings equating to 8.65 gallons per vertical inch. Fluid recovered by the skimmers during the tests was collected in portable recovery tanks positioned adjacent to the test area. These tanks were fitted with 2 inch diameter drain valves at the bottom of the tanks that were used to decant off free water during fluid measurement. Each tank was equipped with a steel measurement ruler securely clamped to the internal sidewall that was used to measure fluid levels. Each ruler was positioned with its zero located exactly such that 3 gallons of fluid would be contained below it in the tank's conical bottom. Calibration of the cylindrical portion of the tank resulted in a conversion value of 1.75 gallons per vertical inch. Measurements were accurate to 1/8 of an inch, or .22 gallons. Figure 9 shows the tote used for dispensing the oil and a view of the inside of one of the calibrated recovery tanks.

Figure 9 – Tote for Dispensing Test Oil and Inside View of Calibrated Recovery Tank

6 Test Procedures

6.1 Boom Tests

The test method used for the boom tests generally followed ASTM F2084-01 "Collecting Containment Boom Performance Data in Controlled Environments". This standard includes multiple types of boom tests including preload tests to determine the proper amount of oil to use for first loss tow speed tests, among others. First loss is defined as the point where droplets shed continuously from the oil contained within the boom during towing (ASTM 2016b). For this project, preload determination tests were conducted per the ASTM standard using both HOOPS and Hydrocal 300 test oils. After the preload volume was determined, additional testing was conducted using HOOPS at two different tow speeds to compare the boom's ability to contain the oil and oil treated with dispersant. A more detailed description of the tests is provided below.

6.1.1 Preload Tests

ASTM 2084-01 states that a towed boom will experience a "first loss" of oil as a function of amount of oil in the boom and tow speed. Typically this loss occurs as entrainment where oil droplets separate from the oil slick and escape under the boom's apex. See Figure 10 for a view of oil escaping under the boom at first loss.

Six preload tests were conducted on the boom using HOOPS untreated oil. The test oil was pumped into the boom's apex at 20 gallon per minute (gpm). During this process, a gentle surface spray was used to contain the oil within the boom. Once the preload operation was complete, the spray was stopped and the main bridge was slowly accelerated to approximately 0.5 knots and the slick allowed to stabilize to a point where the leading edge of the slick remained a constant distance from the apex. From this point, the speed was accelerated incrementally by 0.1 knots and held at that speed for 10 seconds before the next increment. This procedure was continued until first loss was identified by viewing the underside of the boom apex via high definition underwater cameras.

For preload tests P1 through P6, first loss tow speed was independent of the amount of oil loaded into the boom and was observed to be consistently 0.9 knots. This result was unexpected, given the guidance in the ASTM F2084-01 standard, which suggests that the tow speed at which first loss occurs gradually decreases to an asymptotic speed as the volume of oil increases. This result led to four additional preload tests being conducted with Hydrocal 300 to determine if oil volume would be more of an influence on first loss tow speed when using a more viscous oil. However, first loss tow speed remained consistent at 0.9 knots. Table 2 shows oil type, preload volume, and recorded first loss tow speed for these tests. The load cell measured an average tow force of 38 lb. at the tow speed of 0.9 knots.

Figure 10 – Underwater View of First Loss

Table 2 – Test Data for Preload Tests

Test #	Test Oil	Preload Volume (gallons)	Tow Speed at First Loss (knot)
P1	HOOPS, untreated	35	0.9
P2	HOOPS, untreated	25	0.9
P3	HOOPS, untreated	50	0.9
P4	HOOPS, untreated	11	0.9
P5	HOOPS, untreated	75	0.9
P6	HOOPS, untreated	150	0.9
P7	Hydrocal 300	15	0.9
P8	Hydrocal 300	30	0.9
P9	Hydrocal 300	59	0.9
P10	Hydrocal 300	100	0.9

Since preload volume did not affect the first loss tow speed, a volume of 80 gallons was chosen to conduct all further tests because it was the largest volume that could be loaded and easily contained within the boom apex prior to the start of towing operations.

6.1.2 Containment Comparison Tests

The goal of these tests was to compare the boom's ability to contain untreated oil and dispersant treated oil while being towed. Preload tests of both the HOOPS and Hydrocal 300 oils indicated that while oil was lost at the first loss tow speed of 0.9 knots, the volume lost during the entire test run was minimal and would be hard to measure. Therefore, comparison testing was conducted both at 0.9 knots and at 1.2 knots. The second tow speed was chosen as a speed at which the amount of oil lost could be quantified.

Tests were conducted without waves as a baseline condition. The oil or oil/dispersant mixture was released in the apex of the boom while a gentle water spray was applied to contain the oil within the boom apex. The main bridge was then consistently accelerated to the test speed over a distance of approximately 75 feet. Once at speed, the boom was towed for 300 feet at constant speed before deceleration and stopping. As the boom with oil was gradually brought to a stop, gentle water spray was started again to contain the remaining oil within the apex of the boom. The oil remaining in the boom's apex was recovered using the J trap skimmer into collection tanks. After a minimum thirty-minute settling period, free water was decanted from the bottom of the collection tank. Immediately following decant, the remaining fluid was stirred and a representative sample was taken to Ohmsett's on-site lab to determine emulsification and Bottom Solids and Water (BS&W), as measured in accordance with ASTM D4007 "Standard Test Method for Water and Sediment in Crude Oil by the Centrifuge Method" (ASTM, 2013). Calculated volumes of free and entrained water were then subtracted from the total fluid recovered, resulting in a total volume of oil recovered.

6.1.3 Performance Measurements

Performance measurements included the tow speed at which first loss occurred and the amount of oil remaining in the boom after the test. Both first loss tow speed and oil remaining in the boom can indicate how effective a boom is in containing oil. First loss tow speed indicates the speed at which responders can tow boom during recovery operations. A lower tow speed equates to a lower encounter and collection rate which reduces overall recovery effectiveness. Oil remaining in the boom is a quantifiable measurement that can be used to compare a boom's ability to contain different types of oils or, for these tests, compare effects of dispersant on a boom's containment ability.

6.2 Skimmer Tests

The test method used for each skimmer followed ASTM F2709-15 "Standard Test Method for Determining a Measured Nameplate Recovery Rate of Stationary Oil Skimmer Systems" (ASTM, 2016a) in most respects. One variance, the starting thickness for each test, was made in order to conserve oil. The ASTM standard specifies testing a stationary skimmer as it recovers oil from a starting thickness of 3 inches to a final thickness of 2 inches. For this set of tests, however, the starting slick thickness was chosen to be 2 inches with an ending slick thickness of 1 inch. This allowed each test to start with fresh, unused oil/dispersant and still allowed for appropriate comparison of the collected data.

Optimization tests were initially performed on each skimmer to determine operational settings to use for the subsequent tests. After this optimization procedure, three qualifying tests were performed for each oil or oil/dispersant mixture. Data was collected which was used to calculate skimmer performance measures, and these performance measures were used to compare skimmer performance. A more detailed description is provided below.

6.2.1 Optimization Tests

Skimmer performance is affected by operational parameters. In the case of the disc and drum skimmer types, rotational speed can greatly affect the skimmer's performance. Each skimmer was tested with weathered HOOPS at various rotational speeds to determine its optimum setting. The rotational speed was considered optimum when oil recovery rate was maximized and the amount of water collected along with the oil was less than 15%. This setting was then used for each skimmer's entire series of tests. Table 3 shows the drum and disc speeds chosen based on results of the optimization tests.

Table 3 – Optimum Rotational Speeds for Skimmers

Skimmer	Rotational Speed (RPM)
Drum	70
Disc	100

6.2.2 Qualifying Tests

ASTM 2709-15 requires that a test be repeated three times for a given set of parameters and that test results shall be considered valid if no values deviate more than 20% from the arithmetic mean. Three qualifying tests were conducted for each skimmer in each condition to adhere to this standard.

At the start of each test, the recovered fluid was sent to a tank designated as slop. Once the skimmer had reached steady state and fluid contained in the recovery hose from the previous test had been discharged, the flow of recovered fluid was diverted from the slop tank to a collection tank, and the timer was started to measure the recovery period. Recovery continued for a minimum of 30 seconds and until one inch of oil thickness was collected. After collection, the timer was stopped and the fluid redirected to the slop tank. After the test, the volume of total fluid recovered was measured. After a minimum thirty minute settling period, free water was decanted from the bottom of the collection tank. Immediately following decant, the remaining fluid was stirred and a representative sample was taken to Ohmsett's on-site lab to determine emulsification and Bottom Solids and Water (BS&W), as measured in accordance with ASTM D4007 "Standard Test Method for Water and Sediment in Crude Oil by the Centrifuge Method" (ASTM, 2013). Calculated volumes of free and entrained water were then subtracted from the total fluid recovered, resulting in a total volume of oil recovered. Figure 11 shows timing of a drum skimmer test, and Figure 12 shows collection of fluid to a recovery tank.

Figure 11 – Timing a Drum Skimmer Test

Figure 12 – Collection of Recovered Fluid

6.2.3 Performance Measurements

Skimmer performance measurements included Oil Recovery Rate (ORR) and Recovery Efficiency (RE). ORR is the total volume of oil recovered by the device per unit of time (water that is recovered along with the oil is not included in this calculation). RE is the ratio of the volume of oil recovered to the volume of total fluid recovered, expressed as a percentage. These two measurements were calculated using the following formulas:

ORR = V_{oil}/t (gallons per minute)

Where: V_{oil} = Volume of oil recovered, gallons (decanted and lab corrected)
t = Elapsed time of recovery, minutes

RE = $\frac{V_{oil}}{V_{fluid}} x\ 100$ (percentage)

Where: V_{oil} = Volume of oil recovered, gallons (decanted and lab corrected)
V_{fluid} = Volume of total fluid (water and oil) recovered, gallons

7 Results

7.1 Boom Test Results

Results of the boom containment comparison tests are shown below in Table 4, and presented graphically in Figure 13. These results show clearly that treating the HOOPS oil with dispersant had a significant detrimental effect on its ability to be contained within a boom at both tow speeds and that the effect increased with increasing amount of dispersant. At a tow speed of 0.9 knots, minimal loss was measured with HOOPS untreated oil. However, average loss increased to 15% for HOOPS treated at a DOR 1:200. Only one test was conducted with HOOPS treated at DOR 1:50. At this DOR, the dispersant treated oil started dispersing immediately during the process of dispensing it into the boom and continued to completely disperse during the towing operation. After the test, no recoverable oil remained in the boom's apex. Figure 14 shows an underwater view of the oil dispersing and flowing under the boom during the DOR 1:50 test. Figure 15 shows a view of the oil dispersed along the tank behind the boom, and the oil left in the boom after the DOR 1:50 test.

Testing conducted at the higher tow speed of 1.2 knots also showed that adding dispersant to the oil affected its ability to be contained within a boom. For the untreated HOOPS test at 1.2 knots, 32% of the oil was lost. This percentage increased to 82% for the DOR 1:200 test. Testing was not conducted on the DOR 1:50 at 1.2 knots tow speed.

It should be noted that although there was a reduction in the boom's ability to contain the dispersant treated oil, the mixing energy introduced by the boom may generate sufficient small enough droplets to successfully disperse the oil.

Table 4 – Boom Containment Comparison Test Results

Boom Containment Results						
Test Fluid	**Tow Speed (knots)**	**Preload (gallons)**	**Oil Lost (gallons)**	**Percent Lost (%)**	**Avg. Loss (gallons)**	**Avg Percent Loss (%)**
HOOPS	0.9	75	0	0	0	0
HOOPS DOR 1:200	0.9	81	15.6	19.2	12.3	15
		81	9.1	11.2		
		81	12.1	14.9		
HOOPS DOR 1:50	0.9	81	80	98.8	80	98
HOOPS	1.2	80	9.3	11.6	25.4	32
		80	37.2	46.5		
		80	29.9	37.4		
HOOPS DOR 1:200	1.2	82	64.9	79.1	66.4	82
		81	75.1	92.7		
		81	59.2	73.1		

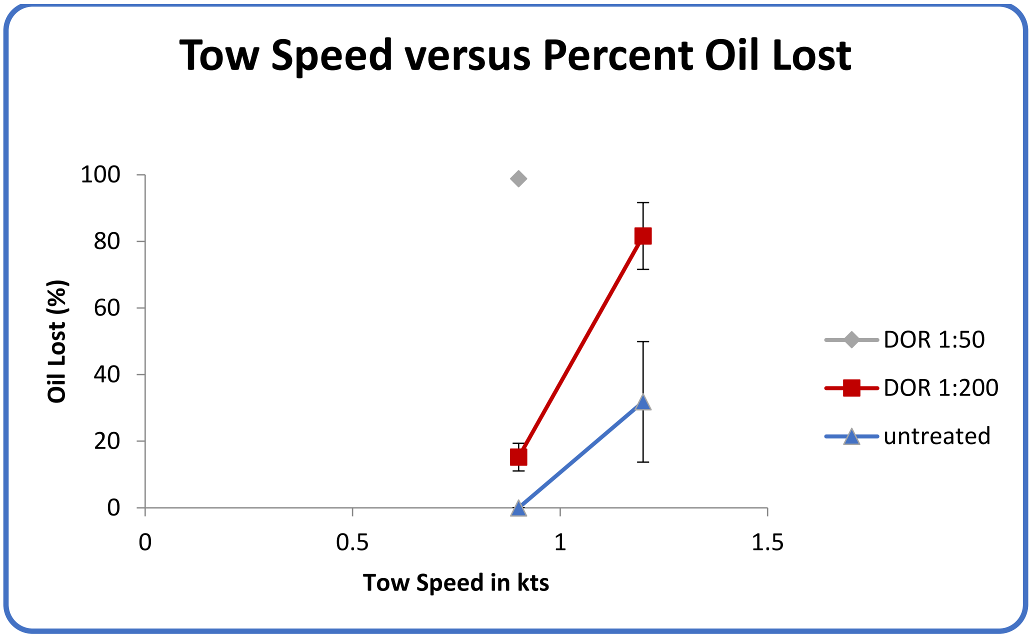

Figure 13 – Tow Speed versus Percent Oil Lost

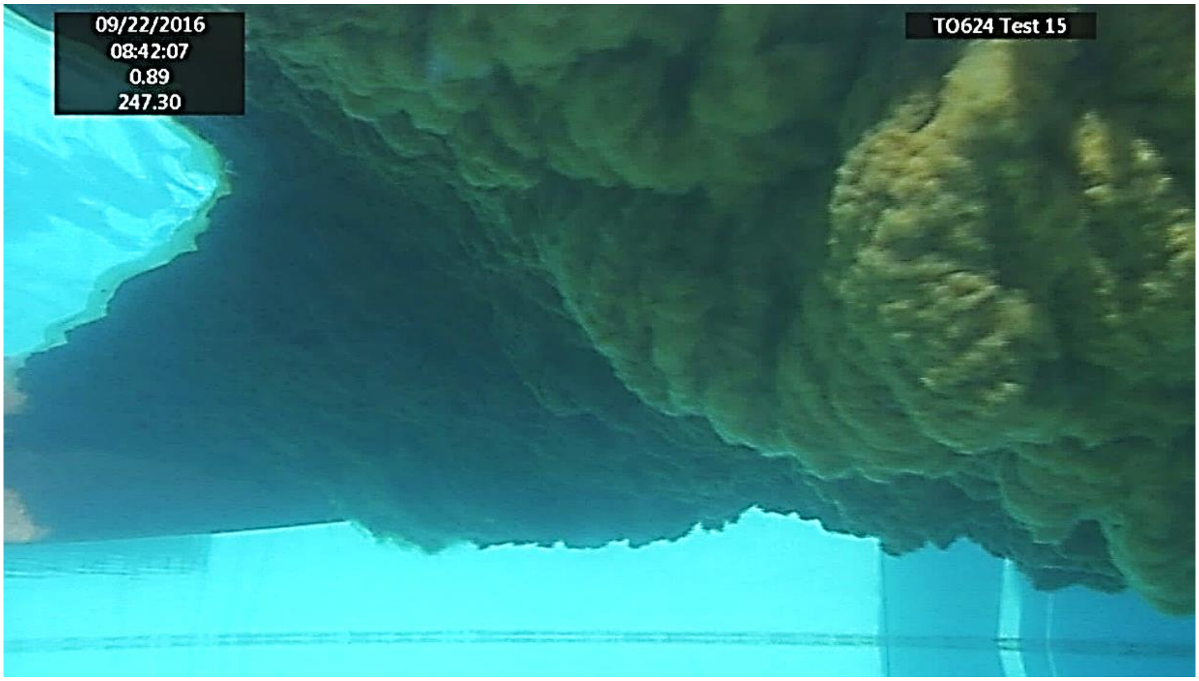

Figure 14 – Underwater View of Oil Dispersing and Flowing Under Boom – DOR 1:50

Figure 15 – Oil Dispersed Behind Boom (left) and Remaining after DOR 1:50 test (right)

7.2 Skimmer Test Results

A total of eighteen qualifying tests were performed. Tables 5 and 6 show tabulated results for the disc and drum skimmers including fluid recovery rates (amount of oil and water recovered per unit time), ORR and RE data. Figures 16 and 17 compare the fluid recovery rate and ORR for the untreated HOOPS versus HOOPS mixed with dispersant for each skimmer, and Figure 18 graphs percentage of free and emulsified water in the recovered fluid for both skimmers.

7.2.1 Fluid Recovery Rate Comparison

Total fluid recovery appeared to be somewhat affected by the presence of the dispersant. The disc skimmer exhibited an 18% increase in fluid recovery rate between the untreated condition and the DOR 1:50 treatment, although most of the increased fluid was water entrained in the oil. The drum skimmer exhibited a 10% reduction in fluid recovery rate between the untreated and DOR 1:50 treatment, with an increasing amount of water entrained in the oil.

7.2.2 ORR Comparison

The disc skimmer's ORR values were consistent throughout the test series with a slightly increased average ORR for the DOR 1:200 treatment. The drum skimmer, however, exhibited reduced ORRs as amount of dispersant within the oil increased. Although the drum skimmer's overall fluid recovery rate declined only by 10% between the untreated oil and DOR 1:50 treatment, the corresponding ORR decreased by approximately 43% because the recovered fluid contained increasing amounts of water.

7.2.3 Recovery Efficiency Comparison

RE is a measurement of the percentage of oil recovered to the total fluid recovered. RE for the disc skimmer remained above 90% for both the untreated oil and the DOR 1:200 tests, where both fluid rate and oil recovery rate increased slightly. However, for the DOR 1:50 tests, the oil contained in the fluid decreased slightly, and therefore the RE dropped to 81%, and all of the water was emulsified and did not separate out during the decant operation.

RE for the drum skimmer decreased significantly as DOR increased. RE for the untreated oil tests averaged 88%, and decreased to 69% for the DOR 1:50 tests and to 57% for the DOR 1:50 tests. All of the recovered water was emulsified and did not separate out during the decant operation.

7.2.4 Water Content in Recovered Fluids

Figure 18 shows that the amount of emulsified water in the recovered fluid increased as the DOR increased for both the disc and drum skimmers. For the disc skimmer, the amount of free water contained within the recovered fluid was minimal for all cases. The amount of emulsified water, however, increased from an average of 0.5% to 19%.

For the drum skimmer, the amount of free water within the recovered fluid decreased as DOR increased. However, emulsified water significantly increased, from an average of 4% for the untreated case to an average of 43% for the DOR 1:50 tests.

Table 5 – Disc Skimmer Test Results

Disc Skimmer Results									
Test Fluid	**Time (min)**	**Fluid Recovery Rate (gpm)**	**Free Water Collected(%)**	**Entrained Water Collected (%)**	**ORR (gpm)**	**RE (%)**	**Avg. Fluid Recovery Rate (gpm)**	**Avg. ORR (gpm)**	**Avg. RE (%)**
HOOPS	3.25	7.9	0.0	0.4	7.9	99.6	8.0	8.0	99.5
	3.30	8.0	0.0	0.4	8.0	99.6			
	3.30	8.1	0.0	0.7	8.0	99.3			
DOR 1:200	2.65	10.2	2.0	2.5	9.7	95.5	9.4	8.9	94.8
	3.05	8.9	2.1	2.5	8.5	95.5			
	2.97	9.0	1.6	5.0	8.4	93.4			
DOR 1:50	2.92	9.30	0.0	14.0	8.00	86.0	9.5	7.7	81.0
	2.97	9.15	0.0	22.0	7.1	78.0			
	2.68	10.10	0.0	21.0	8.0	79.0			

Table 6 – Drum Skimmer Test Results

Drum Skimmer Results									
Test Fluid	**Time (min)**	**Fluid Recovery Rate (gpm)**	**Free Water Collected (%)**	**Entrained Water Collected (%)**	**ORR (gpm)**	**RE (%)**	**Avg. Fluid Recovery Rate (gpm)**	**Avg. ORR (gpm)**	**Avg. RE (%)**
HOOPS	2.23	21.6	12.2	5.0	18.0	83.4	19.9	17.5	88.4
	2.48	19.2	6.6	4.0	17.3	89.6			
	2.55	18.7	3.7	4.3	17.3	92.3			
DOR 1:200	2.77	17.6	0.5	32.0	11.9	67.7	17.7	12.3	69.7
	2.83	17.3	0.2	30.0	12.1	69.8			
	2.70	18.1	0.4	28.0	13.0	71.7			
DOR 1:50	2.82	17.6	0.00	44.0	9.9	56.0	17.7	10.1	57.0
	2.77	17.9	0.00	43.0	10.2	57.0			
	2.82	17.6	0.00	42.0	10.2	58.0			

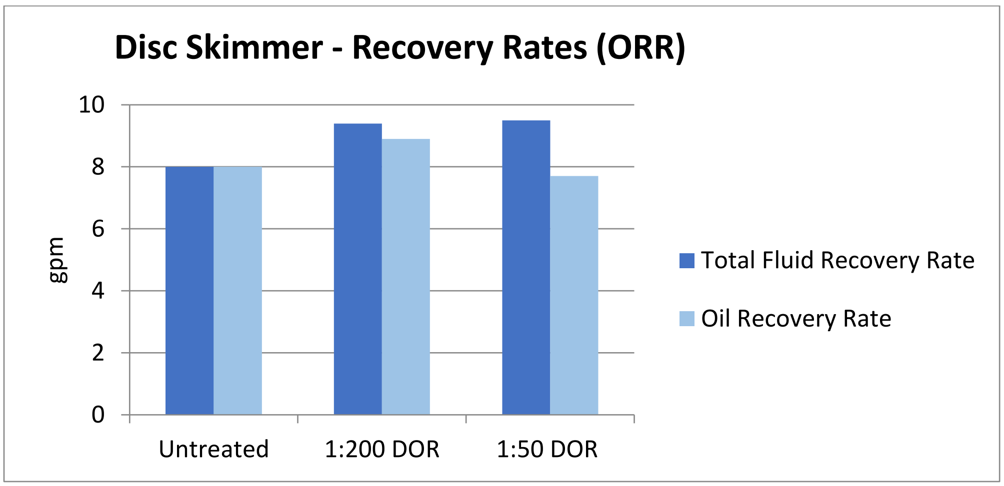

Figure 16 – Fluid and Oil Recovery Rates - Disc Skimmer

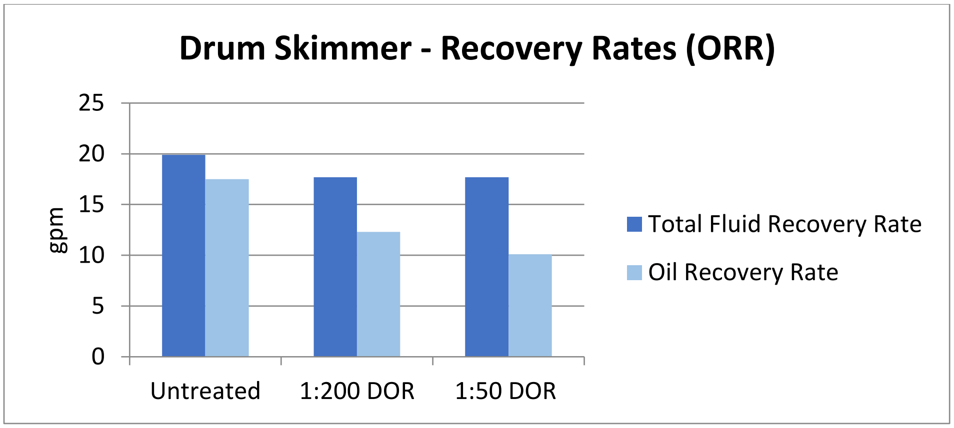

Figure 17 – Fluid and Oil Recovery Rates - Drum Skimmer

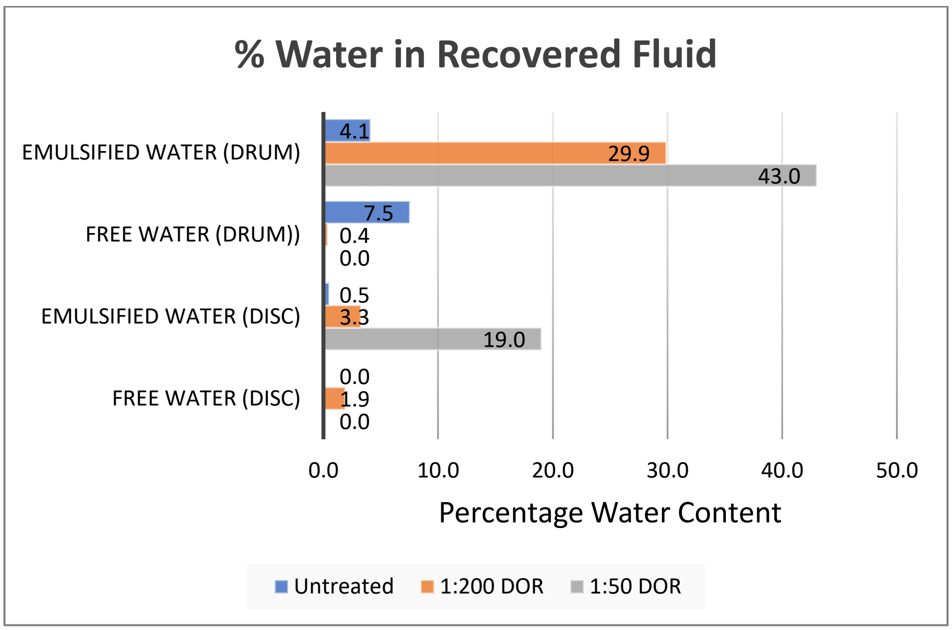

Figure 18 – Percent Water Content in Recovered Fluid

8 Conclusions

The presence of dispersants impacted every stage of the mechanical recovery process, from collecting the oil with booms, to the efficiency of the skimmers recovering the collected oil. As more dispersant is used, the interference with mechanical recovery operations increases.

The presence of dispersant had a significant effect on the boom's containment ability, even at low DOR. The boom adequately contained the untreated oil at a tow speed that would typically be used in field operations, losing essentially no oil at 0.9 knot tow speed. However, for this oil treated with a small amount of dispersant (DOR 1:200) the boom towed at the same 0.9 knots lost an average of 15% of the oil. At the DOR 1:50 treatment, the full oil volume was unsuccessfully contained in the boom and was dispersed by the energy provided by the towing operation. The color and depth of the resulting dispersion indicated a relatively small median droplet size. No instrumentation was deployed in the tank to measure droplet size as that was beyond the scope of this project.

Each skimmer reacted differently when recovering oil with increasing amounts of dispersant. The disc skimmer maintained a fairly consistent fluid recovery rate, although it picked up increasing amounts of water along with the oil which did not separate out during the standard settling time of 30 minutes. The drum skimmer was more significantly impacted by the presence of dispersants, exhibiting both a decrease of 10% in fluid recovery rate and a more significant decrease of 43% in ORR with the increasing presence of dispersant.

For both skimmers, the presence of dispersant caused the recovered fluid to entrain increasing amounts of water that did not separate out within a standard settling time of 30 minutes. This effect increased with the increasing presence of dispersants and affected the recovery efficiency (RE) of both skimmers. This effect was more apparent with the drum skimmer, possibly because its action imparted greater mixing energy in the area of recovery. RE decreased for the disc skimmer from 99% to 81% and for the drum skimmer from 88% to 57%.

It is important to remember that in field operations, neither collecting the oil using a boom nor recovering the oil with a skimmer happens in isolation. These two steps occur sequentially as a process, and the losses at each stage of the process compound to impact the final effectiveness. With this perspective, losses of efficiency become even more significant.

9 Recommendations

While findings suggest that treatment with dispersants could reduce the effectiveness of subsequent mechanical recovery, depending on the technology and dosage, it is important to note the limitations of this initial study and its practical applications.

In oil spill response, mechanical recovery and dispersants have fundamentally different remediation objectives. While mechanical recovery focuses on thickening the oil to physically remove it from the water surface, dispersant use aims to break the oil slick down into small droplets that are distributed within the water column. In the field, these two remediation tactics would not by typically used in conjunction, as they have fundamentally different, and conflicting, objectives. However, when oil slicks previously treated with dispersants do reach the surface, as in the Deepwater Horizon spill, mechanical recovery may be attempted as a secondary tactic. When turbulence is the limiting factor in the efficacy of dispersant action (e.g., Bittler 2017), the action of dragging the boom through the water column may introduce the needed turbulence to contribute to dispersion, but at the cost of efficacy for the mechanical recovery process.

It is also important to recognize that this testing was conducted with only one crude oil which is a relatively low viscosity crude oil and is readily dispersible. Testing with different crudes could provide different results, as other reviews have shown that oil properties have a significant impact on dispersibility (Bittler 2017.) The same factors that influence the dispersibility of an oil may also influence the ability of that oil to be mechanically contained and recovered should it be treated with dispersants. In addition, the properties of oil have a significant impact on recovery and emulsification absent of treatment by dispersants. This testing should be conducted on additional types of crude oils, with other skimmer technologies, and possibly in environmental conditions to apply the results to actual spill scenarios.

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Appendix A: Technical Summary

REPORT TITLE: Collection and Recovery of chemically treated, undispersed oil

CONTRACT NUMBER: E16PD00093

FISCAL YEARS(S) OF PROJECT FUNDING: FY2017

CUMULATIVE PROJECT COST: $100,092.70

COMPLETION DATE OF REPORT: June 2024

BSEE COR(S): Kristi McKinney

BSEE CO(S): Christopher Bondy

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KEY WORDS: Oil Skimmer, dispersant, undispersed oil, Recovery Efficiency, Oil Recovery Rate, Ohmsett

Department of the Interior (DOI)
The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation’s trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Safety and Environmental Enforcement (BSEE)
The mission of the Bureau of Safety and Environmental Enforcement works to promote safety, protect the environment, and conserve resources offshore through vigorous regulatory oversight and enforcement.

BSEE Oil Spill Preparedness Program
BSEE administers a robust Oil Spill Preparedness Program through its Oil Spill Preparedness Division (OSPD) to ensure owners and operators of offshore facilities are ready to mitigate and respond to substantial threats of actual oil spills that may result from their activities. The Program draws its mandate and purpose from the Federal Water Pollution Control Act of October 18, 1972, as amended, and the Oil Pollution Act of 1990 (October 18, 1991). It is framed by the regulations in 30 CFR Part 254 – *Oil Spill Response Requirements for Facilities Located Seaward of the Coastline*, and 40 CFR Part 300 – *National Oil and Hazardous Substances Pollution Contingency Plan*. Acknowledging these authorities and their associated responsibilities, BSEE established the program with three primary and interdependent roles:

- Preparedness Verification,
- Oil Spill Response Research, and
- Management of Ohmsett - the National Oil Spill Response Research and Renewable Energy Test Facility.

The research conducted for this Program aims to improve oil spill response and preparedness by advancing the state of the science and the technologies needed for these emergencies. The research supports the Bureau’s needs while ensuring the highest level of scientific integrity by adhering to BSEE’s peer review protocols. The proposal, selection, research, review, collaboration, production, and dissemination of OSPD’s technical reports and studies follows the appropriate requirements and guidance such as the Federal Acquisition Regulation and the Department of Interior’s policies on scientific and scholarly conduct.