H_2OBeef

A decision tool for water management in beef feedlots

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Executive summary

In many intensive beef production enterprises water is not considered limiting and commands a price that is too insignificant to be included in any decision based models. However, water allocation will have greater importance in future decision making associated with intensive animal production enterprises due to it becoming increasingly scarce in many regions around the world. Furthermore, there is increasing potential to treat water. The decision as to whether this should be done will depend on the net benefits of the water treatment process in question with part of these benefits being realized by the end-user of this water.

This report is designed to provide readers with a complete overview of how the H_2OBeef computer model works. Hence detailed descriptions of biological and economic relationships are presented throughout the chapters.

H_2OBeef is a tool designed to help decision makers evaluate long-term options associated with water management in beef feedlots. It is also an integral part of a larger systems model that has been developed to evaluate the net benefits of abstracting, treating and reusing saline ground water from under Western Australian rural towns. As the model is a simulation model several management strategies are considered and run through the model. Based on the output generated, the decision maker can decide on the optimal management regime to implement.

A single feedlot is represented in H_2OBeef. The user can specify the number of cattle, entering the feedlot, diet and water type, quality and quantity. An alternative water type other than desalinated water is also included in the model so that if desalinated water is not produced in sufficient quantities the feedlot will still be able to function.

H_2OBeef is relevant for any town providing the relevant model parameters are altered to reflect the characteristics of a particular town. While the model does not represent year to year variation in weather or advances in technology associated with beef production, changes in costs and/or benefits connected with these factors can be manually entered into the model.

The biological equations in the H_2OBeef are ultimately used to determine the water demand for the feedlot, including water intake and water used for dust control. Feed intake is a main driver of water intake and is modified by salt content of the ration and the environmental impact of temperature and rainfall to maintain animal production. In this model the feed is assumed to be a dry ration with no access to pastures and hence water intake is an important component of production. Water consumption is calculated on a monthly basis in the model and hence maximum temperatures are used in the water intake calculations.

Net economic benefits for a desired project over a 10 or 20-year period are produced in H_2OBeef. However, it must be noted that the results are contingent upon the assumptions driving them and should be interpreted accordingly. To provide information to help with this interpretation, an outline for conducting a sensitivity analysis is provided in Chapter 8.

While extensive detail regarding composition of the feedlot, feed intake and weight gain, waste management, water demand and balance and the economic analyses are all presented in this report, H_2OBeef does have some limitations. Understanding these shortcomings is important and hence they are described in the final chapter of this document. Furthermore the authors welcome any constructive feedback on any aspects of H_2OBeef.

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Chapter

One

Introduction

This chapter gives a brief introduction to H_2OBeef, this document and its intended users.

Water is not often a limiting factor in many intensive beef production enterprises and usually is priced so low that the cost of water is not considered in decision based models. However, water use and cost is likely to have a greater importance in future decision making associated with intensive animal production enterprises due to it becoming increasingly scarce in many regions around the world. One consequence of this scarcity will be the increased amount of treated water made available. However, the amount of treated water that will be produced will depend on the benefits returned by the consumers of the water.

H_2OBeef is a decision support tool that is designed to provide information and insight to users in helping them make long-term decisions about water management in beef feedlots. More specifically, it is an integral part of a larger systems model designed to evaluate saline water that has been abstracted from under Western Australian rural towns, treated and reused.

As the model is not an optimisation model, the optimal strategies are determined for different scenarios through a series of runs. H_2OBeef allows the user to simulate different management options including those associated with water. The user considers management strategies and using the model decides on the optimal management regime to implement. Economic and biological components are integrated into the model with the time step for economic aspects being annual. For biological processes, cattle input can be varied and so the length of time cattle are in the system depends on management plans that are selected by the user. It is possible to generate results from H_2OBeef for either a 10 or 20 year time period. The model is implemented in a spreadsheet program, Microsoft Excel®.

H_2OBeef represents a single feedlot. The user can specify number of cattle, *Bos indicus* and/or *Bos Taurus,* entering the feedlot, diet and water type, quality and quantity. If desalinated water is in short supply and does not meet the feedlot requirement the model specifies the amount of alternative water that would be required so that the feedlot is still able to function. This also means that H_2OBeef can easily be used for decision making other than that associated with desalinated water.

The applicability of H_2OBeef is not limited to a specific town but rather parameters within the model can be altered to reflect the town that it is used in. Default values pertain to Wagin, Western Australia (Latitude:-33.3075 S Longitude: 117.3403 E). Although it is recognised that climatic conditions, in particular temperature and rainfall, influence output as do changes in technology, H_2OBeef does not represent year to year variation in weather or advances in technology associated with beef production. However, there is scope in the model to manually account for these changes.

The key factors that drive water intake in cattle over time include, feed intake, temperature, rainfall and salt content of the feed. In this model the feed is assumed to be a dry ration with no access to pastures and hence such an operation requires extra water to account for the lack of water in the feed ration. The biological equations in H_2OBeef are predominately used to determine the water demand for the feedlot, including water intake and water used for dust control and relief from heat stress.

For the purpose of this model, the year is broken into a number of lots of equal time with equal time in between lots. This option can be changed depending on the starting and finishing live weights that are required to meet market specifications. Live weight changes are determined by feed intake and the energy density of the ration with the final live weight being determined from the surplus energy available for growth and the planned duration of the growth phase.

Solid excreta are estimated as the non-digestible dry matter component of the ration. The concentrations of nitrogen in the faeces are estimated from protein not digested and all urinary nitrogen is assumed to be lost to the atmosphere as ammonia. Faecal and urine phosphorus is calculated using nominal apparent digestibility and live weight. Total sodium and potassium excretions were calculated using nominal values from the literature. All values are estimated on a daily basis per head and then converted to annual production rates.

H_2OBeef does not include detailed simulation of cattle growth, water intake or total excretion as the parameters used represent these biological functions in relatively simple ways and is a summation of the feedlot periods defined in the model. The water consumption models produce monthly intakes and in the model in the present format do not estimated daily water intakes. This limitation should be born in mind for periods of extremely high temperatures that can occur in summer. If there is a requirement to estimate likely peak demands then the monthly temperatures could be set to the estimated extreme temperatures to estimate likely water requirements for the period of interest

The main outputs that can be obtained from H_2OBeef are the effect of feed composition on growth rate and water intake, the effect of climate on water intake and the effect these parameters together with alternative costs and benefits have on the net return for the project over a 10 or 20-year period. In addition, other biological and economic aspects are provided in the various sheets as outlined in the following chapters.

Results derived from a model such as H_2OBeef are contingent upon the assumptions driving them and should be interpreted accordingly. The principal assumptions have been presented in this chapter with minor assumptions described in relevant proceeding sections. Please note that as it is possible to input different values for the parameters pertaining to a specific breed of cattle, any parameters with a subscript, $_{BT}$ refers specifically to *Bos taurus* and likewise $_{BI}$ refers to *Bos indicus*. Where the equations are the same for each cattle type, either a generic equation is presented (in which case there is no subscript) or that for *Bos taurus* is given as an example.

Outline of this report

This report is designed to provide readers with a complete overview of how the H_2OBeef computer model works. Details regarding the number, type and characteristics of cattle in the feedlot are presented in Chapter 2. The derivation of feed intake and weight gain is described in Chapter 3. An overview of a waste management plan is presented in Chapter 4. The detail underpinning the expected water demand is outlined in Chapter 5 along with the explanation for water balance in the feedlot. Economic data requirements are outlined in Chapter 6 and a description of the economic analyses are presented in Chapter 7. The capacity of H_2OBeef is described in Chapter 8. The key variables used in the equations are listed in the Appendix.

Chapter

Two

Cattle in the feedlot

This chapter presents specific details regarding the cattle in the feedlot at any one time.

The number of cattle in the feedlot and time that they are there throughout the year is based on two Microsoft Excel® sheets. The **Cattle** sheet provides the structure for the feedlot, and change in weight of the cattle over time. The **Lots** sheet relies on input in the Cattle sheet and shows the duration in days for each lot for the corresponding months and the times during the year when the feedlot is free of cattle.

Cattle sheet

The total number of cattle expected to go through the feedlot in a year, the days the cattle are in each lot (i.e. the period of time the cattle are in the feedlot from day of entry to day of exit) and the days between each lot are entered directly into the spreadsheet by the user. The user also enters the percentage of *Bos taurus* and *Bos indicus* with in the herd. The percentages entered should not exceed 100 percent. If they do an "error" message will appear in this row, otherwise the message will read, "ok". Likewise, the natural death rate per annum and the purchase live weight are all deemed to be feedlot specific and so are directly entered into this sheet. The remaining parameters are calculated within this sheet as described in the sections below.

Number of lots per year

The number of lots per year (B) will influence the time the cattle are in the feedlot and the weight that they ultimately gain. It is calculated using the inputted information regarding time cattle are in the lot, t_c, (days) and time in between lots t_b (days) and is assumed to be the same for all cattle.

$$B = \frac{365}{t_c + t_b}$$

Natural death rate

The total number of cattle that go through the feedlot during a year, *N* (hd/yr) as well as the percentage that are *Bos taurus* (τ) and *Bos indicus* (ι) are selected by the user. These parameters together with the natural death rate (*d*) of each cattle breed in the feedlot are directly entered by the user. Hence the number of natural deaths per annum (d_{yr}) and per day (d_{day}) for *Bos taurus* would be:

$$d_{yBT} = N\tau d_{BT}$$

$$d_{dayBT} = \frac{d_{yrBT}}{365}$$

Cattle entering and exiting the feedlot

Using parameters described in the above sections, the number of *Bos taurus* entering the feedlot at the beginning of each lot (e_{BT}) would be:

$$e_{BT} = \frac{N\tau}{B}$$

The number of *Bos taurus* exiting the feedlot (x_{BT}) accounts for natural deaths that are expected to occur over the period of time cattle are in the lot.

$$x_{BT} = e_{BT} - (d_{dayBT} t_c)$$

Likewise the procedure for *Bos indicus* is similar but specific parameters for this cattle breed would need to be entered.

The total number of cattle in the feedlot at any one time (ς) could be approximated by taking the average number of *Bos taurus* and *Bos indicus.*

$$\varsigma = \frac{e_{BT} + x_{BT}}{2} + \frac{e_{BI} + x_{BI}}{2}$$

Cattle weights

The live weight of cattle at purchase (W_p) (kg/hd) is assumed to reflect the average live weight for yearling steers. In the model, a default of 220kg is used but this figure may be simply altered as required. Sale live weight (W_s) is a function of kilograms live weight gain per day (W_{day}) (from the **LWT Prediction** sheet as described in Chapter 3), the number of days that the cattle stay in the feedlot and the purchase weight. While different values for these parameters can be entered for different cattle breeds, the generic equation is:

$$W_S = W_P + (t_c W_{day})$$

Feedlot area required

The land area (ha) required for the feedlot (A) is based on the maximum number of cattle present at any one time multiplied by the square meters required per head *Bos taurus* (A_{BT}) or *Bos indicus* (A_{BI}) plus a miscellaneous area (A_M) (ha).

$$A = \frac{e_{BT} A_{BT} + e_{BI} A_{BI}}{1000} + A_M$$

According to Powell (1994) the recommended area for feedlot cattle is 15m^2 per head. A miscellaneous area of 3 hectares is assumed to be reasonable. These values are the default values used in this model but can be changed to reflect individual feedlot circumstances.

Lots sheet

The **Lots** sheet in H_2OBeef provides a calendar of cattle activities for a typical year. Users are not required to input any data into the two tables in this sheet. Instead the figures in these tables will change depending on the time users select for the cattle to be in the feedlot and the time in between lots. In summary this sheet shows the days per month where activity in each lot occurs. Table 1 as displayed in this sheet, shows the time cattle in each lot spend in the feedlot as well as the 'resting' time after removal of cattle from the feedlot. The months that cattle are in particular lots can be clearly identified. Table 2 in the **Lots** sheet shows the total days of 'resting' time after removal of cattle from each lot. Managers can use this table to see the months when this activity will occur. Information from both tables is also used in other sheets that require information about specific cattle numbers in specific months e.g. for the calculation of water intake.

Chapter

Three

Feed intake and weight gain

The parts of the H_2OBeef model detailing feed issue, intake and weight gain of cattle are described in this chapter.

Feed intake is assumed to be the main driver of water intake but is modified by salt content of the ration and the environmental impact of temperature and rainfall to maintain animal production. Hence dietary components and total quantity of feed given to each animal is explored in the **Feed Issue** sheet. The process of feed intake, conversion and waste output is detailed in the **Live weight (LWT) Prediction** sheet. Parameters associated with each of these activities are used to predict individual live weight gain, water demand and other factors required by the sheets that provide economic output.

Feed Issue sheet

The total quantity of ration fed per head per day, *F*, (kg/hd/day) is entered by the user into this sheet. The amount entered has a direct bearing on feed intake and water demand.

There are a total of 53 different dietary components (Table 1) presented in the **Feed Issue** sheet of H_2OBeef with space for inclusion of an additional 36 components should the user have feed ingredients not included in the list. However, if additional components are added then their associated nutritional parameters must also be included in the appropriate rows. There is also a row representing a 'no feed component' option with a "code 0" that may be selected if the user wishes to have less than seven components in the diet (see below for more detail). It is assumed in H_2OBeef, that cattle do not have any access to pasture. For each component the nutritional parameters specified are dry matter content (*DM*), metabolisable energy (*ME*), fermentable metabolisable energy (*FME*), crude protein (*CP*), gross energy (*GE*), fat, neutral detergent fibre (*NDF*), acid detergent insoluble nitrogen (*ADIN*), nylon bag nitrogen degradation parameters (*aN, bN, cN*) and dry matter digestibility (*DMD*). Values for these parameters are included in the table and should only be changed if the user has good reason to do so.

Table 1. The list of dietary components and codes listed in the H_2OBeef model.

Code	Component	Code	Component
0	No feed component	27	Moist barley
1	Apple pomace(wet)	28	Molasses cane
2	Apples	29	Oat grain
3	Barley straw	30	Oaten straw
4	Barley grain	31	Orange peel
5	Bread	32	Palm kernel ex.
6	Brewer's grains	33	Pea Straw
7	Cabbage	34	Peas
8	Carrots	35	Potatoes
9	Cassave meal	36	Rape
10	Cereal straw	37	Rapeseed meal
11	Citrus pulp	38	Rye grain
12	Cottonseed meal	39	Silage 55-60D
13	Fat	40	Silage 60-65D
14	Fishmeal (white)	41	Silage 65-70D
15	Fodder beet	42	Silage, 70D vg
16	Grass silage	43	Sorghum grain
17	Hay, 50% DMD	44	Soyabean meal exp
18	Hay, 60% DMD	45	Soyabean meal ext
19	Hay,65% DMD	46	Sugar beet
20	Hay, 72% DMD	47	Turnips (W/stb)
21	Hay, 79% DMD	48	Urea
22	Lucerne silage	49	Wheat bran
23	Lupins	50	Wheat grain
24	Maize gluten feed	51	Wheat straw
25	Maize silage	52	Whey
26	Milk	53	Whole cotton

Each component has a diet selection code that is used to represent that component should it be selected in the feedlot ration. Users select 7 dietary components 'codes' in total along with the percentage of each component, n, in the ration (f_n.). Code "0" (no feed component) can be selected more than once if fewer than 7 components are required. However, each of the 7 spaces most be completed. An 'error' check is provided in this sheet to ensure that the total percentage of dietary components is 100%.

Live weight (LWT) prediction sheet

Unless otherwise stated, specified estimations are based on published feeding standards. Specific references are recorded in the **LWT prediction** sheet and can be found by scrolling to the right of the sheet.

Dry matter intake and output

The total dry matter intake, D, (kg/hd/day) is the summation of the feed ration, F, (kg/hd) multiplied by the percentage of each component in the ration (f_n.) and the percentage dry matter content (α_n) for each component selected using the following formula:

$$D = \sum_n F f_n \alpha_n$$

Faecal output (dry matter) per head per day, K, (kg/hd/day) is determined by multiplying the dry matter intake by one minus the average percentage dry matter digestibility of the components in the feed ration, where G_n is the percentage dry matter digestibility of component, n.

$$K = D - \left\{ 1 - \left(\frac{\sum_n G_n}{n} \right) \right\}$$

The total salt added to diet, S, (g/hd/day) is determined from dry matter intake (in grams) multiplied by percentage dietary salt added, s.

$$S = 1000 D s$$

Energy and live weight gain

Total metabolisable energy in the ration, M, (MJ/hd/day) is the summation of the energy density of each component in the ration, e_n, (MJ/kg dry matter) multiplied by the dry matter intake of each component.

$$M = \sum_n e_n F f_n \alpha_n$$

Net energy stored (E_g) is calculated using the prediction equation in Bulletin 33 (1977) where:

$$E_g = 0.0414 \left(\frac{M}{D} \right) \left\{ M - (8.3 + 0.091 L) \right\}$$

and L is live weight (kg).

Live weight gain (L_g) is calculated using the prediction equation in Bulletin 33 (1977) where:

$$L_g = \frac{E_g}{6.28 + 0.3E_g + 0.0188L}$$

The NRC beef cattle feeding standards (1996) indicated that *Bos indicus* breeds of cattle maintenance energy requirements are about 10% lower than the *Bos taurus* breeds. The maintenance requirement in E_g has been modified in line with this finding and there are no reported differences between the two breeds in the efficiency of utilization of energy for live weight gain.

This sheet also allows for an alternative estimation of live weight change, energy requirements, as well as, protein surpluses or deficiencies as a guide to the adequacies of the proposed dietary formulations. The calculations are based on AFRC (1995) and are independent of the parameters used to estimate live weight change for this model. The AFRC (1993) parameters used in this sheet were initially developed by S. Liu (pers. comm.), primarily to determine the energy and protein adequacy, or in-adequacies of rations, and have the potential to include other classes of cattle. The AFRC (1993) parameters calculated are presented in Appendix 2.

A mean value for the gross energy of ruminant diets is assumed to be 18.8 MJ/kg DM (AFRC 1993) and has been used throughout when tabulating metabolisable energy requirements. Gross energy intake, E, (MJ/hd/day) is calculated from the sum of the gross energy contained in each of the dietary components ε_n, (MJ/kg) multiplied by daily dry matter intake of each component per head.

$$E = \sum_n \varepsilon_n F f_n \alpha_n$$

Metabolisable energy intake is calculated using the same formulae as for total metabolisable energy in the ration (M).

The metabolisability of the gross energy in the diet dry matter (q_m) is defined as the proportion of metabolisable energy in the gross energy of the feed using the following formulae.

$$q_m = \frac{M}{E}$$

The fasting metabolism, q_f, (MJ/hd/day) requirements for cattle are calculated using the following formulae with c_1= 1.15 for bulls and 1.0 for other cattle and W_p is the live weight of cattle at purchase:

$$q_f = c_1 \left\{ 0.53 \frac{W_p}{1.08} \right\} 0.67$$

Assuming horizontal movement of 200 metres, 12 hours of standing and six changes in position, AFRC (1993) estimated the energy costs of activity, *a*, (MJ/hd/day) in beef cattle from the following formulae:

$$a = 0.0071W_p$$

Net energy for maintenance, E_m, (MJ/head.day) is the sum of energy required for fasting metabolism and activity. This net energy evaluation is adjusted using an estimation of the efficiency of utilization of ME for maintenance (k_m).

$$k_m = 0.35q_m + 0.503$$

The efficiency of utilization of ME for weight gain (k_f) is estimated using the following formulae:

$$k_f = 0.78q_m + 0.006$$

Energy value of tissue gained or lost, E_v, (MJ/kg) is estimated using the following equation:

$$E_v = \frac{C_2\left(4.1 + 0.0332W_p - 0.000009W_p^2\right)}{1 - C_3\left(0.1475W_{day}\right)}$$

where C_3 =1 where the value of λ is assumed t >1 for feedlots. C_2 corrects for mature body size and sex of the animal, in accordance with the values given in Tables 2 and 3.

Table 2. Values of correction factor C_2 for E_v content of live weight gains in cattle by maturity group and sex.

Maturity type	Bulls	Castrates	Heifers
Early	1.00	1.15	1.30
Medium	0.85	1.00	1.15
Late	0.70	0.85	1.00

Table 3. Classification of cattle breeds into maturity groups.

Early	Medium	Late
Aberdeen Angus	Hereford	Charolais
North Devon	Lincoln Red	Limousin
Friesian	Sussex	Simmental
		Bos indicus

Initial live weight (W_p) and the predicted live weight gains (W_{day}) are used from the model to predict live weight gains.

Level of feeding as a multiplier of megajoules of metabolisable energy for maintenance (λ) is estimated as a ratio of M_{mp} to M_m where:

$$\lambda = \frac{M_{mp}}{M_m}$$

The metabolisable energy required for maintenance, M_m, (MJ/day) is estimated using the following formulae:

$$M_m = \frac{E_m}{k_m}$$

The metabolisable energy requirement for maintenance and production, M_{mp}, (MJ/day) can be estimated using the prediction equation:

$$M_{mp} = \left(\frac{E_m}{k_m \ln \frac{k_m}{k_f}} \right) \ln\left(\frac{\beta}{\beta - E_r - 1} \right)$$

β is found through calculation of the formulae:

$$\beta = \frac{k_m}{k_m - k_f}$$

and E_r is the retention of Net Energy estimated from:

$$E_r = \beta\left(1 - e^{-\left(k_m \ln\frac{k_m}{k_f}\right)\frac{M}{q_f}}\right) - 1$$

The net energy retained by the growing cattle, E_f, (MJ/hd/day) is determined from:

$$E_f = E_r E_m$$

Live weight gain per day, W_{day} (kg/hd/day) is predicted using the following formulae:

$$W_{day} = \frac{E_f}{C_4\left(4.1 + 0.0332W_p - 0.000009W_p^2 + 0.1475E_f\right)}$$

where C_4 is correction factor for cattle sex ; 1.15 for bulls and castrate males, 1.10 for heifers.

Protein

Net protein equivalent of basal endogenous nitrogen requirements, N_b, (gCP/hd/day), is estimated using the following formulae:

$$N_b = 6.25\left(0.35W_p^{0.75}\right)$$

Net protein requirements for scurf and hair growth, N_d, (gCP/hd/day) is found from:

$$N_d = 6.25\left(0.18W_p^{0.75}\right)$$

Net protein requirements for maintenance, N_m, (gCP/hd/day) is the sum of N_b and N_d.

$$N_m = N_b + N_d$$

The efficiency of utilization of N_m for maintenance (k_{nm}) is defined in ARFC (1993) as k_{nm}=1.

Metabolisable protein required for basal maintenance, M_b, (gCP/hd/day) is calculated using the following formulae:

$$M_b = 2.1875W_p^{0.75}$$

Metabolisable protein required for scurf and hair growth, M_d, (gCP/day) is estimated using the equation:

$$M_d = 0.1125 W_p^{0.75}$$

Metabolisable protein required for maintenance, M_p, (gCP/hd/day) is found using from:

$$M_p = M_b + M_d$$

Crude protein supplied by the diet, J, is the summation of the crude protein content of each dietary component, ρ, (gCP/kg) multiplied by the dry matter content of each component consumed in the total diet.

$$J = \sum_n \rho_n F f_n \alpha_n$$

Rumen degradable protein, D_p, (gCP/hd/day) in the diet for a given rumen outflow rate is predicted from the summation of quickly degradable protein, D_q, (g/kg) in the dietary components plus the summation of slowly degradable protein, D_s, (g/kg) in the dietary components multiplied by the dry matter intake of each component per head.

$$D_p = \sum_n \left(D_{qn} + D_{sn}\right) F f_n \alpha_n$$

with

$$D_{qn} = \rho_n a_n$$

where a_n is the constant measured on the feed component. (quickly degradable protein is the cold water extracted fraction on the feed total crude protein content).

and

$$D_{sn} = \rho_n \left(\frac{a_n b_n}{c_n + r_n} \right)$$

with a, b, c and r being parameters measured on the feed components (slowly degradable protein is the amount of protein slowly degradable during the residence of the feed in the rumen).

The measure of the total nitrogen supply that is captured and utilized by the rumen microbes for growth and synthesis purposes is called effective rumen degradable protein, D_e, (gCP/kgDM) and is calculated using the following formulae:

$$D_e = \sum_n \left(0.8 D_{qn} + D_{sn}\right) F f_n \alpha_n$$

Undegradable protein, D_u, (gCP/day) is estimated as crude protein minus the rumen degradable protein:

$$D_u = J - D_p$$

Digestible undegraded protein (gCP/day) is the amount of undegraded feed protein that is truly absorbed and is calculated using the following formulae:

$$D_d = 0.9D_u - 6.25N_a$$

where N_a is acid detergent insoluble nitrogen in the diet.

Yield of rumen microbial protein synthesis Y_r, (gMCP/MJ FME) is predicted as follows:

$$Y_r = 7.0 + 6.0\left(1 - e^{-0.35\frac{E_f}{M_m}}\right)$$

Fermentable metabolisable energy of the diet, M_f, (MJ/day) is a product of the sum of the intake of the individual FME components of the ration and the dry matter intake of each component per head.

$$M_f = \sum_n \xi_n F f_n \alpha_n$$

An estimation of the microbial crude protein, M_c, (gMCP/day) supplied by the rumen is calculated from fermentable metabolisable energy of the diet and yield of rumen microbial protein synthesis.

$$M_c = M_f Y_r$$

The ratio of effective rumen degradable protein (D_e) and fermentable metabolisable energy of the diet (M_f) has three possible outcomes and is used to balance the protein component in the diets:

1. If D_e supply is less than D_e requirement, then the diet is D_e limited and the microbial crude protein supply is equivalent to D_e.

2. If D_e supply exceeds D_e requirements, then M_f is first limiting microbial crude protein supply and is determined from M_f and yield of rumen microbial protein synthesis.

3. If D_e supply matches the supply of M_f, this is the objective of diet formulations using the metabolisable protein system. This avoids both unnecessary surplus nitrogen excretions, which has environmental implications in feedlots, or else limitations of forage/diet intake caused by a shortage of D_e.

Digestible microbial true protein, M_t, (gCP/day) is produced by the activities of the rumen microbes, which synthesis protein from fermentable energy sources in and amino acids or non-protein nitrogen from the breakdown of feed proteins in the rumen.

$$M_t = 0.6375M_c$$

Total metabolisable protein, M_T, (gCP/day) is calculated from:

$$M_T = 0.6375M_c + D_d$$

Chapter

Four

Waste management

How the H_2OBeef model deals with waste generated from the feedlot is described in the following chapter.

While waste management associated with a beef feedlot does not require additional water, the products derived from processing the waste contribute to the total returns generated by the enterprise. Furthermore regulations associated with feedlots generally require effluent produced from such operations to be dealt with in a manner that meets health and safety standards. The following sections outline the waste output, treatment, costs and returns as described in the **Waste Management** sheet.

Waste output

Dietary concentration of nitrogen, N_D (g/kgDM) is calculated using crude protein intake and dry matter intake as found in the **LWT prediction** sheet.

$$N_D = \left(\frac{J}{6.25}\right)\left(\frac{1}{D}\right)$$

For all other components, being phosphorus, potassium and sodium, the dietary concentrations of each have been directly placed into H_2OBeef. These concentrations are estimated using operator selected values for excretion based on Spears *et al.* (1989) for apparent digestion of minerals. These concentrations are required in H_2OBeef to work out how much of each component is retained in the faeces and urine as described in the sections below.

Faeces

The proportion of each of the elements in the faeces is currently estimated in the model based again on Spears *et al.* (1989), except for faecal nitrogen (N_f), which is calculated using total metabolisable protein supplied and total crude protein intake from the diet, so as to estimate the non-metabolisable component. The generic equation used to determine the proportion of nitrogen in faeces is:

$$N_f = 1 - \left(\frac{M_T}{J}\right)$$

Faecal concentration will then simply be the dietary concentration multiplied by the proportion of the element found in the faeces. Hence for nitrogen, the faecal concentration, N_F (g/kgDM) would be:

$$N_F = N_D N_f$$

The total dry matter of elements in the faeces can then be determined from the faecal concentration for that element multiplied by the remainder left from the feed digestible fraction reported as faecal output in the **LWT prediction** sheet. Therefore the total amount of nitrogen derived from the faeces and available for sale, N_S (kg) would be:

$$N_S = N_F K$$

All faecal nitrogen is assumed to be stable and remain in the faeces.

Urine

Urinary volume output, U_O (g/hd/day) is estimated using the prediction equation of Fox *et al.* (2004) using the parameters of total DMI intake, crude protein intake and live weight.

$$U_O = 3.55 + 0.16D + \left(\frac{6.73J}{1000}\right)\left\{\left(\frac{W_p + W_s}{2}\right)\left(\frac{0.9}{454}\right)\right\}$$

All urinary nitrogen is assumed to be lost to the atmosphere as ammonia, thus making no contribution to mature nitrogen levels. Urinary phosphorus output, U_P (g/hd/day) is determined as a function of body weight (Fox *et al.* 2004).

$$U_P = \left(\frac{W_p + W_s}{2}\right)\left(\frac{2}{1000}\right)$$

Urinary sodium, U_{Na} (g/hd/day) and potassium U_K (g/hd/day) outputs are estimated using excretion coefficients based on Spears *et al.* (1989).

$$U_{Na} = 0.79 N_D D$$

$$U_K = 0.35 N_D D$$

The total amount of each mineral excreted per day in the feedlot is simply the total faecal and urinary outputs for those minerals converted from grams to kilograms.

Processing costs

The annual processing costs for an element, e.g. for nitrogen C_N ($/yr) is estimated in H_2OBeef by multiplying the cost of processing for that element, c_N ($/kg) by the total amount of nitrogen produced, N_T (kg/day) and the number of days per year that the cattle are in the feedlot, t_y (days).

$$C_N = c_N N_T t_y$$

The total annual processing costs for all waste produced are found by summing the processing costs for each mineral.

Revenue from minerals

The annual revenue derived from selling a mineral processed from feedlot waste, e.g. for nitrogen R_N ($/yr) is estimated in H_2OBeef by multiplying the price that element can be sold for, P_N ($/kg) by the total amount of nitrogen produced, N_T (kg/day) and the number of days per year that the cattle are in the feedlot, t_y (days).

$$R_N = P_N N_T t_y$$

The total annual revenue that can be derived from mineral sales is the sum of revenue produced by each mineral. It is assumed that these minerals will be sold as compost at a price equivalent to fertilser containing similar elements. It should also be noted that waste water passing into the ground water table meets regulation quantity and quality.

Chapter

Five

Water demand and balance

Total feedlot water demand and balance as described in the H_2OBeef model is the focus of this chapter.

Water demand is a factor that is commonly overlooked in most animal enterprises. Usually this is because water is not a limiting input and its cost is often seen as being insignificant when compared to the costs of other inputs. However, as water becomes less available and/or more expensive it should not be overlooked in animal enterprises. In the following sections, details describing how water demand is calculated in H_2OBeef are provided. Furthermore, a description regarding the water sources for the feedlot and water balance will be provided. The parameters are inclusive for determination of water intake and are based upon feedlot measurements, although the data is for US feedlots that include lower temperatures and less extreme temperatures than those experienced in Australian feedlots. Nevertheless it is possible to alter these values if the user wishes to assume different variables for the parameters based on their own experiences.

Water demand sheet

The **Water demand** sheet relies on rainfall and temperature data for the area that the feedlot is located in so as to calculate water required for dust control and water intake for cattle.

Climatic data

For each month of the year average monthly rainfall data, W_m (mm), average days each month where the rainfall is less than 3mm, W_l (days), the maximum temperature in each month, T (^oC) and that amount of water required for dust control on a daily basis, W_d (mm) are all directly placed in H_2OBeef.

Dust control and spray for heat stress

The **Water demand** sheet includes estimations of total water used for dust control and spray for heat stress in the feedlot. As a default, it is assumed that watering would be required to maintain the manure surface moisture content at 25 to 35 percent. Assuming 1mm/ha is equivalent to 10,000L, it would be necessary to spray 3L/m^2 to ensure the equivalent of 3mm/day.

The water required for dust and stress control for *Bos taurus* cattle in the feedlot in any one month, W_{BT} (L/mth) would be:

$$W_{BT} = A_{BT} e_{BT} W_d W_l$$

Likewise the water needed for dust and stress control for *Bos indicus* cattle in the feedlot in any one month W_{BI} (L/mth) could be calculated using relevant data for this cattle type.

Water intake for cattle

Daily water intake for a cow, H_A is estimated from Hicks *et al.* (1988) and uses dry matter intake (D) (kg /hd/day), maximum daily temperature, T (^{o}C), average monthly precipitation, W_m (mm) divided by the number of days in a specific month, t_m and dietary salt added, s (Na %). Therefore the feedlot monthly water intake for *Bos taurus*, H_A (L/mth) can be estimated as:

$$H_A = e_{BT} t_m \left\{ -6.1 + 0.708T + 2.44D - 0.387\left(\frac{W_m}{t_m}\right) - 4.445s \right\}$$

where t_m represents the number of days in a specific month.

This prediction of water intake needs to be treated with caution for salt inclusions in the diet of greater that 0.5%. The equation predicts decreasing water intakes with increasing salt content in the diet. This is contrary to the prediction equation developed by Murphy *et al* (1983) were increasing salt content in the diet resulted in increased water consumption. However, the above estimation of water intake based on Hicks *et al.* (1988) is similar to that produced by Winchester and Morris (1956) for cattle 450 kg at 20^{o}C but diverges for larger cattle at higher temperatures.

As there are few available published references for estimation of water intake the model developed by Hicks *et al.* (1988) was selected for H_2OBeef as it is the most inclusive and the temperature range was appropriate for this environment. However, there needs to be some caution exercised using this model with large cattle in extreme temperatures. The Winchester and Morris (1956) predictions also differentiated between *Bos indicus* and *Bos taurus* cattle. Hence, substituting the relevant parameters for *Bos indicus* into the equation suggested by Hicks *et al.* (1988) and multiplying by this correction factor would give the monthly water intake for that cattle type.

$$H_A = e_{BT}\, t_m\, \phi \left\{ -6.1 + 0.708T + 2.44D - 0.387\left(\frac{W_m}{t_m}\right) - 4.445s \right\}$$

Where: ϕ is the correction factor for water intake for *Bos indicus*. Please note that the outputs from the Hicks *et al.* (1988) calculation for water intake is referred to as *"Option 1"* in the **Water demand** sheet.

The predictions for daily water intake based on Winchester and Morris (1956) for *Bos taurus* (H_{BT}) and *Bos indicus* (H_{BI}) are also included in the **Water demand** sheet as an alternative estimation of daily water requirements and is referred to as *"Option 2"*. The equations used are:

$$H_{BT} = D\left\{3.413 + 0.01595\left(-e^{0.17596\,T_a}\right)\right\}$$

$$H_{BI} = D\left\{3.076 + 0.008461\left(-e^{0.17596\,T_a}\right)\right\}$$

Where T_a is the average daily maximum temperature for the year.

A further check predicts minimum water intake based on Doreau *et al.* (2004) assuming that water intake will be 25.3 ml/kg live weight/day. Intake is doubled if cattle are fed ad libertum. The generic equation for both cattle types is presented as:

$$H = \left(\frac{W_p + W_s}{2}\right)\left(\frac{25.3 * 2}{1000}\right)$$

This check is referred to as *"Option 3"* in the **Water demand** sheet and serves as warning in cases where cattle are fed very restricted intakes and the weather conditions can then start to become a prime determinant of water intake. These minimal metabolic requirements should be considered as the minimal water allowance for beef cattle.

Total water requirements for the feedlot

The total feedlot water requirements each month, W_R (L/mth) are simply the sum of water required per month for both cattle types for dust control and water intake. These amounts can then be fed directly into the **Water** sheet.

Water sheet

The **Water** sheet presents an overview of the water balance for the feedlot for each month of the year.

Water sources

Any water source can be used in the model with the quantity of water available per month for each month of the year W_D (L/mth) being entered directly into the **Water** sheet. However, the main reason for the development of H_2OBeef was to integrate desalinated water and therefore it will be assumed that this source of water refers to that water type. More specifically, the exact amount available will be derived from the larger systems model that will provide an estimation of the desalinated water that has been derived from abstracted water from under a specific rural town.

The water balance, W_B (L/mth) can then be calculated as the difference between the water requirements as calculated in the **Water demand** sheet and the desalinated water available.

$$W_B = W_D - W_R$$

If the water balance is positive the remaining desalinated water is displayed in the **Water** sheet and if it is negative the quantity of water required from another source, e.g. scheme, is also presented.

Please note that as a check regarding the quantity of salt in the water sources, the user is required to input the Moles of NaCl/m^3 in the water into the **Water** sheet. Depending on the quantity a message as outlined in Table 4 will appear.

Table 4. Symptoms occurring in cattle when consuming water with various salt contents

Moles of NaCl/m^3 in water	**Symptoms in the Cattle**
Up to 12.7	no problems
Over 12.7 and up to 38.2	temporary diarrhea in unaccustomed stock, won't restrict long term performance
Over 38.2 and up to 63.7	satisfactory but can cause serious problems in unaccustomed stock
Over 63.7	can cause serious problems in all stock

Cost of water

The price of desalinated water, P_T ($/kL) and of the alternative source P_S ($/kL) are directly placed into the **Water** sheet in H_2OBeef. The cost of desalinated water will be derived from the larger systems model while the cost of the 'other' water should equal the marginal cost of scheme (or other) water. The total cost of desalinated water C_T ($/mth) will therefore be the quantity of desalinated water used in the feedlot multiplied by the price.

$$C_T = P_T W_D$$

Likewise the cost of scheme or 'other' water can be calculated in the same way. The total cost of water is then simply the summation of the water costs for each type.

There is facility in H_2OBeef to also include water transport costs. In the case of desalinated water it is assumed that the feedlot will be some distance away from the desalination plant and hence the cost of transport would be the total amount of desalinated water used multiplied by the cost of transporting each litre of water over each kilometer.

Chapter

Six

Economic Data

This chapter outlines the economic data that is required in the H_2OBeef model.

H_2OBeef provides a long-term view of the economics of beef feedlot management with special consideration of water. Management decisions will impact on the output of the feedlot, and these decisions together with input costs and output prices, will determine whether the feedlot produces long term economic benefits. In the following sections data that is required for the economic analysis in this model is outlined. Details regarding assets, revenue and most costs are contained within the **Econs data** sheet whilst those pertaining to loan repayments are presented in the **Loan repay** sheet and those describing indirect costs and benefits are outlined in the **Indirect B&C** sheet. The parameters in these sheets are either based directly on data obtained from various sources or derived from calculations based on this data, some of which are described in previous chapters of this document.

Costs

Cattle purchases

The total value of cattle purchases (C_C) ($/yr) is a function of number of lots per year, L_n (rounded up to the nearest whole number), cattle inputs per lot, purchase live weight (from **Cattle** sheet) and purchase price in dollars per kilogram live weight *Bos taurus* (P_{pBT}) or *Bos indicus* (P_{pBI}).

$$C_C = L_n(e_{BT}W_{pBT}P_{pBT} + e_{BI}W_{pBI}P_{pBI})$$

The purchase price will change depending on the market and weight and type of cattle bought. Therefore the model allows for the default value of $1.90/kg to be changed.

Feed costs

The feed cost per animal per day (c_F) ($/hd/day) is calculated using feed in the ration, F (kg/hd/day), percentage of each component in the ration, f_n (%) and the price of each component, P_n ($/t) as found in the **Feed Issue** sheet.

$$c_F = \sum_{n=0}^{n} Ff L_n \frac{P_n}{1000}$$

Total cost of feed used in the feedlot each year, C_F ($/yr) can then be found by including the time that the cattle are in the feedlot throughout the year and the number in the feedlot at any one time.

$$C_F = c_F t_y (e_{BT} + e_{BI})$$

Water costs

Annual water costs are taken directly from the **Water** sheet.

Health and veterinary costs

Average health and veterinary costs are calculated on a per head basis for the time the animal is in the feedlot (c_{HV}). As a small percentage will die a natural death some animals will not incur the full cost. However, to ensure these costs are not underestimated, total health and veterinary costs per year (C_{HV}) are based on the number of cattle entering the feedlot in each lot and the number of lots per year (rounded up to the nearest whole number).

$$C_{HV} = c_{HV} L_n (e_{BT} + e_{BI})$$

Cattle transport costs

It is assumed that the enterprise pays for transporting the cattle to the feedlot and also to the place of sale. As a default, average input, c_{TI} and output, c_{TO} transport costs ($/hd) are estimated based on the distance from the Mount Barker sale yards to Wagin. While this value is used as a default in the model, it is possible to use alternative values to represent transport costs. The total cost of transport per year for cattle entering the feedlot (C_{TI}) is found by multiplying the average input cost by number of cattle entering the feedlot in each lot and the number of lots per year (rounded up to the nearest whole number).

$$C_{TI} = c_{TI} L_n (e_{BT} + e_{BI})$$

Likewise the total transport costs per year for cattle leaving the feedlot (C_{TO}) are based on the number of cattle exiting the feedlot in each lot and the number of lots per year (rounded down to the nearest whole number).

$$C_{TO} = c_{TO} L_n (x_{BT} + x_{BI})$$

Waste management costs

Annual waste management costs are taken directly from the **Waste management** sheet.

Labour costs

Whilst it is recognized that the feedlot will require a minimum amount of 'fixed' labour no matter the number of cattle, it is assumed that the feedlot would be running to capacity and would require labour every day of the year. It is also assumed that during the 'time in between lots' labour costs will remain the same as there will be some requirement for cleaning etc. as well as provision made for employees to take leave. Hence for simplicity, the labour required per day is estimated on a per hundred head of cattle basis (L_{day}). Basing labour on the input number of cattle, maximum total labour required per year (L_{yr}) is therefore:

$$L_{yr} = L_{day}(e_{BT} + e_{BI})/100$$

The total annual labour cost (C_L) will then be a function of labour required per year and the average annual wage (ϖ) (includes all on-costs etc and recognizes that employees will be scheduled to work some weekends)

$$C_L = L_{yr}\varpi$$

Cost of fuel

The default fuel is assumed to be diesel with the total cost per year, C_D ($) being based on the price of diesel, P_D ($/L) and the average quantity used per day, Q_D (L/d). Other fuel costs such as for oil and grease are assumed to be negligible so are not included as individual costs.

$$C_D = 365(P_D Q_D)$$

Other costs

The cost of machinery expenses, C_M ($/yr), repairs and maintenance, C_R ($/yr), electricity and phone, C_E ($/yr), rates and insurance, C_I ($/yr), and contingencies, C_G ($/yr), are all directly inputted into the **Econs data** sheet.

Indirect costs

Costs arising out of a cattle feedlot that impose upon an external party can be referred to as indirect costs. Such costs may include pollution arising from odour and/or from nurtient flow into the ground water. The simplest way to recognize these costs would be to relocate the feedlot site far enough from the town for these costs to be negligible. To enable this relocation to occur, water would then have to be transported to the site from the town. Hence the costs associated with water transport could be considered to represent the upper-bounds of these indirect costs. Care must be taken so as not to double count water transport costs if these same costs are included in the **Water** sheet as direct costs.

Sensitivity analysis can be completed to determine the impact of such costs on the project. This indirect cost, Cp ($/yr) could then be calculated by multiplying the amount of desalinated water required by the feedlot by the distance the feedlot is from town, D_T (km) and the cost of transporting the water to the feedlot C_B ($/km).

$$C_p = W_D D_T C_B$$

Total variable costs

The total variable input cost (C_V) ($/yr) is found by summing all of the variable costs as described above.

$$C_V = C_C + C_F + C_W + C_{HV} + C_{TI} + C_{TO} + C_L + C_D + C_P + C_M + C_R + C_E + C_I + C_G$$

Assets

Total assets

In dollar terms, total fixed assets, A_T ($) are assumed to include the value of: cattle held in the feedlot at any one time, V_C ($); land as described below, C_A ($); feedlot sheds and infrastructure, V_{SI} ($); feed silos V_{FS} ($); waste storage V_{WS} ($), and other assets as specified V_{OS} ($); where:

$$V_C = (e_{BT} W_{BT} P_{pBT}) + (e_{BI} W_{BI} P_{pBI})$$

$$A_T = V_C + C_A + V_{SI} + V_{FS} + V_{WS} + V_{OS}$$

The value of the feedlot sheds and associated infrastructure will depend on the number of cattle that are kept in each lot. However, because there are other factors associated with quality of building materials used and other like costs, for simplicity, the default value of $1,000,000 is used in this model. Likewise the value of feed silos is set at $150,000, waste facilities at $100,000 and other assets at $0. Nevertheless, the option to alter any of these values is available. It is assumed that the feedlot is custom built depending on the expected number of cattle that will be held within the feedlot.

Cost of land

The total cost of land for the feedlot, C_A ($) will be a function of land area required (from the **Cattle** sheet) multiplied by the price of land per hectare (it assumed that this price includes any costs required to make the land 'building ready') (P_A).

$$C_A = AP_A$$

Land prices vary depending on location. However, in the model it is assumed that the feedlot will be located just outside the Wagin townsite in an area not favoured for residential development and hence will have a lower value of around $5,000/ha.

Net assets

Net assets are simply total assets minus liabilities. In H_2OBeef there is the option to enter the percentage of total assets (not including the value of cattle) that are on loan. The total amount on loan is taken from the **Loan repay** sheet (described in Chapter 7) and this amount represents total liabilities. Initial equity is the ratio of net assets over total assets and provides an indication of the viability of the enterprise. According to Kerrigan and Kelliher, (1992) the greater the equity, the greater the proportion of the business owned by decision maker and hence the greater the capacity he or she has in decision making. They recommend that a reasonable amount of equity in a business should be around 70 percent.

Revenue

Cattle sales

The total value of cattle sales, R_C ($/yr) is a function of the number of lots per year, cattle outputs, sale live weight (from the **Cattle** sheet) and sale price in dollars per kilogram live weight *Bos taurus* (P_{sBT}) or *Bos indicus* (P_{sBI}).

$$R_C = L_n(x_{BT}W_{sBT}P_{sBT} + x_{BI}W_{sBI}P_{sBI})$$

The sale price will change depending on the supply, demand, weight and type of cattle sold. Therefore the model allows for the default value of $2.50/kg to be changed as necessary.

Feedlot waste sales

Revenue derived from annual waste management, R_W ($/yr), is taken directly from the **Waste management** sheet.

Other revenue

There is facility in H_2OBeef to directly enter into the **Econs data** sheet, an amount for other revenue that is directly related to the feedlot and has not already been included in the above categories, R_O (\$/yr).

Indirect revenue

Flow-on effects from the beef feedlot to local communities are used as a proxy for indirect benefits. To calculate these flow-on effects input-output multipliers are used. It is assumed that for the feedlot business, for every \$1 spent on wages, X_W (\$), will be spent locally. Also for the wage earner, for every \$1 earned, X_E (\$), will be spent in local businesses.

A direct increase in employment (full-time equivalents) in the town as a result of the feedlot is equivalent to total labour required per year in the feedlot (L_y) as noted above. The salary level (\$/yr) is equivalent to the total annual labour cost (C_L) also as noted above. It is also assumed that there will not be any expansion over time. Annual indirect benefits, R_I (\$/yr) can then be calculated as:

$$R_I = (X_W + X_E) L_y C_L$$

Total revenue

Total revenue, R (\$) is the returns before production costs have been deducted for all enterprises associated with the feedlot and are calculated by summing revenue as outlined above.

$$R = R_C + R_W + R_O + R_I$$

Chapter Seven

Economic Analysis

The economic analysis that is central to H_2OBeef is presented in this chapter.

As explained in numerous texts such as in Robison and Barry (1996), long-term investments are analysed by adding all costs and benefits for each year of the project (as present day values) and using a discounting approach so as to calculate the net present value. In its simplest form this method does not include differing inflationary effects associated with inputs and/or outputs, revenue earned from interest on profit or tax implications. The components of the cost benefit analysis as presented in H_2OBeef are described in the following sections. In addition a description of how sensitivity analysis can be conducted is presented at the end of the chapter.

Costs

The current costs as identified in the **Econs data** sheet (described in the preceding chapter) are used as default total annual costs for each of the 20 years, C_n (\$/yr). However there is an option to independently increase or decrease each of these costs over the time period. This option may be selected to account for changes in risk and hence changes in expected costs, or for costs such as machinery replacement. The loan principle and interest costs are calculated separately in the **Loan repay** sheet as described below.

Repayment costs on loan

In the **Loan repay** sheet the interest rate, length of the loan, total number of repayments per year, principle left at the end of the loan, and time when the payments are due are all entered by the user. The total loan on fixed assets is selected in the **Econs data** sheet and as a consequence the principle and interest at the end of each year for the time of the loan can be calculated. This calculation is based on a constant payment at the end of each payment period. As outlined in Malcolm *et al.* (2005), the payment, P_m (\$/yr) is calculated using a constant interest rate, r (%), the value of the fixed costs on loan, L_f (\$), and a time period stretching over the life of the project, t (yr).

$$P_m = \frac{L_f \left[r(1+r)^t \right]}{(1+r)^t - 1}$$

It must be noted that the repayments are due each month in H_2OBeef and hence this yearly repayment is divided evenly over a 12 month period.

There is also the option to take out a short-term loan. As a default in H_2OBeef, it is assumed that finance for significant purchases over the first four months of the year is sought with the full amount repaid at the end of this period. However, these default values can be easily changed in the model to reflect an actual situation.

Benefits

As for costs, the time period for which benefits are considered in H_2OBeef is 20 years. Current revenue from cattle sales, fertiliser revenue, other revenue directly related to the feedlot and indirect benefits as detailed in the **Econs data** sheet (as described in Chapter 7) are transferred into the **Benefits** sheet for each year R_n (\$/yr). However, there is facility in this sheet for total revenue in any one of the 20 years to be altered if required. This alteration may be required to reflect a change in benefits due to e.g. price risk and other such changes in benefits that may occur in a particular year.

Net benefits

Simple net benefits

To calculate the net benefits, B_n (\$/yr) for any one year, the total costs are subtracted from the total returns for that year.

$$B_n = R_n - C_n$$

However, this calculation does not include inflation, interest or tax. Inclusion of these parameters is discussed in the section below.

Inflation, interest and tax

In H_2OBeef it is assumed that production doesn't increase over time and the inflation rate for costs and revenue is constant and therefore is not included in the model. However if production and/or inflationary effects are important in certain years then these can be indirectly added into the model by increasing the percentage costs and/or benefits in any one year.

Furthermore, if a profit is made in any one year within the feedlot then this profit could be invested and hence would generate additional revenue. As a simple proxy for this additional revenue there is the option in H_2OBeef to enter the interest rate that would be associated with this investment and hence the resulting revenue can be calculated.

Pannell (2004) suggests including taxation implications in cost benefit analyses that pertain to private investment. If H_2OBeef is considered only in such terms then the effects of taxation should be considered in the decision making. Hence the user indicates that this is the case by entering the marginal tax rate into the model where it is assumed that tax is simply calculated on the previous year's earnings. Alternatively if H_2OBeef is part of a government program aimed at reducing saline ground water in rural towns then it would not necessary be appropriate to include tax as a cost.

Net present value

To calculate the net present value, *NPV* ($) for the period of the project the total costs are subtracted from the total returns for each year, summed and discounted. While the discount rate can be selected by the user, it is suggested that the discount rate should be equivalent to the real bank interest rate.

$$NPV = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t}$$

The preferred strategy has the highest *NPV*. The internal rate of return, *IRR* is calculated as the discount rate when the *NPV* is set equal to zero. A strategy would be preferred if the *IRR* is greater than the discount rate. The benefit cost ratio is simply the net benefits divided by the net costs and if greater than zero it indicates that benefits derived from the project are greater than the costs.

Sensitivity analysis

In bioeconomic models, parameter values and assumptions presented in a base case analysis may not be perfect and hence sensitivity analysis can be done to investigate how changing these values and/or assumptions can impact on outcomes derived from model results. Pannell (1997) presents a detailed account of how sensitivity analyses can be effectively carried out. The following account is loosely based on his paper and provides a brief overview of a plan that could be followed for conducting sensitivity analyses for H_2OBeef.

It is not feasible to vary the values of every parameter in a model and therefore only the parameters that are most likely to impact on the results should be selected as part of a sensitivity analysis. Having selected a parameter, it is best to identify a realistic range of values with a maximum and minimum value. Entering these values one at a time in place of the base case value generates a new set of results. If these results are not particularly different from those of the base case then it can be assumed that the model outcome is not very responsive to that parameter. However, if the outcome does change significantly with a change in value of a parameter then the model is responsive to this parameter. The first step then is to review the base case model and make sure that the initial values were reasonable. This being the case, the results need to be documented in a sensible manner so that it is very clear what they mean. This may involve the use of graphs or tables with a logical explanation as to how they affect the outcome of the base case model. This procedure can be done for every parameter selected as part of the sensitivity analysis. However, care is required to make sure that none of the parameters are correlated. If they are then the values of the parameters should be altered together. While this procedure could involve a great number of combinations to run through an analysis, common sense should prevail in selecting only the values that are likely to impact upon the outcome so that a feasible number of model runs can be completed.

An alternative to selecting various values for parameters and then determining the effect on the outcome is to work backwards. This involves altering the value of the parameter until a breakeven point is reached. So in the case of H_2OBeef, the price of water might be increased until the feedlot returns a zero NPV. Often results of such an analysis provide an interesting story.

The results of a sensitivity analysis should provide justification for arguing how confident the researcher is about the outcomes generated from the base case scenario. Even if the probability of an event occurring is not known, a subjective assessment on how likely a parameter is likely to change can be presented. This information can then be passed on to decision makers who need to be able to assess a project before they can decide on progressing with it. Part of this process also requires that they are very much aware of the parameters that may change the outcome so that they can take appropriate steps to account for these changes should they occur.

Chapter

Eight

Capacity of H_2OBeef

This Chapter explains the capacity of H_2OBeef and gives contact details if you need further information about the model.

H_2OBeef was developed to enable water usage and subsequent costs in beef feedlots to be included in decision making associated with such an enterprise. While the model is comprehensive there are limitations that need to be acknowledged by users of the model and those interpreting the results derived from the model.

H_2OBeef will not automatically calculate which strategy is 'best'. Users evaluate strategies using experimentation and 'trial and error'. That is a number of model runs with varying parameter values are required to work out desired strategies. Furthermore, H_2OBeef does not represent year-to-year variation in climate, beef output or prices. However, general changes can be manually placed in the model to reflect these variations.

Even though great care has been taken in data collection and model development so as to create a robust model, there may be times when constant figures in equations need to be altered. Justification for making these changes should always be carefully documented so that the results can be interpreted correctly. Also, as many of the default values included in this version of H_2OBeef are representative of a typical town in a region of Western Australia, these values will need adjusting for other towns and for other regions so that the model output is relevant for a particular situation.

As with most computer-based models, time and funding constraints have restricted further model development and refinement of H_2OBeef. Nevertheless, the authors welcome constructive feedback regarding this model.

Contact details for information regarding H_2OBeef

For information about H_2OBeef or to suggest improvements or changes contact Jo Pluske or Tony Schlink.

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Appendix 1: Key to Variables used in Equations

Variable	Data Name	Units
α	% dry matter content for each dietary component	%
β	Parameter	
b	Percentage of Bos taurus in the feedlot	%
ε	Gross energy in each dietary component	
ξ_n	Fermentable metabolizable energy of components in each feed ration	
ρ_n	Protein content of components in each feed ration	gCP/kg
ϕ	Correction factor for water intake for *Bos indicus*	constant
τ	Percentage Bos taurus in feedlot	%
λ	Level of feeding as a multiplier of MJ of ME for maintenance	
ι	Percentage Bos indicus in feedlot	%
ς	Total number of cattle in the feed lot at any one time	hd
A	Land area required for the feedlot	ha
A_{BT}	Land area required per head Bos taurus	m^2
A_{BI}	Land area required per head Bos indicus	m^2
A_M	Miscellaneous area required for feedlot	ha
A	Energy costs of activity	MJ/hd/day
B	Number of lots per year	lots/yr
B_n	Net benefits	$/yr
C_A	Total cost of land for the feedlot	$
C_B	Cost of transporting the water to the feedlot	$/km
C_C	Total value of cattle purchases	$/yr
C_D	Total cost of fuel per year	$/yr
C_E	Electricity and phone	$/yr
C_F	Total feed costs	$/yr
c_F	Feed cost per animal per day	$/hd/day
C_G	Cost of contingencies	$/yr
C_{HV}	Total health and veterinary costs per year	$/yr
c_{HV}	Average health & veterinary costs whilst the animal is in the feedlot	$/hd
C_I	Cost if insurance per year	$/yr
C_L	Total annual labour cost (equivalent to salary level)	$/yr
C_M	Cost of machinery expenses	$/yr
C_N	Annual processing costs for an element, e.g. for nitrogen	$/yr
c_N	Cost of processing for element, e.g. for nitrogen	$/kg

Variable	Data Name	Units
C_n	Total annual costs for each of the 20 years	\$/yr
C_p	Indirect costs	\$/yr
C_R	Costs of repairs and maintenance	\$/yr
C_{TI}	Total cost of input transport per year	\$/yr
c_{TI}	Average input transport costs	\$/hd
C_T	Total cost of desalinated water	\$/mth
C_{TO}	Total cost of output transport per year	\$/yr
c_{TO}	Average output transport costs	\$/hd
C_V	Total variable input costs	\$/ha
D	Dry matter intake	kg/hd/day
D_d	Digestible undegradable protein	gCP/day
d_{day}	Natural deaths/day	No./day
D_e	Effective rumen degradable protein	gCP/kg DM
D_p	Ruman digestible protein	gCP/day
D_q	Quickly degradable protein	g/kg
D_s	Slowly degradable protein	g/kg
D_u	Undegradable protein	gCP/day
D_T	Distance the feedlot is from town	km
d_{yr}	Natural deaths/annum	No./yr
E	Gross energy intake	MJ/hd/day
e_{BI}	No. Bos indicus entering the feedlot at the beginning of each lot	hd
e_{BT}	No. Bos taurus entering the feedlot at the beginning of each lot	hd
E_f	Net energy retained by the growing cattle	
E_g	Net energy stored	
E_m	Net energy for maintenane	MJ/hd/day
e_n	Energy density of each component in feed ration	MJ/kgDM
E_r	Retention of net energy	
E_v	Energy value of tissue gained or lost	MJ/kg
F	Feed ration	kg/hd/day
f_n	% of component in feed ration	%
G_n	% dry matter digestion of component n in feed ration	%
H	Water intake	

Variable	Data Name	Units
H_{BI}	Water intake for Bos indicus	L/day
H_{BT}	Water intake for Bos taurus	L/day
I	Daily precipitation	mm
J	Crude protein in diet	gCP/kg
K	Faecal output (drymatter)	Kg/hd/day
k_f	Efficiency of utilization of ME for weight gain	MJ/hd/day
k_m	Estimation of efficiency of utilization of ME	
L	Live weight	kg
L_{day}	Labour required per day	No./day
L_f	Value of the fixed costs on loan	$
L_n	Number of lots per year	
L_{yr}	Maximum total labour required per year	No./yr
L_y	Total labour required per year in the feedlot	
M	Metabolisable energy in the ration	MJ
M_b	Metabolisable protein required for basal maintenance	gCP/hd/day
M_c	Metabolisable crude protein	gCP/day
M_d	Metabolisable protein required for scurf & hair growth	gCP/hd/day
M_f	Fermentable metabolisable energy of the diet	MJ/day
M_m	Metabolisable energy for maintenance	MJ/day
M_{mp}	Metabolisable energy for maintenance and production	MJ/day
M_p	Metabolisable protein required for maintenance	gCP/hd/day
M_T	Total metabolisable protein	gCP/day
M_t	Digestible microbial true protein	gCP/day
N	Total number of cattle that go through the feedlot during a year	hd/yr
n	A dietary component	
N_a	Acid detergent insoluble nitrogen in diet	gCP/hd/day
N_b	Basal endogenous nitrogen requirements	gCP/day
n_{BI}	Number of lots of Bos indicus cattle	Lots/yr
n_{BT}	Number of lots of Bos taurus cattle	Lots/yr
N_D	Dietary concentration of nitrogen	g/kgDM
N_d	Net protein requirements for scurf & hair growth	gCP/day
N_F	Faecal concentration: nitrogen	g/kgDM
N_f	Faecal nitrogen	proportion
N_m	Net protein requirements for maintenance	gCP/hd/day
NPV	Net present value	$
N_S	Total nitrogen derived from faeces and available for sale	kg

Variable	Data Name	Units
N_T	Total amount of nitrogen produced	kg/day
P_A	Price of land per hectare	$/ha
P_D	Price of fuel (diesel)	$/L
P_{pBI}	Live weight purchase price Bos indicus	$/kg
P_{pBT}	Live weight purchase price Bos taurus	$/kg
P_m	Loan payment	$/yr
P_N	Price that element can be sold for e.g. nitrogen	$/kg
P_n	Price of each component	$/t
P_S	Price of alternative water source	$/kL
P_{sBI}	Live weight sale price Bos indicus	$/kg
P_{sBT}	Live weight sale price Bos taurus	$/kg
P_T	Price of desalinated water	$/kL
Q_D	Average quantity diesel used per day	L/d
q_f	Fasting metabolism	MJ/day
q_m	Metabolisability of gross energy	MJ/day
R	Total revenue	$/yr
r	Long term interest rate	%
R_C	Total value of cattle sales	$/yr
R_I	Indirect benefits	$/yr
R_N	Revenue processed from feedlot waste, e.g. for nitrogen	$/yr
R_n	Revenue each year	$/yr
R_O	Other revenue directly related to the feedlot	$/yr
R_W	Revenue from annual waste management	$/yr
S	Total salt added to diet	g/hd/day
s	Dietary salt added	Na%
T	Daily maximum temperature	°C
t	Life of the project	yr
TA	Total assets	$
T_a	Average daily maximum temperature for the year	°C
T_b	Time in between lots	days
T_c	Time cattle are in each lot	days
t_m	Number of days in a specific month	days
t_y	Days per year that cattle are in the feedlot	days
U_{Na}	Urinary sodium	g/hd/day
U_K	Urinary potassium	g/hd/day
U_O	Urinary volume output	g/hd/day
U_P	Urinary phosphorus output	g/hd/day

Variable	Data Name	Units
V_C	Value of cattle held in the feedlot at any one time	$
V_{FS}	Value of feed silos	$
V_{OS}	Value of other assets	$
V_{SI}	Value of feedlot sheds and infrastructure	$
V_{WS}	Value of waste storage	$
W_A	Feedlot monthly water intake for *Bos taurus*	L/mth
W_B	Water balance	L/mth
W_D	Quantity water available per month for each month of the year	L/mth
W_d	Amount of water required for dust control on a daily basis	Mm
W_{day}	Live weight gain per day	Kg/hd/day
w_{BI}	No. weeks that Bos indicus cattle stay in the feedlot	Weeks
W_{BT}	Water required for dust control in any one month: *Bos taurus*	L/mth
w_{BT}	No. weeks that Bos taurus cattle stay in the feedlot	Weeks
W_{BI}	Water needed in any one month for dust control: *Bos indicus*	L/mth
W_l	Average days each month where the rainfall is less than 3mm	Days
W_m	Average monthly rainfall data	Mm
W_p	Live weight of cattle at purchase	kg/hd
W_R	Total water requirements each month	L/mth
W_s	Live weight of cattle at sale	Kg/hd
x_{BI}	No. Bos indicus exiting the feedlot at the end of each lot	Hd
x_{BT}	No. Bos taurus exiting the feedlot at the end of each lot	Hd
ϖ	Average annual wage	$/yr
X_E	For every $1 earned, amount spent locally: wage earner	$
X_W	For every $1 spent on wages amount spent locally: business	$
Y_r	Yield rumen microbial protein synthesis	gl

Appendix 2: Recommendations for dairy cows (AFRC 1993)

Abbreviation	Units	Decription	Formulae	Page No.
GE:	MJ/day	Gross energy in the feeds *DMI	18.8MJ/kgDM	p. 02
ME:	MJ/day	Metabolisable energy of feeds *DMI	[ME]* DMI	-
qm:	decimal	The metabolisability of [GE] at maintenance	[ME]/[GE]	p. 02
F:	MJ/day	Fasting metabolism		p. 23
C1:	decimal	1.15 for bulls and 1.0 for other cattle	1.0 for all cattle, 1.5 bulls	p. 23
A:	MJ/day	Activity allowance	0.0095W	p. 24
Em:	MJ/day	Net energy for maintenance	F+A	p. 23-24
Km:	decimal	Efficiency of utilising ME for maintenance	0.35qm+0.503	p. 03
Kc:	decimal	Efficiency of utilising ME for growth of concepta	0.133	p. 04
Mg (gain)/kg:	MJ/kg	ME needed/kg of LW gain	19/Kg	p. 31
L:	decimal	Level of feeding as a multiple of ME for maintenance, Mmp/Mm	Mmp(unadjusted)/MEm	p. 54
Maintenance (Mm):	MJ/day	ME requirement for maintenance	(F+A)/Km	p. 23
Mmp (unadjusted):	MJ/day	ME for maint & prod.- no correction for feed level	Mm+Ml+Mc+Mg	p. 09
CL:	decimal	Feed level correction	1+0.018(L-1)	p. 04
Total ME required:	MJ/day	ME requirement for maintenance and production	Mmp=CL*(Mm+Ml+Mg+Mc)	p. 09
ME supplied by the diet:	MJ/day	ME available from the diet	DMI * ME pasture	-
ME supply - ME required:	MJ/day	If +ive = excess ME in diet, if -ive = diet is energy deficient	ME from diet - Total ME required	-
NPb:	g/day	Net protein equivalent of basal endogenous N	6.25 * 0.35*W0.75	-
NPd:	g/day	Net protein for scurf and hair growth	6.25*0.018*W0.75	-
NPm:	g/day	Net protein requirements for maintenance	NPb + NPd	p. 33
Knm:	decimal	Efficiency of MP utilisation for maintenance	1	p. 33
MPb:	g/day	MP requirement for basal maintenance	2.1875W0.75 or NPb/Knm	p. 34
MPd:	g/day	MP requirement for scurf and hair growth	0.1125W0.75 or NPd/Knm	p. 19
MPm:	g/day	MP requirement for maintenance	MPb+MPd or 2.30W0.75	p. 35
Total MP required:	g/day	Total MP required for maintenance and production	MPR = MPm+MPl+MPg+MPc	p. 35
CPI:	g CP/day	Crude protein intake	DMI*CP in pasture	p. 34
RDP:	g/day	Rumen degradable protein or QDP + SDP	CP intake * p	p. 33
ERDP:	g/day	Effective rumen degradable protein	CP intake * ERDP	-
UDP:	g/day	Undegradable protein	CPI-p (in g/day)	-
DUP:	g/day	Digestible undegraded protein	(0.9*[UDP-(ADIN)*6.25])*DMI	-
y:	gMCP/MJ FME	Rumen microbial protein yield	7.0+6.0(1-exp-0.35L)	p. 13
FME:	MJ/day	Fermentable metabolisable energy per day	FME per kgDM * DMI	p. 14
MCPenergy = y*FME:	g MCP/day	MCP per day (limited by energy in diet)	FME * y	p. 14
ERDP/FME:	g /MJ of FME	If > y than FME is limiting, if <y than ERDP limiting	ERDP/FME	p. 16
ERDP/FME is >/< than y:		Energy supply is limiting microbial activity so MCP=MCPenergy	See explanation	-
MCP:	g/day	(If ERDP>y*FME)=(MCP=y*FME),(if ERDP<y*FME)=(MCP=ERDP)	See explanation	p. 17
DMTP:	g/day	Digestible microbial true protein	0.75*0.85*MCP	p. 17
Total MP supplied:	g/day	Metabolisable protein (protein supply to the animal from MCP+UDP)	0.6375 MCP + DUP	p. 17
MP supply - MP required:	g/day	If +ive = excess CP in diet, if -ive = diet is protein deficient	Total MP supply - total MP required	p. 17