FINAL REPORT

A TWO-YEAR RESEARCH PROGRAM ON EMPLOYING CHEMICAL HERDERS TO IMPROVE MARINE OIL SPILL RESPONSE OPERATIONS

for:

US Department of the Interior

Bureau of Ocean Energy Management, Regulation and Enforcement

Technology Assessment & Research Program

Herndon, VA

by:

S.L. Ross Environmental Research Ltd.

Ottawa, ON

August 4, 2010

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Executive Summary

Research on using chemical herding agents to thicken oil slicks in pack ice conditions for *in situ* burning has proved successful. Herding agents applied to the water surface around the edge of spills of fluid oil in broken ice conditions cause the oil slicks to contract and thicken to ignitable thicknesses. As a result of that success, a two-year program of R&D was undertaken to determine if there was a potential to use herding agents to improve other areas of marine oil spill response, specifically:

- Employing herding agents in drift ice to enhance recovery of spilled oil with skimmers;
- Using herders to clear oil from marsh areas; and,
- Applying chemical herders around oil slicks on the open ocean to improve the operational effectiveness of subsequent dispersant application

Laboratory and Ohmsett experiments on the use of herders to enhance mechanical recovery in drift ice showed that:

- The use of herders in drift ice conditions could potentially improve the Oil Recovery Rate and Oil Recovery Efficiency performance of weir skimmers by factors of 2 to 10; however, the oil thicknesses produced by the herder were too low to permit optimal performance of the weir skimmer.
- No significant improvement was measured in the performance of a disc skimmer in herded slicks compared to unherded slicks.

Results from preliminary salt mash tests indicated that:

- In none of the static tests did the herder clear the oil completely from the marsh plants.
- In some tests the herder caused the oil slicks to contract in size sufficiently to significantly reduce the oiled area of the marsh; however, even in these cases, there remained a ring of oil at the waterline around the originally oiled stalks of the marsh plants.
- In all cases, after herder had been added, the slicks were thick enough to support ignition. This is a significant finding, since even though the herder did not clear the oil out of the marsh plants; it could contract the oil sufficiently to allow *in situ* burning.

In the case of the experiments on using herders to improve operational efficiency of dispersants:

- The use of herders on an oil slick did not detract from the effectiveness of chemical dispersant application.
- Using herders to contract slicks on open water can improve the operational efficiency of dispersants applied by vessels.
- Herding a slick to be sprayed with dispersants from aircraft could reduce operational efficiency (by wasting large amounts of the dispersant).

1 Introduction

As a result of the experimental success thickening oil slicks for *in situ* burning in pack ice a two-year research project was completed to begin to study whether herders can assist with other areas of spill response that have inherent restrictions on effectiveness, specifically:

- The use of herding agents in pack ice to enhance mechanical recovery of spilled oil with skimmers;
- Using herders to clear oil from marsh areas; and,
- Applying chemical herders around oil slicks on the open ocean to improve the operational effectiveness of subsequent dispersant application.

1.1 Background

Field deployment tests of booms and skimmers in broken ice conditions in the Alaskan Beaufort Sea highlighted the severe limitations of conventional equipment in even trace concentrations of broken ice (Bronson *et al.* 2002). *In situ* burning may be one of the few viable options to quickly remove oil spilled in such situations. One fundamental problem with the application of *in situ* burning to oil well blowouts or subsea oil pipeline leaks is that the slicks are initially too thin, or they can thin quickly, preventing effective ignition and burning. Effective burns could be carried out in drift ice conditions (up to 6 tenths coverage), even with no possibility of booming, if these slicks could be thickened to the 2- to 5-mm range (SL Ross 2003). Conventional fire booms may not work efficiently in these ice conditions.

The use of specific chemical surface-active agents, sometimes called oil herders or oil collecting agents, to clear and contain oil slicks on an open water surface is well known (Garrett and Barger 1972, Rijkwaterstaat 1974, Pope et al 1985, MSRC 1995). These agents have the ability to spread rapidly over a water surface into a monomolecular layer, as a result of their high spreading coefficients, or spreading pressures. The best agents have spreading pressures in the mid-40 mN/m range, whereas most crude oils have spreading pressures in the 10 to 20 mN/m range. Consequently, small quantities of these surfactants (about 5 L per lineal kilometre or 2 gallons/mile) will quickly clear thin films of oil from large areas of water surface, contracting it into thicker slicks. Appendix A contains an explanation of how herders work. Field tests of herders on open water with a 25-gallon fuel oil slick in Chesapeake Bay (Garrett and Barger 1972) and a 5-ton crude oil slick in the North Sea (Rijkwaterstaat 1974) have shown them to retain their efficacy for several hours in winds of 6 m/s (12 knots) with 2-m (6-foot) seas, providing the herder is replenished periodically. Preventing a slick on water from spreading for many hours among drift ice should be achievable and would offer a valuable extension to the window of opportunity for slick ignition.

Although commercialized in the 1970s herders were not used offshore because they only work in very calm conditions: physical containment booms are still needed to hold or divert slicks in winds above 4 knots and breaking waves disrupt the herder layer. For application in loose pack ice, the intention would be to contract freely-drifting oil slicks to a burnable thickness, then ignite them with a Helitorch or hand-held igniters. The herders will work in conjunction with the limited containment provided by the ice to allow a longer window of opportunity for burning.

A very small scale (1 m^2) preliminary assessment of a shoreline-cleaning agent with oil herding properties was funded by ExxonMobil in 2003 to assess its ability to herd oil on cold water and among ice (SL Ross 2004). The results were promising:

- Using the shoreline cleaner on cold water (2°C) greatly reduced the area of sheens of fluid oils, but the thickness of the herded oil was only in the 1-mm range.
- On thicker (about 1 mm) slicks, the shoreline cleaner effect was much more promising and could herd slicks to thicknesses of 2 to 4 mm.
- Although the presence of ice slightly retarded the effectiveness of the herding agent, it still considerably thickened oil among ice.
- The composition of the oil appeared to play a strong role in determining potential efficacy: oils that gelled or did not spread readily on cold water could not be herded.

Further experiments were then performed: small-scale experiments (1 m^2) to explore the relative effectiveness of three oil-herding agents in simulated ice conditions; larger scale (10 m^2)

quiescent pan experiments to explore scaling effects; small-scale (2 to 6 m^2) wind/wave tank testing to investigate wind and wave effects on herding efficiency; and, small-scale (0.33 L) *in situ* ignition and burn testing (SL Ross 2005). The results from these experiments showed that the application of a herder to thin oil slicks in pack ice has considerable promise for thickening the oil for *in situ* burning. One herder formulation (65% Span-20 with 35% 2-ethyl butanol tested by the U.S. Navy – Garret and Barger 1972) proved to be the best suited for cold conditions. The herded thickness produced by this formulation was consistently in the 3+ mm range for 1-L and greater slicks. This would allow ignition using conventional gelled gasoline igniters and result in 66 to 75% removal efficiencies (SL Ross 2003). Small oil slicks herded by the chemical were successfully ignited and burned. The burn efficiencies measured were similar to those for physically contained slicks of the same dimensions. In a real spill situation, once a large, 3 to 4 mm slick of oil on water had been ignited around its periphery, it is possible that the inward air flow generated by the combustion would further herd the oil to thicknesses of 10 mm (Buist 1987), resulting in even higher oil removal efficiencies.

Next, a comprehensive, multi-year, multi-partner research program to study the use of chemical herding agents to thicken oil slicks in order to ignite and burn the oil *in situ* in loose pack ice was initiated (SL Ross 2007). The program included:

1. Experiments at the scale of 100 m^2 in the indoor Ice Engineering Research Facility Test Basin at the US Army Cold Regions Research and Engineering Laboratory (CRREL) in November 2005.
2. Experiments at the scale of 1000 m^2 at Ohmsett – The National Oil Spill Response Test Facility, in artificial pack ice in February 2006.
3. A series of 20 burn experiments at the scale of 30 m^2 with herders and crude oil in a specially prepared test basin containing broken sea ice in November 2006 at the Fire Training Grounds in Prudhoe Bay, AK.

The U.S. Navy cold-water herder formulation (65% Span-20 and 35% 2-ethyl butanol) used in these experiments proved effective in significantly contracting fluid crude and refined oil slicks in brash and slush ice concentrations of up to 70% ice coverage. Slick thicknesses in excess of 3 mm, the minimum required for ignition of weathered oil *in situ*, were routinely achieved. The presence of frazil ice restricted the spreading of the oil and the effectiveness of the herder. Short, choppy waves in the test ice caused a herded slick to break up into small slicklets, although this may be an artifact of the relatively small volumes of oil used in the experiments. Longer, non-breaking waves, simulating a swell in pack ice, did not appear to cause a herded slick to break up, and in fact may have assisted the process by promoting spreading of the herder over water to the slick's edge.

Application of the herder to the water prior to the oil being spilled resulted in thicker slicks than post-spill application. This approach might be useful in the event of a chronic spill event in pack ice conditions, such as a blowout or a pipeline leak.

Otherwise unignitable crude oil slicks that were contracted by the USN herder could be ignited and burned *in situ* in both brash and slush ice conditions at air temperatures as low as –17°C. Measured oil removal efficiencies for herded slicks averaged 50% for 7.5-L slicks and 70% for 15-L slicks. The efficiencies measured for the herded slicks were only slightly less than the theoretical maximums achievable for equivalent-sized, mechanically contained slicks on open water. The type of ice (brash or slush) did not significantly affect the burn efficiency.

When ignited, the herded slicks did spread slightly, but once the flames began to die down, the residue was re-herded by the agent remaining on the water surrounding the slick. Generally, it was not possible to reignite re-herded residue. Steeper, cresting waves detracted from the burn efficiency while longer, non-breaking waves did not. The oil removal rate for the slicks was in the range expected for equivalent-sized, mechanically contained slicks on open water.

In the spring of 2008, as one component of a large field program co-ordinated by SINTEF as part of a Joint Industry Project (Sørstrøm *et al.* 2010), a field trial was carried out in pack ice east of Svalbard involving the release of 630 L of fresh crude onto water in a large lead. The free-drifting oil was allowed to spread for 15 minutes until it was far too thin to ignite, and then USN herder was applied around the slick periphery. The slick contracted and thickened for 20 minutes at which time the upwind end was ignited. A 9-minute burn ensued that consumed an estimated 90% of the oil (Buist *et al.* 2010).

1.2 Objective

The objective of this multi-project research program was to determine whether herding agents could contract oil slicks in specific spill situations where conventional countermeasures have limited effectiveness and thereby enhance marine oil spill response operations.

1.3 Goals

Specifically, the goals of the program were to:

1. Research the use of herding agents in pack ice to enhance mechanical recovery of spilled oil with skimmers.
2. Conduct preliminary experiments to determine the feasibility of using herders to clear oil from marsh areas.
3. Carry out experiments to study if applying chemical herders around oil slicks on the open ocean could improve the operational effectiveness of subsequent dispersant application.

2 Using Herders to Enhance Mechanical Recovery of Oil in Drift Ice

The main problem with using mechanical recovery systems in drift ice conditions is that the booms, deployed to collect and concentrate oil for effective skimming, also collect and concentrate ice pieces that quickly render the skimmers ineffective (Bronson *et al.* 2002). The research on using herding agents to thicken slicks for *in situ* burning has shown that they can significantly contract and thicken oil slicks among ice, without concentrating the surrounding ice (SL Ross 2007). This could be beneficial to mechanical recovery. In fact, as a skimmer removes oil from the center of a herded slick, the action of the herding agent may cause the slick to continuously contract towards the skimmer, eliminating the need to move the skimmer around to contact all the oil. However, it has been observed that the active ingredient in herding agents (the surfactant) renders sorbent pads less hydrophobic and their water retention increases considerably. This could be a significant detriment to oleophilic skimmers such as drums, discs and rope mops whose recovery surfaces contact herding agent. This should not be an issue with other skimmers types such as weirs and vacuums. This part of the test program involved experiments at the SL Ross laboratory, followed by large-scale experiments at Ohmsett.

2.1 Laboratory Experiments

2.1.1 Methods

As a precursor to large-scale experiments with real skimmers, a series of bench-scale and wind/wave tank experiments was undertaken at the SL Ross laboratory to determine the feasibility of using herders to enhance skimming operations in pack ice.

The first series of tests involved 54 individual dip tests to determine if common oleophilic materials used in oleophilic skimmers would be detrimentally affected by contact with herding agent prior to contacting the oil to be recovered. Pre-weighed samples of aluminum, PVC and a section of Lamor Corporation stiff brush were dipped into a glass bowl containing either water or USN herder on the water (at a nominal dose of 250 mg/m^2). Next the material sample was dipped into a bowl with a 10-mm layer of oil on the water, removed and allowed to drip for 1 minute before being reweighed. Five repeats were done, and the average retention of oil on the samples was calculated. The following parameters were varied in the dip tests:

- Three water salinities - 0, 15 and 30 ‰;
- Three oil types -Alaska North Slope (ANS) and Kuparuk crudes and No. 2 Fuel oil (diesel);
- Three oleophilic materials.

The next series of tests was carried out in the indoor wind/wave tank (with 30 ppt salt water at 0°C) at the SL Ross laboratory (Figure 1). Two sheet metal-wall, open-bottomed enclosures (each 1.1 m wide x 2.4 m long x 20 cm deep) were suspended in the tank at the water surface to create two small test areas (Figure 2). Various sized pieces of 1”-thick, low density polyethylene (LDPE) sheet were floated on the water inside the enclosures to simulate drift ice. The tests involved measuring the performance of both a small surrogate weir skimmer (Figure 3) and a small disc skimmer mock-up (Figure 4) with and without herding agent applied to the slick to be skimmed.

The first of two recovery tests was conducted in a 1-mm thick 2.5-L slick covering the enclosed water surface: the second in an identical slick treated with the USN herder. The slicks were photographed from above (Figure 5) for area (and thus thickness) analysis and the tests were videotaped. Oil recovery rate (ORR – the volume of oil recovered per unit time), Oil Recovery Efficiency (ORE – the fraction of oil in the recovered fluid) and Throughput Efficiency (TE- the percentage of the original oil that was collected) were measured for each test using large, graduated glassware and a vacuum pump to remove oil from the skimmer sumps (Figure 6).

Figure 1: Refrigerated wind/wave tank at the SL Ross laboratory.

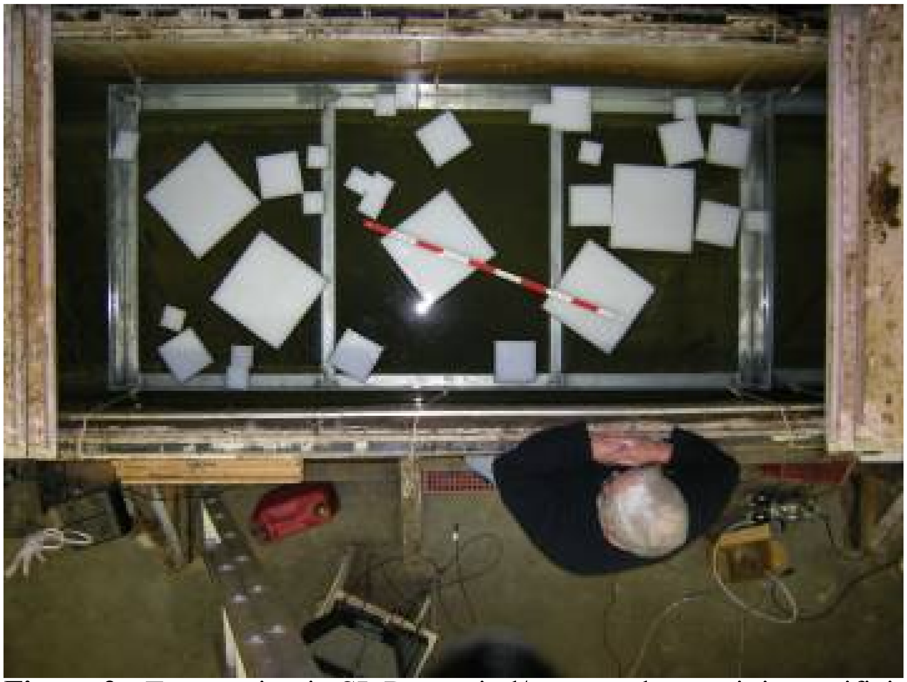


Figure 2: Test section in SL Ross wind/wave tank containing artificial ice floes made from 1”-thick LDPE.

Figure 3: Surrogate weir skimmer used in tests.


Figure 4: Mock disc skimmer used in tests.

a) b) c)

Figure 5: Test area photos a) before herder, b) after herder, and c) after skimming.

Figure 6: Vacuum pump and glass bottles used to collect recovered oil from skimmers.

The following parameters were varied in the 14 wind/wave tank tests completed:

- Three ice covers (0, 10 and 30 %)
- Three oil types (two crudes that are fluid at ambient temperatures and No. 2 Fuel Oil)
- Two skimmer types (weir and oleophilic disc).

2.1.2 Laboratory Results and Discussion

The dip tests results are shown in Table 1. The overall average reduction in adherence of oil to the material dipped in herder was 19% for the PVC and 5% for the Aluminum. There was no significant difference in the adherence results for the stiff brush. Both the ANS crude and No. 2 fuel oils were quite light with low viscosity and thus not very much of either adhered to the clean material samples. This could lead to large errors due to small differences in weights. The Kuparuk crude was more viscous, and adhered better to the materials. The average adherence reductions for the Kuparuk crude were 21% for PVC and 12% for aluminum. Again, there was no difference for the stiff brush. Figure 7 shows the tests results for the two surrogate skimmers in the wind/wave tank. Full data may be found in Appendix B. The top row of graphs presents

Table 1. Results of oleophilic material dip tests at SL Ross laboratory.

US Navy herder
ANS, Kuparuk & Fuel Oil #2
0, 15 & 30 ppt salt water
Aluminum, PVC & brush skimmer coarse brush

Oleophilic material dipped first in either water or herder-covered water, then dipped in water with 10mm oil cover, then allowed to drip for 1 minute
Five repeats, generally

Weight of oil left after 1 minute drip

Material	Oil	Salt (ppt)	Herder	Dip #1 (gm)	Dip #2 (gm)	Dip #3 (gm)	Dip #4 (gm)	Dip #5 (gm)	Dip #6 (gm)	Average (gm)	Percent of no herder
PVC											
	ANS	0	No herder	0.14	0.14	0.15	0.13	0.14		0.140	
			Herder	0.12	0.12	0.11	0.10	0.13		0.116	83%
		15	No herder	0.13	0.11	0.12	0.16	0.12		0.128	
			Herder	0.11	0.09	0.11	0.12	0.08		0.102	80%
		30	No herder	0.12	0.13	0.11	0.11	0.11	0.16	0.123	
			Herder	0.11	0.12	0.15	0.10	0.10		0.116	94%
	Kuparuk	0	No herder	0.28	0.30	0.28	0.34	0.29		0.298	
			Herder	0.21	0.23	0.20	0.24	0.19		0.214	72%
		15	No herder	0.29	0.29	0.28	0.29	0.28		0.286	
			Herder	0.19	0.21	0.17	0.19	0.23		0.198	69%
		30	No herder	0.11	0.13	0.13	0.10	0.14		0.122	
			Herder	0.12	0.13	0.13	0.08	0.12		0.116	95%
	Fuel Oil #2	0	No herder	0.06	0.05	0.07	0.04	0.07		0.058	
			Herder	0.04	0.05	0.06	0.04	0.07		0.052	90%
		15	No herder	0.02	0.04	0.06	0.00	0.05		0.034	
			Herder	0.00	0.02	0.06	0.00	0.03		0.022	65%
		30	No herder	0.04	0.07	0.07	0.04	0.06		0.056	
			Herder	0.04	0.04	0.06	0.07	0.02		0.046	82%
Aluminum											
	ANS	0	No herder	0.12	0.13	0.16	0.16	0.17	0.14	0.147	
			Herder	0.13	0.13	0.12	0.14	0.15		0.134	91%
		15	No herder	0.14	0.12	0.19	0.14	0.17		0.152	
			Herder	0.12	0.11	0.10	0.14	0.10	0.12	0.115	76%
		30	No herder	0.11	0.14	0.12	0.13	0.14		0.128	
			Herder	0.11	0.12	0.14	0.12	0.10		0.118	92%
	Kuparuk	0	No herder	0.31	0.30	0.31	0.33	0.33		0.316	
			Herder	0.32	0.32	0.26	0.20	0.26	0.23	0.265	84%
		15	No herder	0.30	0.29	0.37	0.26	0.29		0.302	
			Herder	0.27	0.22	0.20	0.18	0.25		0.224	74%
		30	No herder	0.13	0.13	0.14	0.11	0.13		0.128	
			Herder	0.14	0.13	0.14	0.12	0.14		0.134	105%
	Fuel Oil #2	0	No herder	0.06	0.02	0.01	0.06	0.01		0.032	
			Herder	0.00	0.03	0.05	0.06	0.03		0.034	106%
		15	No herder	0.00	0.04	0.03	0.04	0.02		0.026	
			Herder	0.00	0.05	0.06	0.01	0.04		0.032	123%
		30	No herder	0.12	0.05	0.09	0.07	0.04		0.074	
			Herder	0.10	0.07	0.07	0.07	0.07		0.076	103%
Brush											
	ANS	0	No herder	0.66	0.66	0.63	0.51	0.61		0.614	
			Herder	0.64	0.58	0.68	0.61	0.68		0.638	104%
		15	No herder	0.63	0.68	0.66	0.79	0.61	0.80	0.695	
			Herder	0.67	0.69	0.64	0.60	0.67		0.654	94%
		30	No herder	0.68	0.63	0.60	0.64	0.59		0.628	
			Herder	0.66	0.61	0.56	0.62	0.58		0.606	96%
	Kuparuk	0	No herder	0.86	0.84	0.90	0.92	0.94		0.892	
			Herder	0.90	0.87	0.94	0.96	0.88		0.910	102%
		15	No herder	0.95	0.93	0.84	0.83	0.84	0.82	0.868	
			Herder	0.86	0.82	0.89	0.82	0.84		0.846	97%
		30	No herder	0.66	0.64	0.60	0.54	0.68		0.624	
			Herder	0.66	0.69	0.64	0.63	0.62		0.648	104%
	Fuel Oil #2	0	No herder	0.54	0.51	0.47	0.44	0.47		0.486	
			Herder	0.46	0.56	0.49	0.61	0.52		0.528	109%
		15	No herder	0.52	0.43	0.44	0.47	0.55		0.482	
			Herder	0.48	0.46	0.49	0.55	0.52		0.500	104%
		30	No herder	0.46	0.51	0.41	0.45	0.43		0.452	
			Herder	0.51	0.52	0.44	0.55	0.61	0.50	0.522	115%

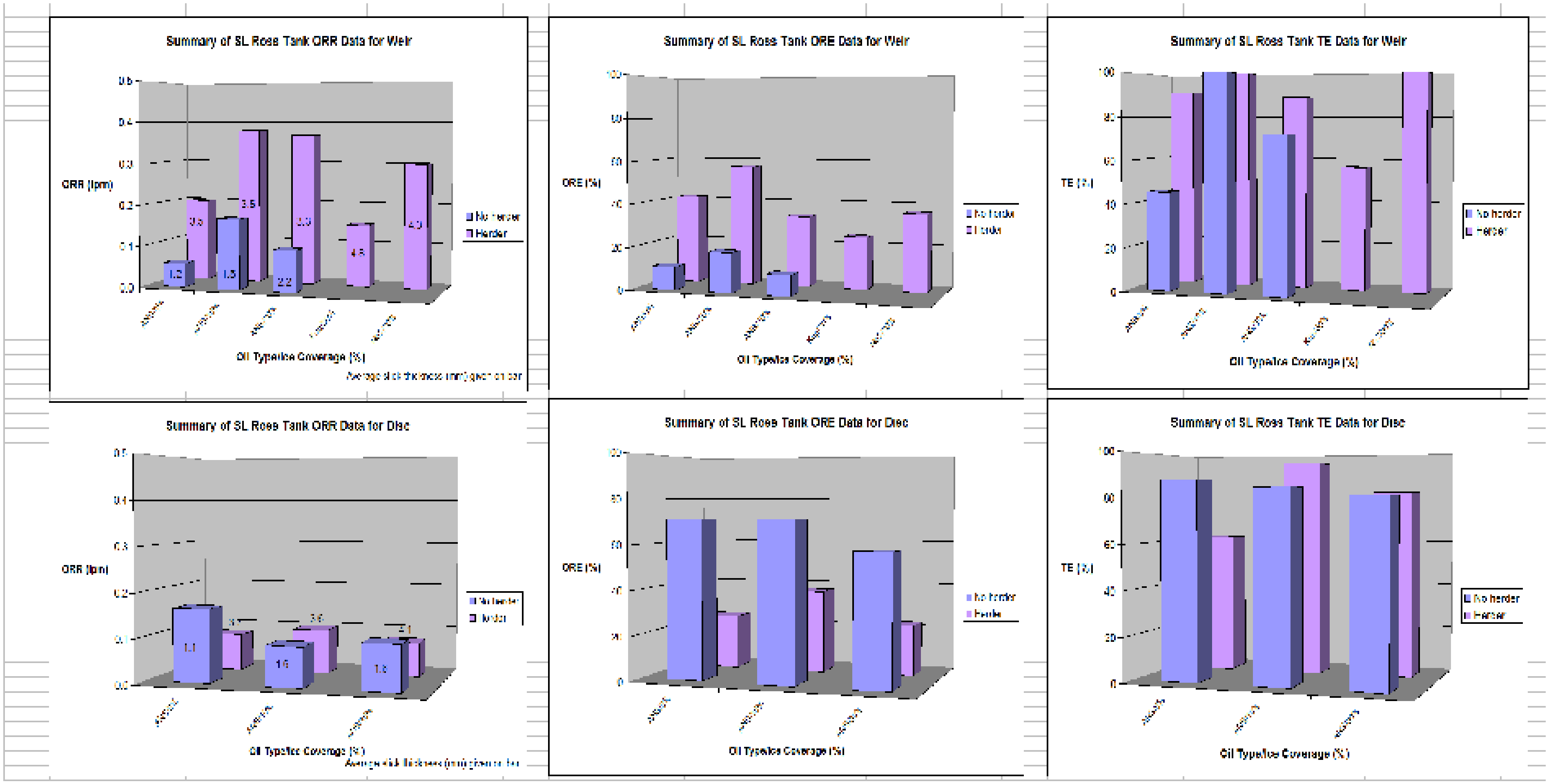


Figure 7: Skimmer test results from SL Ross wind/wave tank.

the results for the tests with the weir skimmer surrogate and the bottom row gives the results for the disc skimmer surrogate. The front row of columns for each graph gives the calculated result for the no-herder test while the back row presents the result with the herder applied. On the leftmost graph of each row (Oil Recovery Rate), the calculated average slick thickness, in mm, is printed on the column. The center graphs give the Oil Recovery Efficiency data and the right-hand graphs present the Throughput Efficiency results. Tests with herded Kuparuk and herded No. 2 Fuel oil were performed only with the weir skimmer.

Generally, the herder improved the ORR and ORE performance of the weir skimmer by factor of two to three. No significant improvement was noted with the disc skimmer. The ORE for the disc skimmer was actually much worse with the application of herder because the disc contacted more water than when the oil was not herded.

2.2 Ohmsett Experiments

The goal of the work described here was to conduct experiments at the scale of 75 m^2 at Ohmsett on the efficacy of herders in thickening oil slicks among broken ice for mechanical recovery.

2.2.1 Ohmsett Experimental Methods

A test plan and protocol for conducting full-scale experiments at Ohmsett on using herders to enhance mechanical recovery of oil in pack ice was submitted for review and comment prior to commencing the testing (see Appendix C).

The general test procedure was to put 1.2 m x 1.2 m x 20 cm (4' x 4' x 8") slabs of freshwater ice supplied by CRREL into a 32-foot diameter boom circle with the desired ice piece size distribution (55% 4'x4'+ 30% 2"x2" + 15% small fragments – Buist *et al.* 2002), then move it to the upwind end/side of the tank. Next, the boom was released and allowed to accelerate to its terminal drift speed. Once terminal velocity was reached the oil was placed in the circle, allowed to spread, photographed, herder applied (if required) and skimming started. A schematic of the test set-up is given in Figure 8.

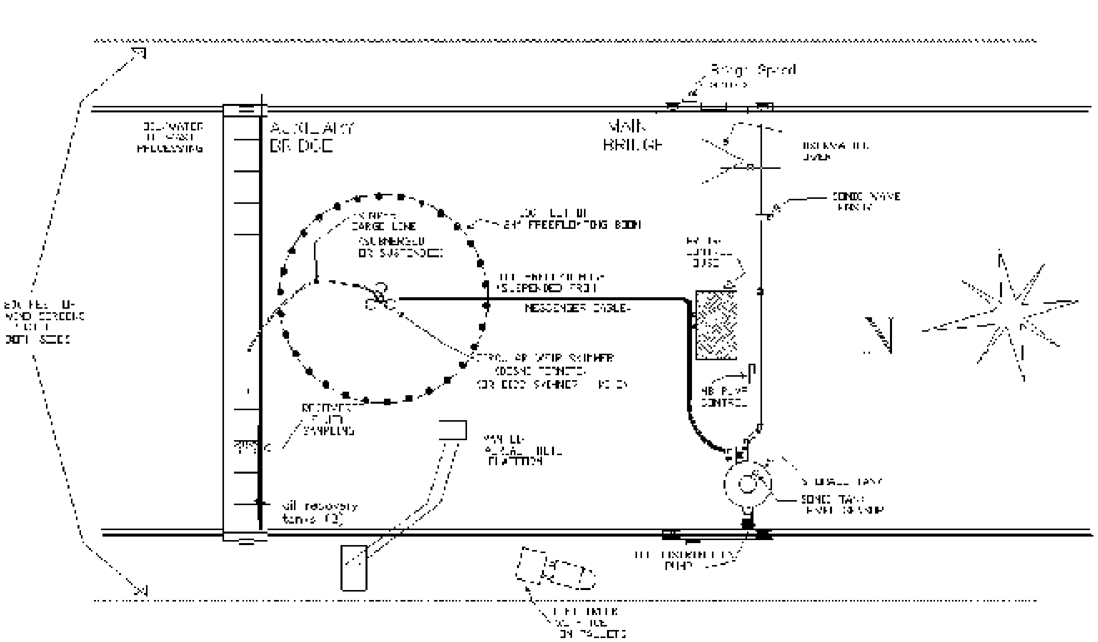


Figure 8: Schematic of Ohmsett test set-up.

The windscreens were erected along the sides of the tank, and proved very effective in reducing wind speeds at the tank water surface, allowing greatly extended test times.

Immediately prior to each test, the boom circles were placed beside the west side of the tank and the ice floes to produce the desired coverage were added from pallets.

The nominal oil coverage was 1 mm on the water surface in the test ring (75L = 20 gallons added for 0% ice; 68 L = 18 gallons added for 10% ice; and, 53 L = 14 gallons added for 30% ice). The oil for each test was added manually from plastic buckets from the man-lift. If required, herder was also applied via syringe from the man lift to the periphery of the slick.

Just before the herder was applied, an overhead digital picture/video was taken (Figure 9). The target herder application rate was 150 mg/m^2, yielding a maximum total volume of 12 g (12 mL) per test. After the herder was applied and the contraction of the slick had ceased, a second digital picture was taken from the man lift (Figure 10). Time- and date-stamped digital video was recorded continuously from the video tower and the Main Bridge.

Figure 9: Photograph of disc skimmer test with 10% ice from man lift prior to herder.

Figure 10: Photograph of same disc skimmer test from man lift after herder applied to slick.

Next, the skimmer (pre-positioned in the boom circle) was started and manually moved around in the boom circle to recover as much oil as possible. The flow from the Desmi Termite weir skimmer was directed to the recovery tanks on the Auxiliary Bridge for subsequent recovered oil and water measurements. The flow from the Morris Industries MI-2 disc skimmer was directed to open-topped drums located on the Main Bridge for subsequent recovered oil and water measurements. The use of open-topped drums for the disc skimmer tests was to allow more accurate measurement of oil and water recovered. The skimming was timed with a watch. The recovered oil tanks (or open-topped drums) were measured and samples taken and analyzed as per standard ASTM and Ohmsett operating procedures to determine Oil Recovery Rate, Recovery Efficiency and Throughput Efficiency. The wind speed, air and water temperature were monitored and recorded.

In total 26 tests were successfully completed varying:

- Three ice coverage's
  - 0, 10 and 30%
- Three oils
  - One crude oil (Alyeska Pump Station 1) used for a full suite of 12 tests
  - One crude (Pt. MacIntyre) used for a partial suite of 8 tests (10% and 30% ice only)
  - Marine Gas Oil (MGO) used for a partial suite of 4 tests (30% ice only)
- Two chemical herder application rates
  - None and USN herder applied at 150 mg/m^2 (12 mL/test)
- Two skimmers
  - The Desmi Termite weir skimmer and the Morris MI-2 disc skimmer

Two duplicate tests were also completed.

2.2.2 Ohmsett Experiment Results and Discussion

The Ohmsett experiment results are given in Figure 11. Full data sets may be found in Appendix D. The top row of graphs presents the results for the tests with the weir skimmer and the bottom row gives the results for the disc skimmer. The front row of columns for each graph gives the calculated result for the no-herder test while the back row presents the result with the herder applied. On the leftmost graph of each row (Oil Recovery Rate), the calculated average slick

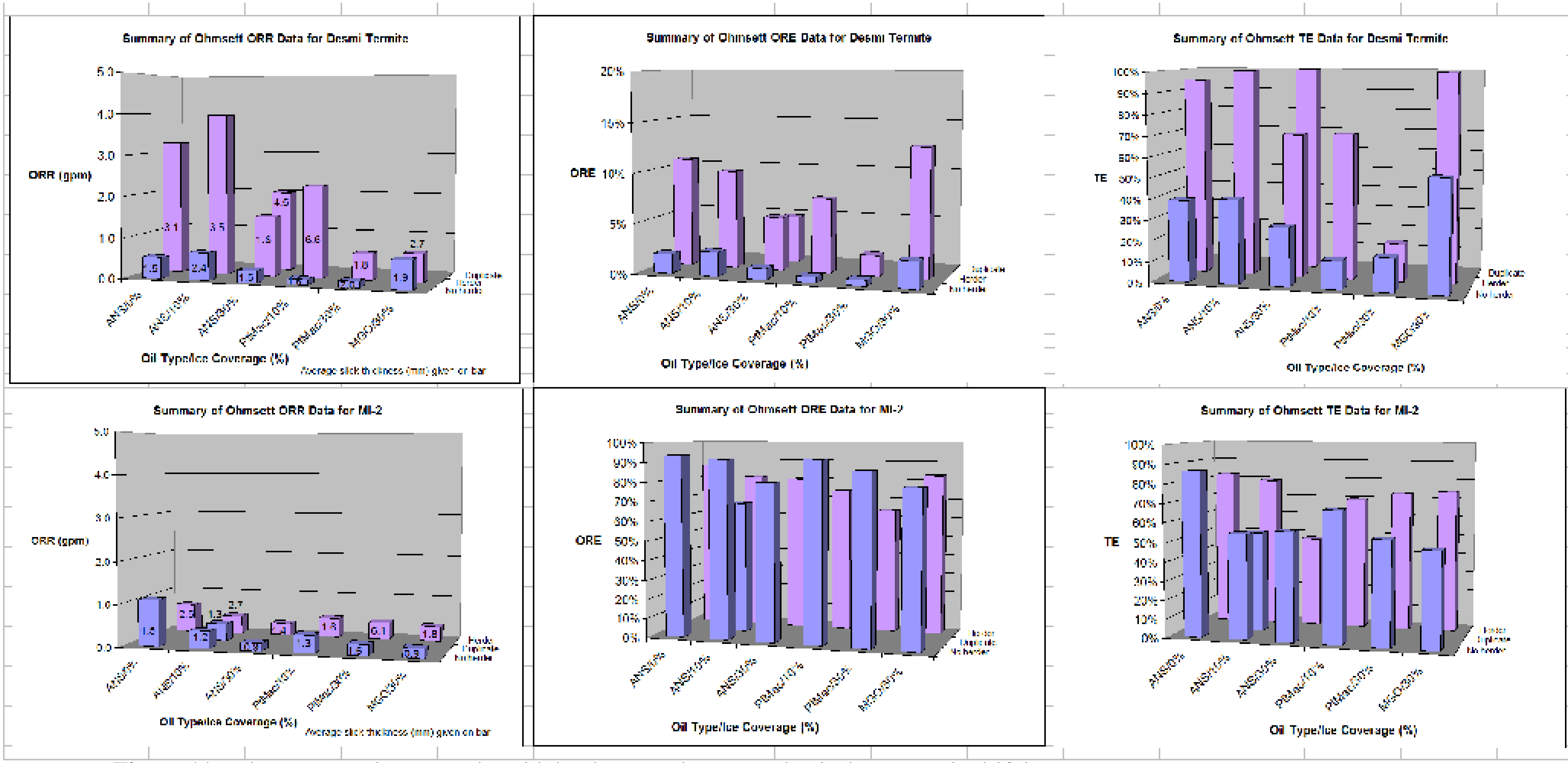


Figure 11. Ohmsett experiment results with herders to enhance mechanical recovery in drift ice.

thickness, in mm, is printed on the column. The center graphs give the Oil Recovery Efficiency data and the right-hand graphs present the Throughput Efficiency results. Since these experiments were conducted outdoors, the wind did influence some of the slicks. Even with the calming influence of the wind screens and allowing the test rings to drift during the experiments, in some cases the unherded slicks were pushed by the wind to one side of the test ring and thickened considerably more than the 1-mm target for unherded slick thickness (particularly the test with the Desmi and Pt McIntyre crude in 30% ice cover and the MGO in 30% ice cover when the wind was from the ends of the tank, not the sides). In the test with the Desmi weir skimmer with ANS crude in 10% ice cover with no herder, the ring contained residual hydraulic fluid from a leak the previous day that prevented the oil from spreading fully.

Generally, the addition of herder improved the ORR and ORE performance of the weir skimmer by factors of 3 to 10 and improved the TE by factors of 1.1 to 5. The highest recovery rate achieved with herded slicks by the Desmi Termite was 4 gpm, compared to the rated capacity of the pump of 132 gpm. Slick thicknesses produced by herders in drift ice conditions, though better than un-herded slicks, are not sufficient for optimum performance of weir skimmers.

No significant improvement was measured in the performance of the disc skimmer. Comparing the disc skimmer ORE results at Ohmsett to those in the SL Ross tank tests, the Ohmsett ORE were not significantly worsened with the application of herder. This is believed to be due to the greater size of the herded slicks at Ohmsett relative to the skimmer in comparison to the sizes of the skimmer and herded slick in the SL Ross tank tests. In only one test was it noted that the disc skimmer "drew" the herded slick towards itself without the need to move the skimmer around.

2.3 Summary

The experimental results indicate that the use of herders in drift ice conditions could potentially improve the Oil Recovery Rate and Oil Recovery Efficiency performance of weir skimmers by factors of 2 to 10; however, the oil thicknesses produced by the herder were too low to permit optimal performance of the weir skimmer. No significant improvement was measured in the performance of the disc skimmer in herded slicks compared to unherded slicks.

3 Herders to Clear Oil Slicks in Salt Marshes

The use of mechanical recovery equipment in salt marsh environments is generally not appropriate due to concerns over damaging the marsh substrate. This task, requested by MMS as an add-on to the original White Paper submission, involved some preliminary laboratory experiments in small-scale simulated marshes to determine whether or not herders might play a role in clearing spilled oil from a marsh. Specifically, the goal of this task of the test program was to determine the feasibility of using the US Navy herder formulation to clear oil from salt marsh areas.

3.1 Experimental Methods

A test plan and protocol for experimenting with herding agents to clear oil slicks from salt marshes at SL Ross was submitted for review and comment prior to commencing the testing (Appendix E).

A series of small-scale experiments was then undertaken at the SL Ross laboratory to determine the feasibility of using herders to clear oil slicks from salt marshes. The experiments utilized local fresh water marsh plants (Figure 13) as surrogates for salt marsh species (Figure 12). Initial screening tests were conducted in 1-m^2 metal pans (Figure 14). For all subsequent tests, the plants were placed in lined, rectangular plastic pans (about 0.3 m^2 in size) and flooded with water (Figure 15). The marsh plants occupied about one half of the surface area of the pans. The above-water foliage was cut back to just above the waterline to allow photo analysis of the slick areas. Enough oil to produce a 1-mm thick slick was poured gently onto the water surface and allowed to spread to equilibrium. Herder was applied to the water and its effects noted, including water surface clearing efficiency, location of the herded oil lenses and oil residue remaining on plant stems, substrates, etc. The effect of the following parameters was evaluated in the tests:

- Three ambient temperatures (0°, 10° and 20°C)
- Three water salinities (0, 15 and 35‰)
- Three oil types (two crudes ANS and Kuparuk and No. 2 fuel oil)

Figure 12. Common salt marsh grass (S*partina alterniflora).*

Figure 13. Freshwater marsh grass used in laboratory experiments.

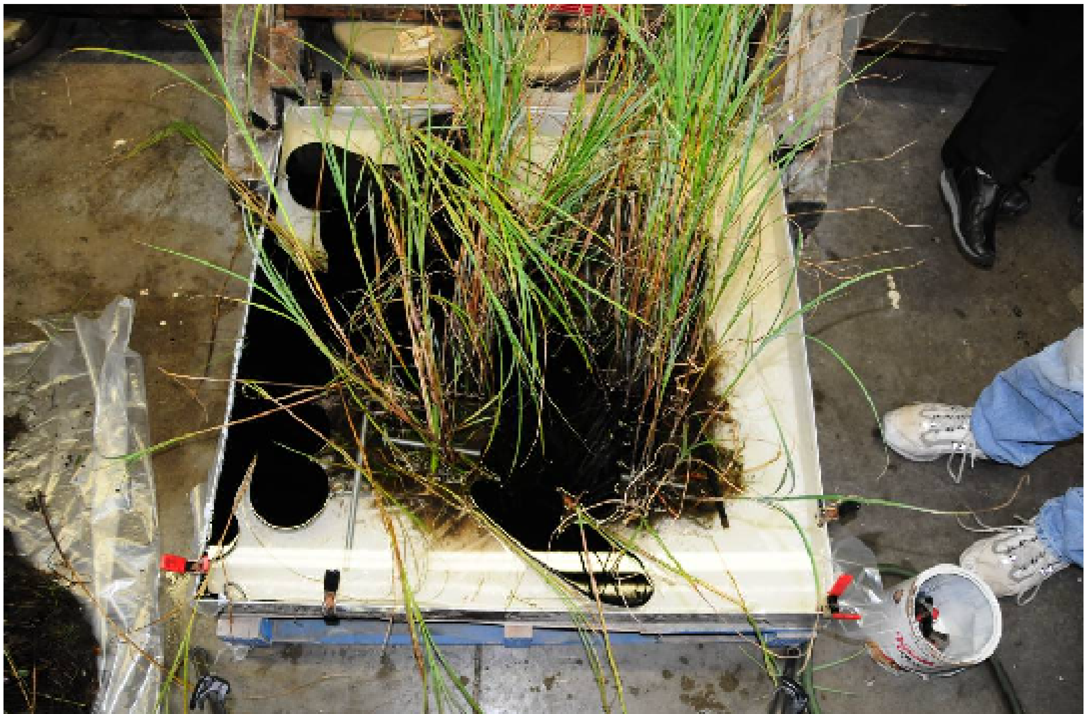


Figure 14. 1 m^2 pan with "oiled" marsh plants used for initial screening tests

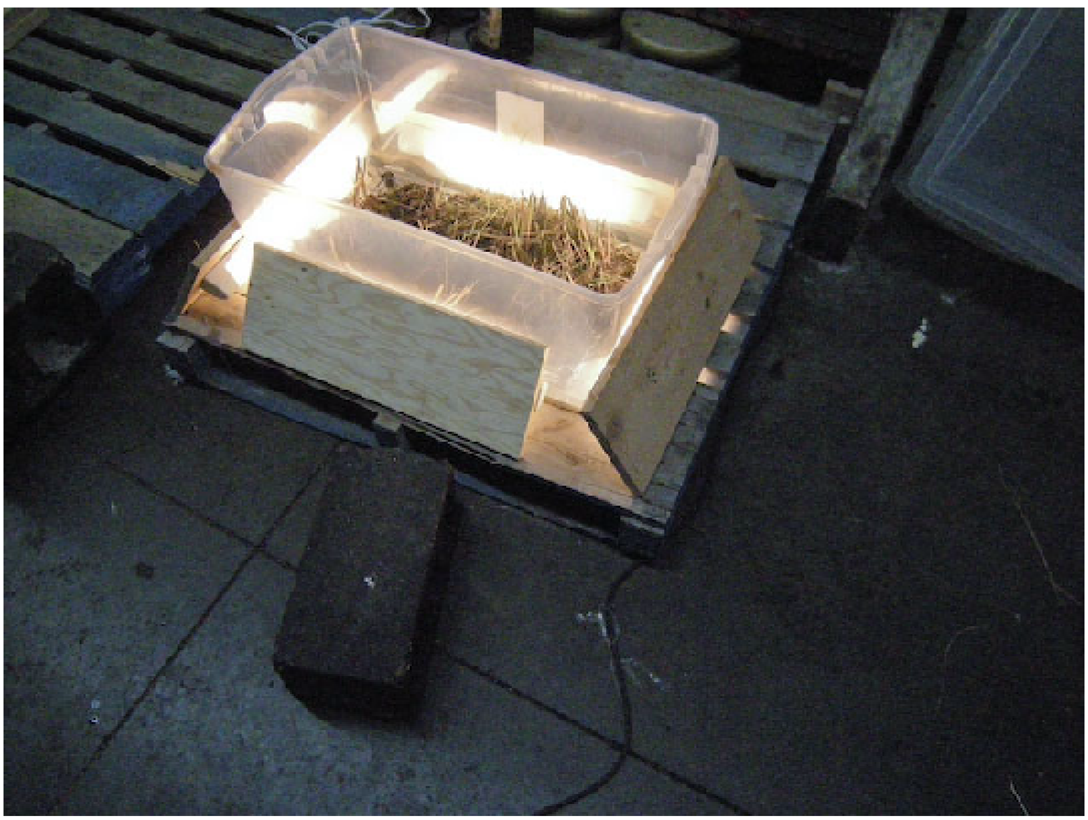


Figure 15. Plastic storage bin used for most tests.

The general procedure for a bin test was:

1. Place a section of trimmed (the stalks of the plants are cut back to just above the waterline to permit easier photographing of the oil slick) marsh “sod”, wired to a metal mesh substrate, in the bottom of each of three plastic bins.
2. Add a sufficient amount of the desired water (temperature and salinity) to each of three plastic bins (Figure 3) to inundate the sod, but not cover the plant stalks.
3. Carefully pour 0.5 L of the crude on the water; making sure that it doesn’t stick to the bottom of the bin or the sod while being poured.
4. Allow the oil to spread to equilibrium and take a digital photograph from overhead for subsequent oil area analysis.
5. Apply the prescribed amount of herding agent to the open water area with a micropipette.
6. Allow the oil to contract and take another digital photograph after one minute, 10 minutes, 30 minutes and 1 hour.
7. Sorb free oil from water surface, lift out sod sample, empty water from bins, rinse and dry bins with paper towels.

The overhead digital photographs were later analyzed using a computer program to determine slick area and thickness.

In addition, six tests were run in the bin apparatus (three with no herder and three with herder) to see if the application of herding agent to the seaward edge of a salt marsh at low tide might restrain oil from entering the marsh on a rising tide. Tilting the pan and slowly adding water to cause the level to rise accomplished this (Figure 16). These tests were also videotaped.

3.2 Results and Discussion

All the data from the tests may be found in Appendix F. Table 2 gives the test matrix for the 27 static tests and Table 3 gives the results of the digital photo analysis and the visual observations for the static tests. To summarize, in none of the static tests did the herder clear the oil completely from the marsh plants. In some tests the herder caused the oil slicks to contract in size sufficiently to significantly reduce the oiled area of the marsh; however, even in these cases, there remained a ring of oil at the waterline around the originally oiled stalks of the marsh plants.

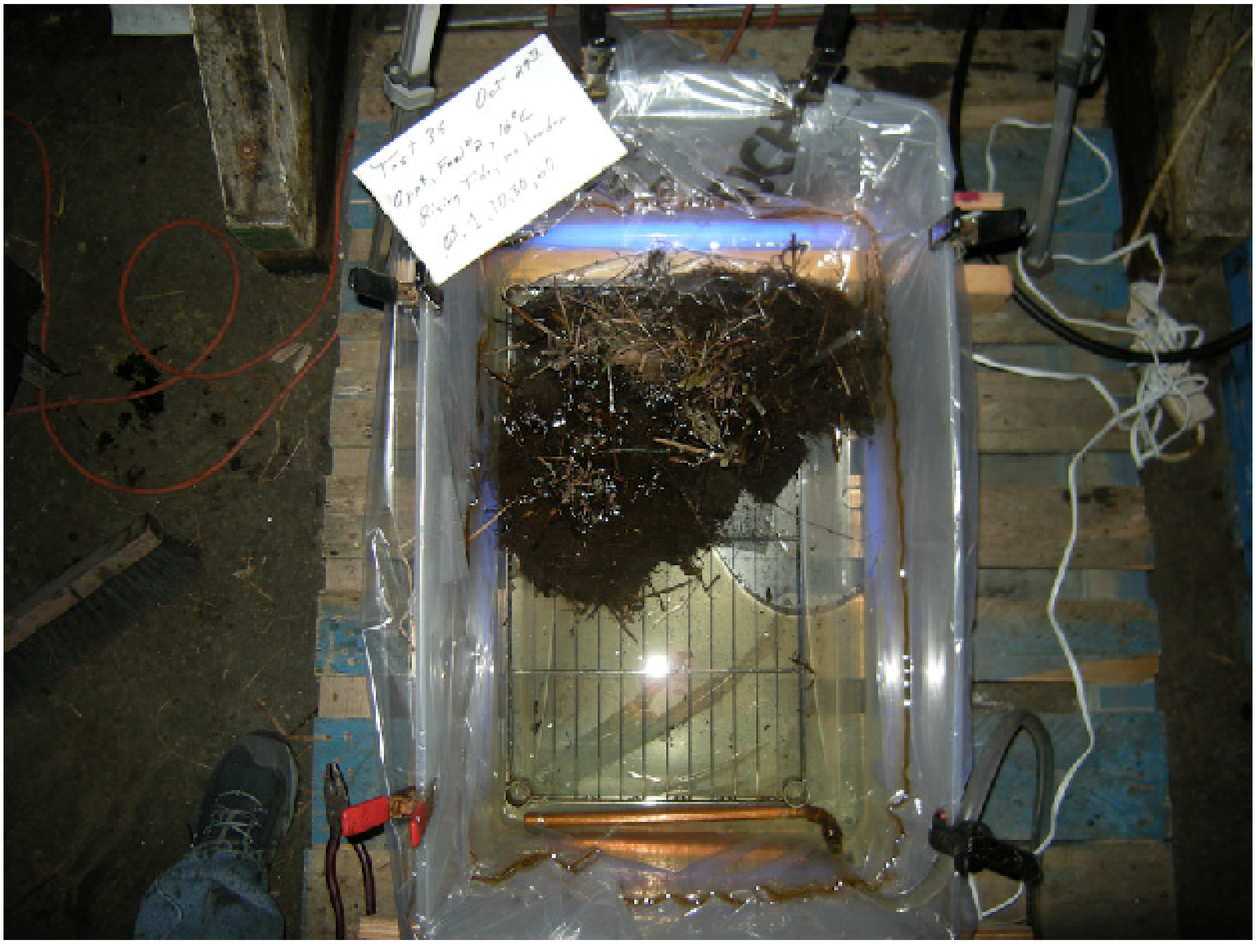


Figure 16. "Rising Tide" test apparatus. Note copper pipe water diffuser at low end and marsh plants at high end of pan.

Table 2. Static Herder Test Matrix

	0 ‰			15 ‰			30 ‰		
	0°	10°	20°	0°	10°	20°	0°	10°	20°
ANS	Test # 13	Test # 28	Test # 1	Test # 4	Test # 24	Test # 17	Test # 7	Test # 23	Test # 15
FUEL # 2	Test # 11	Test # 29	Test 19	Test # 5	Test # 25	Test # 12	Test # 9	Test # 21	Test # 10
KUPARUK	Test # 14	Test # 27	test # 20	Test # 3	Test # 26	Test # 18	Test # 8	Test # 22	Test # 16

Table 3. Static Herder Test Results

Oil	Water Temperature (°C)	Salinity (‰)	Test #	Oil Area (m^2)					Average Oil Thickness (mm)					Did the herder move the oil around in the test marsh?	Did the herder clear the oil out of the test marsh?
				0 min	1 min	10 min	30 min	60 min	0 min	1 min	10 min	30 min	60 min		
ANS	0	0	13	0.137	0.079	0.078	0.087	0.089	2.4	4.2	4.3	3.8	3.7	No	No
		15	4	0.088	0.086	0.088	0.090	0.092	3.8	3.9	3.8	3.7	3.6	No	No
		30	7	0.069	0.074	0.086	0.076	0.092	4.8	4.5	3.9	4.4	3.6	No	No
	10	0	28	0.129	0.088	0.107	0.103	0.109	2.6	3.8	3.1	3.2	3.0	No	No
		15	24	0.135	0.094	0.122	0.120	0.108	2.5	3.6	2.7	2.8	3.1	No	No
		30	23	0.186	0.143	0.145	0.155	0.117	1.8	2.3	2.3	2.2	2.9	***Yes***	No
	20	0	1	0.185	0.129	0.152	0.127	0.172	1.8	2.6	2.2	2.6	1.9	***Yes***	No
		15	17	0.204	0.114	0.118	0.104	0.098	1.6	2.9	2.8	3.2	3.4	***Yes***	No
		30	15	0.167	0.140	0.145	0.130	0.122	2.0	2.4	2.3	2.6	2.7	No	No
Fuel Oil #2	0	0	11	0.152	0.088	0.092	0.077	0.087	2.2	3.8	3.6	4.3	3.8	Yes	No
		15	5	0.211	0.100	0.102	0.151	0.112	1.6	3.3	3.3	2.2	3.0	No	No
		30	9	0.171	0.142	0.138	0.113	0.112	1.9	2.3	2.4	2.9	3.0	***Yes***	No
	10	0	29	0.126	0.104	0.095	0.095	0.078	2.6	3.2	3.5	3.5	4.3	***Yes***	No
		15	25	0.160	0.104	0.119	0.109	0.107	2.1	3.2	2.8	3.1	3.1	***Yes***	No
		30	21	0.184	0.153	0.162	0.146	0.127	1.8	2.2	2.1	2.3	2.6	No	No
	20	0	19	0.161	0.130	0.135	0.128	0.133	2.1	2.6	2.5	2.6	2.5	***Yes***	No
		15	12	0.169	0.099	0.111	0.103	0.107	2.0	3.4	3.0	3.2	3.1	***Yes***	No
		30	10	0.117	0.129	0.131	0.109	0.113	2.8	2.6	2.5	3.1	2.9	***Yes***	No
Kuparuk	0	0	14	0.096	0.062	0.062	0.058	0.054	3.5	5.3	5.4	5.8	6.1	***Yes***	No
		15	3	0.138	0.053	0.048	0.049	0.053	2.4	6.3	7.0	6.8	6.3	***Yes***	No
		30	8	0.092	0.059	0.057	0.060	0.060	3.6	5.6	5.9	5.5	5.6	No	No
	10	0	27	0.092	0.067	0.070	0.068	0.065	3.6	5.0	4.7	4.9	5.1	No	No
		15	26	0.092	0.067	0.070	0.068	0.065	3.6	5.0	4.7	4.9	5.1	No	No
		30	22	0.098	0.080	0.076	0.067	0.072	3.4	4.1	4.4	5.0	4.6	No	No
	20	0	20	0.120	0.072	0.072	0.076	0.076	2.8	4.6	4.6	4.4	4.4	***Yes***	No
		15	18	0.088	0.075	0.067	0.068	0.063	3.8	4.4	5.0	4.9	5.3	No	No
		30	16	0.080	0.056	0.074	0.064	0.064	4.2	6.0	4.5	5.2	5.2	No	No

Table 4. "Rising Tide" Herder Test Results

Oil	Herder	Test #	Oil Area (m^2)					Average Oil Thickness (mm)					Did herder prevent oil from entering test marsh?
			Before rise	1 min	10 min	30 min	60 min	Before rise	1 min	10 min	30 min	60 min	
ANS	none	31	0.078	0.204	0.252	0.264	0.280	4.3	1.6	1.3	1.3	1.2	No
	preapplied	32	0.120	0.124	0.150	0.174	0.174	2.8	2.7	2.2	1.9	1.9	
Kuparuk	none	33	0.174	0.294	0.293	0.289	0.289	1.9	1.1	1.1	1.2	1.2	***Yes***
	preapplied	34	0.289	0.059	0.063	0.061	0.061	1.2	5.7	5.3	5.5	5.5	
Fuel #2	none	35	0.126	0.196	0.213	0.223	0.223	2.6	1.7	1.6	1.5	1.5	***Partially***
	preapplied	36	0.116	0.057	0.058	0.059	0.059	2.9	5.8	5.8	5.6	5.6	

NB. All tests done in fresh water at room temperature.

It should be noted that the mash plants themselves affected the spreading of the oil prior to the addition of herder. In all cases, the equilibrium thickness of the oil slick before the herder addition was much greater than the expected 1 mm, sometimes as high as 4 mm. This was likely due to the presence of natural surfactants exuded by the plant stems and/or soil attached to the roots. In all cases, after herder had been added, the slick thickness was great enough to support ignition. This is a significant finding, since even though the herder did not clear the oil out of the marsh plants, it could contract the oil sufficiently to allow *in situ* burning, an accepted oil removal practice for salt marsh environments (Myers 2006).

Table 4 summarizes the results of the "rising tide" tests. In one of the three test series the application of herder to the test marsh at one end of the pan did prevent the Kuparuk oil slick on the water at the other end of the test pan from entering the test marsh as the "tide" rose. In another test, the herder prevented a significant amount of the Fuel Oil #2 slick from entering the marsh (two small slicklets did enter). In the third case, the herder did not prevent the ANS crude from entering the test marsh.

4 Herders to Improve Operational Efficiency of Dispersants

One of the identified weaknesses of chemical dispersants is that they consistently either under-dose or over-dose real oil slicks due to the inherent large variability in oil thickness at sea. Dispersant drops that fall on thin oil or sheen tend to penetrate through to the underlying water and are wasted. In addition, the surfactants in dispersants also act as herders causing sheens or thin oil slicks to rapidly contract resulting in much of the dispersant being wasted as it falls on open water.

Dispersant drops that fall on thicker slicks will mix with the slick, if conditions are right. However, it is impossible to visually determine the thickness of the "black" portions of a slick, making accurate dosing with dispersant difficult - thin portions of the slick are overdosed and thick portions are under-dosed. The application of a herding agent around the periphery of a slick just prior to it being treated with dispersant would cause the slick to contract into much thicker oil, covering a much smaller area with a more uniform, and predictable, thickness. This could allow more precise application of dispersant to a smaller area of oil at a more predictable dosage.

Herders will contract free-spreading oils with thicknesses ranging from <1 µm to 1+ mm into slicks of ~1 to 4 mm thickness, eliminating the sheen overdosing problem and allowing better dosing for the thick slick. This offers the possibility of significantly improving dispersant targeting. Slicks that have spread to «1 mm thickness could be shrunk and thickened with a chemical herder applied with a helicopter-slung bucket delivery systems, or vessel-based delivery systems, then treated with dispersant from ships or aircraft. Another possibility is the application of herding agents around slicks in calm seas to prevent them from spreading until the wind picks up and breaking waves (necessary for effective chemical dispersion) appear.

4.1 Experimental Methods

The general test procedure used at Ohmsett was to rig the tank for dispersant testing, lay down a slick of crude oil on the tank using the Main Bridge oil discharge system, allow the oil slick to spread until it reached an equilibrium thickness, then apply herder to contract the slick. Dispersant was applied next, either with a hand wand at a rate to simulate vessel-based application or with the spray bar mounted on the Main Bridge at a rate to simulate aerial application from a C-130. Experiments were also run with no herder as controls. Four tests involved fresh Oseberg crude and three involved artificially evaporated Oseberg crude. The test plan may be found in Appendix F.

The preparations for the tests included:

- Erecting the windscreens on either side of the tank and positioning the man lift on the west deck. (Figure 17)
- Setting up the dispersant effectiveness testing equipment (see, for example, SL Ross 2006 for details on the standard dispersant test set-up) with the dispersant spray bar mounted on a trolley on the Main Bridge so it could move to target the free-drifting slicks.
- Conducting several dry run tests to set the new wave maker to produce breaking waves and fine-tune the oil release and test procedures.

The dispersant spray system used in the testing employed the spray bar mounted on a trolley so that it could be easily re-positioned to spray the free-drifting slick (Figure 18). The dispersant flow rate and bridge speed were combined to apply dispersant at a rate typical of what a C-130 ADDS pack system would produce. The hand-held sprayer was also used to treat herded slicks in several tests (Figure 19). Its flow rate was set to simulate what would be applied by a single nozzle vessel application spray system (such as the AFEDO nozzle system http://www.aylesfernie.co.uk/Dispersant-Spray-System-Products/afedo.html). Corexit 9500 dispersant was used in all of the tests. The USN herder was the only one tested.

The wave paddle settings used in the previous dispersant tests at Ohmsett was a 3.5 inch stroke and 34 to 35 strokes per minute: with the installation of a totally new wave maker system, it was necessary to spend time determining what setting of the new wave maker produces equivalent waves. The new wave paddle was eventually set at an amplitude of 12" (equivalent to the old paddle setting of 3") with a 13" offset and a rate of 35 cpm. This produced waves visually equivalent to the settings used for dispersant tests with the old wave maker.

Figure 17. Windscreens along west side of tank and man lift on deck.

Figure 18. Dispersant spray bar mounted on trolley on north side of Main Bridge. Note sorbent sweep below Bridge.

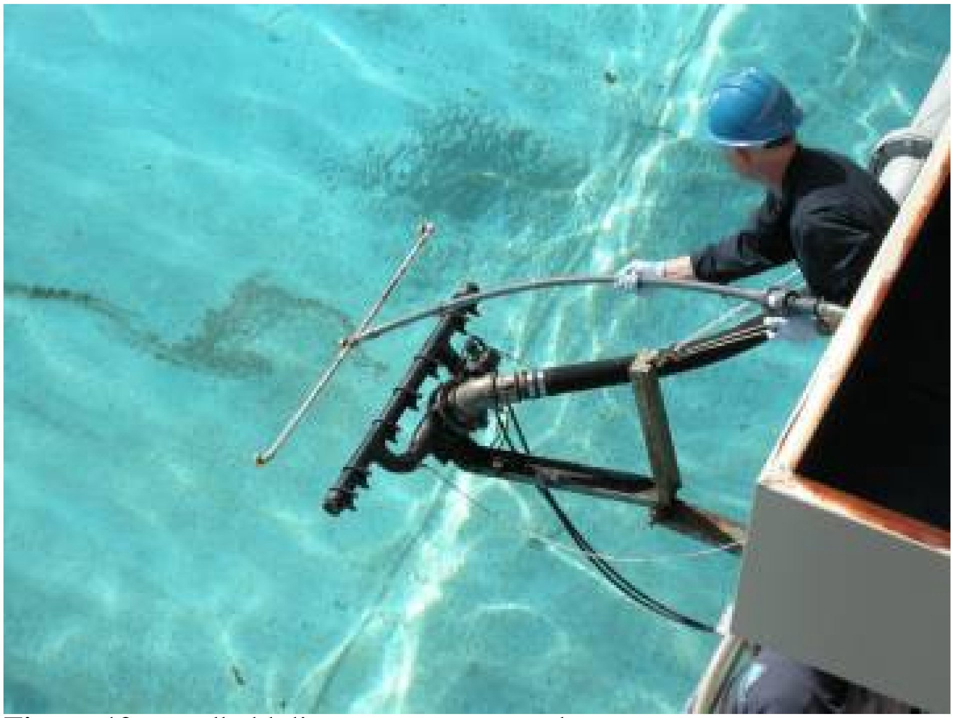


Figure 19. Handheld dispersant spray wand.

The basic test procedure used for all herder/dispersant effectiveness tests was as follows.

1. The oil containment area was established in the Ohmsett tank.
2. The oil and dispersant were loaded into their respective supply tanks on the Main Bridge.
3. The Main Bridge was positioned at the southern quarter point of the tank.
4. The bridge was moved north at the required speed to achieve proper slick dimensions (between 0.25 and 1 knots). A sorbent sweep spanning the width of the tank, was rigged on the north side of the Main Bridge, in front of the oil discharge manifold (Figure 18) except for Test 1.
5. The oil was pumped at the required rate onto the surface through the discharge manifold mounted on the south side of the bridge (Figure 20).
6. The sorbent sweep was removed from the water.
7. The Main Bridge was re-positioned to apply herder.
8. The man lift was moved into position for digital overhead photographs.
9. The slick was allowed to spread to equilibrium, and a digital photo of the slick was taken from the man lift.
10. Then, herder was applied to the water, from two hand-held spray bottles (Figure 21).
11. After the contraction of the slick was judged visually to be over, a second digital photo of the herded slick was taken from the man lift (if required - Figure 22).
12. The Main Bridge was re-positioned to apply dispersant.
13. The dispersant was applied onto the oil slick from either the trolley-mounted spray bar on the north side of the bridge in one or two passes, or the hand-held sprayer.
14. The wave maker was started and the waves were left on for 30 minutes and then the wave maker was stopped (Figures 23 and 24).

15. The LISST particle size analyzer and the C3 fluorometer were towed through the dispersed oil cloud.
16. The water spray from the Main Bridge fire monitors was then used to sweep any surface oil remaining on the water surface at the end of the test to a collection area at one corner of the containment boom.
17. The oil was then removed from the water surface using a double-diaphragm pump and suction wand and placed in a collection drum.
18. The drum was allowed to stand at least overnight and most of the free water present was pumped from the bottom of the drum.
19. The remaining oil and water were thoroughly mixed and a sample was taken for water content and physical property determination.
20. The quantity of liquid in the drum was measured and the amount of oil determined by subtracting the amount of water as determined by the water content analysis.
21. The effectiveness of the dispersant was reported as the volume of oil discharged minus the amount collected from the surface all divided by the amount discharged (times 100).
22. Each test was video taped for future reference.
23. At the end of each test the residual herder and dispersant were removed from the water surface. This was accomplished by running a train of breaking waves down the tank for several minutes, using the Main Bridge fire hoses to disperse the herder and dispersant into the water column and, finally, cleaning the water surface with the sorbent sweep just prior to the next oil discharge.

Figure 20. Slick spreading before herder application

Figure 21. Applying herder from handheld spray bottle.


Figure 22. Herded slick before dispersant applied


Figure 23. Waves just hitting herded slick after dispersant applied.

Figure 24. Dispersion underway as cresting waves create small droplets.

Figure 25. Main Bridge towing LISST and C3 through dispersed oil cloud.

Just before the herder was applied (or the dispersant, in the case of the control tests), an overhead digital picture was taken from the man lift in order to document spreading and herding. After the herder was applied and the contraction of the slick had ceased, a second digital picture was taken from the man lift. Time- and date-stamped digital video was recorded continuously from the video tower on the Main Bridge. During the testing the LISST droplet size analyzer and the C3 Submersible Fluorometer were towed through the dispersed oil cloud to obtain dispersed oil droplet concentration and particle size data (Figure 25). The standard technique of sweeping the tank surface and collecting the surface oil once the waves were turned off was used to estimate overall dispersant effectiveness.

At the conclusion of each test any herder and dispersant remaining on the water surface was dispersed into the tank with breaking waves and the fire monitors on the Main Bridge. Just prior to each test, except Test 1, the test area was swept with sorbent to remove any surfactant that has resurfaced. Preliminary testing at the SL Ross laboratory showed that only if the oil was put on the water immediately after it has been swept with sorbent, would it spread to a thin slick.

In total, seven experiments were completed, varying:

1. Oil type (Fresh Oseberg crude and 27% evaporated Oseberg crude);
2. Dispersant application technique (spray bar or hand-held sprayer); and,
3. Herder application, or not.

In order to minimize dissolved dispersant effects on the results of the tests using herder, these were completed first, before the corresponding control (no herder) tests.

4.2 Results and Discussion

The herding and dispersant effectiveness results are given in Tables 5 and 6. Table 7 presents the dispersed oil measurements. Figures 26 through 32 show the LISST droplet size data and the C3 oil concentration data for each experiment.

Table 5. Test slick areas and calculated average thickness.

Herd-Disperse at Ohmsett							
	Areas (sq. ft)		**Areas (sq. m)**		**Slick Thickness (mm)**		**Oil Volume (L)**
	Oil	**Herded**	**Oil**	**Herded**	**Oil**	**Herded**	
Test 1 20_10_2009	879	439	82	41	1.15	2.30	94.0
Test 2 21_10_2009	12,016	1,856	1,117	173	0.06	0.37	63.9
Test 3 21_10_2009	2,369	No	220	No	0.29	-	63.1
Test 4 22_10_2009	4,284	No	398	No	0.19	-	77.0
Test 5 22_10_2009	3,338	403	310	37	0.23	1.94	72.8
Test 6 23_10_2009	4,433	336	412	31	0.17	2.26	70.7
Test 7 23_10_2009	790	No	73	No	1.03	-	75.9

Table 6. Dispersant application data and measured effectiveness.

Herd-Disperse at Ohmsett							
	Oil Volume & Evap'n	Total Dispersant and Application Analog	Dispersant Hitting Target	DOR	Comments	Visual Estimates (from Video record)	Dispersant Effectiveness (based on surface oil recovered)
	(L)	(L)	(L)				(%)
Test 1 20_10_2009 **Herded**	94.0 **Fresh**	4.1 **Vessel**	4.1	1:23	Hand wand	all dispersant applied hit oil	99
Test 2 21_10_2009 **Herded**	63.9 **Fresh**	2.9 **C-130**	~0.48	1:90 to 1:280	Wide slick DOR versus narrow slick DOR	Approx. 1/6 of dispersant spray hit oil. 1:130 DOR	99
Test 3 21_10_2009 **Not herded Control**	63.1 **Fresh**	2.3 **C-130**	~0.77	1:40 to 1:110	Wide slick DOR versus narrow slick DOR	Approx. 1/3 of dispersant spray hit oil. 1:80 DOR	86
Test 4 (repeat 3) 22_10_2009 **Not herded Control**	77.0 **Fresh**	2.4 **C-130**	~2.04	1:35 to 1:38	1:35 by thickness estimate	Approx. 85% of dispersant hit oil. 1:38 DOR	94
Test 5 22_10_2009 **Herded**	72.8 **Evap'd**	4.6 **Vessel**	3.0	1:22	Hand wand	90% of oil hit by 3 L of dispersant	98
Test 6 23_10_2009 **Herded**	70.7 **Evap'd**	2.4 **C-130**	0.22	1:320	1:325 by thickness 1:321 by ~% disp hitting oil	Slick was wind herded prior to herder application	67
Test 7 23_10_2009 **Not herded Control**	75.9 **Evap'd**	2.8 **C-130**	0.89	1:100 to 1:244	Wide (10' at start) DOR versus Narrow (4' at end) DOR	1:85 by ~amount of dispersant hitting oil	66

Table 7. Dispersed oil data.

Oil/Herder	DOR	Links to Oil Drop Size / Concentration Graphs	Test # Dispersant Application Analog	Oil Drop Size (Average D50) (microns)	Volume % < 70 microns	Avg. Elevated Oil Conc. by LISST (ppm)	Peak Oil Conc. by LISST (ppm)	% Dispersed /Lost
Fresh Oseberg **Herded**	1:10	Figure26	1 **Vessel**	111	56	23	105	99
Fresh Oseberg **Herded**	1:280 to 1:90	Figure27	2 **C-130**	63	67	27	173	99
Fresh Oseberg **Not herded Control**	1:110 to 1:40	Figure28	3 **C-130**	46	76	54	395	86
Fresh Oseberg **Not herded Control**	1:35	Figure29	4 **C-130**	52	72	29	161	94
Weathered Oseberg **Herded**	1:20	Figure30	5 **Vessel**	20	90	60	171	98
Weathered Oseberg **Herded**	1:320	Figure31	6 **C-130**	72	57	63	448	67
Weathered Oseberg **Not herded Control**	1:245 to 1:98 OR 1:450 to 1:180	Figure32	7 **C-130**	46	73	92	460	66

Explanatory notes for oil-in-water concentration graphs:

In Tests 1 through 3 the C3 fluorometer was set to record in "oil mode" using the calibration last entered for the device (i.e., from a previous set of dispersant experiments). The oil used for this calibration is not known. In graphs 1 through 3 the "raw oil" curves refer to this raw "oil mode" reading recorded by the C3. A calibration of the C3 was completed using the fresh Oseberg oil with the C3 set to the same "oil mode" setting used to capture the data during the tests. This calibration was then applied to the 'raw oil" data to attempt to calibrate the C3 to the fresh Oseberg oil. In test #1 the additional calibration improved the C3 match to the LISST results but in tests 2 and 3 the 'raw oil' reading matched the LISST results better than the calibrated results.

The C3 data for Test 4 was corrupted. The C3 data in Tests 5 through 7 were captured in 'raw mode' with no oil calibration applied to the captured data. This raw data was then adjusted using calibration curves developed for both the fresh and weathered Oseberg oils. For some reason the C3 data adjusted using the fresh oil calibration matched the LISST concentrations better than when it was adjusted using the weathered calibration data. For these reasons, only the LISST oil concentration in water data is reported in Table 7.

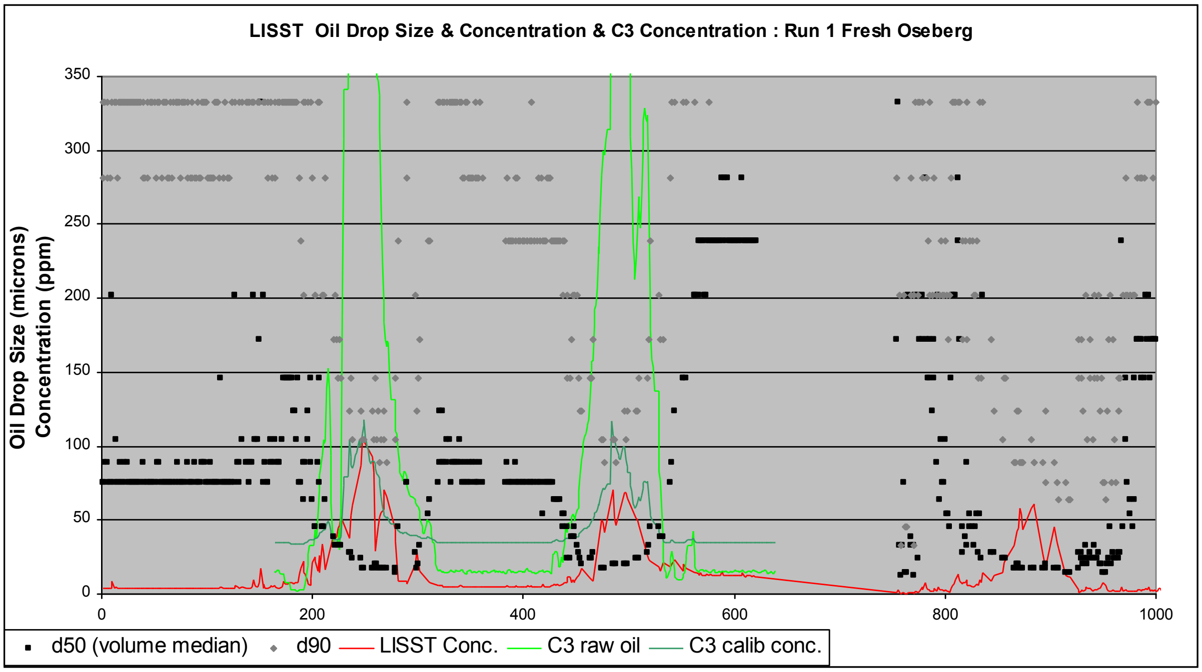


Figure 26. LISST and C3 Data: Run 1

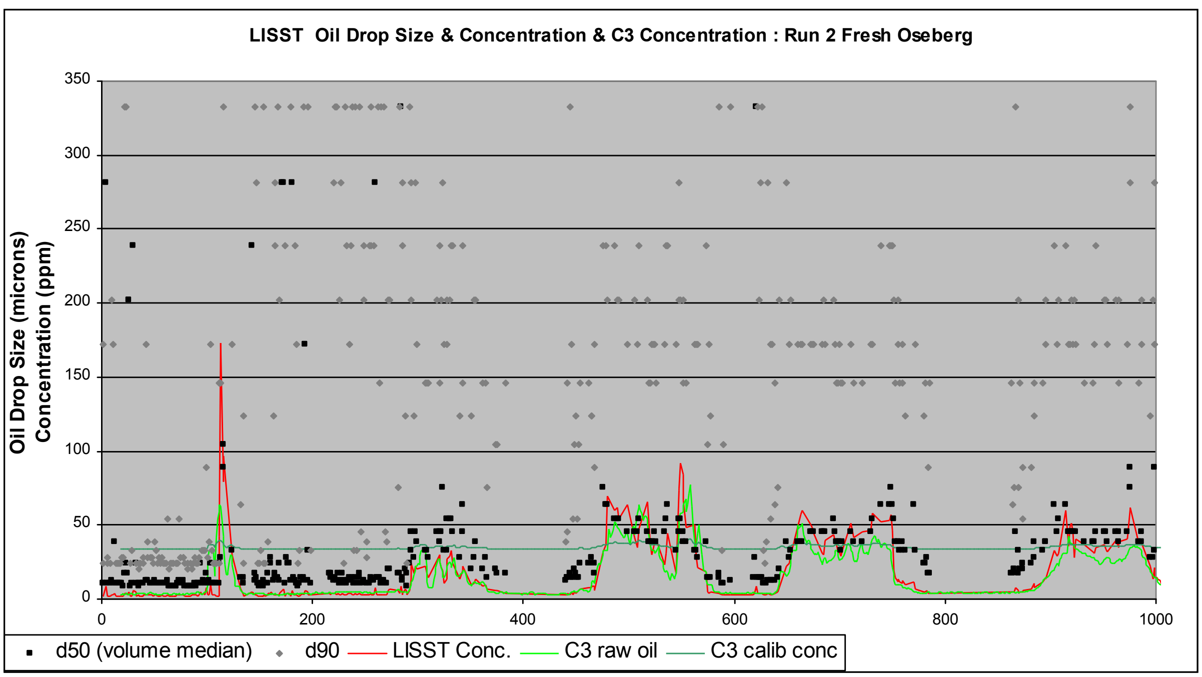


Figure 27. LISST and C3 Data: Run 2

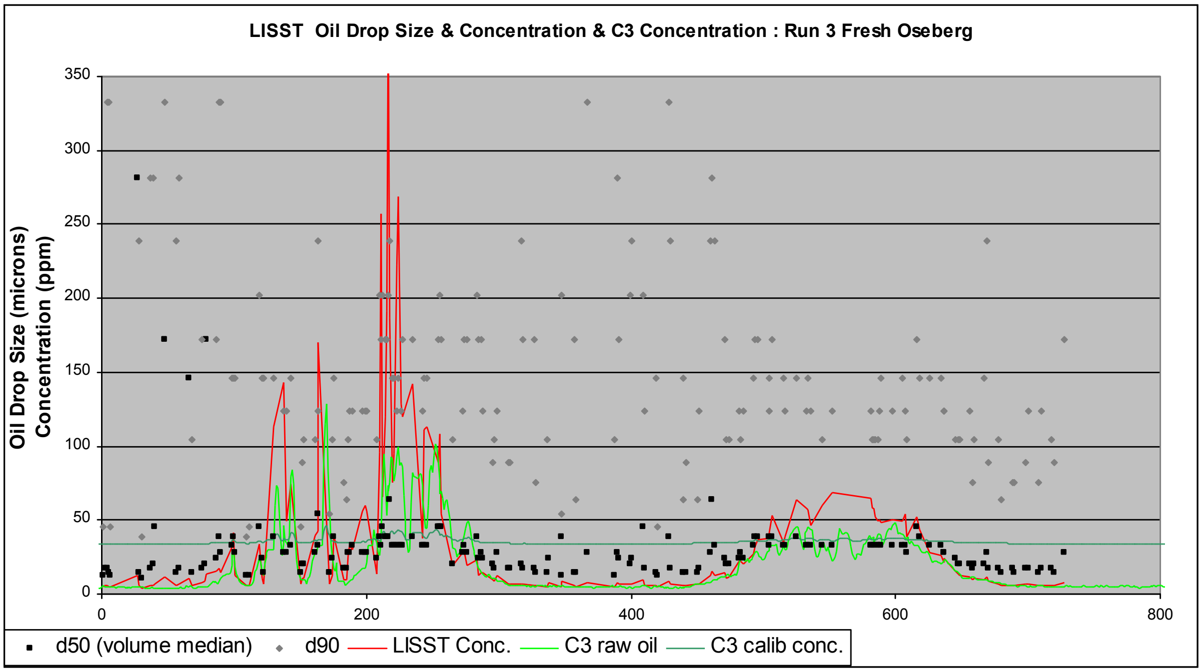


Figure 28. LISST and C3 Data: Run 3

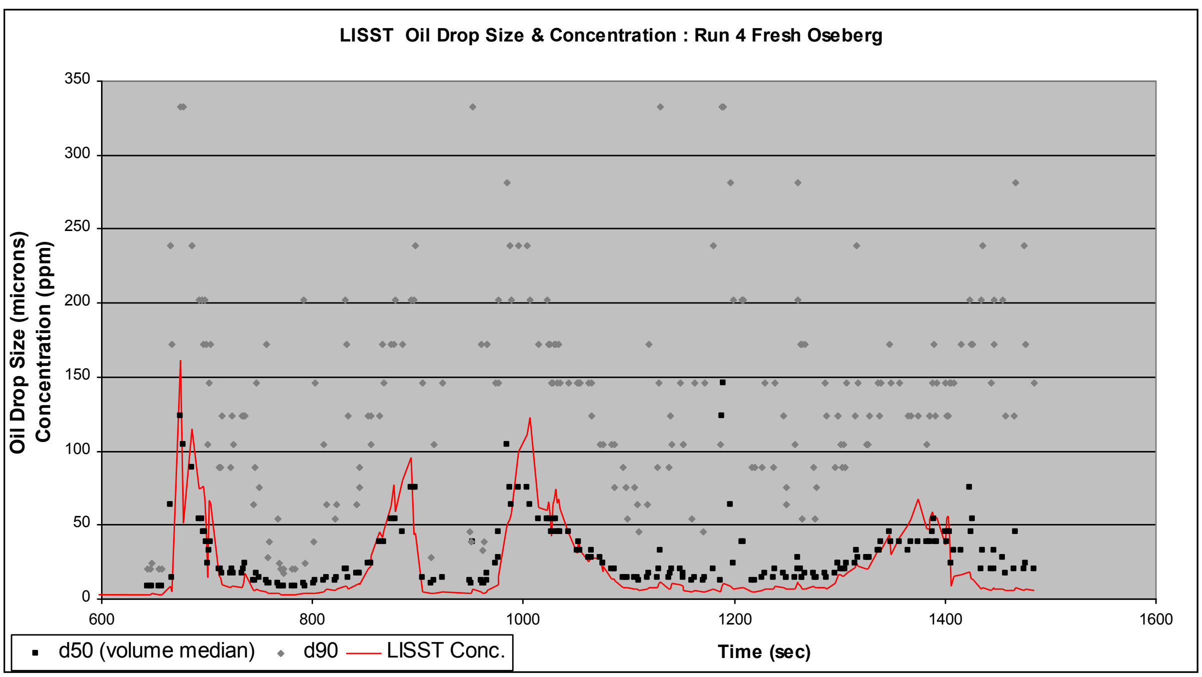


Figure 29. LISST and C3 Data: Run 4

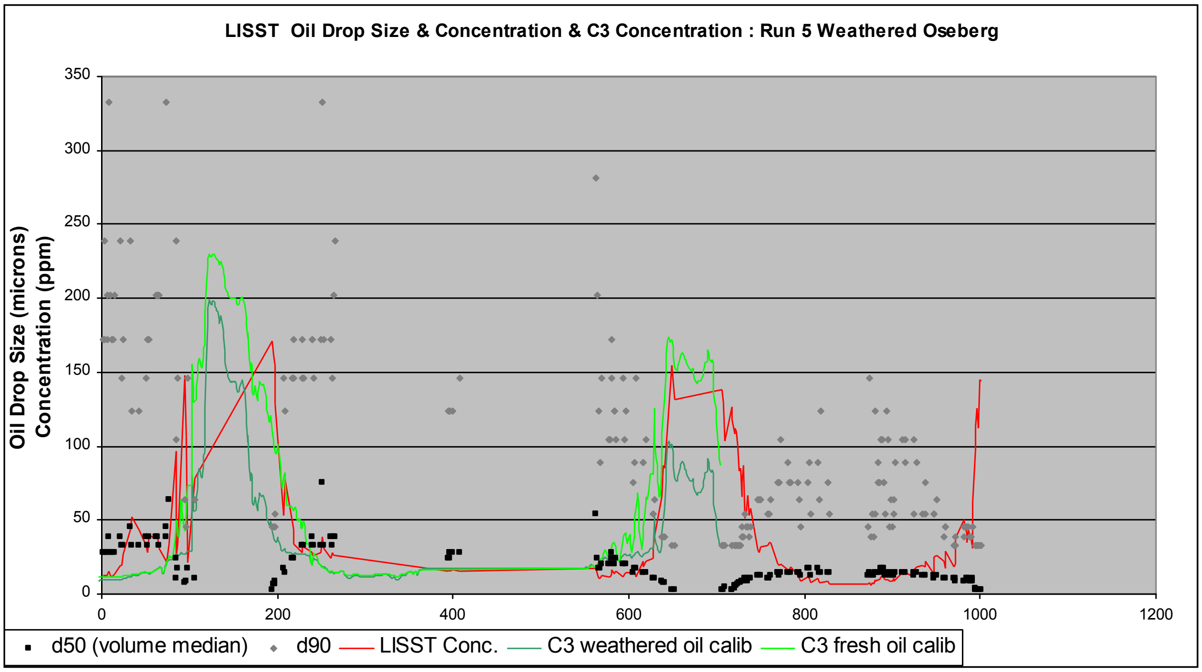


Figure 30. LISST and C3 Data: Run 5

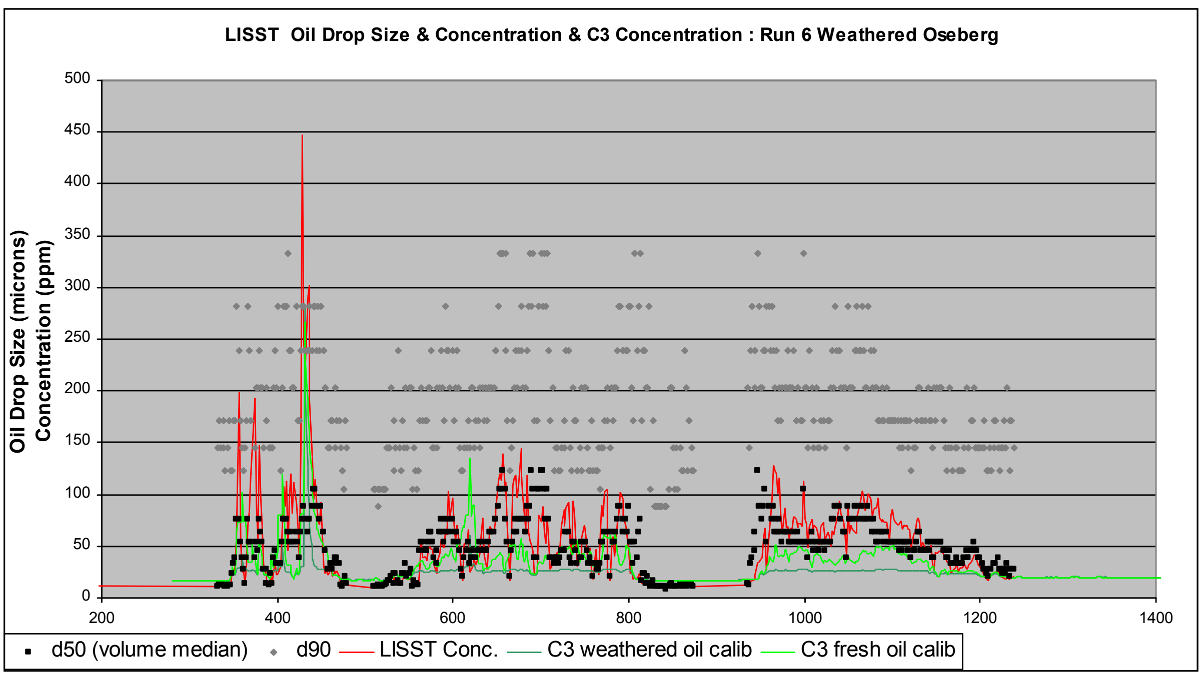


Figure 31. LISST and C3 Data: Run 6

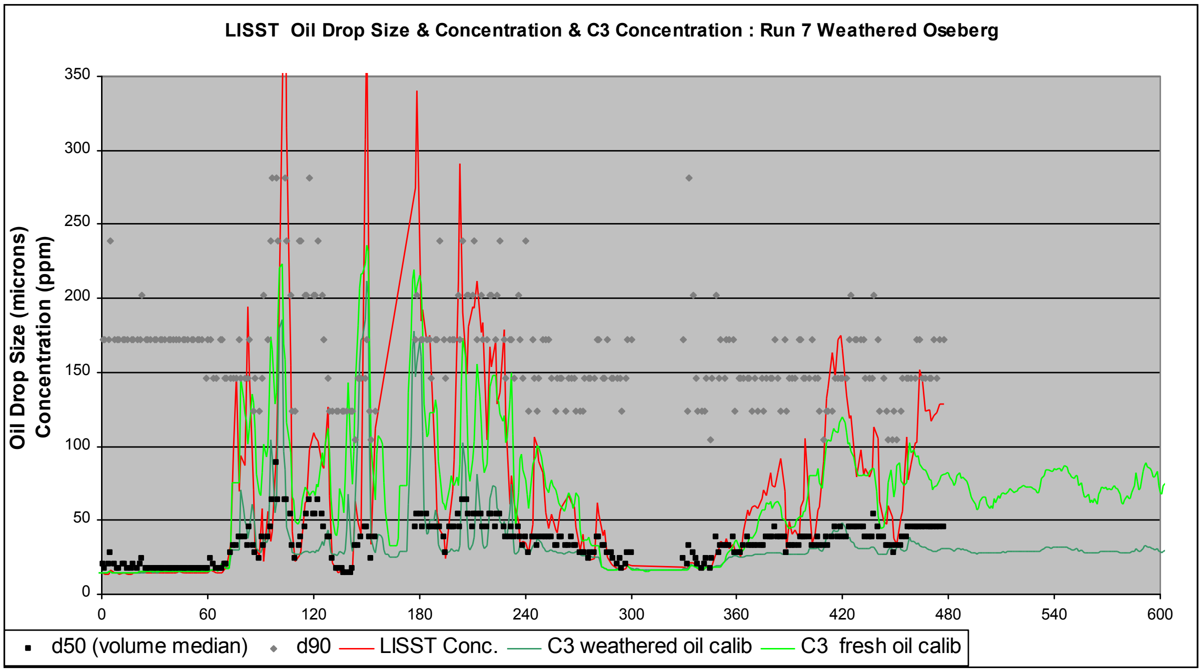


Figure 32. LISST and C3 Data: Run 7

The data in Table 6 shows that the application of the herder did significantly contract the slicks, increasing their average thickness by factors of 2 to 13. For slicks that initially spread to sub-millimeter average thickness (i.e., excluding Test 1, in which the sorbent sweep was not deployed), the average herded thickness increased by an average factor of 9.

Three observations can be made from Table 6:

1. Comparing Test 2 to Tests 3 and 4 (repeat of 3) and Test 6 to Test 7, the use of the herder did not detract from dispersant effectiveness;
2. Comparing Test 5 to Tests 6 and 7, herders can improve the operational efficiency of dispersants applied by vessels, achieving better dispersant targeting (amount and percentage of dispersant hitting the target slicks) and effectiveness; and,
3. Herding a slick to be sprayed by an aircraft reduces operational efficiency, i.e. the amount and the ratio of dispersant applied to the same amount of oil (Tests 2 vs. 3 / 4 and Tests 6 vs. 7).

Analysis of the in-water droplet size and concentration showed no correlation with percent dispersed (Appendix G).

4.3 Summary

The experimental results indicated that:

- The use of herders on an oil slick did not detract from the effectiveness of chemical dispersant application.
- Using herders to contract slicks on open water can improve the operational efficiency of dispersants applied by vessels.
- Herding a slick to be sprayed with dispersants from aircraft reduces operational efficiency (by wasting large amounts of the dispersant).

5 Conclusions

For the use of herders to enhance mechanical recovery in drift ice:

- The use of herders in drift ice conditions could potentially improve the Oil Recovery Rate and Oil Recovery Efficiency performance of weir skimmers by factors of 2 to 10; however, the oil thicknesses produced by the herder were too low to permit optimal performance of the weir skimmer.
- No significant improvement was measured in the performance of a disc skimmer in herded slicks compared to unherded slicks.

For the salt mash preliminary tests:

- In none of the static tests did the herder clear the oil completely from the marsh plants.
- In some tests the herder caused the oil slicks to contract in size sufficiently to significantly reduce the oiled area of the marsh; however, even in these cases, there remained a ring of oil at the waterline around the originally oiled stalks of the marsh plants.
- In all cases, after herder had been added, the slick thickness was great enough to support ignition. This is a significant finding, since even though the herder did not clear the oil out of the marsh plants, it could contract the oil sufficiently to allow *in situ* burning.

In the case of using herders to improve operational efficiency of dispersants:

- The use of herders on an oil slick did not detract from the effectiveness of chemical dispersant application.
- Using herders to contract slicks on open water can improve the operational efficiency of dispersants applied by vessels.
- Herding a slick to be sprayed with dispersants from aircraft could reduce operational efficiency (by wasting large amounts of the dispersant).

References

Bronson, M., E. Thompson, F. McAdams and J. McHale. 2002. Ice Effects on a Barge-Based Oil Spill Response Systems in the Alaskan Beaufort Sea. *Proceedings of the Twenty-fifth Arctic and Marine Oilspill Program Technical Seminar*, Environment Canada, Ottawa, pp 1253-1269

Buist, I.A., 1987. A Preliminary Feasibility Study of In Situ Burning of Spreading Oil Slicks. *Proceedings of the 1987 Oil Spill Conference*. American Petroleum Institute, Washington, D.C. pp 359-367

Buist, I., D. Dickins, D. Devitis, A. Guarino, K. Nolan, J. Mullin and J. Lane. 2002. Technical Aspects of Testing in Brash Ice at Ohmsett. *Proceedings of the Twenty-fifth Arctic and Marine Oilspill Program Technical Seminar*, Environment Canada, Ottawa, pp 1225-1252.

Buist, I., S. Potter and E. Sorstrom. 2010. Barents Sea Field Test of Herder to Thicken Oil for *In Situ* Burning in Drift Ice. *Proceedings of the Thirty-third AMOP Technical Seminar on Environmental Contamination and Response*, Environment Canada, Ottawa, pp 725-742.

Garrett, W.D. and W.R. Barger, 1972, *Control and Confinement of Oil Pollution on Water with Monomolecular Surface Films*. Final Report to U.S. Coast Guard, Nov 1971, Project No. 724110.1/4.1 (also reprinted as U.S. Navy Naval Research Laboratory Memorandum Report 2451, June 1972, AD 744-943)

Marine Spill Response Corporation (MSRC), 1995, *Chemical Oil Spill Treating Agents*, MSRC Technical Report Series 93-105, Herndon, VA

Myers, J., 2006. In Situ Burn and Initial Recovery of a South Louisiana Intermediate Marsh, *Proceedings of the Twenty-ninth Arctic and Marine Oilspill Program Technical Seminar*, Environment Canada, Ottawa, pp 977-988.

Pope, P., A. Allen and W. G. Nelson, 1985, Assessment of Three Surface Collecting Agents during Temperate and Arctic Conditions. *Proceedings of the 1985 Oil Spill Conference*, API/EPA/USCG, Washington, DC, pp 199-201.

Rijkwaterstaat, 1974, *Shell Herder Trials*, Report to the Dutch Ministry of Transport, Gravenhage, Holland

SL Ross Environmental Research, 2003, *Tests To Determine The Limits To In situ Burning of Thin Oil Slicks In Broken Ice*, Report to MMS and ExxonMobil Upstream Research, Herndon VA , May 2003

SL Ross Environmental Research, 2004, *Preliminary Research On Using Oil Herding Surfactant To Thicken Oil Slicks In Broken Ice Conditions*, Report to ExxonMobil Upstream Research, Houston , January 2004

SL Ross Environmental Research, 2005, *Small-Scale Test Tank Research on Using Oil Herding Surfactants to Thicken Oil Slicks in Broken Ice for In situ Burning,* Report to ExxonMobil Upstream Research, Houston, TX

SL Ross Environmental Research. 2006. *Dispersant Effectiveness Testing On Viscous, U.S. Outer Continental Shelf Crude Oils*. Report to U.S. Minerals Management Service, 2006.

SL Ross Environmental Research, 2007, *Mid-scale Test Tank Research on Using Oil Herding Surfactants to Thicken Oil Slicks in Broken Ice*, Report to MMS, ExxonMobil Upstream Research Company, Agip Kashagan North Caspian Operating Company, Sakhalin Energy Investment Company and Statoil ASA, Herndon VA.

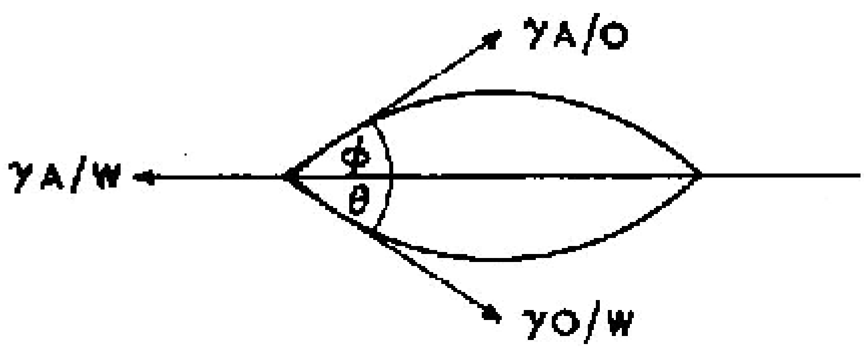
Stein Erik Sørstrøm, Per Johan Brandvik, Ian Buist, Per Daling, David Dickins, Liv Guri Faksness, Steve Potter, Janne Fritt Rasmussen and Ivar Singsaas. 2010. *Summary report on The Joint Industry Program on oil spill contingency for Arctic and ice covered waters.* SINTEF Report, Trondheim, Norway.

Warren Spring Laboratory (WSL). 1975. *Surface Films for the Containment of Oil Slicks*. UK Department of Industry Publication, Stevenage, UK

Appendix A – How Herding Agents Work

From WSL 1975

When crude oil is spilt, the indigenous surface active agents cause it to spread out into thin slicks which often show characteristic light interference colours. If the water is already occupied by a surface active film, spreading may be retarded. Water-insoluble surface active agents can spread rapidly into extremely thin films. When applied to the edges of a relatively fresh oil spill, the surface film prevents the spreading of the oil over the water surface and the pollutant oil can be held in thick layers occupying much reduced areas. It is convenient to think of the film pushing the oil into a thicker layer but what actually happens is a reduction in the surface tension of the water surrounding the oil. This alters the balance of interfacial forces acting at the water-air-oil interface.



$\gamma A/W$ = surface tension of water
$\gamma A/O$ = surface tension of oil
$\gamma O/W$ = interfacial tension of oil and water

$$\gamma A/W = \gamma A/O \cos\phi + \gamma O/W \cos\theta$$

The surface tension of the water is reduced and therefore A/O and O/W act together to draw the oil back into a thicker layer. Therefore no boundary is necessary for the molecular film to push against.

Appendix B – Laboratory Wind/Wave Tank Herder and Skimmer Test Data

Test		Oil Area (m2) Initial	Herded	Skimmed	Oil Thickness (mm) Initial	Herded	H_2O	Oil	Skimming Time (min)	Recovery ORR (L/min)	TE (% of original oil recovered)	ORE (% oil in recovered fluid)
1	ANS Weir 30% No	1.1		1.6	2.2		17.1	1.8	18.0	0.10	72.0	9.5
2	ANS Weir 30% Yes	1.2	0.7	0.3	2.0	3.3	4.4	2.2	6.1	0.37	88.8	33.3
3	ANS Weir 10% No	1.6		1.8	1.5		14.3	3.5	19.3	0.17	131.2	18.7
4	ANS Weir 10% Yes	1.2	0.7	0.2	2.0	3.6	2.0	2.6	6.9	0.38	105.2	56.8
5	ANS Weir 0% Yes	2.1	0.7	0.0	1.2	3.5	3.2	2.3	11.4	0.20	91.2	41.7
6	ANS Weir 0% No	2.1		2.3	1.2		9.5	1.1	20.1	0.06	45.6	10.7
7	ANS Disc 0% Yes	1.3	0.7	0.1	1.9	3.7	4.8	1.5	18.7	0.08	61.9	24.4
8	ANS Disc 0% No	2.3		0.6	1.1		0.9	2.2	13.6	0.16	88.0	71.1
9	ANS Disc 10% Yes	1.9	0.7	0.1	1.3	3.6	4.0	2.4	24.0	0.10	95.8	37.2
10	ANS Disc 10% No	1.5		1.2	1.6		0.8	2.1	23.9	0.09	84.7	71.4
11	ANS Disc 30% Yes	1.3	0.6	1.2	2.0	4.1	7.1	2.1	26.7	0.08	82.8	22.7
12	ANS Disc 30% No	1.5		1.2	1.6		1.3	2.0	20.1	0.10	81.5	58.1
13	Kuparuk Weir 30% Yes	1.1	0.5	0.2	2.3	4.8	4.4	1.4	9.5	0.15	56.7	24.5
14	Diesel Weir 30% Yes	1.1	0.6	0.3	2.4	4.3	4.8	2.6	9.2	0.30	110.1	30.3

Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice

oil	2.5	l
herder	300	ul
temp	2.5	°C
test area	2.64	m^2
	D (cm)	A (cm^2)
Cylinder	14.7	169.87019
Carboy	22.5	397.60782
Clear Jug	15	176.71459

Test	Skimmer	Oil	Ice Cover (%)	Herded?	Recovery H_2O	Oil	Skimming Time (min)	ORR (L/min)	TE (% of original oil recovered)	ORE (% oil in recovered fluid)	Clear Jug H_2O	Total	Carboy H_2O	Total	Cylinder H_2O	Total				
1	Weir	ANS	30	No	17.1	1.8	18.00	0.10	72	10			25.7	30.5						
2	Weir	ANS	30	Yes	4.4	2.2	6.05	0.37	89	33			12	18						
3	Weir	ANS	10	No	14.3	3.3	19.33	0.17	131	19	12.5	15	24.5	29.7	13.8	19.8				
4	Weir	ANS	10	Yes	2.0	2.6	6.93	0.38	105	57			3.4	12.5						
5	Weir	ANS	0	Yes	3.2	2.3	11.40	0.20	91	42					10.9	33.6	Cylinder 1		Cylinder 2	
6	Weir	ANS	0	No	9.5	1.1	20.10	0.06	46	11					55.5	65.5	25.5	30.5	30	35
7	Disc	ANS	0	Yes	4.8	1.5	18.72	0.08	62	24					20.5	30				
8	Disc	ANS	0	No	0.9	2.2	13.55	0.16	88	71					5.5	14				
9	Disc	ANS	10	Yes	4.0	2.4	23.97	0.10	96	37					21.0	29.5				
10	Disc	ANS	10	No	0.8	2.1	23.93	0.09	85	71					7.2	18.2				
11	Disc	ANS	30	Yes	7.1	2.1	26.67	0.08	83	23					43.3	56	30	39	15.3	17
12	Disc	ANS	30	No	1.3	2.0	20.07	0.10	81	58					9	21.5				
13	Weir	Kuparuk	30	Yes	4.4	1.4	9.50	0.15	57	25					26.8	35.5				
14	Weir	Fuel #2	30	Yes	4.3	2.0	9.18	0.30	110	30					29.7	40.0	21	34.5	3.7	12.1

Skimmer operating time

Test	Time (min.)	Start Min	Sec	Stop Min	Sec	Duration (sec)	Start Min	Sec	Stop Min	Sec	Duration (sec)	Start Min	Sec	Stop Min	Sec	Duration (sec)	Start Min	Sec	Stop Min	Sec	Duration (sec)
1	18.00	2	35	9	21	409	10	7	12	55	168	17	18	23	2	344	25	29	28	8	159
2	8.05	6	0	9	19	79	10	48	15	33	285										
3	19.33	8	20	17	56	576	20	36	30	20	584										
4	8.93	10	29	17	25	416															
5	11.40	6	48	18	12	684															
6	20.10	4	35	16	40	725	29	59	33	12	193	39	20	43	8	228					
7	18.72	11	47	13	58	131	15	18	16	40	82	18	30	28	30	600	29	40	34	50	310
8	13.55	5	30	19	3	813															
9	23.97	7	12	31	10	1438															
10	23.93	6	4	30		1436															
11	26.67	9	20	36		1600															
12	20.07	4	15	24	19	1204															
13	9.50	5	45	15	15	570															
14	9.18	22	50	32	9	551															

Appendix C – Test Plan for Ohmsett Herder and Skimmer Testing

Second Draft

Test Plan for
Task Order No. 418

Sub-Task 3.3 - Full-scale Experiments at Ohmsett

Task 3 - Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice
of
A TWO-YEAR RESEARCH PROGRAM
ON
EMPLOYING CHEMICAL HERDERS
TO
IMPROVE MARINE OIL SPILL RESPONSE OPERATIONS

Sponsors: U.S. DEPARTMENT OF THE INTERIOR
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Time Frame: FEBRUARY 2009

February 3, 2009

Test Plan for

Sub-Task 3.3 - Full-scale Experiments at Ohmsett a part of Task 3 - Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice

Task Order No. 418

Sponsors: US DEPARTMENT OF THE INTERIOR
Minerals Management Service
Contact: Joe Mullin COTR
(703) 787-1556

Client: S.L. Ross Environmental Research Ltd.
200-717 Belfast Rd.
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Time Frame: February 2009

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APPROVALS:

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DOI - MMS __________________________
Joe Mullin - COTR

SL Ross: __________________________
Ian Buist - Project Manager

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1. INTRODUCTION

A 9-day test program is planned at Ohmsett to research the efficacy of a chemical herding agent in thickening oil slicks on water among broken ice for mechanical recovery.

1.1 Background

Field deployment tests of booms and skimmers in broken ice conditions in the Alaskan Beaufort Sea highlighted the severe limitations of conventional containment and recovery equipment in even trace ice (Bronson *et al.* 2002). The main problem is that booms, deployed to collect and concentrate oil for effective skimming, also collect and concentrate ice pieces that quickly render the skimmers ineffective. The research on using herding agents to thicken slicks for *in situ* burning has shown that they can significantly contract and thicken oil among ice, without concentrating the surrounding ice. This could be beneficial to mechanical recovery. In fact, as a skimmer removes oil from the center of a herded slick, the action of the herding agent may cause the slick to continuously contract towards the skimmer, eliminating the need to move the skimmer around to contact all the oil. However, it has been observed that the active ingredient in herding agents (the surfactant) renders sorbent pads less hydrophobic and their water retention increases considerably. This could be a significant detriment to oleophilic skimmers such as drums, discs and rope mops whose recovery surfaces contact herding agent. This should not be an issue with other skimmers types such as weirs and vacuums. Experiments would be carried out both in the lab and at Ohmsett to explore the capabilities and limitations of using herding agents to thicken oil in loose pack ice for recovery by skimmers.

1.2 Objective and Goal

The objective of the multi-project research program is to determine whether herding agents can contract oil slicks in certain spill situations where conventional countermeasures have limited effectiveness and thereby enhance marine oil spill response operations. Specifically, the purpose of this task of the test program is to research the use of herding agents in pack ice to enhance mechanical recovery of spilled oil with skimmers.

More specifically, the goal of the work described here is to conduct experiments at the scale of 75 m^2 at Ohmsett on the efficacy of herders in thickening fluid oil slicks among broken ice at sub-zero temperatures for mechanical recovery.

1.3 Organizations Participating in the Testing

All those who will be at the Ohmsett Facility are advised that they are subject to US Navy, Naval Weapons Station Earle (NWS-Earle) and Department of Interior, Minerals Management Service rules and regulations. The most obvious of those regulations involve health, safety, and security. All operational personnel must have 40-hour or 24-hour HAZWOPER training and an introductory Ohmsett Health & Safety training session. Access to the site is controlled by NWS-

Earle. Use of a camera requires a permit issued by a NWS-Earle Base Security Officer. **Unless informed otherwise by the Site Manager, testing is on weekdays only, and begins at 0700.**

Minerals Management Service (MMS):

- Funds the operation of Ohmsett
- Reviews and approves the Work Order Proposal
- Provides the Work Order to MAR, Inc.
- Funds and administers the participation CRREL in Task 3
- Funds and administers the participation SL Ross in Task 3
- Reviews and approves the Final Report

SL Ross Environmental Research

- Prepares the Test Plan with MAR input
- Designs the experiments
- Provides the herding agent
- Assists with the equipment assembly and operation
- Directs the testing
- Takes overhead digital photos for area analysis
- Analyses the data
- Writes the final report

MAR, Inc:

- Prepares the Test Plan with SL Ross
- Operates the chiller (if necessary) to maintain sub-freezing water temperatures in the tank during the testing
- Erects 200 feet of wind screen on either side of the tank
- Deploys boom in the tank in two circular, free-floating test areas of approximately 75 m^2 area (100 feet of containment boom).
- Prepares broken ice fields in boomed areas as per the test matrix
- Prepares test fluids and confirms suitability
- Prepares oil release systems
- Provides and operates the Desmi Termite weir skimmer and the Morris MI-2 disc skimmer
- Collects test data including oil distribution volumes, initial oil properties, recovered oil volumes and flowrates and overhead digital video and photography
- Collects background data including oil/water temperatures, ice coverage and wave data
- Operates man lift
- Photographs and videotapes the trials
- Cleans and demobilizes the test equipment after the experiments have been completed
- Provides raw data to SL Ross
- Reviews the Draft Final Report

1.4 Test Personnel

The test personnel assignments are listed in Table 1.

Table 1: Test Personnel Assignments

Personnel	**Location**	**Duties**
Program Manager Bill Schmidt	Control Tower	Oversight
Test Engineer/Director Paul Meyer	Test Basin	Overall supervision of testing
QA Engineer Alan Guarino	Roving	Monitors fluid sampling, data collection and test parameter accuracy.
Chemical Technician Susan Cunneff	Oil Analysis Lab	Handles and analyzes fluid samples.
H&S Specialist Rich Naples	Roving	Monitors personnel safety.
Fluid Transfer Technician Dave Knapp	Main Tank Deck	Operates oil transfer system, Operates fill and off-loading pumps
Video Technician Bob Stewart	Roving	Operates hand-held video and digital still camera
Rigger/Oil Transfer Technicians Don Snyder, Bob Carneval,	Roving	Deploy boom, transfer oil, prepare ice fields, collect oil, clean and demobilize equipment
SL Ross Sr. Engineers Ian Buist and Steve Potter	Roving	Design and direct tests. Apply herding agent. Provide advice on test suitability

2. TEST PROCEDURES

2.1 Preparation

The preparations for the tests include:

- CRREL shipping an 8”-thick ice sheet (cut in 4’ x 4’ slabs) to Ohmsett (approximately 330 m^2 of ice)
- SL Ross supplying 500 mL USN herder (65% v/v Sorbitan Monolaurate [Span 20] and 35% 2-ethyl butanol)
- Identifying two crude oils and one light fuel oil in existing Ohmsett inventory to be used for tests (for a full suite of tests, four drums [790 L = 208 gallons] is required). If three suitable oils cannot be found in sufficient quantity, a dyed Hydrocal 300 can be substituted for one (this was the test oil used for the herder experiments at CRREL in 2005). The suggested crudes are:
  Alyeska Pump Station 1 – 293 gallons available
  Pt. Macintyre – 266 gallons available
  MGO – 330 gallons available
- Creating two, free-floating circles of 100 feet of containment boom (held in shape with external PVC pipe) with a diameter of 32 feet (9.7 m) with an enclosed area of 800 ft^2 (74 m^2)
- Erect 200 feet of wind screen on either side of the tank
- Distributing the CRREL ice into the boom circles and adding new ice, as required, to make up desired coverage (0, 10 or 30% coverage) and the target piece size distribution (55% 4’x4’+ 30% 2”x2” + 15% small fragments)
- Preparing and operating the Desmi Termite weir skimmer and the Morris MI-2 disc skimmer and the Auxiliary Bridge recovered oil fluid measurement systems
- Obtaining sorbent to remove herder and sheen from boom circles after a series of two tests is completed
- Positioning and operating the man lift for aerial photos
- Positioning, checking and calibrating overhead camera(s) for data collection
- Conducting required safety checks and notifications.
- Conducting several dry run tests with ice only to fine tune release and test procedures

2.2 Test Set-up, Instrumentation and Procedures

The general test procedure is to put the ice in a boom circle, then move it to the upwind end/side of the tank. The boom is then released to accelerate to its terminal drift speed. Once terminal velocity is reached the oil would be placed in the circle, allowed to spread, photographed, herder applied (if required) and skimming started. The skimming should ideally be completed before the boomed area reaches the opposite end/edge of the tank. A schematic of the test set-up is given in Figure 1.

Immediately prior to each test, the boom circles will be placed beside the east side of the tank and the ice floes to produce the desired coverage while drifting will be added from pallets. It will be necessary to experiment with releasing the ice field (without oil) on the first day to

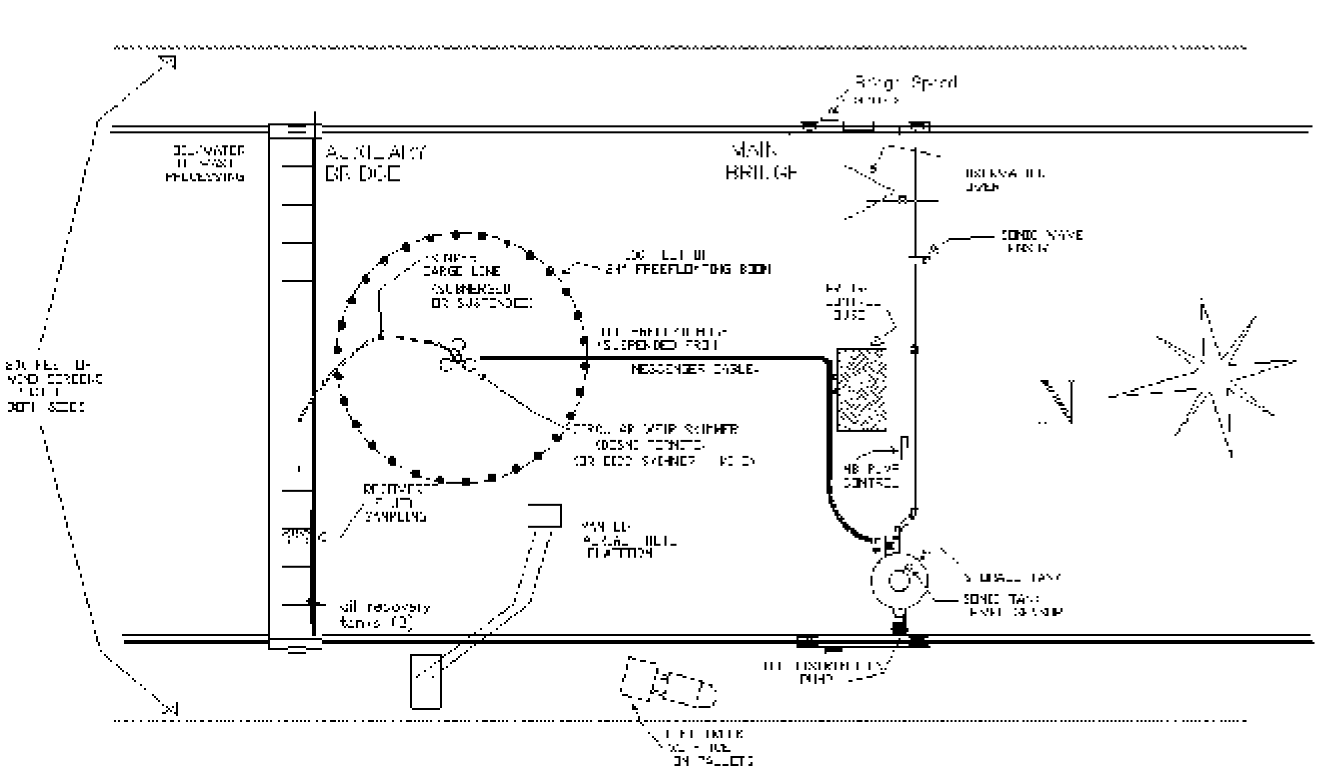

Figure 1: Schematic of test set-up.

determine its drift behaviour as it moves across/down the tank in order to estimate the timing of the oil release and herder application to maximize the available test time. It may be necessary at the beginning of each day to repeat this dry run based on the days predicted wind speed and direction. Next, the oil would be released from the Main Bridge in the upwind end of the contained area, and allowed to spread to cover the contained area evenly (to be determined visually from an overhead position). The nominal oil coverage will be 1 mm on the open water (75L = 20 gallons for 0% ice; 68 L = 18 gallons for 10% ice; and, 53 L = 14 gallons for 30% ice). At a suitable point, if required, herder will be applied from the Main Bridge (travelling with the drifting boom circle) to the periphery of the slick.

Just before the herder is applied, an overhead digital picture/video will be taken and the digital video started. The suggested herder application rate is 150 mg/m^2, yielding a maximum total volume of 12 g (12 mL) per test. Time- and date-stamped overhead digital video (encompassing the entire test area and calibrated with a surface scale marker) will be recorded continuously. Still images will be collected regularly from the video tower as a backup.

Next the skimmer (pre-positioned in the boom circle) will be started and manually moved around in the boom circle to recover as much oil as possible. The flow from the skimmer will be directed to the recovery tanks for subsequent recovered oil and water measurements. Since relatively small volumes of oil are to be used, open-topped drums placed on the Auxiliary Bridge may be substituted for the recovery tanks to allow more accurate measurement of oil and water recovered. The skimming will be timed with a stopwatch. The recovered oil tanks (or open-topped drums) will be measured and samples taken and analysed as per standard ASTM and Ohmsett operating procedures to determine Oil Recovery Rate, Recovery Efficiency and Throughput Efficiency.

Portable video and still cameras will be used to record the testing from tank-side. The air and water temperature will be monitored and recorded.

2.3 Test Matrix and Schedule

Test Matrix Variables

- One nominal initial slick thickness
  - 1 mm
- Three broken ice covers
  - 0, 10 and 30% ice cover
- Three oils
  - One (Alyeska Pump Station 1) crude oil used for a full suite of 12 tests
  - One crude (Pt. MacIntyre) used for a partial suite of 8 tests (10% and 30% ice only)
  - Marine Gas Oil (MGO) used for a partial suite of 4 tests (30% ice only)
- Two chemical herder application rates
  - None and USN recipe applied at 150 mg/m^2 (12 mL/test)
- Two skimmers
  - The Desmi Termite weir skimmer and the Morris MI-2 disc skimmer

Using one crude for 12 tests, another crude for 8 tests and the MGO for 4 tests gives a total of 24 individual tests. If sufficient time remains at the end of the program, up to three duplicate tests will be completed.

Table 2 gives the proposed matrix for the tests. Testing is to take place February 9 to 20, 2009.

Table 2. Preliminary Matrix of Tests

Feb	Day	Test	Crude Oil	Areal Ice Coverage (%)	Skimmer	Herder
9	1	Set-up				
10	2	1	ALY PS1	0	Desmi	N
		2	ALY PS1	0	Desmi	Y
		3	ALY PS1	10	Desmi	N
		4	ALY PS1	10	Desmi	Y
11	3	5	ALY PS1	30	Desmi	N
		6	ALY PS1	30	Desmi	Y
		7	ALY PS1	0	Morris	N
		8	ALY PS1	0	Morris	Y
12	4	9	ALY PS1	10	Morris	N
		10	ALY PS1	10	Morris	Y
		11	ALY PS1	30	Morris	N
		12	ALY PS1	30	Morris	Y
13	5	13	Pt Mac	10	Desmi	N
		14	Pt Mac	10	Desmi	Y
		15	Pt Mac	30	Desmi	N
		16	Pt Mac	30	Desmi	Y
17	6	17	Pt Mac	10	Morris	N
		18	Pt Mac	10	Morris	Y
		19	Pt Mac	30	Morris	N
		20	Pt Mac	30	Morris	Y
18	7	21	MGO	30	Desmi	N
		22	MGO	30	Desmi	Y
		23	MGO	30	Morris	N
		24	MGO	30	Morris	Y
19	8	Duplicate	Select	Select	Select	Select
		Duplicate	Select	Select	Select	Select
		Duplicate	Select	Select	Select	Select
20	9	Clean-up				

At the conclusion of each test, sorbent will be used to recover as much sheen and herder as possible, then the remainder would be dispersed into the tank with the fire monitors on the Main Bridge.

Final tank clean up would involve sweeping the length of the tank with boom, polishing several times with sorbent sweeps and running breaking waves and fire hoses to disperse any remaining herder or sheen from the surface. Even if all the herder applied in up to 15 tests were completely dispersed into the water column, it would only amount to 0.018 ppm (15 x 12/10,000).

3. DELIVERABLES

3.1 Test Data

Original data logs, computer generated data files, video, digital images and photos will be kept on file at Ohmsett. Copies or duplicates will be created and delivered to SL Ross to generate the final data report. The Ohmsett deliverable items will include:

- Raw computer generated data files.
- Observations on tests.
- All manually generated test logs.
- Digital and film photographs and digital video.
- Ohmsett laboratory analyses.

7.1 3.2 Video Documentation

High-resolution, digital videos shall be produced with titles that clearly state the test name, time of day, date and test number. Video documentation will be duplicated in VHS or DVD format as deliverable items for SL Ross. Logs will accompany the videos specifying test number, date, time and location on the videotape. Photos, digital and 35 mm, will also be duplicated as deliverables. All original video and photographic documentation will be maintained at Ohmsett.

4. HEALTH AND SAFETY JOB HAZARD ANALYSIS

4.1 Introduction

A job hazard analysis is a means of preventing or controlling hazardous conditions associated with testing activity. Analysis begins by determining the basic tasks of a job. Each task is then analysed to identify potential hazards associated with it. It will then be possible to develop control measures for the hazards identified. Prior to any test activity, personnel involved with the test are informed of potential hazards and controls for an understanding of their health and safety responsibilities.

4.2 Hazardous Materials

Liquid Hydrocarbons:

- Crude oil (MSDS in Appendix)
- Hydrocal –300 with 5% IFO 380 (MSDS in Appendix)

Other Products/Chemicals:

- USN herder (65% Sorbitan Monolaurate and 35% 2-ethyl butanol – MSDSs attached)

According to available product safety information, respiratory protection is not needed, as:

- o the evaporation rate of the oil is negligible, resulting in the off-gassing of little, if any, vapors sorbitan monolaurate has a low vapor pressure at room temperature and is not identified as a particular inhalation hazard
- o 2-ethyl butanol may be harmful if inhaled, but has a low vapor pressure at room temperature and only small amounts will be used in each experiment (about 4.2 mL per test)

All personnel involved in testing will be informed of associated health hazards, as well as the proper personal protective measures required to eliminate exposure to the oil and chemicals, in accordance with OSHA Hazard Communication Standard requirements. A Material Safety Data Sheet is maintained for test oils, chemicals or various products, and will be available to each person involved in testing.

4.3 Generic Job Safety Analysis

The following table lists basic or generic tasks necessary for the “Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice” Tests at Ohmsett. Hazards associated with the tasks are listed with preventive measures to be followed by affected personnel.

Table 3. Task Hazard Prevention

TASK	HAZARDS	PREVENTION/CONTROL
1) Materials handling, general set-up	a) Lifting material(s) (muscle strains, back injuries) b) Forklift operations (objects striking) c) Jib crane(s) operations (objects striking) d) Mobile crane (contractor personnel, objects striking) e) Hand/power tools (muscle strains, pinch points, electrocution)	a) Use proper lifting techniques; lift with your legs, not your back; get help for heavy loads, use mechanical devices (i.e., fork lift, job cranes). b) Follow acceptable safe practices for operators. c) Do not stand under raised loads. Do not exceed capacity of jib crane. Use one signal man. d) Only qualified crane operator and signal man will control lift operations. Do not stand under raised loads. e) Use correct tool for the job, use correct PPE and proper body positioning when handling tools. Inspect all power tools to ensure no frayed or exposed wires exist, equipment is grounded and insulated and GFI's extension cords etc. are functioning properly.
2) Boom assembly and placement into tank (set-up)	a) Rigging from work boat or bridge (falls) b) Cable handling (pinch points) c) Positioning bridges (objects striking) d) Positioning boom equipment. Mobile crane operations (objects striking)	a) Personnel on work boat MUST wear PFD's. Evenly distribute weight and do not overload. Life preservers are in place as needed. b) Wear hand protection during rigging. c) Have appropriate lines of continual communication. d) No one permitted under heavy loads. Only contract operator and signal man will control lift operations.
3) Oil transfer	a) Spilled oil/deck area (slip/fall hazard) b) Pressurized equipment/pumps/hoses/ lines (pressure release, objects striking)	a) Clean spills on deck/bridges immediately. Utilize spill equipment, as required. b) Inspect all equipment prior to use. Do not use damaged equipment. Replace cracked hoses, broken gauges prior to pressurization. Inspect for leaks. Use adequate PPE (hard hat, gloves, face shield).

4) Bridge operation positioning and movement	a) Bridge movement (objects striking, falls)	a) No personnel permitted on the deck, under moving cables or in motor perimeter while in operation. b) All guard rails must be in place and secured while working on moving bridge. c) Continued and open communications with bridge operator is mandatory. While testing, only authorized personnel involved with the test allowed in bridge control area (third floor).
5) Oil addition to test tank	a) Splashing/spraying oils while transferring to Test Tank. [Slips/falls, exposure (skin/eyes), exposure (inhalation)] b) Pressure release (object striking, pinch points)	a) Wear appropriate PPE (protective clothes, goggles/face shield, nitrile gloves). Air sample base line tests will be taken. Appropriate respirators will be worn as required. Technician will keep bridge/deck as oil-free as possible. b) Utilization of damaged hoses for faulty equipment is prohibited. Check all piping, hoses, hose connections, etc. prior to use. Bleed pressure prior to disconnect. Wear PPE to include protective clothes, goggles/face shield, hard hat, nitrile gloves.
6) Addition of Herding Agent		a) Wear appropriate PPE (protective clothes goggles/face shield, gloves, appropriate respirators will be worn as required.
7) Wave generation	a) Moving wave generating equipment (pinch points, objects striking).	a) No personnel permitted in wave generating room during operations. PPE must be utilized when adjusting mechanics of wave generation equipment. Use correct tools for the job and use them safely.
8) Removal of oil from test tank	a) Oil exposure (skin/eye contact) b) Falls, slips c) Sorbent boom sweeping.	a) Wear protective clothing, goggles/face shields and nitrile gloves. b) When moving oil from the water with high pressure hose streams, avoid direct contact of oil with water stream. Clean any splashed oil from the deck with absorbent pads.

9) Cleanup of equipment	a) Disassembly of rigging from work boat/ bridges (falls). b) Pressurized water/water lines (objects striking) c) Hot water/steam wash (burns) d) Oil/cleaning agent exposure (skin, eye contact) e) Slippery surfaces from excess oil/cleaning agents (falls/slips)	a) Personnel on work boat must wear PFD's. Evenly distribute weight and do not overload. Life preservers are in place as needed. b) Inspect all equipment prior to use. Ensure hoses/fittings, etc. Are in good condition with no signs of deterioration/cracks damage. c) Wear appropriate PPE (face shield, goggles, gloves, protective clothes). d) Wear appropriate PPE (face shield, goggles, protective clothes, Sarnac or Tyvek suits, gloves). e) Keep deck as oil and soap free as possible, watch footing and remove obstacles. Creation of a decontamination zone will be mandatory.
10) Pack up	a) Fork lift operations (objects striking) b) Material handling (muscle strains, back injuries)	a) Follow acceptable safe practices for fork lift operations. b) Use proper lifting techniques, lift with your legs and not with your back, get help for heavy loads (i.e. fork truck, jib crane, etc.).

Finally, personal protective equipment guidelines (for items such as hard hats, steel toed boots, and the like) will be followed based on a Health & Safety Site Plan. The assessment is based only on generic or basic steps. Chemical Hazards will be discussed based on hazard communication standards with MSDS's reviewed.

Material Safety Data Sheets are available to participants at Ohmsett.

4.4 Personal Protective Equipment

The following personal protective equipment shall be available at all times. Specific use requirements may be found in Section 4.2.

- Work gloves
- Insulated coveralls (Temperatures will be 0°C to –15°C)
- Warm hat
- Oil resistant gloves (neoprene, nitrile)
- Eye protection (safety glasses, goggles)
- Safety shoes

- Personal flotation devices (for workboat operations) mandatory
- Life rings
- Splash suits, for tank clean up
- Fall-arrest system (life line, safety belt, tie-off point)

4.5 Communication Plan

Good communication is essential to the safe execution of the test. The following types of communication tools and skills will be available for use:

- Two-way radios
- Intercom system
- PA system
- Hand signals

4.6 Contingency Plan

In case of medical emergency, fire, major oil spill, or other emergency, it is necessary to notify Naval Weapons Station Earle. The OHMSETT Spill Response Plan shall be followed in the event of any oil spill.

A) Emergency Telephone Numbers:
- Naval Weapons Station Earle X 2911
- Leonardo First-Aid 9 – 732 - 615 - 2100
- Riverview Medical Center 9 – 732 - 741 - 2700
- Bayshore Hospital 9 – 732 - 739 - 5900
- Poison Control Center 9 - 1 - (800) 962-1253

5. Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice Quality Assurance

5.1 Introduction

Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice Test Quality is the active application of The Ohmsett "General Quality Procedures and Documentation Plan Manual" and the "Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice Test Quality Checklist."

The Quality Checklist has a list of those items in the Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice Test Plan (see Section 5.2) that are deemed important elements in creating a quality test. This list will be used by the QA Engineer to record spot checks of key quality elements, along with appropriate comments, where necessary. A description of these key quality elements follows. The QA Checklist will be provided in the Final Test Plan.

5.2 Procedures

Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice Test Quality Checklist is implemented as follows:

Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice Test Quality Checklist consists of a complete list of Quality concern items that the QA Engineer uses to spot check items, and confirm adherence to the Test Plan. This checklist is used before, during and after the test to make sure all areas of the test plan receive the same thorough Quality attention. These areas include:

A. Initial calibration data
B. Pre- and post-test checks and conditions
C. Test checks and conditions
D. Sampling
E. Significant occurrences/variations
F. Data reduction and validation
G. Data accuracy and precision
H. Documentation of the tests
I. Technical project report

5.3 Initial Calibration Data

A check is made to ensure that data is available to show the initial source of calibration data for each piece of instrumentation used in the test. This includes any calibration information necessary to assure that the calibration data is current for this test.

5.4 Pre- and Post-Test Checks and Conditions

These are checks that are performed on the instrumentation and weather conditions each morning before testing starts and at the end of the day when testing stops. This is done on all days that testing occurs. Note is made of any unusual conditions that occur. These conditions must be evaluated before testing is started or if noted at the end of the day, the day's data is examined to determine its validity and whether the affected tests need to be repeated.

5.5 Test Checks and Conditions

These checks ensure that the test plan's instructions on how the test is to be done are followed and that the records that are to be made during the test are completed accurately.

5.6 Sampling

Sampling will be checked for compliance with the instructions in this plan.

5.7 Significant Occurrences/Variations

This part of the Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice Test Quality checks will be concerned with recording any significant occurrences/variations that might occur during the tests. These will be immediately reported to the Test Director.

5.8 Data Reduction and Validation

All data reduction and validation will be performed in accordance with approved and accepted methods. When non-standard methods are utilized, they shall be included in the Technical Project Report and sufficiently described so that they can be used by independent sources to duplicate the results. The treatment of data is described in Section 3.

6. SCHEDULE

The following schedule is planned for the Using Herders to Enhance Mechanical Recovery of Oil in Pack Ice Tests.

DATE	EVENT
January 26, 2009	Submit Draft Test Plan
February 9 to 20, 2009.	Tests at Ohmsett
March 31, 2009	Deliver Raw and Processed Data, Observations and Photo Video Documentation to SL Ross
November 30, 2009	Submission of Draft Final Report

7. REFERENCES

Bronson, M., E. Thompson, F. McAdams and J. McHale. 2002. Ice Effects on a Barge-Based Oil Spill Response Systems in the Alaskan Beaufort Sea. *Proceedings of the Twenty-fifth Arctic and Marine Oilspill Program Technical Seminar*, Environment Canada, Ottawa, pp 1253-1269

Appendix A – MSDS Sheets

Material Safety Data Sheet

2-ETHYL-1-BUTANOL, 98%

Section 1 - Chemical Product and Company Identification

MSDS Name:	2-ETHYL-1-BUTANOL, 98%
Catalog Numbers:	11817-0000, 11817-1000
Synonyms:	2-Ethylbutyl alcohol
Company Identification:	Acros Organics BVBA Janssen Pharmaceuticalaan 3a 2440 Geel, Belgium
Company Identification: (USA)	Acros Organics One Reagent Lane Fair Lawn, NJ 07410
For information in the US, call:	800-ACROS-01
For information in Europe, call:	+32 14 57 52 11
Emergency Number, Europe:	+32 14 57 52 99
Emergency Number US:	201-796-7100
CHEMTREC Phone Number, US:	800-424-9300
CHEMTREC Phone Number, Europe:	703-527-3887

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name:	%	EINECS#
97-95-0	2-ETHYL-1-BUTANOL	98%	202-621-4

Hazard Symbols: XN

Risk Phrases: 21/22

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Harmful in contact with skin and if swallowed.

Potential Health Effects

Eye:	May cause eye irritation.
Skin:	May cause skin irritation. Harmful if absorbed through the skin.
Ingestion:	Harmful if swallowed. May cause irritation of the digestive tract.
Inhalation:	May cause respiratory tract irritation. May be harmful if inhaled.
Chronic:	Not available.

Section 4 - First Aid Measures

Eyes:	Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid immediately.
Skin:	Get medical aid. Flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Remove contaminated clothing and shoes.
Ingestion:	If victim is conscious and alert, give 2-4 cupfuls of milk or water. Get medical aid immediately. Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.

Inhalation:	Get medical aid immediately. Remove from exposure and move to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen.
Notes to Physician:	

Section 5 - Fire Fighting Measures

General Information:	As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Flammable liquid and vapor.
Extinguishing Media:	In case of fire, use water, dry chemical, chemical foam, or alcohol-resistant foam. Use agent most appropriate to extinguish fire.

Section 6 - Accidental Release Measures

General Information:	Use proper personal protective equipment as indicated in Section 8.
Spills/Leaks:	Absorb spill with inert material (e.g. vermiculite, sand or earth), then place in suitable container. Clean up spills immediately, observing precautions in the Protective Equipment section. Remove all sources of ignition. Use a spark-proof tool.

Section 7 - Handling and Storage

Handling:	Use spark-proof tools and explosion proof equipment. Empty containers retain product residue, (liquid and/or vapor), and can be dangerous. Keep away from heat, sparks and flame.
Storage:	Keep away from heat, sparks, and flame. Keep away from sources of ignition.

Section 8 - Exposure Controls, Personal Protection

Engineering Controls:

Use adequate general or local explosion-proof ventilation to keep airborne levels to acceptable levels.

Exposure Limits

CAS# 97-95-0:

Personal Protective Equipment

Eyes:	Wear chemical splash goggles.
Skin:	Wear appropriate protective gloves to prevent skin exposure.
Clothing:	Wear appropriate protective clothing to minimize contact with skin.
Respirators:	A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements or European Standard EN 149 must be followed whenever workplace conditions warrant a respirator's use. Wear a NIOSH/MSHA or European Standard EN 149 approved full-facepiece airline respirator in the positive pressure mode with emergency escape provisions.

Section 9 - Physical and Chemical Properties

Physical State:	Clear liquid
Color:	colorless - light yellow
Odor:	None reported.
pH:	Not available.
Vapor Pressure:	1.7 hPa @ 20 C
Viscosity:	7.6 MPA 20.00 deg C
Boiling Point:	146 deg C @ 760.00mm Hg (294.80°F)
Freezing/Melting Point:	0 deg C (32.00°F)
Autoignition Temperature:	315 deg C (599.00 deg F)
Flash Point:	57 deg C (134.60 deg F)
Explosion Limits: Lower:	Not available.
Explosion Limits: Upper:	Not available.
Decomposition Temperature:	
Solubility in water:	10 g/l (20°C)
Specific Gravity/Density:	.8300g/cm3
Molecular Formula:	C6H14O
Molecular Weight:	102.18

Section 10 - Stability and Reactivity

Chemical Stability:	Stable under normal temperatures and pressures.

Conditions to Avoid:	Incompatible materials, ignition sources.
Incompatibilities with Other Materials	Strong oxidizing agents, strong acids.
Hazardous Decomposition Products	Carbon monoxide, irritating and toxic fumes and gases, carbon dioxide.
Hazardous Polymerization	**Has not been reported.**

Section 11 - Toxicological Information

RTECS#:	CAS# 97-95-0: EL3850000
LD50/LC50:	**CAS# 97-95-0**: Oral, rabbit: LD50 = 1200 mg/kg; Oral, rat: LD50 = 1850 mg/kg; Skin, rabbit: LD50 = 1260 uL/kg;
Carcinogenicity:	2-ETHYL-1-BUTANOL - Not listed as a carcinogen by ACGIH, IARC, or NTP.
Other:	See actual entry in RTECS for complete information.

Section 12 - Ecological Information

Not available.

Section 13 - Disposal Considerations

Dispose of in a manner consistent with federal, state, and local regulations.

Section 14 - Transport Information

	IATA	IMO	RID/ADR
Shipping Name:	2-ETHYLBUTANOL	2-ETHYLBUTANOL	2-ETHYLBUTANOL
Hazard Class:	3	3	3
UN Number:	2275	2275	2275
Packing Group:	III	III	III

Section 15 - Regulatory Information

European/International Regulations

European Labeling in Accordance with EC Directives

Hazard Symbols: XN

Risk Phrases:

R 21/22 Harmful in contact with skin and if swallowed.

Safety Phrases:

WGK (Water Danger/Protection)

CAS# 97-95-0: 1

Canada

CAS# 97-95-0 is listed on Canada's DSL List

US Federal

TSCA

CAS# 97-95-0 is listed on the TSCA Inventory.

Section 16 - Other Information

MSDS Creation Date: 7/16/1996

Revision #0 Date Original.

BASF Corporation

Material Safety Data Sheet

Page : 1

Original Date: 03/03/1999

Revision Date: 09/13/2002

BASF CORPORATION
PERFORMANCE CHEMICALS
3000 CONTINENTAL DRIVE NORTH
MOUNT OLIVE, NJ 07828
(800) 832-HELP

EMERGENCY TELEPHONE: (800) 424-9300 CHEMTREC
(800) 832-HELP (BASF Hotline)
BOTH NUMBERS ARE AVAILABLE DAYS, NIGHTS, WEEKENDS, & HOLIDAYS.

SECTION 1 - PRODUCT INFORMATION

S-MAZ® 20 K1 SORBITAN MONOLAURATE
Product ID: NCS 558695
Common Chemical Name:
SORBITAN MONOLAURATE
Synonyms:
NONE
Molecular Formula:

Chemical Family: Not Applicable
Molecular Wt.: NOT APPLICABLE

SECTION 2 - INGREDIENTS

Chemical Name:	CAS	Amount
SORBITAN, MONODODECANOATE	1338-39-2	~ 100.0 %
PEL/TLV NOT ESTABLISHED		
Vitamine E Alcohol	10191-41-0	~ 100.0 PPM
PEL/TLV NOT ESTABLISHED		

SECTION 3 - PHYSICAL PROPERTIES

Color: Dark Brown
Form/Appearance: Liquid
Odor: Ester
Odor Intensity: Mild

	Typical	Low/High	U.O.M.			
Specific Gravity:	1.0[illegible]			@	20	DEG C
pH:	NOT AVAILABLE					

	Typical	Low/High	Deg.	@	Pressure
Boiling Pt:	> 300		F	1	ATMOSPHERES
Freezing Pt:	NOT AVAILABLE				
Decomp. Tmp:	NOT AVAILABLE				

Solubility in Water Description: Dispersible
Vapor Pressure: < 1 MM HG @ 25 DEG. C XX
Vapor Density (Air = 1): >1
Volatile by Vol. %: < 1

SECTION 4 - FIRE AND EXPLOSION DATA

	Typical	Low/High	Deg.	Method
Flash Point:	> 200		F	PENSKY-MARTENS CLOSED C
Autoignition:	NOT AVAILABLE			

Extinguishing Media:
Use water, dry extinguishing media, carbon dioxide (CO2) or foam.

Fire Fighting Procedures:
Firefighters should be equipped with self contained breathing apparatus and turn out gear.

Unusual Hazards:
There are no known unusual fire or explosion hazards.

SECTION 5 - HEALTH EFFECTS

Routes of entry for solids and liquids include eye and skin contact, ingestion and inhalation. Routes of entry for gases include inhalation and eye contact. Skin contact may be a route of entry for liquified gases.

Acute Overexposure Effects:
Contact with the eyes and skin may result in irritation. Inhalation may result in respiratory irritation. Ingestion may result in gastric disturbances.

Chronic Overexposure Effects:
There are no known chronic effects associated with this material.

First Aid Procedures - Skin:
Wash affected areas with soap and water. Remove and launder contaminated clothing before reuse. If irritation develops, get medical attention.

First Aid Procedures - Eyes:
Immediately rinse eyes with running water for 15 minutes. If irritation develops, get medical attention.

First Aid Procedures - Ingestion:
If swallowed, dilute with water and immediately induce vomiting. Never give fluids or induce vomiting if the victim is unconscious or having convulsions. Get immediate medical attention.

First Aid Procedures - Inhalation:
Move to fresh air. Aid in breathing, if necessary, and get immediate medical attention.

First Aid Procedures - Notes to Physicians:
None known.

First Aid Procedures - Aggravated Medical Conditions:
No data is available which addresses medical conditions that are generally recognized as being aggravated by exposure to this product. Please refer to the effects of overexposure and/or for effects (if any) observed in animals.

First Aid Procedures - Special Procedures:
None

SECTION 6 - REACTIVITY DATA

Stability Data:
Stable

SECTION 6 - REACTIVITY DATA (cont)

Incompatibility:
  Strong oxidizers.
Conditions/Hazards to Avoid:
  No data available.
Hazardous Decomposition/Polymerization:
  Hazardous Decomposition Products: No Data Available.
Corrosive Properties:
  Not corrosive.
Oxidizer Properties:
  Not an oxidizer.
Other Reactivity Data:
  None known.

SECTION 7 - PERSONAL PROTECTION

Clothing:
  Gloves, coveralls, apron, boots as necessary to minimize contact.
Eyes:
  Chemical goggles; also wear a face shield if splashing hazard exists.
Respiration:
  Approved organic vapor mist respirator as necessary.
Ventilation:
  Use local exhaust to control vapors/mists.
Explosion Proofing:
  None required.

SECTION 8 - SPILL-LEAK/ENVIRONMENTAL

General:
  Spills should be contained, solidified, and placed in suitable containers for disposal in a licensed facility. This material is not regulated by RCRA or CERCLA ("Superfund"). Wear appropriate respiratory protection and protective clothing and provide adequate ventilation during clean-up.
Waste Disposal:
  Incinerate in a licensed facility. Do not discharge into waterways or sewer systems.
Container Disposal:
  Dispose of in a licensed facility. Recommend crushing or other means to prevent unauthorized reuse.

SECTION 9 - STORAGE AND HANDLING

General:
  Keep containers closed.
  Store in well ventilated areas below 120 F.

SECTION 10 - REGULATORY INFORMATION

TSCA Inventory Status
  Listed on Inventory: YES

RCRA Haz. Waste No.: NA
CERCLA: NO Reportable Qty.: (if YES)

SECTION 10 - REGULATORY INFORMATION (cont)

State Regulatory Information: (By Component) NJ/PA/MA RTK

CAS:	1338-39-2	NO
NAME:	SORBITAN, MONODODECANOATE	
CAS:	10191-41-0	NO
NAME:	Vitamine E Alcohol	

Hazard Ratings:

	Health:	Fire:	Reactivity:	Special:
HMIS	1	1	0	NA
NFPA	1	1	0	NA

This product is not hazardous according to the OSHA Hazard Communication Standard.

SECTION 11 - TRANSPORTATION INFORMATION

DOT Proper Shipping Name:
N/A
DOT Technical Name:
N/A
DOT Primary Hazard Class:
N/A
DOT Secondary Hazard Class:
N/A
DOT Label Required:
N/A
DOT Placard Required:
N/A
DOT Poison Constituent:
N/A
BASF Commodity Codes: NA NA UN/NA Code: E/R Guide: N/A
Bill of Lading Description:
NOT REGULATED BY THE DEPARTMENT OF TRANSPORTATION

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END OF DATA SHEET

MSDS Document

Product Hydrocal 300

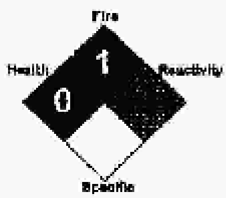
1. Chemical Product and Company Identification

Trade Name of this Product Hydrocal 300
Synonyms: 1250-00

MSDS ID 1250-00

Manufacturer
Calumet Lubricants Company
2780 Waterfront Pkwy E. Suite 200
Indianapolis, IN 46214

Contact Name
Anne Goldsmith
Phone Number
(317) 328-5660
Emergency Phone
CHEMTREC (800) 424-9300
Revision Date 06/16/03



2. Composition and Information on Ingredients

Ingredient	CAS Number	Weight %	ACGIH TLV	PEL	STEL
Heavy Hydrotreated Naphthenic Distillates (petroleum)	64742-52-5	100.0 %	5	5	

3. Hazard Identification

Hazards
This product is a clear, pale-straw to water-white, viscous liquid. It has a light petroleum odor.

This product is slightly combustible (Flammability Class III B) but will burn. The flash point is >201°F and autoignition temperature is 650°F. Heated product will produce colorless vapors. Heated vapors in the presence of an ignition source can be explosive if confined. When burned, the product will produce carbon monoxide and other asphyxiants during combustion.

Prolong unprotected exposure to this product will cause skin irritation. Material splashed in eyes will irritate tissues. Gently flush material from eyes with clean water. Remove product soaked clothing and wash with mild soap.

As with any petroleum product, avoid mixing this product with strong oxidizers.

Carcinogen listed by: National Toxicology Program (NO)
I. A. R. C. (NO)
OSHA (NO)
ACGIH (NO)
This product does not require a cancer hazard warning in accordance with the OSHA Hazard Communication Standard.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE
Personnel with pre-existing skin disorders should avoid contact with this product.

Health studies have shown that many petroleum hydrocarbons and synthetic lubricants pose potential human health risks which may vary from person to person. As a precaution, exposure to liquids, vapors, mists or fumes should be minimized.

4. First Aid Information

First Aid Measures
EYES
If splashed into eyes, flush with clear water for 15 minutes or until irritation subsides. If irritation persists, call a physician.

SKIN
In case of skin contact, remove any contaminated clothing and wash skin with soap and water. Launder or dry-clean clothing before reuse. If product is injected into or under the skin, or into any part of the body, regardless of the appearance of the wound or its size, the individual should be evaluated immediately by a physician as a surgical emergency. Even though initial symptoms from high pressure injection may be minimal or absent, early surgical treatment within the first few hours may significantly reduce the ultimate extent of injury. Prolonged or repeated skin contact may cause skin irritation.

INGESTION
Product is practically non-toxic. Do not induce vomiting. Obtain emergency medical attention.

INHALATION
Vapor pressure is very low. Vapor inhalation under ambient conditions is normally not a problem. If overcome by vapor from hot product, immediately remove from exposure and call a physician. If breathing is irregular or has stopped, start resuscitation; administer oxygen, if available. If overexposed to oil mist, remove from exposure until excessive oil mist condition subsides.

5. Fire Fighting Measures

Flash Point 350

FP Method ASTM D92

Fire Fighting
FIRE AND EXPLOSION HAZARDS
Slightly combustible. OSHA/NFPA Class IIIB Combustible Liquid. If heated above its flash point will release flammable vapors which can burn in the open or be explosive in confined spaces if exposed to ignition source. Mists or sprays may be flammable below oils normal flash point. Keep away from extreme heat or open flame.

EXTINGUISHING MEDIA
Foam, water spray (fog), dry chemical, carbon dioxide, and vaporizing liquid type extinguishing agents mat all be suitable for extinguishing fires involving this type of product, depending on size or potential size of fire and circumstances related to the situation. Plan fire protection and response strategy through consultation with local fire protection authorities or appropriate specialists.

The following procedures for this type of product are based on the recommendations in the National Fire Protection Association's "Fire Protection Guide on Hazardous Materials", Tenth Edition (1991):

Use water spray, dry chemical, foam or carbon dioxide to extinguish the fire. Use water to keep fire-exposed containers cool. If a leak or spill has not ignited, use water spray to disperse the vapors and to provide protection for persons attempting to stop a leak. Water spray may be used to flush spills away from exposures. Minimize breathing of gases, vapor, fumes or decomposition products. Use supplied-air breathing equipment for enclosed or confined spaces or as otherwise needed.

DECOMPOSITION PRODUCTS UNDER FIRE CONDITIONS
Fumes, smoke, carbon monoxide, aldehydes and other decomposition products, in the case of incomplete combustion.

FLAMMABLE PROPERTIES
FLASH POINT: >350°F >177°C COC ASTM D92
AUTO IGNITION: >650°F >343°C
FLAMMABILITY CLASS: IIIB

6. Accidental Release Measures

Release Measures
Extinguish any open flames and remove heat sources.

This material will float on water and will be transported by stormwater runoff. Spills to the ground should be immobilized and removed immediately. Spills to watercourses such as stormdrains, sewers, ditches, streams, ponds, etc. must be contained with dikes, dams, floating booms, pads, etc. as appropriate. Remove trapped product immediately.

Spills that enter a waterbody must be immediately reported to the USEPA's National Response Center at (800)546-2972.
Check with your local and state regulators regarding their reporting requirements.

Cleanup personnel should wear appropriate personnel protective equipment including impervious clothing, rubber boots, gloves, and splash goggles.

7. Handling and Storage

Handling and Storage
HANDLING AND STORAGE PRECAUTIONS
Keep away from flames, sparks or hot surfaces. Never use a torch to cut or weld on or near container. Empty oil containers can contain explosive vapors. NFPA Class IIIB storage. Wash thoroughly after handling.

WORK/HYGIENIC PRACTICES
Wash hands with soap and water before eating, drinking, smoking or use of toilet facilities. Do not use gasoline, solvents, kerosene, or harsh abrasive skin cleaners for washing exposed skin areas. Take a shower after work if general contact occurs. Remove oil-soaked clothing and launder before reuse. Launder or discard contaminated shoes and leather gloves.

"EMPTY" CONTAINER WARNING
"Empty" containers retain residue (liquid and/or vapor) and can be dangerous. DO NOT PRESSURIZE, CUT, WELD, BRAZE, SOLDER, DRILL, GRIND OR EXPOSE SUCH CONTAINERS TO HEAT, FLAME, SPARKS, STATIC ELECTRICITY, OR OTHER SOURCES OF IGNITION; THEY MAY EXPLODE AND CAUSE INJURY OR DEATH.

Do not attempt to refill or clean containers since residue is difficult to remove. "Empty" drums should be completely drained, properly bunged and promptly returned to a drum reconditioner. All other containers should be disposed of in an environmentally safe manner and in accordance with governmental regulations.

For work on tanks refer to Occupational Safety and Health Administration regulations, ANSI Z49.1, and other governmental and industrial references pertaining to cleaning, repairing, welding, or other contemplated operations.

8. Exposure Controls and Personal Protection

Exposure/PPE/Heavy
VENTILATION
Use local exhaust to capture vapor, mists or fumes, if necessary. Provide ventilation sufficient to prevent exceeding recommended exposure limit or buildup of explosive concentrations of vapor in air. No smoking, or use of flame or other ignition sources.

EYE/FACE PROTECTION
Use safety glasses or splash goggles when eye contact may occur. Have suitable eye wash water available.

SKIN PROTECTION
Avoid prolonged and/or repeated skin contact. If prolonged contact cannot be avoided, wear protective impervious gloves and clothing. Acceptable materials for gloves are polyvinyl chloride; neoprene; nitrile; polyvinyl alcohol; viton.

RESPIRATORY PROTECTION
Normally not required if adequate ventilation. If occupational exposure limits are exceeded wear NIOSH/MSHA approved apparatus.

OTHER/GENERAL PROTECTION
If there is a likelihood of splashing, an oil resistant clothing should be worn. Never wear oil soaked clothing. Launder or dry clean before wearing. Discard oil soaked shoes. Affix warning labels on containers in accordance with 29 CFR 1910.1200 (Hazard Communication Standard).

CONCEN
TRATION
INGREDIENT NAME EXPOSURE LIMITS PERCENT
BY VOLUME

Heavy Hydrotreated Naphthenic Distillates (petroleum)
100.0
CAS NUMBER: 64742-52-5 Exposure Limits: OIL MIST
OSHA PEL MIST 5 MG/M3 8 HRS
ACGIH TLV MIST 5 MG/M3 8 HRS

9. Physical and Chemical Properties

Specific Gravity	0.9053
Density lbs/Gal.	7.55

APPEARANCE: Clear, pale straw to water white, viscous liquid
ODOR: Light bland petroleum
PHYSICAL STATE: Liquid
BOILING POINT: IBP >526°F >274°C
MELTING POINT: -52°F -45°C ASTM D97
VAPOR PRESSURE: <0.0001 mm Hg @ 20°C
VAPOR DENSITY (AIR=1): >5 Air=1
SPECIFIC GRAVITY: 0.9053 Water = 1
MOLECULAR WEIGHT: N/A
SOLUBILITY (H2O): negligible in water
VISCOSITY: 307.5 SUS at 100°F

10. Stability and Reactivity

Stability/Reactivity
STABILITY: Stable. Will not react violently with water.

CONDITIONS TO AVOID
Sources of ignition.

INCOMPATIBLE MATERIALS
Strong oxidizers such as liquid chlorine, concentrated oxygen, sodium hypochlorite, calcium hypochlorite, etc., as this presents a serious explosion hazard.

HAZARDOUS DECOMPOSITION PRODUCTS
Combustion may produce carbon monoxide and other asphyxiants.

HAZARDOUS POLYMERIZATION: will not occur

11. Toxicological Information

Toxicological
ACUTE STUDIES
Product has a low order of acute and dermal toxicity, but minute amounts aspirated into the lungs during ingestion or vomiting may cause mild to severe pulmonary injury and possibly death.

EYE EFFECTS
Product contacting the eyes may cause eye irritation.

SKIN EFFECTS
Prolonged or repeated skin contact with this product tends to remove skin oils, possibly leading to irritation and dermatitis; however, based on human experience and available toxicological data, this product is judged to be neither a "corrosive" nor an "irritant" by OSHA criteria.

ACUTE ORAL EFFECTS
Product has a low order of acute and dermal toxicity, but minute amounts aspirated into the lungs during ingestion or vomiting may cause mild to severe pulmonary injury and possibly death.

ACUTE INHALATION EFFECTS
Product has a low order of acute and dermal toxicity, but minute amounts aspirated into the lungs during ingestion or vomiting may cause mild to severe pulmonary injury and possibly death.

In accordance with the current OSHA Hazard Communication Standard criteria, this product does not require a cancer hazard warning. This is because the product is formulated from base stocks which are severely hydrotreated, severely solvent extracted, and/or processed by mild hydrotreatment and extraction. Alternatively, it may consist of components not otherwise affected by IARC criteria, such as atmospheric distillates or synthetically derived materials, and as such is not characterized by current IARC classification criteria

12. Ecological Information

Ecological Info
If applied to leaves, this product may kill grasses and small plants by interfering with transpiration and respiration. This product is not toxic to fish but may coat gill structures resulting in suffocation if spilled in shallow, running water. Product may be moderately toxic to amphibians by preventing dermal respiration. This product may cause gastrointestinal distress to birds and mammals through ingestion during pelage grooming.

This product is rapidly biodegradable. Biodegradation is possible within 90 to 120 days in aerobic environments at temperatures above 70°F (21°C).

13. Disposal Considerations

Disposal
Product, as supplied, does not meet the characteristics of a hazardous waste as defined in

40 CFR 261.21-24. If mixed with other products, waste mixture must be characterized. DO NOT dispose of this product in drains or storm sewers. DO NOT dispose of this product in a landfill without prior solidification. Waste product should be recycled. Consider waste brokering.

14. Transportation Information

Transport Info
PROPER SHIPPING NAME: Not regulated by DOT
HAZARD CLASS: Not applicable
DOT IDENTIFICATION NUMBER: N/A
DOT SHIPPING LABEL: Not regulated by DOT

15. Regulatory Information

Compliance
U.S. FEDERAL REGULATORY INFORMATION
SARA 302 Threshold Planning Quantity: NOT APPLICABLE
SARA 304 Reportable Quantity: NOT APPLICABLE
SARA 311 Categories: Immediate (Acute) Health Effects --N
Delayed (Chronic) Health Effects --Y
Fire Hazard --N
Sudden Release of Pressure --N
Reactivity Hazard --N

EPA/TSCA Inventory: The components of this product are listed on the EPA/TSCA inventory of chemicals.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA): No chemicals in this product are subject to the reporting requirements of CERCLA.

SARA TITLE III - SECTION 313 SUPPLIER NOTIFICATION
No chemicals in this product exceed the De Minimus reporting level established by SARA Title III, Section 313 and 40 CFR 372.

EUROPEAN (ECC) REGULATORY INFORMATION
This product is listed on the European Inventory of Existing Commercial Substances.

CANADIAN REGULATORY INFORMATION
This product is listed on the Canadian (DSL) Domestic Substances List.
WHMIS Classification: NOT CONTROLLED

16. Other Information

Supercedes MSDS Dated: 02/10/2003

Revision: 06-16-2003 - revised composition to 100% heavy hydrotreated naphthenic distillate

Appendix D – Data from Ohmsett Skimmer Testing with Herder

Summary of Header / Skimmer Tests

Skimming stopped when slick uniformly showing discontinuities

Skimmer appeared to ride too high in water - only outer [illegible] of discs appeared to have oil. Collection stopped [illegible]

Small ice regularly [illegible] flow of oil to discs, [illegible] oil in thick patches between floes

Test	Device	Fluid Depth Initial	Fluid Volume Initial	Fluid Depth Decanted	Fluid Volume Decanted	Oil	Sample #	Notes	Container
		(in)	(gal)	(in)	(gal)				
1	Terraine	41.75	243.40	1.25	7.29	ANS	1	Tank 1	
1	Terraine	17.25	100.57	1.25	7.29	ANS	3	Tank 2 (slop)	
1	Terraine	1.50	8.75	1.50	8.75	ANS	2	Tank 3 (Did not decant, vol too small)	
1	x								
2	Terraine	36.50	212.80	2.50	14.58	ANS	6	Tank 1	
2	Terraine	10.25	59.76	2.00	11.66	ANS	5	Tank 2	
2	Terraine	6.75	39.35	3.00	17.49	ANS	4	Tank 3 (slop)	
2	x								
3	Terraine	6.75	39.35	4.00	23.32	PDMac	7	Tank 4 (slop)	
3	Terraine	37.50	218.64	2.75	16.03	PDMac	8	Tank 5	
3	z								
4	Terraine	7.75	45.18	2.00	11.66	PDMac	9	Tank 6 (slop)	
4	Terraine	42.50	247.78	2.50	14.58	PDMac	10	Tank 7	
4	Terraine	6.25	36.44	1.00	5.83	PDMac	11	Tank 8	
4	x								
5	Terraine	7.25	42.27	2.50	14.58	ANS	12	Tank 1 (slop)	
5	Terraine	41.50	241.95	2.25	13.12	ANS	13	Tank 2	
5	Terraine	21.75	126.80	2.25	13.12	ANS	14	Tank 3	
5	x								
6	Terraine	7.00	40.81	1.50	8.75	MCO	15	Tank 4 (slop)	
6	Terraine	39.00	227.37	2.00	11.66	MCO	16	Tank 5	
6	z								
7	Terraine	7.25	42.27	2.00	11.66	ANS	17	Tank 6 (slop)	
7	Terraine	12.50	72.88	3.00	17.49	ANS	18	Tank 7	
7	Terraine	15.25	88.91	1.50	8.75	ANS	19	Tank 8	
7	x								
8	Terraine	6.75	39.35	1.75	10.20	PDMac	20	Tank 1 (slop)	
8	Terraine	10.50	61.22	3.00	17.49	PDMac	21	Tank 2	
8	Terraine	6.50	37.90	0.63	3.64	PDMac	22	Tank 3	
8	x								
9	Terraine	5.50	32.07	2.25	13.12	MCO	23	Tank 4 (slop)	
9	Terraine	21.75	126.80	4.00	23.32	MCO	24	Tank 5	
9	x								
10	Terraine	6.00	34.98	3.00	17.49	ANS	25	Tank 1 (slop)	
10	Terraine	21.50	125.35	2.75	16.03	ANS	26	Tank 2	
10	Terraine	8.50	49.56	2.75	16.03	ANS	27	Tank 3	
10	x								
11	Terraine	6.50	37.90	3.25	18.95	ANS	28	Tank 4 (slop)	
11	Terraine	38.00	221.54	3.25	18.95	ANS	29	Tank 5	
11	Terraine	9.50	55.39	2.75	16.03	ANS	30	Tank 6	
11	z								
12	Terraine	5.50	32.07	3.00	17.49	PDMac	31	Tank 1 (slop)	
12	Terraine	26.00	151.58	2.75	16.03	PDMac	32	Tank 2	
12	x								
13	Terraine	6.50	37.90	3.25	18.95	ANS	33	Tank 3 (slop)	
13	Terraine	41.25	240.49	2.50	14.58	ANS	34	Tank 4	
13	Terraine	13.00	75.79	2.50	14.58	ANS	35	Tank 5	
13	x								
14	Morris	13.38	5.14	12.63	4.53	ANS	37	collect drum 1 (then pail 1a (3)@5 gal	
14	Morris	13.38	5.14	12.63	4.53	ANS	37	collect drum 1 (then pail 1b (3)@5 gal	
14	Morris	13.38	5.14	12.63	4.53	ANS	37	collect drum 1 (then pail 1c (3)@5 gal	
14	Morris	missed	######	7.75	2.85	ANS	36	slop pail	5 gal
14	z								
15	Morris	8.38	3.09	6.50	2.36	ANS	38	slop pail	5 gal
15	Morris	4.88	8.19	4.50	7.56	ANS	39	collect drum 2	55 gal
15	x								
16	Morris	11.00	4.15	8.88	3.29	ANS	40	slop pail	5 gal
16	Morris	7.25	12.18	5.00	8.40	ANS	41	collect drum 3	55 gal
		1.00	1.68					initail collection in drum	
16	x								
17	Morris	6.75	2.46	3.50	1.24	PDMac	42	slop pail	5 gal
17	Morris	7.13	11.97	6.63	11.13	PDMac	43	collect drum 4	55 gal
17	z								
18	Morris	5.25	1.89	4.50	1.61	PDMac	44	slop pail	5 gal
18	Morris	4.13	6.92	3.63	6.09	PDMac	45	collect drum 5	55 gal
18	x								
19	Morris	6.13	2.22	4.75	1.70	ANS	46	slop pail	5 gal
19	Morris	4.63	7.77	3.75	6.30	ANS	47	collect drum 6	55 gal
19	z								
20	Morris	5.50	1.98	3.25	1.23	MCO	48	slop pail	5 gal
20	Morris	4.25	7.14	3.50	5.88	MCO	49	collect drum 7	55 gal
20	x								
21	Morris	6.00	2.17	4.50	1.61	ANS	50	slop pail	5 gal
21	Morris	3.75	6.30	3.00	5.04	ANS	51	collect drum 8	55 gal
21	z								
22	Morris	5.88	2.12	2.63	0.92	ANS	52	slop pail	5 gal
22	Morris	10.63	17.85	9.25	15.54	ANS	53	collect drum 9	55 gal
22	x								
23	Morris	6.38	2.32	4.00	1.42	ANS	54	slop pail	5 gal
23	Morris	9.38	15.75	7.63	12.81	ANS	55	collect drum 10	55 gal
23	z								
24	Morris	5.88	2.12	3.25	1.23	PDMac	56	slop pail	5 gal
24	Morris	9.00	15.12	7.25	12.18	PDMac	57	collect drum 11	55 gal
24	x								
25	Morris	6.75	2.46	3.63	1.29	PDMac	58	slop pail	5 gal
25	Morris	8.38	14.07	5.88	9.87	PDMac	59	collect drum 12	55 gal
25	z								
26	Morris	4.75	1.70	4.00	1.42	MCO	60	slop pail	5 gal
26	Morris	6.50	10.92	5.50	9.24	MCO	61	collect drum 13	55 gal
26	x								

009

Tank	Test	% H2O
1	1	15.0
2	1	92.0
2 slop	1	88.0
3 slop	2	96.0
2	2	85.0
1	2	67.0
4 slop	3	95.0
5	3	92.0
6 slop	4	95.0
7	4	90.0
8	4	96.0
1 slop	5	99.0
2	5	91.0
3	5	80.0
4 slop	6	83.0
5	6	48.0
6 slop	7	90.0
7	7	85.0
8	7	32.0
1	8	95.0
2	8	95.0
3	8	68.0
4	9	92.0
5	9	30.0
1 slop	10	99.9
2	10	26.0
3	10	55.0
4 slop	11	85.0
5	11	9.0
6	11	38.0
1 slop	12	92.0
2	12	30.0
3	13	37.0
4	13	33.0
5	13	65.0

Date	ID	Oil Descr.	Tank	Test	% H2O
2/13/09	418-36	ANS	Morris Slop	14	0.2
2/13/09	418-37	ANS	Collect	14	0.2
2/13/09	418-38	ANS	Morris Slop	15	0.4
2/13/09	418-39	ANS	Morris Collect	15	0.5
2/13/09	418-40	ANS	Morris Slop	16	0.2
2/13/09	418-41	ANS	Morris Collect	16	1.5
2/13/09	418-42	PT MAC	Slop	17	0.7
2/13/09	418-43	PT MAC	Collect	17	0.7
2/13/09	418-44	PT MAC	Morris Slop	18	0.4
2/13/09	418-45	PT MAC	Collect	18	0.8
2/13/09	418-46	ANS	Slop	19	0.5
2/13/09	418-47	ANS	Collect	19	0.6
2/13/09	418-48	MGO	Slop	20	0.6
2/13/09	418-49	MGO	Collect	20	3.5
2/13/09	418-50	ANS	Slop	21	0.3
2/13/09	418-51	ANS	Collect	21	0.1
2/13/09	418-52	ANS	Slop	22	0.4
2/13/09	418-53	ANS	Collect	22	0.1
2/13/09	418-54	ANS	Slop	23	1.0
2/13/09	418-55	ANS	Collect	23	0.2
2/13/09	418-56	PT MAC	Slop	24	4.5
2/13/09	418-57	PT MAC	Collect	24	8.0
2/13/09	418-58	PT MAC	Slop	25	6.8
2/13/09	418-59	PT MAC	Collect	25	8.8
2/13/09	418-60	MGO	Slop	26	3.0
2/13/09	418-61	MGO	Collect	26	2.0

Appendix E – Test Plan for Herder in Salt Marsh Tests at the SL Ross Lab

Test Plan

for

Herders to Clear Oil Slicks in Salt Marshes

Task 5 of the Research Project
SMALL-SCALE EXPERIMENTS
to
IDENTIFY BETTER HERDING AGENTS
for
FREEZING-WEATHER OIL SPILL RESPONSE

For

U.S. Department of the Interior
Minerals Management Service
TA&R

By

S.L. Ross Environmental Research Ltd.
Ottawa, ON

October 14, 2008

1 Introduction

A multi-year joint industry project was just completed that studied oil-herding agents as an alternative to booms for thickening slicks in drift (or broken) ice conditions for *in situ* burning. The U.S. Navy cold-water herder formulation (65% Span-20 and 35% 2-ethyl butanol) used in these experiments proved effective in significantly contracting fluid crude and refined oil slicks in brash and slush ice concentrations of up to 70% coverage. Slick thicknesses in excess of 3 mm, the minimum required for ignition of weathered oil *in situ*, were routinely achieved. The presence of frazil ice restricted the spreading of the oil and the effectiveness of the herder. Short, choppy waves in the test ice caused a herded slick to break up into small slicklets, although this may be an artifact of the relatively small volumes of oil used in the experiments. Longer, non-breaking waves, simulating a swell in drift ice, did not appear to cause a herded slick to break up, and in fact may have assisted the process by promoting spreading of the herder.

Otherwise unignitable crude oil slicks that were contracted by the USN herder could be ignited and burned *in situ* in both brash and slush ice conditions at air temperatures as low as –17°C. Measured oil removal efficiencies for herded slicks averaged 50% for 7.5-L slicks and 70% for 15-L slicks. The efficiencies measured for the herded slicks were only slightly less than the theoretical maximums achievable for equivalent-sized, mechanically contained slicks on open water. The type of ice (brash or slush) did not significantly affect the burn efficiency.

When ignited, the herded slicks did spread slightly, but once the flames began to die down, the residue was re-herded by the agent remaining on the water surrounding the slick. Generally, it was not possible to reignite re-herded residue. Steeper, cresting waves detracted from the burn efficiency while longer, non-breaking waves did not. The oil removal rate for the slicks was in the range expected for equivalent-sized, mechanically contained slicks on open water.

As a result of the experimental success to date thickening slicks for *in situ* burning in drift ice, a multi-project research program was proposed to continue the R&D on the use of herding agents. This test plan covers the fifth task of the portions of the research being funded by MMS.

2 Objective

The objective of the multi-project research program is to determine whether herding agents can contract oil slicks in specific spill situations where conventional countermeasures have limited effectiveness and thereby enhance marine oil spill response operations. Specifically, the goal of this task of the test program is to conduct preliminary experiments to determine the feasibility of using the US Navy herder formulation to clear oil from salt marsh areas..

3 Work Plan

A series of small-scale experiments will be undertaken at the SL Ross lab to determine the feasibility of using herders to clear oil from salt marshes. The experiments will utilize local marsh grass (Figure 2) as surrogates for salt marsh species (Figure 1). The plants would be placed in rectangular pans and oiled as if on a rising tide. Herder would then be applied to the water and its effects noted, including water surface clearing efficiency, location of the herded oil lenses and oil residue remaining on plant stems, substrates, etc. The effect of the following parameters would be evaluated in the tests:

- Three ambient temperatures (0°, 10° and 20°C)
- Three water salinities (0, 15 and 35‰)
- Three oil types (two crudes that are fluid at ambient temperatures – ANS and Kuparuk from the North Slope of Alaska) and No. 2 fuel oil)

Most experiments will be conducted in deeper plastic containers in order to minimize water, oil and herder use and turnaround time between experiments (Figure 3). A series of experiments to see if herder applied to the water prior to the arrival of an oil slick can help prevent oiling of a salt marsh will be carried out in larger, shallower 1-m^2 metal pans (Figure 4).

Figure 1. Common salt marsh grass (S*partina alterniflora).*

Figure 2. Freshwater marsh grass used in experiments.

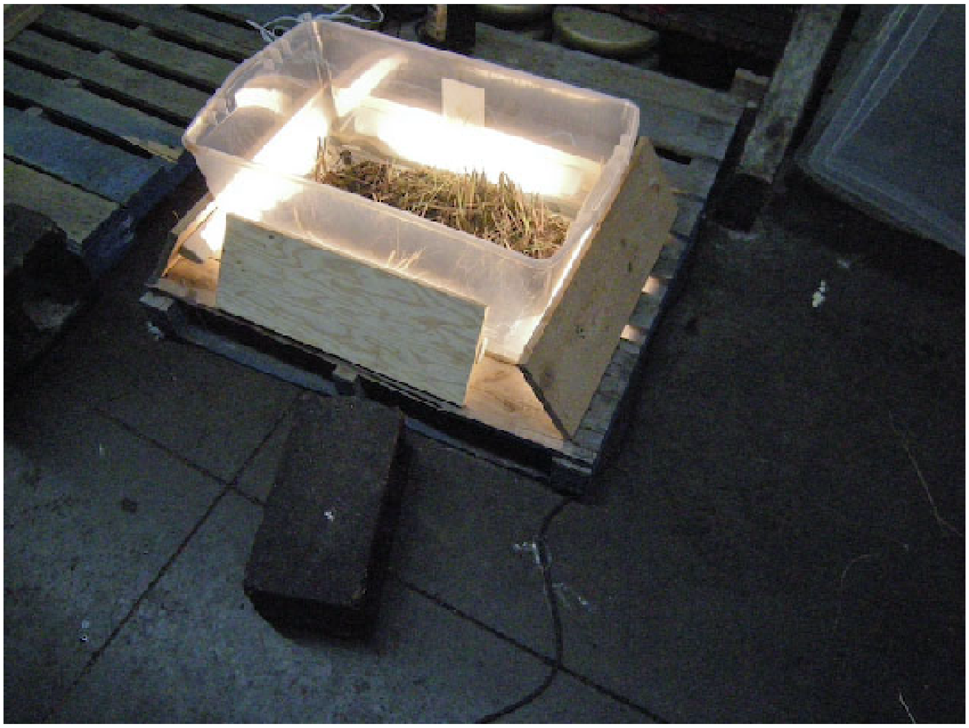


Figure 3. Plastic storage bin used for most tests.

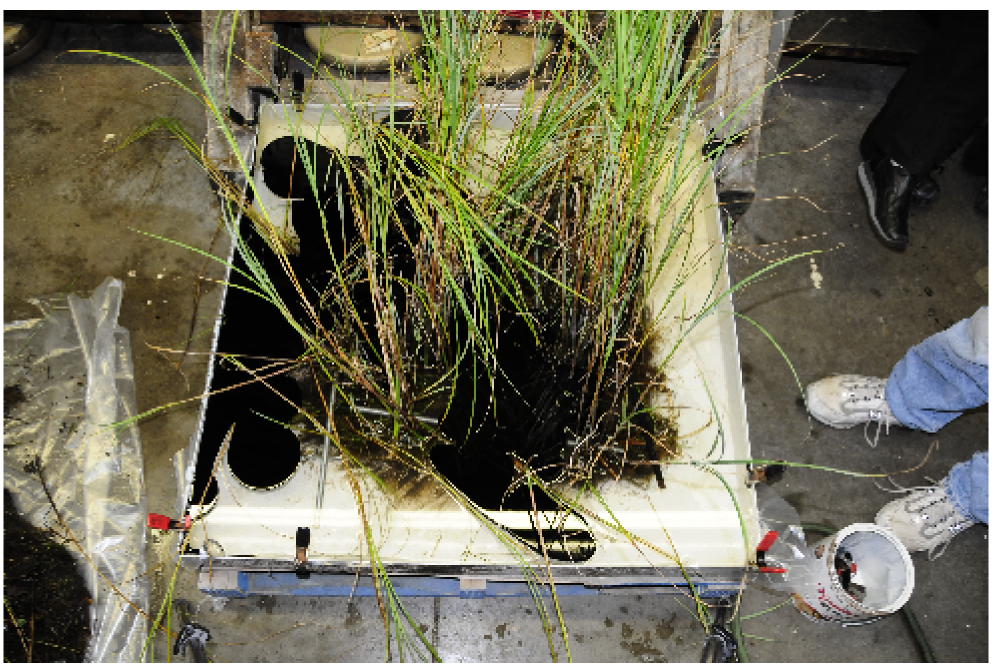


Figure 4. 1 m^2 pan with “oiled” marsh plants.

The general test procedure for a bin test is:

1. Place a section of trimmed (the stalks of the plants are cut back to just above the waterline to permit easier photographing of the oil slick) marsh “sod”, wired to a metal mesh substrate, in the bottom of each of three plastic bins.
2. Add a sufficient amount of the desired water (temperature and salinity) to each of three plastic bins (Figure 3) to inundate the sod, but not cover the plant stalks.
3. Carefully pour 0.5 L of the crude on the water; making sure that it doesn’t stick to the bottom of the bin or the sod while being poured.
4. Allow the oil to spread to equilibrium and take a digital photograph from overhead for subsequent oil area analysis.
5. Apply the prescribed amount of herding agent to the open water area with a micropipette.
6. Allow the oil to contract and take another digital photograph after one minute, 10 minutes, 30 minutes and 1 hour.
7. Sorb free oil from water surface, lift out sod sample, empty water from bins, rinse and dry bins with paper towels.

Table 1 illustrates the test matrix.

Table 1: Test matrix for plastic bin experiments.

OIL	SALINITY (‰)	TEMPERATURE (°C)
ANS	0	0
		10
		20
	15	0
		10
		20
	30	0
		10
		20
Kuparuk	0	0
		10
		20
	15	0
		10
		20
	30	0
		10
		20
No.2 FO	0	0
		10
		20
	15	0
		10
		20
	30	0
		10
		20

The overhead digital photographs will be analyzed by computer to determine slick areas. All the data collected will be processed, analyzed and collated. A summary data report will be written documenting results, conclusions and recommendations arising from this task of the research program.

Appendix F – Test Plan for Ohmsett Experiments on Using Herders to Improve Operational Efficiency of Dispersants

Second Draft

Test Plan for

Task Order No. 420

Sub-Task 6.2 – Testing at Ohmsett

Task 6 - Herders to Improve Operational Efficiency of Dispersant Operations
of
A TWO-YEAR RESEARCH PROGRAM
ON
EMPLOYING CHEMICAL HERDERS
TO
IMPROVE MARINE OIL SPILL RESPONSE OPERATIONS

Sponsors: U.S. DEPARTMENT OF THE INTERIOR
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Client: S.L. Ross Environmental Research Ltd
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Ian@slross.com or Steve@slross.com

Time Frame: OCTOBER 2009

October 1, 2009

Test Plan for

Sub-Task 6.2 – Testing at Ohmsett part of Task 6 - Herders to Improve Operational Efficiency of Dispersant Operations

Task Order No. 420

Sponsors: US DEPARTMENT OF THE INTERIOR
Minerals Management Service
Contact: Joe Mullin COTR
(703) 787-1556

Client: S.L. Ross Environmental Research Ltd.
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Time Frame: October 2009

Prepared By: ______________________________ and ______________________________
Paul Meyer - Test Director Ian Buist - SL Ross Project Manager

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William Schmidt - Site Manager

DOI - MMS ___________________________
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SL Ross: ___________________________
Ian Buist - Project Manager

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1. INTRODUCTION

A 5-day test program is planned at Ohmsett to determine if herding agents applied around a spreading slick affect the operational efficiency of subsequent dispersant application.

1.1 Background

One of the identified weaknesses of chemical dispersants is that they consistently either under-dose or over-dose real slicks due to the inherent large variability in oil thickness at sea. Dispersant drops that fall on thin oil or sheen tend to penetrate through to the underlying water and are wasted. In addition, the surfactants in dispersants also act as herders causing sheens or thin oil slicks to rapidly contract resulting in much of the dispersant being wasted as it falls on open water.

Dispersant drops that fall on thicker slicks will mix with the slick, if conditions are right. However, it is impossible to tell the thickness of the "black" portions of a slick visually making accurate dosing with dispersant difficult—thin portions of the slick are overdosed and thick portions are under-dosed. The application of a herding agent around the periphery of a slick just prior to it being treated with dispersant would cause the slick to contract into much thicker oil, covering a much smaller area with a more uniform, and predictable, thickness. This would allow more precise application of dispersant to a smaller area of oil at a more predictable dosage.

Herders will contract free-spreading oils with thicknesses ranging from <1 μm to 1+ mm into slicks of ~1 to 4 mm thickness, eliminating the sheen overdosing problem and greatly aiding the thick slick under-dosing problem. This offers the possibility of significantly improving dispersant targeting. Slicks that have spread to «1 mm thickness could be shrunk and thickened with a chemical herder applied with a helicopter-slung bucket delivery systems, or vessel-based delivery systems, then treated with dispersant from ships or aircraft. Another possibility is the application of herding agents around slicks in calm seas to prevent them from spreading until the wind picks up and breaking waves (necessary for effective chemical dispersion) appear.

1.2 Objective and Goal

The objective of the multi-project research program is to determine whether herding agents can contract oil slicks in certain spill situations where conventional countermeasures have limited effectiveness and thereby enhance marine oil spill response operations. Specifically, the purpose of this task of the test program is to carry out experiments to study if applying chemical herders around oil slicks on the open ocean can improve the overall operational effectiveness of subsequent dispersant application.

More specifically, the goal of the work described here is to conduct dispersant effectiveness experiments at Ohmsett to quantify the operational efficacy of herders in thickening fluid oil slicks for subsequent treatment with chemical dispersants.

1.3 Organizations Participating in the Testing

All those who will be at the Ohmsett Facility are advised that they are subject to US Navy, Naval Weapons Station Earle (NWS-Earle) and Department of Interior, Minerals Management Service rules and regulations. The most obvious of those regulations involve health, safety, and security. All operational personnel must have 40-hour or 24-hour HAZWOPER training and an introductory Ohmsett Health & Safety training session. Access to the site is controlled by NWS-Earle. Use of a camera requires a permit issued by a NWS-Earle Base Security Officer. **Unless informed otherwise by the Site Manager, testing is on weekdays only, and begins at 0700.**

Minerals Management Service (MMS):

- Funds the operation of Ohmsett
- Reviews and approves the Work Order Proposal
- Provides the Work Order to MAR, Inc.
- Funds and administers the participation CRREL in Task 3
- Funds and administers the participation SL Ross in Task 3
- Reviews and approves the Final Report

SL Ross Environmental Research

- Prepares the Test Plan with MAR input
- Designs the experiments
- Provides the herding agent
- Assists with the equipment assembly and operation
- Directs the testing
- Takes overhead digital photos for area analysis
- Analyses the data
- Writes the final report

MAR, Inc:

- Prepares the Test Plan with SL Ross
- Erects the wind screen on either side of the tank
- Prepares the dispersant effectiveness testing equipment
- Provides and operates man lift
- Prepares test fluids and confirms suitability
- Collects test data including oil distribution volumes, initial oil properties, recovered oil volumes and overhead digital video and photography
- Collects background data including oil/water temperatures, and wave data
- Photographs and videotapes the trials
- Cleans and demobilizes the test equipment after the experiments have been completed
- Provides raw data to SL Ross
- Reviews the Draft Final Report

1.4 Test Personnel

The test personnel assignments are listed in Table 1.

Table 1: Test Personnel Assignments

Personnel	Location	Duties
Program Manager Bill Schmidt	Control Tower	Oversight
Test Engineer/Director Paul Meyer	Test Basin	Overall supervision of testing
QA Engineer Alan Guarino	Roving	Monitors fluid sampling, data collection and test parameter accuracy.
Chemical Technician Susan Cunneff	Oil Analysis Lab	Handles and analyzes fluid samples.
H&S Specialist Rich Naples	Roving	Monitors personnel safety.
Fluid Transfer Technician Dave Knapp	Main Tank Deck	Operates oil transfer system, Operates fill and off-loading pumps
Video Technician Bob Stewart	Roving	Operates hand-held video and digital still camera
Rigger/Oil Transfer Technicians Don Snyder, Tom Schmidt and/or John Marcelliano,	Roving	Deploy boom, transfer oil, , collect oil, clean and demobilize equipment
SL Ross Sr. Engineers Ian Buist and Randy Belore	Roving	Design and direct tests. Apply herding agent. Take overhead video and still photographs Provide advice on test

2. TEST PROCEDURES

2.1 Preparation

The preparations for the tests include:

- SL Ross supplying 500 mL USN herder (65% v/v Sorbitan Monolaurate [Span 20] and 35% 2-ethyl butanol)
- MAR providing a man lift
- Identifying two crude oils in existing Ohmsett inventory to be used for the tests (for a full suite of 8 tests, three drums [605 L = 160 gallons] is required). The suggested crudes are:
  Oseberg Blend (both fresh and weathered) - 140 gallons available fresh; 83 gallons weathered
  Northstar – 22.4 gallons fresh
- Erecting windscreen on either side of the tank
- Setting up standard dispersant effectiveness testing equipment (Corexit 9500 will be the dispersant) with the spray bar mounted on a trolley on the Main Bridge so it can be moved to target the free-drifting slicks.
- Obtaining sorbent to remove herder and sheen from tank after a test is completed
- Positioning, checking and calibrating overhead camera(s) for data collection
- Conducting required safety checks and notifications.
- Conducting several dry run tests to set new wave maker to produce breaking waves and fine tune release and test procedures

2.2 Test Set-up, Instrumentation and Procedures

In order to minimize dissolved dispersant effects on the results, the control (no herder) tests will be completed after the all the tests with herder applied (the SL Ross lab testing showed that only if the oil is put on the water immediately after it has been swept with sorbent, will it spread to a thin slick). The effects of the herding agent would be quantified by measuring the change in surface area of the slick after herder application using overhead video and digital photography taken from a lift basket positioned over the tank. Dispersant effectiveness would be measured using the standard Ohmsett protocols, modified to account for herder use, as described below.

The amounts of herder used for each test are small (the recommended dose rate is 50 mg/m^2 or only 200 mL [20 m x 203 m x 50 mg/m^2] to cover the entire surface of the Ohmsett tank). Even if all the herder from one test were dispersed into the water at Ohmsett, it would amount to a concentration of only 0.02 ppm. Visual observation of the spreading of a small amount (ca. 10 mL) of test oil inside several small (1 m^2 area) floating plastic circles, randomly placed on the test area's surface, can be used to confirm that the herder has been removed from the water surface prior to each test.

The dispersant spray system to be used in the testing will involve a spray bar mounted on a trolley so that it can be positioned to spray the free-drifting slick when the time comes. The hand-held sprayer will also be used to treat herded slicks in two tests. Corexit 9500 dispersant will be used in all of the tests. The USN herder will be the only one tested.

The wave paddle settings used in all dispersant tests at Ohmsett earlier tests were a 3.5 inch stroke and 34 to 35 strokes per minute: with the installation of a totally new wave maker system, it will be necessary to spend time on Day 1 determining what setting for the new wave maker produces equivalent waves.

The basic test procedure used for all herder/dispersant effectiveness tests will be as follows.

1. The oil containment area is established in the Ohmsett tank.
2. The oil and dispersant are loaded into their respective supply tanks on the Main Bridge deck.
3. The Main Bridge is used to clean the entire length and width of the test area with a sorbent sweep.
4. The Main Bridge is positioned at the southern quarter point of the tank within the boomed area. The wave paddle is started and the waves are allowed to develop to a stage just prior to the formation of breaking waves.
5. The bridge is moved south at the required speed to achieve proper slick dimensions (between 0.25 and 1 knots).
6. The oil is pumped at the required rate onto the surface through the discharge manifold mounted on the south side of the bridge.
7. The Main Bridge is re-positioned to apply herder from two hand-held spray bottles.
8. The man lift is moved into position for digital overhead photographs.
9. The slick is allowed to spread to equilibrium, and a digital photo of the slick is taken from the man lift.
10. Then, herder is applied to contract the slick (for the last two tests, no herder is applied).
11. A second digital photo of the herded slick is taken from the man lift.
12. The Main Bridge is re-positioned to apply dispersant.
13. The dispersant is applied onto the oil slick from one or more of the three spray bars mounted on the north side of the bridge in the same pass, or the hand-held sprayer.
14. The waves are left on for 30 minutes and then the wave maker is stopped.
15. The water spray from the Main Bridge fire monitors is used to sweep any surface oil remaining on the water surface at the end of the test to a common collection area at one corner of the containment boom.
16. The oil is then removed from the water surface using a double-diaphragm pump and suction wand and placed in a collection drum.
17. The drum is allowed to stand at least overnight and most of the free water present is pumped from the bottom of the drum.
18. The remaining oil and water are well mixed and a sample is taken for water content and physical property determination.
19. The quantity of liquid in the drum is measured and the amount of oil determined by subtracting the amount of water as determined using the water content analysis.
20. The effectiveness of the dispersant is reported as the volume of oil discharged minus the amount collected from the surface all divided by the amount discharged (times

100 to convert to a percentage).
21. Each test is video taped for future visual reference.
22. At the end of each test it will be necessary to remove the residual herder and dispersant from the water surface. This would be accomplished by running a train of breaking waves down the tank for several minutes and using the Main Bridge fire hoses to disperse the herder and dispersant into the water column.

2.3 Test Matrix and Schedule

Test Matrix Variables

1. Oil type (two fresh crude oils, and one weathered for several hours);
2. Dispersant application technique (spray bar or hand-held sprayer; and,
3. Herder application, or not.

A total of eight tests are planned over a four-day test period. Table 2 gives the proposed matrix for the tests. Testing is to take place October 19 to 23, 2009.

Table 2. Preliminary Matrix of Tests

Oct	Day	Test	Crude Oil	Herder	Dispersant Application
19	1	Setup/calibrate wave maker			
20	2	1	Oseberg Fresh	Y	Spray Bar(s)
		2	Oseberg Weathered	Y	Spray Bar(s)
21	3	3	Oseberg Fresh	Y	Hand Held
		4	Oseberg Weathered	Y	Hand Held
22	4	5	Oseberg Repeat	Y	To Be Determined
		6	Northstar	Y	To Be Determined
23	5	7	Oseberg Fresh	N	Spray Bar(s)
		8	Oseberg Weathered	N	Spray Bar(s)

At the conclusion of each test any herder and dispersant remaining on the water surface would be dispersed into the tank with breaking waves and the fire monitors on the Main Bridge. Just prior to each test, the test area would be swept with sorbent to remove any surfactant that has resurfaced.

Final tank clean up would involve sweeping the length of the tank with boom, polishing several times with sorbent sweeps and running breaking waves and fire hoses to disperse any remaining herder or sheen from the surface.

3. DELIVERABLES

3.1 Test Data

Original data logs, computer generated data files, video, digital images and photos will be kept on file at Ohmsett. Copies or duplicates will be created and delivered to SL Ross to generate the final data report. The Ohmsett deliverable items will include:

- Raw computer generated data files.
- Observations on tests.
- All manually generated test logs.
- Digital and film photographs and digital video.
- Ohmsett laboratory analyses.

3.2 Video Documentation

High-resolution, digital videos shall be produced with titles that clearly state the test name, time of day, date and test number. Video documentation will be duplicated in VHS or DVD format as deliverable items for SL Ross. Logs will accompany the videos specifying test number, date, time and location on the videotape. Photos, digital and 35 mm, will also be duplicated as deliverables. All original video and photographic documentation will be maintained at Ohmsett.

4. HEALTH AND SAFETY JOB HAZARD ANALYSIS

4.1 Introduction

A job hazard analysis is a means of preventing or controlling hazardous conditions associated with testing activity. Analysis begins by determining the basic tasks of a job. Each task is then analysed to identify potential hazards associated with it. It will then be possible to develop control measures for the hazards identified. Prior to any test activity, personnel involved with the test are informed of potential hazards and controls for an understanding of their health and safety responsibilities.

4.2 Hazardous Materials

Liquid Hydrocarbons:

- Crude oil

Other Products/Chemicals:

- USN herder (65% Sorbitan Monolaurate and 35% 2-ethyl butanol – MSDSs attached)

According to available product safety information, respiratory protection is not needed, as:

- the evaporation rate of the oil is negligible, resulting in the off-gassing of little, if any
- sorbitan monolaurate has a low vapor pressure at room temperature and is not identified as a particular inhalation hazard
- 2-ethyl butanol may be harmful if inhaled, but has a low vapor pressure at room temperature and only small amounts will be used in each experiment (about 4.2 mL per test)

All personnel involved in testing will be informed of associated health hazards, as well as the proper personal protective measures required to eliminate exposure to the oil and chemicals, in accordance with OSHA Hazard Communication Standard requirements. A Material Safety Data Sheet is maintained for test oils, chemicals or various products, and will be available to each person involved in testing.

4.3 Generic Job Safety Analysis

The following table lists basic or generic tasks necessary for the "Herders to Improve Operational Efficiency of Dispersant Operations" Tests at Ohmsett. Hazards associated with the tasks are listed with preventive measures to be followed by affected personnel.

Table 3. Task Hazard Prevention

TASK	HAZARDS	PREVENTION/CONTROL
1) Materials handling, general set-up	a) Lifting material(s) (muscle strains, back injuries) b) Forklift operations (objects striking) c) Jib crane(s) operations (objects striking) d) Mobile crane (contractor personnel, objects striking) e) Hand/power tools (muscle strains, pinch points, electrocution)	a) Use proper lifting techniques; lift with your legs, not your back; get help for heavy loads, use mechanical devices (i.e., fork lift, job cranes). b) Follow acceptable safe practices for operators. c) Do not stand under raised loads. Do not exceed capacity of jib crane. Use one signal man. d) Only qualified crane operator and signal man will control lift operations. Do not stand under raised loads. e) Use correct tool for the job, use correct PPE and proper body positioning when handling tools. Inspect all power tools to ensure no frayed or exposed wires exist, equipment is grounded and insulated and GFI's extension cords etc. are functioning properly.
2) Boom assembly and placement into tank (set-up)	a) Rigging from work boat or bridge (falls) b) Cable handling (pinch points) c) Positioning bridges (objects striking) d) Positioning boom equipment. Mobile crane operations (objects striking)	a) Personnel on work boat MUST wear PFD's. Evenly distribute weight and do not overload. Life preservers are in place as needed. b) Wear hand protection during rigging. c) Have appropriate lines of continual communication. d) No one permitted under heavy loads. Only contract operator and signal man will control lift operations.
3) Oil transfer	a) Spilled oil/deck area (slip/fall hazard) b) Pressurized equipment/pumps/hoses/ lines (pressure release, objects striking)	a) Clean spills on deck/bridges immediately. Utilize spill equipment, as required. b) Inspect all equipment prior to use. Do not use damaged equipment. Replace cracked hoses, broken gauges prior to pressurization. Inspect for leaks. Use adequate PPE (hard hat, gloves, face shield).

4) Bridge operation positioning and movement	a) Bridge movement (objects striking, falls)	a) No personnel permitted on the deck, under moving cables or in motor perimeter while in operation. b) All guard rails must be in place and secured while working on moving bridge. c) Continued and open communications with bridge operator is mandatory. While testing, only authorized personnel involved with the test allowed in bridge control area (third floor).
5) Oil addition to test tank	a) Splashing/spraying oils while transferring to Test Tank. [Slips/falls, exposure (skin/eyes), exposure (inhalation)] b) Pressure release (object striking, pinch points)	a) Wear appropriate PPE (protective clothes, goggles/face shield, nitrile gloves). Air sample base line tests will be taken. Appropriate respirators will be worn as required. Technician will keep bridge/deck as oil-free as possible. b) Utilization of damaged hoses for faulty equipment is prohibited. Check all piping, hoses, hose connections, etc. prior to use. Bleed pressure prior to disconnect. Wear PPE to include protective clothes, goggles/face shield, hard hat, nitrile gloves.
6) Addition of Herding Agent	b) Working on bridges c) Deployment and general operations (testing)	a) Wear appropriate PPE (protective clothes goggles/face shield, gloves, appropriate respirators will be worn as required.
7) Wave generation	a) Moving wave generating equipment (pinch points, objects striking).	a) No personnel permitted in wave generating room during operations. PPE must be utilized when adjusting mechanics of wave generation equipment. Use correct tools for the job and use them safely.
8) Removal of oil from test tank	a) Oil exposure (skin/eye contact) b) Falls, slips c) Sorbent boom sweeping.	a) Wear protective clothing, goggles/face shields and nitrile gloves. b) When moving oil from the water with high pressure hose streams, avoid direct contact of oil with water stream. Clean any splashed oil from the deck with absorbent pads.

9) Cleanup of equipment	a) Disassembly of rigging from work boat/ bridges (falls). b) Pressurized water/water lines (objects striking) c) Hot water/steam wash (burns) d) Oil/cleaning agent exposure (skin, eye contact) e) Slippery surfaces from excess oil/cleaning agents (falls/slips)	a) Personnel on work boat must wear PFD's. Evenly distribute weight and do not overload. Life preservers are in place as needed. b) Inspect all equipment prior to use. Ensure hoses/fittings, etc. Are in good condition with no signs of deterioration/cracks damage. c) Wear appropriate PPE (face shield, goggles, gloves, protective clothes). d) Wear appropriate PPE (face shield, goggles, protective clothes, Sarnac or Tyvek suits, gloves). e) Keep deck as oil and soap free as possible, watch footing and remove obstacles. Creation of a decontamination zone will be mandatory.
10) Pack up	a) Fork lift operations (objects striking) b) Material handling (muscle strains, back injuries)	a) Follow acceptable safe practices for fork lift operations. b) Use proper lifting techniques, lift with your legs and not with your back, get help for heavy loads (i.e. fork truck, jib crane, etc.).

Finally, personal protective equipment guidelines (for items such as hard hats, steel toed boots, and the like) will be followed based on a Health & Safety Site Plan. The assessment is based only on generic or basic steps. Chemical Hazards will be discussed based on hazard communication standards with MSDS's reviewed.

Material Safety Data Sheets are available to participants at Ohmsett.

4.4 Personal Protective Equipment

The following personal protective equipment shall be available at all times. Specific use requirements may be found in Section 4.2.

- Work gloves
- Insulated coveralls (Temperatures will be 0°C to –15°C)
- Warm hat
- Oil resistant gloves (neoprene, nitrile)
- Eye protection (safety glasses, goggles)
- Safety shoes
- Personal flotation devices (for workboat operations) mandatory
- Life rings

- Splash suits, for tank clean up
- Fall-arrest system (life line, safety belt, tie-off point)

4.5 Communication Plan

Good communication is essential to the safe execution of the test. The following types of communication tools and skills will be available for use:

- Two-way radios
- Intercom system
- PA system
- Hand signals

4.6 Contingency Plan

In case of medical emergency, fire, major oil spill, or other emergency, it is necessary to notify Naval Weapons Station Earle. The OHMSETT Spill Response Plan shall be followed in the event of any oil spill.

A) Emergency Telephone Numbers:

- Naval Weapons Station Earle X 2911
- Leonardo First-Aid 9 – 732 - 615 - 2100
- Riverview Medical Center 9 – 732 - 741 - 2700
- Bayshore Hospital 9 – 732 - 739 - 5900
- Poison Control Center 9 - 1 - (800) 962-1253

5. Herders to Improve Operational Efficiency of Dispersant Operations Quality Assurance

5.1 Introduction

Herders to Improve Operational Efficiency of Dispersant Operations Test Quality is the active application of The Ohmsett "General Quality Procedures and Documentation Plan Manual" and the "Herders to Improve Operational Efficiency of Dispersant Operations Test Quality Checklist."

The Quality Checklist has a list of those items in the Herders to Improve Operational Efficiency of Dispersant Operations Test Plan (see Section 5.2) that are deemed important elements in creating a quality test. This list will be used by the QA Engineer to record spot checks of key quality elements, along with appropriate comments, where necessary. A description of these key quality elements follows. The QA Checklist will be provided in the Final Test Plan.

5.2 Procedures

Herders to Improve Operational Efficiency of Dispersant Operations Test Quality Checklist is implemented as follows:

Herders to Improve Operational Efficiency of Dispersant Operations Test Quality Checklist consists of a complete list of Quality concern items that the QA Engineer uses to spot check items, and confirm adherence to the Test Plan. This checklist is used before, during and after the test to make sure all areas of the test plan receive the same thorough Quality attention. These areas include:

A. Initial calibration data
B. Pre- and post-test checks and conditions
C. Test checks and conditions
D. Sampling
E. Significant occurrences/variations
F. Data reduction and validation
G. Data accuracy and precision
H. Documentation of the tests
I. Technical project report

5.3 Initial Calibration Data

A check is made to ensure that data is available to show the initial source of calibration data for each piece of instrumentation used in the test. This includes any calibration information necessary to assure that the calibration data is current for this test.

5.4 Pre- and Post-Test Checks and Conditions

These are checks that are performed on the instrumentation and weather conditions each morning before testing starts and at the end of the day when testing stops. This is done on all days that testing occurs. Note is made of any unusual conditions that occur. These conditions must be evaluated before testing is started or if noted at the end of the day, the day's data is examined to determine its validity and whether the affected tests need to be repeated.

5.5 Test Checks and Conditions

These checks ensure that the test plan's instructions on how the test is to be done are followed and that the records that are to be made during the test are completed accurately.

5.6 Sampling

Sampling will be checked for compliance with the instructions in this plan.

5.7 Significant Occurrences/Variations

This part of the Herders to Improve Operational Efficiency of Dispersant Operations Test Quality checks will be concerned with recording any significant occurrences/variations that might occur during the tests. These will be immediately reported to the Test Director.

5.8 Data Reduction and Validation

All data reduction and validation will be performed in accordance with approved and accepted methods. When non-standard methods are utilized, they shall be included in the Technical Project Report and sufficiently described so that they can be used by independent sources to duplicate the results. The treatment of data is described in Section 3.

6. SCHEDULE

The following schedule is planned for the Herders to Improve Operational Efficiency of Dispersant Operations Tests.

DATE	EVENT
October 1, 2009	Submit Draft Test Plan
October 19 to 23, 2009.	Tests at Ohmsett
November 30, 2009	Deliver Raw and Processed Data, Observations and Photo Video Documentation to SL Ross
December 31, 2009	Submission of Draft Final Report

Appendix G – Data for Ohmsett Tests on Herders to Improve Operational Efficiency of Dispersants

Oil/Herder	DOR	Links to Oil Drop Size / Concentration Graphs	Test # Dispersant Application Analog	Oil Drop Size (Average D50) (microns)	Volume % < 70 microns	Avg. Elevated Oil Conc. by LISST (ppm)	Peak Oil Conc. by LISST (ppm)	% Dispersed /Lost
Fresh Oseberg Herded	1:10	figureL1	1 Vessel	111	56	23	105	99
Fresh Oseberg Herded	1:300 to 1:60	figureL2	2 C-130	63	67	27	173	99
Fresh Oseberg Not herded	1:110 to 1:40	figureL3	3 C-130	46	76	54	305	86
Fresh Oseberg Not herded	1:23	figureL4	4 C-130	52	72	29	161	91
Weathered Oseberg Herded	1:20	figureL5	5 Vessel	20	90	60	171	98
Weathered Oseberg Herded	0.0283333333	figureL6	6 C-130	72	57	63	448	67
Weathered Oseberg Not herded	1:315 to 1:98 OR 1:150 to 1:130	figureL7	7 C-130	46	73	92	400	66