

Work-related fatigue assessment.

**Report prepared by Sally Ferguson
May 2002.**

(Tasmanian rosters)

The fatigue assessment was undertaken using proprietary software [FAID] that has been commercialised by an Australian software company called InterDynamics. The software uses algorithms developed by the Centre for Sleep Research at the University of South Australia and published in international peer-reviewed journals. In the interests of brevity, detailed discussion of the background to this methodology and software are presented in Appendix A.

The FAID software estimates work-related fatigue by statistically modeling the amount of sleep likely to be obtained by employees based on the time of day and duration of work and non-work periods over a seven-day period. Benchmarking and validation studies suggest that fatigue scores below 80 are broadly consistent with a safe system of work. The base roster was assessed for work-related fatigue.

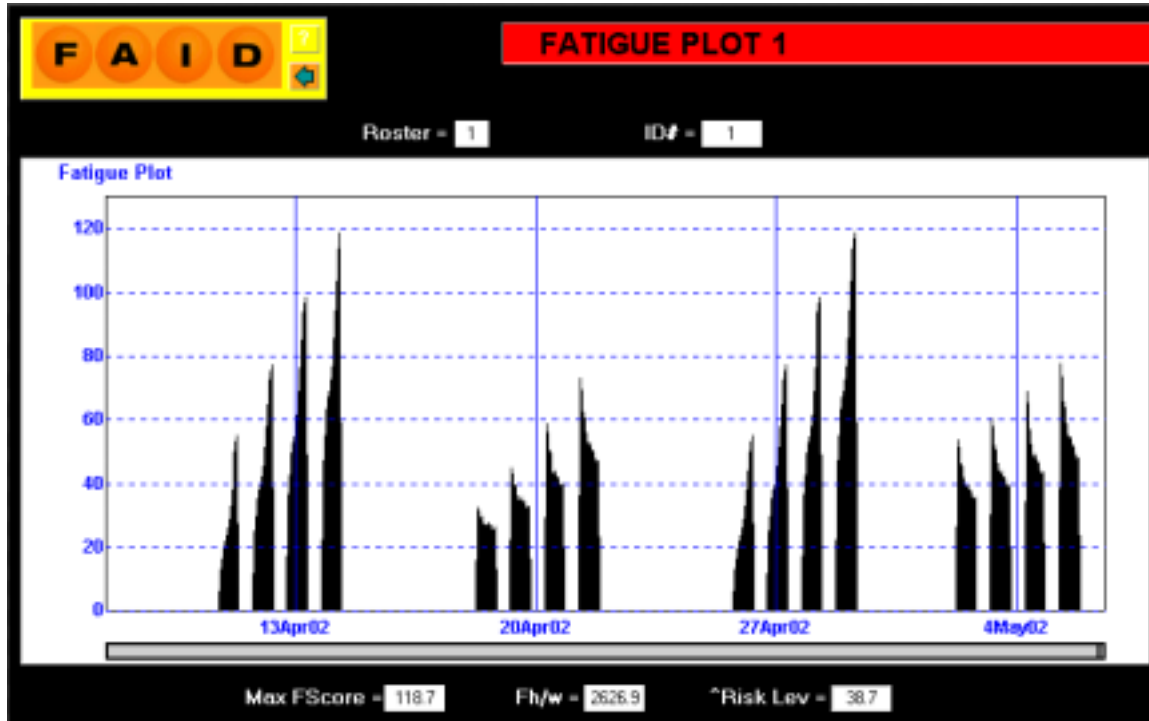
The results of this report are based solely on the roster data and the information supplied by Kathryn Heiler. Therefore, all results and conclusions have been drawn only from the information supplied.

The results of the fatigue analysis are presented on the following page in two forms. Figure 1 represents the fatigue predictions for the rostered work hours. The horizontal axis represents the number of weeks (4) entered into the FAID model. The vertical axis represents the fatigue score. The black bars indicate the fatigue levels associated with each hour of each duty period. The table gives details of each work shift, including the length of the break preceding the work shift, the length of the work shift and the maximum fatigue score associated with the work shift. Further, each work shift is colour-coded according to the maximum fatigue score.

Fatigue score	0-70 →	white
	70-75 →	green
	75-80 →	yellow
	80-90 →	red
	+90 →	black

Therefore work shifts colour-coded either red or black are associated with extremely high levels of fatigue.

Figure 1. The Rosebery roster contains a number of shifts that are associated with fatigue scores above 80. As can be seen from the fatigue plot, the third and fourth night shifts in the roster have maximum fatigue scores above 90 (indicated by the black coding in the table). In addition, the second night and final day shifts are associated with maximum fatigue scores between 70-80 (as indicated by the green coding in the table below).



Work shift	Prior break	Shift length	Fatigue score
Night	95.5	12.5	55
Night	11.5	12.5	77
Night	11.5	12.5	99
Night	11.5	12.5	119
Day	95.5	12.5	33
Day	11.5	12.5	45
Day	11.5	12.5	59
Day	11.5	12.5	73
Night	95.5	12.5	55
Night	11.5	12.5	77
Night	11.5	12.5	99
Night	11.5	12.5	119
Day	95.5	12.5	33
Day	11.5	12.5	45
Day	11.5	12.5	59
Day	11.5	12.5	73






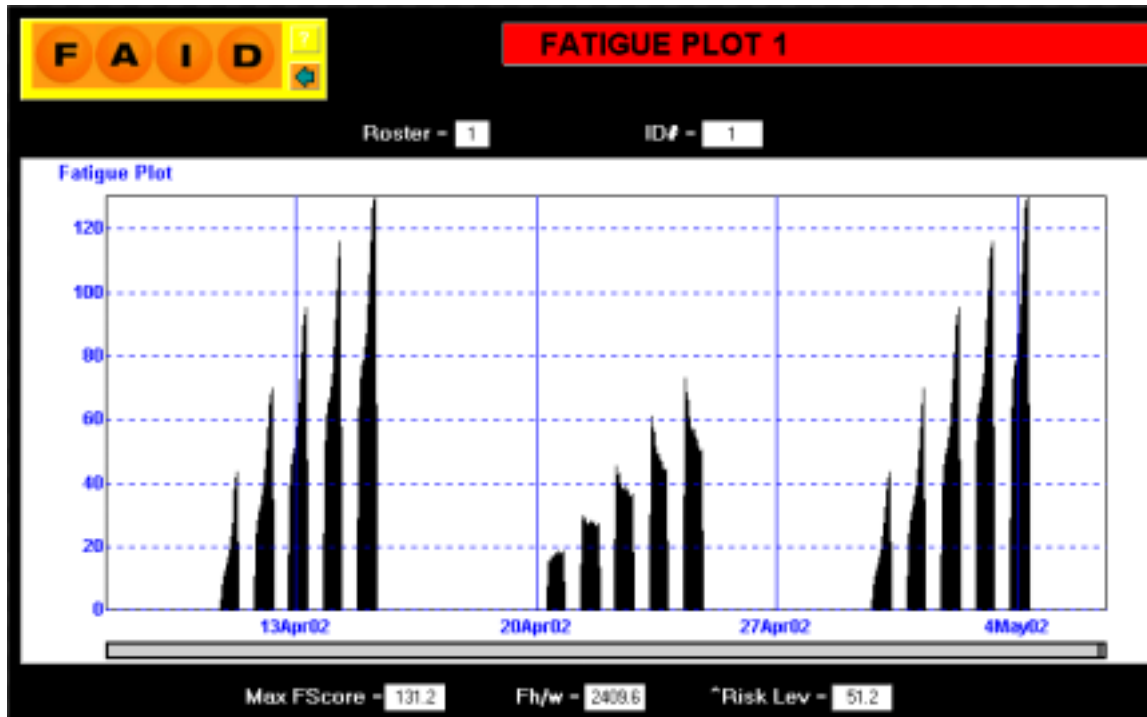
0-70 →	white	
70-75 →	green	
75-80 →	yellow	
80-90 →	red	
+90 →	black	

Figure 2. The Henty roster also contains a number of shifts that are associated with fatigue scores above 80. The fatigue plot indicates that the third, fourth and fifth night shifts in the roster have maximum fatigue scores above 90 (indicated by the black coding in the table). The addition of a fifth night shift in succession significantly increases the maximum fatigue score as compared to the previous roster schedule. The fatigue plot also shows that the highest fatigue scores are associated with the early morning hours.



Work shift	Prior break	Shift length	Fatigue score
Night	120	12	44
Night	12	12	70
Night	12	12	95
Night	12	12	116
Night	12	12	131
Day	120	12	19
Day	12	12	30
Day	12	12	46
Day	12	12	61
Day	12	12	73
Night	120	12	44
Night	12	12	70
Night	12	12	95
Night	12	12	116
Night	12	12	131






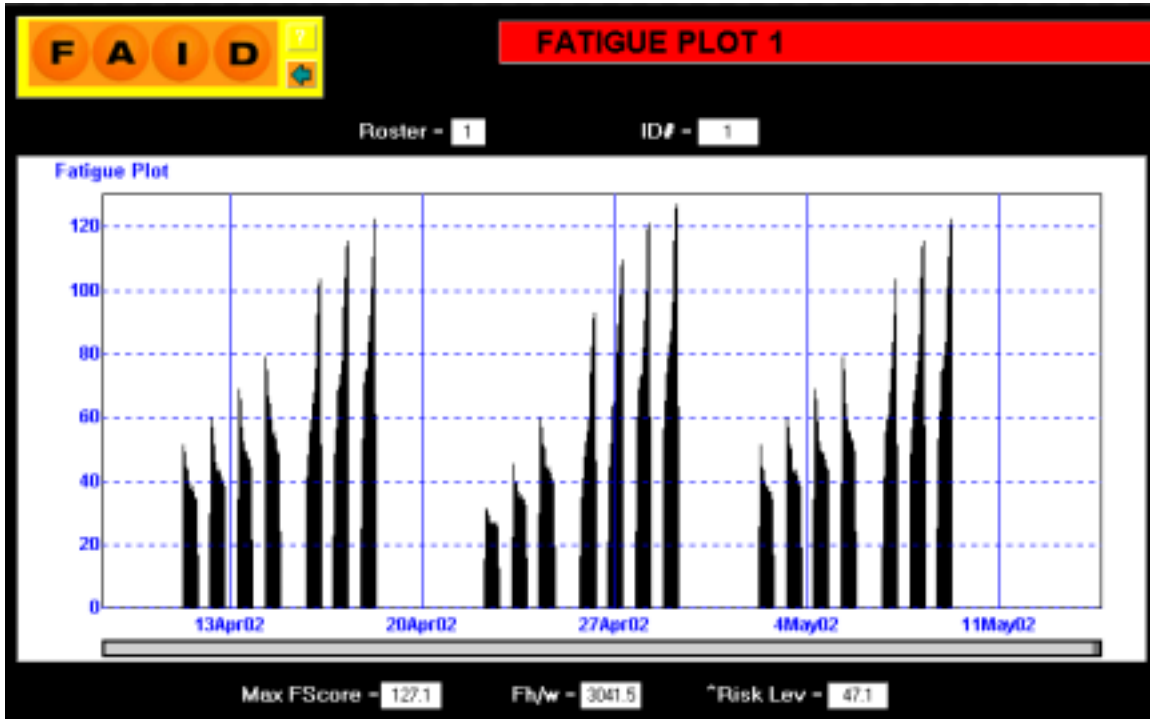
0-70 →	white	
70-75 →	green	
75-80 →	yellow	
80-90 →	red	
+90 →	black	

Figure 3. The Renison roster with 6am and 6pm start times produces very high levels of fatigue on all night shifts in the rotation. The consecutive night shifts occur immediately following a series of day shifts, with only a 24-hour period available for recovery. The highest fatigue scores are associated with the final hours of the night shift (early morning)



Work shift	Prior break	Shift length	Fatigue score
Day	72	12	51
Day	12	12	60
Day	12	12	69
Day	12	12	79
Night	24	12	103
Night	12	12	115
Night	12	12	122
Day	96	12	32
Day	12	12	46
Day	12	12	60
Night	24	12	93
Night	12	12	110
Night	12	12	121
Night	12	12	127
Day	72	12	51
Day	12	12	60
Day	12	12	69
Day	12	12	79
Night	24	12	103
Night	12	12	115
Night	12	12	122






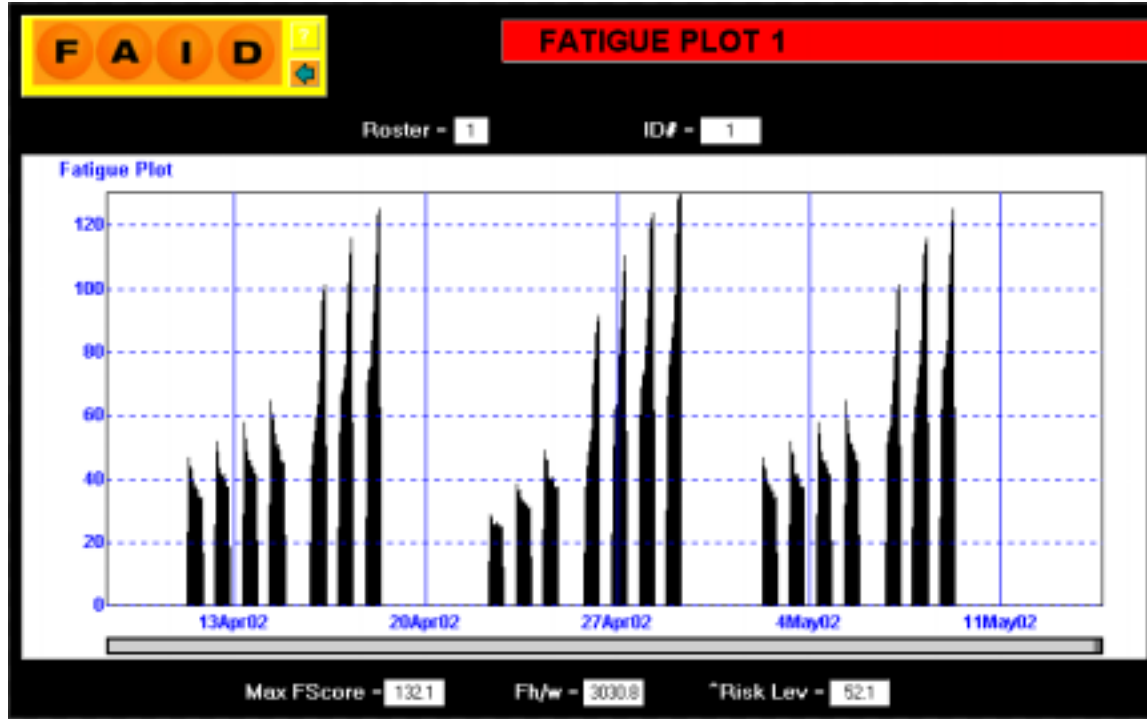
0-70 →	white	
70-75 →	green	
75-80 →	yellow	
80-90 →	red	
+90 →	black	

Figure 4. The Renison roster with 7am and 7pm start times also produces very high levels of fatigue on all night shifts in the rotation. The highest fatigue scores are associated with the final hours of the night shift (early morning). The different start times do not alter the fatigue scores for the night shifts significantly. The later start time for the day shifts does result in lower fatigue scores for the day shifts.



Work shift	Prior break	Shift length	Fatigue score
Day	72	12	47
Day	12	12	52
Day	12	12	58
Day	12	12	65
Night	24	12	101
Night	12	12	116
Night	12	12	125
Day	96	12	25
Day	12	12	38
Day	12	12	49
Night	24	12	91
Night	12	12	110
Night	12	12	124
Night	12	12	132
Day	72	12	47
Day	12	12	52
Day	12	12	58
Day	12	12	65
Night	24	12	101
Night	12	12	116
Night	12	12	125

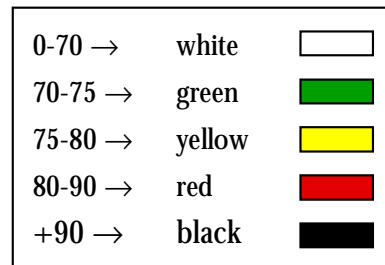
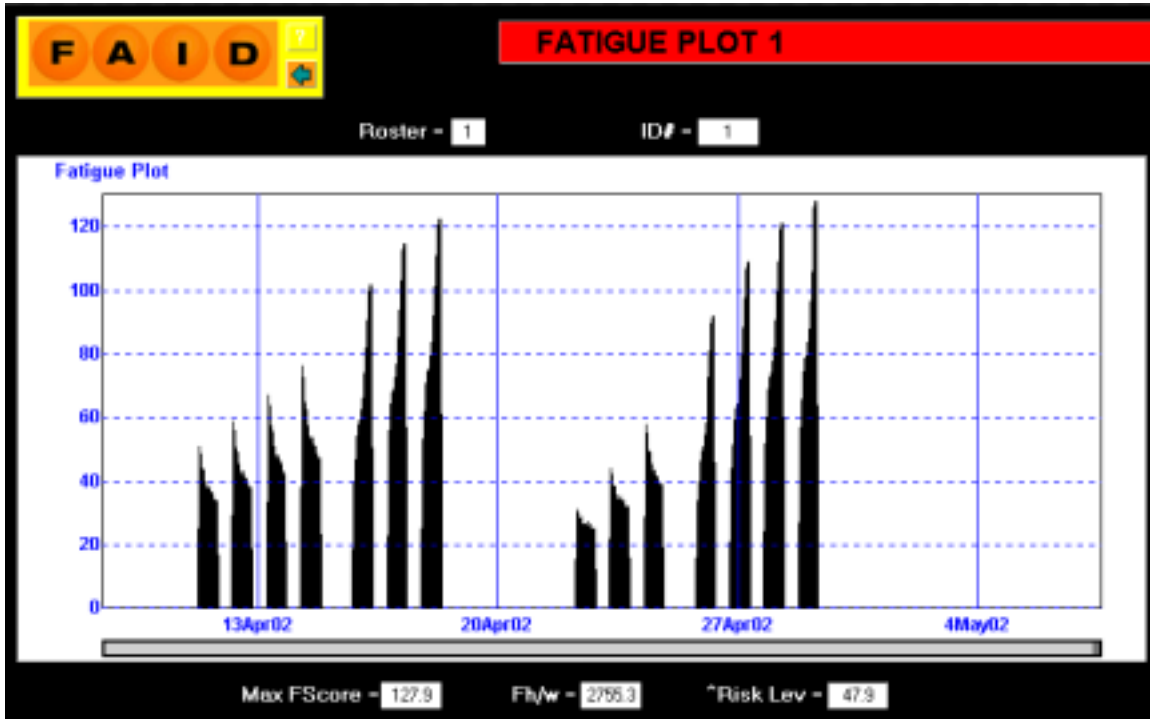


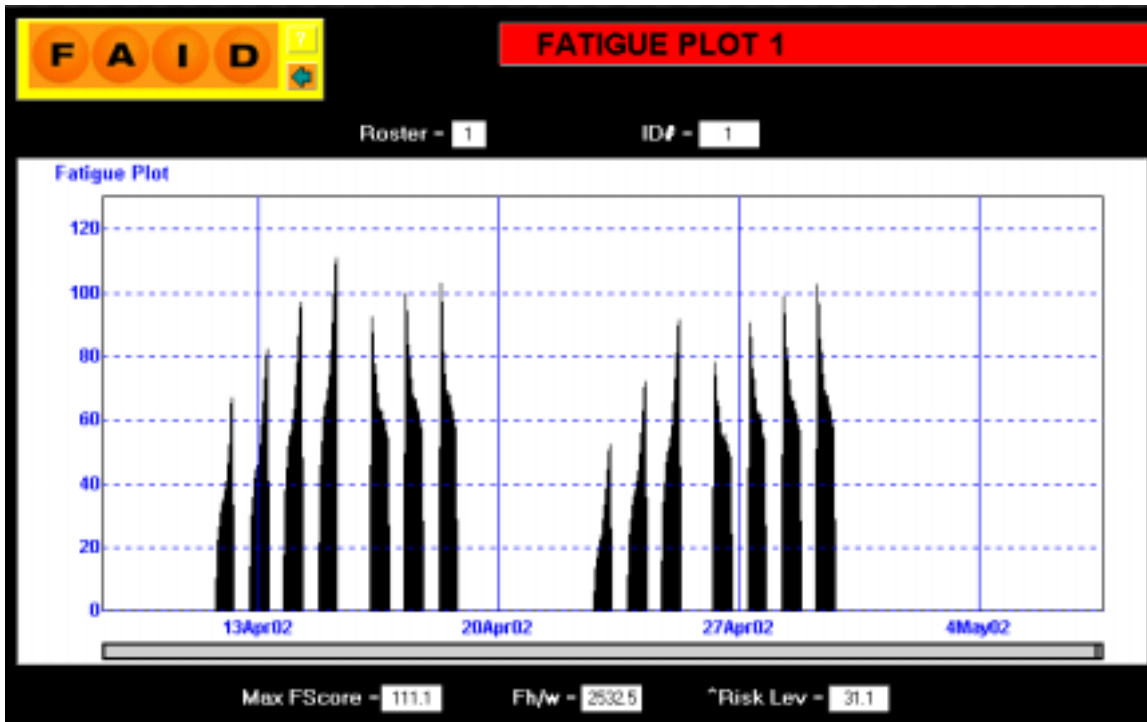
Figure 5. The first of the CMT rosters schedules day shifts followed by night shifts. As with the Renison schedule, the night shifts are all associated with fatigue scores above 80. Again, the time available for recovery after the series of day shifts is minimal.



Work shift	Prior break	Shift length	Fatigue score
Day	72	12	51
Day	12	12	59
Day	12	12	67
Day	12	12	76
Night	24	12	102
Night	12	12	115
Night	12	12	122
Day	96	12	31
Day	12	12	44
Day	12	12	58
Night	24	12	92
Night	12	12	109
Night	12	12	121
Night	12	12	128

0-70 →	white	
70-75 →	green	
75-80 →	yellow	
80-90 →	red	
+90 →	black	

Figure 6. The second of the CMT rosters schedules night shifts followed by day shifts. In this situation there are a large number of shifts associated with maximum fatigue scores above 80. In this roster the majority of the day shifts are associated with high fatigue scores. This is mainly attributed to the lack of recovery time after a series of night shifts, in addition to the early morning start times (6am). Further, the third and fourth consecutive night shifts are also associated with very high scores.



Work shift	Prior break	Shift length	Fatigue score
Night	72	12	67
Night	12	12	83
Night	12	12	97
Night	12	12	111
Day	24	12	92
Day	12	12	100
Day	12	12	103
Night	96	12	53
Night	12	12	72
Night	12	12	91
Day	24	12	78
Day	12	12	91
Day	12	12	99
Day	12	12	103






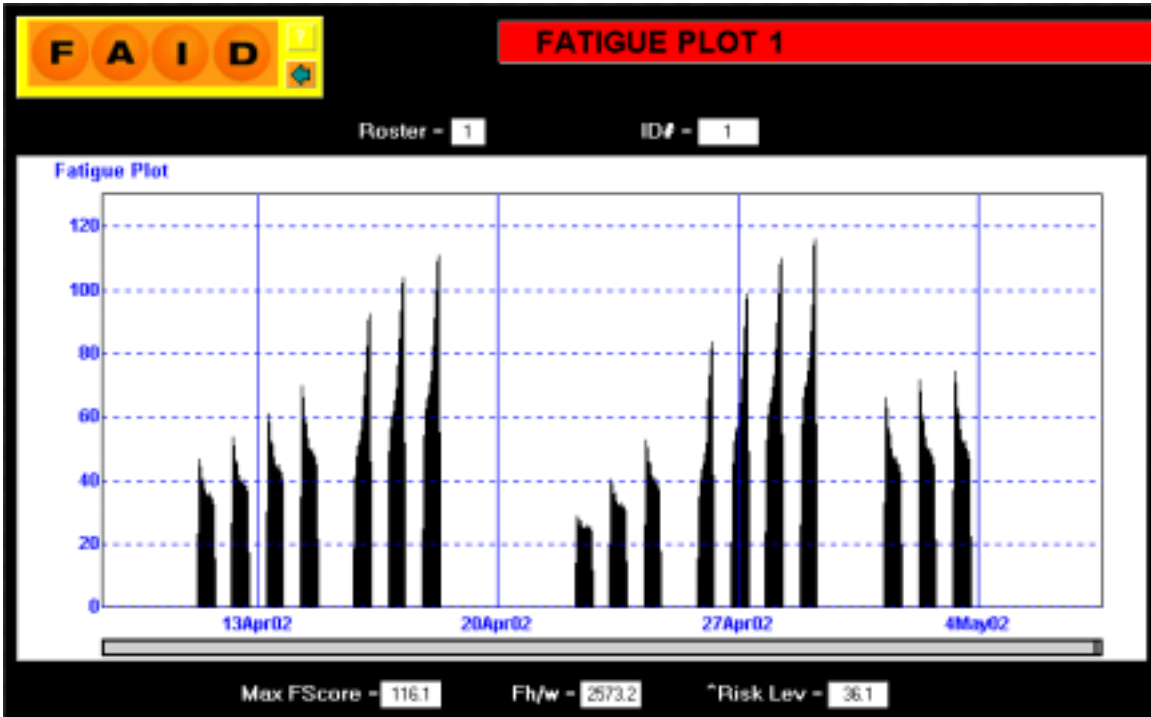
0-70 →	white	
70-75 →	green	
75-80 →	yellow	
80-90 →	red	
+90 →	black	

Figure 7. The Beaconsfield roster operates with a series of day shifts followed by a series of night shifts, similar to the CMT system. All of the night shifts are associated with fatigue scores above 80 as the opportunity for recovery after the day shifts is just over 24 hours. The highest scores are associated with the early morning hours. The maximum fatigue scores are lower than the corresponding CMT schedule due to the shorter work period (10.5 hours).



Work shift	Prior break	Shift length	Fatigue score
Day	72.45	10.5	47
Day	13.5	10.5	54
Day	13.5	10.5	61
Day	13.5	10.5	70
Night	26.75	10.5	93
Night	13.5	10.5	105
Night	13.5	10.5	111
Day	96.25	10.5	29
Day	13.5	10.5	40
Day	13.5	10.5	53
Night	26.75	10.5	84
Night	13.5	10.5	99
Night	13.5	10.5	110
Night	13.5	10.5	116
Day	48.25	10.5	66
Day	13.5	10.5	72
Day	13.5	10.5	75






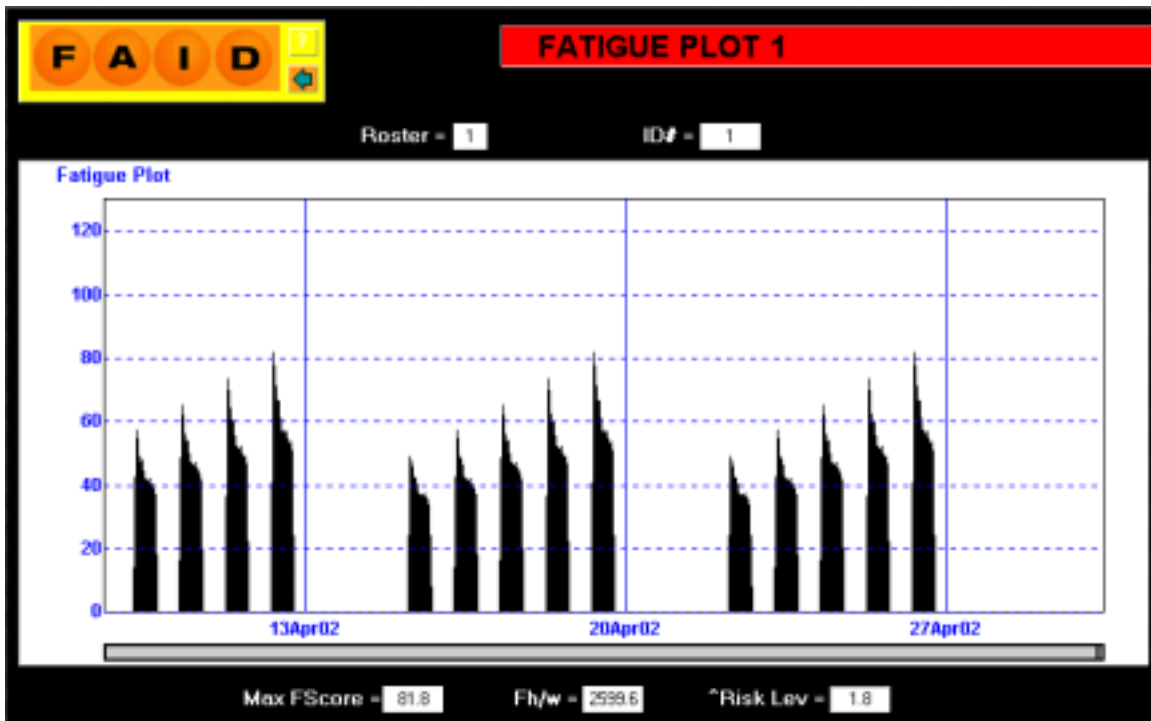
0-70 →	white	
70-75 →	green	
75-80 →	yellow	
80-90 →	red	
+90 →	black	

Figure 8. The Beaconsfield roster is associated with a single shift above 80. The fifth successive day shift has a maximum fatigue score of 82, just above the 80 threshold. This occurs because of the 61m start time of the shift, and is demonstrated in the fatigue plot by the spike at the beginning of the work period. Early start times significantly truncate the sleep period due to the body's inability to go to sleep earlier on the previous night. Thus, waking early for work reduces the recovery time available between work shifts.



Work shift	Prior break	Shift length	Fatigue score
Day	13.5	10.5	57
Day	13.5	10.5	65
Day	13.5	10.5	74
Day	13.5	10.5	82
Day	61.5	10.5	49
Day	13.5	10.5	57
Day	13.5	10.5	65
Day	13.5	10.5	74
Day	13.5	10.5	82
Day	61.5	10.5	49
Day	13.5	10.5	57
Day	13.5	10.5	65
Day	13.5	10.5	74
Day	13.5	10.5	82






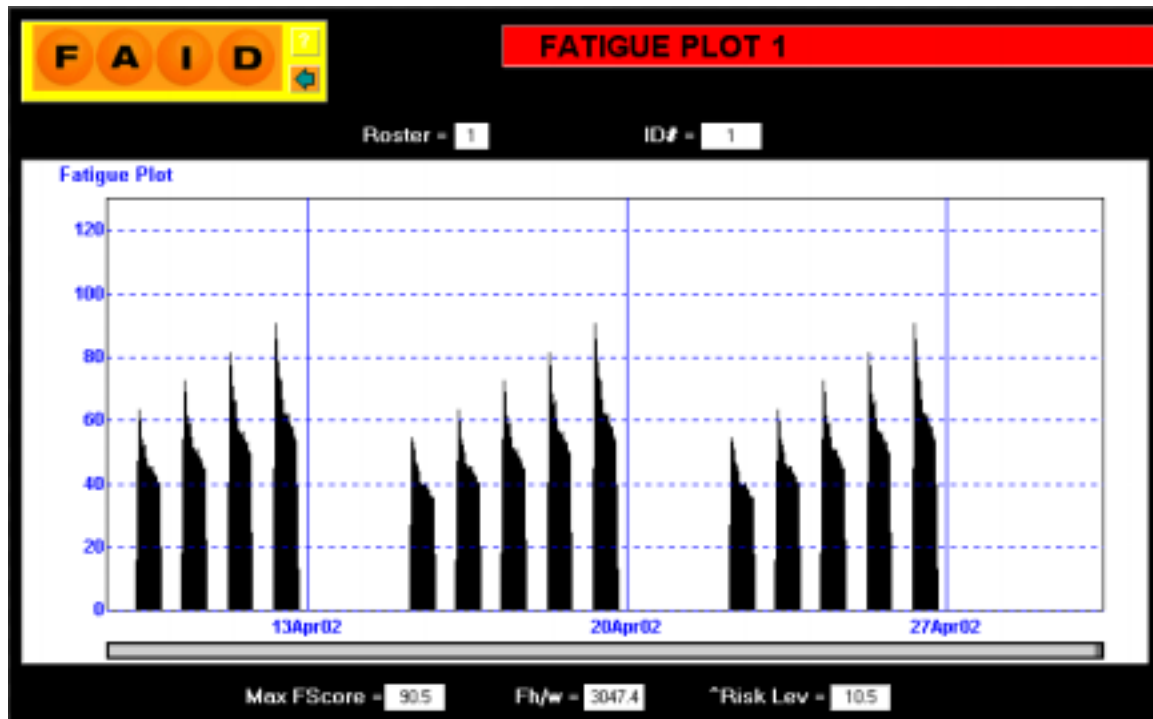
0-70 →	white	
70-75 →	green	
75-80 →	yellow	
80-90 →	red	
+90 →	black	

Figure 9. The 12-hour day shift is associated with high fatigue scores on the fourth and fifth consecutive shifts. Again, the early start time of 6am is contributing significantly to the high fatigue at the start of the shift. Extended shifts reduce the opportunity for recovery between work periods, thereby contributing to higher levels of fatigue.



Work shift	Prior break	Shift length	Fatigue score
Day	12	12	64
Day	12	12	72
Day	12	12	82
Day	12	12	91
Day	60	12	54
Day	12	12	64
Day	12	12	72
Day	12	12	82
Day	12	12	91
Day	60	12	54
Day	12	12	64
Day	12	12	72
Day	12	12	82
Day	12	12	91






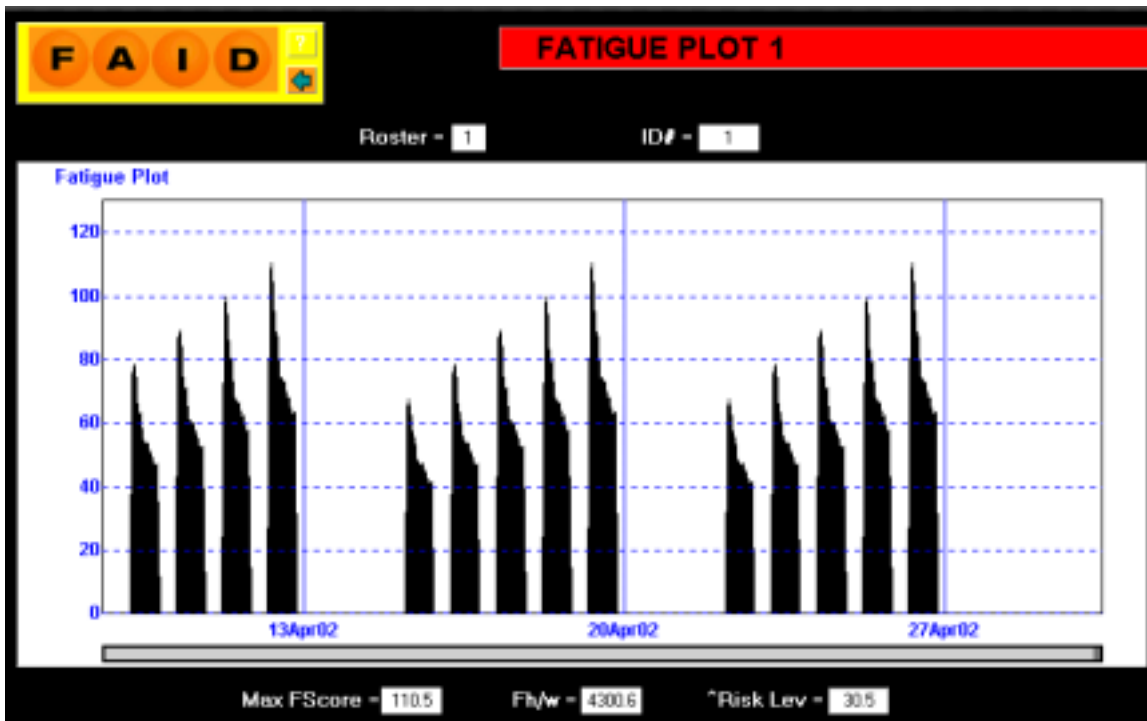
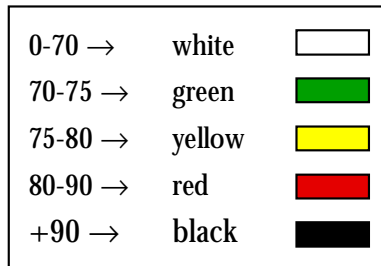
0-70 →	white	
70-75 →	green	
75-80 →	yellow	
80-90 →	red	
+90 →	black	

Figure 10. The 14-hour day shift is associated with high fatigue scores on the third, fourth and fifth consecutive shifts. The day shifts begin even earlier than the previous roster, at 5am. The fatigue associated with the early start time of 5am is obvious in the slightly flatter spike at the beginning of the shift. In addition, the longer shift of 14 hours further reduces the time available for recovery between work periods. Only 10 hours are available for sleep. This combined with the 5am start results in very high levels of fatigue at the beginning of the third, fourth and fifth day shifts.



Work shift	Prior break	Shift length	Fatigue score
Day	10	14	78
Day	10	14	89
Day	10	14	100
Day	10	14	111
Day	58	14	68
Day	10	14	78
Day	10	14	89
Day	10	14	100
Day	10	14	111
Day	58	14	68
Day	10	14	78
Day	10	14	89
Day	10	14	100
Day	10	14	111



Interpretation of results.

The fatigue score is calculated based on four factors:

- duration of shifts and breaks;
- timing of shifts and breaks;
- prior (seven-day) work history of individuals; and
- biological limitations on sleep and recovery.

Fatigue levels are naturally higher in the early morning hours (0300 ñ 0600) independent of the amount of sleep an individual has obtained. Further, early start times can truncate the sleep period of an individual and reduce the amount of recovery sleep they obtain prior to a work period. Finally, extended workshifts (ie shifts longer than 8 hours) also reduce the length of opportunity for recovery sleep between work periods. Each of the fatigue plots included above, provide an indication of the time in the work period that the highest fatigue occurs.

Any recommendations regarding alterations to the rotation should be made in the context of a risk management approach. The score of 80 is used as a benchmark score based on studies showing that individuals performance at scores higher than 80 is comparable to performance at a blood alcohol concentration of above .05%. However, a risk management approach will take into account organisation and task specific factors in any determination of an acceptable fatigue score.

Appendix A: Description of FAID

A work-related fatigue model

The working definition of fatigue is that of a dynamic balance between two competing forces. That is, forces producing fatigue and forces reversing the effects of fatigue, that is recovery.

Essentially, the model allocates fatigue or recovery value to work and break periods based on four factors:

- duration of shifts and breaks;
- timing of shifts and breaks;
- prior (seven-day) work history of individuals; and
- biological limitations on sleep and recovery.

The information on which this model is based has been produced as a result of significant experimental studies into the effects of shift lengths, the timing of shifts and the importance of work periods at different times in the past. This experimentation has been undertaken over the previous decades at various facilities throughout the world. In addition to this information, the model has been developed and validated within our own facility, within simulated work environments and in field-based situations. The development and validation work is considerable as has been published in a range of international peer-reviewed journals and books (see references 1 to 7 below; these can be supplied to Dampier Salt Limited upon request).

The model does not make decisions on which work schedules are most appropriate in specific workplaces. What the model does however, is provide information that can be useful when decisions about fatigue management need to be made. Tracking fatigue scores in relation to incident frequency, absenteeism levels, employee sick days or other organisationally meaningful data would allow a clearer illustration of the relationship between hours-of-work and its related costs.

Defining the Scores Produced

To differentiate between schedules, four levels of work-related fatigue scores are defined. Standard fatigue represents fatigue scores up to the maximum fatigue scores produced for a Monday to Friday 0900 to 1700hr standard work week; that is, a score of approximately 40. Moderate fatigue scores are those which are up to 200% of the maximum score produced by the standard work week; that is, a score of approximately 80. High fatigue scores are those which are between 200 and 250% of the maximum scores produced by the standard work week; that is, a score of approximately 100. Very high fatigue scores are those which are between 250 and 300% of the maximum scores produced by the standard work week; that is, a score of 120 or greater.

A recent study indicated that scores between 80 and 100 (that is, high fatigue) are equivalent to the predicted level of work-related fatigue achieved after 23-24 hours of continuous sleep deprivation (starting at 0800h). This result was observed when the sleep deprivation started at 0800h on a Monday, following a week working Monday to Friday 0900-1700h and with Saturday and Sunday off. Performance impairment at such a level of sleep deprivation has been associated with blood alcohol concentration over 0.05% in a recent study (8). This finding was also supported by numerous validations from a recent PhD thesis (5).

- 1) Fletcher, A. & Dawson, D. (2001). Field-based validations of a work-related fatigue model based on hours of work. *Transportation Research, Part F4*: 75-88.

- 2) Dawson, D. & Fletcher, A. (2001). A quantitative model of work-related fatigue: Background and definition. *Ergonomics*, 44(2): 144-163.
- 3) Fletcher, A. & Dawson, D. (2001). A quantitative model of work-related fatigue: empirical evaluations. *Ergonomics*, 44(5): 475-488.
- 4) Fletcher, A., Roach, G.D., Lamond, N. & Dawson, D. (2000). Laboratory based validations of a work-related fatigue model based on hours of work. In: S. Hornberger, P. Knauth, G. Costa, S. Folkard (Eds.) *Shiftwork in the 21st Century: Challenges for Research and Practice*. Peter Lang, Frankfurt am Main, Germany.
- 5) Fletcher, A. Measurement and management of work-related fatigue: Development and preliminary validations of a predictive model. Ph.D. Thesis, 1999, The University of South Australia.
- 6) Fletcher, A. & Dawson, D. A work-related fatigue model based on hours-of-work (1998). In: L. Hartley (Ed.) *Managing Fatigue in Transportation*, Oxford, Pergamon Press, 189-208.
- 7) Fletcher, A & Dawson, D. (1997). A predictive model of work-related fatigue based on hours of work. *Journal of Occupational Health and Safety - Australia and New Zealand*, 13(5): 471-485.
- 8) Dawson, D & Reid, K. (1997). Fatigue, alcohol and performance impairment. *Nature*, July 1997, 388:235.