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Part A – Weather station review

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Abstract

A range of weather stations were reviewed in order to provide recommendations for feedlot operators that may need to collect weather data for feedlot accreditation in future and for calculations of HLI and AHLU to effectively manage heat stress events. Features including purchase and ongoing costs, parameters measured, accuracy, functionality and durability were included in the review and used to calculate an overall score for each weather station considered. While the purchase costs of weather stations ranged from several hundred dollars to greater than ten thousand dollars, the weather stations with the highest overall score were also relatively low-priced. A trade-off between price and accuracy was found. Because of this, it is important that feedlot operators understand the uncertainties in HLI and AHLU that would result from uncertainties in measurements from their weather station prior to purchase, and also once the weather station is operational. A range of options to transfer data from the weather station to (e.g. an office or website) were found, which should be investigated on a site-by-site basis as the best option depends on location, mobile coverage, and budget.

Executive summary

Katestone was commissioned to review weather stations available for purchase to allow MLA to provide better information to feedlot operators who may need to collect weather data at their feedlot. Models, prices and specifications were gathered from internet websites, manufacturers, and through discussion with some suppliers who were willing to create a customised weather station specifically for feedlot operators. A ranking system was designed that accounted for the following features:

- purchase price
- ongoing maintenance and repair costs
- accuracy of measurements
- functionality
- durability

The prices of available weather stations ranged from several hundreds of dollars to approximately $9,000. The lowest-priced models did not have enough sensors to calculate HLI and are therefore not suitable. The ongoing maintenance costs of most models were relatively low, and it is recommended that feedlot operators keep their weather station clean to ensure accurate measurements regardless of model. Replacement parts each few years rather than calibrations are recommended for the lower priced weather stations. The highest ranked weather stations were relatively low cost, easy to install and maintain, and reasonably durable. However, some of the higher priced options were more accurate. The accuracy of measurements determines the uncertainty in HLI and AHLU calculations, and it is important that feedlot operators understand this.

Discussion with suppliers identified that a number of options are possible to transfer data from the weather station to an on-site computer or website. This is required in order to upload data through the internet to the Heat Load Data Network. The communication option is best selected on a site-by-site basis, as options include WIFI or radio transfer, mobile network and satellite options, and the best option depends on location, mobile coverage and budget.

A set of general guidelines on where to site a weather station were also provided, based on the requirements specified in the Australian Standard (which contains strict siting guidelines that it may not be practical to meet at all sites).

1. Introduction

To address the recommendations from a review of the impacts of heat stress on lot fed cattle associated with weather conditions during the 2012-13 summer, Meat & Livestock Australia (MLA) was requested to provide better information to feedlot operators regarding suitable on-site weather stations.

This document comprises a review undertaken by Katestone of available weather stations. The aim of the review was to provide feedlot managers with one document that details suitable weather stations to meet the requirements of monitoring heat load at a site. There are a wide variety of weather stations available from inexpensive hobbyist units to scientific stations which meet with the Australian Standards. This review covers the full range of stations and identifies units that, as a minimum, meet the accreditation requirements. The review also looked at functionality, durability, maintenance requirements and operating costs to determine units that provided the best value for money.

2. Scope of work

Collection of weather data may be made mandatory for feedlot accreditation in the future. This is likely to include:

- real time collection of temperature, relative humidity, solar radiation, wind speed, wind direction and rain
- daily monitoring of cattle along with HLI and AHLU

Wind direction and rain are not required to calculate HLI or AHLU. Solar radiation and temperature are not required if black globe temperature is available.

This review focused on delivering options to meet these requirements and covers the following scope:

- Reliability
- Functionality (with reference to the project objectives)
- Affordability (upfront and ongoing costs)
- Durability
- Physical suitability for application at feedlots
- Maintenance and serving requirements and availability of service suppliers
- Supplier quality

The operating costs for each system will vary depending on the location of the feedlot and proximity to the service provider. The availability of internet connection, power and other site requirements will also impact on the cost of each system. The review has attempted to incorporate these into a matrix to provide an easy process for each site to determine the most suitable weather station(s) for their needs.

3. Weather station requirements

3.1 Hardware

The sensors listed below are required to calculate HLI and AHLU. These sensors should be mounted approximately 2m above the surface.

- Black globe temperature **or** solar radiation and free air / dry bulb temperature
- Wind speed
- Relative humidity **or** wet bulb temperature

The above parameters need to be logged with an interval of no longer than 1 hour.

Rainfall is listed as one of the parameters required for accreditation. As rain is not used in real time in the HLI calculation, it was assumed that a manual rain gauge is adequate for this purpose.

Calculation of the HLI (and AHLUs) within the data logger is an advantage as immediate information will be available to assess the heat load situation.

3.2 Communication

If the station does not calculate HLI or AHLU in the logger, there is a need to download the data from the weather station in order to calculate HLI and then AHLU.

The HLI and AHLU can be calculated on a computer using a spreadsheet or by a simple customised program. Alternatively, the data can be uploaded to the MLA Heat Load Data Network (HLDN), which will then calculate the HLI and AHLU. The HLDN is operated by Katestone Environmental in conjunction with the forecasting service.

Options for transferring data from a weather station onto a computer capable of calculating HLI and AHLU include:

- physically walking out to the weather station and downloading data e.g. by plugging a USB drive into the weather station, then uploading the data onto a computer
- WIFI or radio link (see below): this is a wireless data transfer from the data logger to an on-site computer less than several hundreds of metres from the weather station
- Cellular data modem or satellite connection (see below): this transfers data using a mobile network and the data can be accessed on any computer that is connected to the internet

To ensure maximum benefit from a weather station, a connection to the internet is required in order to connect the weather station to the Heat Load Data Network. This can be done in various ways:

- **WIFI or radio link to site computer:** If a weather station sends data through a WIFI or radio link to an on-site computer, and if the computer is connected to the internet, then the data can be automatically uploaded to the Heat Load Data Network by a scheduled task. This requires line of sight between the weather station and the computer, and typically works if the distance between them is a few hundred metres or less.

- **Cellular data modem**: A weather station can be connected directly to the internet via a cellular data modem which would be mounted on the weather station, if there is mobile coverage at the weather station location. These modems use a mobile phone network to transfer data (e.g 3G, Next G or GSM) and so a mobile SIM card and data plan is required. Some companies (e.g. Saros) can arrange and manage this, otherwise the user will need to arrange for the connection and manage the ongoing costs. As a guide a typical data plan and SIM card will cost about $20 per month. This option would allow weather station data to be uploaded directly to Katestone without needing to set up a scheduled task on an on-site computer, and the data could be viewed on a computer that is connected to the internet.
- **Satellite**: This option is similar to the cellular data modem but instead of using the mobile phone network it uses a satellite network to transfer data. A satellite modem or terminal would be mounted on the weather station. This option is recommended for locations with poor mobile coverage. The costs are similar to the mobile option ($20 per month connection fee) but data upload costs are extra. Assuming data only needs to be uploaded once a day the cost would be about $5 per month. More frequent uploads could cost more. There is also an option to choose the upload frequency and change it if more frequent uploads during an impending heat event are required.

Various weather station options have data plans that include the delivery of weather station data to a web site.

3.3 Weather station costing

3.3.1 Base Cost

As a way of ensuring that weather station costings were comparable, a minimum specification in terms of sensors, components and data access was developed to determine the base cost of each AWS:

- Sensors required:
  - Black globe or temperature and solar radiation
  - Wind speed
  - Relative humidity
- Components required:
  - Solar panel and battery
- Data access:
  - Local data access only

Where provided costs for optional functions and components have been included for each weather station considered, these include:

- Option for integrating HLI and ALHU calculation into the datalogger firmware or software (if not included in base cost)
- Remote telemetry options and data plan estimates where provided

All ‘Base Costs’ provided are GST exclusive and should be taken as indicative as at November 2013. Costs for optional functions/components are not included in the base cost estimate.

3.3.2 Maintenance Costs

For each AWS considered suitable, an indicative 10 year maintenance cost has been estimated. These estimates have been developed in consultation with the AWS supplier. Where there was an option of on-site services compared to operator replacement the lower cost option has been included. All maintenance costs are only indicative and generally based on a conservative approach to sensor/component maintenance or replacement recommendations. Costs can be greatly affected by general system maintenance in the first instance as well as the characteristics of the operating environment.

3.4 Uncontrollable events

During the passage of Ex-Tropical Cyclone in January this year most sites in its path experienced loss of power and mobile communication networks were down. It is worth considering how HLI and AHLU would be calculated if either power or mobile network coverage was lost.

In the event of a power failure weather stations may require a battery backup or solar panel to maintain collection of data, unless there is a backup generator on site. A method for calculating the HLI in this event should be developed. A laptop could be used for these calculations for a weather station that does not calculate it in the logger.

For sites relying on the mobile network to upload the data to provide the HLI and AHLU calculations, consider if there is a back up (e.g. USB connection) or similar manual method to download the data if the mobile network is down. Some units have a LCD screen to allow visual inspection of the data. In this event internal calculation of the HLI and AHLU is recommended.

The satellite option may be more reliable during extreme weather events as the satellites themselves will not be damaged during the event, whereas mobile network or other infrastructure may be. However, the same planning is needed to ensure a continued power supply to the weather station and satellite terminal.

3.5 Where to site a weather station

The weather station should be sited so the variables measured are representative of the general surrounds. Subtle variations in the environment may mean that the data are not representative. For example, a tree shadow falling across a BGT sensor will result in HLI and AHLU values that are lower than they should be for as long as that shadow is on the sensor.

Weather stations operated by the Australian Bureau of Meteorology have strict siting requirements and have to meet an Australian Standard (AS 3580.14). The siting requirements from the Australian Standard for wind, temperature, relative humidity and solar radiation are summarised below.

Wind sensors:

- measurements at a height of 10m over a flat open area clear of obstructions
- to be clear of obstructions, this means there should be a clearance distance of at least 10 times the height of the obstruction for wind sensors

Temperature and relative humidity:

- mounted over a plot of open level ground at least 9m in diameter free of obstructions, and freely exposed to sunshine and wind
- to be clear of obstructions, this means a clearance distance of at least four times the obstruction height
- located at least 30m from large paved areas and not close to hollows or ridges or other changes in terrain
- area should ideally be unwatered short grass, or natural earth (not concrete)
- should not be located close to artificial or natural sources of moisture
- measurements at 2m or higher above ground

Solar radiation and black globe temperature:

- an upward-looking solar radiation sensor should be free from any obstructions above the sensor
- no shadows should be cast on the sensor
- should be located away from light-coloured walls or other objects likely to reflect sunlight

If is sometimes not practical to meet these standards at a particular location. In these instances, the station should ideally be located:

- on a flat cleared area - either a grassy surface, or one that is similar to the feedlot
- clear from obstructions such as buildings and trees (a rule of thumb would be to locate the weather station at a distance from any obstruction of ten times the height of the obstruction)

The station should not be:

- in a gully or other depression
- on a geological formation such as a rock outcrop
- on or near steep slopes, cliffs, or ridges
- on a veranda or under an awning

If there is a solar panel, this should face north.

4. Weather station overview - basic requirements

Table 1 Feedlot weather station - basic requirements

Model	Manufacturer	Base Cost ($ excl GST)	Required						Suitable
			Wind speed	Relative humidity	BGT preferred		BGT[3]	Solar power	
					Air temp[2]	Solar radiation[2]			
Deluxe Weather Station	Celestron	$170	Y	Y	Y	N	N	N	N
Wireless Weather Station	Instrument Choice	$194	Y	Y	Y	N	N	Y	N
Lacrosse professional weather station	Lacrosse	$359	Y	Y	Y	N	N	N	N
WMR200A Advanced Pro Weather Station	Oregon Scientific	$500	Y	Y	Y	N	N	N	N
Vantage Vue	Davis	$540	Y	Y	Y	N	N	Y	N
Vantage Pro 2	Davis	$780	Y	Y	Y	N	N	Y	N
Davis Vantage Pro 2 Plus	Davis	$1,620[1]	Y	Y	Y	Y	N	Y	Y

Model	Manufacturer	Base Cost ($ excl GST)	Required						Suitable
			Wind speed	Relative humidity	BGT preferred		BGT[3]	Solar power	
					Air temp[2]	Solar radiation[2]			
Pacific Data Systems Custom Weather Station	Pacific Data Systems	$1,960	Y	Y	Y	N	Y	Y	Y
Saros Custom Weather Station	Saros	$4,400	Y	Y	Y	N	Y	Y	Y
HOBO U30	Instrument Choice	$5,421	Y	Y	Y	Y	N	Y	Y
Campbell Scientific Custom AWS	Campbell Scientific	$6,269	Y	Y	Y	N	Y	Y	Y
Feedlot Weather Station	MEA	$7,350	Y	Y	Y	N	Y	Y	Y
Weather Maestro	Environdata	$7,695	Y	Y	N	N	Y	Y	Y
Weathermaster 2000	Environdata	$8,816	Y	Y	Y	Y	Y	Y	Y

Table notes:
[1] Includes, fan aspirated radiation shield, data logger and Weatherlink data access software
[2] Solar radiation and temperature are not required if BGT is available
[3] Where BGT is available temperature and solar radiation sensors are not required

5. Weather station costs and options for suitable stations

Table 2 Weather station purchase/maintenance costs and options 1

Weather Station	Estimated base cost[2]	Estimated ongoing annual cost for first 10 years[3]	Total cost over 10 years (including purchase and maintenance)	Features				
				HLI calc method	Data access to internet	Data accessible on site	Meets Australian Standard[4]	Estimated uncertainty in AHLU over 8 hours[5]
Pacific Data Systems Custom Weather Station *	$1,960	$217	$4,130	In logger	3G connection included in base cost	USB	Temp only	27
Saros Custom Weather Station*	$4,400	$299	$7,390	In logger	Via computer or 3G Data modem at additional cost	LCD, WIFI and USB	No	27
Vantage Pro 2 Plus - Davis	$1,620	$255	$4,170	External	Via computer or Next G option at additional cost	USB or console display	No	32
HOBO U30	$5,421	$310	$8,521	External	GSM included in base cost	USB, WIFI, ethernet options available	Wind speed only	27
Campbell Scientific Custom AWS	$6,269	$627	$12,538	In logger	Range of options at additional cost	Short haul modem included in base cost, Serial cable.	Wind speed only	24

Weather Station	Estimated base cost[2]	Estimated ongoing annual cost for first 10 years[3]	Total cost over 10 years (including purchase and maintenance)	Features				
				HLI calc method	Data access to internet	Data accessible on site	Meets Australian Standard[4]	Estimated uncertainty in AHLU over 8 hours[5]
Feedlot Weather Station (MEA)	$7,350	$187	$9,220	In logger	Next G included as standard.	USB, other options available	Yes	9
Weather Maestro 6 Channel Environdata	$7,695	$227	$9,960	In logger	Next G available at additional cost	Serial cable or radio link	Yes	17
Weathermaster 2000 Environdata	$8,816	$227	$11,081	Software calculation	Next G available at additional cost	Serial cable or radio link	Wind speed only	17

Note
[1] All prices are estimates only, and exclude GST.
[2] This does not include installation requiring a site visit by service provider or electrician. This would be additional if needed and will depend on location of the feedlot and service provider base. Remote telemetry costs and associated data costs are not included.
[3] This is an estimate of ongoing maintenance costs. This does not include maintenance requiring a site visit by service provider or electrician. These will be additional if needed and will depend on location of the feedlot and service provider base.
[4] Considers wind speed, relative humidity, and temperature and solar radiation where BGT is not available. There is currently no Australian Standard accuracy for BGT.
[5] Uncertainty is calculated from the instrument error.

[*] The PDS and Saros system are not available for immediate delivery. They both require some development and customisation. Saros have estimated 6-12 weeks lead time for the first system (2 weeks for each system thereafter) and PDS will not have a system available until March 2014.

6. Weather station summary matrix

To allow a comparison between the weather stations with different accuracies, functionality and costs a rating system was used to determine the overall score for each weather station. The information used to determine the score in each category is presented in Section 7 for each system reviewed. The four categories were:

- Functionality
- Affordability
- Durability
- Accuracy

The ratings for functionality were high if a system included a black globe sensor and also calculated the HLI/AHLU within the units logger. A system also scored points if a customised program was supplied with the weather station which calculated the HLI and AHLU values.

Affordability was rated on the 10 year estimated cost for purchase, installation, maintenance, replacement sensors and data costs. A system with a 10 year cost of less than $5,000 rated highest with a 5, down to a rating of 2 if the cost was greater than $20,000.

Durability was difficult to determine as all suppliers indicated that their systems are robust. Systems that were stated to be industrial quality were rated high as well as those with no moving parts.

The greatest range in the systems reviewed can be seen in the accuracy of the sensors and hence the HLI and AHLU values. Based on the instrument accuracy, an estimate of the worst case error was determined for an 8 hour period during an extreme event. The additional error associated with use of a solar radiation sensor rather than a black globe sensor was also considered. An error of less than 5 AHLU scored the highest with 5, down to a score of 1 if the error was greater than 30 AHLU.

The following table presents the ranking for each system reviewed.

Table 3 Weather station summary rating matrix

Model	Manufacturer/Supplier	Category rating (1 to 5, 5 is Good)				Score
		Functionality	Affordability	Durability	Accuracy	
Pacific Data Systems Custom Weather Station	Pacific Data Systems	5	5	5	2	**17**
Feedlot Weather Station	MEA	5	4	4	4	**17**
Weather Maestro	Environdata	5	4	4	3	**16**
Saros Custom Weather Station	Saros	5	4	5	2	**16**
Weathermaster 2000	Environdata	4	3	4	3	**14**
Campbell Scientific Custom AWS	Campbell Scientific	5	3	4	2	**14**
HOBO U30	HOBO /Instrument Choice	1	4	4	2	**11**
Vantage Pro 2 Plus	Davis/ Instrument Choice	1	5	2	1	**9**

7. Review of weather stations

All prices in the following sections exclude GST.

7.1 Pacific Data Systems (PDS) custom weather station

Pacific Data Systems have designed these systems specifically to meet the needs of the feedlot industry. They are developing their own Black globe temperature sensor and dedicated data logger to allow calculation of the HLI (Heat Load Index) in real time. There will be some lead time required to develop and test the sensors (expected to be available by March 2014).

7.1.1 Indicative costing

Description	Cost (excl GST)	Inclusions
Base price	$1,960	• Sensors: Ultrasonic wind sensor, temperature, relative humidity (Fig 2), BGT (Fig 3) • Internal HLI/AHLU calculation • 3G cellular data for remote communications • Solar power and battery • USB connection for local data retrieval and LCD screen
Monthly Data Cost (estimate only)	$30	• Monthly 3G cellular data modem costs (est $20-30 per month extra)
Optional	Cost available on request	• Satellite modem

Fig.1 *PDS AWS with solar panel*

Fig.2
Ultrasonic wind speed, temperature, relative humidity sensor

Fig.3
Black Globe Temperature sensor

7.1.2 Sensor accuracy

Sensor	Accuracy	AS (Australian Standard)
Wind speed	±0.5m/s or 10% winds < 5 m/s ±1m/s or 5% winds > 5 m/s	±2 m/s or 1%,
Wind direction	±5^{o} winds < 5 m/s ±2^{o} winds > 5 m/s	±3^{o}
Relative humidity	±4%	±2% (10-90%), ±4% (90-100%)
Air temperature	±0.2^{o}C	±0.3^{o}C
BGT	±0.2^{o}C	-

7.1.3 Installation requirements

- Mast (30-50mm diameter)
- The system is designed to be installed by the end user - professional installer not required

7.1.4 Data access

- Data can be downloaded locally via the supplied USB port, or remotely via web portal - 3G or satellite modem.

- Sampling frequency and averaging period is customer selectable

7.1.5 HLI calculation method

Based on inputs from the wind speed, black globe temperature and relative humidity sensors the HLI and AHLUs will be calculated on the logger.

7.1.6 Maintenance requirements

Ultrasonic wind sensor has no moving parts and thus requires no maintenance. Sensors are field replaceable; replacement sensors are priced as below. Over a ten year period, recommended maintenance is expected to cost $2,170 or $217 annually.

Component	Maintenance	Cost estimate
Wind sensor (ultrasonic)	➢ Replace every 5-10 year	$500
BGT sensor	➢ Replace every 5-10 year	$260
Temperature/RH sensor	➢ Replace every 5-10 year	$120
Solar panel	➢ Replace every 10 years	$250

7.2 Saros custom weather station

Saros have designed these systems specifically to meet the needs of the feedlot industry. They are developing their own instrument data control board to allow calculation of the HLI in real time. There will be some lead time required to develop and test the systems. Saros currently provides customized weather stations for the quarry industry.

7.2.1 Indicative costing

Description	Cost (excl GST)	Inclusions
Custom Design	$4,400	• Sensors: wind speed, temperature, relative humidity, BGT • Custom enclosure • Solar panel • Internal calculation of HLI
Monthly Data Cost (estimate only) Managed Service Option (estimate only)	$65 $350/mth	• Communication costs are extra (est $50-$75 per month extra) • 3yr contract for lease, maintenance and data plan
Extras	$650	• Remote telemetry - 3G cellular data modem including high gain antenna

Representative Picture of a Quarry based weather station

7.2.2 Sensor accuracy

Sensor	Accuracy	AS
Wind speed	±0.5m/s or 10% winds < 5 m/s ±1m/s or 5% winds > 5 m/s	±2 m/s or 1%,
Relative humidity	±4%	±2% (10-90%), ±4% (90-100%)
Air temperature	±1^{o}C	±0.3^{o}C
BGT	±0.2%	-

7.2.3 Installation requirements

These weather stations do not need to be installed by a professional. Simple rules and guidelines need to be followed. Saros will provide both written installation instructions as well as general phone support.

The weather stations can be installed with various methods:

- Pole mounted
- Roof / structure mounted
- Saros can customize brackets / attachments to suit most requirements

The units need to be installed in consideration of the following principles:

- Weather stations without solar panels require mains power.
- Solar panel units should have the solar panel facing north.
- Antenna units need to have the antenna at the highest point achievable.

Saros can provide installation services which will be costed on a quote basis.

7.2.4 Data access

- Data is stored locally on the weather station for over 6 months
- 3G enabled units will be programmed to automatically send the data at agreed time intervals. The time intervals can be programmed for different frequencies as needed
- Non 3G enabled units will require a laptop to be connected directly or via WIFI to download the data.

7.2.5 HLI calculation method

- Standard methods will be used to calculate the Heat Load Index (HLI) within the data logger
- Saros can customize alerts and warning settings for specific measures

7.2.6 Maintenance requirements

All components typically have a standard manufacturer's limited warranty for a 12 month period. Saros will provide a guide for how to maintain the units which is

typically cleaning and visual inspection. The main weather station component is a marine grade part that requires minimal to no maintenance. The faulty weather stations or components need to be sent back to Saros' office in Brisbane at the cost of the feed lot owner. All servicing for the units will be undertaken at Saros' Brisbane office. Saros will maintain spare units in their Brisbane office for emergency replacements. Units can also be provided on a rental basis.

Sensor/s	**Replacement frequency**	**Cost estimate**
Airmar weather sensor	10 years	$1,200
BGT sensor	5+ years	$700
Solar radiation sensor	5+ years	$500
Saros customised control board	10 years	$600
Modem	5+ years	$650
Solar panel	5+ years	$250
Battery	2 + years	$60
Note - prices are for part replacement and installation undertaken by the feedlot owner under Saros instruction		

All recommended sensor and unit replacements can be completed by the user. Over a 10 year period the scheduled maintenance is expected to cost $2,990 or $299 annually.

7.2.7 Rental option

Saros provide a rental price option for units. The price would vary per unit depending on the unit type and rental duration. They are currently estimating a rental price of $500 per month. Prices can be scaled based on duration and unit type.

7.2.8 Managed service approach

Saros uses a managed service approach for pricing their environmental monitoring services in appropriate scenarios. The key benefit is the offset of capital costs by the end user. The typical; managed service scenario allows Saros to take full responsibility for the delivery of the service, including hardware. It allows for inclusion and control of all the related factors for a successful service:

a. Hardware provision – installation, monitoring and maintenance
b. Remote communication and telemetry support
c. Data reporting and consultation
d. Support and 'handholding'
e. Maintenance

Current estimation of costs for a typical managed service for a Saros designed weather station with solar panels and remote telemetry would be:

- $350 per month
- 3 year contract period
- Additional SIM costs of $50 to $75 per month

7.3 Davis Vantage Pro 2 Plus

Davis weather stations are manufactured by David Instruments in America. There is a wide range of different Davis weather stations ranging from about $500 up to $6,500. The lowest priced units are not suitable for determining heat load as they do not include solar radiation. The recommended base unit is the Vantage Pro 2 Plus as this includes solar radiation. Davis weather stations are sold by a number of suppliers in Australia (e.g. Instrument Choice and Pacific Data Systems).

Note that some of the Davis systems include a Heat Index. This is NOT the HLI and should not be used. The Heat Index included in the Davis systems is based on the Steadman formulation which is for human heat stress.

The NextG option is the base unit as well as a modem that allows data to be transferred from the weather station via a mobile phone network, and the cost includes the first 12 months of data access. This can be used in a location with NextG mobile coverage. With this model, data can be viewed or downloaded through a website from anywhere with internet connection. After a Telstra NextG Data Sim card has been purchased, the ongoing cost is approximately $5 per week for data transfer.

7.3.1 Indicative costing

Description	Cost (excl GST)	Inclusions	
Base Unit (6162 model)	$1,620	• Sensors: temperature, rainfall, relative humidity, barometric pressure, solar radiation, UV, wind speed/direction • Includes Data logger and Weatherlink IP software • Solar panel and battery	
Next G connectivity (alternative base price)	$6,500	As above plus • Cellular data modem. • 12 months of data access (additional access available at $120/annum)	
Optional extras	$389	• Solar powered wireless repeater adds 300m line of sight or typically 60-120m (not needed with Next G option)	

7.3.2 Sensor accuracy

Sensor	Accuracy	AS
Wind speed	±1m/s or 5%	±2 m/s or 1%,
Wind direction	±3^{o}	±3^{o}
Relative humidity	±3% (0 to 90% RH), ±4% (90 to 100% RH)	±2% (10-90%), ±4% (90-100%)
Air temperature	±0.5^{o}C	±0.3^{o}C
Solar radiation	±5%	-
Rainfall	±3% or 0.2mm	±5% (0 – 120mm/hr)

7.3.3 Installation requirements

- Solar panel and battery included in standard configuration, can also be connected to AC as standard
- An extra mast or pole is required to mount the unit on. A simple mounting tripod can be purchased for $199. Alternatively it can be mounted on a user installed square post.
- System is off-the-shelf and can be installed by the end user.

7.3.4 Data access

- Instantaneous and limited historical data (last 24 hours) can be viewed on console display
- Local download of historical data requires logger dongle and Weatherlink software
- Remote data access requires $120 annual subscription. Data can be exported to most popular spreadsheets, databases, and word processing programs.
- Choose 1, 5, 10, 15, 30, 60, or 120 minutes. Store up to six months' worth of data depending on the storage interval.

7.3.5 HLI calculation method

There is no option for HLI calculation to be integrated into data logger firmware or software. The HLI calculation could be performed either locally or remotely. Both options require download of a data file and upload of data into a purpose built calculation platform for determining HLI.

1. Local data access – calculation would require:
   - local download of data file
   - upload of data into calculation platform

2. Remote data access – calculation would require:
   - local download of data file
   - upload of data into calculation platform
   - remote user would also require Weatherlink software ($190) – each user required their own copy of the Weatherlink software.

7.3.6 Maintenance requirements

Davis weather stations are an entry level weather station. Advice from the manufacturer indicates that the weather station should require only basic maintenance and that sensors are robust and experience only limited creep. However in addition to regular inspection and cleaning, the following sensor replacement schedule would be recommended:

Component	Maintenance	Cost estimate
Wind sensor	➢ Replace at 2.5 and 7.5 years	$200
Solar radiation sensor	➢ Replace at 2.5 and 7.5 years	$200
ISS replacement – all sensors replaced	➢ Replace every 5 years	$750[1]
Solar panel and battery	➢ Replace every 5 years	$280

Table note:

[1] Includes $500 for standard ISS replacement, $200 for solar radiation sensor and a freight allowance of $50

All recommended sensor and ISS unit replacements can be completed by the user. Over a 10 year period the scheduled maintenance is expected to cost $2,860 or $286 annually.

7.4 HOBO U30

The HOBO U30 is built by Onset (an American company) and available in Australia from Instrument Choice. There are lots of options to choose from depending on the power and communication requirements at a feedlot. Two options have been selected to provide an estimate of the cost and range of units available.

All electronics are housed in an industrial-grade, tamperproof enclosure. Setup is quick and easy with all plug-and-play sensors.

7.4.1 Indicative costing

Description	Cost (excl GST)	Inclusions
Base option	$5,421	• Sensors: temperature, rainfall, relative humidity, barometric pressure, solar radiation, wind speed/direction • Tripod and cross-arm • Solar panel • GSM communications included as standard First year data plan included (approximately $400 -$540 per year after the first year)
Optional extras	N/A	• A range of communications and data download including WIFI options available with minimum data plan free

Figure 1 HOBO U30 Weather Station

7.4.2 Sensor accuracy

Sensor	Accuracy	AS
Wind speed	±1.1m/s or 4% Starting threshold – 0.78m/s	±2 m/s or 1%,
Wind direction	±5^{o}	±3^{o}
Relative humidity	±2.5% (10 - 90% RH), ±3.5% maximum	±2% (10-90%), ±4% (90-100%)
Air temperature	±0.21^{o}C	±0.3^{o}C
Solar radiation	±10W/m^{2} or ±5%	-
Rainfall	±1%	±5% (0 – 120mm/hr)

7.4.3 Installation requirements

- The system is designed to be installed by the end user - professional installer not required
- All sensors are plug-and-play

7.4.4 Data access

- GSM option automatically uploads the data to a HOBOlink website from this website and data can be viewed online as well as archives downloaded.
- WIFI option also uploads automatically to HOBOlink website.
- Maximum logging rate of 1 minute, although the data is only uploaded every 10 minutes, 512 kB data storage with non-volatile flash memory
- Alternatively data can be manually downloaded from the unit logger via a USB connection

Note that the only option for mobile coverage is via the GSM network. Feedlots should check their area coverage before selecting this option.

7.4.5 HLI calculation method

The HLI calculation could be performed either locally or remotely in provided software. Both options require download of a data file through HOBOlink and upload of data into a purpose built calculation platform for determining HLI.

1. Local data access – calculation would require:
   - local download of data file
   - upload of data into calculation platform

2. Remote data access – calculation would require:
   - local download of data file
   - upload of data into calculation platform

7.4.6 Maintenance requirements

HOBO weather stations are robust and designed for remote location with limited maintenance. Advice from the manufacturer indicates that the weather station should require only basic maintenance and that sensors are robust and experience only limited creep. However in addition to regular inspection and cleaning, the following sensor replacement schedule would be suggested:

Component	Maintenance	Cost estimate
Temperature/RH sensor	➢ Replace every 5 years	$300
Wind speed/direction	➢ Replace every 5 years	$1,200
Battery replacement	➢ Replace every 2 years	$20

All recommended sensors can be completed by the user. Over a 10 year period the scheduled maintenance is expected to cost $3,100 or $310 annually.

7.5 Campbell Scientific custom weather station

The Campbell Scientific Custom AWS is based on the CR800 research grade measurement that very flexible and can be easily customised to suit a range of applications. The basic configuration presented includes a pole ground mounting kit, solar panel and weather proof enclosure and costs associated with programming the HLI calculations into the data logger.

7.5.1 Indicative costing

Description	Cost (excl GST)	Inclusions
Base price	$6,269	• Sensors: BGT, wind speed, relative humidity and temperature • Viewpro software • In logger HLI calculation • Short-haul modem connection
Optional extras	$740 $740 $890	• Cellular network connection • Loggernet support software for graphical user interface • 10ft tripod

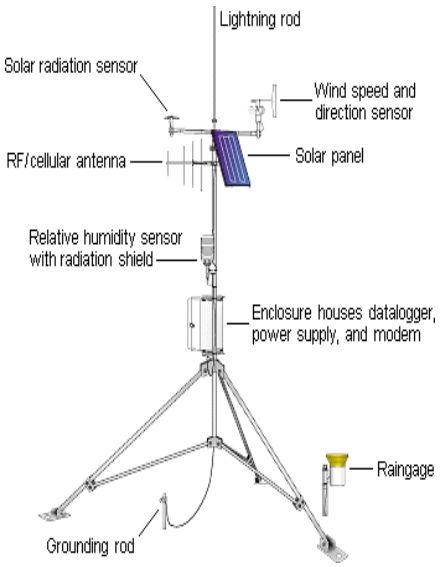

Figure 2 Campbell Scientific Generic AWS Schematic

7.5.2 Sensor accuracy

Sensor	Accuracy	AS
Wind speed	±0.5m/s	±2 m/s or 1%,
Relative humidity	±3% (10 - 90% RH), ±5% (90 - 100% RH),	±2% (10-90%), ±4% (90-100%)
Air temperature	±0.6^{o}C	±0.3^{o}C
Black globe temperature	±0.2^{o}C	-

7.5.3 Installation requirements

This is a solar powered station with straightforward user installation requirement. It comes with a six foot pole and mounting kit.

7.5.4 Data access

- Option for web enabling - $740
- Data can be accessed by hard connection via a serial port of serial port/USB adaptor
- Short haul modem connection is included in the base price

7.5.5 HLI calculation method

The HLI calculation can be programmed into the data logger, the cost of this ($500) is included in the base price. Data from the logger is in dot.dat format and can be viewed in t a number of ways. The HLI could most simply be viewed on ‘Viewpro’, free software provided by Campbell Scientific or using Loggernet Support software that allows for more sophisticated displays of logger data. Loggernet Support software is required for the remote telemetry option.

7.5.6 Maintenance requirements

All sensors can be serviced or repaired with replacement components that do not require field calibration, specialised tools or training.

A maintenance schedule has not been provided. In addition to regular cleaning, maintenance costs based on replacing the entire station once each five years would be $6,269 or $627 annually.

7.6 Feedlot Weather Station (MEA)

The MEA Feedlot Weather Station is a sturdy tripod mast, solar power station which calculates and records accumulated heat load index. It has been designed for use in feedlots, and all instruments meet the Australian Standards.

7.6.1 Indicative costing

Description	Cost (excl GST)	Inclusions
Base price	$7,350	• Sensors: BGT, relative humidity/temperature, wind speed • Next G communication module included as standard • Solar panel • In logger HLI/AHLU calculation • Mounting tripod included
Optional extras		An adaptable unit, with a range of additional sensors and options available

Figure 3 MEA Feedlot Weather Station

7.6.2 Sensor accuracy

Sensor	Accuracy	AS
Wind speed	±0.3m/s	±2 m/s or 1%,
Relative humidity	±0.8%	±2% (10-90%), ±4% (90-100%)
Temperature	±0.1^{o}C	±0.3^{o}C
Black globe temperature	±0.2^{o}C	-

7.6.3 Installation requirements

This station comes with a solar panel and tripod mast. It can be installed by the user as it arrives largely assembled. Cables for the ground based sensors should be routed through conduit when installed.

7.6.4 Data access

A serial cable attached to a PC can be used to communicate directly with the data logger. Data can be unloaded from the logger, sensor inputs can be viewed in 'real time' and the data recorder can be re-programmed if required. Local remote data access options are available

The station has a built in modem as standard which connects to the Telstra network. Data is transferred to the internet and viewed using Magpie software. If an ftp site can be set up, this would cost approximately $10 per month (alternatively, MEA can manage the data and ftp site for $295 plus GST per year).

7.6.5 HLI calculation method

The HLI/AHLU calculation can be completed within the logger. The ability to incorporate the calculation into the logger eliminates the data handling steps required to complete the calculation in an external software application. Additionally Magpie software provided free of charge with most systems is able to perform complex calculations derived from the input of one or multiple sensors and make these available as 'virtual' instruments.

7.6.6 Maintenance requirements

Maintenance is minimal if care is taken with basic checks. The solar panel and pyranometer need to be cleaned periodically with a damp soft cloth. This will protect the battery life and ensure the solar radiation readings are unaffected by dust. The sensor shelter should be cleaned to ensure wind flow is not impeded (e.g. spiders).

Regular sensor recalibration is recommended for the air temperature and relative humidity sensor and BGT sensor. The reality is that few customers recalibrate sensors at the recommended frequency; both sensors hold their calibration quite well and a five year (or more) period between calibrations is common. The wind sensor needs bearing replacements from time to time. In addition to regular inspection and cleaning, the following sensor replacement schedule would be recommended:

Component	Maintenance	Cost estimate
Sensor calibration (RH and BGT) [1]	➢ Recalibrate every 2 years	$290
Wind speed/direction	➢ Replace bearing at Yr4 and Yr8	$210

Table Note:

[1] Solar radiation and temperature/relative humidity need to be sent back to MEA, so a freight allowance of $50 has been included

If a sensor fails a replacement can be fitted by the station owner – it does not require an MEA site visit. Over a 10 year period the scheduled maintenance is expected to cost $1,870 or $187 annually.

MEA also assign a unique reference number to every weather station sold. A record is kept for each AWS including its original condition, sensors and serial numbers and any customer assistance that has been provided. MEA have found this approach to be time saving and cost effective.

7.7 Weather Maestro Weather Station (Environdata)

Australian owned company operating in Warwick, Queensland. Weather stations are locally made and designed. All Weather Maestro sensors meet the Australian Standards.

7.7.1 Indicative costing

Description	Cost (excl GST)	Inclusions
Base price	$7,695	• Sensors: temperature, BGT, relative humidity and wind speed • Solar panel • Environdata's EasyAccess software • In logger HLI calculation • Mounting post included
Optional extras	$1,045	• Next G modem package • An adaptable unit, with a range of additional sensors and options available

Figure 4 Environdata Weather Maestro AWS

7.7.2 Sensor Accuracy

Sensor	Accuracy	AS
Wind speed	±0.2 m/s	±2 m/s or 1%,
Relative humidity	±2% (10 - 90% RH), ±4% maximum	±2% (10-90%), ±4% (90-100%)
Black globe temperature	±0.2^{o}C	-

7.7.3 Installation

Easy to assemble and use, comes with a solar panel and battery allow for up to 3 week's operation without sunlight so no power supply is required.

7.7.4 Data access

- A communications or telemetry method that transmits the stored data to a chosen computer, PLC or control system.
- Environdata supplies UHF radio links for short range (up to 5km) to medium range (up to 15km), and VHF radio links for longer distances.
- Next G modems can also be used on the Telstra network.
- Direct cable connection is also an option.
- Ethernet converters & Internet page display means Environdata can get the weather data from a Weather Maestro Weather Station to any web browser.
- In real terms, the Weather Maestro Weather Station has capacity for more than 1 year of data including ten minute, hourly and daily summaries, all in secure non-volatile flash memory.
- The collected weather data is sent to the collecting device (usually a PC, PLC or RTU) as ASCII text, with a native output in RS232 Serial format. This data is easily readable by humans and also easily interpreted by any third party application for custom integration. Environdata also provides a MODBUS interface if required, further enhancing the ease of connecting to the control system.

7.7.5 HLI calculation method

The HLI calculation can be done through Environdata firmware and has been included in the base price. All data collected by the Weather Maestro data logger is time and date stamped. The ability to incorporate the calculation into the logger eliminates the data handling steps required to complete the calculation in external software application. The calculated HLI could be simply viewed in Environdata's EasyAccess software provided with the AWS.

7.7.6 Maintenance requirements

The Weather Maestro weather stations are designed and built in Australia to survive in harsh conditions. Environdata weather stations are located throughout Australia: the Simpson Desert, several kilometres off the Tasmanian coast, Uluru, tropical Cape Tribulation and remote Gove in the Northern Territory are just a few of the more extreme examples

These robust, modular weather stations are specifically designed to be easy to install, easy to use, and easy to maintain. However in addition to regular inspection and cleaning, the sensor replacement schedule below would be suggested. All recommended sensor replacements can be completed by the user. Over a 10 year period the scheduled maintenance is expected to cost $2,265 or $226 annually.

Component	Maintenance	Cost estimate
BGT Sensor	➢ Recalibrate every 2 years	$80
Relative humidity sensor	➢ Replace every 2 years	$195
Wind speed sensor	➢ Replace bearings every 5 years	$360[1]
Solar battery	➢ Replace every 5 years	$85
Table Note: [1] A freight allowance of $50 has been included		

Environdata recommend an annual in-field service to maintain system reliability and accuracy.

7.8 Weathermaster 2000 Weather Station (Environdata)

Australian owned company operating in Warwick, Queensland. Weather stations are locally made and designed. The Weathermaster 2000 AWS is an integrated sensor unit with the option of adding one additional sensor, in this case the BGT.

7.8.1 Indicative costing

Description	Cost (excl GST)	Inclusions
Base price	$8,816	• Sensors: temperature, BGT, relative humidity, wind speed and direction • Solar panel • Environdata's EasyAccess software • Software based HLI calculation • Mounting post included
Optional extras	$1,890	• Next G modem package •

Figure 5 Environdata Weathermaster 2000 AWS

7.8.2 Sensor accuracy

Sensor	Accuracy	AS
Wind speed	±0.2 m/s	±2 m/s or 1%,
Relative humidity	±3% (10 - 90% RH), ±4% maximum	±2% (10-90%), ±4% (90-100%)
Temperature	±0.2^{o}C	±0.3^{o}C
Black globe temperature	±0.2^{o}C	-
Solar radiation	±0.5^{o}C	-
Wind direction	±2^{o}	±3^{o}

7.8.3 Installation

Easy to assemble and use, comes with a solar panel and battery allow for up to 3 week's operation without sunlight so no power supply is required.

7.8.4 Data access

- A communications or telemetry method that transmits the stored data to a chosen computer, PLC or control system.
- Environdata supplies UHF radio links for short range (up to 5km) to medium range (up to 15km), and VHF radio links for longer distances.
- Next G modems can also be used on the Telstra network.
- Direct cable connection is also an option.
- Ethernet converters & Internet page display means Environdata can get the weather data from a Weather Maestro Weather Station to any web browser.
- In real terms, the Weather Maestro Weather Station has capacity for more than 1 year of data including ten minute, hourly and daily summaries, all in secure non-volatile flash memory.
- The collected weather data is sent to the collecting device (usually a PC, PLC or RTU) as ASCII text, with a native output in RS232 Serial format. This data is easily readable by humans and also easily interpreted by any third party application for custom integration. Environdata also provides a MODBUS interface if required, further enhancing the ease of connecting to the control system.

7.8.5 HLI Calculation Method

The HLI calculation can be done through Environdata firmware and has been included in the base price. All data collected by the Weathermaster data logger is time and date stamped. The ability to incorporate the calculation into the logger eliminates the data handling steps required to complete the calculation in an external software application. The calculated HLI could be simply viewed in Environdata's EasyAccess software provided with the AWS.

7.8.6 Maintenance requirements

The Weathermaster 2000 maintenance requirements are identical to the Weather Maestro weather station.

These robust, modular weather stations are specifically designed to be easy to install, easy to use, and easy to maintain. However in addition to regular inspection and cleaning, the sensor replacement schedule below would be suggested. All recommended sensor replacements can be completed by the user. Over a 10 year period the scheduled maintenance is expected to cost $2,265 or $226 annually.

Component	Maintenance	Cost estimate
BGT Sensor	➢ Recalibrate every 2 years	$80
Relative humidity sensor	➢ Replace every 2 years	$195
Wind speed sensor	➢ Replace bearings every 5 years	$360[1]
Solar battery	➢ Replace every 5 years	$85
Table Note: [1] A freight allowance of $50 has been included		

Environdata recommend an annual in-field service to maintain system reliability and accuracy.

8. Weather station service/purchase locations

Weather Station	Suppliers/ Service locations	Contact details	Contact person
Pacific Data Systems Custom Weather Station	Pacific Data Systems, Brisbane, QLD	27 Hi-Tech Court Eight Mile Plains QLD 4113 Phone: 07 3361 2000 Email: sales@pacdatasys.com.au	Adam Carter
Saros Custom Weather Station	Saros, Milton, QLD	27 Douglas St / PO Box 2079 MILTON QLD 4064 Phone: 07 3367 3400 Website: www.saros.com.au	Rob Brook or Andrew Niven
Davis* Vantage Pro 2 Plus	Pacific Data Systems	27 Hi-Tech Court Eight Mile Plains QLD 4113 Phone: 07 3361 2000 Email: sales@pacdatasys.com.au	Adam Carter
	Instrument Choice	22A Cavan Road Dry Creek SA 5094 Phone: 1300 737 871 Email: tim@instrumentchoice.com.au Website: www.instrumentchoice.com.au	Tim Trainor
Campbell Scientific Custom AWS	Campbell Scientific	411 Bayswater Road Garbutt, QLD 4814 Phone: 07 4772 0444 Email: ghewitt@campbellsci.com.au Website: http://www.campbellsci.com.au	Gavin Hewitt
HOBO U30	Instrument Choice	22A Cavan Road Dry Creek SA 5094 Phone: 1300 737 871 Email: tim@instrumentchoice.com.au Website: www.instrumentchoice.com.au	Tim Trainor
Feedlot Weather Station	MEA	41 Vine Street MAGILL SA 5072 Phone: 08 8332 9044 Website: www.mea.com.au	Joe Hoogland
Weather Maestro Weathermaster 2000	Environdata	42-44 Percy Street Warwick Queensland Phone: 07 4661 4699 Email: sales@environdata.com.au Website: www.environdata.com.au	Sandra Wilson

Table note:
* A number of other retailers also sell these weather stations but were not contacted during this review. For example, www.davisnet.com.au and www.davisinstruments.com.au