MkII Airborne Laser Fluorosensor Survey Reprocessing And Interpretation Report: Arafura Sea, Australia

Prepared For
AGSO – Geoscience Australia

June 2001

Record 2001/22

AGSOCAT No. 35926

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Date:	June 2001

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ISSN: 1039-0073
ISBN: 0 642 467013

Bibliographic reference: Cowley, R., 2001. MkII Airborne Laser Fluorosensor Survey Reprocessing And Interpretation Report: Arafura Sea, Australia. AGSO – Geoscience Australia, Record 2001/22. AGSOCAT NO. 35926.

Contents

Summary

The Arafura Sea airborne laser fluorosensor (ALF) MkII survey was flown in 1989 by BP. The survey was designed to detect natural oil seepage over a region of the Arafura Sea, Northern Australia, in an effort to refine the petroleum prospectivity assessment.

An area of about 400km by ~150km was surveyed at 5km line spacing. A total of 534,022 fluorosensor spectra were recorded.

This report is a re-interpretation of the BP data by Signalworks Pty Ltd using the *ALF Explorer™* software. A total of 1894 fluors were picked out of the 534,022 recorded spectra in the final interpretation. This is an average fluor density of 3.55 fluors per thousand spectra.

The fluorescence response over most of the survey area consisted mainly of relatively low confidence fluors (compared to the more reliable MkIII survey data).

While fluor density variations can be seen on the fluor map the geological implications are not clear. Because of its susceptibility to noise, the MkII ALF system produces less confident fluor maps than the MkIII system. Some mapped fluor density variations may be influenced by sea state or water property variations.

1. Introduction

The Arafura Sea airborne laser fluorosensor (ALF) MkII survey (Figure 1) was flown in 1989 by BP. The MkII system used a 308nm laser wavelength, which is longer than the 266nm used in the later MkIII system. The Raman peak wavelength is 344nm (293nm MkIII) and the fluorescence region is 370nm to 580nm (320nm to 580nm MkIII).

Each recorded spectrum is the average of ten detected spectra. The averaging was done by BP to reduce the data recording rate, which was limited by the available 1980's hardware. The MkIII system uses faster hardware and records all detected spectra without averaging.

This report presents a re-interpretation of the original BP data using the *ALF Explorer™* software that consists of a database linked to a set of data processing, analysis and display modules. BP documented the original data processing and interpretation in report by Williams and Mackintosh (1990*).

83 lines were acquired at line spacings of about 5,000m in a N-S orientation (Figure 2) and a flying height of 100m. A total of 534,022 spectra were collected at an average spacing of 15m to 21m. About 9,300 km of line data were acquired.

Some lines in a MkII ALF survey may use the same Line and Point values as other lines. The main ALF data table in the *ALF Explorer™* database (RawAlfData) uses the Line and Point fields as key fields, which cannot contain duplicates. Lines that contain duplicated Line and Point values are stored in separate tables (eg. RawAlfData2).

The main ALF data table contains 450,967 ALF spectra. An additional table (RawAlfData2) contains 83,055 ALF spectra.

The survey area is shaded in red on the location map (Figure 1). Other MkII ALF surveys are shaded in light green (Cowley, 2001a-c*).

1894 confident fluors were selected from the 534,022 spectra recorded. This is an average fluor density of 3.55 fluors per thousand spectra.

* Bibliographic references:

Williams, A.K. and Mackintosh, J.M., 1990. ALF Survey of the western margin of Australia. 3. Arafura Sea. Volume 1, A – Basic Data Report; Volume 2, B – Interpretive Data Report; Volume 3, C – BP In-house Report. Remote Sensing Group, BP Exploration (unpubl. report).
Cowley. R., 2001a. MkII Airborne Laser Fluorosensor Survey Reprocessing and Interpretation Report: Timor Sea, Australia. Record 2001/23, AGSOCAT 34394
Cowley. R., 2001b. MkII Airborne Laser Fluorosensor Survey Reprocessing and Interpretation Report: Bonaparte Basin, Timor Sea, Australia. Record 2001/24, AGSOCAT 35930
Cowley. R., 2001c. MkII Airborne Laser Fluorosensor Survey Reprocessing and Interpretation Report: Timor Gap, Timor Sea, Australia. Record 2001/25, AGSOCAT 35635

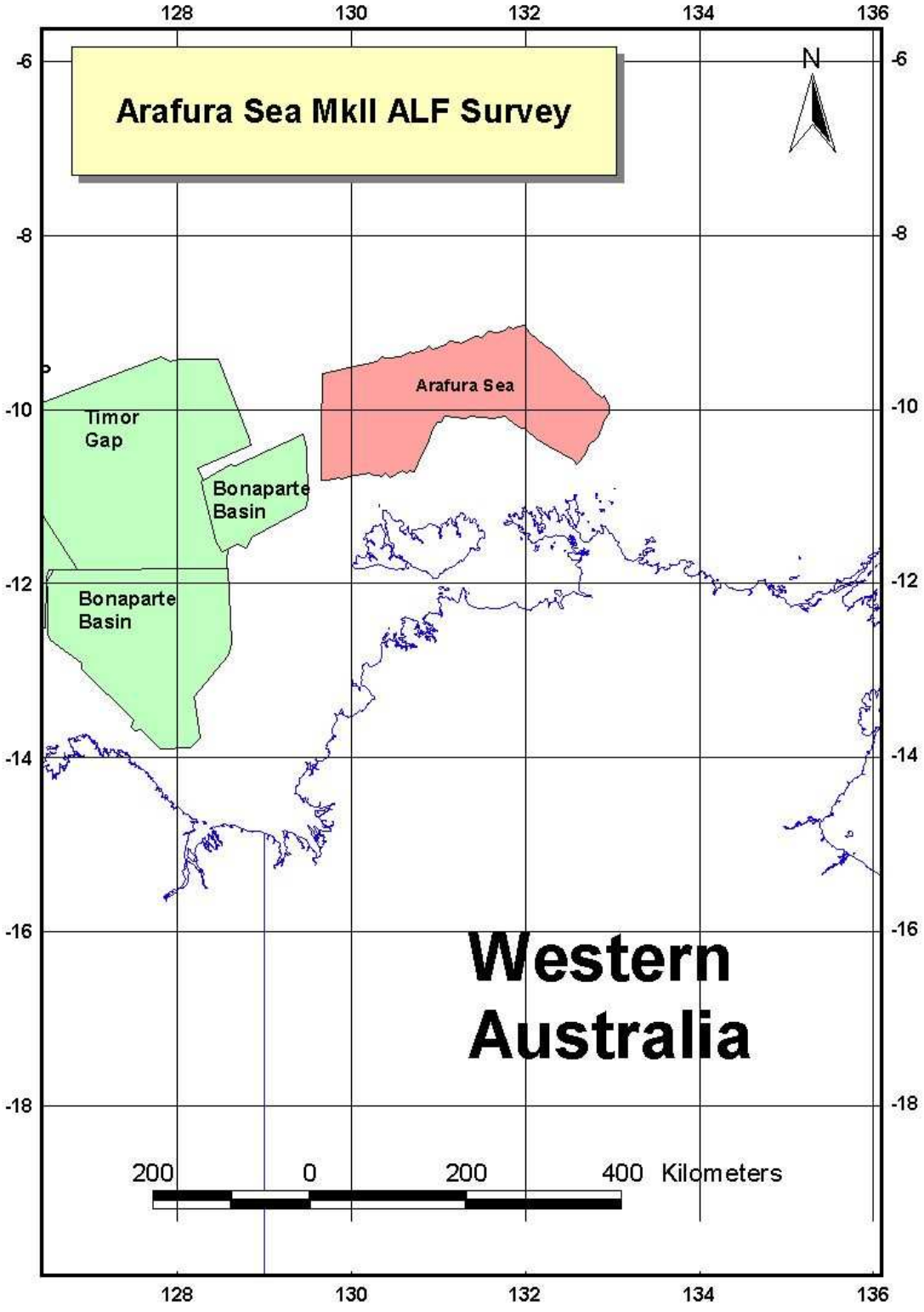


Figure 1. Arafura Sea MkII ALF Survey Location Map.
(Blue areas are later MkIII ALF surveys.)
(Light green areas are other MkII ALF surveys.)

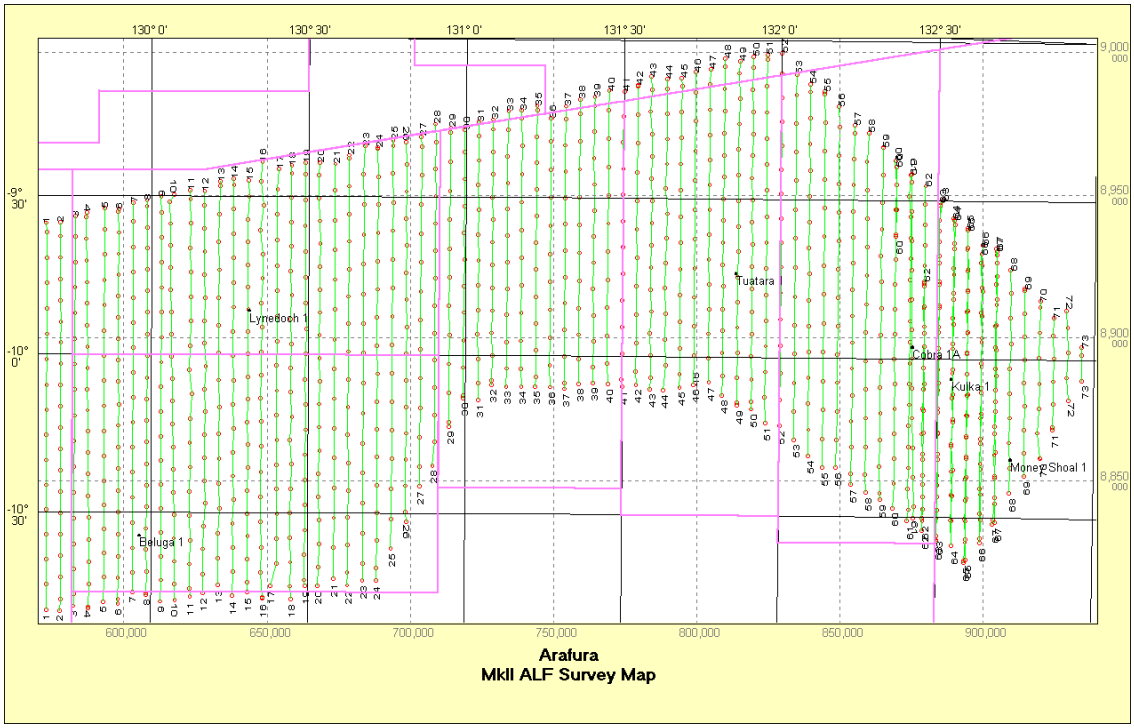


Figure 2. The Arafura Sea MkII ALF Survey.

Figure 2 shows a map of the Arafura Sea MkII ALF survey with point symbols annotated in red at a spacing of 500 points.

Mapping Specifications:
The geodetic coordinates of the supplied ALF data used the AGD66 geodetic datum. Because of inconsistencies in the AGD66 datum, there is no single set of transformation parameters that can accurately transform the coordinates into the WGS84 or AGD84 datums. The AGD66 datum coordinates were assumed to be approximately equal to the AGD84 coordinates for the accuracy of mapping required in this report.

Projection: Southern UTM Zone 52 (Central Meridian 129 degrees east)

Min Easting:	570,000
Max Easting:	940,000
Min Northing:	8,800,000
Max Northing:	9,005,000

2. ALF Survey Analysis

2.1. Fluor Mapping

A fluorescence anomaly (fluor) is detected by an increase in the area of the fluorescence response region of the ALF spectrum. For a variety of reasons the magnitude of each ALF spectrum can vary significantly from shot to shot. The fluorescence area value is usually normalized using the Raman area to produce a more consistent measure of fluorescence intensity. The ratio is called the fluorescence on Raman area ratio, usually denoted as F/R.

In this analysis, the Raman area is calculated between the wavelengths 330.77nm and 360.13nm (channels 26 to 54). The fluorescence area is calculated between the wavelengths 360.13nm to 600.83nm (channels 54 to 154). Oil fluorescence usually extends over the Raman region but the Raman response distorts the value if it is calculated over this region.

The F/R ratio typically shows varying intensity trends over a survey area, probably because of changing water properties. A map of the smoothed F/R ratio over the Arafura Sea survey is shown in Figure 12 (Appendix 1). The F/R ratio generally increases to the north and east. There is a small zone of increased F/R in the SW corner of the survey.

Figure 3 shows the F/R plot for line 3. The values are high to the south over the region of high F/R to the SW of the Beluga-1 well.

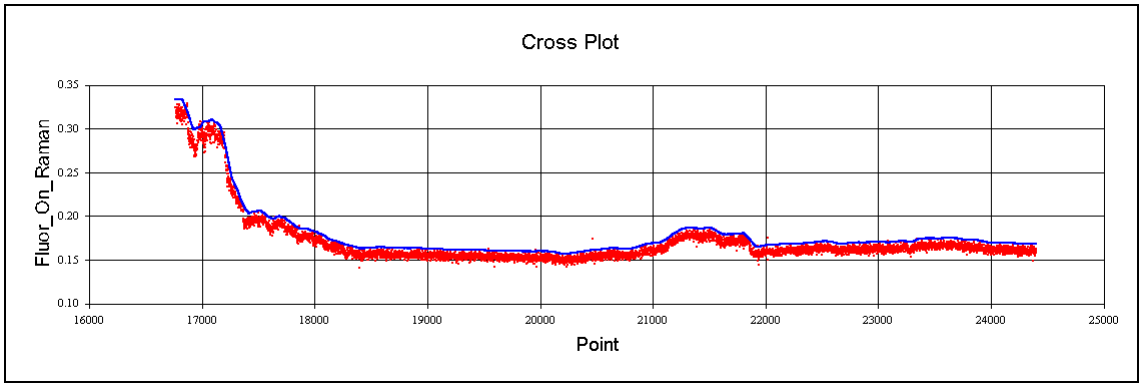


Figure 3. The F/R Plot for Line 3.

Because of the changing F/R trends, a constant F/R cutoff level cannot be used to detect fluorescence anomalies (fluors). An average of the F/R ratio is used as an estimate of the background F/R level at any point. Only spectra having an F/R value significantly above the background level are selected as possible fluors.

The blue line shown in Figure 3 is the (101 point) average F/R rescaled by a factor of 1.05. The rescaling moves the averaged curve above the F/R values of most of the spectra. Only spectra having an F/R value above the blue curve are selected as possible fluors. The scaling factor is usually selected between

values of 1.05 and 1.5 for each line, depending on the amount of scatter in the F/R plot.

3,270 fluors were initially selected from the raw ALF data tables (2,863 from RawAlfData and 407 from RawAlfData2). Figure 4 shows a map of the first pass fluors.

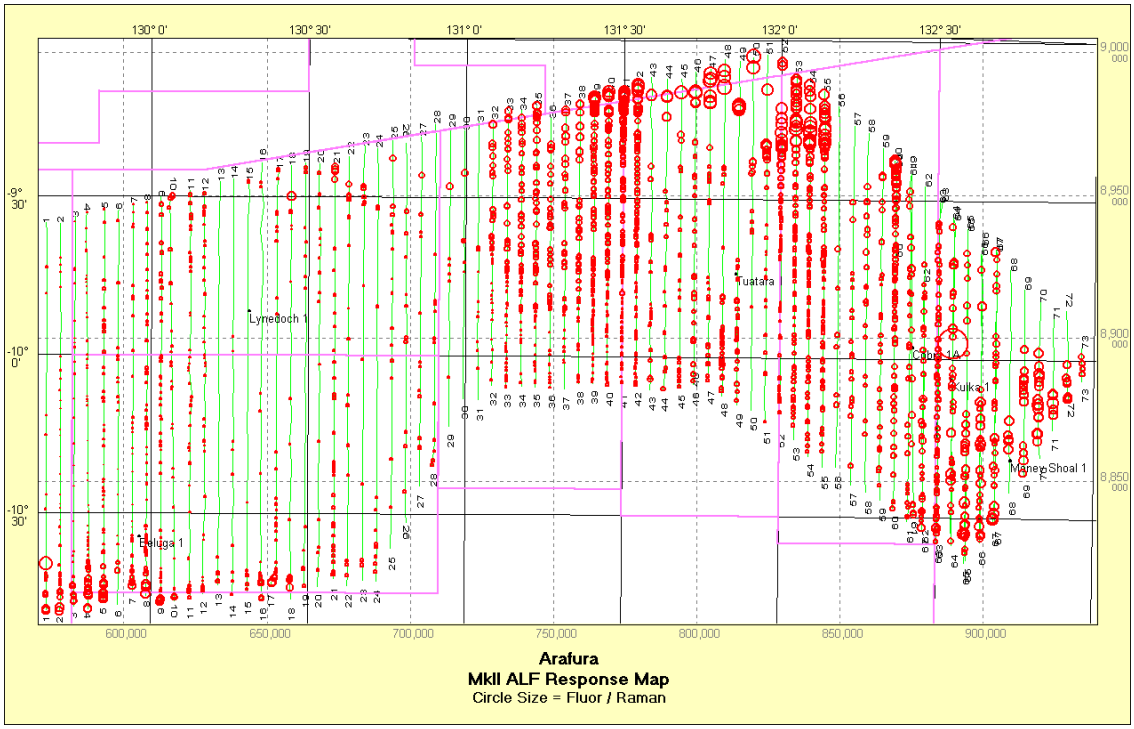


Figure 4. Edited First Pass Fluor Map.

Noisy fluors were removed from the tables of spectrum parameters using the following queries in the View Calculation Tables form:

SELECT * FROM [Picked Fluors 1 Spectra Params] Where Fluor_Jitter_On_Area > 0 And Fluor_Jitter_On_Area < 0.001

SELECT * FROM [Picked Fluors 2 Spectra Params] Where Fluor_Jitter_On_Area > 0 And Fluor_Jitter_On_Area < 0.001

This reduces the fluors picked from the RawAlfData table from 2863 to 1707. The fluors picked from RawAlfData2 are reduced from 407 to 187.

Corresponding ALF spectra were selected using the following query in the View Records form:

SELECT [Picked Fluors 1 Edited].* FROM [Picked Fluors 1 Edited], [Conf Picked Fluors 1 Spectra Params] WHERE [Picked Fluors 1 Edited.Line] = [Conf Picked Fluors 1 Spectra Params.Line] AND [Picked Fluors 1 Edited.Point] = [Conf Picked Fluors 1 Spectra Params.Point]

SELECT [Picked Fluors 2 Edited].* FROM [Picked Fluors 2 Edited], [Conf Picked Fluors 2 Spectra Params] WHERE [Picked Fluors 2 Edited.Line] = [Conf Picked Fluors 2 Spectra Params.Line] AND [Picked Fluors 2 Edited.Point] = [Conf Picked Fluors 2 Spectra Params.Point]

Figure 5 shows a map of the confident fluors. The fluor density is greatest near the middle of the survey over an area ~130km x 100km (EW x NS), or about 13,000 sq km. The density is very low to the east and relatively low to the west.

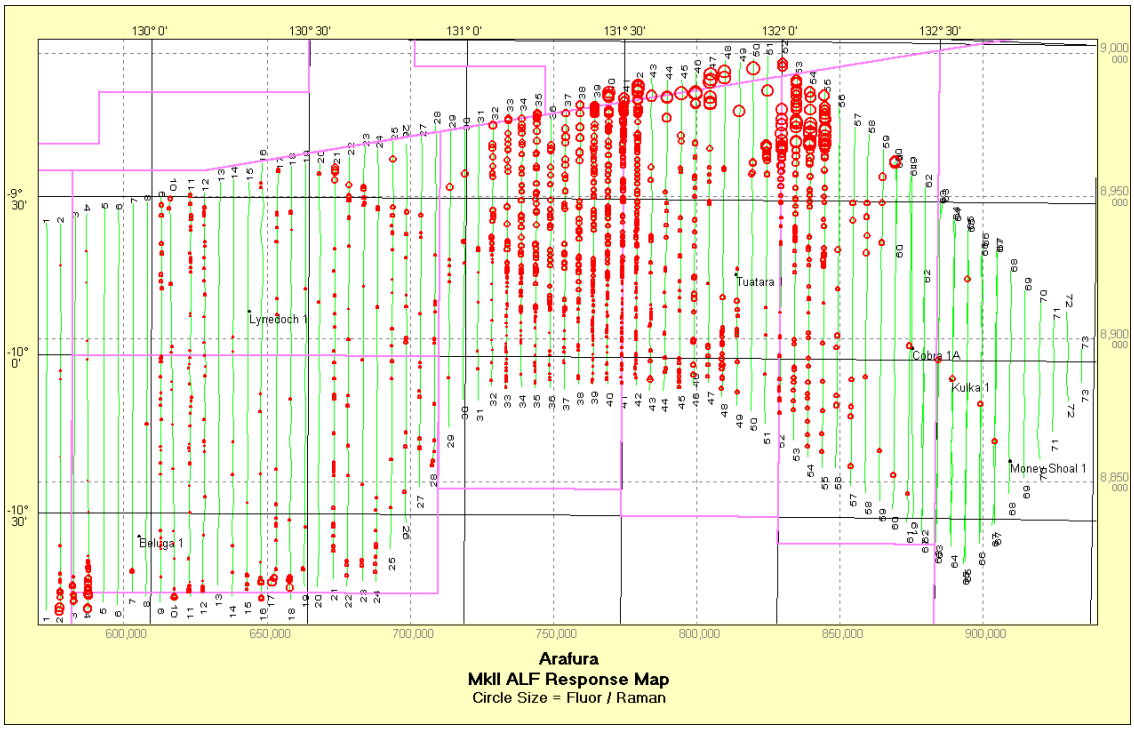


Figure 5. Confident Fluor Map.

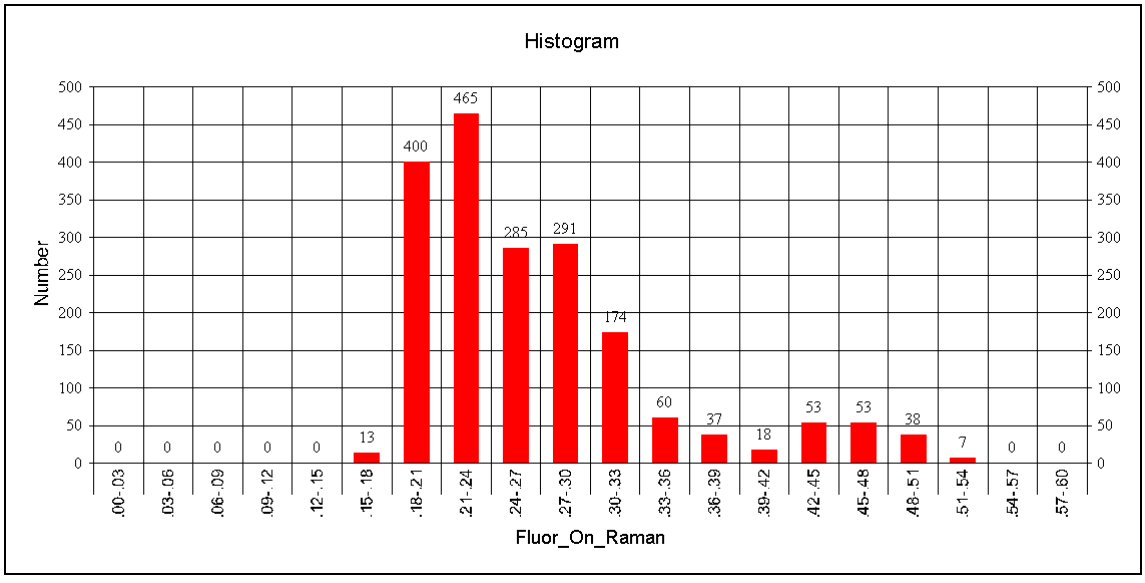
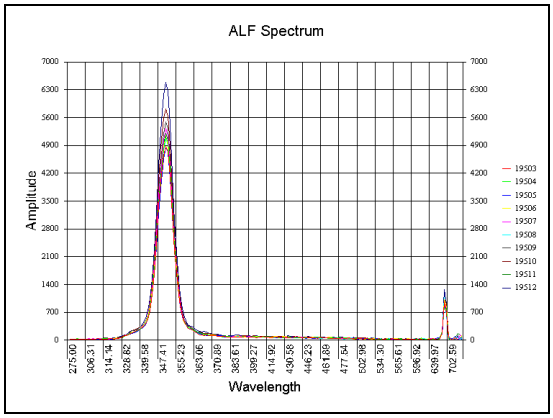
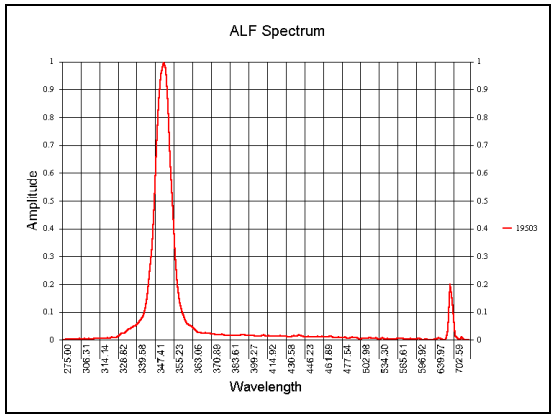


Figure 6. The F/R Histogram for the Confident Fluors.

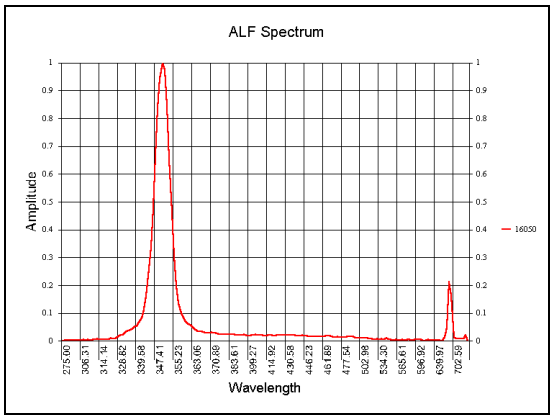
Figure 6 shows the fluors intensity (F/R) histogram for the confident fluor picks. Because a varying fluor intensity cutoff level is used to select likely fluors, the histogram bars gradually reduce in size towards the low F/R end of the graph.



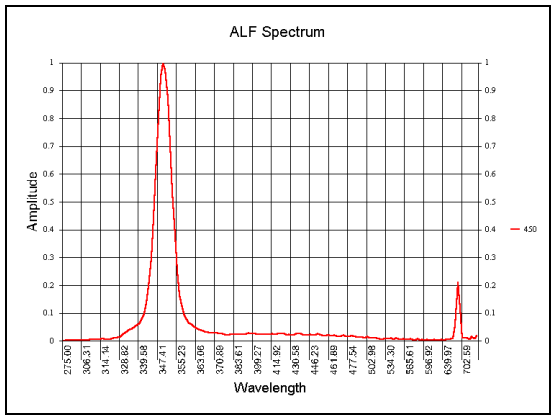
a) Line 7 Ten Adjacent Spectra.



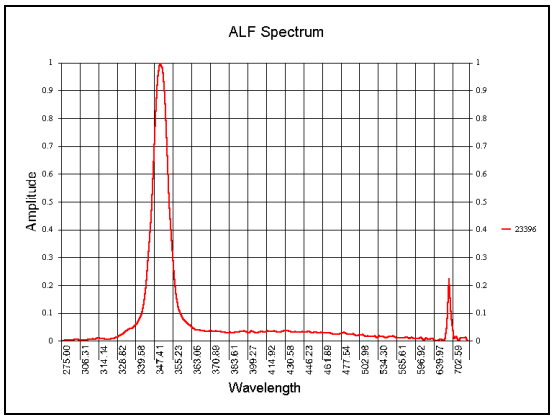
b) Line11 No Fluor



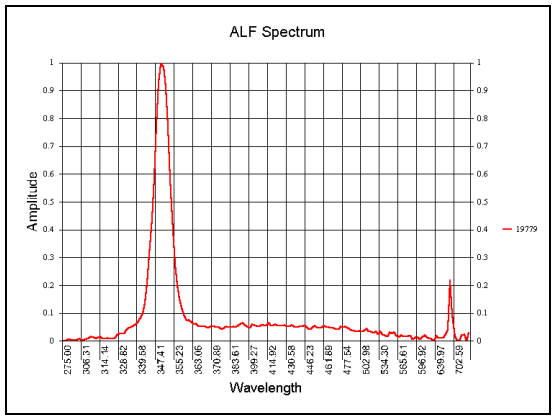
c) Line 2 Small Fluor



d) Line 44 Small to Medium Fluor



e) Line 50 Medium to Large Fluor.



f) Line 49 Large Fluor.

Figure 7. Arafura Sea MkII ALF Survey, Selected Spectra.

Figure 7 shows a selection of spectra from the Arafura Sea MkII ALF survey. The fluors tend to be weak and masked by the high background F/R patterns over the survey area.

3. Conclusions and Recommendations

The fluorescence response over most of the survey area consisted mostly of relatively low confidence fluors, at least compared to the more reliable and modern MkIII survey data.

The 10 spectra averaging method used to record the MkII data tends to filter out the isolated fluorescence response and enhance anomalous water response.

The ~5km line spacing is not sufficiently close to detect most fluor clusters. For example, the line spacing of 300m used on the MkIII ALF survey over the Skua field, Timor Sea (Cowley, 2000*), was only just sufficient to detect the fluor cluster lying near that accumulation.

Some of the regions of increased fluor density correspond to regions having generally higher F/R values, probably caused by changing water properties. These areas may not necessarily have increased levels of hydrocarbon leakage.

The Arafura Sea MkII ALF data is probably not suitable for identifying the isolated, low intensity fluors that are usually detectable on ALF MkIII surveys in the region.

*Bibliographic reference:
Cowley. R., 2000. 1996 Vulcan Sub-basin Airborne Laser Fluorosensor Survey Interpretation Report. Record 2000/33.

Appendix 1. Data Acquisition QC

Line	Sections	Clipped	Avg Raman Peak	Avg Raman Variance
1	75	0	23	15
2	90	0	27	18
3	76	0	30	22
4	90	0	33	26
5	78	0	20	15
6	91	0	26	19
7	76	0	28	21
8	91	0	29	570
13	74	0	34	27
14	85	0	38	28
15	90	0	42	33
16	89	0	34	25
17	82	0	30	19
18	88	0	40	33
19	83	0	30	22
20	91	0	29	22
21	68	0	35	25
22	77	0	43	37
23	71	0	45	34
24	77	0	43	32
25	69	0	38	29
26	70	0	42	459
27	59	0	44	40
28	62	0	44	34
29	50	0	47	38
30	49	0	41	33
31	55	0	33	25
32	57	0	35	29
33	51	0	35	22
34	49	0	37	23
35	51	0	39	25
36	47	0	42	28
37	53	0	45	32
38	51	0	45	32
39	53	0	30	18
40	51	0	31	18
41	55	0	31	18

Table 1a. Arafura Sea MkII ALF Survey Data Acquisition Summary.

Line	Sections	Clipped	Avg Raman Peak	Avg Raman Variance
42	52	0	29	18
43	69	0	32	19
44	61	0	34	22
45	58	0	31	19
46	0	0	0	0
46	52	0	41	27
47	62	0	21	11
48	75	0	22	11
49	67	0	21	12
50	78	0	22	14
51	69	0	19	9
52	73	0	20	10
53	62	0	23	15
54	70	0	24	16
55	65	0	22	13
56	62	0	21	12
57	67	0	20	12
58	62	0	20	13
59	66	0	21	14
60	68	0	15	9
61	82	0	16	10
62	47	0	16	9
63	79	0	16	9
64	64	0	16	9
65	79	0	16	9
66	57	0	16	10
67	54	0	16	10
68	43	0	15	11
69	39	0	15	12
70	31	0	14	13
71	23	0	14	11
72	17	0	15	11
73	5	0	14	13
1	0	0	0	0
9	82	0	25	13
10	89	0	28	16
11	82	0	31	19

Table 1b. Arafura Sea MkII ALF Survey Data Acquisition Summary.

Line	Sections	Clipped	Avg Raman Peak	Avg Raman Variance
12	87	0	30	22
60	13	0	15	10
61	58	0	15	10
62	81	0	16	10
63	64	0	15	9
64	64	0	13	9
65	78	0	14	10
66	56	0	13	9
67	64	0	13	9

Table 1c. Arafura Sea MkII ALF Survey Data Acquisition Summary.

The average Raman peak levels (averaged over each line) ranged from 0 to 48. This parameter is mapped over the survey in Figure 8.

The Raman variance, calculated over 100 point windows and averaged over each line, usually ranged from 9 to 27. This parameter is mapped over the survey in Figure 9. Lines 8 and 26 are extremely noisy and have very high Raman variances.

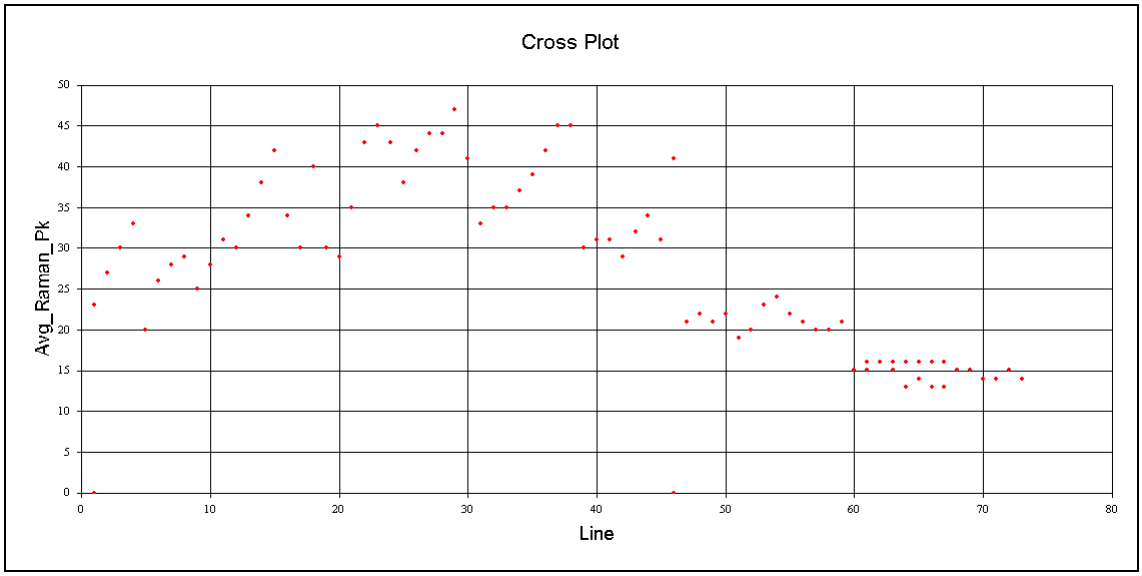


Figure 8. The Average Raman Peak Plotted for All Lines.

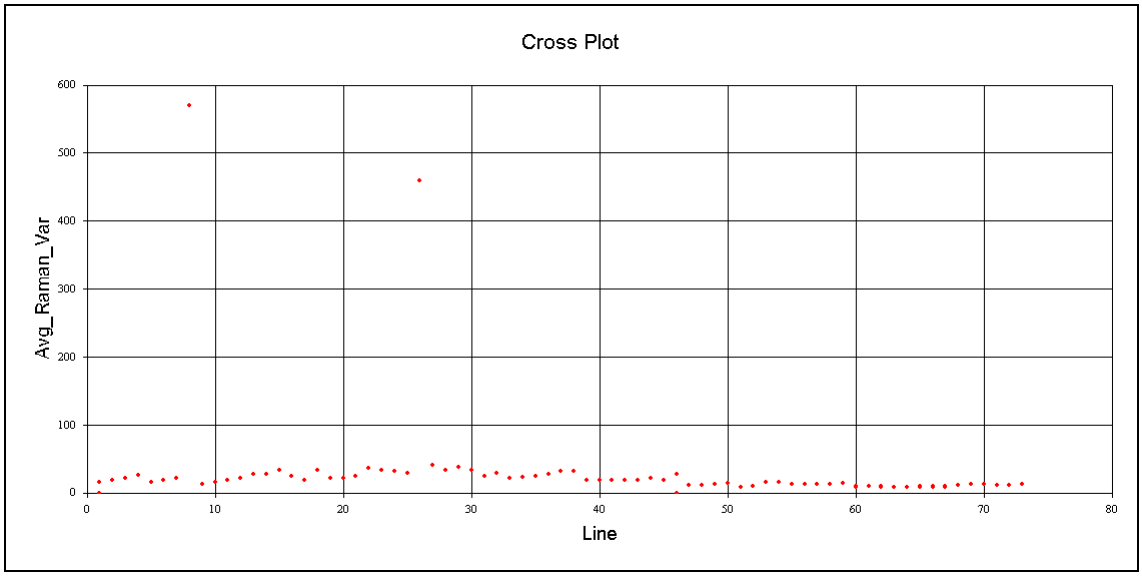


Figure 9. The Average Raman Variance Plotted for All Lines.

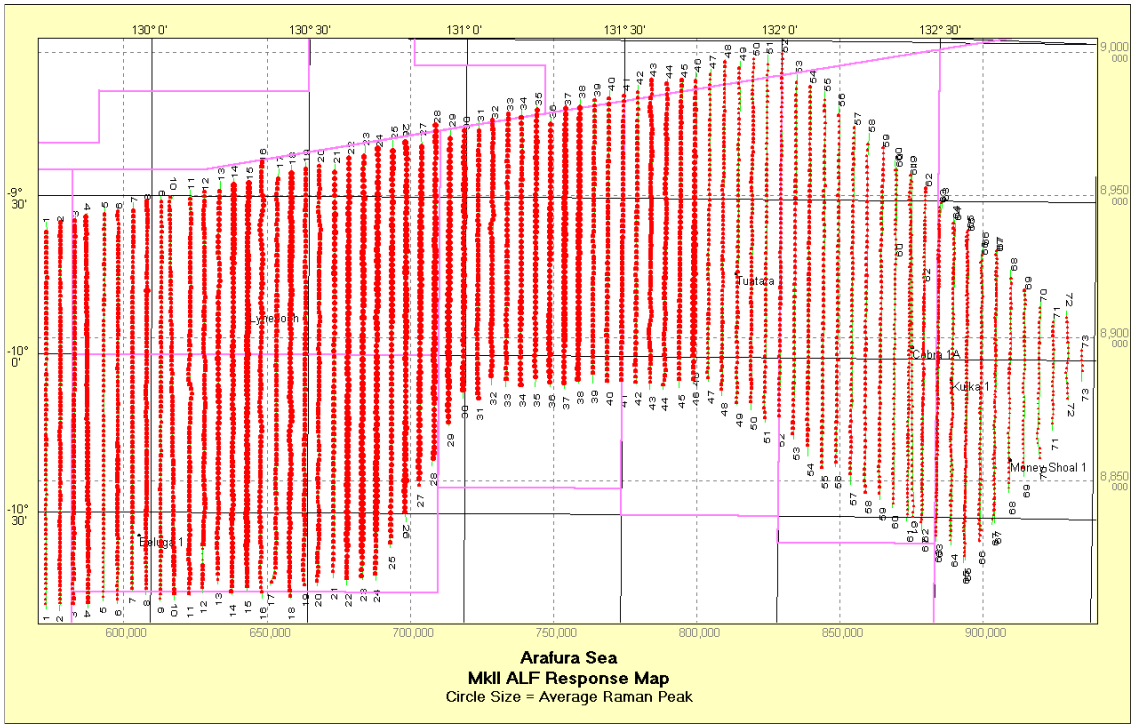


Figure 10. Average Raman Peak Map.

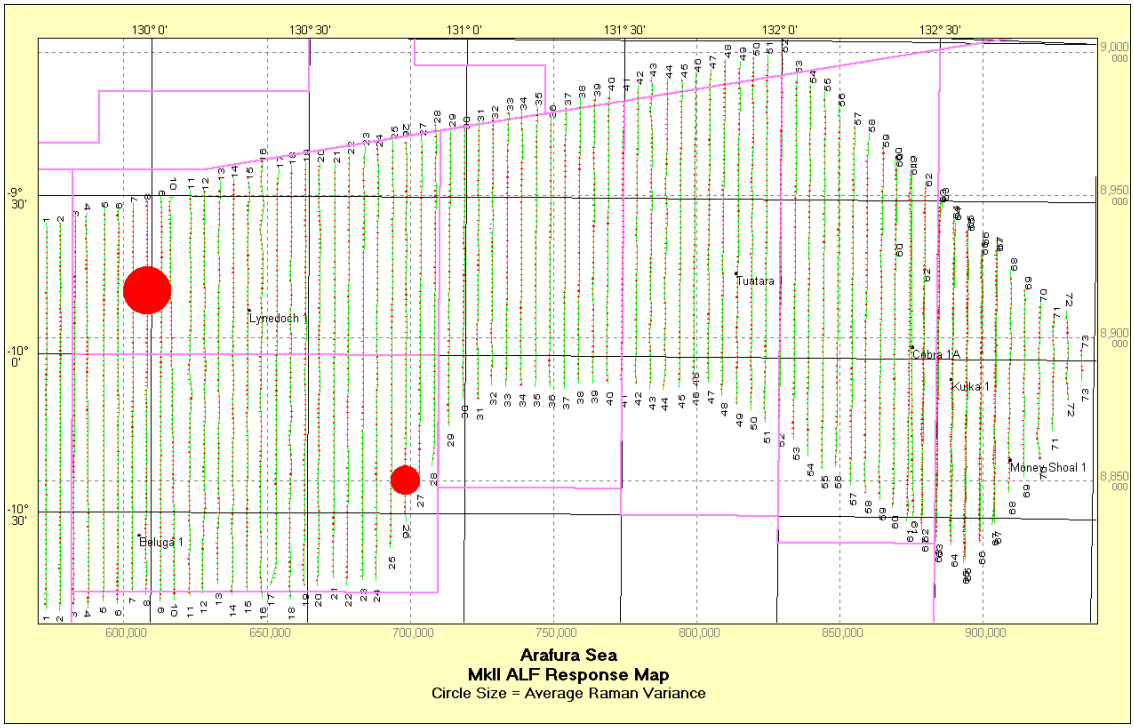


Figure 11. Raman Variance Map.

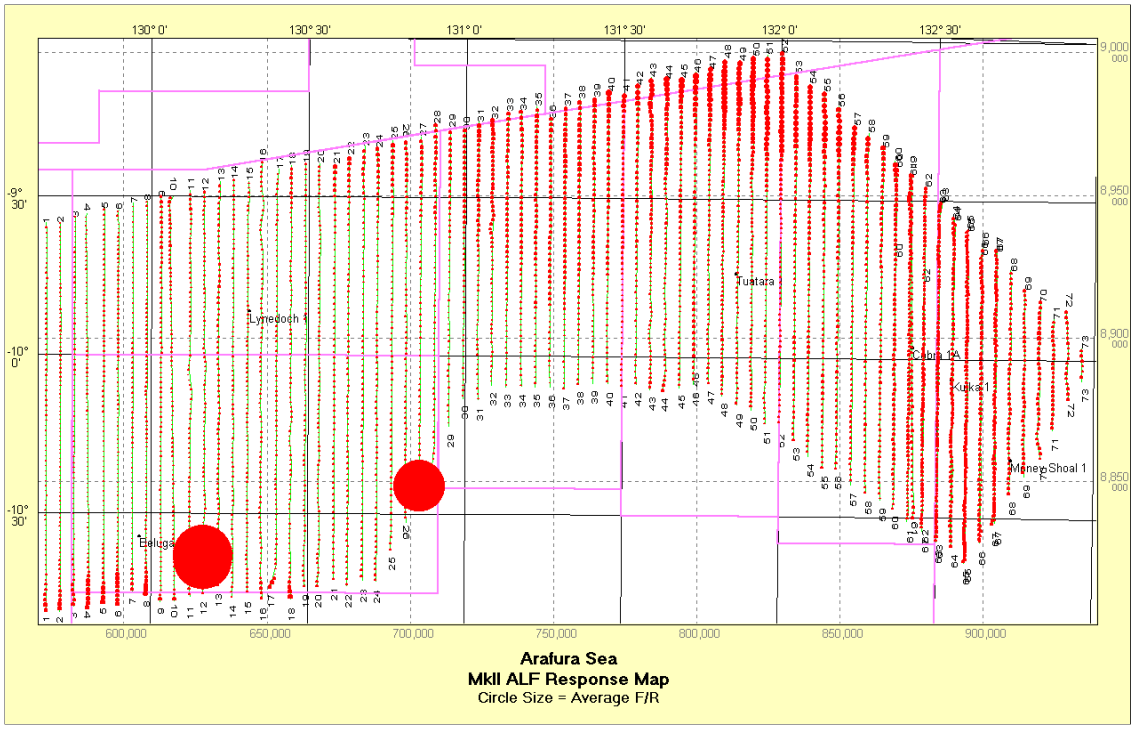


Figure 12. Smoothed F/R Map.

Figure 12 shows the smoothed F/R value over the survey area. The map shows F/R variations that can be correlated between lines. Line 12 has a patch of very high F/R value data. This corresponds to a segment of very low amplitude data with high noise levels, probably caused by a data acquisition problem. The end of line 27 also has a patch of very high F/R values corresponding to very low amplitude data. This is probably caused by a poor acquisition configuration as the aircraft turned into the start of the line.

Appendix 2. Data Navigation QC

Line	Heading (Deg)	Straight Line Distance (m)	Acquisition Time (seconds)	Avg Straight Line Velocity (km/hr)	Points	Flight Distance (m)	Avg Flying Velocity	Avg Point Spacing (m)
1	0.04	135,242.50	0	0	7,684	135,366.60	0	17.62
2	180.13	135,813.00	0	0	9,080	135,929.00	0	14.97
3	0.29	136,181.00	0	0	7,640	136,380.00	0	17.86
4	179.91	138,367.40	0	0	9,128	138,589.80	0	15.19
5	0.22	137,642.30	0	0	7,934	137,666.10	0	17.36
6	180.16	138,200.90	0	0	9,191	138,373.80	0	15.06
7	0.17	136,005.60	0	0	7,740	136,005.60	0	17.58
8	180.17	137,835.30	0	0	9,174	137,980.30	0	15.04
13	0.36	141,174.30	0	0	7,595	141,375.70	0	18.62
14	0.22	145,956.10	0	0	8,639	146,164.60	0	16.92
15	180.23	143,947.50	0	0	9,090	144,152.10	0	15.86
16	180.10	152,781.00	0	0	8,934	153,262.30	0	17.16
17	1.17	145,813.30	0	0	8,385	146,333.30	0	17.46
18	0.18	151,679.40	0	0	8,939	151,973.80	0	17.01
19	0.19	147,809.30	0	0	8,339	148,032.60	0	17.76
20	180.34	147,815.10	0	0	9,179	148,184.00	0	16.15
21	0.28	144,871.20	0	0	6,945	144,906.70	0	20.87
22	180.35	150,413.20	0	0	7,780	150,580.70	0	19.36
23	0.36	151,891.50	0	0	7,260	151,990.70	0	20.94
24	180.30	151,341.20	0	0	7,740	151,491.90	0	19.58
25	0.38	142,848.70	0	0	7,094	142,914.70	0	20.15
26	180.00	132,722.40	0	0	7,095	132,905.90	0	18.74
27	0.40	122,403.80	0	0	5,985	122,492.10	0	20.47
28	180.59	119,440.30	0	0	6,249	119,653.80	0	19.15
29	0.43	104,509.80	0	0	5,164	104,585.80	0	20.26
30	180.45	93,836.16	0	0	4,960	93,935.89	0	18.95
31	0.13	97,269.79	0	0	5,606	97,394.55	0	17.38
32	180.35	92,722.45	0	0	5,809	93,074.42	0	16.03
33	180.57	96,412.28	0	0	5,209	96,535.26	0	18.54
34	0.04	96,594.76	0	0	4,964	96,622.88	0	19.47
35	180.37	98,108.95	0	0	5,255	98,221.00	0	18.70
36	0.27	94,006.95	0	0	4,804	94,032.09	0	19.58
37	180.39	98,817.48	0	0	5,359	98,879.95	0	18.46
38	0.40	99,372.33	0	0	5,254	99,378.38	0	18.92
39	180.51	99,890.29	0	0	5,457	99,986.71	0	18.33
40	0.31	102,678.40	0	0	5,208	102,710.60	0	19.73
41	180.52	103,256.00	0	0	5,609	103,302.00	0	18.42

Table 2a. Arafura Sea MkII ALF Survey Line Navigation Summary.

Line	Heading (Deg)	Straight Line Distance (m)	Acquisition Time (seconds)	Avg Straight Line Velocity (km/hr)	Points	Flight Distance (m)	Avg Flying Velocity	Avg Point Spacing (m)
42	0.43	104,752.60	0	0	5,265	104,854.40	0	19.92
43	180.24	109,169.50	0	0	7,044	109,554.80	0	15.56
44	0.73	108,820.40	0	0	6,205	109,062.40	0	17.58
45	180.45	108,251.30	0	0	5,904	108,293.40	0	18.35
46	0.48	111.40	0	0	5	111.40	0	37.13
46	0.36	109,153.40	0	0	5,346	109,169.60	0	20.43
47	0.37	109,551.40	0	0	6,304	109,652.30	0	17.40
48	180.65	117,879.00	0	0	7,640	118,092.90	0	15.46
49	0.57	120,463.80	0	0	6,800	120,646.40	0	17.75
50	180.49	123,349.70	0	0	7,935	123,608.40	0	15.58
51	0.41	128,760.40	0	0	7,094	128,874.40	0	18.17
52	180.50	130,237.40	0	0	7,389	130,365.80	0	17.65
53	0.51	127,678.80	0	0	6,345	127,694.90	0	20.13
54	180.44	129,901.20	0	0	7,150	129,992.40	0	18.19
55	0.37	131,381.70	0	0	6,550	131,500.30	0	20.08
56	0.54	126,201.50	0	0	6,354	126,301.00	0	19.88
57	180.72	125,543.30	0	0	6,843	125,696.30	0	18.37
58	0.56	125,633.00	0	0	6,298	125,817.00	0	19.98
59	180.57	123,099.90	0	0	6,645	123,269.90	0	18.56
60	0.48	121,538.20	0	0	6,988	121,741.20	0	17.43
61	180.68	121,083.10	0	0	8,285	121,374.50	0	14.65
62	0.48	83,629.55	0	0	4,766	83,782.65	0	17.59
63	181.12	118,981.70	0	0	7,989	119,406.80	0	14.95
64	0.44	114,438.00	0	0	6,504	114,677.20	0	17.64
65	180.72	116,861.70	0	0	8,040	117,201.70	0	14.58
66	0.64	104,112.60	0	0	5,854	104,346.40	0	17.83
67	180.43	94,898.13	0	0	5,465	95,072.24	0	17.40
68	0.52	77,915.67	0	0	4,465	78,064.90	0	17.49
69	180.34	65,542.45	0	0	4,025	65,710.91	0	16.33
70	0.10	55,012.66	0	0	3,129	55,349.09	0	17.70
71	180.95	38,954.27	0	0	2,430	39,061.23	0	16.09
72	359.02	31,567.19	0	0	1,789	31,701.99	0	17.74
73	180.69	11,619.83	0	0	645	11,679.01	0	18.16
1	323.65	904.47	0	0	50	904.47	0	18.84
9	0.18	141,533.40	0	0	8,255	141,708.00	0	17.17
10	179.89	141,711.80	0	0	9,029	142,400.20	0	15.77
11	0.05	142,093.90	0	0	8,345	142,519.10	0	17.08

Table 2b. Arafura Sea MkII ALF Survey Line Navigation Summary.

Line	Heading (Deg)	Straight Line Distance (m)	Acquisition Time (seconds)	Avg Straight Line Velocity (km/hr)	Points	Flight Distance (m)	Avg Flying Velocity	Avg Point Spacing (m)
12	180.28	140,421.50	0	0	8,723	140,764.20	0	16.14
60	180.56	24,364.52	0	0	1,406	24,384.42	0	17.37
61	359.89	120,167.80	0	0	5,850	120,315.30	0	20.57
62	180.60	120,350.60	0	0	8,235	120,594.50	0	14.65
63	0.70	116,457.70	0	0	6,549	116,500.60	0	17.79
64	0.62	113,696.80	0	0	6,594	113,926.90	0	17.28
65	180.54	115,221.80	0	0	7,825	115,572.10	0	14.77
66	0.43	100,964.50	0	0	5,749	101,103.30	0	17.59
67	180.86	96,228.35	0	0	6,445	96,664.13	0	15.00
Total:		**9,355,883.83**			**534,022**	**9,370,450.67**		

Table 2c. Arafura Sea MkII ALF Survey Line Navigation Summary.

A total of 534,022 ALF spectra were recorded on 83 lines. About 9,370 km of lines were flown during the survey.

Figure 13 shows the average point spacing plotted for all lines. The spacing typically lies between 14 and 21m.

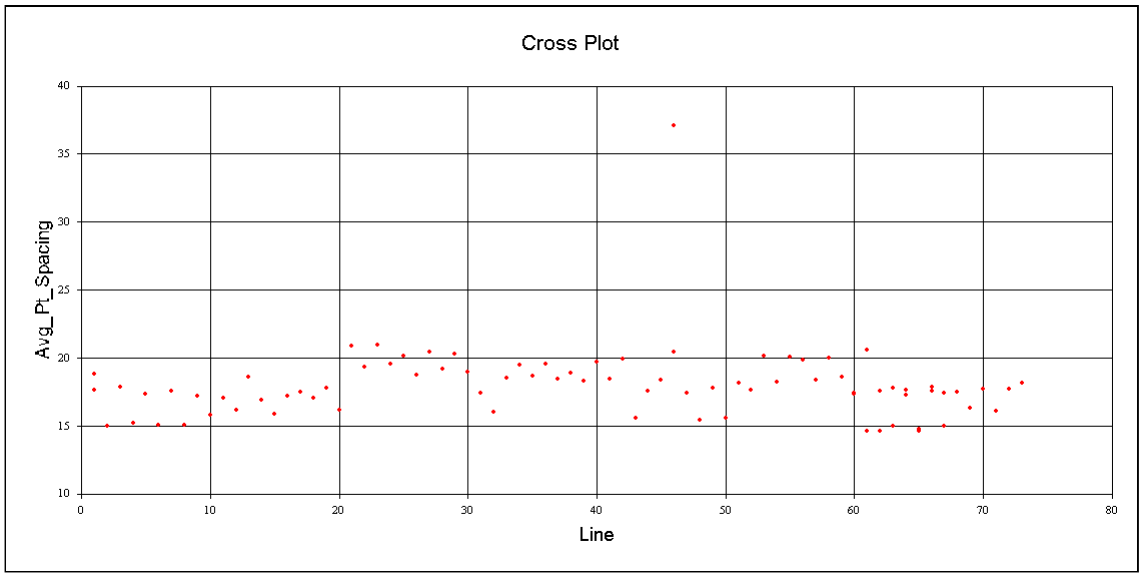
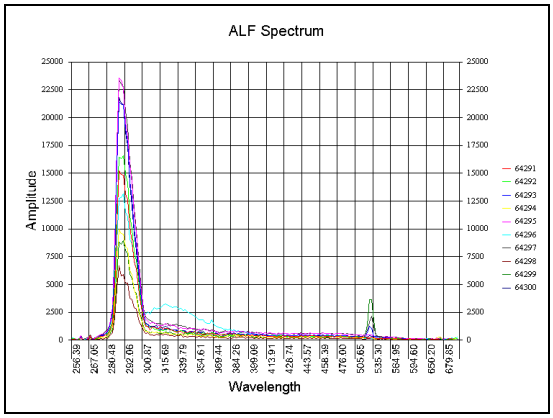


Figure 13. The Average Point Spacing Plotted for All Lines.

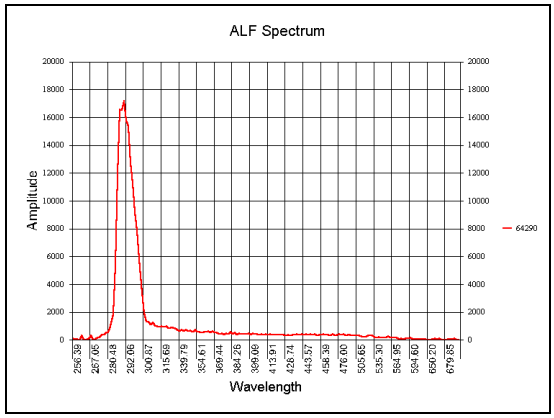
Appendix 3. **Comparison of MkII and MkIII ALF Survey Data**

Figure 14 shows a comparison of ALF MkIII survey data from the Skua region with the Timor ALF MkII data. Figure 14a shows a typical isolated MkIII fluor within ten adjacent spectra. Figure 14b shows a typical non-fluorescing spectrum. A medium intensity fluor is shown in Figure 14c. When the fluor is averaged with the surrounding non-fluor spectra (Figure 14d), the response is difficult to distinguish from the non-fluor spectra. The averaging process has tended to filter out the fluorescence response and enhance the more consistent water response.

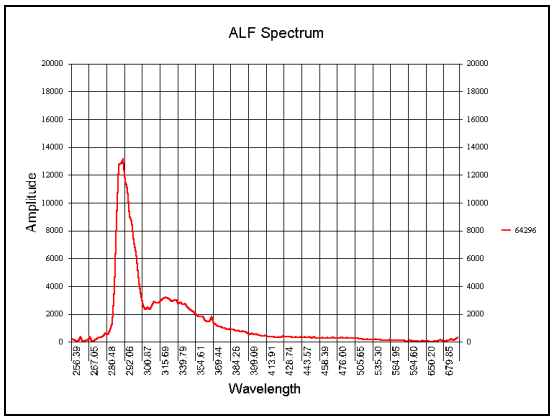
Figures 14e and 14f show a typical non-fluor and interpreted medium intensity fluor from the Timor MkII ALF survey. The refined interpretation method is required to distinguish the more subtle MkII fluors.



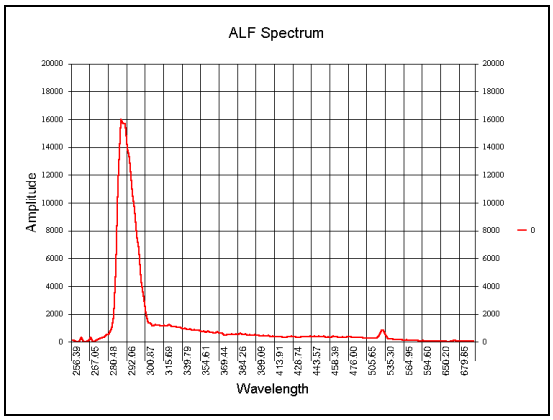
a) Skua ALF MkIII Ten Adjacent Spectra



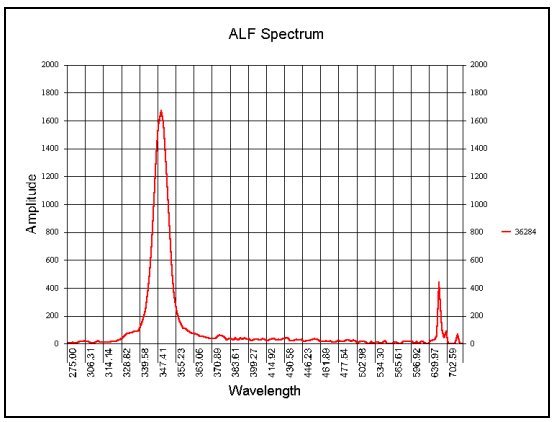
b) Skua Line 30130 No Fluor



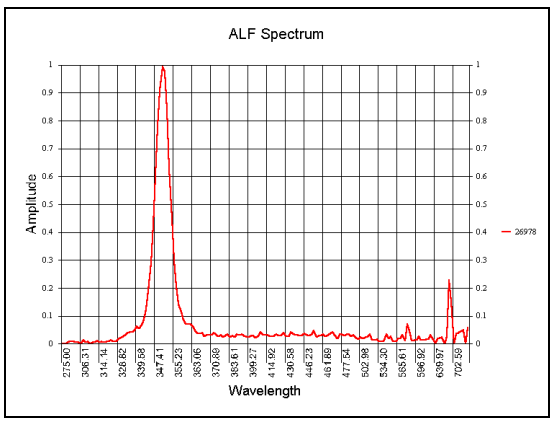
c) Skua Line 30130 Medium Fluor



d) Skua Line 30130 Ten Spectra Averaged



e) Timor MkII Line 15 No Fluor



f) Timor MkII Line 21 Medium Fluor.

Figure 14. Comparison of Skua MkIII and Timor Sea MkII ALF Data.

Appendix 4. CD Contents

The CD contains the following files:

Arafura Sea MkII ALF Project.zip
: the *ALF Explorer™* project

Arafura MkII ALF Survey Interpretation Report.doc
: the interpretation report document file

Arafura Sea MkII ALF Picked Fluors.txt
: an ASCII data file of the fluors selected during the interpretation

Arafura Sea MkII ALF Survey Summary.xls
: Excel spreadsheet containing the survey acquisition and navigation QC summaries

Figures
: Directory containing figures used in the interpretation report