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Farm Wealth Implications of Ecological Goods and Services Practices and Policies

by

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Abstract

Ecological goods and services (EG&S) represent the benefits that humans derive from ecosystem functions. The private wealth implications of on-farm EG&S practices that promote wildlife habitat are determined for the Lower Souris River Watershed in South-eastern Saskatchewan. Monte Carlo simulation is used, coupled with NPV analysis, to examine the impacts of practices at a representative farm level. Linear programming is utilized to determine the farm wealth implications of imposing landscape targets across selected parts of the study area.

In both models, implementing an EG&S policy or practice comes with costs to farm wealth. Potential exceptions include converting cropland to tame pasture, and EG&S enhancing herd management practices. However, without policy intervention there is continued conversion of native prairie, perennial forage, and lotic riparian landscapes to cropland. Imposing landscape targets preserves these landscape uses, but with a loss in private economic value ranging from $3,196 to $7,179 per quarter section.

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1 Introduction

1.1 Background

Ecological goods and services (EG&S) represent the benefits that humans derive from ecosystem functions (Prairie Habitat Joint Venture, 2005; Costanza et al., 1997; Costanza et al., 1998). EG&S can be categorized into four separate categories: provisional services, regulating services, cultural services, and supporting services (Millennium Ecological Assessment, 2005; Swinton, 2008) (explained further in section 2.2). Examples of EG&S include groundwater recharge, flood and erosion control, carbon sequestration, biodiversity, and air and water purification. EG&S may provide benefits to people whether they are aware of it or not. Whether it is the clean air they breathe, the clean water they drink, or the sight-seeing of wildlife they enjoy, people attach value to protecting and enhancing EG&S. For this reason, if property rights could easily be distinguished for an individual's clean air, the price he or she would be willing to pay would likely be substantial.

Farmers maintain and manage land for food production and concurrently provide EG&S through the preservation of healthy ecosystems. Depending on land management practices, farmers have the ability to increase, hold steady, or decrease the level of EG&S production. Historically, land use practices have served mainly for the purposes of provisional services (i.e. food production), usually at the expense of environmental protection (Ruhl, 2008; Olewiler, 2004). However, EG&S production may be further increased through implementation of specific agricultural practices and programs. Examples of these practices include, but are not limited to: buffer strips, rotational herd management, no-tillage seeding, and habitat conservation. Some of these practices can be implemented at no cost to the farmer, while others result in a hindrance to farm profitability (e.g., Koeckhoven, 2008; Brethour et al., 2007). In fact, farmers may have direct incentives to decrease the level of EG&S production. For example, a farmer may use herbicides to reduce pest weeds in crop production, and at the same time, pollute nearby waterways. As a result, there may be limited private incentives to increase EG&S production on the agricultural landscape.

One form of EG&S is the conservation and enhancement of wildlife habitat. White (2008, pg. 2) defines wildlife habitat as "a distinct set of physical environmental factors that a species uses for survival and reproduction". Wildlife habitat is unique in that it affords EG&S through all the categories of ecosystem services as described by Swinton (2008), meaning provisional, regulating, cultural, and supporting services. With regards to cultural services, wildlife habitat is an important recreational resource in Canada (van Kooten, 1992). Belcher et al. (2001) estimated that society benefits \$10.71/hectare/year for increased wildlife hunting, and \$4.16/hectare/year for increased wildlife viewing in the Upper Assiniboine River Basin. With regards to supporting and regulating services, wildlife habitat can preserve wildlife species required for predator-prey relationships that stop the form of pathogens, and can increase soil quality for food production through gradual decomposition. This is discussed further in section 2.2.

Farmers can manage their respective lands to enhance wildlife habitat areas. Miller (2002) found that farmers can achieve stable and favourable financial results when using a conservative grazing strategy that promotes a healthy range. Many farmers utilize available programs to plant shelterbelts and woodlots that both increase wildlife habitat, and provide protection to crops from wind and pests (Agriculture and Agri-Food Canada, 2001). Despite this, the problem of wildlife habitat preservation in the face of alternative land uses that displace wildlife is still widespread. According to Agricultural and Agri-Food Canada (2007-b, pg. 1), “since the late 1800s, nearly 99% of the wild mammal biomass has been eliminated in the prairie and parkland biome”. Specifically, agriculture land use practice continually encroaches into wildlife habitat areas to retrieve the full market-value out of the land (Cortus, 2005; Ruhl, 2008; Heimlich et al., 1998). This suggests that the private costs of maintaining wildlife habitat on agricultural land exceeds the private benefits. However, given there might exist a substantial social (i.e. public) benefit in wildlife habitat protection, there is potential for conflict with regards to the appropriate level of wildlife habitat on the landscape.

1.2 Economic Problem

There are conflicting interests at work in decisions related to the provision of wildlife habitat on the agricultural landscape. Agricultural practices that increase the level of food production but also decrease the level of EG&S provided by wildlife habitat may result in a net loss to society. Conversely, those practices that may be employed by farmers to further increase EG&S production may provide a net social benefit but also a cost to the farmer, and are therefore not implemented. For this reason, there is likely a need for government intervention to realize the socially optimal level of wildlife habitat.

The type of intervention to use for wildlife habitat conservation is unclear. Pannell (2008) provides a framework for choosing alternative policy schemes for land-use change for environmental improvement. Pannell states that the policy chosen should depend on whether public and/or private net benefits associated with a land-use action are positive or negative, and the relative magnitude of the result in changing private or public net benefits. Furthermore, the policy action should also depend on the changing of circumstances from the land-use change that is sought from the policy (Pannell, 2008). For example, if a farmer restores a riparian area by blocking a drainage ditch, and the public net benefits of increased waterfowl habitat outweigh the costs the farmer receives from having land out of production, then there is justification for a positive incentive from the public to the farmer. Conversely, consider a scenario where a farmer ploughs native range to seed for crop production. Here, the decrease in public net benefits due to soil integrity and native prairie wildlife habitat loss outweigh the private benefits the farmer enjoys from increased crop production. In this case there is justification for an negative incentive policy, such as regulation or a tax (Pannell, 2008).

The types of policy mechanisms that may be utilized for wildlife habitat enhancement or conservation include positive incentives or negative incentives, such as financial instruments; extension policies, such as technology transfer, education, and communication; or technological innovation, such as research and development into technologies to improve use of existing land, and new land management constructs (Pannell, 2008). However, there is limited information as to the change in private or public net benefits resulting from various land-use actions.

Unless there is information available regarding the extent of public and private net benefits associated with alternative land uses, the choice of policy to realize a targeted level of wildlife habitat for a region remains uncertain. For a policymaker to properly evaluate the trade-off between the EG&S benefits of wildlife habitat and additional land for agricultural production, one must be able to compare the value of EG&S lost versus the value of provisional services gained (Costanza et al., 1998; Daly, 1998). However, public benefits are difficult to determine, as there is often no market mechanism to provide price signals (Kroeger and Casey, 2007). To warrant this, there have been studies undertaken that attempt to measure the social value or public benefit of wildlife habitat conservation (Phillips et al., 1993; Kramer and Jenkins, 2009; Kulshreshtha and Loewen, 1997).

The purpose of this study is to determine the change in private net benefits of various land-use practices and policies that either maintain or enhance the level of wildlife habitat on the agricultural landscape. Combined with the information from other studies regarding valuation of the public benefits of conserving wildlife habitat, this study provides policymakers with an effective dataset as to determine appropriate policy-making. Previous studies have determined the private net benefits or costs to farmers of providing other types of EG&S production (e.g., Miller, 2002; Cortus, 2005; Koeckhoven, 2008). This study focuses on the EG&S afforded through wildlife habitat provision. EG&S from wildlife habitat encompasses a wide spectrum of landscape types, along with the respective habitat quality associated with various landscape types.

1.3 Research Problem and Objectives

In this study, the opportunity cost or benefit to farmers of maintaining, and improving wildlife habitat is considered. The study focuses on farmers in the Lower Souris watershed region in southeast Saskatchewan. The goal here is to quantify private net benefits or costs associated with land use practices and potential land use changes that promote EG&S production within the watershed. In this manner, dollar amounts of benefits or costs can be compared to results from valuation studies of wildlife habitat in a social welfare benefit-cost analysis. However, since a valuation study of the public benefit of wildlife habitat has not been done for the Lower Souris region, this study does not undertake a social welfare benefit-cost analysis to derive conclusions.

First, a representative farm for the region is defined and used to determine the net benefit or cost of implementing practices that promote wildlife habitat conservation and restoration. Here, the objective is to determine which on-farm practices can be implemented that result in the most public (EG&S) benefit and least private cost to farmers. It is expected that greatest EG&S practices will result in a private cost to farmers. However, another objective was to determine whether there any possible practices that may result in a private benefit to farmers in the Lower Souris region.

The second part of the study seeks to determine the cumulative impact on farmers, meaning the total change in farm wealth across all farms in a specific area, of a regional EG&S policy that promotes wildlife habitat conservation. Analysis is done on the farm wealth impact across a large land area, equal to a township of agricultural land. Considering the cumulative impact on private net benefits provides information useful for policy decisions, as efficiencies could be gained in the preservation of wildlife habitat across neighbouring farms. In this manner, the actual cumulative cost to individual farmers of preserving large tracts of wildlife habitat can be determined.

Other specific objectives were considered in this study, as follows:

- The nature of landscape change required to ensure maintenance of targeted levels of wildlife habitat is examined. These results may be used to predict land-use change trends from wildlife habitat preservation policy that may occur in regions similar to the one utilized for the current study.

- The net costs or benefits associated on-farm practices are analyzed in order to determine which practices may increase EG&S production at the least cost to farmers. These comparisons provide information for policy-makers as to what may be the least costly on-farm practice to promote on the agricultural landscape. In addition, light is shed on whether there are certain agricultural land use practices that would provide both increased wildlife habitat and a financial benefit to farmers if they were implemented.

- The impact of enforcing a wildlife habitat EG&S policy on farmers specifically within the study area is determined. The preservation and enhancement of wildlife habitat is a pressing issue in the region, and the impact of current land use practices is a sensitive topic for farmers. Through the research presented in this study, land-use planning and policy recommendations for providing EG&S for public benefit can be established with specific regard to the impact on farmers in the region

The objectives of the second part of the study are achieved through linear programming optimization, which is explained further in Chapter 4. It is important to note that a model of this nature has not been utilized to inspect the impact of EG&S practices on farmers, or other firms that seek to determine the impact of environmental policy. In this sense, this study serves to act as a proof of principle of using a linear programming approach for these purposes. Many of the objectives listed above (i.e. the total amount of expected landscape change) could not have been properly answered without the use of linear programming.

1.4 Organization of the Study

The remainder of this thesis is divided into six chapters. In Chapter 2, further background information is provided regarding the research and economic problem addressed in the study. A review of the importance of protecting and enhancing land for wildlife habitat to society and people is undertaken. A review of studies that attempt to assign a value to EG&S and wildlife habitat is provided. This leads to a general discussion about the relationship between wildlife habitat and agricultural practices and a synthesis of existing farm programs and policies to encourage wildlife habitat protection.

In Chapter 3, the study area in question is introduced and described. The Lower Souris region's geographical area, wildlife and landscape types, and vegetative land-use mix across the watershed is discussed. From this, the activities that influence wildlife habitat in the region can be generalized. This is followed by a review of the descriptive statistics derived from Agricultural Census data for the region, from which a representative farm was established.

Chapter 4 provides background on the modelling structures utilized, and the economic theory that encompasses these structures. A review of capital budgeting modelling and Monte Carlo simulation used for the representative farm simulation model is provided. The economic theory behind linear programming for resource allocation is then described. Finally, the general theory behind hedonic estimation models specific to land use is provided. The chapter presents the general structure of the two models used in the study.

The empirical methods used to carry out the modelling are presented in Chapter 5. First, the work to construct the representative farm simulation model (RFSM) is discussed, including the development of stochastic variables and biophysical relationships within the model. Following this is a breakdown of the steps taken to construct the landscape target optimization model (LTOM). A description of the scenarios imposed on the RFSM, and the land-use targets imposed on the LTOM is provided. The results from these analyses are presented and discussed in Chapter 6.

Finally, Chapter 7 presents the conclusions from the research study. Conclusions relate to the potential extent of positive incentives required for habitat enhancement, and other forms of policy that may be utilized for the region given the results. The limitations of the empirical methods and possible future research extensions end the chapter.

2 Chapter 2: Preliminary Research

2.1 Overview

This chapter presents the background and issues relevant to the research objectives of this study. It is a general discussion of previous studies, literature, and types of programs and policies specific to the research problem. It gives explanation as to the purpose of the study, the problems around the research question, and the usefulness of results and conclusions with regards to policy decision-making. Through reading the background and issues of the research problem, justification for undertaking of this study is established. Furthermore, an overview of existing studies that determine the public benefit of the EG&S afforded from wildlife habitat is given for comparison purposes. The results of this study can be compared to valuations of public benefit of wildlife to determine to what extent policy is warranted.

This chapter provides insight into what wildlife habitat conservation entails, and whether conservation aligns with current agricultural practices. Wildlife habitat conservation is important because society may attach a substantial positive value to a habitat's existence. An explanation as to the various benefits society receives from wildlife habitat is explained here. However, farmers may have direct incentives to reduce the amount of wildlife habitat. The continual conversion of habitat to agricultural land uses has led to private wealth benefits for farmers. As a result, a number of farm programs have been designed in recent years to conserve wildlife habitat.

2.2 EG&S Production

This section provides a general review of literature associated with EG&S production. To reiterate, EG&S are the direct benefits that humans receive from nature (Prairie Habitat Joint Venture, 2005; Costanza et al., 1997; Costanza et al., 1998). There are many types of EG&S, a few of which were described earlier in Section 1.1. Swinton (2008, pg. 28) clarifies four broad categories of ecosystem services (i.e. EG&S) as determined by the Millennium Ecological Assessment (2005):

- "*Provisioning services* include food, fiber, wood, fuel and fresh water that provide for human subsistence.
- *Regulating services* maintain the balance of the Earth's systems at levels that enable human survival. These services include climate, flood, water quality, and disease regulation. Examples include vegetation that buffers the effects of natural flooding, or predator–prey systems that limit the spread of pathogens.
- *Cultural services* include the spiritual, inspirational, aesthetic, heritage, recreational and tourism benefits.
- *Supporting services* include the myriad natural systems that enable the three tiers above. For example, organic matter cycling contributes to soil creation,

> which makes food provisioning possible. Photosynthesis transforms solar energy into plant matter, enabling provisioning services, carbon cycling, and various other services."

The types of EG&S that humans receive from wildlife habitat are numerous and fall across each of the above categories. Wildlife provides many assorted uses for people, including food, bird watching, nature enjoyment, and a number of recreational activities. However, non-users of wildlife habitat attribute value in preserving habitat due to concern over issues including species at risk, ecological fragmentation, climate change, threats from introduced disease and exotic species, and decreased biodiversity (Environment Canada, 2000). This concern for wildlife habitat conservation has resulted in a steady increase in membership for conservation organizations, and high expectations of government agencies for conservation action (Environment Canada, 2000). As such, the benefits of wildlife habitat conservation are sufficient to induce government policies that protect habitat on the agricultural landscape.

Wildlife habitat users often place the highest value on wildlife habitat protection. Phillips et al. (1993) found that hunters and anglers that participated in the Buck for Wildlife Program (Macnab and Brusnyk, 1993) were willing to pay upwards of $767.63 per acre to improve wildlife habitat quality. Furthermore, it is clear that there are a substantial number of wildlife habitat users in Canada. In a 1991 survey, the Canadian Wildlife Service found that an estimated 91% of Canadians were involved in wildlife-related recreational activities (Filion, 1993). These users understand that the fate of wildlife is directly tied to the fate of its habitat (Saskatchewan Wetland Conservation Corporation, 2009). Access to wildlife habitat areas is also important for occasional sightseeing, hiking, camping, and other sports for outdoor enthusiasts (Environment Canada, 2000). Recently, wildlife recreation activities have emerged as an increasing income stream for farm operators (Henderson and Moore, 2006). People, whether from urban or rural areas, use wildlife habitat directly.

The non-use value of wildlife habitat conservation may be much more significant to society than the use value. Non-use, or 'passive use' value exists where people associate value to the protection of wilderness area, despite not belonging to a particular user group. People may place considerable value in keeping species such as elephants, tigers, and rhinoceros intact, despite never seeing these species in their lifetime (Bulte et al. 2003). As mentioned above, there is growing concern over global issues such as species at risk, decreasing biodiversity, and ecological integrity that in part, stem from wildlife habitat loss. In this context, loss of wildlife habitat can be characterized as a global problem as everyone receives benefit (at various levels) from keeping habitat intact. Wildlife habitat also provides regulating and supporting services through its existence, rather than just assisting in mitigating problems. Wildlife habitat affords increased water filtration, germination, pest control, nutrient cycling, soil generation, pollination, carbon sequestration, and environmental quality for pollutant degradation, on which a functioning healthy ecosystem depends (Egan et al., 1995). As for provisional services, many medicines, consumer products, and advances in science can be attributed to wildlife habitat preservation (Egan et al., 1995).

The benefits of preserving wildlife habitat are not lost on Canadians, as indicated in the 1996 survey by Environment Canada. The survey titled "*The Importance of Nature to Canadians"* (Environment Canada, 1999, pg. 11) found that "an estimated 9.0 million Canadians (38.3 percent of the population aged 15 years and over) participated in residential wildlife-related activities". Furthermore, the survey found that "an estimated 4.4 million Canadians (18.6 percent of the population aged 15 years and over) participated in wildife viewing in Canada" (Environment Canada, 1999, pg. 11). In the same survey initiated in 1991, it was found that 86% of Canadians believe that it is important to maintain abundant wildlife, while 83% of Canadians believe that endangered or declining wildlife species need to be protected (Filion, 1993). Although wildlife habitat has not historically been thought of as contributing to human welfare, Canadians are becoming increasingly aware of the benefits of its maintenance.

2.3 Valuation of EG&S

The nature of most EG&S, especially those that fall in the regulating, cultural, and supporting service categories, is such that the benefits and costs of levels of production are difficult to ascertain through a market mechanism. For example, land allocation based on the 'private' productive capability and for housing and urban development is quite efficient with respect to reflecting current price signals. However, the public benefits of the land, which include other EG&S, are not captured within these land values (Bowker, 1994). Because of limited incentives for EG&S due to a lack of market mechanisms, EG&S are often not provided efficiently (Polasky, 2008). The nature of most EG&S is such that the amount of good or service available changes over time. Consumers are unaware of what level of benefit they retrieve from EG&S, and the amount of EG&S left for future use is uncertain after consumption (Prairie Habitat Joint Venture, 2005). These challenges make up most of the difficulty economists face in placing a value for given levels of EG&S.

Despite the challenges, a number of methods have been developed to try to properly assign value to EG&S production. Farber et al. (2002, pg. 375) clarify the term 'value' to mean "the contribution of an action or object to user-specified goals, objectives or conditions". In the context of EG&S, value is the contribution of an ecological good (e.g., biodiversity) to human welfare. 'Valuation', on the other hand, is the "process for expressing a value for a specific object or action" (Farber et al., 2002, pg. 376). Typically, this process is achieved for non-market goods and services through either a revealed preference approach, such as travel cost or hedonic methods, or an expressed preference approach, such as conjoint analysis or contingent valuation (Heimlich et al., 1998). Studies where the public benefits of EG&S are derived typically use one or more of these approaches.

There are often large discrepancies as to the results generated from valuation studies. In a meta-analysis of wetland valuation studies, Brander et al. (2006) found that these studies are diverse in terms of the values estimated, and that this was most likely a result of the methods employed and wetland type considered. In fact, of 33 wetland valuation studies done over 26 years the value per acre has ranged from US$0.06 to US$22,050 (Brander et al., 2006). Nevertheless, the non-market valuation of EG&S is required for the purpose of comparison in policy development.

A number of studies have attempted to value the benefit from wildlife habitat preservation or enrichment. Determination of the existence value of wilderness in Saskatchewan is the objective of a study by Kulshreshtha and Loewen (1997). Specifically, the study estimates the non-use value of wilderness protection. The total economic value of a wilderness area is the sum of the use and non-use values for that area. Open-ended contingent valuation methodology is employed throughout the study. The full dataset, collected from surveys distributed randomly across the province for non-aboriginals and 30 aboriginal households in Prince Albert, were separated by aboriginal versus non-aboriginal to retrieve qualitative willingness-to-pay results specified for aborginal populations (Kulshreshtha and Loewn, 1997). Results give an average willingness-to-pay for non-aboriginals of $60.89 per household, while for aboriginals, willingness-to pay was $80 per household (Kulshreshtha and Loewn, 1997). This would equate roughly to $100 per hectare or $40.47 per acre, considering the number of households in Saskatchewan and the given landscape. Respondents were also asked to assign percentages to the types of use for attributing their payment. The majority of value (approximately 69.4%) was assigned to non-use or passive uses. These results demonstrate that there is merit to having a wildlife habitat protection as a province-wide policy goal, as people place significant non-use value on the existence of wildlife habitat.

A second study used valuation methods to determine farmers’ willingness-to-accept wildlife habitat programs. The benefits of EG&S programs associated with conserving red wolf habitat in North Carolina were estimated by Kramer and Jenkins (2009). Kramer and Jenkins (2009, pg. 8) state “through the Red Wolf Recovery Program (RWRP), the U.S. Fish and Wildlife Service manages the only wild red wolf (*Canis rufus*) population in the world”. This study used surveys collected from farmers in the program area to determine perceptions of current conservation programs (Kramer and Jenkins, 2009). A total of 298 usable surveys were collected, indicating that 63% of respondents would participate in a payment program to conserve EG&S on their land. Contingent valuation questions were given for both red wolf habitat and general wildlife habitat found in the study area. From these questions, the mean willingness-to-accept of a conservation payment program to provide red wolf habitat was $202 per acre, but only $36 per acre for general wildlife habitat (Kramer and Jenkins, 2009). The results signify that a generic wildlife habitat protection program (rather than one specific to red wolf habitat) would be attractive to farmers, as their willingness-to-accept a generic program is $166 per acre less (202 – 36) than one for red wolf habitat. It is clear that wildlife habitat conservation provides value to individuals and farmers alike.

2.4 Wildlife Habitat and Agriculture

Despite the human benefits from maintaining wildlife habitat, the quantity and quality of this habitat present on Western Canadian agricultural land has been declining historically. Historically, government policihave directly and indirectly encouraged farmers to increase the amount of productive land for crop production, through converting natural pasture, wetlands, and other marginal lands into cropland. For example, at one time governments in Canada and the U.S. provided subsidies to drain wetlands in order to increase the amount of productive land (Danielson and Leitch, 1986; Douglas, 1989). Furthermore, the Farm Credit Act of 1959 encouraged the mechanization and growth of farm size and provided government-subsidized credit to do so (Skogstad, 2007). With the rapid growth of the size of farms, annual cropland became dominant over other land uses due to its alignment with mechanization. The widespread conversion of lands led to a immense loss of habitat across the praire pothole region of Western Canada (van Kooten and Schmitz, 1992). This loss in habitat resulted in a decline in wildlife diversity as explained by Environment Canada: “by 1999, 340 wildlife species in Canada, including 52 birds, had formal classification as species at risk, and three of the 12 species confirmed as extinct were birds.” (Environment Canada, 2000, pg. 4).

Farmers continue to expand their respective operations to include more cultivated land. This places strain on forested, riparian, and native grassland areas located across agricultural land. Hobson et al. (2002) completed a study in Saskatchewan that indicated the risk to the boreal forest posed by the rapid expansion of agriculture along its southern border. The authors estimate deforestation rates for central Saskatchewan to be higher than the world average (0.3% per annum) between the years 1966 and 1994 (Hobson et al., 2002). The continued search for agricultural land is but one incentive farmers have to continue wildife habitat loss. There are nuisance and direct costs to farm operations in maintaining wildlife habitat areas on the agricultural landscape. In this manner, farmers might achieve more benefits from clearing wildlife habitat areas, in both forgone costs and added direct benefits, than that individually received from conserving wildlife habitat.

2.4.1 Private Costs of Conserving Wildlife Habitat

Farmers must deal with financial and operational costs in maintenance of wildlife habitat on their land. Areas within the agricultural landscape that provide habitat for wildlife can be difficult to manage from a farm operator perspective. Wetlands and aspen bluffs are spotted across quarter sections leadiung to difficulty in machinery practices (due to driving around these areas), perennial flooding of surrounding land, and a large portion of prime agricultural land being kept out of production. Wildlife may also be a direct nuisance to farm operation, as species such as ducks, deer, moose, and antelope eat and use crops for habitat. Insect species that may prove a pest to farmers may be hatched and flourish from areas that provide wildlife habitat. For these reasons, farmers may perceive a large cost to maintaining wildlife habitat on their agricultural lands.

Wetlands are a source of significant wildlife habitat on agricultural lands, but might prove unprofitable for farmers to maintain. Cortus (2005) determined the economic feasibility of draining wetlands on farms in eastern Saskatchewan. From this analysis, it was found that a rational farm operator would drain wetland areas, rather than purchase new lands to expand his cultivated land base. The cost of purchasing land in the study area averaged around $640 per hectare, while the cost of draining wetlands was approximately $500 per hectare (Cortus, 2005). Conducting drainage on existing lands was profitable to the farm operator if there was access to a land scaper. Wetland areas do not provide direct financial benefits to crop producers, so the incentive to convert wetlands can be considerable.

Furthermore, in a survey of landowners, Gelso et al. (2009) found that farmers` perceived costs of wetland areas in cropland can be as high as 56% of farmland rental value. This perceived cost of maintaining wetland areas is high enough to warrant conversion of wetland areas to cropland. A large part of this perception may be due to direct nuisance costs associated with maintaining wetlands. Cortus (2005) found that forgone nuisance costs make up approximately 35% of the benefits achieved from draining wetlands, and estimated that total nuisance costs of wetlands were $2,126 to $2,245 for a eight quarter section sized farm ($4,675 to $5,225 for a 16 quarter section sized farm). Similar characteristics can be found in other areas that provide wildlife habitat, such as aspen bluffs, lotic riparian areas, or native range, as these areas are dotted across the agricultural landscape similar to wetlands. The perceived costs of maintaining wildlife habitat on agricultural land may provide a limitation to the success of wildlife habitat conservation practices.

2.4.2 Improvements in Managing for Wildlife Habitat

In recent years, governments, not-for-profit organizations, and agricultural associations have been promoting the management of agricultural land in balance with environmental priorities. From this, a number of management practices (referred to as Beneficial Management Practices, or BMPs) have been identified to foster an improved state for ecosystems on the farm. There are many simple changes that a farmer can undertake to increase the quality of wildlife habitat and other forms of EG&S production on the farm land. The planting of shelterbelts to protect crops from wind and neighbouring volunteer crops provide corridors for wildlife to travel. Inclusion of winter wheat and other fall-seeded crops in the crop rotation can dramatically increase waterfowl nesting habitat (Devries and Moats, 2009). Enhancing native prairie forage habitat can be attained through decreasing stocking rate for pasture. In some cases, small changes in managing agricultural land can increase wildlife habitat quality with minimal impact to the farm operation.

In recent years, many farmers are adopting environmentally sensitive practices, such as integrated pest management, and precision farming methods (Agriculture and Agri-Food Canada, 2001). These practices have direct benefits for farm operations and at the same time enhance the natural system on which wildlife depend. Practices such as keeping a clean farm yard and limiting agricultural waste from operational practices, lead to efficiency gains, reduced costs, and improved environmental quality on the farm. Low tillage seeding, crop rotation, and nutrient cycling plans are being utilized to improve soil and farm ecosystem quality (Agriculture and Agri-Food Canada, 2001). In addition to farm operational benefits, there may exist direct financial incentives to maintain healthy wildlife habitat on the farm. Henderson and Moore (2006, pg. 597) state that “according to the 2002 U.S. Census of Agriculture, more than 2800 farms averaged $7,217 from recreation services, where recreation service income was characterized by hunting and fishing”. Farmers can implement management practices to reap both biophysical and financial benefits from enhanced ecosystem services.

In many cases, farmers only need information as to what they can do to improve environmental quality to instigate change. Agriculture and Agri-Food Canada (2001, pg. 6) points out that “farmers understand that good land stewardship promotes economically viable farms”. As farmers become more aware of the environmental and economic benefits that wetlands, native grasslands, and lush forests provide, some may change practices to enhance environmental quality and still maintain profitability. As an example, a farmer may maintain a wetland because they know it enhances water quality and quantity, increases forage production, reduces soil erosion, and improves air quality (Ducks Unlimited Canada, 2007). Providing farmers with information is but one type of policy that policymakers have at their disposal to encourage wildlife habitat conservation. In the next section, a review of the existing government policies and programs to conserve wildlife habitat is undertaken.

2.5 Farm Programs and Policies

There have been a number of farm programs and policies at the federal, provincial, and local level that encourage environmental sustainable land management on private agricultural lands. In their infancy, environmental stewardship policies focused solely on soil quality retention, herbicide and pesticide usage, and manure management. Recently, however, the EG&S benefits from wildlife habitat have been increasingly important in policy formulation. A number of national programs have been created to link agricultural activities to wildlife habitat preservation and enhancement, including the Conservation Security Program, United States; the Environmental Stewardship Scheme, England; the Environmental Quality Incentives Program, United States; and the National Farm Stewardship Program, Canada (Rae and Beale, 2008). These programs along with others, signify the start of a shift in agriculture policy from production related income-support toward farmers recieving payments for the provision of EG&S.

2.5.1 Information and Encouragement Programs

Information programs rely on brochures, manuals, workshops, and seminars to increase awareness of environmental issues on agricultural land. In this manner, the information received can provide farmers with additional tools and skills for environmental land management. Of the large number of information programs from governments, not-for-profit organizations, and farmer-group associations, one national information-oriented encouragement program that has seen extended success is the Environmental Farm Plan Initiative. This program, first developed in Ontario in 1993 (Agriculture and Agri-Food Canada, 2008), focuses on increasing awareness and understanding of the BMPs that may be employed by a farmer. Every province manages an Environmental Farm Plan (EFP) program that is directed by Agriculture and Agri-Food Canada. The programs, which are completely voluntary, encourage farmers to adopt BMPs. As part of their EFP, farmers develop their own action plan, and identify practices they can partake in to reduce environmental risk on their farm. In Saskatchewan, the Provincial Council of Agriculture Development and Diversification Boards (PCAB) is responsible for delivery of the EFP initiative to all farmers in the province, and staffs representatives to implement the program throughout the province (PCAB, 2010). A large factor associated with the program’s success was the requirement that every farm must complete an EFP before being eligible for the farm stewardship program described below. However, the Environmental Farm Planning initiative ended on March 31, 2009 and was replaced by the new Growing Forward policy framework (Agriculture and Agri-Food Canada, 2010-a).

Pannell (2008) refers to information programs as examples of extension policies. This form of policy is also associated with technology transfer, education, communication, and community support (Pannell, 2008). Pannell concludes that extension policies are effective if there are actions that landholders can take that increase both public and private net benefits. It may be the case that there are a number of actions farmers can undertake that increase public benefits, such as increased EG&S, and increase private benefits, such as farm wealth. If this is the case, information and encouragement programs would be an appropriate and cost-effective strategy to instigate change (Pannell, 2008). In this study, a number of practices (i.e. BMPs) that are supposed to lead to increases in EG&S are modelled to determine cases where the practice leads to an increase in private net benefits. If it is assumed that these practices also increase public benefits, then the appropriate policy would be a policy by extension to promote change.

2.5.2 Regulation

In general, regulation is used in cases where the objective is to discourage landholders from undertaking a particular action and are instead encouraged to maintain the status quo. Regulation is effective to employ for those cases where the action is considered extremely harmful if carried out. For example, if a pollutant leaching into a vulnerable waterway causes substantial human health concerns from drinking water, regulation (along with enforcement) could be used to immediately stop further pollution. Examples of this in the agriculture-environment realm include manure management, and location of intensive livestock operations, both of which are regulated under the Agricultural Operations Act in Saskatchewan (Saskatchewan Agriculture, 2008-j).

Similar to information programs, Pannell (2008) explores the circumstances where a negative incentive policy, such as regulation or a polluter-pays mechanism, would be most appropriate to implement. If public net costs outweigh private net benefits, and the individual is partaking in action outside his or her level of property rights, then the use of regulation or a negative incentive would be most appropriate (Pannell, 2008). The relatively small loss of forgone private net benefits due to regulating preventative action would pale in comparison to the public costs (e.g., an environmental disaster) of unregulated market forces.

In many circumstances, the loss of wildlife habitat on agricultural land may be an example where public net costs outweigh private net benefits. This may be especially true when considering the impact of a loss of a wildlife species due to loss of habitat. In this regard, the province of Saskatchewan has created regulation around the protection of particularly sensitive habitat areas associated with species-at-risk, referred to as the Wildlife Habitat Protection Act (originally enacted in 1984). The Act protects 3.4 million acres of crown land (i.e., public land) in Saskatchewan, or one third of wildlife habitat found in the agricultural region (Saskatchewan Environment, 2008). Deemed wildlife habitat lands, permission is required before any land is altered in any way and land is restricted from being transferred to private land (Government of Saskatchewan, 2008). Interestingly, these lands are mainly leased to cattle farmers in Saskatchewan who use the land for grazing or haying purposes (Saskatchewan Environment, 2008).

2.5.3 Economic Incentive Policies

There have been a number of economic incentive policies, in Canada and internationally, that encourage wildlife habitat maintenance on agricultural lands. Economic incentive policies can take the form of negative (polluter pays) or positive (beneficiary-pays) incentive policies (Pannell, 2008). Many of the established programs to encourage wildlife habitat conservation are positive incentive policies. In this sense, the public is the beneficiary as the EG&S benefits of wildlife habitat are public benefits for which most individuals are willing to pay (see section 2.3 for an explanation). Beneficiary-pays policies provide income to farmers in light of the perceived cost of maintaining wildife habitat. In this regard, beneficiary-pay policies are more acceptable to farmers, as they are more willing to participate in programs if they receive a payment for doing so. The following programs have all been implemented to conserve or enhance wildlife habitat on agricultural land at some level, and with varying degrees of success.

Initiated in 2002, the Conservation Security Program is delivered nationally in the United States by the Natural Resources Conservation Service (NRCS), and is a voluntary, performance-based program that provides financial incentives to farmers that adopt conservation practices (Rae and Beale, 2008). As the NRCS is within the federal

Department of Agriculture (USDA), this can be considered a beneficiary-pays policy whereby the public pays for the conservation practices. The program is unique in that it provides payments to previous and ongoing conservation practices, and it targets specific watersheds (Rae and Beale, 2008). Payment amount depends on the percentage of the farm that is included, on the ability to meet minimum requirements for soil and water quality, and the ability to meet resource concerns determined to be important for the watershed (Rae and Beale, 2008). The farmer can earn more money depending on the practices adopted (Rae and Beale, 2008). The program has been very profitable and popular among farmers, with 90% of farmers in five midwestern states saying they are happy with the payments that they received (Gieseke, 2007). However, challenges have arisen from the program that include guideline inconsistencies, since each state sets its own environmental guidelines; insufficient monitoring to enforce conservation practices; and, the lack of processes to identify farmers that are already involved in another conservation program (Rae and Beale, 2008).

The Environmental Stewardship Scheme in England is a program initiated to encourage BMPs that afford EG&S benefits across the whole farm (Rae and Beale, 2008). The scheme was developed due to public concern with declining on-farm environmental integrity, and to internalize the public goods of agricultural operations (Rae and Beale, 2008). Similar to the Conservation Security Program, the Stewardship Scheme is a beneficiary-pays policy where the government pays farmers to implement BMPs. The scheme is a three tiered incentive scheme with three categories of stewardship: entry level, organic level, and higher level. Contracts commit farmers to five year terms. Farmers receive financial payments every six months (Rae and Beale, 2008). Farmers have over 50 options of various BMPs they could partake in to increase payment amounts (Rae and Beale, 2008). For the higher level contracts, local program advisors have the role of maximizing the amount of conservation benefit for public dollars spent, and there is increased payment for additional EG&S provided (Rae and Beale, 2008). Challenges include farmers picking stewardship options that are easiest and least costly to implement, and only the higher level tier ties indicators of improvement to actions on the farm (Rae and Beale, 2008).

According to Rae and Beale (2008, pg. 12), the Environmental Quality Incentive Program (EQIP) in the United States is intended to “improve on-farm environmental practices through the delivery of direct technical, educational, and financial assistance to farmers and ranchers”. It is operated by the USDA, but is delivered by state conservation authorities. The program provides assistance to farmers in meeting state and federal environmental regulations, including conservation priorities such as water quality, and point source emissions (Rae and Beale, 2008). This program is a positive incentive policy, due to the financial incentives being provided to prevent action, where the beneficiary is the government. The program offers a cost-sharing payment system to encourage implementation of specific BMPs, including practices related to nutrient management, soil erosion, habitat protection for at-risk species, and water resources management (Rae and Beale, 2008). The EQIP program focuses on farmer flexibility and local decision-making of implementation of BMPs, and is the largest USDA program providing financial and technical assistance to farmers (Rae and Beale, 2008). However, and similar to the Conservation Security Program, major challenges include inconsistent practices being implemented across state lines, and the amount each state receives is unclear to participants (Rae and Beale, 2008).

The National Farm Stewardship Program was Canada's national financial incentive program for the implementation of on-farm BMPs to improve environmental outcomes on agricultural land. This program ended on March 31, 2009 and was replaced by the new Growing Forward policy framework (Agriculture and Agri-Food Canada, 2010-a). Similar to the Environmental Quality Incentive Program, the National Farm Stewardship program provided financial and technical assistance to farmers in the implementation of BMPs, and was delivered through provincial programs (Agriculture and Agri-Food Canada, 2007-a). Also similar to the EQIP program, the federal government cost-shared up to 50% of the project costs upon implementation, with the payment amount depending on the BMP-type category (Agriculture and Agri-Food Canada, 2007-a). Provincial lists of BMPs that were eligible for financial and technical assistance were derived from a national list of BMPs (Agriculture and Agri-Food Canada, 2007-a). In Saskatchewan, examples of BMPs that were eligible for funding included the re-location of livestock facilities away from riparian areas, planting forages as buffer to protect stream banks and shores, equipment modification for improved pesticide application, improved watering site management, and well water management (Provincial Council of Agriculture Development and Diversification Boards of Saskatchewan, 2010). The Farm Stewardship Program was also a beneficiary-pays program with financial incentives to encourage on-farm actions.

Canada's Greencover Canada program was a $110 million initiative to help farmers improve their grassland-management practices, protect water quality, reduce greenhouse gases, and enhance wildlife habitat, and was a five year program that ended on March 31, 2009 (Agriculture and Agri-Food Canada, 2010-b). The Greencover program provided financial remuneration to farmers for implementation of BMPs and other on-farm environmental actions that were outside the national lists of the National Farm Stewardship Program. Greencover focused on five components: land conversion, critical areas, technical assistance, shelterbelts, and the watershed evaluation of BMPs (WEBs) (Agriculture and Agri-Food Canada, 2010-b). The primary funding available under the Greencover program provided an incentive to farmers to convert low-quality annual cropland, or land that is severly degraded due to wind and water erosion, to a perennial forage (Manitoba Riparian Health Council, 2010). The program was available only to registered landowners of environmentally sensitive lands. The program paid $20 per acre for seeding tame forages or trees, and $75 per acre for the seeding of native species for the area.

2.6 Chapter Summary

The information presented in this chapter provides justification for undertaking the present study. The chapter provides background on three main questions: What is EG&S production and what have been the attempts to assign value to the EG&S afforded from wildlife habitat? What is the nature of the relationship between wildlife habitat on agricultural land and traditional agricultural practices? What are the various policies that attempt to rectify the relationship between wildlife habitat conservation and agriculture? Previous studies that have attempted to 'valuate' the EG&S afforded from wildlife habitat vary widely in their assessments. To date, there has not been any attempt to value the EG&S benefits of wildlife habitat protection for the current study area. However, this study tries to capture the financial impact of potential EG&S-focused government policy on farmers in the Lower Souris region. It is the hope of the researcher that the results of this study can be compared to an EG&S valuation of wildlife habitat for the study area to determine policy implications.

The large-scale conversion of land to agricultural uses has led to a substantial loss of wildlife habitat across the Western Prairies, and this trend may continue without policy intervention. Farmers receive direct benefits when converting wildlife habitat to agricultural uses. Farmers are able to reduce costs such as double seeding, and nuisance costs due to the elimination of immovable obstacles in their fields. Farmers also experience financial gains through seeding additional land to crop or perennial forage production, and converting this land may often be cheaper than purchasing new land acreage (Cortus, 2005). In recent years, there have been attempts from organizations and farmers alike to reduce agriculture's impact on the natural environment. However, without policy intervention, this movement might see limited success due to the presence of incentives to continue conversion. This study attempts to provide a linkage between farm wealth impacts, a main driver of on-farm action, and wildlife habitat conservation. In this manner, a policy maker can effectively determine the extent of impact on farmers with respect to wildlife habitat protection for any type of EG&S policy.

There are a number of policies implemented at the national and regional level to encourage wildlife habitat conservation on agricultural land. Some of these policies are information programs or regulation, but many are positive incentive policies to farmers to implement wildlife habitat preservation practices (i.e. BMPs). After results of this study have been compiled, and conclusions determined, a clear picture with respect to policy implications is determined from reviewing these past policies and from reviewing Pannell (2008). It is hypothesized that, similar to most of the policies implemented, a beneficiary-pays, positive incentive policy would be most warranted for the Lower Souris region.

3 Chapter 3: Study Area

3.1 Overview

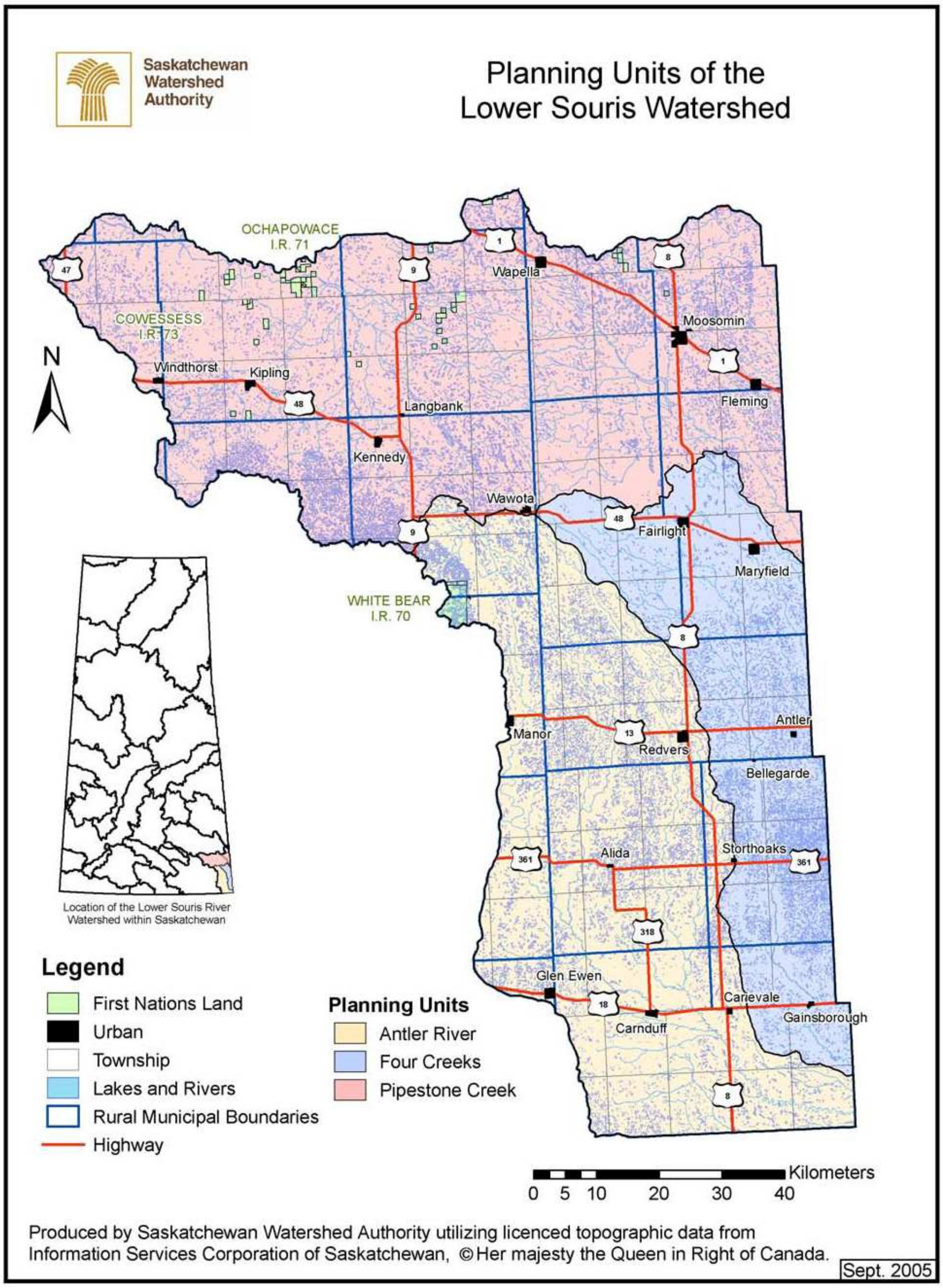
This chapter provides a general review of the study region, its agricultural practices, wildlife species types, and ecological characteristics. A description of the study region is required to understand the methods chosen for modelling purposes and to justify the types of data used for the analysis. The Lower Souris Watershed Committee was the main contact for the researcher throughout the study. As a result, policy goals for model development revolve around local watershed committee priorities. The various types of landscapes found across the study region are described and are later utilized in the landscape target optimization model (LTOM). Data on regional farm characteristics are described and later utilized in the construction of the representative farm simulation model (RFSM).

First, the Lower Souris River Watershed's geographic area, the mandate and organization of the Watershed committee, and the various programs the committee delivers, are discussed in some detail to provide context. This is followed by a description of the various types of landscapes found across the watershed, and the wildlife species present in each landscape type. A description of 10-year trends of wildlife habitat conversion on agricultural lands is then provided for the study area. Finally, an account of current agricultural characteristics in the watershed is provided. Data are presented regarding the average characteristics of farms within the watershed. These data include farm size, crops grown, total herd size, revenues, and expenses.

3.2 The Lower Souris River Watershed

The Lower Souris River Watershed (LSRW), shown in Figure 3.1, is "located in the south-eastern corner of Saskatchewan, bounded to the east by the province of Manitoba and to the south by the state of North Dakota" (Saskatchewan Watershed Authority, 2005, pg. 9). The LSRW is located in the prairie pothole region of North America, which is characterized by wetlands and lakes that were formed during the retreat of glaciers (Saskatchewan Watershed Authority, 2005, Cortus, 2005). On the western side of the LSRW, the Moose Mountain area provides continuous forest and the highest elevations for the watershed, reaching 800 metres (Saskatchewan Watershed Authority, 2005). The LSRW comprises three sub-watersheds that all drain into the Souris River in Manitoba: the Antler River, Pipestone Creek, and Four Creeks sub-watersheds (shown in Figure 3.1). The Antler River sub-watershed is located in the southeast portion of the LSRW, Four Creeks in the southwest portion, and Pipestone Creek in the north portion. The Four Creeks sub-watershed contains the Stony, Jackson, Graham, and Gainsborough creeks, while the Antler River sub-watershed contains the Antler river, and the Pipestone Creek sub-watershed contains Pipestone creek, Little Pipestone creek, and Montgomery creek (Saskatchewan Watershed Authority, 2005).

Figure 3.1 Planning Units for the Lower Souris River Watershed



Source: Saskatchewan Watershed Authority, 2005, pg. 6[1]

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[1] Copyright authorization to include this picture was granted by Etienne Soloudre, Range Ecologist for the Saskatchewan Watershed Authority

The LSRW committee's mandate is to "balance the economic, environmental, and social values to sustain and improve the watershed for future generations" (Lower Souris River Watershed Committee, 2010, pg. 2). The committee does this through partnering with local rural municipalities, conservation groups such as Ducks Unlimited and Wildlife Habitat Canada, and the Saskatchewan Watershed Authority. These partners actively encourage the use of BMPs associated with cropland management, such as buffer strips and forage establishment. BMPs associated with grazing management, such as rotational grazing management, providing off-stream watering sources, and restoring native rangeland, are also encouraged. The watershed committee also supports adoption of BMPs by intensive livestock operations (e.g., vegetative buffer strips to absorb pollutants) (Lower Souris River Watershed Committee, 2010). Furthermore, the LSRW committee is involved in a number of projects to maintain habitat integrity and water quality across the watershed. These projects include an EcoAction ground water project, an agri-environmental group plan that provides incentives for wintering site management and riparian area managment, and water quality monitoring reports (Lower Souris River Watershed Committee, 2010).

The LSRW committee seeks to engage in research projects that analyze agri-environmental outcomes (Lower Souris River Watershed Committee, 2010). The present study arose from the Lower Souris Ecological Goods and Services Pilot project. According to the Lower Souris River Watershed Committee Inc. (2006-a, pg. 1) this project's objective is to "examine how EG&S policy tools could be used in a real working landscape to achieve desired environmental endpoints". To do this, the project had three objectives (Lower Souris River Watershed Committee Inc., 2006-a, pg. 1):

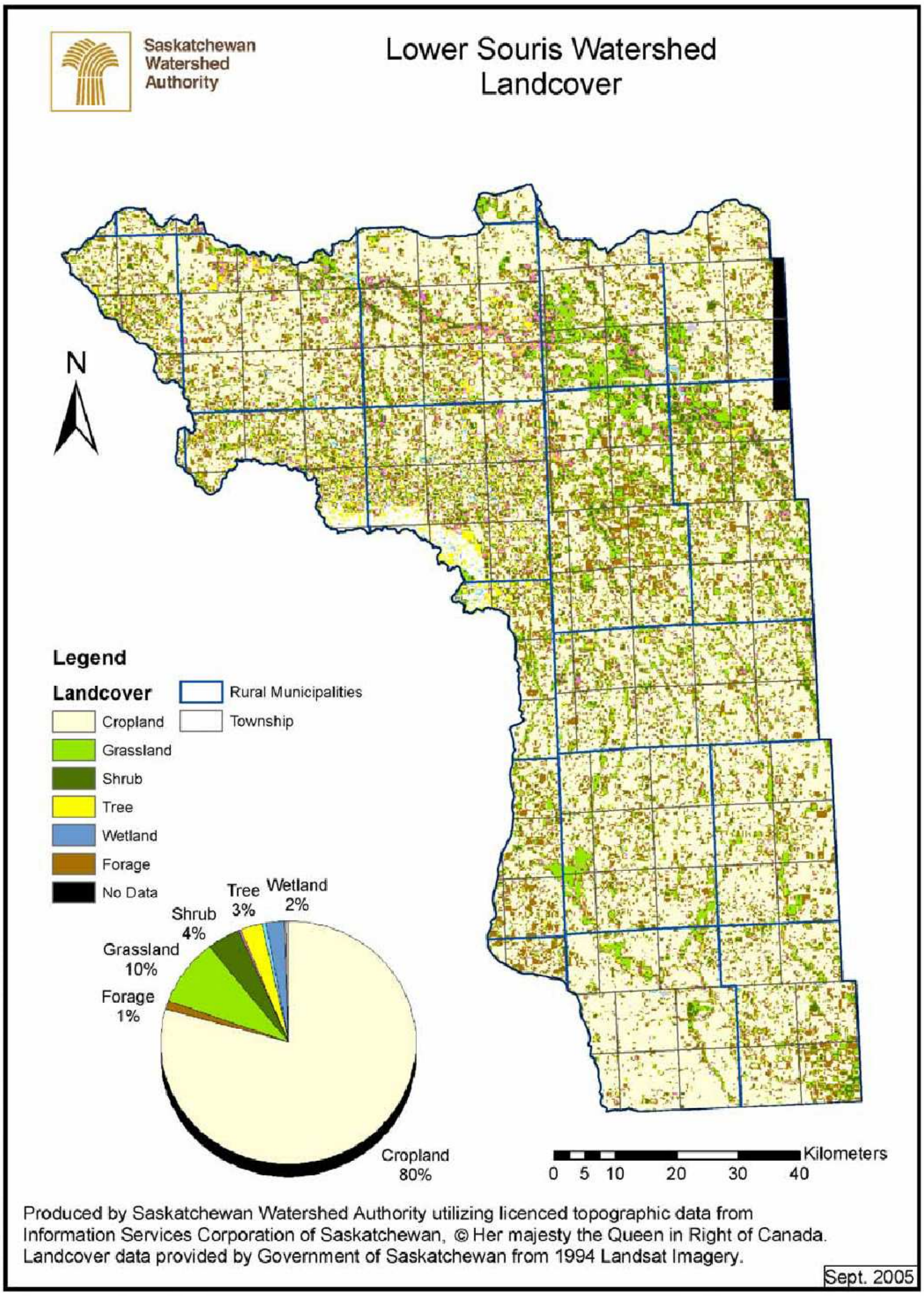
1. "To set specific landscape goals for the quality and quantity of riparian, aspen parkland, and tame grassland wildlife habitat in the Lower Souris Watershed;
2. To determine the net costs (or lack thereof) borne by farmers in the Lower Souris to provide target quality and quantity of riparian, aspen parkland, and tame grassland wildlife habitat;
3. And to conduct a policy analysis of EG&S or non-EG&S tools to achieve specific landscape goals for the quality and quantity of riparian, aspen parkland, and tame grassland wildlife habitat."

Of these three objectives, the second relates directly to the objectives and analysis in this study.

3.3 Landscape and Wildlife Species Types

The Lower Souris River Watershed is located in the Aspen Parkland biome, which historically includes a mix of aspen groves and fescue grasslands (Saskatchewan Watershed Authority, 2005). The dominant soils in the LSRW are the Oxbow loams black chernozemic (Saskatchewan Watershed Authority, 2005). These soils have a loamy texture and are found within the black soil zone. Although aspen and grassland vegetation is native to the Aspen Parkland biome, this type of vegetation has been continually altered since settlement. Native prairie vegetation can now only be found in river valleys, school sections, and on land of extremely poor soil (Saskatchewan Watershed Authority, 2005). Further, upland native prairie has been altered due to invasion of exotic species, including Kentucky Blue Grass and Smooth Brome (Saskatchewan Watershed Authority, 2005). The LSRW also contains large riparian areas in the north, surrounded by continuous aspen forest. This area serves as the headwaters of Pipestone Creek and Antler River. The six most common landscape types found throughout the LSRW are cropland (80%), grasslands such as perennial forage or native prairie (10%), shrubs or treed vegetation (7%), and riparian areas (2%) (Entem et al., 2009). Figure 3.2 provides a schematic of the landscape types found throughout the LSRW.

Figure 3.2 Lower Souris River Watershed Land Cover



Source: Saskatchewan Watershed Authority, 2005, pg. 8[2]

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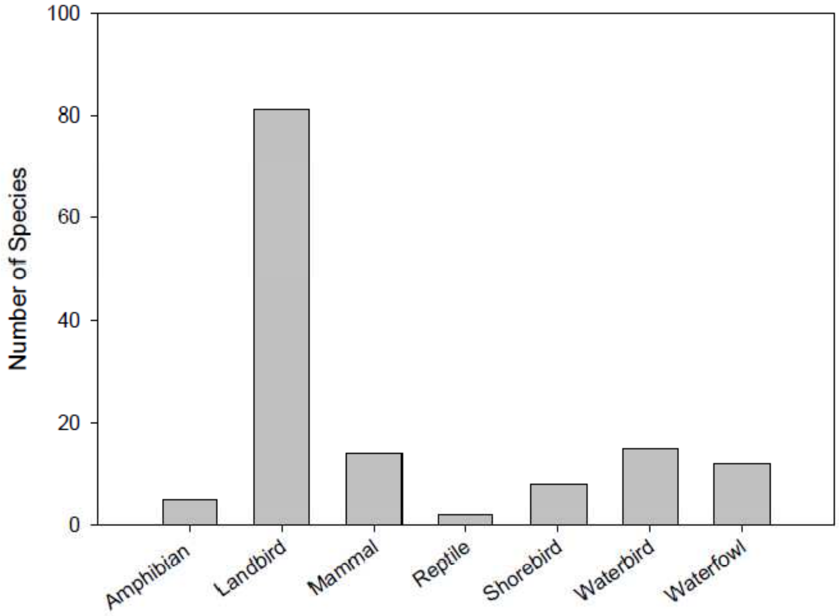
[2] Copyright authorization to include this picture was granted by Etienne Soulodre, Range Ecologist for the Saskatchewan Watershed Authority

Wildlife species found across the LSRW include many avian species (birds), mammals, reptiles, and amphibians. White (2008) found that most of the common species in the watershed are of the land bird taxonomic group, as shown in Figure 3.3. Of the total 137 wildlife species included in his inventory, 116 were avian species, of which 81 were landbirds (White, 2008). These species are found throughout the watershed, but can be most often found in particular types of habitat or landscapes. Further, the amount of wildlife species found within a particular habitat type depended greatly on the relative health of that habitat. In White's (2008) study, the six habitat types found in the LSRW, including cropland, perennial forage, native prairie, aspen, lentic riparian, and lotic riparian, were used to construct 10 species-habitat groups in order to integrate biological responses to landscape change. Species were grouped based on the habitats in which they were found in the greatest relative abundance, and with the other species that showed similar habitat associations (White, 2008). White (2008, pg. 8 and 9) defines the various types of species-habitat groups as follows:

- "*Generalist* - Species with similar relative abundance across all fine scale habitat types as a result of displaying no particular habitat association. This group also included species that displayed low abundance across multiple habitat types.
- *Grassland* ('Tall dense' or 'short-sparse') - Species that have similar abundance in both native grassland and perennial forage habitat categories
- *Native grassland* - Species which displayed increased abundance in native grasslands that reflect their specific requirement for vegetation composition."

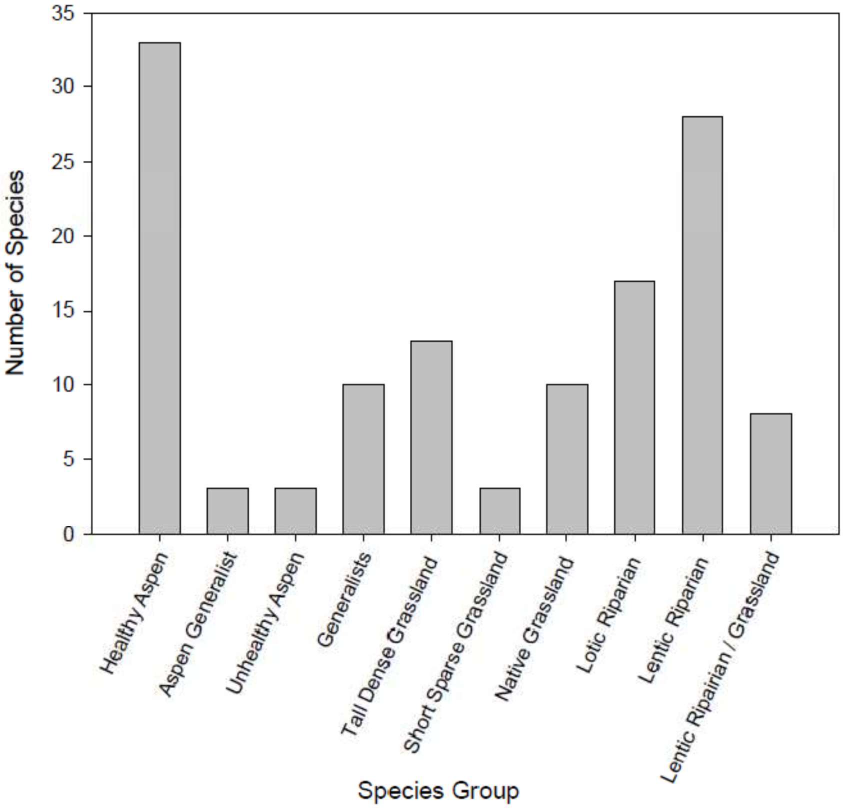
Figure 3.3 Number of Wildlife Species per Classification in the LSRW



Source: White, 2008, pg. 7

For the remaining species-habitat groups (e.g. healthy aspen, lentic riparian), the species were allocated to the various types of habitats found for the remaining landscape types, and their degree of healthiness (White, 2008). Figure 3.4 provides the number of species, of the total 137 wildlife species found across the LSRW, that can be found in each created, species-habitat groups. The healthy aspen species group contained the most number of species, with 33.

Figure 3.4 Number of Species per Species-Habitat Group in the LSRW



Source: White, 2008, pg. 9

The relationship between wildlife species and landscape change in the LSRW is also examined by White (2008). White clarifies that awareness of what a wildlife species needs in terms of habitat is important for the conservation of that species. Further, White (2008, pg. 1) explains that “landscapes are like a patchwork quilt: they are made up of habitat patches. These habitat patches are spread throughout a landscape and the pattern of these habitat patches influences the abundance and distribution of wildlife using those landscapes”. Abundance is determined through habitat selection based on a particular species’ niche requirements. A species niche can be based on “how the species catches its food, what type of food it eats, how much food is available in an area, or where it nests” (White, 2008, pg. 3). With regards to landscape changes, White (2008) found that the magnitude of species abundances increases as the landscape includes more habitat types. Further, White found that there is a positive abundance of species groups as the quantity of grassland habitat (native prairie and perennial forage) increases, as more habitat types are present and as cropland decreases (2008). These results were utilized to construct the landscape targets developed by the Lower Souris River Watershed Committee, which are used in the present study.

3.3.1 Landscape Conversion for Agricultural Purposes

The Lower Souris River Watershed Committee conducted a survey of farms in the watershed during the winter of 2008. The purpose of the survey was to collect data regarding current practices related to the production of EG&S. As part of the survey, data on farm characteristics were also collected. From the survey of 87 farmers in the LSRW, Entem et al. (2009) examined the various land-use practices for a unit of land dedicated to only one use per year, whether that unit of land is crop, forage, or pasture, for each farmer interviewed. Of the acreage summed across all the land units described by farmers, 49% was in annual cropland production, followed by 32% in tame forage production, 13% in riparian habitat, and 14% in aspen parkland habitat (Entem et al., 2009). During the period from 1998 to 2008, there was a substantial amount of land converted to tame forage landscape types, with a corresponding substantial decrease in the amount of land allocated to cropland production. The overall loss of cropland amongst all land units was 1,089 acres, while the overall increase in tame forage was 1,466 acres over the 10 year period (Entem et al., 2009). In addition, the amount of aspen parkland acreage decreased by 54 acres, while the overall loss of riparian habitat was 21 acres (including all acres drained minus acres restored) (Entem et al. 2009).

Although the trend towards loss of riparian habitat and aspen parkland is expected (i.e., is consistent with discussion in Section 2.4), it is at first unclear why land in annual cropland production has been converted to perennial forage over the last 10 years in the LSRW. Entem et al. (2009) indicate that farmers perceive this conversion to have occurred due to poorer productive capacity and/or poor past crop prices. Entem et al. clarify that “some farmers stated that the decreased returns from annual cropping prompted them to either adopt livestock as a farm operation, or to increase their cattle herd.” (2009, pg. 12). Others stated that sloughs and bluffs (and their associated nuisance costs) made the land more suitable for grass and livestock (Entem et al., 2009). This suggests that some farmers only require information about the environmental impacts of land in annual crop production versus tame forage production to encourage conversion. Still, overall results from Entem et al. (2009) indicate that perhaps existing stewardship policies (as discussed in Section 2.5) and watershed priorities (as outlined in Section 3.1), along with economic conditions (i.e. changes in prices), are influencing farmers in the study area to enhance wildlife habitat, through conversion to perennial forages.

3.4 Agricultural Production in Southeast Saskatchewan

Agricultural production in the LSRW is primarily focused on annual crop production and cow-calf livestock operations. The beef herd in the region has grown due to low grain prices in some years, various forage seeding programs, previously strong cattle prices, and an influx of ranchers coming from western Saskatchewan and Alberta (Saskatchewan Watershed Authority, 2005). The LSRW covers the majority of two agricultural census districts, 1A and 1B. The total number of cattle and calves has been consistently increasing in Agricultural Districts 1A and 1B since the 1980s (Harper et al., 2008). Further, the southeast region has historically had a high percentage of the provincial cow herd. Despite this, the land area attributed to native pasture has been steadily declining since the 1980s. Conversely, land area devoted to annual cropland and perennial forages has been increasing during this time period (Harper et al., 2008). Over time, the acres devoted to wheat production have decreased, while the area for oilseeds such as canola, flax, and sunflowers has increased (Saskatchewan Watershed Authority, 2005).

The total number of farms has decreased in the LSRW over the last 30 years. A total of 3,566 farms were reported in the 2006 agricultural census for districts 1A and 1B, while a total of 5,559 farms were reported in the region in 1981 (Harper et al., 2008). Despite this, the amount of land put into agricultural production has increased over the same time period. As a result, average farm size in the region has increased. The average farm size in the area was 948 acres in 1981, while in 2006 average farm size was 1,402 acres (Harper et al., 2008). Along with average farm size, Table 3.1 provides average farm characteristics for Agricultural Districts 1A and 1B, along with two rural municipalities, Moosomin # 121, and Redvers # 61, retrieved from the 2006 agricultural census. These rural municipalities are examined to identify differences between the somewhat moister climate in the north part of the watershed (Moosomin, found in Agricultural District 1A) and the drier climate in the south (Redvers, found in Agricultural District 1B). The average statistics in Table 3.1 represent characteristics of farms within the LSRW and are utilized to construct the representative farm for this study. The annual crops that consistently have the largest area across the watershed include canola, spring wheat, barley, flax, and oats. Furthermore, these five types were recognized by Entem et al. (2009) as being the primary annual crop types grown in the area. These five crop types are the types considered for the representative farm (used in the RFSM) and included in the crop rotation. The largest planted crop types of these five types are canola and spring wheat.

Other average farm characteristics are given in Table 3.1 and are also utilized to construct the RFSM. The average number of cattle and calves for the LSRW is approximately 189 for agricultural district 1B, and 162 for agricultural district 1A. The average number of animals is likely higher than these values for farms that solely include cow-calf operations, and lower for those farms with mixed enterprises (i.e., both crops and beef). Further, land in tame and native pasture follow similar average trends, as among the two districts and two RMs the acreage attributed to each fluctuates around 300 acres per farm. The area of land in native pasture is higher for agricultural district 1A with an average of

529 acres. Land in annual crops is between 800 and 900 acres on average for farms across the four regions. In addition, the average value of farm machinery per farm ranges from $170,000 to $210,000, while the average gross farm reciepts ranges from $120,000 to $140,000. These average farm characteristics for the LSRW are compared to the machinery complement (explained in Section 5.2.1.3) and model results to ensure accuracy of the RFSM.

Table 3-1 Average Farm Characteristics in Lower Souris Region

	Agricultural Region 1B	Agricultural Region 1A	Moosomin (#121)	Redvers (#61)
Farm Size (Acres)	1327	1474	1108	1277
Land in Crops (Acres)	834	998	812	931
Land in Summerfallow	202	287	195	187
Land in Tame Pasture	342	357	277	213
Land in Native Pasture	344	529	306	205
Spring Wheat (Acres)	416	481	-	445
Oats (Acres)	207	176	211	158
Barley (Acres)	246	256	269	258
Canola (Acres)	373	448	438	389
Flax (Acres)	249	291	361	305
Alfalfa (Acres)	209	221	184	161
Tame hay (Acres)	146	198	172	137
Number of Cattle and calves	189	162	199	141
Number of Beef cows	86	-	84	70
Number of Bulls	4	5	-	4
Total farm capital ($)	720,999	779,525	706,382	761,351
Value of farm machinery ($)	183,034	210,122	173,306	206,731
Total gross farm receipts ($)	155,759	130,504	157,831	140,312
Total operating expenses ($)	137,964	119,309	139,394	127,929

Source: Statistics Canada (2006)

3.5 Chapter Summary

In this chapter, a description of the study area is provided. The discussion addresses the role of the Lower Souris watershed in the region, the geography, landscapes, and wildlife species found in the region, and the characteristics of agriculture and farm operations for the study area. The mandate of the Lower Souris watershed committee is important for understanding the objectives of the study. The research attempts to determine the cost or benefits of EG&S policy to farmers with specific regard to policy-making at the watershed level. The relationship between wildlife species and habitat requirements and between habitat requirements and landscape types provides justification for targeting landscapes as a wildlife habitat conservation goal. The LTOM (landscape target optimization model) used in the present analysis determines the impact of maintaining landscape type acreages. Further, the study seeks to determine if landscape conversions will continue as done in the past and found by Entem et al. (2009). From these results there may be implications for wildlife habitat conservation.

The average farm characteristics presented in Table 3-1 are primarily utilized to construct the RFSM (representative farm simulation model). The Lower Souris region contains both crop, beef, and mixed farm operations. Average measurements of acreage per crop type, number of cattle, and financial estimates, etc., from all farm operations in the study region are used to determine a representative farm of the region. By understanding how agriculture works in the Lower Souris region, and what operations and practices are currently most common, one can more effectively build a model that simulates those operations, and proceed with accurate estimation of impacts.

4 Chapter 4: Theoretical Models

4.1 Overview

In this chapter, the theory behind the two models that are used to estimate the costs or benefits to farmers of EG&S practices and policies for the study area is presented. Capital budgeting in the form of NPV analysis is used to represent the yearly cash flow of an individual farm. Simulation analysis is utilized to construct the representative farm simulation model (RFSM) with linkages to important uncertain and uncontrollable on-farm characteristics. Following the discussion of the simulation model used for the present study is an analysis of the economic theory applying to optimization models and linear programming. The landscape target optimization model (LTOM) is used to determine both farm wealth and landscape impacts of a regional EG&S policy, as well as to predict these impacts for the study area given no policy intervention. Hedonic estimation is required to relate landscape changes to farm wealth estimates. The chapter concludes with a discussion of hedonic methodology. In addition, an outline of the general structure of both models utilized for the present study is provided.

4.2 Capital Budgeting

4.2.1 Various methods of Budgeting

Capital budgeting is an investment decision tool used by many businesses to determine the value of long term investments. In this manner, it was used in the present study to determine the private net benefits of implementing EG&S practices on the farm. Many of the on-farm EG&S practices require an initial investment, whether it be the cost of converting landscape types, or fencing for rotational grazing. These practices also often have long-term consequences for farm performance. Given an assumption that farmers seek to maximize wealth, capital budgeting is appropriate to use in evaluating these types of investment decisions.

The various types of capital budgeting techniques include net present value (NPV), internal rate of return (IRR), payback period, and accounting rate of return (Copeland et al., 2005). Of these techniques the most commonly used are NPV and IRR, which use discounted cash flow calculations. As the practices examined in this study are characterized by an initial investment followed by a series of cash flows, the technique used to evaluate the investments had to incorporate these considerations. An additional requirement is that the method should determine the impact on wealth generated from the investment, relative to the opportunity cost of the initial investment. Both NPV and IRR meet these criteria. In addition, Copeland et al. (2005) state that the capital budgeting technique to be used should best satisfy the following criteria:

1. All cash flows are considered.
2. Cash flows are discounted at the opportunity cost of the investment funds.

3. The technique selects from a set of mutually exclusive investments the one that maximizes wealth.
4. Managers are able to consider one investment independently from all others.

NPV was chosen for this study due to its simplicity and its alignment with wealth maximization principles. This aligns with the analysis done by Copeland et al. (2005) who determine that NPV is the technique that best satisfies the criteria, as it is consistent with wealth maximization.

4.2.2 NPV Analysis

NPV analysis uses a discount rate to discount future cash flows. This discount rate is determined through the rate of return of the initial investment (Copeland et al., 2005). The rate of return and therefore, the discount rate, reflects the expected risk of the investment. Copeland et al. (2005) provide the calculation for NPV:

$$NPV = \sum_{t=1}^{N} \frac{CF_t}{(1+k)^t} - I_0 \tag{4.1}$$

where CF_t is the net cash flow in time period t; k is the discount rate, N is the useful life of the investment (in years) and I_0 is the initial investment. A particular investment is acceptable (i.e., has a positive impact on wealth) if the NPV value is greater than zero (Copeland et al., 2005). In this study, farmers are assumed to consider decisions related to implementation of an on-farm EG&S practice in terms of their effect on wealth maximization, and in doing so, would implement a project where a positive NPV is found. As such, any practice resulting in a positive change in farm NPV is considered to provide a direct, private benefit to the farmer. Conversely, any practice where a negative change in NPV is found is considered to result in a net private cost. Furthermore, in those cases where the farm operator has the choice between positive NPV investments, the investment with the largest NPV value would be implemented (Copeland et al., 2005).

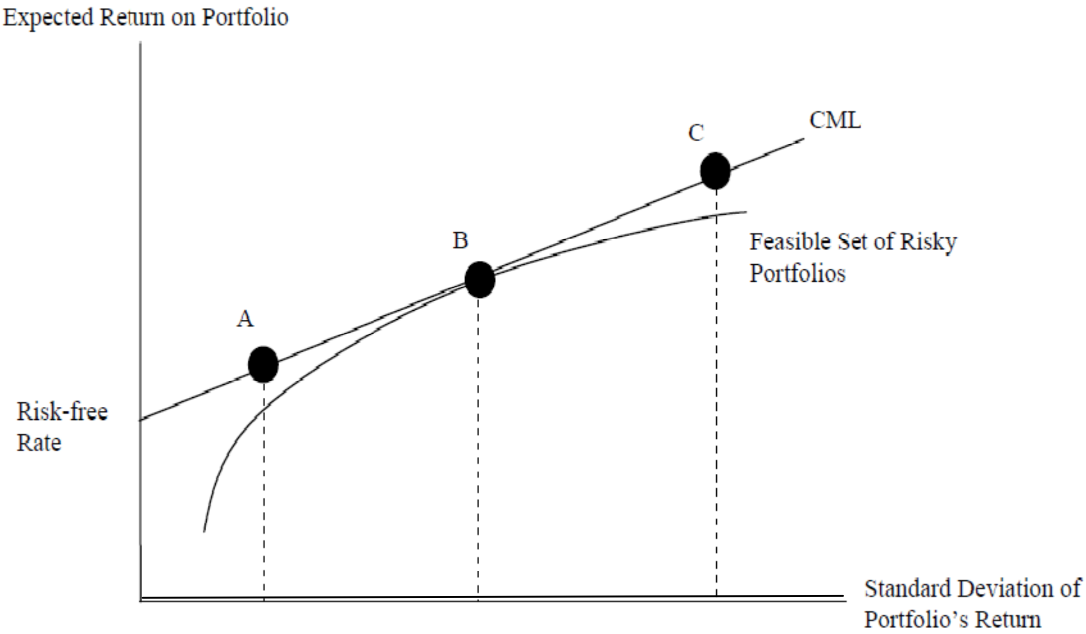
4.2.3 Determining the Discount Rate

The choice of discount rate is of importance as it is often a key element in determining whether a NPV is positive or negative. In this analysis, the magnitude of future cash flows is not known with certainty. As a result, the determination of an appropriate discount rate needs to include some consideration of future risk with regards to investment decisions. Ross et al. (2003, pg. 255) state that “investors will only hold a risky security if its expected return is high enough to compensate for risk”. Riskier investments should have a higher discount rate than less risky investments (Ross et al., 2003). Capital Market Line (CML) theory is a way to determine expected returns for an investment that incorporates risk. Once expected returns are found, a discount rate can be calculated based on the expected return.

Capital Market Line theory determines the optimal portfolio investment from a set of different portfolios, their associated risk, and expected returns. An optimal portfolio can be found for an investor without any knowledge about the risk preferences of the investor (Sharpe et al., 2000). All portfolios located in the efficient set involve an investment in a tangency portfolio combined with varying degrees of risk-free borrowing (Sharpe et al., 2000). Each investor faces the exact same efficient set of portfolio investments, as each person faces the same amount of risk for each portfolio, and thus, will choose a portfolio on an upward sloping linear set with proportional increases in risk and return. This is referred to as the Capital Market Line. All other portfolios that are not efficient are found underneath the line, albeit some could be close to it.

Figure 4.1 provides a graphical representation of CML theory. The upward sloping tangent line is the Capital Market Line. The vertical intercept is the risk free rate of return, r_f. The curved line, referred to as the feasible set of risky portfolios, represents all bundles of investments defined in terms of their expected return and risk (measured in standard deviation of a portfolio's return). From the tangency of the feasible set and the CML line, one can find the market portfolio for the investor. Sharpe et al. (2000, pg. 218) clarifies "the market portfolio is a portfolio consisting of an investment in all securities where the proportion to be invested in each security corresponds to its relative market value". Point B in Figure 4.1 represents the market portfolio and it is the portfolio of risky assets that will be held by everyone in the market given homogeneous expectations (Ross et al., 2003).

Figure 4.1 Capital Market Line Theory



Source: Koeckhoven, 2008, pg. 46

Given non-homogeneous expectations, investors will choose a portfolio that lies somewhere on the CML line depending on their level of risk aversion. The farther outwards along the line chosen, the more risk-loving is the investor (as shown at point C). Points along the line and past the market portfolio (point B) can be reached by this investor by borrowing at the riskless rate to buy more of an risky asset (Ross et al., 2003). However, the closer the efficient set chosen is closer to the risk-free rate, the more risk-adverse is the investor (as shown in point A). In this case, points before point B can be attained by having some combination of the risk-free asset with the assets required for point B (Ross et al., 2003).

The slope of the CML is equal to the ratio of the difference between the expected return of the market portfolio (or any other efficient portfolio on the Capital Market Line), $\overline{r_M}$, and that of the riskless security ,r_f, and the difference in the levels of risk, (σ_M - 0). Here, σ_M is the standard deviation (the measure of risk) for the market portfolio. The riskless security, r_f, has a standard deviation equal to zero (i.e., no risk). Sharpe et al. (2000) provides the CML calculation as follows,

$$\overline{r_p} = r_f + \left[\frac{\overline{r_M} - r_f}{\sigma_M}\right]\sigma_p \tag{4.2}$$

where $\overline{r_p}$ and σ_p are the expected return and standard deviation of an efficient portfolio. In essence, the intercept, r_f, and slope of the CML can be referred to as the 'price of time' and the 'price of risk', respectively (Sharpe et al., 2000).

The above formula from CML theory is used to calculate expected returns from an investment, and then an appropriate discount rate. In calculating expected returns, $\overline{r_p}$, the return on goverment issued treasury bills is used as the risk-free rate, r_f, while the return on an index for the Toronto Stock Exchange is used as the expected rate of return and standard deviation of the market portfolio, $\overline{r_M}$ and σ_M. However, calculating the standard deviation of expected returns of efficient portfolios, σ_p, can be difficult. As such, Copeland & Antikarov (2003) develop a way to estimate the standard deviation, σ_p, using Monte Carlo Simulation for a farm operation.

Since no two investors (or farmers) have exactly the same management styles or expectations it is hard to generalize the volatility of one investor's returns. Copeland and Antikarov (2003) use Monte Carlo Simulation to estimate volatility of rate of return for one farm. The following relationship is modelled with simulation for a farm operation,

$$\overline{r_p} = \frac{NPV_1 - NPV_0}{NPV_0} \tag{4.3}$$

where $\overline{r_p}$ is the farm's expected return, NPV_1 is the net present value from period 1 to *n*, and NPV_0 is the net present value from period 0 to *n*. Initially, an arbitrary discount rate is chosen. For the present study this is 10%, as determined by Koeckhoven (2008) from literature related to calculating initial discount factors for farms. The simulation is then run for a number of iterations to generate a probability distribution around $\overline{r_p}$. From this distribution one can calculate an estimate for σ_p. This estimate is then substituted into equation 4.2 to determine expected returns. As mentioned before, from the estimate for expected returns, one can then determine the discount rate used for NPV estimates.

4.3 Simulation Analysis

Simulation modelling is used in this study to determine the on-farm impacts of EG&S practices that enhance or maintain wildlife habitat. With regards to using straight-forward NPV calculation, optimization, or simulation to determine on-farm impacts, simulation is used as it affords flexibility and the inclusion of a greater number of variables and relationships that are characteristic to the nature of operating a farm. Simulation modelling is defined by Evans and Olson (2002, pg. 2) as "the process of building a mathematical or logical model of a system or a decision problem, and experimenting with the problem to obtain insight into the system's behavior or to assist in solving the decision problem". As such, the model is constructed to gain some form of understanding of the behaviour for the system (Law, 2007). Evaluation of simulation models is done numerically, and data are gathered to estimate the true characteristics of the model. Simulation models are particularly useful when a system or problem exhibits uncertainty, and to gather understanding of the underlying relationships of the system in response to changes in operation (Evans and Olson, 2002; Law, 2007). However, there are many perceived drawbacks to simulation analysis, including: models for large-scale systems tend to be very complex, and a large amount of computer time is required to run a simulation (Law, 2007).

Simulation models are classified in a variety of different manners. A static simulation model is representative of a system at a particular time, or a system where time plays no role, while a dynamic simulation model represents a system that evolves over time (Law, 2007). If a simulation model does not contain any probablistic components or elements of risk, it is referred to as a deterministic model. However, many systems must be modelled with having some probablistic components, and these are referred to as stochastic simulation models (Law, 2007). Finally, a simulation can be further classified as being either continuous or discrete. A discrete model is for a system where the state variables change instantaneously at separate points of time. Meanwhile, a continuous model is for a system where the variables change continuously with respect to time (Law, 2007). For the present study, the model utilized is dynamic, stochastic, and discrete.

4.3.1 Monte Carlo Simulation

Monte Carlo simulation is defined by Evans and Olson (2002, pg. 6) as a ‘‘sampling experiment whose purpose is to estimate the distribution of an outcome variable that depends on several probabilistic input variables”. Monte Carlo simulation uses known, or estimated stochastic distributions of input variables to create distributions of output variables. It is often used to evaluate the expected impact of policy changes that involve risk (Evans and Olson, 2002). Monte Carlo simulation incorporates risk through specification of probabilistic distributions for stochastic input variables. In this sense, one can use Monte Carlo simulation to model systems with inherent uncertainty to gauge how much risk and random variation affects outcomes, such as NPV estimates. However, Monte Carlo simulation involves running the model for a number of iterations (anywhere from 1000 to 10,000) to generate proper outcome distributions. The higher number of iterations, the more accurate is the characterization of outcome distributions (Evans and Olson, 2002). For this reason, a significant amount of computing time might be required to retrieve results. In addition, the analysis of results from Monte Carlo simulation may cause problems as there is no set approach to interpreting the output distributions. Often descriptive statistics are used, as in this study, that include the mean, median, and standard deviation of outcome distributions. However, in some cases the construction of confidence intervals or expressing the distribution in precentiles is preferred (Evans and Olson, 2002).

In the present study, Monte Carlo simulation uses the relationship between on-farm stochastic input variables (e.g., prices, yields) to determine distributions for resulting output variables (e.g., NPV). The model is constructed to simulate the operations of a mixed-enterprise farm in the LSRW. The cash flow relationships are included in the model, where the farm obtains revenues from selling calves and steers, crops, and hay, while incurring expenses associated with producing these goods. In addition, the model incorporates uncertainty as farm operators take on considerable risk relying on variables outside their control, such as prices and weather. Biophysical relationships are included, where crop and forage yields are a direct function of weather, and weaning weights are a direct function of feed availability. Most importantly, the simulation is able to compare the performance of the farm when an EG&S practice is implemented and when a practice is not implemented. The model also includes additional flexibility to incorporate other dynamics, such as participation in farm programs, decisions regarding what is grown on the farm at what time, and a feed inventory for the beef herd.

To model these relationships, @Risk© software from Palisade Corporation coupled with Microsoft Excel© is utilized to construct the Monte Carlo simulation for the study. @Risk© is a software program used specifically to model situations where agents make decisions under uncertainty (Winston, 2000). Distributions of outcomes are created through iterations of the model being solved using sets of stochastic variables drawn from pre-determined distributions (Palisade Corporation, 2007). The distributions created for each simulation run are then compared to determine the impact of EG&S practices on the mixed-enterprise farm.

4.3.2 Representative Farm Simulation Model (RFSM) Structure

The RFSM incorporates key working relationships of a mixed-enterprise farm operation with both crop and cow-calf enterprises. Economic relationships are included as expenses or revenues and summed to determine a final net cash flow for both the crop and beef enterprises. Expenses include expenditures associated with seed, fertilizer, trucking, purchased feed, machinery, etc., while revenues are calculated as crop and cattle production multiplied by prices, plus any returns from participation in government programs, such as crop insurance and AgriStability. More specifically, crop revenues are a function of crop yields realized, based on regional weather patterns, multiplied by randomly generated prices. Beef revenues are a function of calf (weaning) weights at the end of the grazing season, which is also tied to regional weather patterns.

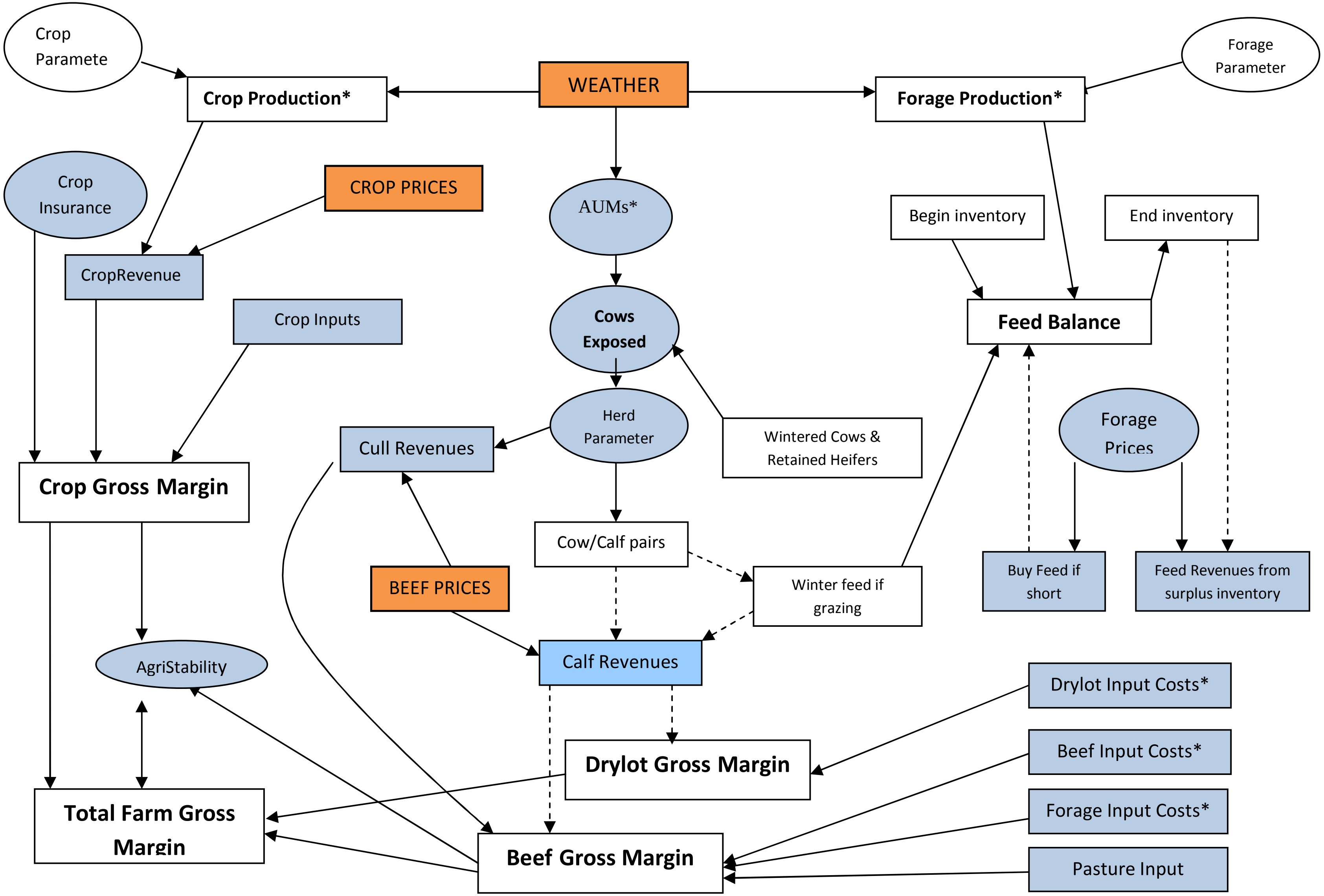
A conceptual diagram of the RFSM is provided in Figure 4.2. The circled objects are predefined variables before the simulation model is run. This includes the government programs, the amount of land allocated to crop and forage production, forage prices, and the beef herd dynamics. Shaded objects in Figure 4.2 are those relationships that are directly related to cash flow on the farm and are used to calculate net cash flow estimates, including the crop modified net cash flow and the beef modified net cash flow.

Modified net cash flow (MNCF) is used as a measure of farm wealth calculated by subtracting expenses from revenues. It is similar to gross margin in that it represents a contribution towards wealth. However, gross margin is defined as revenue minus the cost of goods sold. The cost of goods sold is the summation of all variable expenses required to produce goods. Net cash flow, on the other hand, is the difference between all cash inflows and all cash outflows for either enterprise. Each measurement is useful depending on if decisions are made in the short term, when only variable expenses can be adjusted, or the long term, such that fixed expenses can be adjusted. Given that the simulation model has a twenty year horizon, it is believed that the farmer can change fixed expenses and net cash flow is utilized as the measure of contribution towards wealth. Debt financing expenditures are not included in the net cash flow estimate used in the simulation as these expenditures do not directly relate to on-farm decision making examined in this study. Furthermore, cash outflows for machinery depreciation are included in the net cash flow estimate (i.e. as a proxy for machinery replacement expenditures), whereas they would not usually be considered as a cash flow. In this regard, the wealth measurement is referred to as ‘modified’ net cash flow or MNCF.

The objects in upper case letters in Figure 4.2 represent the stochastic elements in the simulation model; weather, crop prices, and beef prices. The stochastic variables are chosen randomly from fitted distributions as the simulation is run. This is referred to as a random draw, and distributions are determined from historical data. Crop yields are stochastic as well. Annual crop yields are a function of weather patterns in that year. Weather variables are drawn from fitted distributions and are used to determine yields. Weather impacts crop yields in a manner such that extreme events, such as little or no precipitation, negatively affect yields, while a balanced proportion of rain and heat from sunlight positively affects yields (explained in Chapter 5, section 5.2.2.1).

Weather also impacts the forage yield in a given year for both pasture and tame hay production purposes. Forage for tame hay production is used to feed the herd in winter months, while forage for pasture purposes is used to graze the beef herd. In years with favourable weather patterns, tame hay forage may be sold for additional revenue, while forage on pasture can increase grazing season length and increase weaning weights. If the grazing season length is extended, there is less corresponding hay feed required for winter months. Therefore, this would further free up tame hay for forage sales. However, if weather patterns are adverse, additional tame hay may need to be purchased to sustain the beef herd over the winter months. As a result, the dynamics in the feed inventory have an impact on both the crop enterprise MNCF and beef enterprise MNCF. In this manner, the feed inventory is the only simulation component that directly links the crop enterprise with the beef enterprise for the representative farm. Further, the dashed lines in Figure 4.2 represent the inherent model decisions that are made over each year of the simulation, based on yearly dynamics and relationships. These on-farm (within simulation) decisions include: how much hay is sold, how much hay is bought, how many calves are sold, and how much feed is required to sustain the herd over winter.

Figure 4.2 Conceptual Diagram with Modelled Farm Relationships



Source: Koeckhoven, 2008, pg. 58

4.4 Linear Programming

Optimization is a term that refers to the mathematical process of finding goal equilibrium. Chiang and Wainright (2004, pg. 232) define this equilibrium as “the optimum position for a given economic unit (a household, a business firm, or even an entire economy)”. An optimization problem begins with a set of independent variables, and includes restrictions that define acceptable values or combinations of those variables, referred to as *constraints* (Gill et al., 1981). Further, an essential component is the *objective* function, which depends on the independent variables. The independent variables can be referred to as decision variables as the optimizer can pick and choose among these variables in order to achieve his or her goal. The equilibrium state is found when a set of allowable decision variables is determined to generate the ‘optimal’ value, being the extreme point, from the objective function. For economists, optimization is most useful in finding solutions where the objective function seeks to *maximize* or *minimize* something, such as profit or costs (Chiang and Wainright, 2004). Furthermore, it is common to pose optimization problems in a standard form. The general form of an optimization problem developed by Gill et al. (1981) is given below, where $F(x)$ is the objective function and $c_i(x)$ are the constraints,

$$\underset{x \in \mathcal{R}^n}{Minimize} \; F(x)$$

$$subject\ to \; \begin{matrix} c_i\,(x) \; = \; 0, \;\; i = \; 1,2,\ldots, m' \\ c_i\,(x) \geq \; 0, \;\; i = m' + \; 1,\ldots, m \end{matrix} \tag{4.4}$$

A form of optimization called linear programming was utilized to construct the second model, the landscape target optimization model (LTOM), utilized in this study. Mathematical programming refers to all optimization models where the objective function is optimized subject to inequality constraints (Chiang and Wainright, 2004). Linear programming is a special case of mathematical programming where all relationships are linear. For a linear programming problem the objective function is a linear sum of decision variables each multiplied by a coefficient. This is the case for either a profit or cost function utilized as the objective function. Adapting the general form of an optimization by Gill et al. (1981) from equation 4.4 above, the linear programming problem can be labelled as (from Dorfman et al., 1958, pg. 12):

$$Max.\ Z = p_1x_1 + \cdots + \ p_nx_n$$

that is subject to the following constraints,

$$a_{11}x_1 + \ \ldots + \ a_{1n}x_n \leq C_1$$

$$a_{21}x_1 + \ \ldots + \ a_{2n}x_n \leq \ C_2$$

$$a_{31}x_1 + \ \ldots + \ a_{3n}x_n \leq \ C_3$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

$$a_{m1}x_1 + \ \ldots + \ a_{mn}x_n \leq \ C_m$$

$$x_1, \ldots., x_n \ \geq 0$$

(4.5)

where p_n is the price per unit of x_n, and a_{ij} is the coefficient of x_j for a respective constraint function, C_i. The linear constraints specify the main structure of the problem, while the objective function represents the main goal of the problem. The constraints act to 'constrain' the amount of units allocated to each variable from reaching a point that is too high, if it is a maximization problem. If the constraints were greater-than signs rather than less-than signs, the objective function would be unrestricted and the optimization would be unbounded (i.e. the amount of units would increase to infinity).

Linear programming is best used to determine the most efficient way to achieve a certain outcome subject to physical and organizational constraints. In some cases, it is not feasible to determine optimal activity levels through whole farm capital budgeting (Dent et al., 1986). The capital budgeting model type is considered to have too many tedious calculations if a number of farms are to be compared, or summed to determine regional impacts. In addition, capital budgeting does not provide a rigorous search of all combinations of activity levels to determine the optimal combination (Dent et al., 1986). Linear programming overcomes these limitations. Furthermore, Hazell and Norton (1986) state that the optimal values determined from linear programming, given well-articulated on-farm goals and constraints, often predict quite accurately what most farmers do. As such, its predictive nature makes linear programming useful in agricultural sector models for aggregate policy analysis. It is for these reasons linear programming is utilized to inspect the impact of EG&S policy across the LSRW.

Linear programming is one of the most widely used operations research techniques, and is used extensively for planning purposes with regards to agriculture (Dent et al., 1986). Linear programming allows one to test a wide range of alternative combinations and to analyze their consequences with a small amount of solution time (Beneke and Winterboer, 1973). In this regard, linear programming is a good tool in determining the optimal combination of activity levels with regards to a specific goal, such as maximizing farm wealth or minimizing habitat conversion. Dent et al. (1986) provides characteristics of problems to which linear programming can be applied:

1. A range of unit choices (i.e. decision variables) exist and the manager can select the amount of units for each variable he or she wishes.
2. Constraints prevent free selection of unit amounts; and
3. A combination of unit levels relates to a measure of the contibution to a goal (i.e farm wealth) associated with each variable.

However, with linear programming, as with all other models, one must make a variety of assumptions. Paris (1991) defines the three 'crucial assumptions' for a linear programming problem; proportionality, additivity, and divisibility. Hazell and Norton (1986) add additional assumptions to formulate a total of eight assumptions of linear programming with respect to the nature of the production process. These are described below (note: decision variables are termed activities):

1. "*Optimization.* It is assumed that an appropriate objective function is either maximized or minimized...
2. *Fixedness.* At least one constraint has a nonzero right hand side coefficient
3. *Finiteness.* It is assumed that there are only a finite number of activities and constraints to be considered so that a solution may be sought.
4. *Determinisim.* All coefficients [including those for left and right hand side of constraint functions, and right hand side of objective function] in the model are assumed to be known constants.
5. *Continuity.* It is assumed that resources can be used and activities produced in quantities that are fractional units.
6. *Homogeneity.* It is assumed that all units of the same resource or activity are identical.
7. *Additivity.* The activites are assumed to be additive in the sense when two or more are used, their total product is the sum of their individual products...
8. *Proportionality.* The gross margin and resource requirements per unit of activity are assumed to be constant regardless of the level of the activity used..."

(Hazell and Norton, 1986, pg. 13)

The assumptions of additivity and proportionality above ensure that all decision variables (i.e. activities) are linear. As well, additivity and proportionality ensure linearity between the activities and the value of the objective function, *Z.* When activity levels increase by a certain percentage, so too does the percentage increase in the returns from these activity levels. As such, linear programming always assumes constant returns to scale (Hazell and Norton, 1986). Further, linear programming cannot accommodate stochastic price expectations, and cannot incorporate more complex relationships between activity levels and returns (Beneke and Winterboer, 1973). In any of these cases, including linearity between outputs and inputs, additional work must be done outside the realm of linear programming in order to properly include in the model.

The above eight linear programming assumptions have implications for the present study. Given the assumptions of additivity and proportionality, with the implied assumption of constant returns to scale, farm wealth is directly and linearly related to the number of acres per landscape type. Thus, if the number of acres for each landscape type are increased by a factor of *k*, then the level of farm wealth will also increase by a factor of *k*. The homogeneity assumption implies that all acres associated with a specific landscape type are identical, which might not be the case. The 'farm wealth potential' for a respective acre can vary significantly depending on weather, region, soil quality, and soil type. For the purposes of the study, differences in land characteristics are assumed to be more substantial between landscape types than within landscape types.

There are a number of methods that can be utilized to solve a linear programming problem. In the two-decision variable case, an optimal solution can be determined graphically without difficulty. In a linear programming problem, the feasible set is the area where the decision variables can satisfy all constraints simultaneously (Chaing and Wainright, 2004). While an extreme point "occur[s] either at the intersection of two constraint lines, or at the intersection of a constraint line and one axis" (Chaing and Wainright, 2004, pg. 654). Given a maximization problem, one can plot the constraints on a graph, along with the objective function line, and then move the objective function outwards until it touches one feasible, extreme point. However, once a third variable is included this method breaks down. For problems with three or more variables, it is possible to use an algebraic iterative method to determine which extreme point in the feasible set represents the optimal solution. The method used to find solutions in linear programming is called the simplex method. Paris (1991, Chapter 7) provides a detailed discussion of the mathematical process associated with the simplex method.

A number of software programs have been developed to solve linear programming problems, using variants of the simplex method. The Solver add-in for Microsoft Excel (or other spreadsheet programs) can solve simple linear programming problems in a very straight forward manner. However, for large problems with many variables additional software that is compatible with Excel can be purchased, including Premium or Evolver Solver Platforms© from the Palisades Corporation. Specialized programs have been developed specifically for large linear programming problems. GAMS, or General Algebraic Modelling System, is an often used linear programming program. For the purposes of this study, the Premium Solver Platform© was combined with Microsoft Excel to run the linear programming problem and determine solutions.

There are a few computational issues with linear programming that are worth mentioning. In some cases, linear programming problems cannot be solved, while in other cases an optimal solution may exist, but the simplex method takes too long to converge to this solution. A linear programming problem is said to be infeasible if there is no solution that satisfies all the constraints (Hazell and Norton, 1986). Further, a linear programming problem is said to be unbounded if a feasible solution exists that has an infinite value for the objective function (Hazell and Norton, 1986). In both these cases, no optimal solution can be found.

4.4.1 Landscape Target Optimization Model (LTOM) Structure

In the present study, linear programming is used to determine the farm wealth impact of an EG&S landscape target policy throughout the LSRW. An objective is to determine what may be the expected landscape change across the watershed region given policy or no policy intervention. The linear programming problem is based on the assumption that farmers in the study region seek to maximize farm wealth. As such, the objective function seeks to maximize farm wealth subject to a number of constraints. The linear programming model is developed for the township level with the LSRW. It was believed that the township level would provide a good representation of a regional impact of policy. The decision variables (or activity levels) were the number of acres dedicated to the six main landscape types found on agricultural land. These landscape types include cropland, perennial forage, native prairie, aspen habitat, lentic riparian habitat, and lotic riparian habitat. The constraints in the linear programming problem specify the nature of having land in a particular landscape type and the imposition of landscape targets required by the EG&S policy. There are relatively few constraining factors in the base case model prior to imposing the landscape targets constraint.

In the model, a decision variable unit (an acre) is assumed to be freely convertible from its current landscape type to any of the other landscape types. This provides flexibility in the linear programming model, as the optimal solution can be found from every combination of acres per landscape type in the watershed. There are a total of 36 decision variables for every parcel of land found in the LSRW, as every acre of land on each landscape type could remain unchanged, or could be converted to another landscape type. Furthermore, an assumption is made that the level of on-farm decision-making is twofold. A farmer can decide how much of each landscape type (1st decision) and on each quarter section (2nd decision) should make up his total farm acreage. Thus, the total number of decision variables is found by segregating the total number of quarter sections per township (144), then the total number of landscape type conversions (6 * 6 = 36) that can occur on each quarter section.

There is expected to be significant variability between quarter sections (a 160 acre square plot) in terms of how that land parcel relates to overall farm wealth. Thus, it is assumed that the level of acreage per landscape type occurs on a per-quarter section basis. This is a reasonable assumption as quarter sections make up the main form of field size in the

LSRW. In the early settlement of the Western Canadian prairies, agricultural land was originally segregated by townships (consisting of 36 sections), then sections (consisting of 4 quarter sections), then quarter sections (consisting of 160 acres of land), which were individually sold to private buyers, such as farmers (Alberta Land Surveyors Association, 2010; McKercher and Wolfe, 1997). Today, agricultural land parcels are still bought, sold and organized by quarter sections (Saskatchewan Assessment Management Agency, 2007-a).

When the landscape target constraint is not imposed, the linear programming problem is referred to in this study as being ‘unrestricted’. This is not to be confused with the definition of an unrestricted optimization, as the linear programming problem is still subject to inequality constraints. However, the maximization of the wealth objective is done with a limited number of constraining factors. Chapter 5, section 5.3.2 provides the conceptual linear programming problem for the present study and includes equations for the constraints included for both the unrestricted and restricted optimizations. In the unrestricted optimization, the optimization is run with a constraint imposed that ensures that the number of acres converted away from a particular landscape type does not surpass the original acreage found for the quarter section and for the landscape type. In the restricted optimization, the optimization is run including another constraint such that the total acreage per landscape type is at least as much required for the landscape target to be met.

The landscape targets are determined for each sub-watershed within the LSRW (see Chapter 5, section 5.3.6 for further explanation). Three versions of the LTOM model are constructed; one for each sub-watershed in the LSRW. For each sub-watershed, a representative township is chosen to be utilized as a regional area of each sub-watershed. Further detail on these three townships is provided in section 5.3.1. The linear programming model for each township is constructed in Microsoft Excel© using columns as the decision variables and rows as the constraint and objective functions. The Premium Solver Platform© from the Palisade Corporation was purchased to run the linear programming problem using the ‘Large-Scale LP’ engine.

The objective function is such that both the revenue and cost streams of converting landscape types are included in determining farm wealth. There is a cost associated with converting landscape types and this cost is deducted from the wealth coefficients. This cost of conversion further constrains free conversion in establishing an optimal solution, but is important so that the model represents on-farm reality. As well, each respective landscape type for each parcel of land has a specific wealth-generating coefficient that relates the number of acres attributed to the landscape target to overall farm wealth (see section 5.3.4 for an explanation for how the wealth coefficients are determined). To determine the wealth coefficients, hedonic econometric methods were utilized. These methods established an empirical relationship between landscape type acreage and farm wealth. This is the topic of the next section.

4.5 Hedonic Models

Hedonic modelling is used to estimate the relationship between landscape type characteristics and observed farm wealth. In order to determine wealth coefficients, it is necessary to estimate how each individual landscape type contributes to farm wealth for each respective quarter section. Hedonic models are mainly utilized to determine the extent to which attributes of a good or service contribute to the observed price (Ekeland et al., 2004). Rosen (1974) first classified 'hedonic' prices as implicit prices that can be defined by specific amounts of characteristics associated with a good. Hedonic prices assume that the value of a good can be determined by summing the marginal contribution of each characteristic inherent to that good. In the context of the present study, the price of a quarter section of land (i.e. assessed land value) is assumed to be a function of the number of acres for each landscape type found on that quarter section. Furthermore, the choices of agricultural land parcels and their associated wealth values imply choices of landscape acreage attributes. Assessed wealth values and acreage per landscape type per quarter section found in the LSRW were provided to the researcher. Therefore, a model can be created to estimate an implicit price of having an acre of land within a specific landscape type on a specific quarter section. This implicit price can then be incorporated in the objective function of the linear programming problem as the coefficient relating acres per landscape type and farm wealth (i.e. assessed wealth).

Rosen (1974) originally defined a theory of hedonic prices as a problem of spatial equilibrium in which the entire set of hedonic prices guides both consumer and producer decisions in the characteristics space. Rosen (1974) clarifies that the hedonic function can be viewed as the binding constraint in the individual optimization problems of producers and consumers. For example consider a consumer's utility function. In Rosen's view, an individual consumer's utility of a specific good is based on a function of that good's particular characteristics. If more of the desirable characteristics of the good are provided, the consumer will extract more utility from the good (Tauchen and Witte, 2001). Since the consumer retrieves higher utility from the good, he or she places more inherent value in the good and the price of the good may increase accordingly (according to demand theory). In the same manner, for the present study, it is assumed that if more of a desirable landscape type (i.e. the attribute) is provided (such as cropland), then assessed wealth (i.e. price) for the particular quarter section (i.e. good) will be greater. As such, an implicit (or hedonic) price can be revealed for the cropland landscape type by observing the assessed value of the parcel and the amount of acres in cropland (Verbeek, 2004).

Econometrically, hedonic methods are utilized simply by regressing an observed, differentiated product price on the product's characteristics, using the best fitting functional form (Rosen, 1974). Hedonic regression models decompose the dependent variable (i.e. price) being researched into the characteristics that influence the dependent variable (i.e. landscape type), and obtain estimates of the contribution of each characteristic to the dependent variable (i.e. implicit prices). From Rosen's (1974) theory, it is likely that the functional form for hedonic models chosen should be nonlinear. Further, there have been a number of problems in estimating hedonic models. Usually, highly dimensional hedonic models that are estimated with multiple characteristics are required to represent a specific market and can become quite complicated (Ekeland et al., 2004).

The general literature on hedonic models is vast and covers many aspects of the modelling. In almost every case, a price, well-being, or a measure of wealth for a specific good or service is regressed on the characteristics that embody them. Hedonic pricing is especially valuable in markets of heterogeneous goods, where it might be unclear whether one good is preferred by a consumer over the other. For example, in real estate, it is unclear why one home should be priced higher than another. However, it is commonly held that those characteristics that are specific to a home determine the price. In a similar fashion, land can be considered a heterogeneous good. It is unclear why consumers of available land (mainly farmers with regards to the study area) choose one land parcel over another. Only from inspecting the land’s characterstics can trends in land prices be determined.

As stated by Boxall et al. (2004), spatial hedonic models have three basic issues that arise in their construction. These include the choice of functional form, the model specification, and the treatment of spatial dependencies. A linear functional form is needed to calculate the wealth coefficients, as described in section 5.3.3.2, as the degree of wealth impact had to be included as a per acre amount of acreage in a respective landscape type. If a double-log functional form was utilized, the regression coefficients could not be directly included into the linear programming model effectively. For the model specification, multicollinearity is expected among the dependent variables (landscape types). It may be expected that the degree to which riparian habitat influences farm wealth may depend on the degree to which cropland inflences farm wealth, and vice versa, on a respective quarter section. However, none of the dependent variables could be omitted from the model specification because all acres on a quarter section had to be accounted for. As such, the regression analysis is carried out in spite of the potential of bias due to multicollinearity. Lastly, the spatial dependencies inherent to landscape type acreage are directly related to the specific quarter section’s spatial location. In this regard, each quarter section’s spatial location does not impact farm wealth within the LTOM. The next chapter, Chapter 5 - Empirical Methods, provides the methodology followed for construction of both the LTOM and the representative farm simulation model (RFSM).

4.6 Chapter Summary

Net present value analysis combined with Monte Carlo simulation is used to estimate the on-farm impact of EG&S practices that enhance wildlife habitat. Net present value analysis is used over other capital budgeting methods because of its alignment with the wealth maximization principles. A number of key relationships are required to be modelled in the RFSM, and Monte Carlo simulation affords the ability to include these and primary stochastic elements common in farm operation. The RFSM is constructed to simulate a mixed-enterprise (cow-calf and crop) operation that is located in the LSRW. Revenues for the farm include sales of calves, grain, and hay, multiplied by respective market prices. Expenses include expenditures associated with seed, fertilizer, chemical, trucking, purchased feed, and machinery. These revenues and costs are annually summed across the farm to produce modified net cash flow estimates. By modelling the key economic relationships on a representative farm, one can best determine if implementing a respective EG&S practice benefits or does not benefit an individual farmer. If net present value over the twenty year life of the farm modelled increases, there is benefit to the farmer. If net present values decreases, there exists a private cost.

A linear programming model, referred to as the LTOM, is constructed to estimate the cumulative wealth impact of an EG&S policy in the LSRW. Linear programming is often used to determine the best way to achieve a goal that is subject to a number of physical, or other, constraints. Linear programming also allows for a number of farms to be modelled at the same time to determine the impact of the EG&S policy. Here, the goal is to maximize farm wealth across the region subject to land conversion and landscape target (i.e. the EG&S policy) constraints. It is assumed that landscape types implicitly determine the wealth associated with a particular land parcel, through hedonic prices. It is also assumed that farmers can make changes regarding how much acreage per landscape type is found on each quarter section through the region. In this sense, the LTOM model provides enhanced flexibility to farmers in meeting the landscape targets. Furthermore, most-efficient landscape trends that arise from policy or no-policy intervention can be assessed for the private (i.e. farmer) controlled agricultural landscape.

5 Chapter 5: Empirical Methods

5.1 Overview

A description of the empirical methods used to construct the representative farm simulation model (RFSM), as well as the landscape target optimization model (LTOM) is discussed in this chapter. First, the RFSM is presented including all stochastic elements, relationships, and cash flows modelled. The RFSM uses scenario analysis to determine the perceived farm wealth ‘cost’ or ‘benefit’ of practices that arise from managing for enhanced EG&S production. From this analysis, annual costs or benefits per acre of land conserved or managed for EG&S production can be estimated.

This is followed by a description of the empirical methods used to construct the LTOM. As explained in the previous chapter, linear programming is used. The LTOM maximizes farm wealth subject to landscape targets designed to promote EG&S production across the three sub-watersheds located within the Lower Souris River Watershed (LSRW). Separate versions of the LTOM are generated for each of the three sub-watersheds. At the end of the chapter, a specific description of the three sub-watershed townships models is provided.

In both models (i.e. RFSM and LTOM), farm wealth maximization is consistently assumed to be the behavioural objective for farmers. Farmers are assumed to be rational in that they are wealth-maximizers, despite some evidence demonstrating that farm operators may be willing to take on a minor wealth loss in order to protect the natural environment (Agriculture and Agri-Food Canada, 2001; Ducks Unlimited Canada, 2007). However, it is reasonable to assume that farm operators seek practices that increase modified net cash flow estimates (i.e. the estimate of farm wealth used in the RFSM and discussed in the previous chapter) and that increase the assessed wealth of their land (for the LTOM). For the RFSM, it is not necessarily required to assume that farmers are wealth maximizing to determine the impact of various practices on NPV estimates. However, the assumption of wealth maximization is maintained in interpreting the results, as a farmer is expected to undertake practices that increase levels of NPV.

5.2 Representative Farm Simulation Model (RFSM)

The important aspects of a representative farm are incorporated in a Monte Carlo simulation model. The simulation model is a stochastic, dynamic model that simulated the performance of a farm (measured in NPV) over a 20-year horizon. The model utilizes @Risk© software from the Palisade Corporation (2007), an ‘add-in’ for Microsoft Excel, in order to incorporate stochastic elements. Stochastic elements included weather, crop yields, crop prices, and beef prices. Random draws from the distributions of the stochastic elements are made in all simulation iterations and in each scenario run. A total of 1000 iterations are used in this study to generate distributions for NPV results, each with their own respective standard deviation. A total of 1000 iterations are used as this amount has been proven acceptable through a number of previous studies that used Monte Carlo simulation to model a representative farm (e.g. Cortus, 2005; Koeckhoven, 2008). Furthermore, this amount provides consistent and stable distributions of stochastic variables, but is not yet time-burdensome to run a simulation[3].

The Kolmogorov Smirnov test static is "used to decide if a sample comes from a population with a specific distribution" (Croarkin and Tobias, 2006, Section 1.3.5.16). If the test statistic widely improves from moving from 1000, to 2500, to 5000 iterations, than there is justification for using a larger amount of iterations. However, if there is no notable improvement in the test statistic across the three distributions with varying iterations, there is justification for going with the smallest amount of iterations.

It is important to note that the RFSM simulation model was originally constructed by Steve Koekhoven for his M.Sc. thesis (2008) titled *"Economics of Agricultural Best Management Practices in the Lower Little Bow Watershed"*. Koeckhoven's Monte Carlo simulation model was also constructed for a mixed enterprise farm, albeit a much larger one, in Southeast Alberta. The simulation model is adapted and the relationships changed to reflect the representative farm in the Lower Souris region. After receiving the model from Koeckhoven, new data specific to the study area had to be first analyzed and incorporated into the simulation model. Next, the deterministic parameters, such as cow herd size, stocking rates, crop rotation, and feed requirements that reflect the representative farm in the LSRW are adjusted. Regional data for crop prices, beef prices, yields and weather are collected and incorporated into the simulation using the methods described below (section 5.2.2). A new machinery complement is incorporated that is reflective of the representative farm operation (described in section 5.2.1.3). Finally, the economic relationships are adjusted such that the input costs are reflective of southern Saskatchewan farmers; and crop insurance and AgriStability payment calculations are the same faced for Saskatchewan farmers (described in section 5.2.3).

The simulation is used to determine NPVs for each of several scenarios. Scenarios are defined in terms of the various EG&S practices that foster wildlife habitat conservation or enhancement. In the simulation model, the crop rotation, inputs used, and machinery complement remain fixed over the life of the farm. In this manner, the simulation model did not incorporate an element of optimization between limiting constraints (such as land, input costs, and machinery costs). A decision is made as to what is the amount of machinery, type of input costs, and the types of crops grown, given the representative

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[3] A statistical method can be utilized to determine the appropriate amount of iterations for the RFSM. The simulation model could have been run with varying amounts of iterations; for example, 1000, 2500, and 5000 iterations. From these simulation runs, outcome distributions would be compared using the Kolmogorov-Smirnov two sample test. This test determines whether two samples come from the same distribution (NIST, 2003). Of note in this test, one is not testing to determine for a specific underlying distribution (NIST, 2003). The Kolmogorov-Smirnov two sample distribution test could be use to test whether the outcome distributions from 1000, 2500, and 5000 are significantly different from each other.

farm and the study region (described in Chapter 3). In each scenario, the NPV results are compared to a base case scenario. The difference in NPV estimates from the EG&S practice scenario and the base case scenario determines the ‘cost’ or ‘benefit’ of the practice to the farmer. The on-farm simulation linkages that eventually result in annual MNCF estimates are described throughout the rest of this section.

5.2.1 Representative Farm

The representative farm is a typical mixed enterprise operation located within the study area. This farm is developed based on expert opinion (Kyle, 2008; Soulodre, 2008) and data from the 2006 Canadian Census of Agriculture (as shown in Chapter 3, Table 3.1). The land base for the representative farm is based on the number of quarter sections required to run an efficient mixed-farm operation in the Lower Souris region and the average farm size for the study region (Table 3.1). A mixed enterprise farm is one that is involved in both annual crop production as well as livestock (i.e. cow-calf) production. It was decided that a mixed-enterprise farm operation is the best farm-operation type to model since it is typical of many of the farms in the study region (Kyle, 2008; Soulodre, 2008).

Using 2006 Census of Agriculture data, acreage is allocated for a mixed-enterprise farm. The resulting representative farm acreage has a total of 1920 acres or 12 quarter sections. Of this acreage, six quarter sections are in annual crop production, two quarter sections are in forage production for hay, and four quarter sections are in pasture production (both tame and native pasture). For purposes of the RFSM, forage is defined as the hay or silage produced that is used for winter feeding the beef herd. Native pasture is land that provides grazing for livestock and wildlife that has not yet been broken up through cultivation. Tame pasture refers to land that provides grazing for livestock and wildlife that has been cultivated and seeded. Riparian habitat is defined as any land that is influence by water and found in proximity to wetlands, streams, and rivers (Wagstaff, 1986). Often in biology and ecology research, riparian areas are considered as just the transition area (or buffer) between land and water. However, many farmers in the Lower Souris consider any land not used for agricultural purposes due to the location of water features to be riparian. It is this much broader definition that is utilized for the RFSM analysis. Here, riparian habitat includes the area taken up by all water features. Finally, forested habitat is defined as any bush, aspen treed, or native grasses found in the Lower Souris region that is not in proximity to a water feature, but is still not utilizable for agricultural operation (except grazing).

In terms of habitat found across the 12 quarter sections, a typical annually cropped quarter section of land in the LSRW has approximately 10% riparian or forested habitat acreage (Soloudre et al., 2008). On pasture and forage lands, since the farmer can graze cows within riparian and forested habitat, the full 160 acres per quarter section are assumed to be available for use. However, Soloudre et al. (2008) state that usually more riparian or forested habitat is currently found on pasture land than cropland. For modelling purposes, it is assumed that 20% of the acreage is forested or riparian habitat on all quarters utilized for pasture (Soloudre et al., 2008). For a 160 acre quarter section, these percentages work out to 16 acres dedicated to habitat on a cropland quarter section and 32 acres dedicated to habitat on a pasture quarter section. The land allocation to alternative land use types is shown in Table 5-1.

Table 5-1: Representative Farm Acreage

Crop	**Acres**	**Pasture**	**Acres (AUM[a])**	**Habitat**	**Acres[b]**
Spring Wheat	288	Native Pasture	256 (0.65)	Forested	256
Barley	144	Tame Pasture	256 (1.3)	Riparian	256
Canola	288				
Flax	144	**Forage**			
Oats	-	Alfalfa-Grass	288		
		Tame Grass	-		
Total	**864**		**800**		**256**
Overall Total	**1920**				

[a] AUM = Animal Unit Months

[b] The acres per habitat type (forested versus riparian) depend on the scenario considered. For the riparian habitat focused scenarios, habitat acreage is 256 acres in riparian habitat and zero acres for forested habitat. For the forested habitat scenarios, the habitat acreage is vice versa. In the base case scenario, it is assumed that all habitat (256 acres) is riparian habitat.

Land is allocated based on the assumption the crop field size is 144 acres and one crop is allocated per field. In other words, land is allocated to alternative uses in units of 144 acres. In addition, it is assumed that aftermath grazing would occur on all land dedicated to wheat, barley, and tame hay, for an annual total of 720 upland acres being used for this purpose. Use of these crops for aftermath grazing provides significant AUMs and adds to the grazing season length. In addition, for the time period that cattle are allowed to aftermath graze, it is assumed that cattle also have access to riparian areas found on cropland. As a result, an annual total of 80 acres are dedicated to riparian habitat for aftermath grazing on cropland fields. All acreage dedicated to forage is grown for winter feeding purposes only, while pasture utilization occurred over a 4 month grazing season, from June to September. Aftermath grazing is used during the months of October and November for the present analysis.

5.2.1.1 Crop and Forage Production

For soil productivity purposes, crop rotation is inherently important. An effective yearly crop rotation can increase the soil structure with nitrogen and organic matter, improve soil tilth, and conserve plant nutrient (Crisostomo et al., 1993). The simulation uses a six year fixed rotation of spring wheat – canola - spring wheat – canola – barley - flax. Since a total of six quarter sections are used for annual crop production year over year, one quarter section (144 acres) is allocated to each crop type in the six year rotation for each year. In other words, in every year of the simulation there are 288 acres of wheat, 288 acres of canola, 144 acres of barley, and 144 acres of flax, but the specific quarter sections on which crops are grown. The crop rotation is developed based on Census data and on the 2008 survey results from Entem et al. (2009). The rotations capture elements of the average amount of crops grown and reported in the 2006 Census of Agriculture for the region (see section 3.4). In addition, each year of a cereal planted (wheat, barley) is followed by a year of oilseed production (canola, flax), which is most agronomically appropriate (Saskatchewan Soil Conservation Association, 2008).

One benefit provided by a mixed enterprise farm operation is the planting of a forage stand within periods of annual crop production. Entz et al. (1995) surveyed Saskatchewan farmers and found that 71% reported a yield benefit when adding forages into crop rotations. The forage stand rotation for the representative farm is developed based on information from the survey results of Entz et al. (1995) of LSRW farmers, and from the expert opinion of Kyle (2008) and Soulodre (2008). Average forage stand length is seven years and a cover crop (utilized for greenfeed) is usually grown in the first year to establish the crop (Entz et al., 1995). A cover crop adds nutrients and organic matter to the soil, while protecting the forage stand in the early growth stages. Thus, the stand rotation used in the simulation analysis is a cover crop and forage establishment the first year, followed by seven years of alfalfa-grass mix growth (Table 5-2). After the last year of the forage stand, the parcel converts back into the annual crop rotation without a fallow year. After each six year annual crop rotation, on four of the eight quarter sections dedicated to annual crop production for the farm, a forage stand is planted for tame hay purposes. After completion of the eight year forage stand rotation, the quarter section enters the six year annual crop rotation once again.

Table 5-2: Forage Stand Progression

Year	Forage
1	Greenfeed (Barley Cover Crop)
2	Alfalfa-Grass Mix
3	Alfalfa-Grass Mix
4	Alfalfa-Grass Mix
5	Alfalfa-Grass Mix
6	Alfalfa-Grass Mix
7	Alfalfa-Grass Mix
8	Alfalfa-Grass Mix

Forage yield changes with the age of the forage stand. Annual forage yield tends to increase over time until reaching a peak, and then decreases. Leyshon et al. (1981) studied the effects of seeding rates and row spacing of forage crops in southwestern Saskatchewan. Table 5-3 provides a summary of the results from Leyshon et al. (1981), in terms of yield pattern over time for a five year, alfalfa grass mix stand. After establishment of the stand, average yields first increase and then decrease later in the life of the stand. This pattern of change in yield over the life of a forage stand was incorporated into the model. However, the actual forage yields exhibited over the twenty year horizon are randomly drawn from stochastic distributions, discussed later in this chapter.

Table 5-3: Alfalfa/Grass Yield Variation over Time

Year	% yield Differential Relative to 5 year mean
1	+10.00%
2	+34.20%
3	+20.38%
4	-14.98%
5	-53.88%
6	-53.88%
7	0.00%

Source: Leyshon et al. (1981)

5.2.1.2 Cow-calf Production

The cow-calf enterprise makes up one half of the total agricultural land base for the representative farm, including both pasture and forage production. Based on a four month grazing season and stocking rates for the study area, herd size is determined from the grazing carrying capacity allowed on 640 acres of tame and native combined pasture (Table 5-1). The stocking rate is used to describe pasture productivity based on how many animal unit months (AUM) are provided. One animal unit month is defined as the pasture needed to support a 1,000 pound beef cow, with or without a calf. Soulodre (2008) recommended using a stocking rate of 0.65 AUM per acre for native pasture (Table 5-5). For tame pasture, the stocking rate of 1.3 AUM per acre is obtained from Saskatchewan Agriculture (2006-a) for meadow bromegrass in black, light soil, for a stand of seven or more years, and a fertilizer application rate of 100 lbs of nitrogen per acre. The decision to use meadow bromegrass as the representative tame grass and the rate of 1.3 AUM/acre was also recommended by Soulodre (2008) and so it is deemed credible. Furthermore, the soils found in the LSRW are considered to be of the sandy loam black variety (i.e. light soil) and the fertilizer application of 100 lbs of nitrogen is believed to be representative (Soulodre, 2008). In addition to upland stocking, it is assumed that riparian and forested habitat found on pasture lands is not fenced off and therefore had its own stocking rates. The stocking rates used, including those for riparian and forested zones (retrieved from Saskatchewan Agriculture, 2008-a), are reported in Table 5-4. A lower stocking rate (albeit a difference of only 0.1 AUM/acre) is allowed for riparian areas relative to upland pasture. This stocking rate for riparian habitat is considered quite conservative. As noted by Bork (2010), riparian habitat often affords a higher stocking rate than upland tame pasture. However, this discrepancy might be due to how the different (i.e., broader) definition of riparian area used in this study (noted earlier).

Table 5-4: Stocking rates for Upland, Riparian, and Forested land (AUM/acre)

	Upland	**Riparian**	**Forested**
Tame pasture	1.3	1.2	0.15
Native pasture	0.65	1.2	0.15
Aftermath	0.3	1.2	0.15

Based on this information, a herd size of 116 cow-calf pairs could be supported by the carrying capacity of the representative farm. The herd size is calculated by multiplying the stocking rates for native and tame pasture by the amount of acres attributed to native and tame pasture per year (native: 0.65 × 320 = 208 AUMs, tame: 1.3 × 320 = 416 AUMs). The average cow weight used in the analysis is 1,350 pounds. Thus, the amount of AUMs attributed to the pasture acreage are converted to animal unit equivalents (AUE) in the analysis by dividing by 1.35[4] (native: 208 ÷ 1.35 = 154.07 AUEs, tame: 416 ÷ 1.35 = 308.15 AUEs). Finally, given the assumption of a four month average grazing season for the area, the amount of AUEs had to be divided by the number of months on pasture to derive total number of AUE that can be sustained (native: 154.07 ÷ 4 = 38.52 AUEs, tame: 308.15 ÷ 4 = 77.04 AUEs). Adding the amount of AUEs attributed to native pasture and tame pasture provides a total of 116 AUEs (38.52 + 77.04 = 115.58). This herd size is slightly smaller than the average herd size for the area reported in the 2006 Agricultural Census (Chapter 3, Table 3-1). However, a smaller than average herd size is expected given the mixed-enterprise nature of the representative farm.

Within the simulation model the herd size remains fixed; that is, herd size is exogenous to the analysis. Therefore any change in pasture forage availability associated with scenario analysis is assumed to be reflected only in grazing season length and calf weaning weights. In reality, a farm operator would most likely change his herd size to take advantage of increased forage availability. The herd size is kept fixed among all scenarios to facilitate comparability with the base case scenario.

Aftermath grazing is utilized by the farm on land used for annual crop production. The stocking rate used for aftermath grazing is 0.3 AUM per acre (Koeckhoven, 2008; Agriculture and Agri-food Canada, 2003). The average length of time that cows are grazed on aftermath in the simulation is 57 days, given 720 acres available for aftermath grazing, a 0.30 AUM per acre stocking rate, a cow herd size of 116, and an average month length of 30.5 days (i.e., 720 × 0.30 ÷ 116 × 30.5 = 57 days).

The production cycle starts when the cow or heifer is bred, which is followed by calving and then weaning[5]. Table 5-5 shows the basic parameters used for the cow-calf herd in the model (e.g., calf sale weight, weaning rate). Calving and breeding seasons are

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[4] As noted by Bork (2010), this is a simplification of the true relationship between cow size and forage requirements. It is not necessarily the case that this relationship is a linear one.

[5] Weaning is the process of removing a calf from its mother.

predetermined and set to specific months following discussion with Kyle (2008) and Soulodre (2008), and following the analysis done by Koeckhoven (2008). Breeding occurs in June while calving occurs nine months after, in February. The conception rate is the percentage of animals that become pregnant after breeding, while the calving rate is the percentage of animals that give birth to a calf, after being confirmed pregnant. These values include factors such as miscarriages, and remain constant through the simulation horizon. The weaning rate is the percentage of calves that survive the grazing season and are eventually weaned. The 'desired market weight' is the target selling weight for weaned animals. If the target calf market weight is not reached by the end of the grazing season (pasture and aftermath), the calves are assumed to be fed in a drylot (i.e., winter feeding) until the desired weight is reached. However, if the target weight is reached or exceeded, the calves are then sold to a feedlot or backgrounding operation.

Table 5-5: Beef Herd Production Parameters

Basic Herd	116
Bulls	4
Mean cow weight (lbs)	1,350
Conception Rate (%)	89
Calving Rate (%)	98
Weaning Rate (%)	97
Cow Death Loss (%)	1
Calf Weight Gain (lbs/day)	1.9
Desired Market Weight (lbs)	550

Culled cows include all cows sold due to disease, inability to conceive, or inability to produce a calf for any other reason (e.g., post-conception problems). The number of cows that are culled each season is a function of the herd statistics used (Table 5-5) from breeding to weaning. Given the calving, conception, weaning and cow death loss rates in Table 5-5, the culling percentage for this operation is approximately 16% per year. Based on this culling rate and the assumed herd size, 19 replacement heifers are kept in the drylot (with winter-feeding requirements) until breeding in order to maintain a steady-state herd size. The number of bulls for the herd is based on having one bull for every 25 – 30 cows, which is typical for an operation in the Lower Souris region (Kyle, 2008; Soulodre, 2008).

The link between the cropping and beef enterprises exists within the feed inventory. Feed for the cow herd comes from crop production in the form of barley greenfeed and alfalfa/grass hay, and enters the cow-calf enterprise as cattle feed during the winter season. Demand for winter feed is based on animal diets and the length of winter season. Winter season length is equal to 365 days less the grazing season length.

Winter diets (Saskatchewan Agriculture, 2008-b; AARD, 2007) used are summarized in Table 5-6. These diets are in dry matter terms, while the incoming hay feed from the crop enterprise is calculated on a 'wet' matter basis. To be consistent, hay transferred from crop production to the cow-calf enterprise is converted to a dry matter basis. Hay is assumed to be 85% dry matter, with this value being based on the optimal moisture of hay (AARD, 2005). Any hay produced but not required for the herd over the winter season is sold at the market price for alfalfa grass hay. Conversely, if there is a shortage of hay for feed purposes (over the winter season), alfalfa grass hay is purchased at the market price. It should be noted that in many instances farmers will store excess hay production. This is done as a risk management strategy against the possibility of a deficit in the following year. The 'no storage' assumption is made in this case to limit model complexity.[6]

Table 5-6: Winter Feeding Diet (lbs of dry matter/animal/day) by Animal Type

Feed/type	**Cows**	**Bulls**	**Replacement Heifers**	**Market Calves**[a]
Hay/Greenfeed	35.00	45.50	35.00	7.60
Barley Grain	-	-	-	11.50
Minerals	0.08	0.10	0.08	-

[a] Market calves are those that do not meet the desired market weight of 550lbs at the end of the grazing season and are fed in the drylot until this weight is reached.

5.2.1.3 Machinery Complement

To operate a representative farm of this size, equipment is required for seeding, harvesting, and other on-farm activities. Most often, farm operators purchase and own the machinery required to perform these activities, referred to as the machinery complement. In terms of determining a machinery complement for the representative farm, there are alternative approaches that may be used. Cortus (2005) states that an optimal machinery complement for a farm can be determined by using existing machinery selection algorithms. As an example, Oklahoma State University's Optimum Machinery Complement Selection System (OMCSS) can select machinery combinations that cost minimizes performing field operations for a specific time period (Epplin et al., 1982). Alternatively, an ad-hoc selection procedure can be used based on estimates of the requirements for field operations, farm size, and the amount of available farm operator time. For the current study, this ad hoc approach is used for two reasons. First, machinery selection algorithms used in previous studies (e.g., Rotz et al., 1983; Siemens, et al., 1990) required data that are not available for the LSRW region. For example, Siemens et al. (1990) analysis required machine list prices, productivity values, work-day probabilities, and equation constants for computing machine costs. Second, Rotz et al. (1983) explains that farms appeared to possess a larger machinery complement than what

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[6] This assumption that all extra hay is sold rather than stored is a fairly safe one to make as the amount of forage sales and purchases year-over-year had a limited impact on NPV estimates in comparison to the fluctuation of revenues generated from annual crop production and cow-calf sales.

would be optimal using the algorithm, suggesting that the complement chosen from the algorithm may not reflect reality.

The machinery complement for the representative farm in this study is reported in Table 5-7. This machinery complement is developed, in part, through use of expert opinion (Soloudre et al., 2008) in terms of what would be required for a representative farm of this size and structure. It is assumed that the farm operator uses custom spraying and custom grain handling (trucking), and so the machinery required to perform these activities is not included in the machinery complement.

Table 5-7: Machinery Complement

Power Equipment	**Size**	**Drawn Equipment**	**Size**
Tractor	(150 - 200 hp)	Seeder (with tank)	25 foot
Combine	(150 - 250 hp)	Cultivator	25 foot
Grain Truck	single axle, one ton	Bale Mover	7-8 bales
Swather (pull-type)	25 foot	Round Baler (1000	
		Cattle trailer (bumper)	

There are two types of cash flows associated with machinery operations that are relevant for the farm simulation analysis; variable costs of machinery (e.g., fuel, repairs) and replacement costs. Machinery variable costs are discussed later in this chapter, in the section dealing with crop input costs. With respect to replacement costs, farmers in the study region are assumed to replace machinery every five to fifteen years, due to depreciation and technological advances. However, rather than explicitly incorporating machinery replacement decisions and associated costs in the simulation analysis, replacement is modelled as a constant annual cost, similar to the approach taken by Cortus (2005) and Koeckhoven (2008). The assumption is that the farmer allocates funds each year to maintain the initial value of the machinery. This approach is taken because:

a) explicitly modelling machinery replacement decisions requires a considerable amount of extra programming (i.e., to model the decision making process of when it is optimal to replace individual pieces of machinery), and these decisions are not the focus of the current study, and

b) incorporating machinery replacement might influence the simulation results, and thus ‘bias’ the conclusions with respect to the impact of alternative EG&S production practices

The annual replacement cost used in the study is calculated through the annual machinery complement depreciation. Depreciation is a measure of the loss of value of a machine over time. To calculate this cost, an initial book value of the machinery is required. The value of new equipment is estimated based on information gathered from Saskatchewan Agriculture (2008-c). To obtain a realistic machinery value for the farm at the start of the simulation, the machinery complement is depreciated to 8 years of age. That is, the assumption was made that the average machine on the farm was eight years old. A depreciation rate of 8% is utilized as Unterschultz & Mumey (1996) found that combines depreciated between 7% and 9% annually, while tractors historically depreciated between 4% and 8%, depending on the manufacturer.

The resulting depreciated machinery complement value of approximately $294,591 represented the economic value of all machinery at the start of the simulation analysis. This value is higher than the average value of farm machinery for the LSRW (i.e., approximately $200,000 as described in Section 3.3, Table 3-1). However, it was felt that lowering the machinery complement amount could not be achieved without eliminating required machinery for farm operations, or using an unrealistically large depreciation rate.

The 8% depreciation rate for the eight year old machinery complement is then applied to this initial machinery complement book value to obtain the fixed annual replacement cost for the simulation analysis. The calculated value of annual machinery replacement cost is $23,567. As noted above, this value is applied as cash outflow in order to maintain the initial machinery economic value, and is included in MNCF calculation.

5.2.2 Stochastic Variables

All biophysical and economic relationships in the representative farm model are connected to stochastic variables in some form. However, specific parameters of the model are explicitly modelled as being stochastic; crop yields (through stochastic weather conditions), and crop and beef prices. For these parameters, annual values are obtained by randomly drawing from pre-specified distributions. In this manner, the risky properties of a farm operation are incorporated into the Monte Carlo simulation.

5.2.2.1 Weather

For the purposes of this study, it is assumed that weather changes are the greatest driver of crop yield variability. Therefore, weather variables are included in estimated yield equations to incorporate the impact of weather on yield variability for crops and forage. Inclusion of weather variables is thought to be most important, due to the fact that excessive moisture or excessive dry weather can have a severely limiting effect on yield production. As discussed below, the weather variables are calculated using measures of temperature (growing degree days) and growing season precipitation from a local weather station in the LSRW.

Growing degree days are defined as a value representing the buildup of heat over the growing season. Growing degree days for a specific day are calculated using the following equation (Corbally and Dang, 2002):

$$Max\left\{\left[\frac{(MaxTemp + MinTemp)}{2}\right] - K, 0\right\}$$

(5.1)

where, *MaxTemp* is the maximum daily temperature, *MinTemp* is the minimum temperature and *K* is the threshold temperature. The threshold temperature is the temperature at which a plant would start to grow. A generally accepted threshold temperature is approximately 5 degrees Celsuis for plant growth (Corbally and Dang, 2002). Daily values summed over the growing season represent total growing degree days for the year. Growing season precipitation is defined as the total precipitation that falls throughout the growing season (in millimeters).

The growing season is assumed to be from May 1 to October 31, for a total of 185 days. Based on this, total growing season precipitation and growing degree days are determined. Historical daily weather data for the period 1971-2006 are obtained from Environment Canada for the Broadview[7] weather station. This is the nearest weather station to the LSRW that had a complete set of temperature and precipitation data for the relevant period.

To simulate the randomness of weather, probability distributions for growing season precipitation and growing degree days are determined for the simulation analysis using @Risk© distribution fitting functions. Random draws from each distribution are used to represent growing conditions in a particular year. Three test statistics are used to determine the distributions that best fit the cumulative growing season precipitation (GS) and growing degree days (GDD) data; the Chi-Squared statistic, Anderson-Darling statistic and the Kolmogorov-Smirnov statistic. These three test statistics are used to test whether the data can be fitted to a specific distribution (Croarkin and Tobias, 2006). Table 5-8 provides the 'top' three distributions, in terms of fit, based on each of the three test statistics (in bold). In each case, the closer the test statistic is to zero, the better the distribution fits the historical data (Palisade Corporation, 2007). For GDD, the logistic distribution had the lowest test statistics for all three tests, and so it is used in the simulation. For GS, the log-logistic distribution had the lowest test statistics for all three tests, and so it is used in the simulation.

Table 5-8: Weather Distribution Test Statistics

Variable	Chi-Square	Anderson-Darling	Kolmogorov-Smirnov
GDD	**Logistic (2.1111)**	**Logistic (0.4847)**	**Logistic (0.1094)**
	Normal (5.6111)	Normal (0.8041)	Normal (0.1244)
	Triangle (6.7778)	Triangle (1.6905)	Triangle (0.1803)
GS	**LogLogistic**	**LogLogistic**	**LogLogistic (0.0581)**
	LogNorm (1.7222)	Log Norm (0.2702)	Logistic (0.0725)
	Logistic (2.8889)	Logistic (0.3327)	LogNorm (0.0833)

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[7] The Broadview weather station is located in southeastern Saskatchewan in the town of Broadview. This community is located just outside the northwest corner of the LSRW. Looking at Figure 3.1, Broadview would be directly north of Kipling and on Highway 1 (west of Wapella).

5.2.2.2 Crop Yields

As noted in the previous section, variability in weather (i.e., temperature and precipitation) is assumed to influence crop yields. As a result, historical crop yields for the area are modelled statistically as a function of the ratio of growing season precipitation (GS) to growing degree days (GDD). Average yield data for Rural Municipality (RM) # 123, Silverwood, (Saskatchewan Agriculture, 2008-c) for the years 1970 to 2007 are used. The RM#123 of Silverwood is located close, just southeast, to the Broadview weather station. There is no adjustment made to account for the fact that average yield data may not show the same variation as that found for an individual field in the LSRW. Rudstrom et al. (2002) found that aggregating data from small units (i.e. quarter sections) hides differences in yield variability for a region despite heterogenous variance characteristics. Thus the yield variability at the individual field level is higher than that found by aggregating for a region (such as an RM) (Marra and Schurle, 1994; Popp et al., 2005). Popp et al. (2005) found that for wheat, individual field variance could be as high as 11 times greater than aggregated yield variance. However, it is difficult to attain a complete dataset of yields per field for a specific agricultural region.

Marra and Schurle (1994) provide a solution to the problem of underestimating yield variablility. In a meta-analysis of studies that determine the difference of field and county differences in yield variability, Marra and Schurle determine an adjustment factor that can be utilized to adjust aggregate data. They find that regional data variability should be adjusted by 0.1% for every 1% difference in crop acreage at the regional level and crop acreage at the farm level (Marra and Schurle, 1994). This adjustment factor could have been used to adjust the standard errors of the yield equations given in Table 5-9.[8] However, for this study purposes, the adjustment of standard errors due to the use of aggregated yield data is not undertaken.

The equation used to estimate annual crop yields is as follows:

$$y_t^C = a_0^C + a_1^C \frac{GC}{GDD} + a_2^C \left(\frac{GS}{GDD}\right)^2 + \varepsilon_t^C \tag{5.2}$$

where y_t^c represents the yield for crop c (i.e., canola, wheat, barley or flax) in year t, in tonnes per acre. The α's are parameters to be estimated and ε_t is the error term. The independent variable (GS/GDD), included in linear and quadratic forms, represents a water availability-water demand ratio. Greater values of GS represent greater availability of water for use by plants. Greater values of GDD represent warmer growing conditions,

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[8] If the standard errors were adjusted there would have been a minimal impact on NPV estimates. From the results of the RFSM, this study compares the mean value of NPV distributions, rather than the variance to determine the wealth impact of various practices. Additional variation from the crop yield equations would have almost no impact on the mean values of crop production, meaning no impact on mean values of NPV estimates.

resulting in greater demand by plants for water. A quadratic term is included so that the impact of extreme values could be captured separately from normal growing conditions. Extreme values are hypothesized to have a negative impact on yield. An implicit assumption made in using this approach is that crop inputs do not vary in the simulation model; that is, they are assumed to be constant from year to year.

Seemingly unrelated regressions (SUR) are used to estimate these yield equations following the methods described in Koeckhoven (2008) and Cortus (2005). A system of equations is generated so that correlations between different crop type yields are captured in the regression. Regression results for the crop yield equations are provided in Table 5-9. The overall system of crop yield equations in Table 5-9 has an R^2 value of 0.31.

Table 5-9: Estimated Crop Yield Equations

	Estimated Coefficients			
Independent Variable	**Flax**	**Wheat**	**Barley**	**Canola**
(GS/GDD)	0.97766	2.4357**	3.1134	0.46954
SD [a]	*(1.095)*	*(1.082)*	*(1.913)*	*(1.078)*
$(GS/GDD)^2$	-0.9454	-3.572*	-3.9619	-0.07103
SD	*(1.958)*	*(1.934)*	*(3.422)*	*(1.928)*
Constant	0.27293**	0.38407***	0.46308*	0.35223***
Std. Error [b]	0.13248	0.1309	0.23156	0.13048
R^2	0.083	0.1623	0.1347	0.0693

[a] *SD* is the standard deviation of the independent variable found above it.

[b] Standard Error is the total standard error for the regression.

***=significance at 1% **=significance at 5% *=significance at 10%

Calculating crop yields for each year is done through random draws from the two weather distributions (i.e., GS and GDD), along with a draw from a standard normal distribution. This last draw is done to model the variability in yields that is independent of weather variability, and is captured through an error term. In the SUR estimation, the assumption is made that the errors of the various crop types are correlated. As a result, this non-weather variability in yield for each corrected error is calculated based on yield correlations and scaled to their respective standard deviation. The correlations between crop yield equations are captured through the variance-covariance matrix in the SUR estimation. Similar to Cortus (2005) and Koeckhoven (2008), the corrected errors are found according to Hull, (1997) using the following structure:

$$\varepsilon_m = \sum_{k=1}^{k=m} \alpha_{mik} x_k$$

$$\begin{aligned} &\textit{subject to:} \\ &\qquad \sum_k \alpha_{mk}^2 = 1 \\ &\qquad \sum_k \alpha_{mk} \alpha_{jk} = \rho_{m,j}\ , \end{aligned}$$

(5.3)

where ε_m is the corrected error for crop type m, and x_k is the initial standard normal error draw for crop k. Further, $\rho_{m,j}$ is the correlation between the errors for any two crop types, m and j. The α_{mk} terms are calculated from the two constraints given that the constraints are based on the yield correlations of $\rho_{m,j}$. In this sense, ε_m is the corrected error for a particular crop type that depends on the adjusted yield correlations, α_{mk}, and uncorrected error from another crop type, x_k. Since the crop rotation included four different crop types, four correlated error equations are required. Solving for the α_{mk} terms in equation 5.3 gives the following corrected errors provided below, similar to the methodology taken by Cortus (2005) and Koeckhoven (2008):

$$\varepsilon_W - x_W$$

$$\varepsilon_C = \rho_{W,C} x_W + \left(\sqrt{1-\rho_{W,C}^2}\right) x_C$$

$$\varepsilon_B = \rho_{W,B} x_W + \left(\frac{\rho_{C,B} - \rho_{W,C}\rho_{W,B}}{\sqrt{1-\rho_{W,C}^2}}\right) x_C + \left[\sqrt{1-\rho_{W,B}^2 - \left(\frac{\rho_{C,B} - \rho_{W,C}\rho_{W,B}}{\sqrt{1-\rho_{W,C}^2}}\right)^2}\,\right] x_B$$

$$\varepsilon_F = \rho_{W,F} x_W + \left(\frac{\rho_{C,F} - \rho_{W,C}\rho_{W,F}}{\sqrt{1-\rho_{W,C}^2}}\right) x_C + \left[\frac{\rho_{B,F} - \rho_{W,B}\rho_{W,F} - \left(\frac{\rho_{C,B} - \rho_{W,C}\rho_{W,B}}{\sqrt{1-\rho_{W,C}^2}}\right)\left(\frac{\rho_{C,F} - \rho_{W,C}\rho_{W,F}}{\sqrt{1-\rho_{W,C}^2}}\right)}{\sqrt{1-\rho_{W,B}^2 - \left(\frac{\rho_{C,B} - \rho_{W,C}\rho_{W,B}}{\sqrt{1-\rho_{W,C}^2}}\right)^2}}\right] x_B$$

$$+\left\{\sqrt{1-\rho_{W,F}^{2}-\left(\frac{\rho_{C,F}-\rho_{W,C}\rho_{W,F}}{\sqrt{1-\rho_{W,C}^{2}}}\right)^{2}-\left[\frac{\rho_{B,F}-\rho_{W,B}\rho_{W,F}-\left(\frac{\rho_{C,B}-\rho_{W,C}\rho_{W,B}}{\sqrt{1-\rho_{W,C}^{2}}}\right)\left(\frac{\rho_{C,F}-\rho_{W,C}\rho_{W,F}}{\sqrt{1-\rho_{W,C}^{2}}}\right)}{\sqrt{1-\rho_{W,B}^{2}-\left(\frac{\rho_{C,B}-\rho_{W,C}\rho_{W,B}}{\sqrt{1-\rho_{W,C}^{2}}}\right)^{2}}}\right]^{2}}\right\}x_F \tag{5.4}$$

where *W*, *F*, *B* and *C* represent, respectively, wheat, flax, barley, and canola. The GS/GDD ratios and the adjusted errors are then substituted into each crop yield equations to calculate annual yields per crop type.

Before using the estimated crop yield 'sub-model' in the simulation analysis, the yield equations are validated. Specifically, they are tested to determine if the yield distributions generated by the system of yield equations, weather distributions and corrected error equations are consistent with actual area yields. Farmer yield estimates from Entem et al. (2009) are compared to the average from the RM# 123, Silverwood data (Saskatchewan Agriculture, 2008-c) and the @Risk simulation mean yields. In the surveys collected in Entem et al. (2009), farmers are asked to estimate their historical yield averages for the years 2003 to 2007. As shown in Table 5-10, the resulting estimates are substantially higher than the 25 year historical average from Saskatchewan Agriculture (2008-c) and the mean yields generated from the simulation model. For example, the simulated mean for wheat yield is 0.74 tonnes/acre, while the perceived 5-year average for farmers in the region is 1.00 tonne/acre. As a result, the long run average yields in the model simulation are increased by adjusting the equation constants upwards until the model means are equal to the yield estimate means from the survey. The post-adjusted @Risk© simulation mean in Table 5-10 provides the long run average yield after adjusting the constants of the crop yield equations. The resulting yield equations are used to calculate crop yields for each crop in each year of the simulation.

Table 5-10: Comparison of Historical Means, Survey yield estimate Means, and Pre-adjusted Simulated Means (tonnes/acre)

	Flax	**Wheat**	**Barley**	**Canola**
Historical Mean (Sask. Ag. – RM#123)	0.47	0.75	0.98	0.48
Yield Estimate Overall Mean (LS-EG&S)	0.49	1.00	1.29	0.62
Pre-Adjusted @Risk Simulation Mean	0.44	0.74	0.94	0.45
Post-Adjusted @Risk Simulation Mean	0.49	1.00	1.29	0.62
Adjusted constant	1.1877	1.6752	1.7584	1.4742

5.2.2.3 Forage Yields

Due to a lack of yield data for the study region, forage and pasture yields are not generated in the same manner as annual crops. Rather, the co-variability between forage yields and annual crop yields is established using a correlation matrix obtained from Alberta Agriculture and Rural Development (Kaliel, 2007). It is assumed that the correlation matrix between crop yields and forage yields would be similar in southern Saskatchewan as that for southern Alberta, as similar cropping systems (use of barley for greenfeed, and similar hay mixtures) and a similar growing environment (climate, soil type) can be found in both regions. The simulation used the correlation between barley yield and forage yield (i.e., greenfeed and alfalfa-grass hay) to establish yields for the alternative forage crops in each year. Barley is the crop chosen for the correlation because greenfeed is often made from standing barley. The correlations used are provided in Table 5-11. For every 1% change in barley yield, a 0.6% change in greenfeed and a 0.3% change in alfalfa-grass hay occurred, from one year to the next. Average yields for greenfeed and alfalfa-grass hay are obtained from Saskatchewan Agriculture, (2008-e, and 2008-f, respectively) and these are used as starting values for the forage yields. In this manner, stochastic variability in barley yield is a proxy for the stochastic variability of forage yield.

Table 5-11: Crop, Forage, and Pasture Yield Correlation Matrix

	Tame Pasture	**Alfalfa/Grass Pasture**	**Greenfeed**	**Alfalfa/Grass Hay**
Native	0.6	0.6	-	-
Barley	-	-	0.6	0.3

5.2.2.4 Pasture Yields

A pasture yield equation is estimated for the representative farm using precipitation as the main determining factor. Although sunlight and temperature are important for pasture yield, precipitation is assumed to be the major contributing factor to varying native pasture yields. As noted earlier, a lack of pasture yield data for the study area precludes the estimation of yield equations. However, Bork et al. (2001) analyzed the herbage response of native boreal pasture to precipitation in Alberta. The study uses 12 years of data where yield is reported in kg/hectare. The forage yield index (FYI) model is estimated such that FYI is a linear regression of corresponding precipitation (PI) in that year. Indices for forage yield (FYI) and precipitation (PI) are calculated by dividing each annual observation by their respective sample median and multiplying the result by 100 (Unterschultz et al., 2004). The estimated equation from Bork et al.'s data for native boreal pasture is as follows,

$$FYI_t = 4.19 + 1.02PI_t \tag{5.5}$$

The types of forages native to the boreal grasslands of central Alberta are similar to the forages found in the aspen parkland biome of the LSRW (Soloudre, 2008). In addition, both regions have similar precipitation levels. For this reason, the Bork et al. (2001) FYI model (i.e., equation 5.3) is chosen to determine the FYI model parameters for upland pasture yield. The FYI model from Bork et al. (2001) is calibrated for the current simulation analysis using the Broadview weather data, given a growing season assumed to last from May to October. Since the median value is the same as the starting value for the first year in the simulation, the starting FYI and PI values are 100. The forage index, measured in kg/hectare, is converted into AUMs for the simulation following the procedures described in Koeckhoven (2008). Doing this, an AUM yield amount is found for upland native pasture in every year of the simulation.

Variability in tame pasture yields is modelled in a similar manner as greenfeed or alfalfa-grass hay. A correlation value of 0.6 (shown in Table 5-11) captures tame pasture yield changes in relation to native pasture (rather than barley for greenfeed or alfalfa grass hay). Starting values are based on the amount of forage yield required on pasture to maintain stocking rates.

5.2.2.5 Crop and Forage Prices

Similar to crop yields, crop prices are incorporated into the simulation model stochastically. Annual spring wheat and barley Canadian Wheat Board desk prices in-store, Saskatoon for the period 1970-2006 (Saskatchewan Agriculture, 2006), and annual Saskatchewan prices for flax and canola (Statistics Canada, 2008) for the years 1943 to 2006 are obtained for the analysis. Prices are converted to $/tonne and adjusted for inflation using the CPI for all products from the Statistics Canada CANSIM database.

It is hypothesized that crop prices should be modelled using a time-series model that includes lagged prices as explanatory variables. However, the appropriateness of this approach is dependent on whether the data exhibited stationarity for the sample period. Verbeek (2004) states that a stochastic process is stationary if its properties are unaffected by an arbitrary shift along the time axis. Non-stationarity will lead to variances, and means being skewed as the distribution of the dependent variable will change over time. The standard test for testing for non-stationarity is the augmented Dickey Fuller test for unit roots (Verbeek, 2004). Using this test, the null hypothesis of non-stationarity is rejected for all cases without trend for crop prices between 1970 and 2006. Thus, there is sufficient evidence that unit roots are not present in the data, and as such, stationarity exists in the data. For this reason, crop price equations based on lagged dependent variables could be incorporated in the simulation without risk of variances and means being skewed (and thus, incorrect statistical testing) as a result of a moving distribution over time.

As discussed by Verbeek (2004), a more general model will always provide a better fit (within the sample) than a restricted version. Therefore, criteria are required to measure the tradeoff between goodness of fit and the number of parameters used to obtain the fit.

Aikaike’s Information Criterion (AIC) and Bayesian Information Criterion (BIC)[9] are often used to determine the appropriate lag length of lagged time series models. Verbeek (2004) notes that both these criteria represent a tradeoff between fit, as measured by the likelihood value, and parsimony, as measured by the number of free parameters.

Both of these criteria are employed to determine the lag-length of the crop price forecasting equations for canola, hard red spring wheat, flax, and barley. Ordinary least squares regressions with lagged prices from one to five years are tested with these criteria, as it is expected the lowest AIC or BIC criterion is found in regressions with less than five years of lagged prices (shown in Table 5-12). Those lags with the lowest value based on AIC and BIC criterion are shaded in grey in Table 5-12, and as such, are the lag length utilized for the crop price equations. The resulting lag lengths for the crop price models are four years for canola and wheat, and five years for flax and barley.

Table 5-12: AIC and BIC Criterion Statistic for Crop Price Lags

		Canola	**Flax**	**Wheat**	**Barley**
Five Lag	Bayesian (BIC)	8011.2	10597	2175.8	1937.4
	Akaike's (AIC)	6037.3	7986.2	1639.7	1460
Four Lag	Bayesian (BIC)	7326.6	11596	1987.6	1956.4
	Akaike's (AIC)	5800.7	9180	1573.6	1548.9
Three Lag	Bayesian (BIC)	8093.3	14264	2322.3	3057.3
	Akaike's (AIC)	6726.1	11854	1930	2540.9
Two Lag	Bayesian (BIC)	9907.2	15162	2375.4	2810.6
	Akaike's (AIC)	8635.3	13215	2070.5	2449.7
One Lag	Bayesian (BIC)	13108	16036	6994.5	5786.9
	Akaike's (AIC)	11972	14646	6388	5285.1

After determining lag length, a SUR system of equations, similar to that done for crop yields, is estimated for the current year price dependent on lagged prices. This type of SUR estimation is referred to as a vector autoregression (VAR) model. A VAR model includes the lags of the dependent variable and other variables that might play a part in influencing the change of the dependent variable through time. It has a dynamic structure where the lags of all variables are used as independent variables and all current values of the variables are used as the dependent variable. In this manner, historical prices are used to forecast future prices for the farm. The crop price estimated equations are then,

$$P_t^C = \beta_0 + \beta_1 P_{t-1}^C + \beta_2 P_{t-2}^C + \beta_3 P_{t-3}^C + \beta_4 P_{t-4}^C + \beta_5 P_{t-5}^C + \varepsilon_t^C \tag{5.6}$$

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[9] Formulas and an explanation of the Aikaike’s Information Criterion (AIC) and Bayesian Information Criterion (BIC) criterion are provided by Verbeek (2004).

where P_t^C is the price for crop type *C* in time period *t*, β_t's are the coefficients, P_{t-n}^C is the price lagged *n* years from the current year *t*, and ε_t^C is the error term. The advantages of considering the different crop type variables simultaneously are that the model may be more parsimonious and include fewer lags, and that extending the information set to include the history of other variables makes more accurate forecasting possible (Verbeek, 2004). Parameter estimates from this SUR estimation are provided in Table 5-13.

Table 5-13: Estimated Crop Price Equations

	Estimated Coefficients			
Independent Variable	**Canola**	**HRS**	**Flax**	**Barley**
Lag 1	0.74936***	1.0796***	0.59308***	1.1019***
SD [a]	*(0.1403)*	*(0.1394)*	*(0.1132)*	*(0.1102)*
Lag 2	-0.23514	-0.57802***	-0.090975	-0.82623***
SD	*(0.1562)*	*(0.208)*	*(0.1282)*	*(0.155)*
Lag 3	0.059573	0.12182	-0.16591	0.51693***
SD	*(0.1185)*	*(0.1574)*	*(0.1139)*	*(0.1413)*
Lag 4	0.19297**	0.22467***	0.22969***	-0.055817
SD	*(0.09852)*	*(0.08236)*	*(0.08332)*	*(0.1207)*
Lag 5			0.13280***	0.11735*
SD			*(0.03916)*	*(0.0652)*
Constant	78.111**	23.447	91.780***	18.162
Std. Error [b]	64.584	33.822	72.054	31.537
R^2	0.8614	0.8755	0.8469	0.8833

[a] *SD* is the standard deviation of the independent variable found above it.

[b] Standard Error is the total standard error for the regression.

***=significance at 1% **=significance at 5% *=significance at 10%

The SUR estimation results in a total system R^2 of 0.989. Individual crop price equation R^2 values range from 0.85 to 0.88. These R^2 values indicate that most of the variability in historical prices can be explained by these simple time series models.

Since crop prices are a function of lagged prices, initial prices for P_{t-n}^C had to be determined for the starting price where *t* = 0 in the simulation. The historical average price (calculated from the price dataset used in the SUR estimation) is used as the starting value for each of the lagged prices in this period. As in the crop yield estimations, it is assumed that the errors of crop prices are correlated. Using the same methodology for crop yields, values for the error term are taken from a random draw of a standard normal distribution. Since the crop price data are stationary, the stochastic prices reported in the simulation trended towards a long-run mean. In validation of the crop price equations, it was noted that the simulated long-run crop price means are significantly lower than the historical means used as the starting value (shown in Table 5-14). As a result, the price forecasting equations are corrected by increasing the constant until the simulated mean in year 20 of the model equaled the historical unconditional mean.

Table 5-14: Comparison of Historical Crop Price Means vs. Simulation Means ($/tonne)

	Canola	Wheat	Flax	Barley
Historical Mean	357.24	178.55	341.73	167.86
Pre-Adjusted @Risk Simulation Mean	335.34	155.78	305.33	128.49
Post-Adjusted @Risk Simulation	357.24	178.55	341.73	167.86
Adjusted constant	1.0667	1.1569	1.1219	1.3481

The price of forage grown for sale is not included in the SUR estimation. Instead, forage price is modelled deterministically. This is done due to a lack of sufficient data to include forages in the crop price equation estimation process. The market price for any alfalfa/grass hay that is bought or sold in the simulation is assumed to be $64/tonne. This value is chosen based on the long-run average farm price for hay in Saskatchewan for the years 1970 to 2004 (Saskatchewan Agriculture, 2008-g) and from expert opinion (Soloudre, 2008). Including a forage price deterministically in the model had little impact on the simulation results. Average forage sales over the life of representative farm contributed only $2,952 to the average twenty year NPV amount of $971,313 (approximately 0.3% of farm wealth), while average forage purchases is even lower at $991. The main sources of farm revenue included annual crop sales, and the selling of feeder steers and calves.

5.2.2.6 Beef Prices

Stochastic cattle prices are incorporated into the simulation model in a manner similar to crop prices. Prices for different 'classes' of beef animals in dollars per hundredweight (cwt) are obtained from Saskatchewan Agriculture (2008-h). Price data are provided for cull cows, and the various weight classes of feeder steers and feeder heifers. All data are adjusted for inflation using the CPI of all products from Statistics Canada. An assumption is made that cows and calves are sold twice a year, in May and November. This timing is representative of many cow-calf operations in the LSRW (Kyle, 2008) as calves are sold after weaning to backgrounders and feedlots in November and wintered cows may be sold in May if they don't calve. This is important in incorporating into the simulation, as the cow-calf enterprise received revenues two times per year. For every year, revenues are collected in November from weaned calves, and in May from cull cows.

A SUR estimation is developed by first determining the appropriate lag lengths for feeder heifers, feeder steers, and cull cows. As with crop prices, before proceeding with the estimations it is necessary to test the data for stationarity. The data exhibited non-stationarity based on the augmented Dickey-Fuller tests, as the null hypothesis of non-stationarity is not rejected. Despite non-stationarity being present, this result is ignored and stationarity is assumed due to problems when incorporating a non-stationary price model. Dixit and Pindyck (1994) offer support for this assumption. They state that the price of commodities should over the long run, revert towards the marginal cost of production. Thus, if prices are expected to trend toward a stationary price, non-stationarity is not expected. Furthermore, Dixit and Pindyck (1994) state that there may be limited difference in stationary and non-stationary price models with small data sets of less than 30 years. The total data set for beef prices consisted of 32 data points, 16 years of data (1992 – 2008) with two times a year designated when the farm operator could sell - May and November. As a result, stationarity is assumed and beef prices are incorporated in the simulation using the same stationary model format done for crop prices.

The optimal lag length is determined by AIC and BIC criterion using the same methodology used for crop prices, shown in Table 5-15. The lags shaded in grey are the ones used in the SUR estimation for feeder heifer, feeder steers, and cull cows, and are the lowest values for AIC and BIC criteria found. Feeder heifers and steers used a lag of two years, while cull cows used a lag of three years.

Table 5-15: AIC and BIC Values for Beef Price Equations

	Feeder		**Feeder**		**Cull Cows**	
Variable	**AIC**	**BIC**	**AIC**	**BIC**	**AIC**	**BIC**
Lag 1	5.38	5.47	5.42	5.51	5.18	5.27
Lag 2	▨ 5.32	▨ 5.46	▨ 5.34	▨ 5.48	4.88	5.02
Lag 3	5.36	5.55	5.4	5.59	▨ 4.66	▨ 4.85
Lag 4	5.46	5.7	5.5	5.73	4.76	5.00
Lag 5	5.57	5.86	5.61	5.89	4.85	5.14
Lag 6	5.64	5.98	5.71	6.05	4.93	5.26

After determining the appropriate lag length, three equations are estimated and incorporated in the SUR system of equations. These equations included one for feeder heifers, feeder steers, and cull cows. The feeder steer and heifer equations are estimated using prices for the 500-600 lb weight class as the target selling weight in the simulation is 550 lbs. The beef price equation used for heifers is,

$$P_t^H = \gamma_0 + \gamma_1 P_{t-1}^H + \gamma_2 P_{t-2}^H + \varepsilon_t^H \tag{5.7}$$

where P_t^H is the price of the heifer in time *t*, γ_t is the coefficient, P_{t-n}^H is the price of the heifer lagged *n* periods, and ε_t^H is the error term. The estimated equation for feeder steers and cull cows is the same as feeder heifers, except cull cows are lagged for three periods. The parameter estimates for these three equations are reported in Table 5-16. The one period lag coefficient is statistically significant at the 1% level in all three equations and the R^2 values ranged from 0.69 to 0.75. The system R^2 value was 0.82.

Table 5-16: Estimated Beef Price Coefficients

	Estimated Coefficients		
Independent Variable	**Feeder Heifers**	**Feeder Steers**	**Cull Cows**
Lag 1	0.87123***	0.84592***	0.41603***
SD [a]	*(0.1295)*	*(0.1279)*	*(0.1414)*
Lag 2	-0.10531	-0.08469	0.66559***
SD	*(0.1356)*	*(0.1337)*	*(0.1217)*
Lag 3			-0.31938**
SD			*(0.1398)*
Constant	28.694**	32.21**	11.339**
Std Error [b]	13.769	13.503	9.1963
R^2	0.7031	0.694	0.74727

[a] *SD* is the standard deviation of the independent variable found above it.
[b] Standard Error is the total standard error for the regression.
***=significance at 1% **=significance at 5% *=significance at 10%

In years where pasture production is significantly greater than average, feeder animal weights could fall upwards of the 500-600 lb weight class. For this reason, prices for animals in other weight ranges (i.e., greater than 500-600 lb) are needed for the simulation. To do this, ordinary least squares (OLS) estimations are done with the price for 500-600 lb calves as the independent variable and the prices of other weight classes as the dependent variables. The other weight classes used are 600-700 lbs, and 700-800 lbs. The estimation results are shown in Table 5-17. All of the coefficients are significant at the 1% level and R^2 values ranged from 0.96 to 0.99. These relationships are used to obtain annual prices for the other weight classes by substituting in the simulated price for the 500-600 lb animals, generated from the time series equations.

Table 5-17: Price Equations for Alternative Steer and Heifer Weight Classes

	Steer Price Estimation		**Heifer Price Estimation**	
Variable	**6-7 cwt**	**7-8 cwt**	**6-7 cwt**	**7-8 cwt**
5-6 cwt	0.8682***	0.77122***	0.87307***	0.76244***
SD [a]	*(0.01782)*	*(0.02398)*	*(0.01856)*	*(0.02864)*
constant	9.2065***	14.278***	8.8228***	16.877***
Std. Error [b]	2.3821	3.2065	2.5689	3.9639
R^2	0.9884	0.9736	0.9875	0.962

[a] *SD* is the standard deviation of the independent variable found above it.
[b] Standard Error is the total standard error for the regression.
***=significance at 1% **=significance at 5% *=significance at 10%

Incorporating the beef price estimation into the simulation is done in a similar manner as that for crop prices. The historical mean from the beef price dataset is used for all lagged prices required before time period $t = 0$, meaning the starting values of the simulation. With regards to the prices of weight classes outside of the 500-600 lb weight level, starting prices came from using the OLS estimation results (i.e. equations) shown in Table 5-17, and the historical means for the 500-600 lb weight class. In validating beef prices, the pre-adjusted simulation means are very close to the historical means used as a starting value. As a result, no adjustments are required for the constraints.

5.2.3 On-farm Relationships

A number of economic, on-farm relationships had to be included in the simulation model to represent the dynamics found between biophysical production and cash flow. Properly incorporating these relationships ensures that the MNCF generated from each EG&S-promoting scenario is representative of farms in the area, especially when including those expenses and income sources that contribute most to on-farm cash flow. Most important cash inflows and outflows associated with the farm are included in the simulation. However, one exception is debt servicing requirements. These are not included because the cash flow requirements associated with debt payments will vary significantly between farm businesses. In addition, debt financing may not directly influence on-farm activities from year to year, nor change outcomes between scenario comparisons. Regardless, not including these cash outflows could serve to potentially overestimate farm wealth calculated by the model. For this reason, comparison of NPV differences across scenarios should be focused on rather than the absolute NPV amounts reported.

Cash inflow coming from the main government support programs is included in the RFSM, including both federal and provincial risk management programs (i.e. crop insurance and AgriStability). Revenues for the farm include crop, forage, calf, and cull cow sales, as well as government program payouts. Expenses include input costs and the cost of maintaining machinery. As discussed earlier, a yearly depreciation cost for maintaining a required amount of on-farm machinery is incorporated.

5.2.3.1 Revenues

In each year of the simulation, revenue is generated from calf and crop sales. In some years, additional revenue is provided from sale of excess hay inventory left over from the winter season, sale of cull cows, and government payments (i.e., from crop insurance and/or AgriStability). Crop revenues are calculated by multiplying crop production by the price for that particular year, and summing across all crop types. Additional crop revenues from forage sales are calculated by multiplying the excess forage after meeting winter feed requirements by the deterministic hay price. Revenues from calf or cow sales are calculated by multiplying the relevant cattle price (based on the weight and type of the animal) by the number of animals sold, and summing across all animal types. The timing of when these revenues are received throughout the year is dependent on the animal type (as explained in section 5.2.1.2).

5.2.3.2 Input costs

Input costs are the costs incurred for the production process of an agricultural commodity. On the farm, input costs include fertilizer, chemicals, equipment maintenance, seed, fuel, and veterinary costs. Input costs are incorporated into the model (Tables 5-18 and 5-19) and are used to calculate MNCF. For any activities related to crop and forage production, input costs are included in $/acre units, while activities related to managing the beef herd are included in $/cow units. Direct annual crop input costs are based on budgets developed for Saskatchewan crop producers using direct seeding in the Black/Grey soil zone in 2005[10]. These budgets came from the annual Crop Planning Guides developed by Saskatchewan Agriculture (2008-k).

As neither spraying nor trucking equipment is included in the machinery complement, due to the high cost of owning this equipment, custom work costs for spraying and trucking are included as an input cost. Custom work costs for grain handling and spraying are obtained from Saskatchewan Agriculture (2008-c). Machinery repair costs are also included as an input cost.

Input costs for forages and pasture came from a variety of sources. Annual input costs per acre for tame and native pasture are based on cost profile information received from Alberta Agriculture and Rural Development (Kaliel, 2007). This cost profile information is developed from surveys of farmers in southern Alberta, between the years 2005 and 2007. The input cost information retrieved in these cost profiles is assumed to be representative of Southern Saskatchewan farmers in the same time period, as Saskatchewan and Alberta farmers face similar cost environments due to similar application practices, crops grown, input suppliers, and equipment usage. Input costs for alfalfa-grass hay are based on estimates received from Soulodre (2008). Barley greenfeed input costs are based on figures reported by Saskatchewan Agriculture (2008-i). A fixed cost for taxes, licenses, and insurance per acre of agricultural land used is provided by Alberta Agriculture and Rural Development (Kaliel, 2007). Table 5-18 provides a summary of these input costs.

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[10] Crop prices in 2007 and 2008 are higher than the prices that the 2005 input cost budgets are based on. Price forecasting models used in the model are based on historical data and consequently do not generally capture the recent high prices. Using input costs from 2005 provided a better match to the price forecasting models for estimating farm modified net cash flows.

Table 5-18: Crop/Forage Enterprise Input Costs ($/acre/year)

	Wheat	Flax	Canola	Barley	Greenfeed	Alf/Grs	Tame	Native
Seed	7.58	8.75	27.36	6.37	5.25	3	0	0
Fertilizer	30.58	26.7	33.2	30.6	18	6.75	0	0
Chemical	24.38	27.43	29.79	22.37	0	0	0	0
Crop Insurance	4.59	6.6	7.16	4.48	1.69	0.55	1.98	0.29
Fuel, Oil & Lube	8.26	9.44	8.85	8.26	7	12.44	0.07	0.14
Machinery Repairs	9.5	11.4	9.5	9.5	7	10.63	0.15	0.08
Building Repairs	1.6	1.6	1.6	1.6	0.78	0.33	0.19	0.17
Utilities & Misc.	4.93	4.93	4.93	4.93	3.86	3.08	0.13	0.12
Custom Work								
Spraying	2.97	2.97	2.97	2.97	2.97	3.46	0	0
Grain Handling	4.18	2.7	3.15	6.77	-	-	-	-
Capital Costs								
Taxes & Licenses	5	5	5	5	5	5	1	0.2
Total	103.57	107.52	133.51	102.85	51.55	45.24	3.52	1

Sources: Kaliel, 2007; Saskatchewan Agriculture, 2008-k

Input costs for the cow-calf enterprise are based on Saskatchewan budgets produced by the Western Beef Development Centre (Lang, 2006). These budgets are used to estimate expenses for having cows on pasture and keeping them over winter (Table 5-19). Direct costs for keeping cows on pasture and winter feeding are included for purposes of calculating NPVs for only the beef enterprise. The cost of planting and harvesting forage (i.e., tame hay) is only incorporated in the crop enterprise. However, without incorporating this cost, the beef enterprise NPV would be overestimated. For this reason, budget costs for pasture and winter feeding are utilized to determine the NPV for the beef enterprise, shown in Table 5-19 below. In this sense, the costs of feeding cows during winter are counted in the crop enterprise (as the cost of growing forage crops) and in the beef enterprise (as the budget cost of keeping cows winter fed). However, the total farm NPV only includes the cost of growing forage crops in the crop enterprise and does not include the budget costs of pasture and winter feeding. As a result, the cost of winter feeding is not double counted in the total farm NPV.

Table 5-19: Beef Enterprise Input Costs

Direct Expenses	Cow/Calf ($/cow)	Drylot ($/cow/day)
Vet. & Medicine	19.06	0.13
Fuel	17.82	0.05
Machinery Repairs	12.71	0.07
Corral & Building Repairs	5.14	0.08
Utilities & Misc.	16	0.13
Custom Work	15.62	0.05
Capital costs		
Taxes, Water Rates, lic. & Ins.	5.03	-
Direct costs (beef enterprise)		
Winter Feeding & Bedding	156.59	0.96
Pasture	146.35	-

5.2.3.3 Crop Insurance and AgriStability

Canadian farmers are eligible for additional revenue, particularly in unfavourable climate years, through participation in government programs such as crop insurance and AgriStability. The basic structure of crop insurance for Saskatchewan farmers is incorporated into the RFSM following the same approach taken by Koeckhoven (2008) for Alberta farmers. Crop insurance is a risk reduction program that offsets cash flow losses due to low crop yield. Saskatchewan crop insurance offers the choice of four different coverage levels: 50%, 60%, 70%, and 80% of the difference between a farmers predetermined average yield and the actual yield found on a given year. The program cost is shared by government (60%) and farmers (40%) (Saskatchewan Crop Insurance, 2009-a). Farmers choose a coverage level and pay the associated premium for that level. The higher the coverage level, the higher the premium the farmer must pay for crop insurance. The farmer in this study is assumed to use an 80% coverage level for all crops which is typical of most farmers in the region (Kyle, 2008; Soulodre, 2008). The reference yield from which the level of yield coverage is calculated is based on the historical crop yield average in the surrounding area. In the model, if the actual crop yield for a year is below this predetermined level, a payout is triggered based on coverage level. The calculation to determine payout per acre is,

$$P_t = p\left(C * (Y_t^P - Y_t^A)\right) \tag{5.8}$$

where, P_t is the payout amount, p is the insurance floor price, C is the coverage level (as a percentage), and $(Y_t^P - Y_t^A)$ is the difference between the predetermined average yield and the actual yield found on the farm. The predetermined average yield (Y_t^P) is calculated using 90% of the farmer’s previous average yield and 10% of the most recent recorded yield (Saskatchewa Crop Insurance, 2009-b). There is a one year lag for this calculation. Since no average is available as a starting point for the simulation analysis, the 1982-2007 average yield is determined from the data (Saskatchewan Agriculture, 2008-d) and used as the estimate of Y_t^P (given in the first row of Table 5-10). Through the simulation analysis, the predetermined average yield is recalculated annually based on simulated annual crop yields. The floor price used to calculate payouts in the model is the 2008 Base Commercial Price taken from Saskatchewan Crop Insurance (2008). These prices are \$9.19, \$3.27, \$11.56, and \$5.31 per bushel for canola, barley, flax and wheat, respectively. These floor prices are assumed to remain constant (deterministic) throughout the simulation.

AgriStability is the federal/provincial business risk management program (i.e., public safety net) that replaced the Canadian Agricultural Income Stabilization (CAIS) program in 2008. AgriStability works in basically the same manner as CAIS, as it protects farmer income (referred to as 'producer margin' in AgriStability) from extreme events and risks. Farmers receive a payment if the current year's income is less than the average from the past five years. It is assumed that the representative farm in the simulation analysis participates in AgriStability. AgriStability is incorporated into the simulation model in the same manner as Koeckhoven (2008). In order to determine if a program payment is triggered, the program margin for the current year is compared to the reference margin. The reference margin is calculated by taking the average program margin over the last five years, and removing the two years with the highest and lowest program margins. The program margin is not necessarily the same as the MNCF contribution margin. The program margin is found by deducting non-allowable revenues (i.e. crop insurance receipts), and adding non-allowable expenses (i.e. custom work, land taxes, machinery repairs, and building repairs) from the MNCF contribution margin.

With the AgriStability program, farmers must again choose a coverage level: either 70 – 85% (second tier), or 0 – 70% (third tier) coverage level. For the purposes of this study, the farmer is assumed to have second tier coverage, meaning the highest available coverage under AgriStability. Hence, in the RFSM, the production margin must fall below 85% of the reference margin before a payment is triggered. Payments within the second tier cover 70% of the shortfall up to the top of the tier, while payments within the third tier cover 80% of the shortfall. This coverage difference between tiers is represented in equation 5.9 and 5.10 below: a factor of 0.7 reduces the payout retrieved from the second tier, while a factor of 0.8 reduces the payout retrieved from the third tier. The calculation for a payout received when the program margin is in the second tier range (i.e., 70-85% of the reference margin) is then,

$$P_t = \big((RM_t * 0.85) - PM_t\big) * 0.7 \tag{5.9}$$

where P_t is the payout amount, RM_t is the reference margin, and PM_t is the program margin in time *t*. The payment when the program margin is in the third tier range (i.e., <70% of the reference margin) is calculated as:

$$P_t = \left((RM_t * 0.85) - (RM_t * 0.7)\right) * 0.7 + \left((RM_t * \ 0.7) - \ PM_t\right) * 0.8 \tag{5.10}$$

5.2.4 Scenarios

The main purpose of this study is to assess the costs and benefits of adopting practices that promote EG&S production of wildlife habitat. The representative farm simulation model (RFSM) is used initially to determine the private net financial benefits attributed to an individual farm of maintaining healthy wildlife habitat. For comparison purposes, a base case scenario is established. The base case scenario is the RFSM simulated for 20 years without any environmental or management practice constraints implemented on the farm. The base case scenario is used as a reference for all simulation scenarios to determine the extent to which alternative scenarios change farm wealth. The base case assumes that the farm operator undertakes no conversion of current riparian or forested areas over time, keeps land currently in agricultural production constant, and does not reduce stocking rates below carrying capacity on grazed quarter sections.

In regards to scenarios associated with EG&S production of wildlife habitat, three types of changes in general on-farm decisions are modelled with the RFSM. These situations, where a farm operator must make an informed decision, are defined as follows:

1. A farm operator maintains habitat rather than converting habitat to cropland, either by draining wetlands or clearing bush;
2. A farm operator converts cropland to tame grass, through converting a whole field; and
3. A farm operator reduces grazing pressure on pasture lands, through a lower stocking rate or a different management strategy.

5.2.4.1 Scenarios 1-4: Habitat vs. Converting to Productive Land Uses

The first general on-farm decision-making situation relates to conservation of current habitat. In each case, the impact of bulldozing or draining wildlife habitat on agricultural land versus conserving natural areas on the agricultural landscape is modelled. In these scenarios, the base case is considered the practice that promotes EG&S production, while the modelled scenario is a management decision that decreases wildlife habitat quality and quantity. This is consistent with the argument that there are strict on-farm incentives to decrease habitat areas on agricultural land through time. Four separate scenarios representing situations frequently faced by farm managers in the region are evaluated:

- Scenario 1: riparian habitat on land is converted to cropland
- Scenario 2: riparian habitat on land is converted to tame pasture
- Scenario 3: forested habitat on land is converted to cropland
- Scenario 4: forested habitat on land is converted to tame pasture

There is expected to be a cost of conversion associated with converting habitat to another landscape type. This cost of conversion, given in Section 5.3.5 for all four scenarios, is deducted from NPV estimates post-simulation. Thus, on-farm decisions captured while the RFSM is running do so without reflecting on the cost of converting landscapes. Furthermore, it is assumed that the landscape conversions on the representative farm occur instantaneously.

In reality, there would be a time delay in the conversion of landscape types, particularly the conversion of landscapes with large differences in physical attributes (i.e. forested habitat to cropland). In particular, from the time that conversion was initiated until it was completed and the land became agriculturally productive, there would be a time 'lag' of one or more years. It would be possible to model the timing of adopting these changes in habitat. For example, consider the conversion of forested habitat to cropland. A farmer might expect to first bulldoze the trees one year, burn the brush and disk the ground the following year, and disk and cultivate the land for the remaining year, for a total of three years delay until crops can be planted. The cost of converting forested habitat could then be spread out among the three years and the land kept out of the production until year four of the simulation. Doing this would decrease the NPV benefits estimated of converting forested habitat to cropland as land is not put into crop production until the fourth year. However, the length of time required for conversion of habitat to agricultural production is considered to be sufficiently short compared to the overall 20-year time horizon. As a result, this would have limited impact on NPV estimates.

In all four of these scenarios, model parameters are unchanged from the base case scenario, with the exception of the reduction of habitat acreage being protected. In the base case, 10% of the land in crop production is attributed to riparian or forested habitat and is therefore not utilized for agricultural production. As well, any fields dedicated to pasture in the base case are assumed to include 20% riparian or forested habitat. For Scenario 2 and 4, where habitat is converted to tame pasture, cows are assumed to graze on the newly converted tame grass. The stocking rate attributed to this area changes from the original riparian or forested stocking rate to be consistent with the rest of the tame pasture on the farm. The conversion modelled here is assumed to be done for riparian areas that lie within the area initially devoted to tame pasture. Riparian areas within native pasture areas on the farm are not converted.

In each of the four scenarios, results for three sub-scenarios are modelled and reported. These sub-scenarios represent different 'degrees' of conversion, In particular, conversion of ⅓ and ⅔ of the current habitat area, along with complete (i.e., 100%) conversion, is modelled. Given the initial assumption that of 16 acres per cropland quarter is habitat area, the three sub-scenarios are 10.66 acres, 5.33 acres and zero acres of habitat per cropland quarter remaining after conversion. Any land converted from either forested habitat or riparian habitat to cropland or tame pasture is assumed to have equal productive capabilities as the surrounding area. For the purposes of converting from forested habitat scenarios the base case was re-simulated, assuming grazing in forested areas instead of riparian area with associated adjustments in stocking rates. The difference between the results for these scenarios, and the base scenario, represent the direct economic impact to farmers of habitat conservation.

5.2.4.2 Scenarios 5-6: Converting Cropland to Tame Hay or Pasture

The second on-farm decision-making situation is whether a farmer would convert cropland to tame hay or pasture, given the wildlife habitat benefits associated with tame forages versus annual crops. One means by which wildlife habitat can be increased and protected is by converting currently usable agriculture lands from cropland to tame forages (Soloudre, 2008). The results from Scenarios 5 and 6 provide an indication of whether incentives may be required to convert existing cropland to land dedicated to perennial forage, or whether the conversion provides direct economic benefits to the farmer.

In these scenarios, the farmer converts one quarter section of cropland to forage production or pastureland. Again, the cost of converting cropland to perennial forage is provided in Section 5.3.5. The conversion corresponds with a decrease in the number of acres allocated to crop production and an equal subsequent increase in acres allocated to tame pasture (Scenario 5) or tame hay production (Scenario 6). The impact of increased pasture acres is captured in the model by allowing for an extended grazing season. With an extended grazing season, weaning weights will potentially increase, wintering costs may decrease and/or there may be increased forage sales. In Scenario 6, the farmer can take advantage of the extra quarter section dedicated to hay by decreasing the grazing season, increasing weaning weights, or increasing forage sales.

5.2.4.3 Scenario 7-8: Grazing Strategies to Increase Habitat Quality

The third on-farm decision-making situation is when the farm operator partakes in grazing management practices that promote wildlife habitat enhancement. A farmer could change the pasture stocking rate (Scenario 7) or implement rotational grazing (Scenario 8) to preserve biological diversity on native or tame pasture. Scenario 7 examines the impact of a farmer changing stocking rates for pasture that has been overgrazed (i.e., poor pasture condition). The assumption is made that all land dedicated to pasture is in a degraded state. As a result, a revised base case scenario is created with reduced forage availability. Within the RFSM, this reduced forage availability due to pasture in a degraded state is captured through a decrease in the forage utilization factor as a proxy. Decreasing forage utilization limits the amount of forage that cows use for weight gain, and thus, scenario analysis uses changes in forage utilization to increase the amount of forage available to cows similar to forage rejuvenation.

In response to the degraded state, the farm operator could potentially decrease stocking rate in order to allow improvement in the pasture condition (Scenario 7). The trade-off from decreasing stocking rates is that the farmer could increase forage availability from letting the pasture condition improve, but then would have to reduce herd size or provide supplementary feed during the grazing season.

In Scenario 8, the farm operator incorporates additional fencing in order to implement rotational grazing. The assumption is made that the farmer has two quarter sections of tame pasture that are adjacent to each another and two quarter sections of native pasture, also adjacent to each another (i.e., there is a single perimeter fence around the full 320 acres for both tame and native pasture). In the base case scenario, cows can graze within each of the two half-section pasture areas without limitation.

In this adjusted management scenario, the farm operator splits each 320 acre pasture area into two quarter sections by adding a 2640 foot fence ‘down the middle’ of the two joined quarter sections. The cattle are now grazed using a rotation system (i.e., they are periodically moved from one quarter section pasture area to another). Given existing literature on pasture management, the forage availability of these tame and native pasture areas should improve under this management strategy (Miller, 2002; Jacobo et al., 2006). Three assumptions are made regarding rotational grazing management and the change in pasture conditions generated by the adjustment in management. These are that:

a) there exists only one natural watering source in each of the two 320 acre parcels; for this reason, an off-stream watering source is constructed for one of the fenced quarter sections, in each of the tame and native pasture areas – an additional cost;
b) the construction of new watering sources and additional fencing is initiated and completed over a two year period, with 50% being completed within the first year of the simulation and the other 50% of construction occurring in the second year of the simulation; the farmer initiates rotational grazing in year 2 of the simulation on one 320 acre parcel, and in year 3 of the simulation on the other 320 acre parcel;
c) pasture conditions for all four quarter sections improve after the first year of the simulation with implementation of rotational grazing; this improvement is represented in the model by an incremental annual increase in the forage utilization factor.

5.3 Landscape Target Optimization Model (LTOM)

5.3.1 Model Description

The landscape target optimization model (LTOM) is constructed to determine cumulative effects of a hypothetical regional policy that encourages maintenance of wildlife habitat on agricultural lands. The purpose of the analysis is to find the actual cumulative impact on farm wealth in the study region of imposing the EG&S policy. The policy can be considered as a form of regulation: strict landscape targets that the watershed committee wants to maintain on the landscape to ensure wildlife habitat protection. There are a total of three models constructed, one for each sub-watershed in the LSRW. Each entire sub-watershed could not be modelled, but a township provided a large enough area to determine the possible impact of the landscape targets (see Section 5.3.4 for more information). Within each township there exist a total of 144 quarter sections. Three of these quarter sections are eliminated from each township model due to either not being agricultural land, inconclusive data, or having extremely high or low assessed wealth values. As there are 141 quarter sections in each model, and 6 landscape types, there are 5,076 (141 × 6 × 6) different landscape type conversions that are captured in the model, meaning 5,076 total decision variables.

As explained, three townships are chosen to run the LTOM. One township is selected for each sub-watershed: the Antler River, Pipestone Creek, and Four Creeks sub-watersheds. The model is run separately for each sub-watershed because the LSRW is a large region in Southeast Saskatchewan and there exist substantial landscape differences between the three sub-watersheds. The specific townships used for each sub-watershed are chosen due to being representative of general landscape types found throughout the sub-watershed. The township chosen for the Antler River sub-watershed is township 5-33-W1. Figure 5.1 provides the landscape geography found in this township. In the figure, the red line marks the boundary of the township, the dashed line separates the sections found within the township, and green areas define areas of wetlands or bodies of water, while purple areas define areas of forested or bush vegetation. Figures 5.2 and 5.3 detail the landscape geography found in the township chosen for the Pipestone Creek sub-watershed (township 13-2-W2) and the Four Creeks sub-watershed (township 4-30-W1), respectively. From the three figures, it is clear that there are broad landscape differences between the three townships. The Antler River township has limited forested habitat and numerous small wetlands scattered across the landscape. The Pipestone Creek township has larger areas of forested vegetation and larger wetland sizes, but not as many individual wetlands compared to the Antler River township. Meanwhile, the Four Creek township also has forested areas (although not as large as the Pipestone Creek township) and again, several small wetlands similar to Antler River.

Figure 5.1: Antler River -Township 5-33-W1 (GeoSask, Information Services Corporation)

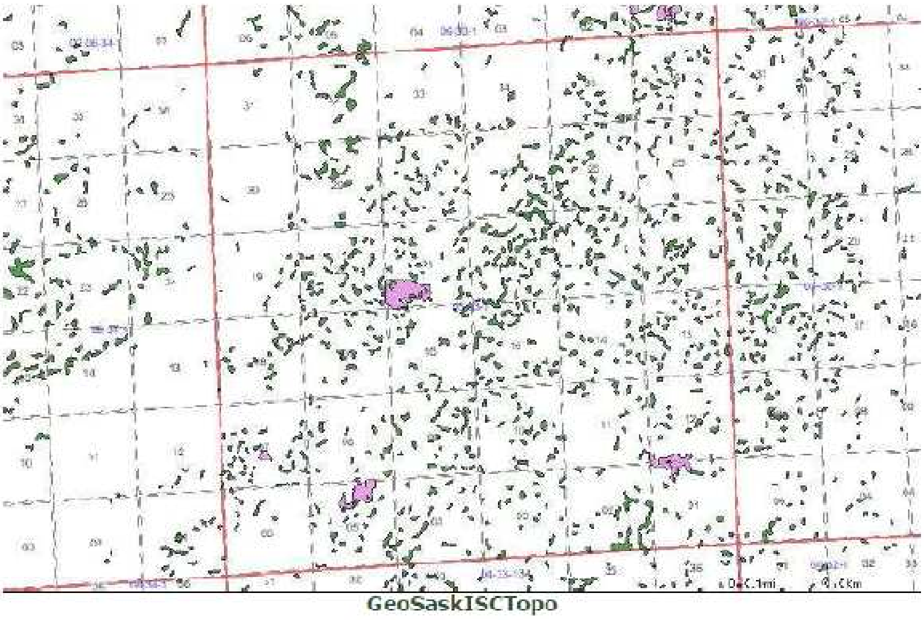
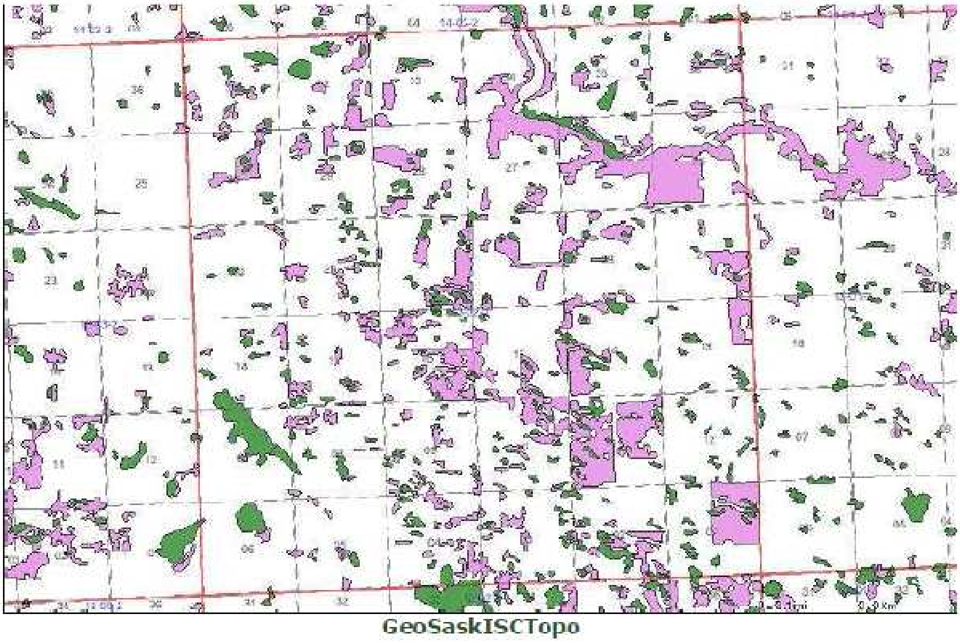
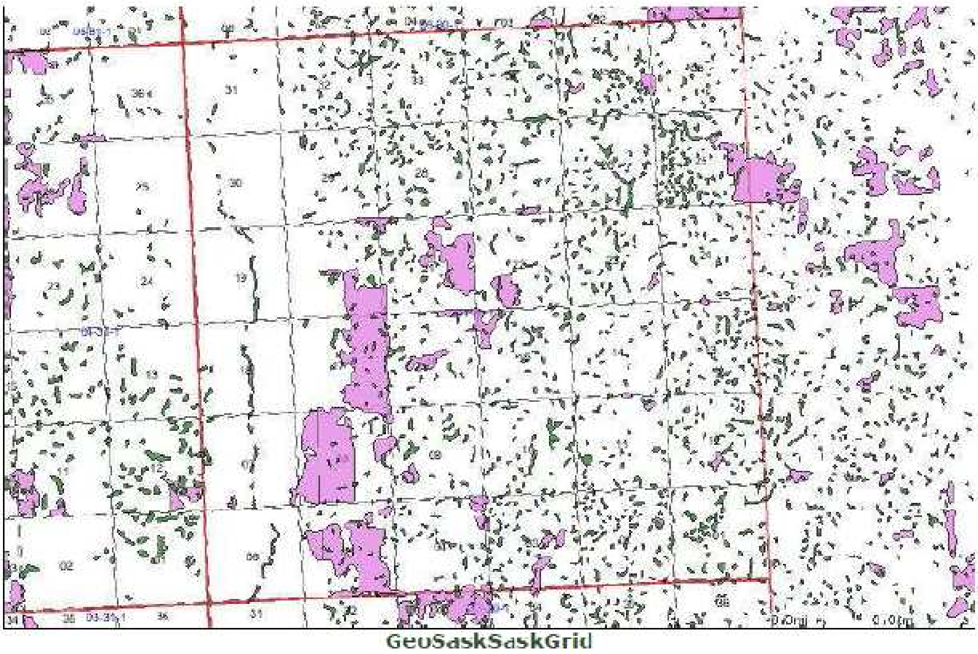


Figure 5.2: Pipestone Creek -Township 13-2-W2



Source: GeoSask – Information Services Corporation

Figure 5.3: Four Creeks -Township 4-30-W1



Source: GeoSask – Information Services Corporation

5.3.2 Model Structure

The general model structure is a constrained maximization, where the maximization function is subject to a number of fixed inequality constraints. The model maximizes farm wealth subject to the physical limitations of converting landscapes, and the landscape targets. For each township that is modelled, an unrestricted optimization (base case) is run to determine the extent of potential landscape change, given current incentives to convert land. A restricted optimization (landscape targets run) is then solved to determine the net impact on farm wealth of ensuring that landscape targets are met.

The maximization objective function for each respective township is:

$$FW = \sum_{k=1}^{141} \sum_{i=1}^{6} \sum_{j=1}^{6} \left(\left(\delta_k^j - \beta^{ij} \right) AC_k^{ij} \right) \tag{5.11}$$

Subject to the constraints:

$$\sum_{j=1}^{6} AC_k^{ij} \leq A_k^i \ \forall \ i, k \tag{5.12}$$

$$\sum_{k=1}^{141} \sum_{i=1}^{6} AC_k^{ij} \ \geq \ T^j \ \forall \ j \tag{5.13}$$

Where AC_k^{ij} are the decision variables, representing acres in quarter section k that are converted from landscape type i to landscape type j.

The parameters of the model are defined as follows:

δ_k^j = per acre assessed wealth coefficient for the j^th landscape type on the k^th quarter section of land

β^{ij} = per acre cost of converting land from the i^th landscape type to the j^th landscape type

A_k^i = the initial (starting) number of acres for the i^th landscape type on the k^th quarter section of land

T^j = the landscape target (in acres) for the j^th landscape type

FW = cumulative farm wealth (assessed value of all land in township)

It is important to note that for the decision variables (AC_k^{ij}), the case where i and j are the same landscape type represents no conversion of landscape types, and the associated conversion cost (β^{ij}) is zero. The per acre wealth coefficient for each landscape type, δ_k^j, is defined based on the relationship between the various combinations of landscape types found on a particular quarter section and the assessed wealth for that quarter section. An assumption is made that the fair market assessed value of the quarter section is a reasonable proxy of farm wealth. In the case of Saskatchewan agricultural lands, higher productive lands (those with good soil quality, drainage, less riparian and forested areas, and good for annual crop production) are generally assessed as having higher value than marginal lands. The cost of conversion, β^{ij}, is the direct financial cost to the farm operator of converting landscape types on their land.

Of the two sets of constraints defined for the model, the first set (equation 5.12) is adding up constraints. Equation 5.12 ensures that the number of acres converted from each specific landscape type (e.g., cropland) does not exceed the initial number of acres allocated to that landscape type. Since there are 6 landscape types, and 141 quarter sections, there are 846 (6 × 141) constraints of this nature. The second set of constraints (equation 5.13) is included in the landscape target runs for the optimization model. These constraints ensure that the ending (i.e. values for the model solution) number of acres per landscape type across the entire township meets or exceeds the landscape type targets set by the LSRW. The landscape targets are incorporated as constraints as to ensure that the proportion of acreage attributed to one landscape type does not decrease beyond the targeted amount. In this manner, the target constraints (i.e. regulation) are the main instrument to maintain wildlife habitat and promote enhancement of priority areas.

5.3.3 The Landscape Types and GIS Data

There are six different landscape types found across each of the respective townships used in the LTOM. These landscape types include: cropland, perennial forage, native prairie, aspen habitat, lotic riparian habitat, and lentic riparian habitat. These six forms of landscapes are commonly found on agricultural land across the LSRW (as discussed in Chapter 3, Section 3.3), and are usually maintained or controlled by farmers. In fact, over 98% of all the land provided in the LSRW (meaning over 14,000 quarter sections) is dedicated to one of these landscape types, as defined in this study. For the purposes of the LTOM, cropland is any land seeded to annual crops, native prairie is defined as native grassland landscapes, perennial forage is defined as any landscapes seeded to tame grasses, aspen habitat includes shrub, treed, or generic grassland landscapes, lentic riparian habitat is any wetland or standing water habitat, while lotic riparian habitat is any habitat close to running water (e.g., streams, creeks, rivers) (Soloudre, 2008).

The amount of acres attributed to each landscape type in each quarter section is determined through analysis of GIS data. These GIS data, obtained from Etienne

Soloudre (Soloudre, 2008), are originally collected by Ducks Unlimited. Included with the GIS data from Etienne Soloudre is the current assessed value for each respective quarter section. Assessed value refers to the fair market assessed value of each parcel of land as calculated by the Saskatchewan Assessment Management Agency for tax and other purposes (Saskatchewan Assement Management Agency, 2007-a). Table 5-20 provides summary statistics for the assessed wealth valuations for the three sub-watershed townships, and specifically for those 141 quarter sections found in each township model. Across all three townships, average assessed wealth per quarter section is approximately $40,000, while cumulative assessed wealth is approximately $6 million.

Table 5-20: Initial Assessed Value Per Township and Per Quarter Section ($)

	Total Assessed Value	**Average Assessed $ per quarter**	**Standard Deviation**
Antler River	$ 6,047,000	$ 42,886.52	*$ (10,069.82)*
Pipestone Creek	$ 5,646,300	$ 40,044.68	*$ (8,803.97)*
Four Creeks	$ 5,553,800	$ 39,388.65	*$ (8,304.58)*

5.3.4 Wealth Coefficients

The wealth coefficients for the linear programming objective function coefficients are determined through hedonic regression analysis. As noted earlier, the assessed value of land is used as a proxy for farm wealth. As such, it is believed that assessed values reflect the discounted value of all future agricultural wealth potentially generated by the land. Generally, for land utilized for agricultural purposes, and isolated from large urban centres, industrial developments, transportation corridors, and other resource commodities (e.g., oil and gas fields), the potential for agricultural production forms the basis of determining the land’s assessed value (Saskatchewan Assement Management Agency, 2007-a). In the Lower Souris region, a case can be made that land is characterized in this manner, as there is limited proximity to large urban centres, etc., and the region is in the heart of the grain-growing agriculture belt in southern Saskatchewan. In addition, when there are recessionary periods in farming (from perhaps low prices or drought) it is somewhat (albeit slowly) reflected in the market price of agricultural land and therefore, the assessed value of agricultural land. For these reasons, there may potentially be a strong, long-run trend correlation between the assessed value of agricultural lands in the LSRW, and the relative degree of wealth generated from farm operations.

Hedonic regression models are constructed with assessed value as the dependent variable and the six landscape types making up the six independent variables. The units for the six independent variables are the number of acres dedicated to each landscape type per quarter section. Furthermore, to provide greater regression strength, quarter sections in each township are split into subsets of high assessed value and low assessed value, and following this, regressions are constructed for each subset. Quarter sections at or above the median assessed value are assigned to the ‘high’ subset, while those below the median value are assigned to the ‘low’ group.

In dividing the quarter sections into subsets, it is assumed that those quarter sections that had a high assessed value have common attributes, including presence of arable land, highly productive soil for annual crop growth, and limited waste land. Waste land is defined by the Saskatchewan Assessment Management Agency (SAMA) as “non-arable agricultural land with no productive potential as arable land, pasture land, or hay land” (2007-b, pg 1) Also, those quarter sections with a low assessed value are assumed to have common attributes: land being suitable only for pasture, forage growth, or containing a significant amount of waste land. To add justification for this step, separating parcels of land in this manner is a common practice for the assessment of agricultural land done by SAMA. SAMA separates all agricultural land into either arable or non-arable land. SAMA assesses arable land through soil rates, climate rates, along with physical, economic, and A-depth[11] factors (Saskatchewan Assement Management Agency, 2007-a). Meanwhile, non-arable land includes all pasture land, hay land, and waste land and is assessed through one general rate, and a provincial factor (Saskatchewan Assessment Management Agency, 2007-b). Often it is the case that arable land is assessed with a much higher value than non-arable land.

For each township, two hedonic regressions are undertaken: high assessed values with a sample size of 71, and low assessed values with a sample size of 70. For the Four Creeks Township the median assessed value is $41,400, for the Pipestone Creek Township the median value is $41,300, while for the Antler River Township the median value is $44,000. Results for the six regressions for high and low assessed values and the three townships used in the study are provided in Table 5-21. The coefficient estimates from the regressions provide an indication of how each landscape type contributes to assessed value. Most of the coefficients are not statistically significant, but in some cases there is a high degree of significance at the 1% level. Despite this, the coefficients are still used as there are no other data available on quarter sections and that they provide a good approximation of the influence of acreage per landscape type on assessed wealth.

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[11] A-depth is the thickness of the dark coloured soil surface layer or top soil. The A-depth factor accounts for the detrimental effect of erosion, poor A-depth development, or superior A-depth development on soil productivity (Saskatchewan Assement Management Agency, 2007-a).

Table 5-21: Assessed Value Hedonic Regressions for Sub-watershed Townships

	Four Creeks		Antler River		Pipestone Creek	
	High	**Low**	**High Value**	**Low**	**High**	**Low Value**
CROP	135.74	-2.7722	-355.61**	335.91***	-86.803	-60.779
SD [a]	*(85.64)*	*(170.3)*	*(171.61)*	*(71.73)*	*(83.97)*	*(63.47)*
NATIVE	162.61	-117.15	-332.75	188.65**	-25.771	-178.91***
SD	*(135.8)*	*(176.7)*	*(224.5)*	*(79.03)*	*(154.9)*	*(66.7)*
TAME	136.74	-68.256	-377.52**	263.57***	-87.609	-72.34
SD	*(92.28)*	*(170.6)*	*(173.6)*	*(75.32)*	*(84.24)*	*(65.84)*
ASPEN	0.21485	-30.352	-407.72***	382.75***	-161.79*	-172.37*
SD	*(93.66)*	*(167.1)*	*(152.6)*	*(94.36)*	*(88.69)*	*(67.79)*
LENTIC	64.103	-13.601	-179.79	351.84***	-105.65	-86.676
SD	*(113)*	*(169.2)*	*(177)*	*(122)*	*(90.94)*	*(78.46)*
LOTIC	-85.311	-128.64	-437.55*	115.86	21.754	-83.827
SD	*(202.8)*	*(165.2)*	*(243.6)*	*(137.7)*	*(105.7)*	*(72.76)*
CONSTANT	26997**	37575	102730***	-13187	61982***	49712***
Std. Error [b]	2598.9	4697.8	4859.9	5683.2	3465.9	4457.8
R^2	0.2037	0.5455	0.1684	0.5598	0.1396	0.5444

[a] *SD* is the standard deviation of the independent variable found above it.

[b] Standard Error is the total standard error for the regression.

***=significance at 1% **=significance at 5% *=significance at 10%

Using the results from the regression analysis, a number of steps are taken to incorporate the wealth coefficients in the linear programming objective function (5.10). First, it is assumed that there are characteristics of land that determine assessed wealth on a respective quarter section other than the landscape use. These characteristics include soil quality, location, water quality, etc. A scaling process is used to increase or decrease the applicable regression intercept based on the original market assessment on each quarter section in the township. This scaling process is done to ensure that each quarter section of land has a unique intercept that takes into account the factors unique to the quarter section. It is held that these characteristics are already accounted for in each assessment of value on each quarter section. Therefore, one can use the trend in the assessed value of a quarter section to ‘scale-up’ or ‘scale-down’ the regression intercept for each quarter section in the township. This intercept represents the ‘base value’ assigned to the quarter section notwithstanding the value provided by the type of landscapes found on the parcel. The following is a step-by-step description of this process.

First a scaling factor is calculated by dividing the original intercept of each regression by the average assessed value of quarter sections found in the regression. After determining this scaling factor, the factor is used to transform the original assessed value of every quarter section into a new intercept. This is done through multiplying the scaling factor for the respective regression by the assessed wealth for each quarter section. The adjusted intercept, I_k, is a function of the scaling factor (Regression Intercept, I_a, / Average Assessed Value, AV_a) and initial assessed value, AV_k, shown in the following function:

$$I_k = AV_k * \left(\frac{I_a}{AV_a}\right)$$

(5.14)

In this manner, each quarter section, k, has a specified constant to calculate landscape type effects. By adjusting the constant with the starting assessed value, the variation in assessed value that is not captured in the regression from unknown characteristics is captured. Table 5-22 provides the regression intercept, average assessed value for each regression dataset (AV_a), scaling factor, starting assessed value (AV_k) and adjusted intercept (I_k) for a random quarter section in each township.

Table 5-22: Process to Adjust the Constants per Quarter Section per Township

		Constant	**Average**	**Scaling factor**	**Original Assessed value ($)**	**Adjusted Constant ($)**
Four Creeks	**High Value**	26997.00	45894.00	0.59	26800.00	15765.02
	Low Value	37575.00	32790.00	1.15	26800.00	30710.89
Antler River	**High Value**	102730.00	49608.00	2.07	45000.00	93187.59
	Low Value	-13187.00	34323.00	-0.38	45000.00	-17289.14
Pipestone Creek	**High Value**	61982.00	47145.00	1.31	45000.00	59161.95
	Low Value	49712.00	32843.00	1.51	45000.00	68113.14

Secondly, after calculating adjusted intercepts for each quarter section in each township, the intercept is then divided by the amount of total acres found in that respective quarter section. This is done to retrieve a 'per acre' intercept that, added to the landscape type coefficient from the respective regression, would be the contribution to assessed wealth for each acre in each landscape type. The variation captured in the adjusted intercepts is carried through the resulting per acre wealth coefficient estimate for each landscape type.

For example, for one quarter section (used in Table 5-22 above) the adjusted intercept (I_k) is $15,765.02 for the respective quarter section and the number of acres found for that quarter is 159.92. The adjusted intercept is divided by the number of acres to provide a per acre amount of $98.58 per acre (15,765.02 ÷ 159.92). Adding this per acre amount to the regression coefficient found for each landscape type (Table 5-21) affords the overall wealth coefficients per landscape type: $234.32 (98.58 + 135.74) for cropland, $261.19 (98.58 + 162.61) for perennial forage, $235.32 (98.58 + 136.74) for native prairie, $98.80 (98.58 + 0.21485) for aspen habitat, $162.68 (98.58 + 64.103) for lentic riparian, and $13.27 (98.58 - 85.311) for lotic riparian. Written more generally, wealth coefficient per landscape type is calculated from the following equation, where C_i is the regression landscape coefficient and δ_k^i is the wealth coefficient:

$$\delta_k^i = \frac{I_k}{Number\ of\ Acres} + C_i$$

(5.15)

In some limited cases, generating wealth coefficients (δ_k^j) using the method described above resulted in negative values for some landscape types. In this situation, wealth coefficients in relation to any landscape type on any land are assumed to have a minimum value of $10 per acre. This value is the per acre base land rate for waste land assigned by the Saskatchewan Assessment Management Agency (2007-b). Waste land is defined as any non-arable agricultural land with no productive potential as arable land, pasture land or hay land (Saskatchewan Assessment Management Agency, 2007-b). After adjusting negative coefficients, all coefficients are included in each respective township LTOM for each respective quarter section and landscape type. The summary statistics of the resulting wealth coefficients generated per landscape type for each township are provided in Table 5-23 below. Appendix A provides the wealth coefficients generated for each quarter section of land and for each landscape type. Appendix A also provides the original assessed wealth and estimated assessed wealth based on the wealth coefficients. The legal description for each quarter section is removed due to privacy reasons.

Table 5-23: Summary Statistics for Wealth Coefficients ($)

		Lentic Riparian	**Lotic Riparian**	**Perennial Forage**	**Native Grassland**	**Aspen**	**Crop**
Antler River	Mean	379.02	130.93	229.42	221.56	264.91	273.51
	SD	*(110.99)*	*(101.40)*	*(67.57)*	*(115.53)*	*(59.82)*	*(54.72)*
	Confidence Interval [a]	*[394.40, 363.65]*	*[144.97, 116.88]*	*[238.78, 220.06]*	*[237.57, 205.56]*	*[273.19, 256.62]*	*[281.09, 265.93]*
Pipestone Creek	Mean	273.29	352.11	289.89	287.70	206.97	294.89
	SD	*(67.19)*	*(111.01)*	*(68.11)*	*(127.56)*	*(71.54)*	*(65.53)*
	Confidence Interval	*[263.99, 228.79]*	*[367.49, 336.73]*	*[299.32, 280.45]*	*[305.37, 270.03]*	*[216.88, 197. 06]*	*[303.97, 285.82]*
Four Creeks	Mean	228.79	96.63	238.23	227.01	188.31	270.24
	SD	*(35.51)*	*(36.43)*	*(77.92)*	*(112.66)*	*(39.36)*	*(50.41)*
	Confidence Interval	*[233.71, 223.87]*	*[101.67, 91.58]*	*[249.03, 227.44]*	*[242.61, 211.40]*	*[193.76, 182.85]*	*[277.22, 263. 26]*

[a] The ninety percent (90%) confidence interval around the mean value [+, -].

5.3.5 Landscape Conversion Costs

After generating wealth coefficients for each landscape type on each quarter section of land, determining the cost of conversion (β^{ij}) between landscape types is required for the objective function (5.10). The costs of converting landscape types are derived using information from a number of different sources. The costs for converting riparian and forested habitat to cropland and tame grass, as well as cropland to tame pasture are also used for the scenario analysis of the RFSM. Below, the direct financial costs of conversion between landscape types are provided.

1. Conversion of **riparian habitat** (including lentic and lotic) to **cropland or bare land** is assumed to be carried out through surface drainage. Surface drainage

involves the construction of ditches and/or contouring of the land to remove water from the surface of the soil (Cortus, 2005). The rental rates for a 6.5 yard scraper and heavy disk were set at $131.10/hr and $9.46 per acre, respectively (Saskatchewan Agriculture, 2008-c). Cortus (2005) determined that an average quarter section in the Emerald region of Saskatchewan required a minimum of 200m of scraping, and through using a 6.5 yard scraper drainage would require 0.26 hr/m. The conversion to cropland would cost $6,968.56 per quarter section (131.10 × 0.26 × 200 scraping, plus 9.46 × 16 disking), or $435.45 per acre converted (6,968.56 ÷ 16)[12]. The Saskatchewan Wetland Conservation Corporation (1993) estimated a range for the cost of surface draining lands of $180 to $1,190 per hectare ($72 - $482 per acre), depending on the specific conditions (e.g., size of riparian area). The value calculated for this study falls within the range of estimated values, but is towards the upper end.

2. Conversion of **forested (aspen) habitat** to **cropland or bare land** is assumed to be carried out by a D6 Bulldozer and Heavy Breaking disk. Commonly referred to as ‘breaking land’, converting forested habitat to bare land first requires the use of a bulldozer to push trees and shrubs out of the ground, followed by two passes over the land with a heavy breaking disk to remove roots, stumps and to churn the soil. The custom rate per acre used for the heavy breaking disk is $20.14 per acre (Saskatchewan Agriculture 2008-c). The estimated cost for clearing forested area using a bulldozer was $175 per hour and it is assumed that three hours per acre converted would be required (Gerk, 2009). A flat fee of $360 is charged for transporting the D6 to the farm site. It would cost $9,082.24 per quarter section ((175 × 3 × 16) + 360 for bulldozing, + (20.14 × 16) for disking), or $567.64 per acre converted (9082.24 ÷ 16) to completely change the forested habitat to usable cropland or bare land.

3. Conversion of **native or tame grass (perennial forage)** to **cropland or bare land** is assumed to occur by breaking up the pasture land in order for it to be suitable for seeding annual crops. Using information from the report *“Rejuvenation of tame forages”* by Saskatchewan Agriculture, Food, and Rural Revitalization (1999) it is determined that land with native or tame forages can be made ready for annual crop seeding through two passes of a heavy tandem disk, one pass of a cultivator, and one application of glyphosate chemical. The cost associated with two passes of a heavy tandem disk (assuming rental equipment) is $18.92 per acre ($9.46 per acre × 2) (Saskatchewan Agriculture, 2008-c), the rental rate for one cultivator operation is $6.25 per acre (Saskatchewan Agriculture, 2008-c), and the cost of glyphosate application is $10.00 per acre (Saskatchewan Agriculture, Food, and Rural Revitalization,

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[12] (Soloudre et al., 2008) state that on average, 10% of each quarter section in the Lower Souris River Watershed is generally covered by either riparian habitat or forested habitat. Ten percent of a 160 acre quarter section is 16 acres.

1999). As a result, the total cost of converting forages to cropland is $35.17 per acre (18.92 + 6.25 + 10.00).

4. Conversion of **cropland or bare land** to **tame grass (perennial forage)** requires seeding land to perennial tame forage. The associated cost of $50.12 per acre (Soloudre, 2008) is incorporated to any conversion resulting in planting perennial forage for tame grass (i.e. riparian or forested habitat, to bare land, to tame grass).

5. Conversion of **cropland or bare land** to **native grass (pasture)** is assumed to be done by seeding a grass mixture similar to that found native in the region. The conversion cost was calculated based on a seed mixture cost of $15/lb and a seeding rate of 25 lbs per acre (Tannas, 2009). At this cost of seed and seeding rate, the total cost of seeding native grass is $375.00 per acre (15 × 25).

6. Conversion of **cropland or bare land** to **forested habitat (aspen**) had no associated cost. This is because it is assumed that aspen or forested habitat would re-grow through time if bare land is left idle with no cultivation or operation on the land. Soloudre (2008) recommended this cost of converting to forested habitat (aspen) is most practical on the farm, and avoids tree planting costs.

7. Conversion of **cropland or bare land** to **lentic riparian habitat** is assumed to be accomplished by closing drainage ditches with an earthen plug and seeding to tame grass. The cost of closing drainage ditches is $250 of bulldozer work for each wetland, with each wetland being roughly 0.5 acres (Soloudre, 2008). The cost of seeding perennial forage (tame grass) of $50.12 per acre is added resulting in a total cost of $550.12 per acre ((250 × 2) + 50.12) for restoring lentic riparian areas.

8. Conversion of **cropland or bare land** to **lotic riparian habitat** areas required only seeding tame grass in buffer areas of moving water (i.e. similar to a buffer strip). The associated cost of seeding perennial forage (tame grass) is $50.12 per acre.

For the remaining types of conversions, the total conversion cost is found by adding the cost of converting a landscape type to bare land, and the cost of converting bare land to the specific landscape type. For example, the total cost of converting lentic or lotic riparian areas to native range is found by adding the cost of draining wetlands and riparian areas of $434.45 per acre with the cost of seeding native grass on bare land of $375.00 per acre, for a total cost of $810.45 per acre. Table 5-24 presents the total cost in $ per acre of converting each landscape to every other landscape type.

Table 5-24: Cost of Converting Landscape types ($/acre)

	Future type (after conversion)					
Current type	Cropland	Native	Tame	Aspen	Lentic	Lotic
Cropland	0	375	50.12	0	550.12	50.12
Native	35.17	0	85.29	35.17	585.29	85.29
Tame	35.17	410	0	35.17	585.29	85.29
Aspen	567.64	942.64	617.76	0	1117.76	617.76
Lentic	435.45	810.45	485.66	435.45	0	485.57
Lotic	435.45	810.45	485.66	435.45	985.57	0

In addition to the direct costs of converting landscape types, the direct cost (or benefit) to individual farm wealth had to be included to provide a signal of the incentives faced by farmers when managing their land. This direct cost (or benefit) to individual farm wealth is determined through the RFSM. Scenario results from this model (provided in section 6.1.1 and 6.1.2) are used to adjust the costs of converting landscape types through adding the annualized NPV per acre cost, or subtracting the annualized NPV benefit to the farm operator. The annualized NPV per acre increase or reduction of converting all riparian and forested habitat to cropland for Scenarios 1 to 4, along with the annualized NPV per acre reduction for Scenario 6, are used to adjust the direct costs of conversion provided in Table 5-24. The annualized NPV per acre increase or decreases from the various landscape conversions are provided in Table 5-25. The resulting total direct cost to farm wealth of converting landscape types are provided in Table 5-26.

Table 5-25: Direct cost or benefit to Farm Wealth of Land-use conversion ($/acre) (from Section 6.1.1)

Conversion	**(Cost) or Benefit**
Lotic to Cropland	74.79
Lentic to Cropland	74.79
Aspen to Cropland	48.03
Lotic to Tame	(46.62)
Lentic to Tame	(46.62)
Aspen to Tame	47.58
Cropland to Tame Hay	(49.42)
Cropland to Lotic	(74.79)
Cropland to Lentic	(74.79)
Cropland to Aspen	(48.03)
Tame to Lotic	46.62
Tame to Lentic	46.62
Tame to Aspen	(47.58)
Tame Hay to Cropland	49.42

Table 5-26: Total Cost of Converting Landscape Types - Including cost or benefit to farm wealth ($/acre)

	Future type					
Current type	Cropland	Native	Tame	Aspen	Lentic	Lotic
Cropland	0	375	99.54	98.15	624.91	124.91
Native	35.17	0	85.29	85.29	585.29	85.29
Tame	-14.25	410.17	0	132.87	538.67	38.67
Aspen	519.61	942.64	570.18	0	1117.76	617.76
Lentic	360.66	810.45	532.28	810.45	0	485.57
Lotic	360.66	810.45	532.28	810.45	985.57	0

Due to the fact that some of the conversions of landscape types took more than one year to complete, the conversion costs are converted to an annualized, discounted cost over the period needed to complete the conversion. Cortus (2005) determined that it takes on average four years to completely drain a wetland and have the land suitable for crop production. In addition, Saskatchewan Agriculture, Food, and Rural Revitalization (1999) found that it takes on average three years to have land ready for seeding of grasses and annual crops after it has been cleared of forested (aspen) habitat. Table 5-27 provides the annualized discount costs of conversions between all landscape types. Note that in many cases there is no change to the overall cost of conversion because these conversions may only take one year to complete. The discounting formula:

$$PV = A\left[\frac{1 - (1+i)^{-t}}{i}\right] \tag{5.16}$$

is used to determine annualized costs, where A, i, t, and PV are respectively, the initial value, the discount rate, the number of years, and the present value. Similar to calculating the NPV results for the RFSM, a discount rate (i) of 10% was used in the analysis (explained in section 4.2.3). The annualized discounted costs in Table 5-27 are the final costs of conversion (β^{ij}) included in the objective function of the LTOM.

Table 5-27: Annualized Discounted Cost of Conversion ($/acre)

	Future type					
Current type	Cropland	Native	Tame	Aspen	Lentic	Lotic
Cropland	0	375	99.54	98.15	624.91	124.91
Native	35.17	0	85.29	85.29	585.29	85.29
Tame	-14.25	410.17	0	132.87	538.67	38.67
Aspen	208.94	543.14	229.28	0	449.47	248.41
Lentic	113.78	255.67	167.92	255.67	0	153.18
Lotic	113.78	255.67	167.92	255.67	310.92	0

5.3.6 Development of Landscape targets

The main purpose of the landscape models is to determine the financial cost or benefit to farmers of implementation of fixed landscape targets to maintain wildlife habitat across the LSRW. The Lower Souris Watershed Committee developed landscape targets in a co-management framework, which is a co-operative group decision making process between both resource users and responsible agencies (Lower Souris Watershed Committee Inc., 2006). According to the Lower Souris Watershed Committee, a co-management framework is used to develop targets, rather than valuating the EG&S benefits of wildlife habitat conservation because,

- "The Lower Souris River Watershed (LS) has extensive experience with group decision making processes. The LS has worked since 1998 to develop a watershed management plan for their watershed. The process has been based on interest based decision making whereby a facilitated group decision making process is used.
- Co-management targets have local legitimacy since they are grassroots driven and influenced by local knowledge thereby employing valuable human capital.
- Because of the legitimacy gained above, implementation of beneficial practices is facilitated
- Co-management targets avoid the problem of having to economically value EG&S"

(Lower Souris Watershed Committee Inc., 2006, pg, 4 and 5)

For this study, the co-management framework consisted of decision-making between members of the Lower Souris sub-watershed committees, interacting with wildlife agencies (e.g. Ducks Unlimited Canada, Saskatchewan Watershed Authority, and Canadian Wildlife Service). Landscape target goals are set taking into account wildlife inventory results and species responses to habitat quality and quantity (Lower Souris Watershed Committee Inc., 2006). Table 5-28 gives the landscape targets determined for each landscape type across the three sub-watersheds. These targets are calculated in proportions of total area found in each sub-watershed (adding up-to one). When summing the targets per landscape type for each sub-watershed, one can determine the landscape targets required for the entire LSRW.

Table 5-28: Sub-watershed Landscape Targets (proportion of total landscape area)

	Lentic Riparian	Lotic Riparian	Perennial Forage	Native Grasslands	Aspen	Crop
Antler River	0.07	0.03	0.20	0.08	0.08	0.54
Pipestone Creek	0.07	0.06	0.16	0.11	0.11	0.49
Four Creeks	0.05	0.03	0.11	0.07	0.05	0.69

5.3.7 Township Models for three Sub-Watersheds

Separate LTOMs are created for each of the three sub-watersheds: Antler River, Pipestone Creek, and Four Creeks. The initial landscape type composition of each sub-watershed township is provided in Table 5-29. These shares are determined by summing the total number of acres for each landscape type across all quarter sections in the township and dividing by the total acreage of the township. When comparing Table 5-29 to Table 5-28, one notes that in some cases the existing landscape type composition exceeds the landscape target for the respective township. In these cases, conversion to that landscape type might not be necessarily required (e.g. to lentic riparian). Instead, conservation of the existing lands designated to that landscape type would be sufficient to meet the landscape target.

Table 5-29: Existing Landscape Type Composition for Sub-watershed Townships

	Lentic Riparian	Lotic Riparian	Perennial Forage	Native Grasslands	Aspen	Crop
Antler River	0.12	0.02	0.15	0.02	0.06	0.63
Pipestone Creek	0.11	0.03	0.15	0.05	0.18	0.48
Four Creeks	0.1	0.02	0.08	0.04	0.1	0.65

In generating results, two model runs were required for each township model: a run without the landscape targets imposed (base case run), and a run with the landscape targets imposed (landscape target policy run). The base case run includes no constraints on farm operators from maximizing wealth, other than the physical constraints of conversion costs and the amount of available land. In the base case run, the landscape type target constraint is not imposed. The base case run can be considered a ‘status-quo’ run, as results from the base case run are what might be expected given no policy intervention to prevent and slow the conversion of wildlife habitat for agricultural purposes.

The second optimization maintains the same model structure as for the base case run, with the exception that the constraints to maintain landscape targets throughout each sub-watershed are added. The amount of acres attributed to each landscape type across the township cannot be less than that required for the landscape target share for the specific landscape. In this manner, it is assumed that there is policy intervention (i.e. in the form of regulation) to ensure landscape targets for the watershed are maintained on private agricultural lands. Comparisons with regards to farm wealth, landscape type conversions, and total landscape acreage between the two optimization runs is given for each township model.

The reporting of results from this analysis includes comparison of total assessed wealth for the entire township and its 141 quarter sections before and after each model run. In addition, the change in the number of acres associated with each landscape type is found, along with what form of landscape type conversion is most prolific across the township. Determining these results for each model run allows for additional comparisons between the base case and landscape target runs, as well as comparisons between the three townships located in the three separate sub-watersheds. These results are presented in Chapter 6.

5.4 Chapter Summary

The first model constructed for this study is the RFSM model. It is a Monte Carlo simulation model developed to analyze the financial impact of wildlife habitat conservation practices on a representative farm. The representative farm used in the analysis is derived from the characteristics of farming and farm operations in the Lower Souris region. The representative farm used in this analysis is a mixed enterprise operation, with cow-calf and crop production systems. It has a land base, crop mix, herd size, and grazing season that is typical for the study area. The annual crop types used in the representative farm are barley, wheat, canola, and flax. The on-farm dynamics and relationships are specific to the farming dynamics in the Lower Souris region, and these dynamics are adjusted from the model originally constructed for Steve Koeckhoven's thesis (2008). A total of eight scenarios are modelled using the RFSM to determine the impact of EG&S practices. The first four determine the cost of maintaining existing, untouched habitat areas on agricultural land. Scenarios 5 and 6 determine the impact of converting land once in cropland production to a forage stand. Finally, the last two scenarios determine the impact of herd management practices (i.e. lowered stocking rates, rotational grazing management) that enhance wildlife habitat.

Following the analysis using the RFSM model, the LTOM model is constructed to study the cumulative impacts of regional wildlife habitat conservation policy. The LTOM model is a linear programming model that maximizes farm wealth subject to the original landscape acreage and landscape targets for a township of land. Three separate versions of the model are constructed; one for a representative township from each sub-watershed in the LSRW. Wealth coefficients are found for each quarter section by running hedonic regressions and scaling the regression intercept based on the original assessed wealth found for the quarter section. Many of the costs of conversions utilized for the RFSM are also utilized for the LTOM, and it is through the cost of conversion that the two models are linked. After determining the direct cost of converting landscape types, these costs are adjusted based on the NPV results found from the RFSM (Scenarios 1 through 6). In this manner, the farm wealth benefits or costs of having a particular acre in a landscape type, other than the assessed wealth benefits, are incorporated. As a result, it is expected that those landscape types that are required for agricultural production are valued higher, and those types not required for agricultural production are valued lower, with regards to the amount of cost associated with converting between these landscape types.

The LTOM model uses GIS data on a per-landscape type, per-quarter section basis, and assumes free conversion among landscape types on each quarter section. In this regard, this analysis is more exploratory than the RFSM model. Comparable studies that determine cumulative farm impacts on a landscape type acreage basis for each quarter section, and then, across all quarter sections for a region are rare, if not non-existent. This study can be considered the first attempt to looking at regional impacts of land-use policy more closely and thoroughly to determine impacts. However, since the methodology utilized to construct and operate the LTOM model is exploratory, some leeway is required in interpreting the results.

6 Chapter 6: Results

6.1 Overview

This chapter presents the results from the scenarios for the RFSM, along with the township model runs for the LTOM outlined in Chapter 5. Along with presentation of the results, discussion of key findings occurs throughout the chapter. Since only those results deemed important for key findings are presented, Appendix B provides summary statistics for the simulation results. Explanations of the scenarios (or runs) for both the RFSM and the LTOM follow throughout the chapter. With regards to the farm wealth implications for both models, simulation and optimization runs were compared to a base case run to determine the extent of change in private net benefits associated with the policy inherent to the scenario.

6.2 Representative Farm Simulation Model (RFSM) Results

As explained in Chapter 5, the RFSM is designed and used to determine the extent of the cost or benefit to farmers of practices that promote EG&S for wildlife habitat. The cost or benefit of each scenario to the farm operator is determined by subtracting the representative farm annualized NPV in the base case run from the annualized NPV found in the scenario run. Scenarios 1 through eight 8, complete with results and key findings, are discussed below. Following this analysis, a high input cost scenario is re-run for scenarios 1, 3, 5, and 6 to inspect the impact of increased input costs, such as those experienced by farm operators in 2007 and 2008, on the simulation scenario results.

The first four scenarios (Scenarios 1-4) examined by the RFSM inspect the expected increases in private net benefits to farm wealth when decreasing wildlife habitat area, classified as either riparian or forested land, in order to increase the amount of available land for agricultural production. The newly created arable land is used for cropland (Scenarios 1 and 3) or tame pasture purposes (Scenarios 2 and 4). In these scenarios, the farmer undertakes actions (e.g., bulldozing, draining, or disking) that decrease the level of on-farm EG&S associated with wildlife habitat. In each scenario the impact of varying decreases in natural wildlife habitat from the base case is determined. In this manner, a reduction in NPV wealth can be viewed as a negative impact on farm wealth despite decreasing EG&S, while an increase in NPV can be considered a positive impact on farm wealth when decreasing EG&S.

Results are presented in tabular form for the total farm NPV, as well as the impact on the crop and beef enterprise farm NPV. Additional results provided include mean forage sales, grazing season days, and weaning weight values for the scenarios where the amount of forage availability for pasture purposes is impacted (Scenarios 2 and 4).

As well, three stages of wildlife habitat conversion are carried out to determine the extent of impact on NPVs. Conversion of ⅓ and ⅔ of the current habitat area, along with complete (i.e., 100%) conversion, is modelled. Given the initial assumption that 16 acres per cropland quarter is habitat area, the three sub-scenarios result in 10.66 acres, 5.33 acres, and zero acres of habitat per cropland quarter remaining after conversion. Results therefore show the extent of impact on farm wealth of converting wildlife habitat to agricultural production.

Scenarios 5 and 6 investigate the impact of converting annual cropland production to tame grass production to enhance habitat for many wildlife species. Land dedicated to growth of tame forages encompasses many additional wildlife habitat benefits than are attributed to cropland. In these scenarios, an increase in NPV is associated with a positive impact on farm wealth and increased EG&S, while a decrease in NPV is a negative impact on farm wealth, despite increased EG&S. In this regard, the cost or benefit to the farm operator of increasing EG&S is determined through the simulation results. Again, results are presented in tabular form, with the change in mean total farm, crop enterprise and beef enterprise NPVs and mean forage sales being given. Results provide the expected costs (or benefit) to the farmer of converting cropland to perennial forage.

Lastly, Scenarios 7 and 8 determine the cost or benefit to the farm operator of employing two common beef herd management practices to enhance the wildlife habitat benefits received from the pasture. Farmers can decrease stocking rates (Scenario 7) or implement rotational grazing (Scenario 8) to rejuvenate forages on pasture, and provide added benefits to wildlife through maintaining healthy forages on their land. A decrease in NPV associated with the farm operator partaking in these practices results in a negative impact on farm wealth, while EG&S benefits are increased. The NPV results for the total farm, crop, and beef enterprises are provided, while mean values for forage sales, grazing season length, and weaning weights are also given to show the relative degree of change in these factors due to pasture productivity increases.

An ‘annualized NPV change’ is provided for each scenario. This is the annual value of the cost or benefit per acre converted for the representative farm for the scenario in comparison to the base case. This value is calculated by first dividing the 20-year farm NPV by the number of converted acres to get an NPV per acre. This per acre value is then discounted using a 10% discount rate and t = 20 years (formula given in section 5.3.5, equation 5.14) to get the annual value. Forage sales and purchases represent the annual average values, calculated over all years and iterations. Since there are some years in which forages are sold (i.e., excess production) and other years when forage is purchased by the farm (i.e., excess demand for the beef herd), both purchases and sales have positive averages.

Results tables reported in the following sections also include the reporting of standard deviations for each NPV estimate provided. The simulation is stochastic; therefore, the standard deviations represent the degree of statistical uncertainty associated with these estimates. Standard deviations can be interpreted in terms of whether differences in NPV average values are “significant” or not. One way of determining this would be to construct confidence intervals for comparative NPV estimates with the standard deviation, and then see if these confidence intervals overlap one another. If they do, then it may be the case that the change in average NPV estimates is not substantial enough to warrant consideration.

6.2.1 Scenarios 1-4: Conserving Habitat versus Converting to Productive Land

6.2.1.1 Scenario 1: Conversion of Riparian Habitat to Cropland

In this scenario, riparian habitat on quarter sections dedicated to crops is assumed to be drained and converted to land suitable for crop production. There is a cost of conversion associated with this management decision that is calculated post-simulation and used to adjust NPVs calculated from the simulation. This cost of conversion was $435.45 per acre, as discussed in section 5.3.5. It is important to note that the simulation model was not designed to evaluate 'drainage' on the farm. Hence, the model is simply run with increased crop acres and decreased riparian acres. The costs of drainage and conversion are imposed on the NPVs post-simulation. The adjusted simulation NPV results are presented in Table 6-1 below. The initial NPV results before deducting the cost of conversion are provided in Appendix C.

Table 6-1 Scenario 1 Results: Conversion of Riparian Habitat to Cropland

	Acres of Riparian Habitat Remaining (% of Quarter)			
	Base	10.66(6.67%)	5.33 (3.33%)	0 (0%)
Mean Farm NPV	$ 971,313	$ 992,964	$ 1,012,218	$ 1,032,440
Standard Deviation	$ 233,967	$ 249,591	$ 252,294	$ 262,606
Change in Total NPV		$ 21,651	$ 40,905	$ 61,127
NPV Change ($/acre Converted)		$ 677	$ 640	$ 637
Annualized NPV Change ($/acre Converted)		**$ 79.55**	**$ 75.15**	**$ 74.79**
Mean Annual Forage Sales	$ 2,952	$ 2,361	$ 2,564	$ 3,107
Standard Deviation	$ 1,479	$ 1,659	$ 1,726	$ 1,770
Mean Crop Enterprise NPV	$ 506,064	$ 523,686	$ 540,513	$ 557,519
Standard Deviation	$ 214,621	$ 221,563	$ 228,939	$ 236,073
Mean Beef Enterprise NPV	$ 384,499	$ 385,877	$ 385,610	$ 386,109
Standard Deviation	$ 61,853	$ 60,317	$ 61,608	$ 61,511

The total farm NPV increases as land is converted to cropland production from riparian habitat, despite the inclusion of drainage and other conversion costs. The annual increase when converting land from riparian habitat to cropland ranges from $74.79 to $79.55 per converted acre. As such, this can be interpreted to mean that there is a cost to the farm operator of $74.79 to $79.55 to maintain an acre of riparian habitat. However, when looking at the total farm NPV results, as more land dedicated to riparian habitat is converted, the annual NPV increase received from converting this land decreases. This suggests that there are diminishing returns to farm wealth of converting riparian habitat to cropland. Agricultural farmers would require an incentive above $79.55 per acre of habitat per year to maintain all existing riparian habitat on their cropland, but if an incentive fell between $74.79 per acre and $79.55 per acre maintained per year, then only some of the riparian habitat on agricultural lands would be converted to cropland.

From Table 6-1, NPVs increase for both crop and livestock enterprises when additional land is taken out of riparian habitat and into cropland. The increase is much higher for the crop enterprise (from $506,064 to $557,519, an increase of $51,455 when converting all riparian habitat) than for the beef enterprise. The increase in the crop enterprise NPV is expected as more land is being put into crop production, but the increase in the beef enterprise not intuitive at first. It is expected that converting riparian habitat to cropland would decrease the beef enterprise NPV because riparian habitat is afforded a higher stocking rate (1.2 AUM/acre) than cropland (0.3 AUM/acre) in aftermath grazing. However, putting land into crop production results in more acres being dedicated to barley production. The increase in the beef enterprise NPV can therefore be attributed to the reduction in feed costs due to the availability of more barley for feed purposes. This makes sense looking at the mean forage sales, which increases as land is converted to cropland production (from $2,952 to $3,102, when converting all riparian habitat).

6.2.1.2 Scenario 2: Conversion of Riparian Habitat to Tame Pasture

In this scenario, riparian habitat found on all quarter sections dedicated to tame pasture, equaling 20% per quarter section, is converted to additional tame pasture. This scenario does not involve any changes being made to the production practices for the beef herd. All changes in the beef herd associated with a decrease or increase in forage production are expressed through grazing season days, weaning weights, and forage sales. The same costs of draining riparian habitat from the previous scenario are used in this scenario; that is, $435.45 per acre to convert to bare land. However, there is an extra cost of $50.12 per acre (as discussed in section 5.3.5) incorporated to account for seeding the bare land to a perennial forage. This results in a total cost of draining equal to $485.66 per acre, which is deducted from the NPV post-simulation. This cost is also incorporated into the beef enterprise NPV calculation, as it is assumed to be ‘attributed’ to that enterprise. A summary of the results for this scenario are provided in Table 6-2, again for three sub-scenarios involving differing degrees of conversion.

Table 6-2 Scenario 2 Results: Conversion of Riparian Habitat to Tame Pasture

	Acres of Riparian Habitat Remaining (% of Quarter)			
	Base	21.33 (13.33%)	10.67 (6.67%)	0 (0%)
Mean Farm NPV	$ 971,313	$ 962,832	$ 954,396	$ 945,913
Standard Deviation	$ 233,967	$ 233,951	$ 233,832	$ 233,769
Change in Total NPV		-$ 8,481	-$ 16,917	-$ 25,400
NPV Change ($/acre Converted)		-$ 398	-$ 397	-$ 397
Annualized NPV Change ($/acre Converted)		**-$ 46.70**	**-$ 46.58**	**-$ 46.62**
Mean Annual Forage Sales	$ 2,952	$ 2,983	$ 3,015	$ 3,046
Standard Deviation	$ 1,479	$ 1,480	$ 1,481	$ 1,483
Mean Crop Enterprise NPV	$ 506,064	$ 507,121	$ 508,156	$ 509,186
Standard Deviation	$ 214,621	$ 214,544	$ 214,474	$ 214,404
Mean Beef Enterprise NPV	$ 384,499	$ 374,988	$ 365,540	$ 356,054
Standard Deviation	$ 61,853	$ 61,854	$ 61,829	$ 61,848
Grazing Season Days	259.1	259.67	260.25	260.82
Weaning Weight (lbs)	572.29	573.38	574.47	575.56

Considering the scenario results in Table 6-2, it would appear that there are no positive economic incentives for farmers to convert riparian habitat to tame pasture. Draining wetlands and seeding tame grass for pasture purposes results in an annual reduction in NPV ranging from $46.62 to $46.70 per acre converted. In other words, there is a direct benefit to the farm operator of maintaining riparian habitat rather than converting to tame pasture. This is a reversal from the results found in Scenario 1. It appears that the decrease in NPV when converting riparian habitat is largely attributed to the substantial decline in NPV occurring in the beef enterprise (from $384,499 to $356,054, a decrease of $28,455 when converting all riparian habitat).

The results suggest that the benefits from increased pasture productivity do not outweigh the cost of converting riparian habitat to tame pasture. The beef enterprise NPV declines, despite increasing forage sales, weaning weights, and grazing season days. This is most likely because the stocking rate for riparian areas is only slightly lower than that of upland tame pasture. As mentioned in section 5.2.1.2, cows are assumed to graze within habitat areas albeit with a lower stocking rate. From Table 5-6, upland stocking rates are 1.3 AUM per acre, while riparian stocking rates are 1.2 AUM per acre. In addition, the cost of converting riparian areas is substantial, at $485.66 per acre. The small increase in the stocking rates and thus, pasture productivity, does not warrant the cost of conversion.

6.2.1.3 Scenario 3: Conversion of Forested Habitat to Cropland

In this scenario, all forested (aspen) habitat on cropland quarter sections is converted to cropland. A new base case scenario is initially run assuming the presence of forested habitat across all cropland quarter sections, rather than riparian habitat. The new base case scenario with forested habitat rather than riparian habitat is the ‘revised’ base case scenario. Again, it is assumed that cropland is converted from forested habitat in year one of the simulation. The costs of converting forested land differ from the conversion costs of riparian habitat. From section 5.3.5, the cost of converting forested habitat to cropland is $567.64 per acre. The NPV results after running the Scenario 1 simulations but with forested habitat, and deducting conversion costs are reported in Table 6-3.

Table 6-3 Scenario 3 Results: Conversion of Forested Habitat to Cropland

	Acres of Forested Habitat Remaining (% of Quarter)			
	Revised Base	10.66 (6.67%)	5.33 (3.33%)	0 (0%)
Mean Farm NPV	$ 766,189	$ 778,791	$ 791,852	$ 805,443
Standard Deviation	$ 223,617	$ 231,463	$ 239,456	$ 247,501
Change in Total NPV		$ 12,602	$ 25,663	$ 39,254
NPV Change ($/acre Converted)		$ 394	$ 401	$ 409
Annualized NPV Change ($/acre Converted)		**$ 46.26**	**$ 47.10**	**$ 48.03**
Mean Annual Forage Sales	$ 345	$ 464	$ 611	$ 786
Standard Deviation	$ 730	$ 822	$ 916	$ 1,011
Mean Crop Enterprise NPV	$ 378,711	$ 386,339	$ 394,681	$ 403,845
Standard Deviation	$ 205,138	$ 213,546	$ 222,056	$ 230,585
Mean Beef Enterprise NPV	$ 303,346	$ 305,650	$ 307,685	$ 309,475
Standard Deviation	$ 51,821	$ 51,302	$ 50,839	$ 50,431

Similar to Scenario 1, the results show an increase in total farm NPV when converting forested habitat to cropland, despite the higher costs of conversion. The annual total farm NPV increase ranges from $46.26 to $48.03 per converted acre when converting forested habitat to cropland. Again, this can be interpreted as the cost to the farm operator of maintaining forested habitat on agricultural land. Interestingly, the annual NPV per acre increases as more land is converted to cropland from forested habitat. This suggests increasing returns to converting forested land, as opposed to the diminishing returns found for riparian habitat. As such, farmers would require an incentive of at least $48.03 per acre of habitat per year to maintain existing forested habitat. Increasing returns to converting forested lands may be explained through the fact that there is a fixed component associated with the cost of conversion; specifically, the cost of transporting the rented bulldozer (as described in section 5.3.5) to the field.

Also similar to Scenario 1, both crop and beef enterprise NPVs increase as more forested habitat is converted to cropland. The crop enterprise NPV again exhibits a large increase, from $378,711 to $403,845, an increase of $25,134. The minor increase in the beef enterprise NPV can be expected from increased forage availability through additional tame hay production.

6.2.1.4 Scenario 4: Conversion of Forested Habitat to Tame Pasture

In this scenario, all forested (aspen) habitat on quarter sections dedicated to tame pasture is converted to additional tame pasture. Again, the base case is re-run including forested habitat on all quarter sections rather than riparian habitat. Management of the beef herd is assumed to remain unchanged. The cost of clearing forested habitat for conversion to tame pasture is assumed to be the same as converting to cropland, with the exception that there is an additional cost for seeding tame grass. As with Scenario 2, an additional cost of $50.12 was added to the cost of clearing forested habitat. Thus, an investment cost of $617.76 per acre (567.64 + 50.12) is required to convert forested habitat to tame pasture. The results for this scenario are summarized in Table 6-4.

Table 6-4 Scenario 4 Results: Conversion of Forested Habitat to Tame Pasture

	Acres of Forested Habitat Remaining (% of Quarter)			
	Revised Base	21.33(13.33%)	10.67(6.67%)	0 (0%)
Mean Farm NPV	$ 766,189	$ 773,857	$ 782,742	$ 792,114
Standard Deviation	$ 223,617	$ 225,653	$ 228,721	$ 231,520
Change in Total NPV		$ 7,668	$ 16,552	$ 25,925
NPV Change ($/acre Converted)		$ 359	$ 388	$ 405
Annualized NPV Change ($/acre Converted)		**$ 42.22**	**$ 45.58**	**$ 47.58**
Mean Annual Forage Sales	$ 345	$ 500	$ 699	$ 942
Standard Deviation	$ 730	$ 863	$ 999	$ 1,131
Mean Crop Enterprise NPV	$ 378,711	$ 390,879	$ 404,097	$ 418,298
Standard Deviation	$ 205,138	$ 207,789	$ 210,472	$ 212,928
Mean Beef Enterprise NPV	$ 303,346	$ 299,108	$ 295,048	$ 290,596
Standard Deviation	$ 51,821	$ 51,813	$ 52,156	$ 53,633
Grazing Season Days	200.48	207.1	213.71	220.33
Weaning Weight (lbs)	460.92	473.48	486.05	498.62

The results indicate a similar pattern as is the case for converting forest habitat to cropland. There is an increase in NPVs when converting forested habitat to tame pasture. The cost of maintaining forested habitat rather than converting to tame pasture ranges from $42.22 to $47.58 per converted acre. Looking at the crop and beef enterprise NPVs, it is interesting that the crop enterprise increases with more land conversion, while the beef enterprise decreases. The decrease in the beef enterprise NPV is mainly due to the cost of conversion being attributed to the beef enterprise. Despite increased grazing season days and weaning weights, the cost of conversion more than offsets this and as a result, the change in the beef enterprise NPV is negative. The beef enterprise continues to decline with more habitat acreage conversion due to decreasing beef enterprise NPV returns to having more land in tame pasture and a fixed cost of conversion per acre. This is especially interesting as similar to Scenario 3, the total farm NPV exhibits increasing NPV returns. This suggests that the increasing NPV return from the crop enterprise offsets the decreasing beef enterprise NPV returns. The crop enterprise NPV increases mainly through increased forage sales.

The results in Table 6-4 differ substantially from the results in Scenario 2 (i.e., Table 6-2). Converting forested habitat to tame pasture results in an annual NPV increase up to $47.58 per converted acre, while converting riparian habitat to tame pasture results in an annual NPV decrease of $46.70 per converted acre. This difference is likely due to comparative stocking rates, and thus, comparative pasture productivity. As explained in section 6.1.1.2, riparian habitat has an attributed stocking rate that is similar to that assigned to tame pasture. This similarity results in the cost of conversion being greater than the increase in pasture productivity. However, forested habitat has a stocking rate attributed to it that is much lower than upland pasture (see Table 5-6), enough so that the increase in pasture productivity is substantial. The increase in forage availability when converting land from forested habitat to tame pasture results in an NPV increase that is larger than the cost of conversion.

6.2.2 Scenarios 5-6: Converting Cropland to Tame hay or pasture

6.2.2.1 Scenario 5: Conversion of Cropland to Tame Pasture

In this scenario, the impact on NPVs of converting one quarter section from cropland to tame pasture is determined. As opposed to Scenarios 1 - 4, in these scenarios a negative NPV impact can be considered as the cost of EG&S policy to the farmer. Table 6-5 provides the new land allocation of the representative farm under this scenario. Basically, instead of six quarter sections dedicated to cropland where the farm operator can employ the crop rotation, only five quarter sections are available. Since the crop type in each year and on each quarter section is chosen based on a fixed crop rotation, acreage allocated to all crop types is decreased evenly. NPVs that result from the change in the land acreage described in Table 6-5 for Scenario 5 are compared to the base case, with deducting the cost of conversion. The cost of converting cropland to tame pasture is the cost of seeding tame pasture provided in section 5.3.5, a total of $50.12 per acre. The simulation results are provided in Table 6-6.

Table 6-5 Scenario 5 and Scenario 6: Change in Farm Acreage after Conversion

	Base	**Scenario**	**% change**	**Scenario**	**% change**
Annual Crop Acreage	960	800	-17%	800	-17%
Tame Pasture Acreage	320	480	50%	320	0%
Tame Hay Acreage	640	640	0%	800	25%
Total	**1920**	**1920**		**1920**	

Table 6-6 Scenario 5 Results: Conversion of Cropland to Tame Pasture

	Base	Quarter Converted
Mean Farm NPV	$ 971,313	$ 983,547
Standard Deviation	$ 233,967	$ 199,059
Change in Total NPV		$ 12,234
NPV Change ($/acre Converted)		$ 85
Annualized NPV Change ($/acre Converted)		**$ 9.98**
Mean Annual Forage Sales	$ 2,952	$ 5,766
Standard Deviation	$ 1,479	$ 1,696
Mean Crop Enterprise NPV	$ 506,064	$ 464,054
Standard Deviation	$ 214,621	$ 182,286
Mean Beef Enterprise NPV	$ 384,499	$ 451,811
Standard Deviation	$ 61,853	$ 93,364
Grazing Season Days	259.1	314.31
Weaning Weight (lbs)	572.29	677.2

Converting cropland to tame pasture results in an annualized NPV increase of $9.98 per acre converted. This is primarily driven by an increase in the beef enterprise NPV, which is due to the benefits of a longer grazing season, substantially heavier weaning weights, and reduced winter costs stemming from greater forage availability. It may be unrealistic that the grazing season is 314 days with one extra quarter section dedicated to tame pasture, but again it is assumed that the beef herd remains fixed and only grazing season length and weaning weights are changed to capture any increase in forage availability. In reality, it is likely that farm operator would utilize the increased forage availability by increasing the herd size. Further, there is a negative NPV impact on the cropping enterprise. This is not surprising given that the scenario includes a reduction in overall cropped area (i.e., one quarter dedicated to canola is removed from crop production). The reduced feed requirements for forage purchases and increased forage sales cannot offset the lost revenues from canola production in the crop enterprise.

6.2.2.2 Scenario 6: Conversion of Cropland to Tame Hay

In Scenario 6, the impact on farm wealth of converting one quarter section of cropland to tame forage for haying purposes is modelled. In this regard, the change in the representative farm acreage from the base case for Scenario 6 is shown in Table 6-5. Again the conversion cost of $50.12 per acre of seeding a tame forage stand is deducted from the NPV results. The simulation results of converting this quarter section to tame hay are provided in Table 6-7.

Table 6-7 Scenario 6 Results: Conversion of Cropland to Tame Hay

	Base	Quarter Converted
Mean Farm NPV	$ 971,313	$ 910,724
Standard Deviation	$ 233,967	$ 200,623
Change in Total NPV		-$ 60,588
NPV Change ($/acre Converted)		-$ 421
Annualized NPV Change ($/acre Converted)		**-$ 49.42**
Mean Annual Forage Sales	$ 2,952	$ 7,151
Standard Deviation	$ 1,479	$ 1,578
Mean Crop Enterprise NPV	$ 506,064	$ 441,139
Standard Deviation	$ 214,621	$ 182,141
Mean Beef Enterprise NPV	$ 384,499	$ 396,264
Standard Deviation	$ 61,853	$ 59,841

In contrast to converting cropland to tame pasture, the overall direct economic effect of converting cropland to hay production is negative; the mean farm NPV decreases from $971,313 to $910,724, resulting in an annualized NPV decrease of $49.42 per acre converted to tame hay. The impact of increased hay production for winter feeding on the beef enterprise is negligible, an increase of only $11,765. However, there is a significant decline in the crop enterprise NPV; the NPV decreases from $506,064 to $441,139, a difference of $64,925. This decline is attributable to sales of grain/oilseed production being replaced by increased hay sales, which are not sufficient to offset the loss of grain/oilseed sales. In addition, average forage sales increased by only $4,199 (Table 6-7). Weaning weights and grazing season days remain unchanged as there is no change to pasture production for the beef enterprise.

Given the same loss to the cropping enterprise in both Scenario 5 and 6 of one quarter section taken out of crop production, it may be that the operator of the representative farm would benefit most by taking steps to increase pastureland, rather than land dedicated to hay purposes. This result can be explained through the means by which additional tame hay or tame pasture is incorporated into the simulation model. Increased tame pasture results in increased weaning weights and grazing season days which directly increases beef revenues, and reduces winter feeding costs, to substantially increase the beef enterprise NPV. Conversely, increased tame hay reduces forage purchases and increases forage sales in the crop enterprise. Since an extra quarter section in annual crop production provides more revenue to the crop enterprise than reduced forage purchases and increased forage sales, the crop enterprise NPV decreases while the beef enterprise is held somewhat constant. Thus, the economic impact of having more land in pasture is greater than the impact of having an extra quarter in tame hay. Furthermore, the results are at least partly driven by the model structure of the RFSM. Because the herd size cannot be adjusted within the simulation, there is limited flexibility to taking advantage of additional available forage within the model.

6.2.3 Scenarios 7- 8: Grazing Strategies to Increase Habitat Quality

As described earlier, Scenarios 7 and 8 consider the impact on farm wealth of implementing two herd management practices that correspond with benefits to wildlife habitat. Scenario 7 examines the impact of decreasing stocking rates in order to encourage pasture rejuvenation. It is first assumed that the forage stand is in a degraded state, compared to the base case scenario. Therefore, a revised base case scenario is modelled. Second, using the revised base case scenario, sub-scenarios are run with lowered stocking rates with progressively higher forage utilization rates and growth periods. These sub-scenarios are based on the assumption that the greater that stocking rates decrease, the more likely the forage stand will rejuvenate. However, these results should be interpreted with caution as the extent to which forage may rejuvenate when stocking rates are lowered is uncertain.

In Scenario 8, implementing rotational grazing management to rejuvenate the forage stand instead of decreasing stocking rates is modelled. Rotational grazing management is employed by constructing separate fenced areas across the pasture in order to rotate the beef herd in each area. In this manner, when an area is left vacant the forage stand rejuvenates. Again, it is unclear as to how much the forage stand might rejuvenate when rotational grazing is implemented. For this reason, a range of forage stand health increases is provided with corresponding farm wealth impacts. In addition, it is unclear as to how long forage health will increase. As a consequence, a range of values for the number of years over which stand health increases is considered.

6.2.3.1 Scenario 7: Decreasing Stocking Rates

6.2.3.1.1 Changing Pasture Conditions – ‘Revised’ Base Case Scenario

In the base case scenario, appropriate stocking rates for the forage and soil type, along with the amount of land dedicated to pasture purposes, are used to determine the herd size of the representative farm. Thus, the stocking rates used in the base case scenario are assumed to result in stable pasture conditions in the long term. However, these pasture conditions (i.e. the relative healthiness of forage from pasture) can be artificially changed in the simulation through the use of a forage utilization factor. This utilization factor, as defined within the RFSM, is the amount of available forage produced by the stand that can be effectively utilized by cows. If stocking rates decrease, pasture health increases, and the remaining cows can utilize the forage available more effectively[13]. In the current base case scenario, the utilization factor is 0.50, meaning cows effectively utilize half the available forage produced from the pasture. The 50% utilization rate value used is taken from Koeckhoven (2008). However, this utilization rate is conservative given that most farmers might utilize pasture up to a rate of 70% (Bork, 2010). If a utilization factor of 0.70 was used in this analysis, the base case scenario would have substantially much more forage available to feed cows. As a result, the beef enterprise NPV would increase due to larger weaning weights and an extended grazing season.

An assumption is made in Scenario 7 that grazing practices are such that there is poor forage availability and thus, limited forage utilization by cows. In this sense, the pasture can be pictured as being overgrazed, or in a drought period of time. This assumption is made to inspect possible benefits of decreasing the stocking rate when pasture is in this condition. The worsened state with the lowered utilization factor becomes the new revised base case scenario for Scenario 7. Three sub-scenarios are simulated: a forage utilization factor of 0.466, 0.433, and 0.4. A decrease in the utilization factor from 0.5 to 0.4 represents a 20% decrease in the amount of forage available from tame and native pasture. In order to illustrate the relationship between pasture condition and a given level of the utilization factor, Table 6-8 provides the degree of decrease in forage availability for cows, given decreasing utilization.

Table 6-8 Forage Availability with Decreasing Utilization Factor

		AUM/acre		Utilizable forage per year (lbs)	
Utilization	%	Native	Tame	Native	Tame
0.5		0.67	1.33	253340	500039
0.466	6.67%	0.65	1.3	243014	487553
0.433	13.33%	0.62	1.26	231441.758	473558
0.4	20.00%	0.58	1.22	217959.355	457255

Table 6-9 provides a summary of the simulation results that result from decreasing the utilization factor while maintaining existing stocking rates. NPVs for the total farm, crop and beef enterprises decrease under all three lowered utilization factors because cows cannot attain as much forage as in the base case scenario (shown in Table 6-8). Weaning weights, grazing season days, and forage sales all decrease as well. The crop enterprise

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[13] In Miller (2002), Section 2.3.3 “Livestock Effects on Vegetative Ecology”, a description of a case study by Willms et al (1985) is provided. Willms et al (1985) evaluate the vegetative impacts of stocking rates on a single area of native pasture. The study finds that as grazing is intensified (i.e., stocking rate increased), the amount of Rough Fescue declines. In addition, Parsch et al (1997) indicate that stocking rate affects the amount of forage available. When stocking rates are decreased, forage availability increases, and vice versa.

NPV decreases because the beef herd must rely on more winter feed from tame hay, reflected with decreased forage sales in Table 6-9.

Table 6-9 Scenario 7 Results: Decreasing Utilization Factor (Holding stocking rates constant)

	Utilization Factor			
	Base	0.466	0.433	0.4
Mean Farm NPV	$ 971,313	$ 952,692	$ 931,593	$ 906,252
Standard Deviation	$ 233,967	$ 235,345	$ 236,817	$ 237,623
Change in Total NPV		-$ 18,621	-$ 39,720	-$ 65,060
Annualized NPV Change		**-$ 2,187**	**-$ 4,665**	**-$ 7,642**
Mean Annual Forage Sales	$ 2,952	$ 2,653	$ 2,322	$ 1,947
Standard Deviation	$ 1,479	$ 1,489	$ 1,488	$ 1,464
Mean Crop Enterprise NPV	$ 506,064	$ 495,371	$ 482,523	$ 466,690
Standard Deviation	$ 214,621	$ 215,771	$ 216,897	$ 217,722
Mean Beef Enterprise NPV	$ 384,499	$ 376,083	$ 367,205	$ 357,035
Standard Deviation	$ 61,853	$ 61,540	$ 60,066	$ 57,623

6.2.3.1.2 Decreasing Stocking Rates to Improve Pasture Condition

After assuming that the pasture is now in a worsened condition (less forage available for cows) in the revised base case scenario, the impact of introducing a new grazing practice is modelled. Specifically, stocking rates are lowered in order to increase long run range health. Lowering the stocking rate is achieved by decreasing the number of cows grazing on each acre of pasture land. In this analysis, stocking rates are given in AUM per acre, and when stocking rates are lowered, the number of AUM per acre decreases for both native and tame pasture. Again, the beef herd size remains fixed and all changes from decreased stocking rates are reflected in weaning weights and grazing season length. Decreasing stocking rates is effectively similar to decreasing the amount of pastureland available to the beef herd at the start of the simulation, and thus, a decrease in weaning weights and grazing season days is expected. Furthermore, if pasture is in a worsened condition, there may be economic (i.e. farm wealth) and/or intrinsic (i.e. wildlife habitat) reasons why the farm operator may want to lower stocking rates. Again, the assumption is held that if the farm operator lowers stocking rate, the health of the pasture improves, and cows can utilize more forage from the pasture.

To model the improvement in pasture condition due to the lowering of stocking rates, an incremental increase in the forage utilization factor over time is used. Values for the incremental increase in the utilization factor and the number of years over which this increase occurs are assigned to a set of specific stocking rates. These are provided in Table 6-10. A number of model assumptions are made with regards to the rate at which the pasture condition improves:

a) herd size (i.e., number of calves, bulls, and cows), and grazing parameters all remain unchanged; economic changes are captured through changes in grazing season length and weaning weights;
b) the degree of annual improvement in pasture condition increases with a lower stocking rate;
c) as stocking rates decrease, the length of time over which pasture conditions improve increases;
d) the stocking rate changes occur on both native and tame pasture and they occur concurrently (e.g., a 1% reduction in stocking rate for tame pasture would be done in conjunction with a 1% reduction in the stocking rate for native pasture).

Table 6-10 Scenario 7: Sub-Scenarios for Lowered Stocking Rates

Stocking rates (Upland)	Increase in Utilization factor per year	Number of years
Tame (1.2), Native (0.6)	1.0%	4
Tame (1.1), Native (0.55)	1.5%	5
Tame (1.0), Native (0.5)	2.0%	6

In the revised base case scenario, the starting level of stocking rates is 0.65 AUM per acre for native pasture, and 1.3 AUM per acre for tame pasture, with a corresponding forage utilization factor of 0.4 (rather than a utilization factor of 0.5 as in the original base case scenario). Again, this represents an ‘overgrazed’ state where pasture is in a worsened condition. Stocking rates are then decreased by increments of 0.05 AUMs on native pasture, along with increments of 0.10 AUMs on tame pasture for 3 sub-scenarios, until the final lowered stocking rate of 0.5 AUM per acre for native and 1.0 AUM per acre for tame pasture is reached.

A summary of the simulation results for the three lowered stocking rate sub-scenarios is reported in Table 6-11. The total farm NPV first increases, than decreases after stocking rates are reduced by more than 8%. The impact on the farm NPV, as well as on the crop and beef enterprise NPV, is very minimal. However, results suggest that decreasing stocking rates by a small amount (less than 8%), with a short improvement in pasture condition, can increase farm wealth when pasture is in a worsened condition. In addition, the beef enterprise NPV increases slightly as a result of both increased weaning weights and grazing season length. However, when stocking rates are decreased by more than 8%, NPV losses result. When stocking rates are lowered past this level, the crop enterprise NPV decreases slightly, while the beef enterprise NPV stays relatively constant. This suggests that the lower grazing season is leading to more demand for tame hay (expressed through reduced forage sales), while forage rejuvenation is cancelling out the decline in beef enterprise NPV. Appendix D, Table D-1, provides the offsetting impact of increased forage availability after four to six years of re-growth from a worsened starting condition. It is important to note that the degree to which pasture would improve from a decrease in stocking rates is unknown for the representative farm. For this reason, the ‘cost’ of reducing the number of cows on pasture may be more or less than what is reported. Appendix D provides a summary of the amount of forage generated up to and including the last year of utilization growth.

Table 6-11 Scenario 7 Results: Decreasing Stocking Rates

	Decreasing stocking rate with increasing pasture conditions (AUM/Acre)			
	Revised Base	Tame (1.2), Native (0.6)	Tame (1.1), Native (0.55)	Tame (1.0), Native (0.5)
Mean Farm NPV	$ 906,252	$ 907,700	$ 904,346	$ 904,627
Standard Deviation	$ 237,623	$ 241,858	$ 241,113	$ 243,008
Change in Total NPV		$ 1,448	-$ 1,906	-$ 1,626
Annualized NPV Change		**$ 170.06**	**-$ 223.90**	**-$ 190.96**
Mean Annual Forage Sales	$ 1,947	$ 1,977	$ 1,991	$ 2,045
Standard Deviation	$ 1,464	$ 1,528	$ 1,597	$ 1,670
Mean Crop Enterprise NPV	$ 466,690	$ 466,261	$ 464,855	$ 464,562
Standard Deviation	$ 217,722	$ 218,825	$ 219,760	$ 220,679
Mean Beef Enterprise NPV	$ 357,035	$ 360,063	$ 359,069	$ 360,760
Standard Deviation	$ 57,623	$ 58,558	$ 61,567	$ 63,478

6.2.3.2 Scenario 8: Rotational Grazing Management

The base case scenario assumes that grazing occurs on two half sections (i.e., 320 acre parcels) without rotational grazing. In the base scenario there is no construction of fence or off-stream watering, and there is no pasture improvement. In Scenario 8, rotational grazing is implemented by splitting the two 320 acre parcels (one parcel is native pasture and the other is tame pasture) in half with fencing, and constructing small off-stream watering sites on the newly created parcels. The investment cost for off-stream watering is $47.41 per cow per off-stream watering site. The total cost of constructing two off-stream watering sites is $11,000. In addition, there is a fencing cost of $0.71 per foot, for a total fencing cost of $3,764. Yearly maintenance costs are assumed to be 2% of the initial cost of investment. The breakdown and source of this investment cost information is provided in Appendix E. As noted earlier, there is uncertainty as to the degree to which forage availability increases and the duration of the increase from implementing rotational grazing. As a result, sub-scenarios are modelled that involve varying levels of the degree of forage availability increase per year, while holding the number of years of improvement constant and then, varying levels of the number of years of improvement, while holding the degree of forage availability increase per year constant. In this manner, the sensitivity of performance relative to the uncertainty of forage availability improvement[14] can be determined.

6.2.3.2.1 Improving Forage Utilization due to Rotational Grazing

The main simulation parameter that affects year over year forage availability (without adjusting stocking rate, or herd size) is the utilization factor described in Scenario 7. In the first set of sub-scenarios for Scenario 8 (sub-scenarios 1 through 3), the annual growth in the utilization factor is increased from the base case scenario. The number of years over which the utilization factor increases is fixed at four years. The annual improvement in the pasture condition is varied in each sub-scenario: the growth of the utilization rate is 0.5%, 1%, or 1.5% per year in each sub-scenario. The costs of constructing the additional fencing and off-stream watering sources are included in each of the sub-scenarios. An assumption is made that the costs of constructing the additional fencing are spread over the first two years after starting the simulation, rather than immediately deducted from NPVs in the first year as in all other RFSM scenarios. However, the start in the growth in the utilization factor occurs when moving from year 1 to year 2 (with the last period of growth occurring in year 4) of the 20 year period.

The NPV results are reported in Table 6-12 and suggest that if the utilization factor increases by 0.5% or 1.0% (meaning an increase of 0.0025 or 0.005 from 0.5) per year, then the full costs of construction are not recouped. The impact on total farm NPV is negative with an annualized NPV loss of $868.96 for a 0.5% increase, and a loss of $190.26 for a 1.0% increase. However, with sufficient improvement in pasture condition, such that the utilization factor increases by more than 1.5% per year for four consecutive years, the costs of construction are recouped as total farm NPV increases relative to the base case scenario. Both enterprise NPVs (i.e., crop and beef) increase slightly throughout these sub-scenarios and with continual forage availability improvement. Appendix D, Table D-2, provides the amount that the forage available increases under these three sub-scenarios for the four years of pasture improvement.

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[14] Both scenarios 7 and 8 had uncertainty around the forage improvement of pasture when implementing the EG&S practice. However, Scenario 7 would have been too burdensome to analyze the sensitivity of forage increases. For each lowered stocking rate, sub-sub-scenarios would have to be done with varying degrees of utilization improvement and further sub-sub-scenarios with varying pasture improvement periods, meaning a possible 24 simulation runs (3 × 8) sub-sub-scenarios for lowering stocking rates) required for the one scenario. Instead, assumptions for these two factors are given in Table 6-10.

Table 6-12 Scenario 8 Results: Increasing Utilization Factor Growth Rate (Holding improvement time period constant)

	Utilization Factor Growth Rate			
	Base Case	0.5%	1.0%	1.5%
Mean Farm NPV	$ 971,313	$ 963,915	$ 969,693	$ 976,340
Standard Deviation	$ 233,967	$ 234,862	$ 234,203	$ 233,846
Change in Total NPV		-$ 7,398	-$ 1,620	$ 5,027
Annualized NPV Change		**-$ 868.96**	**-$ 190.26**	**$ 590.46**
Mean Crop Enterprise NPV	$ 506,064	$ 510,160	$ 513,614	$ 517,248
Standard Deviation	$ 214,621	$ 214,368	$ 214,540	$ 214,516
Mean Beef Enterprise NPV	$ 384,499	$ 388,804	$ 391,808	$ 395,448
Standard Deviation	$ 61,853	$ 60,593	$ 63,052	$ 63,241

6.2.3.2.2 Extended Period of Utilization Growth due to Rotational Grazing

The impact of rotational grazing on NPV estimates was also examined with respect to changing the longevity of pasture improvement. Specifically, the number of years over which the pasture improves is varied while keeping the rate at which pasture improves constant; the annual utilization factor increase is held constant at 1.0%. Table 6-13 reports a summary of simulation results for periods of utilization factor improvement ranging from three to six years (for sub-scenarios 4 - 7). Results suggest that if pasture improvement occurs for no more than four years, with an annual 1.0% increase in utilization factor, the costs of implementing rotational grazing are not recouped. The total farm NPV decreases relative to the base case scenario. For longer periods of improvement, however, total farm NPV is improved. As with the previous analysis, the costs of implementation are attributed to the total farm NPV, but not to the individual enterprises. As a result, both enterprise NPVs gradually increase throughout the change in time period, but only slightly. Similar to changing the utilization factor growth rate, Appendix D, Table D-3, reports the results in terms of the amount of forage available from the pasture for each year over the time period.

Table 6-13 Scenario 8 Results: Increasing Utilization Improvement Time Period (Holding utilization rate constant)

	Number of Years the Pasture Improves				
	Base	3	4	5	6
Mean Farm NPV	$ 971,313	$ 966,915	$ 969,693	$ 972,270	$ 974,713
Standard Deviation	$ 233,967	$ 234,189	$ 234,203	$ 233,813	$ 233,909
Change in Total NPV		-$ 4,398	-$ 1,620	$ 957	$ 3,400
Annualized NPV Change		**-$ 516.63**	**-$ 190.26**	**$ 112.42**	**$ 399.41**
Mean Crop Enterprise NPV	$ 506,064	$ 512,045	$ 513,614	$ 514,981	$ 516,189
Standard Deviation	$ 214,621	$ 214,547	$ 214,540	$ 214,542	$ 214,548
Mean Beef Enterprise NPV	$ 384,499	$ 390,319	$ 391,808	$ 393,263	$ 394,758
Standard Deviation	$ 61,853	$ 62,150	$ 63,052	$ 62,816	$ 62,924

6.2.4 High Input Cost Scenario:

2007-2008 Input Costs versus 2005 Input Costs

This analysis is undertaken due to the uncertainty around annual crop input costs that are used to construct the RFSM. As indicated in section 5.2.3.2, input costs are included that matched up, time-wise, with the historical commodity price data used to estimate pricing equations. Input costs of this nature are felt to be more representative of the long-run cost of inputs faced by farmers in the study area. However, recently, input costs have been consistently higher than the historical values used to generate the simulation results and largely different than costs incurred in 2005. In 2008, Canadian crop farmers experienced a substantial increase in energy and fertilizer costs, labour costs, and high freight costs (TD Bank Financial Group, 2008). Scenario analysis is performed using input costs for 2007 and 2008 to investigate whether these higher costs have a significant effect on the NPV estimates and the subsequent incentives (whether positive or negative) for practices that promote EG&S production.

Originally, 2005 crop input costs are used in the RFSM that are based on Saskatchewan farmer crop budgets for direct seeding in the Black/Grey soil zone (see section 5.2.3.2 for reference). In this scenario, input costs are adjusted to reflect an average of 2007 and 2008 Saskatchewan producer crop budgets for direct seeding in the Black/Grey soil zone. The new crop input costs based on the average between 2007 and 2008 are provided in Table 6-14. An explanation is required as to why this average is used, as the crop price data did not go beyond 2007. The costs of inputs are not noticeably greater than the original historical (i.e., 2005) values until after mid-2007. In addition, budgets are constructed prior to the actual crop year, and based on past information. For this reason, the 2008 crop budget might be more representative of actual 2007 costs than the 2007 crop budget.

Only crop input costs are assumed to increase in this scenario, as the cost increase is more profound in cropping than in the beef sector (Erickson, 2008). For this reason, only the scenarios that directly affected the crop enterprise are re-run for the high cost environment. Specifically, Scenarios 1 and 3, converting riparian and forested habitat to cropland, and Scenarios 5 and 6, converting cropland to tame pasture or tame hay, are re-examined. For each scenario, the only change made is the increase in crop input costs. The cost of conversion for forested and riparian habitat is calculated and used to adjust NPVs in the same manner.

Table 6-14 Average of 2007 and 2008 Annual Crop Input Costs ($/acre/year)

	Whea	Flax	Canola	Barley	Greenfeed	Alf/Grs	Tame	Native
Seed	11.365	7.875	26.475	8.92	5.25	3	0	0
Fertilizer	39	33.9	40.2	39	18	6.75	0	0
Chemical	24.52	27.13	28.015	21.835	0	0	0	0
Crop Insurance	4.98	6.965	7.045	4.605	1.69	0.55	1.98	0.29
Fuel, Oil & Lube	10.99	12.56	11.775	10.99	7	12.44	0.07	0.14
Machinery Repairs	5.94	7.92	5.94	5.94	7	10.63	0.15	0.08
Building Repairs	1.6	1.6	1.6	1.6	0.78	0.33	0.19	0.17
Utilities & Misc.	5.355	5.355	5.355	5.355	3.86	3.08	0.13	0.12
Custom Work								
Spraying	2.97	2.97	2.97	2.97	2.97	3.46	0	0
Grain Handling	4.18	2.7	3.15	6.77	-	-	-	-
Capital Costs								
Taxes, & Licenses	5	5	5	5	5	5	1	0.2

Sources: Kaliel, 2007; Saskatchewan Agriculture, 2008-k

6.2.4.1 *Scenario 1: Converting Riparian Habitat to Cropland*

Results for Scenario 1, where riparian habitat is converted to cropland, are summarized in Table 6-15. The higher cost environment results in a reduction of total farm NPV by 11.37% to a new base case level of $860,862. This NPV reduction is expected as increased input costs has the effect of decreasing cash flow in the crop enterprise, shown through a decrease of 21.38% in the base case. There are minimal effects on the beef enterprise and herd management for the farm.

Table 6-15 High Input Costs, Scenario 1 Results: Converting Riparian Habitat to Cropland

	Acres of Riparian Habitat Remaining (% of Quarter)			
	Scenario 1		2007/2008 costs	
	Base	0 (0%)	Base	0 (0%)
Mean Farm NPV	$ 971,313	$ 1,032,440	$ 860,862	$ 910,006
Standard Deviation	$ 233,967	$ 262,606	$ 234,861	$ 255,150
Change in Total NPV		$ 61,127		$ 49,144
NPV Change ($/acre Converted)		$ 637		$ 512
Annualized NPV Change ($/acre Converted)		**$ 74.79**		**$ 60.13**
Mean Crop Enterprise NPV	$ 506,064	$ 557,519	$ 397,886	$ 437,321
Standard Deviation	$ 214,621	$ 236,073	$ 214,621	$ 236,073
Mean Beef Enterprise NPV	$ 384,499	$ 386,109	$ 381,520	$ 383,131
Standard Deviation	$ 61,853	$ 61,511	$ 62,348	$ 61,999

The NPV benefit of converting riparian habitat to cropland is approximately $60.13 per acre per year, which is smaller than the NPV benefit of converting riparian habitat to cropland using 2005 crop input costs ($74.79 per acre, as reported in Table 6-1). Using more recent input costs reduces the benefit per acre of conversion by 19.60%. This reduction demonstrates the potential sensitivity of converting riparian habitat to cropland. In a high cost environment, the farm operator has less incentive to attain new land by converting wildlife habitat areas. A larger incentive may be required in low-cost periods to conserve habitat on agricultural land.

6.2.4.2 Scenario 3: Converting Forested Habitat to Cropland

Results for Scenario 3, where the farmer converts forested habitat to cropland, are given in Table 6-16. Inclusion of 2007/2008 input costs rather than 2005 input costs reduces base case total farm NPV by 14.88%. When converting all forested habitat to cropland, the NPV benefit to the farm operator is $33.44 per converted acre per year. This benefit is 30.38% lower than what is found using 2005 input costs. Similar to converting riparian habitat to cropland, higher crop input costs make it less profitable to convert forested habitat to cropland. In fact, forested habitat is more sensitive to high costs than riparian habitat.

Table 6-16 High Input Costs, Scenario 3: Converting Forested Habitat to Cropland

	Acres of Forested Habitat per Quarter (% of Quarter)			
	Scenario 3		2007/2008 costs	
	Base	0 (0%)	Base	0 (0%)
Mean Farm NPV	$ 766,189	$ 805,443	$ 652,159	$ 679,491
Standard Deviation	$ 223,617	$ 247,501	$ 225,668	$ 249,541
Change in Total NPV		$ 39,254		$ 27,332
NPV Change ($/acre Converted)		$ 409		$ 285
Annualized NPV Change ($/acre Converted)		**$ 48.03**		**$ 33.44**

6.2.4.3 Scenarios 5 and 6: Converting Cropland to Tame Pasture or Hay

Lastly, results associated with conversion of a cropland to tame forage for pasture and hay purposes are provided in Table 6-17. Again, similar to using 2005 input costs, converting cropland to tame pasture leads to a net NPV increase ($24.88 per converted acre), while converting cropland to tame hay leads to a net NPV decrease (-$35.58 per converted acre). However, using higher input costs increases the profitability of converting cropland to tame pasture, and decreases the loss experienced when converting cropland to tame hay. The benefit of converting cropland to tame pasture increases by 149.30%, while the cost of converting cropland to tame hay decreases by 28%. This result is expected as increasing crop input costs has the effect of decreasing the profitability to the farm of growing annual crops in relation to growing tame forage.

Table 6-17 High Input Costs, Scenario 5 and 6: Converting Cropland to Tame Pasture (Scenario 5) or Hay (Scenario 6)

	One Quarter Section converted to Tame Grass			
	2005 costs		2007/2008 costs	
	Scenario 5	Scenario 6	Scenario 5	Scenario 6
Mean Farm NPV	$ 983,547	$ 910,724	$ 891,365	$ 817,237
Standard Deviation	$ 199,059	$ 200,623	$ 199,370	$ 201,267
Change in Total NPV	$ 12,234	-$60,588	$ 30,503	-$43,625
NPV Change ($/acre Converted)	$ 85	-$421	$ 212	-$303
Annualized NPV Change ($/acre Converted)	**$ 9.98**	**-$49.42**	**$ 24.88**	**-$35.58**

6.3 Landscape Target Model (LTOM) Results

Results derived from the landscape target optimization model (LTOM) are provided in this section. To reiterate, the LTOM is constructed to determine cumulative effects of a hypothetical regional policy designed to encourage maintenance and enhancement of wildlife habitat on agricultural lands. The policy is one of regulation, as strict landscape targets are imposed to the objective function of maximizing farm wealth (i.e. assessed wealth of land). These landscape targets are defined by the Lower Souris Watershed Committee to ensure wildlife habitat protection. Three versions of the LTOM are formed; one for each representative township found in the three sub-watersheds of the LSRW. For each township model, two optimization runs are carried out: the base case run and the landscape target run (see section 5.3.7 for further explanation of each optimization run).

Comparisons are made between the two optimization runs to develop a more aggregate estimate of the private costs (or benefits) of a fixed regulatory policy across a large land base and a number of farms. The results demonstrate the potential effectiveness of linear programming in estimating the aggregate impact of environmental policy related to EG&S production. The farm wealth estimates are based on the assessed wealth of land and on changing landscapes over the long term. Landscape changes are driven primarily by the on-farm economic parameters of the linear programming model, explained in Section 5.3, and the landscape target constraint.

Furthermore, comparisons are made to determine the potential impact that each optimization run has on long-term landscape change. In the base case run, it is expected that there will be continued conversion of landscapes sensitive to wildlife habitat (e.g., riparian, forested, and native grass landscapes) to more productive agricultural uses (e.g., tame grass, cropland). In the landscape targets run, it is expected that there will be limited change in current landscape types due to the presence and enforcement of the targeted amount of acreage in the LSRW. This comparison is done to provide some predictive analysis into the land-use impacts of policy intervention, specifically for the LSRW. In this manner, a greater understanding may be provided to policy-makers regarding both the farm wealth impact and expected land use changes under the two scenarios: the status quo and the landscape targets.

The results of the LTOM are given in three stages:

- First, the base case run results are compared to the actual assessed wealth and landscape acreage found in each township. This comparison is done to provide insights into the long term landscape changes when keeping the status quo, particularly as they relate to wildlife habitat. Assessed wealth estimates from the base case run also represent the additional private gains that farmers in the LSRW can expect in the long run from continued landscape conversion.

- Second, the landscape targets run results are compared to the actual assessed wealth and landscape acreage found on each township. Given the current landscape acreage, this comparison determines if imposing proposed landscape targets leads to substantial conversion and change. If substantial conversion is needed, the change in assessed wealth provides the private cost for implementing the targets.

- Thirdly, the landscape target run results are compared to the base case run results for each township. This comparison is done to provide insights into long-term landscape adjustments required to meet the landscape targets; that is, how would the targets cause patterns of landscape change to adjust, and at what cost?

In inspecting these comparisons and the LTOM results, it is important to note that a number of assumptions had to be made in the analysis. Similar to the RFSM, it is assumed that the farmers in the LSRW are all wealth maximizing, and therefore seek landscape conversions that increase their assessed value of land. However, not all farmers or landholders are land wealth maximizing, as some understand the value of keeping land in non-wealth generating landscapes (as explained in section 2.4.2). It is safe to assume that most farmers will try to increase the wealth of his/her land, but in reality, some will not go to all limits to increase the assessed wealth of their land. Furthermore, the assumption is made that the assessed value of land, and the derived coefficients for each landscape type, reflect the measure of wealth for a farm, specifically the productive capabilities of the land and associated values of production drawn from the land. For further information as to why this assumption was made, please refer to section 5.3.4.

The analysis assumes that there are no other long-term constraints associated with landscape change and landscape conversion, other than the cost of conversion and the physical limitation of converting from a previous landscape of some type. In reality, there may be additional financial, weather, physical, and timing constraints of converting landscapes on agricultural land. Furthermore, in reality, farmers may perceive the value of undergoing landscape conversion differently from the assessed wealth valuation used in the optimization model. Cropland may be overvalued with regards to its wealth generating characteristics in the model, or perennial forage may be undervalued given its importance to cow-calf producers.

Results for each optimization run, and the actual levels found on the township, are given in both tabular and chart form. The tabular results compare measures of assessed wealth and determine the net change. Also provided are descriptive statistics for the average assessed wealth per quarter section for each township model. Assessed wealth is measured in total dollars ($) for the entire township or quarter section, and dollars ($) per acre. The charted results compare the overall landscape type changes afforded from both the base case and landscape target runs. In addition to comparing total landscape type acreage allocation, discussion follows regarding where the changes in landscape type acreage are coming from, which landscape type conversions are most prolific, and prevalence of alternative end uses. Overall comparisons between the three sub-watershed townships are provided at the end of this section.

6.3.1 Base Case Run versus Actual Township Levels

6.3.1.1 Assessed Wealth Changes

The first comparison of the results from the LTOM involved comparing the base case to the actual levels found in each respective township model. Again, the base case run did not include the landscape target constraint. Table 6-18 provides the assessed wealth results in the base case run after full conversion of various landscape types. In the Antler River township model, maximizing farm wealth leads to an assessed wealth average increase of $1,594 per quarter section from actual assessed wealth values, and a $9.96 increase per acre. In the Pipestone Creek township model, average assessed wealth per quarter section increases from $40,045 to $45,050, an increase of $5,006 per quarter section and $31.29 per acre. In the Four Creeks model, average assessed wealth per quarter section increases from $39,389 to $40,799, a difference of $1,411 per quarter section, and $8.82 per acre across the township. For all three townships, the base case results in an increase in the total assessed wealth and the average assessed wealth of a quarter section.

Table 6-18 Assessed Wealth Estimates: Actual versus Base Case Run

Sub-Watershed	Antler River		Four Creeks		Pipestone Creek	
	Actual	Base Case	Actual	Base Case	Actual	Base Case
Total Assessed Wealth	$6,047,000	$6,271,755	$5,553,800	$5,752,691	$5,646,300	$6,352,097
Total Wealth Increase from actual		$224,755		$198,891		$705,797
Average Assessed Wealth per Qtr	$42,887	$44,481	$39,389	$40,799	$40,045	$45,050
Wealth Increase from actual ($/Quarter)		$1,594.01		$1,410.57		$5,005.65
Wealth Increase from actual ($/Acre)		**$9.96**		**$8.82**		**$31.29**

All three townships exhibit increased assessed wealth estimates in the base case due to the allowance of free landscape conversion over the long run. Given unlimited time, farmers have added incentives to convert land to maximize assessed wealth. As a result, the base case optimization run results in a substantial increase in assessed wealth from current levels. Part of this pattern is a reflection of the limitation of the model to include all conversion opportunities. However, if there is no policy intervention, and because there is a direct incentive, farmers and landholders will continue to convert landscapes, including those landscapes vulnerable for wildlife habitat, to increase the assessed value of land. Appendix F provides the actual assessed wealth valuations for each quarter section in all three sub-watershed townships, as well as the assessed wealth estimates per quarter section from the base case and landscape target runs.

6.3.1.2 Landscape Changes

In terms of landscape change, the resulting base case run landscape acreages are compared to the original landscape acreages found in each respective township. The total landscape type acreage allocation for the Antler River, Pipestone Creek, and Four Creeks townships associated with the base case run and compared to actual levels are provided in Figures 6.1, 6.2, and 6.3, respectively. For all three townships, the largest change occurs from perennial forage being converted to other uses. For the Antler River and Four Creeks townships, all perennial forage is converted to the cropland landscape type. This can be explained by the fact that the wealth coefficient is much higher for cropland then that for perennial forage, and this type of landscape conversion is relatively inexpensive (refer to Table 5-27 for the costs of conversion). Also, the individual farm wealth benefits of having land in cropland versus perennial forage for a mixed-operation farm are used to adjust this cost of conversion, lessening the cost of conversion between these landscape types even further.

Figure 6.1 Antler River Township: Base Case Run versus Actual Acreage (Initial acreage of each landscape type is marked by the legend)

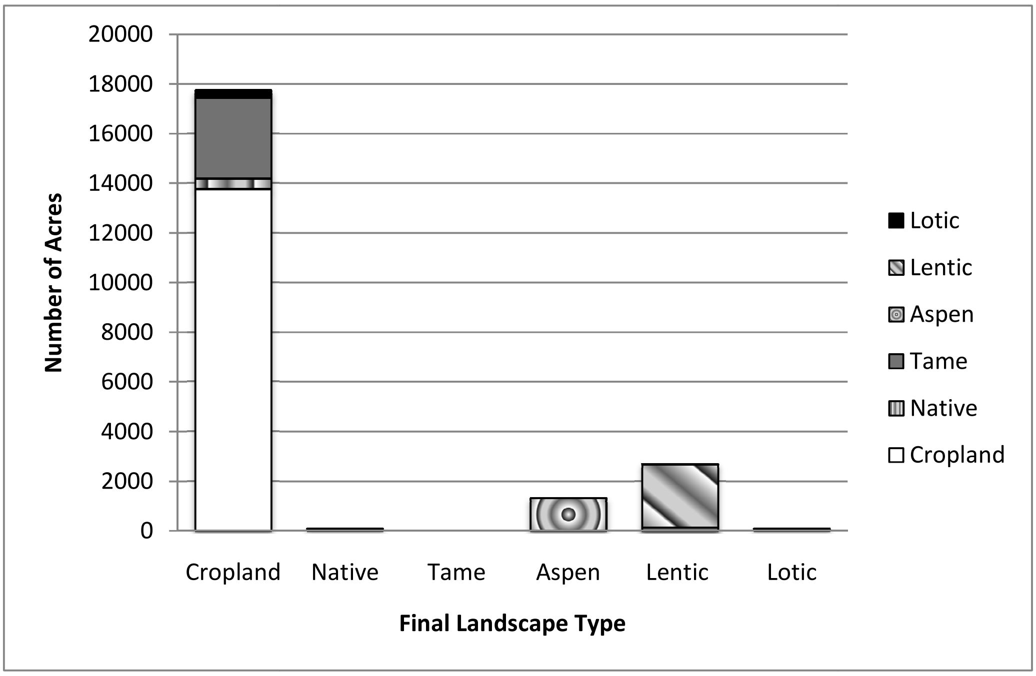


Figure 6.2: Pipestone Creek Township: Base Case Run versus Actual Acreage (Initial acreage of each landscape type is marked by the legend)

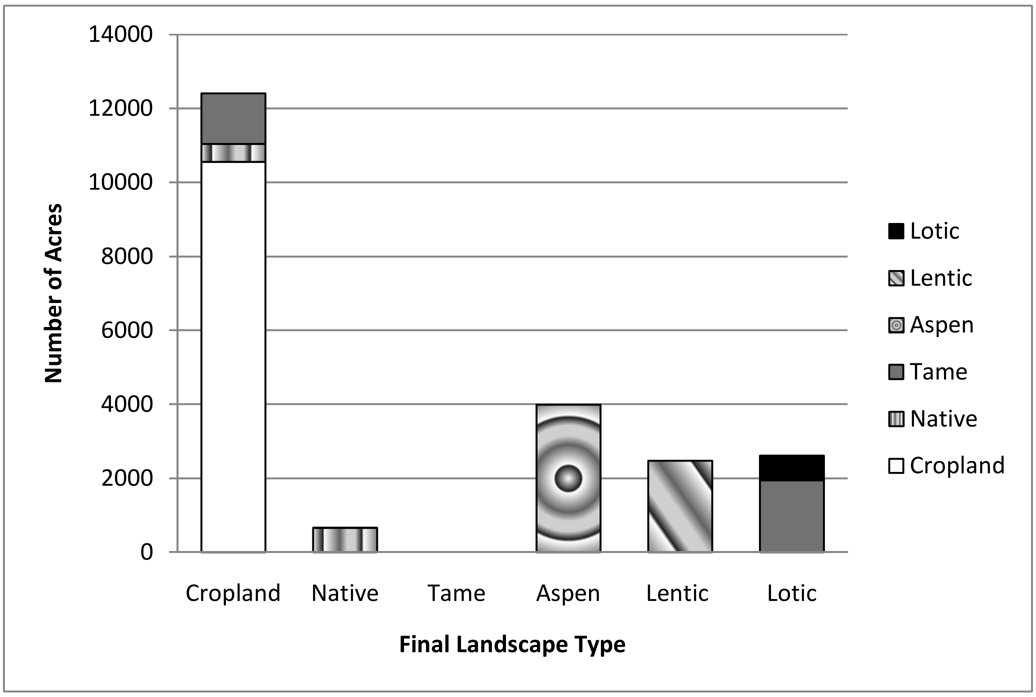
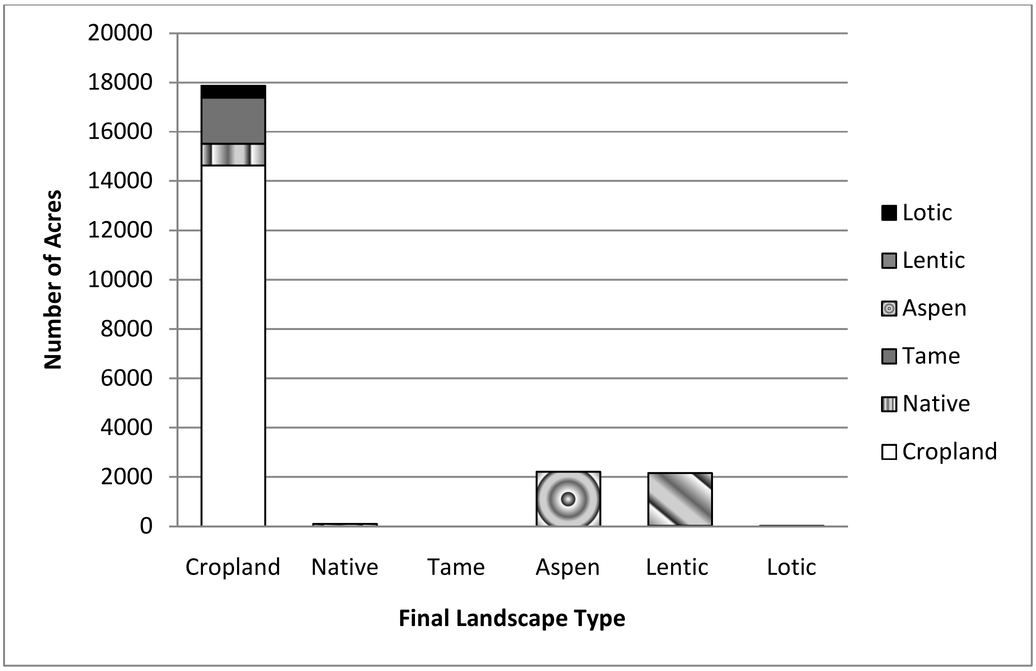


Figure 6.3: Four Creeks Township: Base Case Run versus Actual Acreage (Initial acreage of each landscape type is marked by the legend)



For the Pipestone Creek township some of the perennial forage is converted to the cropland landscape type, while a substantial amount is converted to lotic riparian (51% of all converted acres). The result of land being converted to lotic riparian suggests that the assessed wealth coefficient for lotic riparian in the Pipestone Creek sub-watershed may be over-valued (on average, $352.11 per acre in Appendix F). Any wealth-seeking farmer would not undergo the cost of conversion to convert land to a use not directly utilizable for agricultural production. Following the trend in perennial forage, most, if not all acreage allocated to native prairie is converted to cropland in each township. This indicates that the cost of conversion for native prairie is sufficiently small, and the gap between the wealth coefficients for cropland and native prairie (given in Appendix F) is sufficiently large to warrant conversion. Aspen and lentic riparian landscapes remain relatively unchanged for all three townships. This suggests that the costs of conversion of these landscape types are sufficiently substantial to deter any conversion to another landscape type. However, in looking at Table 5-27, the costs of conversions from aspen habitat seem relatively small. Justification is provided through the wealth coefficients for aspen habitat as they are consistently high for the three townships, as shown in Appendix F.

When looking at the difference between quarter sections in a particular township with regards to landscape change, a couple of trends are present. For the Antler River township, the lotic riparian acreage that is converted to cropland occurs mostly on quarter sections where cropland is the dominant landscape type. In other words, those quarters where cropland is mostly found (i.e. 135 – 150 acres is primarily in cropland) are the ones where lotic riparian is converted to increase landscape acreage. This makes sense as a farmer would have the greatest incentive to remove the few obstacles found on a quarter section primarily for crop production. Interestingly, for both the Antler River and Four Creeks townships, the quarter sections where all native prairie acreage is converted to cropland all have low assessed valuations. However, those quarter sections where native prairie is kept intact are assessed relatively higher. It appears that on low assessed valued quarter sections there is further incentive to convert native prairie to cropland.

It is interesting that in this base case run for each township, all available land is not being converted to the highest wealth-generating landscapes, such as cropland or in Antler River’s case, lentic riparian habitat. This is entirely due to the wealth generation for each quarter section not being the product of the number of acres and the respective wealth coefficient, but instead the product of the number of acres and the respective wealth coefficient *and* cost of conversion. All decisions of landscape type conversion in each optimization run are based on a trade-off between the benefit of wealth coefficient increase versus the cost of conversion of landscape types. Without this trade-off the base case run would simply allocate all acres to the landscape type with the highest wealth coefficient in each quarter section. Furthermore, wealth coefficients vary for each quarter section, so for each quarter section this trade-off varies as well.

6.3.2 Landscape Targets Run versus Actual Township Levels

6.3.2.1 Assessed Wealth Impacts

A summary of the impact on assessed wealth of imposing the landscape targets and a comparison to the original assessed wealth values for each township is provided in Table 6-19. In contrast to the base case run, it is expected that imposing the landscape targets would lead to a decrease in assessed wealth from actual levels. Considering the results in Table 6-19, it seems that the expectation of decreasing assessed wealth is accurate for the Antler River and Four Creeks townships. The average assessed wealth decreases for the Antler River, and Four Creeks townships are $34.91 per acre and $11.16 per acre, respectively. However, for the Pipestone Creek watershed, total assessed wealth increases by $106,120, an average of $4.70 per acre. This result suggests that the landscape targets are more restrictive in the Four Creeks township compared to the Pipestone Creek township, and even more restrictive for the Antler River township compared to the Pipestone Creek township.

Table 6-19 Assessed Wealth Results: Actual versus Landscape Targets Run

Sub-Watershed	Antler River		Four Creeks		Pipestone Creek	
	Actual	Landscape Targets	Actual	Landscape Targets	Actual	Landscape Targets
Total Assessed Wealth	$6,047,000	$5,259,473	$5,553,800	$5,301,989	$5,646,300	$5,752,420
Total Wealth Decrease from actual		$787,527		$251,811		($106,120)
Average Assessed Wealth per Qtr	$42,887	$37,301	$39,389	$37,603	$40,045	$40,797
Wealth Decrease from actual ($/Quarter)		$5,585.30		$1,785.90		($752.62)
Wealth Decrease from actual ($/Acre)		**$34.91**		**$11.16**		**($4.70)**

Despite the inclusion of the landscape targets constraint, it is expected that assessed wealth estimates would increase in the optimization because of the free flow of landscape types and conversion. Again, it is assumed that there are limited physical constraints to conversion, other than those physical conditions included in the cost of conversion. Thus, in the long run, conversion will occur to the most profitable landscape types up until the minimum landscape target requirements.

6.3.2.2 Landscape Changes

The landscape changes that occur with holding the landscape targets fixed are compared to what is originally found on the landscape for all three townships. The landscape changes are shown in Figures 6.4., 6.5, and 6.6. For the Antler River township, it appears that most of the landscape targets, including the acreage required for native prairie, perennial forage, lotic riparian, and aspen habitat for all three townships, are met with conversion from cropland acreage (approximately 66% of all landscape type conversions). For the Four Creeks township, the increase in the native prairie acreage comes directly from conversion from lentic riparian habitat, while the increase in perennial forage is from aspen habitat, and lentic riparian habitat. Furthermore, for the Pipestone Creek township, it is clear that the landscape targets constrain the optimization model as additional conversion is required from aspen, lentic riparian, and lotic riparian landscapes. These types of conversions are a result of the target for native and perennial forage being set higher than actual levels, while the target is set lower for lentic riparian and aspen landscapes for all three townships. Furthermore, the cropland landscape type also has a landscape target that is limiting additional conversion of cropland (which is less expensive to convert) to native prairie and perennial forage.

Figure 6.4: Antler River Township: Landscape Targets Run versus Actual Acreage (Initial acreage of each landscape type is marked by the legend)

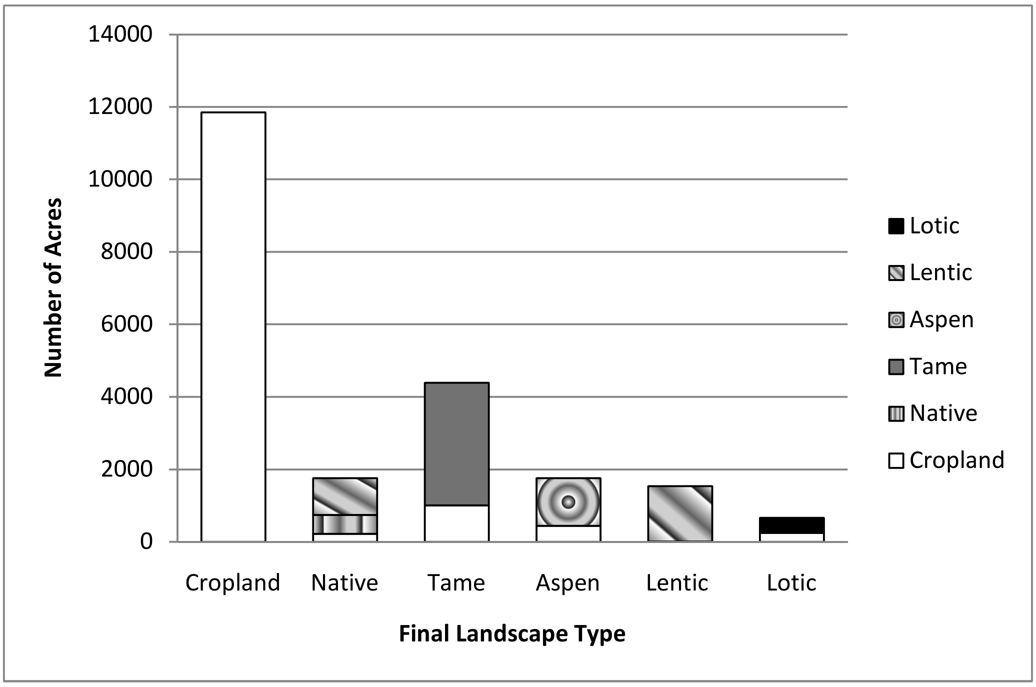


Figure 6.5: Pipestone Creek Township: Landscape Targets Run versus Actual Acreage (Initial acreage of each landscape type is marked by the legend)

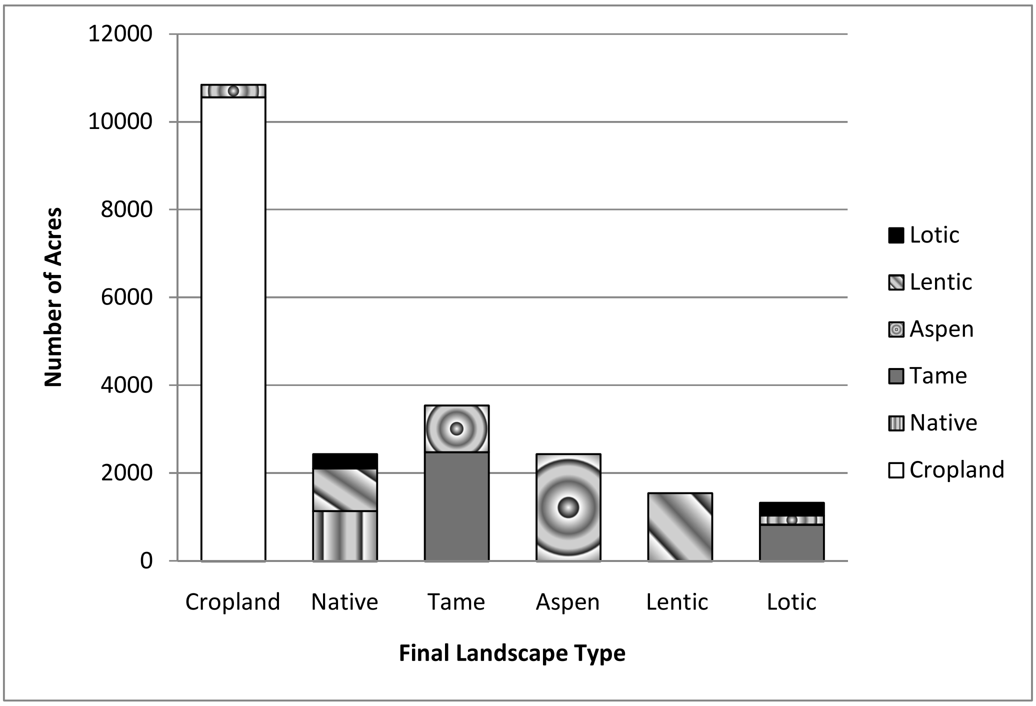
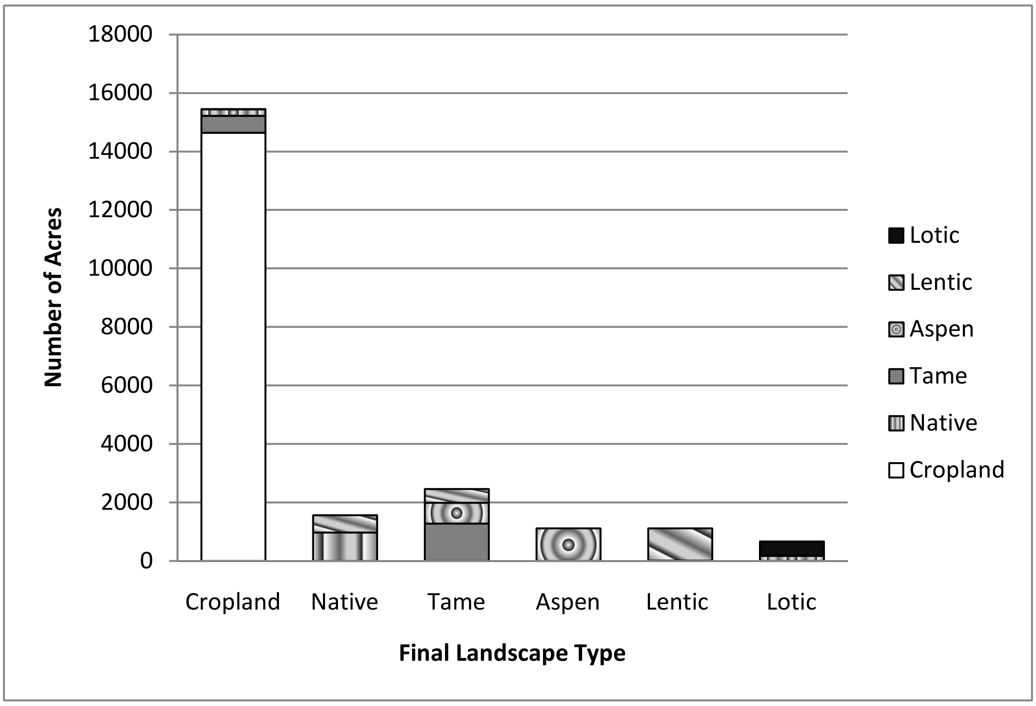


Figure 6.6: Four Creeks Township: Landscape Target Runs versus Actual Acreage (Initial acreage of each landscape type is marked by the legend)



A large portion of the increase in native prairie from levels currently found across all three townships is from conversion of acres from lentic riparian habitat. In fact, almost all land converted away from lentic riparian is converted to native prairie (except for some converted to perennial forage for the Four Creeks township). It is somewhat self-explanatory why cropland acreage is used to convert to other landscapes to meet targets, as there is ample acreage currently in cropland and there are marginal costs of conversion when converting from cropland, but it is not clear why lentic riparian habitat is converted to native prairie. Simply, the high landscape target share afforded to native prairie requires additional acreage from another landscape type, and lentic riparian is the only available landscape with sufficient acreage above its target.

For the Four Creeks township, it appears that on some quarter sections it is wealth maximizing to convert perennial forage to cropland, despite the need to increase the amount of perennial forage for the target requirements. In this sense, there may be specific qualities (i.e. soil type, suitability for cropland, obstacles) that make land more susceptible to being converted to or from perennial forage depending on the quarter section. In addition, for the Pipestone Creek township, it is interesting that at first, lotic riparian habitat is converted to native prairie landscapes to meet its target, but then, land is converted from other sources to lotic riparian habitat in order to meet its target. This suggests that there is wide variations in assessed wealth between quarter sections, and that it may be worthwhile to undergo conversion from lotic riparian on some quarters, and conversion into lotic riparian on other quarters.

In looking at the conversions on specific quarter sections for the three townships, a few trends emerge. In the Four Creeks township, all of the conversion of perennial forage to cropland occurs on quarter sections that have a lower than median assessed value for the township. In addition, aspen habitat is converted to cropland on only low assessed quarter sections. It is hypothesized that this occurs because there is the largest potential for assessed wealth gains from cropland on low assessed quarter sections. On the other hand, lentic riparian habitat is only converted to native prairie on quarter sections with higher than the median assessed value. Perhaps only on these quarter sections is the wealth coefficient high enough to warrant the cost of this type of conversion. For the Pipestone Creek township, the quarter sections where aspen habitat is converted to perennial forage are also the same quarter sections where existing perennial forage habitat is not converted. However, for quarter sections where perennial forage is converted to lentic riparian habitat, no perennial forage remains on the quarter section. This suggests land differences between quarter sections within the same township, as hypothesized above.

6.3.3 Landscape Targets Run versus Base Case Run

6.3.3.1 Assessed Wealth Results

A comparison of the assessed wealth results for the landscape target run with the base case run results is provided in Table 6-20. For all three townships, the landscape target run leads to lower assessed wealth estimates than that for the base case run. For the Antler River township, average assessed wealth per quarter section changes from $44,481 in the base case run to $37,301 in the landscape targets run, a decrease of $7,179 per quarter section, or $44.87 per acre. For the Pipestone Creek township, average assessed wealth per quarter section changes from $45,050 to $40,797, which is a decrease of $4,253 per quarter section, or $26.53 per acre. For the Four Creeks township, average assessed wealth per quarter section changes from $40,799 in the base case to $37,603, meaning a decrease of $3,196 per quarter section or $19.98 per acre. These results indicate that imposing the landscape targets will result in a loss to farm wealth in comparison to keeping the status quo (i.e. base case) with no policy intervention. These results indicate that farmers might require an incentive ranging from at $3,196 to $7,179 per quarter section to maintain the landscape targets across a township in the LSRW. This result is expected, as the landscape targets restrict the amount of conversion to more wealth-generating types of landscapes, such as cropland or lotic riparian.

Table 6-20 Assessed Wealth Results: Base Case Run versus Landscape Targets Run

Sub-Watershed	Antler River		Four Creeks		Pipestone Creek	
	Base Case	Landscape Targets	Base Case	Landscape Targets	Base Case	Landscape Targets
Total Assessed Wealth	$6,271,755	$5,259,473	$5,752,691	$5,301,989	$6,352,097	$5,752,420
Total Wealth Decrease from Base Case		$1,012,283		$450,702		$599,677
Average Assessed Wealth per Qtr.	$44,481	$37,301	$40,799	$37,603	$45,050	$40,797
Wealth Decrease from BC ($/Quarter)		$7,179.31		$3,196.47		$4,253.03
Wealth Decrease from BC ($/Acre)		**$44.87**		**$19.98**		**$26.58**

6.3.3.2 Landscape Acreage Differences

The various landscape acreage changes that occurred in each optimization run, for the landscape targets model and the base case run, are compared and contrasted. Figures 6.7, 6.8, and 6.9 provide the ending landscape acreages for each optimization run and for each township model. The largest differences in landscape type acreage occur for the native prairie, perennial forage, and cropland landscapes for all three townships. For the Antler River township, native prairie increases from 97 acres to 1,755 acres, perennial forage increases from 0 acres to 4,388 acres, and cropland decreases from 17,889 acres to 11,996 acres, a difference of 32.94%. For the Pipestone Creek township, the acreage allocated to cropland decreases, from 12,547 to 10,057 acres, while the acreage allocated to native prairie and perennial forage increases to meet the landscape targets. For the Four Creeks township, perennial forage acreage increases from 0 to 2,461 acres, native prairie increases from 98 to 1,567 acres, and cropland decreases by a difference of 13.61% (from 17,875 acres to 15,442 acres). It is clear that the landscape targets constrain the conversion of native prairie or perennial forage to cropland, which is expected given the results from the base case run.

Figure 6.7 Antler River Township: Landscape Target Runs versus Base Case

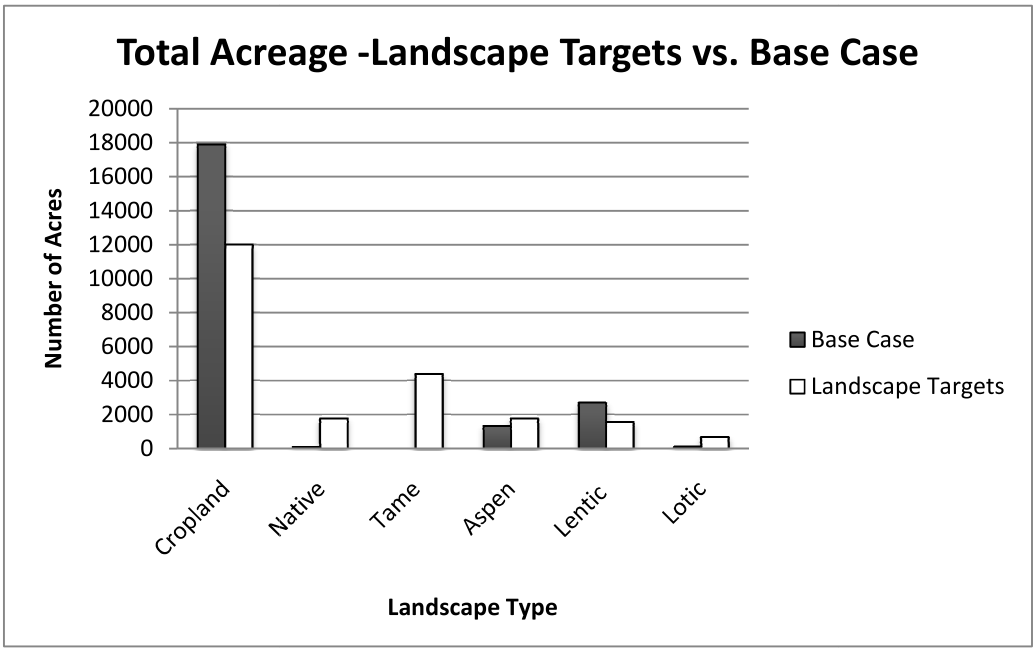


Figure 6.8 Pipestone Creek Township: Landscape Target Runs versus Base Case

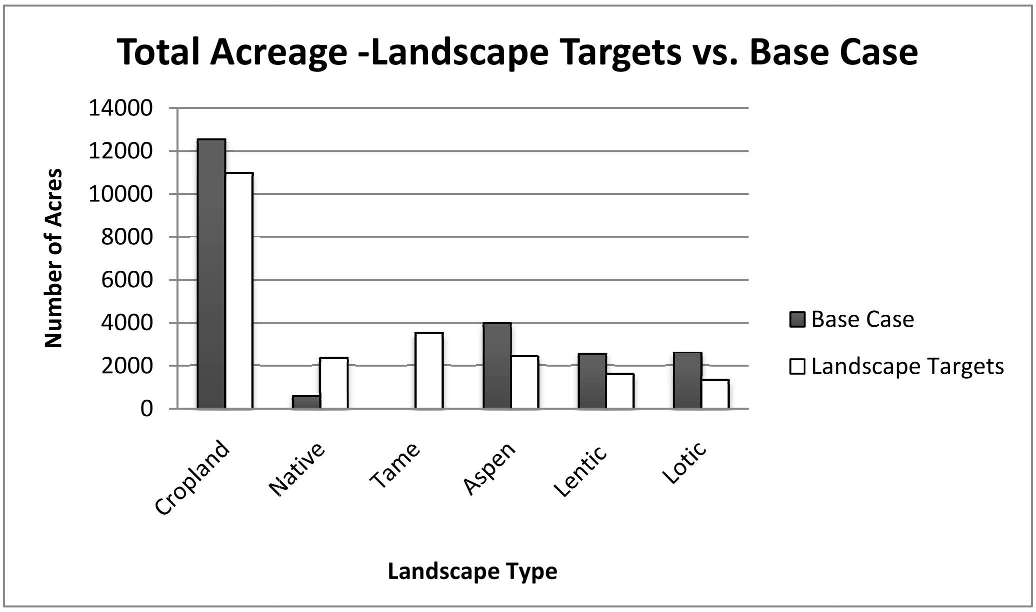
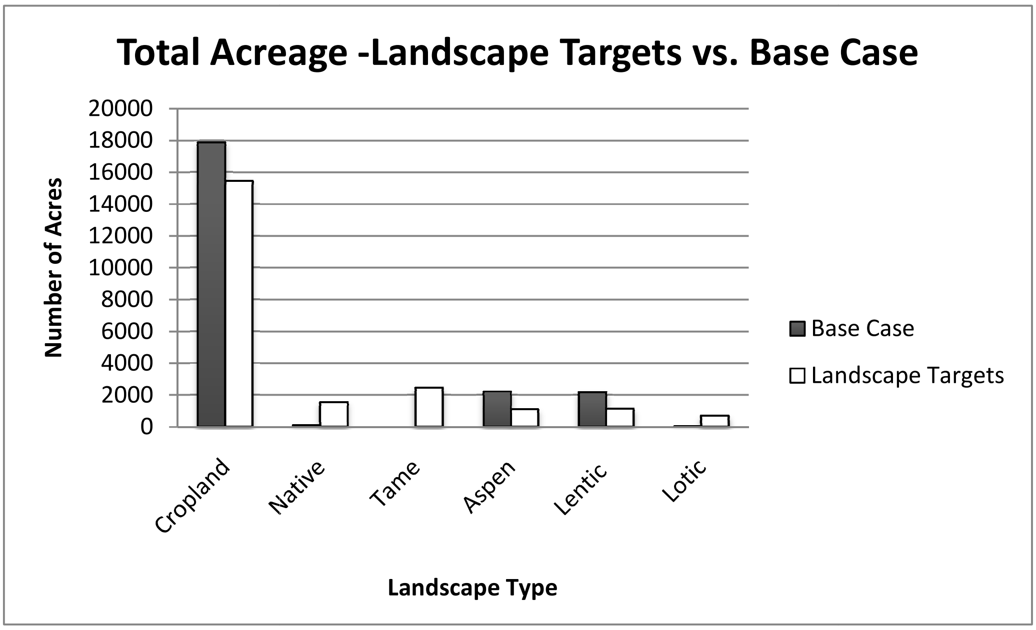


Figure 6.9: Four Creeks Township: Landscape Target Runs versus Base Case



The landscape targets force an increase in native prairie and perennial forage acreage to levels substantially greater than current levels found across each township. For all three townships, the amount of acreage afforded to native prairie and perennial forage has to increase to meet the landscape targets. Barring intrinsic and environmental reasons for setting targets higher for these landscape types, it is this requirement that forces reduced acreage in annual cropland and reduced assessed wealth measurements. However, cropland acreage is lower when imposing the targets, but not below current levels because of the landscape target afforded to cropland acreage. Furthermore, if there is land that is left over after the landscape targets have been met; this land is more advantageous being in cropland for assessed wealth reasons.

Interestingly, for all three townships, the amount of lentic riparian habitat decreases from the base case run to the landscape target run. This suggests that the target for lentic riparian habitat is set sufficiently lower than the amount of acreage found in each township, and that the wealth coefficient attributed to lentic riparian is sufficiently high in each township to limit conversion in the base case run. In addition, the landscape target shares attributed to cropland, perennial forage, and native prairie require more acreage in each of these landscape types than what is currently found in the township. As a result, the acreage provided to these landscapes must come out of conversion of a large amount of acreage of the three remaining landscape types; those of which are attributed with providing a high amount of wildlife habitat (White, 2008).

For the remaining lotic riparian and aspen landscape types, the acreage differences between the base case run and the landscape target run vary by township. Aspen habitat acreage decreases for both the Pipestone Creek and Four Creeks townships, but increases for the Antler River township in the landscape targets run. Lotic riparian habitat acreage, however, increases for the both the Antler River and Four Creeks township, but decreases for the Pipestone Creek township. It is hypothesized that acreage for both these landscape types decreases in the landscape target run when other acreage is needed to meet a target requirement of another landscape type. Further, acreage for these landscapes types increase when needing to meet their own landscape target requirement.

6.3.4 Comparisons between Sub-watershed Townships

When comparing the results from the base case runs across the three sub-watershed townships, it can be noted that for all three sub-watersheds there is an increase in assessed wealth as farmers seek to maximize the level of on-farm wealth. However, the degree to which assessed wealth increases in the base case run is much larger for the Pipestone Creek sub-watershed than for the other two sub-watersheds. Total assessed wealth increases by $224,755 for the Antler River township and $198,891 for the Four Creeks township, but increases by $705,797 for the Pipestone Creek township. Looking at Figures 6.1, 6.2, and 6.3, it first appears this may be due to the decline in perennial forage acreage occurring in the Pipestone Creek township, but looking closer, the Antler River township had approximately the same amount of acres in perennial forage and this acreage is also converted in the base case run. More likely, and despite being counterintuitive, it is the case that the wealth coefficient for lotic riparian habitat is much higher in the Pipestone Creek township. The high wealth coefficient for lotic riparian is counter-intuitive as farmer's perceive lotic riparian as waste land. This could be a limitation of the hedonic analysis used to generate the wealth coefficients. Higher assessed wealth parcels had a higher-than-average amount of lotic riparian habitat and it is for this reason that the coefficient could be higher.

The landscape type conversions that result from implementing the policy target constraint varied across the three townships. For the Antler River township, most of the conversions are from cropland to either lotic riparian, aspen, perennial forage, or native prairie landscapes, and the total amount of cropland acreage decreases by 1,170 acres. However, for the Pipestone Creek and Four Creeks townships, most of the lentic riparian (36% for Pipestone Creek, 48% for Four Creeks) and aspen habitat (39% for Pipestone Creek, 50% for Four Creeks) is converted to other sources; mainly, perennial forage, lotic riparian, and native prairie landscapes. In all three townships, land is converted to native prairie, perennial forage, and lotic riparian habitat in order to satisfy the landscape target requirements. Interestingly, the amount of acreage attributed to lentic riparian and aspen habitat decreases more than the base case run with the landscape targets, especially for the Pipestone Creek and Four Creeks townships.

Comparison of the assessed wealth differences for the base case and landscape target runs for the three sub-watersheds indicates that the landscape targets have the most negative wealth effect on the Antler River township. In the Antler River township, total assessed wealth decreases by $1,012,283 from the base case run. Conversely, for the Pipestone Creek and the Four Creeks township, total assessed wealth decrease by only $599,677 and $450,702 from the base case, respectively. One reason for this difference between townships may be the fact that only for the Antler River township does cropland acreage decrease from actual levels when the landscape targets are imposed. In this sense, the landscape targets might be much more restrictive as there is no additional allowance of land conversion to the landscape type with a high wealth-generating coefficient, being cropland. In addition, a substantial portion of the acreage converted to cropland in the base case run is converted to native prairie, perennial forage, and aspen landscapes in the landscape target run, all of which have a high cost of conversion that further reduces assessed wealth.

The large decrease in assessed wealth for the Antler River township may be a product of the landscape targets in this sub-watershed being more stringent than the other two sub-watersheds. Comparing the landscape targets given in Table 5-31 between the three sub-watersheds, it easy to see that the required amount of perennial forage, native grassland, and aspen habitat is on the high side (compared to the other watersheds), especially considering the existing amounts of landscape acreage, shown in Table 5-32. The large difference between the landscape target shares and the existing landscape type allocation for the Antler River sub-watershed is simply due to the township chosen to represent the Antler River sub-watershed perhaps not being very representative at all. If the optimization model's scale is increased to the sub-watershed level from the township level, this problem might not materialize.

6.4 Chapter Summary

Results from the RFSM model indicate that EG&S practices come with a direct private cost to farmers in the Lower Souris region. Through Scenarios 1, 3, and 4, there is an NPV increase ranging from $42 to $75 per converted acre when converting riparian or forested habitat to an agricultural use. Thus, the practice of maintaining these habitat areas would deny farmers from making additional farm wealth. However, the practice of converting riparian habitat to perennial forage does not result in a NPV increase. This is due to the stocking rates between riparian habitat and perennial forage being similar. There is a limited increase in benefit of grazing cattle on perennial forage in replace of riparian habitat and it does not justify the cost of conversion.

The practice of converting cropland to perennial forage (Scenarios 5 and 6) may result in a benefit to the farmer if the forage is used for pasture purposes. The beef herd can take advantage of the additional pasture to return revenue over and above the loss of crop revenue in the crop enterprise. Despite this, if the perennial forage is used for hay purposes, the crop revenue is not recouped and there is a wealth loss. The crop enterprise generates more revenue from annual crops than tame hay and there is limited benefit to the beef herd. These results may be a direct function of the model construction of the RFSM because the model assumes unlimited grazing season length and weaning weights.

Scenarios 7 and 8 could result in a direct benefit or cost to the farm operator depending on how much the forage stand improves from the EG&S-focused herd management practices. For both lowered stocking rates and rotational grazing, NPV estimates are a direct result of the growth in forage availability per year and the number of years the stand improves. Better understanding of the degree of stand improvement when implementing these practices will provide more accurate model results for interpretation. The high input cost scenarios are predictable in that they result in a reduction in NPV benefits in Scenario 1 and 3, and increase in NPV benefits in Scenarios 5 and 6.

With regards to the LTOM results, it is also clear that an EG&S policy will result in a negative impact on farm wealth across a large land area and multiple farms. Assessed wealth estimates decrease from $3,196 to $7,179 per quarter section on average, depending on the sub-watershed. The landscape targets are a form of regulation and this adds to the cost. Some conversions are required to be undertaken to meet all the landscape targets, despite the fact that the wildlife habitat is already maintained. Furthermore, in some extreme cases, large costs of conversion are required to convert aspen and lentic riparian habitat to grass landscapes (i.e. native prairie and perennial forage) to meet targets. A more practical policy would not require this type of conversion to occur.

The largest differences in landscape acreages between the base case and landscape targets run are with respect to cropland, perennial forage, and native prairie. In the base case run, almost all of the perennial forage and native prairie is converted to cropland landscapes because cropland is afforded a higher wealth coefficient and there is a minor cost of conversion. In the landscape targets run, none of this type of conversion occurs and more land is allocated to native prairie and perennial forage landscapes from aspen and lentic riparian landscapes. This indicates that constraining farmers to maintaining or increasing lands in perennial forage and native prairie landscapes may result in substantial cost to assessed wealth and in consequence, farm wealth.

7 Chapter 7: Conclusions

7.1 Overview

This study investigates the private benefits or costs to farmers of maintaining or enhancing wildlife habitat on agricultural lands. Other objectives included: (1) finding the cumulative farm wealth impact of a policy to promote wildlife habitat conservation on farmers at a regional basis, specifically for the LSRW; (2) predict the landscape change that might occur through implementation of a landscape target, habitat conservation policy; (3) determine the type of on-farm practices that might serve to be the least costly for Lower Souris farmers, and the most beneficial to the public; and (4) verify whether there are agricultural practices that can be implemented to improve Environmental Goods and Services (EG&S) benefits and increase farm wealth at the same time. The focus was not on whether wildlife habitat should be maintained on agricultural lands, but more so, what the direct impacts of policies and practices focused on EG&S enhancement might be on farmers. Dollar amounts of benefits or costs can be compared to results from valuation studies of wildlife habitat in a social welfare benefit-cost analysis. Further, the research inspected a landscape target policy in the study region where the targets are fixed and thus, regulatory in nature. However, this is but one form of policy that can be utilized to encourage greater EG&S benefits derived from wildlife habitat.

The research objectives are analyzed using two modelling approaches: (1) a representative farm simulation model (RFSM) and (2) a landscape target optimization model (LTOM). The RFSM uses NPV analysis and Monte Carlo simulation to determine individual farm wealth impacts of specific on-farm EG&S practices that afford increased wildlife habitat. The LTOM takes the farm wealth analysis to a regional level, through assessing the township-level impacts of widespread landscape change. Both modelling approaches are related in that they assume that farmers are wealth maximizing, and they both seek to find the wealth impacts of maintaining or increasing wildlife habitat on agricultural land. The RFSM compared simulations of an individual, mixed-enterprise farm in terms of implementing an EG&S-associated practice versus no implementation. The LTOM compares implementation of a regional regulatory policy to promote EG&S production to no policy. Results from both models, starting with the RFSM and then the LTOM, are used to form the conclusions presented throughout this chapter. Following the conclusions, the limitations of the research approach are presented, as are areas of future research.

7.2 Private Costs and Benefits of On-farm EG&S Practices

7.2.1 Maintenance of Existing Landscape Types

The private costs of maintaining land in wildlife habitat (i.e. aspen forest or riparian wetland landscapes) are considerable, except when that land is maintained as riparian habitat rather than converted to tame pasture. Results show that when riparian habitat or forested habitat are converted to cropland, or forested habitat is converted to tame pasture, there is an NPV increase in individual farm wealth ranging from \$42 to \$75 per converted acre annually. This result confirms that farmers in the LSRW have a direct incentive to convert remaining wildlife habitat into agriculture productive uses. For incentive type policies to be effective in maintaining existing habitat in the study region, an amount ranging from \$42 to \$75 per converted acre, depending on the type of landscape type conversion being targeted, would be required by farmers.

In general, these results are in line with the results found from previous studies, such as Cortus (2005), and Gelso et al. (2009). Cortus (2005) found that it is economically feasible for crop producers to continue drainage of riparian areas in Saskatchewan. Gelso et al. (2009) found that there is a perceived cost to farmers of at least 56% of rental value of maintaining wetlands on agricultural lands. Indeed, when considering the additional nuisance factors of keeping riparian habitat on cropland quarter sections, the incentive to convert riparian habitat may be greater than the annual \$75 per converted acre estimated in this study.

7.2.2 Conversion of Cropland to Forage Stand Landscapes

Historically, governments encouraged landscape conversion from natural forages found on pastureland into annual cropland. Only recently have the EG&S benefits of having land in forage production been examined (Rae and Beale, 2008). Therefore, EG&S policies are now focused on conversion of cropland back into forage landscapes. From the RFSM results, whether farmers are expected to attain a private cost or a private benefit from converting cropland back to a perennial forage stand depends on whether the forage is used for pasture or hay purposes in a mixed operation farm.

When converting a quarter section of cropland into tame pasture, NPV estimates increase by approximately \$10 per converted acre annually. Thus, converting cropland to tame pasture may be one farm management practice that can be employed to increase wildlife habitat as well as increase farm wealth benefits. As discussed in Chapter 2, there are an increasing number of voluntary programs where farmers are encouraged to increase EG&S production while at the same time increase on-farm profits through implementing specific practices, such as Beneficial Management Practices (BMPs). Findings suggest that, for those farms that include both a crop and beef enterprise, there is benefit to both society and the farmer to convert more land into tame pasture.

7.2.3 Herd Management Practices for EG&S Benefit

From the RFSM results, there is the potential for farmers to increase the EG&S benefits afforded from a healthy perennial forage stand and increase farm wealth with implementation of a specific herd management practice. However, whether or not farm wealth increases when decreasing stocking rate or implementing rotational grazing depends on the extent the forage stand can rejuvenate. NPV estimates increase when stocking rate decreases by 8% and utilizable forage increases by 1.02% per year over the first four years of the 20 year simulation. When implementing rotational grazing management, total farm NPV estimates increase only when utilizable forage increases by at least 1.5% per year over the first four years of the simulation, or 1% per year over the first five years of the simulation. If farmers can implement grazing practices that increase the health of the pasture, there is the potential for both farm wealth and EG&S benefits to be realized.

The results found are similar to those for Miller (2002) and Koeckhoven (2008), where it was found that in very limited cases, application of ecologically friendly grazing practices have the potential to increase farm wealth. However, also similar to these studies, the conditions where farm wealth actually increases are highly specific and perhaps unrealistic for most farm operators. For farm wealth to increase, highly variable conditions such as forage stand re-growth and its association with weather, must be ideal. Nevertheless, the results do show that farmers can implement EG&S by enhancing grazing practices, such as decreasing stocking rates or initiating rotational grazing management, at a small scale and a minor cost to overall farm wealth. As such, farmers may be more willing to adopt a grazing practice of this manner if provided a small financial incentive.

7.3 Economic Impact of a Regional EG&S Policy

The LTOM model is constructed to determine the impacts of having landscape targets in the watershed area. The model approach is unique in that it allows flexibility between landscape types and quarter sections, meaning the decision-points of how much of each landscape type should a farmer have on each quarter section across the township are included. The LTOM also tries to represent on-farm reality as close as possible through incorporating a cost of conversion for each type of conversion and wealth coefficients that vary among quarter sections. Variation among the quarter sections is important as there are characteristics inherent to each quarter section that is captured in the assessed wealth valuation that cannot be appropriately modelled. As a result, the methodology used to determine farm wealth impacts is indepth and incorporates the range of various farmer land-use decisions.

Linear programming has been used extensively to inspect resource constraint problems on farms, in companies, and for governments. However, its application to regional land-use problems is not common. This type of application allows one to analyze a regional problem (i.e. conserving wildlife habitat) for multiple farmers across multiple parcels of land, and for multiple types of landscapes. Using assumptions that all farmers are wealth maximizing, and assessed land wealth is a proxy for farmer wealth, generalizations of how a regional policy will impact farmers as a whole can be assessed. With regards to both the status quo land use trends for a region and the trends that emerge from land-use policy, these trends can be determined before coming to fruition. In this manner, the next two sections inspect the trends that emerge from both the status quo and policy intervention.

7.3.1 The Status Quo

Considering the results from the LTOM, it is clear that the status quo of continued land-use conversion will lead to additional cumulative farm wealth, but fewer habitat places for wildlife. Results from the base case runs for each sub-watershed township model show an assessed wealth increase ranging from \$8.82 to \$31.29 per acre, including all financial costs of conversion, depending on the location of the landscape conversion amongst the three sub-watersheds. Given farmers have ample time and access to the resources used to derive the cost of conversions (see section 5.3.5) this increase in farm wealth is enough to encourage widespread conversion across the agricultural landscape.

In the base case, the amount of landscape conversions is substantial for all three township models. Given sufficient time, farmers could convert a majority of other types of landscapes to cropland. The bulk of the new cropland acreage comes from perennial forage (i.e. tame grass), native prairie, and lotic riparian landscapes across the three townships. Surprisingly, additional cropland acreage does not come from conversion of the aspen or lentic riparian landscapes, and the acreage associated with these two landscapes barely changes in the base case runs for the three townships. This suggests that perhaps the costs of converting these landscape types are sufficiently high enough to deter conversion to cropland.

Overall, findings indicate that farmers still have a direct incentive to convert native prairie, perennial forage, and lotic riparian landscapes to cropland. Native prairie and perennial forage has been gradually converted to annual crop production across the Saskatchewan agricultural landscape (van Kooten and Schmitz, 1992). In addition, as indicated by Olewiler (2004), one of the major threats to the level of natural capital in Saskatchewan includes loss of riparian habitat to agricultural use. It appears that farmers, if assumed to be wealth-maximizing individuals, will continue this trend. These results are in contrast to the results of Entem et al. (2009), who found that the bulk of all landscape conversions in the LSRW have been from cropland into perennial forage over the past 10 years. However, Entem et al.’s (2009) results are a reflection of the fact that a number of farmers were expanding their beef herds in the last 10 years (Entem et al., 2009). Furthermore, Entem et al. (2009) states that farmers expressed reasons for converting land were poorer productive capacity and poor past crop prices, both factors that are not incorporated in the model.

The limited amount of land conversion from aspen and lentic riparian habitat sources to cropland across the three township models takes a different standpoint than the NPV results gathered from the representative farm simulation Scenarios 1 through 4. Perhaps this result can be explained through the fact that farm wealth is measured differently in each model, and the additional farm income benefits of having land in cropland are underestimated (explained further in section 7.5.2 below) in the LTOM. If this is the case, then the amount of landscape conversion to cropland from other landscapes may be even more substantial.

7.3.2 Wealth and Landscape Impact of a Targets Policy

Findings from the landscape targets run show that implementation of a policy consisting of inflexible landscape targets result in a reduction in farm wealth. Comparing the implementation of the policy (restricted optimization) to the base case run (unrestricted optimization), provides an assessed wealth decrease ranging from $20 to $45 per acre, depending on the sub-watershed. However, as indicated in Chapter 2, this assessed wealth decrease is a private cost of the policy, while there is expected to be significant public benefits in implementing the policy (White, 2008; Lower Souris Watershed Committee Inc., 2006). If the public benefit from the landscape targets is greater than the private costs to farmers, this type of policy may be warranted (Pannel, 2008).

From the results of both the base case and landscape target runs, it is clear that the assessed wealth associated with having land in cropland is dominant over other types of landscapes. To maximize wealth with no policy restrictions, all land previously dedicated to native prairie and perennial forage is converted to cropland for all three sub-watersheds. Withholding the Antler Creek sub-watershed, when implementing the landscape target policy, land is converted away from landscape types more costly to convert (such as aspen or riparian habitat) rather than cropland. Converting aspen habitat to perennial forage costs $147.12 per acre more than converting cropland to perennial forage, but the farm wealth benefits of having land in cropland is apparent for both the Pipestone Creek and the Four Creeks sub-watershed. Policies that seek to increase or maintain other types of landscapes on agricultural land to enhance overall wildlife habitat must consider the farm wealth implications of limiting the amount of land afforded to annual crops.

7.4 Policy Implications

As described in Pannell (2008), beneficiary-pay policies are more common when a policy encourages landholders to change their practices away from the status quo, while polluter-pay policies are more common when a policy is used to discourage landowners from changing their current land-use practices. Using this line for the present study, the beneficiary (meaning the public) might pay the farmer for the costs of implementation of on-farm practices. In most cases of the RFSM results, implementation of the on-farm practices results in a net loss to farm NPV, meaning a private cost. A positive-incentive policy, where the public pays for the EG&S that is equal to or above the loss of farm wealth per acre of implementing the practice, is sufficient for widespread adoption. However, in some specific cases, such as converting cropland to tame pasture, an on-farm EG&S practice results in an increase in farm wealth. In these cases an information program (referred to as ‘Extension’ by Pannell, 2008) would be sufficient for widespread adoption.

For the LTOM analysis, it is unclear what policy should be implemented to encourage wildlife habitat maintenance as the extent of public benefits from maintaining habitat in the LSRW is not known with certainty. According to Pannell (2008), if one assumes that public net benefits of maintaining habitat are positive and given the result that the private net benefits of maintaining habitat are negative, the policymaker has two options: technology development (or no action), or the use of a positive incentive policy. Justification for using either policy depends on the extent of both public net benefits and private net costs of maintaining wildlife habitat. If after completion of a valuation study for the LSRW, one finds that public net benefits outweigh private net costs, then a positive incentive policy is justified. However if one finds the vice versa, then the use of technology adaption is justified (Pannell, 2008). For this reason, before any policy conclusions are determined using the results of this study, one should determine the public benefits (i.e. passive and direct use value) of wildlife habitat.

The status quo can refer to continuing with conversion of landscape types across the watershed, while the landscape target policy requires farmers to change from their current practices. In this regard and using Pannell's (2008) reasoning, a beneficiary-pays policy might be the most politically palatable policy choice. From above, if one finds that the public benefits of maintaining habitat outweigh the private costs, a positive incentive policy that at least offsets the loss to assessed wealth could be used to encourage adoption. With respect to the farmers in the LSRW, the landscape target regulation has a long run cost to farmers of approximately \$20 to \$45 per acre in present assessed wealth value, depending on the sub-watershed. Given an arbitrarily picked cost of \$35 per acre present value within this range, a total long run cost of implementing the landscape targets regulations across all acres found in the LSRW would be equal to \$77.4 million (35 × 2,210,906 acres). However, the landscape target policy studied here is rigid, and this may add to the cost of the policy.

When comparing the cost of meeting the landscape targets across the LSRW to the cost of other international programs to meet maintain wildlife habitat on agricultural land (described in section 2.5), the cost is consistent with these programs. For the Environmental Stewardship Scheme in England, farmers receive ₤30 per hectare (approximately \$29 CAN per acre) per year for meeting point targets, and ₤60 per hectare (\$58 CAN per acre) per year for organic farmers (Rae and Beale, 2008). If one considers the cost of the landscape targets on a per farm basis, across the LSRW and using a direct incentive of \$35 per acre, the program cost would be \$49,035 on average per farm (35 × 1401 acres, from Table 3-1). For the Conservation Security Program in the United States, the maximum payment is \$35,000 per year per farm over five to 10 years (Rae and Beale, 2008). The cost of current payments in the Conservation Security Program and the Environmental Stewardship Scheme might be higher than the landscape targets, given that payments are on an annual basis. The landscape targets for the LSRW are much more affordable program considering that only a one-time incentive payment of \$35 per acre or \$49,035 per farm is required to recoup costs.

7.5 Limitations of Research Approach

7.5.1 Representative Farm Simulation Model (RFSM)

In the RFSM, a number of assumptions are employed for model construction and for scenario development. Given the limited amount of research around these assumptions, the model may need to be altered, and thus, the results may change. The representative farm has a strict crop rotation, machinery complement, number of acres, total herd size, mixed-enterprise nature, and a fixed amount of riparian and forested habitat per quarter section, which will be different on every farm in the LSRW. Furthermore, the fixed herd size is a limitation considering the conversion of an extra quarter section to tame pasture from cropland (Scenario 6). In this regard, the increase in total farm NPV when converting cropland to tame pasture is a function of the model structure. In reality, there may be many constraints that impede farm wealth when adding another quarter section to tame pasture. A farmer would have to increase his herd size to take advantage of the additional pasture as there are limitations to grazing season length and weaning weights. Additional constraints could include the marginal forage utilization on the newly converted quarter section, and grazing operational difficulties.

The degree of improvement in forage availability, when implementing rotational grazing management or decreasing stocking rates, is another limitation of the RFSM. The literature is not clear with respect to how much pasture would improve when implementing these practices. A range ecologist or biologist from the LSRW region would be required to inspect how much the pasture would improve when decreasing stocking rates by the varying amounts, or implementing rotational grazing management. Miller (2002) assumes a pasture regeneration amount of 2% per year on uplands pasture, while 6% per year for riparian habitat, after implementing rotational grazing management on a degenerated pasture, but there is no safe assumption that can be made given soil type and weather patterns. Given this limitation, the results for these two scenarios (Scenarios 7 and 8) should be considered carefully with respect to the private net benefits achieved by farmers.

7.5.2 Landscape Target Optimization Model (LTOM)

The LTOM had a number of assumptions made in model construction that must be considered when interpreting the results. These assumptions included the use of the assessed value of land as a proxy for farm wealth, the cost determined for converting landscape types, and the discount rate and conversion time period for some of the cost of conversions. As explained in section 5.3.4, using assessed wealth as a proxy for farm wealth is not exact as there are other factors that contribute to assessed wealth of land. These factors may include location to roads, urban centres, industrial developments, and lakes and streams. In addition, there are many factors that contribute to farm wealth that are not reflected in the assessed wealth of land. These factors include the prices of grains, cattle, and other food products; weather; and the cost of inputs, such as fertilizer, machinery, and chemicals (as included in the representative farm model). In this sense, the assessed wealth measurements should not be considered a true estimate of farm wealth, but rather a proxy for relative changes in wealth when undergoing landscape conversions.

One of the limitations of the optimization models that perhaps could have had a substantial effect on the results, was the imposition of sub-watershed-level landscape targets on township-level optimizations. It may be true that each township represents a good reflection of the various landscapes found in each sub-watershed, but there is nothing to confirm that the entire sub-watershed has less or more proportional landscape type acreage than that found on the township. In this sense, a better method would be to build an optimization model for the entire sub-watershed, or incorporate co-management derived landscape targets determined for the township level in each optimization model. As explained in Chapter 6, the large decrease in assessed wealth when imposing the landscape target in the Antler Creek township may be because the landscape targets for the sub-watershed did not match up well with the acreage allocation across the township. If there are large differences in the acreage allocation in the township when compared to the entire sub-watershed, additional, unnecessary landscape conversion would be required that would decrease overall assessed wealth estimates.

Lastly, there are obvious additional farm wealth benefits to having land in certain landscapes, such as cropland, rather than other landscapes, such as lotic riparian. Using assessed wealth as a proxy of farm wealth may lead to a wealth underestimation of the contribution landscapes such as cropland, perennial forage, and native prairie, and an exaggeration of the wealth attributed to agriculturally non-productive landscapes, such as aspen, lentic riparian, and lotic riparian landscapes. In reality, notwithstanding the assessed value, only those landscapes that are productive for food generation contribute directly to farm wealth. In this sense, the importance of having land in cropland versus aspen or riparian habitat, from a farm wealth perspective, may be lost on the optimization model and the results generated. This is demonstrated in the Pipestone Creek township, as lotic riparian habitat is sometimes given a higher wealth coefficient than that for cropland (which from a farm wealth perspective is counter-intuitive) and so, this is reflected in both the assessed wealth and landscape conversion results.

7.6 Future Research

This study focused on determining the farm wealth implications of EG&S practices and policies to encourage wildlife habitat maintenance on agricultural lands. A specific region in south-east Saskatchewan, the Lower Souris River Watershed, is used to construct the RFSM and the LTOM, using data and sources specific to the region. To add strength to the results in this analysis and for comparison purposes, a similar methodology may be employed in a different agricultural region. Results and scenarios would differ in that there are different farm practices employed and encouraged in different regions, and there may be different landscape types found. However, contrasting the results of this study with a similar one for another region may provide a more accurate picture of the farm wealth impact of EG&S practices, as well as the associated broad-level landscape changes that might occur due to policy.

Further research can also look into the valuation of EG&S afforded from wildlife habitat found on agricultural land, as well as the expected level of EG&S that may be derived from the various practices and policies studied here. There have been a few studies, as discussed in Chapter 2, but nothing specific to the EG&S practices, nor the research area used in this study. Together with the results of this study, a cost-benefit analysis from the public policymaker’s perspective can be undertaken to determine whether EG&S policies should be implemented on a regional or individual farm basis, or at all. Further, the cost benefit analysis may determine what level of incentive payment should be used to encourage EG&S production and practice adoption.

The analysis here provides an initial understanding of the impact of EG&S practices on individual farmers as well as the cumulative impact of EG&S regional policy to maintain wildlife habitat. Three things are certain from the results: that the status quo will result in additional conversion away from landscape types that afford wildlife habitat; that there is a substantial cost to farmers of preventing widespread habitat conversion; and that proper policy creation and implementation is required to ensure both farm wealth stability and wildlife habitat maintenance. Future studies should build on this analysis to provide further clarification as to proper EG&S program development for the individual, regional, and national level. Specific consideration can be given to determining practices that provide the most EG&S benefit at the least private cost, or the type of landscapes that are most vulnerable with regards to wildlife habitat implications. These studies can add to current dialogue searching for programs that may foster a culture of environmental stewardship, while maintaining farm and farm family sustainability.

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Appendices

Appendix A: Wealth Coefficients

Table A-1: Antler River Township Wealth Coefficients ($/acre)

Cropland	Native Grass	Tame Grass	Aspen	Lentic	Lotic	Total Predicted	Actual
$ 227.11	$ 249.97	$ 205.20	$ 175.00	$ 402.93	$ 145.17	$31,771.87	$ 26,800
$ 234.06	$ 86.80	$ 161.72	$ 280.90	$ 249.99	$ 14.01	$35,458.05	$ 32,500
$ 303.76	$ 326.62	$ 281.85	$ 251.65	$ 479.58	$ 221.82	$52,218.71	$ 47,500
$ 300.93	$ 323.79	$ 279.02	$ 248.82	$ 476.75	$ 218.99	$47,118.05	$ 33,400
$ 241.97	$ 94.71	$ 169.63	$ 288.81	$ 257.90	$ 21.92	$36,813.90	$ 44,200
$ 268.90	$ 291.76	$ 246.99	$ 216.79	$ 444.72	$ 186.96	$44,599.14	$ 45,300
$ 208.36	$ 231.22	$ 186.45	$ 156.25	$ 384.18	$ 126.42	$39,134.97	$ 35,600
$ 239.31	$ 262.17	$ 217.40	$ 187.20	$ 415.13	$ 157.37	$39,788.72	$ 42,900
$ 251.82	$ 274.68	$ 229.91	$ 199.71	$ 427.64	$ 169.88	$43,111.01	$ 46,000
$ 266.40	$ 119.14	$ 194.06	$ 313.24	$ 282.33	$ 46.35	$42,158.09	$ 42,400
$ 261.05	$ 113.79	$ 188.71	$ 307.89	$ 276.98	$ 41.00	$42,298.24	$ 43,100
$ 239.41	$ 92.15	$ 167.07	$ 286.25	$ 255.34	$ 19.36	$28,034.06	$ 24,200
$ 253.76	$ 106.50	$ 181.42	$ 300.60	$ 269.69	$ 33.71	$41,160.87	$ 47,000
$ 280.64	$ 303.50	$ 258.73	$ 228.53	$ 456.46	$ 198.70	$46,176.81	$ 47,800
$ 287.58	$ 310.44	$ 265.67	$ 235.47	$ 463.40	$ 205.64	$48,214.06	$ 46,000
$ 253.44	$ 106.18	$ 181.10	$ 300.28	$ 269.37	$ 33.39	$41,115.68	$ 46,300
$ 239.80	$ 92.54	$ 167.46	$ 286.64	$ 255.73	$ 19.75	$39,138.99	$ 39,400
$ 230.89	$ 83.63	$ 158.55	$ 277.73	$ 246.82	$ 10.84	$37,606.04	$ 33,100
$ 278.20	$ 130.94	$ 205.86	$ 325.04	$ 294.13	$ 58.15	$44,296.71	$ 38,500
$ 212.04	$ 234.90	$ 190.13	$ 159.93	$ 387.86	$ 130.10	$29,949.03	$ 25,100
$ 237.11	$ 89.85	$ 164.77	$ 283.95	$ 253.04	$ 17.06	$35,559.24	$ 25,600
$ 243.90	$ 266.76	$ 221.99	$ 191.79	$ 419.72	$ 161.96	$39,577.29	$ 33,500
$ 238.40	$ 91.14	$ 166.06	$ 285.24	$ 254.33	$ 18.35	$32,974.14	$ 33,300
$ 239.38	$ 92.12	$ 167.04	$ 286.22	$ 255.31	$ 19.33	$33,602.14	$ 42,600
$ 257.94	$ 280.80	$ 236.03	$ 205.83	$ 433.76	$ 176.00	$39,379.74	$ 47,200
$ 243.30	$ 96.04	$ 170.96	$ 290.14	$ 259.23	$ 23.25	$37,409.35	$ 45,300
$ 244.99	$ 97.73	$ 172.65	$ 291.83	$ 260.92	$ 24.94	$25,471.13	$ 23,900
$ 249.57	$ 272.43	$ 227.66	$ 197.46	$ 425.39	$ 167.63	$36,152.63	$ 22,700
$ 234.22	$ 86.96	$ 161.88	$ 281.06	$ 250.15	$ 14.17	$37,157.65	$ 30,300
$ 240.23	$ 92.97	$ 167.89	$ 287.07	$ 256.16	$ 20.18	$39,555.00	$ 33,200
$ 221.36	$ 244.22	$ 199.45	$ 169.25	$ 397.18	$ 139.42	$33,411.37	$ 38,300
$ 276.82	$ 129.56	$ 204.48	$ 323.66	$ 292.75	$ 56.77	$44,206.26	$ 45,500
$ 262.26	$ 115.00	$ 189.92	$ 309.10	$ 278.19	$ 42.21	$41,724.38	$ 47,000
$ 267.46	$ 120.20	$ 195.12	$ 314.30	$ 283.39	$ 47.41	$42,626.07	$ 44,300
$ 240.46	$ 263.32	$ 218.55	$ 188.35	$ 416.28	$ 158.52	$40,842.29	$ 42,200
$ 234.72	$ 257.58	$ 212.81	$ 182.61	$ 410.54	$ 152.78	$39,433.34	$ 46,000
$ 364.21	$ 387.07	$ 342.30	$ 312.10	$ 540.03	$ 282.27	$53,113.16	$ 41,400
$ 296.39	$ 319.25	$ 274.48	$ 244.28	$ 472.21	$ 214.45	$50,210.36	$ 42,400
$ 242.74	$ 95.48	$ 170.40	$ 289.58	$ 258.67	$ 22.69	$32,049.59	$ 27,100
$ 259.25	$ 111.99	$ 186.91	$ 306.09	$ 275.18	$ 39.20	$42,182.94	$ 35,800
$ 245.24	$ 97.98	$ 172.90	$ 292.08	$ 261.17	$ 25.19	$39,177.55	$ 41,700
$ 242.98	$ 95.72	$ 170.64	$ 289.82	$ 258.91	$ 22.93	$38,508.06	$ 38,100
$ 258.15	$ 281.01	$ 236.24	$ 206.04	$ 433.97	$ 176.21	$37,821.73	$ 16,400
$ 243.01	$ 265.87	$ 221.10	$ 190.90	$ 418.83	$ 161.07	$39,696.28	$ 32,600
$ 308.41	$ 331.27	$ 286.50	$ 256.30	$ 484.23	$ 226.47	$50,591.13	$ 35,400
$ 364.22	$ 387.08	$ 342.31	$ 312.11	$ 540.04	$ 282.28	$60,506.33	$ 40,400
$ 375.05	$ 397.91	$ 353.14	$ 322.94	$ 550.87	$ 293.11	$61,066.25	$ 41,500
$ 293.60	$ 316.46	$ 271.69	$ 241.49	$ 469.42	$ 211.66	$49,990.66	$ 39,400

$ 209.93	$ 232.79	$ 188.02	$ 157.82	$ 385.75	$ 127.99	$35,557.30	$ 44,200
$ 274.42	$ 297.28	$ 252.51	$ 222.31	$ 450.24	$ 192.48	$45,481.46	$ 45,300
$ 274.60	$ 297.46	$ 252.69	$ 222.49	$ 450.42	$ 192.66	$46,977.17	$ 40,500
$ 351.47	$ 374.33	$ 329.56	$ 299.36	$ 527.29	$ 269.53	$56,117.42	$ 40,100
$ 249.24	$ 101.98	$ 176.90	$ 296.08	$ 265.17	$ 29.19	$37,052.95	$ 30,200
$ 272.98	$ 295.84	$ 251.07	$ 220.87	$ 448.80	$ 191.04	$43,823.83	$ 44,200
$ 266.03	$ 118.77	$ 193.69	$ 312.87	$ 281.96	$ 45.98	$41,893.08	$ 38,800
$ 316.14	$ 339.00	$ 294.23	$ 264.03	$ 491.96	$ 234.20	$53,543.38	$ 36,200
$ 339.79	$ 362.65	$ 317.88	$ 287.68	$ 515.61	$ 257.85	$54,755.02	$ 33,200
$ 216.99	$ 239.85	$ 195.08	$ 164.88	$ 392.81	$ 135.05	$36,486.83	$ 43,900
$ 299.75	$ 152.49	$ 227.41	$ 346.59	$ 315.68	$ 79.70	$48,627.50	$ 41,900
$ 252.15	$ 104.89	$ 179.81	$ 298.99	$ 268.08	$ 32.10	$39,709.17	$ 39,000
$ 237.52	$ 260.38	$ 215.61	$ 185.41	$ 413.34	$ 155.58	$41,955.34	$ 46,800
$ 285.64	$ 138.38	$ 213.30	$ 332.48	$ 301.57	$ 65.59	$47,186.47	$ 40,100
$ 260.30	$ 283.16	$ 238.39	$ 208.19	$ 436.12	$ 178.36	$45,113.85	$ 45,300
$ 238.06	$ 90.80	$ 165.72	$ 284.90	$ 253.99	$ 18.01	$39,427.63	$ 45,300
$ 224.52	$ 247.38	$ 202.61	$ 172.41	$ 400.34	$ 142.58	$36,155.63	$ 38,800
$ 255.38	$ 108.12	$ 183.04	$ 302.22	$ 271.31	$ 35.33	$40,743.33	$ 29,300
$ 233.94	$ 86.68	$ 161.60	$ 280.78	$ 249.87	$ 13.89	$31,174.22	$ 24,300
$ 245.75	$ 98.49	$ 173.41	$ 292.59	$ 261.68	$ 25.70	$33,121.11	$ 24,300
$ 240.75	$ 93.49	$ 168.41	$ 287.59	$ 256.68	$ 20.70	$39,358.70	$ 51,700
$ 250.27	$ 103.01	$ 177.93	$ 297.11	$ 266.20	$ 30.22	$38,841.40	$ 45,500
$ 297.43	$ 150.17	$ 225.09	$ 344.27	$ 313.36	$ 77.38	$35,772.22	$ 21,700
$ 290.54	$ 143.28	$ 218.20	$ 337.38	$ 306.47	$ 70.49	$32,889.27	$ 20,600
$ 252.83	$ 105.57	$ 180.49	$ 299.67	$ 268.76	$ 32.78	$31,034.08	$ 48,900
$ 217.92	$ 70.66	$ 145.58	$ 264.76	$ 233.85	$ 10.00	$23,545.77	$ 39,700
$ 237.41	$ 90.15	$ 165.07	$ 284.25	$ 253.34	$ 17.36	$22,636.78	$ 27,000
$ 277.60	$ 300.46	$ 255.69	$ 225.49	$ 453.42	$ 195.66	$45,931.23	$ 17,500
$ 236.50	$ 259.36	$ 214.59	$ 184.39	$ 412.32	$ 154.56	$39,334.24	$ 23,000
$ 240.51	$ 93.25	$ 168.17	$ 287.35	$ 256.44	$ 20.46	$36,214.84	$ 46,000
$ 237.12	$ 89.86	$ 164.78	$ 283.96	$ 253.05	$ 17.07	$36,948.14	$ 38,500
$ 237.98	$ 90.72	$ 165.64	$ 284.82	$ 253.91	$ 17.93	$39,002.26	$ 41,900
$ 532.51	$ 555.37	$ 510.60	$ 480.40	$ 708.33	$ 450.57	$90,025.49	$ 38,800
$ 259.67	$ 112.41	$ 187.33	$ 306.51	$ 275.60	$ 39.62	$44,301.79	$ 39,300
$ 324.25	$ 347.11	$ 302.34	$ 272.14	$ 500.07	$ 242.31	$52,194.76	$ 40,600
$ 234.70	$ 87.44	$ 162.36	$ 281.54	$ 250.63	$ 14.65	$37,855.77	$ 44,000
$ 253.05	$ 275.91	$ 231.14	$ 200.94	$ 428.87	$ 171.11	$44,058.73	$ 44,000
$ 353.33	$ 376.19	$ 331.42	$ 301.22	$ 529.15	$ 271.39	$58,379.38	$ 43,600
$ 612.79	$ 635.65	$ 590.88	$ 560.68	$ 788.61	$ 530.85	$100,061.17	$ 43,600
$ 334.37	$ 357.23	$ 312.46	$ 282.26	$ 510.19	$ 252.43	$57,476.03	$ 33,500
$ 269.50	$ 292.36	$ 247.59	$ 217.39	$ 445.32	$ 187.56	$47,417.99	$ 35,700
$ 264.46	$ 287.32	$ 242.55	$ 212.35	$ 440.28	$ 182.52	$49,486.97	$ 34,700
$ 244.87	$ 97.61	$ 172.53	$ 291.71	$ 260.80	$ 24.82	$40,030.94	$ 34,800
$ 210.44	$ 233.30	$ 188.53	$ 158.33	$ 386.26	$ 128.50	$37,632.82	$ 43,800
$ 287.82	$ 310.68	$ 265.91	$ 235.71	$ 463.64	$ 205.88	$50,171.47	$ 43,800
$ 352.32	$ 375.18	$ 330.41	$ 300.21	$ 528.14	$ 270.38	$60,327.41	$ 46,000
$ 249.09	$ 271.95	$ 227.18	$ 196.98	$ 424.91	$ 167.15	$43,567.03	$ 47,800
$ 262.05	$ 284.91	$ 240.14	$ 209.94	$ 437.87	$ 180.11	$45,790.95	$ 47,000
$ 249.88	$ 102.62	$ 177.54	$ 296.72	$ 265.81	$ 29.83	$40,610.24	$ 45,300
$ 241.66	$ 94.40	$ 169.32	$ 288.50	$ 257.59	$ 21.61	$39,148.73	$ 37,400
$ 231.51	$ 254.37	$ 209.60	$ 179.40	$ 407.33	$ 149.57	$38,658.14	$ 33,600
$ 304.37	$ 327.23	$ 282.46	$ 252.26	$ 480.19	$ 222.43	$49,819.06	$ 43,000
$ 277.75	$ 300.61	$ 255.84	$ 225.64	$ 453.57	$ 195.81	$48,452.20	$ 31,200
$ 264.96	$ 287.82	$ 243.05	$ 212.85	$ 440.78	$ 183.02	$46,409.68	$ 36,400
$ 242.88	$ 95.62	$ 170.54	$ 289.72	$ 258.81	$ 22.83	$37,250.80	$ 37,400
$ 244.15	$ 96.89	$ 171.81	$ 290.99	$ 260.08	$ 24.10	$36,874.58	$ 38,900
$ 246.29	$ 99.03	$ 173.95	$ 293.13	$ 262.22	$ 26.24	$39,743.86	$ 46,000

$ 233.08	$ 85.82	$ 160.74	$ 279.92	$ 249.01	$ 13.03	$37,837.24	$ 46,800
$ 239.94	$ 262.80	$ 218.03	$ 187.83	$ 415.76	$ 158.00	$41,955.25	$ 48,800
$ 302.31	$ 155.05	$ 229.97	$ 349.15	$ 318.24	$ 82.26	$48,807.80	$ 44,200
$ 240.48	$ 93.22	$ 168.14	$ 287.32	$ 256.41	$ 20.43	$39,100.80	$ 46,800
$ 244.77	$ 267.63	$ 222.86	$ 192.66	$ 420.59	$ 162.83	$42,118.20	$ 50,400
$ 236.24	$ 88.98	$ 163.90	$ 283.08	$ 252.17	$ 16.19	$37,583.17	$ 53,000
$ 214.47	$ 237.33	$ 192.56	$ 162.36	$ 390.29	$ 132.53	$38,205.61	$ 44,500
$ 224.90	$ 247.76	$ 202.99	$ 172.79	$ 400.72	$ 142.96	$38,295.42	$ 45,000
$ 294.99	$ 147.73	$ 222.65	$ 341.83	$ 310.92	$ 74.94	$25,115.41	$ 21,000
$ 294.96	$ 147.70	$ 222.62	$ 341.80	$ 310.89	$ 74.91	$21,759.72	$ 21,300
$ 295.36	$ 148.10	$ 223.02	$ 342.20	$ 311.29	$ 75.31	$45,651.06	$ 46,000
$ 251.40	$ 104.14	$ 179.06	$ 298.24	$ 267.33	$ 31.35	$33,511.70	$ 45,200
$ 253.24	$ 105.98	$ 180.90	$ 300.08	$ 269.17	$ 33.19	$16,598.25	$ 21,600
$ 312.99	$ 335.85	$ 291.08	$ 260.88	$ 488.81	$ 231.05	$46,583.32	$ 31,200
$ 353.71	$ 376.57	$ 331.80	$ 301.60	$ 529.53	$ 271.77	$56,025.02	$ 32,400
$ 224.20	$ 247.06	$ 202.29	$ 172.09	$ 400.02	$ 142.26	$35,886.31	$ 40,300
$ 305.94	$ 328.80	$ 284.03	$ 253.83	$ 481.76	$ 224.00	$50,946.10	$ 47,800
$ 313.67	$ 336.53	$ 291.76	$ 261.56	$ 489.49	$ 231.73	$52,274.98	$ 48,800
$ 353.80	$ 376.66	$ 331.89	$ 301.69	$ 529.62	$ 271.86	$59,950.67	$ 39,300
$ 405.85	$ 428.71	$ 383.94	$ 353.74	$ 581.67	$ 323.91	$59,527.12	$ 46,200
$ 318.02	$ 340.88	$ 296.11	$ 265.91	$ 493.84	$ 236.08	$54,269.80	$ 47,000
$ 356.53	$ 379.39	$ 334.62	$ 304.42	$ 532.35	$ 274.59	$60,197.18	$ 38,800
$ 255.87	$ 278.73	$ 233.96	$ 203.76	$ 431.69	$ 173.93	$43,368.80	$ 47,000
$ 281.60	$ 304.46	$ 259.69	$ 229.49	$ 457.42	$ 199.66	$47,460.78	$ 50,400
$ 335.11	$ 357.97	$ 313.20	$ 283.00	$ 510.93	$ 253.17	$56,289.38	$ 46,400
$ 365.82	$ 388.68	$ 343.91	$ 313.71	$ 541.64	$ 283.88	$58,308.76	$ 39,500
$ 244.43	$ 97.17	$ 172.09	$ 291.27	$ 260.36	$ 24.38	$39,648.76	$ 44,600
$ 364.36	$ 387.22	$ 342.45	$ 312.25	$ 540.18	$ 282.42	$61,160.28	$ 30,400
$ 270.15	$ 293.01	$ 248.24	$ 218.04	$ 445.97	$ 188.21	$45,171.85	$ 31,800
$ 244.14	$ 267.00	$ 222.23	$ 192.03	$ 419.96	$ 162.20	$40,384.16	$ 40,900
$ 327.50	$ 350.36	$ 305.59	$ 275.39	$ 503.32	$ 245.56	$55,229.35	$ 47,500
$ 277.24	$ 300.10	$ 255.33	$ 225.13	$ 453.06	$ 195.30	$46,402.07	$ 37,100
$ 273.50	$ 296.36	$ 251.59	$ 221.39	$ 449.32	$ 191.56	$46,823.86	$ 50,400
$ 322.91	$ 345.77	$ 301.00	$ 270.80	$ 498.73	$ 240.97	$55,273.15	$ 51,900
$ 239.53	$ 92.27	$ 167.19	$ 286.37	$ 255.46	$ 19.48	$39,633.30	$ 53,500
$ 316.88	$ 339.74	$ 294.97	$ 264.77	$ 492.70	$ 234.94	$52,935.84	$ 51,900

Table A-2: Pipestone Creek Township Wealth Coefficients ($/acre)

Cropland	Native Grass	Tame Grass	Aspen	Lentic	Lotic	Total Predicted	Actual
$ 283.15	$ 344.18	$ 282.35	$ 208.16	$ 264.30	$ 391.71	$46,556.58	$ 26,800
$ 261.72	$ 322.75	$ 260.92	$ 186.73	$ 242.87	$ 370.28	$42,907.48	$ 32,500
$ 331.81	$ 392.85	$ 331.01	$ 256.83	$ 312.97	$ 440.37	$53,931.60	$ 47,500
$ 330.01	$ 391.05	$ 329.21	$ 255.03	$ 311.17	$ 438.57	$55,198.65	$ 33,400
$ 309.33	$ 191.20	$ 297.77	$ 197.74	$ 283.43	$ 286.28	$46,042.27	$ 44,200
$ 309.68	$ 370.71	$ 308.87	$ 234.69	$ 290.83	$ 418.24	$47,868.07	$ 45,300
$ 271.25	$ 332.28	$ 270.44	$ 196.26	$ 252.40	$ 379.80	$42,926.91	$ 35,600
$ 290.89	$ 351.92	$ 290.09	$ 215.91	$ 272.05	$ 399.45	$44,941.80	$ 42,900
$ 298.84	$ 359.87	$ 298.03	$ 223.85	$ 279.99	$ 407.39	$45,962.78	$ 46,000
$ 213.07	$ 94.94	$ 201.51	$ 101.48	$ 187.18	$ 190.03	$30,798.88	$ 42,400
$ 234.15	$ 116.02	$ 222.59	$ 122.56	$ 208.25	$ 211.10	$34,216.28	$ 43,100
$ 319.38	$ 201.25	$ 307.82	$ 207.79	$ 293.49	$ 296.34	$36,666.04	$ 24,200
$ 262.87	$ 144.74	$ 251.31	$ 151.28	$ 236.97	$ 239.82	$40,113.10	$ 47,000
$ 317.13	$ 378.16	$ 316.32	$ 242.14	$ 298.28	$ 425.69	$48,191.43	$ 47,800
$ 321.54	$ 382.57	$ 320.73	$ 246.55	$ 302.69	$ 430.09	$49,124.46	$ 46,000
$ 264.12	$ 145.99	$ 252.56	$ 152.53	$ 238.23	$ 241.08	$39,713.89	$ 46,300
$ 317.87	$ 199.74	$ 306.31	$ 206.28	$ 291.98	$ 294.83	$45,449.32	$ 39,400
$ 272.56	$ 333.59	$ 271.75	$ 197.57	$ 253.71	$ 381.11	$40,483.38	$ 33,100
$ 166.59	$ 48.46	$ 155.03	$ 55.00	$ 140.70	$ 143.55	$19,980.71	$ 38,500
$ 273.58	$ 334.61	$ 272.77	$ 198.59	$ 254.73	$ 382.13	$37,157.02	$ 25,100
$ 328.44	$ 210.31	$ 316.88	$ 216.85	$ 302.55	$ 305.40	$51,351.45	$ 25,600
$ 293.81	$ 354.84	$ 293.00	$ 218.82	$ 274.96	$ 402.36	$46,513.56	$ 33,500
$ 323.36	$ 205.23	$ 311.80	$ 211.77	$ 297.46	$ 300.31	$48,912.45	$ 33,300
$ 319.51	$ 201.38	$ 307.95	$ 207.92	$ 293.62	$ 296.47	$48,463.04	$ 42,600
$ 302.72	$ 363.76	$ 301.92	$ 227.74	$ 283.88	$ 411.28	$48,597.35	$ 47,200
$ 304.06	$ 185.93	$ 292.50	$ 192.47	$ 278.16	$ 281.01	$46,449.27	$ 45,300
$ 297.43	$ 179.30	$ 285.87	$ 185.84	$ 271.54	$ 274.38	$42,773.28	$ 23,900
$ 297.41	$ 358.44	$ 296.60	$ 222.42	$ 278.56	$ 405.96	$53,041.11	$ 22,700
$ 261.18	$ 322.21	$ 260.37	$ 186.19	$ 242.33	$ 369.74	$34,774.53	$ 30,300
$ 316.17	$ 198.04	$ 304.61	$ 204.58	$ 290.28	$ 293.13	$32,332.96	$ 33,200
$ 279.50	$ 340.53	$ 278.69	$ 204.51	$ 260.65	$ 388.05	$40,252.00	$ 38,300
$ 172.00	$ 53.87	$ 160.44	$ 60.41	$ 146.10	$ 148.95	$22,005.62	$ 45,500
$ 229.38	$ 111.25	$ 217.82	$ 117.79	$ 203.48	$ 206.33	$33,981.32	$ 47,000
$ 208.91	$ 90.78	$ 197.35	$ 97.32	$ 183.01	$ 185.86	$31,608.15	$ 44,300
$ 291.62	$ 352.65	$ 290.81	$ 216.63	$ 272.77	$ 400.18	$45,617.82	$ 42,200
$ 287.98	$ 349.01	$ 287.17	$ 212.99	$ 269.13	$ 396.53	$44,640.34	$ 46,000
$ 370.19	$ 431.22	$ 369.38	$ 295.20	$ 351.34	$ 478.75	$51,271.75	$ 41,400
$ 327.13	$ 388.16	$ 326.33	$ 252.14	$ 308.28	$ 435.69	$51,215.65	$ 42,400
$ 306.27	$ 188.14	$ 294.71	$ 194.68	$ 280.37	$ 283.22	$45,335.54	$ 27,100
$ 241.24	$ 123.11	$ 229.68	$ 129.65	$ 215.34	$ 218.19	$36,464.68	$ 35,800
$ 296.44	$ 178.31	$ 284.88	$ 184.85	$ 270.55	$ 273.40	$44,987.04	$ 41,700
$ 305.33	$ 187.20	$ 293.77	$ 193.74	$ 279.43	$ 282.28	$46,764.07	$ 38,100
$ 302.86	$ 363.89	$ 302.05	$ 227.87	$ 284.01	$ 411.41	$45,106.60	$ 16,400
$ 293.25	$ 354.28	$ 292.44	$ 218.26	$ 274.40	$ 401.80	$48,376.79	$ 32,600
$ 334.76	$ 395.79	$ 333.96	$ 259.77	$ 315.91	$ 443.32	$53,146.98	$ 35,400
$ 370.20	$ 431.23	$ 369.39	$ 295.21	$ 351.35	$ 478.75	$57,329.23	$ 40,400
$ 377.07	$ 438.10	$ 376.27	$ 302.09	$ 358.23	$ 485.63	$58,278.59	$ 41,500
$ 325.36	$ 386.39	$ 324.55	$ 250.37	$ 306.51	$ 433.92	$50,796.92	$ 39,400
$ 272.24	$ 333.27	$ 271.43	$ 197.25	$ 253.39	$ 380.79	$41,910.88	$ 44,200
$ 313.18	$ 374.22	$ 312.38	$ 238.20	$ 294.34	$ 421.74	$47,888.54	$ 45,300
$ 313.30	$ 374.33	$ 312.49	$ 238.31	$ 294.45	$ 421.86	$48,928.90	$ 40,500
$ 362.10	$ 423.13	$ 361.29	$ 287.11	$ 343.25	$ 470.66	$57,018.52	$ 40,100

$ 280.67	$ 162.54	$ 269.11	$ 169.08	$ 254.77	$ 257.62	$42,762.74	$ 30,200
$ 312.27	$ 373.30	$ 311.46	$ 237.28	$ 293.42	$ 420.83	$48,177.74	$ 44,200
$ 214.52	$ 96.39	$ 202.96	$ 102.93	$ 188.63	$ 191.47	$32,183.63	$ 38,800
$ 339.67	$ 400.70	$ 338.86	$ 264.68	$ 320.82	$ 448.23	$53,240.17	$ 36,200
$ 354.68	$ 415.72	$ 353.88	$ 279.70	$ 335.84	$ 463.24	$54,535.94	$ 33,200
$ 276.72	$ 337.75	$ 275.92	$ 201.74	$ 257.88	$ 385.28	$43,440.42	$ 43,900
$ 81.66	$ 10.00	$ 70.10	$ 10.00	$ 55.77	$ 58.62	$11,168.88	$ 41,900
$ 269.20	$ 151.07	$ 257.64	$ 157.61	$ 243.30	$ 246.15	$41,110.32	$ 39,000
$ 289.76	$ 350.79	$ 288.95	$ 214.77	$ 270.91	$ 398.31	$45,597.28	$ 46,800
$ 137.25	$ 19.12	$ 125.69	$ 25.66	$ 111.35	$ 114.20	$18,556.44	$ 40,100
$ 304.22	$ 365.25	$ 303.41	$ 229.23	$ 285.37	$ 412.77	$47,633.69	$ 45,300
$ 324.71	$ 206.58	$ 313.15	$ 213.12	$ 298.82	$ 301.66	$49,798.37	$ 45,300
$ 281.50	$ 342.54	$ 280.70	$ 206.52	$ 262.66	$ 390.06	$44,178.22	$ 38,800
$ 256.50	$ 138.37	$ 244.94	$ 144.91	$ 230.60	$ 233.45	$39,069.68	$ 29,300
$ 262.14	$ 323.17	$ 261.33	$ 187.15	$ 243.29	$ 370.70	$39,084.11	$ 24,300
$ 294.43	$ 176.30	$ 282.87	$ 182.84	$ 268.53	$ 271.38	$40,421.15	$ 24,300
$ 314.13	$ 195.99	$ 302.56	$ 202.53	$ 288.23	$ 291.08	$49,511.21	$ 51,700
$ 276.59	$ 158.46	$ 265.03	$ 165.00	$ 250.70	$ 253.55	$40,743.00	$ 45,500
$ 90.82	$ 10.00	$ 79.26	$ 10.00	$ 64.92	$ 67.77	$ 9,901.86	$ 21,700
$ 117.96	$ 10.00	$ 106.39	$ 10.00	$ 92.06	$ 94.91	$13,260.92	$ 20,600
$ 266.52	$ 148.39	$ 254.96	$ 154.93	$ 240.63	$ 243.48	$38,321.99	$ 48,900
$ 316.94	$ 377.98	$ 316.14	$ 241.96	$ 298.10	$ 425.50	$46,009.35	$ 39,700
$ 327.27	$ 209.14	$ 315.71	$ 215.68	$ 301.37	$ 304.22	$44,164.18	$ 27,000
$ 315.21	$ 376.24	$ 314.40	$ 240.22	$ 296.36	$ 423.76	$57,350.73	$ 17,500
$ 289.11	$ 350.14	$ 288.30	$ 214.12	$ 270.26	$ 397.66	$44,316.26	$ 23,000
$ 315.08	$ 196.95	$ 303.52	$ 203.49	$ 289.19	$ 292.03	$47,418.43	$ 46,000
$ 328.41	$ 210.28	$ 316.85	$ 216.82	$ 302.51	$ 305.36	$47,990.61	$ 38,500
$ 325.03	$ 206.90	$ 313.47	$ 213.44	$ 299.14	$ 301.99	$50,728.21	$ 41,900
$ 477.04	$ 538.07	$ 476.23	$ 402.05	$ 458.19	$ 585.59	$75,039.48	$ 38,800
$ 239.60	$ 121.47	$ 228.04	$ 128.01	$ 213.70	$ 216.55	$32,904.12	$ 39,300
$ 344.82	$ 405.85	$ 344.01	$ 269.83	$ 325.97	$ 453.38	$51,719.59	$ 40,600
$ 259.52	$ 320.56	$ 258.72	$ 184.54	$ 240.68	$ 368.08	$40,807.30	$ 44,000
$ 299.62	$ 360.65	$ 298.81	$ 224.63	$ 280.77	$ 408.17	$47,127.12	$ 44,000
$ 363.28	$ 424.31	$ 362.47	$ 288.29	$ 344.43	$ 471.84	$55,604.11	$ 43,600
$ 528.01	$ 589.04	$ 527.20	$ 453.02	$ 509.16	$ 636.56	$82,536.03	$ 43,600
$ 351.25	$ 412.28	$ 350.44	$ 276.26	$ 332.40	$ 459.80	$54,819.33	$ 33,500
$ 310.06	$ 371.09	$ 309.25	$ 235.07	$ 291.21	$ 418.62	$48,892.51	$ 35,700
$ 306.86	$ 367.89	$ 306.06	$ 231.87	$ 288.01	$ 415.42	$48,053.67	$ 34,700
$ 297.90	$ 179.77	$ 286.34	$ 186.31	$ 272.00	$ 274.85	$46,270.69	$ 34,800
$ 272.57	$ 333.60	$ 271.76	$ 197.58	$ 253.72	$ 381.12	$43,468.41	$ 43,800
$ 321.69	$ 382.73	$ 320.89	$ 246.71	$ 302.85	$ 430.25	$51,303.68	$ 43,800
$ 362.64	$ 423.67	$ 361.83	$ 287.65	$ 343.79	$ 471.20	$57,724.99	$ 46,000
$ 297.10	$ 358.14	$ 296.30	$ 222.12	$ 278.26	$ 405.66	$47,246.21	$ 47,800
$ 305.33	$ 366.36	$ 304.53	$ 230.34	$ 286.48	$ 413.89	$48,649.68	$ 47,000
$ 278.16	$ 160.03	$ 266.60	$ 166.57	$ 252.27	$ 255.11	$43,890.89	$ 45,300
$ 310.54	$ 192.41	$ 298.98	$ 198.95	$ 284.64	$ 287.49	$47,992.84	$ 37,400
$ 285.94	$ 346.97	$ 285.14	$ 210.96	$ 267.10	$ 394.50	$43,323.80	$ 33,600
$ 332.20	$ 393.23	$ 331.39	$ 257.21	$ 313.35	$ 440.75	$49,888.31	$ 43,000
$ 315.30	$ 376.33	$ 314.49	$ 240.31	$ 296.45	$ 423.86	$48,854.94	$ 31,200
$ 307.18	$ 368.21	$ 306.37	$ 232.19	$ 288.33	$ 415.73	$48,104.72	$ 36,400
$ 305.72	$ 187.59	$ 294.16	$ 194.13	$ 279.83	$ 282.68	$46,148.29	$ 37,400
$ 300.74	$ 182.61	$ 289.18	$ 189.15	$ 274.84	$ 277.69	$43,582.84	$ 38,900
$ 292.28	$ 174.15	$ 280.72	$ 180.69	$ 266.38	$ 269.23	$44,964.60	$ 46,000
$ 265.07	$ 326.10	$ 264.27	$ 190.08	$ 246.22	$ 373.63	$42,079.26	$ 46,800
$ 291.29	$ 352.32	$ 290.49	$ 216.31	$ 272.45	$ 399.85	$46,151.29	$ 48,800
$ 71.59	$ 10.00	$ 60.03	$ 10.00	$ 45.70	$ 48.55	$10,787.04	$ 44,200
$ 315.20	$ 197.07	$ 303.64	$ 203.61	$ 289.30	$ 292.15	$50,067.68	$ 46,800

$ 294.36	$ 355.39	$ 293.55	$ 219.37	$ 275.51	$ 402.91	$46,140.09	$ 50,400
$ 331.87	$ 213.74	$ 320.31	$ 220.28	$ 305.97	$ 308.82	$51,685.17	$ 53,000
$ 275.12	$ 336.16	$ 274.32	$ 200.14	$ 256.28	$ 383.68	$43,305.05	$ 44,500
$ 281.74	$ 342.77	$ 280.94	$ 206.76	$ 262.90	$ 390.30	$44,617.58	$ 45,000
$ 100.42	$ 10.00	$ 88.86	$ 10.00	$ 74.53	$ 77.38	$ 573.94	$ 21,000
$ 100.53	$ 10.00	$ 88.97	$ 10.00	$ 74.64	$ 77.48	$ 6,365.07	$ 21,300
$ 98.97	$ 10.00	$ 87.41	$ 10.00	$ 73.07	$ 75.92	$13,761.01	$ 46,000
$ 272.17	$ 154.04	$ 260.61	$ 160.58	$ 246.27	$ 249.12	$37,263.62	$ 45,200
$ 264.90	$ 146.76	$ 253.33	$ 153.30	$ 239.00	$ 241.85	$32,093.32	$ 21,600
$ 337.67	$ 398.70	$ 336.86	$ 262.68	$ 318.82	$ 446.23	$60,256.35	$ 31,200
$ 363.53	$ 424.56	$ 362.72	$ 288.54	$ 344.68	$ 472.08	$57,812.96	$ 32,400
$ 281.30	$ 342.33	$ 280.49	$ 206.31	$ 262.45	$ 389.86	$44,625.97	$ 40,300
$ 333.19	$ 394.22	$ 332.39	$ 258.20	$ 314.34	$ 441.75	$52,670.05	$ 47,800
$ 338.10	$ 399.14	$ 337.30	$ 263.12	$ 319.26	$ 446.66	$53,570.12	$ 48,800
$ 363.58	$ 424.61	$ 362.78	$ 288.59	$ 344.73	$ 472.14	$57,833.08	$ 39,300
$ 396.63	$ 457.66	$ 395.82	$ 321.64	$ 377.78	$ 505.18	$56,584.18	$ 46,200
$ 340.87	$ 401.90	$ 340.06	$ 265.88	$ 322.02	$ 449.42	$54,113.55	$ 47,000
$ 365.31	$ 426.35	$ 364.51	$ 290.33	$ 346.47	$ 473.87	$58,039.22	$ 38,800
$ 301.41	$ 362.44	$ 300.60	$ 226.42	$ 282.56	$ 409.97	$46,978.51	$ 47,000
$ 317.74	$ 378.78	$ 316.94	$ 242.76	$ 298.90	$ 426.30	$50,012.24	$ 50,400
$ 351.71	$ 412.74	$ 350.91	$ 276.72	$ 332.86	$ 460.27	$56,243.37	$ 46,400
$ 371.21	$ 432.24	$ 370.41	$ 296.22	$ 352.36	$ 479.77	$55,719.91	$ 39,500
$ 299.62	$ 181.49	$ 288.06	$ 188.03	$ 273.72	$ 276.57	$46,500.64	$ 44,600
$ 370.28	$ 431.32	$ 369.48	$ 295.30	$ 351.44	$ 478.84	$59,018.10	$ 30,400
$ 310.47	$ 371.51	$ 309.67	$ 235.49	$ 291.63	$ 419.03	$47,106.43	$ 31,800
$ 293.96	$ 354.99	$ 293.15	$ 218.97	$ 275.11	$ 402.52	$44,786.29	$ 40,900
$ 346.88	$ 407.92	$ 346.08	$ 271.90	$ 328.04	$ 455.44	$53,590.81	$ 47,500
$ 314.97	$ 376.01	$ 314.17	$ 239.99	$ 296.13	$ 423.53	$47,551.22	$ 37,100
$ 312.60	$ 373.63	$ 311.79	$ 237.61	$ 293.75	$ 421.15	$49,763.23	$ 50,400
$ 343.97	$ 405.00	$ 343.16	$ 268.98	$ 325.12	$ 452.52	$54,814.15	$ 51,900
$ 318.91	$ 200.78	$ 307.35	$ 207.32	$ 293.01	$ 295.86	$51,217.95	$ 53,500
$ 340.14	$ 401.17	$ 339.34	$ 265.16	$ 321.30	$ 448.70	$52,571.56	$ 51,900

Table A-3: Four Creeks Township Wealth Coefficients ($/acre)

Cropland	Native Grass	Tame Grass	Aspen	Lentic	Lotic	Total Predicted	Actual
$ 189.27	$ 74.89	$ 123.79	$ 161.69	$ 178.44	$ 63.40	$ 19,148.22	$ 26,800
$ 226.83	$ 112.45	$ 161.35	$ 199.25	$ 216.00	$ 100.96	$ 34,536.14	$ 32,500
$ 306.83	$ 333.70	$ 307.83	$ 171.31	$ 235.20	$ 85.78	$ 46,926.20	$ 47,500
$ 230.58	$ 116.20	$ 165.10	$ 203.00	$ 219.75	$ 104.71	$ 33,616.22	$ 33,400
$ 307.57	$ 334.44	$ 308.57	$ 172.04	$ 235.93	$ 86.51	$ 44,876.15	$ 44,200
$ 303.16	$ 330.03	$ 304.16	$ 167.64	$ 231.52	$ 82.11	$ 45,128.05	$ 45,300
$ 249.73	$ 135.35	$ 184.25	$ 222.15	$ 238.90	$ 123.86	$ 39,206.51	$ 35,600
$ 293.35	$ 320.22	$ 294.35	$ 157.82	$ 221.71	$ 72.29	$ 43,460.80	$ 42,900
$ 308.29	$ 335.16	$ 309.29	$ 172.76	$ 236.65	$ 87.24	$ 45,844.48	$ 46,000
$ 296.90	$ 323.77	$ 297.90	$ 161.38	$ 225.27	$ 75.85	$ 42,749.39	$ 42,400
$ 295.10	$ 321.97	$ 296.10	$ 159.57	$ 223.46	$ 74.05	$ 43,123.99	$ 43,100
$ 171.35	$ 56.98	$ 105.87	$ 143.77	$ 160.53	$ 45.49	$ 16,774.66	$ 24,200
$ 309.61	$ 336.48	$ 310.61	$ 174.09	$ 237.98	$ 88.56	$ 46,268.64	$ 47,000
$ 315.72	$ 342.59	$ 316.72	$ 180.20	$ 244.08	$ 94.67	$ 46,226.14	$ 47,800
$ 307.26	$ 334.13	$ 308.26	$ 171.73	$ 235.62	$ 86.21	$ 44,416.41	$ 46,000
$ 307.69	$ 334.56	$ 308.69	$ 172.16	$ 236.05	$ 86.64	$ 45,490.08	$ 46,300
$ 279.60	$ 165.22	$ 214.11	$ 252.02	$ 268.77	$ 153.73	$ 42,673.04	$ 39,400
$ 238.34	$ 123.96	$ 172.85	$ 210.76	$ 227.51	$ 112.47	$ 36,198.30	$ 33,100
$ 285.37	$ 170.99	$ 219.89	$ 257.79	$ 274.54	$ 159.50	$ 41,982.22	$ 38,500
$ 176.42	$ 62.04	$ 110.93	$ 148.84	$ 165.59	$ 50.55	$ 24,301.64	$ 25,100
$ 181.22	$ 66.84	$ 115.73	$ 153.64	$ 170.39	$ 55.35	$ 26,539.71	$ 25,600
$ 238.83	$ 124.45	$ 173.34	$ 211.25	$ 228.00	$ 112.96	$ 37,648.20	$ 33,500
$ 245.54	$ 131.17	$ 180.06	$ 217.96	$ 234.72	$ 119.68	$ 34,976.40	$ 33,300
$ 293.14	$ 320.01	$ 294.14	$ 157.62	$ 221.50	$ 72.09	$ 41,793.42	$ 42,600
$ 314.57	$ 341.44	$ 315.57	$ 179.05	$ 242.94	$ 93.52	$ 48,066.38	$ 47,200
$ 300.43	$ 327.30	$ 301.43	$ 164.91	$ 228.80	$ 79.38	$ 45,629.76	$ 45,300
$ 167.79	$ 53.42	$ 102.31	$ 140.21	$ 156.97	$ 41.93	$ 15,154.12	$ 23,900
$ 158.97	$ 44.59	$ 93.49	$ 131.39	$ 148.14	$ 33.10	$ 11,453.04	$ 22,700
$ 216.04	$ 101.67	$ 150.56	$ 188.46	$ 205.21	$ 90.18	$ 26,592.24	$ 30,300
$ 240.17	$ 125.79	$ 174.68	$ 212.59	$ 229.34	$ 114.30	$ 30,993.42	$ 33,200
$ 275.14	$ 160.76	$ 209.66	$ 247.56	$ 264.31	$ 149.27	$ 39,187.57	$ 38,300
$ 307.25	$ 334.12	$ 308.25	$ 171.72	$ 235.61	$ 86.20	$ 42,425.33	$ 45,500
$ 312.40	$ 339.27	$ 313.40	$ 176.88	$ 240.77	$ 91.35	$ 45,921.23	$ 47,000
$ 301.56	$ 328.43	$ 302.56	$ 166.04	$ 229.93	$ 80.51	$ 45,158.78	$ 44,300
$ 291.07	$ 317.94	$ 292.07	$ 155.55	$ 219.44	$ 70.02	$ 44,067.33	$ 42,200
$ 307.16	$ 334.03	$ 308.16	$ 171.63	$ 235.52	$ 86.10	$ 46,419.75	$ 46,000
$ 308.50	$ 335.37	$ 309.50	$ 172.97	$ 236.86	$ 87.45	$ 39,617.00	$ 41,400
$ 292.80	$ 319.67	$ 293.80	$ 157.27	$ 221.16	$ 71.75	$ 44,443.21	$ 42,400
$ 190.32	$ 75.94	$ 124.84	$ 162.74	$ 179.49	$ 64.45	$ 22,389.06	$ 27,100
$ 253.03	$ 138.65	$ 187.55	$ 225.45	$ 242.20	$ 127.16	$ 39,766.58	$ 35,800
$ 288.09	$ 314.96	$ 289.09	$ 152.56	$ 216.45	$ 67.04	$ 42,600.19	$ 41,700
$ 268.00	$ 153.62	$ 202.52	$ 240.42	$ 257.17	$ 142.13	$ 41,441.40	$ 38,100
$ 123.82	$ 10.00	$ 58.34	$ 96.24	$ 112.99	$ 10.00	$ 14,472.02	$ 16,400
$ 226.99	$ 112.62	$ 161.51	$ 199.41	$ 216.17	$ 101.13	$ 34,144.66	$ 32,600
$ 247.37	$ 132.99	$ 181.89	$ 219.79	$ 236.54	$ 121.50	$ 38,911.41	$ 35,400
$ 284.59	$ 170.22	$ 219.11	$ 257.01	$ 273.77	$ 158.73	$ 44,622.73	$ 40,400
$ 286.85	$ 313.72	$ 287.85	$ 151.33	$ 215.22	$ 65.80	$ 41,113.72	$ 41,500
$ 274.77	$ 160.39	$ 209.28	$ 247.19	$ 263.94	$ 148.90	$ 43,837.85	$ 39,400
$ 297.12	$ 323.99	$ 298.12	$ 161.59	$ 225.48	$ 76.07	$ 43,729.56	$ 44,200
$ 301.19	$ 328.06	$ 302.19	$ 165.67	$ 229.56	$ 80.14	$ 43,289.14	$ 45,300
$ 285.47	$ 171.09	$ 219.99	$ 257.89	$ 274.64	$ 159.60	$ 45,314.05	$ 40,500
$ 282.50	$ 168.12	$ 217.02	$ 254.92	$ 271.67	$ 156.63	$ 37,176.94	$ 40,100

$ 214.08	$ 99.71	$ 148.60	$ 186.50	$ 203.25	$ 88.22	$ 31,774.28	$ 30,200
$ 300.16	$ 327.03	$ 301.16	$ 164.64	$ 228.53	$ 79.11	$ 43,392.07	$ 44,200
$ 276.08	$ 161.71	$ 210.60	$ 248.50	$ 265.26	$ 150.22	$ 42,695.34	$ 38,800
$ 256.00	$ 141.63	$ 190.52	$ 228.42	$ 245.17	$ 130.14	$ 40,356.83	$ 36,200
$ 238.28	$ 123.90	$ 172.79	$ 210.70	$ 227.45	$ 112.41	$ 36,923.63	$ 33,200
$ 298.02	$ 324.89	$ 299.02	$ 162.50	$ 226.39	$ 76.97	$ 45,879.08	$ 43,900
$ 290.37	$ 317.24	$ 291.37	$ 154.85	$ 218.74	$ 69.32	$ 43,418.89	$ 41,900
$ 283.79	$ 169.41	$ 218.30	$ 256.21	$ 272.96	$ 157.92	$ 43,921.28	$ 39,000
$ 307.16	$ 334.03	$ 308.16	$ 171.63	$ 235.52	$ 86.10	$ 46,701.03	$ 46,800
$ 283.51	$ 169.13	$ 218.02	$ 255.93	$ 272.68	$ 157.64	$ 44,482.26	$ 40,100
$ 300.85	$ 327.72	$ 301.85	$ 165.33	$ 229.22	$ 79.80	$ 45,089.81	$ 45,300
$ 301.27	$ 328.14	$ 302.27	$ 165.74	$ 229.63	$ 80.22	$ 44,984.45	$ 45,300
$ 280.31	$ 165.94	$ 214.83	$ 252.73	$ 269.48	$ 154.45	$ 42,832.65	$ 38,800
$ 210.50	$ 96.12	$ 145.01	$ 182.92	$ 199.67	$ 84.63	$ 32,741.15	$ 29,300
$ 173.20	$ 58.82	$ 107.71	$ 145.62	$ 162.37	$ 47.33	$ 17,283.32	$ 24,300
$ 173.84	$ 59.46	$ 108.36	$ 146.26	$ 163.01	$ 47.97	$ 19,321.12	$ 24,300
$ 324.06	$ 350.93	$ 325.06	$ 188.53	$ 252.42	$ 103.01	$ 50,579.82	$ 51,700
$ 306.19	$ 333.06	$ 307.19	$ 170.66	$ 234.55	$ 85.14	$ 43,843.65	$ 45,500
$ 152.88	$ 38.51	$ 87.40	$ 125.30	$ 142.05	$ 27.02	$ 13,622.84	$ 21,700
$ 143.94	$ 29.56	$ 78.45	$ 116.36	$ 133.11	$ 18.07	$ 11,359.00	$ 20,600
$ 324.23	$ 351.10	$ 325.23	$ 188.70	$ 252.59	$ 103.18	$ 49,149.58	$ 48,900
$ 322.13	$ 207.76	$ 256.65	$ 294.55	$ 311.31	$ 196.27	$ 38,922.23	$ 39,700
$ 190.69	$ 76.32	$ 125.21	$ 163.11	$ 179.86	$ 64.83	$ 17,563.41	$ 27,000
$ 122.37	$ 10.00	$ 56.89	$ 94.79	$ 111.54	$ 10.00	$ 4,020.67	$ 17,500
$ 164.69	$ 50.32	$ 99.21	$ 137.11	$ 153.86	$ 38.83	$ 17,465.46	$ 23,000
$ 308.03	$ 334.90	$ 309.03	$ 172.51	$ 236.39	$ 86.98	$ 45,957.05	$ 46,000
$ 273.90	$ 159.53	$ 208.42	$ 246.32	$ 263.08	$ 148.04	$ 40,809.71	$ 38,500
$ 288.97	$ 315.84	$ 289.97	$ 153.45	$ 217.33	$ 67.92	$ 44,021.88	$ 41,900
$ 273.58	$ 159.20	$ 208.10	$ 246.00	$ 262.75	$ 147.71	$ 43,272.83	$ 38,800
$ 276.51	$ 162.14	$ 211.03	$ 248.93	$ 265.69	$ 150.65	$ 43,074.08	$ 39,300
$ 285.42	$ 171.04	$ 219.93	$ 257.84	$ 274.59	$ 159.55	$ 44,541.01	$ 40,600
$ 298.08	$ 324.95	$ 299.08	$ 162.55	$ 226.44	$ 77.03	$ 45,781.64	$ 44,000
$ 297.60	$ 324.47	$ 298.60	$ 162.08	$ 225.96	$ 76.55	$ 45,346.81	$ 44,000
$ 295.38	$ 322.25	$ 296.38	$ 159.86	$ 223.74	$ 74.33	$ 41,765.54	$ 43,600
$ 295.66	$ 322.53	$ 296.66	$ 160.13	$ 224.02	$ 74.61	$ 42,888.65	$ 43,600
$ 238.56	$ 124.19	$ 173.08	$ 210.98	$ 227.73	$ 112.70	$ 37,455.94	$ 33,500
$ 254.50	$ 140.12	$ 189.02	$ 226.92	$ 243.67	$ 128.63	$ 39,199.18	$ 35,700
$ 245.28	$ 130.90	$ 179.80	$ 217.70	$ 234.45	$ 119.41	$ 38,605.38	$ 34,700
$ 245.91	$ 131.53	$ 180.42	$ 218.33	$ 235.08	$ 120.04	$ 38,944.25	$ 34,800
$ 295.80	$ 322.67	$ 296.80	$ 160.28	$ 224.17	$ 74.75	$ 46,077.23	$ 43,800
$ 295.85	$ 322.72	$ 296.85	$ 160.33	$ 224.21	$ 74.80	$ 45,939.43	$ 43,800
$ 303.93	$ 330.80	$ 304.93	$ 168.40	$ 232.29	$ 82.88	$ 46,952.85	$ 46,000
$ 310.44	$ 337.31	$ 311.44	$ 174.91	$ 238.80	$ 89.39	$ 48,158.40	$ 47,800
$ 307.54	$ 334.41	$ 308.54	$ 172.01	$ 235.90	$ 86.49	$ 47,824.47	$ 47,000
$ 301.49	$ 328.36	$ 302.49	$ 165.97	$ 229.86	$ 80.44	$ 46,511.89	$ 45,300
$ 266.81	$ 152.43	$ 201.33	$ 239.23	$ 255.98	$ 140.94	$ 41,917.95	$ 37,400
$ 239.81	$ 125.44	$ 174.33	$ 212.23	$ 228.99	$ 113.95	$ 36,926.48	$ 33,600
$ 300.26	$ 327.13	$ 301.26	$ 164.73	$ 228.62	$ 79.21	$ 42,785.15	$ 43,000
$ 220.39	$ 106.01	$ 154.91	$ 192.81	$ 209.56	$ 94.52	$ 34,149.72	$ 31,200
$ 257.64	$ 143.26	$ 192.16	$ 230.06	$ 246.81	$ 131.77	$ 40,301.65	$ 36,400
$ 270.32	$ 155.94	$ 204.83	$ 242.74	$ 259.49	$ 144.45	$ 40,723.92	$ 37,400
$ 292.97	$ 178.59	$ 227.49	$ 265.39	$ 282.14	$ 167.10	$ 42,999.47	$ 38,900
$ 306.33	$ 333.20	$ 307.33	$ 170.80	$ 234.69	$ 85.28	$ 46,127.46	$ 46,000
$ 307.09	$ 333.96	$ 308.09	$ 171.57	$ 235.46	$ 86.04	$ 47,758.21	$ 46,800
$ 315.21	$ 342.08	$ 316.21	$ 179.69	$ 243.57	$ 94.16	$ 48,848.48	$ 48,800
$ 298.16	$ 325.03	$ 299.16	$ 162.63	$ 226.52	$ 77.11	$ 45,866.17	$ 44,200
$ 306.70	$ 333.57	$ 307.70	$ 171.17	$ 235.06	$ 85.65	$ 47,865.84	$ 46,800

$ 322.60	$ 349.47	$ 323.60	$ 187.07	$ 250.96	$ 101.55	$ 49,359.02	$ 50,400
$ 333.00	$ 359.87	$ 334.00	$ 197.48	$ 261.36	$ 111.95	$ 51,005.78	$ 53,000
$ 299.52	$ 326.39	$ 300.52	$ 163.99	$ 227.88	$ 78.47	$ 45,791.10	$ 44,500
$ 300.64	$ 327.51	$ 301.64	$ 165.11	$ 229.00	$ 79.59	$ 46,626.84	$ 45,000
$ 147.99	$ 33.61	$ 82.50	$ 120.41	$ 137.16	$ 22.12	$ 6,793.86	$ 21,000
$ 150.24	$ 35.87	$ 84.76	$ 122.66	$ 139.41	$ 24.38	$ 6,793.94	$ 21,300
$ 303.73	$ 330.60	$ 304.73	$ 168.21	$ 232.10	$ 82.68	$ 46,598.44	$ 46,000
$ 324.41	$ 351.28	$ 325.41	$ 188.88	$ 252.77	$ 103.36	$ 44,819.84	$ 45,200
$ 153.87	$ 39.49	$ 88.38	$ 126.29	$ 143.04	$ 28.00	$ 7,890.23	$ 21,600
$ 223.57	$ 109.19	$ 158.08	$ 195.99	$ 212.74	$ 97.70	$ 20,705.25	$ 31,200
$ 232.74	$ 118.36	$ 167.25	$ 205.16	$ 221.91	$ 106.87	$ 34,932.79	$ 32,400
$ 284.56	$ 170.19	$ 219.08	$ 256.98	$ 273.73	$ 158.70	$ 42,101.88	$ 40,300
$ 311.87	$ 338.74	$ 312.87	$ 176.34	$ 240.23	$ 90.82	$ 48,352.75	$ 47,800
$ 314.16	$ 341.03	$ 315.16	$ 178.63	$ 242.52	$ 93.11	$ 48,571.39	$ 48,800
$ 277.73	$ 163.36	$ 212.25	$ 250.15	$ 266.90	$ 151.87	$ 44,317.53	$ 39,300
$ 324.29	$ 351.16	$ 325.29	$ 188.77	$ 252.65	$ 103.24	$ 45,240.19	$ 46,200
$ 308.69	$ 335.56	$ 309.69	$ 173.17	$ 237.06	$ 87.64	$ 47,841.33	$ 47,000
$ 275.23	$ 160.85	$ 209.75	$ 247.65	$ 264.40	$ 149.36	$ 42,974.54	$ 38,800
$ 309.44	$ 336.31	$ 310.44	$ 173.91	$ 237.80	$ 88.39	$ 46,786.95	$ 47,000
$ 321.92	$ 348.79	$ 322.92	$ 186.40	$ 250.28	$ 100.87	$ 49,602.54	$ 50,400
$ 307.51	$ 334.38	$ 308.51	$ 171.99	$ 235.88	$ 86.46	$ 47,659.45	$ 46,400
$ 294.76	$ 180.38	$ 229.27	$ 267.18	$ 283.93	$ 168.89	$ 43,775.70	$ 39,500
$ 300.13	$ 327.00	$ 301.13	$ 164.61	$ 228.49	$ 79.08	$ 45,614.72	$ 44,600
$ 213.51	$ 99.13	$ 148.02	$ 185.93	$ 202.68	$ 87.64	$ 32,066.39	$ 30,400
$ 226.64	$ 112.26	$ 161.15	$ 199.06	$ 215.81	$ 100.77	$ 35,108.57	$ 31,800
$ 292.31	$ 177.93	$ 226.83	$ 264.73	$ 281.48	$ 166.44	$ 45,666.05	$ 40,900
$ 309.65	$ 336.52	$ 310.65	$ 174.12	$ 238.01	$ 88.60	$ 45,063.65	$ 47,500
$ 262.38	$ 148.00	$ 196.89	$ 234.80	$ 251.55	$ 136.51	$ 40,901.35	$ 37,100
$ 319.55	$ 346.42	$ 320.55	$ 184.03	$ 247.91	$ 98.50	$ 49,723.27	$ 50,400
$ 324.48	$ 351.35	$ 325.48	$ 188.96	$ 252.84	$ 103.43	$ 50,277.83	$ 51,900
$ 328.29	$ 355.16	$ 329.29	$ 192.76	$ 256.65	$ 107.24	$ 51,746.84	$ 53,500
$ 330.14	$ 357.01	$ 331.14	$ 194.62	$ 258.50	$ 109.09	$ 49,569.84	$ 51,900

Appendix B: Summary Statistics for RFSM Scenarios

Table B -1: Representative Farm Base Case Summary Statistics

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV	$971,313	$233,967	$1,695,251	$19,139	$1,429,887	$512,738
Beef Enterprise NPV	$384,499	$61,853	$610,326	-$34,802	$505,730	$263,267
Crop Enterprise NPV	$506,064	$214,621	$1,241,705	-$234,856	$926,722	$85,407
NPV in Perpetuity	$1,109,688	$267,832	$1,986,174	$244,195	$1,634,638	$584,738
Forage Sales	$2,952	$1,479	$12,897	$0	$5,850	$54
Net Forage Costs	$991	$607	$4,433	$0	$2,180	-$198
Grazing Season Days	259.1	26.18	475.53	192.93	310.4128	207.7872
Weaning Weights	572.29	49.75	983.5	446.56	669.8	474.78

Table B-2: Summary Statistics for Scenario 1: Riparian Habitat to Cropland

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 6.67%	$1,006,901	$241,835	$1,768,450	$215,867	$1,480,897	$532,905
3.33%	$1,040,093	$247,470	$1,799,778	$209,572	$1,525,134	$555,051
0.00%	$1,074,252	$254,258	$1,851,895	$221,700	$1,572,597	$575,906
Beef NPV - 6.67%	$385,877	$60,317	$613,021	-$38,590	$504,098	$267,655
3.33%	$385,610	$61,608	$610,326	-$34,802	$506,361	$264,859
0.00%	$386,109	$61,511	$610,326	-$34,802	$506,671	$265,547
Crop NPV - 6.67%	$537,623	$221,563	$1,262,708	-$220,999	$971,886	$103,360
3.33%	$568,388	$228,939	$1,343,058	-$229,395	$1,017,109	$119,667
0.00%	$599,330	$236,073	$1,393,754	-$220,845	$1,062,034	$136,627
Forage Sales - 6.67%	$3,269	$1,467	$9,889	$0	$6,145	$393
3.33%	$3,586	$1,488	$13,450	$0	$6,503	$669
0.00%	$3,900	$1,493	$13,726	$0	$6,826	$975
Grazing Season Days - 6.67%	259.11	25.79	408.97	203.46	309.6584	208.5616
3.33%	259.1	26.18	475.53	192.93	310.4128	207.7872
0.00%	259.1	26.18	475.53	192.93	310.4128	207.7872
Weaning Weights - 6.67%	572.31	49	857.03	466.57	668.35	476.27
3.33%	572.29	49.75	983.5	446.56	669.8	474.78
0.00%	572.29	49.75	983.5	446.56	669.8	474.78

Table B-3: Summary Statistics for Scenario 2: Riparian Habitat to Tame Pasture

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 6.67%	$973,191	$233,951	$169,776	$194,389	$1,431,735	$514,648
3.33%	$975,114	$233,832	$1,700,000	$195,637	$1,433,425	$516,803
0.00%	$976,996	$233,769	$1,702,514	$197,062	$1,435,182	$518,809
Beef NPV - 6.67%	$385,347	$61,854	$612,021	-$34,275	$506,582	$264,113
3.33%	$386,258	$61,829	$613,717	-$33,748	$507,443	$265,072
0.00%	$387,137	$61,848	$615,412	-$33,221	$508,358	$265,915
Crop NPV - 6.67%	$507,121	$214,544	$1,242,720	-$234,232	$927,628	$86,614
3.33%	$508,156	$214,474	$1,244,013	-$233,602	$928,525	$87,787
0.00%	$509,186	$214,404	$1,245,327	-$232,894	$929,417	$88,955
Forage Sales - 6.67%	$2,983	$1,480	$12,948	$0	$5,884	$83
3.33%	$3,015	$1,481	$13,008	$0	$5,918	$111
0.00%	$3,046	$1,483	$13,068	$0	$5,952	$140
Grazing Season Days -	259.67	26.25	476.67	193.33	311.12	208.22
3.33%	260.25	26.32	477.82	193.73	311.8372	208.6628
0.00%	260.82	26.39	478.96	194.13	312.5444	209.0956
Weaning Weights - 6.67%	573.38	49.88	985.68	447.33	671.1448	475.6152
3.33%	574.47	50.01	987.85	448.09	672.4896	476.4504
0.00%	575.56	50.14	990.02	448.85	673.8344	477.2856

Table B-4: Summary Statistics for Scenario 3: Forested Habitat to Cropland

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 6.67%	$796,956	$231,463	$1,771,476	$56,878	$1,250,623	$343,289
3.33%	$828,181	$239,456	$1,824,216	$66,178	$1,297,515	$358,847
0.00%	$859,937	$247,501	$1,876,828	$75,007	$1,345,038	$374,835
Beef NPV - 6.67%	$305,650	$51,302	$522,093	$168,804	$406,203	$205,097
3.33%	$307,685	$50,839	$522,093	$172,795	$407,330	$208,040
0.00%	$309,475	$50,431	$522,093	$175,944	$408,321	$210,630
Crop NPV - 6.67%	$404,503	$213,546	$1,176,289	-$290,153	$823,052	-$14,046
3.33%	$431,010	$222,056	$1,226,980	-$290,315	$866,239	-$4,220
0.00%	$458,338	$230,585	$1,277,552	-$290,477	$910,285	$6,391
Forage Sales - 6.67%	$464	$822	$7,950	$0	$2,075	-$1,146
3.33%	$611	$916	$8,225	$0	$2,406	-$1,184
0.00%	$786	$1,011	$8,499	$0	$2,767	-$1,195
Grazing Season Days - 6.67%	200.48	20.43	369.37	148.85	240.5228	160.4372
3.33%	200.48	20.43	369.37	148.85	240.5228	160.4372
0.00%	200.48	20.43	369.37	148.85	240.5228	160.4372
Weaning Weights - 6.67%	460.92	38.82	781.8	362.81	537.0072	384.8328
3.33%	460.92	38.82	781.8	362.81	537.0072	384.8328
0.00%	460.92	38.82	781.8	362.81	537.0072	384.8328

Table B-5: Summary Statistics for Scenario 4: Forested Habitat to Tame Grass

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 6.67%	$787,034	$225,653	$1,729,772	$64,514	$1,229,313	$344,754
3.33%	$809,095	$228,721	$1,765,656	$81,716	$1,257,389	$360,802
0.00%	$831,651	$231,520	$1,789,601	$98,404	$1,285,430	$377,871
Beef NPV - 6.67%	$312,285	$51,813	$520,579	$141,664	$413,837	$210,732
3.33%	$321,402	$52,156	$543,031	$154,241	$423,627	$219,177
0.00%	$330,133	$53,633	$554,243	-$37,881	$435,254	$225,011
Crop NPV - 6.67%	$390,879	$207,789	$1,139,515	-$284,410	$798,145	-$16,387
3.33%	$404,097	$210,472	$1,153,732	-$278,828	$816,621	-$8,428
0.00%	$418,298	$212,928	$1,167,940	-$273,248	$835,636	$960
Forage Sales - 6.67%	$500	$863	$8,314	$0	$2,193	-$1,192
3.33%	$699	$999	$8,967	$0	$2,658	-$1,260
0.00%	$942	$1,131	$9,618	$0	$3,158	-$1,273
Grazing Season Days - 6.67%	207.1	21.22	382.52	153.46	248.6912	165.5088
3.33%	213.71	22.02	394.68	159.08	256.8692	170.5508
0.00%	220.33	22.81	408.83	162.69	265.0376	175.6224
Weaning Weights - 6.67%	473.48	40.32	806.79	371.58	552.5072	394.4528
3.33%	486.05	41.83	831.79	380.35	568.0368	404.0632
0.00%	498.62	43.33	856.78	389.12	583.5468	413.6932

Table B-6: Summary Statistics for Scenario 5: Cropland to Tame Pasture

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV	$983,547	$199,059	$1,588,125	$309,798	$1,373,704	$593,391
Beef Enterprise NPV	$451,811	$93,364	$636,764	-$42,076	$634,805	$268,818
Crop Enterprise NPV	$464,054	$182,286	$1,133,736	-$146,219	$821,334	$106,773
Forage Sales	$5,766	$1,696	$18,303	$1,124	$9,091	$2,441
Grazing Season Days	314.31	32.79	585.34	231.45	378.5784	250.0416
Weaning Weights	677.2	62.3	1192.15	519.76	799.308	555.092

Table B-7: Summary Statistics for Scenario 6: Cropland to Tame Hay

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV	$910,724	$200,623	$1,543,904	$243,404	$1,303,945	$517,503
Beef Enterprise NPV	$396,264	$59,841	$610,986	-$38,204	$513,553	$278,975
Crop Enterprise NPV	$441,139	$182,141	$1,072,843	-$187,984	$798,135	$84,143
Forage Sales	$7,151	$1,578	$16,624	$3,080	$10,245	$4,057
Grazing Season Days	259.1	26.18	475.53	192.93	310.4128	207.7872
Weaning Weights	572.29	49.75	983.5	446.56	669.8	474.78

Table B-8: Summary Statistics for Scenario 7: Decreasing forage conditions for overgrazed state (decreasing utilization factor, %)

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 6.67%	$952,692	$235,345	$1,677,611	$177,574	$1,413,967	$491,416
13.33%	$931,593	$236,817	$1,658,255	$160,771	$1,395,754	$467,433
20.00%	$906,252	$237,623	$1,636,229	$140,429	$1,371,994	$440,511
Beef NPV - 6.67%	$376,083	$61,540	$611,770	-$37,703	$496,702	$255,465
13.33%	$367,205	$60,066	$598,916	-$40,954	$484,935	$249,475
20.00%	$357,035	$57,623	$583,941	-$13,754	$469,975	$244,095
Crop NPV - 6.67%	$495,371	$215,771	$1,234,731	-$242,367	$918,282	$72,459
13.33%	$482,523	$216,897	$1,226,979	-$250,090	$907,641	$57,405
20.00%	$466,690	$217,722	$1,217,965	-$258,638	$893,426	$39,954
Forage Sales - 6.67%	$2,653	$1,489	$12,626	$0	$5,572	-$265
13.33%	$2,322	$1,488	$12,325	$0	$5,238	-$595
20.00%	$1,947	$1,464	$11,975	$0	$4,817	-$923
Grazing Season Days - 6.67%	253.66	26.18	470.09	187.49	304.9728	202.3472
13.33%	247.56	26.18	461.99	181.39	298.8728	196.2472
20.00%	240.46	26.18	456.89	174.29	291.7728	189.1472
Weaning Weights - 6.67%	561.95	49.75	973.17	436.23	659.46	464.44
13.33%	550.36	49.75	961.58	424.64	647.87	452.85
20.00%	536.87	49.75	948.08	411.14	634.38	439.36

Table B-9: Summary Statistics for Scenario 7: Decreasing stocking rates (AUM for tame and native pasture)

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 1.2 and 0.6	$907,700	$241,858	$1,854,607	$150,952	$1,381,742	$433,659
1.1 and 0.55	$904,346	$241,113	$1,663,642	$126,574	$1,376,928	$431,765
1.0 and 0.5	$904,627	$243,008	$1,675,256	$118,676	$1,380,922	$428,332
Beef Enterprise NPV - 1.2 and 0.6	$360,063	$58,558	$598,026	$156,529	$474,835	$245,290
1.1 and 0.55	$359,069	$61,567	$604,233	-$35,549	$479,741	$238,397
1.0 and 0.5	$360,760	$63,478	$609,305	-$29,750	$485,177	$236,344
Crop Enterprise NPV - 1.2 and 0.6	$466,261	$218,825	$1,196,989	-$250,146	$895,158	$37,364
1.1 and 0.55	$464,855	$219,760	$1,237,539	-$263,470	$895,585	$34,125
1.0 and 0.5	$464,562	$220,679	$1,249,305	-$266,091	$897,093	$32,030
Forage Sales - 1.2 and 0.6	$1,977	$1,528	$9,118	$0	$4,973	-$1,018
1.1 and 0.55	$1,991	$1,597	$13,128	$0	$5,121	-$1,139
1.0 and 0.5	$2,045	$1,670	$13,835	$0	$5,317	-$1,228
Grazing Season Days - 1.2 and 0.6	238.58	26.53	392.74	181.33	290.5788	186.5812
1.1 and 0.55	236.33	27.69	465.23	166.35	290.6024	182.0576
1.0 and 0.5	234.45	28.58	470.7	162.23	290.4668	178.4332
Weaning Weights - 1.2 and 0.6	533.3	50.41	826.21	424.52	632.1036	434.4964
1.1 and 0.55	529.03	52.62	963.94	396.07	632.1652	425.8948
1.0 and 0.5	525.46	54.3	974.32	388.23	631.888	419.032

Table B-10: Summary Statistics for Scenario 8: Rotational grazing management (changing utilization factor)

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 0.50%	$963,915	$234,862	$1,695,188	$197,423	$1,424,244	$503,586
1.00%	$969,693	$234,203	$1,699,979	$187,229	$1,428,731	$510,655
1.50%	$976,340	$233,846	$1,701,842	$191,276	$1,434,677	$518,003
Beef Enterprise NPV - 0.50%	$388,804	$60,593	$620,392	-$36,370	$507,567	$270,041
1.00%	$391,808	$63,052	$624,998	-$29,777	$515,390	$268,227
1.50%	$395,448	$63,241	$632,334	-$27,264	$519,400	$271,496
Crop Enterprise NPV - 0.50%	$510,160	$214,368	$1,216,843	-$221,101	$930,321	$90,000
1.00%	$513,614	$214,540	$1,252,755	-$229,821	$934,113	$93,116
1.50%	$517,248	$214,516	$1,258,472	-$227,220	$937,700	$96,797
Forage Sales - 0.50%	$3,081	$1,481	$9,838	$0	$5,985	$178
1.00%	$3,215	$1,514	$13,451	$0	$6,182	$248
1.50%	$3,346	$1,531	$13,729	$0	$6,346	$346
Grazing Season Days - 0.50%	259.79	25.88	410.2	203.93	310.5148	209.0652
1.00%	260.45	26.38	478.5	193.79	312.1548	208.7452
1.50%	261.13	26.48	479.99	194.21	313.0308	209.2292
Weaning Weights - 0.50%	573.6	49.18	859.39	467.46	669.9928	477.2072
1.00%	574.86	50.12	989.16	448.19	673.0952	476.6248
1.50%	576.14	50.31	991.98	449.01	674.7476	477.5324

Table B-11: Summary Statistics for Scenario 8: Rotational grazing management (changing period of forage growth)

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 3 years	$966,915	$234,189	$1,695,970	$185,092	$1,425,925	$507,904
4 years	$969,693	$234,203	$1,699,979	$187,229	$1,428,731	$510,655
5 years	$972,270	$233,813	$1,694,964	$188,990	$1,430,543	$513,997
6 years	$974,713	$233,909	$1,698,498	$190,564	$1,433,175	$516,252
Beef Enterprise NPV - 3 years	$390,319	$62,150	$621,868	-$30,969	$512,132	$268,506
4 years	$391,808	$63,052	$624,998	-$29,777	$515,390	$268,227
5 years	$393,263	$62,816	$627,773	-$28,630	$516,383	$270,143
6 years	$394,758	$62,924	$630,255	-$27,535	$518,089	$271,426
Crop Enterprise NPV - 3 years	$512,045	$214,547	$1,250,369	-$230,952	$932,558	$91,532
4 years	$513,614	$214,540	$1,252,755	-$229,821	$934,113	$93,116
5 years	$514,981	$214,542	$1,254,881	-$228,747	$935,484	$94,478
6 years	$516,189	$214,548	$1,256,934	-$227,722	$936,703	$95,676
Forage Sales - 3 years	$3,154	$1,506	$13,325	$0	$6,105	$202
4 years	$3,215	$1,514	$13,451	$0	$6,182	$248
5 years	$3,273	$1,522	$13,578	$0	$6,255	$290
6 years	$3,328	$1,529	$13,690	$0	$6,325	$332
Grazing Season Days - 3 years	260.45	26.38	478.5	193.79	312.1548	208.7452
4 years	260.45	26.38	478.5	193.79	312.1548	208.7452
5 years	260.45	26.38	478.5	193.79	312.1548	208.7452
6 years	260.45	26.38	478.5	193.79	312.1548	208.7452
Weaning Weights - 3 years	574.86	50.12	989.16	448.19	673.0952	476.6248
4 years	574.86	50.12	989.16	448.19	673.0952	476.6248
5 years	574.86	50.12	989.16	448.19	673.0952	476.6248
6 years	574.86	50.12	989.16	448.19	673.0952	476.6248

Table B-12: Summary Statistics for High Input Cost Scenario: Riparian Habitat to Cropland (% of quarter w/ habitat)

	Mean	Std. Dev.	Maximum	Minimum	95%	5%
Farm NPV - 6.67%	$891,356	$241,604	$1,635,052	$70,360	$1,364,899	$417,813
3.33%	$921,650	$248,362	$1,683,289	$74,818	$1,408,440	$434,861
0.00%	$951,817	$255,150	$1,731,422	$83,471	$1,451,911	$451,724
Beef Enterprise NPV - 6.67%	$382,097	$62,213	$610,004	-$33,369	$504,033	$260,160
3.33%	$382,631	$62,098	$610,004	-$33,369	$504,343	$260,920
0.00%	$383,131	$61,999	$610,004	-$33,369	$504,648	$261,613
Crop Enterprise NPV - 6.67%	$425,146	$221,785	$1,180,244	-$344,760	$859,844	-$9,553
3.33%	$452,194	$228,939	$1,226,865	-$345,589	$900,915	$3,473
0.00%	$479,132	$236,073	$1,273,556	-$341,043	$941,836	$16,429
Forage Sales - 6.67%	$3,270	$1,484	$13,175	$0	$6,179	$362
3.33%	$3,586	$1,488	$13,450	$0	$6,503	$669
0.00%	$3,900	$1,493	$13,726	$0	$6,826	$975
Grazing Season Days - 6.67%	259.1	26.18	475.53	192.93	310.4128	207.7872
3.33%	259.1	26.18	475.53	192.93	310.4128	207.7872
0.00%	259.1	26.18	475.53	192.93	310.4128	207.7872
Weaning Weights - 6.67%	572.29	49.75	983.5	446.56	669.8	474.78
3.33%	572.29	49.75	983.5	446.56	669.8	474.78
0.00%	572.29	49.75	983.5	446.56	669.8	474.78

Appendix C: Scenario 1 Results Excluding Conversion Costs

Table C-1 Scenario 1 Results: Conversion of Riparian Habitat to Cropland Excluding Conversion Costs

	Acres of Riparian Habitat per Quarter (% of Qtr)			
	Base	10.66 (6.67%)	5.33 (3.33%)	0 (0%)
Farm NPV Mean*	$ 971,313	$ 1,006,901	$ 1,040,093	$ 1,074,252
St. Dev.	$ 233,967	$ 241,835	$ 247,470	$ 254,258
Total NPV Increase		$ 35,588	$ 68,780	$ 102,939
NPV Increase ($/ac Converted)		$ 1,113	$ 1,075	$ 1,072
Annualized Increase ($/ac Converted)		**$ 130.71**	**$ 126.31**	**$ 125.95**
Annual Forage Sales Mean	$ 2,952	$ 3,269	$ 3,586	$ 3,900
St. Dev.	$ 1,479	$ 1,467	$ 1,488	$ 1,493
Crop Enterprise NPV Mean*	$ 506,064	$ 537,623	$ 568,388	$ 599,330
St. Dev.	$ 214,621	$ 221,563	$ 228,939	$ 236,073
Beef Enterprise NPV Mean	$ 384,499	$ 385,877	$ 385,610	$ 386,109
St. Dev.	$ 61,853	$ 60,317	$ 61,608	$ 61,511

*Runs from simulation model and excludes all conversion costs.

Appendix D: Forage Availability Changes (Scenarios 7and 8)

Table D -1 Scenario 7: Forage availability from lowered stocking rates (up to and including the last year of utilization growth)

			AUM/acre		Utilizable forage per year (lbs)	
	Year	Grazing season days	Native	Tame	Native	Tame
Tame 1.2, Native 0.6	year 0	236.38	0.56	1.11	212,453	419,337
	year 1	237.54	0.57	1.12	214,634	423,642
	year 2	238.70	0.58	1.14	216,816	427,948
	year 3	239.86	0.58	1.15	218,997	432,254
	year 4	241.02	0.59	1.16	221,179	436,560
Tame 1.1, Native 0.55						
	year 0	233.61	0.55	1.09	207,236	409,040
	year 1	235.28	0.56	1.10	210,375	415,235
	year 2	236.95	0.57	1.12	213,514.	421,431
	year 3	238.61	0.57	1.13	216,653	427,626.
	year 4	240.28	0.58	1.15	219,79	433,822
	year 5	241.95	0.59	1.17	222,931	440,017
Tame 1.0, Native 0.5						
	year 0	231.24	0.54	1.06	202,767	400,219
	year 1	233.37	0.55	1.08	206,774	408,129
	year 2	235.50	0.56	1.10	210,782	416,039
	year 3	237.62	0.57	1.13	214,789	423,948
	year 4	239.75	0.58	1.15	218,797	431,858
	year 5	241.88	0.59	1.17	222,804	439,768
	year 6	244.01	0.60	1.19	226,812	447,678

Table D -2 Scenario 8: Forage availability with increasing utilization factor growth

			AUM/acre		Utilizable forage per year (lbs)	
	Year	Grazing season days	Native	Tame	Native	Tame
0.50%	Year 0	258.10	0.67	1.33	251,126	502,253
	Year 1	258.77	0.67	1.34	252,382	504,764
	Year 2	259.45	0.67	1.35	253,637	507,275
	Year 3	260.12	0.68	1.35	254,893	509,787
	Year 4	260.79	0.68	1.36	256,149	512,298
1.00%	Year 0	258.10	0.67	1.33	251,126	502,253
	Year 1	259.45	0.67	1.35	253,637	507,275
	Year 2	260.79	0.68	1.36	256,149	512,298
	Year 3	262.14	0.69	1.37	258,660	517,320
	Year 4	263.48	0.69	1.39	261,171	522,343
1.50%	Year 0	258.10	0.67	1.33	251,126	502,253
	Year 1	260.12	0.68	1.35	254,893	509,787
	Year 2	262.14	0.69	1.37	258,660	517,320
	Year 3	264.16	0.70	1.39	262,427	524,854
	Year 4	266.18	0.71	1.41	266,194	532,388

Table D- 3 Scenario 8: Forage availability with increasing utilization factor improvement period

			AUM/acre		Utilizable forage per year (lbs)	
	Year	Grazing Season days	Native	Tame	Native	Tame
3.00	Year 0	258.10	0.67	1.33	251,126	502,253
	Year 1	259.45	0.67	1.35	253,637	507,275
	Year 2	260.79	0.68	1.36	256,149	512,298
	Year 3	262.14	0.69	1.37	258,660	517,320
4.00	Year 4	263.48	0.69	1.39	261,171	522,343
5.00	Year 5	264.83	0.70	1.40	263,682	527,365
6.00	Year 6	266.18	0.71	1.41	266,194	532,388

Appendix E: Off-stream watering and Fencing costs

Table E-1: Off-stream watering site construction costs

Construction costs for small off-stream watering site (~100 herd size)	
	Total Cost($)
Wet Well Intake	$ 5,000
Miscellaneous (10%)	$ 500
Total	**$ 5,500**
$/cow (116 herd size)	**$ 47.41**

Source: Koeckhoven S. (2008) and advice given from Soloudre (2008)

Table E-2: Fencing construction costs

Cost to erect 4 standard barbed, 2-strand wire fence	
Total cost ($/mile)*	$ 3,742.24
$/metre	$ 2.34
$/foot	**$ 0.71**

*Source: Soloudre (2008)

Appendix F: Detailed Assessed Wealth Results

Table F-1: Antler River Sub-watershed- Assessed Wealth Results

Quarter Section	Actual	Base Case	Landscape Targets	Difference b/w Runs
SW1-5-33-W1	$ 45,000	$ 38,009	$ 30,688	$ 7,320
NW1-5-33-W1	$ 43,000	$ 38,351	$ 38,351	$ -
NE1-5-33-W1	$ 52,000	$ 50,355	$ 43,152	$ 7,203
SE1-5-33-W1	$ 52,000	$ 51,221	$ 27,341	$ 23,880
SW2-5-33-W1	$ 37,000	$ 38,839	$ 38,482	$ 357
NE2-5-33-W1	$ 48,000	$ 44,345	$ 37,818	$ 6,527
SE2-5-33-W1	$ 44,000	$ 37,486	$ 26,179	$ 11,307
SW3-5-33-W1	$ 46,000	$ 40,408	$ 33,079	$ 7,329
NW3-5-33-W1	$ 46,000	$ 43,199	$ 34,221	$ 8,978
NE3-5-33-W1	$ 28,000	$ 42,686	$ 40,603	$ 2,083
SE3-5-33-W1	$ 31,000	$ 43,035	$ 32,339	$ 10,696
SW4-5-33-W1	$ 40,000	$ 37,885	$ 35,862	$ 2,023
NW4-5-33-W1	$ 34,000	$ 38,858	$ 37,771	$ 1,087
NE4-5-33-W1	$ 48,000	$ 48,137	$ 47,855	$ 282
SE4-5-33-W1	$ 49,000	$ 50,479	$ 50,478	$ 1
SW5-5-33-W1	$ 34,000	$ 43,814	$ 33,924	$ 9,890
NW5-5-33-W1	$ 40,000	$ 39,071	$ 38,461	$ 610
NE5-5-33-W1	$ 43,000	$ 40,135	$ 30,560	$ 9,574
SE5-5-33-W1	$ 23,000	$ 45,930	$ 34,994	$ 10,936
SW6-5-33-W1	$ 44,000	$ 36,181	$ 29,118	$ 7,063
NW6-5-33-W1	$ 41,000	$ 38,668	$ 38,655	$ 13
NE6-5-33-W1	$ 46,000	$ 39,700	$ 33,346	$ 6,354
SE6-5-33-W1	$ 39,000	$ 38,990	$ 31,111	$ 7,879
SW7-5-33-W1	$ 40,000	$ 37,440	$ 37,423	$ 17
NW7-5-33-W1	$ 46,000	$ 41,398	$ 41,397	$ 1
NE7-5-33-W1	$ 39,000	$ 39,398	$ 39,376	$ 22
SE7-5-33-W1	$ 38,000	$ 39,453	$ 39,185	$ 268
SW8-5-33-W1	$ 47,000	$ 40,493	$ 40,384	$ 109
NW8-5-33-W1	$ 42,000	$ 40,433	$ 31,232	$ 9,201
NE8-5-33-W1	$ 39,000	$ 38,755	$ 37,362	$ 1,393
SE8-5-33-W1	$ 44,000	$ 39,433	$ 35,094	$ 4,339
SW9-5-33-W1	$ 24,000	$ 43,694	$ 37,600	$ 6,094
NW9-5-33-W1	$ 30,000	$ 40,835	$ 38,934	$ 1,902
NE9-5-33-W1	$ 28,000	$ 40,484	$ 30,237	$ 10,247
SE9-5-33-W1	$ 46,000	$ 43,895	$ 29,009	$ 14,885
SW10-5-33-W1	$ 45,000	$ 40,640	$ 32,294	$ 8,346
NW10-5-33-W1	$ 49,000	$ 61,881	$ 50,696	$ 11,184
NE10-5-33-W1	$ 50,000	$ 48,862	$ 26,952	$ 21,910
SE10-5-33-W1	$ 39,000	$ 37,028	$ 32,087	$ 4,941
SW11-5-33-W1	$ 32,000	$ 39,739	$ 31,952	$ 7,787
NW11-5-33-W1	$ 38,000	$ 36,426	$ 34,482	$ 1,944
NE11-5-33-W1	$ 39,000	$ 37,255	$ 37,235	$ 20
SE11-5-33-W1	$ 44,000	$ 45,693	$ 35,148	$ 10,545
SW12-5-33-W1	$ 47,000	$ 42,383	$ 32,101	$ 10,281
NW12-5-33-W1	$ 52,000	$ 53,318	$ 53,318	$ -
NE12-5-33-W1	$ 56,000	$ 60,715	$ 60,712	$ 3
SE12-5-33-W1	$ 57,000	$ 65,974	$ 65,974	$ -
SW13-5-33-W1	$ 51,000	$ 48,735	$ 41,969	$ 6,767
NW13-5-33-W1	$ 44,000	$ 34,668	$ 34,596	$ 72
NE13-5-33-W1	$ 49,000	$ 46,674	$ 39,553	$ 7,120
SE13-5-33-W1	$ 49,000	$ 46,476	$ 38,635	$ 7,840

NW14-5-33-W1	$ 55,000	$ 57,180	$ 49,489	$ 7,691
NE14-5-33-W1	$ 36,000	$ 36,046	$ 28,473	$ 7,573
SE14-5-33-W1	$ 48,000	$ 48,041	$ 38,123	$ 9,918
SW15-5-33-W1	$ 29,000	$ 37,421	$ 34,909	$ 2,512
NW15-5-33-W1	$ 52,000	$ 53,731	$ 48,413	$ 5,318
NE15-5-33-W1	$ 53,000	$ 56,409	$ 56,406	$ 4
SE15-5-33-W1	$ 44,000	$ 35,294	$ 35,294	$ -
SW16-5-33-W1	$ 15,000	$ 36,503	$ 31,042	$ 5,462
NW16-5-33-W1	$ 34,000	$ 40,015	$ 33,610	$ 6,405
NE16-5-33-W1	$ 46,000	$ 36,722	$ 35,766	$ 956
SE16-5-33-W1	$ 21,000	$ 25,055	$ 23,438	$ 1,617
SW17-5-33-W1	$ 48,000	$ 44,142	$ 36,255	$ 7,887
NW17-5-33-W1	$ 41,000	$ 37,922	$ 37,908	$ 14
NE17-5-33-W1	$ 44,000	$ 37,722	$ 27,581	$ 10,141
SE17-5-33-W1	$ 33,000	$ 40,091	$ 39,723	$ 368
SW18-5-33-W1	$ 42,000	$ 36,910	$ 36,864	$ 46
NW18-5-33-W1	$ 37,000	$ 38,765	$ 31,263	$ 7,502
NE18-5-33-W1	$ 40,000	$ 37,910	$ 37,895	$ 15
SE18-5-33-W1	$ 35,000	$ 40,614	$ 40,614	$ -
SW19-5-33-W1	$ 16,000	$ 40,499	$ 24,086	$ 16,413
NW19-5-33-W1	$ 19,000	$ 45,223	$ 31,735	$ 13,488
NE19-5-33-W1	$ 33,000	$ 39,483	$ 27,143	$ 12,339
SE19-5-33-W1	$ 43,000	$ 37,516	$ 25,855	$ 11,662
SW20-5-33-W1	$ 41,000	$ 36,849	$ 36,849	$ 0
NW20-5-33-W1	$ 49,000	$ 46,591	$ 46,590	$ 1
NE20-5-33-W1	$ 45,000	$ 42,562	$ 27,205	$ 15,357
SE20-5-33-W1	$ 39,000	$ 38,838	$ 38,838	$ -
SW21-5-33-W1	$ 41,000	$ 38,379	$ 38,097	$ 282
NW21-5-33-W1	$ 41,000	$ 38,697	$ 38,697	$ -
NE21-5-33-W1	$ 69,000	$ 89,734	$ 89,688	$ 46
SE21-5-33-W1	$ 32,000	$ 39,452	$ 34,746	$ 4,706
SW22-5-33-W1	$ 53,000	$ 55,467	$ 55,321	$ 146
NW22-5-33-W1	$ 42,000	$ 36,483	$ 35,191	$ 1,292
NE22-5-33-W1	$ 47,000	$ 44,695	$ 34,713	$ 9,982
SE22-5-33-W1	$ 55,000	$ 60,189	$ 50,614	$ 9,575
SW23-5-33-W1	$ 75,000	$ 91,703	$ 91,505	$ 198
NW23-5-33-W1	$ 53,000	$ 56,440	$ 48,215	$ 8,225
NE23-5-33-W1	$ 48,000	$ 44,673	$ 38,345	$ 6,328
SE23-5-33-W1	$ 48,000	$ 41,682	$ 41,640	$ 41
SW24-5-33-W1	$ 38,000	$ 37,779	$ 35,742	$ 2,037
NW24-5-33-W1	$ 44,000	$ 33,069	$ 28,609	$ 4,460
NE24-5-33-W1	$ 50,000	$ 45,803	$ 10,221	$ 35,582
SE24-5-33-W1	$ 55,000	$ 59,610	$ 51,883	$ 7,726
SW25-5-33-W1	$ 47,000	$ 41,203	$ 36,128	$ 5,074
NW25-5-33-W1	$ 48,000	$ 43,887	$ 36,900	$ 6,987
NE25-5-33-W1	$ 36,000	$ 39,994	$ 35,053	$ 4,941
SE25-5-33-W1	$ 39,000	$ 35,866	$ 29,283	$ 6,583
SW26-5-33-W1	$ 45,000	$ 40,562	$ 15,829	$ 24,733
NW26-5-33-W1	$ 49,000	$ 48,659	$ 42,230	$ 6,429
NE26-5-33-W1	$ 49,000	$ 47,106	$ 23,120	$ 23,985
SE26-5-33-W1	$ 48,000	$ 43,119	$ 37,542	$ 5,577
SW27-5-33-W1	$ 38,000	$ 37,230	$ 32,255	$ 4,975
NW27-5-33-W1	$ 36,000	$ 35,466	$ 26,982	$ 8,485
NE27-5-33-W1	$ 37,000	$ 37,714	$ 34,342	$ 3,371
SW28-5-33-W1	$ 43,000	$ 37,678	$ 37,493	$ 185
NW28-5-33-W1	$ 46,000	$ 43,716	$ 39,125	$ 4,591
NE28-5-33-W1	$ 14,000	$ 46,208	$ 36,651	$ 9,557

SE28-5-33-W1	$ 40,000	$ 39,037	$ 33,685	$ 5,352
SW29-5-33-W1	$ 46,000	$ 39,658	$ 16,816	$ 22,842
NW29-5-33-W1	$ 41,000	$ 36,831	$ 30,518	$ 6,314
NE29-5-33-W1	$ 44,000	$ 38,289	$ 38,289	$ -
SE29-5-33-W1	$ 45,000	$ 38,300	$ 23,583	$ 14,718
SW30-5-33-W1	$ 17,000	$ 44,258	$ 30,787	$ 13,472
NW30-5-33-W1	$ 17,000	$ 45,681	$ 35,469	$ 10,212
NE30-5-33-W1	$ 17,000	$ 45,932	$ 33,264	$ 12,668
SE30-5-33-W1	$ 31,000	$ 41,208	$ 28,635	$ 12,573
SW31-5-33-W1	$ 34,000	$ 38,871	$ 30,864	$ 8,007
NW31-5-33-W1	$ 51,000	$ 49,603	$ 49,603	$ -
NE31-5-33-W1	$ 54,000	$ 55,221	$ 55,221	$ -
SE31-5-33-W1	$ 45,000	$ 36,740	$ 36,740	$ -
SW32-5-33-W1	$ 51,000	$ 53,147	$ 42,261	$ 10,886
NW32-5-33-W1	$ 52,000	$ 54,803	$ 53,579	$ 1,223
NE32-5-33-W1	$ 55,000	$ 60,251	$ 49,636	$ 10,615
SE32-5-33-W1	$ 53,000	$ 65,163	$ 57,274	$ 7,889
SW33-5-33-W1	$ 52,000	$ 54,808	$ 44,565	$ 10,243
NW33-5-33-W1	$ 55,000	$ 61,458	$ 49,511	$ 11,947
NE33-5-33-W1	$ 47,000	$ 43,656	$ 34,238	$ 9,417
SE33-5-33-W1	$ 49,000	$ 49,213	$ 22,790	$ 26,423
SW34-5-33-W1	$ 53,000	$ 55,623	$ 18,750	$ 36,873
NW34-5-33-W1	$ 53,000	$ 61,440	$ 36,254	$ 25,186
NE34-5-33-W1	$ 38,000	$ 38,773	$ 33,762	$ 5,011
SE34-5-33-W1	$ 56,000	$ 57,391	$ 57,365	$ 26
SW35-5-33-W1	$ 48,000	$ 42,682	$ 42,540	$ 142
NW35-5-33-W1	$ 46,000	$ 39,759	$ 39,564	$ 195
NE35-5-33-W1	$ 53,000	$ 53,262	$ 49,533	$ 3,729
SE35-5-33-W1	$ 49,000	$ 47,081	$ 11,513	$ 35,568
SW36-5-33-W1	$ 49,000	$ 46,474	$ (4,955)	$ 51,428
NW36-5-33-W1	$ 53,000	$ 52,200	$ 45,824	$ 6,376
NE36-5-33-W1	$ 41,000	$ 38,944	$ 30,916	$ 8,028
SE36-5-33-W1	$ 51,000	$ 51,721	$ 44,222	$ 7,499
Total	$ 6,047,000	$ 6,271,755	$ 5,259,473	
Average	$ 42,887	$ 44,481	$ 37,301	
SD	10069.8221	9327.100482	11730.84162	
median	$ 44,000	$ 41,203	$ 36,255	

Table F-2: Pipestone Creek Sub-Watershed- Assessed Wealth Results

Quarter Section	Actual	Base Case	Landscape Targets	Difference b/w Runs
SW1-13-2-W2	$ 46,700	$ 44,501	$ 44,309	$
NW1-13-2-W2	$ 48,600	$ 39,504	$ 38,053	$ 1,451
NE1-13-2-W2	$ 18,800	$ 47,398	$ 41,419	$ 5,979
SE1-13-2-W2	$ 37,800	$ 50,560	$ 49,137	$ 1,423
SW2-13-2-W2	$ 28,900	$ 45,187	$ 39,482	$ 5,705
NW2-13-2-W2	$ 28,800	$ 41,171	$ 41,171	$
NE2-13-2-W2	$ 44,200	$ 42,966	$ 38,005	$ 4,961
SE2-13-2-W2	$ 25,700	$ 49,290	$ 45,191	$ 4,099
SW3-13-2-W2	$ 35,500	$ 46,615	$ 46,615	$
NW3-13-2-W2	$ 25,600	$ 28,210	$ 19,094	$ 9,116
NE3-13-2-W2	$ 28,100	$ 32,295	$ 27,312	$ 4,982
SE3-13-2-W2	$ 28,800	$ 47,769	$ 44,978	$ 2,791
SW4-13-2-W2	$ 29,800	$ 25,026	$ 15,300	$ 9,726
NW4-13-2-W2	$ 31,400	$ 48,279	$ 48,279	$
NE4-13-2-W2	$ 42,900	$ 49,078	$ 45,126	$ 3,952
SE4-13-2-W2	$ 28,500	$ 35,558	$ 28,416	$ 7,141
SW5-13-2-W2	$ 51,600	$ 46,293	$ 43,182	$ 3,111
NW5-13-2-W2	$ 43,900	$ 53,491	$ 53,034	$
NE5-13-2-W2	$ 44,400	$ 27,538	$ 23,802	$ 3,736
SE5-13-2-W2	$ 40,600	$ 45,828	$ 43,492	$ 2,336
NW6-13-2-W2	$ 54,600	$ 50,928	$ 50,108	$
NE6-13-2-W2	$ 32,700	$ 52,841	$ 52,841	$
SE6-13-2-W2	$ 53,500	$ 47,880	$ 45,165	$ 2,715
SW7-13-2-W2	$ 47,100	$ 52,904	$ 48,610	$ 4,294
NW7-13-2-W2	$ 37,000	$ 44,816	$ 41,596	$ 3,220
NE7-13-2-W2	$ 35,300	$ 44,816	$ 41,596	$ 3,220
SE7-13-2-W2	$ 36,600	$ 49,018	$ 45,099	$ 3,919
SW8-13-2-W2	$ 24,300	$ 52,648	$ 46,130	$ 6,518
NW8-13-2-W2	$ 23,500	$ 45,632	$ 41,444	$ 4,189
NE8-13-2-W2	$ 44,400	$ 51,053	$ 46,782	$ 4,271
SE8-13-2-W2	$ 37,700	$ 38,916	$ 38,529	$
SW9-13-2-W2	$ 30,800	$ 16,878	$ 9,205	$ 7,673
NW9-13-2-W2	$ 46,600	$ 31,215	$ 30,145	$ 1,070
NE9-13-2-W2	$ 37,700	$ 32,068	$ 28,095	$ 3,974
SE9-13-2-W2	$ 47,200	$ 44,275	$ 39,693	$ 4,581
SW10-13-2-W2	$ 39,000	$ 47,788	$ 35,980	$ 11,809
NW10-13-2-W2	$ 34,400	$ 57,319	$ 54,717	$ 2,602
NE10-13-2-W2	$ 20,500	$ 49,272	$ 49,272	$
SW11-13-2-W2	$ 17,600	$ 34,550	$ 17,227	$ 17,323
NW11-13-2-W2	$ 22,600	$ 27,669	$ 13,501	$ 14,168
NE11-13-2-W2	$ 24,400	$ 36,915	$ 23,472	$ 13,443
SE11-13-2-W2	$ 37,100	$ 35,454	$ 19,385	$ 16,069
SW12-13-2-W2	$ 40,700	$ 46,600	$ 40,757	$ 5,843
NW12-13-2-W2	$ 41,300	$ 45,850	$ 40,654	$ 5,196
NE12-13-2-W2	$ 55,000	$ 45,137	$ 42,434	$ 2,703
SE12-13-2-W2	$ 37,900	$ 57,763	$ 52,912	$ 4,850
SW13-13-2-W2	$ 53,800	$ 59,834	$ 55,921	$ 3,913
NW13-13-2-W2	$ 51,700	$ 51,695	$ 47,176	$ 4,518
NE13-13-2-W2	$ 35,200	$ 39,137	$ 37,480	$ 1,657
SE13-13-2-W2	$ 47,500	$ 53,364	$ 49,315	$ 4,048
SW14-13-2-W2	$ 17,600	$ 46,682	$ 39,792	$ 6,890
NW14-13-2-W2	$ 37,600	$ 55,928	$ 52,507	$ 3,421

NE14-13-2-W2	$ 51,900	$ 43,335	$ 42,421	$
SE14-13-2-W2	$ 46,200	$ 47,965	$ 40,760	$ 7,205
SW15-13-2-W2	$ 35,000	$ 30,405	$ 26,712	$ 3,693
NW15-13-2-W2	$ 44,100	$ 52,768	$ 48,706	$ 4,061
NE15-13-2-W2	$ 40,900	$ 55,156	$ 52,594	$ 2,562
SE15-13-2-W2	$ 35,100	$ 41,644	$ 37,634	$ 4,010
SW16-13-2-W2	$ 47,100	$ 11,764	$ 11,120	$
NW16-13-2-W2	$ 35,800	$ 21,391	$ 12,784	$ 8,607
NE16-13-2-W2	$ 37,700	$ 41,458	$ 41,458	$
SE16-13-2-W2	$ 22,600	$ 10,844	$ (3,466)	$ 14,310
SW17-13-2-W2	$ 33,100	$ 53,333	$ 49,026	$ 4,308
NW17-13-2-W2	$ 47,300	$ 51,198	$ 50,017	$ 1,181
NE17-13-2-W2	$ 45,400	$ 41,793	$ 39,963	$ 1,830
SE17-13-2-W2	$ 48,200	$ 40,846	$ 35,669	$ 5,176
SW18-13-2-W2	$ 34,200	$ 43,659	$ 27,569	$ 16,091
NW18-13-2-W2	$ 46,700	$ 40,796	$ 39,742	$ 1,053
NE18-13-2-W2	$ 37,100	$ 48,646	$ 47,288	$ 1,359
SE18-13-2-W2	$ 48,400	$ 42,402	$ 40,829	$ 1,573
SW19-13-2-W2	$ 48,800	$ 13,362	$ 13,313	$
NW19-13-2-W2	$ 44,200	$ 17,047	$ 15,488	$ 1,558
NE19-13-2-W2	$ 49,800	$ 37,700	$ 34,078	$ 3,622
SE19-13-2-W2	$ 45,800	$ 61,197	$ 45,387	$ 15,809
SW20-13-2-W2	$ 50,500	$ 51,182	$ 47,381	$ 3,801
NW20-13-2-W2	$ 53,000	$ 58,014	$ 45,785	$ 12,229
NE20-13-2-W2	$ 41,000	$ 52,678	$ 43,940	$ 8,738
SE20-13-2-W2	$ 40,000	$ 47,540	$ 44,962	$ 2,578
SW21-13-2-W2	$ 46,100	$ 49,513	$ 47,113	$ 2,400
NW21-13-2-W2	$ 46,200	$ 49,445	$ 47,914	$ 1,531
NE21-13-2-W2	$ 36,500	$ 73,044	$ 67,936	$ 5,108
SE21-13-2-W2	$ 31,300	$ 31,059	$ 22,568	$ 8,491
SW22-13-2-W2	$ 54,900	$ 53,123	$ 51,453	$ 1,670
NW22-13-2-W2	$ 42,000	$ 34,092	$ 30,638	$ 3,454
NE22-13-2-W2	$ 51,400	$ 54,999	$ 52,588	$ 2,411
SE22-13-2-W2	$ 46,100	$ 56,280	$ 56,218	$
SW23-13-2-W2	$ 47,000	$ 83,565	$ 81,549	$ 2,016
NW23-13-2-W2	$ 34,800	$ 49,297	$ 45,781	$ 3,516
NE23-13-2-W2	$ 44,600	$ 45,290	$ 41,303	$ 3,987
SE23-13-2-W2	$ 54,000	$ 50,419	$ 44,591	$ 5,827
SW24-13-2-W2	$ 45,800	$ 46,619	$ 46,487	$
NW24-13-2-W2	$ 49,900	$ 43,567	$ 41,241	$ 2,325
NE24-13-2-W2	$ 50,900	$ 50,354	$ 46,874	$ 3,480
SE24-13-2-W2	$ 34,500	$ 46,616	$ 43,553	$ 3,063
SW25-13-2-W2	$ 17,100	$ 37,848	$ 36,406	$ 1,441
NW25-13-2-W2	$ 33,300	$ 50,978	$ 42,540	$ 8,438
NE25-13-2-W2	$ 27,200	$ 37,262	$ 26,618	$ 10,644
SE25-13-2-W2	$ 45,100	$ 45,650	$ 41,769	$ 3,881
SW26-13-2-W2	$ 43,300	$ 44,353	$ 43,195	$ 1,158
NW26-13-2-W2	$ 27,800	$ 59,567	$ 55,571	$ 3,997
NE26-13-2-W2	$ 34,600	$ 52,386	$ 50,994	$ 1,392
SE26-13-2-W2	$ 34,100	$ 44,781	$ 44,781	$
SW27-13-2-W2	$ 47,700	$ 47,639	$ 46,953	$
NW27-13-2-W2	$ 36,900	$ 42,440	$ 37,720	$ 4,720
NE27-13-2-W2	$ 33,800	$ 39,864	$ 33,949	$ 5,915
SE27-13-2-W2	$ 47,400	$ 38,890	$ 37,246	$ 1,644
SW28-13-2-W2	$ 47,400	$ 43,877	$ 39,153	$ 4,724
NW28-13-2-W2	$ 43,300	$ 8,709	$ 6,294	$ 2,415
NE28-13-2-W2	$ 33,900	$ 49,459	$ 48,770	$

SE28-13-2-W2	$ 39,000	$ 46,966	$ 42,676	$ 4,289
SW29-13-2-W2	$ 43,300	$ 51,331	$ 50,477	$
NW29-13-2-W2	$ 41,500	$ 41,035	$ 39,570	$ 1,465
NE29-13-2-W2	$ 44,000	$ 42,581	$ 40,037	$ 2,543
SE29-13-2-W2	$ 45,300	$ 14,848	$ 14,848	$
SW30-13-2-W2	$ 36,100	$ 15,176	$ 15,176	$
NW30-13-2-W2	$ 48,300	$ 14,589	$ 14,577	$
NE30-13-2-W2	$ 50,300	$ 40,832	$ 38,848	$ 1,984
SE30-13-2-W2	$ 50,100	$ 41,099	$ 40,507	$
SW31-13-2-W2	$ 28,600	$ 55,642	$ 54,184	$ 1,458
NW31-13-2-W2	$ 43,100	$ 57,015	$ 53,638	$ 3,377
NE31-13-2-W2	$ 43,700	$ 39,536	$ 34,310	$ 5,226
SE31-13-2-W2	$ 46,900	$ 50,797	$ 47,174	$ 3,622
SW32-13-2-W2	$ 43,500	$ 51,565	$ 49,941	$ 1,624
NW32-13-2-W2	$ 40,000	$ 63,231	$ 55,450	$ 7,780
NE32-13-2-W2	$ 36,400	$ 67,564	$ 60,108	$ 7,457
SE32-13-2-W2	$ 46,600	$ 56,191	$ 56,191	$
SW33-13-2-W2	$ 50,400	$ 63,471	$ 54,050	$ 9,420
NW33-13-2-W2	$ 39,600	$ 56,191	$ 56,191	$
NE33-13-2-W2	$ 42,000	$ 48,937	$ 46,477	$ 2,460
SE33-13-2-W2	$ 41,600	$ 55,169	$ 54,490	$
SW34-13-2-W2	$ 37,200	$ 56,009	$ 54,320	$ 1,689
NW34-13-2-W2	$ 47,900	$ 46,371	$ 46,067	$
NE34-13-2-W2	$ 51,000	$ 60,706	$ 47,643	$ 13,064
SE34-13-2-W2	$ 32,600	$ 58,398	$ 36,215	$ 22,183
SW35-13-2-W2	$ 40,800	$ 44,393	$ 42,290	$ 2,103
NE35-13-2-W2	$ 45,000	$ 53,451	$ 49,136	$ 4,315
SE35-13-2-W2	$ 42,200	$ 48,259	$ 42,863	$ 5,396
SW36-13-2-W2	$ 45,100	$ 49,571	$ 46,138	$ 3,433
NW36-13-2-W2	$ 39,100	$ 54,617	$ 50,415	$ 4,202
NE36-13-2-W2	$ 39,100	$ 43,331	$ 36,636	$ 6,695
SE36-13-2-W2	$ 33,700	$ 52,449	$ 51,044	$ 1,405
Total	$ 5,646,300	$ 6,353,825	$ 5,765,551	
Average	$ 40,045	$ 45,063	$ 40,890	
SD	8803.971714	12094.90729	12805.3584	
Median	$ 41,300	$ 46,619	$ 43,182	

Table F-3: Four Creeks Sub-Watershed- Assessed Wealth Results

Quarter Section	Actual	Base Case	Landscape Targets	Difference b/w Runs
SW1-4-30-W1	$ 26,800	$ 28,917	$ 26,087	$ 2,830
NW1-4-30-W1	$ 32,500	$ 35,217	$ 33,060	$ 2,156
NE1-4-30-W1	$ 47,500	$ 47,497	$ 43,377	$ 4,121
SE1-4-30-W1	$ 33,400	$ 34,066	$ 29,440	$ 4,626
SW2-4-30-W1	$ 44,200	$ 44,914	$ 41,641	$ 3,273
NW2-4-30-W1	$ 45,300	$ 45,128	$ 42,275	$ 2,853
NE2-4-30-W1	$ 35,600	$ 40,039	$ 38,583	$ 1,456
SE2-4-30-W1	$ 42,900	$ 43,716	$ 40,307	$ 3,409
SW3-4-30-W1	$ 46,000	$ 45,844	$ 41,692	$ 4,153
NW3-4-30-W1	$ 42,400	$ 42,759	$ 39,907	$ 2,852
NE3-4-30-W1	$ 43,100	$ 43,133	$ 38,821	$ 4,312
SE3-4-30-W1	$ 24,200	$ 23,253	$ 8,037	$ 15,216
SW4-4-30-W1	$ 47,000	$ 46,271	$ 43,673	$ 2,598
NW4-4-30-W1	$ 47,800	$ 46,235	$ 42,223	$ 4,012
NE4-4-30-W1	$ 46,000	$ 44,417	$ 42,610	$ 1,807
SE4-4-30-W1	$ 46,300	$ 45,491	$ 41,466	$ 4,025
SW5-4-30-W1	$ 39,400	$ 43,298	$ 35,771	$ 7,527
NW5-4-30-W1	$ 33,100	$ 36,402	$ 30,778	$ 5,624
NE5-4-30-W1	$ 38,500	$ 42,255	$ 34,158	$ 8,097
SE5-4-30-W1	$ 25,100	$ 25,178	$ 22,640	$ 2,538
SW6-4-30-W1	$ 25,600	$ 28,847	$ 27,625	$ 1,222
NW6-4-30-W1	$ 33,500	$ 37,913	$ 37,339	$
NE6-4-30-W1	$ 33,300	$ 36,770	$ 35,886	$
SE6-4-30-W1	$ 42,600	$ 43,574	$ 40,433	$ 3,141
SW7-4-30-W1	$ 47,200	$ 49,420	$ 46,951	$ 2,468
NW7-4-30-W1	$ 45,300	$ 46,168	$ 43,277	$ 2,892
NE7-4-30-W1	$ 23,900	$ 24,656	$ 23,627	$ 1,029
SE7-4-30-W1	$ 22,700	$ 20,446	$ 10,937	$ 9,509
SW8-4-30-W1	$ 30,300	$ 29,623	$ 26,592	$ 3,031
NW8-4-30-W1	$ 33,200	$ 32,809	$ 30,993	$ 1,816
NE8-4-30-W1	$ 38,300	$ 40,810	$ 39,188	$ 1,622
SE8-4-30-W1	$ 45,500	$ 42,425	$ 39,277	$ 3,148
SW9-4-30-W1	$ 47,000	$ 45,921	$ 44,893	$ 1,028
NW9-4-30-W1	$ 44,300	$ 45,161	$ 41,611	$ 3,549
NE9-4-30-W1	$ 42,200	$ 44,068	$ 43,188	$
SE9-4-30-W1	$ 46,000	$ 46,420	$ 45,771	$
SW10-4-30-W1	$ 41,400	$ 39,629	$ 35,911	$ 3,718
NW10-4-30-W1	$ 42,400	$ 44,444	$ 40,946	$ 3,498
NE10-4-30-W1	$ 27,100	$ 31,459	$ 22,389	$ 9,070
SE10-4-30-W1	$ 35,800	$ 39,968	$ 34,712	$ 5,256
SW11-4-30-W1	$ 41,700	$ 42,863	$ 39,100	$ 3,763
NW11-4-30-W1	$ 38,100	$ 42,191	$ 42,134	$
NE11-4-30-W1	$ 16,400	$ 16,208	$ 8,294	$ 7,914
SE11-4-30-W1	$ 32,600	$ 35,239	$ 31,980	$ 3,260
SW12-4-30-W1	$ 35,400	$ 39,028	$ 38,911	$
NW12-4-30-W1	$ 40,400	$ 44,799	$ 44,623	$
NE12-4-30-W1	$ 41,500	$ 41,128	$ 36,964	$ 4,164
SE12-4-30-W1	$ 39,400	$ 43,838	$ 43,838	$
SW13-4-30-W1	$ 44,200	$ 43,730	$ 40,139	$ 3,591
NW13-4-30-W1	$ 45,300	$ 43,289	$ 38,968	$ 4,322
NE13-4-30-W1	$ 40,500	$ 45,330	$ 45,314	$
SE13-4-30-W1	$ 40,100	$ 46,700	$ 37,177	$ 9,523

SW14-4-30-W1	$ 30,200	$ 32,450	$ 31,774	$
NW14-4-30-W1	$ 44,200	$ 44,497	$ 42,862	$ 1,635
NE14-4-30-W1	$ 38,800	$ 42,904	$ 42,695	$
SE14-4-30-W1	$ 36,200	$ 40,450	$ 36,155	$ 4,294
SW15-4-30-W1	$ 33,200	$ 37,056	$ 36,924	$
NW15-4-30-W1	$ 43,900	$ 45,879	$ 44,241	$ 1,638
NE15-4-30-W1	$ 41,900	$ 43,420	$ 40,743	$ 2,677
SE15-4-30-W1	$ 39,000	$ 43,987	$ 43,921	$
SW16-4-30-W1	$ 46,800	$ 46,701	$ 43,797	$ 2,904
NW16-4-30-W1	$ 40,100	$ 44,576	$ 44,482	$
NE16-4-30-W1	$ 45,300	$ 45,090	$ 41,709	$ 3,380
SE16-4-30-W1	$ 45,300	$ 44,984	$ 41,993	$ 2,991
SW17-4-30-W1	$ 38,800	$ 43,987	$ 42,445	$ 1,542
NW17-4-30-W1	$ 29,300	$ 32,767	$ 32,741	$
NE17-4-30-W1	$ 24,300	$ 22,625	$ 17,283	$ 5,341
SE17-4-30-W1	$ 24,300	$ 27,629	$ 19,321	$ 8,308
SW18-4-30-W1	$ 51,700	$ 50,590	$ 48,585	$ 2,005
NW18-4-30-W1	$ 45,500	$ 44,424	$ 41,436	$ 2,988
NE18-4-30-W1	$ 21,700	$ 23,338	$ 22,816	$
SE18-4-30-W1	$ 20,600	$ 20,939	$ 6,213	$ 14,727
SW19-4-30-W1	$ 48,900	$ 50,371	$ 50,027	$
NW19-4-30-W1	$ 39,700	$ 43,896	$ 38,393	$ 5,503
NE19-4-30-W1	$ 27,000	$ 28,252	$ 15,459	$ 12,793
SE19-4-30-W1	$ 17,500	$ 13,000	-$ 2,941	$ 15,941
SW20-4-30-W1	$ 23,000	$ 27,046	$ 15,746	$ 11,300
NW20-4-30-W1	$ 46,000	$ 46,382	$ 43,221	$ 3,161
SE20-4-30-W1	$ 38,500	$ 42,771	$ 40,810	$ 1,961
SW21-4-30-W1	$ 41,900	$ 44,022	$ 40,797	$ 3,225
NW21-4-30-W1	$ 38,800	$ 43,273	$ 43,273	$
NE21-4-30-W1	$ 39,300	$ 43,097	$ 43,074	$
SE21-4-30-W1	$ 40,600	$ 44,579	$ 44,541	$
SW22-4-30-W1	$ 44,000	$ 45,782	$ 43,712	$ 2,069
NW22-4-30-W1	$ 44,000	$ 45,363	$ 42,792	$ 2,571
NE22-4-30-W1	$ 43,600	$ 41,766	$ 37,007	$ 4,759
SE22-4-30-W1	$ 43,600	$ 42,889	$ 38,988	$ 3,901
SW23-4-30-W1	$ 33,500	$ 37,457	$ 37,456	$
NW23-4-30-W1	$ 35,700	$ 39,787	$ 37,509	$ 2,278
NE23-4-30-W1	$ 34,700	$ 38,682	$ 38,605	$
SE23-4-30-W1	$ 34,800	$ 38,945	$ 38,944	$
SW24-4-30-W1	$ 43,800	$ 46,077	$ 42,712	$ 3,365
NW24-4-30-W1	$ 43,800	$ 45,940	$ 43,774	$ 2,166
NE24-4-30-W1	$ 46,000	$ 46,953	$ 43,284	$ 3,669
SE24-4-30-W1	$ 47,800	$ 48,159	$ 45,973	$ 2,186
SW25-4-30-W1	$ 47,000	$ 47,824	$ 45,714	$ 2,110
NW25-4-30-W1	$ 45,300	$ 46,517	$ 44,069	$ 2,448
SW26-4-30-W1	$ 37,400	$ 41,934	$ 41,918	$
NW26-4-30-W1	$ 33,600	$ 37,155	$ 36,926	$
NE26-4-30-W1	$ 43,000	$ 42,786	$ 39,405	$ 3,380
SE26-4-30-W1	$ 31,200	$ 34,406	$ 34,150	$
SW27-4-30-W1	$ 36,400	$ 40,584	$ 36,534	$ 4,050
NW27-4-30-W1	$ 37,400	$ 42,060	$ 38,881	$ 3,179
NE27-4-30-W1	$ 38,900	$ 43,776	$ 42,999	$
SE27-4-30-W1	$ 46,000	$ 46,128	$ 42,369	$ 3,759
SW28-4-30-W1	$ 46,800	$ 47,758	$ 44,769	$ 2,989
NW28-4-30-W1	$ 48,800	$ 48,848	$ 46,823	$ 2,025
NE28-4-30-W1	$ 44,200	$ 45,866	$ 43,387	$ 2,479
SE28-4-30-W1	$ 46,800	$ 47,866	$ 44,980	$ 2,886

SW29-4-30-W1	$ 50,400	$ 49,360	$ 45,979	$ 3,381
NW29-4-30-W1	$ 53,000	$ 51,006	$ 47,581	$ 3,425
NE29-4-30-W1	$ 44,500	$ 45,792	$ 41,853	$ 3,939
SE29-4-30-W1	$ 45,000	$ 46,627	$ 44,006	$ 2,620
SW30-4-30-W1	$ 21,000	$ 15,642	$ 6,794	$ 8,848
NW30-4-30-W1	$ 21,300	$ 13,439	$ 6,153	$ 7,286
NE30-4-30-W1	$ 46,000	$ 47,091	$ 45,270	$ 1,820
SE30-4-30-W1	$ 45,200	$ 45,203	$ 44,349	$
SW31-4-30-W1	$ 21,600	$ 16,779	$ 10,681	$ 6,098
NW31-4-30-W1	$ 31,200	$ 29,535	$ 19,343	$ 10,193
NE31-4-30-W1	$ 32,400	$ 35,148	$ 34,933	$
SE31-4-30-W1	$ 40,300	$ 46,234	$ 42,102	$ 4,132
SW32-4-30-W1	$ 47,800	$ 48,357	$ 45,953	$ 2,403
NW32-4-30-W1	$ 48,800	$ 48,594	$ 45,834	$ 2,759
NE32-4-30-W1	$ 39,300	$ 44,319	$ 44,318	$
SE32-4-30-W1	$ 46,200	$ 45,955	$ 43,525	$ 2,430
SW33-4-30-W1	$ 47,000	$ 47,841	$ 44,666	$ 3,175
NW33-4-30-W1	$ 38,800	$ 43,517	$ 41,337	$ 2,180
NE33-4-30-W1	$ 47,000	$ 47,841	$ 44,666	$ 3,175
SE33-4-30-W1	$ 50,400	$ 49,603	$ 46,735	$ 2,868
SW34-4-30-W1	$ 46,400	$ 47,682	$ 44,777	$ 2,905
NW34-4-30-W1	$ 39,500	$ 44,655	$ 43,776	$
NE34-4-30-W1	$ 44,600	$ 45,615	$ 42,208	$ 3,406
SE34-4-30-W1	$ 30,400	$ 33,593	$ 32,738	$
SW35-4-30-W1	$ 31,800	$ 35,109	$ 35,109	$
NW35-4-30-W1	$ 40,900	$ 45,668	$ 45,666	$
NE35-4-30-W1	$ 47,500	$ 45,064	$ 39,509	$ 5,554
SE35-4-30-W1	$ 37,100	$ 40,901	$ 40,901	$
SW36-4-30-W1	$ 50,400	$ 49,734	$ 46,655	$ 3,079
NW36-4-30-W1	$ 51,900	$ 50,278	$ 46,697	$ 3,581
NE36-4-30-W1	$ 53,500	$ 51,747	$ 48,261	$ 3,486
SE36-4-30-W1	$ 51,900	$ 49,570	$ 45,859	$ 3,711
total	$ 5,553,800	$ 5,752,691	$ 5,301,989	
average	$ 39,389	$ 40,799	$ 37,603	
SD	8304.577844	8429.234047	10262.23535	
Median	$ 41,400	$ 43,776	$ 41,436	