



The economics of revegetation of stripmined land for use as forage by range cattle
by Ralph Peter McQuillan

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Applied Economics
Montana State University
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Abstract:

This study deals with the economics of revegetating stripmined land for use as forage material. The benefits are measured in Animal Unit Months per acre for use by range cattle. The costs are those associated with reestablishing the forage material.

The study focuses on areas similar to those found in Eastern Montana. Stripmining involves the removal of overburden, extraction of coal, backfilling, and revegetation. The area involved in this study only includes revegetation. Revegetation involves planting of seed and maintenance until satisfaction of the bond requirements.

Linear programming is used to find which mixtures of plants give the maximum present value of forage. The objective function contains the machinery, labor, seed, other necessary costs, and the benefits (as pasture rental value). The benefits received are discounted back using an infinite discount horizon in order to keep values the same.

This allowed for analysis of the governmental requirements of a full year pasture versus seasonal pasture, and requiring certain amounts of native species to be planted. It was found the less restriction the higher the value obtainable as forage material.

THE ECONOMICS OF REVEGETATION OF STRIPMINED
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of

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in

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APPROVAL

of a thesis submitted by

Ralph Peter McQuillan

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

This study deals with the economics of revegetating stripmined land for use as forage material. The benefits are measured in Animal Unit Months per acre for use by range cattle. The costs are those associated with reestablishing the forage material.

The study focuses on areas similar to those found in Eastern Montana. Stripmining involves the removal of overburden, extraction of coal, backfilling, and revegetation. The area involved in this study only includes revegetation. Revegetation involves planting of seed and maintenance until satisfaction of the bond requirements.

Linear programming is used to find which mixtures of plants give the maximum present value of forage. The objective function contains the machinery, labor, seed, other necessary costs, and the benefits (as pasture rental value). The benefits received are discounted back using an infinite discount horizon in order to keep values the same.

This allowed for analysis of the governmental requirements of a full year pasture versus seasonal pasture, and requiring certain amounts of native species to be planted. It was found the less restriction the higher the value obtainable as forage material.

CHAPTER 1

INTRODUCTION

STATEMENT OF THE PROBLEM

Federal and Montana state law requires that stripmined land be reclaimed. This reclaimed land could be put to a viable use as forage for range cattle. Through planning for a specific use the reclaimed land should provide an economically useable site. The process involved after removal of the coal seam is reclamation and revegetation of the site. There are numerous reclamation costs associated with the backfilling and recontouring to the approved postmining configuration.¹ Revegetation incurs costs due to preparation for seed, fertilizing, planting, and maintaining the site until the seeded species are established. Coal mining companies face the problem of minimizing the cost of these activities while complying with the laws.

The four phases of mined-land reclamation are 1) design, engineering and overhead, 2) bonding and obtaining permits, 3) backfilling and grading, and 4)

revegetation.² The first three phases are independent of the fourth phase, since the land must be recontoured for any future use. Therefore, only the fourth phase will be examined with regards to revegetation to pasture for range cattle.

Establishment of vegetation upon a stripmined area begins upon completion of recontouring and topsoiling. The various types of species seeded and the method used to seed the species change the cost involved in revegetation. Some of the costs may be a direct result of limits imposed by U.S. Public Law 95-87 and State laws and regulations specifying the method of revegetation and types of plant species. Montana Code states that the operator (the party reclaiming the area)

shall prepare the soil and plant such legumes, grasses, shrubs, and trees as are necessary to establish on the regraded areas and all other lands affected a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area except that introduced species may be used in the revegetation process where desirable and necessary to achieve the approved postmining land use plan.³

Each mine's plan, on file with the Montana Department of State Lands, tells what the vegetative cover will be and the method by which it will be achieved.

In order that the land may be reclaimed to a more usable state, this study will maximize benefits net of revegetation costs received. The reestablished vegetation will be used as forage material for range cattle. This will involve:

(1) estimating the grass species mixture which will maximize the present value of returns generated by use as forage for cattle grazing.

(2) finding the optimal level of revegetation and the stocking rate.

NEED FOR THE PROJECT

Presently, revegetation research has not looked at the alternative vegetative uses of the stripmined site. Revegetation to a more desirable ground cover for future users would enable coal mining companies to improve relations with ranchers and at the same time return the land to non-mining uses. It has been shown that a vegetative cover can be established with relative

success.⁴ The study will help meet the need to show what seed mixtures should be planted. If the optimal vegetative cover is established initially it will lessen the possibility of a costly change in vegetation in the near future.

OBJECTIVES OF THE PROJECT

This study will attempt to assist companies and the state to improve revegetation by:

(1) Identifying and determining the amounts of seed, labor, machinery, the seed mixture, and the number of machine passes needed in order to provide the forage necessary to meet the nutritional requirements of range cattle and still meet the standards allowable under applicable laws and regulations;

(2) Calculating the benefits received by using the dollar value for the AUM's per acre for the value of forage as feed for range cattle.

PROCEDURE OF THE PROJECT

In order to calculate the return on a reclaimed site the following procedure will be used:

A) Identify feasible types of vegetative cover, method of seeding (including machinery types and costs), and the cost or rental value per AUM per acre.

B) Calculate the net present value for revegetation activities:

1) Compute the cost associated with revegetation. Costs per acre will be based on 1982 data. This will be done for mining sites similar to the Peabody, Western Energy, and Decker Coal Mines in eastern Montana. Prices were obtained from various seed and implement dealers.

2) Compute the benefit derived as forage for range cattle. Benefits will be calculated from the revegetated area's pasture rental value for range cattle. This will determine the value of the reclaimed-revegetated site in present value terms, under an infinite horizon.

C) Determine the combinations of activities with the highest net present value as indicated by linear programming.

There will be full year pasture and seasonal pasture models in the study. The grazing will take place for 269 days of the year broken down into segments of ninety-two, eighty-eight, and eighty-nine days for the seasonal pastures. Therefore grazing will be possible for most of the year on a revegetated site. Hay will be feed for the remainder of the year.

RECLAMATION BACKGROUND

As coal becomes a more prevalent energy source more lands will need to be reclaimed because of stripmining for coal. Stripmining is presently the most economical method of removing coal from the ground (except in deep or sloping deposits) and, of all methods, the safest.⁵ After mining, the spoils site is to be reclaimed to remove or reduce any scars upon the land, but primarily for the preservation of the renewable soil resource. This is in essence the reason for Public Law 95-87 as passed by the United States Congress and the prior Montana Stripmining and Reclamation Act.⁶

According to a Bureau of Mines study, the greatest cost incurred in stripmining is derived from the first

three phases (refer to page 1) and only about 2-7% of total cost is for revegetation.⁷ Though revegetation is not a major portion of the total cost it may be the most important portion because of its future benefit for the renewable soil resource, high visibility to all parties, and the amount of variation allowed by law.

The revegetation process begins when a site is selected as a potential mine location. State law requires that revegetation plans be submitted to the Department of State Lands with the mine permit application, prior to the commencement of mining. State law further requires a performance bond to be forfeited if the mining site is not reclaimed to conform to current regulations.⁸ The length of the bonding period is ten years after completion of revegetation. The required paper work takes time, but is designed to ensure that work will be done which results in a site that approximates or improves upon the original state.⁹

Backfilling and grading is time consuming and the most costly of the first three phases of reclamation, according to a Bureau of Mines study in 1977.¹⁰ In this

particular phase the land is recontoured to the approximate original topography unless the mining company is granted a variance due to special circumstances as recognized by the Montana Department of State Lands. Once recontouring is completed the revegetation phase will commence. This study will examine sites that have been reclaimed to a grade of no more than seven percent.

All reclamation-revegetation falls under the jurisdiction of state and federal laws.¹¹ State law takes primacy over Federal law when the State's regulatory program is approved (for being at least as stringent as Federal law) by the United States Department of Interior. In addition to requiring recontouring of stripmined land, Montana law also stipulates the general types of vegetation permitted.¹² Seeded vegetation must be composed primarily of native species with provision for inclusion of other species for special use pastures. These special use pastures must also be approved by the state.

REVEGETATION REVIEW

Most reclamation-revegetation research concentrates on technical methods used to reclaim stripmined lands. There is little literature currently available on the benefits from revegetation of stripmined lands. Steve Young of the Montana State University Reclamation Unit is conducting research on plant response, and grazing effects on stripmine revegetation. Ron Ries of Mandan, North Dakota is currently in the fifth year of a ten year study measuring the effects of grazing on stripmine spoils.¹³ Data on plant dry matter production is very limited and data on compatability among plants and the effect upon growth is even more limited.

There are two general categories of grasses: cool-season and warm-season grasses. The warm-season grasses are harder to establish and maintain than the cool-season grasses.¹⁴ The cool-season grasses are generally used to establish the original ground cover. This provides for a stabilization of the soil and reduces erosion of the redistributed topsoil.¹⁵

Once the soil is stabilized, warm-season grasses which seem to grow more slowly will have a chance to become established. A balance between warm-season and cool-season grasses is implied by Montana's Stripmining and Reclamation Act in order to provide a diverse groundcover capable of regeneration and seasonal growth. The act requires that a primarily native species seed mixture (fifty-one percent or more of the actual productivity) be used in the reclamation of the mine spoil site.¹⁶

The following is a partial list of seeds currently used in reclamation programs:

Thickspike Wheatgrass	Russian Wildrye
Streambank Wheatgrass	Common Buffalograss
Western Wheatgrass	Smooth Brome
Beardless Wheatgrass	Mountain Brome
Slender Wheatgrass	Regar Brome
Pubescent Wheatgrass	Canada Wildrye
Whitman Wheatgrass	Creeping Wildrye
Tall Wheatgrass	Alkali Bluegrass
Crested Wheatgrass	Green Needlegrass
Kentucky Bluegrass	Western Yarrow
Sideoats Grama(+)	Canada Bluegrass
Blue Grama(+)	Alfalfa Medic
Blue Flax	Purple Prairie Clover
Cicer Milkvetch	White Prairie Clover
Prairie Sandreed(+)	Eski Sainfoin
Indian Rice Grass	Switchgrass
Alkali Sakaton(+)	Prairie Cordgrass(+)
Sand Dropseed(+)	Big Bluestem(+)

Weeping Lovegrass(+)
Fourwing Saltbrush
Lewis Flax
Prairie Coneflower

Sand Bluestem(+)
Needle and Thread
Winterfat

These seeds are both warm-season(+) and cool-season grasses. The list of seeds used comes from revegetation plans on file with the Montana Department of State Lands.

Edward J. DePuit showed in his study that forage from the mine site at Colstrip is higher in nutritional value on a dry weight basis during the spring grazing period, than at other times.¹⁷ In his study cattle on mine spoils were able to gain more weight than those grazed on nearby native pasture. Ron Ries at the USDA office in Mandan, North Dakota is also doing studies on cattle weight gain on mine spoils with control plots of native range.¹⁸

Soil variability appears to have little influence upon the nutritional value of forage grown throughout a certain reclamation area. The soil seems to be sufficiently mixed during the mining process to remove variability in its composition.¹⁹ Previous studies showed that the nutritional content appeared constant over a mine spoils site whether the revegetative area was

new, two years old, or fifty years old.²⁰ This permitted the assumption that plant response will be the same throughout the revegetated area. Nutritional value of forage will be assumed to not vary in a planted area.

CHAPTER 2

DEVELOPMENT OF THE MODEL

PROGRAMMING MODEL

Linear programming is the method that will be used to calculate net returns in this study. A budgeting method can not be used because maximum and minimum variables are utilized. The problem does not use any time series data that were not able to be transformed into present value terms. Thus dynamic programming could have been used but was not necessary. Linear programming is the simpler of the two programming techniques to use on this problem.

Linear programming is a mathematical tool used to find an optimal solution to a problem with a linear objective function and linear constraints. These constraints specify maximum or minimum levels for certain variables and linear combinations of variables and precise levels for other variables and combinations. Then through an iterative process the best solution to the problem which satisfies the constraints is found.

The constraints on the linear program are designed to ensure that the vegetation chosen meets the needs of range cattle forage production. The following alternatives will be looked at:

1) Plant the acreage such that there are three separate pastures that may be used over a year. This type of planting will require a special use permit (see figure 1).

2) Plant the acreage so one pasture supplies all the needs for a full year and meets the requirements of a full season pasture as specified in the current regulations (see figure 2).

These two alternatives also have two subparts for each:

a) Plant seed mixtures that are primarily composed of native grass species,

b) Plant seed mixtures in any proportion regardless of whether the species are introduced or native species. If the results are introduced species of fifty percent or greater proportion, then a special permit is required as a variance from existing regulations.

Spring Pasture March 16 - June 15
Summer Pasture June 16 - September 13
Fall Pasture September 14 - December 9

Figure 1. Seasonal Pasture

Full Year Pasture March 16 - December 9
--

Figure 2. Full Year Pasture

Four models will be developed from the alternatives stated above. The first model is seasonal pasture, the second model is seasonal pasture with the native seed constraint, the third model is full year pasture, and the fourth model is full year pasture with the native seed constraint. They will all have the general objective function form:

$$Z = B - C$$

Where Z is the return derived from subtracting the costs (C) from the benefits (B). The values in the objective function are a dollar value for a particular activity. The linear program computes the return in a model from the amount of a particular activity times the dollar value of that activity per unit.

The benefits in this study are evaluated in terms of present value of the rental stream for the AUM (animal unit month) per period.

$$B = \sum \text{AUM rentals (discounted)}$$

By summing the present value of AUM rentals one arrives at the value of the benefits. Thus the only way to increase the benefits is to either increase the value of

the AUM or increase the number of AUM's. Since we are assuming a fixed value of the AUM per period, the stocking rate of the AUM (the number of AUM's per acre) is the only variable that can change.

The costs in the study are the summation of all variable costs costs incurred. Only variable costs are counted because fixed costs are not affected by the levels of the activities.

$$C = \sum \text{Cost of activity}_i$$

The variable costs are the costs of seed and the number of machine passes to plant the site. In order to keep from adding the nutritional value and dry matter amounts across seasons in the models (due to limitations of linear programming and thereby double counting the forage), the seeding costs are separated for each of the three nutritional requirement seasons.

The first model to be derived, which has seasonal pastures and no constraint on the native or non-native seeds, has the fewest actual constraints. The remaining three models include additional constraints.

The first constraints on the model are dietary constraints. These dietary constraints are broken down into requirements for three periods of the year. This is to ensure proper nutrition for the AUM.

The first of these dietary constraints are dry matter(DM) constraints on the maximum and minimum amounts of forage intake. These will regulate the actual weight of the forage material that is consumed by the AUM. The second set of dietary constraints is on the amount of digestible protein(DP) intake, and the third is on the metabolizable energy(ME) intake. These two constraints are necessary to make sure the AUM has the proper nutrient levels.

The next type of constraint is on the acreage. It will be assumed for computational purposes that one acre is being planted and that forage on this acre will meet the needs of a yet to be determined portion of the AUM during the periods under consideration. This makes the model useful for any number of acres as it is on a per acre basis.

In order to keep the number of animals constant throughout the year the value of the AUM increases. This is accounted for in equality constraints which reflect the aging and increase in size and weight of the animals that comprise the AUM. The AUM is then calculated using a herd size and the needs for the herd over a period of time.

The final constraint in the first model is the constraint on the number of machine passes. The initial planting may require more than one pass of the Brillion packer seeder in order to plant the seed mixture. The Brillion packer seeder has two boxes, one will contain the seed mixture and the other will contain fertilizer. Due to differences in the size of the seeds, the seeds will be broken into two groups. Only one group will be able to be planted in a pass, therefore a maximum of two passes may be necessary.

Each pass will be assumed to be made over the entire acreage. A fractional pass was not allowed, and the seed mixture planted was evenly distributed over the acreage. This requirement is necessary for the even distribution

of the seed and is the generally accepted method of planting a seed mixture. This necessitates the use of an integer constraint on the pass activities, so as to make a whole pass over the acreage.

The second model will have all the previous constraints with an additional constraint for the seeding of primarily native grass species. This constraint is used in order to meet one of the two governmental regulations on revegetating a stripmine site.

The third model incorporates the second governmental regulation of planting a site that will provide forage for the AUM on a yearly basis. The method by which this model and the the fourth model make a full year pasture is by equating the seeding requirements for the seasonal pastures. This model does not include the seed constraint the second model incorporated.

The fourth model incorporates the native seeding requirement as does the second model and also the full year requirements of the third model. This is the most restrictive model in that it incorporates both government

regulations. In terms of constraints it is also the most restrictive model.

Since the bonding period is ten years and the grasses in the study are relatively long lived one will not have to worry about a second reseeding in the near future. This will allow for evaluation of the forage on a one time planting horizon. The grass's yield of dry matter will also be considered constant over the ten year period (as more data becomes available this assumption may be changed in future studies as well as incorporating risk).

CHAPTER 3

DEVELOPMENT OF THE COEFFICIENTS AND THE ACTUAL MODEL

SEEDING OF SITE

In seeding a reclaimed area a 110 hp. tractor is used to pull a Brillion packer seeder. Certain of the seeds may be planted together in one pass of the Brillion packer seeder. However, due to size differences the seeds to be used in this study will be broken down into two groups for planting. This will make at most two passes of the Brillion necessary to plant the area. All the seeds planted in a pass will be planted at the same depth in the soil. Germination of a certain seed will be assumed constant throughout any acreage that is planted.

The Brillion packer seeder is twelve feet long and is tractor pulled and is assumed to have an efficiency of seventy percent. The formula used to compute acres per hour is:

$$\text{acres per hour} = \frac{\text{mph} * \text{width of coverage} * .70}{8.25}$$

Using this formula all grasses are planted by the Brillion seeder at a rate of 4.07 acres/hour. The 8.25

is computed by dividing the square feet in an acre by the number of feet in a mile. The rate of pull for the tractor has been assumed at four miles per hour for seeding.

USE OF RANGE CATTLE AS A DATA BASE

Vegetation growth on reclaimed land will be evaluated as forage for range cattle since this is the primary use of range land in Southeastern Montana. The mine site will be grazed by a standardized herd with a stocking rate to be chosen by the optimization process. The standardized AUM used will be computed assuming the following proportions in the herd. For every 100 cows there will be twenty-four replacement heifers, eighty-four calves (forty-two steers and forty-two heifer calves), and four bulls. All calves will be assumed to be born on March 16 and will have a birth weight of seventy-five pounds (Table 1). Calves will be sold on November 1st with a finishing weight of 420 pounds.

The weight of the cattle will be assumed at 1100 pounds for the cows, 783 pounds finishing weight for the

Table 1. Grazing Periods

	Days of Nutritional Requirement	Total Days in Period
PERIOD 1 March 16		92
Cows, bulls, heifers	92	
Heifer calves, steer calves	76	
PERIOD 2 June 16		88
Cows, bulls, heifers	88	
Heifer calves, steer calves	88	
PERIOD 3 September 13		89
Cows, bulls, heifers	89	
Heifer calves, steer calves	50	
All calves born March 16		
Start Foraging April 1		
Sold November 1		

replacement heifers, 420 pounds finishing weight for the calves, and 1764 pounds for the bulls. The calves will be assumed to make a gain of 1.5 pounds per day and the replacement heifers a gain of 1.1 pounds per day. The cows and bulls will be assumed to be on a maintenance diet with no increase in gain.

FORAGE VALUE FOR RANGE CATTLE

The types of vegetation to be used in the study are crested wheatgrass, beardless wheatgrass, intermediate wheatgrass, pubescent wheatgrass, tall wheatgrass, green needlegrass, mountain brome, smooth brome and russian wildrye (Tables 2,3,4,5). These were chosen because of data available as to their nutritional value and dry matter production at different times of the growing season. Beardless wheatgrass, green needlegrass, and mountain brome are the native grasses in this study. No attempt was made at determining the effects of interactions on dry matter production as compatibility data was not available.

The useable forage yield data were reduced to two-thirds of the initial value to allow for soil compaction

Table 2. Seed Cost and Rate of Application

NAME	COST* (\$)	APPLICATION** RATE (LBS/AC.)	COST/AC. (\$)
CRESTED WHEATGRASS (AGROPYRON CRISTATUM)	1.04	4.4	4.58
TALL WHEATGRASS (AGROPYRON ELONGATUM)	1.10	11.0	12.10
INTERMEDIATE WHEATGRASS (AGROPYRON INTERMEDIUM)	1.88	9.4	17.67
PUBESCENT WHEATGRASS (AGROPYRON TRICHOPHORUM)	1.65	9.7	16.01
BEARDLESS WHEATGRASS (AGROPYRON INERME)	6.55	6.1	39.96
MOUNTAIN BROME (BROMUS CARINATUS)	4.30	12.4	53.32
SMOOTH BROME (BROMUS INERMIS)	.70	6.0	4.20
GREEN NEEDLEGRASS (STIPA VIRIDULA)	7.50	4.8	36.00
RUSSIAN WILD RYE (ELYMUS JUNECEUS)	.78	5.0	3.90

* Seed prices came from Big Sky Seeds, Jacklin Seeds, and Buffalo Brand Seeds in Spring of 1982.

** maximum application rate when planted alone.

Larson, John E., Revegetation Equipment (Missoula, Montana, February 1980)

Table 3. Nutritional Requirements for the AUM

	Minimum Dry Matter (lbs.)	Maximum Dry Matter (lbs.)	Minimum Digestible Protein (lbs.)	Minimum Metabolize Energy (lbs.)
Period 1 (Spring-92 days)	2411.20	3402.12	139.82	2244.65
Period 2 (Summer-88 days)	1965.96	3236.23	87.32	1810.10
Period 3 (Fall-89 days)	1616.10	2808.34	70.34	1597.12

Table 4. Metabolizable Energy Available ¹

Name	Period 1	Period 2	Period 3
CRESTED WHEATGRASS	1119.67		
TALL WHEATGRASS	968.67	946.00	750.00
INTERMEDIATE WHEATGRASS	931.34	1002.00	802.00
PUBESCENT WHEATGRASS	1029.67	799.00	750.00
BEARDLESS WHEATGRASS	1175.00	947.50	800.00
MOUNTAIN BROME	1616.00	1312.00	
SMOOTH BROME	1860.50	1634.00	1010.00
GREEN NEEDLEGRASS	1250.00	1072.50	995.00
RUSSIAN WILDRYE	960.00	875.00	820.00

Blank Spaces denote those seasons when grass is not to be used due to palatability for range cattle.

¹ Cook, C. Wayne, R. Dennis Child, Larry L. Larson Digestible Protein in Range Forages as an Index to Nutrient Content and Animal Response (Colorado State University Range Science Department, December 1977).

Table 5. Digestible Protein Available¹

Name	Period 1	Period 2	Period 3
CRESTED WHEATGRASS	83.84		
TALL WHEATGRASS	30.03	49.73	38.35
INTERMEDIATE WHEATGRASS	47.28	104.07	70.59
PUBESCENT WHEATGRASS	40.75	50.72	34.99
BEARDLESS WHEATGRASS	37.44	32.92	19.82
MOUNTAIN BROME	60.22	57.44	
SMOOTH BROME	50.78	46.10	23.45
GREEN NEEDLEGRASS	32.40	52.43	34.01
RUSSIAN WILD RYE	36.19	51.48	13.89

Blank Spaces denote those seasons when grass is not to be used due to palatability for range cattle.

¹ Cook, C. Wayne, R. Dennis Child, Larry L. Larson Digestible Protein in Range Forages as an Index to Nutrient Content and Animal Response (Colorado State University Range Science Department, December 1977).

and sporadic grazing of the site (Table 6).²¹ A coverage of 400 pounds of fertilizer (11-52-0 or 11-55-0) per acre was assumed, this will act as an enricher for the surface soil that has been depleted while in storage.

THE OBJECTIVE FUNCTION AND ACTIVITIES

The maximization of the returns of an AUM will be made in per acre terms. The value of the AUM will be looked upon as a rental value assigned to the use of the pasture (Table 7). The AUM is based on a herd of 212 animals and the needs of such as if it were just one animal. The value of an AUM of carrying capacity used is the present value, with an infinite horizon, of annual AUM rental.

The costs will be those associated with planting seed upon an acre. The costs to be included in the pass are those costs that are variable to a pass (ie. maintenance, fuel, etc.)(Table 8). The ownership costs of the equipment used is not variable as it is used in each pass regardless of the number of passes, and these fixed costs will be spread over a large acreage and

Table 6. Yield of Grasses in Pounds per Acre*

SEED	ORIGINAL			*	TRANSFORMED		
	6/15	8/1	10/1		6/15	8/1	10/1
CRESTED WHEAT	1327.42			*	876.09		
TALL WHEAT	491.42	1506.91	1351.40	*	324.34	994.56	891.92
INTERMEDIATE WHEAT	1090.41	2463.78	1980.76	*	719.67	1626.09	1307.30
PUBESCENT WHEAT	756.62	2022.43	1656.67	*	499.37	1334.80	1093.40
BEARDLESS WHEAT	573.06	1336.17	1201.25	*	378.22	881.87	792.83
MOUNTAIN BROME	912.42	1611.74		*	602.20	1063.75	
SMOOTH BROME	1012.29	1727.73	1184.19	*	668.11	1140.30	781.57
GREEN NEEDLEGRASS	711.47	1588.87	1610.23	*	469.57	1048.65	1062.75
RUSSIAN WILDRYE	676.99	1238.17	701.32	*	446.81	817.19	462.87

Blank spaces denote those seasons when grass is not to be used due to palatability for range cattle. Data is transformed to two-thirds of the original data

* "Yield, Crude Protein, and Palatability of Dryland Grasses in Central Montana" (Montana Agricultural Experiment Station, June 1966)

Table 7. Rental Rate on Pasturing Cattle Adjusted to Grazing Period
in Present Value Terms

Mean adjusted pasture rental rate = \$9.82

Grazing Period	Period Rental	Present Value Rental
Period 1 (92 days)	\$30.11	\$1490.59
Period 2 (88 days)	28.21	1426.24
Period 3 (89 days)	29.13	1442.08

Period Rental
Mean Real Interest Rate* = Present Value Rental with infinite discount horizon

* See Appendix A part 2 for preliminary figures.

Table 8. Estimated per Acre Variable Machinery Cost*

Activity	Fuel & Lub. Cost/ac.	Repair Cost/ac.	Labor cost/ac.	Variable Activity Cost/ac.
Seeding and Fertilizing Pass 1	1.81	1.99	1.56	5.36
Seeding and Fertilizing Pass 2	1.81	1.99	1.56	5.36

* See Appendix A Part 2 for preliminary figures.

several years. These costs will be discussed in the final analysis to explain the relative profit or loss. Whether it is a seasonal pasture or not effects the actual number of activities, not the type. A full season pasture effectively requires one activity per seed while the set of three seasonal pastures (ie. spring, summer, fall) requires one activity per seed for each season.

The price of the seeds is in dollars per acre. The value is determined by multiplying the amount of seed per acre by the cost of a pound of pure live seed.

The two objective functions are respectively:

A) FULL SEASON PASTURE: Returns = - 4.58CWG1 - 12.10TWG1 - 17.67IWG1 - 16.01PWG1 - 39.96BWG1 - 53.32MB1 - 4.20SB1 - 36.00GN1 - 3.90RW1 - 4.58CWG2 - 12.10TWG2 - 17.67IWG2 - 16.01PWG2 - 39.96BWG2 - 53.32MB2 - 4.20SB2 - 36.00GN2 - 3.90RW2 - 4.58CWG3 - 12.10TWG3 - 17.67IWG3 - 16.01PWG3 - 39.96BWG3 - 53.32MB3 - 4.20SB3 - 36.00GN3 - 3.90RW3 + 1490.59A1 + 1426.24A2 + 1442.23A3 - 5.36PASS1 - 5.36PASS2

B) SEASONAL PASTURE: Returns = - 4.58CWG1 - 12.10TWG1 - 17.67IWG1 - 16.01PWG1 - 39.96BWG1 - 53.32MB1

- 4.20SB1 - 36.00GN1 - 3.90RW1 - 4.58CWG2 - 12.10TWG2 -
 17.67IWG2 - 16.01PWG2 - 39.96BWG2 - 53.32MB2 - 4.20SB2 -
 36.00GN2 - 3.90RW2 - 4.58CWG3 - 12.10TWG3 - 17.67IWG3 -
 16.01PWG3 - 39.96BWG3 - 53.32MB3 - 4.20SB3 - 36.00GN3 -
 3.90RW3 + 1490.59A1 + 1426.24A2 + 1442.23A3 - 5.36PASS1.1
 - 5.36PASS2.1 - 5.36PASS1.2 - 5.36PASS2.2 - 5.36PASS1.3 -
 5.36PASS2.3.

CWG = Crested wheatgrass TWG = Tall wheatgrass
 IWG = Intermediate wheatgrass PWG = Pubescent wheatgrass
 BWG = Beardless wheatgrass MB = Mountain Brome
 SB = Smooth Brome GN = Green needlegrass
 RW = Russian Wildrye
 A1 = AUM's required period 1
 A2 = AUM's required period 2
 A3 = AUM's required period 3
 PASS1(.x) = Cost per pass in x seasonal period (either
 1, 2, 3, or blank for full season)

In order to meet the needs of the range cattle AUM
 the following constraints must be met:

1) DM MAX SPG : 0 > 876.09CWG1 + 324.34TWG1 +
 719.67IWG1 + 499.37PWG1 + 378.22BWG1 + 602.20MB1 +
 668.11SB1 + 469.57GN1 + 446.81RW1 - 3402.12A1.

2) DM MIN SPG : 0 < - 876.09CWG1 - 324.34TWG1 -
 719.67IWG1 - 499.37PWG1 - 378.22BWG1 - 602.20MB1 -
 668.11SB1 - 469.57GN1 - 446.81RW1 + 2411.20A1.

3) DM MAX SUM : 0 > 994.56TWG2 + 1626.09IWG2 +
1334.80PWG2 + 881.87BWG2 + 1063.75MB2 + 1140.30SB2 +
1048.65GN2 + 817.19RW2 - 3236.23A2.

4) DM MIN SUM : 0 > - 994.56TWG2 - 1626.09IWG2 -
1334.80PWG2 - 881.87BWG2 - 1063.75MB2 - 1140.30SB2 -
1048.65GN2 - 817.19RW2 + 1965.96A2.

5) DM MAX FALL : 0 > 891.92TWG3 + 1307.30IWG3 +
1093.40PWG3 + 792.83BWG3 + 781.57SB3 + 1062.75GN3 +
462.87RW3 - 2808.34A3.

6) DM MIN FALL : 0 < - 891.92TWG3 - 1307.30IWG3 -
1093.40PWG3 - 792.83BWG3 - 781.57SB3 - 1062.75GN3 -
462.87RW3 + 1616.10A3.

The amount of daily forage that cattle can intake is limited, it is generally in proportion to the body weight of the animal. The dry matter daily maximum is figured at three percent of the body weight and is multiplied by the number of days in the period to arrive at the restriction on maximum forage intake. The dry matter minimum on the other hand is the amount that range cattle must intake to meet minimal existence requirements. This varies for different animals and for different weight

gain requirements. Requirements for the breeding cows were calculated using the first quarter as the nursing period, the second quarter as the middle portion of pregnancy, and the third quarter as part of the last portion of pregnancy. The calves were assumed to start consuming forage on the first of April and stop consuming on the first of November (the sale date).

7) DP MIN SPG : 0 < - 83.84CWG1 - 30.03TWG1 - 47.28IWG1 - 40.75PWG1 - 37.44BWG1 - 60.22MB1 - 50.78SB1 - 32.40GN1 - 36.19RW1 + 139.82A1.

8) DP MIN SUM : 0 < - 49.73TWG2 - 104.07IWG2 - 50.72PWG2 - 32.92BWG2 - 57.44MB2 - 46.18SB2 - 52.43GN2 - 51.48RW2 + 87.32A2.

9) DP MIN FALL : 0 < - 38.35TWG3 - 70.59IWG3 - 34.99PWG3 - 19.82BWG3 - 23.45SB3 - 34.01GN3 - 13.89RW3 + 70.34A3.

The digestible protein constraint is necessary to make sure the AUM has enough usable protein available. The digestible protein minimum must be met prior to meeting the dry matter maximum in order for the cattle to be properly nourished.

10) ME MIN SPG : 0 < - 1119.67CWG1 - 968.67TWG1 -
 931.34IWG1 - 1029.67PWG1 - 1175.00BWG1 - 1616.00MB1 -
 1860.50SB1 - 1250.00GN1 - 960.00RW1 + 2244.65A1.

11) ME MIN SUM : 0 < - 946.00TWG2 - 1002.00IWG2 -
 799.00PWG2 - 947.50BWG2 - 1312.00MB2 - 1634.00SB2 -
 1072.50GN2 - 875.00RW2 + 1810.10A2.

12) ME MIN FALL : 0 < - 750.00TWG3 - 802.00IWG3 -
 750.00PWG3 - 800.00BWG3 - 1010.00SB3 - 995.00GN3 -
 820.00RW3 + 1597.1A3.

The metabolizable energy, like the digestible protein, must also be met prior to reaching the maximum dry matter, in order for proper nutrition.

13) 1 ACRE RESTRICTION : 1 = 1CWG + 1TWG + 1IWG +
 1PWG + 1BWG + 1MB + 1SB + 1GN + 1RW.

A one acre restriction was placed upon the problem so that all calculations are made on a per acre basis. This allows the AUM's to vary in order to check the proportion of an AUM that one acre will feed.

A pass constraint is necessary to limit which seeds will be planted in each pass. Certain seeds may be planted together while others may not due to separation

of the seed in the boxes and the inability of the seeder to handle different sizes of seeds. The planting of green needlegrass is separate from all others due to size and weight differences, all of the other seeds in this study may be planted in the same pass.²²

The pass constraint must be an integer constraint in order to ensure that the seeds from the two passes will be planted over the same area in the pasture. In the case of both the seasonal pasture and the full year pasture, if the seed mixture contains the two different groups, the two passes must be over the same amount of the acre. To satisfy the necessary integer constraints Hurt's integer programming model was used.

The use of a seed constraint is necessary in two of the models in order to meet the provision in the regulations that the majority of the productivity be native species. The native seeds in this study are beardless wheatgrass, mountain brome, and green needlegrass. The following equation is utilized to meet this requirement:

$$\frac{BWGx + MBx + GNx}{CWGx + TWGx + IWGx + PWGx + SBx + RWx} \geq 0.51$$

Table 9. Calculation of the Proportion of the AUM per Period

Animal	# of Animals	AUM Factor	Total
Cow	100	1.0	100.00
Heifer	24	.7	16.80
Bull	4	1.5	6.00
ALL Calves:			
Period 1	84	.1	8.40
Period 2	84	.2	16.80
Period 3	84	.3	25.20

Grazing Period	Total for Period	Percentage of Period 3
Period 1	131.20	89
Period 2	139.60	94
Period 3	148.00	100

This equation is utilized in the model in the form:

$$0 > 0.51CWGx + 0.51TWGx + 0.51IWGx + 0.51PWGx - 0.49BWGx - 0.49MBx + 0.51SBx - 0.49GNx + 0.51RWx.$$

These grasses are multiplied by the amount(x) of dry matter) produced in each season.

An additional constraint that was necessary was to make the AUM proportional throughout the year. As the calves and heifers age the AUM requirement increases numerically. Therefore one must have increasing AUM's, but the increase does not affect the number of animals composing the AUM which remains the same (Table 9).

The two models for the full year pasture required a set of constraints to make the seed distribution the same over all of the acre (see Appendix B). This was done by modifying the seasonal pasture model and requiring the amount of each seed to be the same in each portion of the pasture. This requirement effectively translates into planting the entire pasture the same and removing the seasonality of the pasture.

Looking at the matrix (Table 10) for a seasonal pasture with no restriction on whether or not to plant

Table 10. Seasonal Pasture with No Seed Constraint

ROW	ACTIVITY NAME	ROW	ACTIVITY NAME
1	Objective Function	21	PASS TRF1-2
2	DM MIN SPG	22	PASS TRF2-1
3	DM MAX SPG	23	PASS TRF2-2
4	DM MIN SUM	24	PASS TRF3-1
5	DM MAX SUM	25	PASS TRF3-2
6	DM MIN FALL	26	PASS TRF4-1
7	DM MAX FALL	27	PASS TRF4-2
8	DP MIN SPG	28	PASS TRF5-1
9	DP MIN SUM	29	PASS TRF5-2
10	DP MIN FALL	30	PASS TRF6-1
11	ME MIN SPG	31	PASS TRF6-2
12	ME MIN SUM	32	D1 MAX
13	ME MIN FALL	33	D2 MAX
14	1 ACRE MAX	34	D3 MAX
15	1 ACRE MIN	35	D4 MAX
16	EQUALITY 1	36	D5 MAX
17	EQUALITY 2	37	D6 MAX
18	EQUALITY 3		
19	EQUALITY 4		
20	PASS TRF1-1		

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	RHS	CWGI	TWGI	IWGI	PWGI	BWGI	MBI	SBI
1	0.0	-4.58	-12.10	-17.67	-16.01	-39.96	-53.32	-4.20
2	0.0	-876.09	-324.34	-719.67	-499.37	-378.22	-602.20	-668.11
3	0.0	876.09	324.34	719.67	499.37	378.22	602.20	668.11
4	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.0	-83.84	-30.03	-47.28	-40.75	-37.44	-60.22	-50.78
9	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.0	-1119.67	-968.67	-931.34	-1029.67	-1175.00	-1616.00	-1860.50
12	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	-1.0	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
16	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	20.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	20.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	RHS	CWGI	TWGI	IWGI	PWGI	BWGI	MBI	SBI
31	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	GN1	RW1	CWG2	TWG2	IWG2	PWG2	BWG2	MB2
1	-36.00	-3.90	-4.58	-12.10	-17.67	-16.01	-39.96	-53.32
2	-469.57	-446.81	0.00	0.00	0.00	0.00	0.00	0.00
3	469.57	446.81	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	-994.56	-1626.09	-1334.80	-881.87	-1063.75
5	0.00	0.00	0.00	994.56	1626.09	1334.80	881.87	1063.75
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	-32.40	-36.19	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	-49.73	-104.07	-50.72	-32.92	-57.44
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	-1250.00	-960.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	-946.00	-1002.00	-799.00	-947.50	-1312.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
21	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
22	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
25	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	GN1	RW1	CWG2	TWG2	IWG2	PWG2	BWG2	MB2
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	SB2	GN2	RW2	CWG3	TWG3	IWG3	PWG3	BWG3
1	-4.20	-36.00	-3.90	-4.58	-12.10	-17.67	-16.01	-39.96
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	-1140.30	-1048.65	-817.19	0.00	0.00	0.00	0.00	0.00
5	1140.30	1048.65	817.19	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	-891.92	-1307.30	-1093.40	-792.30
7	0.00	0.00	0.00	0.00	891.92	1307.30	1093.40	792.30
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	-46.18	-52.43	-51.48	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	-38.35	-70.59	-34.99	-19.82
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	-1634.00	-1072.50	-875.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	-750.00	-802.00	-750.00	-800.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
25	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
26	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
27	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
29	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	SB2	GN2	RW2	CWG3	TWG3	IWG3	PWG3	BWG3
31	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	MB3	SB3	GN3	RW3	A1	A2	A3	DI
1	-53.32	-4.20	-36.00	-3.90	1490.59	1426.24	1442.08	0.00
2	0.00	0.00	0.00	0.00	2411.20	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	-3402.12	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	1965.96	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	-3236.25	0.00	0.00
6	0.00	-781.57	-1062.75	-462.87	0.00	0.00	1616.00	0.00
7	0.00	781.57	1062.75	462.87	0.00	0.00	1616.00	0.00
8	0.00	0.00	0.00	0.00	139.82	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	87.32	0.00	0.00
10	0.00	-23.45	-34.01	-13.89	0.00	0.00	70.34	0.00
11	0.00	0.00	0.00	0.00	2244.65	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	1810.10	0.00	0.00
13	0.00	-1010.00	-995.00	-820.00	0.00	0.00	1597.12	0.00
14	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
15	-1.00	-1.00	-1.00	-1.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	1.00	-0.94	0.00	0.00
17	0.00	0.00	0.00	0.00	-1.00	0.94	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.94	-0.89	0.00
19	0.00	0.00	0.00	0.00	0.00	-0.94	0.89	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-20.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
29	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
30	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	MB3	SB3	GN3	RW3	A1	A2	A3	D1
31	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	D2	D3	D4	D5	D6	P1-1	P1-2	P2-1
1	0.00	0.00	0.00	0.00	0.00	-5.36	-5.36	-5.36
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00
22	-20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	20.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00
24	0.00	-20.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	20.00	0.00	0.00	0.00	0.00	0.00	-1.00
26	0.00	0.00	-20.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	-20.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	-20.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	D2	D3	D4	D5	D6	P1-1	P1-2	P2-1
31	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	P2-2	P3-1	P3-2
1	-5.36	-5.36	-5.36
2	0.00	0.00	0.00
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	0.00	0.00	0.00
6	0.00	0.00	0.00
7	0.00	0.00	0.00
8	0.00	0.00	0.00
9	0.00	0.00	0.00
10	0.00	0.00	0.00
11	0.00	0.00	0.00
12	0.00	0.00	0.00
13	0.00	0.00	0.00
14	0.00	0.00	0.00
15	0.00	0.00	0.00
16	0.00	0.00	0.00
17	0.00	0.00	0.00
18	0.00	0.00	0.00
19	0.00	0.00	0.00
20	0.00	0.00	0.00
21	0.00	0.00	0.00
22	0.00	0.00	0.00
23	0.00	0.00	0.00
24	0.00	0.00	0.00
25	0.00	0.00	0.00
26	0.00	0.00	0.00
27	-1.00	0.00	0.00
28	0.00	0.00	0.00
29	0.00	-1.00	0.00
30	0.00	0.00	0.00

Table 10. Seasonal Pasture with No Seed Constraint (Continued)

	P2-2	P3-1	P3-2
31	0.00	0.00	-1.00
33	0.00	0.00	0.00
33	0.00	0.00	0.00
34	0.00	0.00	0.00
35	0.00	0.00	0.00
36	0.00	0.00	0.00
37	0.00	0.00	0.00

native grasses one can see how the previously discussed constraints are utilized. The objective function values (Equation B) are the first row of numbers. The numbers in the columns directly below are the effect of a particular constraint upon the activity. This problem is solved as a maximization problem so a greater than or equals sign is found preceding the right hand side value (actually the numbers in the first column). For example, the third row DM MAX SPG refers to equation 2 or the second constraint. The matrices for the remaining problems can be found in Appendix B.

CHAPTER 4

RESULTS OF THE MODEL

EMPIRICAL RESULTS

The results of this study are not wholly conclusive due to the lack of compatability data and lack of time series data on plant growth over a number of years. The results show the optimal solution obtainable for the nine grasses, maintaining the assumption that dry matter production is constant over the whole revegetated site. The objective function value only includes those portions of the cost that are variable. This maximized value does not include the fixed cost of machinery ownership or the cost of fertilizer. The main objective of this study was to find the optimal solutions with and without government restrictions.

The first model (Table 11) to be discussed is a seasonal pasture with no restriction on whether or not to plant native grasses. The objective has a maximum value of 737.35 dollars per acre. For the seasonal pastures the acre will be divided into three sections and the seed

Table 11. Model 1: Revegetation Analysis; Seasonal Pasture with no Seed Constraint

AMOUNT	PROBLEM BASIS ACTIVITY	NO. GOLD	OBJECTIVE FUNCTION = \$			NON-BASIS ACTIVITY	737.34836	SHADOW PRICE
			HIGH RANGE	LOW RANGE				
.446244442	2	CWG1	184.995	-158.061	3	TWG1	446.454	
.130788308	13	IWG2	255.974	-155.682	4	IWG1	137.527	
.110876237	17	SB2	182.792	-188.688	5	PWG1	311.122	
0.00000000	18	GN2	125.402	-239.575	6	BWG1	431.450	
.116587532	22	IWG3	119.940	-29.2802	7	MB1	266.628	
.195503481	26	SB3	437.907	-7.15052	8	SB1	165.074	
.162139305	29	A1	2012.34	-1012.56	9	GN1	176.318	
.172488623	30	A2	1916.69	464.195	10	RW1	340.825	
.182178995	31	A3	1906.44	1229.20	11	CWG2	636.180	
160.667081	303	DM MAX SPG	.526534	-.678954	12	TWG2	182.024	
219.107123	305	DM MAX SUM	.386098	-.256363	14	PWG2	119.203	
10.7950623	306	DM MIN FALL	.161023E-01	-1.16875	15	BWG2	241.131	
206.406023	307	DM MAX FALL	1.95188	-.167967E-01	16	MB2	132.948	
14.7428163	308	DP MIN SPG	5.73817	-5.71710	19	RW2	237.223	
3.66969729	309	DP MIN SUM	3.49020	-3.30426	20	CWG3	588.143	
135.700523	311	ME MIN SPG	.169051	-4.44152	21	TWG3	105.014	
					23	PWG3	117.621	
					24	BWG3	154.744	
					25	MB3	636.883	
					27	GN3	2.39858	
					28	RW3	123.596	
					302	DM MIN SPG	.795530	
					304	DM MIN SUM	.279861	
					310	DP MIN FAL	2.58834	
					312	ME MIN SUM	.193803	
					313	ME MIN FALL	.521848	

Multiply "amount" by pounds of seed per acre to find pounds per acre of seed to plant.
 Divide "shadow price" by weight of seed per pound to find opportunity cost of non-basis seeds.

mixture that is planted on a section will be evenly distributed over that section. The seasonal pasture is divided into sections for spring, summer, and fall grazing periods.

The area planted for spring grazing in the first model is 44.62 percent of an acre planted with 1.96 pounds of crested wheatgrass. The area planted for summer grazing is 24.17 percent of an acre, this is seeded in a mixture of 1.23 pounds of intermediate wheatgrass and .67 pounds of smooth brome. The area planted for fall grazing is 31.21 percent of an acre, this was seeded in a mixture of 1.10 pounds of intermediate wheatgrass and 1.17 pounds of smooth brome.

This entire acre is planted with non native grasses and provides forage for .18 AUM's per acre. This value is calculated as the optimal amount of AUM's that the forage produced will be able to feed. Planting the seasonal pastures with no restriction to planting native seed would require a special use permit or possibly revision of current laws or regulations.

The next model (Table 12) to be observed is the seasonal pasture requiring the planting of a majority of native species. The second model has a maximum objective function value of 629.33 dollars per acre. This value is 108.02 dollars less than in the preceding model and can be attributed to the added requirement of planting native species.

The area planted for spring grazing is 48.99 percent of an acre, this is seeded with a mixture of 0.86 pounds of crested wheatgrass, 3.66 pounds of mountain brome, and 0.00001 pounds of green needlegrass. The area planted for summer grazing is 23.60 percent of an acre, this is seeded with a mixture of .86 pounds of intermediate wheatgrass, 1.80 pounds of mountain brome. The area planted for fall grazing is 27.41 percent of an acre, this is seeded with a mixture of .70 pounds of intermediate wheatgrass, .35 pounds of smooth brome, and .67 pounds of green needlegrass.

The acreage fulfills the native grass requirement of the regulations and provides forage for .16 AUM's per acre. This is a decrease from the first model of .02

Table 12. Model 2: Revegetation Analysis; Seasonal Pasture with Seed Constraint

AMOUNT	PROBLEM NO. GOLD	OBJECTIVE FUNCTION = \$ 629.32412			SHADOW PRICE
		BASIS ACTIVITY	HIGH RANGE	LOW RANGE	
.194860783	2 CWG1	497.819	-94.0037	3 TWG1	387.930
.295055274	7 MB1	24.7277	-114.647	4 IWG1	120.950
.272625334E-05	9 GN1	84.7051	-101.764	5 PWG1	261.137
.910630466E-01	13 IWG2	1057.38	-133.523	6 BWG1	229.459
.144884267	16 MB2	-45.8480	-74.7824	8 SB1	143.033
.163898798E-07	18 GN2	-14.6197	-43.3813	10 RW1	295.331
.743894021E-01	22 IWG3	-15.2975	-68.8145	11 CWG2	535.034
.406590586E-06	24 BWG3	91.5791	-258.528	12 TWG2	187.064
.591583555E-01	26 SB3	-3.59643	-17.2113	14 PWG2	96.6913
.140585722	27 GN3	-25.4146	-36.4910	15 BWG2	87.4252
.144492016	29 A1	2168.12	1369.99	17 SB2	90.0624
.153714911	30 A2	2063.12	1312.88	19 RW2	236.622
.162350580	31 A3	3343.73	1334.75	20 CWG3	536.981
143.180029	303 DM MAX SPG	.683739	-.121701	21 TWG3	99.6959
195.259440	305 DM MAX SUM	.501373	-.892411E-01	23 PWG3	114.718
30.5186872	306 DM MIN FALL	.710804E-01	-.329729E-02	25 MB3	585.721
163.042168	307 DM MAX FALL	.342266E-02	-.737821E-01	28 RW3	102.203
13.9025713	308 DP MIN SPG	3.75397	-1.27203	302 DM MIN SPG	.890776
4.37669843	309 DP MIN SUM	1.73399	-1.96692	304 DM MIN SUM	.387081
370.658499	311 ME MIN SPG	.155176	-.470293E-01	310 DP MIN FAL	2.53876
3.09398906	312 ME MIN SUM	.334116E-01	-.375055	313 ME MIN FALL	.500616
.321339332E-01	340 SEED CONS3	.107683E-01	-.499522E-03	338 SEED CONS1	.394556
				339 SEED CONS2	.172389
				341	2779.70

Multiply "amount" by pounds of seed per acre to find pounds per acre of seed to plant.
 Divide "shadow price" by weight of seed per pound to find opportunity cost of non-basis seeds.

AUM's per acre. While fulfilling the native species regulation this model does require the rotation of pasture and planting of areas for each season's use. This requires a special permit since it will not provide full year grazing of the area.

The third model (Table 13) is a full year pasture with no restriction on the planting of native species. The third model has a maximum objective function value of 474.38 dollars per acre. This value is 262.97 dollars lower than the first model and 154.95 dollars lower than in the second model and can be attributed to the requirement that the entire acre must provide forage over an entire year. This model does not include the restriction on planting native species as in the second model.

Each acre in this model is planted with a seed mixture of 1.73 pounds of crested wheatgrass, 2.13 pounds of intermediate wheatgrass, and 2.28 pounds of smooth brome. This will provide forage for an entire year's grazing by range cattle.

Table 13. Model 3: Revegetation Analysis; Full Year Pasture with no Seed Constraint

AMOUNT	PROBLEM BASIS ACTIVITY	NO. GOLD	OBJECTIVE FUNCTION = \$			SHADOW PRICE
			HIGH RANGE	LOW RANGE	NON-BASIS ACTIVITY	
					474.38014	
.130731580	2 CWG1		124.907	-103.800	12 TWG2	445.775
0.00000000	3 TWG1		433.675	-58.1648	14 PWG2	163.315
.756857370E-01	4 IWG1		7.97139	-209.647	15 BWG2	412.137
0.00000000	5 PWG1		147.305	-348.445	16 MB2	67.3955
0.00000000	6 BWG1		372.177	-147.523	18 GN2	242.105
0.00000000	7 MB1		14.0755	-518.985	19 RW2	226.264
.126916016	8 SB1		258.152	-36.7199	21 TWG3	226.200
0.00000000	9 GN1		206.105	-298.969	23 PWG3	231.771
0.00000000	10 RW1		222.364	-261.276	24 BWG3	246.778
.130731580	11 CWG2		124.907	-103.800	25 MB3	533.060
.756857370E-01	13 IWG2		7.97139	-209.647	27 GN3	166.359
.126916016	17 SB2		258.152	-36.7199	28 RW3	207.072
.130731580	20 CWG3		124.907	-103.800	302 DM MIN SPG	1.65846
.756857370E-01	22 IWG3		7.97139	-532.420	310 DP MIN FAL	.494511
.126916016	26 SB3		258.152	-36.7199	313 ME MIN FALL	.328901
.105256820	29 A1		9059.76	-1971.85		
.111975340	30 A2		8541.26	-1286.76		
.118266090	31 A3		8712.37	427.203		
104.301088	303 DM MAX SPG		7.63853	-1.22201		
47.6551132	304 DM MIN SUM		.355923E-01	-.120569		
94.5838023	305 DM MAX SUM		.125602	-.358032E-01		
7.00788701	306 DM MIN FALL		.374138E-01	-1.94294		
133.993676	307 DM MAX FALL		4.35745	-.376448E-01		
6.26674408	308 DP MIN SPG		10.6378	-2.34561		
3.95990956	309 DP MIN SUM		.380626	-1.87637		
216.727910	311 ME MIN SPG		.783822E-01	-.328944E-01		
80.5313152	312 ME MIN SUM		.511734E-01	-.845736E-01		

Multiply "amount" by pounds of seed per acre to find pounds per acre of seed to plant.
 Divide "shadow price" by weight of seed per pound to find opportunity cost of non-basis seeds.

This model fulfills the requirement of full year grazing and provides forage for .12 AUM's per acre for a year. This is a decrease of .06 AUM's per acre over the first model and a decrease of .04 AUM's per acre over the second model. This model still does not meet the government regulation for native species.

The fourth model (Table 14) is a full year pasture with the requirement of planting native species. This model has a maximum objective function value of 414.85 dollars per acre. This value is 322.50 dollars lower than in the first model, 214.48 dollars lower than in the second model, and 59.53 dollars lower than in the third model. This decreased value can be attributed to the combination of restrictions of a full year grazing pasture and native species requirements of government regulations.

Each acre in the fourth model is planted with a seed mixture of 2.01 pounds of crested wheatgrass, 1.19 pounds of intermediate wheatgrass, 0.20 pounds of smooth brome, and 1.84 pounds of green needlegrass.

This model fulfills both requirements of full year

Table 14. Model 4: Revegetation Analysis; Full Year Pasture with Seed Constraint

AMOUNT	PROBLEM NO. GOLD BASIS ACTIVITY	OBJECTIVE FUNCTION = \$ 414.85931			SHADOW PRICE
		HIGH RANGE	LOW RANGE	NON-BASIS ACTIVITY	
.152367500	2 CWG1	37.3806	-125.771	12 TWG2	470.794
0.00000000	3 TWG1	458.694	-51.6002	14 FWG2	239.320
.421682361E-01	4 IWG1	117.647	-56.4554	15 BWG2	238.783
0.00000000	5 PWG1	223.310	-310.321	19 RW2	260.091
0.00000000	6 BWG1	198.823	-184.900	21 TWG3	106.291
0.00000000	7 MB1	309.141	-138.355	23 PWG3	136.165
.111748168E-01	8 SB1	138.628	-39.2322	24 BWG3	29.1571
.127622781	9 GN1	94.2877	-98.4863	25 MB3	362.461
0.00000000	10 RW1	256.191	-229.730	28 RW3	102.905
.152367500	11 CWG2	37.3806	-125.771	302 DM MIN SPG	1.53734
.421682361E-01	13 IWG2	117.647	-56.4554	310 DP MIN FAL	2.43643
0.00000000	16 MB2	309.141	-138.355	313 ME MIN FALL	.382369
.111748168E-01	17 SB2	138.628	-39.2322	358 SEED NATIVE	.138493
.127622781	18 GN2	94.2877	-98.4863		
.152367500	20 CWG3	37.3806	-125.771		
.421682361E-01	22 IWG3	117.647	-303.467		
.111748168E-01	26 SB3	138.628	-76.1425		
.127622781	27 GN3	186.211	-98.4863		
.958977659E-01	29 A1	5442.98	-74.7153		
.102018900	30 A2	5141.49	-45.1469		
.107750299	31 A3	.100000E+10	686.345		
95.0270142	303 DM MAX SPG	3.98861	-1.14874		
14.5785433	304 DM MIN SUM	.700109E-01	-.234947E-01		
115.013005	305 DM MAX SUM	.239811E-01	-.689793E-01		
25.3562891	306 DM MIN FALL	.175053	-.687735		
103.107927	307 DM MAX FALL	1.01309	-.170188		
6.06221503	308 DP MIN SPG	1.90290	-5.51462		
2.68747343	309 DP MIN SUM	1.44602	-.357348		
174.936586	311 ME MIN SPG	.114274	-.289884E-01		
12.7232449	312 ME MIN SUM	.634183E-01	-.187690E-01		

Multiply "amount" by pounds of seed per acre to find pounds per acre of seed to plant.
 Divide "shadow price" by weight of seed per pound to find opportunity cost of non-basis seeds.

grazing and native species requirements while providing forage for .11 AUM's per acre. This is a decrease of .07 AUM's per acre over the first model, .05 AUM's per acre decrease over the second model, and .01 AUM's per acre decrease over the third model.

The previous tables are for the four models and the sensitivity analysis is interpreted by the high range and low range being the levels the price of the activity which would cause it to move out of the basis solution. For example in the fourth model (Table 14) to have green needlegrass move out of the basis solution the price of seed for an acre would have to increase from thirty-six dollars to ninety-eight and forty-nine hundredths dollars, a decrease to minus ninety-four and twenty-nine hundredths dollars would also change the activities that are presently in the optimal solution.

All models included crested wheatgrass as forage for spring grazing. Mountain brome was in the second model in the spring to meet the native grass requirement. However, crested wheatgrass is only palatable in the spring, and mountain brome is only palatable in the

spring and summer. Intermediate wheatgrass is planted in both seasonal models for summer and fall grazing. Smooth brome is used in the first model for summer grazing. The second model which has native grass requirements included mountain brome for summer and green needlegrass for fall to meet those requirements. The full year models both have crested wheatgrass, intermediate wheatgrass, and smooth brome. The fourth model (with the native grass requirement) also includes green needlegrass.

CHAPTER 5

CONCLUSIONS

The models presented in this thesis show the effect of full year grazing and native species regulations on the types of grasses planted on a revegetated stripmine site. Without these regulations and with the intent of providing the best possible forage situation for range cattle a seasonal pasture with no requirement as to native species seems to bring the best solution for the nine grasses in this study. The returns in present value terms are much lower when there are government regulations on species and the establishment of yearly grazing on a site; this is due to the high cost of native seed and the low nutritional value of these native species relative to their cost.

Equipment cost for use on the revegetated-reclaimed site would be incurred regardless of what seeds are planted (Table 15) or what the final goal may be. In disregarding these machinery costs (effects of possible changes in machinery not shown) one sees the effect on the actual value of the pasture with the cost of seeding per

Table 15. Ownership Cost for Machinery

Machine	Ownership * Cost/year
Tractor (110 Hp., Diesel)	4007.18
Packer Seeder (Brillion, 12')	702.16
Tandem Disc (12')	615.50
Chisel Plow (10')	566.26

* Computed from data in Stevens, Delwin M., Douglas E. Agee, Using Farm Machinery Efficiently, Bulletin 482, Agricultural Experiment Station, University of Wyoming, Laramie, Wyoming, December 1967

acre and the nutritional value provided by the forage produced for range cattle.

The major difference in the model's optimum return seemed to be from the inclusion of a requirement that the entire acreage planted must be capable of being a full year grazing site. Differences in management practices between seasonal and full year pastures may affect the size of this difference in net returns but are very unlikely to change its direction.

This thesis has also shown where further research is needed on the end use of a reclaimed-revegetated stripmine site. Further data is needed on forage plant production and particularly on the interactions between various species. As such data becomes available it can be incorporated into the model used here.

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REFERENCES CITED

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- 20 Ibid.
- 21 Personal interview with Myles Watts, Montana State University, July 1982
- 22 Personal interview with Loren E. Wiesner, Plant and Soil Science Department, Montana State University, August 1982

APPENDICES

APPENDIX A

Part 1
Nutritional Requirements of Cattle

Table 16. Nutritional Requirements for a 420 Pound Finish Weight Steer Calf Gaining 1.5 Pounds Per Day

	Minimum Dry Matter (lbs.)	Maximum Dry Matter (lbs.)	Minimum Digestible Protein (lbs.)	Minimum Metabolize Energy (lbs.)
Daily	11.84	12.60	0.83	12.35
Period 1 (Spring-76 days)	899.84	957.60	63.08	938.60
Period 2 (Summer-88 days)	1041.92	1108.80	73.04	1086.80
Period 3 (Fall-50 days)	592.00	630.00	41.50	617.50

Nutritional Requirements for forty-two 420 Pound Steer Calves				
Period 1	37793.28	40219.20	2649.36	39421.20
Period 2	43760.64	46569.60	3067.68	45645.60
Period 3	24864.00	26460.00	1743.00	25935.00

Table 17. Nutritional Requirements for a 420 Pound Finish Weight Heifer Calf Gaining 1.5 Pounds Per Day

	Minimum Dry Matter (lbs.)	Maximum Dry Matter (lbs.)	Minimum Digestible Protein (lbs.)	Minimum Metabolize Energy (lbs.)
Daily	12.36	12.60	0.83	12.35
Period 1 (Spring-76 days)	939.36	957.60	63.08	938.60
Period 2 (Summer-88 days)	1087.68	1108.80	73.04	1086.80
Period 3 (Fall-50 days)	618.00	630.00	41.50	617.50

Nutritional Requirements for forty-two Heifer Calves				
Period 1	39453.12	40219.20	2649.36	39421.20
Period 2	45682.56	46546.60	3067.68	45645.60
Period 3	25956.00	26460.00	1743.00	25935.00

Table 18. Nutritional Requirements for a 783 Pound Finish Weight Heifer Gaining 1.1 Pounds Per Day

	Minimum Dry Matter (lbs.)	Maximum Dry Matter (lbs.)	Minimum Digestible Protein (lbs.)	Minimum Metabolize Energy (lbs.)
Daily	17.58	23.49	0.95	18.42
Period 1 (Spring-92 days)	1336.08	1785.24	87.40	1694.64
Period 2 (Summer-88 days)	1547.04	2067.12	83.60	1620.96
Period 3 (Fall-89 days)	879.00	2090.61	84.55	1639.38

Nutritional Requirements for twenty-four Heifers				
Period 1	32065.9	42845.76	2097.60	40671.36
Period 2	37128.96	49610.80	2006.40	38903.04
Period 3	21096.00	50174.64	2029.20	39345.12

Table 19. Nutritional Requirements for a 1764 Pound Bull

	Minimum Dry Matter (lbs.)	Maximum Dry Matter (lbs.)	Minimum Digestible Protein (lbs.)	Minimum Metabolize Energy (lbs.)
Daily	23.10	52.92	0.50	21.00
Period 1 (Spring-92 days)	2125.20	4868.64	46.00	1932.00
Period 2 (Summer-88 days)	2032.80	4656.96	44.00	1848.00
Period 3 (Fall-89 days)	2055.90	4709.88	44.50	1869.00

Nutritional Requirements for Four Bulls

Period 1	8500.80	19474.56	184.00	7728.00
Period 2	8131.20	18627.84	176.00	7392.00
Period 3	8223.60	18839.52	178.00	7476.00

Table 20. Nutritional Requirements for a 1100 Pound Cow

	Minimum Dry Matter (lbs.)	Maximum Dry Matter (lbs.)	Minimum Digestible Protein (lbs.)	Minimum Metabolize Energy (lbs.)
Daily for:				
Period 1	21.58	33.00	1.17	18.18
Period 2	15.88	33.00	0.44	13.08
Period 3	17.87	33.00	0.53	15.47
Period 1 (Spring-92 days)	1985.36	3036.00	107.64	1672.56
Period 2 (Summer-88 days)	1397.44	2904.00	38.72	1151.04
Period 3 (Fall-89 days)	1590.43	2937.00	47.17	1376.83

g

Nutritional Requirements for 100 Cows

Period 1	198536.00	303600.00	10764.00	167256.00
Period 2	139744.00	290400.00	3872.00	115104.00
Period 3	159043.00	293700.00	4717.00	137683.00

Part 2

Cost Determination Figures

Table 21. Machinery Cost Estimates for 1982*

Machine	New Price	Performance ¹ Rate	Machine Life	Fuel & Lub. Cost/hr.	Repairs Cost/hr.	Labor ² Cost/hr.
Tractor 110 Hp., Diesel	37200		12,000	7.24	1.86	6.25
Packer Seeder Brillion, 12'	5704	4.0 Ac/hr.	1,200		.13	
Tandem Disc 12'	5000	4.0 Ac/hr.	2,500		.17	
Chisel Plow 10'	4600	3.4 Ac/hr.	2,500		.31	

1 Assume speed at 4 MPH.

2 Labor valued at \$6.25/hr.

* Fogle, Vernon F., "The Costs of Owning and Operating Farm Machinery in Montana", Cooperative Extension Service, Montana State University, Bozeman, Montana, July 1981.

Table 22. GNP Implicit Price Deflator 1972=100

Year	GNP	Year	GNP
----	-----	----	-----
1950	53.56	1966	76.76
1951	57.09	1967	79.06
1952	57.92	1968	82.54
1953	58.82	1969	86.79
1954	59.55	1970	91.45
1955	60.84	1971	96.01
1956	62.79	1972	100.00
1957	64.93	1973	105.69
1958	66.04	1974	114.92
1959	67.60	1975	125.56
1960	68.70	1976	132.11
1961	69.33	1977	139.83
1962	70.61	1978	150.05
1963	71.67	1979	162.77
1964	72.77	1980	177.36
1965	74.36	1981	193.71
		1982*	201.88

* Preliminary figure for 1982

Source: Economic Indicators (USGPO: Washington, 1982)

Table 23. Average Monthly Rate for Pasturing Cattle on Privately Owned Land

Year	Actual Rate	Adjusted Rate (1982 Dollars)
1966	3.31	8.71
1967	3.59	9.17
1968	3.66	8.95
1969	3.71	8.63
1970	3.87	8.54
1971	4.03	8.47
1972	4.30	8.68
1973	4.80	9.17
1974	6.60	11.59
1975	7.00	11.25
1976	7.40	11.31
1977	7.30	10.54
1978	7.40	9.96
1979	8.40	10.42
1980	9.40	10.69
1981	10.60	11.05

GNP Deflator 1982
GNP Deflator Present Year

* Actual Rate = Adjusted Rate

Mean Adjusted Rate = 9.82

Table 24. Prime Rate Charged by Banks*

Year	Rate	Year	Rate
-----	-----	-----	-----
1950	2.07	1966	5.63
1951	2.56	1967	5.61
1952	3.00	1968	6.30
1953	3.17	1969	7.96
1954	3.05	1970	7.91
1955	3.16	1971	5.72
1956	3.77	1972	5.25
1957	4.20	1973	8.03
1958	3.83	1974	10.81
1959	4.48	1975	7.86
1960	4.82	1976	6.84
1961	4.50	1977	6.83
1962	4.50	1978	9.06
1963	4.50	1979	12.67
1964	4.50	1980	15.27
1965	4.54	1981	18.87

* Average effective rate for the year

Source: Economic Indicators (USGPO: Washington 1982)

Table 25. Prime Rate Adjusted to Real Rate (assumed)

<u>Year</u>	<u>Real Rate</u>	<u>Year</u>	<u>Real Rate</u>
1950	-4.52	1966	2.63
1951	1.11	1967	1.21
1952	1.45	1968	1.15
1953	1.93	1969	2.59
1954	.88	1970	2.92
1955	-.05	1971	1.56
1956	.36	1972	-.44
1957	2.49	1973	-.70
1958	1.47	1974	1.55
1959	2.85	1975	2.64
1960	3.90	1976	1.00
1961	2.65	1977	-.48
1962	3.00	1978	.58
1963	2.97	1979	3.71
1964	2.32	1980	6.05
1965	1.31	1981	14.65

$$\frac{\text{GNP Deflator Next Year}}{\text{GNP Present Year}} * 100 - 100 = \text{Adjusted Rate}$$

Prime Rate - Adjusted Rate = Real Rate

Mean Real Rate = 2.02

APPENDIX B

Table 26. Seasonal Pasture with Seed Constraint

ROW	ACTIVITY NAME	ROW	ACTIVITY NAME
1	Objective Function	21	PASS TRF1-2
2	DM MIN SPG	22	PASS TRF2-1
3	DM MAX SPG	23	PASS TRF2-2
4	DM MIN SUM	24	PASS TRF3-1
5	DM MAX SUM	25	PASS TRF3-2
6	DM MIN FALL	26	PASS TRF4-1
7	DM MAX FALL	27	PASS TRF4-2
8	DP MIN SPG	28	PASS TRF5-1
9	DP MIN SUM	29	PASS TRF5-2
10	DP MIN FALL	30	PASS TRF6-1
11	ME MIN SPG	31	PASS TRF6-2
12	ME MIN SUM	32	D1 MAX
13	ME MIN FALL	33	D2 MAX
14	1 ACRE MAX	34	D3 MAX
15	1 ACRE MIN	35	D4 MAX
16	EQUALITY 1	36	D5 MAX
17	EQUALITY 2	37	D6 MAX
18	EQUALITY 3	38	SEED CONSTRAINT 1
19	EQUALITY 4	39	SEED CONSTRAINT 2
20	PASS TRF1-1	40	SEED CONSTRAINT 3

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	RHS	CWGL	TWGL	IWGL	PWGL	BWGL	MBL	SB1
1	0.0	-4.58	-12.10	-17.67	-16.01	-39.96	-53.32	-4.20
2	0.0	-876.09	-324.34	-719.67	-499.37	-378.22	-602.20	-668.11
3	0.0	876.09	324.34	719.67	499.37	378.22	602.20	668.11
4	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.0	-83.84	-30.03	-47.28	-40.75	-37.44	-60.22	-50.78
9	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.0	-1119.67	-968.67	-931.34	-1029.67	-1175.00	-1616.00	-1860.50
12	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	-1.0	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
16	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	20.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	20.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	RHS	CWGI	TWGI	IWGI	PWGI	BWGI	MBI	SBI
31	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.0	0.50	0.50	0.50	0.50	-0.50	-0.50	0.50
39	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	GN1	RW1	CWG2	TWG2	IWG2	PWG2	BWG2	MB2
1	-36.00	-3.90	-4.58	-12.10	-17.67	-16.01	-39.96	-53.32
2	-469.57	-446.81	0.00	0.00	0.00	0.00	0.00	0.00
3	469.57	446.81	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	-994.56	-1626.09	-1334.80	-881.87	-1063.75
5	0.00	0.00	0.00	994.56	1626.09	1334.80	881.87	1063.75
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	-32.40	-36.19	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	-49.73	-104.07	-50.72	-32.92	-57.44
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	-1250.00	-960.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	-946.00	-1002.00	-799.00	-947.50	-1312.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
21	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
22	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
25	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	GN1	RW1	CWG2	TWG2	IWG2	PWG2	BWG2	MB2
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	-0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.50	0.50	0.50	0.50	-0.50	-0.50
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	SB2	GN2	RW2	CWG3	TWG3	IWG3	PWG3	BWG3
1	-4.20	-36.00	-3.90	-4.58	-12.10	-17.67	-16.01	-39.96
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	-1140.30	-1048.65	-817.19	0.00	0.00	0.00	0.00	0.00
5	1140.30	1048.65	817.19	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	-891.92	-1307.30	-1093.40	-792.30
7	0.00	0.00	0.00	0.00	891.92	1307.30	1093.40	792.30
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	-46.18	-52.43	-51.48	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	-38.35	-70.59	-34.99	-19.82
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	-1634.00	-1072.50	-875.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	-750.00	-802.00	-750.00	-800.00
14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
25	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
26	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
27	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
29	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	SB2	GN2	RW2	CWG3	TWG3	IWG3	PWG3	BWG3
31	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.50	-0.50	0.50	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.50	0.50	0.50	0.50	-0.50

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	MB3	SB3	GN3	RW3	A1	A2	A3	D1
1	-53.32	-4.20	-36.00	-3.90	1490.59	1426.24	1442.08	0.00
2	0.00	0.00	0.00	0.00	2411.20	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	-3402.12	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	1965.96	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	-3236.25	0.00	0.00
6	0.00	-781.57	-1062.75	-462.87	0.00	0.00	1616.00	0.00
7	0.00	781.57	1062.75	462.87	0.00	0.00	1616.00	0.00
8	0.00	0.00	0.00	0.00	139.82	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	87.32	0.00	0.00
10	0.00	-23.45	-34.01	-13.89	0.00	0.00	70.34	0.00
11	0.00	0.00	0.00	0.00	2244.65	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	1810.10	0.00	0.00
13	0.00	-1010.00	-995.00	-820.00	0.00	0.00	1597.12	0.00
14	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
15	-1.00	-1.00	-1.00	-1.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	1.00	-0.94	0.00	0.00
17	0.00	0.00	0.00	0.00	-1.00	0.94	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.94	-0.89	0.00
19	0.00	0.00	0.00	0.00	0.00	-0.94	0.89	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-20.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
29	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
30	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	MB3	SB3	GN3	RW3	A1	A2	A3	D1
31	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	-0.50	0.50	-0.50	0.50	0.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	D2	D3	D4	D5	D6	P1-1	P1-2	P2-1
1	0.00	0.00	0.00	0.00	0.00	-5.36	-5.36	-5.36
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00
22	-20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	20.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00
24	0.00	-20.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	20.00	0.00	0.00	0.00	0.00	0.00	-1.00
26	0.00	0.00	-20.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	-20.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	-20.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	D2	D3	D4	D5	D6	P1-1	P1-2	P2-1
31	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	P2-2	P3-1	P3-2
1	-5.36	-5.36	-5.36
2	0.00	0.00	0.00
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	0.00	0.00	0.00
6	0.00	0.00	0.00
7	0.00	0.00	0.00
8	0.00	0.00	0.00
9	0.00	0.00	0.00
10	0.00	0.00	0.00
11	0.00	0.00	0.00
12	0.00	0.00	0.00
13	0.00	0.00	0.00
14	0.00	0.00	0.00
15	0.00	0.00	0.00
16	0.00	0.00	0.00
17	0.00	0.00	0.00
18	0.00	0.00	0.00
19	0.00	0.00	0.00
20	0.00	0.00	0.00
21	0.00	0.00	0.00
22	0.00	0.00	0.00
23	0.00	0.00	0.00
24	0.00	0.00	0.00
25	0.00	0.00	0.00
26	0.00	0.00	0.00
27	-1.00	0.00	0.00
28	0.00	0.00	0.00
29	0.00	-1.00	0.00
30	0.00	0.00	0.00

Table 26. Seasonal Pasture with Seed Constraint (Continued)

	P2-2	P3-1	P3-2
31	0.00	0.00	-1.00
33	0.00	0.00	0.00
33	0.00	0.00	0.00
34	0.00	0.00	0.00
35	0.00	0.00	0.00
36	0.00	0.00	0.00
37	0.00	0.00	0.00
38	0.00	0.00	0.00
39	0.00	0.00	0.00
40	0.00	0.00	0.00

Table 27. Full Year Pasture with No Seed Constraint

ROW	ACTIVITY NAME	ROW	ACTIVITY NAME
1	Objective Function	31	BWG2=BWG1
2	DM MIN SPG	32	MB1=MB2
3	DM MAX SPG	33	MB2=MB1
4	DM MIN SUM	34	SB1=SB2
5	DM MAX SUM	35	SB2=SB1
6	DM MIN FALL	36	GN1=GN2
7	DM MAX FALL	37	GN2=GN1
8	DP MIN SPG	38	RW1=RW2
9	DP MIN SUM	39	RW2=RW1
10	DP MIN FALL	40	CWG2=CWG3
11	ME MIN SPG	41	CWG3=CWG2
12	ME MIN SUM	42	TWG2=TWG3
13	ME MIN FALL	43	TWG3=TWG2
14	1 ACRE MAX	44	IWG2=IWG3
15	1 ACRE MIN	45	IWG3=IWG2
16	EQUALITY 1	46	PWG2=PWG3
17	EQUALITY 2	47	PWG3=PWG2
18	EQUALITY 3	48	BWG2=BWG3
19	EQUALITY 4	49	BWG3=BWG2
20	PASS1	50	MB2=MB3
21	PASS2	51	MB3=MB2
22	CWG1=CWG2	52	SB2=SB3
23	CWG2=CWG1	53	SB3=SB2
24	TWG1=TWG2	54	GN2=GN3
25	TWG2=TWG1	55	GN3=GN2
26	IWG1=IWG2	56	RW2=RW3
27	IWG2=IWG1	57	RW3=RW2
28	PWG1=PWG2		
29	PWG2=PWG1		
30	BWG1=BWG2		

Table 27. Full Year Pasture with No Seed Constraint (Continued)

	RHS	CWGL	TWGL	IWGL	PWGL	BWGL	MBL	SBL
1	0.0	-4.58	-12.10	-17.67	-16.01	-39.96	-53.32	-4.20
2	0.0	-876.09	-324.34	-719.67	-499.37	-378.22	-602.20	-668.11
3	0.0	876.09	324.34	719.67	499.37	378.22	602.20	668.11
4	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.0	-83.84	-30.03	-47.28	-40.75	-37.44	-60.22	-50.78
9	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.0	-1119.67	-968.67	-931.34	-1029.67	-1175.00	-1616.00	-1860.50
12	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	-1.0	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
16	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	0.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
22	0.0	-1.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.0	1.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.0	0.00	-1.00	0.00	0.00	0.00	0.00	0.00
25	0.0	0.00	1.00	0.00	0.00	0.00	0.00	0.00
26	0.0	0.00	0.00	-1.00	0.00	0.00	0.00	0.00
27	0.0	0.00	0.00	1.00	0.00	0.00	0.00	0.00
28	0.0	0.00	0.00	0.00	-1.00	0.00	0.00	0.00
29	0.0	0.00	0.00	0.00	1.00	0.00	0.00	0.00
30	0.0	0.00	0.00	0.00	0.00	-1.00	0.00	0.00

