final report

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Upgrading the analytical capabilities of the National Beef Recording Scheme

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Acknowledgements

Upgrading the Analytical Capabilities of the National Beef Recording Scheme was an area of work AGBU was involved in long before this current project started. Work on BREEDPLAN started in 1983 and was funded by MRC with various projects over the years. To guarantee a s more stable research team, a long-term commitment to funding was sought by the then Director of AGBU Dr Keith Hammond and granted by MRC in 1991. Over the years the following AGBU staff worked for UNE.35:

Dr Stephen Barwick	Ms Elaine Farrell
Dr Mike Goddard	Dr Keith Hammond
Mr Tony Henzell	Dr David Johnston
Dr Karin Meyer	Dr Tony Reverter
Ms Dorothy Robinson.	Mr Bruce Tier

Dr Richard Kerr and Dr Helen Klieve worked for the PhD degree within this project. Numerous visiting scientists also contributed to the project

A consultative group guided the project, its Non-AGBU members were

Dr Ian Johnston MRC (Chairman) later replaced by Dr Len Stephens

Mr Jack Allen	ABRI
Mr John Croaker	Breed Society
Mr Martin Dumaresq	Producer
Mr Jim Litchfield	Producer
Mr Eric McKeague	Producer
Mr Bob Freer	Industry Consultant
Mr Don Nicol	Industry Consultant
Dr Gerard Davis	Scientist
Dr Scott Newman	Scientist

The contribution of all towards a successful completion of the project is acknowledged.

A special thanks goes to all BREEDPLAN participants, who over the years contributed through constructive criticism to the further enhancement of the Australian beef cattle genetic evaluation system. Staff at ABRI provided AGBU through all the years with countless extracts of the National Beef Recording Scheme's database for different breeds

October 1997

Hans Graser
Technical Director
AGBU

Upgrading the Analytical Capabilities of the National Beef Recording Scheme

Project Number: UNE.035

Abstract

Genetic evaluation is an important component of any livestock improvement program. Under the guidance of an Industry Consultative Group this project funded AGBU to continue the development of BREEDPLAN, the genetic evaluation system for Australian beef cattle. This was achieved by including new traits e.g. fertility and live carcase records, and by improving statistical models, e.g. threshold model for calving ease. Simultaneously genetic parameters and adjustment factors for new traits and smaller breeds were calculated and were made available to the NBRS processing center. The work on BREEDOBJECT and its extension assisted the definition of solid beef breeding objectives. The project resulted in an increase in the accuracy of estimated breeding values and an increase in performance recording at a national and international level. This will increase rate of genetic gain first in seedstock herds and later in the national herd. In 1997 13 breeds published GROUP-BREEDPLAN results. This six-year project kept Australia's beef cattle genetic evaluation system at the international forefront.

Executive Summary

Yearly work plans were developed in consultation with a Consultative Group setting research and development priorities for **BREEDPLAN, BREEDOBJECT** and **BREEDING STRUCTURE**. The Consultative Group responded to industry requirements, new research opportunities and changing staff availability at AGBU. The principal investigators in the project think of the cooperation with the Consultative Group during the time of the project as being successful and fruitful.

The Consultative Group and a Breed Society Technical Officers Liaison group convened by Brian Sundstrom on behalf of Performance Breeders Association developed an ownership of the research program of this project. This is seen as very important for the dissemination and early implementation of the research findings.

The main objectives of the project were achieved!

The Australian Genetic Evaluation system BREEDPLAN was upgraded to provide cattle breeders with better means to select bulls and cows which produce more profitable progeny. In more detail these outcomes of the project were:

Implementation of three major updates to BREEDPLAN in 1993, 1994 and 1995. The groundwork for Version 4.0 was also laid. This version will be delivered late 1997.

Upgrades expanded the number of traits available for analysis including fertility (Days to Calving and Scrotal Size) and live carcase information (Ultrasound scan records on Back-fat, Eye Muscle Area and prediction of Lean Meat Yield)

Research on Days to Calving (h^2 = 0.1) showed how useful this easy and economical to record information is for the genetic improvement of fertility. Days to Calving is highly correlated to calving rate (r_g > 0.8) and Days to Calving for first calf is highly genetically correlated (r_g >0.9) with later records.

Better understanding of the biology of growth resulted in better statistical models and more accurate EBVs

- New genetic parameters and adjustment factors were estimated for growth (12 breeds), scan data (6 breeds) and fertility (3 breeds). Prior to this only three sets of parameters were used across all breeds (British, European, Indicus).

- Dam age adjustment was modified to include a special heifer component. This better described the effect of dam age on their calves growth rate, leading to more accurate comparisons of calves from heifers and older cows.

- Research found that a cow's maternal effect on the 200-day weight of her calves lasted until the calf was 400-days old. Therefore the 400-day weight provides additional information from which to estimate the milk EBV of the cow.

- The apparent negative genetic correlation between an animal's direct and maternal genetic merit for growth is to a large extend an artifact caused by unrecorded management differences between the progeny of different sires. The inclusion of a sire * herd interaction in the statistical model will reduce the impact of this on EBVs.

A new calving ease analysis was introduced combining Calving Ease score, Birth Weight and Gestation Length, all potentially recorded on different animals, in one multi-trait animal model. Calving Ease is treated as a threshold trait in this analysis. So far four breeds are now regularly using this model.

The calculation of accuracy of EBVs was reprogrammed with a new algorithm. This new program requires only about 5% of the computer time of the previous approach with only a slight reduction in precision.

The evaluation programs were modified to accommodate data from progeny of multiple sires mating groups. Sires in the group have to be identified and an average relationship between progeny and all sires in the group is used.

As part of the estimation of variance components the Estimation Software DFREML was further enhanced during this project to expand the range of models that can be used for the estimation of variance components.

The research and development project contributed to considerable increase in performance recording in Australia's beef seedstock industry. ABRI supplied the following figures: Between 1991 and 1996 the number of beef breeds societies in Australia which provide a GROUP BREEDPLAN analysis increased from 8 to 12. More are preparing for group analysis in 1998. Across all breeds the yearly recorded Birth Weight records increased from 58,000 to 85,500. For 400-day weight the increase was similar. Ultrasound recording of Back-fat and Eye Muscle Area increased 15 fold from about 3,000 to 46,000. However these figures might be distorted due to the inclusion of New Zealand data.

The development and application of the computer package BREEDOBJECT, which combines information from all traits to identify the bulls and cows which best suite an individual breeder's objectives, was progressed through:

Establishment of a working party to develop a commercialisation strategy. The group recommended the development of three "systems" of BREEDOBJECT, a full version for consultants, a junior version, which only calculates selection indices for individual cattle using index weights previously calculated for the herd, and a central ABRI calculation of indices.

Organisation of three workshops to train more than 30 interested consultants and beef extension staff in the concept of breeding objective and selection index.

BREEDOBJECT was enhanced by including calving ease in a nonlinear way and marbling.

The software was restructured to accommodate the separate analysis of different industry segments.

Sensitivity analysis was undertaken to identify the variables that have the greatest effect on economic values.

Use of BREEDOBJECT increased slowly during the project. However the first breeding and selection programs based on clearly defined beef selection indexes have been established and there are now breeders who will not buy genetic material without having animals ranked on a BREDDOBJECT index first.

The third aim was to design breeding programs, which maximise the economic benefits to the beef industry from genetic improvement. The consultative group saw this area of BREEDING STRUCTURE as being of lower priority than BREEDPLAN and BREEDOBJECT. Work was therefore restricted to an analysis of the economic value of recording additional traits, the potential benefits from using DNA fingerprinting to progeny test bulls in multiple sire joining programs and mate selection procedures to minimise inbreeding.

A cost benefit analysis of various performance recording options found that recording fertility traits and ultrasound scanning for carcase traits would increase the profit to industry from genetic improvement.

Communicating the results to the industry and servicing their needs for expert assistance on genetics was an important part of the project.

During the duration of the project team members prepared 37 refereed journal articles and 33 published conference contributions. 2 PhD theses by AGBU students were completed co-supervised by UNE.35 staff and directly relevant to AGBU's beef research. Further 4 UNE Honours theses projects related to beef-research were written with guidance by UNE.35 staff.

The project, which was planned for five years, was extended by one year and was still 6% under the original budget.

Main Research Report

Background

Ongoing research and development into genetic evaluation is required to include new traits of economic importance, update the analytical software and statistical procedures used and to advice industry on optimal breeding schemes.

The Animal Genetics and Breeding Unit (AGBU), a joint University of New England (UNE)/NSW Agriculture research unit, has been previously funded under project UNE.015 in a series of rolling 3-year grants to develop the Analytical Software for the National Beef Recording Scheme (NBRS). This five-year contract supported further development of the genetic evaluation software and expansion into breeding objectives and breeding structure analysis. Priorities between the various tasks described in the application and others that arose during the course of the Project were determined by a Corporation-funded Project UNE.035 Consultative Group.

Project Objectives (as stated in the research contract)

(i) In consultation with the Consultative Group, to provide annual primary upgrades to the (GROUP) BREEDPLAN Analytical Software, which will include additional traits and other enhancements and will also improve the computing efficiency of BREEDPLAN analyses, to the (GROUP) BREEDPLAN licensee, ABRI, over the 5 year period to June 1996.

(ii) By June 1996, to design and implement a first generation sub-system called BREEDING STRUCTURE for custom use in optimising the overall design of each breeding program associated with BREEDPLAN, if approved by the Consultative Group.

(iii) By September 1991, to determine, in consultation with the Consultative Group, the release strategy for the first generation B-OBJECT sub-system and by June 1996, to provide any upgrades to the first generation B-OBJECT sub-system subsequently approved by the Consultative Group.

(iv) To provide both ABRI and the industry in general with basic technical support to assist with the implementation of the above upgrades, over the 5-year period to June 1996.

Methodology

An Industry Consultative Group (ICG) was formed at the beginning of the project with members representing breeders, scientists and industry consultants as well as ABRI, the processing center of NBRS. The consultative group met twice a year for 1.5 days in Armidale to discuss results and progress on agreed work programs and to define priorities for the following year's work. Proposals for work areas that should be included into the yearly work program come from the contract and were in the majority made by AGBU staff after consultations with breed society technical officers, own evaluations and request from industry bodies. At the ICG meeting AGBU's proposal was discussed and amended, compared with the projected availability of staff and finally an agreed work program (AWP) was included into the research contract. Delivery of modifications to the analytical software was planned to occur prior to the GROUP-BREEDPLAN runs at the end of each calendar year.

The agreed work was undertaken by a combination of contract AGBU staff, overseas visiting scientists, postgraduate students and on occasions some consultants.

The research and the development concentrated on four main areas

- Prediction of breeding values with improved models and algorithms
- Estimation of population parameters with new statistical procedures and improvements to estimation procedures
- Breeding objectives - Selection Index
- Optimisation of breeding programs

A fifth area of work was communication. This included writing and presentation of scientific papers and extension material, teaching at undergraduate and postgraduate level at UNE, organisation of and participation in technology transfer orientated workshops and consulting to individual breeders, breed societies and other industry bodies. Occasionally such work was paid for separately and AGBU contract staff time was reduced against this project and instead paid for with income from the advisory work.

Results and Discussion

BREEDPLAN

Due to savings in areas of travel and research support as well as delayed appointment of staff and some income from contract work the five-year plan was extended for one year without an additional funding request to the Meat Research Corporation.

The work resulted in BREEDPLAN updates in 1993 (V3.1), 1994 (V3.2), 1995 (V3.3) and Dec 1997 (V4.0). These updates expanded the number of potential traits (fertility and carcase), considerably changed the analysis for the maternal growth component and included modified systems of genetic grouping, multiple sire mating analysis and many new adjustment factors and estimated genetic parameters. Calving Ease analysis was improved by combining all main traits which are phenotypically and genetically correlated, calving ease score, birth weight and gestation length, in one multitrait threshold animal model analysis. More details of those updates are described in the milestone reports that are included in the appendix. The most comprehensive update is Version 4.0, which includes modification to FORTRAN90 code and many new features described in the milestones. Each of the updates included testing by AGBU. However with every release problems with the software were identified at the NBRS processing center. These problems caused confusion and in some instances required additional GROUP-BREEDPLAN runs under very tight deadlines. To avoid similar problems with version 4.0 extensive additional testing resulted in a delay of the release.

Genetic parameters for BREEDPLAN traits were estimated during the 6-year period 1991-97 for the different breeds and traits. These estimations were generally done using univariate and multivariate Animal Models and Restricted Maximum Likelihood procedures with a program (DFREML) that was continuously developed and maintained by K. Meyer at AGBU. Table 1 includes by breed and trait the estimation work done in UNE35 as well as UNE30, the Breedplan Validation Project. In addition groundwork was laid to include other traits into BREEDPLAN these include hip height, pre-weaning gain and canon bone length. Combined Australian New Zealand GROUP BREEDPLAN analysis were supported by testing for Genotype * Environment interactions.

Table 1 Genetic parameters estimated for current BREEDPLAN traits in 1992 to 1997 (UNE.035 and UNE30)

	Breed										
Trait	A	H	PH	MG	SH	SIM	CH	LIM	BH	BR	SG
GL	X										
BW	X	X	X	X	X	X	X	X	X	X	X
200	X	X	X	X	X	X	X	X	X	X	X
400	X	X	X	X	X	X	X	X	X	X	X
600	X	X	X	X	X	X	X	X	X	X	X
900									X		
MCW	X	X	X								
SS	X	X	X								
DC	X	X	X						X		X
P8	X	X	X	X					X		X
12/13	X	X	X	X					X		X
EMA	X	X	X	X					X		X
CE	X										

For many trait * breed combinations insufficient data is currently in the NBRS database to estimate genetic parameters with any confidence, therefore this has not been attempted.

Considerable efforts were also made to improve the modeling of weaning weight with its significant maternal genetic component. It was shown that lack of recording of management groups as well as preferential treatment of animals would cause a negative estimation for the direct maternal covariance. Sire by herd interaction is responsible for a considerable part of this and will now be included in Version 4.0. New ways of modeling multiple growth records on the same animals were developed using covariance functions. However this innovative approach will not be included in BREEDPLAN till version 5.

BREEDOBJECT

BREEDOBJECT a program which calculates for specified production systems the economic values for all traits in the breeding objective has been continuously developed to increase its flexibility, ease of handling, link to BREEDPLAN and the traits included in the objective (calving ease, marbling). As this is a PC based interactive program considerable resources are required to maintain an error free operation if changes to the objectives are required.

The release of BREEDOBJECT to the industry was a very difficult and long process as the interests between the commercialiser (ABRI) and the scientists at AGBU were not identical. ABRI saw the resulting selection index, a weighted sum of estimated breeding values, as the main achievement and task of BREEDOBJECT. This index was in the early days very closely associated with the 600-day EBVs as no other information was available and therefore of little use. The scientists at AGBU put more emphasis on the first part of BREEDOBJECT, the derivation of economic weights, to learn more about the relative importance of the different components of beef production; reproduction, growth and carcase quality. Regular BREEDOBJECT training workshops have been held by AGBU to familiarise interested people in the Australian beef industry with the concept of breeding objectives and the BREEDOBJECT program itself. These workshops closed with a written test to monitor the success of the workshops.

The interest in realistic and economic breeding objectives is increasing and therefore the industry's interest in BREEDOBJECT. AGBU scientists now regularly advice individual breeders and breed societies on the development of breeding objectives and the effect of changes in production costs or market requirements on the relative value of different traits. A series of workshops coordinated by breed society technical officers and supported by AGBU with MRC funding are planned for 1998.

Breeding structure

The area of design of breeding programs did not receive very high priority. The work in this area concentrated on research into the value of recording of fertility and carcase information from ultrasound for beef cattle breeding programs. This was done using a deterministic approach and a computer program developed overseas. A two-week workshop for postgraduate students from all around Australia and New Zealand was also organised. A PhD study submitted in 1996 entitled "Selection and Mating Strategies - Risks and Rewards" will be the starting point for future work to develop programs to assist in the optimal mating design of individual herds, maximising genetic gain while keeping inbreeding to a minimum.

Communication

Considerable resources were used to communicate the research findings and the developments in BREEDPLAN and BREEDOBJECT to the scientific community (published papers) and to the extension staff of Departments of Agriculture and breed societies (workshops, technical notes and articles) and to seedstock producers at seminars, conferences and field days. The publication list is quite impressive (37 Refereed journal articles and 33 published conference contributions, 2PhDs). There is no doubt that some of the work published in the international scientific literature as been noticed outside Australia and has lead to further work overseas and to the improvement of analytical models world-wide. It is difficult to judge the impact of the communication program of UNE.035 on the seedstock producer in Australia, however the level of performance recording has increased and the quality of data has improved and more breed societies publish sire summaries now than 5 years ago. It becomes more and more difficult to sell seedstock without adequate performance data. Where comparisons can be made, performance recorded bulls achieve higher prices and better clearance than bulls without BREEDPLAN figures.

Success in achieving objectives

With occasional delays the work outlined in the approved work programs was successfully completed. Regular updates of the BREEDPLAN software were delivered to the NBRS processing center. These updates allowed ABRI to increase its services to the beef industry by including new traits and reduce its run time. This has attracted new customers. However increased data and more traits analysed means that the real computer time required for each GROUPBREEDPLAN analysis has not been reduced.

The implementation of new estimated adjustment factors and genetic parameters will have improved the accuracy of the Estimated Breeding Values published from the analysis thus allowing for faster genetic gain.

The adoption of Selection Indices through BREEDOBJECT by the industry has no doubt stayed behind the expectations of the scientists involved in its development. This has numerous reasons, two of which are the difficulties in extending the concept of Selection Indices to the beef industry and a misunderstanding of the values of BREEDOBJECT as an extension tool. A further reason for the delayed use is the link of BREEDOBJECT into the BREEDPLAN licence agreement, which requires scientists outside AGBU and extension staff to pay sublicence fees for the use of BREEDOBJECT as an extension tool.

The area of breeding program design (Breeding Structure module) received little priority by the Consultative Group and by AGBU scientists. In hindsight and with the experience of BREEDOBJECT this was correct, as the industry would have made little use of such a tool. However with a complete set of across breed breeding values and solid breeding objectives firmly in place this might change in the future, and programs like optimal mate allocation to maximise genetic gain might be useful and used by seedstock breeders.

The design of breeding programs with respect to the economic value of performance recording and genetic evaluation of some fertility traits and ultrasound carcase information was investigated in 1993 and 1994. The work showed that increased profits from breeding programs which include systematic recording of days to calving and scrotal size and live backfat and eye muscle area can be achieved, although at a reduced cost benefit ratio as more and more information is collected.

Impact on Meat and Livestock Industry

Performance recording and genetic evaluation has become a main tool for the genetic improvement of Australian beef cattle. All major breed societies are now publishing regularly sire summaries from a GROUP BREEDPLAN analysis. The number of evaluated traits was increased to include fertility and live carcase information and the groundwork has been laid to include the direct carcase data in a genetic evaluation.

All large scale beef cattle research project have recognised the value of BREEFPLAN evaluated stock and it is now common practice to insure that the experimental data is connected to the national data base through the use of BREEDPLAN link sires. The industry will benefit immensely in the future as the standard data from these research programs can be used in national evaluations and the specific "project data" can often form the basis for the evaluation of new important traits. Examples of such projects are the beef CRC, Struan crossbreeding work and the Trangie feed efficiency trials.

The beef industry is today more focused on "balanced" breeding than in the early 90s. The new versions of BREEDPLAN facilitate this approach and in combination with BREEDOBJECT the leading breeds are well placed to achieve steady genetic gains at an increasing rate. It was estimated that the additional evaluation of fertility and live carcase information increases the accuracy of a selection index for young bulls by 50 %. Such an increase consistently used in a breeding and production program will increase the net income of $ 3.80 per cow for each year of selection if the commercial sector buys performance recorded and selected bulls from the seedstock industry. The seedstock industry is required to use the very best animals as parents of the next generation. These 3.80 are on top of the 6.80 per cow and year that are achieved from recording and selecting for weight only. These figures were calculated for a domestic market situation. With the domestic market at 40 % of production or 4 million cows and an uptake of only 25 % this would amount to an estimated net benefit of $ 3.8 million (on top of the $ 6.8 million for weight recording) per year of selection.

This represents only the domestic market. For export markets even higher benefits are expected because due to higher prices and heavier slaughter weights the monetary genetic differences between animals are considerable larger. Such calculations are very sensitive to prices received by beef producers, we have used an economic value of live sale weight of $0.75 per kg for these calculations.

Conclusion and Recommendations

As a result of this project the beef industry now possesses a genetic evaluation system that it can use to select cattle for growth, fertility, calving ease and carcase yield. There is also a method for combining EBVs on all these traits to identify the cattle that will breed the most profitable offspring for particular market - management - environment situations. These tools have been commercialised by licensing to ABRI and are already contributing to the genetic improvement of Australia's beef herd.

The cooperation between the Consultative Group appointed by MRC and the principal investigators to manage and guide this large project for six years was successful and should be maintained for future similar projects.

The project delivered improved procedures for genetic evaluation and development of breeding objectives which will help focus the industry to develop breeding schemes that will better match the advanced systems of the poultry and pig industries. However continuous education and extension is required to achieve the full potential of the systems developed. A new audit that identifies the extend of understanding and use of BREEDPLAN in the industry might help to better target such extension work.

Reproduction is an important component of the breeding objectives of nearly all breeds. Days to calving is a valuable piece of information towards improving the underlying fertility of the herd and is easy to record. All breed societies should be encouraged to modify their recording system so that days to calving can be calculated for all cows mated.

Performance recording and genetic evaluation is a very cost-effective method to increase the productivity of the livestock industries provided the breeding objectives meet market demands. These market demands have to be monitored for changes, and recording systems and selection programs have to be adjusted accordingly. Further research work in Australia and overseas will continue to develop improved recording procedures and statistical methods for the analysis of livestock data. Such work needs to be included in Australia's beef cattle genetic evaluation programs to maintain competitiveness of the industry. The analytical software requires a certain level of constant support to guarantee its integrity. Long term funding for this support has to be found.

For many economically important traits it is difficult to collect data in seedstock herds (carcase information). Attempts are being made to collect such information from research projects (CRC, Struan) to the benefit of breed societies' databases. It is recommended that in future industry funded research projects involving cattle of different genetic background (different sires) should only use performance recorded pedigreed sires to generate the research animals. Data from standard performance records should be made available for inclusion into the relevant NBRS database. This could improve the direct value of research projects to the industry considerably if consistently followed across the whole of Australia.

Bibliography: Publications related to AGBU's beef work 1992-1997

1993

Books

Fewson, D., James, J.W., Nitter, G., Kinghorn, B.P., Barwick, S.A., Graser, H.-U. and J. Savicky 1993, *Design of Livestock Breeding Programs*, AGBU-University of New England, Armidale, pp 220. (13 chapters)

Refereed Publications

Klieve, H.M., Kinghorn, B.P. and Barwick, S.A. 1993, "The value of accuracy in making selection decisions", *Journal of Animal Breeding and Genetics* 110, 1-12.

Meyer, K. 1993, "Estimates of covariance components for growth traits of Australian Charolais Cattle", *Australian Journal of Agricultural Research*, 44, 1501-1508.

Meyer, K. 1993, "Estimating covariance matrices for growth traits of Australian Polled Hereford cattle using field data", *Journal of Animal Production*, 57, 37-45.

Meyer, K., M.J. Carrick and B.J.P. Donnelly 1993, "Genetic parameters for growth traits of Australian beef cattle from a multi-breed selection experiment. *Journal of Animal Science*, 71, 2614-2622.

Robinson, D.L., Hammond, K. and McDonald, C.A. 1993, "Live animal measurement of carcass traits - estimation of genetic parameters for beef cattle", *Journal of Animal Science*, 71, 1128-1135.

Swalve, H.H. 1993, "Estimation of direct and maternal (co)variance components for growth traits in Australian Simmental beef cattle", *Journal of Animal Breeding and Genetics*, 110, 241-252.

Tier, B. and Sölkner, J. 1993, "Analysing gametic variation with an animal model", *Theoretical Applied Genetics*, 85, 868-872.

Reports/Monographs

Barwick, S.A. and H.-U. Graser 1993, "Industry results and strategies for implementation of B-OBJECT", *Report to MRC UNE.035 Consultative Group*, AGBU, March, pp28. #

Graser, H.-U. 1993, "What is the most practical and effective method for genetic evaluation of reproductive performance in a beef cattle breeding program?", *Prepared for the BIA Genetics, Breeding and Reproduction Technical Advisory Group*, University of New England, August, pp6.

Johnston, D. 1993, "Pelvic measurements of calving ease EBVs", *Report to 'Dystocia Awareness Day'*, Roma Qld, July, pp6.

Johnston, D. 1993, "Technical feasibility of a trans-Tasman genetic evaluation for beef cattle breeds", *Report to MRC UNE.035 Consultative Group*, AGBU, November, pp4.

Johnston, D. 1993, "Review: Weaning weight modelling", *Report to MRC UNE.035 Consultative Group*, AGBU, March, pp11.

Johnston, D. 1993, "High growth does not mean dystocia", *Letter to the Editor - Beef Improvement News*, May, pp3.

Johnston, D. 1993, "Selection for pelvic area in bulls", *Report prepared for the Australian Polled Hereford Society's Technical Report*, pp3.

Nicol, D.C. and Barwick, S.A. 1993, "Future breeding directions - Balancing the BREEDPLAN EBVs", *BREEDPLAN Expo Workshop Notes*, p39-43.

Upton, W. 1993, "How many EBVs do we need?", *Report prepared for Angus Society Forum*, Albury, March, pp4.

Read to Learned Societies

Van Arendonk, J.A.M., B. Tier and B.P. Kinghorn 1993, "Use of multiple genetic markers in predicting breeding values", In *Proceedings of 17th International Congress of Genetics*, Birmingham UK, 15-21 August.

Van Arendonk, J.A.M., B. Tier and B.P. Kinghorn 1993, "Simultaneous estimation of effects of markers and polygenes on a trait showing quantitative genetic variation", In *Proceedings of 17th International Congress of Genetics*, Birmingham UK, 15-21 August.

1994

Books

Barwick, S.A., A.L. Henzell, H.-U. Graser, W.H. Upton, D.J. Johnston and J. Allen 1994. BREED OBJECT Accreditation School Handbook, AGBU-University of New England, Armidale, pp 70 (12 Chapters).

Refereed Publications

Graser, H.-U., Nitter, G. and Barwick, S.A. 1994, "Evaluation of advanced breeding schemes for Australian beef cattle. II Selection on combinations of growth, reproduction and carcase criteria", *Australian Joumal of Agricultural Research,* 45, 1657-1669.

Kerr, R.J., Graser, H.-U., Kinghorn, B.P. and Johnston, D.J.1994, "Implications of using an average relationship matrix in genetic evaluation for a population using multiple-sire matings", *Journal of Animal Breeding and Genetics,* 111,199-208.

Kerr, R.J., Hammond, K. and Kinghorn, B.P.1994, "Effects of multiple-sire matings on genetic evaluations, selection response and rates of inbreeding", *Livestock Production Science*, 38, 161 -168.

Kerr, R.J., Hammond, K. and Kinghorn, B.P.1994, "Efficiency of multiple-sire mating", Livestock Production Science [submitted].

Klieve, H.M., Kinghorn, B.P. and Barwick, S.A.1994, "The joint regulation of genetic gain and inbreeding under mate selection", *Journal of Animal Breeding and Genetics*, 111, 81 -88.

Meyer, K. 1994, "Estimates of direct and maternal correlations among growth traits in Australian beef cattle", *Livestock Production Science*, 38, 91 -105.
Meyer, K. and Graser, H.-U.1994, "Scope for genetic evaluation and selection of beef cattle for growth traits when birth dates are not recorded", *Australian Journal of Agricultural Research*, 45, 819-827.

Meyer, K., M.J. Carrick and B.J.P. Donnelly 1994, "Genetic parameters for milk production of Australian beef cows and weaning weight of their calves", *Journal of Animal Science*, 72, 1155-1165.

Nitter, G., Graser, H.-U. and Barwick, S.A. 1994, "Evaluation of advanced industry breeding strategies for Australian beef cattle. 1 Method of evaluation and analysis for an example population structure", *Australian Journal of Agricultural Research*, 45, 1641 -1656.

Van Arendonk, J.A.M., B. Tier and B.P. Kinghorn 1994, "Use of multiple genetic markers in prediction of breeding values", *Genetics*, 137:319-329.

Published Conference Proceedings

Barwick, S.A., Henzell, A.L. and Graser, H.-U.1994, "Developments in the construction and use of selection indexes for genetic evaluation of beef cattle in Australia", Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, Guelph Canada, August,18, 227-230.

Grignola, F.E., Hoeschele, I. and Meyer, K.1994, "Empirical best linear unbiased prediction to map QTL", Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, 21, 245-248.

Goddard, M.E. and Howarth, J.1994, "Dynamic selection rules and selection of males to progeny test", Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, 18, 306-309.

Tier, B. and Graser, H.-U. 1994, "Developing effective genetic evaluation systems for beef cattle" Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, Guelph Canada, August,17, 280-287.

Meyer, K.1994, "Derivative-intense restricted maximum likelihood estimation of covariance components for animal models", Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, Guelph Canada, August,18, 365-369.

Robinson, D.R.1994, "Models which might explain negative correlations between direct and maternal effects", Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, Guelph Canada, August,18, 378-381.

Newman, S., MacNeil, M., Golden, B. and Barwick, S.A. 1994. "Implementation and use of selection indexes in genetic evaluation schemes for beef cattle", 4th Genetic Prediction Workshop, U.S. Beef Improvement Federation, Kansas City, January, pp.21

Nitter, G., Graser, H.-U. and S.A. Barwick 1994, "Cost-benefit analysis of increased intensity of recording in the Australian National Beef Recording Scheme", Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, Guelph Canada, August,18, 205-208.

Nitter, G. and H.-U. Graser 1994, "ZPLAN - A PC program to optimize livestock selection programs", Proceedings of the 5th World Congress on Genetics Applied to Livestock Production, Guelph Canada, August, 22, 77-78.

Reports/Monographs

Goddard, M.E.1994. "Breeding feeder cattle - Commercial rewards from using superior genetics", Opportunities in Supplying Feedlots Seminar, Cattle and Beef Industry CRC, Armidale, September, p.35-40.

Graser, H.-U.1994. "The value of recording scrotal size and days to calving", Technical Information Note 1/1994. Animal Genetics and Breeding Unit, pp.2.

Graser, H.-U. 1994. "The value of scanning yearling bulls and heifers", Technical Information Note 11/1994, Animal Genetics and Breeding Unit, pp.2.

Johnston, D.J. and Graser, H.-U.1994. "Bending the growth curve", Beef Improvement Association of Australia Technote No. 94/4, November, pp.12.

Johnston, D.J.1994. "BREEDPLAN: More than just growth EBVs", Australian Rural Science Annual, Rural Science Undergraduate Society, p. 71-72.

Tier, B. and Graser, H.-U. 1994. "Genetic evaluation of stud beef cattle in Australia and New Zealand", Beef Performance Recording and Genetic Evaluation, ICAR Seminar, Ottawa, August, pp.8.

Seminar Presentations

Barwick, S.A. 1994. "BREED OBJECT", NSW Agriculture Beef Products Program Planning Workshop, EMAI, April.

Barwick, S.A. 1994. "Breeding objectives for beef breeders:, NSW Agriculture/Beef Improvement Association Seedstock Producer of the Year Competition Judges, Mudgee, November.

Barwick, S.A. 1994. "Making better use of BREEDPLAN", Producing Quality Beef for Feedlotters, Beef Improvement Association Field Day, Mandurama, September.

Goddard, M.E. 1994. "Genetic technology", BeefeX '94 Conference, Surfers Paradise, August.

Goddard, M.E. 1994. "Present and future requirements for genetic improvement of tropical cattle", Australasian Association of Animal Artificial Breeders, Brisbane, September.

Goddard, M.E. 1994. "The use of EBVs in beef cattle selection", Australian Veterinary Association NSW Branch Meeting, Armidale, April.

Theses

Kerr, R. (1994) Implications of multiple sire mating on the efficiency of beef cattle breeding, University of New England-Armidale, pp190. Doctor of Philosophy

1995

Books

AGBU 1995, Beef Cattle Genetics Workshop, 68pp (Eds, Graser, H.-U. and M. E. Goddard)

Barwick, S.A., Henzell, A.L., Graser, H.-U., Upton, W.H., Johnston, D.J., Allen, J., Sundstrom, B. and Goddard, M.E. 1995, *BREEDOBJECT Training and Accreditation School Handbook (Revised Edition)*, AGBU-University of New England, Armidale, 80pp.

Refereed Journals

Hoeschele, I., Tier, B. and H.-U. Graser 1995, "Multiple trait analysis including one categorical, polychotomous trait and several continuous traits with missing data and unequal models", J. Ani. Sci. 73:1609-1627.

Johnston, D.J., J.M. Thompson and K. Hammond 1995 Additive and nonadditive differences in milk production of 2-year-old Devon, Hereford and reciprocal-cross heifers. Live. Prod. Sci. 41:105-110

Meyer, K. 1995. Estimates of genetic parameters and breeding values for New Zealand and Australian Angus cattle. Aust. J. Agric. Res. 46:1219-1229

Meyer, K. 1995. Estimates of genetic parameters for mature weight of Australian beef cows and its relationship to early growth and skeletal measures. Livest. Prod. Sci. 44: 125-137

AGBU Technical Information Notes

Graser, H.-U. and M. Goddard	(1/1995) Understanding Calving Ease EBVs.
Johnston D.	(2/1995) Days to Calving in BREEDPLAN
M. Goddard	(3/1995) BREEDPLAN for the Northern Industry

Reports/Monographs

Henzell, A.L. and S.A. Barwick 1995. *BREEDOBJECT V2.1: Support Documentation for commercialiser*, AGBU-University of New England, Armidale, pp 85.

Johnston, D. 1995, "Genetics of Marbling in Beef Cattle", *The Australian Angus Journal.*

Papers for 11th AAABG conference related to UNE.035 or UNE.030

Barwick, S.A., Henzell, A.L. and Goddard, M.E. 1995, "Beef breeding for cow fertility: When is it important", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11,443-446.

Bunter, K.L. and Johnston, D.J. 1995, "Genetic associations between days to calving records and weight traits in beef cattle", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 341-344

Goddard, M.E. 1995, "Optimal crossbreeding schemes for beef production", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 434-438

Graser, H.-U., Goddard, M.E. and Allen, J. 1995, "Better genetic technology for the beef industry", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 56-64.

Howarth, J.M. and Johnston, D.J. 1995, "Age of dam adjustment factors for weight traits", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 670-673.

Johnston, D.J. 1995, "Fixed effect modelling for days to calving", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 345-349.

Meyer, K. 1995, "Estimates of genetic parameters for cannon bone length in beef cattle", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 242-245.

Meyer, K. and Carrick, M.J. 1995, "Estimates of genetic parameters for mature weight for beef cows in the Wokalup selection experiment", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 246-249.

Meyer, K. and Garrick, D.J. 1995 "Scope for a joint genetic evaluation of New Zealand and Australian Angus cattle", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 250-253.

Miller, S.P., Wilton, J.W. and Griffiths, S.J. 1995, "Utilising multi-breed genetic evaluations in beef cattle breeding", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 254-257.

Nicol, D.C. and S.A. Barwick 1995, "A Young Bull Proving Scheme for Australian Angus" *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 238-241.

Tier, B. and Graser, H.-U. 1995, "A comparison of fixed effects of ease of calving among three breeds of cattle in Australia", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 610-614.

Upton, W.H. and Bunter, K.L. 1995, "Pelvic measurement as an aid to selection in beef cattle", *Proceedings of the 11th Conference of the Australian Association of Animal Breeding and Genetics*, 11, 615-619.

Theses

Chandler, H. (1995) Genetic Modelling of Mature Cow Weight in Beef Cattle in Australia. UNE Thesis Bachalor Rural Science.

1996 and 1997

Books

Bovenhuis, H. and Meuwissen, T. 1996. , *Detection and Mapping of Quantitative Trait Loci* AGBU-University of New England, Armidale, 189pp

Refereed Journals

Grignola, F.E., I. Hoeschele and B. Tier (1996) "Mapping quantitative trait loci in outcross populations via residual maximum likelihood. I. Methodology" *Genetics Selection Evolution 28:479-478*

Hoeschele, I. and Tier, B. 1996, "Estimation of variance components of threshold characters by marginal posterior modes and means via Gibbs sampling", *Genetics Selection Evolution*, [submitted, October].

Johnston, D.J. and Bunter, K.L. 1996, "Days to calving in Angus cattle: Genetic and environmental effects, and covariances with other traits", *Livestock Production Science* Vol 45 No 1: 13-22

Johnston, D.J., Chandler, H. and Graser, H.-U. 1996, "Genetic parameters for cow weight and condition score in Angus, Hereford and Poll Hereford cattle" *Aust J. Ag. Res 47:1251-1260*

Meyer, K. and Smith, S.P. 1996, "Restricted maximum likelihood estimation for animal models using derivatives of the likelihood", *Genetique Selection Evolution* Vol 28 No 1

Robinson, D.L. 1996, "Estimation and interpretation of direct and maternal genetic parameters for the weights of Australian Angus cattle", *Livestock Production Science* Vol 45 No 1: 1-11

Robinson, D.L. 1996, "Models which might explain negative correlations between direct and maternal genetic effects, *Livestock Production Science* Vol 45 No 2/3: 111-122

Wilton, J.W. and Goddard, M.E. 1996, "Selection for Carcass and Feedlot Traits Considering Alternative Slaughter End Points and Optimized Management" , *J. of Anim. Sci.* 74(1): 37-45

Barwick, S.A. and Henzell, A.L., 1997, "Valuing marbling in beef breeding and consequences for breeding objectives" (submitted *Aust .J. Ag. Res.*)

Bradfield, M., Graser, H.-U. and Johnston, D.J., 1997, "Investigation of genotype x production environment interaction for weaning weight in the Santa Gertrudis Breed in Australia" *Aust .J. Ag. Res.* Vol 48 No 1: 1-5.

Hoeschele, I. and Tier, B., 1997, "Estimation of variance components of threshold characters by marginal posterior modes and means via Gibbs sampling", *Gen. Sel. Evol.* [submitted].

Meyer, K. and Hill, W.G., 1997, "Estimation of genetic and phenotypic covariance functions for longitudinal or 'repeated' records by restricted maximum likelihood" *Livestock Production Science* 47:185-200

Meyer, K., 1997, "An 'average information' restricted maximum likelihood algorithm for estimating reduced rank genetic covariance matrices or covariance functions for animal models with equal design matrices" *Gen. Sel. Evol* 29:97-116

Meyer, K., 1997, "Estimates of genetic parameters for weaning weight of beef cattle fitting a regression on maternal phenotype" (submitted *Livestock Production Science*)

Reverter, A., Tier, B., Johnston, D. and Graser, H.-U., 1997, "Assessing the Efficiency of Multiplicative Mixed Model Equations to Account for Heterogeneous within-Herd Variance in Carcase Scan Traits from Beef Cattle *J. of Anim. Sci* 75:1477-1485.

Reverter, A. and Kaiser, C.J., 1997, "Assessing the Role of Different Pedigree Structures on the Sampling Variance of Heritability Estimates" *J. of Anim. Sci.75:*

Presentations to Outside Bodies

Goddard, M.E. 1996 , "The contribution of Brahman to northern Australia", Northern Territory Cattle Producers Association, April

Johnston, D.J. 1996, "The genetics of fertility in Brahmans", The Brahman Society Technical Sub-Committee, ABBA, Rockhampton, 30 January.

Upton, W.H. 1996, "Validation Results, Breedplan, Scanning for Carcase Traits", Hamilton Beef Expo, Hamilton, Vic, January.

Upton, W.H., Bradfield, M. and Dundon, A. 1996, "Validation Results and Scanning for Carcase Traits, CRC Straight Breeding", MRC Meat Profit Day, Millicent, SA, February.

Published Conference Proceedings

Barwick, S.A. and Henzell, A.L., 1997, "The economic value of marbling and consequences for breeding objectives," *Proc . Assoc. Adv. Anim. Breed. Genet* . **12**

Barwick, S.A. and Yeates, A.P., 1997, "Using BREEDOBJECT in industry to help breed more profitable cattle", *Proc . Assoc. Adv. Anim. Breed. Genet* . **12**

Barwick, S.A. and Newman, S., 1997, "BREEDOBJECT: A PC-program to derive economic values and selection indexes for beef breeding, *Proc. Workshop on Multiple-Trait Selection Technology for North American Beef Production.*

Bradfield, M., Johnston, D.J. Goddard, M.E. and Graser, H-U, 1997, "Prediction of Breeding Values for Cattle Managed Under Extensive Conditions",*Proc AAABG* **12**

Ferguson, D., Thompson, J., Goddard, M. and Oddy, H. "Genetic Variation in Carcass Yield and Meat Quality Traits" (*Beefex 97*)

Henshall, J.M. and Goddard, M.E., 1997 "Comparison of marker assisted selection using mixed model (BLUP) and mixed model with a test for the QTL", *Proc. AAABG* **12**.

Howarth, J..M., Goddard, M.E., and Kinghorn, B., 1997 "Breeding strategies for targeting different breeding objectives", *Proc. AAABG* **12**

Goddard, M.E. and Goddard, D.E., 1997 "Using DNA fingerprinting of extreme offspring to progeny test sires", *Proc AAABG* **12**

Graser, H.-U. and Tier B., 1997 "Applying the Concept of number of effective progeny to approximate accuracies of predictions derived from multiple trait analyses", *Proc AAABG* **12**

Theses

Klieve, H., 1997, Selection and Mating Strategies - Risks and Rewards. PhD Thesis UNE 1997

Appendix

Milestone 1: Establish Project UNE.035 Consultative Group

The first meeting of the Consultative Group was held on 22.-23. August 1991 in Armidale

In relation to B-OBJECT it was resolved that:

> the UNE.035 Consultative Group agrees to the transfer of the B-Object Software Version 1 to the commercialiser in its current form for product testing under a commercial environment and on-going commercialisation. (Compare Minutes of meeting)

This transfer and testing has taken place and ABRI as commercialiser has reported back to the group at its third meeting. Further action has been taken from there to enable B-OBJECT to be successfully released to the industry early 1993

Milestone 4a: Completion of Consultative Group Approved Work Program

An interim work program for UNE.035 was agreed on at the second and third meeting of the consultative group on October 23rd and May 19-20th 92, respectively. Priorities for the work program were reset, and AGBU's work rescheduled along the guidelines. A work program covering October 92 to December 93 is to be finalised at the consultative Group meeting on 20th Sept. 1992 in Rockhampton and will be advised thereafter.

Milestone 4b: Completion of preliminary R&D for MULTIBREEDPLAN

Mr. A. Swan a Postgraduate Student at AGBU submitted his accepted thesis " Multibreed Evaluation Procedures" in May 92. A separate report summarising the research finding is attached.

Milestone 9: AWP1 1993 completed

Research and Development was continued in all four major areas of the program

1) BREEDPLAN prediction software
2) DFREML estimation software
3) Estimation of genetic parameter
4) B-OBJECT software

1.) BREEDPLAN prediction software

Version 3.1 of the BREEDPLAN software was finalised and α-tested by AGBU. The software was subsequently transferred to ABRI for further testing and routine application (ii). It has been used some 6 month ahead of schedule to overcome the disadvantages for Australian breeders created by the unavailability of Version 3.0 in Australia.

Version 3.1 incorporates:

* Expanded capacity to evaluate up to 35 observations in 28 different traits simultaneously

Temperate Breeds	Tropical Breeds Modifications	Maternal Traits
Gestation Length		yes
Birth Weight		yes
200-Day Weight		yes
400-Day Weight	550-Day Weight	
600-Day Weight	900-Day Weight	
Later Weight	700-Day Weight	
Scanning Weight		
P8-Fat		
Rib Fat		
Eye Muscle Area		
Muscle Score		
Estimated lean Meat kg		
Estimated Lean Meat Yield		
Carcase Weight		
Carcase P8 Fat		
Carcase Rib Fat		
Carcase EMA		
Carcase Muscle Score		
Meat Colour		
Fat Colour		
Marbling		
ELMkg		
ELMY		
Scrotal Size		
Days to Calving		

Information is not currently available (carcase data) nor are heritabilities and genetic correlations known for all traits. These traits can however be replaced by other traits (eg. Mature Weight if required.

* Genetic- grouping strategy for introduced animals. (See Attachment A)

* Calculation of interim EBVs for herds included in a GROUP BREEDPLAN analyses as new data are available. The interim EBVs are estimated using the same genetic base as the GBP run and keeps EBVs for animals with progeny in more than one herd constant.

* A new procedure to determine the degree of linkage (pedigree overlaps) between herds for a GBP analyses. Herds without the minimum linkage are utilised in the analyses, however the resulting EBVs are not made available to the breeder.
A further enhancement is planned for 1993.

<u>2.) DFREML estimation software</u> (Dr K. Meyer)

DFREML version 2.0 has been completed and has been made available to researchers worldwide through distribution on diskettes and by making it available for 'anonymous ftp'. (File Transfer Protocol) through the InterNet. Version 2.0 has been expanded and enhanced considerably over version 1.0 as released in 1988, although the basic models of analysis, which it allows to be fitted have remained the same.

There have been major improvements both in computational efficiency and in the number of choices available for the type of analysis to be carried out. These include the implementation of multivariate analyses, a better ordering of equations in the mixed model array, simultaneous likelihood evaluations for multiple right hand sides and saving of all points evaluated, choice of search strategy, facilities to maximise with respect to a subset of parameters only, approximation of sampling errors at convergence and the option to use DFREML to obtain backsolutions for fixed effects and breeding value estimates.

In setting up DFREML version 2.0, it has been attempted to make it flexible and easy to use as well as easy to adapt to different environments. This resulted in highly structured code, subdivided into numerous files. Programs have been made flexible through a considerable number of options. In particular, facilities are provided to break analyses into small steps and to carry out several related, post-estimation tasks.

Code has been modularized to a large extent by assigning individual tasks performed to separate subroutines, resulting in a large number of specific routines for each program. Extensive duplication of code has been avoided by holding the statements replicated over programs in separate file which is then included (via a FORTRAN "INCLUDE" statement) where appropriate. In some cases, the operating system, hardware constellation or size of analysis to be performed may require modifications of array dimensions, logical unit numbers, file names and definitions, or similar. In order to make these changes easy and reduce the opportunities for error in doing so, most have been defined as variables and explicitly been assigned a numerical value (or name). As far as possible, this has been done once, or once per program, only.

Last but not least, considerable effort has been spend to make the programs user-friendlier by reducing the number of individual programs while greatly increasing the number of options in each program. Furthermore, running of programs has been made easier by increased proofing of interactive input, ie. More fault trapping and suggested default options, and more carrying over and cross-checking of information between programs.

Material available via anonymous ftp includes not only the complete FORTRAN code and the corresponding UNIX 'Makefiles' but also test data, description and listings of worked examples using these data and a postscript file with an 85 page user manual.

Work on version 2.1 is in progress; the major enhancement being the incorporation of an alternative matrix factorisation strategy using public domain software for sparse matrices.

3) Estimation of genetic parameters

Estimation of heritabilities and genetic correlations for growth traits for four different breeds have been finalised. Different genetic models have been investigated using DFREML on a number of different subsets of each breed (ANGUS, HEREFORD, Poll HEREFORD and SIMMENTAL) These individual estimates where subsequently combined accounting for the between and within breed differences, to derive "regressed" breed estimates (REML-BLUP estimation on the estimates. These estimates have since been transferred to ABRI and will be used for each breed beginning with the first GROUP-BREEDPLAN analyses after transfer.

The general outcome of these analyses were:

a) Heritability of birth weight is higher than previously used estimates (0.4 versus 0.25). Genetic correlations of birth weight with later weights is slightly less than in the old parameter file. The result will be, that EBVs for birth weight will have a larger spread (standard deviation) while at the same time they are less influenced by later weights. This could reduce the estimated positive genetic trends for birth weights in some breeds.

b) The heritability for 200-day weight direct component has to be increased from 10 to 20 %. No major change is required for the maternal component. The effect of this change will be an increase in the genetic trends for 200-day weight direct component and a slight decrease in the trend for the maternal component.

c) The permanent environmental variance for Hereford and Poll Hereford is significantly larger than for the other breeds. This could be an explanation for some of the problems with milk-EBVs observed in these breeds in the past. Further research is required and already planned in 1993.

d) 400-day weight has a maternal and permanent environmental variance that is equal to the 200-day weight components. These effects should therefor be included in an analysis, but can be treated as repeated observation, making the estimate of the milk-EBV more accurate. This will be implemented in the prediction software during 1993. (BP V3.2)

e) Other parameters require only minor adjustments.

A modified set of genetic parameters for the live carcase traits has also been implemented. This set replaced the preliminary estimates from a part dataset of the National carcass project UNE.027

A set of the genetic variances implemented at ABRI is in Attachment B

4) B-OBJECT software

No major changes for B-Object software were planned in 1992. The Consultative Group for UNE.035 recommended at its 3rd meeting "the establishment of a team to include AGBU, ABRI consultants and the Departments of Agriculture as appropriate, to target a limited number of producers with EBVs other than weight traits, and achieve a goal for the adoption of B-OBJECT over a period up to 31. December 1992.

This team was formed and trained to use B-OBJECT and has subsequently introduced some 15 breeders to B-OBJECT. A separate report is being prepared on the team's work and recommendations. A general comment is, that after an in-depth introduction most members of the team which were critical of the project, could see its value and were able to make use of it for different groups of breeders. However some work to make it easier to use is still required in 1993.

Milestone 14: AWP2 completed

Research and Development was continued in all major areas of the program

1) BREEDPLAN prediction software service of version 3.1, improvement of Version 3.1 and research for Version 4.
2) DFREML estimation software
3) B-OBJECT software
4) Breeding structure

<u>1.) BREEDPLAN prediction software: Service, Research and Development</u>

Service to ABRI to maintain the running of Version 3.1 continued throughout the year, by developing improved diagnostic, providing technical support and editing ABRI BREEDPLAN user manual.

At the beginning of the year a major effort was required to explain to the Hereford Society the large changes in EBVs which occurred with the introduction of the new BREEDPLAN version. It could be shown, that the large majorities of the changes are caused by changes in the data, resulting from the merger of the old separate performance and pedigree systems, and would have also happened with the use of version 3.0 of BREEDPLAN.

Calving ease was reviewed during 1993 and again no anomalies were found which could not be explained through the data, eg preferential mating of certain bulls to older or younger heifers, or heifers with different genetic backgrounds.

Version 3.2 of the BREEDPLAN software was finalised and α-tested by AGBU. The software was transferred in early September to ABRI for further testing and routine application, which started in December.

The new features of the software are:

* Modified modeling of Yearling Weight; research by the AGBU in 1992 and 1993 has shown that yearling weight, is significantly influenced by the maternal ability of the dam. Genetic and environmental correlations of the yearling weight maternal effects with the weaning weight maternal effects are close to unity. Therefore yearling weight can be considered as a repeated measurement to estimate maternal effects in the multitrait model. This has been implemented and the outcome of this change has been investigated for the Angus data.

* A new method of age of dam adjustment developed by AGBU. Allowance has been made in the program to utilise a new dam age adjustment factor, however they can only be used, as they become available for the different breeds during 1994.

* During 1993 a modified version of BREEDPLAN 900 was provided to ABRI and identified as a high priority by the Consultative Group at its autumn meeting. This version now includes 200, 400, 600 and 900 day weight and better represents the actual age at recording. The previous version, developed on request by northern breeders, has become unpopular with the changing market demand for younger slaughter stock.

The current round of estimation of variance components was finalised with the analyses of the Charolais data. However new traits were investigated during 1993 identifying a new trait: gain between marking and weaning, which is of interest to the commercial breeder, as it does not require the recording of birth date. The introduction of this trait into the BREEDPLAN software is planned for 1994.

Research for BREEDPLAN Version 4 concentrated on the development of a combined linear and non linear animal model analyses. This was achieved and the software will be used by AGBU to calculate on a test basis EBVs for calving ease which includes information on birth weight and gestation length.

Two consultative group meetings were held in Armidale. At both meeting AGBU staff reported on their research and development results and presented these in written versions for comments and discussion.

<u>2. DFREML estimation software</u>

Work on DFREML v2.1, begun in 1992, has been finalised, and the user manual and worked examples have been updated accordingly. All material has been made available via anonymous ftp, replacing version 2.0.

The main addition in version 2.1 is the incorporation of an alternative sparse matrix storage scheme and strategy to re-order equations and to factor the mixed model matrix, the computationally most demanding part of each likelihood. This uses the so-called compressed matrix storage, a minimum degree ordering and a Cholesky decomposition to factor the matrix and solve the mixed model equations. All these steps are performed using FORTRAN subroutines given by George and Liu (1981; Computer Solution of Large Positive Definite Systems, Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632.). While the new re-ordering strategy requires about three times as much CPU time than the ad hoc re-ordering strategy incorporated in version 2.0, this needs to be done only once per analysis. Subsequent likelihood evaluations, however, then tend to be 1.5 to 4 times faster. The new strategy proved especially advantageous for models of analyses incorporating maternal effects.

Exploratory work has begun recently for DFREML version 3.0. It is feasible to compute derivatives of the likelihood function indirectly using derivatives of the Cholesky decomposition of the mixed model matrix. These can be determined recursively while carrying out the Cholesky decomposition itself. This allows optimisation strategies using first or second derivatives to be employed in maximising the likelihood. Their suitability for animal model analyses needs to be investigated. If suitable, one or more of them should be incorporated into DFREML in 1994.

3. Breed-Object

The B-Object software was officially transferred to ABRI as the potential commercialiser in April 1993 together with a report prepared by a working party instigated by the consultative group. AGBU received a copy of the ABRI Strategic Plan for commercialisation by the end of September. AGBU responded to that plan asking for some modifications and amendments. It is hoped that this technology will become available to consultants, Department of Agriculture extension staff and interested breeders within the next 6 months. ABRI will provide a processing service using B-Object technology as well as a "Junior version" to be run on personal computers.

Accreditation courses for users of the full version of B-Object (which ABRI suggests may be named Breed Object by the commercialiser) will now be held early in 1994.

It is my personal belief that the license agreement for BREEDPLAN (and its associated software) which provides ABRI with sole commercialisation rights, and therefore prevents AGBU from distributing software like B-Object, has actually hindered the beef industry from systematically developing breeding objectives and identifying shortcomings of current recording practices earlier.

During the year B-Object software was enhanced by including Calving Ease in the objective and allowing for a non linear use of calving ease EBVs as well as birth weight EBVs in the resulting index. A subroutine was included which investigates the supplied variance-covariance matrices for consistency and which will bend these as required to ensure all values fall in the permissible parameter space. The questionnaire was further improved and some anomalies in the code corrected.

4) Breeding Structure

Work on breeding structure commenced with an investigation into breeding scheme having different levels of performance recording. It could be shown, that with the assumed genetic parameters and the breeding objective for a British type breed producing 440 kg slaughter steers in temperate Australia, increasing performance recording will increase genetic gain returns and profit for a population of some 200,000 animals of which 5% are in the breeding unit. This was true for all levels of performance recording, fertility, carcase traits via scanning, calving ease and cow weight. Further work is required to provide the industry with advise for improved breeding schemes.

5) Communication

A considerable time of the AGBU staff is set aside for interactions with the industry. During 1993 AGBU was involved in a number of initiatives, eg BIA technical advisory groups and BIA Biannual Conference as well as the BREEDPLAN EXPO at the end of September . A postgraduate course in the design of livestock breeding programs was organised in June and a number of other meetings addressed by AGBU staff. Two visiting scientist contributed to AGBU's research work for UNE.035 and were supported by MRC funds.

During 1993 Mr. Richard Kerr submitted his PhD thesis on the use of multiple sire mating data for the prediction of breeding values. Richard took up a postdoc position with the Department of Animal Science, UNE. The available studentship will be filled as soon as a suitable candidate has been located.

Milestone 20: AWP 1994 completed

The 1994 work program as approved by AGBU and the Consultative Group had work for 100 months included. This was considerably more than was available from the outset. It was understood that some research work will not be finalised as planned, this is outlined in detail below. In additional AGBU had the opportunity to undertake some short term contract research work for the Australian and New Zealand Angus Societies which further reduced the available staff months. The salary component saved however will be available to either add additional staff for the duration of the project or extend the project beyond June 1996.

The achievements of the 1994 workprogram in detail are:

BREEDPLAN

1. Servicing Version 3.2

Technical support for ABRI during 1994 was less frequent for BREEDPLAN Version 3.2 indicating that the total system became more reliable, however AGBU undertook the additional task of running the Calving Ease analyses for the Angus (twice), Simmental and Limousin breed with forerunner programs of Version 4. Due to data problems this required more time than first anticipated.

Implementation of research findings and transfer of Version 3.3 to ABRI was not satisfactorily completed in time for GROUP BREEDPLAN runs in December 1994. AGBU did not comply with Clause 12.1 of the Analytical Software License Agreement in documenting and testing Version 3.3. Version 3.3 has since been withdrawn to undertake further testing, documentation of test results and documentation of changes. This additional work will be completed by the end of January 1995.

2) Research for improving aspects of Version 3.2

This includes all the work for Version 3.3. A total integration of growth, reproduction and carcase in one analysis (a). This has been achieved, although some of the required covariance components are still literature values as insufficient Australian data is available.

Weight gains up to weaning, yearling and final weight (b) has also been included as well as the Multiple Sire option (f). Suitable field data for complete testing is however, not yet available.

Intensive investigations into days to calving have led to new adjustment factors and modifications to the model which have been included into Version 3.3 (c, e).

Dam age adjustments for Charolais, Limousin, Brahman, Belmont Red, Shorthorn and Murray Grey breeds using the DFREML variance estimation program have been calculated (g). These adjustments will be incorporated into the adjustment parameters files for the breeds.

No new traits from the Validation project (d) have been included in Version 3.3 as the final analysis has yet to be finished. However adjustments for existing traits developed during the analyses of the validation data have been included whenever possible.

3) Research for Version 4

The generalised Mixed Model Prediction work (a) is less advanced than anticipated at the beginning of the year. This work suffered from the lack of cooperation with visiting scientists and the demand in other areas. The expansion of the linear/non linear model is not yet complete, this work will be finalised in 1995. Work on G x E will commence in 1995.

Estimation software for non additive effects (dominance variance) is now available with DFREML's latest version (c). No more development in this area is planned.

A new approach (Gibbs sampling) has been taken to develop the first version of linear and non linear estimation software (d). Currently one version of a Gibbs sampler linear and one of non linear estimation program is being tested. The next step is to combine both for joint estimation. This is not a trivial task, as the computational requirements are enormous and the properties of these estimates are not yet well understood. This work however, keeps us at the forefront of development in this new era of quantitative and qualitative genetic analyses.

BREED OBJECT

4 &5) Servicing Version 2 and Research for improving aspects of Version 2 A first School/Workshop/Accreditation course was held at UNE in July with nine participants. Numerous improvements were recommended during the course which enhance the operational aspects of the BREED OBJECT package. These were subsequently included.

Additional software was prepared to run a 'Junior' and 'Bureau Service' version of the calculations of the indexes which are also part of the main program. Due to these additional unplanned commitments, only the strategy for a sensitivity module and the inclusion of quality traits could be prepared. The actual programming will be done in 1995.

BREEDING STRUCTURE

Research for the design of breeding programs has continued with concentration on breeding programs with progeny testing. A further publication of these results is planned for 1995.

COMMUNICATIONS

During 1994, AGBU UNE.035 staff continued Industry communications by attending industry conferences, addressing breed society boards, and talking at technical officer meetings. More than 20 papers and notes were prepared for publication.

5 staff members traveled to Canada to attend the 5th World Congress of Genetics Applied to Livestock Production in Guelph and presented papers. We also contributed to undergraduate and postgraduate training with the Department of Animal Science, UNE.

An application for an ARC Collaborative Research Grant together with Taurus Technology has been unsuccessful.

Milestone 25: AWP 1995 completed

Research and Development was continued in all major areas of the program

1) BREEDPLAN prediction software service of version 3.2, and 3.3 and research for Version 4.
2) BREEDOBJECT software
3) Breeding structure
4) Communication

1.) BREEDPLAN prediction software: Service, Research and Development

AGBU has supported ABRI attending to any problems incurred with versions 3.2 or 3.3. Calving Ease analyses was performed for the Angus, Limousin and Simmental breed. A test run for the Hereford breed was also undertaken.

BREEDPLAN Version 3.3 was tested intensively by AGBU. Full documentation of changes to models and of test results were provided to ABRI in February in a document containing more than 60 pages. ABRI has used Version 3.3 for a number of GROUP BREEDPLAN analysis in 1995.

AGBU has identified the accuracy program as one bottleneck for large breeds and has rewritten some code to calculate accuracy in a faster way although with less precision. This new code has been tested documented and implemented at ABRI. It requires only a fraction of time and memory resources of the previous version.

Development for the accommodation of across country evaluation using different adjustment files has been completed, tested and transferred to ABRI

Editing of ABRI BREEDPLAN manual has commenced however has not be finalised. This is expected to be done early 1996.

Damaging remarks, which undermine breeders and producers confidence in BREEDPLAN, were published in connection with the extension of M112 results. As part of servicing BREEDPLAN AGBU has spend considerable time analysing M112 data. A technical report on our findings was prepared. In summary the statements made about the relationship between BREEDPLAN Growth EBVs and M112 "Feedlot EBVs" are incorrect and should not be repeated.

Estimation of adjustment factors and some variances for the Santa Gertrudis breed have been finalised, and the results made available to ABRI for use in the first GROUP BREEDPLAN analysis for this breed.

Undergraduate Student Hamish Chandler has submitted his thesis "Genetic Modeling of Mature Cow Weight in Beef Cattle in Australia". Hamish worked under the supervision of Dr David Johnston. Together, David and Hamish also prepared some preliminary EBVs for mature cow weight, which indicate the potential usefulness of this trait for maternal lines of cattle.

A decision at the 9 CG meeting was made to delay structural soundness work. However, as part of the analysis of UNE.30 data, preliminary EBVs for eye pigmentation and eye setting were provided for Hereford, Polled Hereford and Simmental.

Fertility data from the Santa Gertrudis and Brahman breed were obtained from the Herdmagic data recording system of individual herds and merged into one data file per breed. Different models were used to analyse the data, particularly comparing days to calving versus calving success. At the relatively low level of calving rate, calving success seems to be more heritable than days to calving. However using calving success also means losing about 10-15 % of the data, due to the fact that all cows in a contemporary group calve. This problem will increase with increasing calving rate increasing the usefulness of days to calving. Our conclusion from this work is that there is enough genetic variability for female fertility in the Indicus derived breeds and the trait is heritable enough to warrant the calculations of EBVs.

2. Breed Object

Ongoing support was provided to users. Included was a considerable time commitment to meeting requests of industry groups and responding to new inquiries. Versions 2.12 and 2.13 were updated to incorporate user suggestions, and then were made available as Version 2.2. Enhancements included matrices of separate underlying genetic parameter estimates for a further ten breeds, and extension and clarification of the prediction of objective traits.

A procedure for valuing marbling in the breeding objective was developed and implemented on a test basis. Provision was made for Indexes to include either an EBV for scanned Intramuscular Fat % or an EBV for Carcase Marbling Score. Concurrent with valuing marbling, the existing production system model was adapted so that production systems with two or more segments (eg., cow-calf , backgrounding and feedlot) could also be handled.

These changes required extensive restructuring of the program. Procedures for modeling the feedlot segment of the production chain, and combinations of segments, were developed and incorporated on a test basis.

As a consequence of the restructuring to allow for different industry segments, previously developed methods for assessing which inputs have most impact on results (sensitivity) had to be modified. These procedures will not be available until the changes for the industry segments are finalised. To avoid future rehandling, provision was made for Indexes to include a Mature Cow Weight EBV and some other EBVs that might be available in the future. Procedures for valuing earliness of calving (ie. over and above the value of cow weaning rate) were developed. Days to Calving is the trait added to the breeding objective. Gestation Length (direct) is added for terminal sire applications.

3) Breeding Structure

The work on the design of progeny test has been continued at a slow rate. Results were presented at the genetic workshop, but a scientific publication has not yet been written. The outcome of this work is in short, that only well designed and controlled progeny test programs which include the collection of carcase data can compete with well designed and controlled young sire schemes.

Due to the shortage of staff and the higher ranking of other projects DNA fingerprinting commenced only in November 1995 and only early results are available.

4) Communication

The majority of AGBU staff attended the 10th AAABG conference in South Australia and presented invited and contributed papers.

As part of its commitment to extend its research results AGBU has organised a Beef Cattle Genetics Workshop on August 15 and 16. 13 Breed Society Technical Officers, Departmental Beef Cattle Officers and AI organisation staff attended the two day sessions. A 65 page booklet was prepared for the workshop and can be obtained from AGBU (cost $20). Feedback from participants indicates that it was a useful exercise and time well spent.

In the second half of 1995 AGBU staff again contributed to the undergraduate teaching of UNE Department of Animal Science which include responsibilities of marking examine papers. David Johnston supervised one honours project and together with Hans Graser contributed substantially to the training and education of two mature students from Thailand which are at Armidale to get familiar with BREEDPLAN technology. This training is part of an ABRI project to "export" BREEDPLAN to this country for use in cattle and perhaps buffalo. Contributions were also made to the BIA conference at Wagga Wagga at the end of September.

Milestone 28: APW4 completed

BREEDPLAN

Transfer and test of Calving Ease module to ABRI has been completed. New demand for additional diagnostic software has been identified. This will require work at a later stage. All calving ease analysis have been performed as required early in the year. Pilot EBVs for Days to Calving have been calculated for the Brahman, Santa Gertrudis, Hereford and Poll Hereford data pilot Mature weight EBV have also been calculated for the Angus breed and published on a test basis.

New adjustment factors for a number of breeds (e.g. Hereford and Polled Hereford) have been estimated for weight traits including the heifer factor and separate data for spring and autumn calving. These adjustment factors were included into the relevant files at ABRI.

Analysis of CRC carcase data to compare CRC steer carcase results with BREEDPLAN scan EBVs of their sires have been undertaken. Sire EBVs based on ultrasound scanning do predict the carcase traits in their commercial offspring. However, fat EBVs on bulls underestimate the differences in steer fat depth, but eye muscle area EBVs overestimate the differences in steers. Meat Yield EBVs predict differences in yield of steer progeny too, but far underestimate meat yield % differences in the commercial cattle. In BREEDPLAN version 4 we propose that carcase EBVs will be a prediction of steer carcase traits since this is the most commercially important sex.

The project on cow survival with respect to feet and leg score of heifers has been completed by an honors student and prepared for publication. David Johnston has prepared a special Technote. A separate project researching the relationship of eye muscle depth and area in Hereford cattle was also completed. While depth and area are highly correlated there is room to change the shape of the eye muscle through selection. Scanning for eye muscle depth is cheaper than for eye muscle area.

Research for Version 4.

Development of BREEDPLAN Version 4 was the main focus of the work in 1996 and early 1997, however it was interrupted by many activities in servicing and improving version 3.3. AGBU has started to test version 4 in a systematic way starting with a test to get the same results as with version 3.3. All other additional features of version 4 will be tested one by one and in combination. These are:

- Multiple fixed effects
- Sire by herd interactions
- Heterogeneous variances
- New genetic grouping
- Inclusion of external EBVs
- Across breed and crossbred EBVs

Some of these new features will require further development and additional modifications to ABRI software. Breed societies will need to invest to generate the required cross reference list of animal identifications so that EBVs from other countries can be used.

Estimation and Prediction: Developments in DFREML 1996/1997

Estimation of genetic parameters (e.g. genetic correlations) is a frequent task within UNE35 and other projects. AGBU maintains a suite of computer programs for this purpose called DFREML. In 1996 this suite has been upgraded to allow larger, multi-trait data sets to be analysed and to fit covariance functions. Covariance functions are a method of predicting breeding values for a complete growth curve instead of at a few specific ages (200, 400, 600 days). Technical improvements made are:
Programs using the AI-REML algorithm were improved. Improvements included the facility to account for non-estimable covariances (e.g. traits measured on distinct subsets of animals), calculation of approximate sampling errors for genetic parameters (heritabilities and correlations) from the inverse of the average information matrix, and an update of the modified Newton-Raphson algorithm used, making the search for the best step size more robust.

Considerable effort has been expended on programs to estimate covariance functions (CFs). Programs to estimate CFs for the general case and the special case of equal design matrices for all traits were updated and included in AI-REML as well as the derivative-free algorithm, and made more user-friendly. Recently, an alternative way to model CFs via random regressions has been found and this has been programmed. Extensive use of the CF programs has been made by visiting scientists (Drs Veerkamp and Van der Werf).

The univariate program (DFUNI) has been modified to allow the so-called "Integrated Falconer-Willham" model to be fitted, i.e. to allow environmental covariances between dams and their offspring to be taken into account by fitting a regression on maternal phenotype.

BREED OBJECT

Support of Version 2.3 included

- conduct of 3rd Training and Accreditation School
- support of providers of BREEDOBJECT services (e.g. consultants to Simmental, Angus Breed Societies, ABRI)
- invited contribution to Deloraine MRC Meat Profit Day
- provision of client workshops and technical advice to leading industry breeders

- technical advice to Breed Societies and presentation to Angus Society Council
- development of rankings, for ten breeds, for performance classes of the '97 Hamilton Beef Expo

Research for Version 3.0

Version 3.0, which incorporates marbling, other new traits, and procedures for allowing for different industry segments, was further advanced but is not expected to be transferred until later in the year. A scientific paper on the procedures and results incorporating marbling was prepared and a paper presented at AAABG. A software update (Version 2.4) was developed to incorporate the first stages of the fast operational mode. This is being tested. The same developments have still to be added to Version 3.0. The Quick Questionnaire developed for the fast operational mode was tested in the field and improvements made.

Breeding Structure Design.

Research on mating decision software was of the lowest priority on the workplan and had to be abandoned in order to carry out unplanned tasks.

UNE.035 PROJECT - BREEDPLAN/GROUP BREEDPLAN APPROVED WORK PROGRAM FOR OCTOBER 1992 TO DECEMBER 1993

	Anticipated Time per Quarter (months)					
	4/92	1/93	2/93	3/93	4/93	Total
BREEDPLAN/GROUP BREEDPLAN						
1 Servicing Version 3.1						
(a) Transfer	1	-	-	-	-	1
*Weight + Reproduction / Scanning						
*Implement Covariances and adjustment factors						
*Genetic grouping for GBP						
(b) Review Calving Ease	-	2	-	-	-	2
(c) Finalise new connectedness test	-	-	2	-	-	2
(d) Documentation /technical support						
*V3.1 additional Diagnostic	3	-	-	-	-	3
*Technical Support for ABRI	1.5	1.5	1.5	1.5	1.5	7.5
*Editing ABRI BREEDPLAN user manual	1	-	-	-	-	1
(e) Implement Research finding from 1993 prior to GROUP BREEDPLAN runs spring 1993	-	-	-	1.5	1.5	3
2 Research for improving aspects of Version 3.1						
(a) Estimate covariances for weight traits Terminal Sire Breed	2	-	-	-	-	2
(b) Review weaning weight modelling	1	-	-	-	-	1
(c) Improve weaning weight modelling	2	3	-	-	-	5
(d) Review, improve heifer adjustment factors	-	-	2	1	-	3
(e) Review, improve fixed effect (m. group) modelling	-	-	-	2	2	4
(f) Diagnostic upgrades	-	2	2	-	-	4
3 Research for Version 4						
(a) Generalised Mixed Model Prediction: Preliminary research						
*combining linear and non linear traits	-	2	1	-	-	3
*accommodate G * E interaction	1	1	1	-	-	3
*accommodate heterogeneous variances	-	1	2	-	-	3
*major genes	-	1	1	2	2	6
(b) Investigate the modelling of new traits	-	-	-	3	3	6
(c) Develop estimation software for research	-	1	1	2	2	6
*linear and non linear traits						
*non additive variance						
	12.5	**14.5**	**13.5**	**13**	**12**	**65.5**

	Anticipated Time per Quarter (months)					
	4/92	1/93	2/93	3/93	4/93	Total
B-OBJECT						
4 Servicing Version 1.2						
(a) Transfer, Operational and Technical Support Update (Co)variances	2	2	-	-	-	4
(b) School/Workshops	-	1	1	-	-	2
5 Research for improving aspects of Version 1.2						
(a) Include new traits *Calving ease *ELMY	-	-	1	2	-	3
(b) Value of additional traits in BREEDPLAN	-	-	-	2	-	2
(c) Subindex	-	-	-	-	1	1
(d) Accuracy of $ index	-	-	-	-	1	1
	2	**3**	**2**	**4**	**2**	**13**
Breeding Structure						
6 Research for Version 1	**-**	**3**	**4**	**2**	**3**	**12**
Communications						
7 (a) Direct Industry Communication 16.5		2.5	2.5	3.5	3.5	4.5
(b) Education	-	-	1	1	-	2
	2.5	**.5**	**4.5**	**4.5**	**4.5**	**18.5**
TOTAL STAFF BUDGET	**17**	**23**	**24**	**23.5**	**21.5**	**109**
Estimate of available staff time						
* AGBU	16.25	17.25	19.25	19.25	19.25	
* Visiting Scientists	-	4	4	4	3	
	16.25	**21.25**	**23.25**	**23.25**	**22.25**	**106**

UNE.035 Project BREEDPLAN / Group BREEDPLAN Approved Work Program for 1994

BREEDPLAN/GROUP BREEDPLAN	1/94	2/94	3/94	4/94	Total
1 Servicing Version 3.2					
a) Transfer/Implementation or research findings	-	-	1.5	1.5	3
b) Technical Support for ABRI	1.5	1.5	1.5	1.5	6
2 Research for improving aspects of Version 3.2					
a) Integration of growth, carcase and reproduction Estimation of Covariances	3	3	-	-	6
b) Weight gain	2	1	-	-	3
c) Implementation of fixed effect modeling	1	-	3	-	4
d) Add traits from validation project (eg. pelvic size)	-	-	2	2	4
e) Adjustments to fertility model	2	-	-	-	2
f) Multiple Sire implementation	-	3	3	-	6
g) Dam age adjustment new parameter estimation	1	1	1	-	3
Implementation	-	-	1	-	1
h) Development of Crossbreeding option (contingence)	-	-	-	6	6
3 Research for Version 4					
a) Generalised Mixed Model Prediction Expand Linear/Non linear Model to more than two traits	2	2	2	2	8
Define strategy for G*E inclusion	-	2	2	-	4
Define strategy for inclusion/estimation of heterogeneous variances	-	-	2	2	4
b) Investigate new traits	-	-	-	-	-
c) Finalise estimation software for non additive effects	2	2	-	-	4
d) Develop first version of linear and non-linear estimation software	-	-	3	3	6
	14.5	**15.5**	**22**	**18**	**70**

B-OBJECT	1/94	2/94	3/94	4/94	Total

4 Servicing Version 1.3					
a) Operational and Technical Support	0.5	0.5	0.5	0.5	2
b) School/Workshops	1	-	-	-	1
5 Research for improving aspects of Version 1.3					
a) Sensitivity module	1	1	-	-	2
b) Allow for standard objectives	1	1	-	-	2
c) Inclusion of quality traits in the objective	-	2	-	-	2
	3.5	**4.5**	**0.5**	**0.5**	**9**
BREEDING STRUCTURE					
6 Research for Version 1	1	1	1	1	4
a) Development of Front and Backend Software to Breeding Program design Software	2	1	-	-	3
	3	2	1	1	7
COMMUNICATIONS					
a) Direct Industry Communications	2.5	2.5	2.5	2.5	10
b) World Congress in Genetics	-	-	1	-	1
c) Committee preparation and attendance	0.5	-	0.5	-	1
d) Education	-	-	-	2	2
	3	2.5	4	4.5	14
TOTAL STAFF BUDGET	**24**	**24.5**	**27.5**	**24**	**100**
Estimate of available staff time					
AGBU	19.25	19.25	19.25	19.25	77
Visiting Scientists	-	2	4	4	10
	19.25	**21.25**	**23.25**	**23.25**	**87**

UNE.035 PROJECT - BREEDPLAN/GROUP BREEDPLAN APPROVED WORK PROGRAM FOR 1995

	Anticipated Time per Quarter (months)				
	1/95	2/95	3/95	4/95	Total
BREEDPLAN/GROUP BREEDPLAN					
1 Servicing Version 3.3					
(a) Transfer and test improvements	1.0	-	1.0	1.0	3.0
*Implement new Covariances and adjustment factors	1.5	-	-	-	1.5
*Test International GP	-	1.0	-	-	1.0
(b) Documentation /technical support					
*Technical Support for ABRI	1.0	1.0	1.0	1.0	4.0
*Editing ABRI BREEDPLAN user manual	1.0	1.0	-	-	2.0
2 Research for improving aspects of Version 3.3					
(a) Estimate Adj. Factors for weight traits Santa Gertrudis	1.0	-	-	-	1.0
(b) Mature weight EBV ?	-	0.5	-	-	0.5
(c) Intramuscular Fat	-	-	1.0	-	1.0
(d) Structural Soundness ?	-	-	2.0	-	2.0
(e) Development for International GP	-	1.0	-	-	1.0
(f) Fertility Model North reexamined	-	1.5	-	-	1.5
3 Research for Version 4					
(a) Generalised Mixed Model Prediction:					
* Finalise Software	-	2	2	3	7
* Alpha testing of version 4 (to 1996)	-	-	-	-	-
* Research to model G*E	1.5	1.5	1.5	1.5	6
* Include G*E interaction (to 1996)				-	-
(b) Use of crossbred animals(Can. PhD Student)	1.5	1.5	1.5	1.5	6
(c) Genetic evaluation with genetic markers (Aus PhD St.)	-	-	1.5	1.5	3
(d) Development of estimation and prediction software for research using Gibbs sampler	0.5	0.5	0.5	0.5	2
	9	**11.5**	**12**	**10**	**42.5**

	1/95	2/95	3/95	4/95	Total
	Anticipated Time per Quarter (months)				
BREED-OBJECT					
4 Servicing Version 2.0					
(a) Transfer, Operational and Technical Support	1	0.5	0.5	0.5	
2.5					
Update (Co)variances					
(b) School/Workshops	1	-	1	-	2
5 Research for improving aspects of Version 2.0					
(a) Implement sensitivity	1	-	-	-	1
(b) Include marbling and feedlot option	1	1.5	0	1	
3.5					
(c) Input program					
	4	**2**	**1.5**	**1.5**	**9**

Breeding Structure

	1/95	2/95	3/95	4/95	Total
6 Research for Version 1					
Design of Breeding Programs	1	1			2
DNA Fingerprinting			2	2	4
Mating decision software	1	2	1	2	6
	2	**3**	**3**	**4**	**12**

Communications

	1/95	2/95	3/95	4/95	Total
7 (a) Communication	1.5	1.5	1.5	2.5	7.0
(b) Education	-	-	1	1	2.0
(c) BREEDPLAN SCHOOL	-	1	-	-	1.0
(d) AAABG Conference	2	-	1	-	3.0
(e) UNE AGBU review	1	-	-	-	1.0
	4.5	**2.5**	**3.5**	**3.5**	**14**
TOTAL STAFF BUDGET	**19.5**	**19**	**20**	**19**	**77.5**
Estimate of available staff time					
* AGBU confirmed	13	13	13	13	52
* AGBU unconfirmed	0	3	3	3	9
* Visiting Scientists	5	3	4.5	4.5	17
	20	**19**	**20.5**	**20.5**	**78**

UNE.035 PROJECT - BREEDPLAN/GROUP BREEDPLAN

APPROVED PROGRAM FOR 1996

	Anticipated Time per Quarter (months)				
	1/96	2/96	3/96	4/96	Total
BREEDPLAN/GROUP BREEDPLAN					
1 Servicing Version 3.3					
(a) Transfer and test Calving Ease	-	-	1.0	1.0	2.0
(b) Technical support					
* Technical Support for ABRI	1.0	1.0	1.0	1.0	4.0
* EBV Calving Ease 5 breeds	1.5	-	-	-	1.5
* Pilot EBVs Fertility, Mature weight	-	-	1.0	3.0	4.0
2 Research for improving aspects of Version 3.3					
(a) Estimate Adj. Factors for weight traits and GL and SS (A, H, PH , S)	2.0	2.0	2.0	-	6.0
(b) Early analysis of CRC carcase data	-	1.0	-	-	1.0
(c) Belmond Red problems	-	2.0	-	-	2.0
(d) SG and Brahman mangement group definition	2.0	-	-	-	2.0
(e) Cow survival (Honours project)	-		1.0	-	1.0
3 Research for Version 4					
(a) Commercial Version of Calving ease as separate package	-	2	-	-	2.0
(b) Development of Version 4: new: Across breed and crossbred EBVs, Multiple fixed effects, Heterogenous variances, Sire by herd interaction, Genetic grouping, Overseas EPD's	3	3	2	4	12.0
* Alpha testing of version 4 (to 1996)	-	1	1	1	3.0
(c) Genetic evaluation with genetic markers (Aus PhD St.)	1.5	1.5	1.5	1.5	6.0
(d) Estimation and prediction software for research using Gibbs sampler	0.5	-	0.5	-	1.0
	11.5	**13.5**	**11**	**11.5**	**47.5**

	Anticipated Time per Quarter (months) 1/96	2/96	3/96	4/96	Total
BREED-OBJECT					
4 Servicing Version 2.2					
(a) Transfer, Operational and Technical Support	0.5	1.0	0.5	0.5	2.5
(b) School/Workshops	-	1.0	-	-	1.0
5 Research for Version 3.0					
(a) Testing and transfer including Junior and VAX version	2	1	-	-	3.0
(b) Fast operational modes	-	0.5	1.0	-	1.5
(c) Investigate feed efficiency options	-	-	1.0	1.0	2.0
	2.5	**3.5**	**2.5**	**1.5**	**10**
Breeding Structure					
6 Research for Version 1					
DNA Fingerprinting	2	-	-	-	2
Mating decision software	1	1	1	3	6
	3	**1**	**1**	**3**	**8**
Communications					
7 (a) Communication	1.5	1.5	1.5	2.5	7.0
(b) Education	-	-	1	1	2.0
(c) BREEDPLAN SCHOOL	-	-	-	1	1.0
(d) Estimation and QTL School	-	1	0	-	1.0
	1.5	**2.5**	**2.5**	**4.5**	**11**
TOTAL STAFF BUDGET	**18.5**	**20.5**	**17**	**20.5**	**76.5**
Estimate of available staff time					
* AGBU confirmed	17.25	16.25	15.25	17.25	66
* AGBU unconfirmed	0	1	2	0	3
* Visiting Scientists	2	0	0	0	2
	19.25	**17.25**	**14.25**	**17.25**	**71**

Attachment to Milestone 9 (Appendix)

Report on preliminary R&D for MULTIBREEDPLAN

Mr. Andrew Swan spent some four years at the Animal Genetics and Breeding Unit doing a PhD in Animal Genetics. During that time Mr Swan reviewed and developed mixed model prediction methods which incorporate data on both straightbred and crossbred animals: multibreed evaluation procedures. This was planned as an integral part of the development program for upgrading NBRS. His thesis is quite comprehensive in this area and of high quality otherwise.

There are several approaches possible in the development and evolution of a multibreedplan system. These vary as to their place in an industry and in their difficulty and requirements. More than one may eventually be used in different sectors of the beef and pig industries. Briefly, they are:

1. Strategy to account for breed and heterosis effects.

a) Fit breed effect and heterosis effects as classes or as covariates into a model.

b) Preadjust data from the effect, which would require adjustment factors.

2. Strategy to predict for "within breed" breeding values.

a) Genetic group model: This model can account for heterogeneity of variances. Genetic variances in crossbred groups are a linear function of purebred variances. This model does not account for different rankings of animals in different crosses.

b) Multi trait model: This model does allow complete re-rankings of animals in different crosses and also accounts for the heterogeneity but is found a different way than a). Each genotype (pure or cross) will have its record treated as a separate trait, correlated to the performance in other genotypes and with its own genetic parameters.

c) Scaling model: This model accounts for differences of variance in the different genotypes as in b), but genetic correlations are assumed to be in unity.

Mr. Swan has investigated these different approaches and summarises his findings as follows:

Abstract

"A mixed model procedure for analysing crossbreeding data was developed accounting for breed differences and heterosis using a partial regression approach (Dickerson, 1969), Heterogeneous genetic variances as parameterised by Elzo (1986) and heterogeneous environmental variances. Transformed genetic group equations (e.g. Quaas, 1988) were adapted to accommodate breed differences as genetic groups, and heterosis. Elzo's (1986) rules to build the genetic covariance matrix and its inverse when variances are heterogeneous across breed genotypes were also adapted to simplify construction of the genetic group equations. On a test data set, the resulting system of equations contained 30% less non-zero elements than an equivalent untransformed equations, with convergence to the same stopping criterion after 12 iterations, compared to 66 iterations for the untransformed equations.

Elzo's derivation gives the result that additive genetic variances in crossbred groups are linear functions of variances in straightbreds. However, because of the effect of gene frequencies, variances in crossbred genotypes cannot be determined from variances on straightbred genotypes. Consequently, this procedure does not properly model additive genetic variances at the level of the gene.

Mixed model procedures were also developed to account for animal x breed-of-mate interactions, with particular reference to possible changes in rankings of true breeding values in straightbred and crossbred matings. Two models may be used: an interaction model or multi-trait model. The multi-trait model has a more flexible covariance structure, and is more robust when rankings change in straightbred and crossbred matings. The genetic covariance structure was developed for a sire interaction model including single- and multi-locus interactions. This was extended to a multi-trait sire model. Use of an animal model was also justified, and in the multi-trait animal model, each breed genotype represents a "trait", with breeding values related to expression of the character in that genotype.

A gene level parameterisation first described by Griffling (1962) was used to examine the genetic covariance structure of the multi-trait animal model. It was found that this model does not correctly accommodate the true genetic parameters, in particular the correlation between straightbred and crossbred performance ($r_{gs,c}$). The correct model is multi-trait gametic model. A reduced animal model and a reduced gametic model for an Fl crossing system were described.

The number of genetic (co)variances in multi-trait models is large. For a simple Fl crossing system with one character measured, there are 5 (co)variances in an animal model, and 6 (co)variances in a gametic model. For a three-breed cross, there are 29 direct and maternal (co)variances in an animal model, and 34 in a gametic model. Consequently, computing strategies for solving the multi-trait equations are discussed, along with considerations on estimating the variance components.

An F1 crossing system with breeds A and B as parents was simulated. Genotypic values for a single character were simulated at the gene level, with either 4 or 16 loci affecting the character. Gene frequencies of the favourable allele were 0.8 in breed A and 0.2 in breed B at all loci. By varying the number of loci which showed overdominance (Nod), a range of values of rgs c was modelled.

Selection was carried out based on Estimated Breeding Values (EBV's) from the mixed model procedures described above, and other alternative procedures. Two different selection methods were used: Within Breed Selection (WBS), and Reciprocal Recurrent Selection (RRS). Within these methods, seven different evaluations procedures were used:

WBS:

- A single trait animal model including records on straightbreds only (Model SAP).

- The genetic groups procedure described above (Model GG).

RRS:

- Phenotypic averages of crossbred progeny (Model P).

•A single trait animal model using crossbred records only (Model SAC).

• A single trait animal model using crossbred records (Model SGC).

• The multi-trait animal model described above (Model MA).

• The multi-trait gametic model described above (Model MG).

For WBS, both models (SAP and GG) approached an optimum within breed genotypic value for all values of Nod in both 4-locus and 16-locus simulations. Both straightbreeds approached this value, resulting in the loss of heterosis in the Fl cross due to the similarity of allele frequencies between breeds. This also resulted in an increase in the value of rgS c where it is not already 1.

For RRS, the optimum F1 genotypic value occurred where the favourable allele was fixed in both breeds at partially dominant loci, while at overdominant loci, the favourable allele was fixed in breed A and the unfavourable allele was fixed in breed B. Models P, SAC and SGC approached the optimum value over the full range of values of Nod (especially as Nod increased). Models MA and MG approached the optimum value when Nod was high i.e., low or negative values of rgs,c Failure to approach the optimum at low values of Nod was due to the influence of straightbred information on crossbred EBV's. Model MG was more adversely affected than Model MA. Selection resulted in an initial decrease in the value of rgS,c as the allele frequencies at overdominant loci diverged in the straightbreds. When fixation occurred at these loci, they no longer affected rgS,c~ so the influence of partially dominant loci increased the value of rgS,c. As these loci approached fixation, rgs,c approached 0 16-locus simulations took longer to achieve optimum genotypic values that 4-locus simulations.

Estimates of rgS,c were obtained from EBVs of Australian Simmental sires using the method of Calo et al. (1973). These EBVs were derived from separate analyses of data from four progeny breed genotypes: Fl cross, first backcross (Bl: approximately 75% Simmental), second backcross (B2: approximately 88% Simmental), and straightbred calves (S: at least 94% Simmental). EBVs were available for six traits: gestation length (GL), birth weight (BW), 200-day weight direct (WWd) and maternal (WWm), 365-day weight (YW), and 550-day weight (FW). Correlations were estimated for all traits and between all progeny breed genotypes: (F1 and Bl), (Fl and B2), (F1 and S), (Bl and B2), (Bl and S), and (B2 and S). The pattern of estimates agreed with expectations well, ranging from 0.571 to 1.146 fro GL, -0.282 to 1.417 for BW, 0.101 to 0.795 for WWd, 0.347 to 0.513 for WWm, 0.057 to 0.874 for YW, and 0.198 to 0.993 for FW. To examine other potential influences on these estimates, two traits (BW and WW) were analysed using a model including both sire x year interactions and sire x breed-of-dam interactions. In both cases, sire * year interactions were more important than sire x breed-of-dam interactions. Despite this, sire * breed-of-dam interactions were still significant, and it was concluded that reranking of sires in different mating types may be more important in these data.

The results in this thesis show that the multibreed evaluation models developed can give significant improvements in crossbred genetic merit. However, it will be necessary to estimate the genetic parameters involved across a variety of characters and breeds before a practical procedure can be implemented. This is an area requiring further research."

Recommendations

At present insufficient data of crossbred animals is available to obtain reliable estimates of the genetic parameters required, and the whole area has been demonstrated to be quite demanding in terms of achieving a reliable, practical multibreed-plan system for beef industry use. We do not recommend a development of a system providing multibreed evaluation unless a section of the industry is committed to provide substantial numbers of performance records of their crossbreds on a regular basis to a central processing centre for research and development purposes. In fact it will be useful for the beef industry to eventually capitalise on experience with this area of breeding technology in an industry such as the pig industry where better structures and a higher demand for its use already exist. We review the situation again around 1994.