Australian Government
Australian Maritime Safety Authority

MONTARA WELL RELEASE
TIMOR SEA

OPERATIONAL MONITORING STUDY O2

MONITORING OF OIL CHARACTER FATE AND EFFECTS

REPORT 03
DISPERSANT TREATED OIL DISTRIBUTION

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1.0 INTRODUCTION

This Report presents data obtained under the Operational Monitoring programme for the response to the Montara well release. It comprises part of Operational Monitoring Study 02 “Monitoring of Oil Character Fates and Effects”.

The information set out in this report is based on an analysis of water samples taken during a monitoring survey undertaken between 30th September and 9th October 2009 from the vessel “First Class”. This survey is referred to as “Study O2.1” in this report.

It also incorporates available fluorometric data obtained as part of the monitoring of dispersant operations; Operational Monitoring Study 04, “Monitoring of Dispersant Efficiency and Fate of Dispersed Oil”.

1.1 Rationale

Concerns have been expressed with regards the potential for hydrocarbons to enter the water column and to affect marine life. In particular, the distribution of dispersed oil has been a focus of concern. Water samples have been obtained during response operations and these have been analysed for dissolved, miscible or entrained hydrocarbons.

1.2 Study Objectives

Figure 1 Dispersant Application

A sampling survey was undertaken in order to:

- Collect high quality samples of surface oils for weathering and fates analysis (see AMSA Oil Reports No 1, No 4 and later reports).
- Collect water samples from the Timor Sea. These included samples from below surface oil slicks and from areas free of surface oil (“clean seas”) for analysis for hydrocarbons (see AMSA Oil Report No 2).
- Collect samples of water below dispersant treated oil slicks in order to:
  - Calibrate the fluorometric readings of dispersant operations and
  - To measure the distribution and persistence of hydrocarbons in the water column.

Calibration of fluorometric readings involved the determination of the hydrocarbon content of water samples with corresponding fluorometric readings. It was intended that this data would be used to translate past and future fluorometric data (both from the survey and from Study O4) into Total Petroleum Hydrocarbons (TPH, ppm) equivalents.

It should be noted that the determination of dispersant efficiency was not an objective of this study. This was covered by Operational Monitoring Study O4 (ref PTTEPAA, 2009).

This report presents and summarises the data obtained from the operational monitoring programmes and also assesses the strength (or otherwise) of the data presented. Comments and recommendations are also made in this report on the dispersant monitoring methods used.

2.0 METHODS

Methodology for this study is detailed in Leeder and Wardrop Consulting, 2009 and is summarised below.

2.1 Fluorometry

In order to obtain accurate fluorometric data the following samplings were required in the study:

- Background flourescence (no oil, no dispersant). These were to be taken at a fixed depth (1m or 2m depending on conditions) over a 12 or 24 hour period as some of the flourescent plankton periodically move up and down the water column. These samples were to be taken in waters not within the defined impact zone of the spill.
- Dispersant control: A reading of dispersant sprayed over clean water. This is used to detect any flourescence from the dispersant in seawater. This reading need not be taken on every occasion. One or two trial sprays are adequate for each type of dispersant use. Note: If this was not possible in the field then it was to be calculated in the laboratory.
- Oil only control (under oil before dispersant use). Taken under undisturbed surface oil slicks to detect the level of oil in the water column due to natural mixing (waves).
- Oil only in water in wake of response vessel. To detect oil in water as a result of vessel movements.
- Dispersed oil. Initial reading 15 minutes after spraying and then at intervals as per Table 1 until background levels are reached.

Readings were to be taken at the same depths as water samples (see Table 1).

Table 1 Summary of Sampling for Study of Dispersant Use

Sample Type	Background	Dispersant Control	Oil Only (Natural)	Oil & Vessel Mixing	Dispersed Oil in Water
Location	Un-impacted Area		Oiled Area: Dispersant Treatment Site		
Frequency	2 x Per Survey Period		Each Tested Dispersant Application		
Depths	Just below surface (0-0.5m), 1m, 2m, 3m. 5m and 10m if elevated hydrocarbons are noted at 3m and 20m if elevated hydrocarbons are notes at 5m.				
Duration of Reading	1 reading	15, 30 mins, then 1 hour intervals*	1 reading at each depth	15, 30 mins, then 1 hour intervals*	
Water Samples	As per frequency and depth (i.e. 20 samples)		2 x each sample type and as per depth (i.e. 30 samples)		

** Or continuous for 3 hours or until background readings have been reached.*

2.2 Water Sampling and Analysis

Samples of seawater were to be taken for analysis in order to relate field fluorometric readings to concentrations of oil, dispersant and dispersed oil.

Samples were extracted and initially analysed for total petroleum hydrocarbons (TPH). Those showing positive for TPH were to be further analysed for polyaromatic hydrocarbons (PAH).

2.3 Dispersant Efficacy Monitoring (Study O4)

Methods used for this earlier study were supplied by Oil Spill Response (OSR) and comprise an Operational Work Instruction (see OSR, undated) and the manual for the test apparatus (Turner Designs, 2004).

The methodology encompasses getting pre-dispersant application background readings as well as post application readings. Continuous readings over the survey areas are required.

Sampling depths are not stipulated.

3.0 RESULTS

The degree of interpretation of the data obtained during the field survey is limited due to:

- Limited field time available for sampling and monitoring of dispersant. Only 4 operations were monitored during the Study 2.1 survey.
- Use of different dispersants. Three dispersants were used in the 4 monitored operations (Ardrox 6120, Corexit 9500 and Tergo R-40). Corexit 9527 and Dasic Slickgone were also used in non-monitored operations.
- Methods of dispersant application varied between monitored operations. In some cases vessels were used to supply agitation to dispersant treated slicks but not in others.

Descriptions of each of the monitored dispersant operations is provided in Attachment A.

3.1 Fluorometry

As noted in Section 2, the depth of fluorometric readings was restricted to the top 5m of the water column due to the limitations of the equipment used.

Surface samples (<0.5m) were also sometimes not recorded due to wave action exposing the fluorometer probe resulting in inaccurate readings.

Fluorometry readings taken are provided in Attachment B and summarised in Tables 1 and 2.

Table 1 Summary Fluorometry Readings in "Clean" Seawater

Depth	Ave TCF Readings		
	Under Wax Film	Clean Seawater	Under Algae
0.5m	-	0.316	0.213
1m	0.815	0.325	0.348
2m	0.747	0.323	0.195
3m	0.800	0.333	0.182
4m	0.812	0.345	-
5m	0.644	-	0.186

Table 2 Summary Fluorometry Readings

Time after Use Dispersant		Ave TCF Readings		
		Min	Max	Ave
0min	1m	0.27	4.004	1.768
	2m	1.069	3.226	1.811
	3m	0.926	4.018	2.002
	4m	0.933	2.240	1.378
	5m	0.714	2.240	1.357
60min	1m	0.177	0.932	0.593
	2m	0.131	1.612	0.811
	3m	0.123	1.414	0.739
	4m	0.701	1.481	1.042
	5m	0.13	2.177	1.303
120min	1m	0.675	2.358	1.439
	2m	0.607	2.370	1.286
	3m	0.602	2.465	1.442
	4m	1.063	2.557	1.810
	5m	0.643	2.498	1.381

The number of "clean" readings taken within the impacted area was limited due to the widespread distribution of the waxy films. These are the residues from weathered oil.

The limited data provided in Table 1 does suggest an elevated fluorescence below the wax film but this is not supported by analysis of water samples (see also AMSA Oil Report No.2).

Fluorometry indicates a general increase after the application of dispersant although the increase is small and highly variable.

This data does not, in itself, indicate the distribution of the dispersed oil nor the concentration of hydrocarbons in underlying waters. In order to achieve the latter the fluorescent readings must be calibrated against measured hydrocarbons in the water samples (see Section 3.3).

Nor does the data indicate the degree of effectiveness of dispersant use.

In order for the data to allow such an assessment it is necessary to determine the meaning of fluorescence values in terms of oil concentration in the water column (e.g. TPH), the area of the dispersed oil plume over time and the volume of oil on the surface which was treated with dispersant.

3.2 Laboratory Analysis

Samples taken from below dispersant treated surface oil was analysed for TPH and is currently being analysed for PAHs. Samples were taken over a three hour period to detect delayed dispersion and also possible dilution of dispersed oil in water.

Data from three of the four monitored applications are shown in Figure 1.

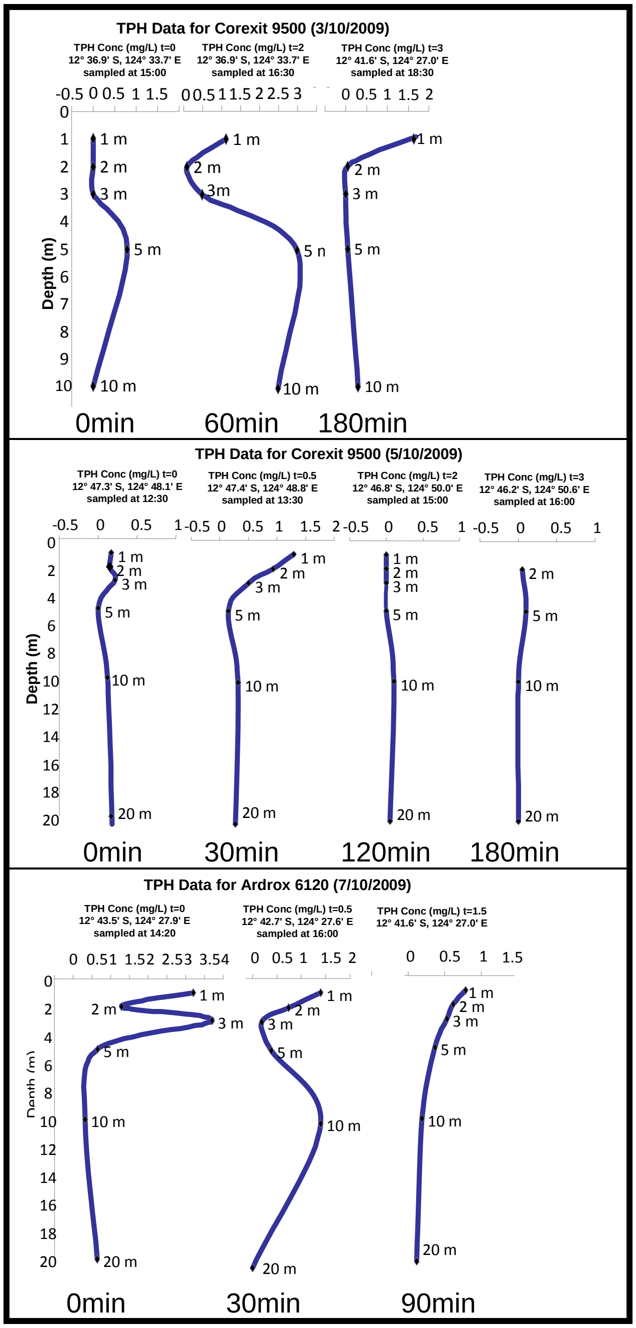
Tergo spraying operations are not shown as these indicate little or no dispersion (see Attachment A).

The top graph shows Corexit 9500 applied without vessel agitation and the middle graph shows the distribution with agitation. Although the differences in oil distribution at depth and overtime are evident it is not possible to explain these due to the limited data. Differences could be ascribed to:

- Different degrees of weathering of the treated oil and consequent differences in amenability to dispersant.
- Different thicknesses of treated slicks and consequences differences in volumes of oil treated and entering the water.
- Effects of agitation.
- Differences in natural processes influencing vertical distribution and dilution (waves, currents).

These could be resolved through additional monitoring of dispersant operations and/or monitoring of each operation over a wider area.

Figure 1 Dispersed Oil Distribution Graphs
(TPH units in ppm)



Nevertheless the graphs do show the distribution of hydrocarbons at depth and over time and provide indicative concentrations of hydrocarbons in the water column.

3.3 Comparison of Field Fluorometry and Laboratory Analysis

As noted in Section 1 it was intended that hydrocarbons in the water column would be measured using both fluorometric readings and laboratory analysis and that results would be compared in order to:

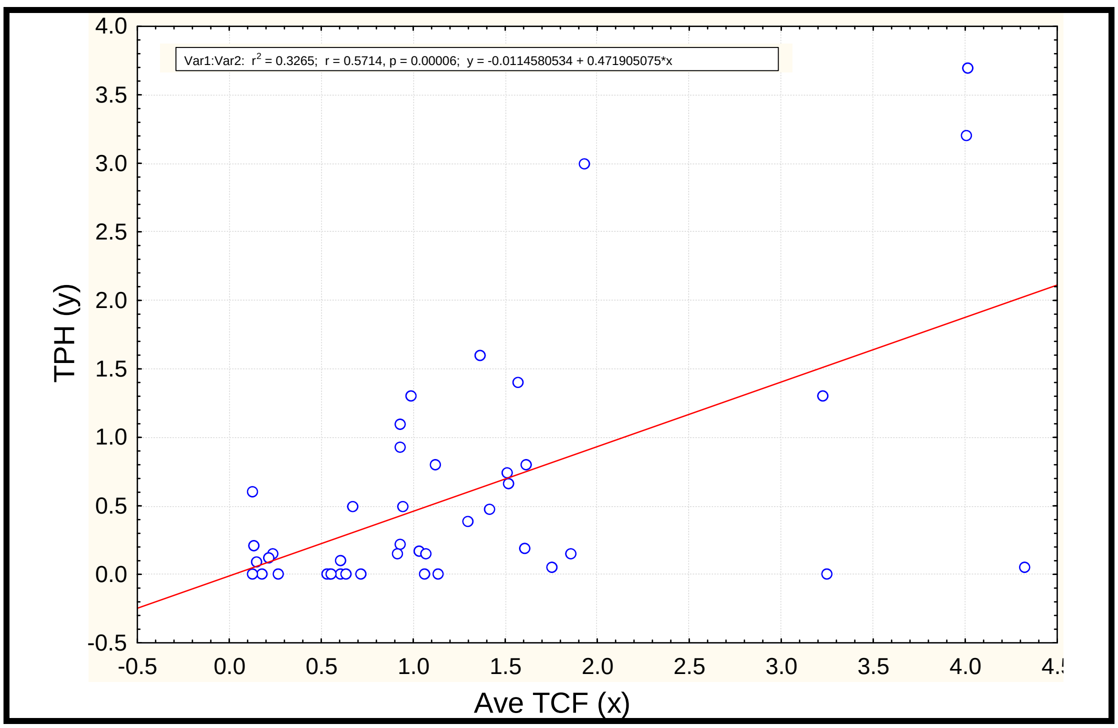
- Determine the relationship between the two data sets.
- Assess the suitability of fluorometry for field assessment of dispersant use.

Paired data is shown in Table 3 and compared graphically in Figure 2.

Table 3 Fluorometric and Corresponding Analytical Data for Paired Water Samples

Average TCF	TPH (ppm)	Average TCF	TPH (ppm)	Average TCF	TPH (ppm)	Average TCF	TPH (ppm)
4.004	3.200	0.714	0	0.551	0	3.248	0
3.226	1.300	0.985	1.3	0.27	0	1.752	0.05
4.018	3.700	0.929	0.93	1.139	0	0.177	0
1.518	0.660	0.942	0.5	1.063	0	0.131	0.21
1.568	1.400	0.918	0.15	1.118	0.8	0.123	0
1.511	0.740	0.675	0.5	0.932	1.1	0.13	0.6
1.609	0.190	0.607	0.1	1.612	0.8	1.857	0.15
1.299	0.390	0.602	0	1.414	0.48	0.237	0.15
1.031	0.17	0.631	0	1.934	3	0.217	0.12
1.069	0.15	0.544	0	1.363	1.6	0.148	0.09
0.926	0.22	0.53	0	4.325	0.05	3.248	0

Figure 2 Comparison of Field and Laboratory Data for Hydrocarbons in Water



TPH = Total Dissolved Hydrocarbons (ppm) laboratory data.
Ave TCF = Temperature corrected fluorescence.

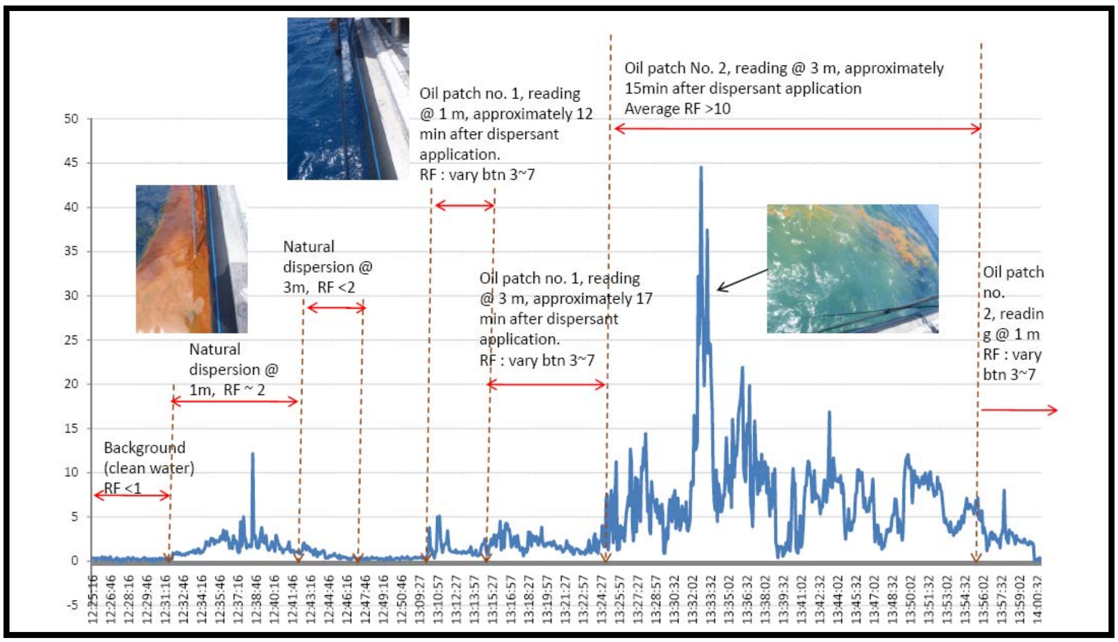
Correlation between TPH and field fluorometry readings is poor. This is probably due in part to the highly variable levels of non-hydrocarbon associated fluorescence; as indicated in Figure 2 by the readings along the “x” access (TPH=0). This is likely be due to natural fluorescence although the range of fluorescence readings is greater than the readings obtained in “clean” water samples (refer to Table 1). Other potential sources of difference could be due to:

- The presence of dispersant in the seawater. Laboratory analysis is currently assessing samples for dispersant. This may help resolve the cause of some of the observed lack of correlation but such analysis cannot be undertaken in the field.
- Time difference between fluorometric reading and obtaining of sample. This could resulting “drift” of the vessel or dispersed oil plume. Significant differences due to this would in any case cast doubt on the validity of “spot” sampling.

3.4 Fluorescence Data Obtained through Operational Study O4.

Only limited data from this programme has been received and reviewed to date, and so will be compared at a later date. Interpretation of the data in terms of measuring dispersant efficiency or the concentration or distribution of oil in the water column is not possible as no calibration against hydrocarbons in water appears to have been undertaken.

Figure 3 Indicative Field Report of Dispersion Operations (Study O4)



Data output does indicate elevated fluorescence after the application of dispersants and this, together with the before and after application data record shown in Figure 3 indicates that successful dispersion was achieved on this occasion (see also photo record in Attachment A).

It should be noted also that Study O4 reporting used Raw Fluorescence (RF) data whereas the Study O2.1 Survey reported Temperature Corrected Fluorescence (TCF). Whilst RF cannot be corrected to TCF now, the consequent error margins are considered small.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 Distribution and Fate of Dispersant Treated Oil

The chemical analysis of sampled waters suggests that concentrations of dispersed oil below treated slicks are low (<5ppm) and are rapidly diluted over depth and time (to <1ppm). However, the sample size of these readings is small and is not supported by longer term sampling.

The use of fluorescent data is problematic in that it cannot be correlated with measured hydrocarbons in water.

Recommendations

For environmental effects assessment purposes, the distribution and concentration of dispersed oil should be modelled using available 3D models. Water quality data from Study O.2.1, and if possible Study O4, should be used to check ("benchmark") model output.

In the absence of laboratory assessment of dispersant efficiencies of different dispersants under varying conditions and applied to varying oil weathering states are undertaken, modelling should assume the "worst case" conditions for water column effects (i.e. 100% effectiveness). Note: It is not possible to undertake the required laboratory studies within a reasonable timeframe.

4.2 Use of Fluorescence as a Field Measurement of Hydrocarbon Distribution

The use of dispersants use is of concern to a number of commercial and environmental organisations and this must be recognised. It is expected that reasonable measurement or predication of dispersed oil distribution and concentrations, supported by measurement, should be incorporated into oil spill planning, response and monitoring.

This has been done to a degree with the implementation of fluorescent monitoring (Study O4) although this is focussed mainly on measuring dispersant efficiency (see Section 4.2.2). Study O2.1 was focussed, in part, on determining dispersed oil distribution.

Neither study provided data enabling an accurate measurement of dispersed oil concentrations, duration, distribution (vertical or horizontal) or of plume trajectory. Supporting aerial; surveillance, if undertaken, may provide some indication of initial trajectory,

While the methods of Study O2.1 includes "controls" which allow for determination of contribution of vessel mixing to oil in water and influence of dispersant and natural fluorescence these take time and the cooperation of operational vessels. This cooperation requires a disruption of operations. If such a study is to be adopted then dispersant spraying protocols should be amended to ensure that they are an integral part of the approved and required procedure.

Study O2.1 methods allow for calibration of fluorometry and analytical data (TPH) but on the basis of the data from the current study this correlation would appear to be poor.

<u>Recommendations</u>

Monitoring of dispersed oil concentrations, duration, distribution (vertical or horizontal) or of plume trajectory should be undertaken as a key element of spill response operations. This requires that methods be incorporated into Standard Operating Procedures for dispersant use. This may be generally applicable or applied under certain conditions.

Alternative methods should be explored. In particular, the use of programmed or remotely controlled ROVs ("e.g. "gliders") with suitable sensors should be assessed. Such systems are currently available within Australia.

The need to be able to convert fluorometry or other field readings into hydrocarbon concentrations must be addressed.

4.3 Use of Fluorescence as a Field Measurement of Dispersant Efficiency

The methods used in Study O4 cannot provide an indication of dispersant efficiency. Apart from the problems noted in Section 4.2.1, the inability to accurately measure surface oil thickness or volumes means that even accurate measurement of oil concentrations in the water column cannot provide data to enable such a calculation.

Calculations of effectiveness must, therefore, rely on visual estimates of oil thicknesses and coverage. Inasmuch as these can be taken before and after dispersant application it would seem that a comparison of before and after observations would be as accurate as any based on fluorometry.

Visual observations were made from the dispersant vessels and these were supported by photographic evidence and "field testing" of the oil for dispersant effectiveness. Electronic transfer of digital images will often allow confirmation of observations from the Incident management Team within an operational timeframe. However, the use of the technique should be uniform in its application, undertaken regularly and formally documented.

Recommendations

The use of fluorometric methods for dispersant efficiency monitoring should be reassessed.

Existing visual assessments methods should be supported by more formal procedures and reporting requirements.

5.0 REFERENCES

- AMSA. 2009a. Monitoring of Oil Character, Fate and Effects Report 01: Oil Character.
- AMSA. 2009b. Monitoring of Oil Character, Fate and Effects Report 02: Water Quality.
- Leeder Consulting. 2009. West Atlas Oil Spill Water Sampling. Report M091522B Prepared for Australian Maritime Safety Authority 22nd October, 2009.
- Leeder Consulting and Wardrop Consulting. 2009. Monitoring Study O2: Monitoring of Oil Fates and Effect. Study Design and Scope. Document No. Montara 04-02.
- Oil Spill Response (OSR). Undated. Operational Work Instruction.
- PTTEPAA. 2009. Monitoring Plan for the Montara Well Release Timor Sea. Document No. PTTEPPAA 04.
- Turner Designs. 2004. SCUFA (Self-contained Underwater Fluorescence Apparatus) User's Manual. Revision 2.3, P/N 998-2002.

ATTACHMENT A: INDIVIDUAL DISPERSANT APPLICATION DESCRIPTIONS AND RESULTS (STUDY O2.1 SURVEY)

Note: All results are in mg/L. nd = not detected (<0.01 mg/L)

A.1		
	Location	**12° 45.4' S, 124° 33.6' E (Initial)**
	Dispersant	**Tergo R-40**
	Operation	A series of water samples was collected from beneath a slick of fresh and emulsified oil on the 1st of October, beginning at 11:00. Dispersant was sprayed over the slick at around 11:10. There was no wind to provide mechanical agitation, and conditions were very still. No agitation was supplied by the vessel.
	Results	

Time	Depth	1m	2m	3m	5m	10	20m
	Sample ID	**2009020369**	**2009020368**	**2009020367**	**2009020366**	**-**	**-**
0 min	TPH C6-C9	nd	nd	nd	nd	-	-
	TPH C10-C14	nd	nd	nd	0.01	-	-
	TPH C15-C28	nd	0.14	nd	0.39	-	-
	TPH C29-C36	nd	0.06	nd	0.21	-	-
	Total TPH	**nd**	**0.21**	**nd**	**0.60**	**-**	**-**
10 min	**Sample ID**	**2009020374**	**2009020373**	**2009020372**	**2009020371**		
	TPH C6-C9	nd	nd	nd	nd	-	-
	TPH C10-C14	nd	nd	nd	nd	-	-
	TPH C15-C28	0.15	0.15	0.12	0.09	-	-
	TPH C29-C36	nd	nd	nd	nd	-	-
	Total TPH	**0.15**	**0.15**	**0.12**	**0.09**	**-**	**-**

A1.1 Top Left: Fresh and emulsified oil slick, no dispersant. Taken at 10:00.

A1.2 Top Right: Dispersant (Tergo) being sprayed onto the oil slick.

A1.3 Right: Surface oil after Tergo dispersant application. Taken 15mins after application.

A.2		
	Location	**12° 36.9' S, 124° 33.7' E (Initial)**
	Dispersant	**Corexit 9500**
	Operation	Dispersant was sprayed over the slick at around 15:30. There was no wind to provide mechanical agitation, and conditions were very still. 3rd October, 2009.
	Results	

Time	Depth	1m	2m	3m	5m	10	20m
	Sample ID	**2009020392**	**2009020393**	**2009020394**	**2009020395**	**2009020396**	**-**
0 min	TPH C6-C9	nd	nd	nd	nd	nd	-
	TPH C10-C14	nd	nd	nd	0.03	nd	-
	TPH C15-C28	nd	nd	nd	0.53	nd	-
	TPH C29-C36	nd	nd	nd	0.24	nd	-
	Total TPH	**nd**	**nd**	**nd**	**0.80**	**nd**	-
	Sample ID	**2009020398**	**2009020399**	**2009020400**	**2009020401**	**2009020402**	**-**
60 min	TPH C6-C9	nd	nd	nd	nd	nd	-
	TPH C10-C14	0.03	nd	nd	0.06	0.07	-
	TPH C15-C28	0.74	0.08	0.36	1.9	1.6	-
	TPH C29-C36	0.34	nd	0.13	1.0	0.78	-
	Total TPH	**1.1**	**0.08**	**0.48**	**3.0**	**2.5**	-
	Sample ID	**2009020404**	**2009020405**	**2009020406**	**2009020407**	**2009020408**	**-**
180 mins	TPH C6-C9	nd	nd	nd	nd	nd	-
	TPH C10-C14	0.11	nd	nd	nd	0.01	-
	TPH C15-C28	1.2	0.05	nd	0.05	0.22	-
	TPH C29-C36	0.37	nd	nd	nd	0.08	-
	Total TPH	**1.6**	**0.05**	**nd**	**0.05**	**0.30**	**-**

A2.1 Left: Fresh and emulsified oil slick – no dispersant. 14:45, 3rd October 2009

A2.2 Bottom Left: Oil slick one hour after dispersant (Corexit 9500) spray. 16:30, 3rd October 2009

A2.3 Bottom Right: Oil slick two hours after dispersant (Corexit 9500) spray. 17:30, 3rd October 2009

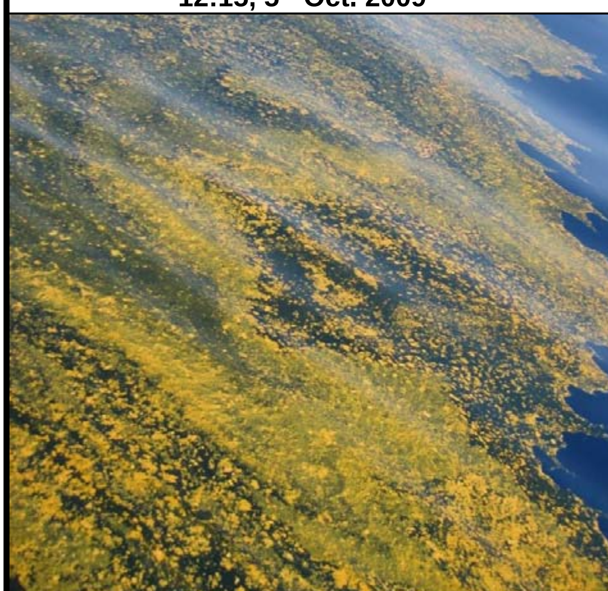
A2.4 Above: Oil slick three hours after dispersant (Corexit 9500) spray. 18:30, 3rd October 2009

A3.1 Right: Sampling surface films from oil slick two hours after dispersant (Corexit 9500) spray. 15:00, 5th October 2009 (see next page)

A.3		
	Location	**12° 47.3' S, 124° 48.1' E (Initial)**
	Dispersant	**Corexit 9500**
	Operation	A series of water samples was collected from beneath a slick of fresh and emulsified oil on the 5th of October, beginning at 12:30. Dispersant was sprayed over the slick between 12:45 and 13:00. Conditions were very still, and there was no wind to provide mechanical agitation. Agitation was applied by driving the vessel in and out of the slick for five minutes.
	Results	

Time	**Depth**	**1m**	**2m**	**3m**	**5m**	**10**	**20m**
	Sample ID	**2009020427**	**2009020428**	**2009020429**	**2009020430**	**2009020431**	**2009020432**
0 min	TPH C6-C9	nd	nd	nd	nd	nd	nd
	TPH C10-C14	nd	nd	nd	nd	nd	nd
	TPH C15-C28	0.11	0.09	0.12	nd	0.05	0.09
	TPH C29-C36	0.06	0.06	0.10	nd	0.07	0.08
	Total TPH	**0.17**	**0.15**	**0.22**	**nd**	**0.12**	**0.17**
30 min	**Sample ID**	**2009020434**	**2009020435**	**2009020436**	**2009020437**	**2009020438**	**2009020439**
	TPH C6-C9	nd	0.01	nd	nd	nd	nd
	TPH C10-C14	0.09	0.07	0.02	nd	nd	nd
	TPH C15-C28	0.79	0.52	0.34	0.10	0.21	0.18
	TPH C29-C36	0.42	0.32	0.15	0.05	0.11	0.08
	Total TPH	**1.3**	**0.93**	**0.50**	**0.15**	**0.32**	**0.27**
120 min	**Sample ID**	**2009020441**	**2009020442**	**2009020443**	**2009020444**	**2009020445**	**2009020446**
	TPH C6-C9	nd	nd	nd	nd	nd	nd
	TPH C10-C14	nd	nd	nd	nd	nd	nd
	TPH C15-C28	nd	nd	nd	nd	0.05	0.05
	TPH C29-C36	nd	nd	nd	nd	0.05	nd
	Total TPH	**nd**	**nd**	**nd**	**nd**	**0.10**	**0.05**
180 min	**Sample ID**	**-**	**2009020448**	**2009020449**	**2009020450**	**2009020451**	**2009020448**
	TPH C6-C9	-	nd	nd	nd	nd	nd
	TPH C10-C14	-	nd	nd	nd	nd	nd
	TPH C15-C28	-	0.05	0.05	nd	nd	0.05
	TPH C29-C36	-	nd	0.05	nd	nd	nd
	Total TPH	**-**	**0.05**	**0.10**	**nd**	**nd**	**0.05**

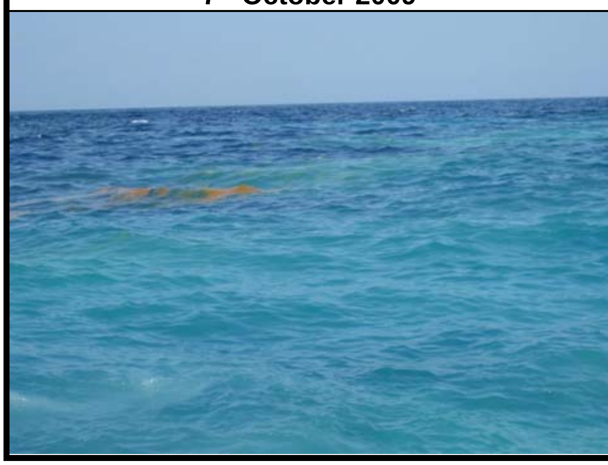
A3.2 Oil slick before dispersant spray. 12:15, 5th Oct. 2009



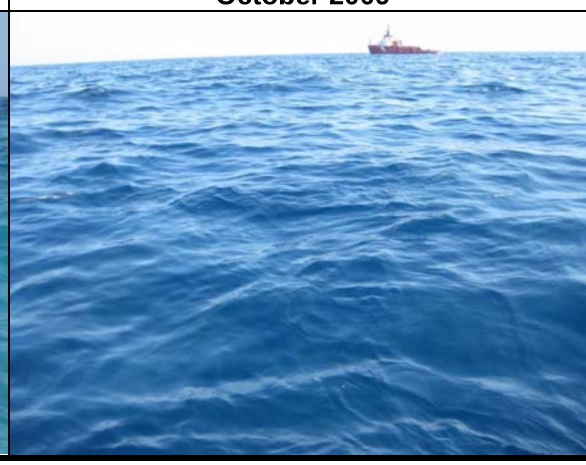
A3.3 Oil slick immediately after dispersant (Corexit 9500) spray.13:00, 5th Oct. 2009

A.4	Location	12° 43.5' S, 124° 27.9' E							
	Dispersant	Ardrox 6120							
	Operation	Dispersant was sprayed over the slick between 15:10 and 15:30. A 5 to 10 knot wind provided mechanical agitation, with waves of around 0.5 m height. 07/10/09							
	Results	Time	Depth	1m	2m	3m	5m	10	20m
			Sample ID	2009020 458	2009020 459	2009020 460	2009020 461	2009020 462	2009020 463
		0 min	TPH C6-C9	nd	nd	nd	nd	nd	nd
			TPH C10-C14	0.26	0.11	0.37	0.06	0.01	0.02
			TPH C15-C28	2.2	0.97	2.5	0.34	0.22	0.47
			TPH C29-C36	0.71	0.24	0.90	0.26	0.09	0.14
			Total TPH	**3.2**	**1.3**	**3.7**	**0.66**	**0.32**	**0.64**
		30 min	Sample ID	2009020 468	2009020 469	2009020 470	2009020 471	2009020 472	2009020 473
			TPH C6-C9	nd	nd	nd	nd	nd	nd
			TPH C10-C14	0.06	0.03	nd	nd	0.10	nd
			TPH C15-C28	1.0	0.50	0.13	0.26	0.94	nd
			TPH C29-C36	0.35	0.21	0.07	0.13	0.33	nd
			Total TPH	**1.4**	**0.74**	**0.19**	**0.39**	**1.4**	**nd**
		90 mins	Sample ID	2009020 475	2009020 476	2009020 477	2009020 478	2009020 479	2009020 480
			TPH C6-C9	nd	nd	nd	nd	nd	nd
			TPH C10-C14	0.03	0.02	0.02	0.01	nd	nd
			TPH C15-C28	0.56	0.47	0.37	0.28	0.13	0.12
			TPH C29-C36	0.20	0.13	0.13	0.08	0.06	nd
			Total TPH	**0.79**	**0.62**	**0.53**	**0.37**	**0.19**	**0.12**

A4.1 Oil slick approximately ten minutes after dispersant (Ardrox 6120) spray.15:30, 7th October 2009



A4.2 Oil slick area ninety minutes after dispersant (Ardrox 6120) spray.16:50, 7th October 2009



ATTACHMENT B: FIELD FLUOROMETRY RESULTS
STUDY O2.1 SURVEY

Date	Condition/ Treatment	Site No	Time after Spray (min)	Depth (m)	Time	Average RF	Average TCF	LAT	LONG	Comment/ Description
7-Oct-09	O	7-10-01.	N/A	0.5	-	-	-	-	-	Small and broken oil, yellow waxy lumps and sheen. Not treated with dispersant. 15knot wind. ½-1 m wave height. Measurements taken within patch of oil- appeared weathered and very waxy, forming small yellow lumps.
				1	13:06:55	0.540	0.554	1243.7119S	12431.8708	
				2	13:04:25	0.520	0.533	1243.7216S	12431.8716	
				3	12:53:00	0.509	0.523	1243.77S	12431.89	
				4	12:58:00	0.517	0.53	1243.75S	12431.88	
				5	13:01:30	0.523	0.536	1243.734S	12431.8758	
	CI	7-10-02.	N/A	1	14:57:00	0.792	0.815	1243.1895S	12428.0428	Water with the slight sheen that appears to be across whole area.
				2	14:59:15	0.726	0.747	1243.1521S	12428.0426	
				3	15:01:35	0.777	0.800	1243.1106S	12428.0393	
				4	15:03:55	0.790	0.812	1243.0721S	12428.0345	
				5	15:06:30	0.627	0.644	1243.0271S	12428.028	
	DA		0mins	1	14:16:20	3.890	4.004	1243.7385S	12427.9589	15knot wind. ½-1 m wave height. Measurements taken within oil slick- appeared fresh and orange coloured. Not yet weathered, broken up into patches and windrows, varying in thickness. Dispersant sprayed at 15:06. Pre dispersant application.
				2	14:19:05	3.135	3.226	1243.7032S	12427.9517	
				3	14:21:30	3.905	4.018	1243.6696S	12427.9458	
				4	14:23:50	2.177	2.240	1243.6459S	12427.9394	
				5	14:26:20	1.475	1.518	1243.6164S	12427.9309E	
	DA		15mins	0.5						Large area. 2-5% coverage. Orange coloured. Fresh, broken patches and forming windrows. Following spray some milky patches were seen- likely to be overspray. Cloudy brown patches observed around 15mins after dispersant application surrounding around the oil slick. After 60min some oil patches were still noticeable- after 120 mins these had disappeared.
				1	15:36:20	7.454	7.674	1242.7189S	12427.7881E	
				2	15:38:50	9.307	9.585	1242.6729S	12427.7792E	
				3	15:41:55	1.982	2.040	1242.6167S	12427.7699E	
				4	15:44:30	1.502	1.545	1242.5974S	12427.7654E	
				5	15:47:00	1.226	1.262	1242.5553S	12427.7543E	

7-Oct-09	DA	7-10-02	15mins	1	15:51:05	1.525	1.568	1242.4897S	12427.7114E	
				2	15:53:50	1.467	1.511	1242.4567S	12427.6933E	
				3	15:56:10	1.563	1.609	1242.4189S	12427.679E	
				4	15:58:35	1.302	1.340	1242.3844S	12427.661E	
				5	16:01:05	1.262	1.299	1242.3467S	12427.6368	
				1	16:21:05	1.897	1.954	1242.2054S	12427.4358	
				2	16:23:55	1.914	1.972	1242.1652S	12427.4135E	
				3	16:28:20	1.987	2.047	1242.1032S	12427.3722E	
				4	16:30:40	2.052	2.112	1242.0668S	12427.3468	
	DA		60 mins	5	16:33:00	2.114	2.177	1242.0288S	12427.3197E	
	DA		120 mins	1	16:47:05	2.288	2.358	1241.8286S	12427.1704E	
				2	16:49:40	2.300	2.370	1241.7892S	12427.1432E	
	DA		120 mins	3	16:52:05	2.393	2.465	1241.7525S	12427.1167E	
				4	16:54:25	2.482	2.557	1241.7171S	12427.0879E	
				5	16:57:15	2.425	2.498	1241.6751S	12427.055E	
5-Oct-09	O	5-10-01	0 mins	0.5	12:16		2.779	12 47.2 S	124 48.0 E	Untreated oil slick
				1	12:20		1.031	12 47.2 S	124 48.0 E	
				2	12:22		1.069	12 47.2 S	124 48.0 E	
				3	12:24		0.926	12 47.2 S	124 48.0 E	
				4	12:27		0.933	12 47.2 S	124 48.0 E	
				5	12:29		0.714	12 47.2 S	124 48.0 E	
	DC		15 mins	0.5	13:17		3.301	12 47.5 S	124 48.7 E	Oil slick 15 mins after spray with Corexit 9500 (agitation using boat, little wind)
				1	13:19		2.043	12 47.5 S	124 48.7 E	
				2	13:21		1.959	12 47.5 S	124 48.7 E	
				3	13:24		1.869	12 47.5 S	124 48.7 E	
				4	13:26		1.738	12 47.5 S	124 48.7 E	
				5	13:29		1.292	12 47.5 S	124 48.7 E	

5-Oct-09	DC	5-10-01	30 mins	0.5	13:32		2.559	12 47.4 S	124 49.0 E	Oil slick 30 mins after dispersant spray
				1	13:34		0.985	12 47.4 S	124 49.0 E	
				2	13:36		0.929	12 47.4 S	124 49.0 E	
				3	13:39		0.942	12 47.4 S	124 49.0 E	
				4	13:41		0.952	12 47.4 S	124 49.0 E	
				5	13:44		0.918	12 47.4 S	124 49.0 E	
	DC		60 mins	0.5	14:02		0.775	12 47.3 S	124 49.3 E	Oil slick 1 hour after dispersant spray
				1	14:05		0.671	12 47.3 S	124 49.3 E	
				2	14:07		0.691	12 47.3 S	124 49.3 E	
				3	14:09		0.679	12 47.3 S	124 49.3 E	
				4	14:12		0.701	12 47.3 S	124 49.3 E	
	DC		60 mins	5	14:14		0.759	12 47.3 S	124 49.3 E	See above
	DC		120 mins	0.5	15:01		0.712	12 46.8 S	124 50.0 E	Oil slick 2 hours after dispersant spray
				1	15:03		0.675	12 46.8 S	124 50.0 E	
				2	15:06		0.607	12 46.8 S	124 50.0 E	
				3	15:09		0.602	12 46.8 S	124 50.0 E	
				4	15:11		0.631	12 46.8 S	124 50.0 E	
				5	15:13		0.643	12 46.8 S	124 50.0 E	
	DC		180 mins	0.5	16:01		0.608	12 46.2 S	124 50.7 E	Oil slick 3 hours after dispersant spray
				1	16:03		0.608	12 46.2 S	124 50.7 E	
				2	16:05		0.544	12 46.2 S	124 50.7 E	
				3	16:08		0.53	12 46.2 S	124 50.7 E	
				4	16:10		0.522	12 46.2 S	124 50.7 E	
				5	16:12		0.551	12 46.2 S	124 50.7 E	
3-Oct-09	O	3-10-01	0 mins	0.5	14:38		15.746	12 37.2 S	124 33.6 E	Untreated oil slick
				1	14:34		0.27	12 37.2 S	124 33.6 E	
				2	14:48		1.139	12 37.2 S	124 33.6 E	
				3	14:45		1.063	12 37.2 S	124 33.6 E	
				4	14:43		0.963	12 37.2 S	124 33.6 E	
				5	14:40		1.118	12 37.2 S	124 33.6 E	

3-Oct-09	DC	3-10-01	15 mins	0.5	15:45		15.783	12 36.3 S	124 34.9 E	Oil slick 15 mins after spray with Corexit 9500 (no agitation, little wind)
				1	15:43		0.568	12 36.3 S	124 34.9 E	
				2	15:55		1.537	12 36.3 S	124 34.9 E	
				3	15:53		0.947	12 36.3 S	124 34.9 E	
				4	15:50		0.522	12 36.3 S	124 34.9 E	
				5	15:47		0.469	12 36.3 S	124 34.9 E	
	DC		30 mins	0.5	16:00		4.461	12 36.1 S	124 34.0 E	Oil slick 30 mins after dispersant spray
				1	15:57		1.732	12 36.1 S	124 34.0 E	
				2	16:09		1.344	12 36.1 S	124 34.0 E	
				3	16:07		1.524	12 36.1 S	124 34.0 E	
	DC		30 mins	4	16:05		0.682	12 36.1 S	124 34.0 E	See above
				5	16:02		0.498	12 36.1 S	124 34.0 E	
	DC		60 mins	0.5	16:30		8.318	12 35.8 S	124 34.1 E	Oil slick 1 hour after dispersant spray
				1	16:28		0.932	12 35.8 S	124 34.1 E	
				2	16:39		1.612	12 35.8 S	124 34.1 E	
				3	16:37		1.414	12 35.8 S	124 34.1 E	
				4	16:35		1.481	12 35.8 S	124 34.1 E	
				5	16:32		1.934	12 35.8 S	124 34.1 E	
	DC		120 mins	0.5	17:35		3.09	12 35.7 S	124 34.3 E	Oil slick 2 hours after dispersant spray
				1	17:32		1.285	12 35.7 S	124 34.3 E	
				2	17:44		0.882	12 35.7 S	124 34.3 E	
				3	17:42		1.26	12 35.7 S	124 34.3 E	
				4	17:40		1.063	12 35.7 S	124 34.3 E	
				5	17:37		1.002	12 35.7 S	124 34.3 E	
	DC		180 mins	0.5	18:39		32.516	12 35.9 S	124 34.6 E	Oil slick 3 hours after dispersant spray
				1	18:36		1.363	12 35.9 S	124 34.6 E	
				2	18:48		4.325	12 35.9 S	124 34.6 E	
				3	18:46		3.248	12 35.9 S	124 34.6 E	
				4	18:44		1.785	12 35.9 S	124 34.6 E	
				5	18:41		1.752	12 35.9 S	124 34.6 E	

3-Oct-09	O	3-10-02		0.5	13:12		0.71	12 34.5 S	124 34.3 E	Mainly sheen, some particles
				1	13:10		0.042	12 34.5 S	124 34.3 E	
				2	13:22		0.023	12 34.5 S	124 34.3 E	
				3	13:19		0.04	12 34.5 S	124 34.3 E	
				4	13:17		0.018	12 34.5 S	124 34.3 E	
				5	13:15		-0.013	12 34.5 S	124 34.3 E	
	O	3-10-03		0.5	13:39		0.51	12 34.4 S	124 34.7 E	Thin brown/yellow slick
				1	13:35		0.189	12 34.4 S	124 34.7 E	
				2	13:50		0.163	12 34.4 S	124 34.7 E	
	O			3	13:47		0.08	12 34.4 S	124 34.7 E	Thin brown/yellow slick
				4	13:45		0.112	12 34.4 S	124 34.7 E	
				5	13:42		0.062	12 34.4 S	124 34.7 E	
	O	3-10-04		0.5	11:10		0.05	12 29.8 S	124 35.2 E	Mainly sheen, some particles
				1	11:06		0.017	12 29.8 S	124 35.2 E	
				2	11:20		0.033	12 29.8 S	124 35.2 E	
				3	11:18		0.026	12 29.8 S	124 35.2 E	
				4	11:15		0.016	12 29.8 S	124 35.2 E	
				5	11:13		0.005	12 29.8 S	124 35.2 E	
	O	3-10-05		0.5	12:20		0.069	12 32.2 S	124 34.8 E	Mainly sheen, some particles
				1	12:17		0.081	12 32.2 S	124 34.8 E	
				2	12:30		0.076	12 32.2 S	124 34.8 E	
				3	12:27		0.064	12 32.2 S	124 34.8 E	
				4	12:25		0.011	12 32.2 S	124 34.8 E	
				5	12:22		0.027	12 32.2 S	124 34.8 E	
	O	3-10-06		0.5	9:03		0.833	12 24.4 S	124 36.5 E	White fine particles
				1	9:16		0.016	12 24.4 S	124 36.5 E	
				2	9:13		0.025	12 24.4 S	124 36.5 E	
				3	9:11		-0.012	12 24.4 S	124 36.5 E	
				4	9:09		0.029	12 24.4 S	124 36.5 E	
				5	9:06		-0.003	12 24.4 S	124 36.5 E	

3-Oct-09	O	3-10-07		0.5	9:44		0.06	12 26.8 S	124 35.8 E	White fine particles
				1	9:42		0.06	12 26.8 S	124 35.8 E	
				2	9:55		0.011	12 26.8 S	124 35.8 E	
				3	9:52		0.028	12 26.8 S	124 35.8 E	
				4	9:50		0.032	12 26.8 S	124 35.8 E	
				5	9:47		0.009	12 26.8 S	124 35.8 E	
	O	3-10-08		0.5	8:28		0.405	12 22.9 S	124 36.9 E	White fine particles
				1	8:42		0.046	12 22.9 S	124 36.9 E	
				2	8:40		0.049	12 22.9 S	124 36.9 E	
				3	8:37		0.028	12 22.9 S	124 36.9 E	
				4	8:34		0.025	12 22.9 S	124 36.9 E	
				5	8:31		0.019	12 22.9 S	124 36.9 E	
1-Oct-09	O	1-10-01	0 mins	0.5	10:55		0.593	12 45.4 S	124 33.5 E	Untreated oil slick (pre-spray)
				1	10:52		0.177	12 45.4 S	124 33.5 E	
				2	10:50		0.131	12 45.4 S	124 33.5 E	
				3	10:48		0.123	12 45.4 S	124 33.5 E	
				5	10:45		0.13	12 45.4 S	124 33.5 E	
	DT		30 mins	0.5	11:13		1.025	12 45.3 S	124 33.7 E	Treated oil slick (post spray) with Tergo. No agitation, calm weather.
				1	11:18		1.857	12 45.3 S	124 33.7 E	
				2	11:20		0.237	12 45.3 S	124 33.7 E	
				3	11:23		0.217	12 45.3 S	124 33.7 E	
				5	11:26		0.148	12 45.3 S	124 33.7 E	
	O	1-10-02	N/A	1	15:40		0.761	12 42.4 S	124 33.8 E	Untreated oil slick
				2	15:42		0.201	12 42.4 S	124 33.8 E	
				3	15:44		0.202	12 42.4 S	124 33.8 E	
30-Sep-09	U	30-09-01	N/A	0.5	17:35		0.213	12 36.2 S	126 49.6 E	Reading taken under algae like slick
				1	17:32		0.348	12 36.2 S	126 49.6 E	
				2	17:29		0.195	12 36.2 S	126 49.6 E	
				3	17:27		0.182	12 36.2 S	126 49.6 E	
				5	17:24		0.186	12 36.2 S	126 49.6 E	

30-Sep-09	CI	30-09-02	N/A	0.5	19:30		0.316	12 37.3 S	126 30.3 E	Reading taken in clean water
				1	19:28		0.325	12 37.3 S	126 30.3 E	
				2	19:25		0.323	12 37.3 S	126 30.3 E	
				3	19:22		0.333	12 37.3 S	126 30.3 E	
				5	19:20		0.345	12 37.3 S	126 30.3 E	See above

RF = Raw Fluorescence

TCF = Temperature Corrected Fluorescence

TRB = Turbidity

TEMP = Temperature (Water)

D = Dispersant only. No oil.

DU= Dispersant Treated. Dispersant Unknown

DA = Dispersant treated; Ardrox 6120

DD = Dispersant Treated; Dasic Slickgone

DT = Dispersant Treated; Tergo R40

DP = Physically dispersed oil (e.g. vessel wake)

CU= Control, Clean water in unimpacted areas

CI = Control. Clean water within impacted area

NT = Sample not taken due to sea state. turbulence or other factor

N/A = Not Applicable

O = Under surface oil slick

U = Under unknown surface material