

Supplementary Materials for Mitigating Oil Spills in the Water Column

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This PDF file includes:

Figs. S1 to S6

Tables S1 to S5

Captions for Movies S1 to S3

Other Supplementary Materials for this manuscript includes the following:

Movies S1 to S3

The tabulated data (see Table S2-S5) provide the following information:

Column 1 – **Test Number and Type** – test index number and type of sorbent examined

Column 2 – **Row/Sample** – Sorbent pads of identical composition in each row were processed and analyzed together. Data listed in the subsequent columns is the cumulative amounts obtained in that particular row.

Column 3 – **# of Foam Pads in each Row** – The number of foam pads contained in each row. For reference, the position of the untreated pad remained fixed in the second row for all tests.

Column 4 / 5 – **Volume of Water/Oil Collected** – The amount of each fluid recovered after wringing the pads.

Column 6 – **Oil Selectivity Ratio** – The fraction of oil, relative to the total amount of fluid collected during the wringing step.

Supplementary Figures:

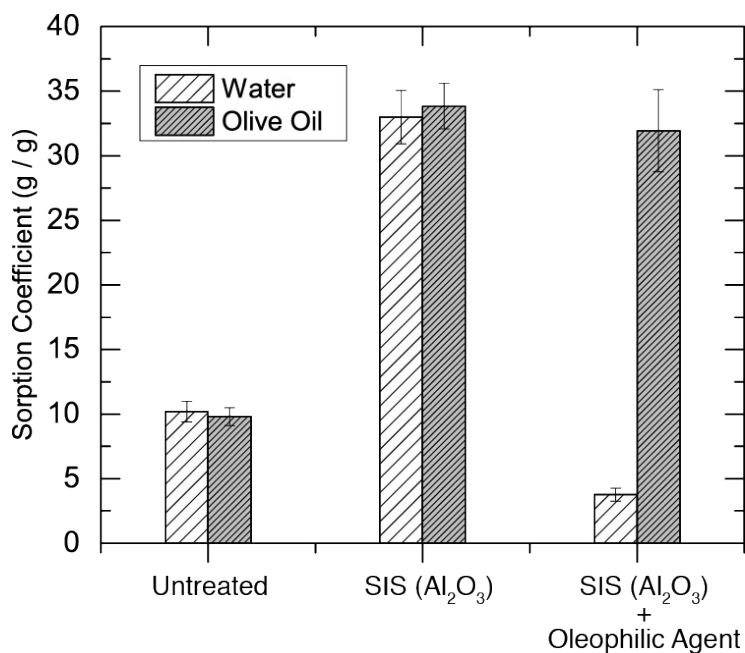


Fig. S1. Pure solvent adsorption under standard conditions. Sorption coefficient for untreated polyurethane foam (left), SIS-treated foam (middle), and SIS/oleophilic-treated foam (right) as measured using 1” foam cubes in the pure liquids.

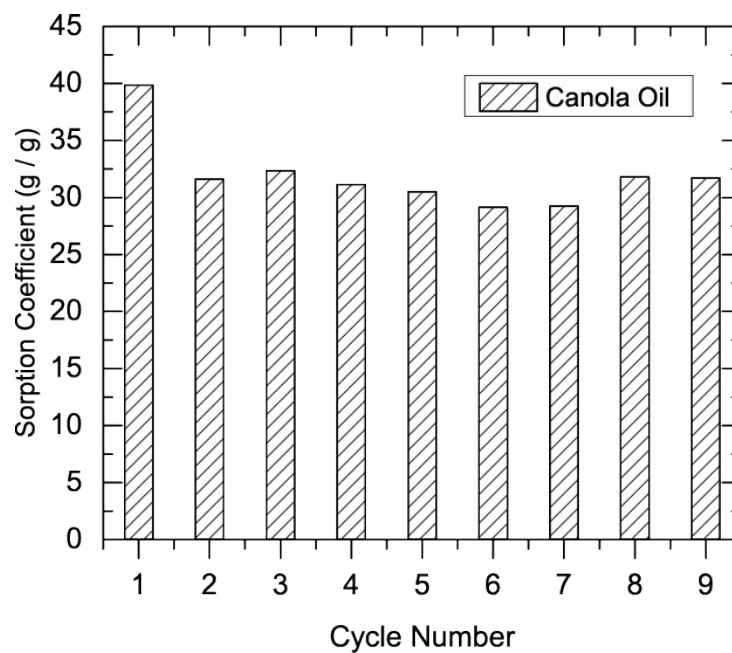


Fig. S2. Reusability. Sorption coefficient for the PU-T as measured over repeated sorption/desorption cycles in a bath of pure canola oil using 1" foam cubes.

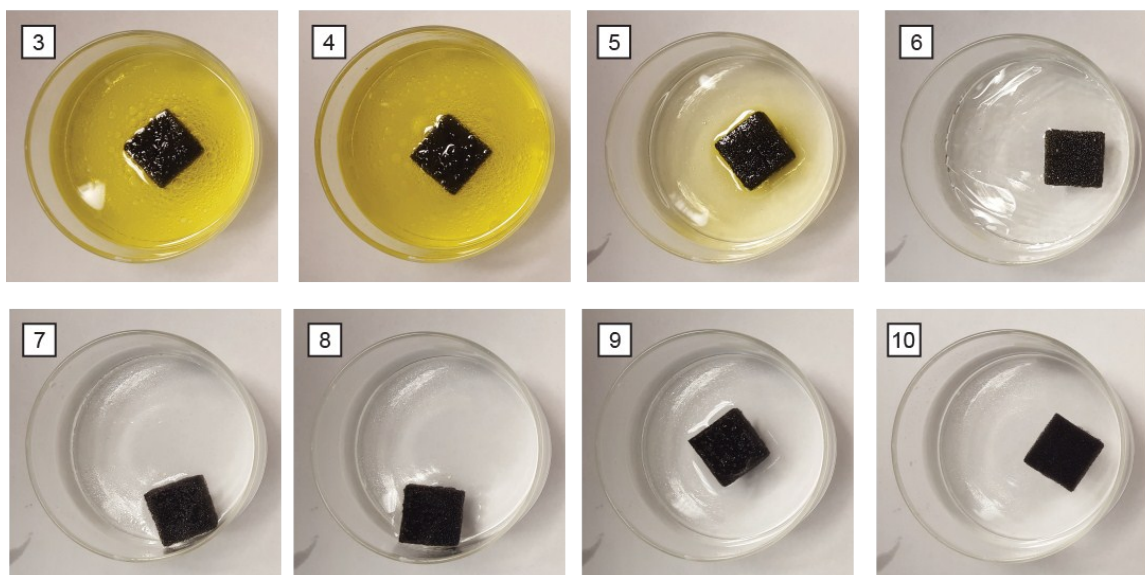
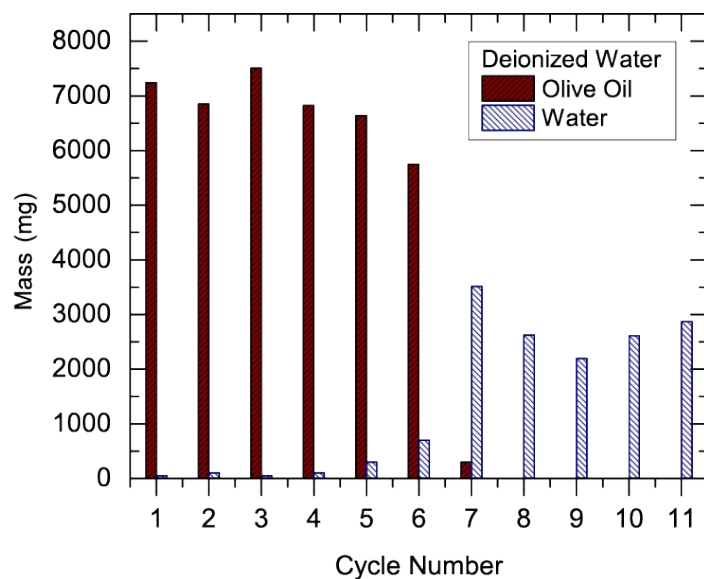


Fig. S3. Oil to water selectivity. The vessel is initially filled with water and a defined amount of olive oil that floats on the top. The amounts of oil and water adsorbed during each testing cycle are measured and shown in the bar graph. Each cycle consisted of placing the foam onto the surface of the liquid and leaving it for sufficient time to saturate with sorbed fluid, then compressing the sorbed fluid into a separate container.

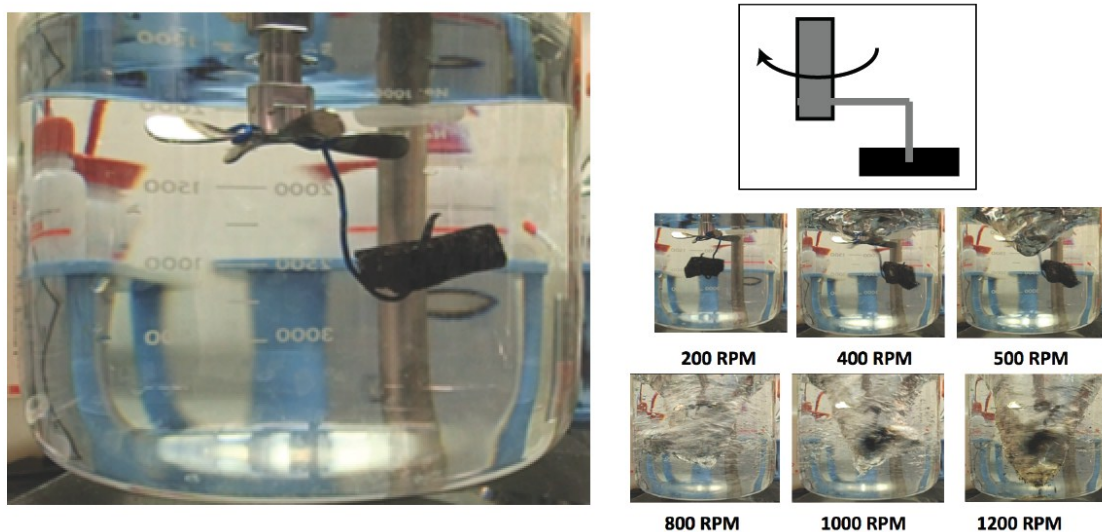


Fig. S4. Oil Saturated Foam on Spinning Rotor

These experiments investigated how mechanical perturbation (such as those encountered during ocean currents or when the foam is being transported by a trawler) would affect the ability for adsorbed oil to stay within the foam. Oil-saturated foam was loaded onto a rotor as shown above, and the behavior for various rotor speeds recorded. Sorbed oil was retained in the foam at rotational speeds up to 1000 RPM. As shown, 1" square cross-section of foam, and ½" thick. The foam was held in place by a paper clip attached to the rotor. ANS crude oil was adsorbed onto the foam at its saturating limit.

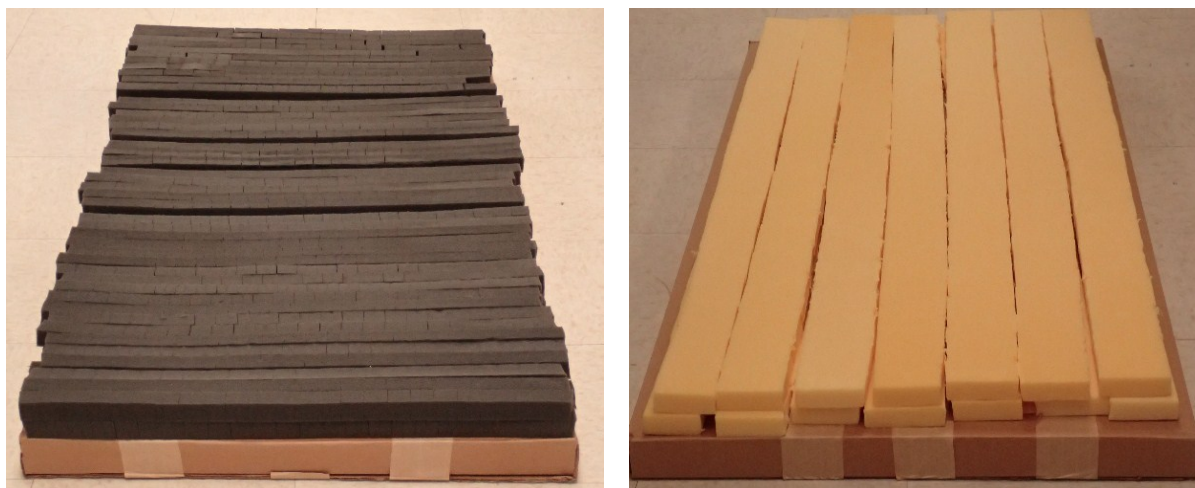


Fig. S5. Foam scale-up. Image showing the scaled-up production of foam, 1" × 1" × 24" strands of polyurethane (left) and ~3" × 1" × 48" strands of polyimide (right). As shown, there are 2× layers of 8 ft² (2 ft × 4 ft) of foam.

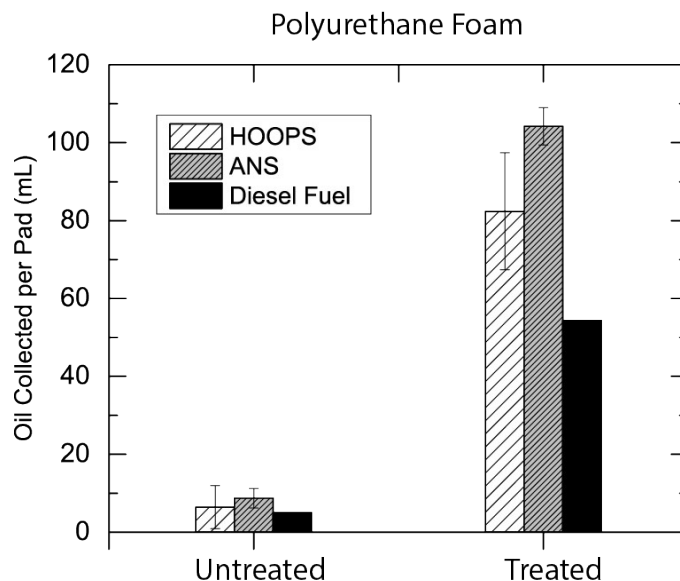


Fig. S6. Water Column Sorption Comparison of PU-U / PU-T. Water-column adsorption tests, showing the amount of oil collected per pad for untreated (PU-U) and SIS/oleophilic treated polyurethane (PU-T) foams, left and right, respectively. Values for HOOPS crude oil testing averaged over 7 independent tests and ANS over 4 different tests. Diesel fuel was measured in 1 test.

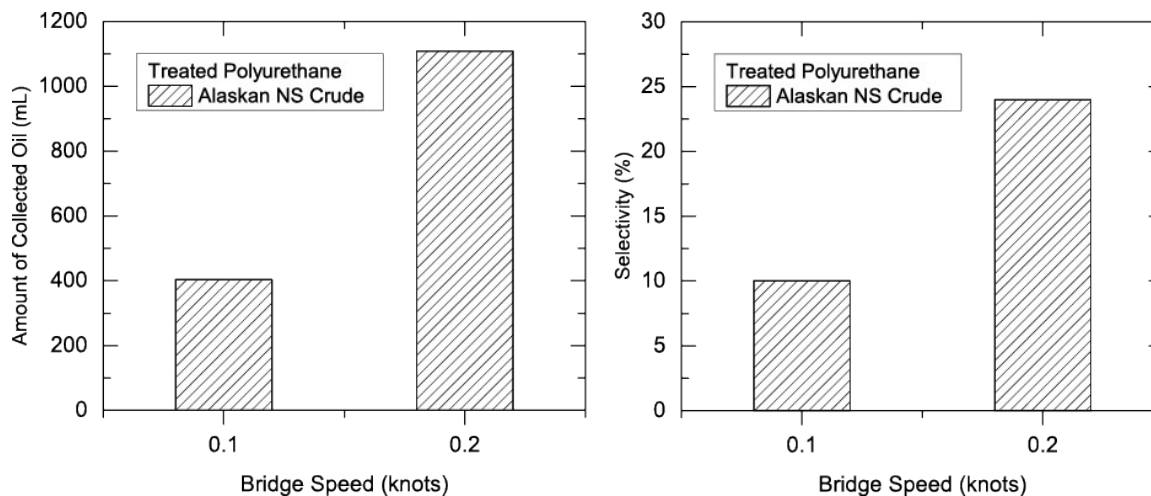


Fig. S7. Bridge Speed. The total amount of oil collected by PU-T foam pads (left) and selectivity of oil to water (right) are plotted as a function of bridge speed.

Table S1. Pure oil sorption capacity measurements.

Pure oil		Mass of foam pad		Sorption capacity	
Foam index	Oil type	Total (lbs)	Foam only (lbs)	No drainage (lbs)	After drainage (lbs)
Foam 1	Canola	0.91	0.49	13.39	10.57
Foam 2	Canola	0.92	0.50	17.76	14.96
Foam 3	Canola	0.99	0.57	13.30	8.27
Foam 5	HOOPS	0.89	0.47	13.85	11.94
Foam 4	Diesel fuel	0.93	0.51	13.85	10.40

Table S2.

See materials and methods for a description of terms and column/row values.

Test Number and Type	Row/Sample	Number of Foam Pads in each Row	Total Volume Collected (Oil+Water) (mL)	Volume of Oil Collected (mL)	Selectivity Ratio of Oil to Total Volume (%)	Testing Parameters		
Test 1 HOOPS Polyurethane	1	4	3465	223.2	6.4	Oil Type	HOOPS	
		2	3	2425	315.3	13.0	Ohmsett Test Number / Date	12.06 - Test 8
		3	4	3140	582	18.5	Speed (knots)	0.1
		4	2	1350	175.8	13.0	Bridge Spacing (feet)	13
		Untreated -PU	1	820	10	1.2	Post Oil Drag	0'
							Nozzle Configuration	8 x .042"
						Duration (min)	3.92	
						Flow Rate (gpm)	1.38	
						Pump Pressure (psi)	80	
						Tank Initial / Final (inches)	2.282 / 2.131	
						Total	Treated - PU	13
Test 2 HOOPS Polyurethane	1	4	3125	244.4	7.8	Oil Type	HOOPS	
		2	3	2230	215	9.6	Ohmsett Test Number / Date	12.06 - Test 9
		3	4	2150	210	9.8	Speed (knots)	.1 to .12
		4	2	900	62.3	6.9	Bridge Spacing (feet)	10
		Untreated -PU	1	750	5	0.7	Post Oil Drag	100'
							Nozzle Configuration	6 x .042"
						Duration (min)	10.58	
						Flow Rate (gpm)	1.13	
						Pump Pressure (psi)	80	
						Tank Initial / Final (inches)	2.111 / 1.776	
						Total	Treated - PU	13
Test 3 HOOPS Polyurethane	1	4	2375	437.4	18.4	Oil Type	HOOPS	
		2	3	1650	369	22.4	Ohmsett Test Number / Date	12.06 - Test 10
		3	4	2140	280.8	13.1	Speed (knots)	0.12
		4	2	1000	81.4	8.1	Bridge Spacing (feet)	11
		Untreated -PU	1	760	0	0.0	Post Oil Drag	0'
							Nozzle Configuration	6 x .042"
						Duration (min)	11.88	
						Flow Rate (gpm)	1.02	
						Pump Pressure (psi)	80	
						Tank Initial / Final (inches)	1.784 / 1.446	
						Total	Treated - PU	13

Table S3.

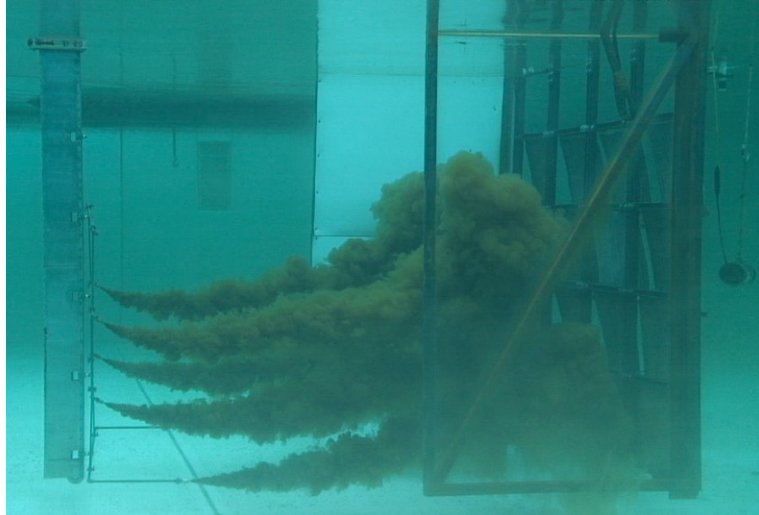
Test Number and Type	Row/Sample	Number of Foam Pads in each Row	Total Volume Collected (Oil+Water) (mL)	Volume of Oil Collected (mL)	Selectivity Ratio of Oil to Total Volume (%)	Testing Parameters	
Test 4 HOOPS Polyurethane	1	4	6850	779	11.4	Oil Type	HOOPS
	2	3				Ohmsett Test Number / Date	12.06 - Test 11
	3	4				Speed (knots)	0.2
	4	2				Bridge Spacing (feet)	15/11
	Untreated -PU	1	850	0	0.0	Post Oil Drag	0'
						Nozzle Configuration	6 x .042"
					Duration (min)	9.9	
					Flow Rate (gpm)	1.19	
					Pump Pressure (psi)	80	
					Tank Initial / Final (inches)	1.452 / 1.123	
Total	Treated - PU	13	6850	779	11.4		
Test 5 HOOPS Polyurethane	1	4	1490	218.4	14.7	Oil Type	HOOPS
	2	3	2600	160	6.2	Ohmsett Test Number / Date	12.07 - Test 12
	3	4	1725	168	9.7	Speed (knots)	0.2
	4	2	840	121.5	14.5	Bridge Spacing (feet)	11
	Untreated -PU	1	795	15	1.9	Post Oil Drag	30 sec
						Nozzle Configuration	8 x .042"
					Duration (min)	7.63	
					Flow Rate (gpm)	1.65	
					Pump Pressure (psi)	80	
					Tank Initial / Final (inches)	2.513 / 2.16	
Total	Treated - PU	13	6655	667.9	11.3		
Test 6 HOOPS Polyurethane	1	4	1650	296.5	18.0	Oil Type	HOOPS
	2	3	1275	240	18.8	Ohmsett Test Number / Date	12.07 - Test 13
	3	4	1800	304	16.9	Speed (knots)	0.2
	4	2	840	100	11.9	Bridge Spacing (feet)	11
	Untreated -PU	1	880	5	0.6	Post Oil Drag	
						Nozzle Configuration	8 x .042"
					Duration (min)	8.82	
					Flow Rate (gpm)	1.36	
					Pump Pressure (psi)	80	
					Tank Initial / Final (inches)	2.16 / 1.824	
Total	Treated - PU	13	5565	940.5	16.4		

Test Number and Type	Row/Sample	Number of Foam Pads in each Row	Total Volume Collected (Oil+Water) (mL)	Volume of Oil Collected (mL)	Selectivity Ratio of Oil to Total Volume (%)	Testing Parameters		
Test 7 HOOPS Polyurethane Polyimide PIG	1 - PU	4	1575	336	21.3	Oil Type	HOOPS	
	2 - PU	3	1275	262.2	20.6	Ohmsett Test Number / Date	12.07 - Test 14	
	4 - PU	2	815	10	1.2	Speed (knots)	0.2	
	3 - PIG	1	420	136.5	32.5	Bridge Spacing (feet)	11	
	3 - Polyimide	3	3425	1084.6	31.7	Post Oil Drag		
	Untreated - PU	1	610	10	1.6	Nozzle Configuration	8 x .042"	
						Duration (min)	8.92	
Total	All Treated	13	7510	1829.3	21.5	Flow Rate (gpm)	1.43	
	Polyurethane	9	3665	608.2	14.4	Pump Pressure (psi)	80	
	Polyimide	3	420	136.5	32.5	Tank Initial (inches)	1.826	
	PIG	1	270	136.5	32.5	Tank Final (inches)	1.47	
Test 8 Diesel Fuel Polyurethane Polyimide PIG	1 - PU	4	1400	317.5	22.7	Oil Type	DIESEL	
	2 - PU	3	1050	121.8	11.6	Ohmsett Test Number / Date	12.08 - Test 15	
	4 - PU	2	710	50	7.0	Speed (knots)	0.2	
	3 - PIG	1	220	20	9.1	Bridge Spacing (feet)	11	
	3 - PI	3	2325	69.4	3.0	Post Oil Drag		
	Untreated - PU	1	440	5	1.1	Nozzle Configuration	8 x .042"	
						Duration (min)	9.32	
Total	Treated - PU	9	3160	489.3	13.8	Flow Rate (gpm)	1.3	
						Pump Pressure (psi)	80	
Test 9 ANS Polyurethane Polyimide PIG	1 - PU	4	1915	375	19.6	Oil Type	ANS	
	2 - PU	3	1450	324	22.3	Ohmsett Test Number / Date	12.08 - Test 16	
	3 - PU	2	840	214.6	25.5	Speed (knots)	0.2	
	4 - PU	2	900	270	30.0	Bridge Spacing (feet)	11	
	3 - PIG	1	250	50	20.0	Post Oil Drag		
	3 - PI	1	900	55	6.1	Nozzle Configuration	8 x .042"	
	Untreated - PU	1	600	5	0.8	Duration (min)	9.02	
						Flow Rate (gpm)	0.96	
	Total	Treated - PU	11	5105	1183.6	24.4	Pump Pressure (psi)	80
							Tank Initial (inches)	3.43

Test Number and Type	Row/Sample	Number of Foam Pads in each Row	Total Volume Collected (Oil+Water) (mL)	Volume of Oil Collected (mL)	Selectivity Ratio of Oil to Total Volume (%)	Testing Parameters	
Test 10 ANS Polyurethane Polyimide PIG	1 - PU	4	1250	390.5	31.2	Oil Type	ANS
	2 - PU	3	1550	365	23.5	Ohmsett Test Number / Date	12.08 - Test 17
						Speed (knots)	0.2
	3 - PU	2	940	181.7	19.3	Bridge Spacing (feet)	11
						Post Oil Drag	
	4 - PU	2	780	171.6	22.0	Nozzle Configuration	8 x .042"
						Duration (min)	10.98
	3 - PIG	1	130	10	7.7	Flow Rate (gpm)	1.27
						Pump Pressure (psi)	80
	3 - PI	1	820	68	8.3	Tank Initial (inches)	3.178
Tank Final (inches)						2.787	
Untreated - PU	1	520	10	1.9			
Total	Treated - PU	11	4520	1108.8	24.0		
Test 11 ANS Polyurethane Polyimide PIG	1 - PU	4	1550	148.5	9.6	Oil Type	ANS
	2 - PU	3	1225	105	8.6	Ohmsett Test Number / Date	12.08 - Test 18
						Speed (knots)	0.1
	3 - PU	2	760	75	9.9	Bridge Spacing (feet)	11
						Post Oil Drag	
	4 - PU	2	625	75	12.0	Nozzle Configuration	8 x .042"
						Duration (min)	7.73
	3 - PIG	1	125	10	8.0	Flow Rate (gpm)	1.51
						Pump Pressure (psi)	80
	3 - PI	1	830	100	12.0	Tank Initial (inches)	2.787
Tank Final (inches)						2.46	
Untreated - PU	1	625	10	1.6			
Total	Treated - PU	11	4160	403.5	10.0		
Test 12 ANS Polyurethane Polyimide PIG	1 - PU	4	1725	80	4.6	Oil Type	ANS
	2 - PU	3	1290	62.5	4.8	Ohmsett Test Number / Date	12.09 - Test 19
						Speed (knots)	0.1
	3 - PU	2	825	90	10.9	Bridge Spacing (feet)	11
						Post Oil Drag	30 sec
	4 - PU	2	740	55	7.4	Nozzle Configuration	8 x .042"
						Duration (min)	8.55
	3 - PIG	1	160	10	6.3	Flow Rate (gpm)	1.49
						Pump Pressure (psi)	80
	3 - PI	1	810	40	4.9	Tank Initial (inches)	2.451
Tank Final (inches)						2.095	
Untreated - PU	1	820	10	1.2			
Total	Treated - PU	11	4580	287.5	7.0		

Test Number and Type	Row/Sample	Number of Foam Pads in each Row	Total Volume Collected (Oil+Water) (mL)	Volume of Oil Collected (mL)	Selectivity Ratio of Oil to Total Volume (%)	Testing Parameters	
Test 10 ANS Polyurethane Polyimide PIG	1 - PU	4	1250	390.5	31.2	Oil Type	ANS
	2 - PU	3	1550	365	23.5	Ohmsett Test Number / Date	12.08 - Test 17
						Speed (knots)	0.2
	3 - PU	2	940	181.7	19.3	Bridge Spacing (feet)	11
						Post Oil Drag	
	4 - PU	2	780	171.6	22.0	Nozzle Configuration	8 x .042"
						Duration (min)	10.98
	3 - PIG	1	130	10	7.7	Flow Rate (gpm)	1.27
						Pump Pressure (psi)	80
	3 - PI	1	820	68	8.3	Tank Initial (inches)	3.178
Tank Final (inches)						2.787	
Untreated - PU	1	520	10	1.9			
Total	Treated - PU	11	4520	1108.8	24.0		
Test 11 ANS Polyurethane Polyimide PIG	1 - PU	4	1550	148.5	9.6	Oil Type	ANS
	2 - PU	3	1225	105	8.6	Ohmsett Test Number / Date	12.08 - Test 18
						Speed (knots)	0.1
	3 - PU	2	760	75	9.9	Bridge Spacing (feet)	11
						Post Oil Drag	
	4 - PU	2	625	75	12.0	Nozzle Configuration	8 x .042"
						Duration (min)	7.73
	3 - PIG	1	125	10	8.0	Flow Rate (gpm)	1.51
						Pump Pressure (psi)	80
	3 - PI	1	830	100	12.0	Tank Initial (inches)	2.787
Tank Final (inches)						2.46	
Untreated - PU	1	625	10	1.6			
Total	Treated - PU	11	4160	403.5	10.0		
Test 12 ANS Polyurethane Polyimide PIG	1 - PU	4	1725	80	4.6	Oil Type	ANS
	2 - PU	3	1290	62.5	4.8	Ohmsett Test Number / Date	12.09 - Test 19
						Speed (knots)	0.1
	3 - PU	2	825	90	10.9	Bridge Spacing (feet)	11
						Post Oil Drag	30 sec
	4 - PU	2	740	55	7.4	Nozzle Configuration	8 x .042"
						Duration (min)	8.55
	3 - PIG	1	160	10	6.3	Flow Rate (gpm)	1.49
						Pump Pressure (psi)	80
	3 - PI	1	810	40	4.9	Tank Initial (inches)	2.451
Tank Final (inches)						2.095	
Untreated - PU	1	820	10	1.2			
Total	Treated - PU	11	4580	287.5	7.0		

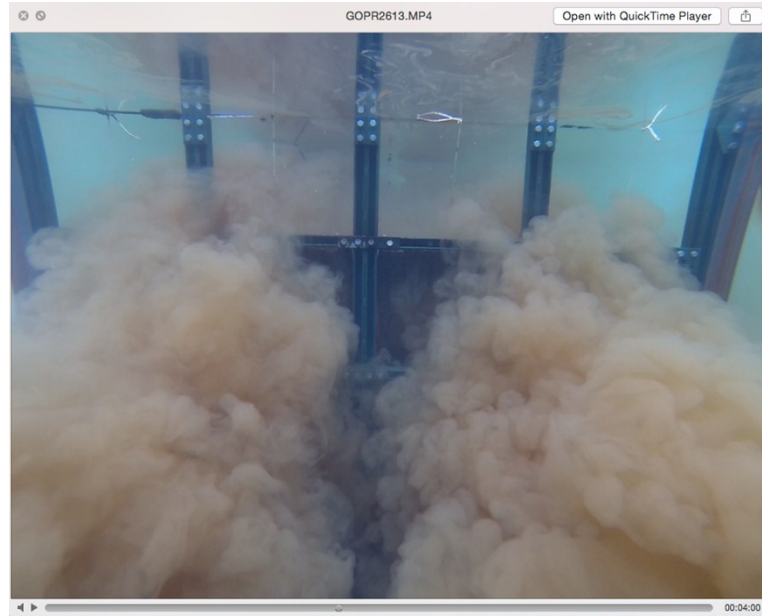
Supplementary Movie Captions.



Movie S1. Oil plume – side view. Oil plume (HOOPS crude), as viewed underwater from the side, perpendicular to the direction of travel during the test. The distance between nozzles and frame was 10 feet. Video sped up by 8 \times .



Movie S3. Oil plume frame view – orientation 1. Oil plume (ANS crude) as viewed underwater with the camera situated directly next to the foam pad frame. Movie is shown in real-time.



Movie S3. Oil plume frame view – orientation 2. Oil plume (HOOPS crude), as viewed from a position in front of the frame. Video is shown in real time.