# final report

**Project code:** FLOT.327

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# Reducing the Risk of Heat Load for the Australian Feedlot Industry

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# Abstract

This project was undertaken to reduce the risk of high heat load events occurring at Australian feedlots in the future. The industry has taken a proactive approach to the heat load issue to prevent the production losses, animal welfare issues and bad media publicity that is associated with such events. The purpose of this project was to refine the Heat Load Index and produce a risk assessment tool to be used in the Australian feedlot industry.

The new Heat Load Index and Accumulated Heat Load Units measures give Australian feedlot operators a more accurate reflection of the climatic heat load their cattle are exposed to at a particular point in time. Use of these measures will allow feedlot operators to better manage climatic heat load and instigate strategies to prevent the occurrence of high heat load events. A Risk Assessment Program (RAP) that can be used by feedlot operators to quantify the risk of high heat load events occurring at their specific feedlot, or pens within their feedlot, has also been produced as part of this project. This will allow feedlot operators to identify specific pens within their feedlot that are at risk, and to implement mitigation strategies that can be used to reduce that risk.

# Executive Summary

The feedlot industry has been under intense scrutiny recently to improve its animal welfare programs in light of a number of catastrophic high heat load events that resulted in large numbers of cattle deaths. The industry has been proactive in this debate and taken steps to reduce the risk of such catastrophic events occurring in the future. This position has driven industry investment in this project.

The purpose of this project was to refine the Heat Load Index (HLI) and produce a Risk Assessment Program (RAP) to be used in assessing the risk of high heat load events occurring at individual feedlots and/or feedlot pens. A new measure of climatic heat load, called Accumulated Heat Load Units (AHLU), has been produced as part of this project. The Accumulated Heat Load Units incorporate both the severity of the heat load imposed on the feedlot animals and the duration of exposure.

The Heat Load Index was developed using datasets collected from 13 feedlots located in both Australia and the United States of America. All of the datasets included both climatic data and a measure of animal comfort (panting score, respiration rate, tympanic or rectal temperature). All of the datasets were collected during periods of high heat load on feedlot cattle and all were collected using a ”reference animal” as the selected standard. The characteristics of the reference animal were:

- Black Angus Steer;
- Condition Score 4-5;
- Kept in an unshaded pen; and
- At least 100 days on feed.

The new Heat Load Index incorporates three climatic variables previously identified as being important in determining the heat load on feedlot cattle. The climatic variables included in the new Heat Load Index are:

- Black Globe Temperature (BGT) (°C);
- Relative Humidity (RH) (%); and
- Wind Speed (WS) (m/s).

It was noticed during the formulation of the new Heat Load Index (HLI) that there was a different animal response at high Black Globe Temperatures than at low Black Globe Temperatures. Thus, two Heat Load Index algorithms were produced: one for Black Globe Temperature above 25°C and one for Black Globe Temperatures below 25°C. The new Heat Load Index is:

For Black Globe Temperatures less than 25°C:

- $HLI = 10.66 + (0.28 \times RH) + (1.3 \times BGT) - WS$

For Black Globe Temperatures above 25°C:

- $HLI = 8.62 + (0.38 \times RH) + (1.55 \times BGT) – (0.5 \times WS) + EXP(-WS + 2.4)$

The Accumulated Heat Load Unit is calculated by measuring the period of time that the Heat Load Index is above an upper Heat Load Index Threshold. When this occurs, the animal is accumulating heat. Alternatively, if the Heat Load Index falls below the Lower Heat Load Index

Threshold, then the animal is dissipating heat to the atmosphere. There are a number of factors that influence the specific values for the Upper Heat Load Index Threshold. For the reference animal, which is described below, the Upper Heat Load Index Threshold is set at 86 and the Lower Heat Load Index Threshold is set at 79. At Heat Load Index values between these thresholds, the animal is neither accumulating nor dissipating heat.

The Risk Assessment Program uses data from Bureau of Meteorology Automatic Weather Stations to quantify the climatic risk of specific feedlot regions. Once the regional climatic risk is quantified, individual feedlot management strategies are then assessed, and the effect of each of these individual feedlot management strategies on the feedlot's heat risk is quantified. The individual feedlot management strategies in the Risk Assessment Program includes, but is not limited to: animal genotype and coat colour, the presence of shade, the manure management regime and water trough temperature. These effects are quantified by estimating the impact that each management strategy has on the Upper Heat Load Index Threshold.

This project has resulted in the production of a Heat Load Index that can be used across the Australian feedlot industry. This Heat Load Index replaces earlier versions and will be consistently used across the entire industry for an extended period of time. The measure for Accumulated Heat Load Units that was produced as a result of this project will give the Australian feedlot industry another index capable of accurately demonstrating the potential heat load on feedlot animals at a particular point in time.

The Risk Assessment Program that has been produced by this project will be used in the feedlot industry to quantify the risk of high heat load events occurring at specific feedlots. The potential to incorporate the Risk Assessment Program into the National Feedlot Accreditation Scheme has been recognized. If this occurs, a minimum risk level would be set and feedlots that do not comply with the minimum risk level would not receive accreditation. This would further reduce the risk of high heat load events occurring in the feedlot industry, as feedlot operators would be forced to improve their heat risk management.

# 1. Introduction

## 1.1 Industry Context

Extreme heat load events that have occurred at Australian feedlots have, in some cases, resulted in the death of cattle. Apart from the obvious losses in production that were a consequence, these events have resulted in bad publicity for the feedlot industry and increased third-party scrutiny on the industry. To address this, the feedlot industry has taken proactive measures to reduce the impact of high heat load events on feedlot cattle. It is within this context that the current project has been undertaken.

The major objectives of this project are to assist feedlot operators to reduce the impact of extreme heat load events occurring at their feedlot.

## 1.2 Project Background

The project FLOT.327 "Reducing the risk of heat load for the Australian feedlot industry," was funded by Meat and Livestock Australia (MLA) with research support from E.A. Systems Pty Limited, Katestone Environmental Pty Limited and The University of Queensland. The project was formally contracted in September 2004 and aimed to be completed by the end of February 2005.

The objectives of the project were to revise the existing Heat Load Index (HLI); investigate the Accumulated Heat Load Units (AHLU) as a measure of heat load; and produce a Risk Assessment Program capable of quantifying the risk of extreme heat load events occurring at individual feedlots. The findings of this project were to be conveyed through a series of industry workshops, jointly organised by the Australian Lot Feeders' Association (ALFA) and Meat and Livestock Australia and a revised output of the MLA document "Heat load in feedlot cattle 2002 – tips and tools."

The need for this research originally flowed from an ALFA Working Party appointed to review two reports that related to an incident in February 2000 where a number of cattle died due to extreme weather conditions. These two reports were:

1. *'A Report to the Director General, NSW Agriculture – Mortalities in Feedlot Cattle at Prime City Feedlot, Tabbita, NSW, February 2000'* K. Entwistle, M. Rose and B. McKiernan;

2. *'Report to the Feedlot Industry Accreditation Committee on the Review of the Prime City Incident'* K. Roberts, K. Sullivan, R. Burton and D. Rinehart.

The Working Party considered both reports and decided on certain target areas that needed further research. Following on from these decisions, a number of MLA funded projects were undertaken in an attempt to improve the understanding within the industry of the factors that cause extreme heat load events. The research projects that have been undertaken include:

- FLOT.307 – Recommendations for reducing the impact of elements of the physical environment on heat load in feedlot cattle.
- FLOT.310 – Measuring microclimate variations in two Australian feedlots.
- FLOT.312 – Heat stress software development.
- FLOT.313 – Forecasting feedlot thermal comfort.
- FLOT.315 – Applied scientific evaluation of feedlot shade design.
- FLOT.316 – Development of an excessive heat load index for use in the Australian feedlot industry.
- FLOT.317 – Measuring the microclimate of eastern Australian feedlots.

The work areas covered in these projects included:

- Identifying the climatic variables crucial to determining the heat load on feedlot cattle;
- Determining the differences in crucial climatic variables between in-pen conditions and conditions in the surrounding area;
- Developing an optimum design for feedlot shade structures; and
- Preliminary development of HLI and associated software to predict the risk of extreme heat load events occurring at individual feedlot sites.

These projects laid the foundation for the work undertaken in project FLOT.327.

## 1.3 Project Objectives

The objectives of project FLOT.327 were to, by 28 February 2005, complete the following:

1. Refine the Heat Load Index (HLI) algorithms so they accurately account for the full range of operational and environmental conditions in the lot-feeding industry in Australia and technical constraints of weather stations. Further development of the accumulation of heat load hours as opposed to an absolute determination of a HLI as a spot measurement will be undertaken.

2. Provide a decision support module that can be used by feedlot operators to:

    a. determine the risk of excessive heat load conditions occurring at specific locations for specific classes of cattle;

    b. determine the ameliorative measures that they will need to adopt to offset the level of identified risk; and

    c. document the outcomes of the Risk Assessment Program (RAP).

3. Deliver the project findings to industry through a series of workshops and related extension activities.

# 2. Methodology

## 2.1 Work Area 1 – Refinement of the Heat Load Index

### *2.1.1 Data Collection Methods*

The data used in the refinement of the HLI was sourced from previous extreme heat load events. The data collection had been completed prior to the commencement of the project. The animal variables of interest that were collected in each dataset were:

- Body Temperature;
- Panting Score; and
- Respiration Rate.

All the datasets used in the refinement of the HLI had either one or all of these variables measured on an hourly basis during an extreme heat load event. Body temperature was collected using either the rectal or tympanic temperature collection methods. Respiration rate was measured by counting the number of breaths per minute. Panting score was measured using the 0 - 4.5 scale, with panting score 0 being an animal under no heat load, and 4.5 being a severely heat stressed animal. The indicators for each panting score are shown in Table 1.

**Table 1.** Panting score system used during data collection

| Panting score | Breathing condition | Associated Respiration Rate (breaths/min) |
|---|---|---|
| 0 | No panting – normal. Difficult to see chest movement | < 40 |
| 1 | Slight panting, mouth closed, no drool or foam. Easy to see chest movement | 40 – 70 |
| 2 | Fast panting, drool or foam present. No open mouth panting | 70 – 120 |
| 2.5 | As for 2 but with occasional open mouth panting, tongue not extended. | 70 – 120 |
| 3 | Open mouth panting + some drooling. Neck extended and head usually up. | 120 – 160 |
| 3.5 | As for 3 but with tongue out slightly & occasionally fully extended for short periods + excessive drooling. | 120 – 160 |
| 4 | Open mouth panting with tongue fully extended for prolonged periods+ excessive drooling. Neck extended and head up. | > 160 |
| 4.5 | As for 4 but head held down. Cattle “breathe” from flank. Drooling may cease. | Variable ~ RR may decrease |

There were a series of reference photographs used during the data collection phase to assist in determining the panting score. These reference photographs are shown in Figure 1.

Panting Score 0

Panting Score 1

Panting Score 2

Panting Score 2.5

Panting Score 3

Panting Score 3.5

Panting Score 4

Panting Score 4.5

**Figure 1.** Panting score reference photos used during data collection

The climatic data collection was completed by utilising weather stations established within the feedlot pens monitored. The climatic variables of interest were:

- ambient temperature (°C);
- black globe temperature (°C);
- relative humidity (%);
- wind speed (m/s); and
- solar radiation ($W/m^2$).

### *2.1.2 Datasets Collected*

Thirteen datasets were used to refine the HLI. Ten were from Australia (9 commercial and 1 research feedlot) and 3 were from the USA (1 commercial and 2 research feedlots). The major breed on all feedlots was Angus. The dates of data collection were January – March 2000; January – March 2002; January – February 2003; January – March 2004; July 2004 (US feedlot data).

In all the datasets used, the animal characteristics were kept relatively constant and based on a chosen 'reference animal'. The reference animal was chosen for two reasons:

1. It represents the animal most susceptible to heat stress; and
2. It was the most common animal in the feedlots studied.

The characteristics of the reference animal are:

- *Bos taurus*;
- Black hide;
- Condition Score 4-5;
- Kept in an unshaded pen;
- At least 100 days on feed.

This reference animal was used in all calculations associated with the Heat Load Index and the Accumulated Heat Load Units. The reference animal is also used as a basis for comparison in the RAP software.

The feedlots used were selected on the basis of and completion level of datasets (i.e. there was some animal data and associated weather data). Where possible, data associated with extreme weather events was included. The datasets from the commercial feedlots contained animal data (panting scores, Dry Matter Intake and in some cases respiration rates). Each dataset had weather data associated with the animal observations. Weather observation ranged from once every 10 minutes to once an hour. In some cases cattle data was recorded three times a day and in others only once per day. The research feedlots had the advantage of also recording body temperature every five to 15 minutes and respiration rate at 15 minute intervals.

The Australian commercial feedlots were located in Queensland, New South Wales and Victoria. The research feedlot was located in Queensland. The US commercial feedlot was located in north eastern Nebraska. The research feedlot was located in south east South

Dakota (both of these areas have summer temperatures and humidity levels similar to south-east Queensland).

### 2.1.3 Statistical Methods

Applying statistical techniques to the datasets was not an easy task. Advice on the best approach was sought from a number of independent sources in Australia and the USA. Following an independent review of previous data analysis by Dr David Mayer (DPI&F), a number of statistical methods/models were applied in the formulation and testing of the new HLI. These included multi-response non-linear models; regression analysis; time series analysis; correlation analysis; general linear models (Snedecor and Cochran 1989, Steel and Torrie 1980). The statistical method used depended on the available information in each data set. Generally it was not possible to analyse animal responses across datasets due to inconsistencies in the type of data collected and the timing of data collection. Animal responses to climatic conditions were further compounded by differences in Dry Matter Intake (DMI), dietary ingredients, pen aspect and general feedlot management. The research data was used as the basis for the new HLI, and this was then tested against the commercial data sets. Further adjustments were then made and the index re-tested against the datasets.

## 2.2 Work Area 2 – Risk Assessment Program Software

### 2.2.1 Climate Data Collection

The climatic data used in the formulation of the RAP Software was collected from Bureau of Meteorology (BOM) Automatic Weather Stations (AWS). A list of sites located in the major lotfeeding regions of Australia, with adequate meteorological monitoring data, was compiled as a starting point for the climatic risk assessment for the feedlot cattle. Some of the sites were omitted from the assessment, as there was inadequate quality data on which to conduct a detailed study. Overall 38 monitoring sites across Australia were used.

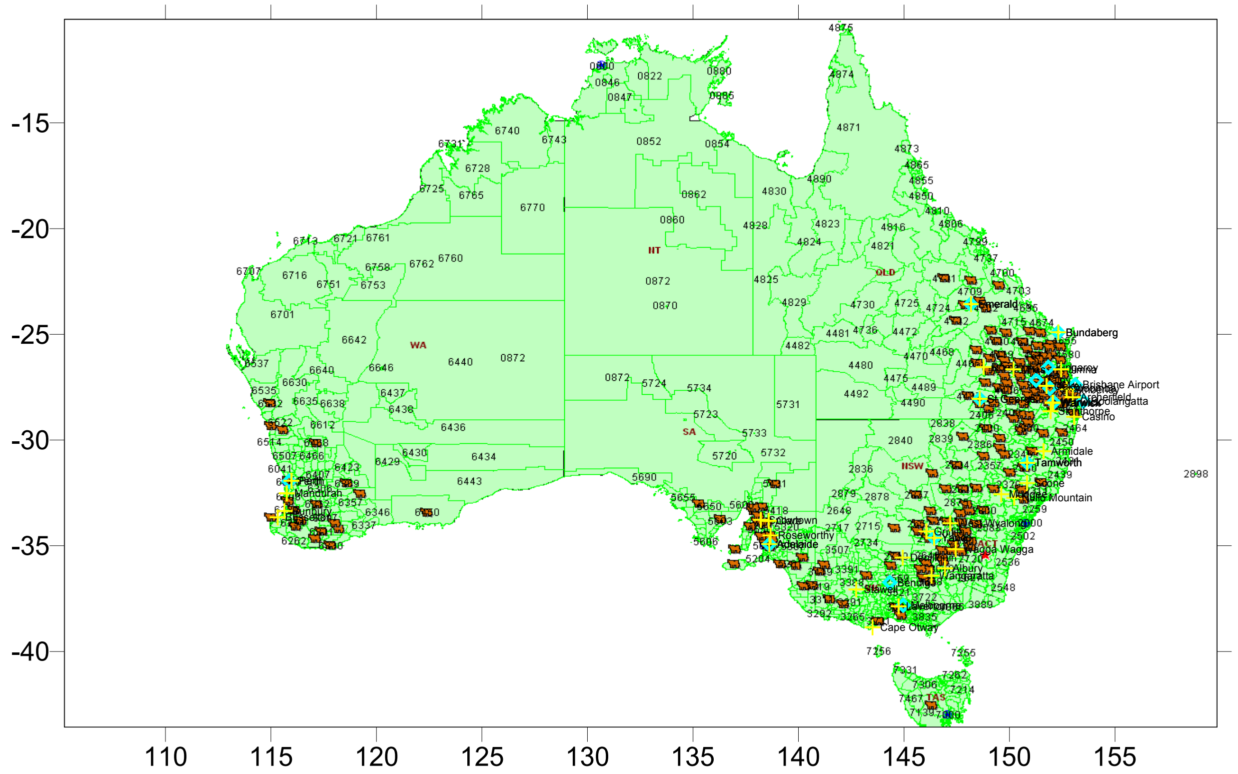


**Figure 2.** Location of feedlots (brown symbols) and monitoring sites (yellow crosses)

### *2.2.2 Suitable BOM Sites*

The meteorological sites initially selected with hourly and three hourly data are shown in Tables 2 and 3 respectively, along with the commencement date and percentage of data available. (Note that the start date for each site is when the site initially started operating, not necessarily the time from when valid data was recorded.)

**Table 2.** Suitable AWS sites (Hourly data)

| Name | Location (Lat, Long) | | State | Elevation of site | Start date | End Date | % Available |
|---|---|---|---|---|---|---|---|
| Albany Airport | -34.9414 | 117.8022 | WA | 68.0 | 1993 | 2004 | 94 |
| Bridgetown | -33.9486 | 116.1311 | WA | 178.7 | 1998 | 2004 | 93 |
| Casino Airport AWS | -28.8775 | 153.0520 | NSW | 20.9 | 1995 | 2004 | 94 |
| Clare High School | -33.8227 | 138.5935 | SA | 395.0 | 1993 | 2004 | 6 |
| Cleve Aerodrome | -33.7081 | 136.5026 | SA | 175.0 | 1996 | 2004 | * |
| Condobolin Airport AWS | -33.0682 | 147.2133 | NSW | 192.6 | 1993 | 2004 | 94 |
| Coonamble Airport AWS | -30.9776 | 148.3798 | NSW | 181.3 | 1997 | 2004 | 98 |
| Dubbo Airport AWS | -32.2206 | 148.5753 | NSW | 284.0 | 1989 | 2004 | 81 |
| Emerald Airport | -23.5694 | 148.1756 | QLD | 189.4 | 1998 | 2004 | 95 |
| Geelong Airport | -38.2242 | 144.3344 | VIC | 33.4 | 1999 | 2004 | 98 |
| Glen Innes Airport AWS | -29.6780 | 151.6940 | NSW | 1044.3 | 1996 | 2004 | 96 |
| Griffith Airport AWS | -34.2487 | 146.0695 | NSW | 134.0 | 2000 | 2004 | 99 |
| Hay CSIRO AWS | -34.5471 | 144.8670 | NSW | 90.0 | 1989 | 2004 | 86 |
| Katanning | -33.6856 | 117.6064 | WA | 320.0 | 1999 | 2004 | 88 |
| Miles Constance Street | -26.6569 | 150.1819 | QLD | 304.8 | 1998 | 2004 | 24 |
| Moree Aero | -29.4914 | 149.8458 | NSW | 213.0 | 1989 | 2004 | 86 |
| Mudgee Airport AWS | -32.5624 | 149.6160 | NSW | 471.0 | 1989 | 2004 | 89 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Naracoorte Aerodrome | -36.9813 | 140.7270 | SA | 49.7 | 1998 | 2004 | 24 |
| Orange Airport AWS | -33.3813 | 149.1269 | NSW | 947.4 | 1996 | 2004 | 92 |
| Parkes Airport AWS | -33.1294 | 148.2417 | NSW | 323.3 | 1997 | 2004 | 97 |
| St George Airport | -28.0489 | 148.5942 | QLD | 198.5 | 1998 | 2004 | 74 |
| Stanthorpe (Granite Belt Hrs) | -28.6214 | 151.9528 | QLD | 871.6 | 1997 | 2004 | 95 |
| Toowoomba Airport | -27.5425 | 151.9134 | QLD | 640.9 | 1996 | 2004 | 94 |
| Wagga Wagga | -35.1583 | 147.4573 | NSW | 212.0 | 1989 | 2004 | 88 |
| Walgett Airport AWS | -30.0372 | 148.1223 | NSW | 133.0 | 1997 | 2004 | 98 |
| Wangaratta Aero | -36.4206 | 146.3056 | VIC | 152.6 | 1999 | 2004 | 98 |
| Warwick | -28.2061 | 152.1003 | QLD | 475.4 | 1998 | 2004 | 33 |

Data available for the above sites were as follows:

- Precipitation since 9am local time in mm.
- Quality of precipitation since 9am local time.
- Air Temperature in Celsius.
- Quality of air temperature.
- Wet bulb temperature in Celsius.
- Quality of Wet bulb temperature.
- Dew point temperature in Celsius.
- Quality of dew point temperature.
- Relative humidity in percentile.
- Quality of relative humidity.
- Wind speed in km/h.
- Wind speed quality.
- Wind direction in degrees true.
- Wind direction quality.
- Cloud amount (of first – fourth group) in eighths.
- Quality of each group of cloud amount.
- Horizontal visibility in km.
- Quality of horizontal visibility.
- Present weather in text.
- Quality of present weather.
- Mean sea level pressure in hPa.
- Quality of mean sea level pressure.

**Table 3.** Suitable AWS sites (3-hourly data)

| **Name** | **Location (Lat, long)** | | **State** | **Elevation of site** | **Start date** | **End Date** | **% Available** |
|---|---|---|---|---|---|---|---|
| Mullewa | -28.5367 | 115.5142 | WA | 268.0 | 1987 | 2004 | 86 |
| Mungindi Post Office | -28.9786 | 148.9899 | NSW | 160.0 | 1983 | 2004 | 92 |
| Narrogin | -32.9342 | 117.1797 | WA | 338.0 | 1983 | 2004 | 99 |
| Texas Post Office | -28.8544 | 151.1681 | QLD | 297.0 | 1983 | 2004 | 91 |
| Warracknabeal Museum | -36.2614 | 142.4050 | VIC | 113.4 | 1983 | 2004 | 99 |
| Lostock Dam | -32.3283 | 151.4583 | NSW | 200.0 | 1983 | 2004 | 99 |
| Colac (Mt Gellibrand) | -38.2333 | 143.7925 | VIC | 261.0 | 2000 | 2004 | 100 |
| Cootamundra Airport | -34.6299 | 148.0364 | NSW | 335.0 | 1995 | 2004 | 100 |
| Colac (Elliminyt) | -38.3933 | 143.5961 | VIC | 248.1 | 1983 | 1998 | 100 |
| Colac Airport | -38.2794 | 143.6614 | VIC | 120.0 | 1998 | 2000 | 100 |
| Inverell Research Centre | -29.7752 | 151.0819 | NSW | 664.0 | 1983 | 2004 | 92 |

| Name | Location (Lat, long) | | State | Elevation of site | Start date | End Date | % Available |
|---|---|---|---|---|---|---|---|
| Kingaroy Airport | -26.5737 | 151.8398 | QLD | 433.7 | 2001 | 2004 | 99 |
| Narrabri Airport AWS | -30.3154 | 149.8302 | NSW | 229.0 | 2001 | 2004 | 99 |
| Armidale Airport AWS | -30.5273 | 151.6158 | NSW | 1079.0 | 1994 | 2004 | 96 |
| Armidale (Radio Station 2AD) | -30.5167 | 151.6681 | NSW | 980.0 | 1983 | 1997 | 100 |

Each of these sites contained the following fields:

- 3 hourly precipitation;
- 3 hourly temperature;
- 3 hourly dewpoint;
- 3 hourly wet bulb;
- 3 hourly relative humidity (percentage);
- 3 hourly wind speed (in kph);
- 3 hourly wind direction (16 compass points);
- 3 hourly "present weather";
- 3 hourly "past weather";
- 3 hourly mean sea level pressure;
- 3 hourly total cloud amount;
- 3 hourly visibility; and
- Daily Max and Min temperature.

For sites where 3-hourly data were available, the observations were filled using linear interpolation techniques, as hourly data are required to calculate the heat load index.

In Queensland, there were four sites selected with more than 10 years of data, five sites with between five and 10 years of data and four sites with less than five years' worth of data. The sites selected in Queensland and the start and end dates are shown in Table 4.

**Table 4.** Meteorological monitoring sites for Queensland used in the RAP software

| Location | State | Beginning date | End date | No of summers |
|---|---|---|---|---|
| Amberley | Qld | 09/96 | 09/04 | 8 |
| Emerald | Qld | 11/98 | 09/04 | 6 |
| Goondiwindi | Qld | 06/91 | 10/04 | 13 |
| Inglewood | Qld | 02/00 | 10/04 | 4 |
| Kingaroy | Qld | 10/01 | 09/04 | 3 |
| Miles | Qld | 01/00 | 10/04 | 3.5 |
| Oakey | Qld | 09/96 | 10/04 | 8 |
| Roma | Qld | 03/97 | 10/04 | 7 |
| St George | Qld | 03/00 | 09/04 | 4 |
| Stanthorpe | Qld | 03/97 | 09/04 | 7 |
| St Lawrence | Qld | 01/93 | 09/04 | 12 |
| Toowoomba | Qld | 10/87 | 09/04 | 17 |

| | | | | |
|---|---|---|---|---|
| Warwick | Qld | 03/94 | 10/04 | 10 |

There were three data sites for South Australia with the site of Clare containing 10 years' of data, and the other sites containing between five and 10 years' of data. The sites selected in South Australia are shown in Table 5.

**Table 5.** Meteorological monitoring sites for South Australia used in the RAP software

| Location | State | Beginning date | End date | No of summers |
|---|---|---|---|---|
| Clare | SA | 10/93 | 10/04 | 11 |
| Cleve | SA | 07/96 | 10/04 | 8 |
| Naracoorte | SA | 1998 | 10/04 | 7 |

All Victorian sites contained between four and five years of detailed data. The AWS sites selected to be included in the RAP software are shown in Table 6.

**Table 6.** Meteorological monitoring sites for Victoria used in the RAP software

| Location | State | Beginning date | End date | No of summers |
|---|---|---|---|---|
| Colac | VIC | 07/07/00 | 09/04 | 4 |
| Geelong | VIC | 20/02/99 | 09/04 | 5 |
| Wangaratta | VIC | 20/02/99 | 09/04 | 5 |

The monitoring network in New South Wales was very extensive, including six sites with data recorded for more than 10 years. Nine sites had between five and 10 years of data and one site had less than 5 years. For details on start and end dates and whether hourly or half hourly information was used refer to Table 7.

**Table 7.** Meteorological monitoring sites for New South Wales used in the RAP software

| Location | State | Beginning date | End date | No of summers |
|---|---|---|---|---|
| Albury | NSW | 09/96 | 11/04 | 11 |
| Armidale | NSW | 09/96 | 11/04 | 11 |
| Casino | NSW | 07/95 | 09/04 | 9 |
| Condobolin | NSW | 02/97 | 09/04 | 7 |
| Coonamble | NSW | 09/97 | 09/04 | 7 |
| Dubbo | NSW | 12/93 | 09/04 | 11 |
| Glen Innes | NSW | 01/97 | 09/04 | 8 |
| Hay | NSW | 11/89 | 09/04 | 15 |
| Moree | NSW | 05/95 | 09/04 | 9 |
| Mudgee | NSW | 09/84 | 09/04 | 20 |
| Orange | NSW | 04/74 | 09/04 | 30 |
| Parkes | NSW | 11/97 | 09/04 | 7 |
| Tamworth | NSW | 09/96 | 09/04 | 8 |
| Wagga Wagga | NSW | 04/51 | 09/04 | 54 |
| Walgett | NSW | 05/97 | 09/04 | 7 |
| Yanco | NSW | 08/99 | 11/04 | 5 |

Western Australia contained one long-term data site at Albany which had 27 years of recorded data. All other sites contained up to six years' worth of data. The AWS sites selected in Western Australia are shown in Table 8.

**Table 8.** Meteorological monitoring sites for Western Australia used in the RAP software

| Location | State | Beginning date | End date | No of summers |
|---|---|---|---|---|
| Albany | WA | 01/77 | 09/04 | 27 |
| Bridgetown | WA | 07/98 | 09/04 | 6 |
| Katanning | WA | 01/99 | 09/04 | 6 |
| Newdegate | WA | 06/96 | 11/04 | 7 |
| Wandering | WA | 02/99 | 11/04 | 6 |

### 2.2.3 Quantifying the Effects of Individual Feedlot Management Strategies

The effects of various individual feedlot management strategies were estimated by quantifying the effect of these variables on the upper HLI threshold. For the reference animal (see Section 2.1.2), the upper HLI threshold is set at 86. Factors that reduced the risk of extreme heat load events had a positive effect on this threshold. For example, installing properly designed shade structures had a positive effect on the upper HLI threshold. Thus, cattle under shade begin accumulating heat at a higher HLI than those not under shade. Factors that increased the risk of extreme heat load, such as an animal suffering from a disease challenge, particularly a respiratory disease, had a negative effect on the upper HLI threshold. Thus, animals with a disease challenge will begin to accumulate heat at a lower HLI than healthy cattle. Using this method, it was possible to quantify the effects of various heat load mitigation strategies.

The effects of individual management factors were quantified, where possible, using real data collected from previous MLA projects (MLA FLOT.310 and FLOT.317). However, this was not possible in all cases. Where it was not possible to quantify the effects of heat load of a specific management factor using real data, the effect was quantified using an estimate produced by the Industry Committee in charge of overseeing this project. This estimate was based on the experience of the members of the committee and will be verified in an upcoming MLA funded project.

### 2.2.4 Development of the Risk Assessment Software

The HLI, as shown in Section 4.1.1, is obtained from measured physical/environmental parameters comprising (dry bulb) temperature, solar radiation, relative humidity and wind speed. In some instances, not all of these parameters are available. Consequently, these need to be determined using alternative methods. Some variables that can be calculated using empirical formulae include solar radiation and relative humidity. In the case of solar radiation, a value for this parameter can be calculated from appropriate equations (See below) to approximate solar loading without the effects of cloud cover. The relative humidity can be calculated from the wet bulb temperature; a readily available measured quantity. This methodology is described below.

Most AWS sites included wind speed, wind direction, temperature (wet and dry bulb), relative humidity and dew point. For those sites that did not include the required parameters, they were calculated using the formulae shown below.

### 2.2.5 Calculation of relative humidity and solar radiation

The relative humidity was calculated from the dry and wet bulb temperatures and atmospheric pressure using the following equations:

**Equation 1** $E_s = 6.112 * \exp((17.67 * T)/(243.5 + T))$

**Equation 2** $E_w = 6.112 * \exp((17.67 * T_w)/(243.5 + T_w))$

**Equation 3** $E = E_w - P * (T - T_w) * 0.00066 * (1 + 0.00115 * T_w)$

and finally

**Equation 4** $RH = 100 * (E/E_s)$

Where:

$T_w$ is the wet bulb temperature ($^oC$)

P is the atmospheric pressure (1013 mb)

T is the (dry bulb) temperature ($^oC$)

$E_s$ is the saturation vapour pressure at temperature T

$E_w$ is the saturation vapour pressure at wet bulb temperature $T_w$

The solar radiation (SolRad) was determined from the time of day, day of the year and latitude of the site using the following equations:

**Equation 5** $LH = 15\pi/180 * (12 - t)$

**Equation 6** $DEC = -23.5\pi /180 * \cos(2\pi (day+10)/365)$

**Equation 7** $EL = \sin^{-1}(\sin(lat) * \sin(DEC) + \cos(lat) * \cos(LH) * \cos(DEC))$

**Equation 8** $SolRad = 1050 * \sin(EL) - 65$

Where

t is the hour of the day (local solar time in hours)

day is the day of the year (i.e. julian day)

LH is the local hour angle

DEC is the solar declination

EL is the solar elevation

lat is the latitude of the site (negative for Southern Hemisphere)

### 2.2.6 Extrapolation of wind speed from 10 m to 2 m

The monitoring sites measure wind speeds at 10 metres, therefore to represent winds at ground level the winds were corrected down to a height of 2 metres. The winds were calculated as follows:

Between 6 am and 6 pm assume D class stability (neutral):

**Equation 9** $U_{2m} = U_{10m} \times (2/10)^{0.15}$

Between 6 pm and 6 am assume F class stability (stable):

**Equation 10** $U_{2m} = U_{10m} \times (2/10)^{0.55}$

where

$U_{2m}$ is the wind speed at 2 m (m/s)

$U_{10m}$ is the wind at 10 m (m/s)

### *2.2.7 Black Globe Temperature*

The black globe temperature (BGT), which is used in the calculation of the Heat Load Index is defined as:

**Equation 11** $BGT = 1.33 * T - 2.65 * \mathrm{sqrt}(T) + 3.21 * \log(SolRad + 1) + 3.5.$

where

T is the temperature in $^{o}C$

SolRad is the solar radiation in $W/m^2$

## 2.3 Work Area 1 – Refinement of the Heat Load Index

### *2.3.1 Climatic Variables of Interest*

The effects of the climatic variables of interest have been investigated in previous MLA funded research projects (MLA FLOT.310 and MLA FLOT.317). The final report from the FLOT.310 project concluded that the occurrence of 'stress events' were related to, but not limited to:

- Constant high ambient temperature (over both days and nights);
- Significant radiant heat loads;
- Low wind speeds; and
- Elevated ammonia ($NH_3$) levels.

An example of one of the datasets used in FLOT.310 is shown in Figure 3. Figure 3 shows a high heat load event occurring at "Feedlot B" a feedlot in the Murrumbidgee Irrigation Area of Southern New South Wales.

The trends identified in FLOT.310 were also noted in this project as shown in Figure 4. Figure 4 shows the climatic variables leading up to, and during a high heat load event at an Australian feedlot, again located in Southern New South Wales. The onset of the event appears to have been brought on by similar circumstances. Features to note in Figure 4 include:

- Consistently high ambient and black globe temperatures;
- Consistently high relative humidity; and
- Low wind speeds.

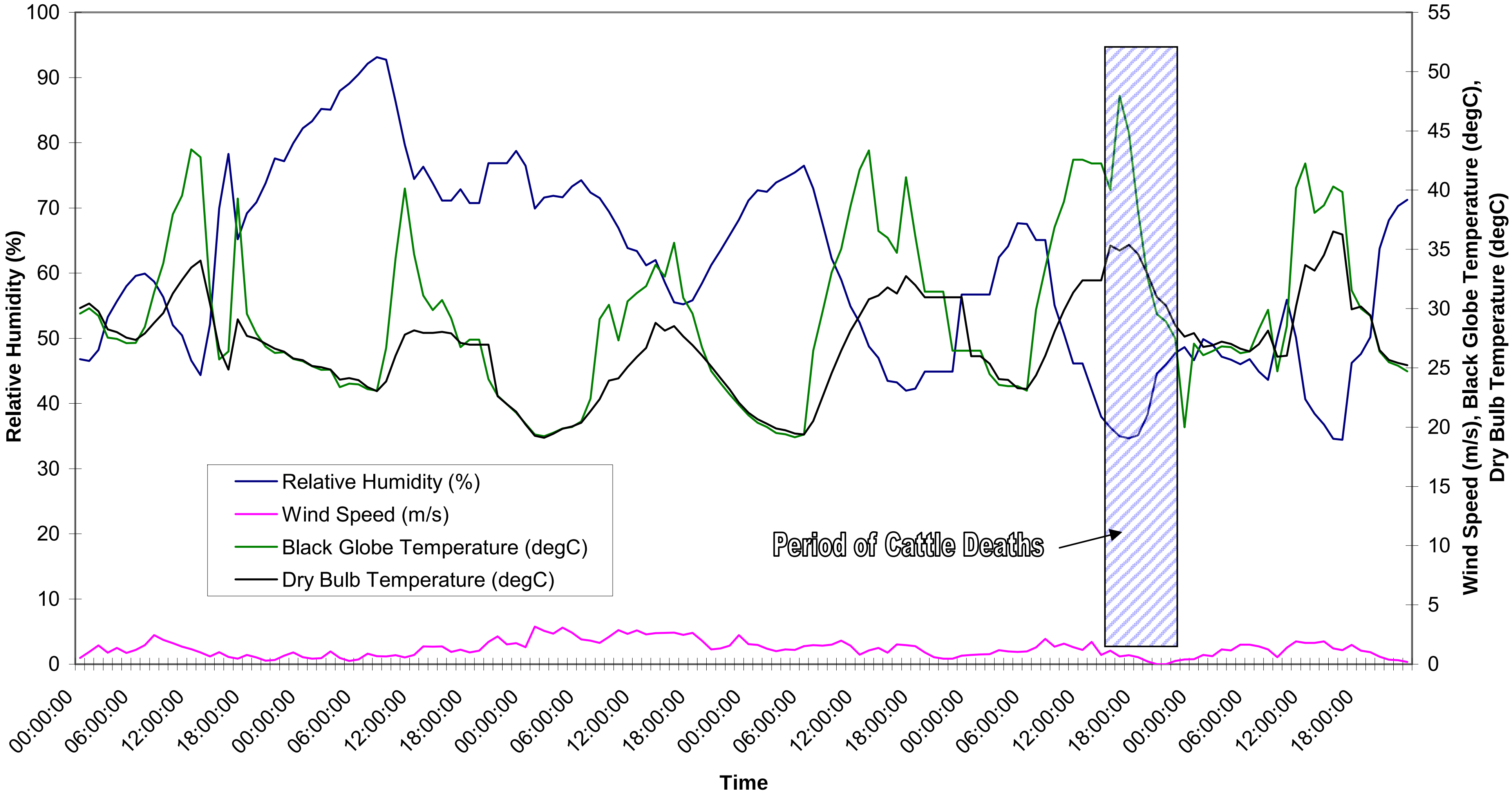


**Figure 3.** Climatic data from a high heat load event at an Australian feedlot (Feedlot B from FLOT.310)

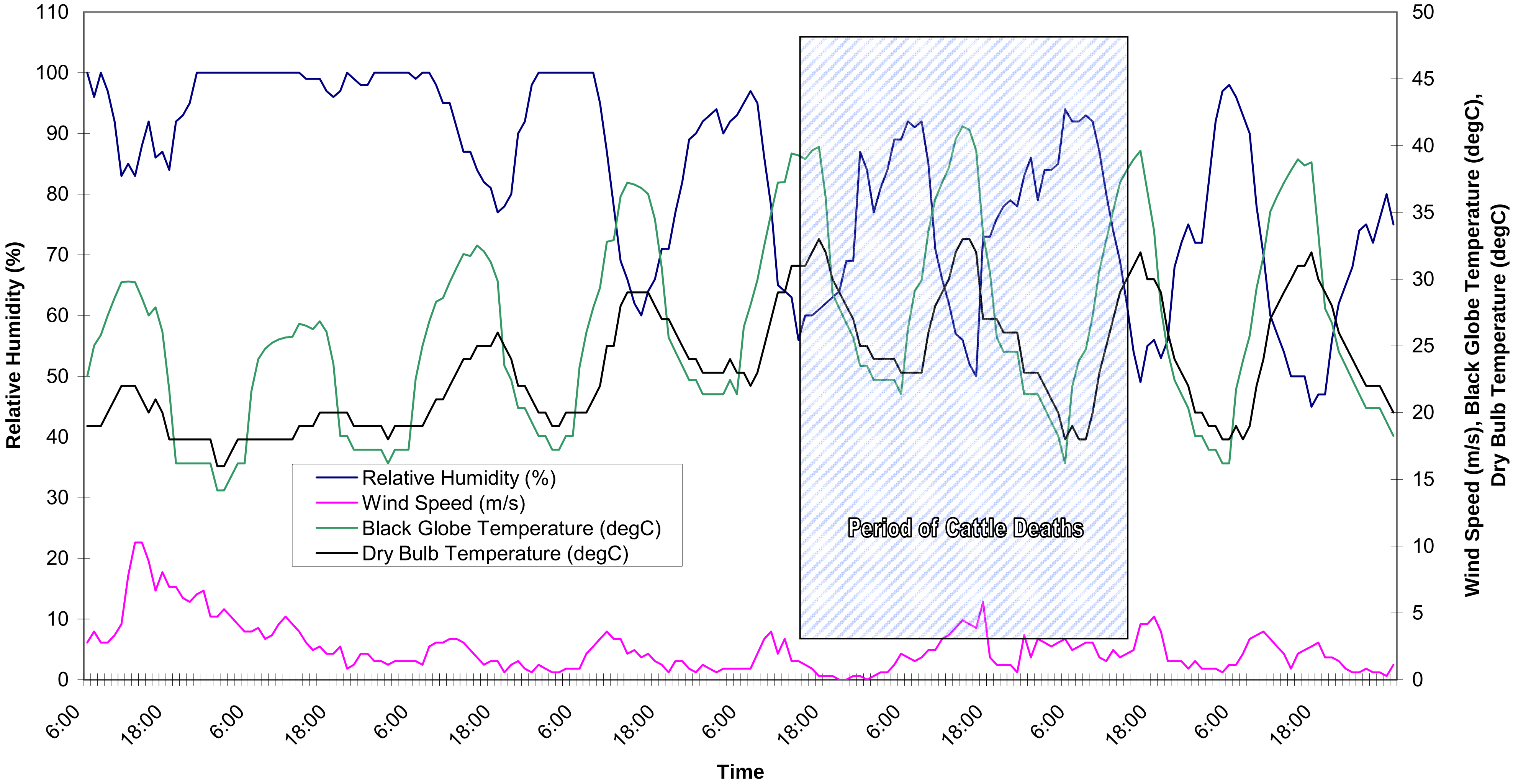


**Figure 4.** Climatic data from a high heat load event at an Australian feedlot in Southern New South Wales

## 2.4 Work Area 2 – Risk Assessment Program Software

### 2.4.1 Accumulated Heat Load Unit Calculations

The AHLU is measured by calculating a "HLI excess" i.e. the difference between the hourly HLI value and a threshold, and summing this excess for all hours of the day subject to the following conditions:

(a) If the HLI is above an upper threshold, the excess (HLI - upper threshold value) for that hour is added to the sum. The upper threshold is determined by environmental and management factors.

(b) If the HLI is below a lower threshold (set at 79), then the excess (lower threshold - HLI) is halved and this final value is subtracted from the sum. This step provides the mechanism to account for the fact that the recovery rate is slower.

(c) It is clear from the above statement that for an extended cool period, the accumulated heat load can become negative. In this case, the AHLU is maintained at zero.

The above procedure is carried out if the meteorological data is in the form of hourly records. In instances where the supplied data is in half hourly records, all excess values are halved to account for the shorter sampling period. More detail on the formulation of the AHLU can be found in Section 4.1.2.

### 2.4.2 Calculation of site statistics

The accumulated heat load was calculated for each site for all upper HLI thresholds ranging from 79 to 95. Events were identified and recorded, thus allowing site statistics to be compiled. Statistics were in the form of recurrence intervals for each event. For example, using a 10 year data set, if one extreme AHLU – four day duration event was found, this event was reported as having a recurrence interval of one decade or one per decade. Similarly, if an event was found to occur 10 times in a 10 year data set, its recurrence interval was reported as one per year.

Monthly statistics were also calculated. The statistics for all the January months in the data set were compiled and stored in files. The same was performed for all months in the data set. Events which overlapped monthly boundaries were included in both months.

The above process was performed for the data sets associated with each of the sites. The list of overall and monthly probabilities was stored in files which are encoded and shipped as part of the RAP system.

### 2.4.3 Feedlot Management Factors

The feedlot management factors included in the Risk Assessment Program software and their relevant effects on the Upper HLI Threshold are shown in Table 9.

**Table 9.** The relative effects of the feedlot management factors included in the RAP software on the upper HLI threshold.

| **Feedlot Management Factor** | **Relative effect on Upper HLI Threshold** |
|---|---|
| Animal Genotype: *Bos indicus* | +9 |
| *Bos taurus* x *Bos indicus* (50:50) | +5 |
| Europeans | +3 |
| *Bos taurus* | 0 |
| Animal Coat Colour: Black | 0 |
| Red | +1 |
| White | +3 |
| Animal Health: Healthy | 0 |
| Sick/recovering/unacclimatised | -5 |
| Shade: No Shade | 0 |
| Shade (>1.5m²/hd, <2m²/hd) | +3 |
| Shade (>2m²/hd, <3m²/hd) | +5 |
| Shade (>3m²/hd) | +7 |
| Trough Water Temperature: (15-20°C) | +1 |
| (20-30°C) | 0 |
| (30-35°C) | -1 |
| (>35°C) | -2 |
| Pen Class (Manure Management): Class 1 | 0 |
| Class 2 | -4 |
| Class 3 | -8 |
| Class 4 | -8 |
| Emergency Mitigation Strategies: | |
| Install Extra Water Troughs | +1 |
| Implement Heat Load Feeding Strategy | +2 |
| Strategic Cleaning of High Deposition Manure Areas | +2 |

Each operator of the RAP software must input the relevant management strategies they have implemented within their feedlot and/or feedlot pen, and the RAP software will then calculate the risk of extreme heat load events occurring at that feedlot or feedlot pen.

# 3. Discussion

## 3.1 Work Area 1 – Refinement of The Heat Load Index

### *3.1.1 Refinement of the Heat Load Index*

Using the datasets outlined in Section 2.1.2, and the statistical methods outlined in Section 2.1.3, a new Heat Load Index (HLI) has been produced. The new HLI includes two separate algorithms, one for Black Globe Temperatures of below 25°C and one for Black Globe Temperatures of above 25°C. The new algorithms include the following climatic variables:

- Black Globe Temperature (BGT) (°C);
- Wind Speed (WS) (m/s); and
- Relative Humidity (RH) (%).

The new Heat Load Index using these variables then becomes:

For Black Globe Temperatures less than 25°C:

- HLI = 10.66 + (0.28 x RH) + (1.3 x BGT) - WS

For Black Globe Temperatures above 25°C:

- HLI = 8.62 + (0.38 x RH) + (1.55 x BGT) – (0.5 x WS) + EXP(-WS +2.4)

Applying these equations to the dataset shown in Figure 3 and Figure 4, a HLI can be derived. The HLI derived from these datasets are shown in Figures 5 and 6. It can be seen from Figures 5 and 6 that there is a consistent increase in the HLI, both day and night, leading up to the onset of a high heat load event. This leads to the conclusion that the duration of exposure to extreme climatic conditions, as well as the intensity of that exposure, is important in determining the onset and severity of a high heat load event. This is discussed in more detail in Section 4.1.2.

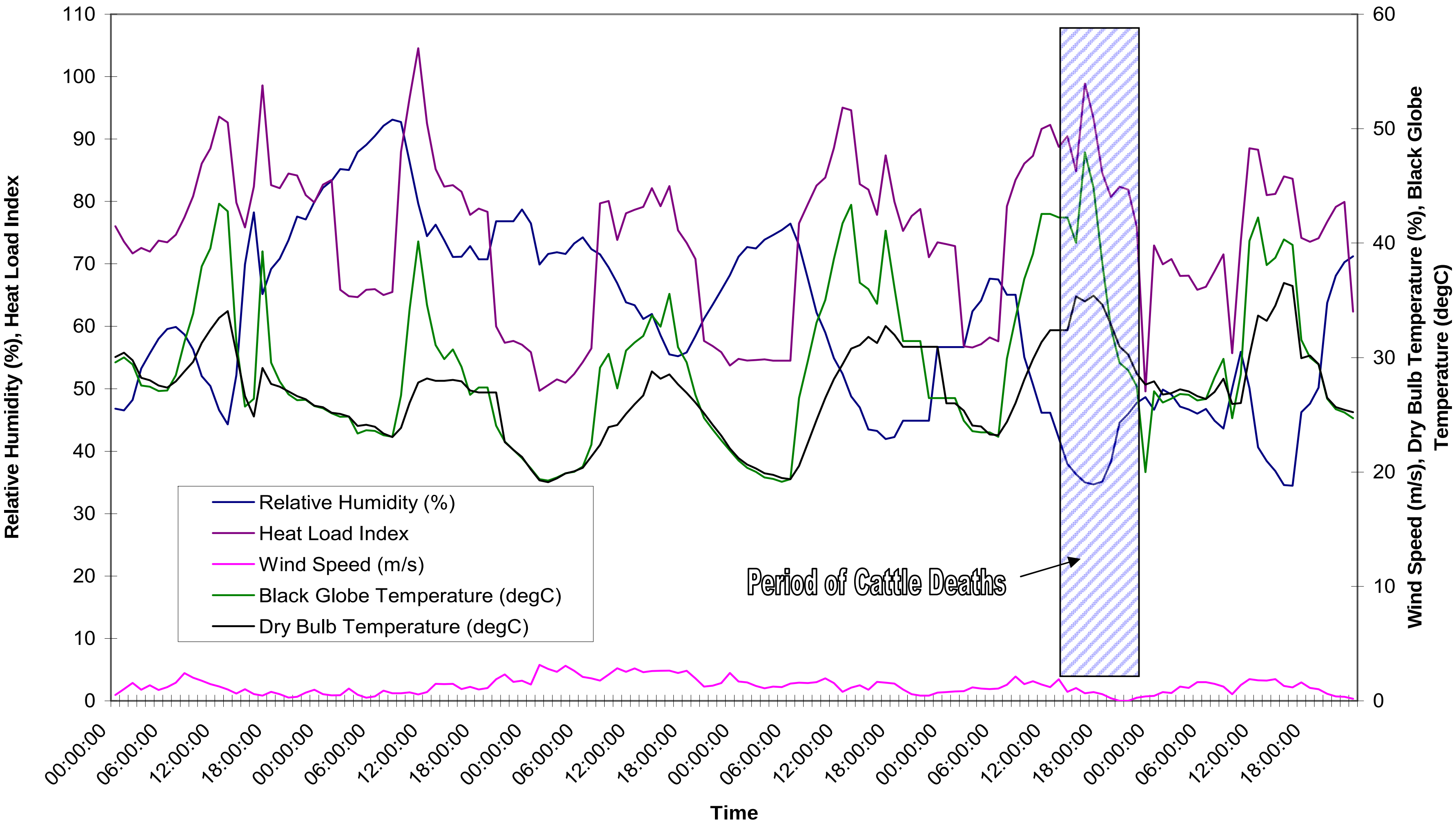


**Figure 5.** Climatic data from a high heat load event at an Australian feedlot, including the new HLI (Feedlot B from FLOT.310)

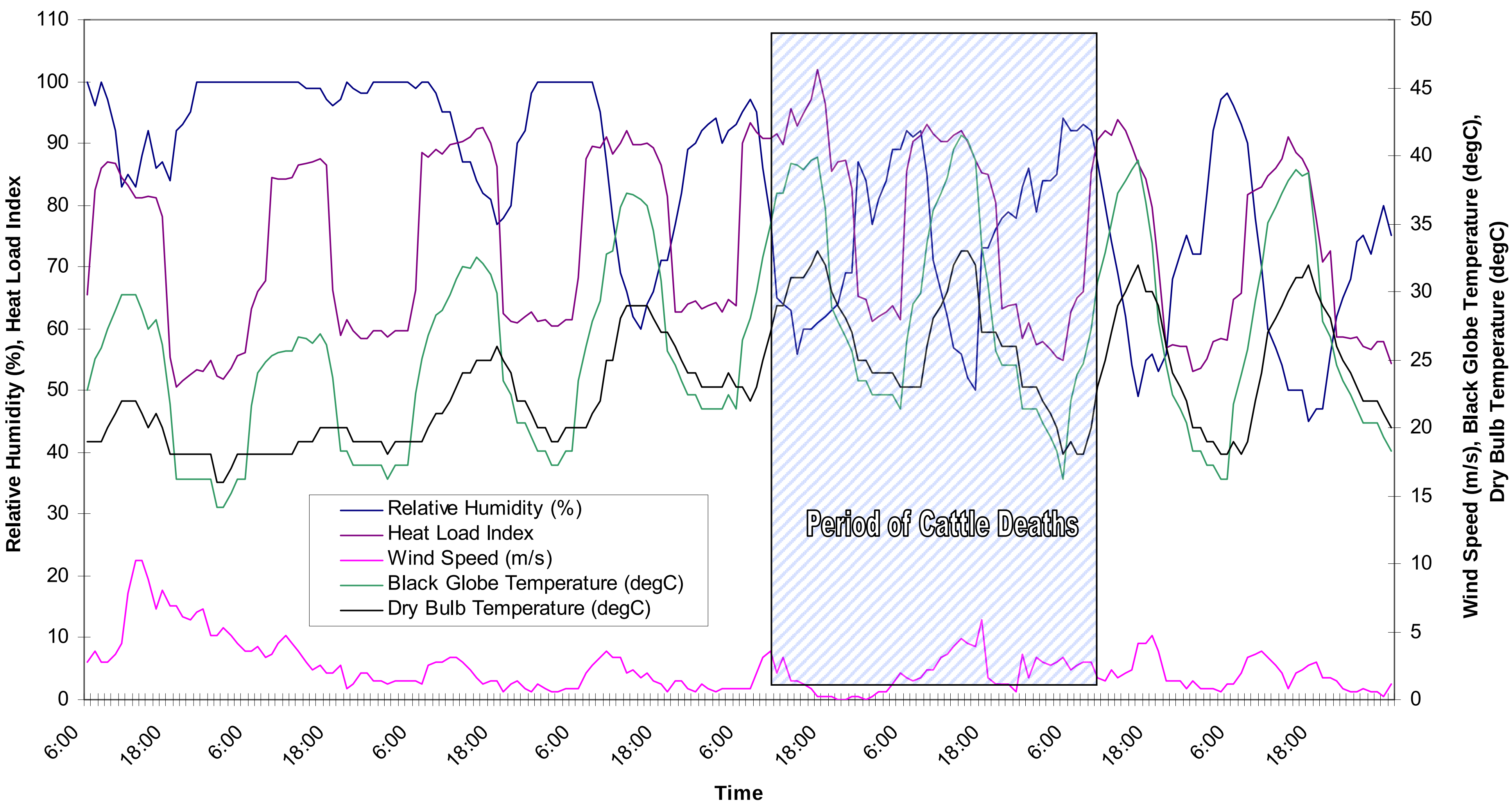


**Figure 6.** Climatic data from a high heat load event at an Australian feedlot in Southern New South Wales, including the new Heat Load Index

### *3.1.2 Accumulated Heat Load Units and Heat Load Thresholds*

Analysis of the biological data used for this project suggests that there are lags between the measured physiological responses and the climatic variables (Gaughan *et al*., 2004; Eigenberg *et al*., 2004). These lags are in the range of 1 – 2 hours and are not consistent. That is, under some conditions Respiration Rate will peak prior to maximum HLI (or ambient temperature) and at other times peak Respiration Rate will occur after the maximum HLI. This means that measurement of spot HLI may not be the best tool for assessing the heat load balance of a feedlot steer. For these reasons the development of the Accumulated Heat Load Units was undertaken.

The Accumulated Heat Load Units (AHLU) is based on the THI-Hrs concept (Hahn and Mader 1997). The AHLU is a two dimensional function incorporating time and heat balance. The AHLU is calculated by determining the difference between the HLI at a given time and an upper and lower threshold HLI. The thresholds have been developed largely from climate room studies, but also from feedlot studies. When the HLI is above the upper threshold, cattle will not be able to effectively shed body heat, which means that there is likely to be an increase in body temperature. When the HLI is below the lower threshold then cattle are likely to shed body heat. When the HLI is between the two thresholds cattle will neither shed nor gain heat.

The upper threshold has been established to be at a HLI of approximately 86, and the lower at a HLI of approximately 79. These values have been validated using the feedlot data sets.

The AHLU model uses the differences between the threshold and the HLI at a given time, and then adds or subtracts the differences. An example of the computations involved in calculating the AHLU is shown in Table 10. The dataset used in both Figures 5 and 6 was also used to demonstrate the effectiveness of the AHLU in reflecting the heat load on a feedlot steer. This data is shown in Figures 7 and 8.

Another dataset which used tympanic temperature to measure the body temperature of a group of 16 Angus steers in an unshaded pen is shown in Figure 9. Figure 9 shows the increase in body temperature typical of a high heat load event, as well as the HLI, HLI Balance and the AHLU. The data shown in Figure 9 has been collected at 30 minute intervals during an event when the Black Globe Temperature rose suddenly and the Wind Speed dropped shortly after. The slight lag between the increase in the HLI and the increase in the animal's body temperature should be noted.

It appears that both the spot HLI and the AHLU should be used i.e. we need to look at the intensity x duration effects. However, the actual number of Accumulated Heat Load Units deemed to be detrimental to cattle has yet to be accurately determined.

**Table 10.** An example of the calculations required to formulate the AHLU measure

| Time | HLI | HLI Balance | AHLU |
|---|---|---|---|
| 8:00:00 | 85 | 0 | 0 |
| 9:00:00 | 86 | 0 | 0 |
| 10:00:00 | 88 | 2 | 2 |
| 11:00:00 | 92 | 6 | 8 |
| 12:00:00 | 94 | 8 | 16 |
| 13:00:00 | 95 | 9 | 25 |
| 14:00:00 | 97 | 11 | 36 |
| 15:00:00 | 96 | 10 | 46 |
| 16:00:00 | 89 | 3 | 49 |
| 17:00:00 | 85 | 0 | 49 |
| 18:00:00 | 79 | 0 | 49 |
| 19:00:00 | 70 | -7 | 42 |
| 20:00:00 | 64 | -13 | 29 |
| 21:00:00 | 62 | -15 | 14 |
| 22:00:00 | 61 | -16 | 0 |

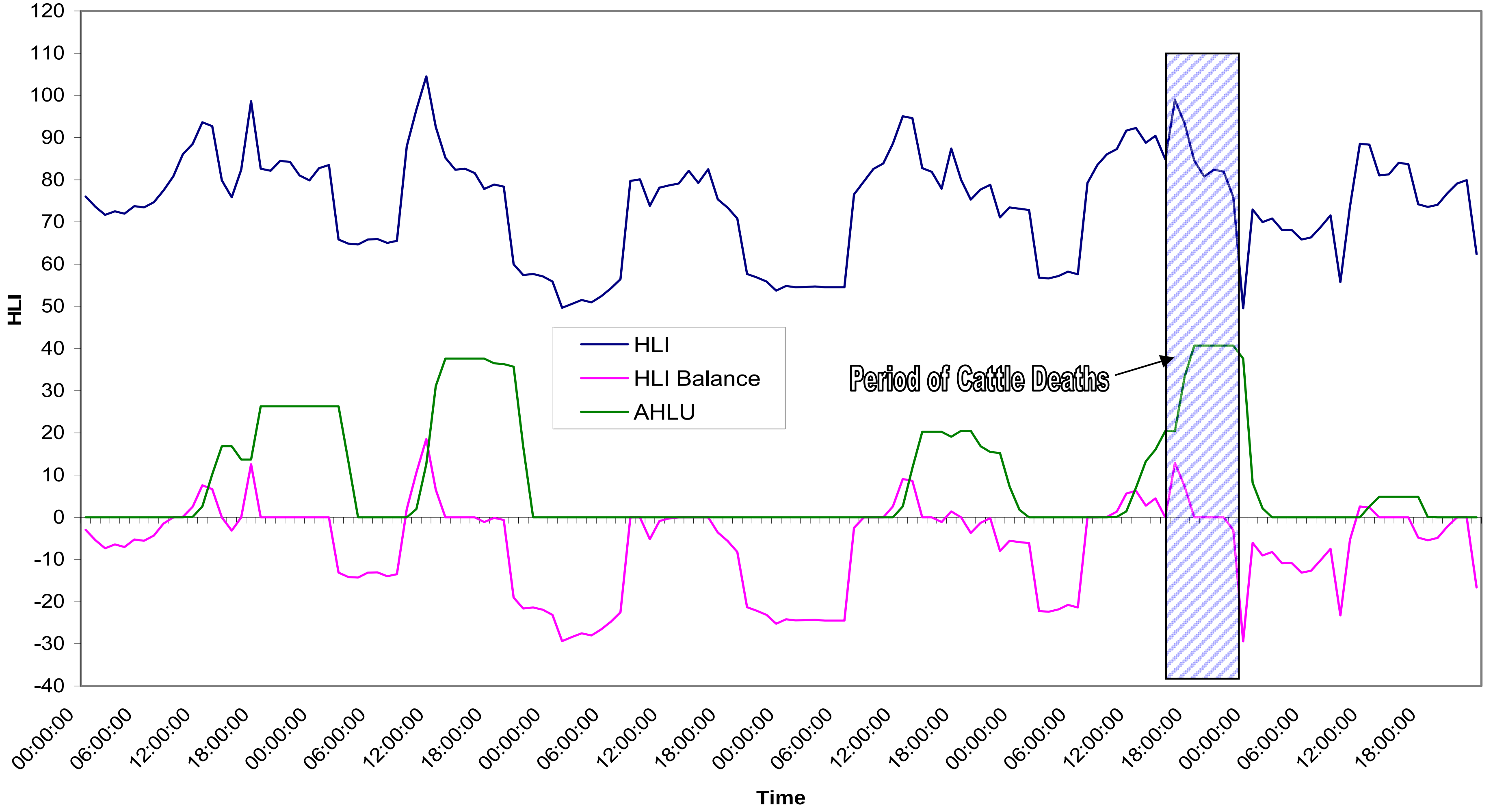


**Figure 7.** The HLI, HLI Balance and AHLU calculated from the same dataset shown in Figures 3 and 4

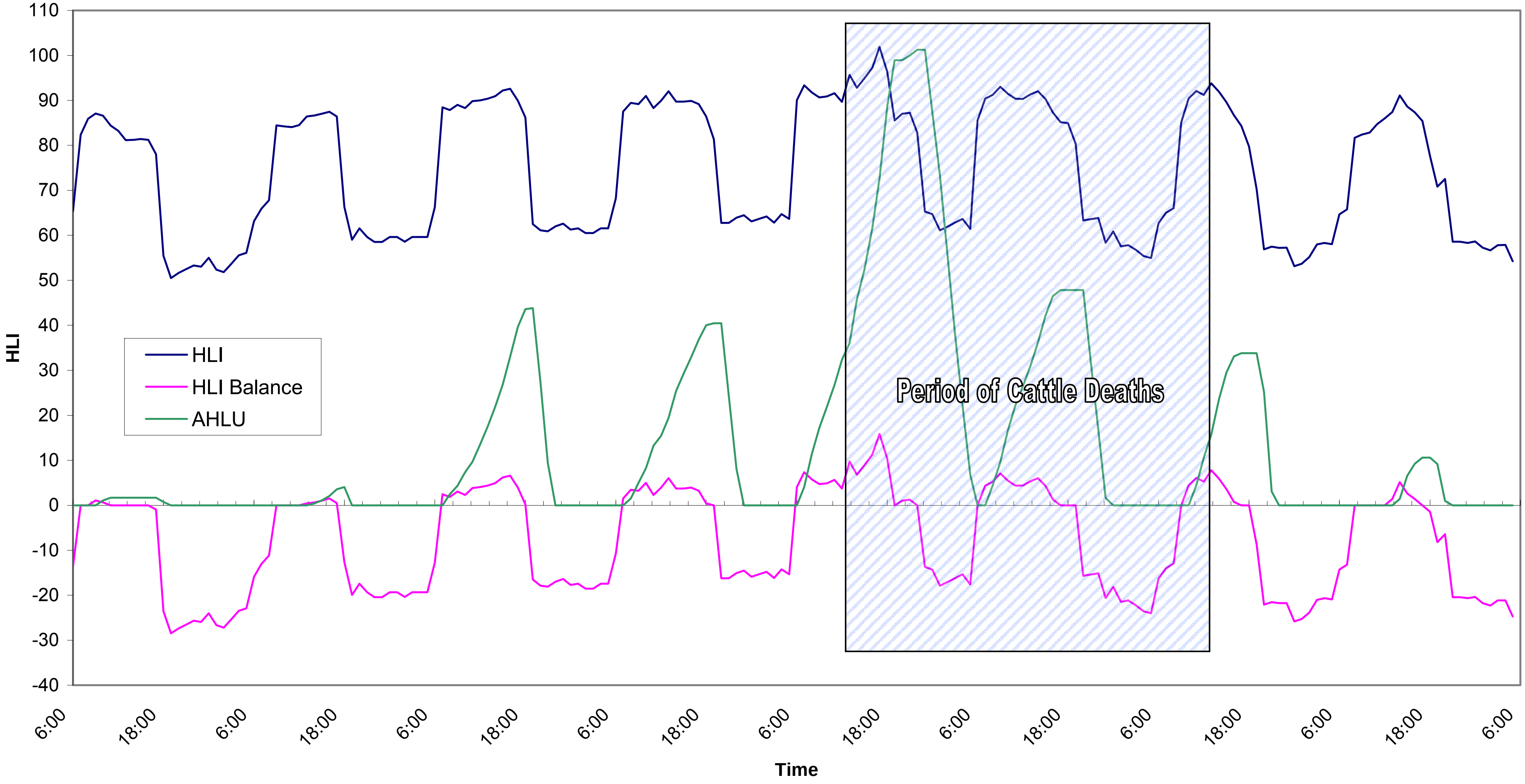


**Figure 8.** The HLI, HLI Balance and AHLU calculated from the same dataset shown in Figures 3 and 4

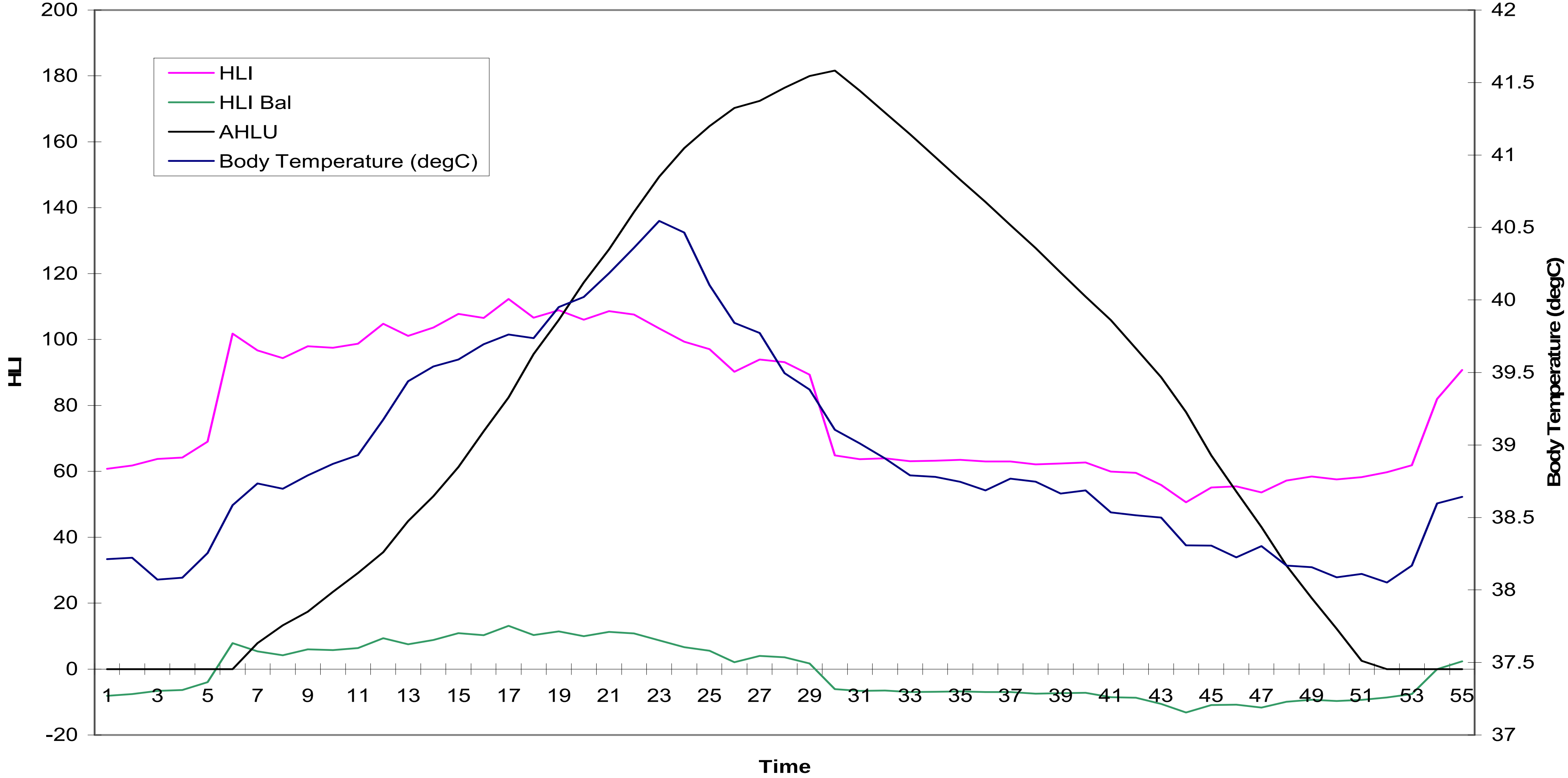


**Figure 9.** Average Tympanic Body Temperature of 16 Angus steers during a high heat load event, along with the HLI, HLI Balance and AHLU (X-axis is time in half-hours).

## 3.2 Work Area 2 – Risk Assessment Program Software

### *3.2.1 Individual Feedlot Management Factors*

The individual feedlot management factors included in the RAP software, shown in Table 9, were included because they were considered the most important feedlot management factors in determining the risk of a high heat load event occurring at individual feedlots. The relative effect of each factor on the upper HLI Threshold was estimated where possible using datasets collected from Australian or American feedlots. This was not possible in a number of cases, because the appropriate data simply does not exist. Where this was the case, an educated guess about the effect of each of the factors was made by the research team and the industry advisory committee. Whilst this is not statistically defendable, it represents the best possible outcome considering the limitations of the datasets used. Additional data collection has been undertaken to strengthen these estimates and will be incorporated into the RAP software.

### *3.2.2 Program Software*

The RAP software has been developed to be run using a Windows based operating systems. Upon opening the RAP software, the user is asked to define which BOM Automatic Weather Station is closest to their operation and would best reflect the climate at their site. This screen is shown in Figure10.

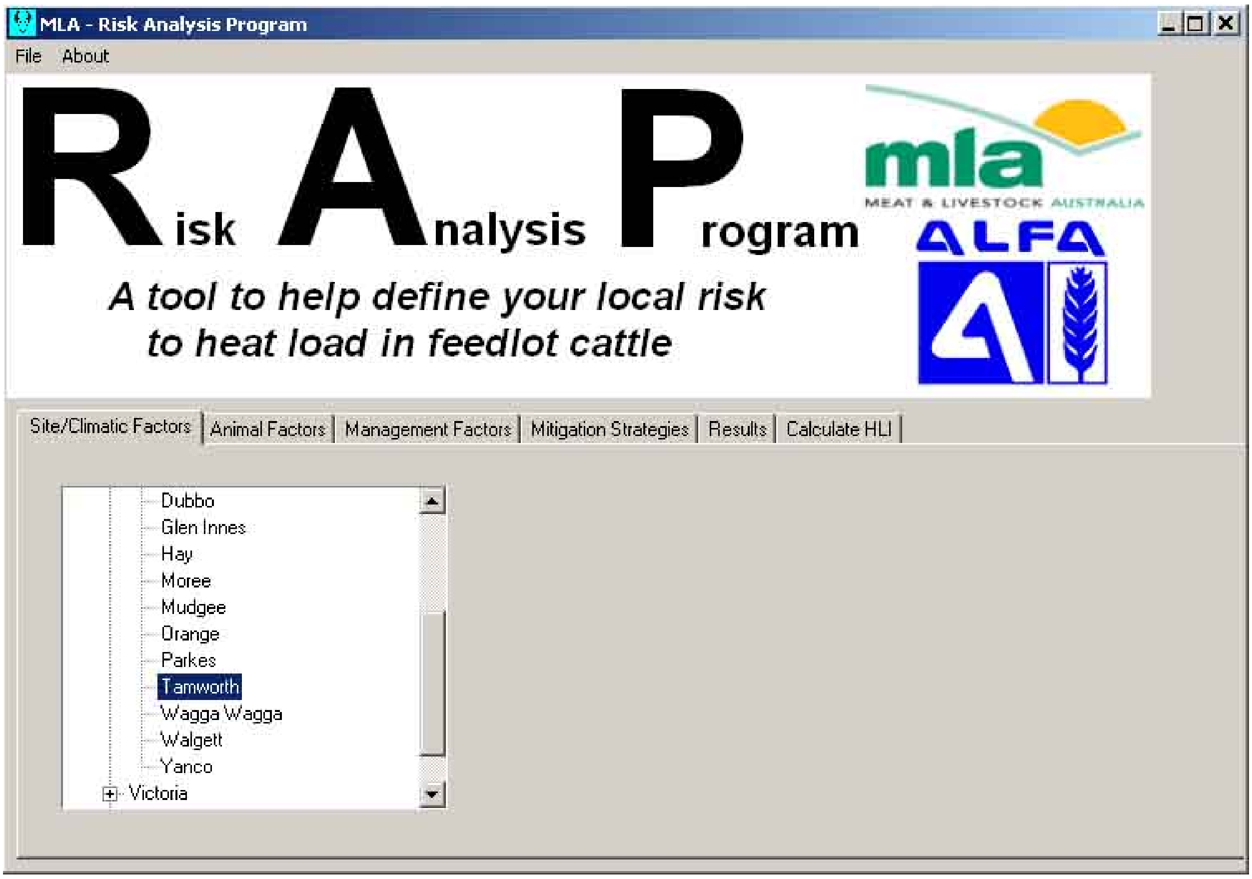


**Figure 10.** The site selection page of the RAP software

After the user has selected the site closest to their feedlot operation, they are asked to describe the animals that they have within their feedlot or feedlot pen of interest. The variables the user is asked to input in this section include the animal genotype and coat colour. The RAP software page which allows users to input the animal variables of interest are shown in Figure 11.

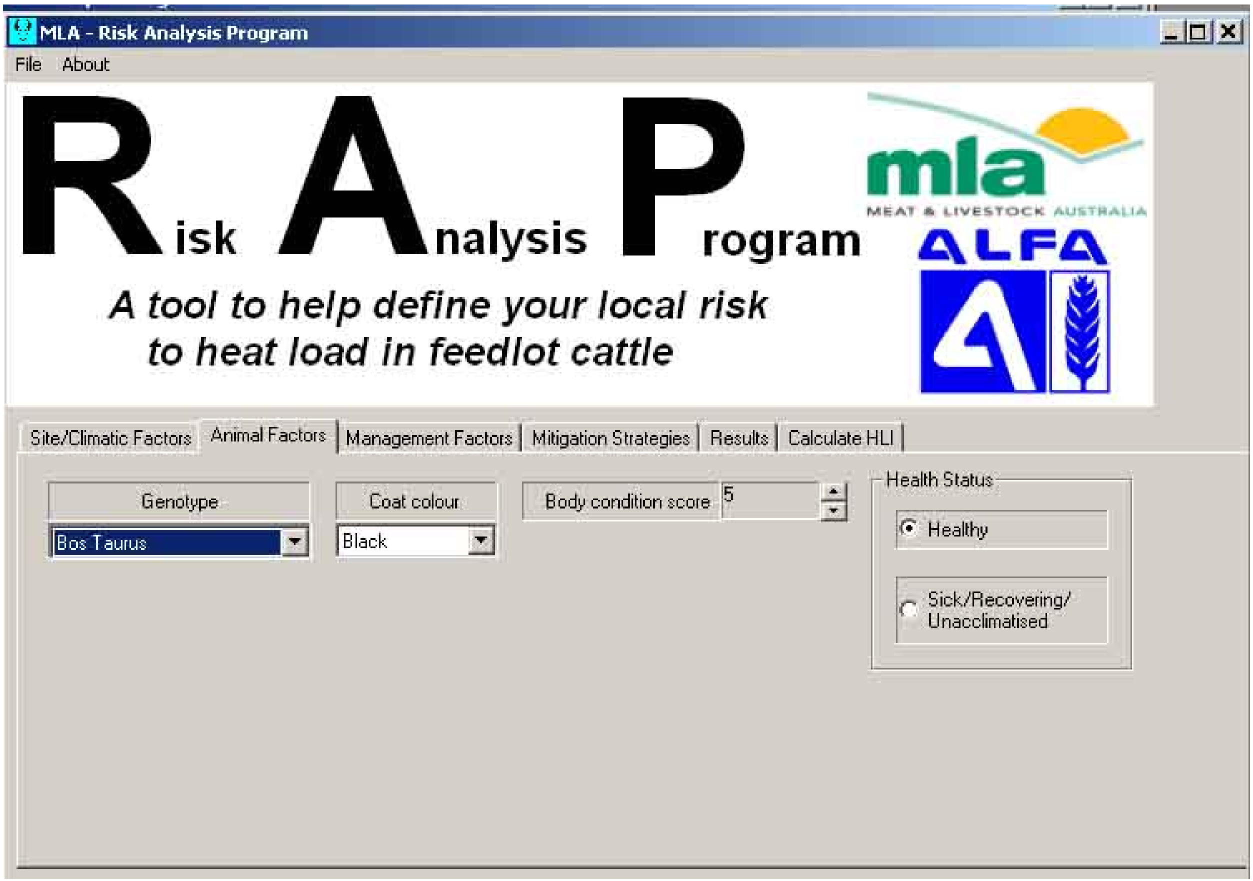


**Figure 11.** The animal factors page of the RAP software

The next page of the RAP software asks the user to input the various management strategies they have implemented within their feedlot. These strategies include the installation of shade, the temperature of the water in the drinking water troughs and the manure management feedlot class, which describes the frequency and thoroughness of pen cleaning. The feedlot management page of the RAP software is shown in Figure 12.

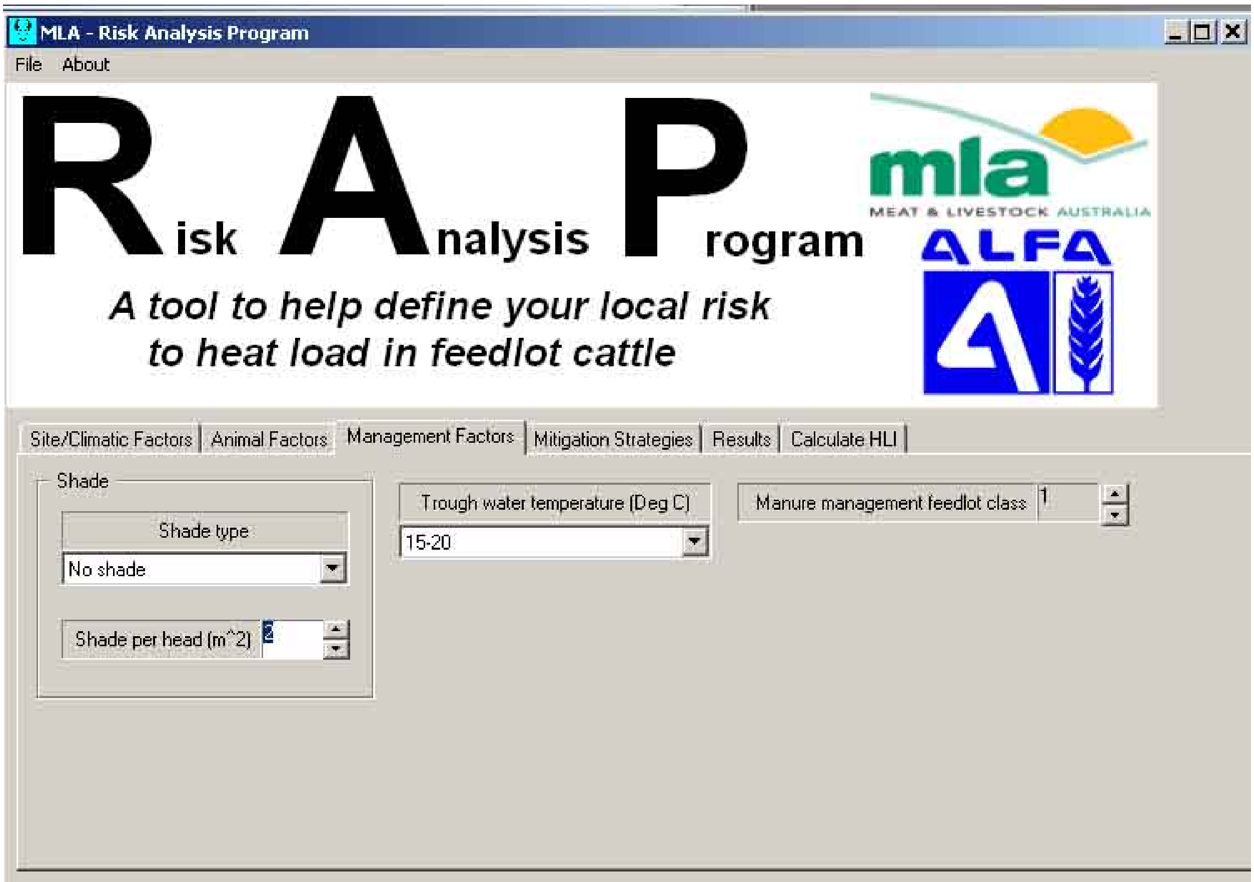


**Figure 12.** The feedlot management factors page within the RAP software

The emergency mitigation strategies are implemented during or just prior to an extreme heat load event. The strategies that are recommended for implementation include adding temporary water troughs to the pens, cleaning high manure deposition areas (around feedbunk and water troughs) and implementing a heat load feeding strategy. The feeding strategies used will vary between feedlots, thus there is no specific feeding strategy described within the RAP. If the user's feedlot operation has an emergency heat load feeding strategy, then this box should be ticked. The emergency mitigation strategies page within the RAP software is shown in Figure 13.

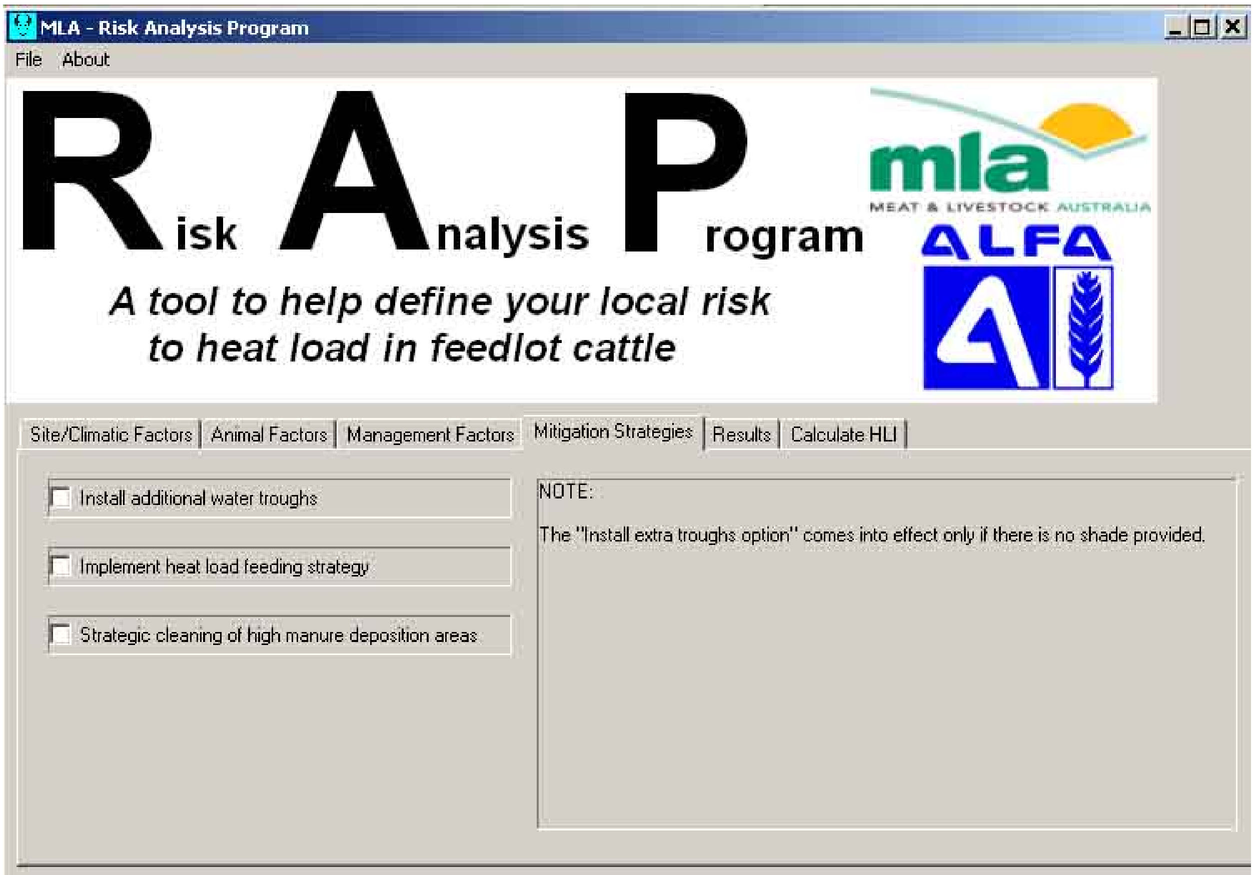


**Figure 13.** The emergency mitigation strategies page within the RAP software

The results of the RAP are outputted to the users by calculating the probability of a high heat load event and an extreme heat load event occurring at the feedlot in question. The severity of the events, expressed as the number of days over which the event will occur, is also shown. The risk of a heat load event occurring is then expressed as the number of events (e.g. 1/decade, 2/year, etc.) of either high or extreme heat load that will occur at that feedlot, and the number of days over which that event will occur. Obviously, the longer the period of time over which the event occurs, the more severe the event. The Upper HLI Threshold for that particular feedlot is also shown, after taking into account all of the factors shown in Table 3. The user is also given the opportunity to review the data they have inputted into the RAP by viewing the "Selected Characteristics" box. The results page from the RAP software is shown in Figure 14.

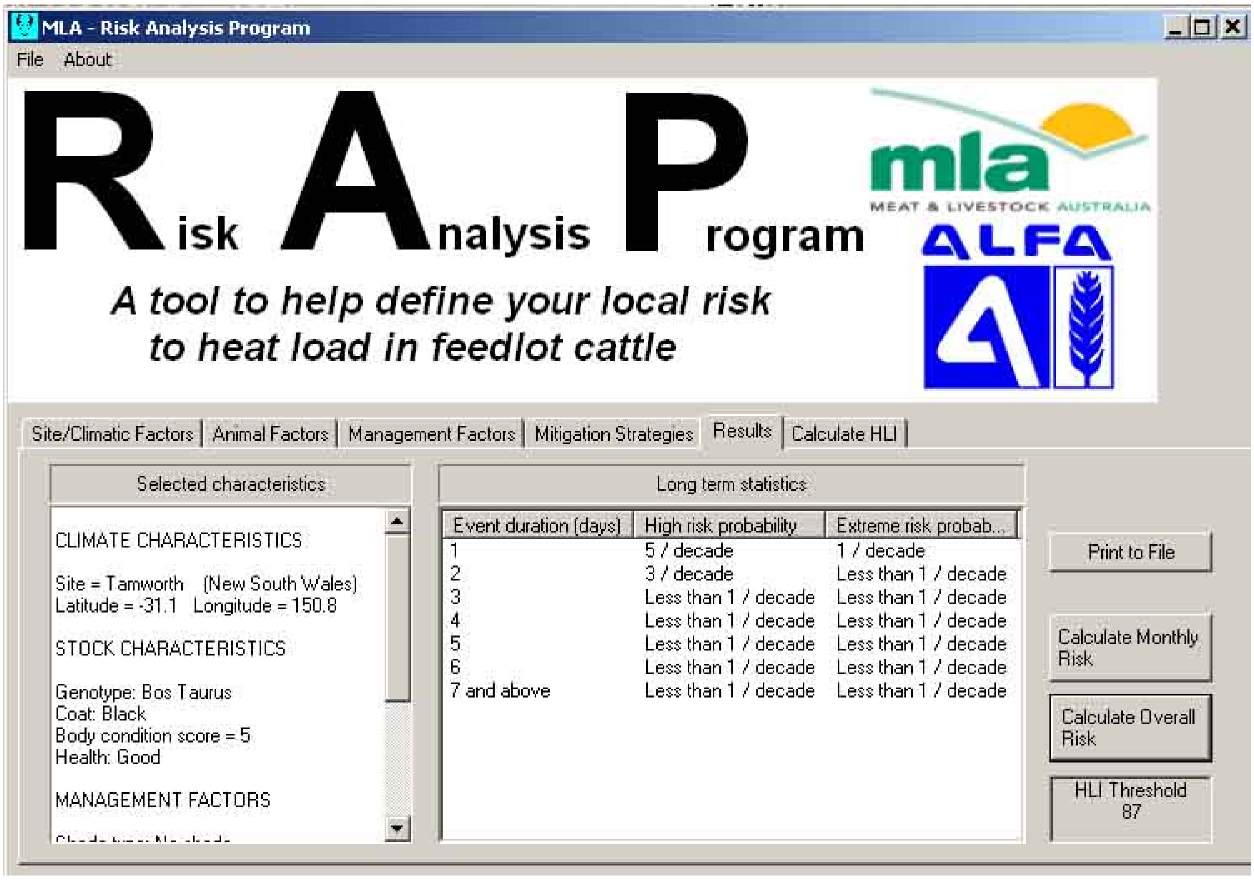


**Figure 14.** The results output page from the RAP software

Another feature of the RAP software is the “Calculate HLI” page. This page has been included to assist users to calculate a spot measure of the HLI. The critical variables that are used to calculate the HLI are shown on this page. There are a number of options for calculating the HLI, for example, if the user does not have a black globe temperature sensor on their weather station, then the black globe temperature can be calculated using the ambient air temperature and incoming solar radiation. There are a number of options for selecting the units of measure for each of the variables. The user must define which unit of measure applies to their specific readings, and the RAP software will calculate a spot measure of the HLI. The HLI calculation page within the RAP software is shown in Figure 15.

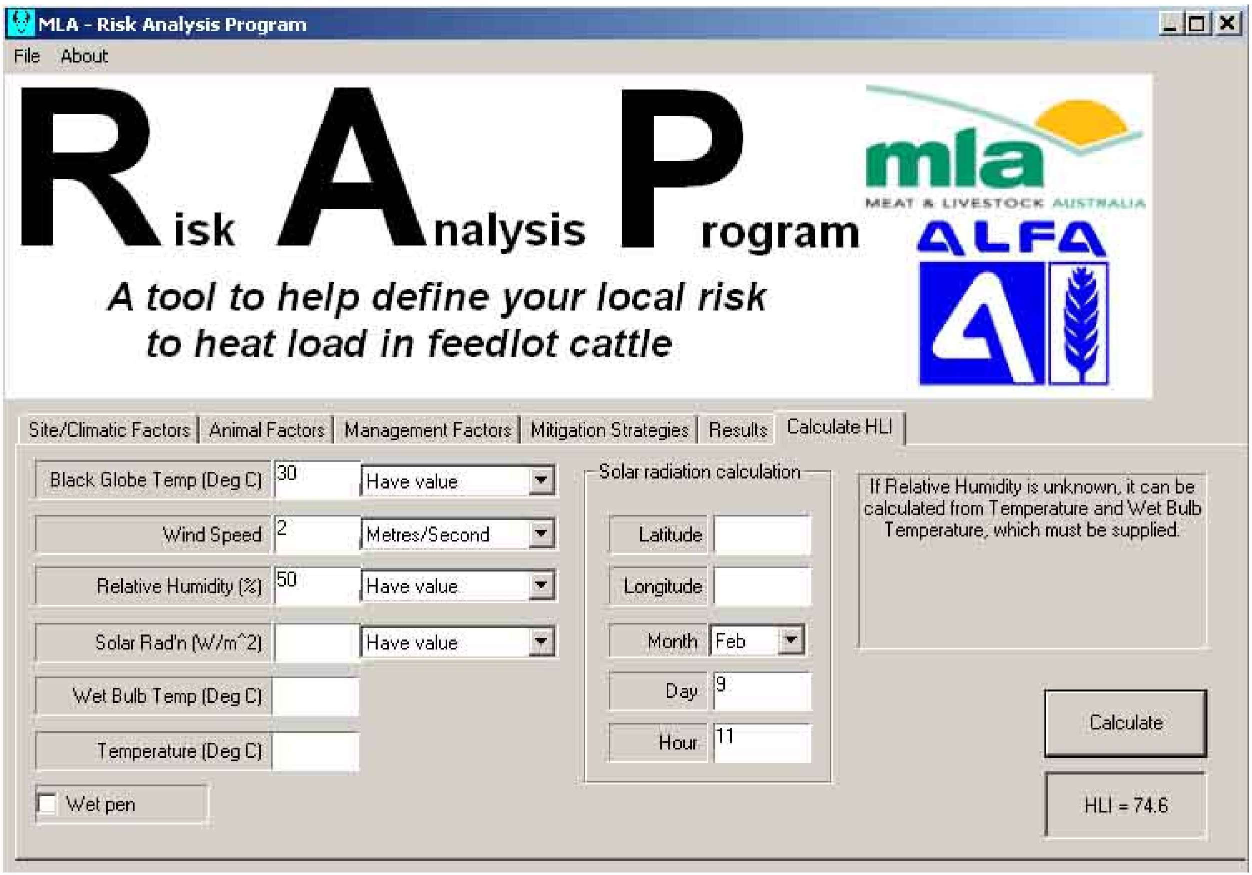


**Figure 15.** The HLI calculation page within the Rap software

# 4. Conclusions

## 4.1 Effectiveness of New Heat Load Indices

The testing of the new HLI and the AHLU concept has been hampered by the lack of datasets containing both animal and climatic data. All datasets with both animal and climatic measurements were used in the formulation of the new indices. To adequately test the statistical validity of the new HLI and AHLU, appropriate independent datasets with both animal and climatic data must be used. There is currently an MLA funded project being undertaken to obtain suitable datasets from feedlots across Eastern Australia.

Whilst it has not been possible to effectively validate the new HLI and AHLU, some datasets of known high heat load events have been used to demonstrate the effectiveness of the new HLI and AHLU concepts in reflecting the heat load on feedlot cattle. Figures 7 and 8 indicate that the HLI and AHLU rise significantly during high heat load events. There are significant rises in both the HLI and AHLU in the days leading up to the observed high heat load events shown in both datasets that do not result in cattle deaths. Why these rises in the HLI and AHLU did not result in cattle deaths is not yet understood.

## 4.2 Risk Assessment Program Software

There has been limited feedback from industry relating to the effectiveness and ease-of-use of the RAP software. This is because the software has only recently been produced and is not yet in a form where it can be completely released to industry. There has been a draft version available to industry on the internet and anecdotally, the feedback from industry regarding this draft version has been positive. All users that have been contacted by the research team have found the software useful and easy to use.

The main reason that the RAP software is still in a draft format is that the relative effects of the various feedlot management factors, shown in Table 9, have not been properly validated. Some of these effects were educated guesses made by the research team and the industry advisory committee and should be validated with field data collected from Australian feedlots prior to the final version of the RAP software being produced.

# 5. Recommendations

## 5.1 Further Research

1. Undertake a validation project aimed at collecting the data required to validate the new HLI and AHLU concepts, as well as the RAP software. The aims of this project would be to:

    a. Collect data from feedlots in a wide range of climatic regions in Australia; and

    b. Within those feedlots, collect data from a wide variety of pens, subject to a wide variety of animal and feedlot management factors.

    A project designed to collect data from Eastern Australian feedlots for the purposes of validating the new HLI, AHLU and RAP software has already commenced with MLA funding.

2. Develop AHLU thresholds to allow for more accurate prediction of the onset of high heat load events. This could allow for early warning alarms to be programmed into feedlot weather stations to alert feedlot managers of the potential onset of a high heat load event.

## 5.2 Practical recommendations for industry

1. The RAP software should be distributed to ensure that it is made available to the entire feedlot industry. Suggested methods of distribution would include, but are not limited to: posting the RAP software on the internet and sending a CD to all registered feedlots in Australia. This should be done after the software has been properly validated.

2. Feedlot managers should use the RAP software as part of a pre-summer review to define the risk of high heat load events occurring within their feedlot and/or within specific pens of animals within the feedlot. This will identify specific feedlots/feedlot pens that are at risk of high heat load events occurring.

3. Whilst using the HLI and AHLU as indicators of the heat status of feedlot cattle is useful, it is not intended to be a substitution for closely monitoring feedlot cattle during adverse climatic conditions.

# 6. References

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# 7. Appendices

# Appendix A. MLA Milestone Reports

MEAT & LIVESTOCK AUSTRALIA

# Milestone Report

MLA project code: FLOT 327

MLA project title: Reducing the risk of heat load for the Australian feedlot industry

Project leader: E.A. Systems Pty Limited

MLA project manager/coordinator: **Des Rinehart**

Milestone number: 1

Milestone:

1.1 Milestone report detailing refined HLI and updated heat load threshold values.

1.2 Advisory committee meeting to review refined HLI and methods for risk assessment process.

Abstract

The Heat Load Index (HLI) has been refined and validated based on a wider range of data sets from feedlots from both Australia and the United States of America. The statistical methods used in its formulation were validated by an independent expert (Dr David Mayer, Queensland Department of Primary Industries & Fisheries).

The new HLI uses three climatic variables: relative humidity (%) (RH), black globe temperature (°C) (BGT) and wind speed (m/s) (WS) to indicate heat stress. The new HLI takes the form:

For black globe temperatures below 23°C:

$$HLI = 8.62 + (0.38 \times RH) + (1.58 \times BGT) - (0.5 \times WS^2)$$

For black globe temperatures above 23°C:

$$HLI = 8.62 + (0.38 \times RH) + (1.58 \times BGT) + EXP(-WS + 2.4) - (0.5 \times WS^2)$$

The heat load thresholds based on this HLI are approximately 79 and 86. That is, above a HLI of 86, cattle begin to accumulate heat, below a HLI of 79 cattle can dissipate any built up heat. Based on these thresholds, the Accumulated HLI can be calculated, which is thought to be more important in deciding heat stress than individual HLI readings. Above a HLI of 86, heat begins to accumulate within the animal and thus the Accumulated HLI will rise. Once the HLI drops below 79, the animal has a chance to dissipate any built up heat and the Accumulated HLI falls. It is thought that once the Accumulated HLI reaches approximately 100 HLI units, more severe stress events will occur.

Project objectives

The objectives of this project are, by 28 February 2005, to achieve the following:

1 Refine the Heat Load Index (HLI) algorithms so that they accurately account for the full range of operational and environmental conditions in the lot-feeding industry in Australia and technical constraints of weather stations. Further development of the accumulation of heat load hours as opposed to an absolute determination of a HLI as a spot measure will be undertaken.

2 Provide a decision support module that can be used by feedlot operators to:
   a) Determine the risk of excessive heat load conditions occurring at specific locations for specific classes of cattle;
   b) Determine the ameliorative measures that they will need to adopt to offset the level of identified risk; and
   c) Document the outcomes of the risk assessment process (RAP).

3 Deliver the project findings to industry through a series of workshops and related extension activities.

Success in achieving milestone

**Development of Heat Load Index, and Accumulated Heat Load Units.**

Twelve Australian feedlot data sets and two US feedlot data sets were used to refine the Heat Load Index (HLI) that was developed in 2002 and 2003. All data sets were between the years 2000 and 2004, and covered the summer months. Not all the data sets had both animal and weather data. Some feedlots provided multiple data sets.

Limitations in data quality restricted the development of the HLI to six Australian data sets and one US data set. Animal data included: Panting score, respiration rate, and body temperature. The animal data was not consistent between data sets. For example one data set contained both respiration rate and body temperature, and another data set only panting scores. There was also considerable variation in the amount of animal information in the data sets. Between the data sets animal observations were made as often as every 15 minutes (via data loggers) to three times a day (daylight hours only). Variations in the frequency of weather data were also evident. In some cases weather parameters were measured every 10 minutes, and in others hourly.

The data sets which were not used in the refinement of the HLI were used as validation tools. Data sets were obtained for the HLI validation from Australian feedlots where adverse weather events had occurred. The refined HLI was then tested against these known events.

Due to the discontinuous nature of the animal data, differences in nutritional status and the lack of similarity between feedlots, statistical analysis was not straight forward. A number of statistical approaches were utilised in the development of the refined HLI model, using SAS (1996). These included linear and non-linear regressions, time series analysis and mixed models (Snedecor and Cochran 1989; Steel and Torrie 1980).

It was not possible to use a single approach to the analysis. The selected algorithm is essentially a result of non-linear regressions based on changes in respiration rate, body temperature and panting scores. Other factors such as changes in behaviour, and changes in DMI were not included in the model, but have been assessed as part of the validation process. The weather variables used in the model are relative humidity (RH), black globe temperature (BG) and wind speed (WS). We have also made the assumption that the weather variables are independent from each other which is not necessarily true.

Another important factor considered in the model development is the duration of exposure to high heat load. As the duration increases there are changes in the respiratory dynamics of cattle (Gaughan *et al.*, 2004), and this means that we needed to make adjustments to account for this biological fact.

In addition to the data sets feedback, end users of the HLI over the summer of 2003/04 suggested that the HLI did not adequately account for RH and WS. With this in mind a further detailed examination was made of data sets used in 2002 and 2003, and data sets obtained after those dates.

A preliminary HLI was developed and then compared to the data sets containing animal data and known extreme events. The preliminary HLI "picked up" the extreme events and appeared to give a good account of what was observed in the field. That is HLI was high when RR, RT and PS were high.

The preliminary HLI is as follows:

$$HLI = 10.61 + (0.4 \times RH) + (1.56 \times BG) - (5.66 \times WS)^{0.2} - LOG(18.98 \times (0.01 + WS^2))$$

Where:

RH = Relative Humidity (non decimal form i.e. 75 not 0.75).
BG = Black Globe Temperature ($^{o}$C).
WS = Wind Speed (m/s).

The LOG function was used to model the expected (based on animal observation and previous research) curvilinear response of RR and PS to increased wind speed. However research by Mader *et a*l (2004) has suggested a linear response.

The "0.01" in the (0.01 + $WS^2$) function is there to give the function a value when WS = 0. This is necessary because the LOG(18.98 x 0) function can not be calculated.

Due to a concern that the new HLI was not adequately accounting for the effects of wind speed when wind speed was between 0 and 3 m/s a re-examination of the data was made. The data sets used in this re-examination were chosen on the basis of the magnitude of air speed in the data set i.e. where air speeds were >3 m/s for significant amounts of time.

A new model was developed using an exponential (based on an exponential decay curve) to account for the effect of wind speed on cattle (i.e. changes in RR, RT and PS) for wind speeds of 0 – 3 m/s. It was also thought that the effect of the wind speed variable on RR, RT and PS would vary depending on the black globe temperature. Previous work suggests that RR in cattle starts to increase between 21 and 25$^{o}$C (see Hahn et al., 1997). Therefore, two HLI algorithms were developed, one for black globe temperatures above 23°C and one for below 23°C.

For black globe temperatures below 23°C:

$$HLI = 8.62 + (0.38 \times RH) + (1.58 \times BGT) - (0.5 \times WS^2)$$

For black globe temperatures above 23°C:

$$HLI = 8.62 + (0.38 \times RH) + (1.58 \times BGT) + EXP(-WS + 2.4) – (0.5 \times WS^2)$$

The added exponential function in the algorithm for black globe temperatures of above 23°C reflects the added importance of even low levels of wind speed at these high temperatures.

**Development of Accumulated HL and Thresholds**

Analysis of the biological data used for this project suggests that there are lags between the measured physiological responses and the climatic variables (Gaughan *et al.*, 2004; Eigenberg *et al.*, 2004). These lags are in the range of 1 – 2 hours and are not consistent. That is, under some conditions RR will peak prior to maximum HLI (or ambient temperature) and at other times peak RR will occur after the maximum HLI. This means that measurement of spot HLI may not be the best tool for assessing the heat load balance of a feedlot steer. For these reasons the development of the Accumulated HLI was undertaken.

The Accumulated Heat Load (Acc HL) is based on the THI-Hrs concept (Hahn and Mader 1997). The Acc HL is a two dimensional function incorporating time and heat balance. The Acc HL is calculated by determining the difference between the HLI at a given time and an upper and lower threshold HLI. The thresholds have been developed largely from climate room studies, but also from feedlot studies. When the HLI is above the upper threshold, cattle will not be able to effectively shed body heat, which means that there is likely to be an increase in body temperature. When the HLI is below the lower threshold then cattle are likely to shed body heat. When the HLI is between the two thresholds cattle will neither shed nor gain heat. The upper threshold has been established to be at a HLI of approximately 86, and the lower at a HLI of approximately 79. These values have been validated using the feedlot data sets.

The Acc HL model uses the differences between the threshold and the HLI at a given time, and then adds or subtracts the differences. For example if the HLI is 90 units at 1300 h then the Acc HL will be 4 units (90 – 86), if the HLI is 91 at 1400 h then the Acc HL will be the 4 units from 1300 h plus the 5 units (91 – 86) at 1400 h which gives an Acc HL of 9 units.

It appears that both the spot HLI and the Acc HL should be used i.e. we need to look at the intensity x duration effects. However, the actual number of units deemed to be detrimental to cattle has yet to be accurately determined.

<u>Overall progress of the project</u>

The other sections of the project not covered in Milestone 1 that have been progressing are outlined below:

1. Organisation of industry workshops
2. Preliminary development of the Risk Assessment Process Software
3. Liaison with weather station manufacturers

The progress on each of these points is outlined below:

1. A series of industry workshops have been organised for late November to convey the findings of this project to industry. The flyer that was produced for distribution to industry during BeefEx advertising the workshops is shown in Appendix 1. The dates and locations shown on this flyer have since changed. The workshop for Western Australia has been postponed until the end of January because of feedback from industry to Dr Simon Lott. During a recent trip to Western Australia, industry representatives told Dr Lott that the attendance at a workshop held during November would be low because it would conflict with the

winter crop harvest. They also think that heat stress is not such a major issue in Western Australia, given their lower humidity and as such think that the workshop would be better held during late January 2005. Expressions of interest to attend the Eastern Australian workshops have already been received as a result of the flyer distributed at BeefEx.

2. Development of the software to be included in the Risk Assessment Process (RAP) has begun. A preliminary format for the software has been produced and will be shown to the Industry Advisory Committee during the first milestone meeting for comment

3. A weather station manufacturers workshop had been planned for Thursday the 14th of October to discuss how best to incorporate the new HLI into weather station software. Whilst only one person was willing to attend that workshop, a number of weather station manufacturers expressed an interest in the project and have requested any relevant technical information. This will be sent to them in the form of a briefing note, which will be formulated after consultation with the weather station manufacturers industry.

Recommendations

The responsibility for the organisation of the industry workshops has been passed to ALFA. Any information sent to E.A. Systems regarding these workshops will be forwarded onto ALFA. Because of the postponement of the Western Australian heat load workshop, it is recommended that the milestones for completion of the industry workshops be amended to reflect this change.

**Acknowledgements:**

Dr Simone Holt (South Dakota State University) – provision of US data sets and statistical analysis.

Dr Roger Eigenberg (US Meat Animal Research Center) – data collection and statistical analysis.

Dr Terry Mader (University of Nebraska) – model validation.

Dr LeRoy Hahn (US Meat Animal Research Center) – model validation (threshold development).

Mr Cesar Casteneda (UQ) – data collection and analysis.
Mr John Goopy (UQ) – data collection and analysis

Management and staff from various Australian feedlots that supplied data sets for this study.

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# Reducing the Risk of Heat Load

This summer, the Meat & Livestock Australia (MLA), is funding a research and extension project on heat load. With the support from Australian Lot Feeders' Association (ALFA), E.A. Systems Pty Limited, will be conducting industry based workshops.

Presentations will be given by Drs Simon Lott (E.A. Systems) and John Gaughan (University of Queensland).

| Tentative dates for the information workshops are: | | |
|---|---|---|
| 22nd November 2004 | Emerald | Qld |
| 23rd November 2004 | Dalby | Qld |
| 25th November 2004 | Tamworth | NSW |
| 26th November 2004 | Wagga Wagga | NSW |
| Jan/Feb 2005 | TBA | WA |

**Topics to be covered to reduce heat load risks:**

- Factors affecting heat load in feedlot cattle
- The refined Heat Load Index (HLI)
- A simple risk assessment process to determine your heat load risk
- Methods to reduce heat load in feedlot cattle including:
    - Shade design
    - Ration formulation
    - Water trough size / placement
- Design and location of new feedlots

*Send your expression of interest to:*

**E.A. Systems Pty Limited**
**PO Box 1251**
**ARMIDALE NSW 2350**
**Phone: 02 6771 4864Fax: 02 6771 4867**
**Email: info@easystems.biz**
**Website: www.easystems.biz**

**For more information please contact:**

Mr Tim Byrne
(02) 6771 4864
0428 714 864
tim.byrne@easystems.biz

If you are interested in attending any of these workshops, please fill out your details below and location of workshop you will be attending, and return to the address listed.

**Name**................................................................................**Location**..............................

**Address**..........................................................................................................................

..............................................................................................................................................

**Phone**................................................................................**Fax**......................................

# Milestone Report

MLA project code: FLOT 327

MLA project title: Reducing the risk of heat load for the Australian feedlot industry

Project leader: E.A. Systems Pty Limited

MLA project manager/coordinator: **Des Rinehart**

Milestone number: 2

Milestone:
2.1 Completion of Beta version of RAP software.
2.2 Completion of draft revised 'Heat Load In Feedlot Cattle' Tips & Tools booklet.
2.3 Advisory committee meeting held to review validation of RAP, Beta Version of RAP software and draft revised 'Heat Load in Feedlot Cattle' Tips & Tools booklet.

Abstract
A computer program entitled 'Risk Analysis Program' (RAP) designed to assess the risk of high heat load events occurring at individual feedlots has been developed. The software associated with this program is compatible with Microsoft operating platforms. The risk is expressed as the probability of a high risk event (50-100 Accumulated Heat Load Units) and an extreme risk event (>100 AHLU) occurring at a range of sites.

This program assesses the risk of high heat load events occurring on a regional basis, based on historical data obtained from Bureau of Meteorology weather stations. It then uses individual feedlot management variables such as the provision of shade and water troughs and animal factors to determine the risk of high heat load events occurring. A Heat Load Index (HLI) calculator has also been included in the RAP software to assist feedlot operators to calculate spot measures of the HLI.

Project objectives

The objectives of this project are, by 28 February 2005, to achieve the following:

1 Refine the Heat Load Index (HLI) algorithms so that they accurately account for the full range of operational and environmental conditions in the lot-feeding industry in Australia and technical constraints of weather stations. Further

development of the accumulation of heat load hours as opposed to an absolute determination of a HLI as a spot measure will be undertaken.

2 Provide a decision support module that can be used by feedlot operators to:
   a) Determine the risk of excessive heat load conditions occurring at specific locations for specific classes of cattle;
   b) Determine the ameliorative measures that they will need to adopt to offset the level of identified risk; and
   c) Document the outcomes of the risk assessment process.

3 Deliver the project findings to industry through a series of workshops and related extension activities.

Success in achieving milestone

**Completion of draft RAP software**

The Beta test version of the Risk Analysis Program software package (RAP) has been completed. The RAP calculates the risk of high heat load events occurring for a selected location. The premise behind the calculation of a risk level is the AHLU and the variability in the level at which heat is accumulated for various types of cattle class/health status and management factors. For the selected threshold the AHLU is analysed over the long-term dataset for the selected location, and the number of events of 1, 2, 3…..up to 7 day duration with an AHLU above 50 and 100 presented. High risk events are defined as an AHLU of 50-100 and extreme risk events are events with AHLU > 100.

Climatic factors, individual management factors and animal factors all contribute to the calculation of risk. Historical data from Bureau of Meteorology (BOM) Automatic Weather Stations (AWS) was used to determine the variation in crucial HLI variables on a regional level. From these data, regions with a higher risk of heat load events occurring were identified.

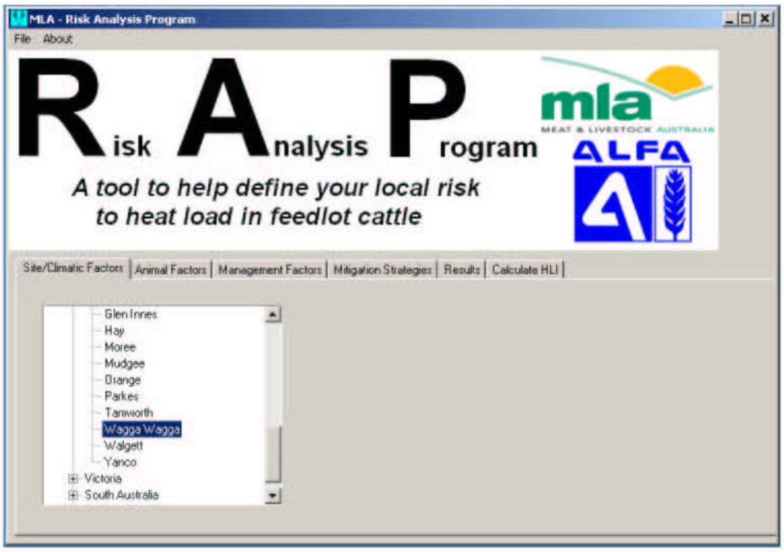
Once the regional risk was defined, individual feedlot management factors were considered. The effect of each of these management factors on the upper HLI threshold, above which cattle begin to accumulate heat was then calculated. This effect is shown below in Table 1. Nominally, the upper HLI threshold is set at 86 (which refers to unshaded, black, Bos Taurus cattle with a body condition score of 4/5). The maximum HLI threshold that can be attained by implementing the mitigation strategies outlined in Table 1 has been set at 95. Any HLI threshold above this level is considered unrealistic.

The RAP software has been designed so that it may be applied at the pen level. This was done so the risk for the various sections of the feedlot (hospital pens, incoming pens, different types of cattle etc.) could be compared and an overall risk for the entire feedlot then calculated.

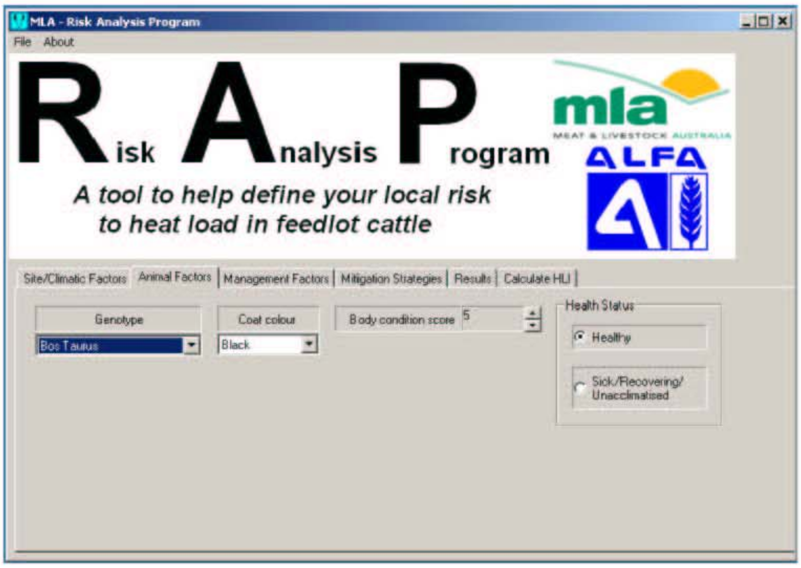
Table 1 The effect of various factors on the upper HLI threshold

| Factor | Effect on upper HLI threshold | Factor | Effect on upper HLI threshold |
|---|---|---|---|
| No shade | 0 | Body condition score = 5 | 0 |
| Shade (1.5m$^2$/SCU – 2m$^2$/SCU) | +3 | Body condition score = 4 | 0 |
| Shade (2m$^2$/SCU – 3m$^2$/SCU) | +5 | Body condition score = 3 | +2 |
| Shade (3m$^2$/SCU – 5m$^2$/SCU) | +7 | Body condition score = 2 | +3 |
| Bos taurus genotype | 0 | Body condition score = 1 | +4 |
| Bos indicus genotype | +9 | Healthy | 0 |
| Bos taurus x Bos indicus cross (50-50) | +5 | Sick/Recovering/Unacclimatised | -5 |
| European genotype | +3 | Temperature of water in troughs = 15-20°C | +1 |
| Black coat colour | 0 | Temperature of water in troughs = 20-30°C | 0 |
| Red coat colour | +1 | Temperature of water in troughs = 30-35°C | -1 |
| White coat colour | +3 | Temperature of water in troughs = >35°C | -2 |
| Manure management feedlot class = 1 | 0 | Install extra water troughs (emergency mitigation) | +1 |
| Manure management feedlot class = 2 | -4 | Implement heat load feeding strategy (emergency) | +2 |
| Manure management feedlot class = 3 | -8 | Strategic clearing of high manure deposition areas | +2 |
| Manure management feedlot class = 4 | -8 | | |

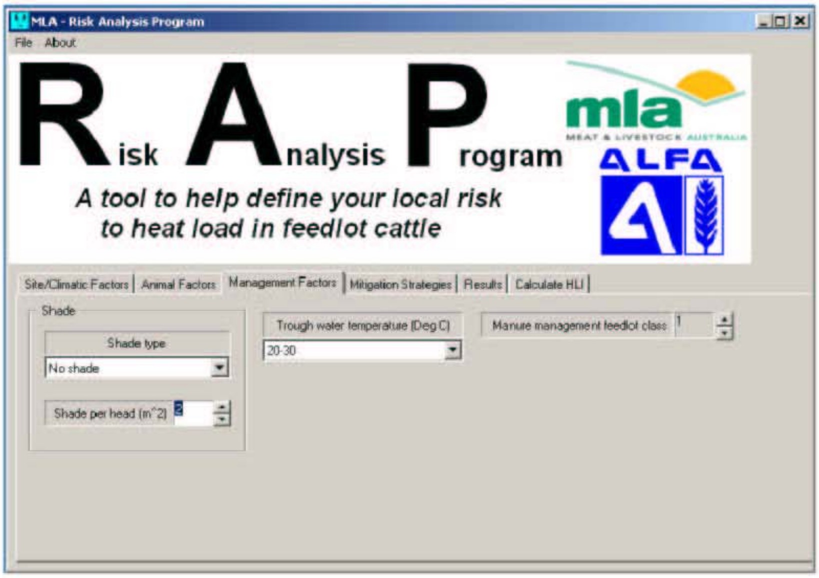
The first page in the RAP (Site/Climatic Factors) is used to select the region closest to the feedlot in question. The areas selected were done so because the AWS data from these sites was relatively good, with 5 or more years of reliable data.



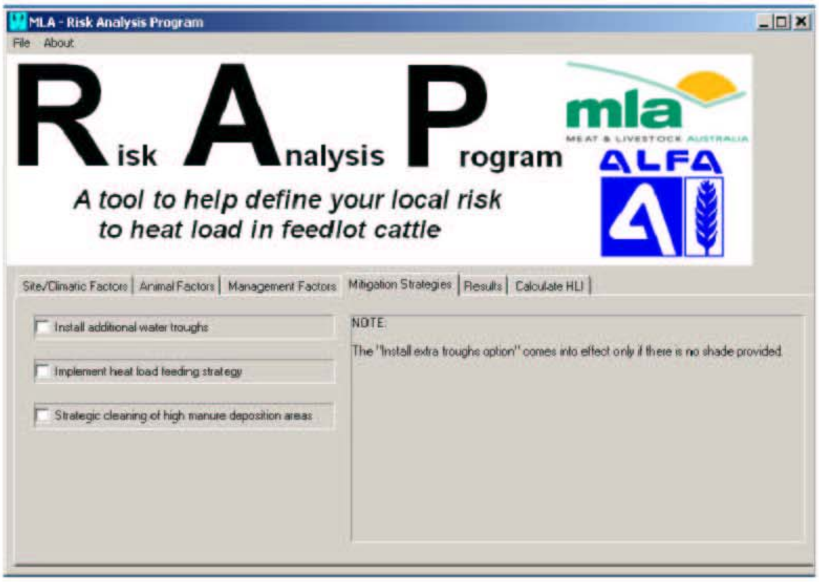
The Animal Factors page is then used to define the type and health status of the animals within the feedlot.



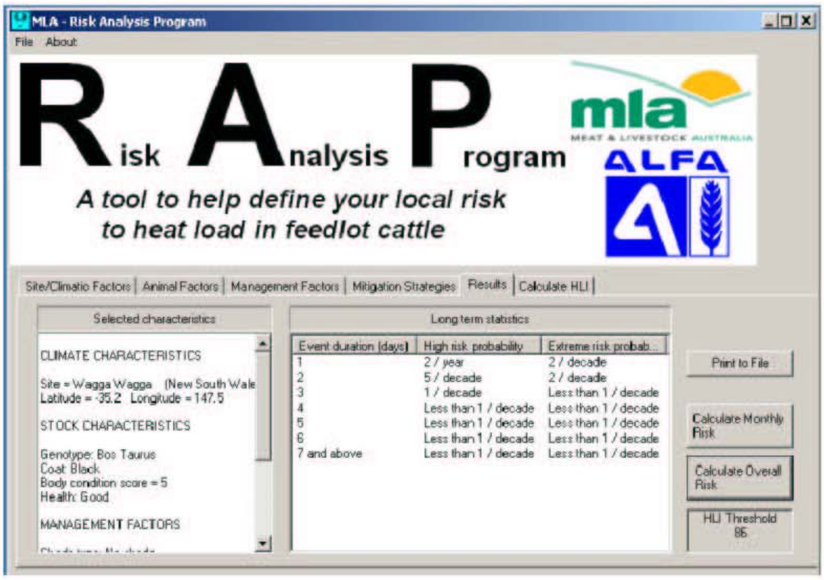

The Management Factors page defines the effect of a number of long-term critical mitigation strategies commonly used in Australian feedlots, such as shade and the supply of cool drinking water.



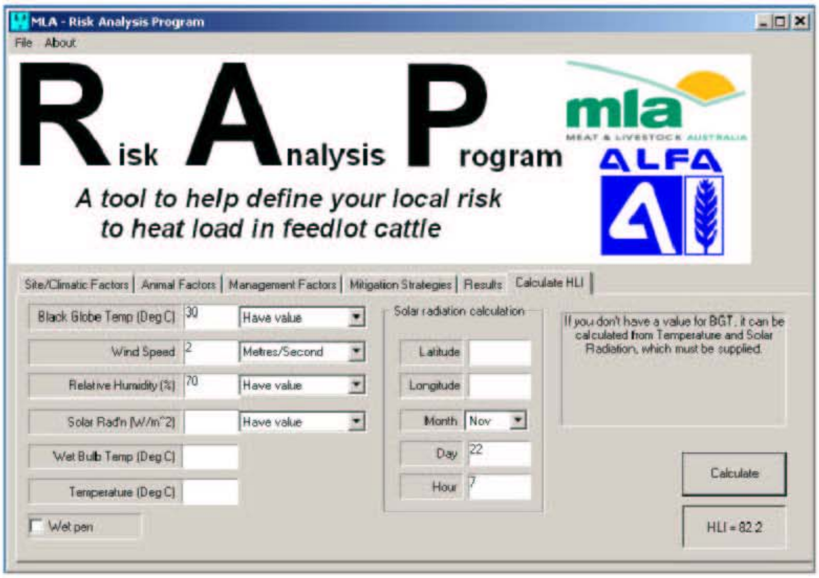

The Mitigation Strategies page then defines the effects of a number of emergency mitigation strategies commonly implemented during a high heat load event. Commonly used emergency mitigation strategies include the installation of extra water troughs, implementing a high heat load feeding strategy and strategic clearing of high manure deposition areas.




The results are presented as the probability of a high (50-100 AHLU) and an extreme risk event (>100 AHLU) occurring at this particular feedlot, given the amended HLI threshold. The first section of this page allows the user to review the options that have been selected and then to see the results. The results can be displayed as long-term statistics over the entire year or for any month.




The results can then be exported into a text file which can be printed by using the 'Print to File' button. An example of a printed results page is shown in Appendix 1. Another feature of the RAP software is a HLI calculator. This will give feedlot operators an idea of the HLI at any point in time, provided they have accurate measures of the required variables (black globe temperature, wind speed and relative humidity as a minimum.)




**Completion of draft revised "Heat Load in Feedlot Cattle" Tips & Tools booklet**

The draft of this booklet is yet to be completed. This is because of the delays in the completion of the HLI and AHLU that resulted from industry feedback. The articles detailing these indicators, as well as the article describing the RAP software could not be finalised until their final format was agreed to. However, work on the articles within this booklet is ongoing and the draft articles will be ready for industry input by the end of December 2004. It was previously agreed that this component of the work would be delayed until the end of the project to allow collation of feedback from users to be incorporated into the revision of the Tips & Tools.

**Advisory committee meeting held to review RAP**

The advisory committee meeting to review the RAP was held in Brisbane on 19 November 2004. The response to the RAP software was generally positive, with the improvements suggested incorporated into the RAP and presented in this report.

<u>Overall progress of the project</u>

The other sections of the project not covered in Milestone 2 that have been progressing are outlined below:

1. Further refinement of the HLI and AHLU
2. Organisation of industry workshops
3. Liaison with weather station manufacturers

The progress on each of these points is outlined below:

1. The final versions of the HLI and AHLU have been produced following input from the industry advisory committee. There have been slight changes to the HLI made to improve the wind speed response. The final HLI takes the form:

For Black Globe Temperatures less than 25°C:

- HLI = 10.66 + 0.28 x RH + 1.3 x BGT - WS

For Black Globe Temperatures above 25°C:

- HLI = 8.62 + 0.38 x RH + 1.55 x BGT – 0.5 x WS + EXP(-WS +2.4)

The thresholds for the calculation of the AHLU have remained the same. The upper threshold is 86 and the lower threshold is 77. At HLI values between those thresholds, the animal is neither gaining nor losing heat. The calculation of the AHLU is based on measurement of the HLI over time in relation to those thresholds, for example:

| Time | HLI | HLI Balance | AHLU |
|---|---|---|---|
| 8:00:00 | 85 | 0 | 0 |
| 9:00:00 | 86 | 0 | 0 |
| 10:00:00 | 88 | 2 | 2 |
| 11:00:00 | 92 | 6 | 8 |
| 12:00:00 | 94 | 8 | 16 |
| 13:00:00 | 95 | 9 | 25 |
| 14:00:00 | 97 | 11 | 36 |
| 15:00:00 | 96 | 10 | 46 |
| 16:00:00 | 89 | 3 | 49 |
| 17:00:00 | 85 | 0 | 49 |
| 18:00:00 | 79 | 0 | 49 |
| 19:00:00 | 70 | -7 | 42 |
| 20:00:00 | 64 | -13 | 29 |
| 21:00:00 | 62 | -15 | 14 |
| 22:00:00 | 61 | -16 | 0 |

The AHLU will give a better indication of high heat load than a spot measure of the HLI, because it combines the intensity of heat with a duration factor.

2. The organisation of the industry workshops to be held in late November 2004 was passed to ALFA. These workshops were held during the week of 22-26 November 2004. Any information regarding these workshops has been passed on to ALFA

3. Liaison with weather station manufacturers continues. The briefing note outlining the new HLI and AHLU and the best way to incorporate them into weather stations is currently being formulated. A draft of this briefing note will be sent to select members of the industry, before it is distributed to the weather station manufacturers industry at large.

<u>Recommendations</u>

Because the draft of the 'Heat Load in Feedlot Cattle' Tips & Tools booklet has not yet been produced, it is recommended that the submission of the document be placed in the next milestone and the milestone requirements be changed to reflect this. Draft papers will be ready for submission by the end of December 2004.

Appendix 1 – Example printout from the RAP software

```
RAPS --- Risk Analysis Program

This report was created on 23/11/2004 11:04

SITE/CLIMATE CHARACTERISTICS

Site = Wagga Wagga    (New South Wales)
Latitude = -35.2   Longitude = 147.5

ANIMAL FACTORS

Genotype: Bos Taurus
Coat: Black
Body condition score = 5
Health: Good

MANAGEMENT FACTORS

Shade type: No shade
Shade area per head =  2.0
Manure management class 1 feedlot
Trough water temperature: 20-30 C

MITIGATION STRATEGIES

Not implementing heat load feeding strategy
Additional troughs NOT installed
Strategic cleaning of high manure deposition areas NOT implemented


******************************** RESULTS *******************************

HLI Threshold = 86

Long term statistics (19260 days processed)

Event duration          High risk probability    Extreme risk probability

1                       2 / year                 2 / decade
2                       5 / decade               2 / decade
3                       1 / decade               Less than 1 / decade
4                       Less than 1 / decade     Less than 1 / decade
5                       Less than 1 / decade     Less than 1 / decade
6                       Less than 1 / decade     Less than 1 / decade
7 and above             Less than 1 / decade     Less than 1 / decade

Results for January (1610 days processed)

1                       7 / decade               1 / decade
2                       2 / decade               1 / decade
3                       Less than 1 / decade     Less than 1 / decade
4                       Less than 1 / decade     Less than 1 / decade
5                       Less than 1 / decade     Less than 1 / decade
6                       Less than 1 / decade     Less than 1 / decade
7 and above             Less than 1 / decade     Less than 1 / decade

Results for February (1491 days processed)

1                       7 / decade               Less than 1 / decade
2                       2 / decade               Less than 1 / decade
3                       Less than 1 / decade     Less than 1 / decade
4                       Less than 1 / decade     Less than 1 / decade
5                       Less than 1 / decade     Less than 1 / decade
6                       Less than 1 / decade     Less than 1 / decade
```

| | | |
|---|---|---|
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for March (1628 days processed)

| | | |
|---|---|---|
| 1 | 2 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for April (1620 days processed)

| | | |
|---|---|---|
| 1 | Less than 1 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for May (1669 days processed)

| | | |
|---|---|---|
| 1 | Less than 1 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for June (1605 days processed)

| | | |
|---|---|---|
| 1 | Less than 1 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for July (1630 days processed)

| | | |
|---|---|---|
| 1 | Less than 1 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for August (1613 days processed)

| | | |
|---|---|---|
| 1 | Less than 1 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for September (1585 days processed)

| | | |
|---|---|---|
| 1 | Less than 1 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |

| | | |
|---|---|---|
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for October (1617 days processed)

| | | |
|---|---|---|
| 1 | Less than 1 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for November (1552 days processed)

| | | |
|---|---|---|
| 1 | Less than 1 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

Results for December (1640 days processed)

| | | |
|---|---|---|
| 1 | 2 / decade | Less than 1 / decade |
| 2 | Less than 1 / decade | Less than 1 / decade |
| 3 | Less than 1 / decade | Less than 1 / decade |
| 4 | Less than 1 / decade | Less than 1 / decade |
| 5 | Less than 1 / decade | Less than 1 / decade |
| 6 | Less than 1 / decade | Less than 1 / decade |
| 7 and above | Less than 1 / decade | Less than 1 / decade |

MEAT & LIVESTOCK AUSTRALIA

# Milestone Report

MLA project code: FLOT 327

MLA project title: Reducing the risk of heat load for the Australian feedlot industry

Project leader: E.A. Systems Pty Limited

MLA project manager/coordinator: **Des Rinehart**

Milestone number: 3

Milestone:

3. Industry workshops completed and feedback survey sheets collected and collated.

Abstract

A series of industry workshops have been organised by ALFA to communicate the results of this project to the broader industry as a whole. These workshops were held in the week of 22 – 26 November 2004. The topics covered at each of these workshops included: the refined HLI; heat load mitigation measures; the new Risk Assessment Program and Biosecurity/Animal health issues. Feedback sheets were distributed at each workshop and have been collected and collated. The results from this feedback are shown below.

Project objectives

The objectives of this project are, by 28 February 2005, to achieve the following:

1 Refine the Heat Load Index (HLI) algorithms so that they accurately account for the full range of operational and environmental conditions in the lot-feeding industry in Australia and technical constraints of weather stations. Further development of the accumulation of heat load hours as opposed to an absolute determination of a HLI as a spot measure will be undertaken.

2 Provide a decision support module that can be used by feedlot operators to:
   a) Determine the risk of excessive heat load conditions occurring at specific locations for specific classes of cattle;
   b) Determine the ameliorative measures that they will need to adopt to offset the level of identified risk; and
   c) Document the outcomes of the risk assessment process.

3 Deliver the project findings to industry through a series of workshops and related extension activities.

Success in achieving milestone

**Completion of industry workshops**

There were four industry workshops held from 22 – 26 November. These workshops were held in the following locations:

- 22 November: Dalby RSL Club, Dalby;
- 23 November: Tamworth Towers Motor Inn, Tamworth;
- 25 November: Quality Inn Carriage House, Wagga Wagga; and
- 26 November: Moama Bowling Club, Moama.

The topics covered at each workshop included:

- The formulation of the new Heat Load Index;
- High heat load mitigation measures;
- The new Risk Assessment Program;
- Nutritional measures for mitigating against high heat load; and
- Biosecurity/animal health issues for feedlotting.

At each workshop, feedback sheets were distributed to assess the effectiveness of each workshop. The number of feedback sheets collected at each workshop is shown below:

| Total | Dalby | Tamworth | Wagga Wagga | Moama |
|---|---|---|---|---|
| 67 | 35 | 11 | 6 | 15 |

The questions asked and the answers given have been collated and are shown below.

| How useful was the workshop for you? | | | | |
|---|---|---|---|---|
| | 1 (Could be better) | 2 (O.K.) | 3 (Good) | 4 (Very Good) |
| All Workshops | 0% | 9% | 40% | 51% |
| Dalby | 0% | 9% | 51% | 40% |
| Tamworth | 0% | 9% | 36% | 55% |
| Wagga Wagga | 0% | 0% | 0% | 100% |
| Moama | 0% | 13% | 33% | 53% |

This indicates that the majority of workshop participants found the workshops either good or very good.

| What parts of the workshop were most beneficial for you? | | | | | | | |
|---|---|---|---|---|---|---|---|
| | All | Nutrition | Mitigation measures | Heat Load Index | Risk Assessment Program | Biosecurity | None |
| All Workshops | 21% | 23% | 21% | 26% | 4% | 3% | 1% |
| Dalby | 12% | 25% | 24% | 29% | 2% | 6% | 2% |
| Tamworth | 42% | 17% | 17% | 25% | 0% | 0% | 0% |
| Wagga Wagga | 0% | 0% | 0% | 50% | 25% | 0% | 25% |
| Moama | 0% | 10% | 0% | 40% | 0% | 30% | 20% |

This seems to indicate that the most beneficial sections for the participants were the sections relating to heat load and how to best deal with periods of high heat load (i.e. the new Heat Load Index, nutrition and other mitigation measures.)

| What parts of the workshops were least beneficial for you? | | | | | | | |
|---|---|---|---|---|---|---|---|
| | All | Nutrition | Mitigation measures | Heat Load Index | Risk Assessment Program | Biosecurity | None |
| All Workshops | 5% | 10% | 0% | 3% | 3% | 24% | 53% |
| Dalby | 6% | 3% | 0% | 3% | 3% | 25% | 59% |
| Tamworth | 0% | 44% | 0% | 11% | 0% | 11% | 33% |
| Wagga Wagga | 0% | 0% | 0% | 0% | 20% | 20% | 60% |
| Moama | 8% | 8% | 0% | 0% | 0% | 33% | 50% |

This seems to suggest that most participants found all of the presentations quite useful. Some participants did not find the biosecurity presentation useful.

| What topics would you have liked more emphasis on? | | | | | | | |
|---|---|---|---|---|---|---|---|
| | All | Nutrition | Mitigation measures | Heat Load Index | Risk Assessment Program | Biosecurity | None |
| All Workshops | 0% | 9% | 11% | 31% | 4% | 16% | 29% |
| Dalby | 0% | 11% | 9% | 29% | 3% | 11% | 34% |
| Tamworth | 0% | 0% | 43% | 14% | 0% | 29% | 14% |
| Wagga Wagga | 0% | 0% | 0% | 50% | 25% | 0% | 25% |
| Moama | 0% | 10% | 0% | 40% | 0% | 30% | 20% |

This response suggests that a third of all respondents would have liked more emphasis on the new Heat Load Index.

| What topics would you have liked less emphasis on? | | | | | | | |
|---|---|---|---|---|---|---|---|
| | All | Nutrition | Mitigation measures | Heat Load Index | Risk Assessment Program | Biosecurity | None |
| All Workshops | 0% | 5% | 5% | 5% | 2% | 9% | 74% |
| Dalby | 0% | 0% | 3% | 3% | 3% | 10% | 80% |
| Tamworth | 0% | 50% | 0% | 0% | 0% | 0% | 50% |
| Wagga Wagga | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| Moama | 0% | 0% | 14% | 14% | 0% | 14% | 57% |

This suggests that the majority of respondents were happy with the content of all of the presentations.

| How would you describe the organisation of the day? | | | | |
|---|---|---|---|---|
| | 1 (Could be better) | 2 (O.K.) | 3 (Good) | 4 (Very Good) |
| All Workshops | 0% | 12% | 48% | 40% |
| Dalby | 0% | 15% | 58% | 27% |
| Tamworth | 0% | 0% | 40% | 60% |
| Wagga Wagga | 0% | 0% | 0% | 100% |
| Moama | 0% | 15% | 46% | 38% |

This suggests that the majority of respondents were happy or very happy with the organisation of the workshops.

| What did you think of the location of the workshop? | | | | |
|---|---|---|---|---|
| | 1 (Could be better) | 2 (O.K.) | 3 (Good) | 4 (Very Good) |
| All Workshops | 3% | 11% | 43% | 43% |
| Dalby | 3% | 15% | 42% | 39% |
| Tamworth | 0% | 0% | 50% | 50% |
| Wagga Wagga | 0% | 0% | 0% | 100% |
| Moama | 7% | 14% | 50% | 29% |

Most respondents were happy with the locations of the workshops. The next questions were focussed on what the respondents would do differently in the future, and what topics they would like to see covered in future workshops.

**What is one thing that you will do, or do differently as a result of this workshop?**

The majority of respondents seemed to be willing to integrate the heat load mitigation strategies (nutrition, forecasting using HLI, etc.) suggested in these workshops into their heat load management strategies. Another common theme was improving staff training to ensure that all employees are aware of the heat load management strategy and the required responses.

**What topics would you like to see covered at future workshops?**

Responses to this question varied from more detailed information regarding the costs of installing shade and the potential benefits to tracking heat load over an animal's lifespan from paddock to feedlot to abattoir and all steps in between. Some respondents commented on the need to hear about the animal health issues related to heat load from a veterinarian.

**Are there any other comments you would like to make?**

Some respondents commented on the need to use "plain English", and to keep each session short and to the point. However, on the whole, respondents were very positive and thankful that the workshops had been organised.

Overall progress of the project

The other sections of the project not covered in Milestone 2 that have been progressing are outlined below:

1. Liaison with weather station manufacturers
2. Refinement of Tips and Tools articles.

The progress on each of these points is outlined below:

1. The briefing note outlining the new HLI and AHLU and the best way to incorporate them into weather stations is in the final draft form. Comment has been sought from some members of the industry on the content and structure of this briefing note. It is expected that this briefing note will soon be finalised, following industry input, and can then be broadly distributed to the industry.

2. The electronic form of the previous Tips & Tools articles has been distributed to the project team. Work on these articles continues, with draft version of the articles due for completion early in 2005.

Recommendations

There are no recommendations at this stage.

## Appendix B. Related article in Today's Feedlotting magazine

# A new Heat Load Index for the Aust feedlot industry

RECENTLY, a research project funded by Meat and Livestock Australia has been undertaken to attempt to reduce the risk of high heat load events occurring at Australian feedlots. The project research team consisted of Dr John Gaughan of The University of Queensland, Christine Killip of Katestone Environmental and Dr Simon Lott, Peter Binns and Tim Byrne (pictured) of E.A. Systems.

One of the major focuses of this project has been to refine the existing Heat Load Index (HLI), so it better reflects the impacts of the surrounding climate on feedlot animals. There has also been a new index called the Accumulated Heat Load Units (AHLU) developed. The AHLU accounts for both the intensity of the heat load on the animal and the duration of time that heat load is sustained without respite. The new HLI has been developed using datasets collected from numerous feedlots located in both Australia and The United States of America. It has been developed by collecting both climatic and animal response data during periods of high heat load. The climatic variables of interest which had the greatest effect on heat load that were focused on during the data collection are:

- Ambient Air Temperature.
- Incoming Solar Radiation.
- Relative Humidity.
- Wind Speed.
- Black Globe Temperature.

The effects of these variables on the animals were monitored by measuring the animal's core body temperature (rectal or tympanic temperature) and its respiration rate. Because the different breeds of feedlot cattle have differing abilities to tolerate heat, it was decided to base all of the heat load calculations on a "reference animal". The reference animal decided upon was an unshaded, healthy, black, smooth coated steer, of condition score 4-5 and at least 100 days on feed. The reason for the selection of this "reference animal" was that this was the animal that featured in almost all of the available datasets used for calculation. These datasets were then used to combine the climatic variables of interest into one index which reflects the heat load at a particular point in time on feedlot animals. The variables included in the index are:

- Black Globe Temperature (°C) (BGT);
- Relative Humidity (%) (RH); and
- Wind Speed (m/s) (WS).

During the formulation process, it was realised that the effects of these variables were slightly different at high Black Globe Temperatures compared to low Black Globe Temperatures. For this reason, there was one equation developed for low Black Globe Temperatures and another equation developed for high Black Globe Temperatures.

The equations developed are:

***For Black Globe Temperatures less than 25°C:***

- $HLI = 10.66 + 0.28 \times RH + 1.3 \times BGT - WS$

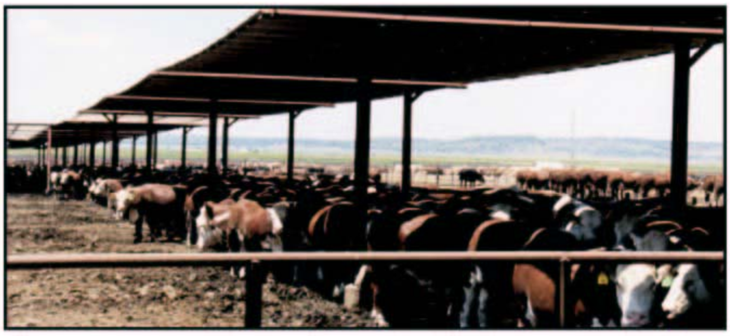
***For Black Globe Temperatures above 25°C:***

- $HLI = 8.62 + 0.38 \times RH + 1.55 \times BGT - 0.5 \times WS + EXP(-WS + 2.4)$

Using these equations, it is possible to predict at what point cattle will begin to accumulate heat from the atmosphere, and similarly, at what point cattle will dissipate >> Page 27

heat to the atmosphere. These predictions are also based on the "reference animal" mentioned above. The point at which other cattle types will begin to accumulate heat will vary depending on a number of factors (e.g. breed, coat colour, condition score, etc.) So, for the reference animal, the point at which they begin to accumulate heat from the atmosphere occurs at a HLI of roughly 86. Similarly, for the reference animal, the point at which they begin to dissipate heat to the atmosphere occurs at a HLI of roughly 77. Between these two "HLI thresholds", the cattle are effectively in a state of equilibrium, neither losing to nor gaining heat from the atmosphere.

Whilst the HLI equations do reflect heat load on feedlot cattle at a particular point in time, the HLI does not account for the duration of time that the cattle have been exposed to high heat load. A new measure, called the Accumulated Heat Load Units (AHLU), has been developed based on the HLI thresholds outlined above.



The AHLU measures both the period of time that an animal is exposed to high heat load, and the intensity of that exposure. For example, if the average HLI during an hour is 89, then the cattle will gain 3 HLI units and the AHLU will be +3. If, during the next hour the average HLI is 92, then the cattle will gain 6 HLI units, and the AHLU will become +9 and so on. The cattle will continue to accumulate heat, as long as the HLI stays above the upper "HLI threshold". The opposite occurs when the HLI falls below the lower "HLI threshold," i.e. the cattle will dissipate heat to the atmosphere and the AHLU will fall.

The AHLU measure allows a more accurate picture of the overall heat load on the feedlot animal by taking into account the length of time that animal is exposed to high heat load, and the length of time it has to recover. This will give feedlot operators a better idea of the heat load the cattle in their yard are exposed to, and reduce the risk of high heat load events occurring in the future.